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REPORT

DOE/NASA CR-161229

SYSTEM INSTALLATION PACKAGE FOR THE NEW HAMPSHIRE  
VOCATIONAL TECHNICAL COLLEGE, MANCHESTER, N. H.

Prepared from documents furnished by

Contemporary Systems, Inc.  
68 Charlonne Street  
Jaffrey, New Hampshire 03452

Under Contract NAS8-32243 with

National Aeronautics and Space Administration  
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy

(NASA-CR-161229) SYSTEM INSTALLATION  
PACKAGE FOR THE NEW HAMPSHIRE VOCATIONAL  
TECHNICAL COLLEGE, MANCHESTER, N. H.  
(Contemporary Systems, Inc.) 71 p  
HC A04/MF A01

CSCL 10A G3/44

N79-25502

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23407



**U.S. Department of Energy**



**Solar Energy**

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## **I. GENERAL SYSTEM DESCRIPTION**

The Contemporary Systems Incorporated integrated, warm air solar heating system eliminates most of the problems encountered by an architect or designer when incorporating solar heating in a construction project. The individual components are fully compatible and have been developed to work together.

The Series V collectors are structural units, fastened directly to the roof or wall framing members (24" o.c.). They form a fully weather-tight assembly which replaces the conventional roofing or siding. The collectors are manufactured in any length up to 24' to meet the design requirements of each installation. They are light weight --less than two pounds per square foot -- and the insulation toward the living space is site-applied according to architectural specifications.

The Universal Switching Unit (USU) accomplishes the air circulating and switching functions. It can be equipped to operate at whatever CFM is dictated by the overall system design. Its main component is an industrial quality centrifugal fan with life lubricated ball bearings, operating at low RPM and powered by a high efficiency GE "Energy Saver" motor.

The control functions are performed by the completely automatic LCU-110 Logic Control Unit. It compares various system conditions and optimizes the use of solar energy while minimizing the use of the auxiliary heating system. The interior environment of a solar-heated house is in no way different from a conventionally heated one and requires no additional user-operated controls other than the standard room temperature thermostat. There is a manual override of the automatic functioning of the LCU Control Unit for servicing and special uses of the system.

The Fail-Safe Thermal Vents protect the collectors against overheating in summer or in the event of a power failure. They operate by thermosiphoning, and are generally connected to the inlet and outlet manifolds of the collector array.



## II. SOLAR SYSTEM OPERATION

The system has six operating modes: standby, storing heat, heating from collectors, heating from storage, auxiliary heating, and combined auxiliary heating and storing heat (see Fig. 1). The order of priority is as follows:

1. Heating from collectors: when the room thermostat demands heat and the collectors are receiving sufficient energy to provide heated air at greater than approximately 85°F to the house.
2. Heating from storage: when the room thermostat demands heat and there is insufficient energy in the collectors but enough energy in storage to provide heated air at greater than about 85°F to the house.
3. Combined Auxiliary heating and storing heat: with heat demand and insufficient energy in collectors and storage for room heating but sufficient energy in the collectors to charge storage. In this case the auxiliary furnace provides for space heating and energy from the collectors is stored concurrently.
4. Auxiliary heating: when the house demands heat and none is available from the collectors or from storage for space heating or storing. The auxiliary furnace provides back-up heating for the house.
5. Storing heat: with no heat demand from the house and sufficient energy in the collectors for storing.
6. Standby: with no heat demand and insufficient collector energy for storing (or a full storage).

The following points concerning system operation should also be noted:

1. In no mode is solar heat ever stored or used when its equivalent value, in auxiliary fuel dollars, would be less than the value of the electrical power needed to run the system.
2. The Fail-Safe Thermal Vents cool the collectors in warm weather when no heat is demanded or needed in storage. The collector array circulates outside air by thermosiphoning. The vents open automatically whenever temperatures exceed 165°F, due either to ambient temperature rise or power failure.

OPERATING MODES :

- A. STORING HEAT
- B. HEATING FROM STORAGE
- C. HEATING FROM COLLECTORS
- D. AUXILIARY HEATING

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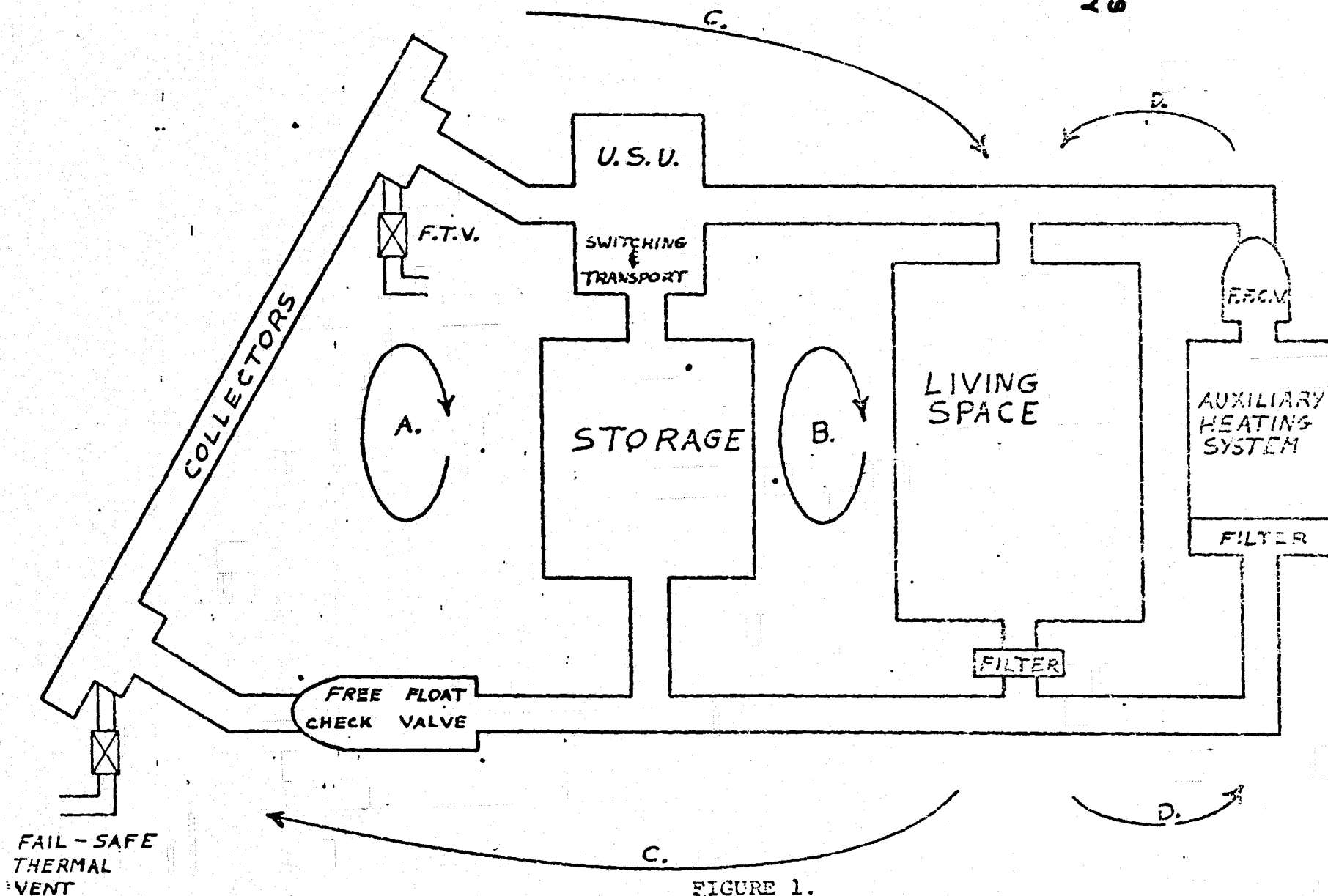


FIGURE 1.

3. The air flow through storage is reversed between storing and heating from storage modes so that temperature stratification is maintained.
4. The LCU-110 solar system control accomplished automatic control of dampers, the USU, the auxiliary furnace and the fail-safe thermal vents. It monitors collector temperature, storage temperatures (hot end and cold end) and the two-stage room thermostat. Settable system parameters include: collector-storage differential and collector and storage output sensible heat temperatures. Storage temperature may also be limited, in summer, to 100°F.
5. Free float check valves are used in the system ducts where needed to prevent unwanted thermosiphoning and backflow through the auxiliary furnace.
6. A replaceable filter must be provided in the return duct from the living space to prevent dust accumulation in the rock storage or collectors. This system must be maintained with filters being replaced every 500 hours of operation.

### III. GENERAL DESIGN CONSIDERATIONS

The general design of the house and its relation to the site have a very significant effect on the overall heating requirement, and consequently the percentage of solar sufficiency obtainable per square foot of collector area. CSI recommends as a minimum the energy-efficient construction standards known as the "Arkansas Plan". These standards are detailed in Owens-Corning's report on "Energy Saving Homes -- The Arkansas Story". The basic approach involves utilizing 2" x 6" studs, 24" o.c., with 6" of fiberglass insulation in the walls and 12" in the ceiling. There are specific recommendations for window area, vapor barriers, flashing, etc., and we strongly advise consulting this report.

There are a few specific guidelines in both house design and orientation which must be considered to accommodate an active solar heating system. The ideal orientation of the house is true south, which generally varies from magnetic south. In Jaffrey, N.H., true south is about 15° west of magnetic south. Architectural Graphic Standards provides the exact deviation figures for all locations in its isogonic map. Sometimes other site considerations will prohibit this exact orientation; a deviation of 20° east or west of true south will still be acceptable.

For roof-mounted collectors, the optimum roof angle is equal to the latitude of the site plus about 15°. There is great room for variation from this figure in applications in New England; the limiting figure at the low end would be about 45° in order to assure effective thermal siphoning to prevent summertime overheating of the collectors. This figure is related to the

collector length specified, as noted in Table I.

<u>Array Elevation</u>	<u>Maximum Length</u>
40 degrees	12 ft.
45	14
50	16
55	18
60	20
65	20
70	20
80	20
90	20

Table I.

#### Array Elevation

An additional consideration would be to avoid any shading of the collectors by either evergreen trees near the house or by elements of the building itself. In calculating possible tree shading effects, a close estimate for this latitude is to make certain the angle to the horizon generated by a line from the top of the tree to the base of the collector is less than  $20^{\circ}$ .

An excellent source for further discussion of energy-efficient house design is Bruce Anderson's The Solar Home Book.

#### IV. SOLAR SYSTEM SIZING

Solar energy is an economical supplementary heat source. Solar sufficiency is the percent of the total annual heating load carried by the solar system. While a system can be designed to carry any portion of the load desired, cost effective solar design generally utilizes solar sufficiencies between 25 and 65%. The size of the collector array, and consequently the size of the storage and air transport subsystems, must be chosen according to several criteria:

1. Overall system effectiveness on a cost vs. return basis.
2. Ability to comply with the budget of the total project.
3. Compatibility with the roof or wall area that is available for collector mounting.

There are several computer programs available to calculate solar sufficiency and the related economics of a given solar installation.

A method for approximate sizing of our warm air solar space heating system is given below. It gives an approximate ratio of collector area to building floor area for a 50% solar sufficiency. Annual degree days of the climate and the heat loss characteristic of the building are required. We recommend this method be used in the initial planning stages of the building. A more accurate determination of solar sufficiency should than be made using SOLCOST or a similar computer sizing program. The system size can then be adjusted to the desired solar sufficiency as based on project economics and architectural requirements.

		Climate Region (DD/year)				
		5000	6000	7000	8000	9000
50% Solar Sufficiency	4	.12	.14	.17	.19	.21
	5	.15	.18	.20	.23	.26
	6	.18	.21	.24	.29	.31
	7	.20	.24	.29	.33	.37
	8	.23	.29	.33	.37	.42

### Table 2

1. Heat Loss

BTU/°F

Calculate the building heat loss in HOUR . Include heat loss through all surfaces and a reasonable loss due to air change (infiltration).

2. Normalized Load

Calculate the normalized heating load: multiply the building heat loss by 24 and divide by the square footage of the heated space:

Normalized Heating Load=

$$\frac{24 \text{ Hrs.} \times \text{building heat loss}/^{\circ}\text{F}}{\text{area of heated space}}$$

3. Collector Area: Floor Area Ratio

Given the degree days per year of the site and the Normalized Heating Load, find the collector area/floor area ratio from Table 2.

4. Active Collector Area

Multiply the square footage of heated space by the collector area/floor area ratio. This gives the approximate active collector area needed to achieve 50% solar sufficiency:

(Active Collector Area) =

$$(\text{Area of Heated Space}) \times \frac{(\text{Active Collector Area})}{(\text{Floor Area})}$$

5. Gross Collector Area

To derive the gross collector area, which is necessary for design calculations, multiply

the active area by 1.15:

(Gross Collector Area) =

$$(\text{Active Collector Area}) \times (1.15)$$

NOTE: the above sizing method is only an approximation. It is based on applications of the CSI integrated warm air solar heating system in energy efficient construction and solar insolation data for Concord, N.H. Areas with distinctly lower solar insolation will have to be derated.

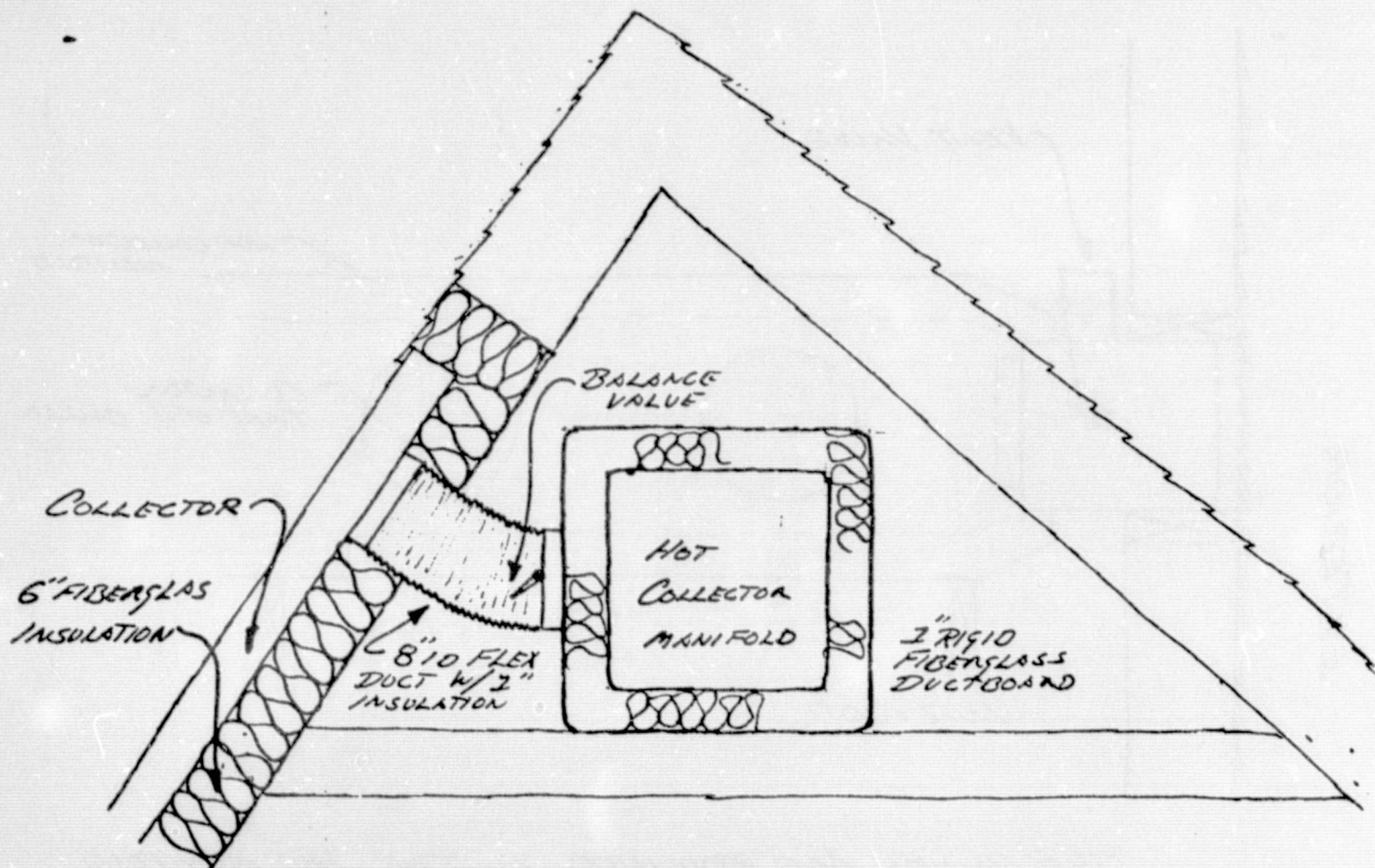
**V. DETAILED INSTALLATION DRAWINGS OF THE NEW HAMPSHIRE  
VOCATIONAL TECHNICAL COLLEGE**

# CONTEMPORARY SYSTEMS, INC.

Jaffrey, N. H.

PROJECT: *NAVTC MANCHESTER, NH*

COMMENTS: *AS INSTALLED DRAWING*



*HOT SIDE COLLECTOR MANIFOLDING DETAIL.*

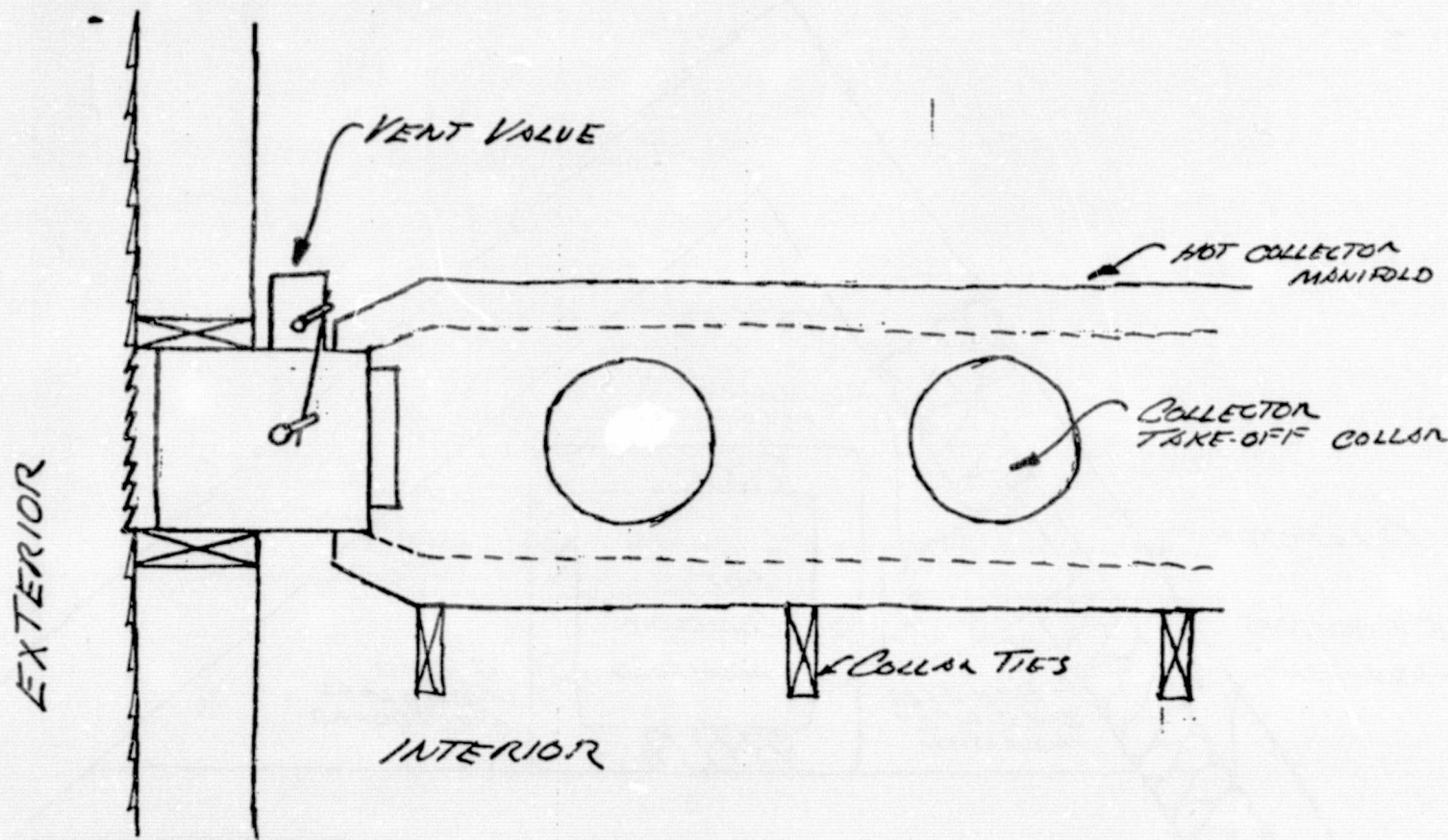


# CONTEMPORARY SYSTEMS, INC.

Jaffrey, N. H.

PROJECT: NAUTC MANCHESTER, NH.

COMMENTS: AS INSTALLED. DRAWINGS



TWO VALVES ARE PROVIDED IN THE HOT MANIFOLD ONE ON THE EAST AND ONE ON THE WEST SIDE.

THE ACTUAL INSTALLATION IS AS PICTURED. THE RIGID DUCT BOARD IS FITTED TO THE MANIFOLD VALVE. ORIGINAL PLANS HAD CALLED FOR A FLEX DUCT CONNECTION THROUGH A 10" INSULATED DUCT. IT IS ANTICIPATED THAT THIS SHOULD BE REVISED TO INCLUDE THE FLEX DUCT WITH A THERMAL TRAP. THIS WILL BE EVALUATED DURING OPERATIONAL PROBLEM RESOLUTION.

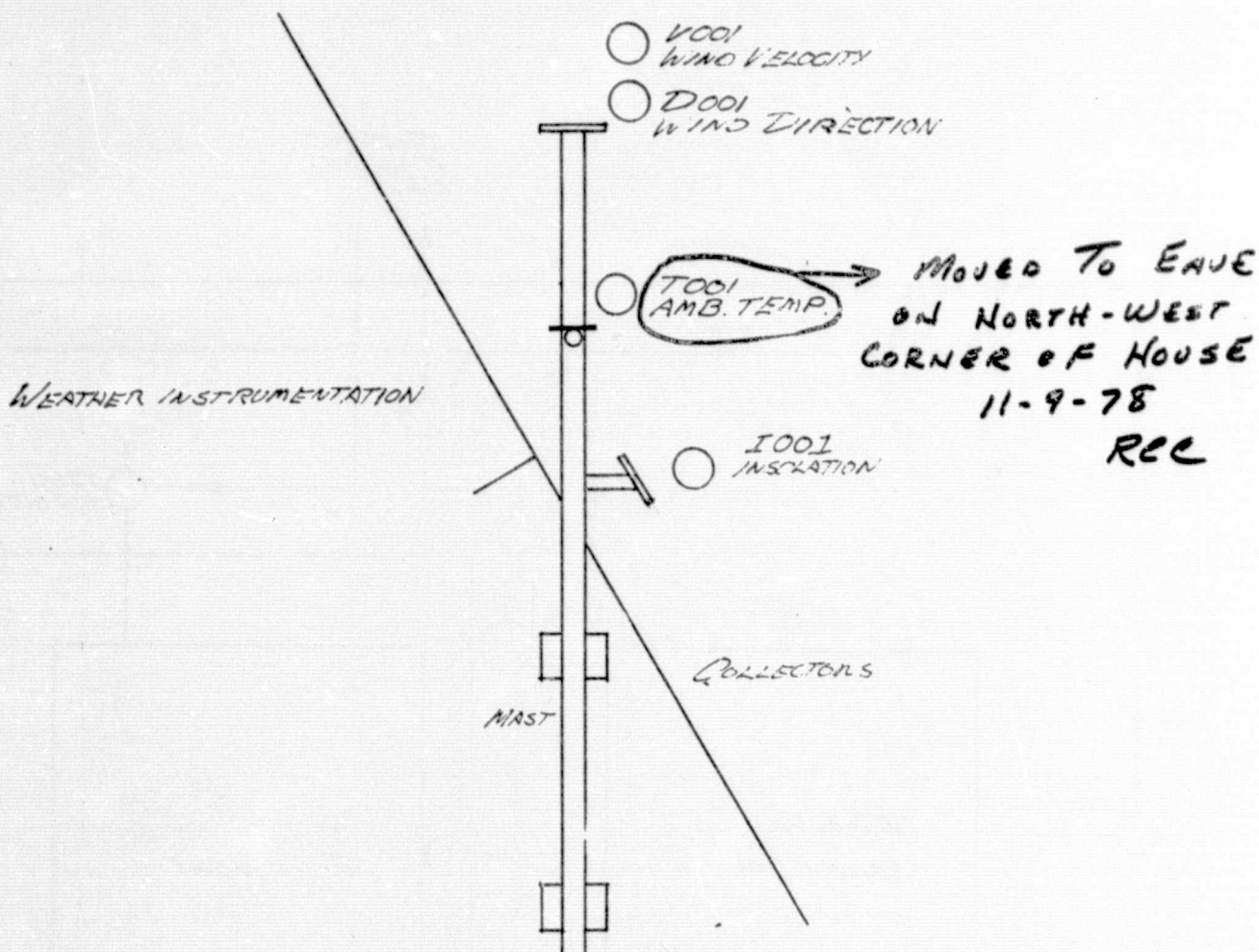


# CONTEMPORARY SYSTEMS, INC.

Jaffrey, N. H.

PROJECT: MANCHESTER, N.H.

COMMENTS: OUTSIDE WEATHER INSTRUMENTS



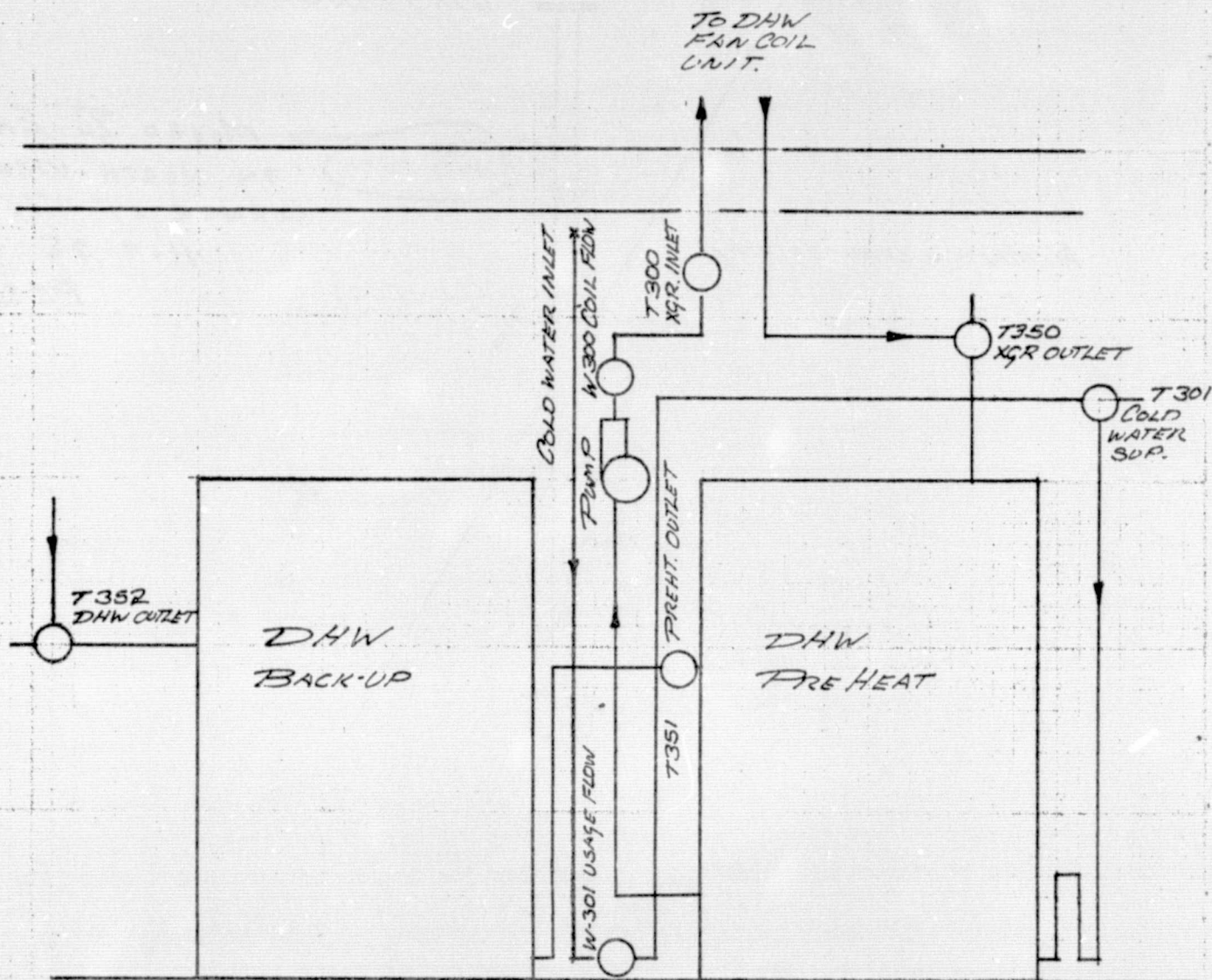


# CONTEMPORARY SYSTEMS, INC.

Jaffrey, N. H.

PROJECT: MANCHESTER, N.H.

COMMENTS: DHW SENSOR LOCATIONS



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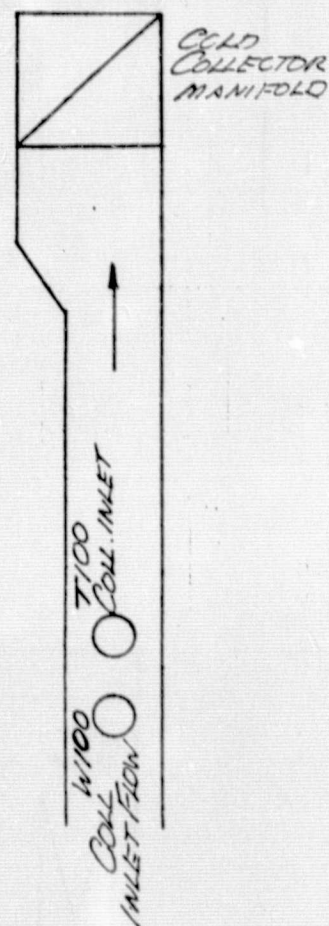
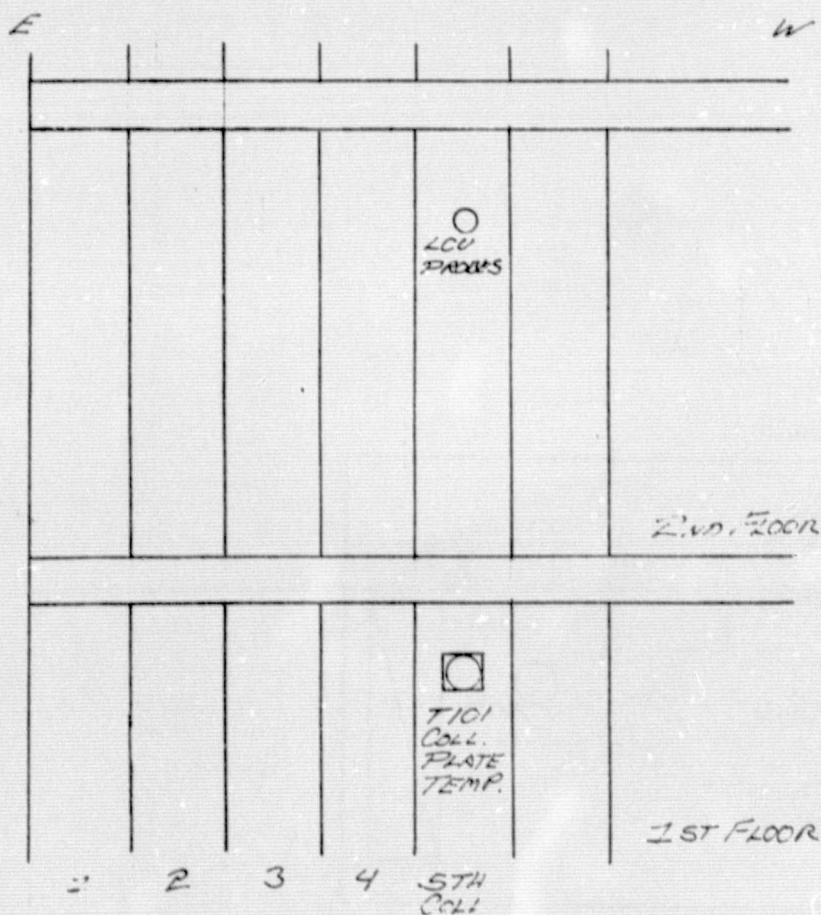
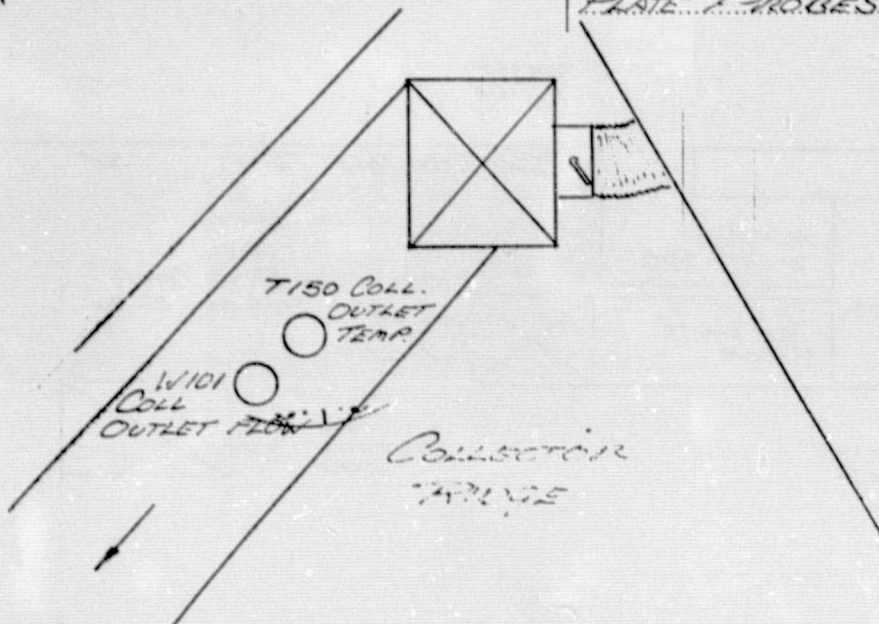
# CONTEMPORARY SYSTEMS, INC.

Jaffrey, N. H.

PROJECT: MANCHESTER, NH

COMMENTS: COLLECTOR OUTPUT, INPUT &

PLATE T PROBES



COLLECTOR PROBES



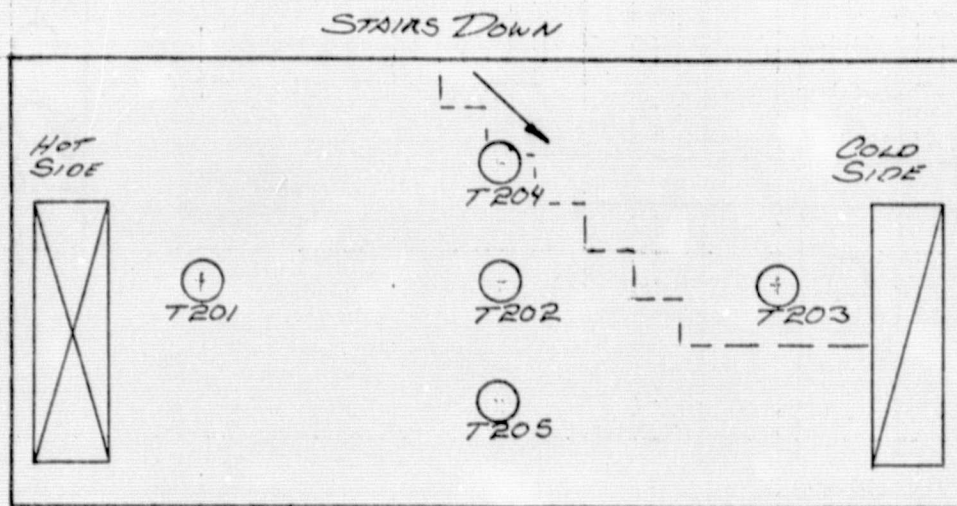
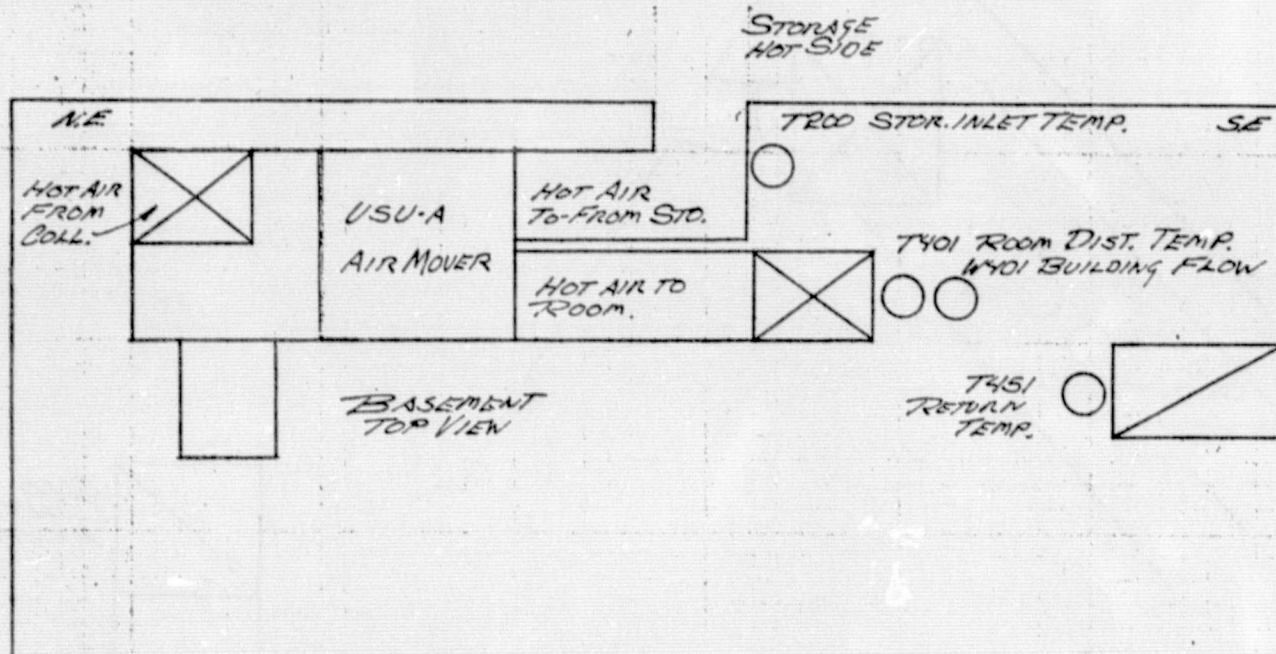
# CONTEMPORARY SYSTEMS, INC.

Jaffrey, N. H.

PROJECT: MANCHESTER, NH

COMMENTS: AIR MOVER & STORAGE SENSOR

LOCATIONS



STORAGE PROCESS, BASEMENT. SIDE VIEW

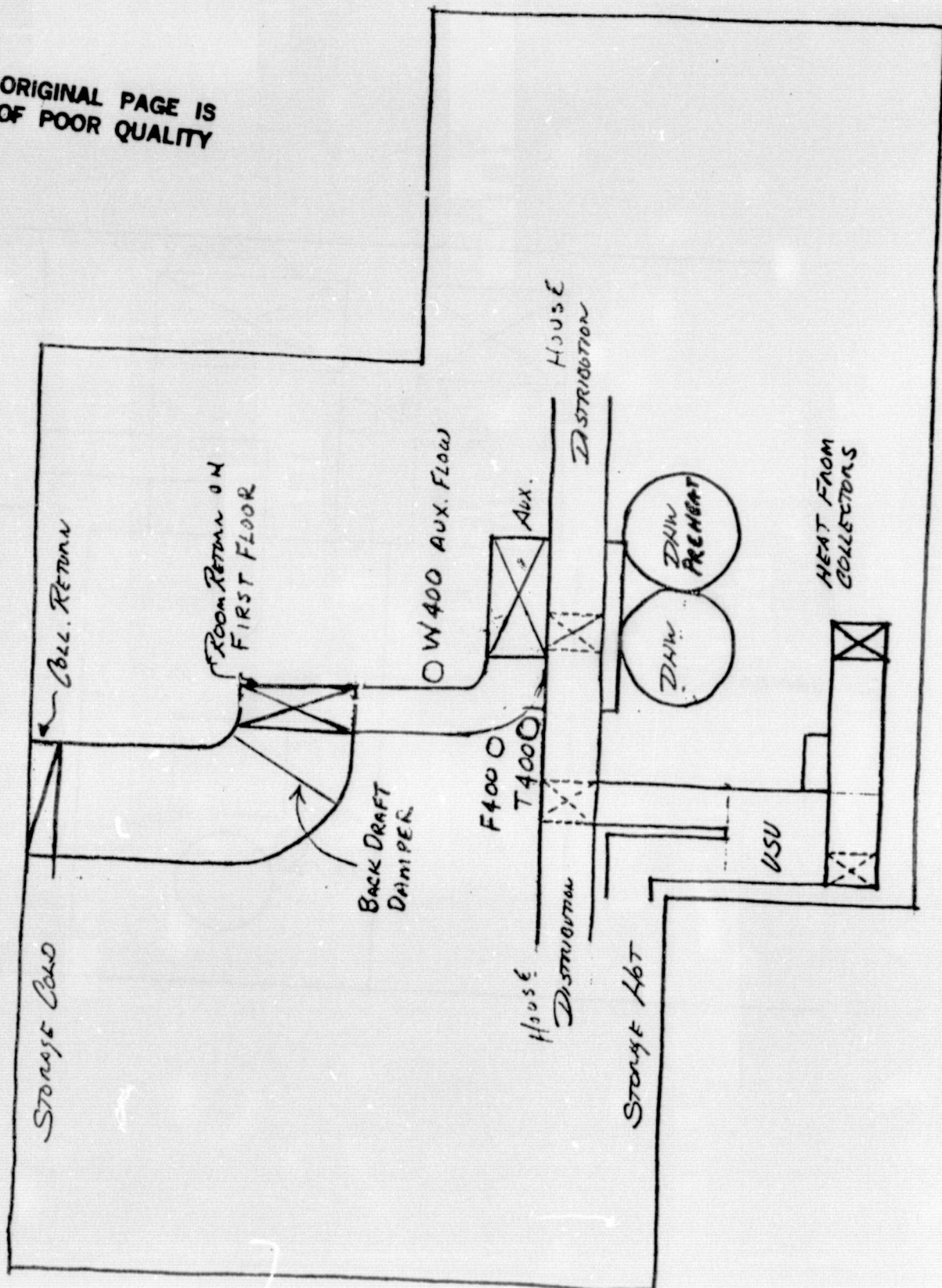


# CONTEMPORARY SYSTEMS, INC

Jaffrey, N. H.

PROJECT: ANUTE MANCHESTER, NH  
COMMENTS: AS INSTALLED DRAWINGS

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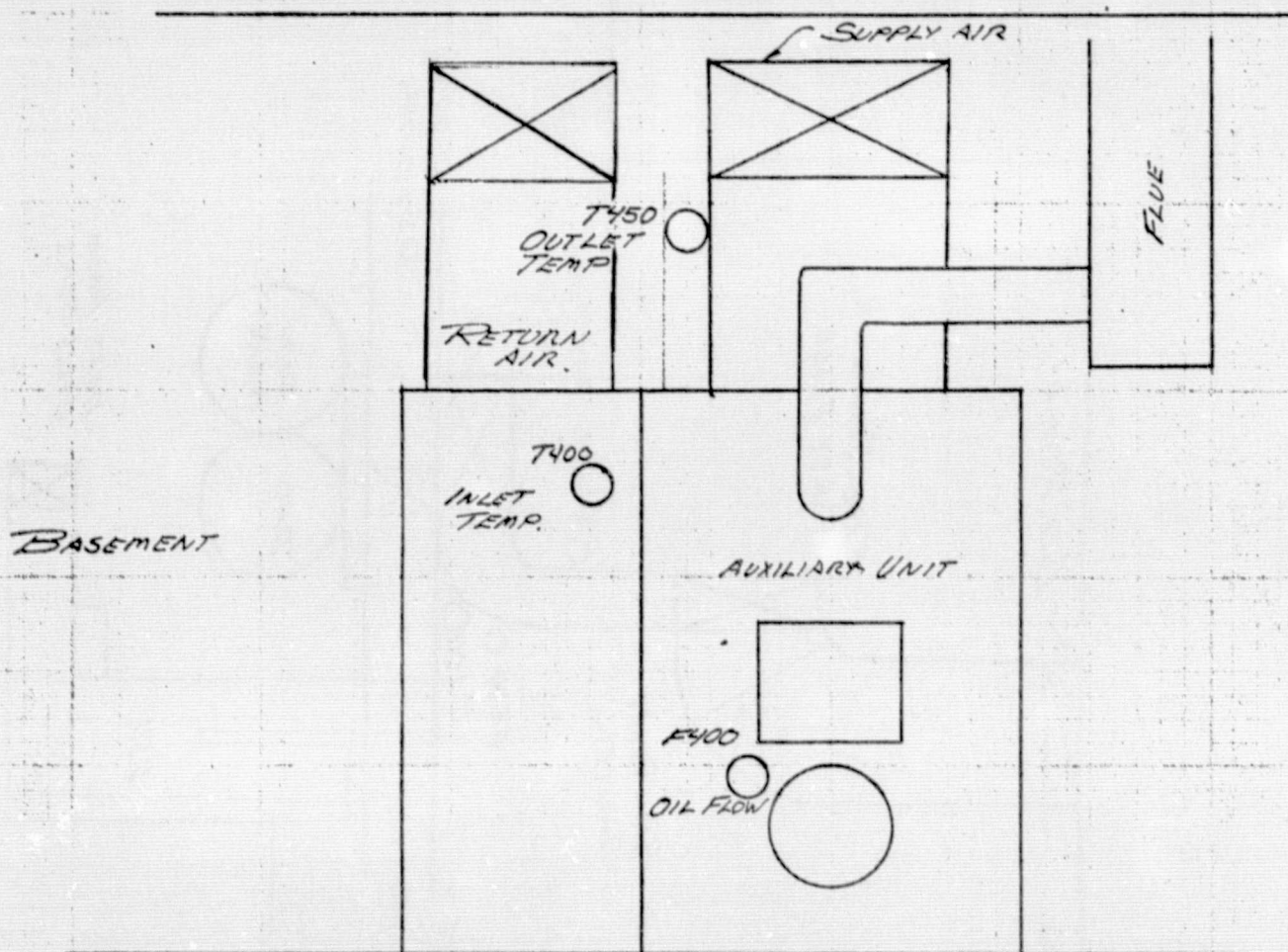


# CONTEMPORARY SYSTEMS, INC.

Jaffrey, N. H.

PROJECT: MANCHESTER, N.H.

COMMENTS: AUXILIARY PROBE LOCATIONS

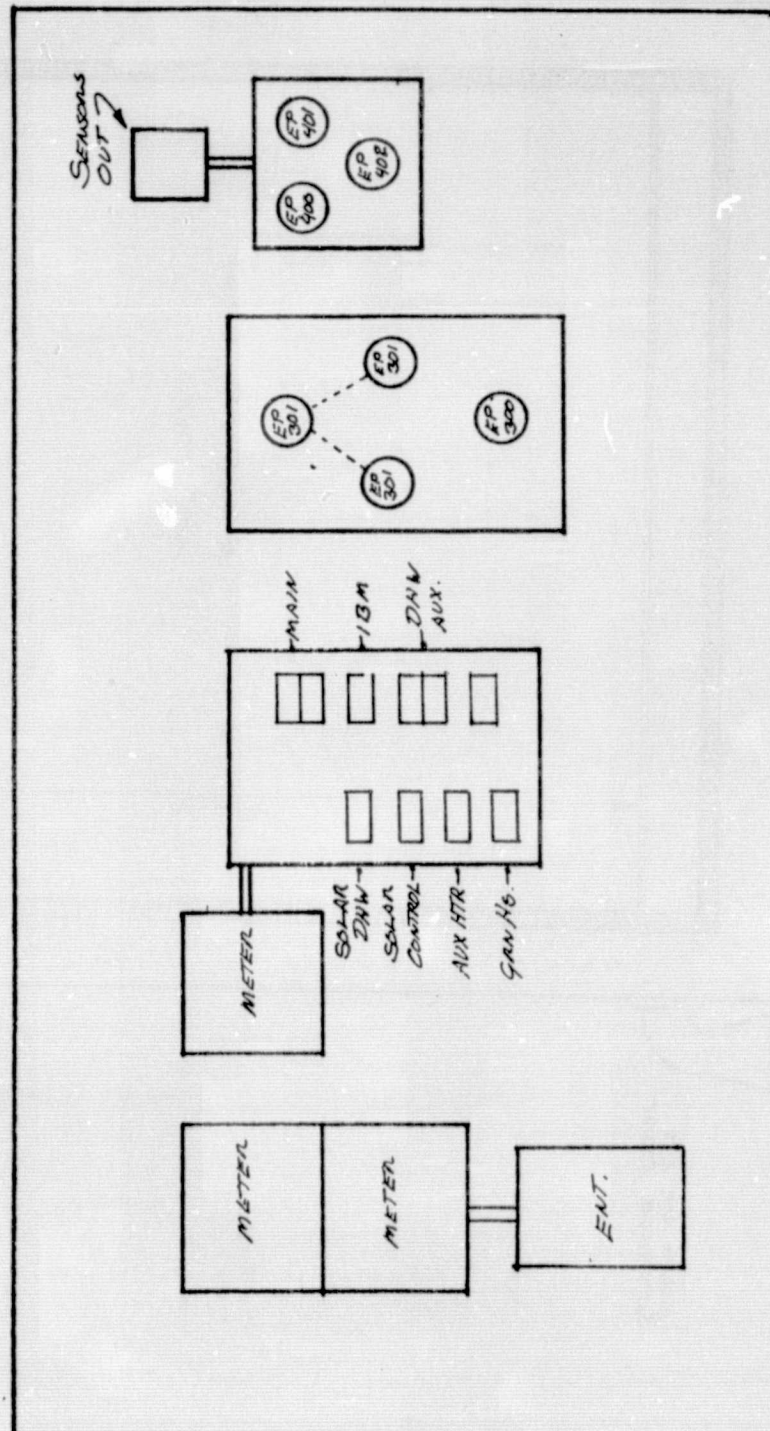


# CONTEMPORARY SYSTEMS, INC.

Jaffrey, N. H.

PROJECT: ELECTRICAL ENTRANCE  
 COMMENTS: 4-T-POWER SENSOR PROBES  
FOR SDAS SYSTEM

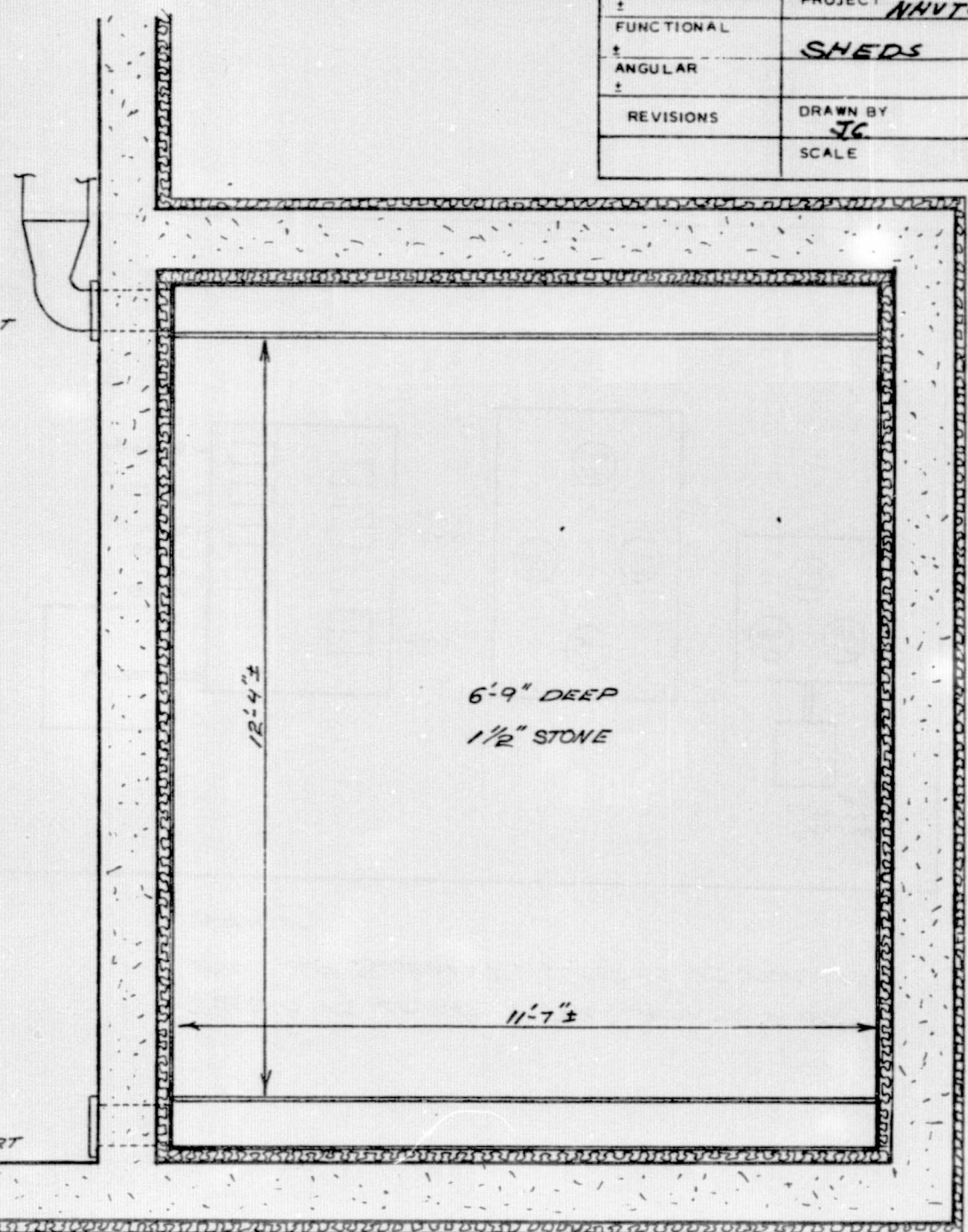
BAND IS LOCATED IN NORTH WEST  
 END OF BASEMENT. ACCESS IS THROUGH  
 HOUSE





WARM AIR I/O  
STORAGE PORT

COOL AIR I/O  
STORAGE PORT



TOLERANCES EXCEPT AS NOTED	TITLE: <i>SOLAR STORAGE</i>	
DECIMAL ±	PROJECT <i>NAVIC PROTECT</i>	
FUNCTIONAL ±	<i>SHEDS</i>	
ANGULAR ±		
REVISIONS	DRAWN BY <i>JC</i>	CHECKED BY
	SCALE	DRAWING # <i>614-007</i>

R UNITS

DELIVERY

SEPT. 30

OCT. 7 - LATEST

TOLERANCES  
EXCEPT AS NOTED

DECIMAL

±

FUNCTIONAL

±

ANGULAR

±

REVISIONS

TITLE: *MANIFOLD, STORAGE*

PROJECT *NHUTC*

DRAWN BY *JL*

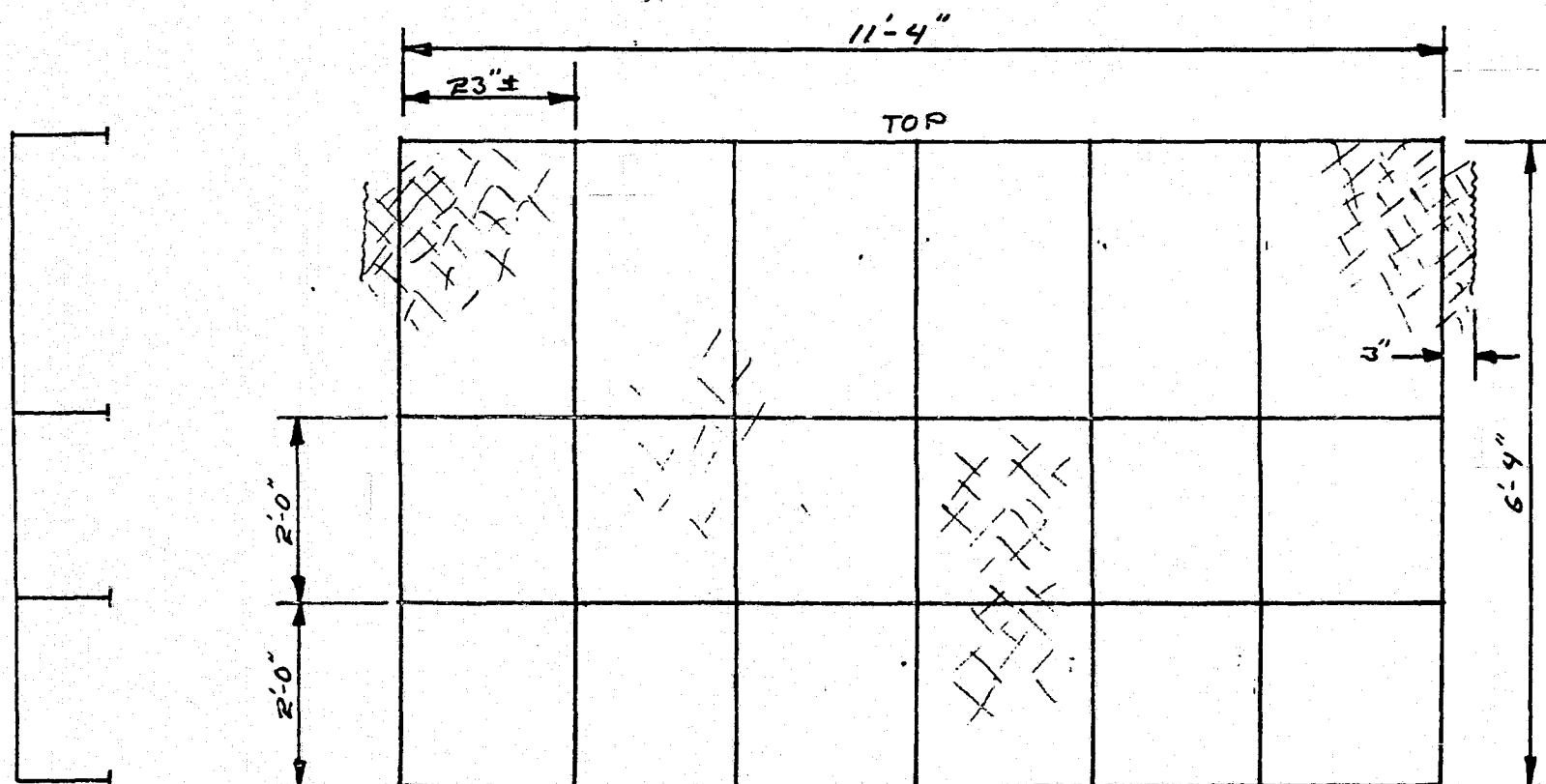
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SCALE

DRAWING #

*614-008*

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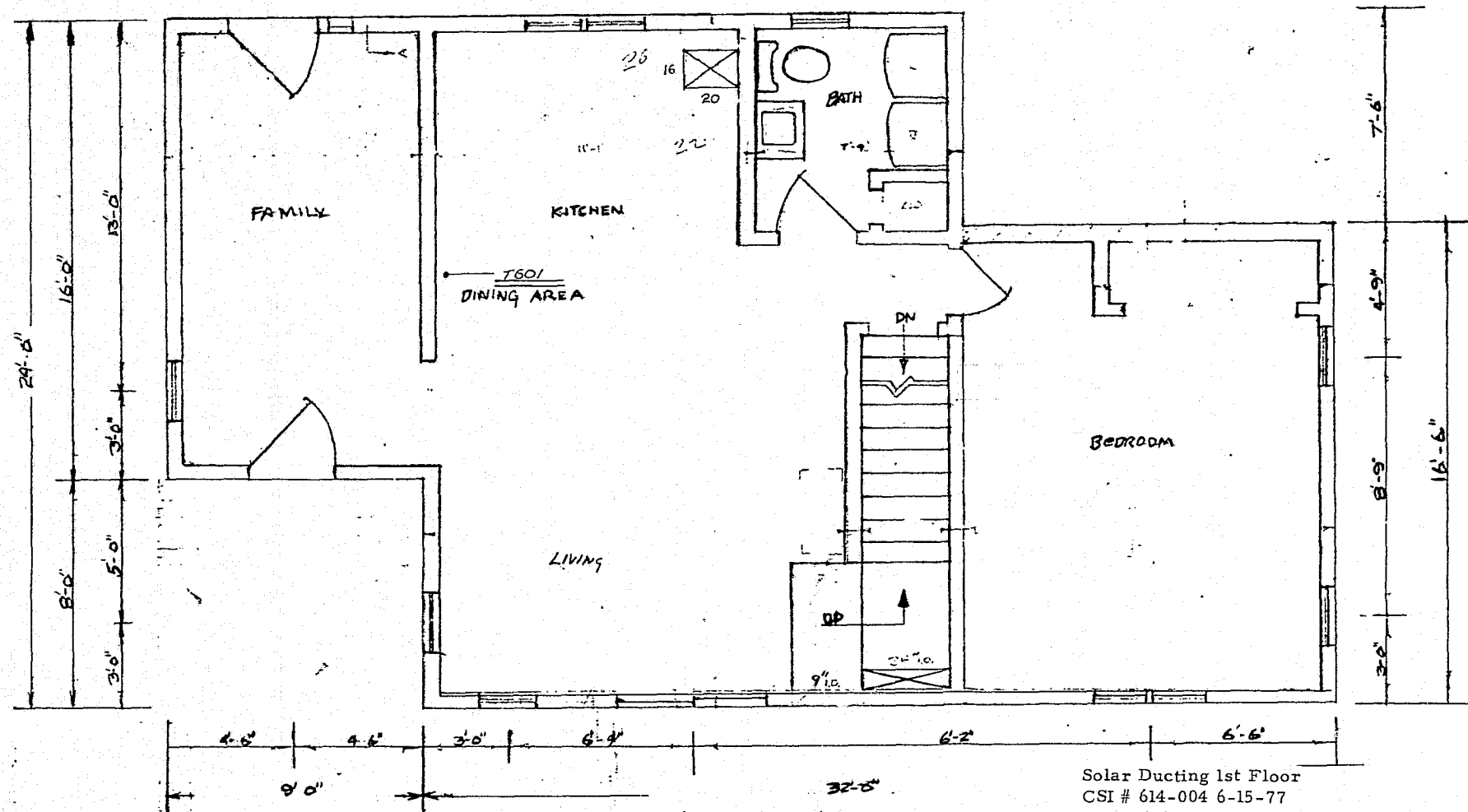


A 10" LEG MUST BE WELDED  
TO EACH FRAME INTERSECTION,  
28 LEGS TOTAL. WELD A 1 INCH  
SQUARE PAD ON EACH LEG END.

FRAME FABRICATE OF 1"x1" STEEL ANGLE x 1/8"  
VERTICAL STRUTS ARE CONTINUOUS, HORIZONTAL ARE  
SECTIONED. WELD 1/2"-18 EXPANDED AND FLATTENED  
MESH OVER SURFACE - WELD 4" O.C. TO ALL FRAME MEMBERS  
MESH IS FLUSH WITH TOP AND BOTTOM OF FRAME.  
MESH EXTENDS 3" ON SIDES.

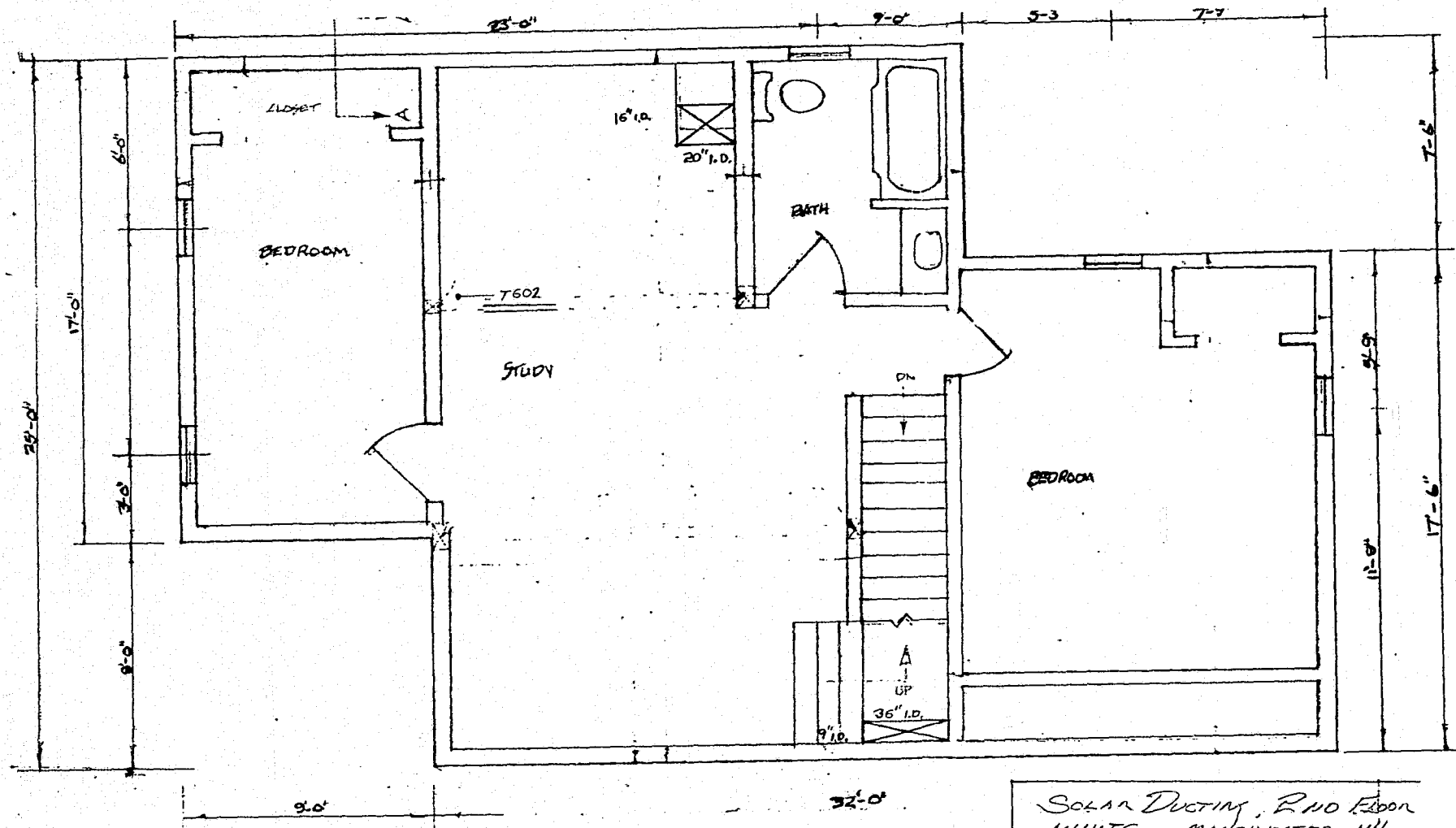
CONTEMPORARY SYSTEMS, INC.

JAFFREY, NEW HAMPSHIRE  
03452 • (603) 532-7972



First Floor Scale 1/4"

Solar Ducting 1st Floor  
 CSI # 614-004 6-15-77  
 NHVTC SOLAR LAB.  
 Manchester, N. H.



Solar Ducting, 2nd Floor  
 N.H.V.T.C., Manchester, N.H.



614-002

HOUSE SECTION, SOLAR  
DUCTING

DRAWN BY: JC

DATE: 6-15-77

PROJECT, NHVTC

REV 11/11/77 JC

717 FT<sup>2</sup>  
COLLECTOR

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FIBERGLASS  
DUCT

T101

DHW  
FAN COIL UNIT.

RAILING

16"  
GAL. DUCT  
UNINSULATED

9'x36"  
T100

W100

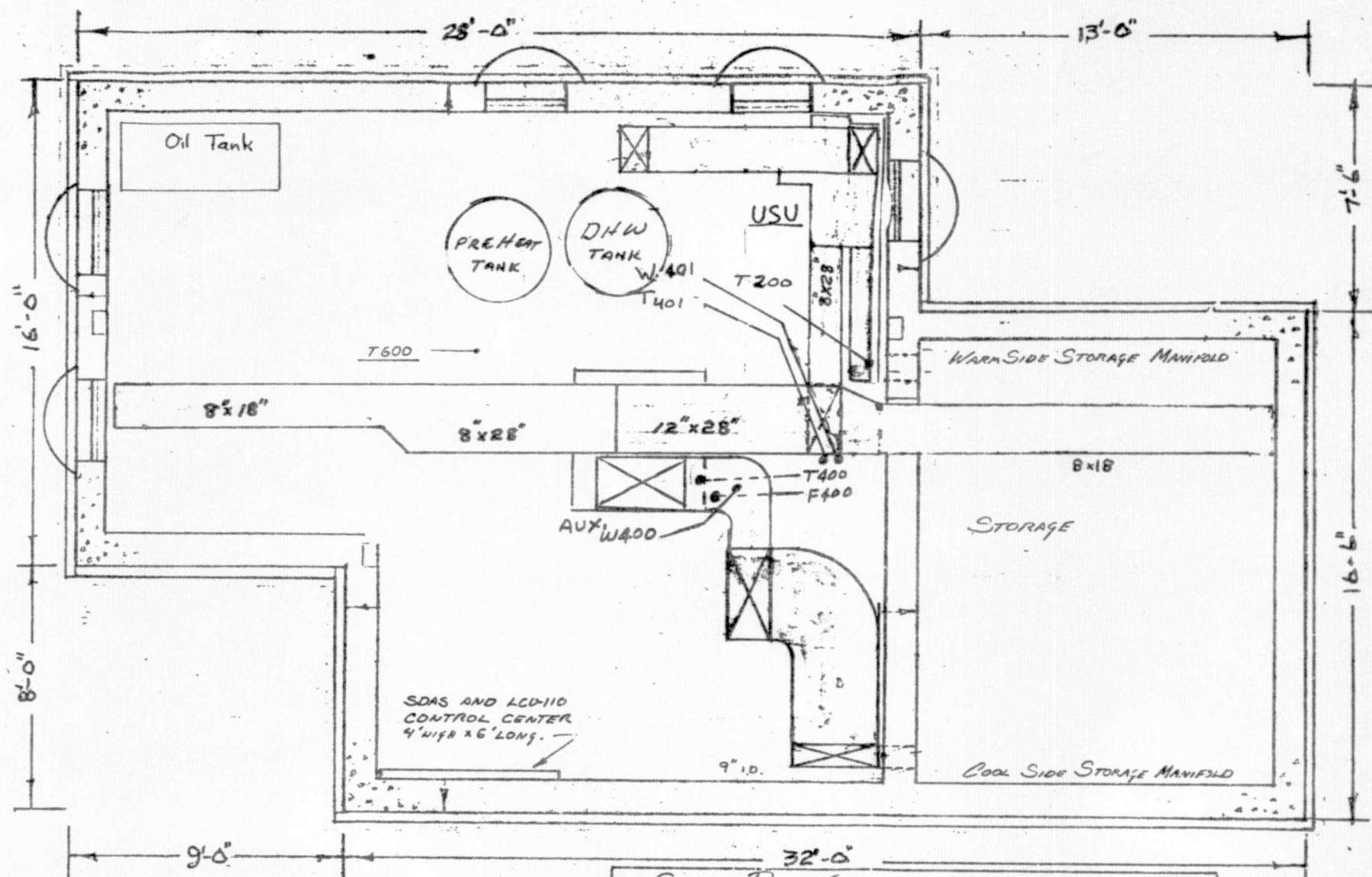
FIBERGLASS  
DUCT

GAL. DUCT  
UNINSULATED

DETAIL "A"

EP400

DETAIL "C"



SOLAR DUCTING  
BASEMENT  
#6.14-003

NHVTC SOLAR LAB  
MANCHESTER, N.H.  
6-15-77

REV 11/11/77  
JC.

CONTEMPORARY SYSTEMS, INC. JAFFREY, N.H.



VI  
MANUAL  
on the  
INSTALLATION, OPERATION AND MAINTENANCE  
of the  
CSI INTEGRATED  
WARM AIR SOLAR HEATING SYSTEM

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Contemporary Systems, Inc.  
68 Charlemagne Street  
La Jolla, New Hampshire 03152

Contract No. NAS8-32243

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Appendix 1: Control System Parameter Settings  
Appendix 2: Ducting/Manifolding Insulation Requirements  
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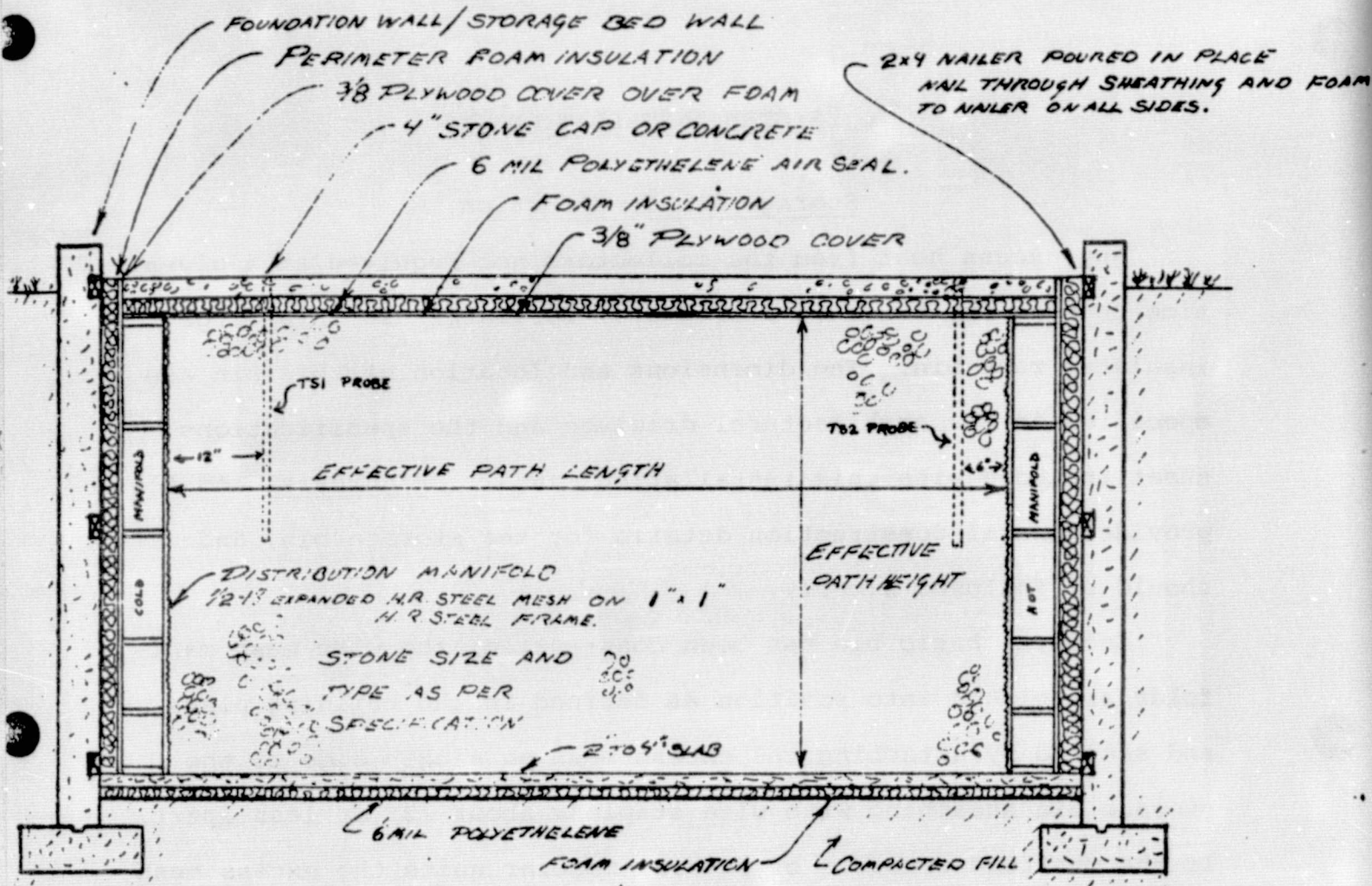
## SYSTEM INSTALLATION

### Storage Bin Construction

Any excess heat from the collectors not required at a given time to heat the house is stored away for later use in a large, insulated rock bin. The dimensions and location of this bin are specified in the architectural drawings and the specifications sheet included with this installation manual. Figures #1 and #1a provide general construction details for the storage bin, and should be followed closely.

Once the basic bin has been constructed, the wire mesh manifolds are placed into position as defined in the building plans, and secured by attaching the excess mesh on either side to the storage bin sheathing with wire staples, about 12" or less apart. If the manifold consists of several modular units the excess mesh should be allowed to overlap the adjoining module and be wired to it securely with soft iron wire. While these units are of welded construction and able to withstand very high inward pressures, they should still be handled with care until in place, and should not be dropped into the bin but handed down carefully.

The particular type and size of rocks to be used in the bin depends on the design of the system. In most cases it is important that they be screened so that they are uniform in size. It is equally important that they be clean and free of clay, silt or dust.



**BOTTOM INSULATION:** suggested in most installations, R3 to R6 is generally satisfactory. Additional insulation may be required if much ground water movement is present.

**WATERPROOFING:** The entire bin must be water and damp proofed. Dampness in contact with the warm stones may prove to be a health hazard.

**SUGGESTED INSULATION TYPE:** Isocyanurate Foam, foil faced Celotex Thermax TF-600 or 610 @ R-8 per inch.

#### ROCK BED INSULATION SPECIFICATION

Storage walls (top & perimeter) common to areas whose temperatures are:

	Ins.	Wall	Total
Above 60°F	R7.5	1.75	9.25
Above 30°F	R11	1.75	12.75
Above 0°F	R15	1.75	16.75
Above -30°F	R19	1.75	20.75

FIGURE #1: ROCK STORAGE

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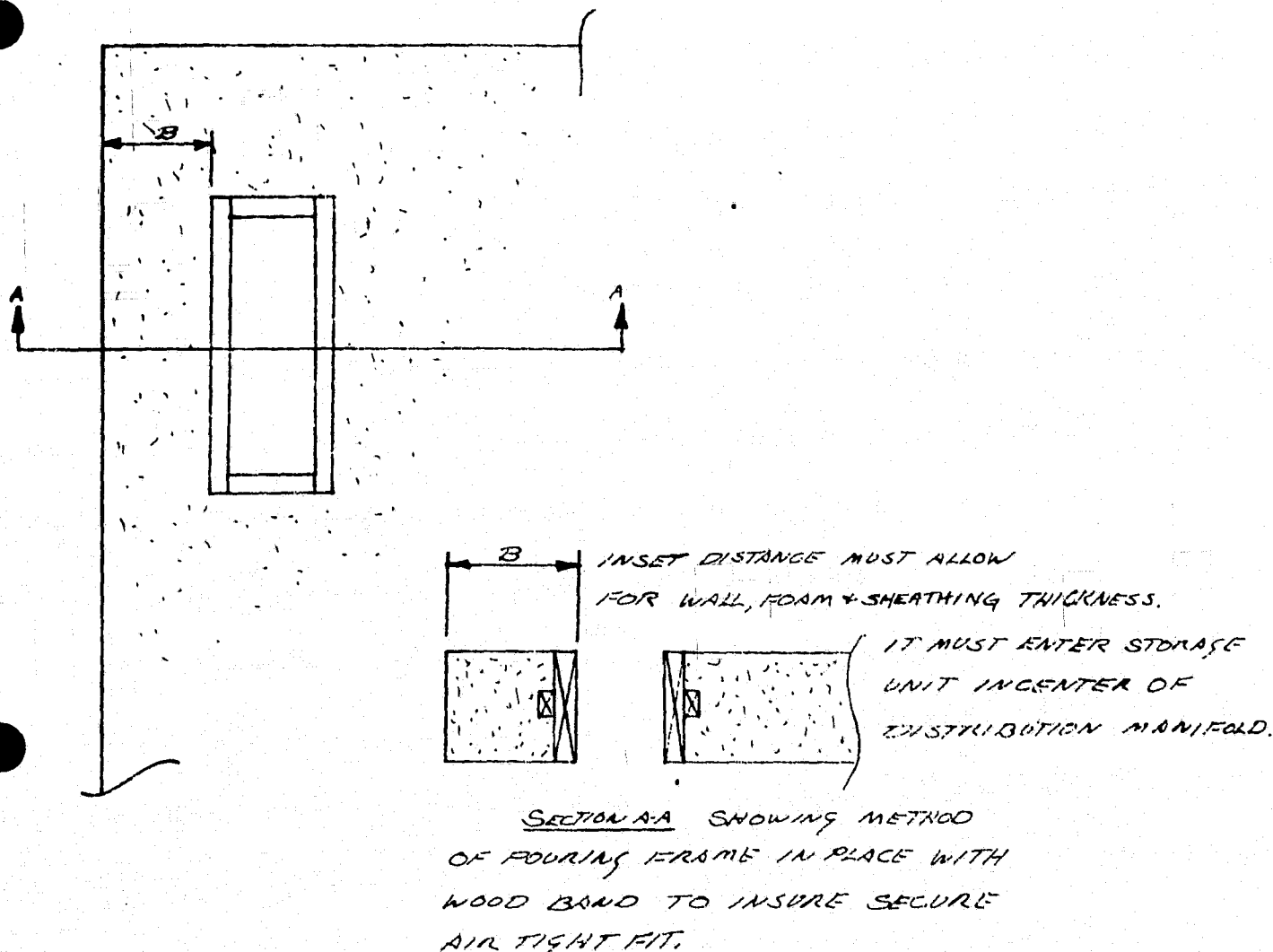


FIGURE #1a: STORAGE INPUT-OUTPUT PORT

These materials tend to insulate the rocks and can reduce the efficiency of the whole solar system, as well as adding unwanted dust to the air. The exact specification for the rocks will be included in the project plans.

It saves time if the rocks are loaded directly from the truck into the storage bin with a minimum of hand work. Care should be

taken, however, to protect the wire mesh manifolds by dumping the rocks gradually and distributing them evenly during the process. If the specifications call for rocks less than 1" in size, they must either be mechanically tamped or allowed to settle for two weeks and then the bin should be refilled before installing the top. If they are to be mechanically tamped, this should be done every 8 inches of depth. The tamping should be even, but care should be exercised to avoid going too close to the wire mesh manifolds.

Once the rock bin has been filled to the top of the wire mesh, and has been tamped or allowed to settle if necessary, the top cover can be put on. Refer to Figure #2 for the details of the whole cover assembly. First a layer of 3/8" plywood (CDX is fine)

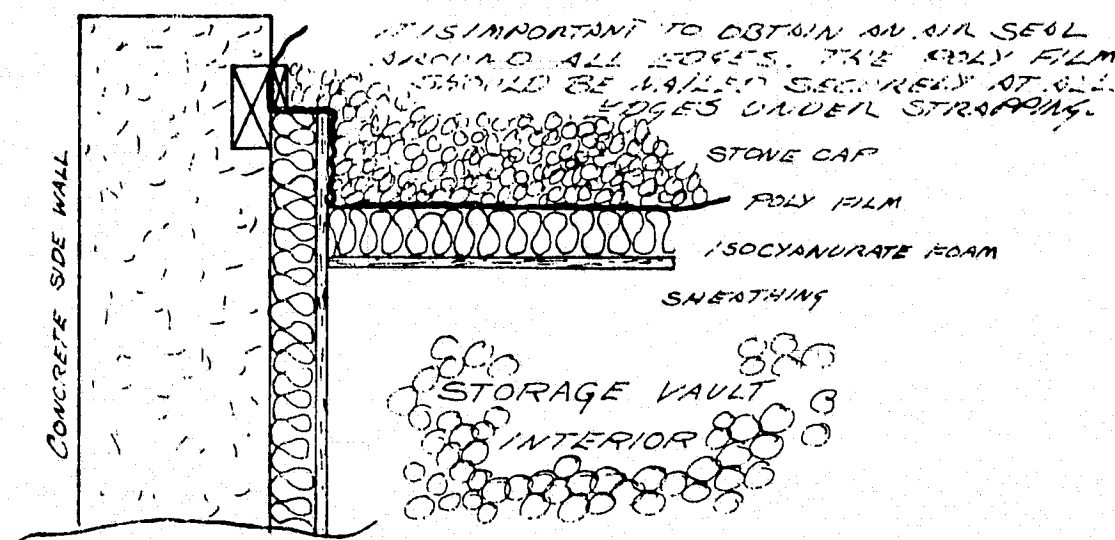


FIGURE #2: STORAGE COVER DETAILS

is put across the entire top from wall to wall. Next the top insulation is installed. The proper insulation is listed on the specification sheet. It is important for safety reasons that no substitutions be made. Then a layer of 6-mil polyethylene is placed

over the entire top, allowing 8" to 10" excess in all directions. If more than one width of poly is used, they should overlap by at least 18" and the joints sealed with duct tape. Finally, either 4" to 5" of rocks or a thin poured slab is added on top of the poly. The excess film is then folded over the plywood side of the bin and secured on the outside wall by stapling or some other suitable method. It must be emphasized that the treatment of this polyethylene layer is very important, for it serves as a final air barrier in the storage system.

### Collectors

The Series V Solar Collectors are designed to make installation a quick and simple process. They are very light in weight, and easily handled by two people. They are constructed of highly durable materials, and designed for a long service life, but must still be handled with care. It is best to handle the collectors by means of the aluminum side rails. They should never be held by the holes in the hardboard backing.

If it is necessary to remove them from the transporting vehicle before they are to be installed in the house, they should be stacked with care, using two or more spacers such as wood strapping, between stacked collectors. If sheet metal takeoff collars are installed, they must be protected by thicker spacers. They should not be stacked more than 8 units high. Until installed, they should be well protected from bad weather and kept out of direct sunshine.

Before collector installation is begun, it is a good idea to verify that the framing members are correctly spaced. It is best to avoid having to apply excessive pressure on the collectors themselves

to force them into place. If the framing members are properly installed (24" on center,  $\pm 1/16"$ , leaving at least 22-1/2" space for the collectors) there will be adequate clearance on all sides for the collectors to slide easily into position. If bowing or warpage of the framing members appears to be a problem, it should be corrected beforehand by temporary blocking, or by replacing any really distorted rafters or studs. Neglecting to do this may well cause larger problems later when placement of the protective batten caps is attempted.

The Series V Solar Collectors can be installed in three different configurations on the house. Some of the details of attaching procedures vary, so a careful review of the directions below will be necessary for the particular type of installation involved.

#### Angulated Mounting

In both the roof mount and the modified wall mount system, collectors are installed at a steep angle, and the mounting procedures are essentially the same. The upper end of the collector should have at least 1/4" clearance from the header or ridge board. If the framing details necessitate over 1/2" space at the top, this space should be filled with fiberglass insulation. The clearance at the bottom should also be about 1/4" to allow both for the expansion of the collector (when it heats up) and proper attachment of the fascia trim.

Depending on the exact details of the house framing, it may be desirable at this point to improvise some form of ladder brace, if necessary, to facilitate leaning a ladder against the framing members adjacent to the bay in which the collector will be installed.



This may be done by nailing a 28" piece of strapping across the top end of the ladder where it will rest on the framing.

Once the correct positioning has been determined, the collector is attached directly to the framing members in the center of its length with one #8x1-1/2" round head wood screw on each side. It may help to use some kind of shim at the upper and lower ends to assure sufficient clearance. After the collector has been secured by these two screws, the rest of the collector can be fastened using the special "U-channel" fasteners supplied. These should be spaced 6" from top and bottom and about every 4 feet along the length of the collector. These fasteners must be positioned correctly, as in Figure #3, using #8x1-1/2" round head wood screws.

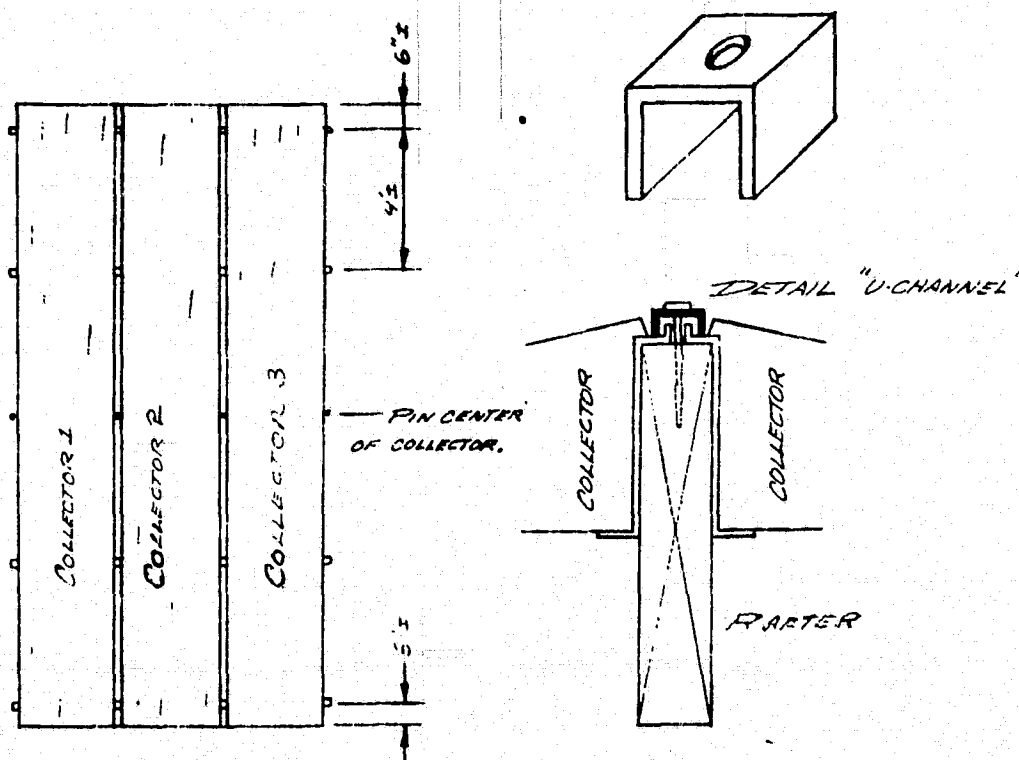


FIGURE #3: "U-CHANNEL" FASTENERS



### Vertical Wall Mounting

The mounting requirements for the vertical wall collector array are somewhat different. The bottom of the collectors will be approximately two feet from the bottom sill in most installations so as to prevent snow buildup from shading the collectors. The lower portion of the stud must be cut and positioned as shown in Figure #4.

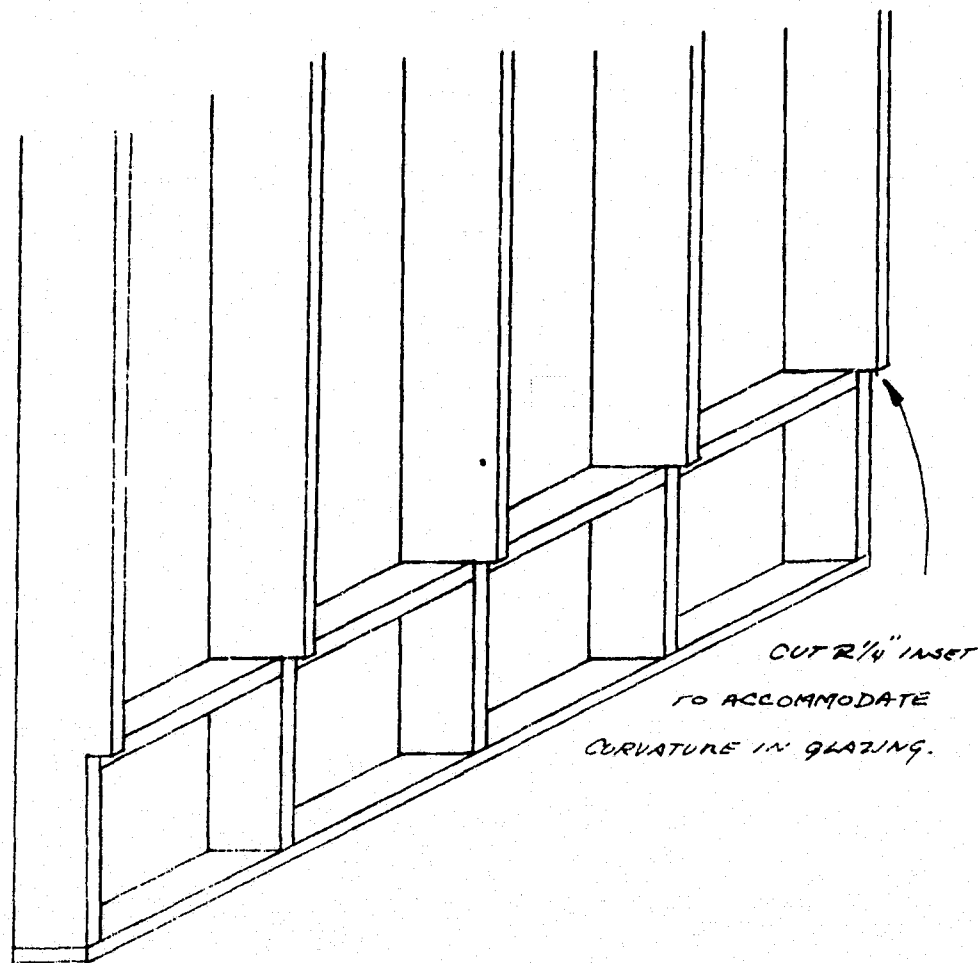


FIGURE #4: WALL FRAMING

Blocking may be used below the collector; however, at least  $1/4$ " should be allowed for expansion. The hardware requirements -- pinning the centers and then using the "U-channel" brackets -- are the

same as in Figure #3. (The details of the flashing and trim are shown in Figure #6.)

### Batten Caps

After the installation of the collector units is complete, the batten caps can be put in place. This should be done as soon as possible because they provide the final weather seal on the area between adjoining collectors, and must be in place before the top flashing can be installed. Once again, it is important to position the ladder so that it isn't bearing directly on the collector glazing, but instead on the edge area attached to the rafters. The same brace used to install the collectors can be used for this purpose also.

The batten caps are designed to snap into place, and will be held tight by the design of the collector side rails. It is easiest to position the batten cap with the bottom flush with the bottom of the collector glazing assembly, push one end into place and continue to snap it on along the length of the cap. A soft mallet or a hammer and wood block can be used to snap the cap into place. The collectors at either side of the array require special trimming arrangements to accommodate the cap, which is shown below in Figure #5.

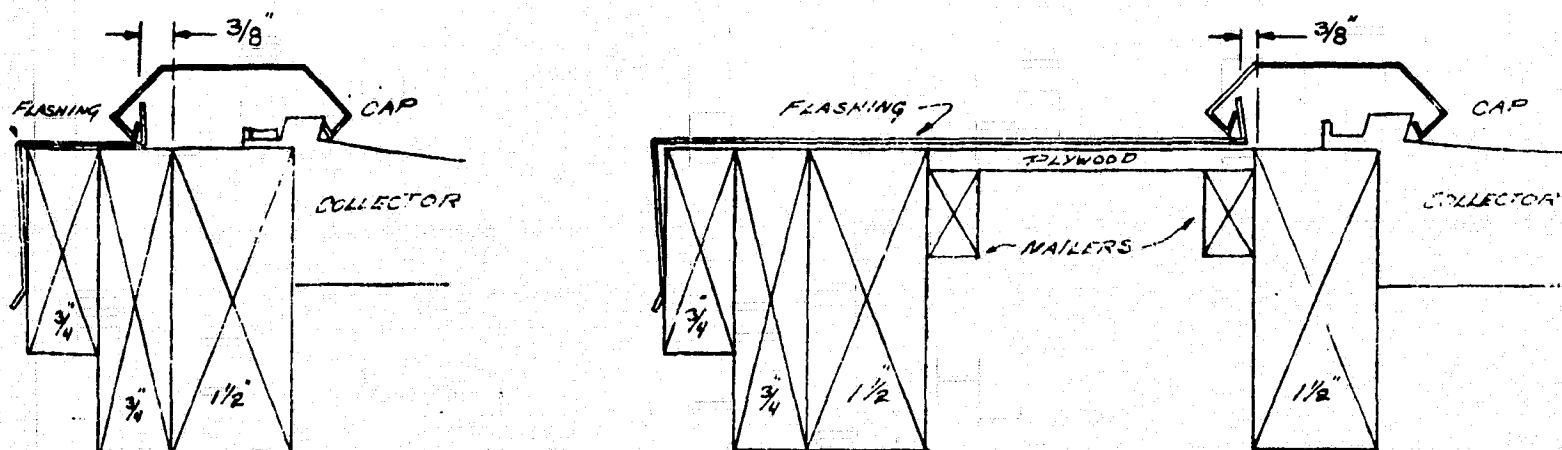
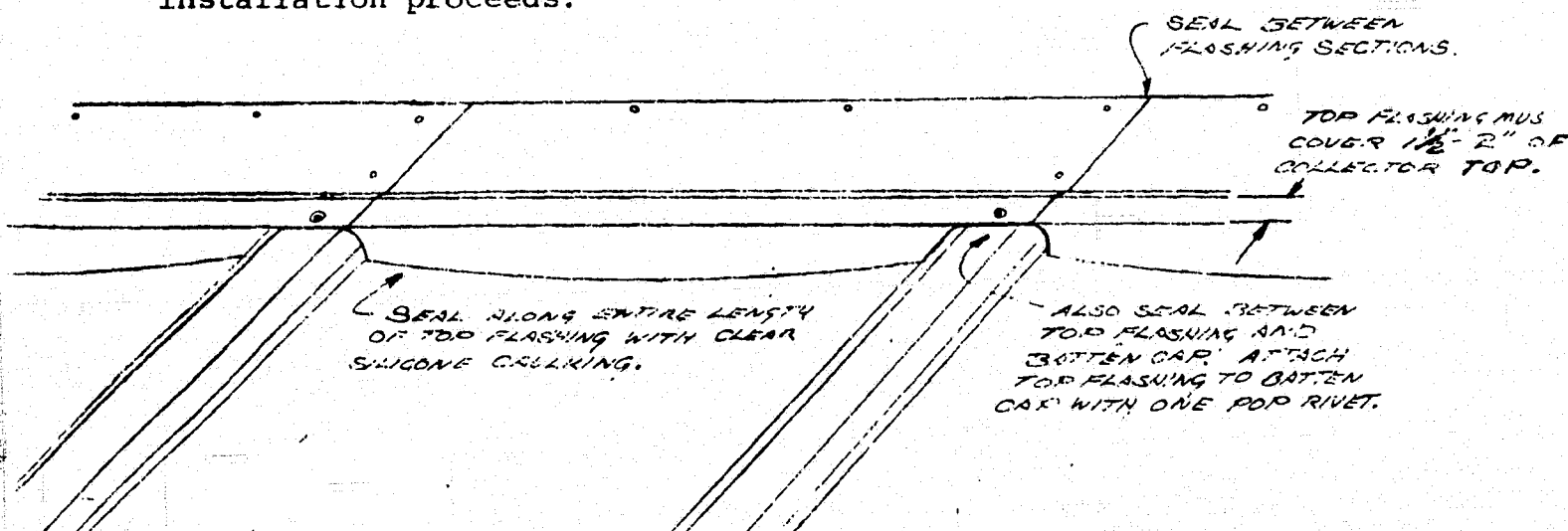


FIGURE #5: BATTEN CAP

After being snapped into place, the lower end of the batten cap should be sealed. This can be accomplished by stuffing some fiberglass insulation into this space. If a finished appearance is required for the particular installation, a filler plug of sheet metal can be improvised and sealed with clear silicone sealant.

### Top Flashing

After the batten caps are fitted, the top flashing pieces should be installed so as to overlap the top of the collector by 1-1/2" to 2", but no more. Roofing cement and felt paper must be used underneath the flashing, and the lap joints should be sealed as well. Any visible sections should be kept neat -- clear silicone sealant may be preferable for this reason on the front lap which will be exposed. The flashing should be secured with common roofing nails, starting at one end of the collector array and working to the other, and then sealed and pop-riveted to the batten cap at each lap joint. This is shown in Figure #6. The curved portion of the flashing should be sealed to the collector cover as the installation proceeds.



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FIGURE #6: FLASHING AND TRIM

When the shingles or top trim (on a vertical wall mount) are installed over the flashing, additional roofing cement should be used over the flashing.

#### Collector Manifolds

Standard four-sided sheet metal ductwork is used for the upper and lower manifolds to the collector array. The size depends on the overall system size, and is provided on the enclosed specification sheet, along with the manifold insulation requirements. Note that the insulation requirements for the upper and lower manifolds are different (because one is considerably hotter than the other in operation).

Takeoff collars should be installed before the manifold is insulated. These provide the means of connecting the individual collectors to the manifold, and in some cases also include balancing dampers to equalize the air flow through each collector. Generally 8" round by 8" long collars are used, unless otherwise noted. The manifolds themselves don't extend the full length of the collector array, but are four feet shorter, so the two end collectors enter at the ends of the manifold. The collars should be installed one foot from each end of the manifold, and then 24" on center for its length, plus the two ends, as in Figure #7. All of the collars should be fastened securely and sealed with silicone sealant.

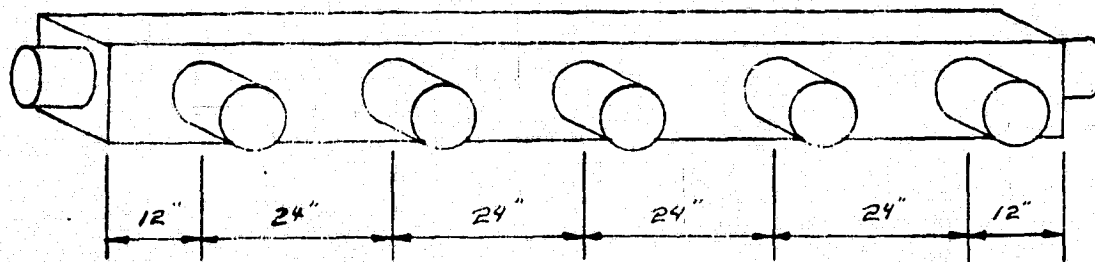


FIGURE #7: MANIFOLD DETAIL

The actual connection from the collars on the manifold to the collars on the collectors is by means of standard 8" round insulated flexible ducting. This should be installed with much care to assure an airtight seal. The outer cover and insulating layer should be pulled back several inches to expose the inner film on the wire frame. This inner layer is then taped securely to each takeoff collar, using a good quality duct tape able to withstand high temperatures. The insulating layer and outer cover are then slid over the collar until they are pressed against the back of the collector or manifold, and fastened by means of a sturdy hose or duct clamp.

The manifolds themselves are supported by means of standard straps or brackets to the house framing members. If those straps are installed over the insulation, metal surface plates should be used to avoid damaging the insulation. The location and size of the main trunk lines to the manifolds are included in the specification sheet.

#### Fail-Safe Thermal Vents

The fail-safe thermal venting units are very simple but vital mechanical units which protect the collectors from overheating. They are operated by the system control unit, the LCU-110, whenever the collector temperature exceeds a pre-determined level (about 150°F). This condition would generally only exist in the summer when the blower is off because the house doesn't require heat and the storage is already "filled" to a suitable capacity. If at any time of year there is a power failure which stops the blower on a sunny day it is possible for the collectors to heat up very quickly.

For this reason the venting unit is designed to open automatically whenever the power goes out. This is its "fail-safe" feature.

These vents operate by thermosiphoning or power venting. Thermosiphoning allows the warm air in the collectors to rise and exit out the top vent, drawing in cool air through the bottom vent. This fresh air cools down the collectors and is in turn heated to some degree, and then rises up and out the top vent continuing the process. For most efficient operation of this thermosiphoning principle, the vertical distance between the top and bottom vents should be as great as possible. Consequently, care should be taken in locating them as widely separated in height as is reasonably convenient. A typical arrangement is shown in Figure #8.

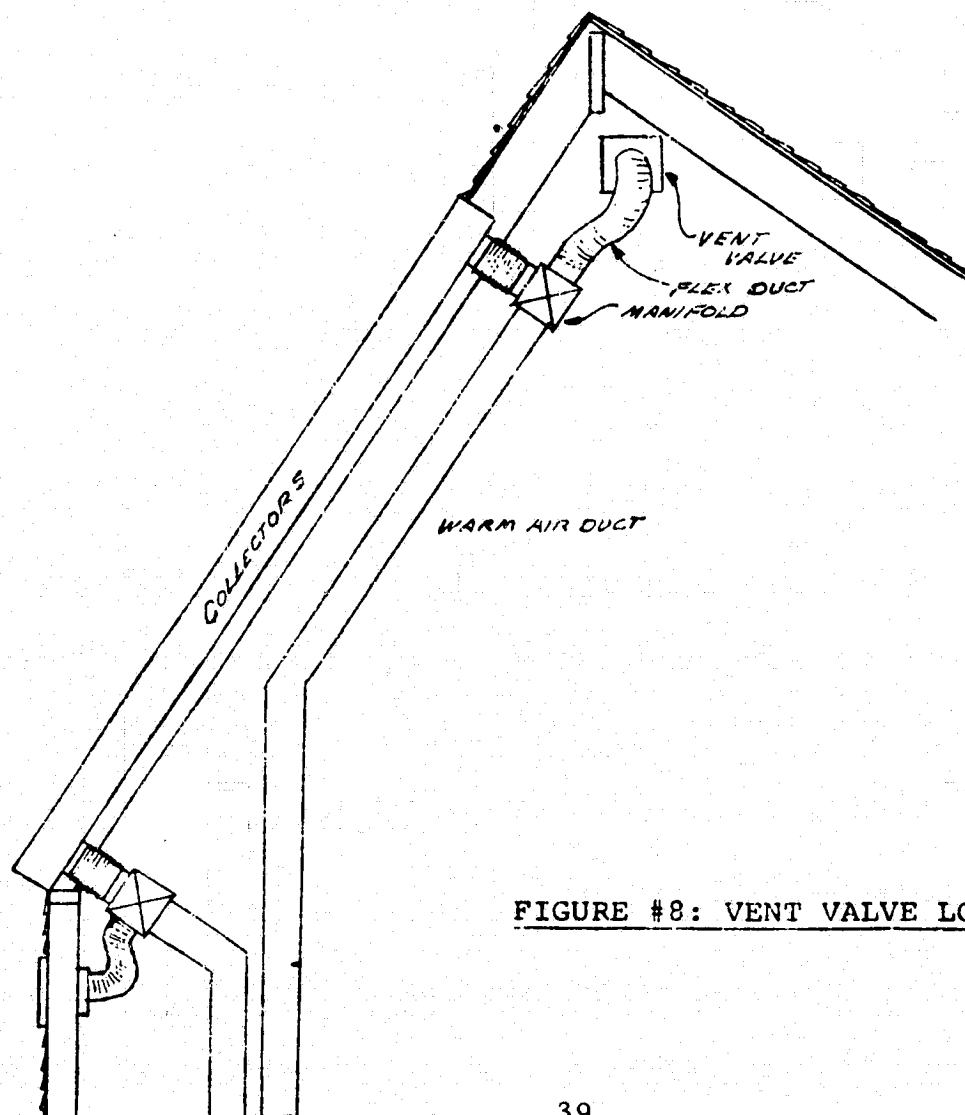


FIGURE #8: VENT VALVE LOCATION



The venting units themselves are installed in the building wall as illustrated in Figure #9. The opening is framed to support and attach the units, and the screened louver is added to provide weather protection and a finished exterior appearance.

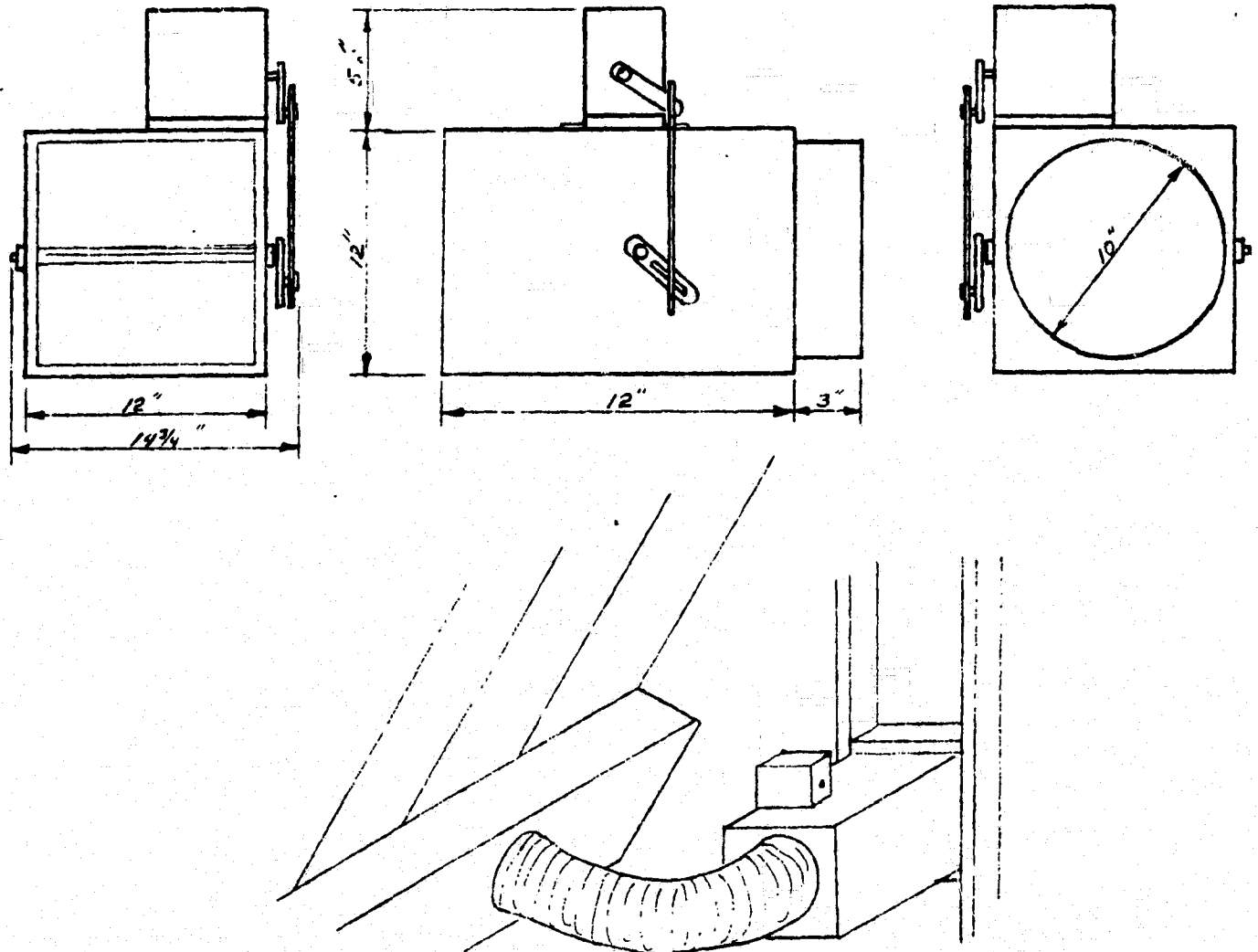


FIGURE #9: VENT VALVE MOUNTING

The two thermal venting units are connected to the collector manifold, one at the top and one at the bottom. The specification sheet enclosed with this manual describes the best place to connect the vents to the manifold. The actual connection is made by means

of round 10" insulated, flexible ducting and the proper adaptor at the manifold end. The flexible ducting should not be excessively long, and should be attached in as straight and direct a line as possible.

#### Universal Switching Unit

The USU air transport and switching unit combines the centrifugal fan and motorized air valves into one component. It handles all of the air moving and switching functions related to the solar system operation.

When it is delivered it may be in two pieces due to clearance limitations, and should be re-assembled on site. Pop rivets, 1/8" steel with a grip range of 1/4", should be used in all of the pre-drilled holes, and care should be taken to insert the rivets flush to the outside face\*. After riveting, a silicone sealant should be used all the way around the joint. See Figure #10.

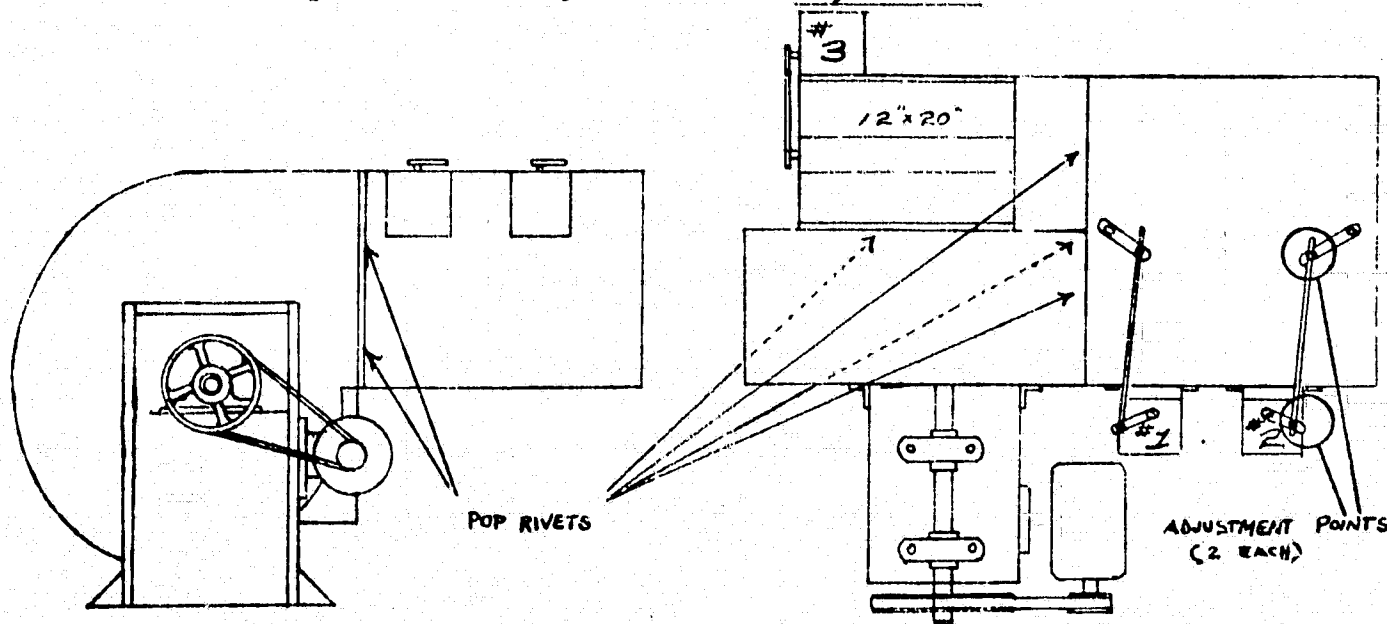


FIGURE #10: UNIVERSAL SWITCHING UNIT

\*It will be necessary to reach inside the switching unit to get to some of the holes. Note that there is one connecting point at the bottom of the fan inlet flange. A strip of adhesive-backed foam tape is set around this flange, and should be slightly compressed when the two components are joined.

The basic location and orientation of the USU are shown on the architectural drawings. The final positioning of the unit should allow adequate clearance for wiring and servicing. There should be nothing in the way to stop the damper arms from moving freely. If the unit is being mounted on a concrete floor it is advisable to use treated lumber spacers bolted to the floor on which to mount the unit. If the floor is not perfectly level, shims will be necessary to avoid any possibility of vibration when the unit is in operation. It should be attached to the floor (or to the spacers) using 3/8" diameter masonry anchors (or bolts).

Once the USU has been installed, the three damper linkage assemblies should be examined. Each one has been adjusted in the factory to the correct setting and painted or marked. It should be apparent if the linkage has slipped in transit, and if so it should be readjusted. Note in Figure #10 that each linkage assembly has four adjustment points to verify. If it is necessary to readjust any of the bolts, repaint that point afterwards for future reference.

#### Interconnecting Ductwork

Conventional sheetmetal duct is used to interconnect the collector manifold, storage, USU air transport and switching unit, auxiliary furnace and the main supply and return lines. Standard HVAC procedures are to be followed, minimizing the length of the runs and the number and severity of bends. Flexible couplings should be used for both of the horizontal outlet connections from the USU. Note also that these two side-by-side outlets are labeled inside to identify the proper connection to be made.

Care should be taken to avoid damaging insulation material when using duct hangers. The size and insulation requirements for the duct work are specified by the architect; CSI's recommendations are included here for reference in Appendix 3. All duct joints must be sealed, either with plastic sealer or permanent duct tape. Great care must be taken in every respect to keep the entire system air tight.

#### Logic Control Unit.

The LCU-110 should be centrally located with respect to the collector and storage probes, the USU, and the auxiliary furnace. It should be easily accessible and mounted in a dry location with temperature variations between 40-90°F. The unit should be screwed to a vertical wood panel through the mounting feet on the sides of the enclosure. When the fastening at the top is released, the front swings down to provide access to system parameter adjustment, fuses, and terminal strips for wiring (see Figure #11).

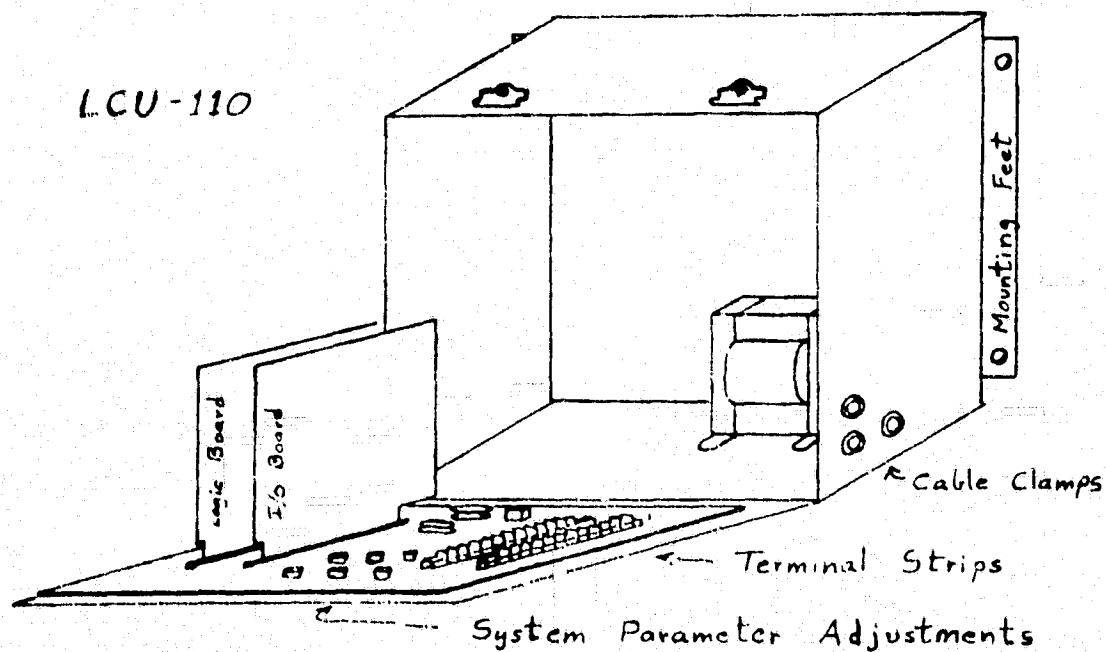
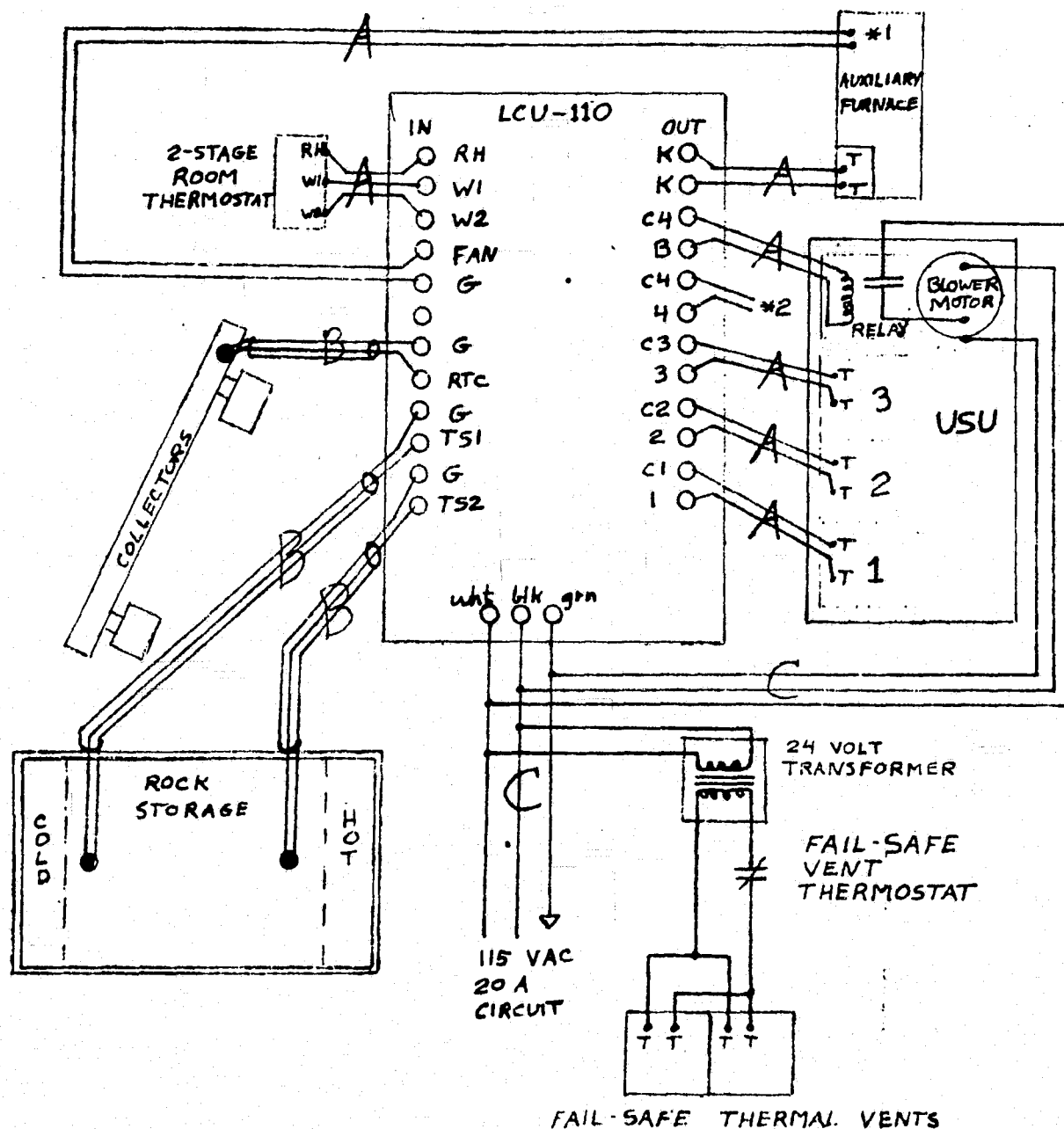


FIGURE #11: LCU-110

Cable is then run for the control system. Figure #12 details the wiring needed between USU, LCU, auxiliary furnace, room thermostat, collectors, storage and 115 VAC circuit panel. Wire labels and accepted wiring methods should be used.

Next comes installation of the two storage probes, TS1 and TS2. These probes are to be located in 1/2" copper pipes or EMT driven into the rock bed. TS1 should be located about 12" (in effective path length) from the cold manifold, in the center of the bed's cross-sectional area. TS2 should be located about 6" (in effective path length) from the hot manifold, in the center of the bed's cross-section. (See Figure #1, page 2.) These positions should be located on the side or top of the bed (allow for insulation and manifolds) and a 1/2" hole drilled through the bed wall. The pipes can be made from common copper pipe by cutting to length (equal to 1/2 the total bed width or height plus insulation and wall thickness) and crimping one end. The crimp must fit through the 1/2" hole in the bed wall. The pipe is driven, crimped end first, through the stone and into position. The probe leads should be soldered to the insulated shielded probe cable and all connections and exposed shield taped. The probe is then inserted in the bottom of the pipe. The pipe and the cable must be protected at the opening.

The collector probe RTC and the fail-safe thermal vent thermostat are located in the collector probe box. This box should be located over an opening in the back of one of the collectors, to one side of the hot port. The box cover should be removed and the probe



- A - Thermostat wire, class 2
- B - Shielded probe cable
- C - Class 1 wiring, compatible with codes

- \*1 - to bonnetstat, sail switch or pressure switch as specified.
- \*2 - to fail-safe thermal vent circuit or other as specified.

FIGURE #12: CONTROL SYSTEM WIRING

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leads soldered to the probe cable. All connections and any exposed shield should then be taped.

The system connections as described in Figure #12 should be completed, using accepted electrical wiring practices and materials. Reference may be made to the Job Specification Sheet included with this manual for any additional wiring.

## SYSTEM OPERATION

The CSI integrated, warm air solar heating system is designed for fully automatic functioning. The interior environment of a solar-heated house is in no way different from a conventionally heated one. Once the LCU-110 control unit has been switched to the SOLAR mode, no user-operated controls are required other than the standard room temperature thermostat. There are some seasonal adjustments possible, and these are discussed in Appendix 2. First, it would seem helpful to review the way the CSI system works.

### Collectors

The collector serves the primary function of admitting sunlight and converting light energy to heat energy. The light passes through the two glazing layers and strikes the absorber plate. Two clear glazing materials are used for insulating value, much the same as a storm window. The absorber plate is painted with a special, highly absorptive black paint, and it is upon striking this surface that light energy becomes heat energy. There is a sealed air channel underneath the absorber plate, and air is blown through that passage, "cooling" the absorber plate, and itself becoming heated.

The chassis of the collector is insulated to further reduce to a minimum the loss of the heat to the outside. The site-applied insulation behind the collector array serves the dual purpose of preventing overheating of the house through losses from the collectors, and increasing the general insulation level of the house itself.

## Storage

There will be many occasions when the collectors are supplying more heat than is necessary to heat the house. When this occurs, the heat is automatically diverted to the storage bin. A great amount of heat can be accumulated there, and later withdrawn to heat the house at night or over a period of cloudy days when the collectors can supply relatively little.

The storage bin is filled with small rocks with air spaces between them, and when the heated air from the collectors is blown through the rocks, they absorb the heat. The cooled air returns to the collectors to once again become heated. The bin is well insulated to avoid excess losses.

The size of the storage system is related to the size of the collector array and the heating requirements of the house, as well as space limitations in the house. The length of time during which the storage can heat the house depends on many variables, and will vary widely depending on the time of year. For example, in the early fall or late spring the collectors will often be capable of supplying the full daytime needs of the house as well as storing enough heat to last through several cloudy days. During these months essentially 100% of the heating requirements will be met by the solar system.

On the other hand, in late January when there have been two straight weeks of sub-zero temperatures and little sunshine, the collectors may not have any excess heat to store away, and what has accumulated in the storage bin may be at such low level that the auxiliary furnace will be automatically turned on quite often.

### Air Circulation

The heat is moved from one part of the system to another by the Universal Switching Unit (USU). The USU incorporates a large, high efficiency centrifugal fan and three motorized switching dampers in one piece of equipment.

The USU circulates air from the collectors to the living space or the storage bin, or directly from the storage bin to the living space. This is done through the system of interconnecting duct work. The fan output is adjusted by means of a variable pulley, sized to provide the optimum air flow for each given installation. This optimum is generally about three cubic feet of air per minute for every square foot of net collector area.

The USU has been designed for very efficient, low-cost operation through the use of a large, industrial quality centrifugal fan with permanently lubricated ball bearings, powered by a special GE "Energy-Saver" electric motor.

### Auxiliary Heating

It is not economical to design a solar heating system to provide 100% of the heating requirements of most houses. The reason for this can be seen clearly in the illustrations which follow. Figure #13A shows graphically the heating requirements of a house, from July to June, with the highest need in December-January. Figure #13B shows the output of a typical solar heating system, with the high points in the summer months, when the days are long and the outside air warm and the lowest point in December-January, when the hours of sunshine are short and the severe outside temperatures decrease the efficiency of the system.

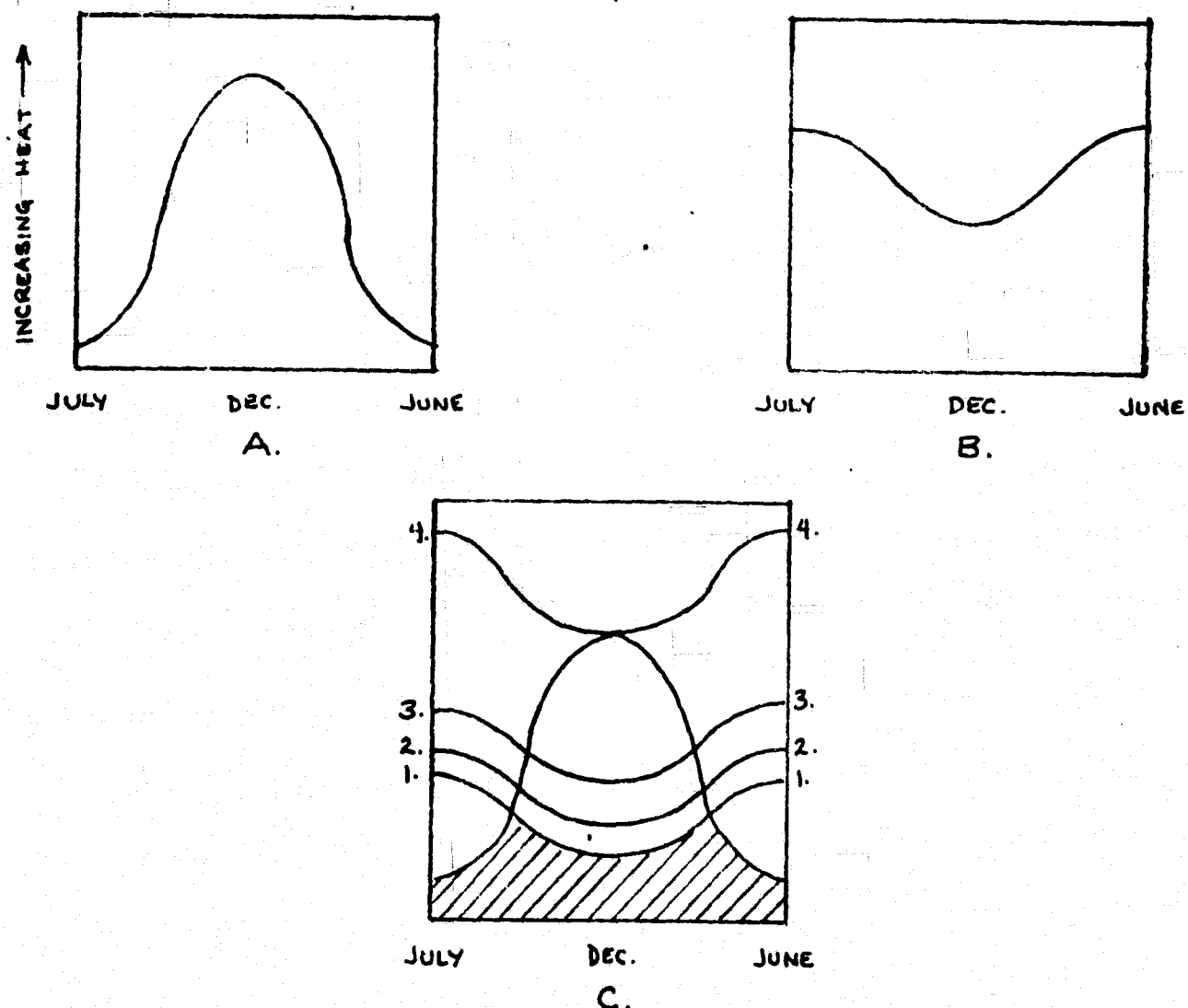


FIGURE #13: HOUSE HEATING REQUIREMENTS/SOLAR CONTRIBUTION

It is clear when these illustrations are compared, as in Figure #13C, why a solar system is generally designed to meet only a portion of the heating requirements. Curves 1, 2 and 3 represent similar systems of different sizes, providing varying percentages of the yearly heating needs. The portion of the heating needs supplied by the solar system is the portion underneath both curves; this is shaded in for Curve 1. Curve 4 represents the smallest system nec-

essary to meet all the heating needs, including that cold winter day on the top of Curve B. It is obvious how much larger it must be than the others, and cost is directly related to this.

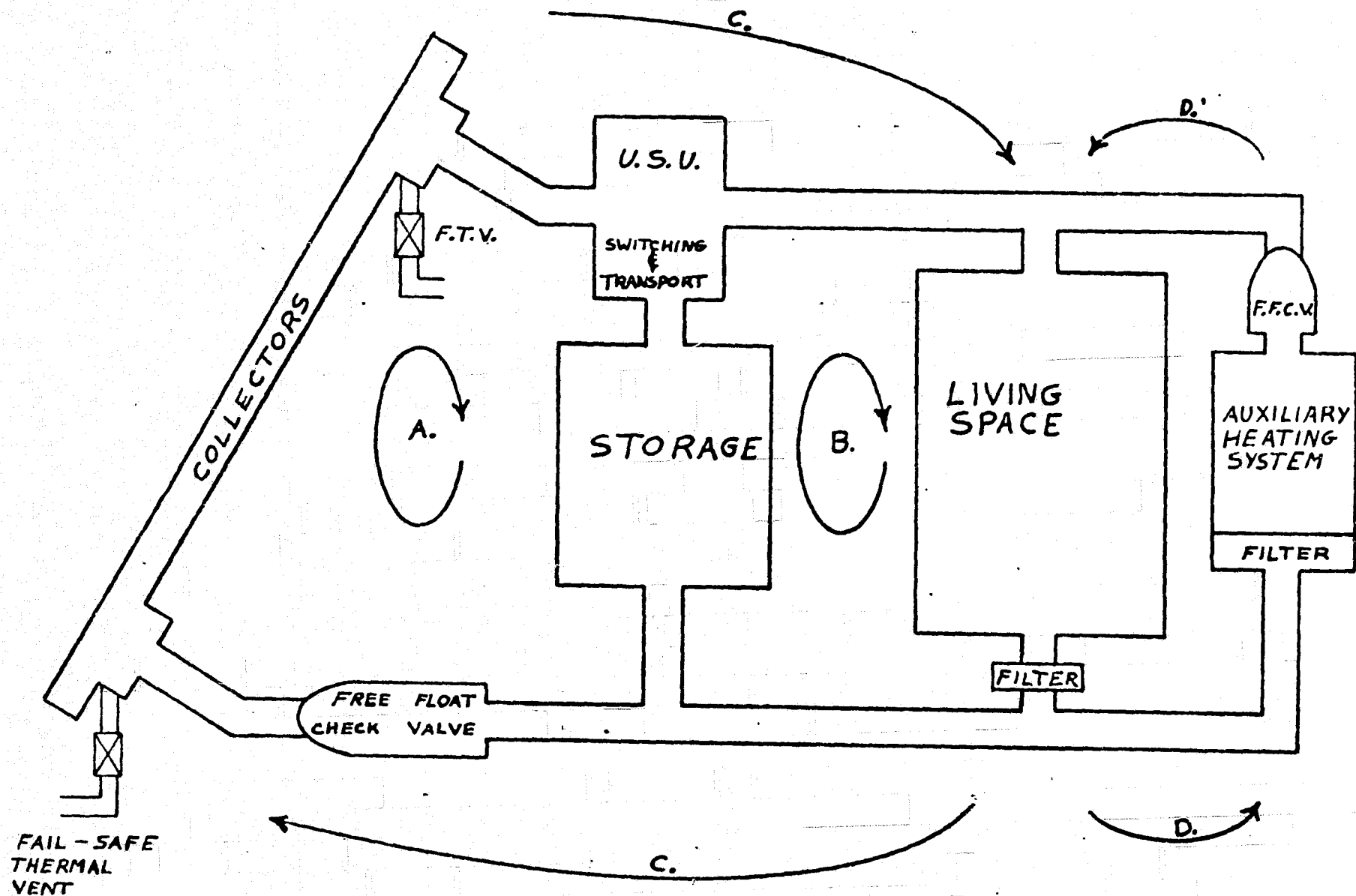
For this reason, the auxiliary heating source is considered an integral part of a solar heating system, and it is connected directly to the solar control unit so that it interacts automatically with the rest of the system.

### Control System

All of the control functions for the total heating system are performed automatically by the LCU-110 Logic Control Unit. It compares various system conditions and "decides" what mode to operate in to optimize the use of solar energy while minimizing the use of the auxiliary heating system. There are six operating modes for the control unit to choose from (see also Figure #14):

1. Standby: when there is no demand for heat and insufficient heat-energy in the collectors to store, or a full storage (STBY).
2. Storing Heat: when there is no demand in the house and there is enough heat-energy in the collectors to store (S).
3. Heating from Storage: when heat is needed, and there isn't enough available in the collectors but there is enough in storage to provide heated air to the house (HS).
4. Heating from Collectors: any time heat is needed in the house, and there is enough available in the collectors, the system gives top priority to this mode (HC).
5. Auxiliary Heating: when heat is required, and insufficient amounts are available from either the collectors or storage, the





GENERAL SYSTEM SCHEMATIC

- A. Storage Heat (S)
- B. Heating from Storage (HS)
- C. Heating from Collectors (HC)

- D. Auxiliary Heating (AUX)
- A & D. Combined Auxiliary Heating/  
Storing Heat (AUX:S)

FIGURE # 14

auxiliary furnace automatically is switched on (AUX).

6. Combined Auxiliary Heat/Storing Heat: when heat is required and neither the collectors nor storage can supply it, the auxiliary furnace is switched on as in #5; but in this mode it is determined that there is enough heat-energy in the collectors to be economically stored, and both functions take place at the same time (AUX:S).

The LCU-110 accomplishes all of the above by controlling the positions of the dampers, switching the main blower motor on and off, and switching the auxiliary furnace on and off. It is designed so that it never directs the use or storage of solar heat when the equivalent heating cost, in the price of auxiliary fuel, would be less than the cost of the electrical power needed to run the solar system (see Appendix 1 for details).

#### Fail-Safe Thermal Vents

These protect the collectors from overheating either in the summer when the system is not being used, or in the event of power failure at any time of year. They are controlled by the LCU-110, and when opened cool the collectors by thermosiphoning.

## SYSTEM STARTUP

### LCU-110

On the front of the LCU-110 are two rotary switches. The SYSTEM MODE switch has three positions. In the CONVENTIONAL position the auxiliary furnace is controlled by the first stage of the thermostat. The solar system remains off and power need not be applied to the LCU-110. In the SOLAR position the LCU-110 controls the solar and auxiliary systems automatically, maximizing use of solar and minimizing use of auxiliary energy. In the MANUAL position the manual rotary switch controls system mode. The thermostat has no effect. Caution should be exercised in manual control so as not to overheat the living space with a heating mode.

There are eight LED indicators on the face panel. The top three indicate energy available for heating (COLLECTOR, STORAGE) and/or storing (DIFFERENTIAL). The bottom five indicate which mode the system is operating in. Two mode indicators on at once indicate a combination mode (S and AUX for systems configured with parallel solar and auxiliary subsystems). In the lower right corner are the LCU-110's power-on switch and fuse. Just above is the SUMMER STORAGE TEMPERATURE LIMIT switch. With it in the ON position, the system will not charge storage to a temperature greater than 100°F.

The front panel of the LCU-110 hinges down once the fastening at the top is released (see Figure #11). With the panel open, the system parameter adjustments, fuses and terminal strips can be ob-

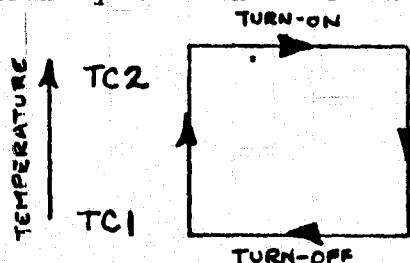
served. The system parameter adjustments are:

1. TC1, TC2-TC1, TC3-TC2 -- collector output minimum temperatures for heating modes. TC1 is the minimum collector output temperature for the HC mode. TC2-TC1 is the turn-on, turn-off hysteresis. TC3-TC2 is the HC turn-on, turn-off hysteresis used with systems with solar and auxiliary subsystems configured in series only. TC2-TC1 becomes the HCA mode hysteresis. See the Job Specification Sheet if you have this system configuration.

2. TS MIN -- minimum storage output temperature for HS mode.

3. C-S DIFF, C-S HYS -- collector/storage minimum temperature differential and hysteresis, for the S mode.

NOTE: a hysteresis in this system means a difference in the temperature at which a system turns on and off. For example:



The initial settings have been calculated and already set for the system and are given in the Job Specification Sheets (see Appendix 1 before changing settings). Once wiring is complete, the LCU-110 should be closed.

With the system parameter settings at their initial values, the SYSTEM MODE switch in manual, and the manual switch in STBY mode, the power switch may be turned on. After about 45 seconds the STBY indicator should light up.

Once the manual switch is turned to S mode, the proper dampers will activate within 45 seconds, and within 90 seconds the USU blower will start. A check should be run at this point for proper damper actuation (according to the table supplied with the Job Specification Sheets) and proper system air flow. It is advisable to proceed through the system modes manually and check for proper damper actuation and system air flow, allowing time for damper change before the blower comes on. When returning from an AUX mode the system will wait for the auxiliary furnace blower to shut down or 7-8 minutes, whichever comes first. A detailed control flow chart is given in the Job Specification Sheets.

The SYSTEM MODE switch may be returned to the SOLAR position and the LCU-110 will take over automatic solar and auxiliary heating. Initially the system will spend most of its time charging storage. If the dwelling is not occupied, the thermostat should be set at its lowest to expedite initial charging of storage.

If at any time during system installation or startup, heat is needed in the dwelling, and if the auxiliary system is complete and solar system wiring has been completed, then the SYSTEM MODE switch should be set to CONVENTIONAL. The thermostat will control the auxiliary switch and power need not be applied to the LCU-110.

#### System Balancing

To obtain efficient collector operation it is necessary to balance or equalize the distribution of air through each collector. The rated air distribution volume for the system is given on the system specification sheet.

With all collector dampers set at full open the output volume in the storage mode should be set at the fan unit by means of the variable ratio drive set. At this point, prior to balancing, the fan volume should be set about 5% higher than the desired (rated) volume. Collector balancing can then be accomplished in two ways. The first is the velometer method in which air volume is directly measured through each collector at the same location on each collector; this method can be used even when the sun is not shining, is generally more accurate, but also is time-consuming. The second method is by measuring output temperature. If the sun is continuous in intensity the output temperature will be inversely proportional to air flow in each collector. Instructions for following both methods are given below.

Velometer Method: Starting at one end of the array, divide the array into quarters and take one measurement in each section. See Figure #7. Use the probe hole provided at the hot manifold input from collector to measure air velocity. Make a table to record these values, as depicted below with sample values:

	<u>Section 1</u>	<u>Section 2</u>	<u>Section 3</u>	<u>Section 4</u>
Test #1	290	350	345	295
Test #2	295	320	315	310
Test #3	310	310	316	310

Adjust all the appropriate valves in each section to achieve balanced flow, and then remeasure air velocities. When all of the values in each quarter are equivalent within 15%, recheck the total air volume at the circulating fan. At this point

the final drive setting can be made. Then go back to the collectors and confirm air flow through each unit. The maximum allowable deviation in most installations is

$$\frac{\text{total air volume}}{\text{no. of collectors}} \pm 10\%$$

Lock all dampers in place after confirming flow rates.

Temperature Method: This method requires a sunny day with constant sunshine during the balancing process. Use the same method as in the previous example but measure the collector output temperature with a quick response temperature probe in the probe hole. Note that the sun brightness should not vary during this operation.



## MAINTENANCE

### CSI Maintenance Services

The CSI solar heating system is manufactured of premium quality components and requires a minimal amount of maintenance. Most of these requirements can easily be performed by the average homeowner, and all of the necessary procedures are discussed below. If desired, however, each CSI representative provides an optional annual maintenance contract, based on the size of the system.

### LCU-110

The LCU-110 Logic Control Unit requires no periodic maintenance. If any difficulties do arise, contact CSI directly. There are no user serviceable components in the LCU-110.

### Collector Maintenance

The CSI Series V solar collectors should require a minimum of maintenance. An examination of the general condition of the collector exterior will reveal any physical damage, such as punctures in the glazing. This should be reported to the CSI representative. Small punctures can be sealed using clear silicone adhesive.

The exterior glazing is the only component which is subject to measurable wear. Periodic washing (with a hose) is advisable especially in the absence of regular rainfall. This will help remove any dust, dirt, leaves or other matter which would begin to affect the protective coating of the glazing, and of course would lower the efficiency of the collectors.

This outer glazing material has a special coating (Kal-laq) which should be renewed every four years. If the surface of the glazing has begun to show visible change, it can be cleaned with a very fine plastic wool, such as Scotchbrite, before applying the new coating. Each CSI representative will be able to supply the materials and instructions necessary.

#### Universal Switching Unit

When the unit is installed it will be checked out in every respect before being started, and under normal operation this system should require cleaning and lubricating only once a year.

It is a good precaution, however, to examine it at regular intervals, i.e. every three months, in between the annual service periods. Basically, you should look for excessive vibration, high bearing temperatures, high motor temperatures, and fan belt wear.

Vibration is most often caused by dirt accumulation on the rotor, or loose mounting bolts. A clean-out access door is provided on the side of the USU opposite the exposed shaft. The mounting bolts should be regularly checked for tightness.

The bearings on this fan are permanently lubricated, and should never require attention. It is normal for them to run fairly hot (up to 150°F) -- this temperature can be checked with a contact thermometer. Excessively high temperatures might be caused by initial under or over lubrication, or misalignment. It is best for experienced personnel to correct these difficulties if they do arise.

High motor temperatures are not normal, and are quite unlikely to occur because of the high quality of the equipment used. In the event they do occur, they should be remedied immediately to avoid

damage to the motor. A check should be made first for anything obstructing the cool air intake to the motor. The rotor shaft should be turning freely with the pillow block bearings functioning properly (i.e. not overheating). If neither of these appear to be the cause of high motor temperatures, contact the local CSI representative for assistance.

Fan belt wear is most often caused by incorrect tension or misalignment of the pulleys. Excessively worn belts should be replaced. Your CSI representative can supply the part.

At the time of these periodic inspections the position of the damper linkages should be re-examined for slippage, as was done at the time of initial installation.

The system filter should be replaced regularly at two-month intervals. It should be examined, however, after the first week or two of normal operation, and replaced then if necessary. This is because the initial operation of the system will clean out accumulated dust in the duct work and the storage, and could reduce the effectiveness of the filter. During this initial start-up period the system will be manually switched through all of its modes of operation, and this should assure an adequate system cleaning.

#### Lubrication

The pillow block bearings should not require any further lubrication under normal operating conditions.

The damper motors require annual lubrication, which is done by removing the snap fit grey cover and lubricating the felt pads on each of the motor bearings (the two small holes on top) as well as

the two shafts in the gear train (the felt pad connecting them will need lubrication). Each of these items will require several drops of light machine oil.

The fan motor should be lubricated with light machine oil every two years.

## APPENDIX 1

### Control System Parameter Settings

1. C-S DIFF: The solar system should not be operated when the cost to operate its fan, in dollars per BTU returned, is greater than the cost per BTU of energy from the auxiliary system. This criterion establishes a minimum temperature difference between air supplied to the collectors and heated air returned from the collectors:  $\Delta T_{\min}$ . We must have twice this  $\Delta T_{\min}$  for energy stored now and used later. Therefore:

$$\text{C-S DIFF} = (\Delta T_{\min}) \times 2$$

$\Delta T_{\min}$  can be computed from the tables and relations shown below and the price of auxiliary fuel.

For oil auxiliary systems: \*

$$\Delta T_{\min} = \frac{(\$ \text{ per KWH})}{(\$ \text{ per gal. oil})} \times C_{\text{oil}}$$

Collector Area (ft <sup>2</sup> )	<u>350</u>		<u>450</u>		<u>550</u>	
Fan Static Pressure (inches H <sub>2</sub> O)	5/8"	7/8"	5/8"	7/8"	5/8"	7/8"
C <sub>oil</sub>	16.6	21.6	15.1	19.0	18.6	23.2

For electric auxiliary heat:

$$\Delta T_{\min} = (\$ \text{ per KWH}) \times C_{\text{electric}}$$

Collector Area (ft <sup>2</sup> )	<u>350</u>		<u>450</u>		<u>550</u>	
Fan Static Pressure (inches H <sub>2</sub> O)	5/8"	7/8"	5/8"	7/8"	5/8"	7/8"
C <sub>electric</sub>	8.01	10.4	7.16	9.03	7.13	8.92

Example: a)

For a 450 ft<sup>2</sup> collector array with system fan static pressure at 5/8" water and oil at \$0.49/gal. and electricity at \$0.065/KWH:

$$\Delta T_{\min} = \frac{(\$0.065)}{(\$0.49)} \times (15.1) = 2.00^{\circ}\text{F}$$

then C-S DIFF should be set at:

$$2 \times (2.00^{\circ}\text{F}) = 4^{\circ}\text{F}$$

Example: b)

For the same size system as above with electric auxiliary system and electricity at \$0.065/KWH:

$$\Delta T_{\min} = (\$0.065) \times (7.16) = .465^{\circ}\text{F}$$

C-S DIFF for this system should be set at:

$$2 \times (.465) = .930^{\circ}\text{F} \text{ or about } 1^{\circ}\text{F}$$

From the two examples above, it can be seen that the solar system can economically store lower grade energy when the price per BTU of auxiliary fuel goes up.

2. C-S HYS: The storage mode hysteresis, or turn-on, turn-off temperature difference should be set to keep the system from cycling on and off. The initial setting of 15°F should be increased if excessive cycling occurs. Consultation with the installer is advised if this situation becomes apparent.

3. TCl: To feel comfortable, the air coming from room registers must be warmer than room temperature to compensate for its velocity and moisture content. At the initial TCl setting of 85°F and 30% relative humidity and with a velocity of 200 feet per minute, the effective temperature of heated air coming from the register is about 73°F. This setting may be increased if delivered air in

HC mode feels cool. It should not be set lower than the thermostat setting plus  $\Delta T_{\min}$ .

4. TC2-TC1: This hysteresis setting is set initially at 15°F to prevent system cycling. If changed it should be the same as C-S HYS.

5. TC3-TC2: This hysteresis setting is only used in systems with solar and auxiliary subsystems configured in series. Consult the Job Specification Sheet if yours is a series system.

6. TS MIN: The minimum acceptable delivered air temperature in HS mode is set for comfort at the same temperature as TC1. It should not be set lower than the thermostat setting plus  $\Delta T_{\min}$ .

# PARALLEL SYSTEM CONTROL OVERVIEW

## Solar modes:

HC - Heating from collectors  
 HS - Heating from storage  
 S - Storing heat  
 AUX - Auxiliary heating  
 STBY - Standby  
 (AUX & S allowed simultaneously)

## priority

1  
2  
4  
3  
5

## Logic inputs:

Tc - Collector manifold temperature has been greater than Tc2 and has not fallen below Tc1.  
 Ts - Storage hot manifold temperature is greater than Ts out setting.  
 D - Collector hot manifold temperature is greater than storage cold side by the diff setting + hys setting (differential + hysteresis).  
 X1 - First stage room thermostat heat demand.  
 X2 - Second stage room thermostat heat demand.  
 ( X2 indicates not X2 )

Mode Logic - defines solar mode as a function of logic inputs.

$$HC = X1 * Tc * X2$$

\* - logical AND

$$HS = X1 * Tc * Ts * X2$$

+ - logical OR

$$S = (X1 * D) + (Tc * Ts * D) + (X2 * D)$$

$$AUX = (X1 * Tc * Ts) + (X2)$$

$$AUX:S = (X1 * Tc * Ts * D) + (X2 * D) \quad \text{AUX \& S simultaneously}$$

STBY = Default mode, no operation.

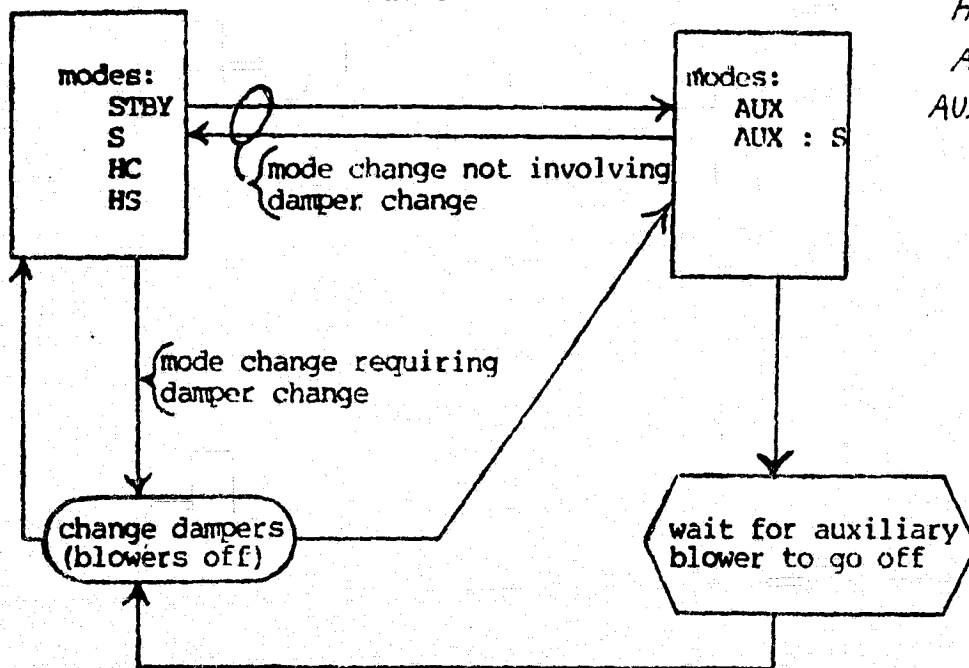
## MODE/DAMPER CHART

	1	2	3	4	Blw	Aux
Stby						
S						
HS						
HC						
AUX						
AUX:S						

0 - not activated or closed

1 - activated or open

## CONTROL FLOW CHART



C-S DIFF

C-S HYS

TC1

Tc2-Tc1

Tc3-Tc2

TS MIN

INITIAL SYSTEM  
PARAMETER SETTINGS

ORIGINAL PAGE IS  
OF POOR QUALITY



## APPENDIX 2

### DUCTING/MANIFOLDING INSULATION REQUIREMENTS

	<u>AVERAGE TEMP. SURROUNDING MANIFOLD</u>	<u>SUGGESTED MANIFOLD INSULATION</u>	<u>TOLERANCE</u>
1. Manifolding:	0°F.	R-10	Loss must not exceed
a. Hot manifold;	20°	R-8	0.7% of total system
assume output temp.	40°	R-6	output/ verify loss
of 120°F.	60°	R-4	is within this spec.
b. Cold manifold;	0°	R-8	Loss must not exceed
assume input temp.	20°	R-6	0.7% of total system
of 65°F.	40°	R-4	output; verify loss
	60°	R-2	is within this spec.
2. Ducting, exterior	0°	R-12	Loss must not exceed
to heated lvg. space:	20°	R-10	1.0% of total system
a. Hot ducting;	40°	R-8	output; verify loss
assume output temp.	60°	R-6	is within this spec.
of 120°F.			
b. Cold ducting;	0°	R-6	Loss must not exceed
assume input temp.	20°	R-5	0.7% of total system
of 65°F.	40°	R-4	output; verify loss
	60°	R-3	is within this spec.
3. Ducting; inside	40°	R-5	Loss must not exceed
heated space:	50°	R-4	6% of total system
a. Hot ducting;	60°	R-4	output; verify loss
assume air temp.	70°	R-3	is within this spec.
of 120°F.			
b. Cold ducting;	40°	R-3	Loss must not exceed
assume air temp.	50°	R-3	2% of total system
of 65°F.	60°	-	output; verify loss
	70°	-	is within this spec.

# JOB SPECIFICATION SHEET

## Storage Bin

Dimensions \_\_\_\_\_

Rock size & type \_\_\_\_\_

Estimated Quantity \_\_\_\_\_

BTU/°F \_\_\_\_\_

## Collectors

Number & size \_\_\_\_\_

Rear insulation (site applied) \_\_\_\_\_

Active area \_\_\_\_\_

$T_a$  \_\_\_\_\_

$U_L$  \_\_\_\_\_

Latitude \_\_\_\_\_

Elevation \_\_\_\_\_

Angle \_\_\_\_\_

## Manifolds

Size \_\_\_\_\_

Insulation: a) Upper \_\_\_\_\_

b) Lower \_\_\_\_\_

## Thermal Vent

Location to exterior \_\_\_\_\_

Connection to manifold \_\_\_\_\_

## USU

Motor size \_\_\_\_\_

System cfm \_\_\_\_\_

Shaft rpm \_\_\_\_\_

Shaft H.P. \_\_\_\_\_

## Interconnecting Ducts

a) Hot manifold supply line

Size \_\_\_\_\_

Insulation \_\_\_\_\_

b) Cold manifold return line

Size \_\_\_\_\_

Insulation \_\_\_\_\_

## System Performance Calculations

Total space heating load \_\_\_\_\_

DHW load \_\_\_\_\_

Solar system coefficient of performance \_\_\_\_\_

Collector costs in \$/sq.ft. \_\_\_\_\_

Fixed system costs (all costs other than collectors) \_\_\_\_\_

## Auxiliary Heat Source

Type \_\_\_\_\_

Capacity \_\_\_\_\_

Manufacturer \_\_\_\_\_