

ENERGY CONSERVATION IN GREENHOUSES
THROUGH THE USE OF RETRACTABLE INSULATION

by
Witold Rybczynski & Vikram Bhatt
Research Paper No.4 July 1980

# minimum cost housing studies

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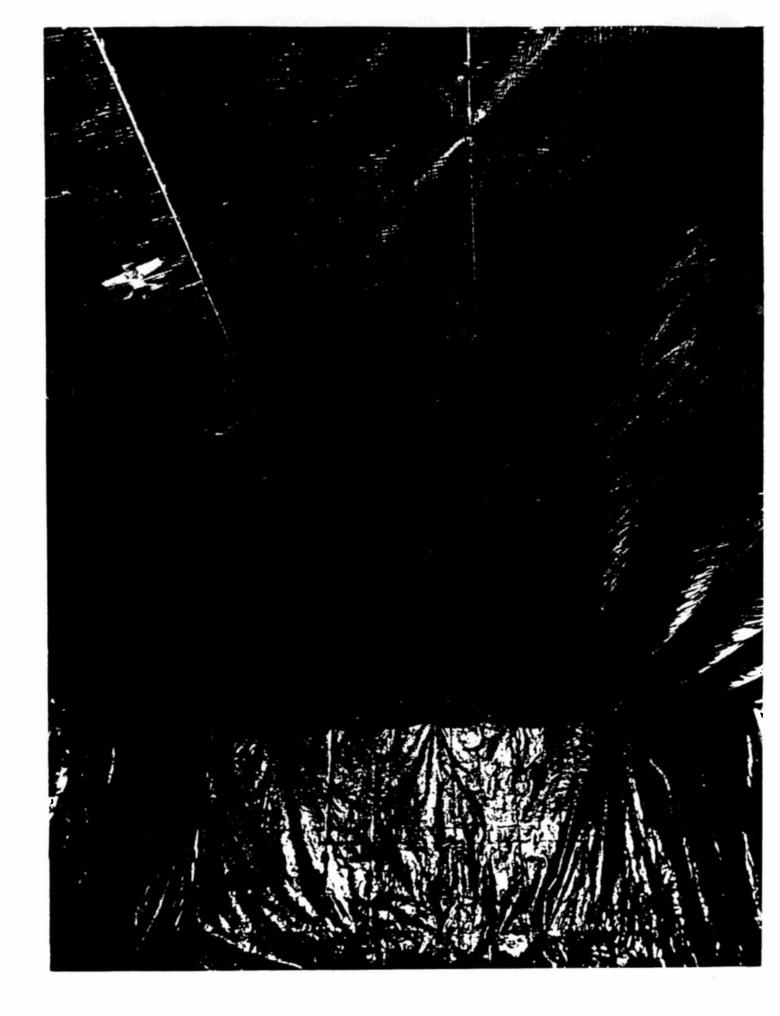
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#### I. INTRUDUCTION

Heat loss from a greenhouse is a function of a number of factors, but is chiefly the result of the difference between the inside and the outside temperatures. Three modes of heat travel (radiation, convection and conduction) are affected to varying degrees by this temperature difference and account for different proportions of the overall heat loss (radiation-15%, convection-25%, conduction-60%). Any attempt to reduce heat loss from greenhouses must address all three modes.

The high conduction losses of greenhouses (both glass and plastic) are the result of the poor thermal insulation of the envelope. The first property of greenhouse insulation must be thermal resistance, and secondly the ability to reduce radiation and convection losses; the former is normally achieved by some degree of reflectivity, and the latter by "air tightness". However, since during the day solar energy is a key ingredient for plant growth, and since materials that combine thermal resistance and high light transmissivity are not presently available, any nighttime thermal insulation must be capable of being retracted during the day.

A number of retractable insulation systems are currently on the market in North America. These are characterized by high quality and high cost, and have been developed for flower producing greenhouses, the economics of which are significantly different from crop greenhouses, the subject of this research project.

The principal costs involved in operating a Canadian crop greenhouse are: a) capital cost, b) heating cost, and c) labour cost. According to a 1975 Statistics Canada report, these costs on an annual square foot basis were \$3.34, 0.26 and 0.29 respectively. If the growers investment were to be amortised at 0% yearly over a 20 year period, he would spend  $2.60/m^2$  on heating,  $2.90/m^2$ 

on labour costs, and \$3.34 on carrying charges. It is clear that heating represents a significant fraction of the operating costs, and that any saving in heating can therefore be reinvested in upgrading the greenhouse, or in mechanizing operations and reducing labour costs.

A simple example illustrates the economics of retractable greenhouse insulation. Assuming that an KSI 0.5 curtain reduces the heat loss by about 50%, the savings expected would be about  $$1.30/m^2$ . In order for this insulation to be economically attractive it must pay for itself in a relatively short time, and should not therefore cost more than about  $$13.00/m^2$ . This is considerably less than any of the commercial systems currently on the market which cost from \$15 to \$25 per square metre.

Preliminary calculations as regards cost effectiveness indicate that an RSI 0.8 thermal curtain can achieve up to 30% energy savings, which would permit an investment of about  $10/m^2$ , assuming a tive year pay back period. Thus the following criteria have been adopted for the development of a low cost retractable insulation system.

- a. Installed cost to be less than \$10/m<sup>2</sup>.
- b. The final thermal resistance of the greenhouse and curtain should be about RSI 0.8 (R5).
- c. The low cost curtain system should be simple enough to be assembled and installed by the grower himself.
- d. The system should avoid condensation problems.
- e. Storage of the open system should not unduly shade plants below.
- f. The system should be adaptable to various greenhouse configurations and sizes.

# 2. SYSTEMS AND HARDWARE

The first stage of the project involved identifying existing hardware and movement systems which could form the basis for a retractable insulation system. Initial research had identified four general categories of retractable systems:

- a. Folding accordion
- b. Roll-away planket
- c. Sliding panels
- d. Suspended curtain

Manufacturers were contacted with an aim of identifying appropriate hardware. Three types of firms were investigated: first, manufacturers of hardware for sliding, rolling and folding doors and shutters, second, manufacturers of retractable insulation systems for domestic use, and third, manufacturers of sun shades and screens specifically designed for large greenhouses (see Appendix V).

The general conclusions were as follows.

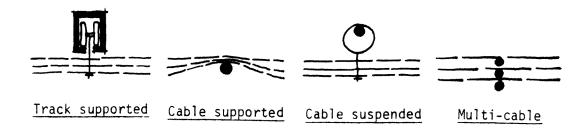
Overhead and folding door hardware is suitable for rugged and heavy performance but difficult to adapt to light, precise tasks. Furthermore, the problem of air tightness is virtually impossible to solve with these type of systems. Sliding doors and shutters are more suitable to tight sealing but generally too expensive to consider for this application. Of all the types of systems looked at the most promising seemed to be lightweight blinds and curtains.

There are a number of recently developed domestic thermal shade systems on the market (primarily in the United States). Though these have somewhat different characteristics than would be found in a greenhouse system (they are small, vertical and high cost), it was felt to be worthwhile to see if they might be modified. Of ten systems surveyed three (all of roller blind type) could have application were it not for the too high cost.

The greatest potential for adaptation of existing hardware lies, not surprisingly, within the greenhouse industry itself. A number of systems presently exist that solve the problem of retractable screens, either for sun shading or thermal insulation. The majority of these have been developed for flower producers and are too expensive to be adapted to crop greenhouses, though they do exhibit the general principles of thermal curtains.

Having identified screens or curtains as the most likely type of retractable insulation, four generic types were available.

- a. Track supported
- b. Cable supported
- c. Cable suspended
- d. Multi-cable



Track-supported systems (e.g.Simtrac, Stuppy) are commonly used to support greenhouse shading systems. They are characterized by high quality (nylon rollers, extruded aluminum tracks) and relatively high cost ( $$12-$16/m^2$$  for tracks only). The installation is relatively complicated as the tracks must be suspended from the roof at intervals. These systems are not usually air tight.

Cable supported systems (e.g.Ickes-Braun) are considerably cheaper than track supported since the wire or filament costs less than \$0.16/m, whereas aluminum track is more than \$2.16/m. The main advantage of cable supported systems is their simplicity and lack of hardware. Cables can easily span most greenhouse widths. The main disadvantage is the inappropriateness of the system when more than one layer of curtain is used, since the cable interferes with

proper hanging.

Cable suspended systems (e.g.Roll-Out) avoid the high cost of tracks and are able to overcome the disadvantage of cable supported systems by hanging the curtain <u>below</u> the cable. Although this introduces additional hardware in the form of hangers, it avoids contact between the cable and the multiple layers of curtain. Moreover, the curtain tends to fold naturally in accordion-like folds.

The multi-cable system (no commercial manufacturers known) is a variant on the cable supported type adapted to multi-layers. Each curtain layer has its own supporting cable, thus eliminating the bunching that occurs when more than one lyer is supported on a single cable. The additional cost of multiple cables is offset by the lack of hangers or curtain spacers.

A thermal insulation system based on the cable suspended type has been designed and tested (see Chapter 3). The multi-cable type has also been investigated and is described in more detail in Appendix II.

#### 3. TEST INSTALLATION

The main purpose of this project was "to design and build an optimal system in prototype form which will allow performance studies to be carried out". The reason for this stage of the project is that very little empirical data exists as to the performance of greenhouse insulation systems. Most of the data on thermal performance has been developed for solid buildings and cannot be adapted to the greenhouse environment. Although it would be relatively easy to determine the thermal resistance of the insulation curtain, there is no data available as to the infiltration rates that should be assumed for such a system, while at the same time most experts agree that reduced infiltration will certainly be one of the chief benefits of a retractable insulation system. It was found that manufacturers literature neglected to give overall thermal performance of curtain systems, and highlighted, rather, the theoretical R-value of the matrix itself.

#### Existing Greenhouse

The test installation was located in a greenhouse belonging to McGill University and situated on McGregor Street on the downtown campus. The greenhouse is part of a larger structure being located at one extremity, and has three exposed walls and one interior wall which was insulated for the duration of the experiment. The greenhouse is a traditional single glass on steel frame (see Figs.1 & 2) spanning 6.32 m and 7.86 m long. The original heating system was hot water carried through overhead pipes. This system was disconnected since not only would the pipes have been outside the curtain, but the quantity of heat input would have been impossible to measure. The floor of the greenhouse is earth.

The greenhouse is situated away from large buildings or trees, a fact which, it was hoped, would contribute to stable nightime temperatures (see Fig.1).



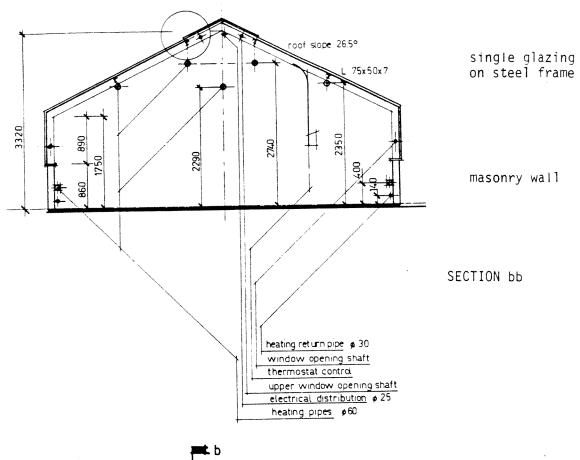
Interior view showing steel structure, eaves vent and overhead heating pipes.



Exterior view along McGregor Avenue.

Fig. 1

EXISTING GREENHOUSE - Interior and exterior



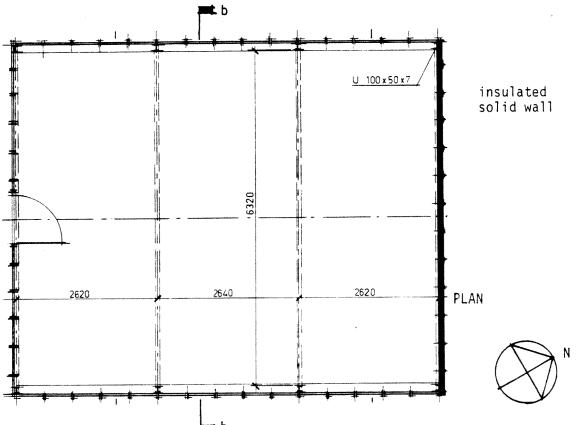
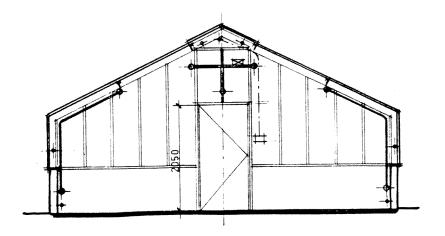
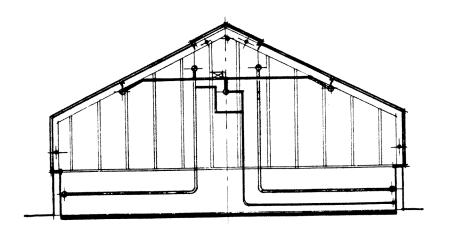


Fig. 2
EXISTING GREENHOUSE - PLAN AND SECTION



Interior elevation looking south west



Interior elevation looking north east

Fig.3

EXISTING GREENHOUSE - ELEVATIONS

### Thermal Screen Material

The main component of a screen or curtain system is the matrix or screen material. There are currently a limited number of options on the market. Some researchers are working with screens of transparent polyethylene (Centre de développement des cultures abritées, ministère de l'agriculture, Chateauguay, Ouébec). This material has no resistance to radiative losses, and since the Chateauguay installation is only one layer, it has little effect on conductive losses either; in fact the main effect will be on convective losses only. Prof.Albright, of Cornell University, has built thermal curtains using Foylon XA-2425, a porous 44 x 40 count 5 oz. polyester, aluminum foil hybrid. He established that a single layer has about 50% the conductance of single strength glass. It is manufactured by the Duracote Corporation. Our own physical experiments with Foylon have not been encouraging. Prolonged exposure to water results in delamination of the foil, and extended abrasion has a similar effect. Prof.Aldrich of Pennsylvania State University has conducted tests with combinations of high thermal resistance blankets (foamed plastics) and low thermal resistance blankets (vinyl films). The results of his work have indirect bearing on this project (expensive track systems were used) but he does indicate that aluminized materials are significantly better.

Mylar coated materials have been known for some time and have been used in greenhouse environments as reflective finishes on north walls (e.g. the Brace south-facing greenhouse). Previous experience has not been encouraging as the mylar layer tends to delaminate as a result of humidity. A recent development seems to have overcome these problems. The Stauffer Chemical Company has begun to produce a mylar coated PVC reinforced film (Ultrafilm) in which the mylar is protected by a polyethylene layer. This material, developed especially for greenhouse thermal curtains, is characterized by high tear strength, resistance to humidity and ultra-violet radiation, high reflectivity on one side as well as low cost  $(\$1.27/m^2)$ .

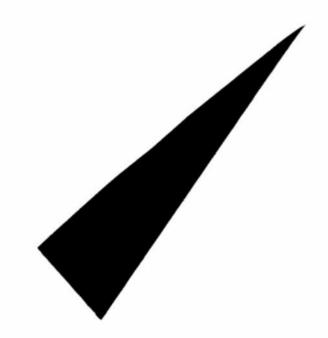


Fig.4 SAMPLE OF ULTRAFILM

On the basis of full-scale testing a prototype system was designed Hardware Design which could be fabricated and installed in the existing greenhouse, and which met the criteria for a low cost retractable greenhouse

The components for a cable suspended system are : the cable and insulation system. turnbuckles, hangers which support the film, a pulley system to open and close the curtain, a method for suspending multiple layers of curtain, a puller mechanism, a horizontal joint at the leading edge of the curtain, a horizontal joint at the ground, vertical joints at the corners.

The design of these elements is based on three main criteria: thermal performance, market availability, simplicity and ease of fabrication (where fabrication is necessary) and low cost.

# Cable

The suspension cable is a 12 guage plastic coated steel wire. This is capable of spanning most greenhouses (8m-12m) and is easily available. Monofilament is also used (e.g.Stuppy) but its cost (\$0.23/m) is somewhat higher than steel (\$0.15/m). The turnbuckles (\$1.22) are a model which is particularly easy to adjust, and being cast aluminum are impervious to humidity. Spacing of the cables is 2m (see Fig.5).

# Hangers

After some experimentation the most appropriate hangers were found to be common shower hooks. These have a number of advantages: low cost (\$0.04), openability, resistance (naturally) to humidity. The hooks are not placed through the material, which would produce air leaks as well as rips, instead they are taped to the surface of the curtain. A 10 cm strip of 2.5 cm wide glass fibre reinforced filament tape (\$.057/m) is taped through the hook and two 10 cm

strips of 5 cm wide polypropylene tape (\$0.038/m) are taped over the filament tape. The total cost of the tapes, per hanger, is \$0.014. It is very important to note that the taping must be done to the silver (polyethylene) side of the curtain and not to the black (vinyl) side. Experiments showed that the tapes would delaminate from the vinyl over an extended period of time due to heat. No such problems were observed when taping to the polyethylene. Spacing of the hangers is 50 cm (see Fig.5).

## Pulley System

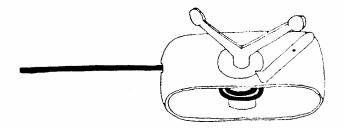
The curtain is opened and closed by means of a pulley system based on conventional practice (Simtrac, Stuppy) and using four marine pulleys (\$3.20 each) and nylon rope (\$1.00/m). These components are relatively expensive but the location of the pulley system at 4m intervals results in a typical cost of less than \$1 per square metre of greenhouse (see Fig.5).

# Puller Pipe

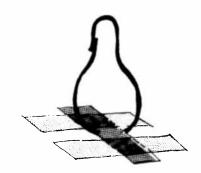
A horizontal puller pipe is suspended below the cables and pulled by the pulley system. Initial work was done using a 2.5cm dia. PVC pipe, chosen for its light weight and relatively low cost (\$2.86/m). Over an extended period this pipe proved to be too flexible and had to be replaced by a similar size steel pipe (\$3.10/m).

#### Ground Joint

The initial design for the joint between the vertical curtain and the ground was a simple free fold, much like a window curtain. This proved to be inadequate since, in a greenhouse installation, the cold air between the curtain and the wall of the house pushes in and creates a pronounced, and awkward, billowing effect. The final detail uses a single course of concrete blocks as a low parapet and in fact a good, tight joint (see Fig.6).



# Cable and turnbuckle



# Hanger and tapes

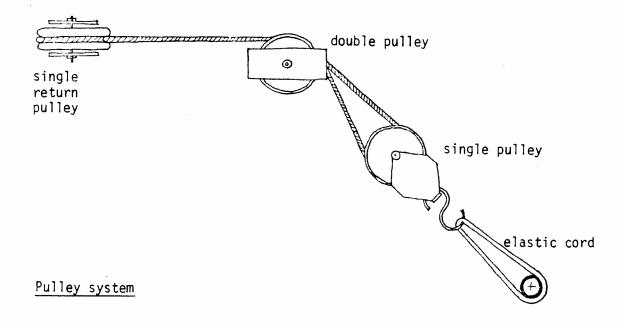
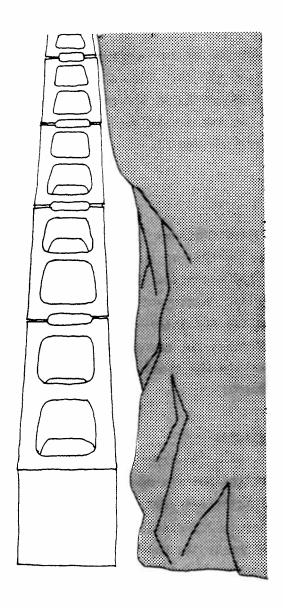


Fig.5 SYSTEM DETAILS - CABLE, HANGER & PULLEY SYSTEM



The blocks are placed on the interior of the heated space to provide a low parapet against which the curtain is pushed by the cold external air mass.

Fig.6

SYSTEM DETAILS - GROUND JUINT

# Leading Joint

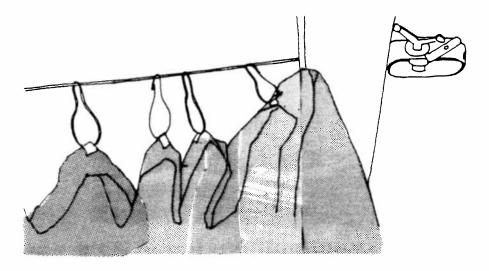
The puller pipe is pulled by the pulley system into an air tight joint that consists of two rectangular strips of foam rubber (\$0.33/m) and spring clips (\$0.79) that hold the pipe in place and are located at intervals of 2m. Since the pulley rope goes through the pipe and between the rubber strips, the pipe is guided directly into the joint (see Fig.7).

# <u>Vertical</u> Joints

The vertical joints offer a particular problem in closure. A simple overlap is not sufficient; an automatic system is too complex and almost certainly too expensive. A compromise solution was arrived at by using a "Velcro" strip which is sealed manually. Though relatively expensive (\$3.50/m) this material provides an excellent sealed joint. Moreover, the number of vertical joints is small. The strip is glued (to the vinyl side of the curtain) with Velcro adhesive No.45.

# Multi-layered Curtains

The suspension of multi-layered curtains presents a particular problem. Prof.Albright has developed an ingenious solution using the plastic label fasteners that are commonly attached to price labels. This device is a small plastic cord with a "T" at each end which is attached to the material with a special hand-tool (\$23.00). The fasteners ("Swiftachment", manufactured by the Dennison Manufacturing Company) come in a variety of lengths, 2.5 cm (\$0.0054), 7.5 cm (\$0.0045) and 12.5 cm(\$0.0054). Up to five layers of curtain were used in the experiments, using different combinations of fasteners (see Fig.8). The fasteners were spaced on a grid approximately 65cm x 25cm (see Fig.8 ). The attachment of the required number of curtain layers is done on the ground before the curtain is hurg. Thanks to the special handtool the attachment process is extremely rapid, less than one second per fastener. A strip of filament tape was installed on the line of the fasteners before punching, to prevent tearing.



Back edge detail of curtain showing cable and turnbuckle

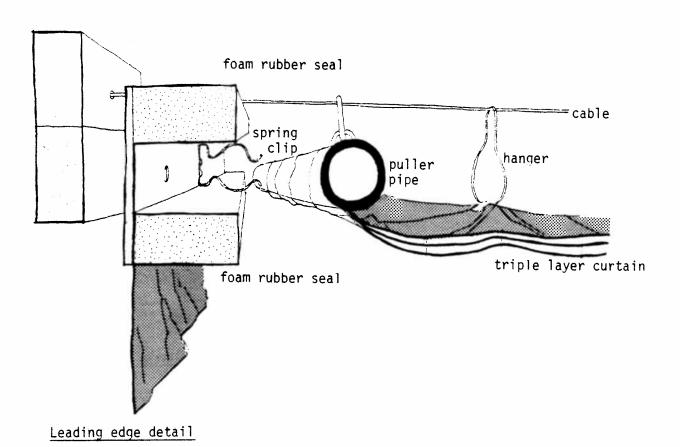
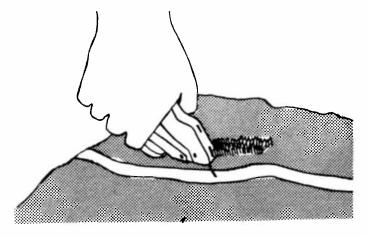


Fig.7
SYSTEM DETAILS- BACK EDGE AND LEADING EDGE DETAIL



Attaching "Swiftachment" label fasteners with hand-tool

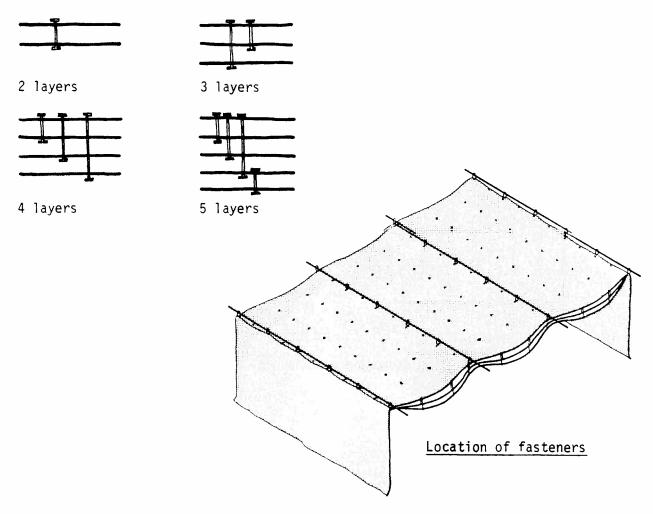
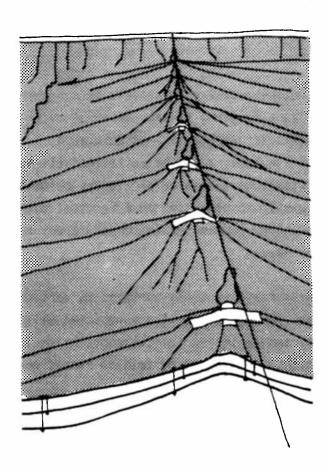
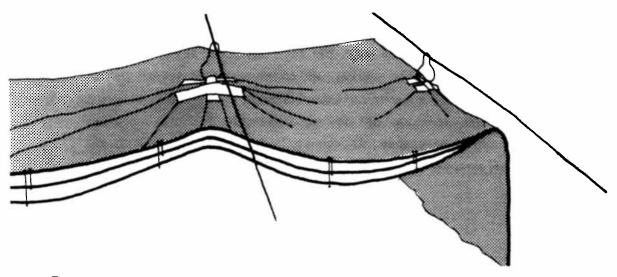


Fig.8

SYSTEM DETAILS - MULTI-LAYERED CURTAINS



Typical situation at hangers and cable- internal location



Typical situation at hangers and cable- edge location

Fig. 9
SYSTEM DETAILS - MULTI-LAYERED CURTAINS

# Vertical Curtains

The vertical curtains represent a relatively lesser problem than the horizontal. In most large multi-span greenhouses they also represent less than 10% of the thermal curtain area, hence it was felt that here a single layer would be sufficient (it is otherwise extremely difficult to guarantee air layers between vertical multi-layered curtains). Condensation on a vertical curtain would simply run down to the ground and would therefore not represent a hazard for the plants.

The movement system for the vertical curtains is vertical, with a fixed joint at the top, somewhat like a venetian blind, and using a similar pulley system as the horizontal curtains. This ensures a good joint, and since only 2m of curtain is stored shading is relatively minor.

The vertical curtain which is parallel to the cables is an integral part of the horizontal and opens and closes in conjunction with it (see Fig.9).

#### Operation

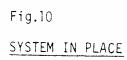
Operation of the curtain proved successful; the suspended curtain folds accordion-like on one side and does not require much space. Problems were experienced with the five layer curtain which was simply too heavy for the cables, which experienced severe deflection. The bulk of the five layer curtain likewise created problems with proper storage. This was not the case with the four layer curtain which was more manageable, though still heavy. The three layer curtain offered no problems.



Cable, hooks and puller pipe



Edge of curtain





Back edge of curtain

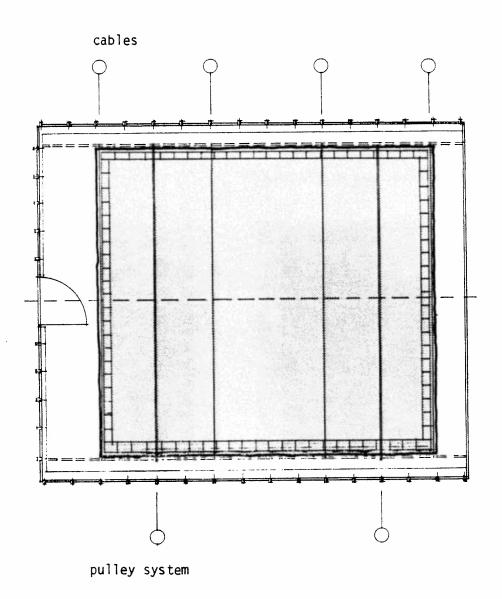
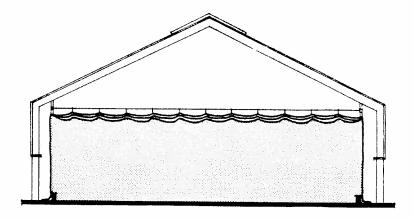
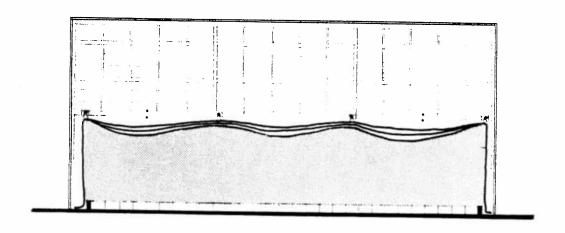


Fig.ll

SYSTEM IN PLACE - PLAN

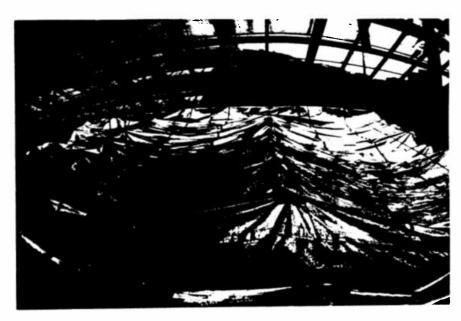


Cross section through existing greenhouse with curtain installed

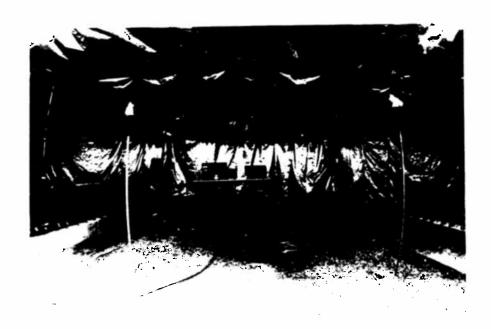


Longitudinal section through greenhouse with curtain installed

Fig.12 SYSTEM IN PLACE - SECTIONS



Exterior view above curtain



Interior view (with monitoring equipment in place)

Fig.13

SYSTEM IN PLACE

# 4. MONITORING THERMAL PERFORMANCE

One of the main goals of this project was to establish the overall thermal performance of the prototype thermal curtain. This implies computing conductive, convective and radiative losses. There is data available on the conductivity of various materials, and, in any case this is easily established through empirical observations. It is much more difficult to establish the convective losses. These are a direct function of the type of joints and jointing material for which operating data are unobtainable. As a result it was necessary to adopt an empirical approach based on nightime monitoring of thermal performance of the curtain. This procedure took place from February until March, 1980, with additional tests in May.

# Monitoring Methodology

The following methodology formed the basis of the monitoring :

- a. Monitor heat input (Q)
- b. Monitor temperature on both sides of the curtain to establish  $\Delta T$ .
- c. Monitor rate of heat flow (r) through the curtain.
- d. Establish the conduction losses (q)

$$q = r \times A \times \Delta T \times t$$

q = conduction losses, Watts

 $r = rate of heat flow, Watts/m^2-oc$ 

 $A = area of curtain, m^2$ 

▲ T = temperature difference, °C

t = time, hours

e. Establish convection and radiation loss (I)

I = Q - q

I = convection and infiltration loss, Watts

Q = heat input, Watts

According to this approach both radiation and convection losses are combined and considered, for the purpose of this analysis, to be convective (or infiltration) losses.

#### Heat Input

The existing hot water heating system was disconnected and replaced with two 5 kWh electric fan-coil heaters. These heaters were connected to a Watt-hour meter which monitored the total amount of heat entering the greenhouse.

# Temperatures

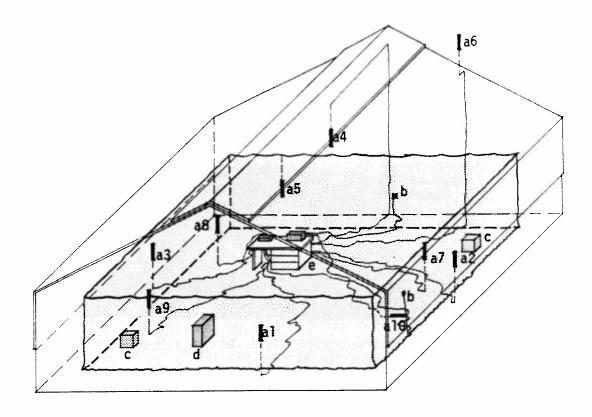
Temperatures were recorded by ten thermocouples (type TC), shrouded against radiation and convection, and linked to an Omega Model 199 DSS Digital Thermocouple Pyrometer that was equipped with a rotary switch for manual reading. Two thermocouples (4 & 5) were located at 2.7m, above the curtain in the "cold" greenhouse, and three more (1,2 & 3) at 1.2m high between the curtain and the greenhouse wall. One thermocouple (6) monitored the exterior temperature, at 3.0m height. Three thermocouples (7,8 & 9) monitored temperature at 1.2m within the "heated" greenhouse, and one (10) was imbedded in the ground. Thus temperature differences were calculated a) across the horizontal curtain, b) across the vertical curtains, and c) across the floor (see Fig.14).

#### Rate of Heat Flow

The rate of heat flow through the thermal curtain was measured using heat flux plates (Hy-Cal Engineering, Model B16WPJ). The heat flux plate is wafer thin and generates its own millivolt output signal which is proportional to the amount of heat flowing through the guage at that time. The heat flux plate was connected to a datalogger. One plate was permanently attached to the underside of the ceiling curtain and on-going measurements were recorded during the tests. The second heat flux plate was used to develop average figures for the vertical curtains and for the ground.

## Humidity

One of the main problems associated with thermal curtains in greenhouses is condensation on the underside of the curtain, which sub-



# Legend

- a Thermocouple (x10)
- b Heat flux plate (x2)
- c Electric space heater (x2)
- d Humidifier
- e Control panel

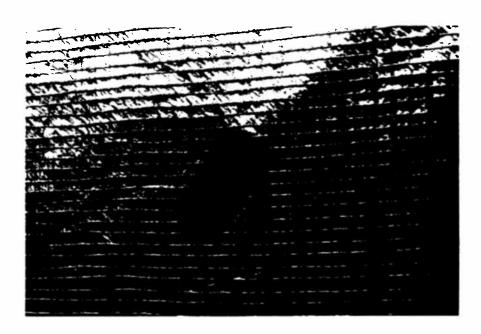
# Thermocouple locations

al, a2, a3	Between curtain and greenhouse, on sides (Height 1.20)
a4, a5	Above curtain (Height 2.70)
a6	Exterior (Height 3.00)
a7, a8, a9	Interior (Height 1.20)
a10	Interior (Underground to 0.6)

Fig. 14
TEST INSTALLATION - MONITORING EQUIPMENT LOCATION

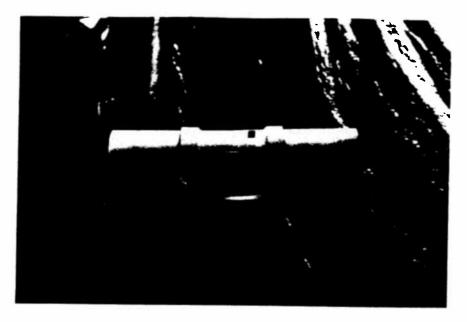


Control panel showing watt meter on left, pyrometer at centre and data logger on right.



A heat flux plate (approx  $2\text{cm} \times 2\text{cm}$ ) about to be attached to the thermal curtain with a piece of masking tape.

Fig.15
MONITORING EQUIPMENT



Thermocouple shroud, fabricated from PVC pipe painted white. The thermocouple is mounted within a second smaller pipe within the horizontal pipe.



A thermocouple stand (1.2m) within the greenhouse. The concrete block parapet wall is visible at the bottom of the picture.

Fig.16
THERMOCOUPLES

sequently can cause damage to the plants. In order to observe this phenomenon, a humidity level of about 60% was maintained within the heated space using a domestic humidifier. This kind of device is not intended to simulate the humidity conditions of a greenhouse but did provide sufficient humidity for purposes of the test.

### Testing Procedure

The typical test took from 1 to 3 hours and was conducted well after dusk, usually beginning between 8.00 and 9.00 pm. Temperatures were recorded manually from all the thermocouples every 10 minutes. The two heat flux plates were likewise recorded every 10 minutes, though automatically. The heaters were adjusted manually to maintain a stable temperature within the greenhouse of 18-22°C. The watt meter was read once at the beginning and once at the end of the test.

The thermal curtains were closed during the day and no attempt was made to record the cycling of temperature that would take place in a greenhouse when thermal curtains are opened and closed.

The data from the tests is included in its entirety in Appendix III.

The variable in the tests was the number of layers of thermal curtain. Three tests (4,29 & 30) were run with curtains open. Two tests (1 & 2) with a single layer, reflective side up, and four (3,5,6 & 7) with reflective side down. Six tests (8-13) were run on two layers, ten (14-17,27,28,31-34) on three layers, five tests (18-22) on four layers, and four tests (23-28) on five layers.

A summary of the test results appears on the following page.

As a result of this table it was possible to calculate a)the thermal resistances of multi-layer curtains, b) the proprtion of heat flowing through wall, floor and ceiling, and c) the proportion of heat lost by conduction and by convection.

		<del></del>			·				
five laye- curtain	Four layer Curtain	Three layer curtain		Two layer curtain	Sinole la Curtainer face in	efloct	Control		- Windows .
23 25 26	27A 27A 27B	179 28 28 28 28 28 28 28	7552	ಪನ <b>ಾ</b> ನ - ಇ			33 33	Chart f	
28.8 28.8 28.8	28 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	72777777 28 7377777788 88 7377777888 88	28.8 8 8 8 8	28.8 28.8 28.8 28.8 28.8	28.8 28.9 28.8 28.8	28.8 28.8		Surface area horizontol curtain	<sub>2</sub> 2
1.13	1.79 1.93 1.58 1.29 1.72	3.22* .50* .22* .88* 1.74* 2.53*	1.54	2.00 4.15 2.25 3.45 3.14	3.34 1.91 4.65 3.25	2.63 3.36	3.53 3.59 6.76	Heat flux plate # 1 and # 2 output signals	m∀
1.14 .97 1.17 1.57*	1.35 1.85 1.56	7.75	25.8	2.69 2.81 2.27 3.18 3.11 1.92	2.58 2.23 5.01 3.51	4. 19 2.79	4.59 3.82 3.97	(f)	
22 20 17	2 <b>2 2 2 2 3</b>		* 22 22 25	87 87 87 87	23 8 8	55	69 70 132	Conductive losses from heat flux plates #1 and #2	¥
23.23	333332	27	### ##	388 <b>4</b> 88	53 46 102 72	86 57	94 81	(q = f x c x 3.155)	•
70 70 70 70 70 70	= 22222	. 27	<b>#23</b> %	S 57 S 4 58 4	59 41 96 67	6.69	81 74 81	Average rate of heat flow through the horizontal curtain	*
3555	755555 55555	13.5 10.5 10.5	3838	19.5 22.5 16 21 20 70	16 10.5 18.5	17.5	115	Temperature difference between inside the curtain and in the greenhouse	c°
602 576 400	927 927 927 927 921 921 892	776 776 588 588 560 448 778	921 77 <b>6</b> 950	1353 198 <b>7</b> 1324 1320 1900 1929	1699 1180 2764 1929	1937 1756		Conductive heat losses from the horizontal curtain (q hori)	¥
33.6 33.6 33.6	33.6 33.6 33.6 33.6	33.6 33.6 33.6 33.6	33.6 33.6	33.6 33.6 33.6 33.6 33.6	33.6 33.6 33.6 33.6	33.6 33.6	33.6 33.6 33.6	Surface area walls glazed section	m <sup>2</sup>
.2664 .2664 .2664 .2664	.2664 .2664 .2664 .2664 .2664 .2664	. 2664 . 2664 . 2664 . 2664 . 2664 . 2664 . 2664 . 2664	.2664 .2664	.2664 .2664 .2664 .2664 .2664 .2664	.2664 .2664 .2664 .2664	. 2664	.2664 .2664 .2664	Thermal resistance of wall curtain(R)	W/ <sub>m</sub> <sup>2</sup> co
8333	75.55.5 5.55.55 5.55.55	200 0 2 3 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	ತಪಡ ಪ	19.5 27.5 15 21 20 26	15 9.5 18.5 13.5	17.5	12 12 12	Temperature difference between inside the curtain and in the preenhouse at wall in plazed section (AT)	c°
3 5 5 5 3 5 5 5	2450 2450 2311 2311 2001 2001	1702 1702 1702 1702 1702 1702 1702 1702	2018 1891 2779	2459 2837 1891 1891 2648 2527 2018	1871 1198 2333 1702	2018 2207		Conductive heat losses from wall curtain $\binom{n}{2}$ hori plazed $\binom{n}{2}$ $\times$ $\binom{n}{4}$ $\times$ $\binom{n}{4}$	٧
0 2 2 2 0 0 2 2 0 0 0 0	വ പ്രത്യം ചെയ്ത്രത്ത്	2022000 00 0000000000000000000000000000	1000 1000 1000 1000	9.6 9.6 9.6 9.6	9.6 9.6 9.6	9.6 9.6		Surface area walla unmlazed section	?
>->	2.5 2.5 2.5 2.5	N===== NN in isis	2.5	2.5 2.5 2.5	2.5 1.5 3	2.5		Temperature difference between inside the curtain and in the greenhouse at wall in unglazed section	c°
3223	333338	75 58 58 77	ខេត	108 125 116 111 116	83 52 103 75	89 97		Conductive heat losses from wall curtain (o hori unglazed) = R x $\Delta$ T x A	¥
	5888888 588888 588888		28.8 28.8 28.8	28, 8 28, 8 28, 8 28, 8 28, 8 28, 8	28.8 28.8 23.9 23.9 28.8	29.8 28.8		Surface area floor	m Z
1.5781 1.5781 1.5781 1.5781	1.578) 1.5781 1.5791 1.5781 1.5781 1.5781	1.5781 1.5781 1.5781 1.5781 1.5781 1.5781 1.5781 1.5781	1.5791 1.5781 1.5781	1.5791 1.5781 1.5781 1.5781 1.5781 1.5781 1.5781	1.5781 1.5781 1.5781 1.5781 1.5781	1.5781	1.5781 1.5781 1.5781	Thermal resistance floor (R)	₩/ <sub>m<sup>2</sup>C</sub> o
2004	437354	±ഗകലായത <b>ശശ</b>	88 53 7	5 5 5 7 5 8	6 6 7	7	5	Temmerature difference at floor (AT)	c <sub>a</sub>
		7 5 5 7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	145	127 145 91 177 177	109 109 109 127	121 72		Conductive heat losses to floor $(c_{floor}) = R \times A T \times A$	٧
2.33	rara <b>ra</b> ra	<sup>လ</sup>	7.75 1.75	22.16	1 2 2.16	1.08	1 2.16 1.53	Duration of the experiment (t)	hr.
=====	32 <b>7</b> 7 2 2 2	3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	22 26	32 32 32 32 32 32 32 32 32 32 32 32 32 3	25 17 30 .	26 27	222	Temperature difference between inside the curtain and out side of the greenhouse $(\Delta {\rm T})$	c°
	8500 5000 5000 5000	1500 6300 3300 2500 1600 2400 7800	9000 8500	4500 15000 9000 12000 7500	5000 12000 8000	7000 7000	8000 10900 15600	Heat inout (Q)	Y
2321 4398 5009 3407	6344 7504 7604 7004 5834 3352	949 4075 2287 3340 1272 1573 1581	5310 5995 6340	4075 10929 6730 9582 4653 10968	3782 5078 11466 7666	4557 4132		Total conductive losses $(q) = \frac{1}{(q_{hori} + q_{wall} \text{ unnlazed}^+q_{floor})}$	٧
				475 4071 2225 2418 2847 1332	2218 534 334	2443 2868		Convective losses $(Q-qxt) \equiv I$	Y
3	1.86 2.40 2.75 2.89	2,140 3,17 2,55 1,98 1,59	2.38 1.70	2.37 2.37 2.10 1.63 4.04	4.20 .70	4.01 4.65		Convection loss rate (1)	W/ <sub>m-C</sub> n

<sup>\*</sup> Refer to Appendix III, Monitoring Data, for location of heat flux plates.

## Summary of Experimental Results

The table on page 31 presents a summary of the experimental results of the 34 tests.

The data is organized according to a) losses through horizontal curtain, b) losses through east, west and south (glazed in greenhouse) walls, c) losses through north (unglazed in greenhouse)wall and d) losses to ground. The losses (conduction) to ground and through the walls are computed by establishing a thermal resistance and temperature difference experimentally, and computing the heat loss with the formula:

R x  $\triangle$ T x A = q R = thermal resistance, Watts/m<sup>2</sup>-oC  $\triangle$ T = temperature difference, oC A = surface area, m<sup>2</sup>

q = heat loss(conduction), Watts

The losses(conductive) through the horizontal curtain were measured directly using the heat flux plate. The first heat flux plate column lists the direct readings in millivolts, the second column lists the actual heat loss in Watts, following the formula:

The final column lists an average 'q' for conductive heat loss through the curtain.

The convective (including radiative) losses are computed according to the formula:

Q - [(q<sub>ceiling</sub> x t) + (q<sub>walls</sub> x t)+ (q<sub>ground</sub> x t)] = I

Q = heat input, Watts

q = heat loss(conductive), Watts

t = time, hours

I = convection loss, Watts

#### Thermal Resistance

From the results established experimentally it is possible to compute the thermal resistance (RSI) of various multi-layered curtains using the formula:

$$R = \frac{q}{A \times AT}$$

 $R = thermal resistance, Watts/m^2-oc$ 

q = conductive heat loss, Watts

 $A = surface area, m^2$ 

△T = temperature difference, °C

The average thermal resistance of the curtain was calculated with the following results:

One layer (reflective up)	0.268	Watts/m <sup>2</sup> -o <sub>C</sub>
One layer (reflective down)	0.259	
Two layers	0.557	
Three layers	0.760	
Four layers	0.829	
Five layers	0.905	

In the 2,3,4 and 5 layer configurations, the topmost layer was always installed reflective side up, and the rest reflective side down.

## Convection Loss Rate

From the total convective losses (I) established experimentally it is likewise possible to compute the convective loss per metre of joint. In order to do this two assumptions were made. First, radiation losses were ignored and included into the convective losses. Second, lacking any experimental evidence as to the different efficiency of the joints, it was assumed that all joints performed equally. This is certainly not true, and future work will have to be done to determine the differences in performance.

The convection loss rates were calculated for each experiment and appear as 'i' in the last column, the following formula was used:

$$i = \frac{I}{35.2 \times \Delta T \times t}$$

i = convection loss rate, Watts/m-OC

I = convection loss, Watts

 $\Delta T$  = temperature difference, OC

t = time, hours

The total length of joints in the test installation was 35.2m. This includes the floor joint, the four vertical joints, the puller pipe joint, but not the fixed back edge joint or the integral joint between the walss and ceiling. As a result of these calculations the average convection rate was found to be 2.13~Watts/m-OC.

#### 5. ECONOMICS OF THERMAL CURTAINS

The test installation, although not done at a full commercial scale, has permitted the development of data as to both the thermal performance of the curtain, and its cost. However, in order to evaluate the economic performance it is necessary to look at a much larger greenhouse where the ratio between edge conditions and surface area is more representative. This exercise involves a) calculating the heat loss of a large multi-span greenhouse, b) designing a thermal curtain for the greenhouse, c)calculating the heat loss of the greenhouse with thermal curtain, d) using the cost of the curtain and the value of the energy savings evaluate the economic performance using life cycle costs.

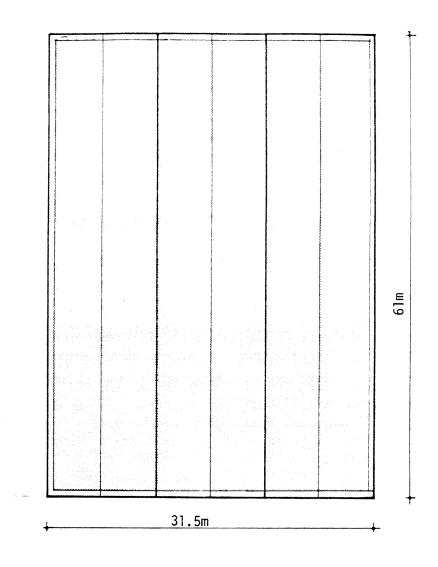
#### The Greenhouse

The greenhouse consists of three bays (10.5m wide), 61m long. The construction is good quality, single layer glass (RSI 0.2025) and reasonably air tight (1 air change/hour). The total area of the greenhouse is  $1921.5 \text{ m}^2$ . The heat loss rate is as follows:

	Area,m <sup>2</sup>	RSI,Watts/m <sup>2</sup> -°C	Watts/OC
Roof	2013.0	0.2025	9940
Walls	618.0	0.2025	3051
Floor	1921.5	1.5781	1217
Infiltrati	on 5947 m <sup>3</sup>		1987
Total		1	6,195 Watts/ <sup>O</sup> C

#### The Thermal Curtain

The thermal curtain is a three later cable suspended type, with single layer curtains on the walls. The thermal resistance of the three layer curtain is 0.760, and of the single curtain is 0.268. The infiltration rate is 2.13 Watts/m-oC of curtain joint; there are 423.5 m of joints. The cables are at the 3m height.



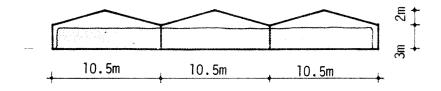


Fig.17

GREENHOUSE USED IN ECONOMIC ANALYSIS

The h	neat i	loss	rate	is	as	fo1	lows:
-------	--------	------	------	----	----	-----	-------

	Area,m <sup>2</sup>	RSI,W/m <sup>2</sup> -oc	Watts/OC
Roof	1921.5	0.7609	2525
Walls	555.0	0.2687	2065
Floor	1921.5	1.5781	1217
Infiltratio	on 423.5m >	2.13 W/m	902
Total			6,709 Watts/°C

## Annual Heating Costs

The following assumptions are made in computing the annual heating costs: fuel cost is 2.5  $\rlap/e/kWh$ , the nightime heating period is 16 hours, the nightime degree days (or degree nights) are 4114 (Montreal region). Using these figures the annual nightime heating cost of the greenhouse is \$26,642, while the annual nightime heating cost of the greenhouse with the thermal curtain is \$11,025. The annual saving is \$15,617.

#### Thermal Curtain Costs

The detailed costs of the thermal curtain are as follows:

a.	Drive mechanism	\$	500.00
b.	Concrete blocks		255.75
c.	Puller pipes		567.30
d.	Pulley systems		537.60
e.	Cables		164.61
f.	Turnbuckles		113.46
g.	Lumber		109.80
h.	Hangers		79.84
i.	Nylon rope	•	1260.00
j.	Velcro tape		84.00
k.	Ultrafilm material	;	7580.00
1.	Foam rubber		120.78

m. Pipe clips	73.47
n. Contact cement	20.95
o. Elastic cord	45.00
p. Fasteners	236.25
q. Tapes	473.70
r. Labour cost (\$1.50/m <sup>2</sup> )	2882.25
TOTAL COST TOTAL UNIT COST	\$ 15,104.76 \$ 7.86/m <sup>2</sup>

#### Payback Period

The simple payback period can be computed by dividing the Capital Investment by the Present Day Annual Savings.

Simple Payback = 
$$\frac{15,105.}{15,617.}$$
 = 0.96 years

Thr true payback period, which takes into account escalation rate (10%) and discount rate (12%) is slightly more than one year.

This meets a very important criteria for the commercial green-house grower who requires an extremely short payback period for his investment. Most growers are rather small businesses with the minimal investment in physical plant (a wood and plastic green-house may cost as little as  $35/m^2$ ) and little capital to invest. A thermal curtain, no matter how efficient, will not find wide-spread application if the pay back period is too long.

#### Life Cycle Costing

It is useful to calculate the life cycle costs in order to be able to compare annual energy savings and capital outlay. Furthermore, there are cyclical renewal costs to be taken into account. It has been assumed that the life of the hardware of the thermal curtain system (motor, pulleys, cables) can be expected to be 15 years. It is expected that the curtain material (including hangers, fasteners and tapes) will require replacement during that time, and renewal

of these components has been assumed to happen every five years.

j. Vel	cro tape	\$ 84.00
k. Ult	rafilm material	7580.00
h. Han	igers	79.84
p. Fas	teners	236.25
q. Tap	es	473.70
r. Lab	our cost (\$0.75/m <sup>2</sup> )	1440.75

TOTAL RENEWAL COST

\$ 9894.54

The life cycle cost analysis assumes a 15 year period of study, a 12% discount rate, a 10% escalation rate for energy costs, and a 8% escalation rate for renewal costs. The Total Present Value of nightime operation of the greenhouse with and without a thermal curtain has been computed and the result shows the definite advantage of the thermal curtain (see pps.40-41).

TPV (without thermal curtains) \$ 347,038.
TPV (with thermal curtains) \$ 173,845.

Option: Without thermal curtain

And the second s							***************************************			
Discount Rate: 1 Enter inflation ra	2%; Period of ates below for	Study: each co	15 yrs ost cate	; Ba	ise Year: Y	19 <u>8</u> 0 (Y	ear 0)			
Cost Category							PV Facto	Present Value		
1. Capital Costs (Escalation	; _%)	Qty	Uni Rat		Est. C 19_	o <b>st</b> \$	SPF			
A B C D E							The second of th			
Total Present	: Value - Capi	tal Cost	ts:					\$		
2. Operations & (Escalation	Maintenance ु	Qty	Unit Rate		t. Annual st 19\$	Years	CSPF			
A B C D E					24.					
Total Present	Value - Oper	ations	د Maint	enar	nce:			\$		
3. Energy	Escal. Rate Cons	umption	Unit Rat <b>e</b>	1	t. Annual st 19 <u>80</u> \$	Years	CSPF			
A Electricity B Gas C Oil D		5 k₩h.	2.5¢	26,	642.	15	13,026	347,038		
Total Present	Value - Ener	gy:	*	<b></b>			<u> </u>	\$347,038.		
4. Cyclical Rene (Escalation		Qty	Unit Rate	Est 19	. Cost	Year	SPF			
A B C D E					-	<b></b> J				
Total Present	Total Present Value - Cyclical Renewal:									
5. Salvage/Resid (Escalation	uals %)			Est 19	. Cost	Year	SPF or SPV			
A B		,								
Total Present	Value - Salva	Total Present Value - Salvage:								

TOTAL PRESENT VALUE - Option # \_\_ (1+2+3+4-5) :

\$347,038.

Option: With Thermal Curtain

Discount Rate: 12%; Period of Study: 15 yrs; Base Year: 1980 (Year 0) Enter inflation rates below for each cost category

Cos	t Category								PV Factor	Present Value
1.	Capital Costs (Escalation	<b>%)</b>		Qty	Uni Rati		Est. Co 19 <u>80</u> \$	1	SPF	
	A Curtain	<u> </u>	e e e e e e e e e e e e e e e e e e e	The state of the s			15,105.			15,105.
	C D E					-				The second distribution with a second
	Total Present	Value -	Capit	al Cost	s:					<b>\$</b> 15,105.
2.	Operations & I (Escalation	Maintena %)	ance	Qty	Unit Rate	3	t. Annual st 19 \$	Years	CSPF	
	A B C D E							-		
	Total Present	Value -	Opera	ations 8	Maint	enar	nce:			\$
3.	Energy	Escal. Rate	Consu	mption	Unit Rate		t. Annual st 19 <u>80</u> \$	Years	CSPF	
e <sup>r</sup>	A Electricity B Gas C Oil D	10 °°	441 k	(Wh	2.5 ¢	11	,025.	15	13 <u>.02</u> 6	143 <b>,</b> 611.
	Total Present	Value -	Energ	3 <b>y</b> :		<b></b>				<b>\$ 1</b> 43,611.
4.	Cyclical Renew (Escalation 8			Qty	Unit Rate	Est 19	. Cost	Year	SPF	·
	A + 5 B + 10 C D E						895. 895.	1985 1990	0.834 0.695	8,252. 6,877.
	Total Present	Value -	Cycli	cal Ren	ewal:					\$ 15,129.
5.	Salvage/Residu (Escalation	ual <b>s</b> %)		1		Est 19	. Cost \$	Year	SPF or SPV	
	<b>А</b> В									
	Total Present	Value -	Salva	ae:						\$

TOTAL PRESENT VALUE - Option # \_\_ (1+2+3+4-5)

\$ 173,845.

#### 6. CONCLUSIONS

#### a. Costs

One of the main criteria has been to develop a thermal curtain system which is low cost. The analysis of economic performance described in Section 5 indicates that this can be achieved. The thermal curtain pays for itself in approximately one year in energy savings, and life cycle costing has established that it is beneficial over a fifteen year cycle, even assuming a relatively short life (5 years) for the curtain material itself. This type of curtain will be particularly attractive to the small producer who cannot invest large amounts in capital equipment, and who requires a short pay back on his investment. One would assume that better capitalized (larger) growers could afford a more expensive retractable insulation system with a longer pay back period, than the  $\$7/m^2$  cost of the low cost system.

#### b. Thermal Resistance

The experimental data described in Section 4 gives the thermal resistances of one to five layer thermal curtains. Empirical observations show that four and five layer curtains are both too heavy and too bulky for practical operation. It is most likely that four and five layer curtains could be used, but only with more expensive track systems, which would not deflect with the greater load. Although theoretically the thermal resistance of multi-layered curtains should increase in direct proportion to the number of layers, experimental data does not bear this out. Fig.18 shows a flattening of the curve after three layers. This may be due to reduced thermal efficiency as the cables deflect and more cold bridges are created by touching layers, though this is not certain.

One of the unknowns in thermal curtains is infiltration or convection loss. Since there are no standards for the performance of thermal curtains it is difficult to say if the 12% infiltration loss of the curtain (in the multi-span example, see Section 5) is good or bad. Interestingly it is the same proportion of overall

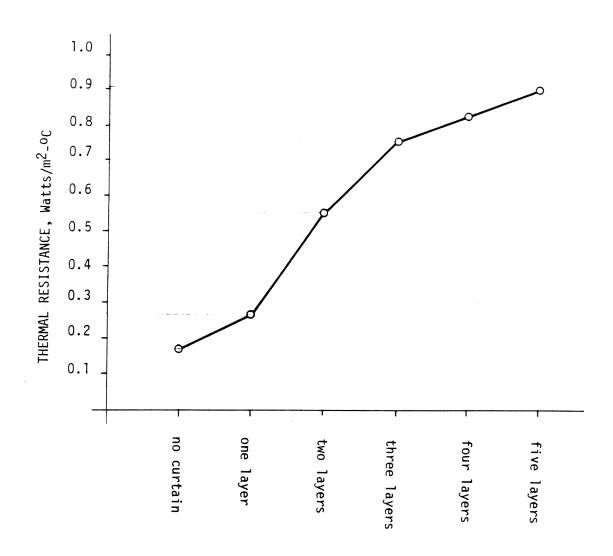


Fig. 18

THE THERMAL RESISTANCE OF A GREENHOUSE WITH AND WITHOUT

THERMAL CURTAINS

heat loss as in the uninsulated greenhouse.

#### c. Fabrication

The operation of the multi-layered thermal curtains proved to be acceptable, with the already mentioned limitation on four and five layered installations. Up to three layers the curtain opened and closed smoothly and stored neatly in a relatively small volume.

The installation of thermal curtains takes place in two steps: the off-site fabrication of the curtain, and the on-site installation of supporting cables and hanging of the curtain. The second step does not present any major problems. A number of requirements must be satisfied by the greenhouse in order to install <u>any</u> retractable insulation system: the heating elements must not be located outside the insulated area, there must not be too many vertical obstructions (structural posts, controls, etc.), and the shape of the greenhouse should be more or less regular. Certain greenhouses, particularly older models, may require extensive modification before a thermal curtain could be installed.

The off-site fabrication of the cable supported curtain is relatively laborious. First of all, all mylar type materials (including Ultrafilm) come in narrow rolls, usually 1.8m wide. This implies extensive taping to produce the large surfaces required. So far this step is unavoidable, though it might be accelerated by using glues (2% VCMH resin dissolved in 98% cyclohexynol). The cable supported system also requires two additional steps: fixing the hangers to the topmost layer, and attaching the layers together with Swiftachment fasteners. Both of these steps are time consuming.

It was with a view to simplifying fabrication that a multi-cable system was investigated (see Appendix II) following the completion

of thermal monitoring of the cable supported systems. The multicable system simplified fabrication dramatically, though cost increased about 20%. It was not possible to evaluate the thermal performance of the multi-cable option, but if it proves to be comparable to the cable supported type systems it may turn out to be an interesting solution.

#### d. Operation

One of the questions frequently asked about thermal curtains concerns problems associated with condensation. Serious condensation was observed to occur on the underside of a single layer curtain. When the installation was increased to two or more layers no condensation problems occured. No condensation was observed in the sealed air spaces. The single layered vertical curtains have extensive condensation, but this does not present any problems as it runs down the curtain surface to the ground.

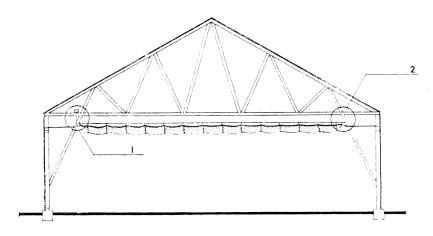
No delamination of the tapes was observed during the tests, whether due to heat or to mechanical stress. A more extensive materials test would have to be carried out to ascertain the life of taped joints (though 5 years is all that would be required), particularly as the matrix (Ultrafilm) is a new material.

# APPENDIX I CABLE SUPPORTED OPTION

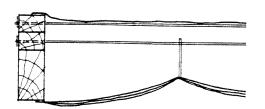
An analysis of the thermal curtain was made by designing the system for a specific greenhouse, in this case a wood & plastic greenhouse on the outskirts of Montreal measuring 61m long and 10.5m wide. Only a horizontal curtain was considered. The following costs were established:

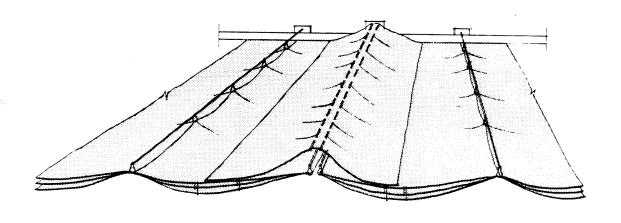
Cables, hangers, turnbuckles tapes	\$ 253.94
Curtain material (3 layers) & fasteners	2378.87
Pulley system & motor drive	1204.20
Puller pipes & lead joint	332.31
Labour (\$1.40/m <sup>2</sup> )	896.70
TOTAL COST	\$ 5066.02
TOTAL UNIT COST	\$ $7.92/m^2$

This particular installation does not permit the curtain to travel to the eaves but only to the diagonal struts. A fixed baffle shields the gap.



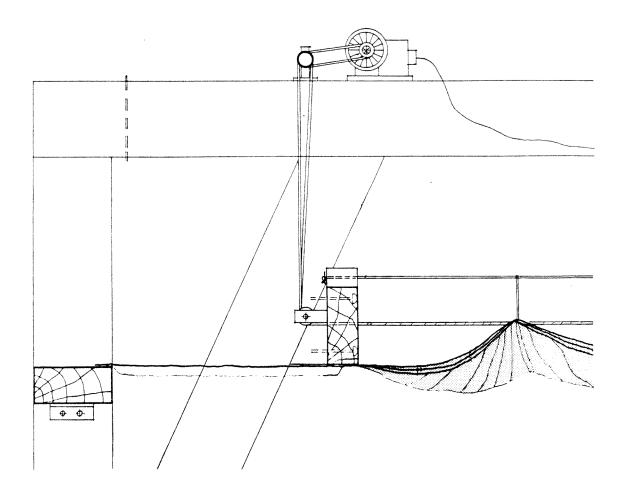
Cross section through greenhouse





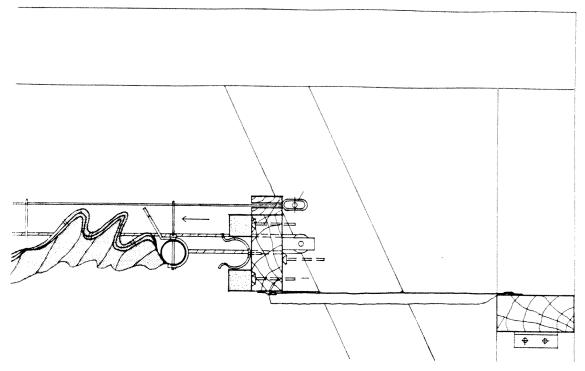
Detail of lapping joint between two sections of multi-layer curtain

Fig.19 LAP JOINT

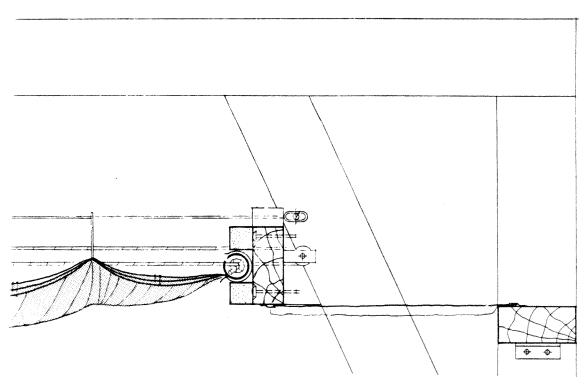


<u>Fig.20</u> Detail 1

Detail of fixed joint showing motor drive mounted above.



Puller pipe approaching joint showing hangers



Puller pipe in closed position showing pulley rope attachment

Fig.21 Detail 2

Detail of puller pipe leading edge joint

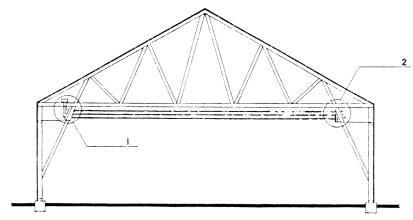
## APPENDIX II MULTI-CABLE OPTION

It was decided to investigate the multi-cable option with a view to comparing cost and operation to the cable supported system. This work took place in June-July so it was not possible to evaluate the thermal performance.

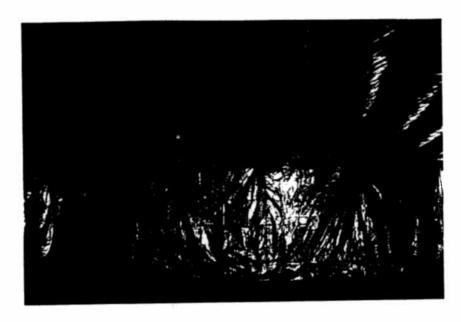
The design of this system dispenses with hangers, instead each layer of curtain is supported by a separate set of cables which are spaced 0.6m apart. The rest of the details of this system are similar to the cable supported option. The cost of the system for the 6lm  $\times$  10.5m greenhouse are as follows:

Cables, hangers, turnbuckles, tapes	\$ 556.49
Curtain material (3 layers)	2305.00
Pulley system & motor drive	1398.80
Puller pipes & lead joints	1066.25
Labour (\$1.25/m <sup>2</sup> )	800.63
TOTAL COST	\$ 6127.17
TOTAL UNIT COST	\$ $9.57/m^2$

The multi-cable option is 20% more expensive than the cable supported option (puller pipes, joints and wires account for this). The advantages are in simpler installation since hangers and layer fasteners are eliminated.



Cross section through greenhouse



Curtain in closed position.



Bottom layer in open position. Note the orderly pattern of folds and relatively small volume of the stored curtain.

Fig.22 MULTI-CABLE CURTAIN

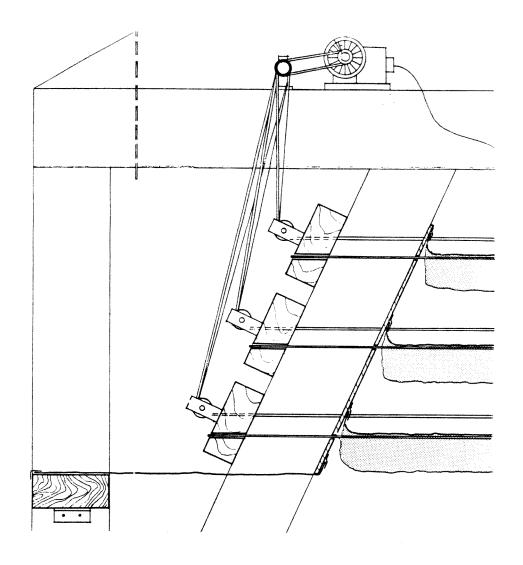


Fig.23

Detail 1

Detail of fixed joint showing motor drive mounted above

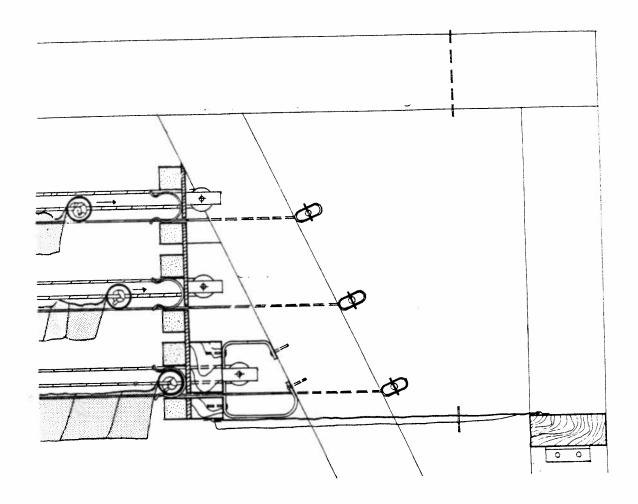
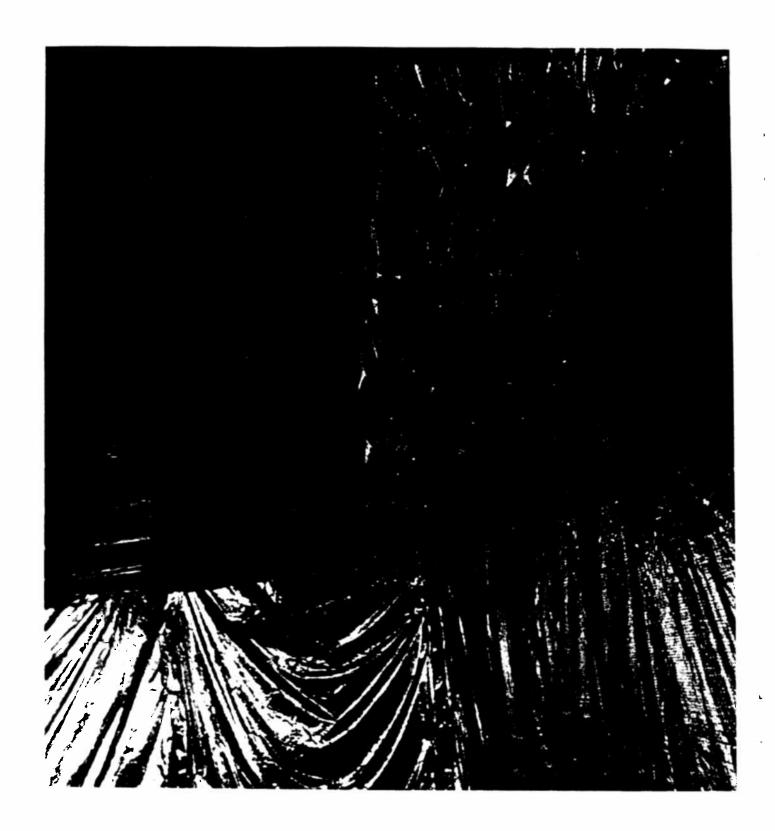


Fig. 24

Detail 2

Detail of puller pipe leading edge joint

# APPENDIX III MONITORING DATA



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							SINGL	E LAY	ER/REF	LECTIV	E SIDE	IN							leater	ا فبا	<u>.</u>
Cha	ert#		lear		XN	o Wind		Ener	9y	Final		798	30	Day,	/Night			11	i.F.Pla .Coupl	C.	- 1*
	5	□ P	artia	1 Cove	r 🗆 M	<b>e</b> odrate	Wind			Previo	us	797	5	Date	Feb.	20,	1980	11		1	÷
		X C	verca	st	H	indy				Net			5	Humi	dity	Sot r	ec'd		ecorde	r L	
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T <sub>4</sub> _	10	10	10	11	11	11	11	11	11	11	11	11	11			T			1		
T <sub>5</sub>	10	10	10	10	10	10	10	10	10	10	10	10	10								
TAV	10	10	10	10-5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10-5								
T <sub>6</sub>	3	3	3	- 3	3	3	3	3	3	3	3	3	3								
7	19	20	21	20	20	20	20	20	20	20	20	20	19								
T <sub>8</sub>	19	20	21	21	21	20	20	20	20	21	20	20	20	,							
ا و	20	21	21	21	21	21	21	20	20	21	20	20	19								
TAV	19.6	20.3	21	20.6	20-6	20.3	20.3	20	20	20·6	20	20	19.6								
10																					
lea:	Flux	Plate																			
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bse	rvatio	ons: E.	ren th	ough t dings	he tem on hea	iperat: :tflux	ro was plates	s main s jump	tained sed us	l with by app	in plu. orox.	s/minu 3.5mV.	s 1/2	C <sup>O</sup> wh	en eve	r the	heat	r fan	Wis Ed	thed a	3

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L						5	SINGLE	LAYER	/REFLE	CTIVE	SIDE	IN	***					D- ne		Tq + [	- P
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	6	P	artia]	Cove	r 🗵 M	e odrate	Wind			Previo	us	318	5	Date	Feb.	21, 1	L980	: :	Couple	1 ~	Ε,
			vercas	s t	□w	indy		<u> </u>		Net		1	2	Hum -	di tyN	ot Rec	<u>'</u> .d	TOT Re	corder	6	
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7,	1	1	0	0	0	0	0	0	0	0	0	0	0	0			1				
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T <sub>4</sub>	2	2	- 2	2	2	2	2	2	2	1	1	1	1	1							
T <sub>5</sub>	2	2	1	1	1	1	1	1	1	1	0	0	1	0							
TAV	2	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1	0.5	0.3	1								
T <sub>6</sub>	-9	-10	-9	-9	-9	-9	-9	-10	-10	-10	-10	-10	-10	-10							
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T <sub>8</sub>	22	22	21	20	19	19	21	22	21	21	20	21	21	21							
<sup>T</sup> 9	22	21	21	20	19	20	22	22	21	20	20	20	20	20							
Ţ <sub>Α</sub> γ	22	21.3	2,1	19.6	19	19.3	21.3	21.6	20-6	20	2.3	20	20	20							
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Hear	: Flux	Plate	s														·····				
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2		4.55		3.22	3.58					4,42		6.17	4.42				1		$\neg \uparrow$		
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						SINGLE	LAYER	/REFLE	CTIVE	SIDE	EN							D- +	Meater	[•°, r	, ,
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T <sub>5</sub>	10	10	10	9	8	9	9	9	9	9	9	9	9								
TA	-	10	10	9.5	8.5	9	9	9	9	9	9	9	9								
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Hea	it Flu	x Plat	es			-			<b></b>	·	<b></b>										
1	*		3.75	1	2.93		2.58	L	3.99	1	3.14	3.49	3.39			-		<u> </u>			ļ
2	*	2.54	3.61	2.18	3.59	4.11	3.74	4.51	4.33	3.32	3.40	3.83	3.0L				<u> </u>	<u> </u>			<u> </u>
C5-					TWO	LAYERS			/ R F	FIFCT				<del></del>				Г			
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			lear			o Wind		Energ	ıy	Final		87	62	Day/I	Night	25 .0		• T	.F.Plat .Couple	1	
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	)		)vercas	st	□ w	indy				Net		00	115	Humi	dity	55%		T Re	corder	<u></u>	
Ter	perat	ure		<del></del>							-		······			***************************************	<del>-</del>				
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Ţ	-1	-0	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1							
T <sub>2</sub>	-1	-1	-1	-1	-1	-1	0	-1	-1	0	-1	-1	-1	-1							
73	0	0	0	0	0	0	0	0	0	0	0	0	0	•0							
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T <sub>5</sub>	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1			-	<u> </u>			
	-0,5	-0.5	-0.5	-0.5	-0.5		-0.5	-0.5	1	-0.5	-0.5	-0.5	-0.5	-0.5			ļ	-			
6	-16	-15	-14	-14	-15	-15	-15	-15	-15	-15	-15	-15	-15	-15				-			
T7	23	24	21	20	22	23	24	24	24	24	24	2.5	25	24			<u> </u>				
Т <sub>8</sub>	22	24	20	19	21	22	22	22	22	23	23	23	23	23			ļ	-			
	22.3			<del> </del>		<del> </del>				<del> </del>	<del> </del>		22	-				<del> </del>			
1 Ay	22.3	23.3	20.6	19.3	20.6	21.6	22	22.3	22.3	22.6	22.6	23	23.3	22.6			<del> </del>	<del> </del>			
10		<u> </u>															<u> </u>	<u> </u>			
неа	t Flux	Plate	25	,	,		,	,	·	·		·	,	,			,		, ,		
1	*	3.92					4.48			4.36	4.39	<del> </del>	4.32				ļ	-			
2	*	4.03	3.40	3.36	3.54	3.48	3,46	3.13	3.34	3.01	3.09	2.93	B.18	3.13			<u> </u>	<u> </u>			
Obse	rvati	ons:	•																		

							TWO LA	YERS/	REFLEC	TIVE S	IDE I	N (BOT	H LAYE	RS)				□- не		]	7
Cha	rt#		lear		□ N	o Wind		Energ	ЭУ	Final		918	8,5	Day/	Night			1	F.Plat Couple	<b>. 4</b>	
]	0a	Р	artial	Cove	- 🗆 M	odrate	Wind		1	Previo	us	917	9.0	Date	Feb	. 27,	1980	1	couple	1	Z .
		<u> </u>	vercas	t	□w	indy				Net			315	Humi	dity	557		Like	corder	<u> </u>	
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-	0	10	20	30	40	50	1	10	20	30	40	50	2			T	T				
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T <sub>2</sub>	4	4	3	3	3	3	3	3	2	2	. 2	2	2								Г
T <sub>3</sub>	6	6	5	5	5	4	4	4	4	4	3	4	3			1					Γ
Av	5	5	4.3	4	4	3.6	3.6	3.6	3	3	2.6	3	2.6								
T <sub>4</sub> _	6	6	-6	6	5	5	5	5	4	4	4	4	4								
T <sub>5</sub>	6	6	5	5	5	4	4	4	4	3	3	3	3								
TAV	6	6	5.5	5.5	5	4,5	4.5	4.5	4	3.5	3.5	3.5	3.5								
	-10	-9	-9	-9	-9	-9	-9	-10	-10	-10	-10	-10	-10								
7	26	24	22	20	20	20	20	21	1.7	19	20	20	19								
8	24	22	20	20	19	20	20	20	17	20	19	19	19								
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lea	Flux	Plate	es																		
1		2.13	·	2.03	1.86	2.03	3.09	3.53	1.38	3.23	2.29	2,49	1.96	T		T		T			
2	2 70	2 13	2.09	2.22	1.91	2.08	2 10	3.14	1.05	2 81	2.54	2.27	2.37	1		1					

Observations: The most of condensation took place along the lower half of the vertical curtain. Later on in the experiment when the temperature was allowed to drop the condensate did deposite it solf on the opper part of the vertical curtain but there was no condensation at all on the double-layer horizontal curtain.

	- non-derlane - o Anadografia			*************************		DC	UBLE	LAYERS	/ REFI	ECTIVE	E SIDE	IN			-		D+ H	eater	D+	
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		] Parti	al Cov	er 🗌	Modras	te Win	d		Prev	ious					27, 1	980	11	.Coup1		7
В		Overc	ast		Windy				Net				1	idity			,¤, ʁ	ecorde	r <u>  •                                   </u>	: <u>-</u>
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10		+		<del>                                     </del>	+	1	+	+	+-	-	-	+-	+	+	-	<del> </del>	-	-		┼
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2 2.	11.38 53 1.18			-	1.21	1.09		+	-		<del> </del>	-	ļ	<del> </del>	<del> </del>	-	-	<u> </u>		<u> </u>
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		allow	out if ed to a ondensa	drop r	edical	ly. I	rten t urtain t was	would observ	prevered that	ent th	ture w. e form layer:	as all ation sigve	of con suffec	densa Lant	e evel therma	n wher L resi	the tistance	emp. w : to pr	as event	7-1
		allow	ed to a	drop r	edical	ly. I	t was	observ	red tha	et two	ture w.e form. layer.	skive	suffec	densa:	therma	n wher l resi	Stance , □ He	to pr	event 、	13
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	, N	allow the c	ed to condens:	drop ration.	TWO  O Wind  odrate	LAYER	S/ REI	observ	ve SID	E IN	layer	LAYERS	Suffec	iant Night	therma	l rest	□ He  H.	eater F.Plat	event چ [	13
Chart (	, N	allow the d	ed to condens:	drop ration.	TWO	LAYER	S/ REI	observ	ve SID	E IN	(BOTH I	LAYERS	Day/	Night Feb.	therma	980	□ He  H.	eater	event &	13
Chart (		allow the c	ed to condens:	drop ration.	TWO  O Wind  odrate	LAYER	S/ REI	observ	VE SID	E IN	(BOTH 1 92 92	LAYERS	Day/	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	event &	13
Chart (	X  0	Clear Partia Overca	l Cover	Nr ∑Mr 40	TWO O Wino odrate indy	LAYER	S/ REI	observ	VE SID	E IN	(BOTH 1 92 92	LAYERS	Day/	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	event &	13
Chart :	iture	Clear Partia	ed to condens.	mr X M	TWO lo Wind codrate	LAYER	Ener	FLECTI	VE SID Final Previo	Dus	(BOTH t 92 92 00	LAYERS	Day/	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	event &	13
Chart / 11  Tempera	\( \times \)   \( \	Clear Partia Overca	l Coverst	Nr XM	TWO O Wind odrate indy 50 0	LAYER  Wind	Ener	FLECTI Tgy  20 0	Final Previo	0E IN 0	92 92 00 50 -1	LAYERS 43 31 21	Day/	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	event &	13
Chart # 11  Tempera	X	Clear Partia Overca  20 0 1	Covered to condens.	N   W   40   0   0	TWO To Wind Todate The state of	LAYER  LAYER  LO  O  O	Ener 10 0 0 0	FLECTI  Table 1	VE SID Final Previo	Dus 40	92 92 00	2 - 1	Day/	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	event &	13
Chart (1) Tempere 0 T1 0 T2 0 T3 1 TAW0.3	X	Clear Partia Overca  20 0 1 0.3	Covers t	N   N   W   40   0   0   0   0	TWO O Wind codrate indy  50 0 0	LAYER  LAYER  1  0  0  0	Ener	20 0 0	Final Previo	0 0 0 0 0	92   92   00   50   -1   0   0   0   3	2 2 -1 0 0 0 0 3	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	event &	13
Chart / 11  Tempera	X	Clear Partia Overca  20 0 1	Covered to condens.	N   W   40   0   0	TWO To Wind Todate The state of	LAYER  LAYER  1  0  0  0  0	Ener	20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	VE SID Final Previo	40 0 0 0 0 0 0	92   92   00   50   -1   0   0   3   0	21 21 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	event &	13
Tempera 0 T1 0 T2 0 T3 1 TAVO.3 T4 1 T5 0 TAVO.5	X	Clear   Partia   O   O   O   O   O   O   O   O   O	1 Covers t 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	N   N   W   W   W   W   W   W   W   W	TWO Windows of a control of the cont	LAYER  LAYER  1  0  0  0  0	Ener  10 0 0 0 0 0 0	20	VE SID  Final  Previous  0 0 0 0 0 0 0 0	40 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	92   92   00   50   -1   0   0   0   0   0   0	2 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	event &	13
Tempera 0 T1 0 T2 0 T3 1 TAVO.3 T4 1 T5 0 TAVO.5	X	Clear   Partia   O   O   O   O   O   O   O   O   O	Covers 30 0 0 0 0 0	N   N   N   N   N   N   N   N   N   N	Two  o Wince ended in the contract of the cont	LAYER  LAYER  1  0  0  0  0	Ener	20 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	VE SID Final Previo	40 0 0 0 0 0 0	92   92   00   50   -1   0   0   3   0	2 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	event &	13
Chart / 11  Fempera	X     X	Clear   Partia   O   O   O   O   O   O   O   O   O	1 Covers 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	N   N   W   W   W   W   W   W   W   W	TWO Windows of a term of the control	LAYER  1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Ener  10 0 0 0 0 0 0 0	20 0 0 0 0	30	40 0 0 0 0 0	92   92   00   50   -1   0   0   0   0   -14	2 -1 0 0 0 -14	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	event &	13
Chart , 11  Tempere	X   X   X   X   X   X   X   X   X   X	20 0 0 1 0.3 -1 0 0.5 -12	1 Coverst 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	N   N   N   N   N   N   N   N   N   N	Two O Winco Gate indy  50 0 0 0 0 0 0 0 0 0 1	LAYER  1	Ener  10 0 0 0 0 0 0 14	20	VE SID  Final Previous Net  30 0 0 0 0 0 0 0 0 0 0 0 0	40 0 0 0 0 0 0 0 0 0 0	92   92   00   0   0   0   0   0   0   0   0	2 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	& [	13
Tempera  0 T1 0 T2 0 T3 1 TAV0.3 T4 1 T5 0 TAV0.5 T6 -13 T7 23 T8 21 T9 22	X   X   X   X   X   X   X   X   X   X	20 0 0 1 0.3 -1 0 0.5 -12 22	1 Coverst  30 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1	N   N   N   N   N   N   N   N   N   N	Two  O Winco  Gate indy  50  0  0  0  0  0  1  22	LAYER  1	Ener  10 0 0 0 0 0 -14 23	20 0 0 0 0 0	VE SID Final Previo Net  30 0 0 0 0 0 0 -14 22	40 0 0 0 0 0 0	92   92   00   50   -1   0   0   0   -14   22	2 2 -1 0 0 0 -14 20	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	& [	13
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Chart / 11  Tempera	ture 10 0 1 0.3 1 0 0.5 -13 22 21 22	Clear   Partia   20   0   0   1   0   0   5   -12   22   21   21   21	1 Covers st 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	N   N   W   W   W   W   W   W   W   W	TWO O Winco odrate indy  50 0 0 0 0 0 0 -13 22 21	LAYER    Wind	Ener  10 0 0 0 0 0 -14 23 21	20	VE SID  Final Previous Net  30 0 0 0 0 0 0 -14 22 21	40 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	92   92   00   50   -1   0   0   0   -14   22   21   21	2 -1 0 0 0 0 -14 20 20 20	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	& [	13
Chart , 11  Tempere	X   X	Clear   Partia   O   O   O   O   O   O   O   O   O	1 Covers st 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	N   N   W   W   W   W   W   W   W   W	TWO O Winco odrate indy  50 0 0 0 0 0 0 -13 22 21	LAYER    Wind	Ener  10 0 0 0 0 0 -14 23 21	20	VE SID  Final Previous Net  30 0 0 0 0 0 0 -14 22 21	40 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	92   92   00   50   -1   0   0   0   -14   22   21   21	2 -1 0 0 0 0 -14 20 20 20	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	& [	13
Chart / 11  Tempera	No.3   1   0   0.5   -13   22   21   22   21   6	20 0 0 1 1 0.3 -1 2 2 2 2 1 2 1 . 3	1 Coverst  30 0 0 0 0 0 -13 21 21 21	□ N N □ W M	Two drate indy 50 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	LAYER  LAYER  LAYER  1  0  0  0  0  0  -13  22  21  21.3	Ener    10	20 0 0 0 0 0 0 0 -14 21 20 22	VE SID Final Previous 0 0 0 0 0 0 -14 22 21 20.3	E IN 1  40 0 0 0 0 0 0 -14 23 22 22.3	SOTH   1   92   92   00   0   0   0   0   0   0   0   0	AYERS 43 31 21 0 0 0 0 0 1 20 20 20	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	& [	13
Chart (1)  Tempera	X   X	20 0 0 1 1 0.3 -1 2 2 2 2 1 2 1 . 3 . 0 5	1 Coverst  30 0 0 0 0 0 0 -13 21 21 21 21	□ N N	Two drate indy 50 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	LAYER  LAYER  LAYER  LAYER  LAYER  LAYER  LOO  O  O  O  O  O  O  O  O  O  O  O	Ener    10	20   0   0   0   0   0   0   0   14   21   20   22     3.24     3.24	VE SID  Final Previous Net  30 0 0 0 0 0 0 -14 22 21	E IN 6  40  0  0  0  0  0  -14  23  22  22  22  34.02	SOTH   1   92   92   00   0   0   0   0   0   0   0   0	AYERS 43 31 21 0 0 0 0 0 1 20 20 20	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	& [	13
Chart (1)  Tempera 0  T1 0  T2 0  T3 1  TAVO.3  T4 1  T5 0  TAVO.5  T6 -13  T7 23  T8 21  T9 22  TAV 21  T0 10	X   X	Clear   Partia   Dverca	1 Coverst  30 0 0 0 0 0 0 -13 21 21 21 21	□ N N	Two drate indy 50 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	LAYER  LAYER  LAYER  LAYER  LAYER  LAYER  LOO  O  O  O  O  O  O  O  O  O  O  O	Ener    10	20   0   0   0   0   0   0   0   14   21   20   22     3.24     3.24	VE SID Final Previous 0 0 0 0 0 0 -14 22 21 21 20.3	E IN 6  40  0  0  0  0  0  -14  23  22  22  22  34.02	SOTH   1   92   92   00   0   0   0   0   0   0   0   0	AYERS 43 31 21 -1 0 0 0 0 0 -14 20 20 3.18	Day/Date	Night Feb.	28, 1°	980	□ He  H.	eater F.Plat	& [	13 13

						TW	O LAYE	RS / REI	FLECTI	VE SID	E IN						□- Не		3	, <sup>7</sup> ,
Chart #	<b>X</b> 0	lear			lo Wind	!	Ener	ЭУ	Final		07.	21	Day/	Night			§	F.Plat	4	
12	ПР	artia	1 Cove	r 🖾 M	e lodrate	Wind	1		Previo	1115	07	133		***************************************	h 2,	1980	1	Couple	1	্টু হ
	-	verca:			lindy				Net		00	07 <del>1</del>	Humfe	dity	50%		T Re	corder	<u> </u>	
Temperati	ure						٠	~		***************************************		······································								
0	10	20	30	40	50	60								Ī			T			
T <sub>1</sub> -4	-3	-3	-2	-2	-2	-2														
T <sub>2</sub> -4	-3	-3	-2	-2	~2	-2			The state of the s								<u> </u>			
T <sub>3</sub> -3	-2	-2	-2	-1	-1	-1														
TAV		-	-	ļ	-			ļ												
T <sub>4</sub> -3	-2	=1	-1	-1	-1	-1														
T <sub>5</sub> -3	-2	-2	-2	-2	-2	-2	-			-							-			
TAV T <sub>6</sub> -15		<del> </del>	-		-	<u> </u>	<del> </del>	<del> </del>		-										
<sup>1</sup> 6 -15 T <sub>7</sub> 19	-13 19	-14 19	-14 21	-13 19	-13 19	-13 20	-													
T <sub>8</sub> 19	18	19	20	1.8	19	19				<del>                                     </del>							<del>                                     </del>			
T <sub>9</sub> 19	18	19	19	18	19	19	<del>                                     </del>	-		<u> </u>							<del> </del>			<b></b>
T <sub>AV</sub> 19	18.3		20	18.3	19	19.0	-		<del>                                     </del>											<del> </del>
T <sub>10</sub>																				
Base 51	03		h								<u> </u>									<u></u>
Heat Flux			T	3.35	12.27				T	Ī	I					<del></del> -				Γ
1 3.73	4.14 3.19	<del></del>	<del> </del>	3.08	<del> </del>															
Observation									<u> </u>	<u> </u>							<u> </u>			<u> </u>
			,	TWO L	AYERS/	REFLI	ECTIVE	SIDE	IN (BC	OTH LA	YERS)						1	ater		
Chart #	⊠c	lear			.AYERS/		Ener		IN (BO		YERS) 888	.8	Day/	Night			⇒ н.	F.Plat	r di	- 2 - 2
				N	·		Ener	gy			T		Date	March	3, 19		<b>≕</b> н. • т.	F.Plat	•	<b>== 2</b>
Chart # 13	ПР		l Cove	□N r ⊠m	o Wind		Ener	gy	Final		888	. 5	Date	March	3, 19 60%-60		<b>≕</b> н. • т.	F.Plat	•	<b>== 2</b>
	□ p	artial	l Cove	□N r ⊠m	lo Wind		Ener	gy	Final Previo		888	. 5	Date	March			<b>≕</b> н. • т.	F.Plat	•	<b>== 2</b>
13	□ p	artial	l Cove	□N r ⊠m	lo Wind		Ener	gy	Final Previo		888	. 5	Date	March			<b>≕</b> н. • т.	F.Plat	•	<b>== 2</b>
Temperatu  0 T, 3	□p □0	artial vercas	l Cove	□N r ⊠m □W	lo Wind lod <sup>e</sup> ate	Wind	Ener	gy	Final Previo	ous	888 0876 012	.3	Date Humi	March dity	60%-60	7 ]	→ н. • т. <del>ш</del> Re	F.Plan Couple	•	= 2
Temperatu  0 T, 3		artial vercas	Cove	N rM H	o Wind odrate	Wind	Energy 10	gy 20	Final Previo	ous 40	888 0876 012	.5	Date Humi  10 2	March dity 20	30	40	→ H. • T. ☐ Re	F.Plan Couple corder	•	= 2
13	P   O   O   O   O   O   O   O   O   O	artial vercas 20 3	30 3	N r ∑ M W 40 3	lo Wind lodrate	Wind  1 3	10 2	20 2	Final Previo	40 2	888 0876 012 50 2	.5	Date Humi	March dity	30 2	40 2	- H. • T. □ Re	F.Plan Couple corder	•	<b>== 2</b>
Temperatu  0 T1 3 T2 3 T3 4 TAV 3.3	P	artial vercas  20 3 3	30 3 3 3 3	N N N N N N N N N N N N N N N N N N N	lo Wind lodrate lindy	1   3   2   3   2.6	10 2 2 3 2.3	20 2 2 3 2.3	30   2   3   2.3	40 2 2 3 2.3	888 0876 012 50 2 2 3 2.3	2 2 2 2 2 2	Date   Humi   10   2   2   2   2   2   2	March dity  20 2 2 2 2 2	30 2 2 2 2 2	2 2 2 2	50 2 2 2 2 2	F.Plan Couple corder	•	<b>== 2</b>
Temperatu  0 T1 3 T2 3 T3 4 TAW 3.3 T4 4	10 3 3 4 3.3 4	20 3 3 4 3.3	30 3 3 3 3 4	Nr XM 40 3 3 3 4	o Wind odrate indy	Wind  1 3 2 3 2.6 3	10 2 2 3 2.3 3	20 2 2 3 2.3	30   2   2   3   2.3   3	2 2 3 2.3 3	50 2 2 3 2.3 3	2 2 2 2 2 3	Date   Humi   10   2   2   2   2   2   2	20   2   2   2   2   2   2   2   2   2	30 2 2 2 2 2 2	2 2 2 2 2	50 2 2 2 2 2 2 2	F.Plan Couple Corder	•	<b>== 2</b>
Temperatu  0  T1 3  T2 3  T3 4  TAV 3.3  T4 4  T5 3	10 3 3 4 3 3 4 3 3	20 3 3 4 3.3 4	30 3 3 3 3 4 3	□ N r ⊠ M 40 3 3 3 3 3 4 4 3 3	50 Sindy Sin	## Wind   1   3   2   3   2   6   3   3   3	10 2 2 3 2.3 3	20 2 2 3 2.3 3	30   2   3   2   3   2   3   2	2 2 3 3 2 2 3	50 2 2 3 2.3 3 2	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	10   2   2   2   2   2   2	20   2   2   2   2   2   2   2   2   2	30 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2	50 2 2 2 2 2 2 2 2 2	F.Plan Couple Corder	•	<b>== 2</b>
Temperatu  0  T1 3  T2 3  T3 4  TAV 3.3  T4 4  T5 3  TAV 3.5	10 3 3 4 3 3 4 3 3 5 5	20 3 3 4 3.3 4 3.3	30 3 3 3 3 4 3	Nr X Mr 40 3 3 3 4 3 3 5	50 Wind od ate indy  50 3 2.6 3.3 3.3	1 3 2 3 2 .6 3 3 3 3	10 2 2 3 2.3 3 2.5	20 2 2 3 2.3 3 2.5	30   2   2   3   2   3   2   2   5	2 2 3 2 . 3 2 . 2 . 5	50 2 3 2.3 3 2.5	.5 .3 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2 .2	Date Humi  10 2 2 2 2 2 2 2	March dity 20 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	30 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	50 2 2 2 2 2 2 2 2 2 2 2	3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	•	<b>== 2</b>
Temperatu  O T <sub>1</sub> 3  T <sub>2</sub> 3  T <sub>3</sub> 4  TAV 3.3  I <sub>4</sub> 4  T <sub>5</sub> 3  TAV 3.5  C 6 -6	10 3 3 4 3.3 4 3.5	20 3 3 4 3.3 4 3.3	30 3 3 3 3 4 3 3.5	N N X M A A A A A A A A A A A A A A A A A A	50 3 2 3 2 6 3 3 3 3 -5	Wind  1 3 2 3 2.6 3 3 3 -4	10 2 2 3 2.3 3 2 2.5	20 2 2 3 2.3 3 2.5	30 2 2 3 2.3 3 2 2.5 -4	2 2 3 2 2 3 2 2 5 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	888 0876 012 50 2 2 3 2.3 3 2 2.5	.5 .3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 4 2 4 2 4	Date Humi  10 2 2 2 2 2 2 2 2 4	March dity  20 2 2 2 2 2 2 2 2 2 -4	30 2 2 2 2 2 2 2 2 -4	2 2 2 2 2 2 2 -4	50 2 2 2 2 2 2 2 2 2 2 4	3 2 2 2 2 2 2 2 2 2 4 4	•	<b>== 2</b>
Temperatu  0 T <sub>1</sub> 3 T <sub>2</sub> 3 T <sub>3</sub> 4 TAV 3.3 T <sub>4</sub> 4 T <sub>5</sub> 3 TAV 3.5 T <sub>6</sub> -6 T <sub>7</sub> 26	10 3 4 3 3 4 3 3 5 -5 25	20 3 3 4 3.3 4 3.3 5 -5 24	30 3 3 3 3 4 3 3.5 -5	N N N N N N N N N N N N N N N N N N N	50 Windy 50 3 2.6 3 3.3 -5 20	1 3 2 3 2.6 3 3 3 -4 28	10 2 2 3 2.3 3 2 2.5 -4	20 2 2 2 3 2,3 3 2 2,5 -4	30   2   2   3   2   3   2   2   2   3   2   2	2 2 3 2 2 3 2 2 5 4 20	50 2 2 3 2.3 3 2.3 12.9	.5 .3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Date Humi  10 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	20   2   2   2   2   2   2   2   2   2	30 2 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2 1 2 1 2 1 2 1	50 2 2 2 2 2 2 2 2 2	3   2   2   2   2   2   2   2   1   9	•	<b>== 2</b>
Temperatu  0 T1 3 T2 3 T3 4 TAW 3.3 T4 4 T5 3 TAV 3.5 T6 -6 T7 26 T8 25	10 3 3 4 3 3 3 5 -5 25 24	20 3 3 4 3.3 4 3.5 -5 24	30 3 3 3 3 4 3 3.5 -5 19	N N N N N N N N N N N N N N N N N N N	50 Wind wind wind wind wind wind wind wind w	1 3 2 3 2.6 3 3 3 -4 28	10 2 2 3 2.3 3 2 2.5 -4 20	20 2 2 2 3 2.3 3 2 2.5 -4 20	30   2   2   3   2   3   2   2   2   2   2	2 2 3 2 2 3 2 2 5 4 2 0 2 0	50 2 2 3 2.3 3 2 2.5 -4 19	.5 .3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Date Humi  10 2 2 2 2 2 2 2 2 4	March dity  20 2 2 2 2 2 2 2 2 2 -4	30 2 2 2 2 2 2 2 2 -4	2 2 2 2 2 2 2 -4	50 2 2 2 2 2 2 2 2 2 2 4	3 2 2 2 2 2 2 2 2 2 4 4	•	<b>== 2</b>
Temperatu  0 T1 3 T2 3 T3 4 TAV 3.3 T4 4 T5 3 TAV 3.5 T6 -6 T7 26 T8 25 T9 26	P 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	20 3 3 4 3.3 4 3.5 -5 24 23	30 3 3 3 3 4 3 3 .5 -5 19 19 20	N N N N N N N N N N N N N N N N N N N	SO   3   2   3   2   6   3   3   -5   20   21   21	Wind  1 3 2 3 2.6 3 3 -4 28 20 20	10 2 2 3 2.3 3 2.5 -4 20 20	20 2 2 3 2.3 3 2.5 -4 20 20	30   2   3   2   3   2   2   5   -4   20   20   20	2 2 3 2.5 -4 20 20 20	50 2 2 3 2.3 3 2.5 -4 19	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	10 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	March ddity 20 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	30 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	50 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	F.Platic Couple coorder  3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	•	<b>== 2</b>
Temperatu  0 T1 3 T2 3 T3 4 TAV 3.3 T4 4 T5 3 TAV 3.5 T6 -6 T7 26 T8 25 T9 26 TAV 25.6	10 3 3 4 3 3 3 5 -5 25 24	20 3 3 4 3.3 4 3.5 -5 24 23	30 3 3 3 3 4 3 3.5 -5 19	N N N N N N N N N N N N N N N N N N N	50 Wind wind wind wind wind wind wind wind w	1 3 2 3 2.6 3 3 3 -4 28	10 2 2 3 2.3 3 2 2.5 -4 20	20 2 2 2 3 2.3 3 2 2.5 -4 20	30   2   2   3   2   3   2   2   2   2   2	2 2 3 2 2 3 2 2 5 4 2 0 2 0	50 2 2 3 2.3 3 2 2.5 -4 19	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	10 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	March dity	30 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	50 2 2 2 2 2 2 2 2 2 2 2 2 2 2	F.Plant Couple coorder  3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	•	<b>== 2</b>
Temperatu  0 T1 3 T2 3 T3 4 TAV 3.3  T4 4 T5 3  TAV 3.5 T6 -6 T7 26 T8 25 T9 26  TAV 25.6 T10	P 0 0 orre 10 3 3 4 4 3 3 3 5 -5 25 24 25 24 6	20 3 3 4 3.3 4 3.5 -5 24 23 23 23.3	30 3 3 3 3 4 3 3 .5 -5 19 19 20	N N N N N N N N N N N N N N N N N N N	SO   3   2   3   2   6   3   3   -5   20   21   21	Wind  1 3 2 3 2.6 3 3 -4 28 20 20	10 2 2 3 2.3 3 2.5 -4 20 20	20 2 2 3 2.3 3 2.5 -4 20 20	30   2   3   2   3   2   2   5   -4   20   20   20	2 2 3 2.5 -4 20 20 20	50 2 2 3 2.3 3 2.5 -4 19	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	10 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	March ddity 20 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	30 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	50 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	3   2   2   2   2   2   2   2   2   2	•	<b>== 2</b>
Temperatu  0 T1 3 T2 3 T3 4 TAV 3.3  T4 4 T5 3  TAV 3.5 T6 -6 T7 26 T8 25 T9 26 TAV 25.6 T10  Heat Flux	P P P P P P P P P P P P P P P P P P P	20 3 3 4 3.3 4 3.5 -5 24 23 23.3	30 3 3 3 4 3 3 5 5 19 19 20 19.6	N N N N N N N N N N N N N N N N N N N	SO   3   2   3   2   6   3   3   -5   20   21   21   20   6	Wind  1 3 2 3 2.6 3 3 -4 28 20 20	10 2 2 3 2.3 3 2 2.5 -4 20 20 19	20 2 2 3 2.3 3 2.5 -4 20 20 19	30   2   3   3   2   2   5   4   20   20   20   20	2 2 3 2 2 5 4 2 2 0 2 0 2 0 2 0	50 2 3 2.3 3 2.5 -4 19 20	.5 .3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Date Humi  10 2 2 2 2 2 2 2 2 1 9 19 19.6	March ddity 20 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	30   2   2   2   2   2   2   2   2   2	2 2 2 2 2 2 2 2 2 2 1 2 1 2 1 2 1	50 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	F.Platic Couple coorder  3	•	<b>== 2</b>
Temperatu    O   T   3     T   2   3     T   3   4     T   4   4     T   5   3     T   4   4     T   5   3     T   7   26     T   8   25     T   9   26     T   T   T   T     T   T   T   T     T   T	P P 10 0 3 3 4 4 3 3 3 .5 -5 25 24 .6 P P l a te 1 . 90	20 3 3 4 3.3 4 3.3 5 -5 24 23 23.3 23.3	30 3 3 3 3 3 4 3 3.5 -5 19 19.6	N N N N N N N N N N N N N N N N N N N	50 Wind od ate indy  50 3 2.6 3.3 -5.20 21 20.6	Wind  1 3 2 3 2.6 3 3 -4 28 20 20 20	10 2 2 3 2.3 3 2.5 -4 20 20 19	20 2 2 2 3 2.3 3 2 2.5 -4 20 20 19	30   2   3   2   3   2   2   5   -4   20   20   20   1   8   5	2.3 3 2.3 2.5 -4 20 20	888 0876 012 50 2 3 2.3 3 2 2.5 -4 19 19 20 19.3	2 2 2 2 2 2 2 2 3 2 2 2.5 -4 20 20 19 19.6	Date Humi  10 2 2 2 2 2 2 2 2 2 1 9 19 19.6	March ddity 20 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	601-60 30 2 2 2 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 1 2 1 2 1 1 . 87	50 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	F.Plant Couple coorder  3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	•	<b>== 2</b>
Temperatu    O   T1   3     T2   3     T3   4     TAV   3.3     T4   4     T5   3     TAV   3.5     T6   -6     T7   26     T8   25     T9   26     TAV   25.6     T10	P 10 3 3 4 4 3 3 3 5 -5 25 24 6 P 1 ate 1 1 9 0 3 1 1 4	20 3 3 4 3.3 4 3.3 5 -5 24 23 23.3 23.3	30 3 3 3 3 3 4 3 3.5 -5 19 19.6	N N N N N N N N N N N N N N N N N N N	50 Wind od ate indy  50 3 2.6 3.3 -5.20 21 20.6	Wind  1 3 2 3 2.6 3 3 -4 28 20 20 20	10 2 2 3 2.3 3 2.5 -4 20 20 19	20 2 2 2 3 2.3 3 2 2.5 -4 20 20 19	30   2   3   2   3   2   2   5   -4   20   20   20   1   8   5	2.3 3 2.3 2.5 -4 20 20	888 0876 012 50 2 3 2.3 3 2 2.5 -4 19 19 20 19.3	2 2 2 2 2 2 2 2 3 2 2 2.5 -4 20 20 19 19.6	Date Humi  10 2 2 2 2 2 2 2 2 2 1 9 19 19.6	March ddity 20 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	601-60 30 2 2 2 2 2 2 2 2 2 2 2 2 2	2 2 2 2 2 2 2 2 1 2 1 2 1 1 . 87	50 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	F.Plant Couple coorder  3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	•	== 2

THREE LAYERS/TWO REFLECTIVE SIDES FACING IN & ONE of the Control o	FACING OCT	,	
14 Partial Cover Modrate Wind Previous Overcast Windy Net  Temperature	956.5		D- Heater
14 Partial Cover Modrate Wind Previous Overcast Windy Net  Temperature		Day/Night	H.F.Plate
Overcast Windy Net	947.5	Date March 4 1980	• T.Couple  Recorder
Temperature	9.0	Humidity 603	Recorder =
0   10   20   30   40   50   60   70   80   90   100			
	110 120		
<del>                                     </del>	4		
	5 5		
T <sub>AM</sub> 5.3 4.6 5.3 5 5.3 5 4.6 4.0 4.3 4.			
	5 5	+ + + + + + + + + + + + + + + + + + + +	
<u>-</u>  -	4 4		
T <sub>AV</sub> 5.5 4.5 5 5 5 5 4.5 4.5 5 4			
T <sub>6</sub> -2 -1 -1 -1 -1 -1 -1 -1 -2	2 -2		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	.22		
T <sub>8</sub> 19 22 22 22 23 23 23 22 21 21 2	1 20		
Tg 21 21 21 21 20 20 20 21 21 21 2			
TAY 20 21.3 21.3 21.3 21.3 21 21.3 21.3 21 21.	21		
T <sub>10</sub>			
Heat Flux Plates			
1 2.03 1.73 1.64 1.56 1.46 1.77 1.67 1.57 1.53 1.49 1.60	1.60		
2 2.56 1.21 1.50 1.38 1.41 1.33 1.67 1.42 1.28 1.30 1.5.			
Observations:			
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		······································	
TRIPLE LAYERS/REFLECTIVE SIDE IN			□ Heater
		Day/Night	H.F.Plate
Chart # Clear No Wind Energy Final	0081	Day/Night	• T.Couple
Chart # Clear No Wind Energy Final Partial Cover Moderate Wind Previous	0075	Date March 5, 1980	H.F.Plate
Chart # Clear No Wind Energy Final  Partial Cover \( \overline{X}\) ModFate Wind Previous  Overcast (rain) \( \overline{W}\) Windy Net		<u> </u>	• T.Couple
Chart # Clear No Wind Energy Final Partial Cover Modeate Wind Previous Net  Temperature	6	Date March 5, 1980	• T.Couple
Chart #   Clear	50 2	Date March 5, 1980 Humidity 60%-65%	• T.Couple
Clear   No Wind   Energy   Final	6	Date March 5, 1980 Humidity 60%-65%	• T.Couple
Chart #         ☐ Clear         ☐ No Wind         Energy         Final Previous Net           15         ☐ Partial Cover         ☒ Modrate Wind         Previous Net           Temperature           0         10         20         30         40         50         1         10         20         30         40           7         7         7         7         7         7         6         6         6           7         7         6         6         6         6         6         6         6	50 2 6 6 6 6	Date March 5, 1980 Humidity 60%-65%	• T.Couple
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	50 2 6 6	Date March 5, 1980 Humidity 60%-65%	• T.Couple
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	0075 6 50 2 6 6 6 6 6 6 6 6	Date March 5, 1980 Humidity 60%-65%	• T.Couple
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	50 2 6 6 6 6 6 6 6 6 6	Date March 5, 1980 Humidity 607-657  10 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	• T.Couple
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	0075 6 50 2 6 6 6 6 6 6 6 6	Date March 5, 1980 Humidity 60%-65%  10 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	• T.Couple
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	50 2 6 6 6 6 6 6 6 6 6	Date March 5, 1980 Humidity 607-657  10 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	• T.Couple
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	50 2 6 6 6 6 6 6 6 6 7 6 6	Date March 5, 1980 Humidity 60%-65%  10 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	• T.Couple

Т <sub>9</sub>	28 28	24	22	23	22 22	22	22	22	22	21	22	21	21	20 19.6				<u> </u>	-
Ay 10	20	23.3	22.3	22.3	22	- 44	21.0	21.3	41.0	21.3							<del>                                     </del>		-
Hear	t Flux	Plate	?S							-									
Hea 1	t Flux 1.54		,																<u> </u>

Observations: The heat was not turned on for the first 25min.

							TRI	TPLE L	AYER/R	EFLECT	IVE S	IDE IN						D- Ne	ater		747
	irt #	X p	lear artia	l Cove	r XM	o Wind odrate indy		Ener		Final Previo Net	us	0201		Date		ch 16,		• T.	F.Plat Couple corder	132	**
Ter	perati																				
	0	10	20	30	40	50	1	10	20	30	40	50	2	10			T		-	-	
T,	4	4	4	4	4	4	4	4	4	4	4	-+	4								
Т2	4	4	4	4	4	4	4	4	4	4	4	4	4								
T <sub>3</sub>	4	4	3	- 5	5	5	5	5	5	5	5	5	5								
TAV	4	4	4.3	4.3	4.3	4.3	4,3	4.3	4,3	4.3	4.3	4.3	4.3		-						
<b>7</b> 4	4	4	-4	4	5	5	5	4	4	4	4	4	4		non-						
T <sub>5</sub>	4	4	4	4	4	4	4	4	4	4	4	4	4								
TAV		4	4	4	4.5	4.5	4.5	4	4	4	4	4	4								
T <sub>6</sub>	<b>-</b> 5	<b>-</b> 5	-4	4	-4	+ 5	-4	-4	-3	- 3	-3	-3	}								
<sup>†</sup> 7	22	21	22	22	23	23	23	23	23	23	23	22	22								
T <sub>e</sub> T <sub>e</sub>	23	22	22	22	22	22	22	2.2	22	22	22	2.2	22								
	23	22	22	22	23	23	23	23	23	22	23	22	23						1		
TAY	23.6	21.6	22	22	22.6	22.6	22.6	22.6	22.6	22.5	22.6	22	22.6					1			
T <sub>10</sub>																					
Hea	Flux	Plate	s																		
1	1.61	1.64	1.71	1.73	1.70	1,63	1.64	1.72	*	1.69	1.66	1.52	1.63		T	T	T	T			
2	*	1.60	1.66	1.65	1.70	1.56	1.58	1.62	1.60	1.68	1.61	1.56	1.51				1				
Obse	rvatio	ons:	The	heat	: was	s no	t tu	rne	d on	for	the	fi	rst	10mi	n.						

THREE LAYERS/TWO REFLECTIVE SIDES FACING IN & ONE FACING OUT □ Heater - H.F.Plate 0581 Clear No Wind Final Chart # Energy D**áý**/Night • T.Couple Partial Cover Modrate Wind 0573 Date March 10 1980 Previous Recorder 17 Overcast (rain Windy Net В Temperature 20 | 30 40 70 80 90 100 110 120 50 60 10 8 8 8 8 3 8 8 8 9 9 8 8 9 9 8.6 8.6 8.6 8.6 8.6 8.6 8.6 8.6 9 9 9 8 8 8 8 8.5 8.5 8.5 8.5 8.5 8.5 8.5 8.5 8.5 8.5 8.5 8.5 2 2 2 24 23 24 23 23 23 23 24 24 23 24 24 24 24 24 23 23 23 24 2.5 2.5 25 24 24 25 24 23 23 25 Т9 23 23 23 23 23.3 23.6 24 24 34 24.3 23.3 23.6 23.3 23.3 23.3 Heat Flux Plates 1 2.20 2.05 1.53 1.75 3.47 3.22 3.49 3.03 3.26 3.22 3.04 3.17

Observations: The heat was not turned on for the first 10min.

2 1.97 1.66 1.36 1.46 1.46 1.48 1.45 1.24 1.29 1.22 1.24 1.28 1.31

			FOU	R LAYE	RS/THK	EE REI	FLECTI	VE SIL	E IS 8	ONE (	REFLECT	rived s	SIDE O	LT ·			□н	eater	<u> </u>	3.7
Chart #	N	Clear			No Win	d	Ene	rgy	Final		06	46.5	Day,	Night			11	.F.Pla	1	ਧ' &
18		Partia	1 Cove	er 🗌	Modra t	e Wind			Previ	ous	06	38	Date	Marc	h 11,	1980		.Couple	1 2	, T. T.
		Overca	st	X	Windy		<u> </u>		Net			8.5	Hum	dity	682		TR	corde	<u> </u>	•
Tempera	ture			***************************************						·····	~			~		······································				
0	10	30	30	40	50	Ĭ.	10	20	30	40	50	2	1	T		T	T	T		Т
7, 1	1	1	1	2	2	2	2	2	2	2	2	2		1	<b>†</b>	1	<b>†</b>	1		
T <sub>2</sub> 1	1	1	1	2	2	2	2	2	2	2	2	2			1		T			
T <sub>3</sub> 1	1	1	2	2	2	2	2	2	2	2	3	2					1			
T <sub>AV</sub> 1	1	1	1.3	2	2	2	2	2	2	2	2.3	2								
<u>[4 1 1 </u>	1	- 1	1	2	2	2	2	2	2	2	2	2								
<sup>T</sup> 5 0	+	0	1	1	1	1	1	1	1	1	1	1								
TAV . 5	1	. 5	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.3	1.5		-	-		ļ			
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bservati	ons:		2.03	1.95	1.41	1.73	1.53	1.79	1.32	1.37	1.48	1.39	.38							
bservat	ons:				1						1.48	1.39	.97		>					
bservat				EE LAY	ERS/NE	W CURT	AIN TW	O REFL	LECTIVI		1.48	1.39	.97		3 OUT		□+ Hea □ H.f		→** □	
bservat:	X c	lear	THRE	EE LAY	ERS/NE	W CURT		O REFL	.ECTIVI	E SIDE:	1.48	NG IN	.97 & ONE		GOUT		<b>-</b> H.F			
	X C	lear	THR	EE LAY	ERS/NE  O Wind  godrate	W CURT	AIN TW	O REFL	ECTIVI	E SIDE:	1.48 S FACIN	1.39 NG IN	& ONE Day/N Date	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		
Chart #	X C   Pe	lear	THR	EE LAY	ERS/NE	W CURT	AIN TW	O REFL	.ECTIVI	E SIDE:	1.48 S FACIN	NG IN	.97 & ONE	ight	G OUT		<b>-</b> H.F	.Plate ouple		= <sup>2</sup>
hart#	X C   Pe	lear	THR	EE LAY	ERS/NE  O Wind  godrate	W CURT	AIN TW	O REFL	ECTIVI	E SIDE:	1.48 S FACIN	1.39 NG IN	& ONE Day/N Date	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
hart # 27 emperat 0	X C   P c   O v	lear artial vercas	THRE Cover	EEE LAY NO X MM	ERS/NE  D Wind  odrate  indy	W CURT	Energ	O REFL  y F P N	LECTIVI Tinal reviouet	E SIDE:	1.48 S FACIN	1.39 NG IN	& ONE Day/N Date	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
hart # 27 emperat 0, 12	XC P.	lear artial vercas	THRE	EE LAY	ERS/NE  D Wind  odrate  indy	W CURT	Energ	O REFL	ECTIVE	E SIDE:	1.48 S FACIN	1.39 NG IN	& ONE Day/N Date	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
hart # 27 emperat 0 1 12 2 12	X C   P c   O v	lear artial vercas	THRE Cover	EEE LAY NO X MM	ERS/NE  D Wind  odrate  indy	W CURT	Energ	O REFL  y F P N	LECTIVI Tinal reviouet	E SIDE:	1.48 S FACIN	1.39 NG IN	& ONE Day/N Date	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
hart # 27 emperat 0 1 12 2 12 3 12	X C	lear artial vercas	Covert	EE LAY  NN  X MM  W  40  13	ERS/NE  D Wind  Odrate  indy  50  13	W CURT	Energ	O REFL  Y  P  N  20  12	ECTIVE reviouet	E SIDE:	1.48 S FACIN	1.39 NG IN	& ONE Day/N Date	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
hart # 27 emperat 0 12 2 12 3 12 Av 12	X C   Po	lear artial vercas	THR:  Covert  30 13	N: N: W:	EERS/NE D Wind Odrate indy  50 13	Wind  1 12 12	Energ.	00 REFL  P P N  20 12 12 12	.ECTIVI	E SIDE:	1.48 S FACIN	1.39 NG IN	4 ONE  Day/N  Date  Humid	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
27 emperat 0 1 12 2 12 3 12 4 13	X C   Po	lear artial vercas	THR:  Covert  30 13 13	Ni N	EERS/NE  Wind  which  observed the served of	Wind  1 12 12 13	Energ.	00 REFL  P P N  20 12 12 12 12 12	30 12 12 12	E SIDE:	1.48 S FACIN	1.39 NG IN	4 ONE  Day/N  Date  Humid	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
27 emperat 0 1 12 2 12 3 12 4 13	X C   P c   O v	lear 20 12 13 12.3	THR:  Cover.t  30 13 13 13	■ No.   No.	b Wind appropriate the state of	Wind  1 12 12 13 12.3	Energ	20   12   12   12   12   12   12   12	30 12 12 12 12 12	E SIDE:	1.48 S FACIN	1.39 NG IN	4 ONE  Day/N  Date  Humid	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
hart #  27  emperat  0  1 12 2 12 3 12 4 13 5 12	X C   Po	20 12 13 12.3	THR:  Covert  30 13 13 13 13	N   N   N   N   N   N   N   N   N   N	So Windy  50 13 13 13	Wind  1 12 12 13 12.3	Energ.  10 12 12 12 12 12 12 12	20 12 12 12 12 12 12 12 12 12 12 12 12 12	30 12 12 12 12 12 12 12 12 12 12 12 12 12	E SIDE:	1.48 S FACIN	1.39 NG IN	4 ONE  Day/N  Date  Humid	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
hart #  27  emperat  0  1 12  2 12  3 12  4 13  6 12  1 12.5  11	X C   Po	20 12 13 12.3 14	THR:  Covert  30 13 13 13 13	No.	so Windows South State S	Wind  1 12 13 12.3 13 12	Energ.  10 12 12 12 12 12 12 12	20 12 12 12 12 12 12 12	30 12 12 12 12 12 12 12 12 12 12 12 12 12	E SIDE:	1.48 S FACIN	1.39 NG IN	4 ONE  Day/N  Date  Humid	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
hart #  27  emperat  0  1 12  2 12  3 12  Av 12  4 13  5 12  Av 12.5  11	X C   P. Ovure   10   12   12   13   13   12   12.5	20 12 13 12.3 14 13 13.5	THR:  Covert  30 13 13 13 13 13	□ N. M. W W W W W W W W W W W W W W W W W W	50 13 13 13 12 12.5	Wind  1 12 12 13 12.3 13 12 12.5	Energy  10 12 12 12 12 12 12 12 12	20 12 12 12 12 12 12 12 12 12 12 12 12 12	30 12 12 12 12 12 12 12 12 12 12 12 12 12	E SIDE:	1.48 S FACIN	1.39 NG IN	4 ONE  Day/N  Date  Humid	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
hart #  27  emperat  0 1 12 2 12 3 12 4 13 5 12 4 12.5 6 11 7 15	X C   Poor   P	20 12 13 12.3 14 13 13.5 10	THR:  Covert  30 13 13 13 13 13 10	□ N: Mr. □ W Mr. □ W 40 13 13 13 13 13 13 13 10	50 13 13 13 12 12.5 10	Wind  1 12 13 12.3 13 12 12.5 9	Energy 10 12 12 12 12 12 12 12 12 19	20 12 12 12 12 12 12 19 9	30 12 12 12 12 12 12 12 19 9	E SIDE:	1.48 S FACIN	1.39 NG IN	4 ONE  Day/N  Date  Humid	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
hart #  27  emperat  0 1 12 2 12 3 12 4 13 5 12 4 13 5 12 4 12.5	X C   Po	20 12 12 13 14 13 13.3 10 25	THR:  Covert  30 13 13 13 13 13 10 21	No.	So	Wind  1 12 13 12.3 13 12 12.5 9 20	Energ.  10 12 12 12 12 12 12 19 19	20 PP N N 20 12 12 12 12 12 12 12 12 12 12 12 12 12	30 12 12 12 12 12 12 12 18 18	E SIDE:	1.48 S FACIN	1.39 NG IN	4 ONE  Day/N  Date  Humid	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>
mhart #  27  emperat  0  1	X C   Po   Po   Po   Po   Po   Po   Po	20 12 12 13 12.3 14 13 13.5 10 25	THR:  Covert  30 13 13 13 13 13 10 21 23	40 13 13 13 13 13 10 20 22	So	Wind  1 12 13 12,3 13 12 12,5 9 20 21	Energ.  10 12 12 12 12 12 12 12 12 12 12 12 12 12	20 12 12 12 12 12 12 12 12 12 19 19 20 19	30 12 12 12 12 12 12 12 12 19 18 19	E SIDE:	1.48 S FACIN	1.39 NG IN	4 ONE  Day/N  Date  Humid	ight			<ul><li>H.F</li><li>T.C</li></ul>	.Plate ouple		= <sup>2</sup>

Heat	Flux	Plate	s								*****	 ·····	 			 
1	*	.25	.69	.79	.59	.47	. 56	.55	. 40	.28						Г
2	*	.23	.60	.71	. 59	, 47	. 52	.52	. 40	. 28						

Observations: Special test to determine the thermal resistance of the greenhouse floor.

			THR	EE LAY	YERS/NI	ew cur	TAIN T	WO REE	LECTI	/E SID	ES FAC	ING IN	\$ ONE	FACI	NĞ ƏUT			□• He		<u>_</u>	F F
Cha	rt *	ПС	lear		No	Wind		Energ	y F	inal		184	4.8	Day/	light				F.Plat Couple	1	
	28	ΧP	artial	Cover	. ⊠Mo	drate	Wind		Р	reviou	is	184	2.2	Date					corder	÷.	* T
	40	0	vercasi	t	_ Wi	ndy			ħ	let			2.6	Hum is	iity						
Tem	peratu	ire																	,		
	Ö	10	30	30	40	50	1	10	20	30	40	50	2	10	20						
Т,	12	12	12	1.2	1.2	12	11	-11	10	11	11	10	10	10	9						
Ť2	12	12	1.2	12	11	11	11	11	11	11	. 10	10	10	10	9						<b> </b>
Ť 3	13	13	13	12	12	12	12	11	11	11	11	10	10	10	10						
Av	12.3	12.3	12.3	13	11.6	11.6	11.3	11	10.6	11	10.6	10	10	10	9.3						
T <sub>4</sub> _	12	13	1.2	1.2	12	1.2	12	11	11	11	11	10	10	10	10						
T <sub>5</sub>	1.2	12	12	12	11	11	11	11	10	10	11	9	9	9	9	-					
TAV	12	13.5	1.2	12	11.5	11.5	11.5	11	10.5	10.5	11	9,5	9.3	9.5	9.5	-					
76	7	7	7	7	7	7	7	7	7	6	6	6	- 6	6	6				<del> </del>		-
T <sub>7</sub>	31	28	24	22	21	23	72	20	25	24	21	20	23	21	20					7	
Ţ <sub>8</sub>	29	27	24	23	21	22	22	21	24	24	22	21	2.2	21	20				<del>                                     </del>		<del> </del>
T <sub>9</sub>	30	27	25	23	22	22	22	21	24	23	22	20	22	21	20			ļ	<del>                                     </del>	<del> </del> -	<u> </u>
T <sub>A</sub> y	30	27.3	24.3	22.5	21.3	22.3	22		24.3	23.6	21.6	20.3	22.3		20				<u> </u>		
<sup>T</sup> 10	18	13	19	19	19	19	19	19	19	19	19	12	19	19	1 19				<u></u>		
Неа	t Flux	Plate	25				,	<del>-,</del>	,					1	· · · · · · · · · · · · · · · · · · ·			1	Ι	T	т—
	.69	.72	. 57	. 37	.21	.13	.16	.11	.01	.13	.07	.02	.08	.01	.02			-			-
2	1.10	1.05	.87	.65	. 30	. 39	. 34	.25	.21	. 24	.18	.11	.08	.ll	.06			<u> </u>	<u> </u>	<u></u>	<u></u>

Observations: Special test to determine the thermal resistance of the greenhouse floor.

The heat was not turned on for the first 45 min.

			CON	TRÓL/V	vIIHOň.	I ANY	CURTAI	INS										□- не	ater	• -	- <del>-</del>
Cha	rt #			Cover		Wind G drate	Hind	Energ		inal reviou			06.6 95.9	Day/N Date		6, 19	80	• T.	Cauple	•4	· •
2	9		ercas			ndy	WING			let	15		10.9	Humic	lity	52%		Re	corder		
Tem	peratu	re												,		,	,		<del></del> 1		
	0.6	10	20	30	40	50	60	70	80	90	100	110	120	130				ļ			
T <sub>1</sub>	23	23	22	22	22	21	21	21	21	22	22	22	21	21			ļ	-			
T <sub>2</sub>	20	20	20	19	19	19	19	20	19	19	19	19	19	19				-			
T <sub>3</sub>	21	21	21	20	20	19	19	20	20	20	20	20	19	. 19			ļ	-	1		
TAV	21.3	21.3	21.0	20.3	20.3	19.6	19.6	20.3	20.0	20.3	20.3		19.6	19.6		ļ	ļ	ļ			
T <sub>4</sub>	24	24	24	23	22	22	22	23	23	2.2	22	22	22	22				<del> </del>			
T <sub>5</sub>	23	23	22	22	22	22	21	22	22	22	22	22	22	21				<del> </del>			
TAV	23.5	23.5	23.0	22.5	22.0	22.0	22.5	22.5	22.5	22.0	22.0	22.0	22.0	21.5			-	-	<u> </u>		
T <sub>6</sub>	9	9	9	9	9	9	9	9	9	10	10	10	10	10							
T <sub>7</sub>	23	23	22	22	21	21	21	22	21	21	21	21	21	21			-		ļ		
T <sub>8</sub>	23	23	23	23	22	22	21	22	22	22	22	22	21	21			ļ				
T <sub>9</sub>	22	22	22	22	21	21	21	21	21	21	21	21	21	21							
+	22.6	22.6	22.3	22.3	21.3	21.3	21.0	21.6	21.3	21.3	21.3	21.3	21.0	21.0			ļ	<del> </del>	-		
+	15	15	15	16	16	16	16	16	16	16	16	17	16	16							
i i a -	t Flux	01																			
nea 1	4.15		3.90	3 90	3.39	3 90	3.74	4.17	3 35	2,69	2.51	3.10	3.39	3,75			Τ	I			
2	4.13	4,52		-	3.94	3.70	<b></b>		3.92	3.35	3.20	<del> </del>	3.37	3.61				1			
		<u></u>																			
Obs	ervatí	ons:	*																		

			CONT	ROL/WI	THOUT	-ANY CI	JRTAIN	s										□- не	ater	, s	
Chi	art #	[X] C	lear		[X] N	o Wind		Ener	ЭУ	Final	*******	265	3.6	Day/	Night	**********				1	
,	0		artia	Cove	r 🗆 M	odra te	Wind			Previo	us	263	8.0	Date	May 7	198	0	11	Couple		<b>₽</b> 77
			vercas	st	□₩	indy				Net		1	5.6	Hum-i	dity	593		TIT KE	corder	L	
Ter	perati	ure	~~~~~	***********************						***************************************											
	- 0	10	20	30	40	30	60	70	80	90 -	100	110		T		T		T			
Т,	20	22	22	2.2	22	12	22	22	22	22	2.2	22									
T <sub>2</sub>	18	19	19	19	19	19	19	19	19	19	19	18									
73	20	21	21	21	21	21	21	21	21	21	21	20		-							
TAV	19.3	20.6	20.5	+	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20									
T4	23	24	23	24	24	24	24	24	24	24	24	23	<u> </u>								
T <sub>5</sub>	20	21	22	22	22	22	22	22	22	22	22	22		<u> </u>							
TAV	21.5 8	23	22.5	23	23	23	23	23	23	23	23	22.5		-	-						
T <sub>6</sub>						<del> </del>			23	23	23			<del> </del>				+	_		
T <sub>8</sub>	21	22	23	23	23	23	23	23	23	23	23	23				ļ	<del> </del>	+			
1 <sub>8</sub>	21	22	22	22	22	23	23	23	22	23	22	22	<u> </u>	<u> </u>				+			
T <sub>AY</sub>		<del> </del>		-	<del> </del>	<del> </del>	23	ļ	22.0	<b> </b>	22.6	<del> </del>		<del> </del>			<del>                                     </del>	+			
T <sub>10</sub>	21.3	22.3	22.3	17	22.6	17	17	23 17	17	17	17	18					<del>                                     </del>	1			
						1											L				
Hea 1	t Flux	Plate	*	6.69	6.78	6,91	6 19	6.98	7.05	n 20	6.62	7.02	r	· ·	T		Τ	T			
2		ļ	*	3.92	4.03	4.06		4.09	4.03		ļ	4.02	ļ	ļ				<del>                                     </del>			
	3.43	3.83		3.72	4.03	4.315	14.15	4.09	4.03	r.'''	14.17.7	[4.0]	<u> </u>	<u> </u>		<u></u>	<u> </u>				
0bse	ervati	ons:																			
	***************************************								***************************************												
			THR	EE LAYI	ERS/NE	W CURT	AIN TW	O REF	LECTIV	E SIDE	S FACI	NG IN	& ONE	FACIN	G OUT			□- He		• • -	
Cha	irt#	[X] C	lear		XN	o Wind		Energ	у	Final		9	9.3	Day/!	Night				F.Plat	7	2 2
		ПР	artial	Cove	r $\square$ M	odrate	Wind			Previo	us.	2657	1.5	+		8, 198	30	1	Couple		<b>T</b> 7
	31		vercas		□ w					Net	• • • • • • • • • • • • • • • • • • • •	1	.8	Humid	dity 6	0%-657	7	'ਧਾ Re	corder	13-	
Ten	perati	ure					***************************************														==
	0	10	20	30	40	50	60	70		Ī							<u> </u>	Т		Т	
T,	12	12	12	12	12	11	11	11		<del>                                     </del>	<b></b>	<b> </b>					-	+			
	12	12	12	12	12	12	12	11		<b> </b>				<b> </b>							-
T,	12	12	12	12	12	12	11	11			<u> </u>										
<sup>Т</sup> 3	12	12	12	12	12	11.6	11.3	<del></del>						<u> </u>			<u> </u>				-1
T <sub>4</sub>	14	13	13	12	12	12	12	11													

Partia	1 Cove	r 🗆 M	odřate	المحاليا											į - i,	CUUDIE		
				MIIIU			Previo	us	2651	7.5	Date	May	8, 19	30		Couple corde	*	<b>∀</b>
Overca	st	□ w	indy				Net			L.8	Humi	dity f	0%-65	7.	шке	corde	· L	
		·····				***************************************												
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3 12.5	12	11.5	11.5	11.5	11													
7 6	. 6	7	7	7	7													
1 21	21	21	21	21	20													
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2 22	21	21	22	21	20													
.3 22	21	21	21.6	21.3	20.3													
8 19	19	19	19	19	19													
	20 20 20 22 12 22 12 22 12 33 13 33 12 33 12 34 22 22 22 33 22 22 33 22 22 33 22	0         20         30           2         12         12           2         12         12           2         12         12           2         12         12           3         13         12           3         12         12           7         6         6           1         21         21           4         23         21           2         22         21           .3         22         21	.0         20         30         40           .2         12         12         12           .2         12         12         12           .2         12         12         12           .2         12         12         12           .3         13         12         12           .3         12         12         11           .3         12.5         12         11.5           .7         6         6         7           1         21         21         21           4         23         21         21           2         22         21         21           .3         22         21         21	.0         20         30         40         50           .2         12         12         12         11           .2         12         12         12         12           .2         12         12         12         12           .2         12         12         12         11.6           .3         13         12         12         12           .3         12         12         11         11           .3         12.5         12         11.5         11.5           .7         6         6         7         7           1         21         21         21         21           4         23         21         21         22           2         22         21         21         22           .3         22         21         21         21         21	.0         20         30         40         50         60           .2         12         12         12         11         11           .2         12         12         12         12         12           .2         12         12         12         12         11           .2         12         12         12         11.6         11.3           .3         13         12         12         12         12           .3         12         12         11         11         11           .3         12.5         12         11.5         11.5         11.5           .7         6         6         7         7         7           .1         21         21         21         21         21           .4         23         21         21         22         22           .2         22         21         21         22         21           .3         22         21         21         21         21         21	.0         20         30         40         50         60         70           .2         12         12         12         11         11         11           .2         12         12         12         12         12         11           .2         12         12         12         12         11         11           .2         12         12         12         12         11         11         11           .3         13         12         12         12         12         12         11           .3         12         12         11         11         11         11           .3         12.5         12         11.5         11.5         11.5         11           .6         .6         .7         .7         .7         .7           .1         21         21         21         21         20           .4         23         21         21         22         22         21           .2         22         21         21         21         20         23           .3         22         21         21         21         21	0         20         30         40         50         60         70           2         12         12         12         11         11         11           2         12         12         12         12         12         11           2         12         12         12         12         11         11           2         12         12         12         12         11         11           2         12         12         12         11.6         11.3         11           3         13         12         12         12         12         11           3         12.5         12         11.5         11.5         11.5         11           7         6         6         7         7         7         7           1         21         21         21         21         20           4         23         21         21         22         22         21           2         22         21         21         21         20         20           3         22         21         21         21         21         20         3<	.0     20     30     40     50     60     70       .2     12     12     12     11     11     11       .2     12     12     12     12     12     11       .2     12     12     12     12     11     11       .2     12     12     12     11     11     11       .3     13     12     12 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Observations: Special test to determine the thormal gradient of the vertical curtain. The side along the adjoining greenhouse looses 30% less heat than the other three sides.

The heat was not turned on for the first 30 min.

2 2.52 1.43 1.20 1.07 1.43 1.84 1.18 1.15

	<u>and and the state of the state</u>	TH	REE LA	YERS/1	iew cui	RTAIN TWO R	EFLECTI	VE SI	IDES FA	ACING	(N & OI	NE FA	CING OU	т			□• Hea		- <del>-</del>	-= C
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Ch	art #	Clear			<u>\</u>	No Wind			gy	Final		3386.8		Day/Night				] = m.r.Plate				
	34	Partial Cover Modrate Wind						Previous				3379		Date May 18, 1980				• J.Couple				
			v Overcast (rain) Windy					Net				7.8		Humidity 60%				Recorder == ==				
Te	Temperature															***************************************						
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TAY		ļ	ļ	ļ		-												ļ				
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Неа	Heat Flux Plates																					
1	1.07	1.14	1.37	.82	.51	1.13	1.23	1.14	1.27	.56	.80	1.15	1.18									
2	.94	1.50	1.63	1.12	1.01	1.12	1.18	1.25	1.01	1.28	1.52	1.04	1.37									

Observations: Special test to determine the gradient (thermal) of the horizontal curtain. Within the curtain  $T_1$  was located in contact with the heat flux plate #1,  $T_2$  was nlaced 2cm away from the heat flux plate,  $T_3$  was kept 10cm away from the heat flux plate; outside the curtain  $T_1$  was kept in contact with the hfp. and  $T_5$  was placed 10cm away from the hfp.

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## GREENHOUSE MANUFACTURERS/SUPPLIERS

65000

Ickes-Braun Glasshouses of Canada, Ltd. 90 Bartlett Road P.O. Box 2000 Beamsville, Ont. LOR 1BO

Irrigation St. Thomas, Inc. 1044 rue Principle St. Thomas de Joliette Quebec JOK 3LO

Lord and Burnham Co. Ltd. 4422 Graham Drive Pierrefonds, Quebec H9H 2C2

National Greenhouse Co. P.O. Box 100/Pana. 111 62557. U.S.A.

Solagro Ltée 52, Victor Léger Valleyfield, Qué. J6T 3J1

Stuppy Inc. 120 East 12th Ave. North Kansas City MO 64116 U.S.A.

Vary Greenhouses Inc. Canadian Greenhouses Box 5000 Beamsville, Ont. LOR 1B0

Vegetable Factory Greenhouses 100 Court Street Cofiagne, L.I. N.Y. 11726 U.S.A.

## GREENHOUSE INSULATION MATERIAL AND SUPPORT SYSTEM SUPPLIERS

Duracote Corporation 350 North Diamond Street Ravenna, Ohio 44266 U.S.A.

Greenshield Systems
Division of Automatic Devices Co.
2121 South Twelfth Street
Allentown, PA 18103
U.S.A.

Roll-Out Insulation Systems, Inc. P.O. Box 31 East Aurora, New York 14052 U.S.A.

Simtrac Inc. 8243 N. Christiana Ave. Skokie, Ill. 60076 U.S.A.

Stauffer Chemical Co. Plastics Division One Metroplaza Edison, N.J. 08817 U.S.A.

Stuppy Inc. 120 East 12th Ave. North Kansas City, MO 64116 U.S.A.

Wadsworth Control Systems A Division of the Roper Corporation 5541 Marshall Street Arvada, Colorado 80002 U.S.A.

## DOMESTIC THERMAL SCREEN MFGS/SUPPLIERS

Appropriate Technology Corporation P.O. Box 975 Brattleboro Vt. 05301 U.S.A.

Centre for Community Technology University of Wisconsin Extension Service 1121 University Ave. Madison, Wis. 53715 U.S.A.

Drape Masters 266 Prospect Ave. Hartford CT. 06106 U.S.A.

Homesworth Corporation 34 Cumberland St. Brunswick ME. 04011 U.S.A.

Insulating Shade Company, Inc. P.O. Box 282 Branford, CT 06405 U.S.A.

Insul Shutters
110 N. Seventh Street
Silt, Col. 81652 U.S.A.

Solar Energy Components Inc. 212 Welsh-pool Road Lionville, PA 19353 U.S.A.

Sun Flake 625 Goddard Ave. P.O. Box 676 Ignacio, Colo. 81137 U.S.A.

Thermal Technology Corporation P.O. Box 130 Snowman, Colorado 81654 U.S.A.