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SOLAR HEATED AND COOLED BUILDING

Annual Progress Report

for the period

September 1, 1973 to January 31, 1974

Prepared for

The National Science Foundation

Research Applied to National Needs

Washington D.C.

Supported by NFS Grant GI-40457

Initiated September 1, 1973

Prepared by

Colorado State University

Fort Collins, Colorado

The University of Wisconsin

Madison, Wisconsin

Honeywell, Inc

Minneapolis, Minnesota

FEBRUARY 1974

Report: NSF/RANN/SE/GI-40457/PR/74/4

MASTER

COLORADO STATE UNIVERSITY

Solar Energy Applications Laboratory
Engineering Research Center

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Report: NSF/RANN/SE/GI-40457/PR/74/4

DESIGN, CONSTRUCTION, AND TESTING OF RESIDENTIAL
SOLAR HEATING AND COOLING SYSTEMS

Annual Progress Report
Covering the period September 1, 1973 to January 31, 1974

March 1, 1974

Prepared by
Solar Energy Applications Laboratory
Colorado State University
Fort Collins, Colorado 80521

in cooperation with
The University of Wisconsin

and

Honeywell, Inc.

George O.G. Löf and Dan S. Ward

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Supported by the National Science Foundation, Research Applied to National Needs (RANN), under Grant No. GI-40457, Initiated September 1, 1973.

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16. Abstracts This is the first progress report on a two year effort to design, construct, test, and evaluate an experimental residential sized laboratory equipped with an integrated system utilizing solar energy to drive heating, cooling, and hot water subsystems combined with auxiliary fuel and thermal storage. It details the design phase of the project and discusses the rationale on which the various design decisions were based. The area of subsystem designs include the solar collector, the heating/cooling system, the building design, the control instrumentation, and the testing and measuring instrumentation.			
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Statement of Objectives

This project is a nominal two-year effort to design, construct, test, and evaluate an experimental residential sized laboratory equipped with an integrated system utilizing solar energy to drive heating, cooling, and hot water subsystems combined with auxiliary (oil or gas) fuel and thermal storage.

The program is designed to provide the following information:

- a. design data for integrated systems and the various subsystems,
- b. system performance for heating, cooling, and water heating,
- c. operating economics,
- d. verification of the University of Wisconsin model,
- e. design and operation of automatic controls,
- f. correlation of standard Weather Bureau data with on-site insolation data, and
- g. system reliability evaluation.

System design has now been scheduled for the first four months; construction during the next four month period; and operation and evaluation through a summer air conditioning cycle and a winter heating cycle during the final 12 months. The refrigeration system will be provided by a specially modified LiBr/water absorption system operated with hot water.

The building will be designed so that the various subsystems can be removed and replaced, so that the facility can serve in the evaluation of other solar components and systems. This project will derive information which will be directly beneficial to the Heating and Cooling of Buildings Proof-of-Concept Experiments Program and will provide a facility for evaluating subsystems developed for that program.

The original two-year program has been reduced by approximately four months and the design and construction phase greatly accelerated at the request of the National Science Foundation.

Summary of Research Results

During the first phase of this project, design studies were completed. These included the basic laboratory design (Section I), the solar collector and solar heating and cooling system design (Section II), the control instrumentation requirements and design (Section III), and the testing and measuring instrumentation design (Section IV). By use of their computer program, the University of Wisconsin group provided data necessary for establishing the size, slope, and glazing features of the solar collector. It was predicted by the computer program that a collector having an area of 800 sq. ft., a tilt of 45° toward the south, and two glass covers, would provide approximately 82% of the heating load and 88% of the cooling load in a randomly selected prior year.

Following completion of building design, bids for construction were solicited. The successful bidder was awarded a contract (in early February), for immediate start and tentative completion in May, 1974. It is expected that the heating and cooling system can be fabricated and made operational by 15 April 1974, which will allow approximately one month of solar heating testing and a full season of cooling operation (approximately May thru September) prior to a complete winter heating evaluation in 1974 and 1975. All materials and equipment for the solar collector, the solar heating and cooling system, and the testing and measuring instrumentation have been placed on order with expected delivery dates in accord with scheduled completion dates. The control instrumentation requirements have been submitted to Honeywell, Inc. for detailed design and supply.

Section II of this report will be submitted, in slightly modified form, for publication in the Solar Energy Journal. The laboratory plans and specifications have been submitted to the National Association of Home Builders for their evaluation and comments.

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Narrative

Progress on Objectives

The immediate objectives of design, ordering of materials, and awarding the laboratory construction contract have been achieved. Primarily because of statutory and administrative requirements, the construction phase is commencing approximately one month later than scheduled, but every effort will be made during the next three months to overcome this delay.

The design of the building has been completed and the construction contract awarded to the lowest bidder among five finalists. A total contract award of \$59,800 has been made. The detailed laboratory plans are contained in Section I.

Solar collector design details are shown in figures 1, 2, 3, and 4. Figure 1 shows a perspective view of the solar collector with two double-strength glass covers, an absorber plate, insulation, and miscellaneous supports. It also provides for a short-term weather roof below the collector to allow for flexibility in experimenting with different collector designs. Figure 2 shows the interface between the solar collector and the laboratory roof system.

The collector is made of 16 units, three ft wide and 16 ft long, totaling 16' x 48' or 768 sq. ft (71.38 m^2). It is tilted at an angle of 45° from the horizontal, and faces due south. Hot water will flow from the lower bottom corner through the lower header and up the collector panels on a "one-pass" basis and exit at the opposite top corner of the collector.

Figure 3 is a diagram of the absorber plates to be fabricated by OLIN Brass Co., by their ROLL-BOND[®] process. Two panels of 1100 alloy

Figure 1

Collector Integration Into Structure

Figure 2(a)

Figure 2(b)

Section A-A

Section B-B

Figure 3

Figure 4

aluminum, each eight ft. long, will be heliarc welded together to provide a continuous 16-foot panel without perforations or openings (Figure 4).

Figure 5 shows a schematic layout (drawn to vertical scale) of the heating and cooling system components other than the collector. Its operation in several modes is discussed in Section III.

The design requirements, methods of analysis, and results of the solar heating and cooling system design study are contained in Section II.

Control instrumentation requirements have been submitted to Honeywell, Inc. for their design and implementation. Section III contains an analysis of the system control aspects of the project.

Problems Encountered

Two problems have been encountered. The first is a nationwide shortage of numerous materials and products. Several individual design efforts had to be given priorities above their normal level in order to allow sufficient time for procurement of specific materials and equipment. The long lead times for some key components have been the determinants of estimated completion dates.

A second problem has involved the location of the facility on state property. This situation has resulted in unavoidable schedule delays and inhibits accelerated activity. The present project has required ten approvals from 5 different state and local governmental agencies.

Plans for Next Reporting Period

The primary effort during the next three months will be the fabrication and construction of the solar collector, solar heating and cooling system, and the laboratory building. It is expected that the solar system will be operational in April, and that the laboratory will be completed in May.

Figure 5

The control equipment, and measuring instrumentation should be installed and operational along with the solar systems.

Testing will commence after the solar systems are operational and checked out. It is expected that a limited amount of solar heating data will be obtained in April and May. Collection of solar cooling data will be initiated in June, or earlier.

Assessment of the Next Reporting Period

The primary concern in accomplishing the tasks set forth in the previous section is the uncertainty of the weather. Normal periods of highly inclement weather could produce construction delays of one to two weeks. These would be most crucial in the month of February. After the structure is effectively "closed-in", inclement weather will have considerably less effect.

While the effects of some delays may be reduced by accelerated efforts on other tasks, some loss of time would have to be expected.

SECTION I

Laboratory Design (Blueprints)

										REMARKS
1	7'-0" x 2'-0" x 1'-0"	B	SC	WOOD	1	3		TYP.		
2	7'-0" x 2'-0" x 1'-0"	B	SC	WOOD	4	4				
3	(2) 7'-0" x 1'-0" x 1'-0"	B	SC	G.B.	6	6				B-FOLD LOWERED
4	7'-0" x 5'-0" x 1'-0"	C	SC	WOOD	1	5		TYP.		
5	7'-0" x 5'-0" x 1'-0"	D	ALUM. STEEL		1	3		TYP.		STEEL SCREEN GATE
6	6'-0" x 3'-0" x 1'-0"	B	HC	WOOD	4	4				
7	(4) 6'-0" x 2'-0" x 1'-0"	C	WOOD	G.B.	6	6				B-FOLD LOWERED
8	6'-0" x 3'-0" x 1'-0"	B	HC	WOOD	4	4				
9	(4) 6'-0" x 2'-0" x 1'-0"	C	WOOD	G.B.	6	6				B-FOLD LOWERED
10	(4) 6'-0" x 2'-0" x 1'-0"	B	WOOD	WOOD	4	4				B-FOLD LOWERED
11	6'-0" x 2'-0" x 1'-0"	C	HC	WOOD	4	4				LOWERED
12	6'-0" x 2'-0" x 1'-0"	B	HC	WOOD	1	1				POCKET
13	(4) 6'-0" x 1'-0" x 1'-0"	C	WOOD	G.B.	6	6				B-FOLD LOWERED
14	6'-0" x 2'-0" x 1'-0"	B	HC	WOOD	4	4				
15	6'-0" x 5'-0" x 1'-0"	B	HC	WOOD	4	4				
16	6'-0" x 2'-0" x 1'-0"	B	HC	WOOD	4	4				
17	6'-0" x 2'-0" x 1'-0"	B	HC	WOOD	1	1				POCKET
18	(4) 6'-0" x 1'-0" x 1'-0"	C	WOOD	G.B.	6	6				B-FOLD LOWERED
19	7'-0" x 5'-0" x 1'-0"	B	SC	WOOD	4	4				
20	6'-0" x 5'-0" x 1'-0"	B	SC	WOOD	1	1		TYP.		
21	6'-0" x 5'-0" x 1'-0"	B	SC	WOOD	4	4				
22	7'-0" x 10'-0"	B	WATER TIGHT	WOOD	4	1				
23	(4) 6'-0" x 1'-0" x 1'-0"	C	WOOD	G.B.	6	6				B-FOLD LOWERED
24	6'-0" x 2'-0" x 1'-0"	F	WOOD	WOOD	4	4				LOWERED
25	6'-0" x 5'-0" x 1'-0"	F	WOOD	WOOD	4	4				TELL CLAD OR 44A

100	ENTRY	WOOD CASP	VB.	GB	P	GB	P	GB	P	GB	P	WNG
101	CLOSET	WOOD CASP										8"0
102	LIVING RM	WOOD CASP	VB									WNG
103	DINING	WOOD CASP	VB									WNG
104	KITCHEN	WOOD CASP				GB	P	GB	P	GB	P	7"0
105	BEDROOM	WOOD CASP	VB.			GB	P	GB	P			8"0
106	CLOSET	WOOD CASP										8"0
107	BEDROOM	WOOD CASP	VB.									8"0
108	CLOSET	WOOD CASP										8"0
109	CLOSET	WOOD CASP										8"0
110	VANITY	WOOD CASP	VB.									8"0
111	BATH	WOOD S.V.	FD.									8"0
112	CLOSET	WOOD CASP										8"0
113	HALL	WOOD CASP	VB.									8"0
114	DBN	WOOD CASP	VB.									8"0
115	VANITY	WOOD CASP	VB									7"0
116	BATH	WOOD S.V.	FD.									7"0
117	CLOSET	WOOD CASP										8"0
118	UTILITY	WOOD S.V.	FD.									8"6
119	GARAGE	CONC H.C.										8"0
120	CLOSET	WOOD CASP										8"0
121	STAIRS	WOOD CASP										WNG
122	STAIRS	WOOD CASP				GB	P					WNG
123	LANDING	CONC CASP				GB	P					9"0
124	BASEMENT	CONC H.C.		CONC	CONC	CONC	CONC	CONC				9"0

MB - VPOO EAST P - DINT

TYPE 'F'

A-TELLA CLAD BUILDING
GLASS FRONT

B-FLYH, STAINED
WOOD ROOF

C - LOUVERED DOOR

D-STORM SCREED
BOOK

4 E-MASONITE GARAGE DOOR

845
42-21-73
CRM

PROJECT N: 1966

GENERAL STRUCTURAL NOTES:

1. CONCRETE SHALL BE IN ACCORDANCE WITH ACI 318-71. MINIMUM COMP. STRENGTH IN 28 DAYS SHALL BE 3000 PSI.
2. REINFORCING SHALL BE IN ACCORDANCE WITH ASTM A615. GRAB OR PROVIDE CORNER BARS TO MATCH ALL HORIZONTAL REBAR. PROVIDE MIN. 2# ALL SIDES OF OPENINGS IN WALLS. EXTEND BARS 2'-0" AT EDGES OF OPENINGS.
3. STEEL JOIST SHALL BE IN ACCORDANCE WITH A.I.S.C. SPECIFICATION & CODE OF STANDARD PRACTICE. USE A36 STEEL A-307 BOLTS.
4. WOOD JOISTS SHALL BE GRADE NO. 2 DOUGLAS FIR - LATCH WITH AN ALLOWABLE BENDING STRESS (FBI) OF 1250 PSI. (SINGLE MEMBER USE). USE 1/4" BRIDGING BETWEEN JOISTS AT 8'-0" O.C. MAX. PROVIDE SOLID BACKING BETWEEN JOISTS AT BEARING. PROVIDE DOUBLE JOIST UNDER ETLD WALLS.
5. LIVE LOADS USED IN DESIGN:
ROOF (SNOW) - 20 PSF (EXCEPT 15 PSF ON STEEP ROOF)
FLOORS - 40 PSF
SOLAR ENERGY EQUIPMENT ON ROOF - 25 PSF.

1/2" FOR ALL INTERIOR WALLS ON SLAB ON GRADE - AS REQUIRED TO BASEMENT

PROJECT - MCC

DATE 12-21-75
BY GUM
RD.

3

EAST ELEVATION

SOUTH ELEVATION

PROJECT NO. 1966

045
12-21-75
CHM
JLM, RD

045
12-21-75
0124
Hix, R.D.

9

PROJECT NO. 1160

6-10
12-11-75
JRB
ED

2

1 ELEV. VANITY II & BATH III
5'-0" x 10'-0"

2 ELEV. VANITY II & BATH III
5'-0" x 10'-0"

3 ELEV. BATH III
5'-0" x 10'-0"

4 ELEV. KITCHEN
8'-0" x 10'-0"

5 ELEV. KITCHEN
8'-0" x 10'-0"

6 ELEV. KITCHEN
8'-0" x 10'-0"

7 ELEV. KITCHEN
8'-0" x 10'-0"

8 COLLECTOR BOTTOM CONNECTION
1'-0" x 1'-0"

9 COLLECTOR TOP CONNECTION
1'-0" x 1'-0"

10 COLLECTOR SIDE CONNECTION
1'-0" x 1'-0"

11 BENCH DETAIL
6'-0" x 1'-0"

12 HANDRAIL/WALL CONNECTION
6'-0" x 1'-0"

13 WALL SECTION
3'-0" x 1'-0"

14 WALL SECTION
3'-0" x 1'-0"

15 WALL SECTION
3'-0" x 1'-0"

16

17

DRILLED PIER SCHEDULE			
Pier No.	Ø	Elevation Top of Pier	Required Penetration
1	12"	95'-0"	6'-0"
2	12"	95'-0"	
3	12"	95'-0"	
4	12"	95'-0"	
5	12"	95'-0"	
6	12"	95'-0"	
7	12"	95'-0"	
8	12"	95'-0"	
9	12"	89'-8"	
10	20"	89'-8"	
11	12"	89'-8"	
12	20"	89'-8"	
13	12"	89'-8"	
14	12"	89'-8"	
15	16"	89'-8"	
16	16"	89'-8"	
17	12"	89'-4"	
18	12"	89'-4"	
19	12"	89'-4"	
20	20"	89'-4"	
21	12"	87'-0"	
22	12"	87'-0"	
23	20"	87'-0"	
24	12"	87'-0"	
25	12"	87'-0"	
26	12"	87'-0"	
27	12"	87'-0"	
28	16"	87'-0"	
29	16"	89'-8"	
30	16"	89'-8"	
31	12"	91'-10"	
32	12"	95'-0"	
33	12"	95'-0"	
34	10"	93'-10"	
35	10"	93'-10"	
36	10"	93'-10"	
37	10"	93'-10"	

* Penetration into Firm Bedrock

GENERAL NOTES AND SPECIFICATIONS

SOILS

- Foundation design based on "Report of a Soils and Foundation Investigation", Project No. 1563-73, prepared by Empire Laboratories, Inc., Fort Collins, Colorado.
- Allowable soil pressures used in design:
 - Maximum End Bearing = 30 KSF
 - Minimum End Bearing = 15 KSF
 - Maximum Skin Friction = 3 KSF (in firm bedrock)
- Basement floor slabs shall be placed directly on the subgrade which has been scarified a minimum of 12 inches in depth; thoroughly mixed with 6 pounds of hydrated lime per square foot; wetted to 2% wet of optimum moisture and compacted to 90% of Standard Proctor Density (ASTM D698-70).
- Basement subgrade treatment as specified above shall be performed prior to drilling any piers.
- Fill material supporting the garage and utility room floor slabs shall be an approved, imported, non-expansive cohesive soil compacted at optimum moisture to 90% of Standard Proctor Density (ASTM D698-70). These floor slabs shall be placed directly on the compacted fill. Prior to placing the fill, the upper 6 inches of the topsoil shall be removed and the subgrade shall be scarified a minimum depth of 8 inches, wetted to 2% wet of optimum moisture, and compacted to 90% of Standard Proctor Density (ASTM D698-70).
- Backfill around the structure (both inside and outside) shall be an approved, imported, non-expansive cohesive soil compacted at optimum moisture to 90% of Standard Proctor Density (ASTM D698-70).
- Moisture contents of the sub-slab material shall be taken prior to concrete placement. In areas where the moisture contents are below optimum moisture, the sub-slab material shall be thoroughly prewetted.
- Compliance with all compaction requirements and moisture content requirements as specified above shall be verified in the field with density and moisture tests performed under the supervision of an experienced soils engineer.
- All piers shall be located as shown on the plans; drilled to the diameter and depth shown on the plans, and poured to the elevations shown on the plans.
- All piers shall be drilled plumb and shall be thoroughly cleaned prior to concrete placement.
- Concrete shall be placed in the drill holes immediately upon completion of the drilling and cleaning of the hole.
- Continuous inspection by an experienced soils engineer shall be made during the pier drilling operations to: (1) identify the bedrock stratum, (2) make certain the required penetration into the firm bedrock is obtained, and (3) make sure that the holes are thoroughly cleaned prior to concrete placement.
- The spoils from pier drilling shall be removed from the site and shall not be used as fill under floor slabs or as a backfill material.
- All piers shall be reinforced their full length with two #5 bars.
- The finished grade shall be sloped away from the structure on all sides at a minimum slope of 10% for the first 10 feet away from the structure, except in those areas that are to be paved.
- All non-bearing partitions placed on slabs on grade shall have a slip joint either top or bottom.
- All bearing members shall be isolated from slabs on grade with a 1/2" expansion joint.

CONCRETE

- All concrete shall be in accordance with ACI 301-72 "Specifications For Structural Concrete For Buildings."
- All cement used in the concrete shall conform to ASTM C150 "Specifications for Portland Cement" and shall be Type II.
- All aggregates used in the concrete shall conform to ASTM C 33, "Specifications For Concrete Aggregates."
- All concrete shall contain a minimum of 5-1/2 sacks of cement per cubic yard and shall develop a minimum compressive strength of 3000 PSI in 28 days.
- All concrete shall be air-entrained and contain 5% ± 1% air.
- The slump of the concrete shall be 3" ± 1".
- The maximum size coarse aggregate shall not be more than one-fifth of the narrowest dimension between the sides of the forms, one-third of the depth of slabs, nor three-fourths of the minimum spacing between bars.
- All concrete shall be tested in accordance with ASTM procedures at least once during every pour.
- All grade beams and foundation walls spanning drilled piers shall have a 4-inch minimum void between the bottom of wall and the soil below.

REINFORCEMENT

- Reinforcing bars shall conform to ASTM A615-68, Grade 60 "Specifications for Deformed Billet Steel Bars for Concrete Reinforcement", and shall be free from dirt, grease, rust, scale, etc., and shall be tied in accordance with A. C. I.
- All lap splices shall be a minimum of 36 bar diameters and all bars shall be continuous around corners.
- All reinforcing shall have a minimum cover of 1-1/2".
- All walls, beams and slabs shall be reinforced as shown and detailed on the plans.
- All welded wire fabric used to reinforce floor slabs shall conform to ASTM A 185, "Specifications for Welded Steel Wire Fabric For Concrete Reinforcement."
- The reinforcing steel placement shall be inspected and verified to be in accordance with the plans prior to concrete placement.
- All dimensions on the foundation plan shall be checked against architectural plans.

STATE PROJECT NO. 1966

FOUNDATION PLAN
SOLAR ENERGY HOUSE
COLORADO STATE UNIVERSITY

EMPIRE LABORATORIES, INC.
214 N. HUNTER ST. Ft. Collins, Colorado

DESIGNED BY P. L. H.	CHECKED BY S. J. H.	DATE 5-14-78	REVISION 1. ADD PIER 35-1311 CHY. DUNE ON PIER 11-21 (12-20-78)
APPROVED BY G. H. S.			

9

ELEVATION of PIER #28

(See Plan for Location)

Scale: 1" = 1'

(Stepping of bottom of footing also occurs at Pier #27)

SECTION C-C

Scale: 1" = 1'

SECTION B-B

Scale: 1" = 1'

SECTION A-A

Scale: 1" = 1'

SECTION D-D

Scale: 1" = 1'

SECTION E-E

Scale: 1" = 1'

STATE PROJECT NO. 1966		
FOUNDATION DETAILS		
SOLAR ENERGY HOUSE		
COLORADO STATE UNIVERSITY		
EMPIRE LABORATORIES, INC.		
215 E. HARRIS ST. FT. COLLINS, CO. 80501		
DESIGNED BY P.L.B.	DATE 12-8-73	REVISION
DRAWN BY J.H.B.	SCALE As Noted	
CHECKED BY C.C.E.		

10

DUCTWORK PLAN
1/4\"/>

NOTES:

1. RETURN AIR TO HVAC UNIT IS VIA STAIRS INTO BASEMENT.
2. FLOOR REGISTERS ARE LIMA SERIES P-93
3. WALL REGISTERS ARE LIMA SERIES 10

DESIGNED BY: [Signature]
 DRAWN BY: [Signature]
 CHECKED BY: [Signature]
 DATE: 11/12/79

NO. 245
 ALL RIGHTS RESERVED
 MADE IN U.S.A.
 120

120

[illegible]

NO. 045
 DATE 12 21 70
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CSU SOLAR
HOUSE

SECTION II

DESIGN ELEMENTS

Introduction

On September 1, 1973, the Solar Energy Applications Laboratory of Colorado State University commenced work on a National Science Foundation grant to design, construct, and test a residential solar heating and cooling system. This report contains the design requirements, methodology, and results, as well as the plans for construction and testing.

The laboratory building, shown in Figure 1 and in Section I, contains 1580 sq. ft. (147 m^2) of floor space on the main floor and a nearly equal area in the basement. The actual heating/cooling space comprises 3,023 sq. ft. (281 m^2)

System Design

The complete heating and cooling system has been designed as shown in Figure 2. This design includes four alternate modes of operation. Variations of these are shown in some detail in Section III.

Certain aspects of the design were evolved from the experimental nature of the present project. For example, the service hot water preheat tank is separated from the heat storage tank, to allow flexibility for experimentation.

Cooling - The only commercially available cooling device suitable for solar operation is an absorption refrigeration unit. For the CSU solar laboratory, the choice is an ARKLA three ton, LiBr, absorption cooling unit, modified to utilize hot water (instead of natural gas) as heat supply to the generator.

A schematic of the air conditioner is shown in figure 3. The generator in a gas-fired ARKLA machine was modified to operate with hot water entering

Figure 1. Perspective drawing of Solar Energy Applications Laboratory Building to be constructed on the Foothills Campus of Colorado State University near Fort Collins, Colorado. This will be the world's first solar heated and cooled building.

Figure 2

Figure 2. Schematic Flow Diagram of Arkla-Serve Model 501 Hot-Water-Heated Air Conditioning Unit.

the generator from the bottom. With cooling water at 75°F, a hot water supply of 11 gpm at 202°F will provide full 3-ton capacity. At lower hot water temperatures, cooling capacity is lower, reaching the level of half output of about 180° to 185°F. Performance testing now in progress may alter these preliminary estimates.

As the air cooling capacity of the unit decreases (due to lower generator temperatures), dehumidification performance also declines.

Figure 4

Operating at full capacity, the refrigerant finishes vaporizing at point C, (Figure 4), thereby cooling the entire evaporator surface on which moisture condenses. At 60% cooling capacity, the refrigerant finishes vaporization at point B, and the condensate will now cover only the upper 60% of the finned area. Air temperature reduction will be about 60% of the full capacity reduction, but about ten percent of the condensate formed on the upper portion of the finned area will re-evaporate as it flows down over the lower, uncooled area. The net result is an air cooling capacity of 60% and a dehumidification capacity of about 50%.

In order that heat supply temperatures slightly lower than standard can be employed, the concentration of the LiBr solution will be reduced to 51 to 54%, from the customary 54 - 57% concentration. Temperature - concentration diagrams show that crystallization cannot occur in the absorber or in the generator provided that operation is maintained above the 50 percent capacity level. The unit has been modified by the installing of a diverter valve for the absorber which is actuated by low temperature cooling water. The valve will divert approximately 50% of the cooling water flow, when in operation, (at temperatures $< 65^{\circ}\text{F}$). Still lower temperatures will activate a shut-off switch on the pump.

These modifications permit advantage to be taken of prevailing cooling water temperatures and consequently, allow the use of lower generator temperatures (approximately 180°F - 202°F). The location of the CSU solar house at 5,200 ft. elevation, puts an upper limit of 203°F on hot water temperature (local boiling point), if a non-pressurized system is to be used. The unit will operate satisfactorily if boiling water is entering the generator, as the vapor will simply condense.

With a central forced air system, and hot water as the solar heat transport fluid, the following design conditions have been established. For cooling, hot water temperatures must be in the 180° to 202°F range (82°C - 95°C). For heating the hot water is circulated at temperatures from 80°F to 202°F , (26°C - 95°C), with a design point of 140°F (60°C).

auxiliary - A standard hot water boiler has the advantages of simple interfacing with the rest of the solar system, and ready commercial availability. The size of the unit is determined in a normal fashion by the maximum heating/cooling demands of the building. The temperature of the hot water in the boiler will be maintained at 202°F (95°C) for use in the absorption cooling unit. This temperature will be maintained for auxiliary heating as well.

The manner in which auxiliary heat is supplied affects overall system performance and cost. The auxiliary may be used to boost the temperature of the hot water coming from the heat storage subsystem, if its temperature does not meet heating and cooling requirements, or the auxiliary may be used exclusively when storage temperatures are too low to be useful. A third method involves using stored solar heat and auxiliary heat simultaneously, in independent water-to-air heat exchangers.

A fault in the first method can be shown by examining the system when used for cooling. If the storage temperature is 180°F the auxiliary could be used to raise the temperature of the water to 200°F , a 20°F boost. But the water temperature drop through the generator is only 10 or 15°F . Hence, storage water at 180°F would be heated to 200°F and returned to storage at 185°F , thereby using some of the storage space for fuel energy. Collector efficiency and useful solar storage would both be reduced by this procedure. The same situation would be encountered in the heating mode, so this manner of using storage has not been adopted. Normal operations will utilize the auxiliary's direct heating. A flexible system design will allow experimentation in the third method as shown in Figure 5.

Figure 5

In this arrangement, the auxiliary boosts the air temperature in the duct. This has the advantage, in the heating application, that storage temperatures of only 75 - 100°F could be effectively utilized; the auxiliary being used only when higher demands are encountered. The disadvantage of this method is the cost of the additional heating coil, and additional pump.

Heat Storage - The simplest method in a solar hot water system is the use of a large hot water container for thermal storage. The size of the unit to provide heat storage capability overnight has been determined to be approximately 1.5 gallons per sq. ft. (61.1 l/m^2). For the CSU solar house, this corresponds to about 1200 gallons (4543 l). While this may seem excessively large, a cylindrical tank of this capacity has dimensions of only 6 ft (1.83 m) high and 5 1/2 ft (1.68 m) in diameter. The common generalization of a massive storage tank is thus not vindicated.

Service Hot Water - In the design of the solar system to provide service hot water, the use of the hot water storage tank as a direct source of domestic hot water was decided against. One reason is that the system is not pressurized, as is the service hot water system, and while the heat storage system could be pressurized, this involves considerable cost. Secondly, when the heat storage temperature is low, it would be extremely costly to heat the entire storage volume to a high enough temperature to meet comfort standards. It was decided to utilize a separate hot water tank.

The actual system design provides a preheat capability of the service hot water, and does not attempt to recycle the water in the hot water tank when its temperature falls below the selected value. The advantage of the preheat method is lower cost and a simpler control system. If the storage volume is likely to contain any anti-freeze or corrosion

inhibitors, the possibility of contamination of the water supply in this design is a consideration (although the greater pressure of the domestic hot water subsystem would work to your advantage). The size and shape of the hot water preheat tank would probably require twice the capacity of the domestic hot water tank, and sufficient exterior surface area to provide reasonable heat transfer.

Solar Collector - The determination of the solar collector design factors (collector slope from the horizontal, total area of the collector, number and composition of materials for the transparent covers) was accomplished by the use of a University of Wisconsin computer program, which evaluated these collector variables on the percentage load carried by the auxiliary fuel source. Since the effect of a solar system is to save on fuel only (and not eliminate any of the normal costs of a conventional heating and cooling system), this provides an excellent gauge of the solar collector characteristics.

Table 1 gives some sample output. From this data we see that the higher angle (53°) is closer to optimum for heating, the lower angle (37°) is closer to optimum for cooling, and the compromise angle (45°) is better for the combination (Fort Collins is at a latitude of approximately 41°). From this it was decided to face the solar collector toward the south at a 45° angle.

To determine an optimum collector area, we would require additional information (e.g., fuel costs), and then compare additional costs of the larger solar collector against the fuel savings. However, for this experimental unit it was determined that the collector should provide for a substantial portion of the heating and cooling load. The actual area of the collector was designed at 768 ft^2 , to provide approximately

Table 1

Area	Slope (from horizontal)	Auxiliary Energy Supplied to:			Total Load		% Load Carried by Auxiliary		Overall
		Hot Water (*)	Space Heat (*)	Space Cool (*)	Heat (*)	Cool (*)	Heat (%)	Cool (%)	
650	53°	2.034	6.387	4.532	35.634	12.518	23.6	36.2	26.9
650	37°	2.607	7.689	2.156	35.616	13.215	28.9	16.3	25.5
800	53°	1.512	4.550	3.002	35.796	13.516	16.9	22.2	18.4
800	37°	1.951	5.614	1.188	35.931	14.152	21.1	8.4	17.5
800	45°	1.611	4.829	1.749	35.124	13.843	18.3	12.6	16.7

*(x 10⁶ Btu) Numbers based on the first 14 days of 9 months.

3/4th of the heating and cooling loads, and to allow for flexibility in future solar collector testing by using the (16' x 48') dimensions of the total collector area.

Each solar collector panel is 3 ft. x 16 ft (0.914 m x 4.88 m). The 16 panels are connected in parallel with manifolds at the bottom and top of the collector area. The basic principle followed in the manifolding is that of a "diagonal crossing" see figure 6.

Figure 6

This design provides uniform channel lengths and best flow distribution through the collector.

The collector panels are designed so that the water-ethylene glycol mixture (the heat transport fluid) will run from the bottom of the collector to the top through each panel on a "one-pass" basis. This will provide a temperature rise of approximately 15°F (8°C) across each panel at a flow rate of 16 gpm when solar intensity is about 300 Btu/hr ft² and collection efficiency is about 40 percent.

Absorber Plate - The absorber plate chosen was of the tube-in-sheet design. One advantage of this type of absorber panel is that there are no solder joints of any kind connecting the absorber plate to the tubes; the tubes are actually formed out of the panel, and consist of continuous aluminum. Thus the heat transfer from the absorber plate to the heat transport fluid is maximized. A variety of metals can be used, but on a national scale, the cost and availability of aluminum over, e.g. copper, make aluminum more practical.

The second advantage of the tube-in-sheet aluminum panel is the versatility in the tube pattern design. Any tube pattern can be utilized depending on the requirements of the heat transport fluid flow; and this, with virtually no increase in cost. Thirdly, such panels are readily available at quite reasonable costs (approximately \$.75/ft²).

The actual tube pattern (Figure 7) is based on two concerns: Rate of flow and drainage. The latter simply allows for the flexibility to drain the solar collector during non-daylight hours. This would help alleviate any freezing problems, and in addition would prevent the heat loss from the water in the collector during nighttime.

The absorber panel will be painted with a good, flat black, high absorptivity paint.

The use of aluminum in the solar energy collector will require that certain precautions be taken to avoid possible corrosion problems or corrosion failures. The coolant which circulates through the system will be a water-ethylene glycol mixture with the ethylene glycol containing various inhibitors and buffers intended to make it compatible with the multi-metal system.

Figure 7

Section A-A

Section B-B

It is recognized that ethylene glycol degrades in service and that organic acids are among the degradation products. Since a significant reduction in pH would make the mixture more corrosive, buffers are used to control pH. Additionally the pH value will be closely monitored.

Transparent Panes - Numerous possibilities for the transparent panes were considered, including, glass, fiberglass reinforced polyester (FRP), acrylics, polycarbonates, and various films (TEDLAR, ACLAR, MYLAR, NYLON, TEFLON, etc). However, in view of the uncertainties in the durability, transmission qualities, etc., a somewhat conservative approach was taken and a decision to use glass on all surfaces was made. In this way we will assume known liabilities in lieu of uncertain advantages.

The University of Wisconsin Program was then again utilized to determine the actual number of transparent, glass panes. Table two gives a portion of the computer output, comparing two glass panes versus three glass panes in the solar collector. Values of U_L (coefficient of transmission,) for three covers of 0.5, and for two covers of 0.75 were assumed. QXM is the space heating/cooling heat energy supplied by the auxiliary heating unit.

Table 2

	JAN	FEB	JULY	AUGUST
QXM (2 covers)	4.531	0.788	2.485	2.655
QXM (3 covers)	4.165	0.550	1.656	1.754

(all numbers given in units of 10^6 Btu (1.055×10^9 joules))

Over the entire year the amount of energy supplied by the auxiliary for two covers is only about 3×10^6 Btu (3.17×10^9 joules) greater than that required for three covers. This amount of energy, at present fuel prices, amounts to only about \$10; whereas the cost of the third

glazing would be of the order of \$300 (for 800 ft² of collector). It was determined that from an economic viewpoint, in order to obtain a specified heat supply it was preferable to enlarge the size of the collector rather than add the third glazing.

SECTION III

Modes of Operation

A. Mode 1 - Collector to storage via heat exchanger (see Figure 1).

1. Pumps P4 and P3 come on when collector exit temperature exceeds bottom of storage by preset amount, e.g., 20°F. They shut off when temperature difference falls below lower preset amount, e.g., 10°F.
2. Let 70° be median temperature of house interior (adjustable).
 - a) When thermostat reaches 68°F↓ - Pump P1 comes on, valve V1 allows flow in heating mode. Valve V2 directs return flow to water storage tank (providing temperature in top of water storage tank is > (e.g.) 100°F, otherwise directs to auxiliary heater). Air duct fan comes on (See Figure 2).

Note: Airduct fan will have an override to allow continuous ventilation. The air blower provided in the ARKLA unit will be used for heating as well as cooling. The blower could be actuated with P1 as their service is concurrent.

- b) When temperature reaches 66°F↓, Valve V2 changes to direct flow to auxiliary heater.
- c) When temperature reaches 67°F↓ and temperature of water in top of storage tank is > 100°F, Valve V2 changes to direct flow to water storage tank. If storage top < 100°F, nothing changes.
- d) When temperature reaches 69°F↓, Pump 1 shuts off. Airduct fan shuts off.
- e) When temperature reaches 72°F↓, Valve V1 directs flow to cooling mode, Valve V2 directs flow to water storage tank, and pump P1 comes on. See Figure 3. This is true if the temperature in the top of the water storage tank is > 185°F; otherwise Valve V2 directs flow to auxiliary heater. Airduct fan, cooling tower pump P5, and cooling tower fan come on.
- f) When temperature reaches 74°F↓, Valve V2 directs flow to auxiliary boiler.
- g) When temperature reaches 73°F↓, and temperature in top of water storage tank is > 185°F, then Valve V2 directs flow to water storage tank. If storage top < 185°F, nothing changes.
- h) When temperature reaches 71°F↓, Pump P1 shuts off, airduct fan, cooling tower pump P5, and cooling tower fan shut off.

SOLAR ENERGY HOUSE

Heating - Air Conditioning - Hot Water Equipment

Figure 1

SOLAR ENERGY HOUSE

Heating - Air Conditioning - Hot Water Equipment

Figure 2

Figure 3

Note: Cooling pump P5 receives power from the ARKLA unit. The cooling tower fan would require that pump P5 be running and the temperature of the cooling water exceed 75°F. The cooling tower pump and fan controls will be supplied by ARKLA and the cooling tower vendor. In all modes of cooling the ARKLA unit will have a 24v (or 110v) signal to pump P1 to shut it off if the ARKLA unit shuts down for any reason.

Note: Low temperature (< 180°) water to the generator (but not shut off) is a damaging condition to the unit. This low temperature condition would not occur under our control scheme unless the auxiliary boiler were down, i.e., the gas pilot was out. This will require a low limit aquastat in the boiler or boiler circuit to shut down P1 and the blower. Thus we need an "AND" signal to the P1 and blower relay (or two relays).

Note: The auxiliary boiler will be set at 200°F (heating) and 200°F (cooling).

B. Mode 2 - Collector to storage, direct. See Figure 4.

1. Pump P4 comes on when temperature of collector exceeds temperature of water storage tank bottom by preset amount, e.g., 10°F. Pump shuts off when temperature difference falls below lower preset amount, e.g. 5°F.

2. Same as A-2.

C. Mode 3 - Collector to cooling unit-direct. See Figure 5.

System would be operated in mode 3 in summer and in mode 2 or mode 1 in winter.

1. Same as A-2, (steps e,f,g,h) except that water storage tank temperature is replaced by collector temperature, and storage tank is replaced by collector. A-1 and A-2 a,b,c are inoperative.

In block form this becomes for modes 1, 2, and 3:

Thermostat Condition	V1	V2	P1
68°F↓	Position 1	Position 3*	on
66°F↓	Position 1	Position 4	on
67°F↑	Position 1	Position 3*	on
69°F↑	--	--	off
72°F↑	Position 2	Position 3**	on
74°F↑	Position 2	Position 4	on
73°F↓	Position 2	Position 3**	on
71°F↓	--	--	off

Continued on next page.

Figure 4

Figure 5

- Position 1 directs flow to heating mode
 Position 2 directs flow to cooling mode
 Position 3 directs flow to water storage tank (collector)
 Position 4 directs flow to auxiliary heater
 * Providing temperature of water storage tank top exceeds 100°F,
 otherwise goes to position 4.
 **Providing temperature of water storage tank top exceeds 185°F,
 otherwise goes to position 4.

Note: All switching of modes would be done manually.

D. Alternate Mode, See Figure 6.

For all modes (1,2, and 3):

- When temperature reaches 68°F↑, Valve V1 directs flow to solar heating coils, Valve V2 directs flow to water storage tank (or collector) providing temperature of water in top of storage tank (or collector) is >75°F. Pump P1 is turned on. Air fan is turned on.
- When temperature reaches 66°F↑, Valve V3 directs flow to auxiliary heating coil, and pump P7 comes on.
- When temperature reaches 67°F↑, and providing temperature in top of water storage tank (or collector) is > 75°F, Pump P7 goes off. If storage tank top is < 75°F, Pump P7 stays on.
- When temperature reaches 69°F↑, Pump P1 goes off. Air fan shuts off. If P7 has been running, it shuts off.
- When temperature reaches 72°F, Valve V3 directs flow to cooling mode; all other conditions (A-2; e.) f.) g.) and h.) remain the same.

In summary, for the alternate mode (heating only):

Thermostat condition	Temp. of water storage tank top	V1	V2	V3	P1	P7
68°F↑	≥ 75°F	Pos. 1	Pos. 3	--	on	off
68°F↓	< 75°F	--	--	Pos. 1	off	on
66°F↓	≥ 75°F	Pos. 1	Pos. 3	Pos. 1	on	on
66°F↑	< 75°F	--	--	Pos. 1	off	on
67°F↑	≥ 75°F	Pos. 1	Pos. 3	--	on	off
67°F↓	< 75°F	--	--	Pos. 1	off	on
69°F↑	--	--	--	--	off	off
72°F↑	--	Pos. 2	Pos. 3**	Pos. 2	on	off
74°F↑	--	Pos. 2	Pos. 4	Pos. 2	on	off
73°F↓	--	Pos. 2	Pos. 3**	Pos. 2	on	off
71°F↓	--	--	--	--	off	off

Continued on next page.

SOLAR ENERGY HOUSE Heating - Air Conditioning - Hot Water Equipment

Figure 6

**Providing temperature of water storage tank top exceeds 185°F (otherwise goes to position 4)

Position 1 directs flow to heating coils.
 Position 2 directs flow to cooling coils.
 Position 3 directs flow to water storage tank.
 Position 4 directs flow to auxiliary heater.

Note: In the alternate mode the auxiliary may act as a booster, but within the air duct. It may be that we can utilize relatively low temperatures from the collector (75-100°F) for heating purposes.

Note: In general we do not expect to use the auxiliary heater as a booster. If the solar portion cannot carry the load, the auxiliary assumes the complete load. This is always true of the cooling. It is also true of heating modes 1, 2, and 3.

Note: The three valves V1, V2, and V3 will be required to pass 11 GPM. We have designed for, and hope to have, 2 psi or less drop through these valves. This would be for water at a minimum of 75°F with a maximum viscosity of 1.0 centipoise.

E. Hot water system (same for all modes), see Figure 7.

1. Pumps P2 & P6 come on when two conditions are met:

- a) Temperature in bottom of hot water preheat tank drops below specified value, e.g., 130°F, and
- b) Temperature in top of water storage tank exceeds temperature in bottom of hot water preheat tank by, e.g., 20°F.

Pumps P2 and P6 operate concurrently to preheat domestic hot water. When the storage exceeds the preheat tank temperature by about 20°F the pumps would run until this differential reaches 10°F or the preheat tank temperature reaches a high limit. The 10° differential dead band is to prevent cycling. The requirement then is for differential and high limit aquastat control.

Incoming cold water is expected to be about 40°F year round. This means that temperatures down to 50°F in the 1,000 gallon solar heat storage tank could be effectively used to reduce hot water heating energy requirements. It should be pointed out that in a routine installation (as opposed to this experimental installation), pumps P2 and P6 as well as the hot water heat exchanger would not be necessary, and the 80 gallon hot water preheat tank would be in the 1,000 gallon solar heat storage tank, so that storage tank temperatures down to incoming water temperatures could be used. Having the 80 gallon hot water preheat tank outside the 1,000 gallon solar heat storage permits easy access and isolation.

Figure 7

SECTION IV

Testing and Measuring Instrumentation

The data acquisition system consists of five components: the measurement sensors, signal conditioning interfaces, a multi-channel digital data logger, a magnetic tape coupler, and a magnetic tape recorder.

All parameters such as, temperature, flow rates, meteorological data and on-off function indicators which relate to the system performance will be recorded in five minute intervals. Attachment I is a tabulation of the measurement points with a diagram showing their locations in the system. The solar input (radiometers), natural gas flow, and electrical power signals will be integrated to supply a totalized measurement of these parameters each five minutes*.

The data logging system receives the measurement signals in analog (millivolt) form. A zero point reference and linearization is provided for the thermocouple inputs. The thermocouple channels are also scaled to read directly in °C. The signals are converted to digital data where they are displayed, scanned and placed on magnetic tape (for computer processing) and on paper tape (for immediate observation).* A more detailed description of the data logging system is provided in the specifications (attachment 2).

*the system is capable of 2 scans per minute if such speed should prove necessary.

From five competitive bids submitted for the data logging system the lowest bid for the system meeting the design requirements was selected. A Doric Scientific Corporation System will be purchased with the options described in attachment 3.

Data stored on 1/2 inch magnetic tape, will be available for processing by the CSU CDC 6400 at any future time.

MEASUREMENT SENSORS ATTACHMENT I

A. Copper-constantan thermocouples	Sensor Number
1. System	
Collectors in	1
Collectors out (manually switched into one channel)	2-1 to 2-16
Collector Heat Exchanger	
hot in/out	3/4
cold in/out	5/6
Storage tank	7-8-9
top-mid-bottom	
Storage out	10
Storage return	11
Auxiliary out	12
Auxiliary return	13
Duct air in-out	14-15
Cooling water in-out	16-17
Flu gas	
Auxiliary	18
HW heater	19
Hot water heat exchanger	
Hot in-out	20-21
Cold in-out	22-23
Arkla Unit	24-25
2. Climatic	
Dry bulb	26
Wet Bulb (Cambridge Hygrometer)	27
3. House	
Dry bulb	28
Wet Bulb (Cambridge Hygrometer)	29
B. Flow Measurement	
Collector flow	30
Flow from storage	31
Service hot water flow	32
Natural gas	
Auxiliary	33
Hot water heater	34
Wind speed	35
C. On-Off Function Indicators	
Collector pumps P3 & P4	36
Water heater pumps (P2 & P6)	37
Water heater gas valve	38

Auxiliary gas valve	39
Pump P1 & blower	40
Cooling water pump	41
Hygrometer valve	42
Automatic valves V1,V2, & V3	43-45
D. Radiometers (2)	46-47
E. Electrical Power (on solar equipment circuits only)	48

SOLAR ENERGY HOUSE

Heating - Air Conditioning - Hot Water Equipment

Measurement Points:

x Temperature

() Flow

0 1 2 3 4
Scale - Feet

DIGITAL DATA SYSTEM

1. GENERAL SPECIFICATION

- 1.1 The following is a specification for a digital data system for the residential solar heating and cooling system at Colorado State University:
- 1.2 The system shall have the following main components:
 - 1.2.1 Multiplexer (with appropriate signal conditioning).
 - 1.2.2 A-D convector (with linearizing and scaling).
 - 1.2.3 Display and control panel.
 - 1.2.4 Real time clock.
 - 1.2.5 Printer
 - 1.2.6 Tape recorder interface.
- 1.3 For ease of maintenance and trouble shooting, the system shall be of modular construction using solid state circuitry utilizing DTL and TTL logic circuitry (self test voltage desirable).
- 1.4 The quantity of units shall be one (1) system.
- 1.5 Delivery time shall be specified. Any delivery times in excess of 90 days after receiving order or 60 days after receiving tape recorder shall be unacceptable. If the specified delivery date is not met the contract may be cancelled at no cost to purchaser.

2. SPECIFICS

- 2.1 Input to Multiplexer:
 - 2.1.1 Thermocouple channels:

2. SPECIFICS

2.1.1.1 Quantity: 70

2.1.1.2 Type: T (copper-constantan).

2.1.1.3 Reference: Built-in reference required, specify accuracy and type termination.

2.1.1.4 Range of reading: -30° to $+200^{\circ}\text{C}$ (-25° to 400°F)

2.1.1.5 Linearization: Linearization and scaling for Type T thermocouple to readout directly in $^{\circ}\text{C}$ ($^{\circ}\text{F}$).

2.1.1.6 Minimum resolution of data: $.5^{\circ}\text{C}$ (1°F).

2.1.2 Millivolt channels

2.1.2.1 Quantity: 30

2.1.2.2 Range: 0 to ± 100 MV, and 0 to ± 10 extendable to ± 20 MV.

2.1.2.3 Minimum resolution: 10 microvolt

2.1.2.4 Termination (mechanical): specify

2.1.3 Input characteristics

2.1.3.1 Input impedance: 10 megohm or greater.

2.1.3.2 Source impedance: Specify maximum tolerable without degrading system performance.

2.1.3.3 Type input: Differential floating.

2.1.3.4 Maximum input voltage without damage: specify

2.1.3.5 Maximum common mode voltage: specify

2.1.3.6 Common mode and normal mode rejection: specify

SPECIFICS

2.2 Multiplexer

- 2.2.1 Maximum system sampling rate: Specify (2 channels/sec. minimum acceptable).
- 2.2.2 Type of multiplexer: Describe
- 2.2.3 Expansion: Specify the maximum number of channels available.
- 2.2.4 Selectable sampling rate: If sampling rates selectable specify selection and means of selecting.

2.3 A-D Converter

- 2.3.1 Number of bits: Specify (12 bits minimum acceptable).
- 2.3.2 Accuracy: Specify
- 2.3.3 Digital form: Specify
- 2.3.4 Type: Specify technique used and if autozero unit available.

2.4 Real Time Clock

- 2.4.1 Units desired: Hours, minutes, seconds.
- 2.4.2 Type reference: Specify type and accuracy.
- 2.4.3 Display: Hours and minutes (at least) shall be displayed in a decimal display (or on a shared basis at the data display).
- 2.4.4 Resetting or correcting: Describe method for accomplishing this

2.5 Control Panel

2.5.1 Data Display

- 2.5.1.1 Number of digits: 4 (minimum)
- 2.5.1.2 Type of display: Specify

2. SPECIFICS

2.5.1.3 Display selection: Channel selectable by thumb-wheel switches.

2.5.2 Time shall be displayed on the control panel. (Either a dedicated display or by sharing the data display).

2.5.3 The following controls shall be located on the control panel.

2.5.3.1 Sampling rate selector (see 2.2.4).

2.5.3.2 Scan interval (specify selection).

2.5.3.3 Fixed data entry (desirable but not essential).

2.5.3.4 System operating controls and main power switch.

2.6 Printer

2.6.1 Number of columns: Specify

2.6.2 Digit arrangement: Describe

2.6.3 Speed: 2 lines/sec. minimum

2.6.4 The following items are to be printed.

2.6.4.1 Channel number

2.6.4.2 Data value (sign + digits)

2.6.4.3 Engineering units of data

2.6.4.4 Time of day for each scan (if applicable)

2.6.4.5 Fixed data (if available)

2.6.5 For set-up and monitoring purposes, the printer shall have the option of printing or being disabled.

2.7 Digital output

2.7.1 A BCD output of the data to interface to incremental magnetic tape recorder or mini-computer is required.

2.7.2 Form and levels: Specify

2. SPECIFICS

2.8 Tape Recorder Interface

2.8.1 The data shall be outputted on a digital magnetic tape recorder. The recorder shall be a seven track, 1/2 inch incremental type with write and erase heads. Packing density and writing speed shall be specified and shall be consistent with the maximum sampling rate. (Densities of 200 or 556 are acceptable).

2.8.2 The manufacturer, model number, and reel diameter of the suggested tape recorder shall be specified.

2.8.3 The system may be priced without the suggested tape recorder if considerable cost savings to the buyer could be realized by purchasing separately and drop shipping to the system manufacturer. The interface for the tape recorder should be included as part of the system regardless of which pricing alternative selected.

2.8.4 The following information shall be recorded on tape during system operation:

2.8.4.1 Fixed data may be entered automatically at the beginning of each record or entered manually on command. Specify which method used.

2.8.4.2 Time-of-day (corresponding to the time of scan) shall be written at the beginning of each scan (provision for future addition if optional real

SPECIFICS

- 2.8.4.3 Data written on tape (in BCD format) in sequence corresponding to channel scanning.
- 2.8.4.4 Necessary file marks and parity bits.
- 2.8.5 The system shall have the capability of inserting inter record gaps onto magnetic tape on command. Specify whether this will be accomplished at the data logger or at the tape recorder.
- 2.8.6 The tape format shall be compatible with the CDC-6400 computer at Colorado State University. All necessary parity bits, record gaps and file marks shall be provided.
- 2.8.7 The system shall be capable of operating normally without writing on tape for set-up and monitoring purposes.
- 2.8.8 The system shall operate on 105-125, 47-63 HZ, single phase power without any degradation of performance.
- 2.8.9 The system shall operate normally under the following environmental conditions:
 - 2.8.9.1 Temperature: 0°C to $+50^{\circ}\text{C}$ operating
 -30°C to $+60^{\circ}\text{C}$ storage
 - 2.8.9.2 Humidity: 0 - 100% RH (non-condensing)
 - 2.8.9.3 Altitude: 0 - 6000 ft operating
0 - 40,000 ft non-operating
- 2.9 Environmental Specifications
 - 2.9.1 Operating temperature range: 0°C to 50°C .
 - 2.9.2 System temperature drift: Specify in % full scale/ $^{\circ}\text{C}$
 - 2.9.3 Altitude: 0-6,000 feet

2. SPECIFICS

2.10 Power Requirements

2.10.1 Voltage: 105-125 volts single phase

2.10.2 Frequency: 47-63 HZ

2.10.3 Power Drain: Specify

3. WARRANTY

3.1 The system shall have a one (1) year warranty from date of delivery.

3.2 This warranty shall cover all defects in workmanship and material.

3.3 This warranty shall pertain to operating the system as specified in this document.

3.4 All expenses incurred shall be the responsibility of the manufacturer except the transportation cost to the manufacturer's place of business. Transportation return costs will be the manufacturer's responsibility.

4. ACCEPTANCE

4.1 The systems shall be accepted at Purchasers facility.

4.2 Acceptance tests will be conducted by representatives of the Solar Energy Applications Laboratory, at CSU.

Acceptance tests shall consist of satisfactorily demonstrating that the system will perform as defined.

4.3 The manufacturer has the option of sending a representative to the acceptance tests.

4.4 Within ten (10) days after delivery, the manufacturer will be notified of the system's failing the acceptance tests. At this time, the purchaser has the option to have the systems repaired at his facility or to return to the manufacturer. Either option shall be at no cost to the purchaser.

- 4.5 All payment will be withheld until completion of acceptance tests.

5. DRAWINGS, MAINTENANCE MANUALS AND INSTRUCTION MANUALS

- 5.1 The manufacturer shall furnish two (2) copies of the following for each system.

- 5.1.1 Detailed operating manuals

- 5.1.2 Detailed schematic and wiring diagrams of the actual electrical and electronic equipment furnished under this order.

- 5.1.3 Detailed maintenance manuals including trouble shooting procedure and periodic preventive maintenance.

- 5.1.4 Spare parts lists and price lists of items that may need replacement during the life of this equipment. This is to include name and address of the manufacturer, and the manufacturer's stock numbers.

- 5.1.5 Assembly drawings for mechanical components of the system.

6. DEVIATIONS AND EXCEPTIONS

- 6.1 Deviations from or exceptions to the specification shall not exclude potential bidders provided the general requirements of the system are not compromised and provided that all such deviations or exceptions are explained to the satisfaction of the representatives of the Solar Energy Applications Laboratory, at CSU.

- 6.2 Deviations from or exceptions to the specifications should either improve reliability or performance, or simplify the system with no sacrifice in performance.

Doric Scientific Corporation's DIGITREND System

Model, Digitrend 210-01-K2-T202-01-32-215A which includes:

<u>DESCRIPTION</u>	<u>MODEL/OPTION #</u>
Digitrend Multipoint Data Logger (100-point)	210-100
Group-function select	01
Coupler and incremental magnetic tape recorder	215A
Isolated BCD Outputs & Remote Signals	32

With Options

<u>DESCRIPTION</u>	<u>MODEL/OPTION</u>
High-Speed A/D Conversion	31
Time of day clock (Hours-Minutes)	213
or Time of day clock (Hrs.-Mins.- seconds)	214
Precision Self Test	04
Point Skip Pinboard	03
Extended Range	06

Research Utilization

Considerable effort has been and will continue to be expended to investigate and study user needs. Numerous talks, speeches, radio/TV announcements, and discussions at various symposiums have been presented toward educating the general user of solar heating and cooling, and in determining their responses. Typical of these activities include talks and discussions before: 1) the National Association of Home Builders Annual Meeting in Houston, Texas, 2) Regional School District Study Groups (Ft. Collins, Denver, etc), 3) local business groups and clubs (optimists, Kiwanas, Chamber of Commerce, etc), 4) regional energy symposiums, and 5) at NSF-sponsored symposia and workshops.

In addition, a large number of individuals and organizations (architects, businesses, and clubs) have been communicated with through a variety of media (telephone, interviews, information pamphlets, etc.). Articles and Editorials in Magazines and newspapers have also been provided.

A set of laboratory plans has been provided to the National Association of Home Builders for their evaluation and comments. Numerous contacts have been established between the project personnel and members of proposed or funded projects to accomplish Consumer Demand Analysis of Solar Heating and Cooling Systems.

Contacts have been established with a variety of industrial and commercial organizations, with potential or existing interest in solar heating and cooling. These include but are not limited to: Aluminum procedures and fabrication, glass and plastics manufacturers, equipment and appliance manufacturers, distributors, industrial research organizations, plus numerous Universities and Colleges.

In addition to the distribution of this report, a paper based on the design procedure and results will be submitted for publication in the Solar Energy Journal. Preprints of the article will be available. An invited paper (IEEE) will also be derived from this research and presented to their annual meeting in July of this year.

APPENDIX A

List of Research Contributors

Senior Researchers

Dr. George O.G. Löf, Principal Investigator	CSU
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Junior Researchers

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Mr. Charles Smith	CSU
Mr. Richard Arber	CSU
Mr. Walter Loss	CSU
Mr. David Pogany	CSU
Mr. Steven Orzynski	CSU

APPENDIX B

Bibliography of Reports and Papers Generated

George O.G. Löf and Dan S. Ward, A Solar Heated and Cooled House, to be presented at the ISES Conference (August 1974).

Dan S. Ward and Charles Smith, Harnessing the Sun for Heating and Cooling, Submitted to Western Engineer for publication (April 1974).

George O.G. Löf, Report presented at the NSF Solar Cooling Workshop, Los Angeles (February 1974).

APPENDIX C

Report Distribution List

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