CASTONE - Composite Panel Cladding

Prepared for:

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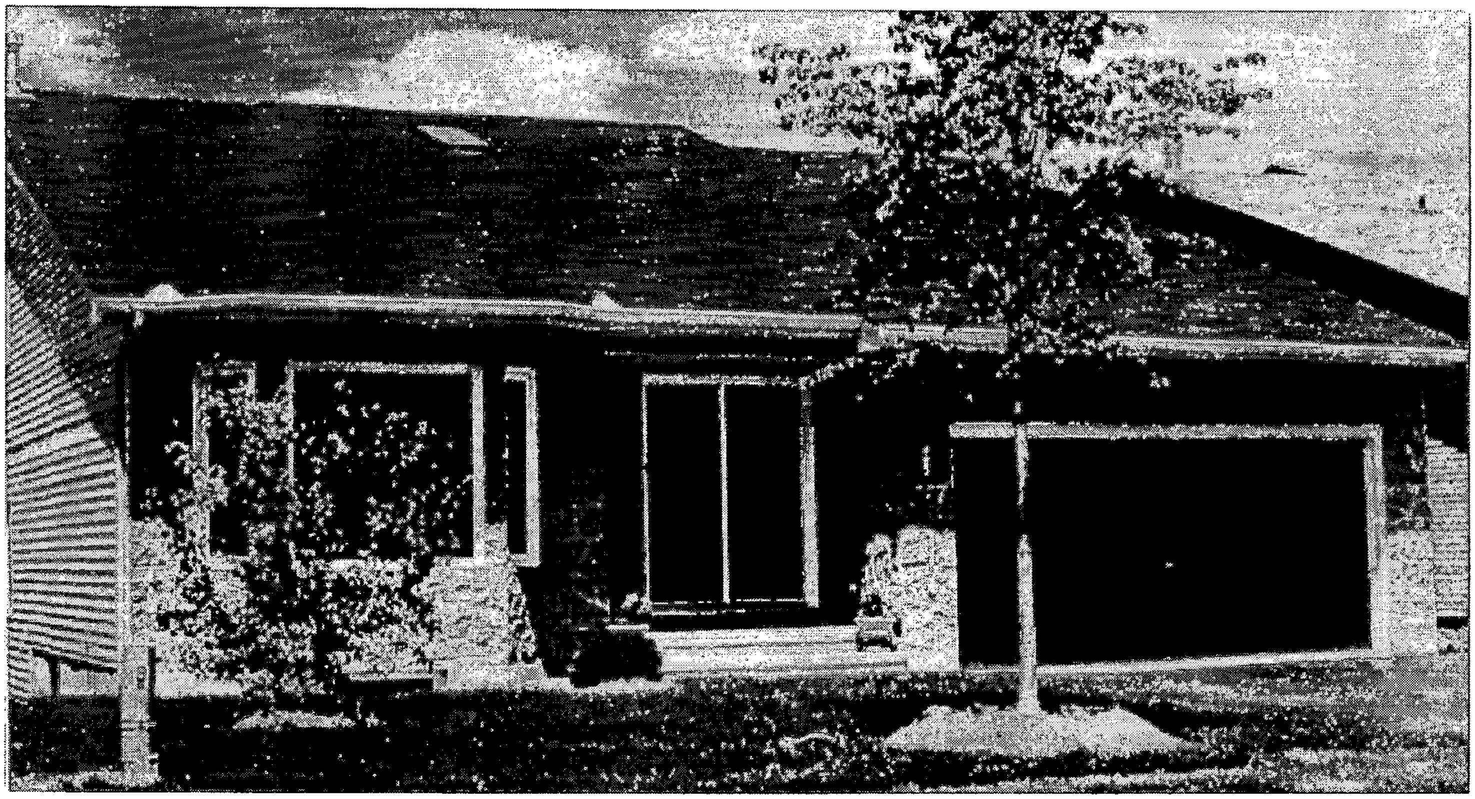

Project Title:	CASTONE - Composite Panel Cladding
Author's Name:	Peter J. Goodings, B.Sc.(Eng)
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DISCLAIMER

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

ACKNOWLEDGEMENT

CMHC's Housing Technology Incentive Program provides much needed support for the introduction of new products to the Canadian and world-wide marketplace. Product testing and evaluation is the key to ensuring that new products meet the ever increasing demands of the building materials industry. We wish to take this opportunity to express our appreciation to CMHC for their financial support, encouragement and advice in the development of the CASTONE product line and its innovative technology.

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RÉSUMÉ

Le panneau CASTONE est un produit de construction qui imite la pierre naturelle ou toute autre surface granuleuse. Chaque panneau est composé d'une enveloppe cimentaire, moulée de manière à lui conférer la texture désirée, collée à un support de polyuréthane haute densité. Le panneau entier a environ 2 po d'épais et pèse 4,5 lb le pi². À l'origine, le panneau CASTONE avait 4 pi x 4 pi et faisait partie d'un ensemble de huit panneaux. Le panneau de deuxième génération se compose maintenant de nouveaux matériaux et est plus léger puisqu'il est présenté en panneaux simples de 3 pi x 2 pi. Le panneau CASTONE offre une valeur isolante élevée ainsi qu'une qualité esthétique et une durabilité supérieures à un prix pouvant concurrencer les bardages de vinyle et d'aluminium.

Posé à l'intérieur ou à l'extérieur, le panneau CASTONE constitue une solution de rechange innovante aux parements résidentiels classiques comme le vinyle, l'aluminium et la brique sans entraîner les coûts et les problèmes d'application de ces autres matériaux. Le panneau CASTONE représente une amélioration par rapport aux panneaux de construction composites existants puisque sa surface permet de reproduire la texture et l'apparence de n'importe quel revêtement traditionnel, naturel ou fabriqué, et qu'il possède de meilleures propriétés isolantes. En outre, le panneau est relativement léger et nécessite une ossature moins solide pour supporter le poids de la façade comparativement à ce que requiert la pierre naturelle. De plus, il est facile à poser, même pour les personnes inexpérimentées. La pose peut se faire à longueur d'année dans toutes les conditions climatiques grâce à un système pratique de rails et d'attaches. Le panneau peut être coupé au moyen d'outils standards comme une scie égoïne, une scie circulaire ou une scie sauteuse et peut être percé avec des forets à grande vitesse.

Notre étude de marché a révélé que les propriétaires-occupants canadiens et américains disposent d'un choix très limité de revêtements de finition pour leurs maisons. Comme la brique et la pierre coûtent habituellement trop cher pour être mises en oeuvre sur des habitations destinées aux ménages à revenu faible ou moyen, les constructeurs optent plutôt pour des matériaux de bardage abordables comme le vinyle et l'aluminium. Peu de propriétaires-occupants considèrent que les bardages de vinyle ou d'aluminium constituent des caractéristiques attrayantes pour leurs maisons. Le panneau CASTONE représente donc la solution idéale. Il offre aux architectes, aux constructeurs et, en fin de compte, aux propriétaires-occupants une nouvelle surface tout à fait esthétique et agréable qui ne demande aucun entretien. La facilité d'installation du panneau CASTONE permet de ne plus faire appel aux services rares et coûteux des briqueteurs ou des poseurs de pierres, donc de réduire les coûts de construction. Le panneau CASTONE évite aussi de recourir à des ressources épuisables comme le bois. C'est pourquoi nous croyons que le marché des logements pour ménages à revenu faible ou moyen bénéficierait grandement des caractéristiques de ce produit.

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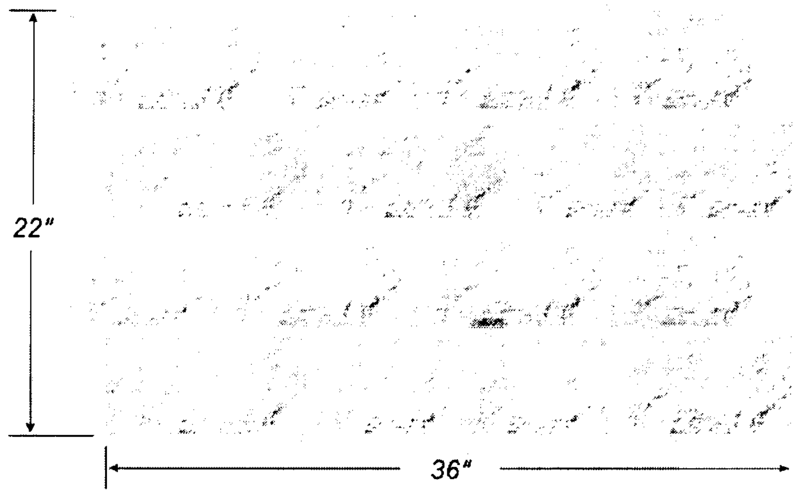
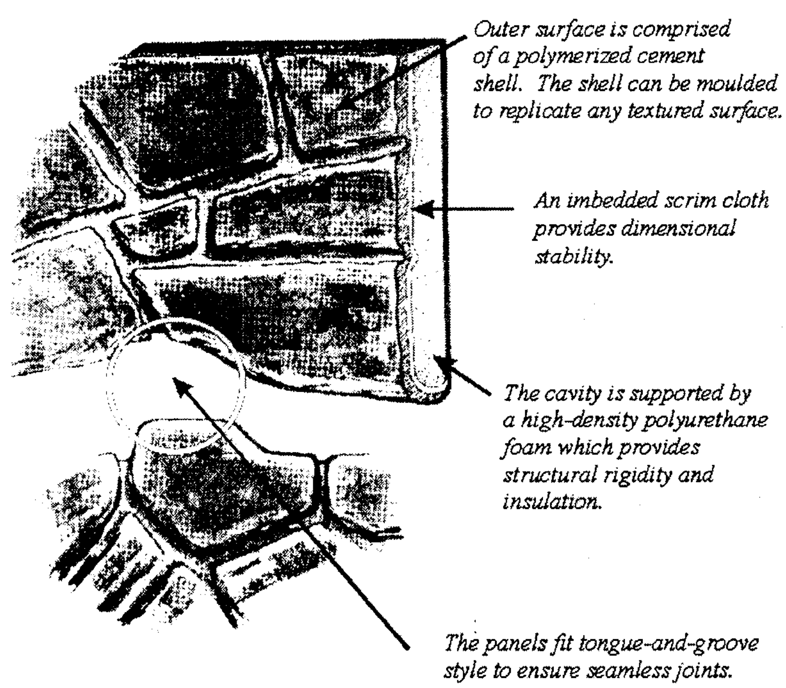
EXECUTIVE SUMMARY

CASTONE is a panel building product simulating natural stone or any textured surface. Each panel has a cementitious outer shell, which is moulded to impart any desired texture, bonded to a high-density polyurethane core/backing. The entire panel is about 2" thick with a weight of 4.5 lbs. per square foot. Originally, CASTONE was made in a 4' x 4' panel size, using an eight-panel system. A second generation panel has been designed and employs a new-materials formulation and a lighter weight 3' x 2' uni-panel design. CASTONE has a high insulation value with superior aesthetics and durability at a price to complement both vinyl and aluminium sidings.

THE CASTONE PANEL



CASTONE panels provide a new and innovative exterior/interior surfacing alternative to conventional residential siding materials such as vinyl, aluminium and brick, without their costs and application problems. CASTONE represents an improvement over existing composite building panels in that the surface of the panel can be made to replicate any conventional surfacing material, either natural or man-made, in texture and appearance, while exceeding their insulative properties. In addition, the panels are relatively lightweight, requiring less structure to support the weight of the facade as compared with that for natural stone. Furthermore, they can be easily installed, even by inexperienced persons. Installation can be achieved year-round in all weather conditions, employing an



easy-to-use track and clip system. The panels can be cut using standard tools such as carpenter's hand saws, circular saws or sabre saws, and can be conveniently drilled using standard high-speed drill bits.

Our market research has found that homeowners in Canada and the United States are quite restricted in the finishing systems used on their homes. As brick and stone are typically too expensive for use on low to middle income housing, builders opt instead for cheaper vinyl and aluminium sidings. Few homeowners ever acknowledge vinyl or aluminium as positive attributes of their homes. CASTONE is an ideal alternative. It provides architects, builders and ultimately homeowners with an exciting, new and aesthetically pleasing surface which is maintenance free. CASTONE's ease of installation negates the need for expensive and increasingly rare brick layers and stone masons, thus cutting building costs. CASTONE also avoids the use of environmentally restricted materials such as wood. We feel that the low to middle-income housing market would greatly benefit from these features.

Summary of Test Results

(For a more detailed description of test results and conclusions, please refer to the ORTECH Corporation Report in the Appendix.)

TEST	*METHOD*	*RESULT*	*CONCLUSION*
Expansion/ Contraction		1.8×10^{-5} mm 7.9×10^{-4} mm	No physical deterioration from heat-cold cycling
Thermal Durability of Wall Section		No physical deterioration No delamination	Passed
Air Leakage of Wall Section	ASTM E283	$0.0002/L/s/m^2$	Passed
Water Leakage of Wall Section	ASTM E547	No leaks after 24 cycles at 600 Pa	Passed
Wind Load Resistance of Wall Section	ASTM E330	Maximum allowable deflection +/- 1600 Pa (equivalent to wind speed of 186 km/h	Passed
Water Penetration	Static Pressure	No water penetration or absorption	Passed
Freeze-Thaw	ASTM C666-92	No damage	Passed
Impact Resistance	ASTM D2794-92	No damage at 1.57 J	Passed
Tensile Testing		Average strength at break between cement and foam was at 235.1 kPa	Bond interface greatly exceeds leeward pressure expected due to wind pressure

RESEARCH & DEVELOPMENT BACKGROUND

CASTONE has been developed steadily, over the last three years, to meet the requirements of the construction market. In 1989, the Research and Development Program began with the development of small sections of the product (3′ x 3′ x 2″) using a variety of cement-based materials and foam products. In-house testing was undertaken to determine the ability of the product to withstand freeze-thaw cycling, water penetration, impact resistance and surface fire resistance conditions. The testing helped to determine the thickness of the cement shell and highlighted the need to imbed a scrim cloth into the cement shell to prove dimensional stability. Once a satisfactory formulation was arrived at, full size tooling (4′ x 4′ x 2″) was produced using a random stone design. A six panel system made it possible to install an 8′ x 12′ wall section without excessive pattern repetition. Installation of a prototype home was achieved using construction adhesive supported by 4 plated screws (1 in each corner).

In 1990, Warnock Hersey was commissioned to undertake a more rigorous and independent testing program. The test were undertaken with the support of an HTIP grant from Canada Mortgage & Housing Corporation. A comprehensive report on the testing program was published by CMHC on July 27, 1990. A summary of the tests and their results are presented below:

TEST	*TEST METHODOLOGY*	*TEST RESULT*
Freeze Thaw	ASTM C67	No significant deterioration - PASSED
Air Leakage	ASTM E-283	Leakage rate of 0.008/L/sec/m^2 - PASSED
Water Infiltration	ASTM E-547	Performed satisfactorily - PASSED
Surface Burning Characteristics	CAN4-S102-M88	
Flame Spread		Class = 5
Fuel Contributed		Class = 0
Smoke Developed		Class = 50*

* The results for the three trials were 0, 121 and 24. The second and third trial were done, in error, on damaged panel surface with exposed polyurethane foam. Had the trials been done properly, as in Trial 1, the Smoke Developed Classification would have been reduced considerably.

In May of 1993, the CASTONE Project was revived with new financing and a renewed commitment to cost, quality and innovation. This commitment extended to our customers as well as our shareholders. To achieve these goals, Castone Industries Inc. embarked on a second phase of product development to address several problems with the first generation product. The R&D included the development of a new product with a change in materials formulation and product dimensions. Also, a new installation system was designed to combine ease of installation with system integrity. Subsequent to a new prototype design, a comprehensive testing program was designed by ORTECH International, with assistance from the Canadian Construction Materials Centre, to test the performance of the panel system.

SPECIFIC PROJECT OBJECTIVES

Following the first round of testing, it was concluded that the basic product concept had merit. Subsequent market research showed that the public was receptive to the introduction of a high performance building product with the aesthetics of real stone, and other textured surfaces, to replace vinyl and aluminium siding. Vinyl and aluminium siding suffer from poor market perception and durability problems. Also, it was felt that owing to a long-term shortage of brick layers, that the price of brick would increase sharply over the decade. This would leave a large gap between low priced siding and high priced brick. It was felt that CASTONE would fit neatly into this gap by offering a good looking insulating panel at an installed price at or below brick.

However, before embarking on a plan to construct a modern production facility and implement a marketing plan, it was decided that a new panel design and materials formulation along with comprehensive testing would be necessary to assure investors, distributors and the ultimate consumer of a high performance product able to survive the rigours of the Canadian climate.

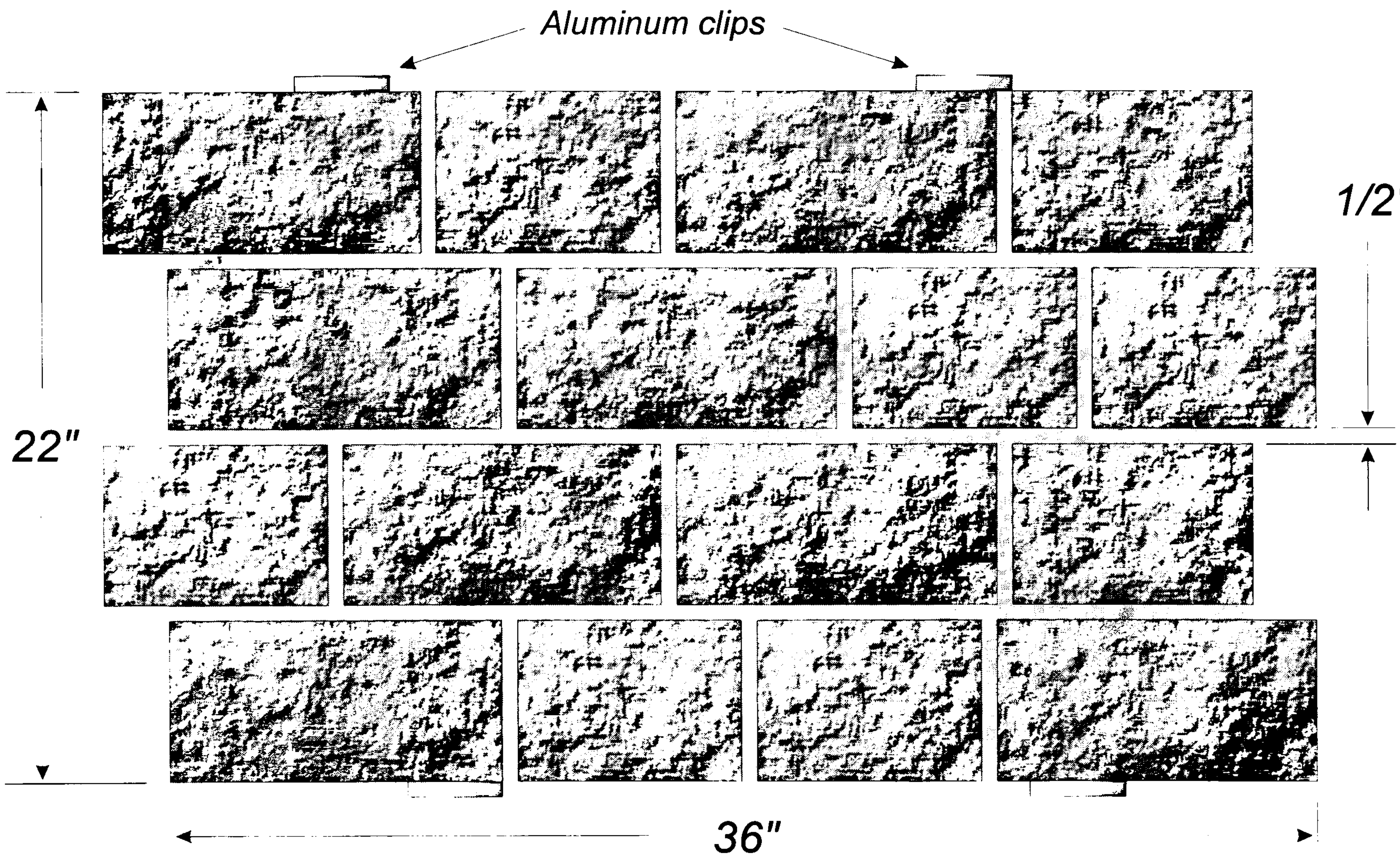
Some key objectives had to be met with this project. The most significant of these were:

- Determine Coefficient of Thermal Expansion
- Test for stress cracks from manufacturing process and long-term weathering
- Test for extended freeze-thaw cycling
- Test for water infiltration and penetration
- Test joint material for adherence, flexibility and water absorption
- Test adhesion of surface cementitious material to polyurethane core
- Examine kinetics of cement curing
- Test of mechanical fastening system.

DETAILED DESCRIPTION OF THE SYSTEM

The next 11 pages contain a detailed description of the CASTONE panel as well as the technique for installation.

THE CASTONE PANEL



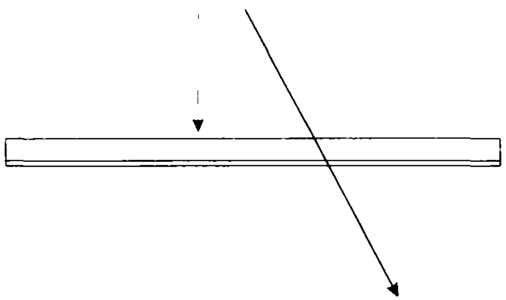
CASTONE INSTALLATION GUIDE

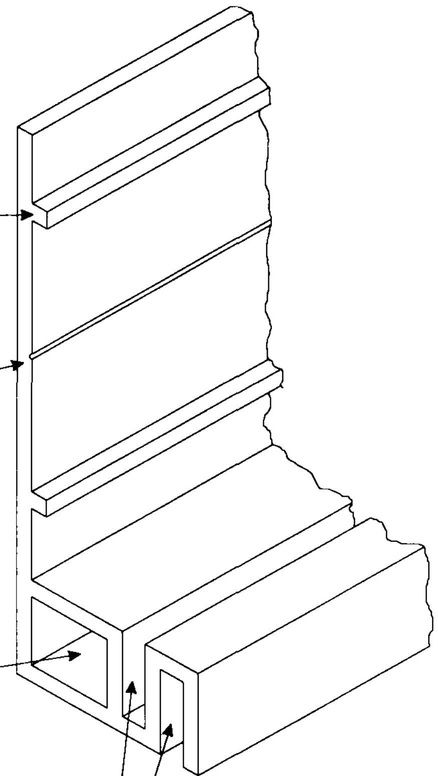
The Castone Panel System can be easily applied to virtually any structurally sound wall. The following illustrations will show the step by step procedures that will be employed in covering buildings of many different types from start to finish.

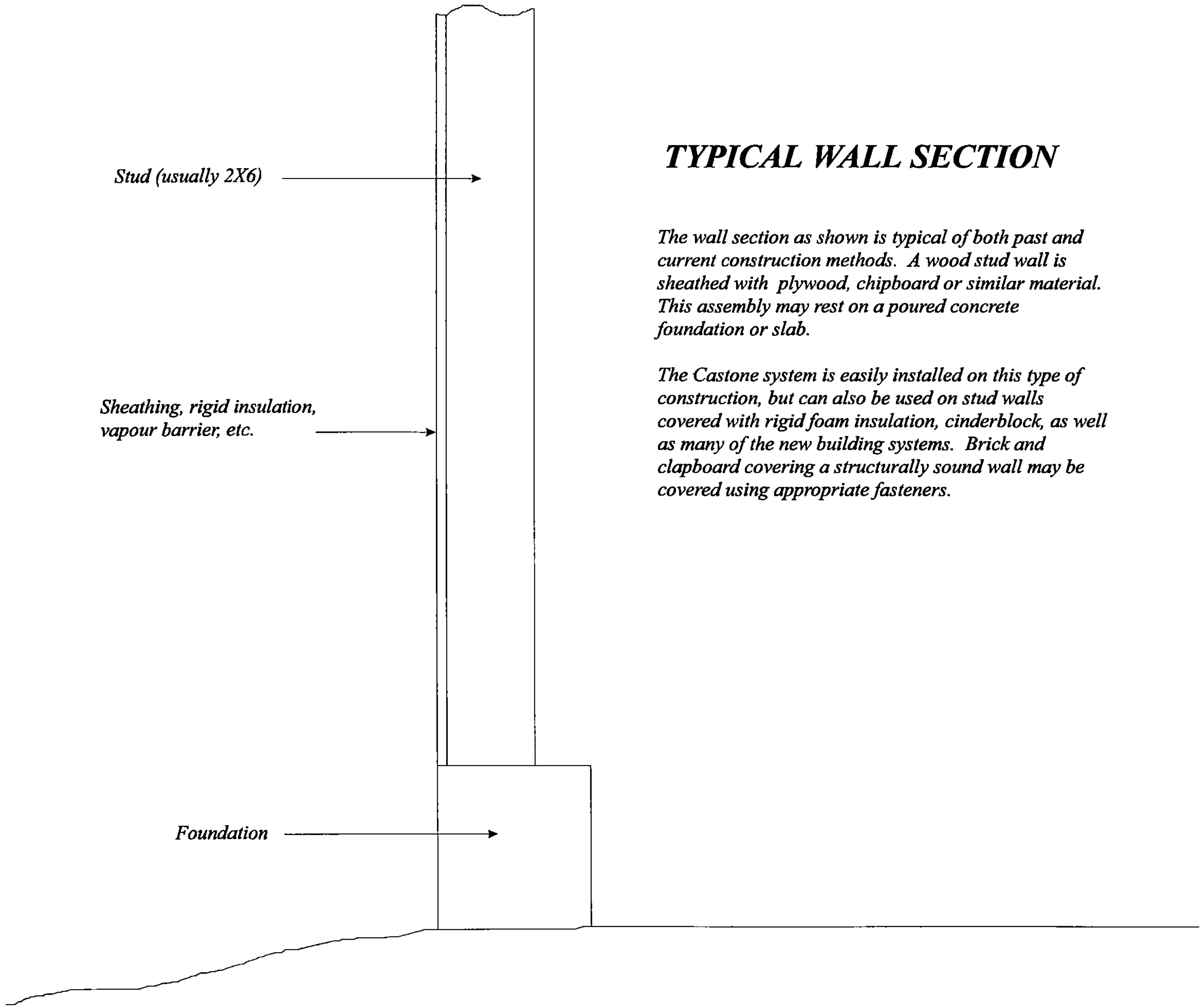
Aluminum Tracking System

An aluminum tracking system is used in all ordinary installations. The tracks come pre-cut in easy to use lengths and allow panels to be oriented quickly and easily with a minimum of measurement.

The track comes in two standard lengths: 33-1/2 inch and 10 foot. The ten foot lengths, or base tracks, are used to support the bottom row of panels only. The 33-1/2 inch lengths, or cap tracks, are used in the rest of the installation.





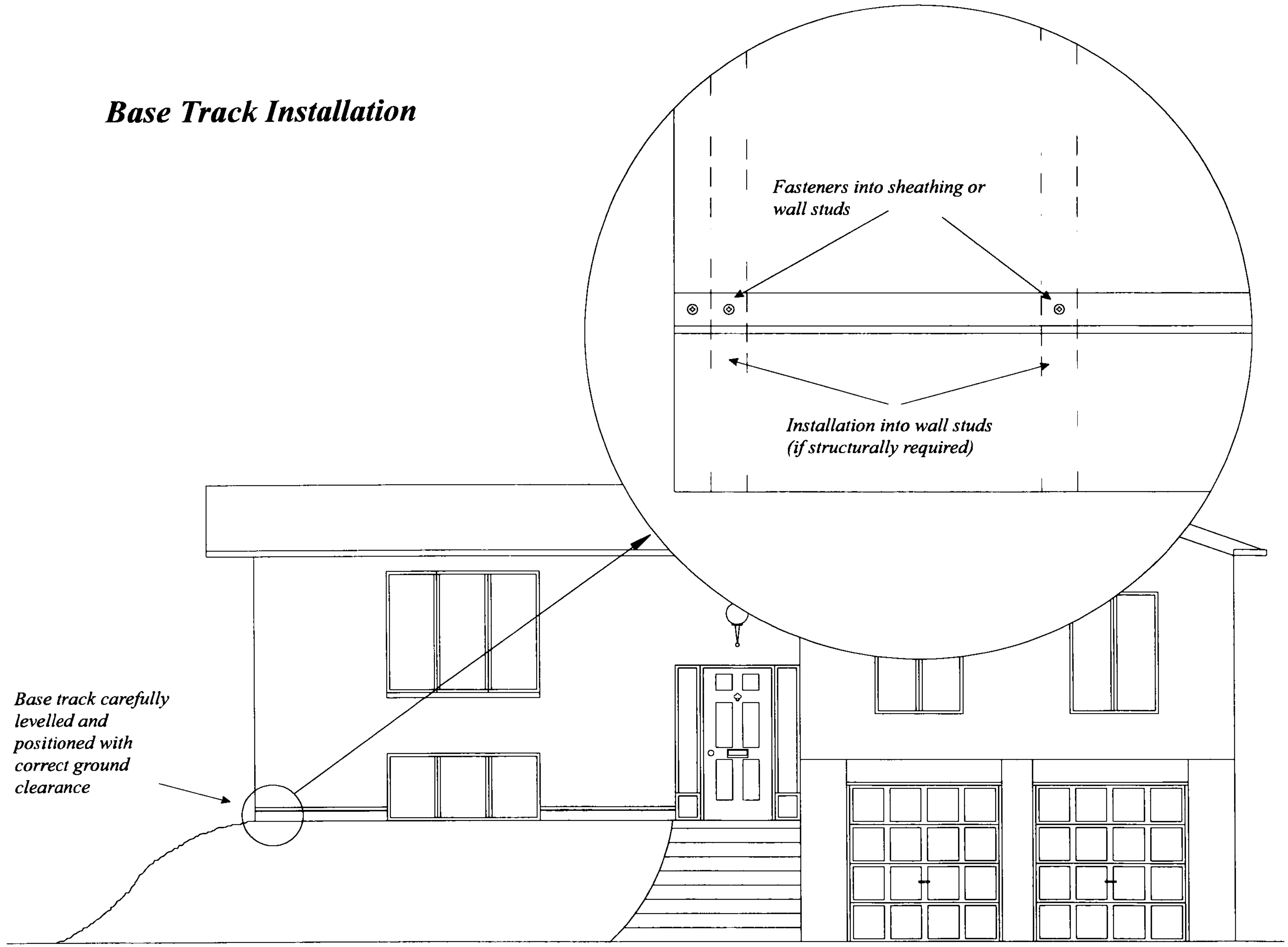


TYPICAL WALL SECTION

The wall section as shown is typical of both past and current construction methods. A wood stud wall is sheathed with plywood, chipboard or similar material. This assembly may rest on a poured concrete foundation or slab.

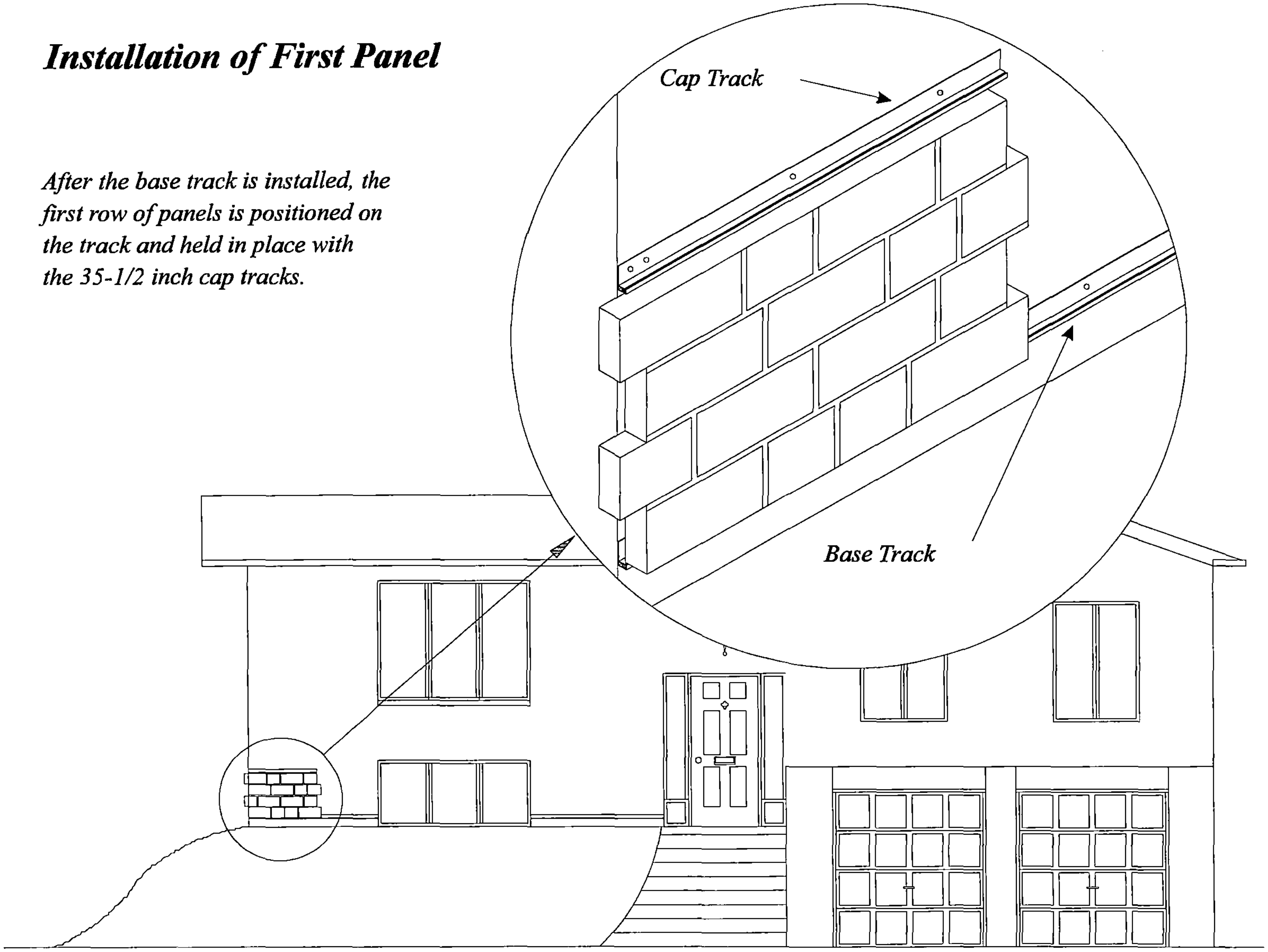
The Castone system is easily installed on this type of construction, but can also be used on stud walls covered with rigid foam insulation, cinderblock, as well as many of the new building systems. Brick and clapboard covering a structurally sound wall may be covered using appropriate fasteners.

Base Track Installation



Installation of First Panel

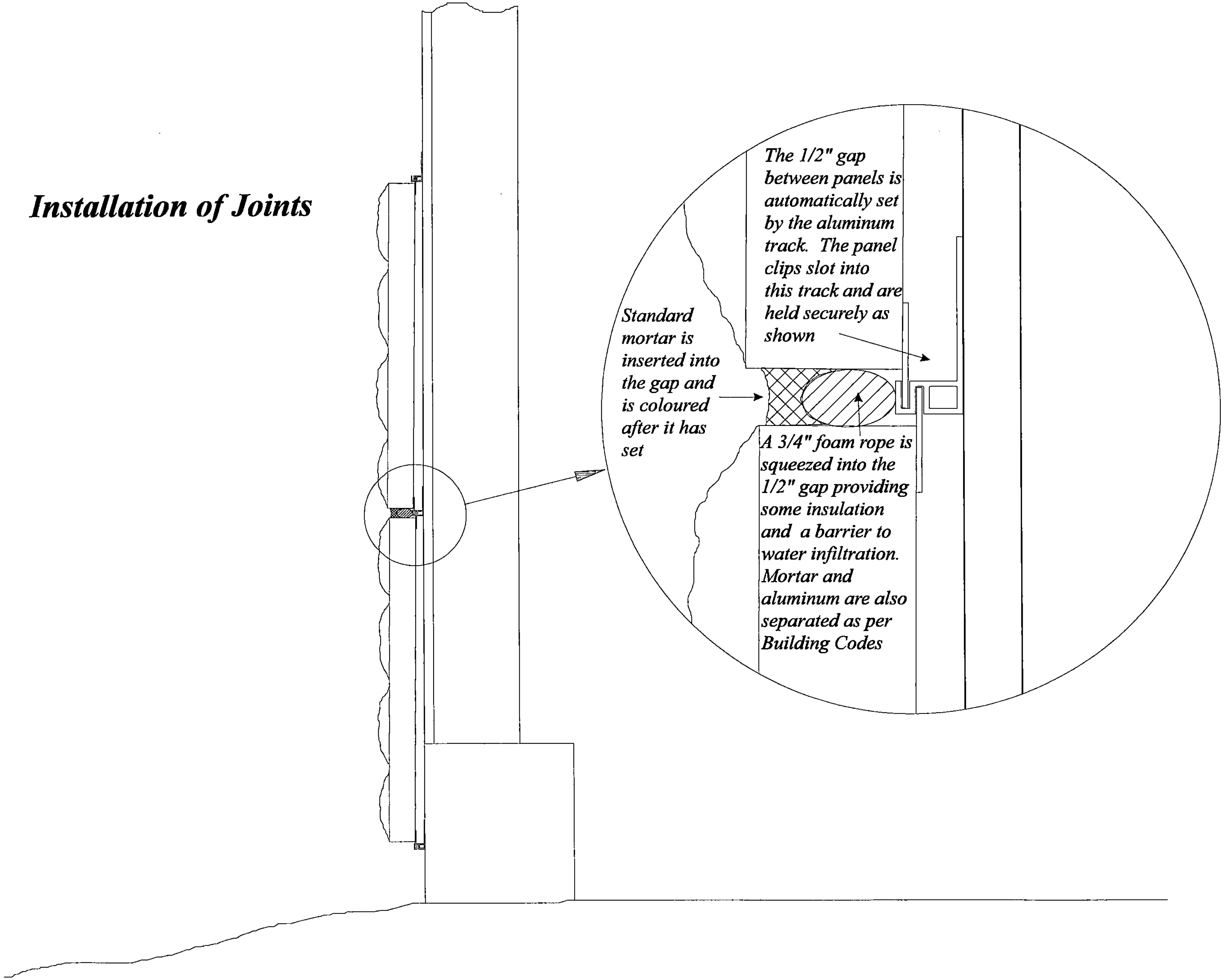
After the base track is installed, the first row of panels is positioned on the track and held in place with the 35-1/2 inch cap tracks.



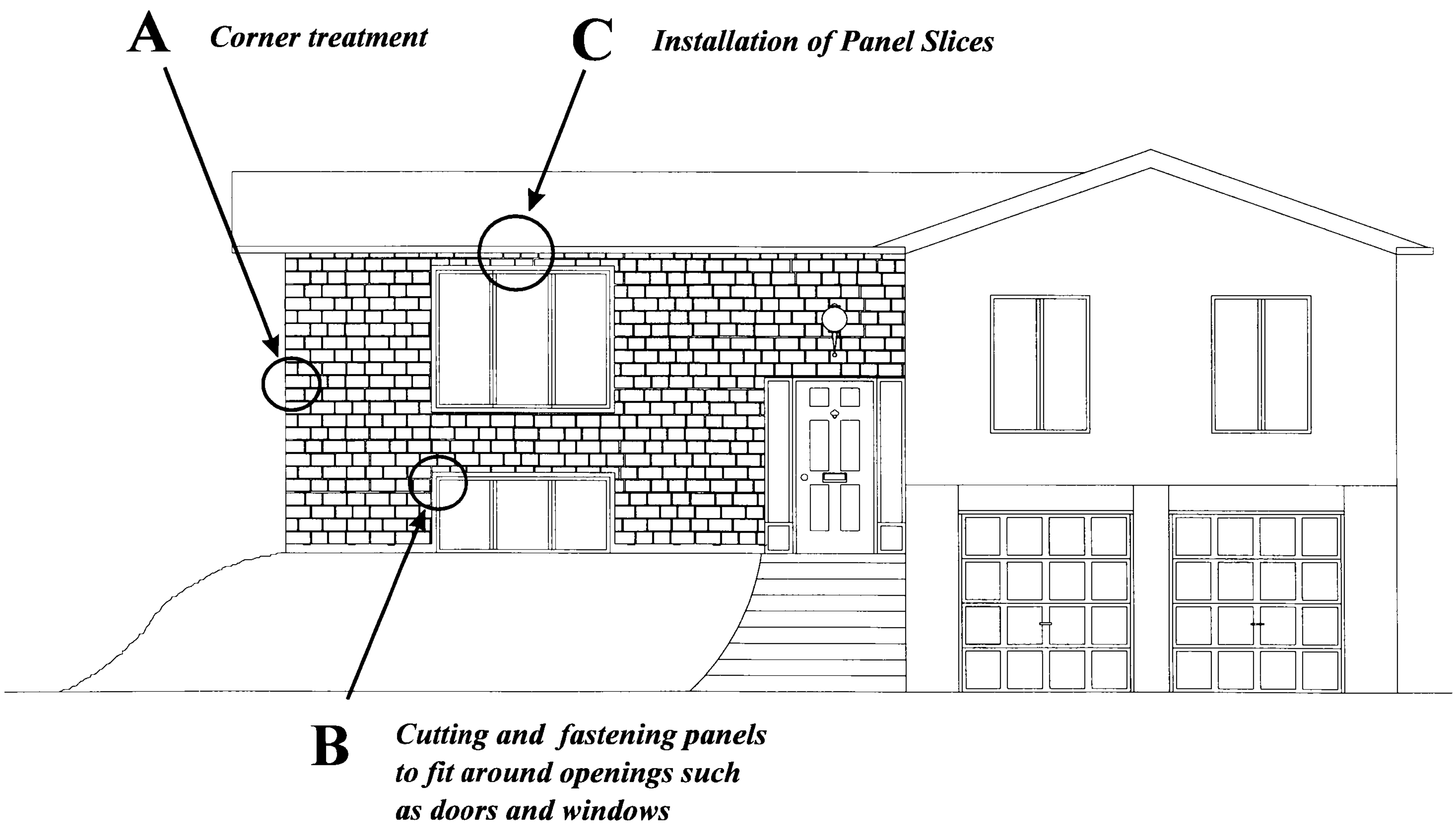
Installation of Second Row

After the first row of panels has been installed, the cap tracks from this first row act as the base tracks for the second. Because the placement of all rows is determined by the first row, the importance of levelling the base track cannot be overemphasized. The mechanics of the installation is similar to that of the first row.

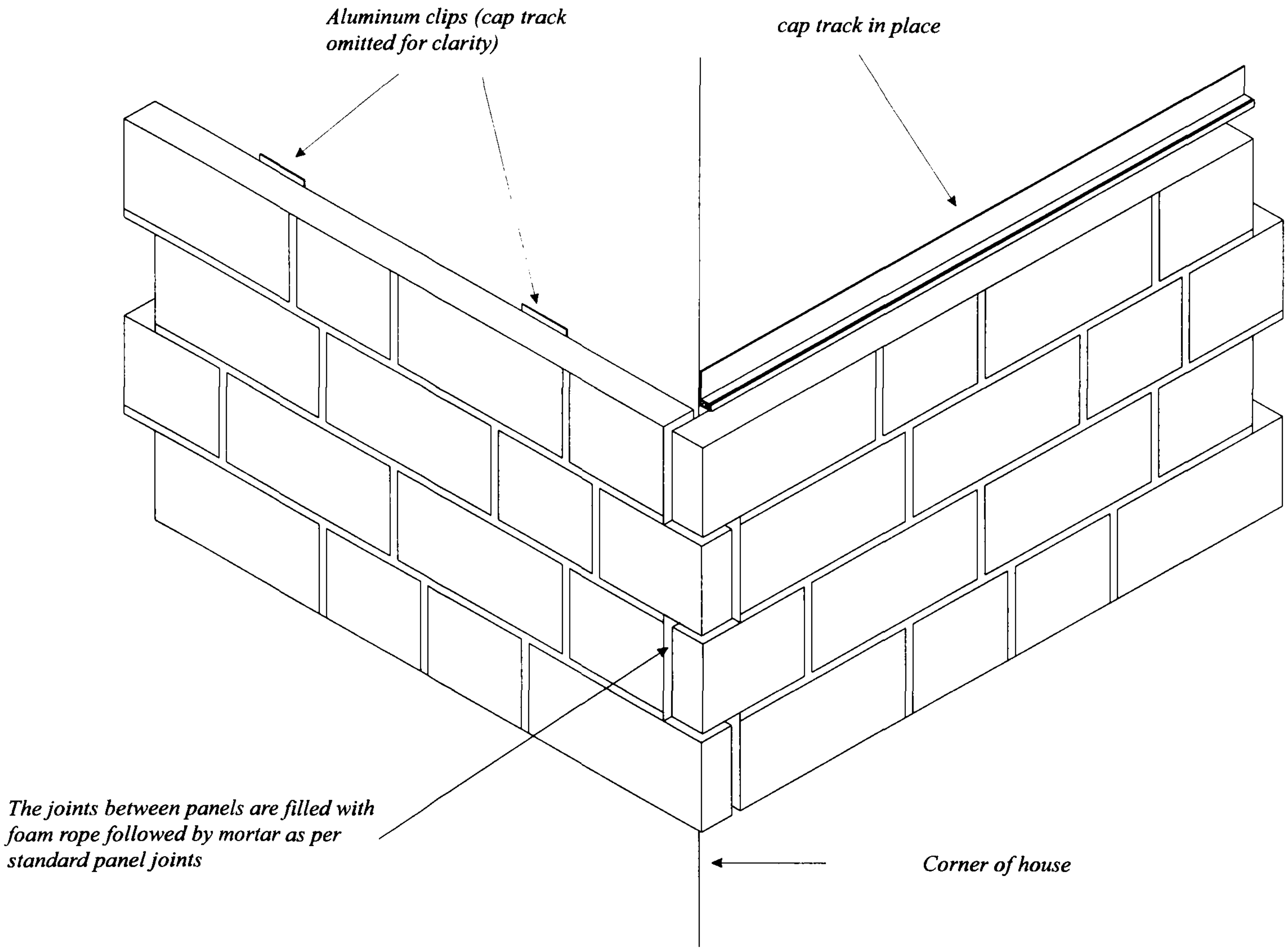
Installation of Joints



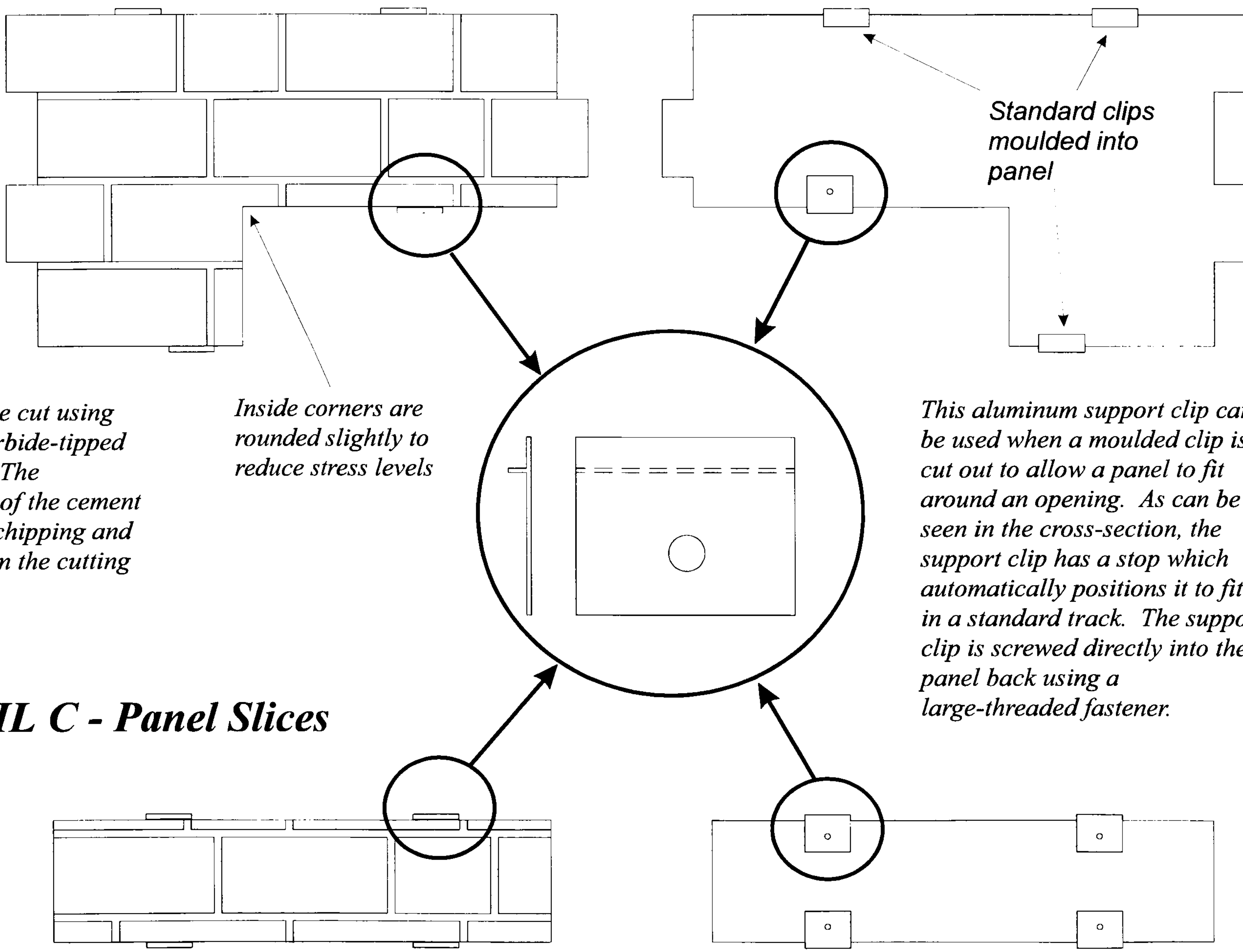
Common Installation Details



Detail A - Corner Treatment



DETAIL B - Cutting and Fastening



Panels can be cut using standard, carbide-tipped saw blades. The high-density of the cement shell resists chipping and cracking from the cutting action.

This aluminum support clip can be used when a moulded clip is cut out to allow a panel to fit around an opening. As can be seen in the cross-section, the support clip has a stop which automatically positions it to fit in a standard track. The support clip is screwed directly into the panel back using a large-threaded fastener.

DETAIL C - Panel Slices

PROTOTYPE DEVELOPMENT

The prototypes development phase of this project began in early June, 1993. The original panel had to be changed for the reasons outlined earlier in this report.

The first decision taken in panel design had to do with drastically changing the dimensions of the panel. The 4′ x 4′ panel was too difficult to manufacture as well as difficult to install. Siding installers were worried about the excessive cutting required in using the panels around doors and windows as well as the impractical weight (96 lbs. each). After speaking with a number of siding installers, do-it-yourself retailers, builders and architects, it was decided that a 3′ x 2′ panel would be more manageable for manufacturing and installation. Also, rather than using an 8 panel system, with a random stone design, a standard cut stone block uni-panel design was developed. The uni-panel design meant that a single panel would fit into itself on all four sides and would form an attractive corner when joined at 90^0 with another panel. This also had positive implications for manufacturing. Only one type of tooling would be required for mass production. Packaging and shipping would also be considerably simpler.

In terms of chemical composition, there were several improvements made in the new prototype. The cement shell was left intact; however, a polysiloxane sealant was added to the material to ensure that the panel surface would survive the effects of acid rain, UV exposure and water infiltration. The chemical composition of the cement shell was not altered because it was determined, through testing, that the material performed very well. It was also felt that altering an already complex material would lead to too many random variables in production. The polyurethane core was modified with a lighter density foam. While the foam was still of the structural variety, rather than insulating, it nonetheless improved insulation value while lowering production costs. The lighter density foam also yielded a lighter panel.

The system design also evolved in the installation technique. It was determined that a rainscreen design would offer the best combination of ease of installation and insulation value. The original installation technique involved joining the 4′ x 4′ panels with other panels as part of an 8 panel system and then screwing and gluing them to the substrate. The 'glue and screw' technique put a significant stress on the panel surface which was not always uniformly flat in earlier models. There was also no guarantee as to the longevity of the construction adhesive and plated screws. The new system using a track and clip technique was designed to allow for simple installation over any substrate (wood, foam insulation, masonry). Please refer to System Description section for a detailed look at the new system.

TEST RESULTS

On March 3, 1994, the Building Performance Technology (Materials Validation Section) Department of ORTECH Corporation submitted its final report on the testing program completed by CASTONE. The complete results with the conclusions and recommendations of ORTECH, can be found in the Appendix of this Report. The report results are summarised below:

Expansion and Contraction Testing of the Castone Panels

The average values obtained for coefficient of thermal expansion/contraction were 1.8×10^{-5} for the panels and 7.9×10^{-4} for the joints. Hence the thermally induced differential movement will be minimal for field applications of the Castone panels. There did not appear to be any physical deterioration of the panels following exposure to heating and cooling cycles.

Thermal Durability Testing of the Castone Panel System

Thermocouples positioned in the middle section of the wall indicated that the joint areas were colder than the panels which was in agreement with thermographic images. Typical convective heat loss characteristics, cooler at the bottom and warmer at the top, were displayed by the test wall in both the thermocouple bar chart and the thermographic images. Physical deterioration of the test wall due to thermal cycling does not appear to be a concern. No delamination of materials was apparent in the test wall. The thermal performance of the Castone wall system would improve if an insulating material was incorporated into the design of the joints during manufacturing, or if an appropriate insulating material was applied during its installation.

Air Leakage, Water Leakage and Wind Load Resistance Testing

The Castone wall system performed very well in resistance to air leakage (ASTM E283), water leakage (ASTM E547) and wind load resistance (ASTM E330).

Water Penetration Testing

The water did not penetrate the surface of the panel. The panel did not absorb any water. Water penetration and/or water absorption through the surface of the Castone panel is not a concern.

Freeze-Thaw Testing

There was no evidence of cracking or spalling in either the panels or the joint following the freeze-thaw cycling program (ASTM C666-92). The joint in the panels remained slightly darker in colour than the moulded panel joints. The cyclic freeze-thaw testing conducted did not cause any damage to the panels. Hence, cyclic freezing and thawing of the panels in field applications should not be a concern.

Impact Resistance Testing

CCMC's Technical Guide for Reinforced, Cementitious Board Masterformat Section: 03560 states: "The products proposed for exterior installations as sheathing with such protective finish as a thin coat system, ceramic tile, or other evaluated finishes are required to exhibit no damage to top or bottom" following impact from a steel ball (0.534 kg) released from a height of 300 mm (ASTM D2794-92 Standard). The energy at impact is equivalent to 1.57 J and the Castone panels exceed this requirement.

Tensile Testing

The average strength at break for all the specimens tested was 235.1 kPa. The different conditioning situations do not indicate any trending patterns in the bond interface strength of the cementitious layer to the high density rigid polyurethane foam insulation. Once the Castone panel is cured, the bond interface strength does not appear to be affected by temperature or humidity. Hence the bond interface strength is determined during the manufacturing stage. For comparison purposes, according to the National Building Code of Canada (NBC) 1990, the maximum expected pressure acting on the leeward wall of a residential type dwelling (i.e. suction pressure) is -0.7 of the acting wind pressure. The values obtained during testing for bond interface strength, at break, greatly exceed the leeward pressure values expected due to wind pressure.

ASSESSMENT & INTERPRETATION OF TEST RESULTS

The test results were uniformly excellent. The panel exceeded our expectations in all aspects. Due to our success with the testing program, ORTECH Corporation nominated Castone for the Flavelle Award, for product innovation. Castone was a finalist in the competition which included over 100 nominees.

The series of testing which most greatly affected system design was the Air, Wind and Water Leakage test. The system performed very well using a sealed joint which included a polyurethane caulking and foam backer-rod. While the system worked well under laboratory conditions, ORTECH was concerned that site labour would not take adequate care in ensuring a completely sealed wall section. This result led to the development of a stand-off track system which is described in an earlier section. The track system spaces the panels nearly 3/4 of an inch off the substrate allowing water to run down the back of the panels and escape through weep holes. This technique also allows for limited air circulation. The track system allows the panels to be installed on a wide variety of substrates, including foam and fibreglass sheathing. By including weep holes, the insulation value of the system has been somewhat reduced. However, the benefits of easy and versatile installation far out-weighs the decreased R Value.

The Water Penetration Test indicated that water did not penetrate or absorb into the panel. However, during manufacturing, a high-performance pigmented water sealant is sprayed onto the finished panels for added protection. During system installation, the same pigmented water sealant is applied to the mortared panel joints. This has the double benefit of sealing the cement joint and hiding it by using the same base colour as the moulded 'joints' on the panels themselves.

The testing program was conducted on prototype, hand-made panels. It is expected that the performance of a quality assured, production panel would be even better.

CONCLUSION

This R&D program was undertaken to enhance the performance of the Castone panel system, and to simplify both manufacturing and installation. The testing program served as a third-party verification of whether these goals had been realised. The end result of this program is a product which offers superior aesthetics, ease of installation and durability at an affordable price. The implications of this accomplishment are that builders, architects and ultimately homeowners, now have a viable, high-performance alternative to traditional building products.

APPENDIX

Please find attached the complete Report of Testing by ORTECH Corporation.

Summary Report

A Report to:	**Castone Industries Inc.** PO Box 10 Carleton Place, Ontario K7C 3P3
Attention:	Mr. Peter Goodings
Submitted by:	Pamela Miki Shinkoda, B.Eng. Building Performance Technology Materials Validation
Report No.	94-J53-B0035 (Final) 27 Pages, 3 Appendices Project No. 1099
Date:	3 March 1994

ORTECH

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INTRODUCTION

This summary report is a compilation report based upon the following tests and reports:

Report No. 93-J53-B0788	Expansion and Contraction Testing of the Castone Panels
Report No. 93-J53-B0790	Thermal Durability Testing of the Castone Panel System
Report No. 93-J53-B0829	Air Leakage, Water Leakage and Wind Load Resistance Testing
Report No. 93-J53-B0835	Water Penetration Testing
Report No. 94-J53-B0846	Freeze-Thaw Testing
Report No. 94-J53-B0001	Impact Resistance Testing of the Castone Panels
Report No. 94-J53-B0034	Tensile Bond Testing

EXPANSION AND CONTRACTION TESTING OF THE CASTONE PANELS

Introduction

At the request of Mr. Peter Goodings of Castone Industries Inc., ORTECH was contracted to conduct expansion and contraction testing of their Castone panels to determine the thermal differential movement under heating and cooling conditions. In addition any physical changes in the panels after exposure would be noted.

Sample Identification

ORTECH Sample Nos.	Sample Identification
93-J53-W0056A	Contraction Sample
93-J53-W0056B	Expansion Sample

Sample Description

The Castone panels were constructed by Castone and transported to ORTECH for testing. The panels are comprised of an outer cementitious layer, approximately 1 cm in thickness, which resembles stone in texture and appearance, a scrim cloth middle layer which provides structural strength and reinforcement, and a high density rigid polyurethane foam insulation of approximately 3.5 cm in thickness.

The samples were constructed of two panels mounted onto a plywood base and fastened with four screws. Each sample incorporated a joint mortared with Type-N mortar.

Test Program

Contraction Testing

The Castone panel was placed into a cold room set at -30°C, simulating winter temperatures, for a period of 96 hours. In order to determine the differential movement experienced by the system one gauge was mounted on the panel and another gauge mounted across the joint. An initial measurement was taken at a room temperature of 20.1°C. The final reading was taken at a room temperature of -30°C after the 96 hour period.

Expansion Testing

The Castone panel was placed into an oven set at 58°C, simulating summer temperatures, for a period of 96 hours. In order to determine the differential movement experienced by the system one gauge was mounted on the panel and another gauge mounted across the joint. An initial measurement was taken at a room temperature of 20.1°C. The final reading was taken at a room temperature of 58°C after the 96 hour period.

Test Results

Table 1 - Results of Expansion and Contraction Tests

	Contraction		Expansion	
	Panel	Joint	Panel	Joint
Initial value (mm)	244.01	92.93	230.82	113.22
Final value (mm)	243.79	92.43	230.97	113.56
Difference (mm)	-0.22	-0.50	0.15	0.34
% difference	-0.09	-0.50	0.06	0.30
coefficients of thermal exp./contr.	$1.8x10^{-5}$	$8.3x10^{-4}$	$1.7x10^{-5}$	$7.5x10^{-4}$

Conclusion

1) The greatest differential movement was experienced in the joints. The average values obtained for coefficient of thermal expansion/contraction were 1.8×10^{-5} for the panels and 7.9×10^{-4} for the joints. Hence the thermally induced differential movement will be minimal for field applications of the Castone panels.

2) There did not appear to be any physical deterioration of the panels following exposure to heating and cooling cycles.

THERMAL DURABILITY TESTING OF THE CASTONE PANEL SYSTEM

Introduction

At the request of Mr. Peter Goodings of Castone Industries Inc., ORTECH was contracted to conduct thermal durability testing on a full scale mock-up of the Castone panel building system.

Sample Identification

ORTECH Sample No. 93-J53-W0050B
Wall Dimensions: 1940 mm wide x 2400 mm high

Sample Description

The panels were constructed by Castone Industries and transported to ORTECH for testing. The panels are comprised of an outer cementitious layer, approximately 1 cm in thickness which resembles stone in texture and appearance, a scrim cloth middle layer which provides structural strength and reinforcement, and a high density rigid polyurethane foam insulation of approximately 3.5 cm in thickness.

The Castone system was installed by two Castone representatives into a wooden test buck constructed by ORTECH. The wall system is comprised of 2" x 4" wood studs placed at 16" centre-to-centre with plywood backing. Six Castone panels were screwed into the plywood backing, 2 panels wide and 3 panels high. In the joint areas 3/4" and/or 1" backerod was installed prior to mortaring with Type-N mortar.

The upper two panels were sealed with a water penetrating sealer.

Test Program

The full scale mock-up test wall was placed into the Environmental Chamber. The interior temperature was maintained at 20°C while the exterior temperature was cycled from -30°C to 20°C in 24 hour cycles over a period of 240 hours. The test program consisted of five (5) cycles where each cycle was comprised of 24 hours at 20°C and 24 hours at -30°C. The wall was then exposed to an exterior temperature of -30°C for an additional 24 hour period.

After each thermal cycle, the test wall was thermographically scanned using an IR camera to determine if any problems such as delamination or deterioration had occurred during and/or following testing. In addition if any problem areas were discovered during the test program, their progress would be monitored throughout the remainder of the test program.

Preliminary Observations

1) During the installation process a crack was discovered in the bottom right panel (3rd layer from the bottom, 3rd from the right) of the test wall. The crack appeared as a hairline fracture 87 mm in length. There was no visible surface damage, spalling or branching of the crack in the area.

2) After spraying of the upper panels with a water penetrating sealer, there was a noticeable initial change in the colour of the panels. After 2 days of curing the colour of the treated panels remained slightly darker than the untreated panels.

Test Results

See the Appendix 1 for the thermocouple locations and temperatures for cycles 1-5. In addition a bar chart illustrating the thermocouple temperatures over the five (5) cycles has been included.

As the bar chart in the Appendix 1 indicates, the thermocouple temperature readings were consistent throughout the test program. The thermocouples across the middle of the test wall (X4, X5, and X6) which were placed in the region of the plywood joint, showed consistently lower temperatures as did thermocouples X10, X11, and X12 which were located at the bottom edge of the test wall.

Thermographic Test Results and Interpretation

Figures 1a, 1b, 1c, and 1d are thermographic images taken of the test wall from the interior conditions side of the Environmental Chamber at a mid-scale temperature of 20°C for the shown colour display.

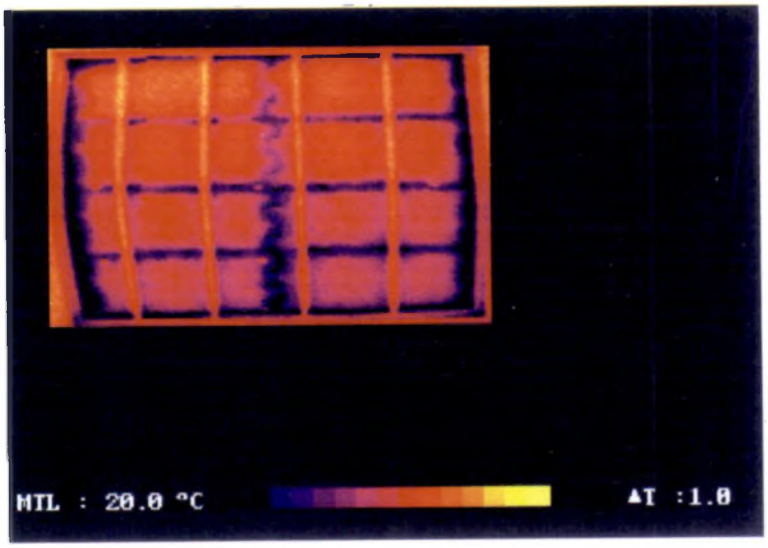

Figure 1a
September 20, 1993
Cycle 1

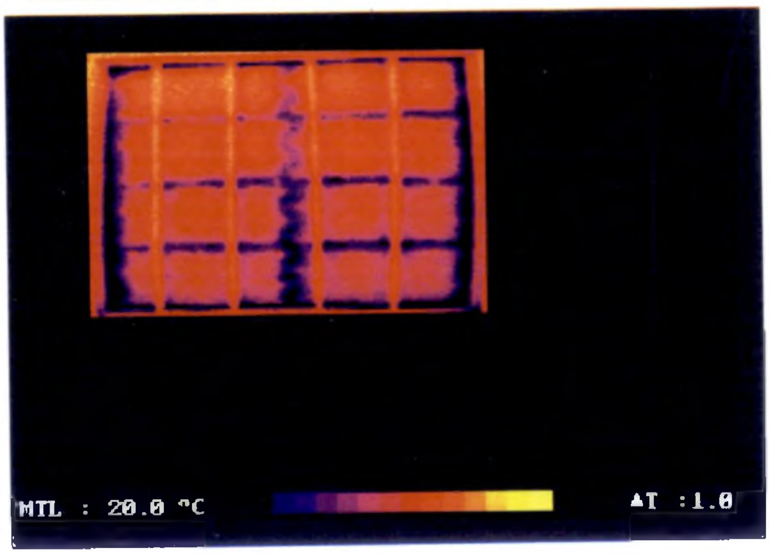

Figure 1b
September 22, 1993
Cycle 2

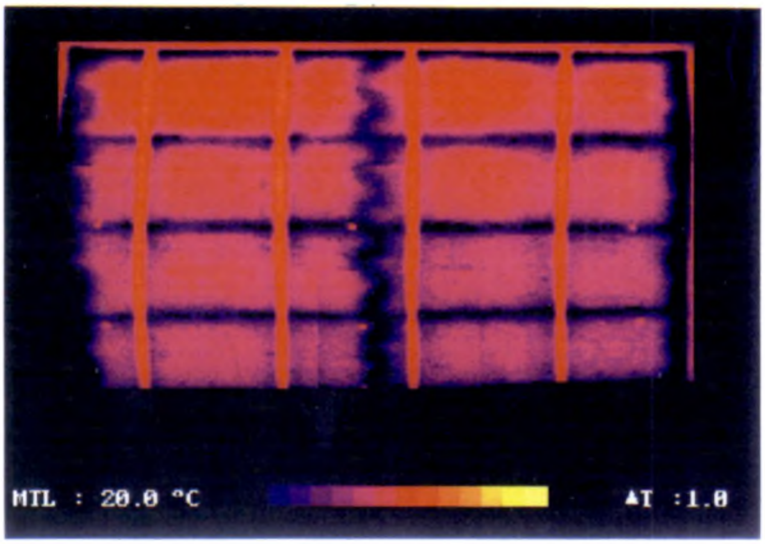

Figure 1c
September 24, 1993
Cycle 3

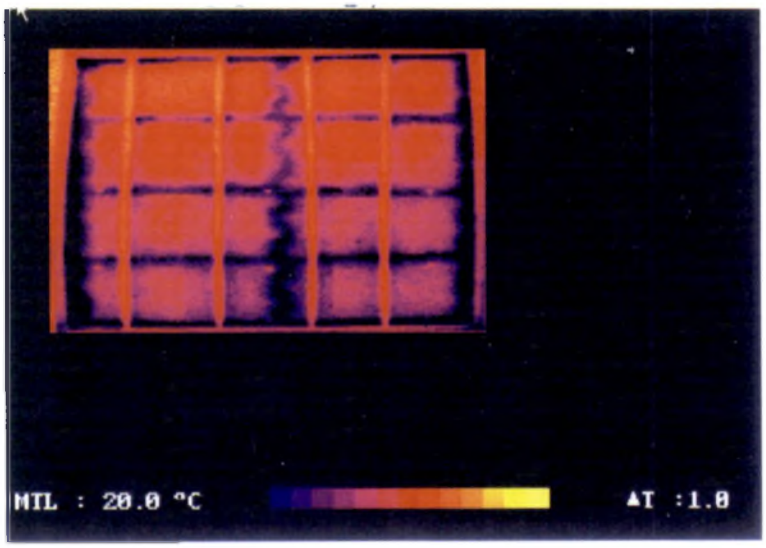

Figure 1d
September 28, 1993
Cycle 4

Interpretation

The Figure 1 images are actually composite images, made from nine (9) images taken from within the Environmental Chamber; the close confines of the chamber did not allow for a single-shot view of the wall. Due to limitations of the imaging software, the composite images are shown with a compressed vertical dimension; however, the temperature profiles remain accurate.

The vertical orange/yellow lines seen in Figures 1a, b, c, and d are the wood studs which are almost at room temperature. The large red rectangular portions of the thermographic images are of the insulated Castone panels. The Castone panels exhibit a relatively uniform surface temperature of 18°C at the bottom two panels to 21°C at the top two panels. Since the joints have uninsulated cavities, they are displaying cold characteristics, ranging from 11°C at the lowest regions of the cavity to 18°C near the top of the cavity. This wide range of stratified temperatures in the cavity is indicative of convective heat loss due to the unrestricted circulation of air within the cavity.

Over the four thermal cycles, the thermal signature of the wall system remains consistent, as is apparent from the four images of Figure 1.

The uniformity of heat transfer in each image, and of the images over time, indicates that the wall system has consistent thermal properties. No separation of the product from the plywood wall or degradation of the insulating quality of the materials occurred.

Figure 2 is a thermographic image taken of the test wall from the cold side on September 28, 1993, one minute after its removal from the Environmental Chamber (cycle 5).

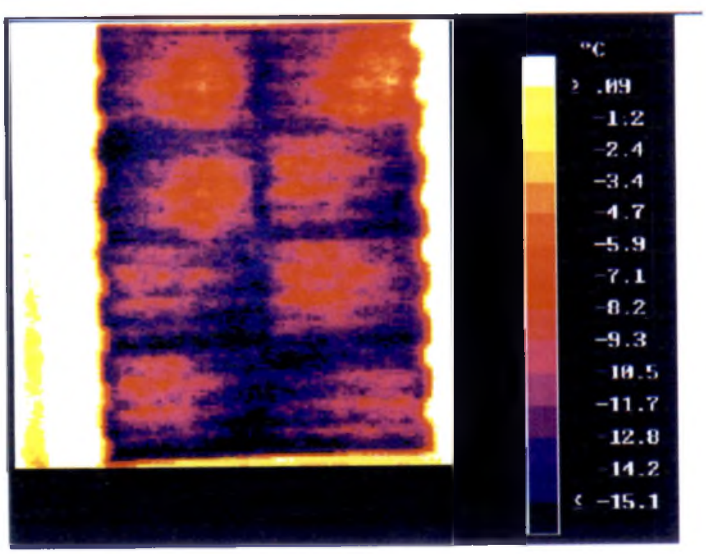

Figure 2

Interpretation

The thermographic image shown in Figure 2 is taken of the cold side of the wall, one minute after the end of the last thermal cycle, where it had been maintained at -30°C.

The wall system was separated from the Environmental Chamber so that a single-shot image of the wall could be recorded.

The centre of the panels show uniform warming during the one minute exposure to room temperature; the surface of the stone warms quickly where the insulation is present. The joint areas remain cold (approximately 15°C colder than in the centre of the panels) as they radiate heat at a high rate due to lack of insulation.

The uniform and relatively high temperature of the surface of the panels after brief exposure to room temperature is indicative of good bonding between the stone surface and its underlying insulation. The cold joint areas are indicative of poor thermal properties, ie. lack of insulation at the joints.

Final Observations

1) The crack which was noted during installation did not lengthen or exhibit any changes such as spalling or branching, following the test program.

2) Following testing the two upper panels which were sprayed with a water penetrating sealer remained unchanged in colour from the start of the test program, ie. slightly darker than the unsprayed portion of the test wall.

3) No spalling or cracking was observed in the test wall following the test program.

Conclusions

1) The thermocouples positioned in the middle section of the wall indicate that the joint areas are colder than the panels which is in agreement with the thermographic images.

2) Typical convective heat loss characteristics, cooler at the bottom and warmer at the top, are displayed by the test wall in both the thermocouple bar chart (see Appendix 1) and the thermographic images.

3) Physical deterioration of the test wall due to thermal cycling does not appear to be a concern.

4) No delamination of materials was apparent in the test wall. The thermal performance of the Castone wall system would improve if an insulating material was incorporated into the design of the joints during manufacturing, or if an appropriate insulating material was applied during its installation.

AIR LEAKAGE, WATER LEAKAGE AND WIND LOAD RESISTANCE TESTING

Introduction

At the request of Mr. Peter Goodings of Castone Industries Inc., ORTECH was contracted to conduct air leakage, water leakage and wind load resistance testing on their Castone system in accordance with the following ASTM standards:

ASTM E283: Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors

ASTM E547: Water Penetration of Exterior Window, Curtain Walls, and Doors by Cyclic Static Air Pressure Differential

ASTM E330: Structural performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference

Sample Identification

ORTECH Sample No. 93-1J53-W0050A
Wall Dimensions: 1940 mm wide x 2400 mm high

Sample Description

The panels were constructed by Castone Industries and transported to ORTECH for testing. The panels are comprised of an outer cementitious layer, approximately 1 cm in thickness which resembles stone in texture and appearance, a scrim cloth middle layer which provides structural strength and reinforcement, and a high density rigid polyurethane foam insulation of approximately 3.5 cm in thickness.

The Castone system was installed into a wooden test buck constructed by ORTECH. The wall system is comprised of 2" x 4" wood studs placed at 16" centre-to-centre with plywood backing. Six Castone panels were screwed into the plywood backing, 2 panels wide and 3 panels high.

The testing was conducted in two stages; the test wall was tested first for wind load resistance (see ORTECH Report No. 93-J53-B0785) and then following non-structural modifications it was retested for air and water leakage. For the wind load resistance testing the joints were filled and finished with a one-component, high-performance, polyurethane sealant and the upper two panels were sealed with a water penetrating sealer. For the air and water leakage testing the joints were filled with a one-component, high-performance, polyurethane sealant and then finished with a layer of the cementitious material. Then the entire test wall was sealed with a water repellent sealant which was applied with a hand sprayer.

Test Results

Table 2 - Air Leakage Test Results

ASTM E283

November 25, 1993

Temperature 22°C: RH 34%: Barometric Pressure 100.5 KPa

Pressure (Pa)	Air Leakage (L/s)
25	negligible
75	negligible
200	0.001
400	0.001
500	0.001

Re-Test at 75 Pa

Pressure (Pa)	Air Leakage (L/s)
75	negligible

Comments

All the leaks that were present in the wooden test buck were resealed with silicone and using Leak Tec any leaks discovered in the joints and perimeter were sealed. The air leakage was so minimal that readings were taken where attainable.

Table 3 - Water Leakage Test Results

ASTM E547

November 25, 1993

Temperature 22°C: RH 34%: Barometric Pressure 100.5 KPa

Cycles (minutes)		Pressure (Pa)						
DP + H_2O	H_2O	150	200	250	400	500	600	700
0-5		Pass	Pass	Pass	Pass	Pass	Pass	Pass
	5-6	Pass	Pass	Pass	Pass	Pass	Pass	Fail
6-11		Pass	Pass	Pass	Pass	Pass	Pass	
	11-12	Pass	Pass	Pass	Pass	Pass	Pass	
12-17		Pass	Pass	Pass	Pass	Pass	Pass	
	17-18	Pass	Pass	Pass	Pass	Pass	Pass	
18-23		Pass	Pass	Pass	Pass	Pass	Pass	
	23-24	Pass	Pass	Pass	Pass	Pass	Pass	

Comments

All the leaks that were present in the wooden test buck were resealed with silicone and using Leak Tec any leaks discovered in the joints and perimeter were sealed.

Table 4 - Wind Load Resistance Test Results*

ASTM E330

September 28, 1993

Temperature 20.5°C: RH 52%: Barometric Pressure 99.1 KPa

Horizontal Deflection

L=1940 mm; Maximum Allowable Deflection = L/175 = 11.086 mm**

Pressure (Pa)	Left (Deflection (mm))	Middle (Deflection (mm))	Right (Deflection (mm))	Net Deflection (mm)
-500	0.211	1.484	0.187	1.285
+500	0.323	2.379	0.330	2.057
-750	0.366	2.827	0.357	2.465
+750	0.598	4.446	0.596	3.849
-1200	0.701	5.322	0.683	4.630
+1200	1.115	8.763	1.136	7.637
-1600	1.041	7.742	1.009	6.717
+1600	1.672	13.505	1.760	10.789
-2000	1.385	10.205	1.335	8.845
+2000	2.177	16.217	2.366	13.945
+2250	Cracks appear in the mortared joints			

Vertical Deflection

L=2400 mm; Maximum Allowable Deflection = L/175 = 13.714 mm**

Pressure (Pa)	Top (Deflection (mm))	Middle (Deflection (mm))	Bottom (Deflection (mm))	Net Deflection (mm)
-500	0.226	1.484	0.121	1.310
+500	0.336	2.379	0.160	2.131
-750	0.432	2.827	0.226	2.498
+750	0.638	4.446	0.316	3.969
-1200	0.818	5.322	0.440	4.693
+1200	1.207	8.763	0.660	7.829
-1600	1.182	7.742	0.638	6.832
+1600	1.948	13.505	1.109	11.976
-2000	1.526	10.205	0.885	9.000
+2000	2.669	16.217	1.680	14.042
+2250	Cracks appear in the mortared joints			

* Please note that this data has been excerpted from ORTECH Report No. 93-J53-B0785.

** Assumed maximum allowable deflection.

Comments

Based upon the assumed maximum allowable deflection the test wall performed well to an applied pressure of ±1600 Pa (approximately equivalent to a wind speed of 186 km/h). See Appendix 2 for deflection chart.

Conclusion

The Castone wall system performed very well in resistance to air leakage, water leakage and wind load resistance. The only problem area remaining is the sealing of the joints. The present system appears to function adequately, but extreme care must be taken during installation and this is not appropriate for field application procedures.

Recommendation

In order to improve the system an alternate method of sealing the joints must be determined. If the joints cannot be well sealed then a different approach such as weep holes should be implemented into the system.

WATER PENETRATION TESTING

Introduction

At the request of Mr. Marcus Colgan of Castone Industries Inc., ORTECH was contracted to conduct water penetration testing on the Castone panels.

Sample Identification

ORTECH Sample Nos.	Sample Identification
93-1J53-W0056-2I	Water Penetration Sample

Sample Description

The Castone panels were constructed by Castone and transported to ORTECH for testing. The panels are comprised of an outer cementitious layer, approximately 1 cm in thickness, which resembles stone in texture and appearance, a scrim cloth middle layer which provides structural strength and reinforcement, and a high density rigid polyurethane foam insulation of approximately 3.5 cm in thickness.

Test Program

A cylinder 1000 mm in height and 37 mm (1.5") in inner diameter was sealed with silicone onto the surface of a sample of Castone panel and filled to a height of two (2) feet with water which was colour treated for easy identification. The system was observed over a twenty-five (25) day period to determine if the water penetrated the surface of the sample and/or was absorbed into the sample. Following the test period the sample was cut apart to determine if the water penetration had occurred.

Test Results

1) The water did not penetrate the surface of the panel.

2) The panel did not absorb any water.

Conclusions

Water penetration and/or water absorption through the surface of the Castone panel is not a concern.

FREEZE-THAW TESTING

Introduction

At the request of Mr. Peter Goodings of Castone Industries Inc., ORTECH was contracted to conduct freeze-thaw testing in accordance with the ASTM C666-92: "Standard Test Method for Resistance of Concrete To Rapid Freezing and Thawing: Procedure B" on a Castone test sample.

Sample Identification

ORTECH Sample No.	Sample Identification
93-J53-P0119	Freeze-Thaw Sample

Sample Description

The panels were constructed by Castone and transported to ORTECH for testing. The panels are comprised of an outer cementitious layer, approximately 1 cm in thickness, which resembles stone in texture and appearance, a scrim cloth middle layer which provides structural strength and reinforcement, and a high density rigid polyurethane foam insulation of approximately 3.5 cm in thickness.

The test sample is comprised of two panel sections mounted onto a plywood substructure with a joint in the centre. The joint is filled with a one-component, high-performance, polyurethane sealant and finished with a layer of cementitious material. The test sample was sealed with a water repellent sealer which was applied with a hand sprayer.

Sample Preparation

Under normal application conditions only the face of the Castone panels would be subjected to moisture exposure. Therefore in order to simulate actual on-site conditions the sides of the panels and the plywood substrate were sealed with silicone to prevent the penetration of water from the sides and the back.

Test Program

The test sample was placed into the automated freeze-thaw chamber for 50 freeze-thaw cycles. Due to the nature of the application of this product as a building cladding material, under normal applications it would not be subjected to immersion in water. Therefore the following modification was made to the test method to reflect this. In the place of immersion in water, the face of the test sample was exposed to 18 minutes of continuous water spray. The panel was placed at an angle in the test chamber to allow the water to flow unrestricted across the test sample.

The cycling diagram, which is included in the Appendix 3, is based upon the requirement of the ASTM C666 Standard: Procedure B.

Test Results and Observations

1) There was no evidence of cracking or spalling in either the panels or the joint following the freeze-thaw cycling program.

2) The joint in the panels remained slightly darker in colour than the moulded panel joints.

Conclusion

The cyclic freeze-thaw testing conducted did not cause any damage to the panels. Hence cyclic freezing and thawing of the panels in field applications should not be a concern.

IMPACT RESISTANCE TESTING

Introduction

At the request of Mr. Peter Goodings of Castone Industries Inc., ORTECH was contracted to conduct impact resistance testing of their Castone panels in accordance with ASTM D2794-92 Standard, "Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)".

Sample Identification

ORTECH Sample No.	Sample Identification
94-J23-C0034	4" x 4" blocks of Castone panels

Sample Description

The Castone panels were constructed by Castone and transported to ORTECH for testing. The panels are comprised of an outer cementitious layer, approximately 1 cm in thickness, which resembles stone in texture and appearance, a scrim cloth middle layer which provides structural strength and reinforcement, and a high density rigid polyurethane foam insulation of approximately 3.5 cm in thickness.

Test Program

The impact resistance test was conducted using a Gardner impact tester, which is a cylindrical two pound weight with a 0.625 inch diameter indenter punch. The impact resistance values of seven specimens were measured at 1, 1.5 and 2 foot·pound (ft·lbs) levels.

Test Results

1) The specimens did not exhibit any cracking at the 1 ft·lbs (1.36 J) level.

2) The specimens did not exhibit any cracking at the 1.5 ft·lbs (2.03 J) level.

3) The specimens did exhibit hairline cracking at the 2 ft·lbs (2.71 J) level and testing was terminated.

Conclusion

Since there is no present standard for the Castone panels, for comparative purposes only the results of this test will be evaluated to the technical requirements for "CCMC's Technical Guide for Reinforced, Cementitious Board Masterformat Section: 03560". Please note that CCMC has not designated this technical guide as the appropriate applicable reference for the Castone panels.

"The products proposed for exterior installations as sheathing with such protective finish as a thin coat system, ceramic tile, or other evaluated finishes are required to exhibit no damage to top or bottom" following impact from a steel ball (0.534 kg) released from a height of 300 mm. The energy at impact is equivalent to 1.57 J and the Castone panels exceed this requirement.

TENSILE TESTING

Introduction

At the request of Mr. Peter Goodings of Castone Industries Inc., ORTECH was contracted to conduct tensile testing of their Castone panel system in order to determine the bond interface strength of the cementitious layer to the high density rigid polyurethane foam insulation. The samples were tested following exposure to several different conditioning situations, following normal curing, to determine if deterioration in the bond interface strength occurs.

Sample Identification

ORTECH Sample No.	Sample Conditioning
93-J53-W0056-2A 93-J53-W0056-2B 93-J53-W0056-2C 93-J53-W0056-2D	Heat aged for 48 hours at 50°C
93-J53-W0056-30A 93-J53-W0056-30B 93-J53-W0056-30C 93-J53-W0056-30D	Cooled for 48 hours at -30°C
93-J53-W0050-A1 93-J53-W0050-A2 93-J53-W0050-A3 93-J53-W0050-A4	50% relative humidity
93-J53-W0050-A5 93-J53-W0050-A6 93-J53-W0050-A7 93-J53-W0050-A8	No conditioning
93-J53-W0050-A9 93-J53-W0050-A10 93-J53-W0050-A11 93-J53-W0050-A12	99% relative humidity and 30°C

ORTECH Sample No.	Sample Conditioning
93-J53-W0050-A13 93-J53-W0050-A14 93-J53-W0050-A15 93-J53-W0050-A16	Immersed completely in water
93-J53-P00119-1 93-J53-P00119-2 93-J53-P00119-3 93-J53-P00119-4	Freeze-thaw exposure

Sample Description

The Castone panels were constructed by Castone and transported to ORTECH for testing. The panels are comprised of an outer cementitious layer, approximately 1 cm in thickness, which resembles stone in texture and appearance, a scrim cloth middle layer which provides structural strength and reinforcement, and a high density rigid polyurethane foam insulation of approximately 3.5 cm in thickness.

Test Program

Four specimens 12.5 cm x 12.5 cm were prepared for each conditioning situation. The surface of the specimens were leveled by the addition of an epoxy resin and then bonded with an epoxy cement to 12.5 mm thick plywood plates. The specimens were then mounted in the Instron and the strength at break recorded.

Test Results

Table 5- Tensile Bond Strength Results

Sample No.	Strength at Break (kPa)	Type of Failure
93-J53-W0056-2A	163.2	100% adhesive
93-J53-W0056-2B	123.5	100% adhesive
93-J53-W0056-2C	244.5	80% adhesive and 20% cohesive
93-J53-W0056-2D	315.0	100% adhesive
Average	211.6	
93-J53-W0056-30A	151.7	70% adhesive and 30% cohesive
93-J53-W0056-30B	48.3*	50% adhesive and 50% cohesive
93-J53-W0056-30C	242.5	plywood
93-J53-W0056-30D	232.8	plywood
Average	168.8	
93-J53-W0050-A1	275.2	100% adhesive
93-J53-W0050-A2	287.2	plywood
93-J53-W0050-A3	359.7	plywood
93-J53-W0050-A4	174.9	100% adhesive
Average	274.3	
93-J53-W0050-A5	264.7	100% adhesive
93-J53-W0050-A6	200.7	plywood
93-J53-W0050-A7	203.9	plywood
93-J53-W0050-A8	217.2	plywood
Average	221.6	
93-J53-W0050-A9	236.3	plywood
93-J53-W0050-A10	209.0	100% cohesive foam
93-J53-W0050-A11	303.6	100% adhesive
93-J53-W0050-A12	275.7	100% adhesive
Average	256.2	
93-J53-W0050-A13	273.0	plywood
93-J53-W0050-A14	290.4	plywood
93-J53-W0050-A15	248.4	100% adhesive
93-J53-W0050-A16	198.2	plywood
Average	252.5	
93-J53-P00119-1	197.7	100% adhesive
93-J53-P00119-2	309.9	plywood
93-J53-P00119-3	294.9	100% adhesive
93-J53-P00119-4	239.2	100% adhesive
Average	260.4	

* This value appears to be an anomaly.

Conclusions

1) The average strength at break for all the specimens tested was 235.1 kPa.

2) The different conditioning situations do not indicate any trending patterns in the bond interface strength of the cementitious layer to the high density rigid polyurethane foam insulation. Once the Castone panel is cured the bond interface strength does not appear to be effected by temperature or humidity. Hence the bond interface strength is determined during the manufacturing stage.

For comparison purposes, according to the National Building Code of Canada (NBC) 1990, the maximum expected pressure acting on the leeward wall of a residential type dwelling (ie. suction pressure) is -0.7 of the acting wind pressure. The following table shows the hourly wind pressures which occur once in every 100 years of some major Canadian cities and the corresponding maximum leeward pressure.

Table 6 - Wind Pressures

City	Hourly Wind Pressure* once in 100 years (kPa)	Corresponding Leeward Pressure (kPa)
Vancouver, BC	0.67	0.39
Regina, Sask	0.46	0.32
Toronto, Ontario	0.58	0.41
Montreal, Quebec	0.44	0.31
Halifax, NS	0.67	0.47

* From the Supplement to the National Building Code of Canada 1990

The values obtained during testing for bond interface strength at break greatly exceed the leeward pressure values expected due to wind pressure.

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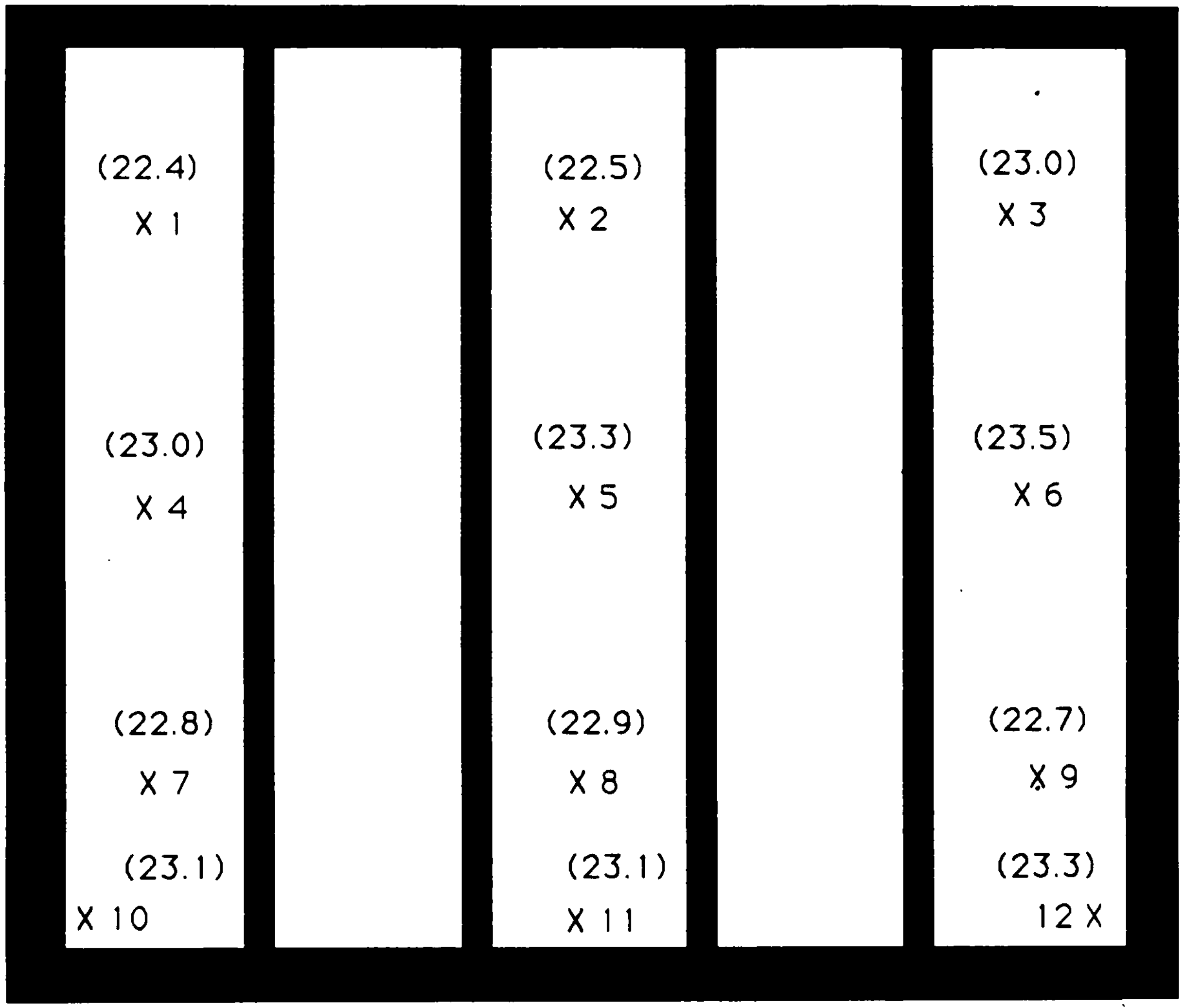
APPENDIX 1

(11 Pages)

Thermocouple Locations and
Bar Chart

CASTONE WALL--SYSTEM

CYCLE# 1 WARM(24Hr)



THERMOCOUPLE LOCATION

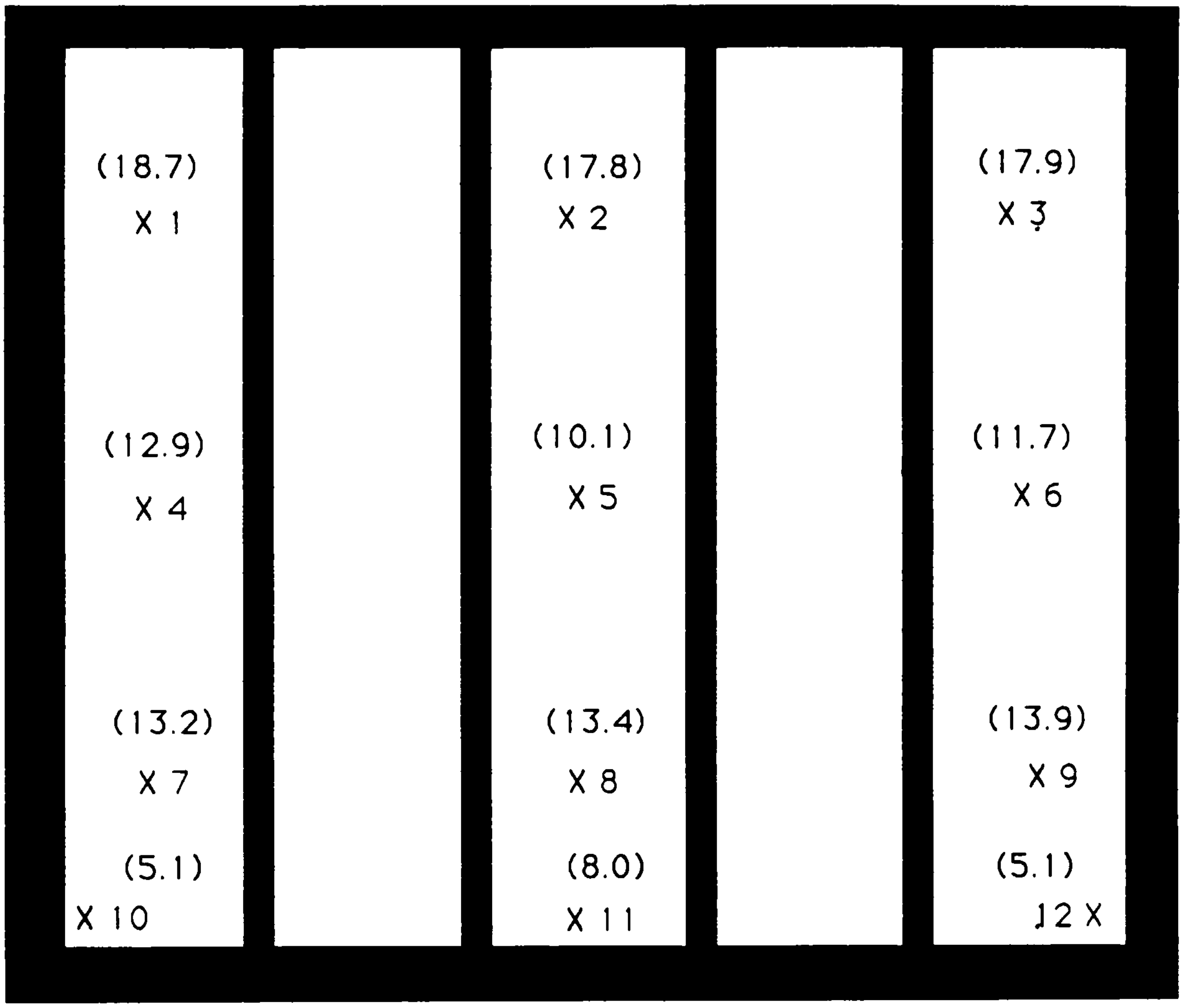
TEMPERATURES IN °C

T1= 22.4	T7= 22.8
T2= 22.5	T8= 22.9
T3= 23.0	T9= 22.7
T4= 23.0	T10=23.1
T5= 23.3	T11=23.1
T6= 23.5	T12=23.3

COLD-SIDE 28.77 WARM-SIDE 22.55

CASTONE WALL--SYSTEM

CYCLE#1 COLD(24Hr) Total Time=48Hrs



THERMOCOUPLE LOCATION

TEMPERATURES IN °C

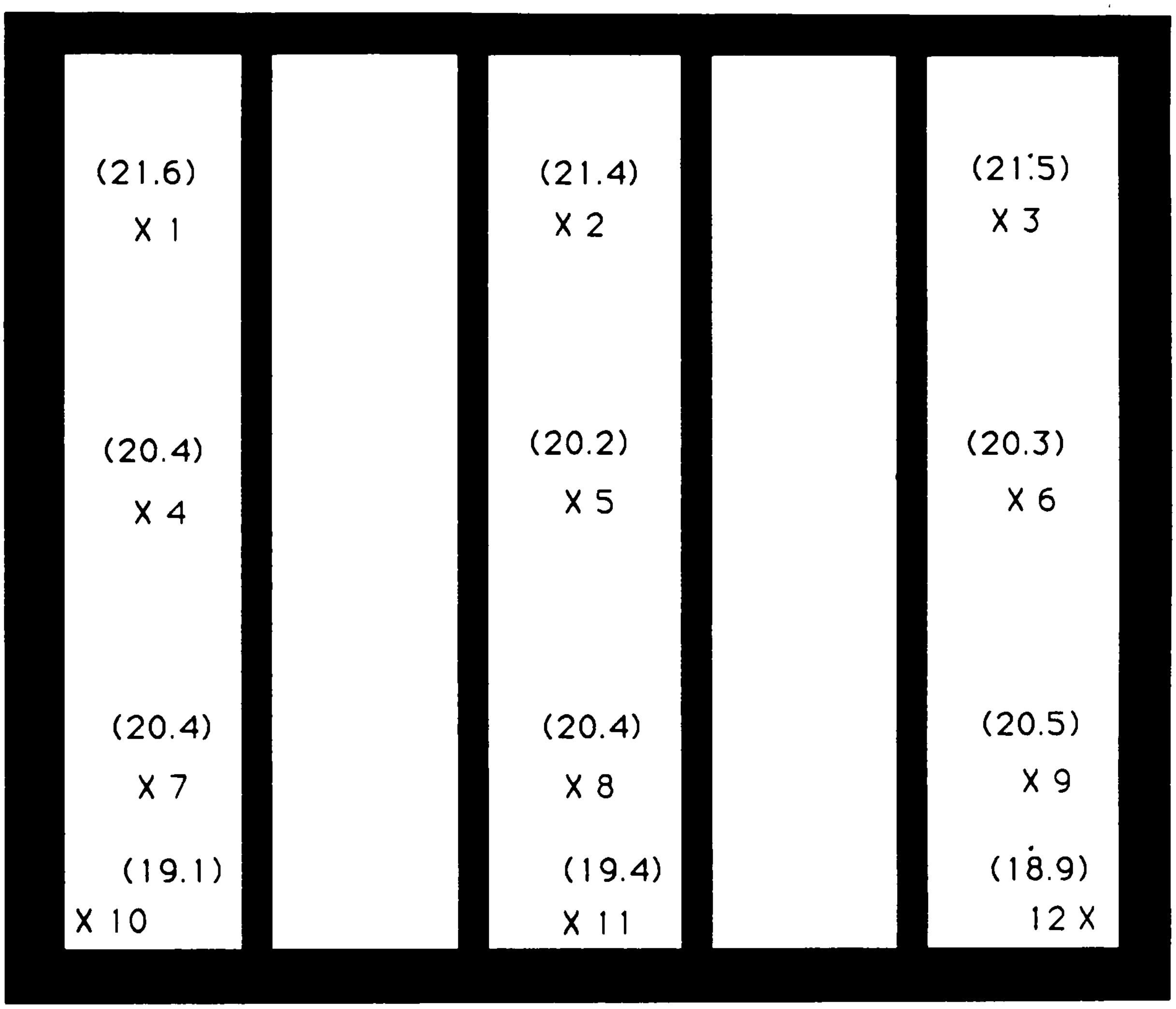
T1= 18.7	T7= 13.2
T2= 17.8	T8= 13.4
T3= 17.9	T9= 13.9
T4= 12.9	T10=5.1
T5= 10.1	T11=8.0
T6= 11.7	T12=5.1

COLD-SIDE -30.6 WARM-SIDE +20.7

ORTECH

CASTONE WALL--SYSTEM

CYCLE#2 WARM(24Hr) Total Time=72Hrs



THERMOCOUPLE LOCATION

TEMPERATURES IN °C

T1= 21.6
T2= 21.4
T3= 21.5
T4= 21.4
T5= 20.2
T6= 20.3

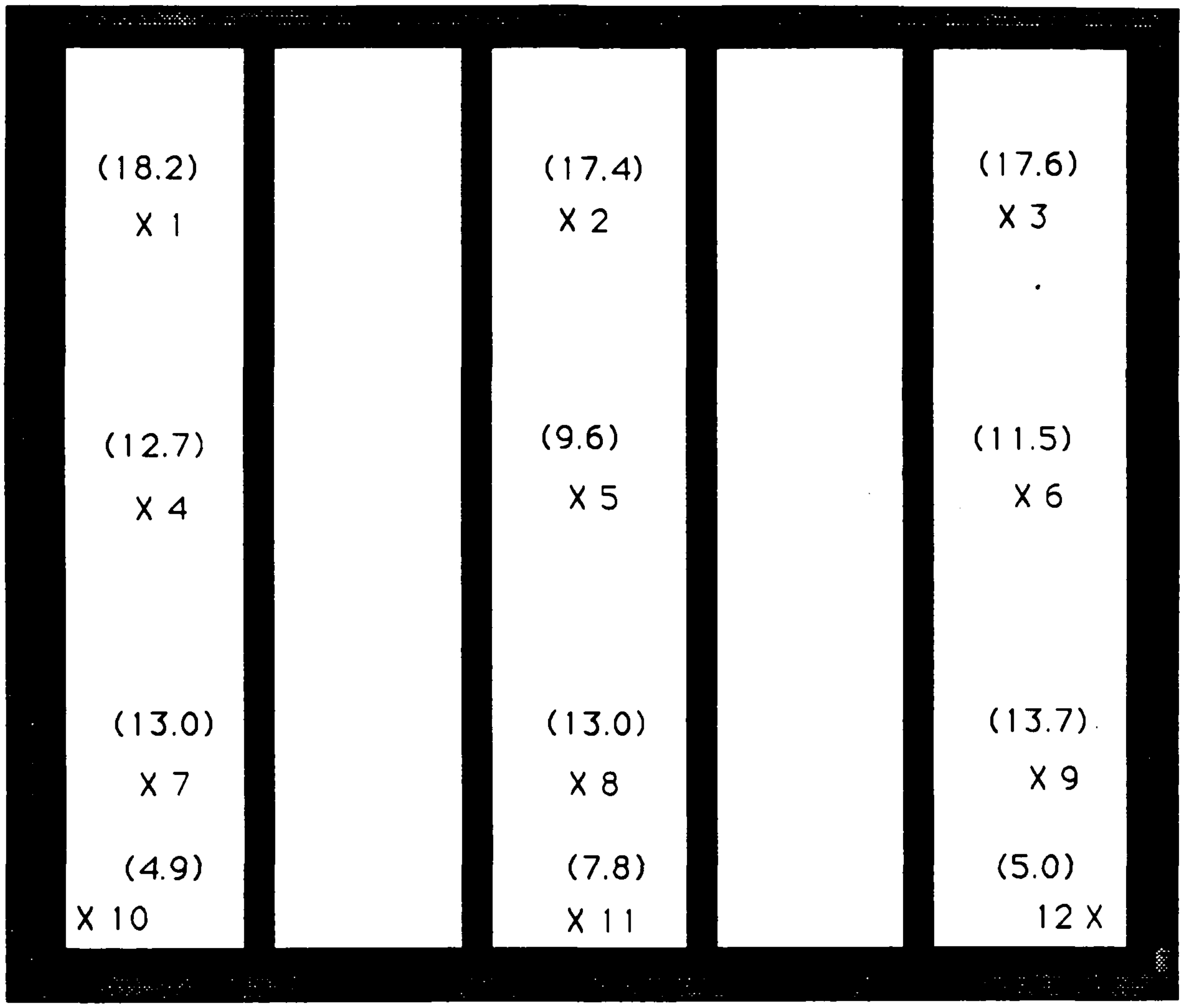
T7= 20.4
T8= 20.4
T9= 20.5
T10=19.1
T11=19.4
T12=18.9

COLD-SIDE 16.7

WARM-SIDE +21.5

CASTONE WALL--SYSTEM

CYCLE#2 COLD(24Hr) Total Time=96Hrs



THERMOCOUPLE LOCATION

TEMPERATURES IN °C

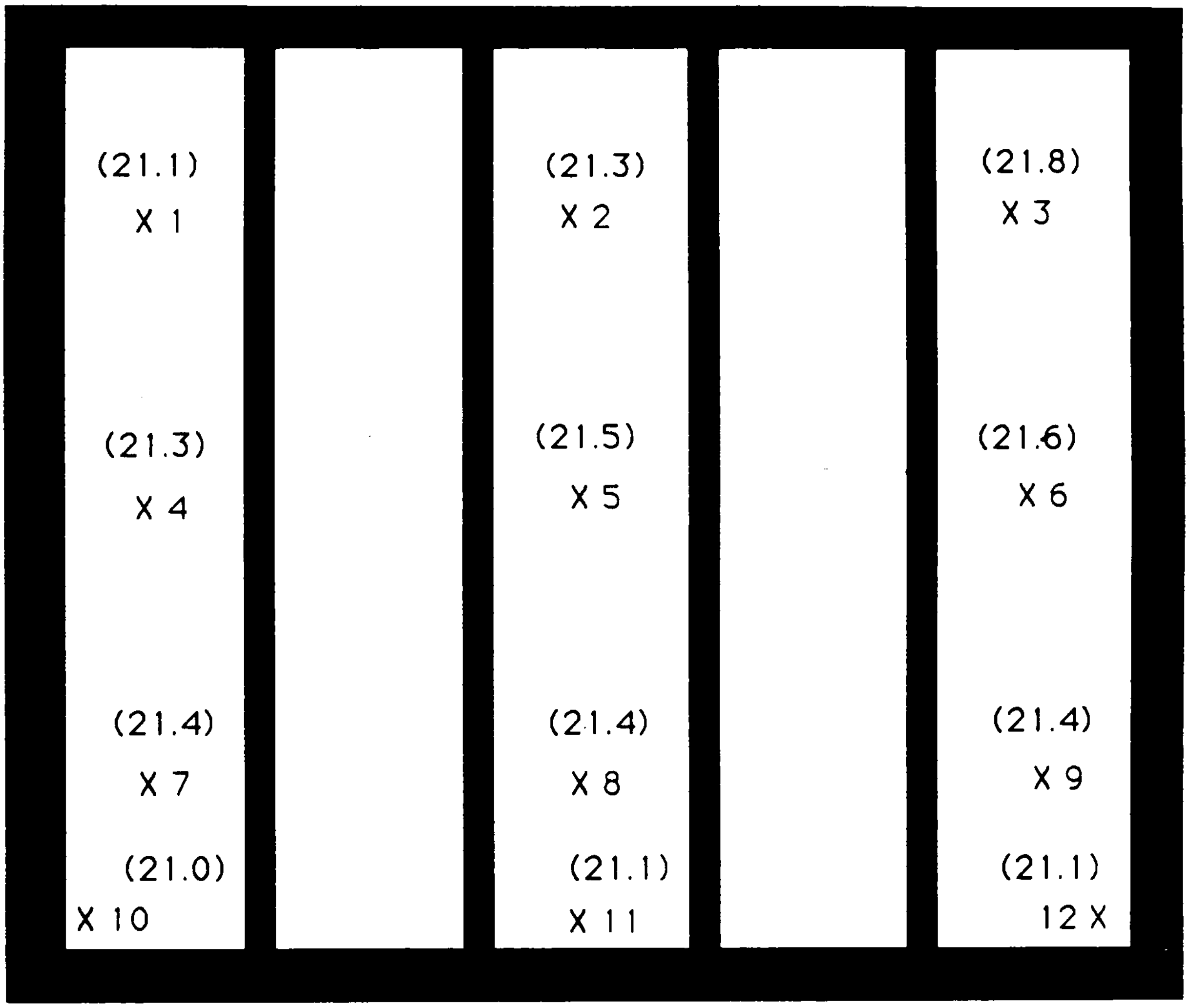
T1= 18.2	T7= 13.0
T2= 17.4	T8= 13.0
T3= 17.6	T9= 13.7
T4= 12.7	T10=4.9
T5= 9.6	T11=7.8
T6= 11.5	T12=5.0

COLD-SIDE -30.6 WARM-SIDE +20.1

ORTECH

CASTONE WALL--SYSTEM

CYCLE#3 WARM(24Hr) Total Time=120Hrs



THERMOCOUPLE LOCATION

TEMPERATURES IN °C

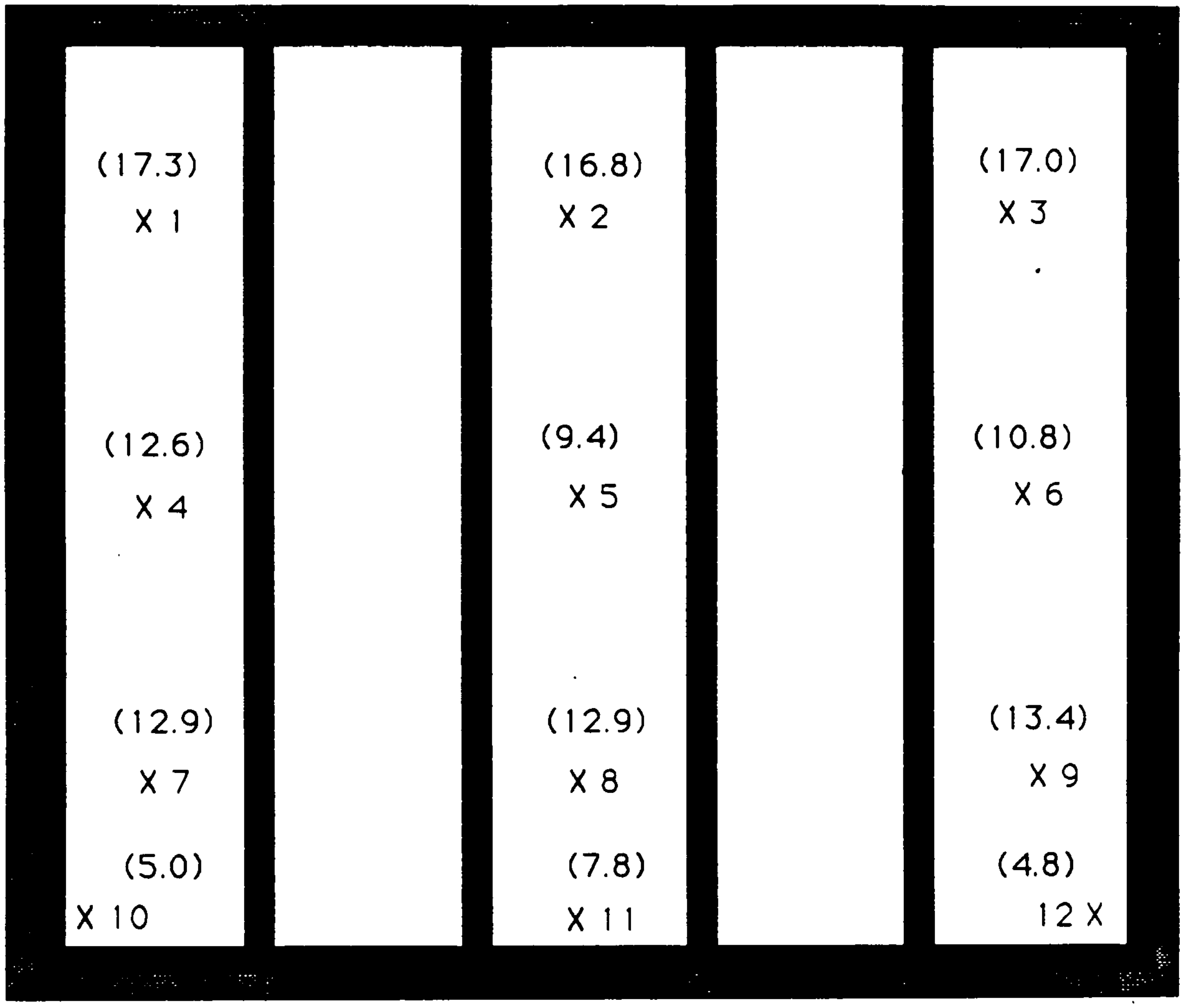
T1= 21.1	T7= 21.4
T2= 21.3	T8= 21.4
T3= 21.8	T9= 21.4
T4= 21.3	T10=21.0
T5= 21.5	T11=21.1
T6= 21.6	T12=21.1

COLD-SIDE +22.5 WARM-SIDE +21.2

ORTECH

CASTONE WALL--SYSTEM

CYCLE#3 COLD(24Hr) Total Time=144Hrs



THERMOCOUPLE LOCATION

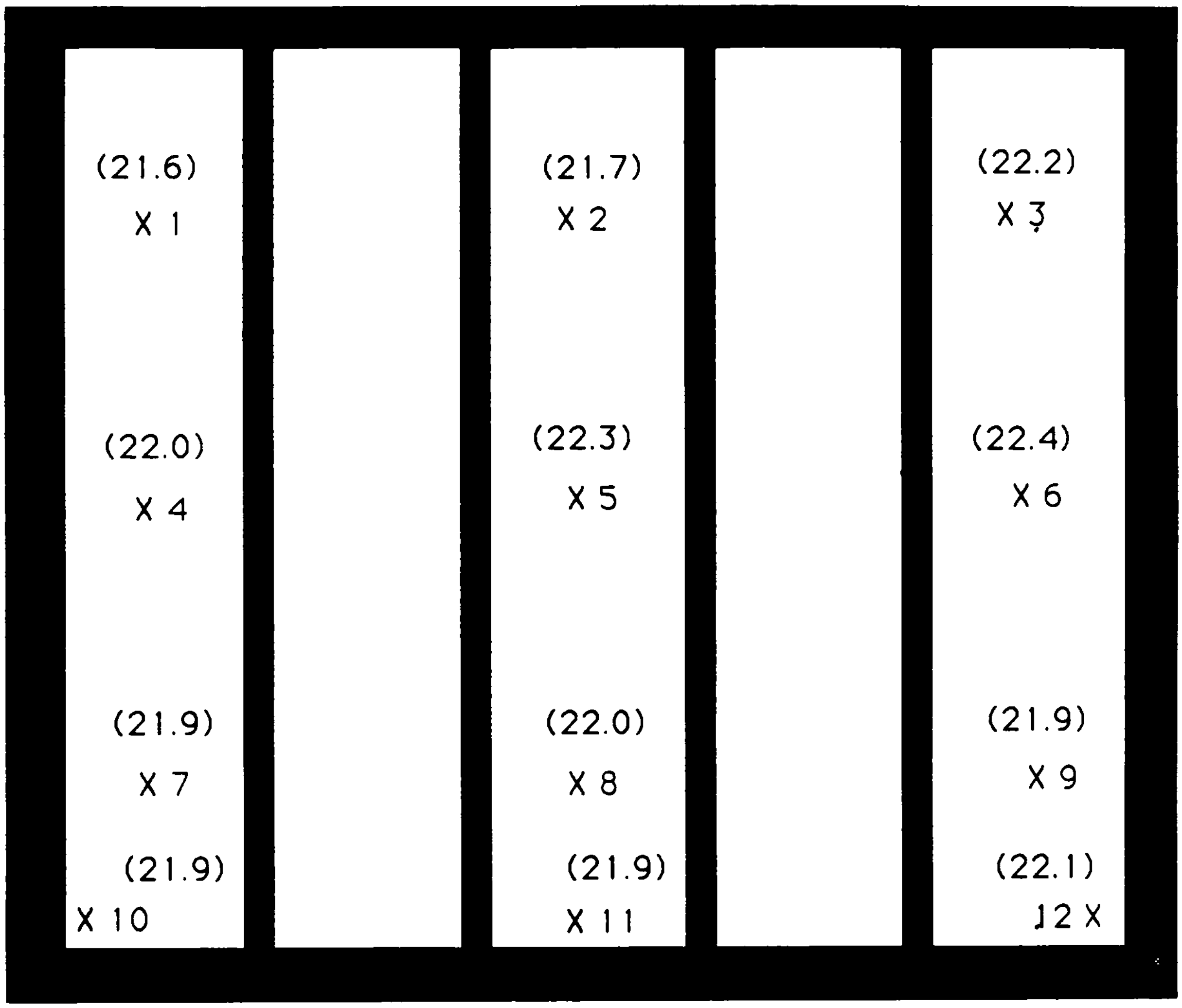
TEMPERATURES IN °C

T1= 17.3	T7= 12.9
T2= 16.8	T8= 12.9
T3= 17.0	T9= 13.4
T4= 12.6	T10=5.0
T5= 9.4	T11=7.8
T6= 10.8	T12=4.8

COLD-SIDE -30.5 WARM-SIDE +20.2

CASTONE WALL--SYSTEM

CYCLE#4 WARM(24Hr) Total Time=168Hrs



THERMOCOUPLE LOCATION

TEMPERATURES IN °C

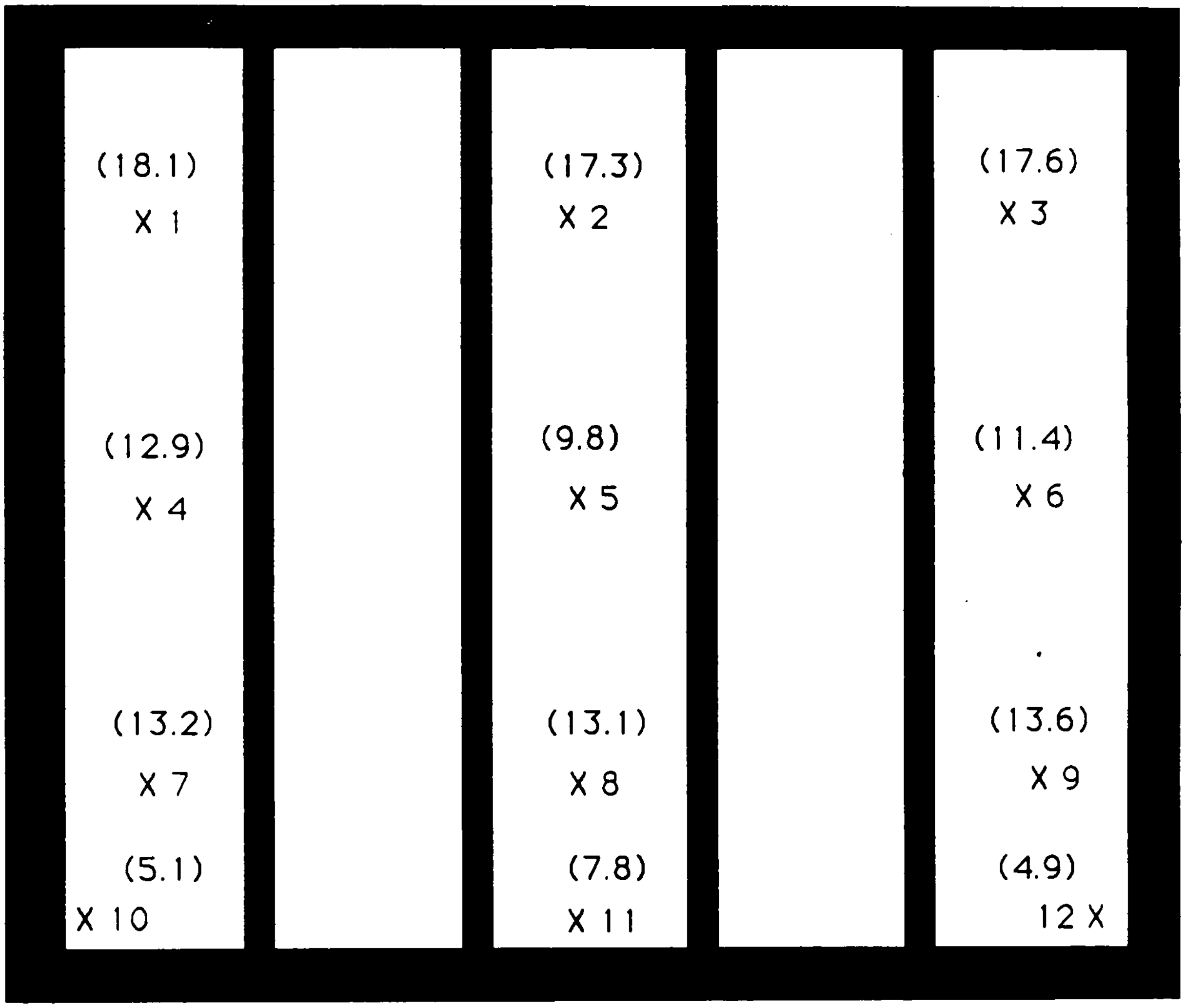
T1= 21.6	T7= 21.9
T2= 21.7	T8= 22.0
T3= 22.2	T9= 21.9
T4= 22.0	T10=21.9
T5= 22.3	T11=21.9
T6= 22.4	T12=22.1

COLD-SIDE +25.2 WARM-SIDE +21.4

ORTECH

CASTONE WALL--SYSTEM

CYCLE#4 COLD(24Hr) Total Time= 192Hrs



THERMOCOUPLE LOCATION

TEMPERATURES IN °C

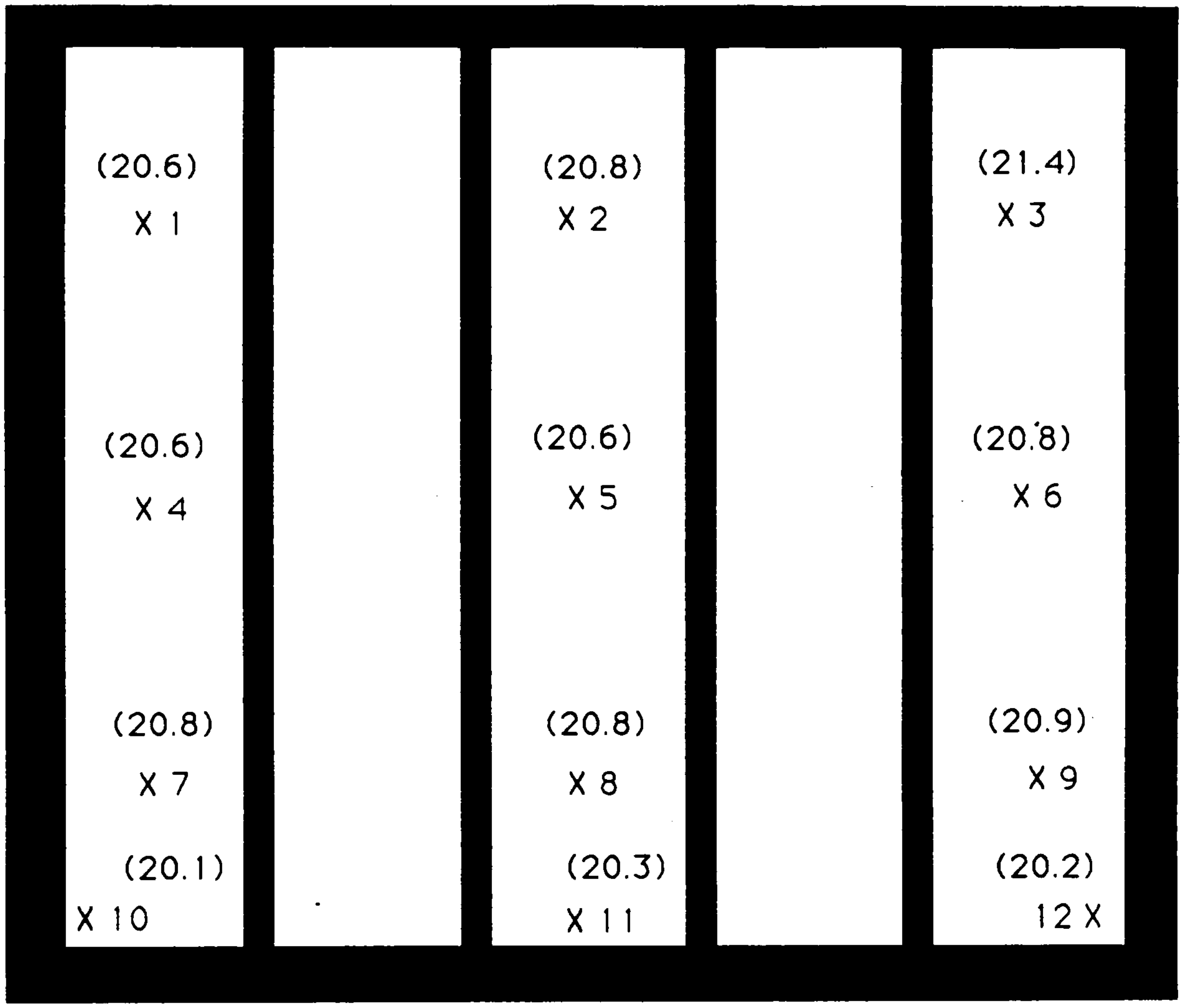
T1= 18.1	T7= 13.2
T2= 17.3	T8= 13.1
T3= 17.6	T9= 13.6
T4= 12.9	T10=5.1
T5= 9.8	T11=7.8
T6= 11.4	T12=4.9

COLD-SIDE -30.3 WARM-SIDE +20.0

ORTECH

CASTONE WALL--SYSTEM

CYCLE#5 WARM(24Hr) Total Time=216Hrs



THERMOCOUPLE LOCATION

TEMPERATURES IN °C

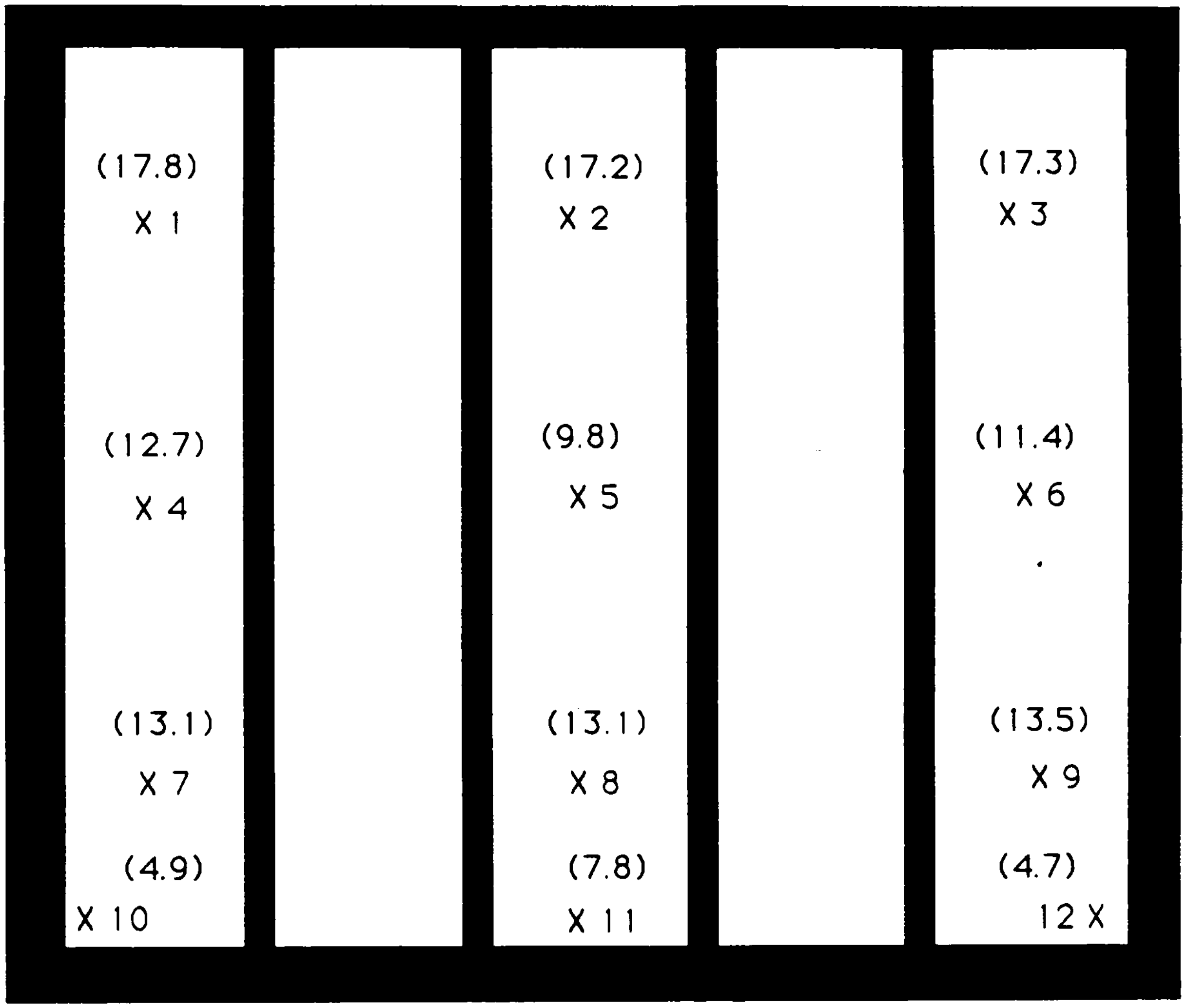
T1= 20.6
T2= 20.8
T3= 21.4
T4= 20.6
T5= 20.6
T6= 20.8
T7= 20.8
T8= 20.8
T9= 20.9
T10=20.1
T11=20.3
T12=20.2

COLD-SIDE +19.6

WARM-SIDE +21.2

CASTONE WALL--SYSTEM

CYCLE#5 COLD(24Hr) Total Time= 240Hrs



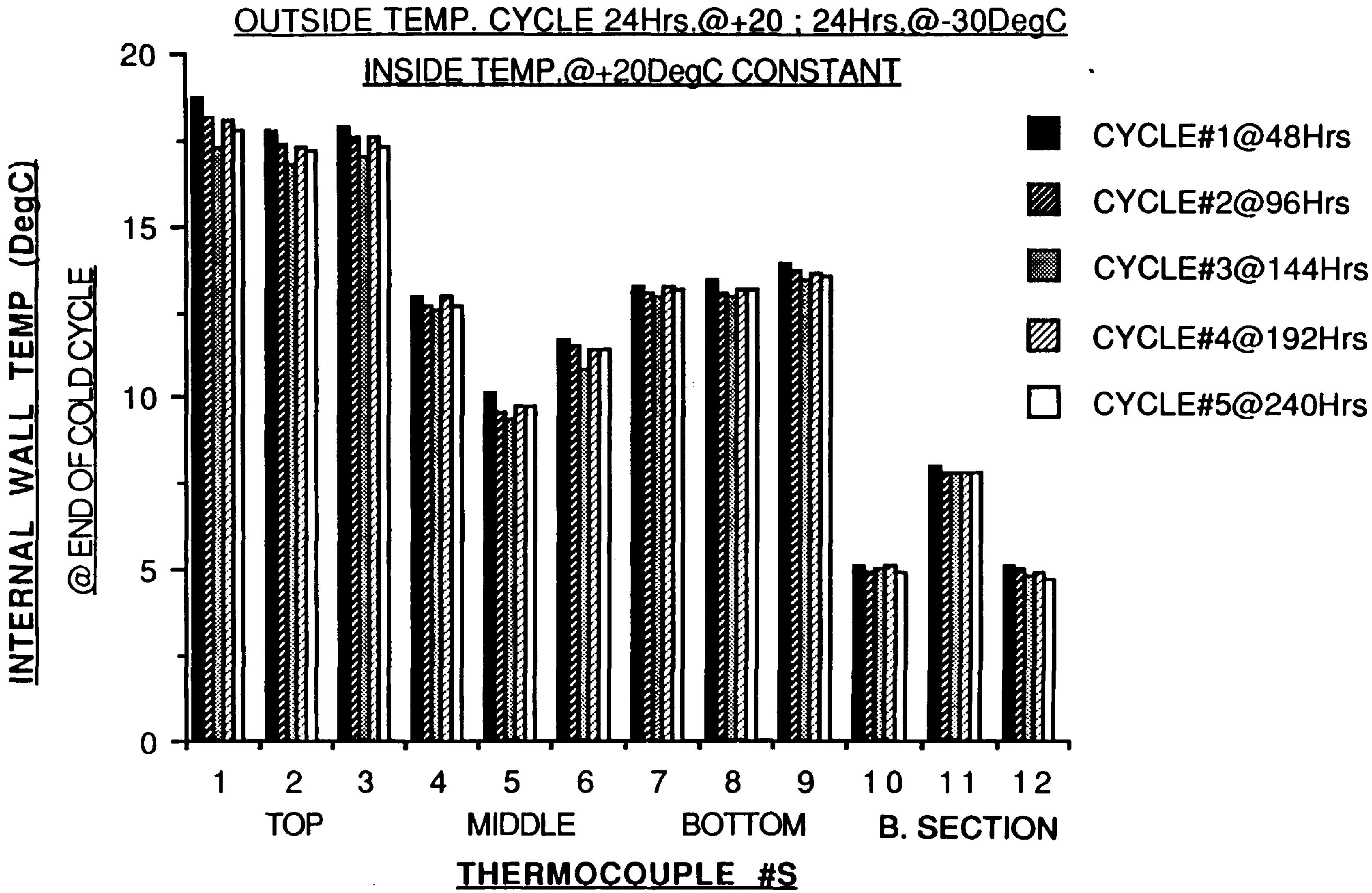
THERMOCOUPLE LOCATION

TEMPERATURES IN °C

T1= 17.8	T7= 13.1
T2= 17.2	T8= 13.1
T3= 17.3	T9= 13.5
T4= 12.7	T10=4.9
T5= 9.8	T11=7.8
T6= 11.4	T12=4.7

COLD-SIDE -30.4 WARM-SIDE +19.9

TEMPERATURE CYCLING CASTONE WALL SYSTEM



ORTECH

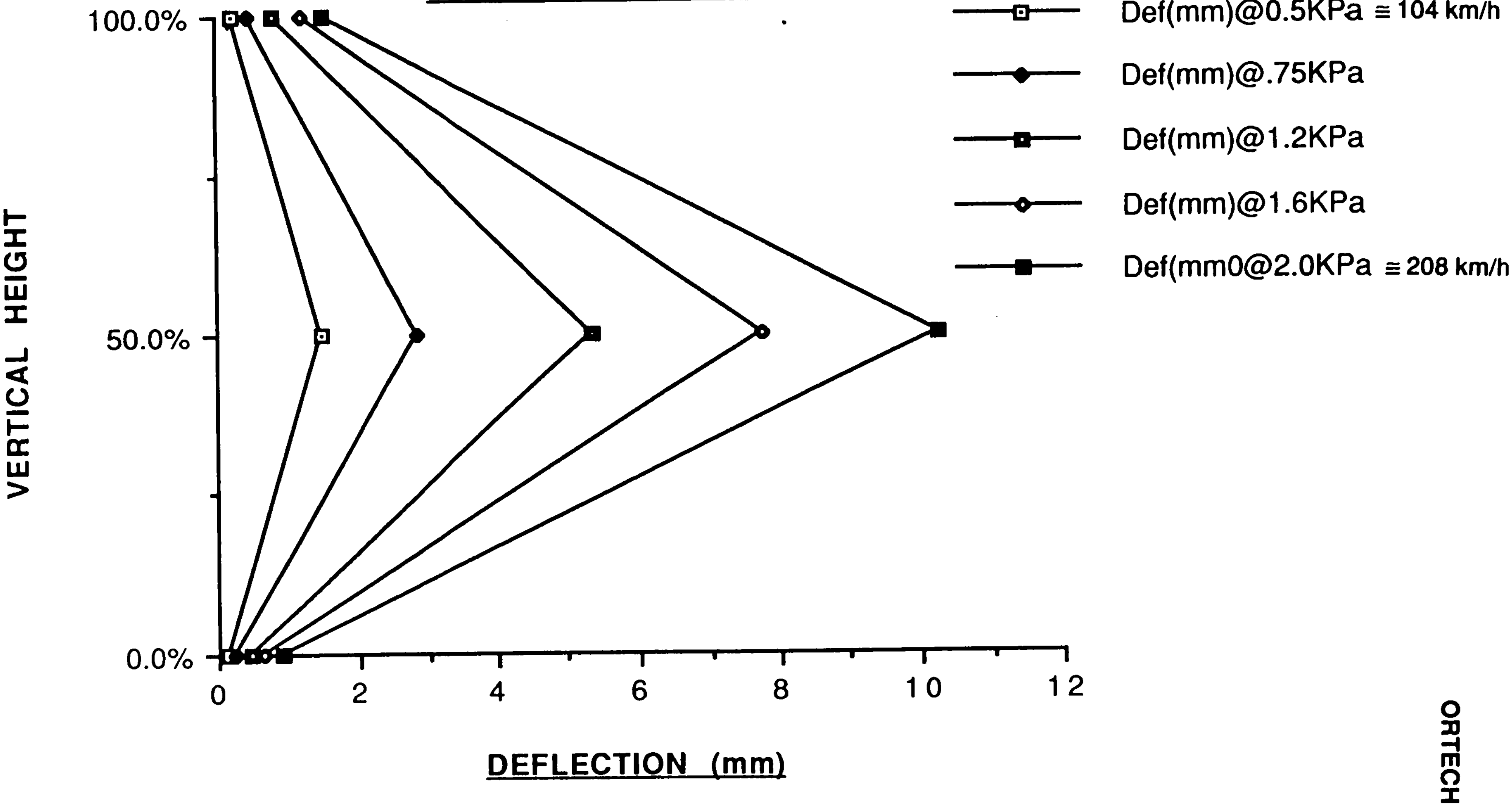
APPENDIX 2

(1 Page)

Deflection Graph

CASTONE WALL SYSTEM

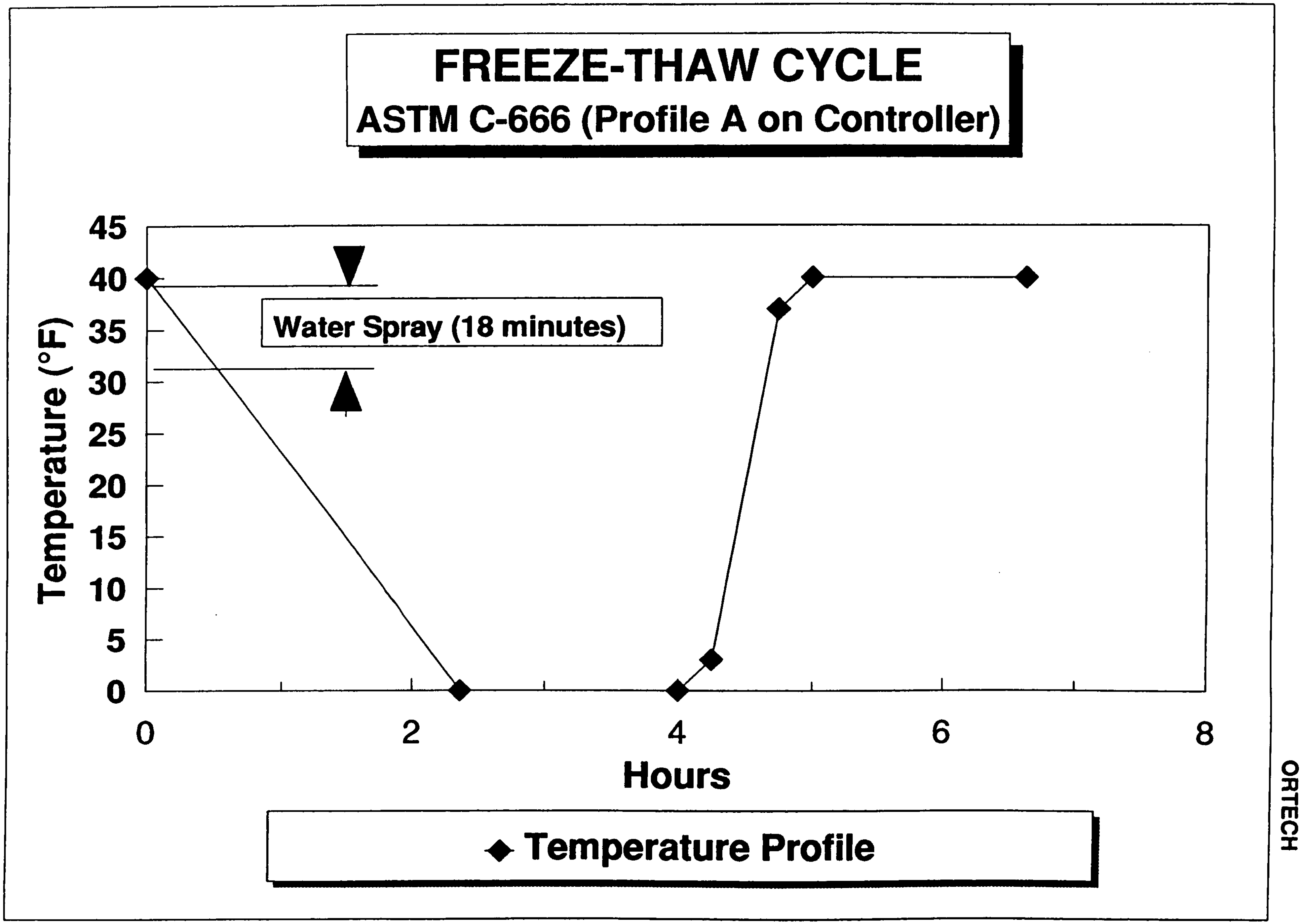
VERTICAL DEFLECTION TEST



APPENDIX 3

(1 Page)

Cycling Chart


FREEZE-THAW CYCLE
ASTM C-666 (Profile A on Controller)
Water Spray (18 minutes)
Temperature (°F)
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
Hours
Temperature Profile
ORTECH