DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-161151

DESIGN PACKAGE FOR PROGRAMMABLE CONTROLLER AND HYDRONIC SUBSYSTEM

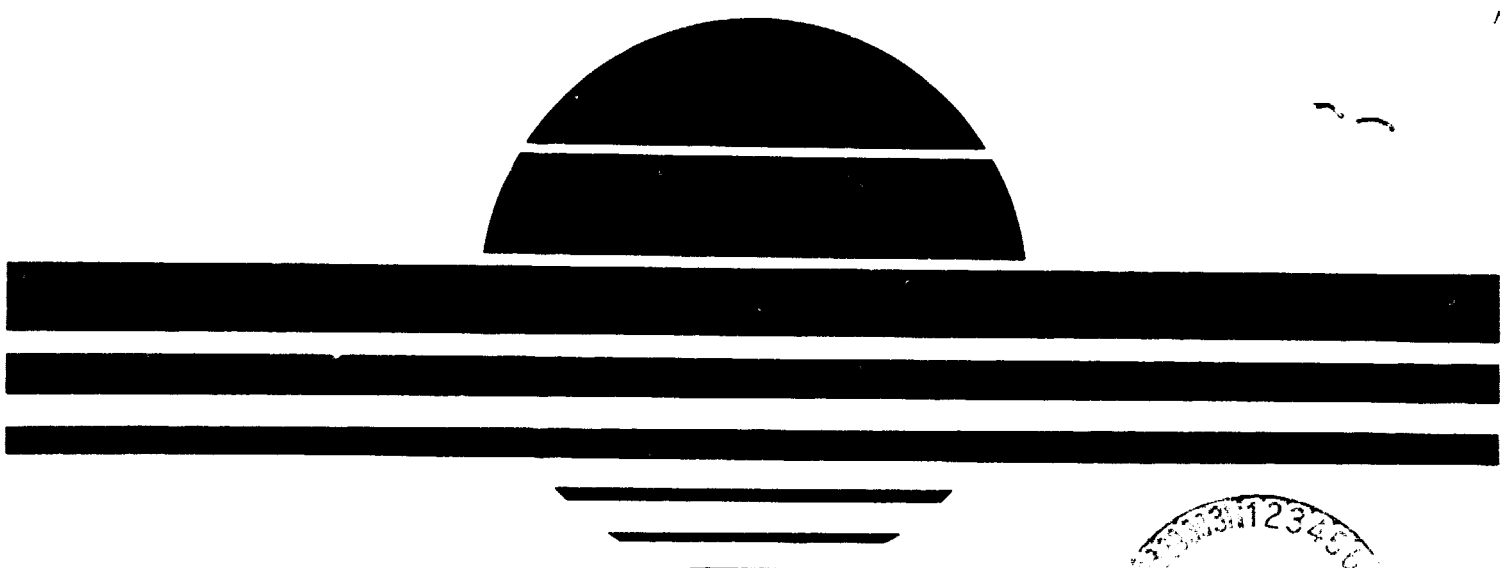
Prepared from documents furnished by

Sunkeeper Control Corporation
P. O. Box 34
Shawsheen Village Station
Andover, Massachusetts 01810

Under Contract NAS8-32257 with

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

For the U. S. Department of Energy



U.S. Department of Energy

Solar Energy

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TABLE OF CONTENTS

ANDOVER CONTROLS CORPORATION

I. P. E. C. H. SUBASSEMBLY MODEL 1070

PERFORMANCE SPECIFICATION

SUBSYSTEM ENVIRONMENT

Temperature: 40° to 100°F
Relative Humidity: 5% to 95%
Primary Power: 117 ± 10% Volts, single phase, three wire 60HZ., 30 amp service.

SOLAR COLLECTOR CIRCULATION SYSTEM

Flow Rate: 1.8 gal/minute/zone ± 10%
Max. Pressure: 30 PSI
Pressure Head: 20 feet maximum
Fluid Temperature: 240°F Max.
Pump Control: Manual or Automatic
Pump Duty Cycle: Up to 100%, under program control
Automatic Valves: Eight electrically valved ports for array control at 3.3 Cv/valve.

ZONE WATER SYSTEM

Flow Rate: 5 gal/minute/zone ± 10%
Max. Pressure: 30 PSI
Pressure Head: 30 ft. Max.
Fluid Temperature: 240°F Max.
Pump Control: Manual or Automatic
Pump Duty Cycle: Up to 100%, under program control
Automatic Valves: Eight electrically valved ports for zone control at 4.1 Cv/valve.

COLLECTOR PANEL MANIFOLD VALVE MODULE

Max. Pressure: 125 PSI
Valve Actuator: 6 Watts at 24V
Valve Actuation Time: 15 Seconds Maximum
Max. Temperature: 240°F
Pipe Size: 3/4 Inch Output, 1 1/2 inch inlet

ZONE MANIFOLD VALVE MODULE

Max. Pressure: 125 PSI
Valve Actuator: 6 Watts at 24V
Valve Actuation Time: 15 Seconds Maximum
Max. Temperature: 240°F
Pipe Size: 1 inch Output, 1 1/2 inch inlet

PHYSICAL

Size: 32" D X 6'H X 4'W
Weight: Approximately 400 pounds

DESIGN LIFE

Hydronics: 20 years
Controller: 20 years

ANALOG INPUTS

Thermistor: Quantity of 24, compatible with Fenwal type UUT43J1 bead
Voltage: Quantity of 8, 0 to 5.110 volts., Z in >3K Ω

SWITCH INPUTS

Quantity: 32
Rising Threshold: 9.2 - 15.5 volts
Falling Threshold: 1.75 - 7.3 volts
Input Impedance: 1.5K Ω
State Definition: Open = Gnd = OFF
LED Indicators: Light when input is ON

DIGITAL OUTPUTS

Quantity: 32 (16 used to control I. P. E. C. H. Zones)
(16 Available to User)

Current Capability: 100mA sink Max.
Voltage: Clamped to + 24v, - 0.3v
LED Indicators: Lights when associated output is closed to ground.
(Sinks current)

VOLTAGES (Available to User)

+5, +24, ± 12 volts at 250 mA. each Max.

OVERVOLTAGE PROTECTION

Inputs and Outputs withstand monetary short to 120 VAC.

MODERN CHANNEL

Interface: RS232-C
Band Rate: Selectable 110, 300, 9600, or 19200.

REAL TIME CLOCK

Calender: Automatic Calender good to year 2000

Battery-Backup: Real time clock switches from 60HZ line control to quartz crystal. Back-up good for two days minimum. Batteries recharge after power up.

PROGRAMMABILITY

The Sunkeeper control language simplifies the use of the controllers capabilities. With a single statement, it specifies the analog and digital input conditions under which the unit turns digital outputs ON and OFF. The unit can also vary the action of the control programming depending on the time of day or time of year. It is also supported by 160 interval timers: 40 seconds timers, 40 minutes timers, 40 hours timers and 40 days timers. Timers have a capacity of up to 256 units.

Analog input voltages are automatically converted to appropriate units so that limit points are in terms of degrees per volts. The automatic scaling simplifies the control programming and makes it easy to understand and maintain.

DESIGN DATA BROCHURE

A) GENERAL DESCRIPTION - INTEGRATED PROGRAMMABLE ELECTRONIC CONTROLLER & HYDRONIC SUB-SYSTEM

The Sunkeeper I.P.E.C.H. subsystem is a completely assembled, piped, wired and tested package. It is designed to be used in large residential and small commercial solar heating applications. The package consists of three basic systems, a power panel and programmable microprocessor, a hydronic solar collection pumping system and a hydronic heating hot water pumping system.

The package requires only field connection of piping, power and sensor devices. It may be programmed to collect solar energy from the user's collector based on a number of user determined inputs such as solar insolation, date, time of day, outdoor ambient conditions, etc. In addition, it may be programmed to heat various zones of the user's facility as determined by user installed zone thermostats or to store collected solar energy in user supplied storage tanks. Once user supplied inputs are connected, sequence of operation, set-points, and priorities may be changed at will without the need for field wiring changes.

The user may, through the use of a compatible portable printer terminal, have access to the controller either on site or remotely by telephone mode . Access features include a 32 hour history file of user selected data, print-out of all inputs and outputs, location of control sequence in program, ability to edit program and program print-out. In addition, the controller may be connected to a remote master computer for data logging or master command, interrogation or program editing.

DESIGN DATA BROCHURE

PARTS & MATERIALS SPECIFICATIONS (B)

1. General Description
2. Piping
3. Fittings
4. Control Valves
5. Constant Flow Control Devices
6. Valves
7. Strainers
8. Pressure Gauges
9. Pumps
10. Hangers
11. Structural Frame
12. Insulation

1. General Description

a) The mechanical sub-system shall be a completely assembled and tested package. The package shall consist of all required piping, fittings, valves, control valves, constant flow control devices, strainers, pressure gauges, pumps, hangers, piping insulation, integrated programmable controller, motor starters, convenience outlets, relays, transformers, wiring, all mounted on a structural steel frame suitable for shipping. The package shall require only field connections to piping, power wiring and sensor device wiring.

b) The dimensional requirements given on the drawings are based on the names of manufacturers materials given in the following specifications. Substitutions shall require a review of the drawings for dimensional compatibility.

2. Piping

a) All piping shall be type L copper tubing as manufactured by Anaconda American Brass Company. All tubing shall be manufactured in accordance with Federal Specification WW-T-799A and ASTM B-88.

b) All soldered joints shall be made with 95-5 tin-antimony or 95-5 tin-lead per ASTM B-32, Grade 5A. All ends of tubing shall be reamed after cutting to remove burrs and tubing and fittings cleaned bright with emery cloth before application of flux and soldering joints.

3. Fittings

a) All fittings shall be wrought copper or cast brass as shown on the drawings. All fittings shall be Anaconda American Brass Co. or equal. Wrought copper

fittings shall meet A.S.A. Std. B16.22-1951 and all cast brass fittings shall meet A.S.A. Std. B-16.18-1950. Threaded ends shall conform to American Standard Taper Pipe Thread (N.P.T.), A.S.A. B2.1.

4. Control Valves

a) All control valves shall be Bell & Gossett Modumate Zone Control Valves of the two-way pattern type. Valves shall be for 24 Volt operation and of the normally closed type. A removable heat motor shall drive the valve to the open position. The valve body shall be of cast brass, the seal cartridge shall be of stainless steel and brass construction. All operating components shall be enclosed in a steel cover and frame. Valve shall provide 100% close off at pump heads to 60 ft. Valve shall have a manual operating lever and valve position shall be externally indicated. Valve shall be suitable for 125 p.s.i.g. operating pressure at 40° to 240°F.

5. Constant Flow Control Devices

a) Constant flow control devices shall be as manufactured by Griswold Controls, Santa Ana, California. Valves shall be factory calibrated, direct acting, automatic pressure compensating type, and shall limit flow rates to within ± 5% accuracy. Control mechanism shall be of stainless steel construction. Body shall be of wrought-copper construction suitable for sweat-type installation.

6. Valves

a) Gate valves, ball valves and check valves shall be as manufactured by Jenkins Brothers. Gate valves shall be solder end type and bronze con-

construction for 200 lb. non-shock cold water service, Jenkins Fig. 1240. Ball valves shall be forged bronze solder end for 400 lbs. non-shock cold water, oil or gas, Jenkins Fig. 1100-T with teflon seal. Check valves shall be bronze swing type solder end for 300 lbs. non-shock cold water, Jenkins Fig. 1222.

b) Balancing valves shall be Bell & Gossett circuit setter balance valve, bronze construction with bronze disc, for 125 p.s.i.g. service at maximum 250°F. Valve shall have solder ends, integral pointer and scale to indicate position, and provision for connection to portable differential pressure meter. Connections for meter shall have built-in check valves.

7. Strainers

a) Strainers shall be Muessco, Muller Steam Specialty Co., Brooklyn, N.Y. No. 352 - 1/2 with solder ends, perforated Monel screens with 1/16" perforation for water service, for 250 P.S.I. SWP at 425°F service.

8. Pressure Gauges

Pressure gauges shall be Marsh Instrument Company copper alloy bourdon tube type J4148, 2 1/2" dial size, 0 - 100 P.S.I. range with 1/8" N.P.T. bottom male threaded connection.

9. Pumps

a) Pumps shall be Bell & Gossett Series 60 in-line circulators, Models 60-15, 60-16 or 60-17 as required. Pump shall be single stage vertical split case design all bronze construction, with enclosed type impellor, hydraulically and dynamically balanced. Pump shall have mechanical seal of carbon (Remite), oil lubricated journal bearings, hardened alloy steel shaft, shaft sleeve, flexible coupling between motor and shaft, and

resilient mounted motor for 115/230V. 3 phase 60 Hz. service.

10. Hangers

a) All pipe hangers shall be I.T.T. Grinnell. The following models shall be provided.

Figure 138R extension split pipe clamp for 3/8" threaded rod.

Figure 128R rod threaded flange for 3/8" threaded rod. Flange shall have two countersunk holes to accept 12-32 screw for mounting.

Figure 120 light weight U-bolt, 1/4" diameter threaded 1/4-20 and two 1/4-20 hex-nuts each.

11. Structural Steel Frame

a) A structural steel frame shall be shop fabricated as shown on the drawings. This frame shall support all components of the mechanical sub-system and used in conjunction with wood blocking shall be used for shipping purposes.

b) The frame shall be entirely constructed of A.S.T.M. A-36 structural steel. All joints shall be electric resistance arc welded, frame shall be cleaned, prime coated with red-lead and painted.

12. Insulation

All piping and fittings shall be insulated and covered with 1/2" thick Armaflex fire rated insulation.

C) SUBSYSTEM PERFORMANCE SPECIFICATIONS

SUBSYSTEM ENVIRONMENT

TEMPERATURE:	40° to 100°F
RELATIVE HUMIDITY:	5 - 95% non-condensing
PRIMARY POWER:	117 ± 10%, single phase, two wire 60 Hz 30 amp service

HYDRONICS

COLLECTOR CIRCULATION SYSTEM

FLOW RATE:	15 gal./min.
MAX PRESSURE:	30 PSI
PRESSURE HEAD:	20 feet maximum
FLUID TEMPERATURE:	240°F
PUMP DUTY CYCLE:	100%

UP TO EIGHT (8) ELECTRICALLY VALVED PORTS FOR ARRAY CONTROL AT 3.3 Cv/VALVE

ZONE WATER SYSTEM

FLOW RATE:	40 GPM
MAX PRESSURE:	30 PSI
PRESSURE HEAD:	30 ft. max.
FLUID TEMPERATURE:	240°F Max.
PUMP DUTY CYCLE:	100%

UP TO EIGHT (8) ELECTRICALLY VALVED PORTS FOR ZONE CONTROL AT 4.1 Cv/VALVE

COLLECTOR PANEL MANIFOLD VALVE MODULE

MAX. PRESSURE:	125 PSI
VALVE ACTUATOR:	6 Watts @ 24VAC
VALVE ACTUATION TIME:	10 Seconds
MAX TEMPERATURE:	240°F
PIPE SIZE:	3/4 Inch Output, 1 1/2 Inch Inlet

ZONE MANIFOLD VALVE MODULE

MAX. PRESSURE.	125 PSI
VALVE ACTUATOR:	6 Watts @ 24VAC
VALVE ACTUATION TIME:	10 Seconds
MAX. TEMPERATURE:	240°F
PIPE SIZE:	1 Inch Output, 1 1/2 Inch Inlet

AUXILIARY ENERGY SOURCE CIRCULATOR PUMP

CONTROL IS AVAILABLE FOR UP TO 1 HP PUMP

PHYSICAL SIZE

SIZE: Dust Tight NEMA Cabinet 32"x41"x6' Height
SUBSYSTEM WEIGHT: Approximately 900 pounds

DESIGN LIFE

DESIGN LIFE OF ALL SUBSYSTEM MODULES: 20 Years

CONTROLLER

POWER: 117VAC ± 20%, 60 Hz, 25 Watts
SIZE: 24.0" X 16.0" X 4.75"

ANALOG INPUTS

THERMISTOR: Potentiometric measurement with pull up resistor (3K Ω) to +6.2V
ANALOG: .0 to 6.2V., Zin > 3K

SWITCH INPUTS

RISING THRESHOLD: 9.2 - 15.5 Volts
FALLING THRESHOLD: 1.75 - 7.3 Volts
INPUT IMPEDANCE: 1.5K
STATE DEFINITION: OPEN = GND = OFF
LED INDICATOR WITH EACH INPUT

DIGITAL OUTPUT

CURRENT CAPABILITY: 100 mA sink max.
VOLTAGE: Clamped to +24V, -0.3V
LED INDICATOR WITH EACH OUTPUT

VOLTAGES (AVAILABLE FOR USER)

+5, +8, +24, ±12 Volts Available On Connectors @ 250 mA Max. Each

AUXILIARY ENERGY SOURCE CIRCULATOR PUMP

CONTROL IS AVAILABLE FOR UP TO 1 HP PUMP

PHYSICAL SIZE

SIZE: Dust Tight NEMA Cabinet 32"x4'x6' Height
SUBSYSTEM WEIGHT: Approximately 900 pounds

DESIGN LIFE

DESIGN LIFE OF ALL SUBSYSTEM MODULES: 20 Years

CONTROLLER

POWER: 117VAC + 20%, 60 Hz, 25 Watts
SIZE: 24.0" X 16.0" X 4.75"

ANALOG INPUTS

THERMISTOR: Potentiometric measurement with pull up resistor (3K Ω) to +6.2V
ANALOG: .0 to 6.2V., Zin > 3K

SWITCH INPUTS

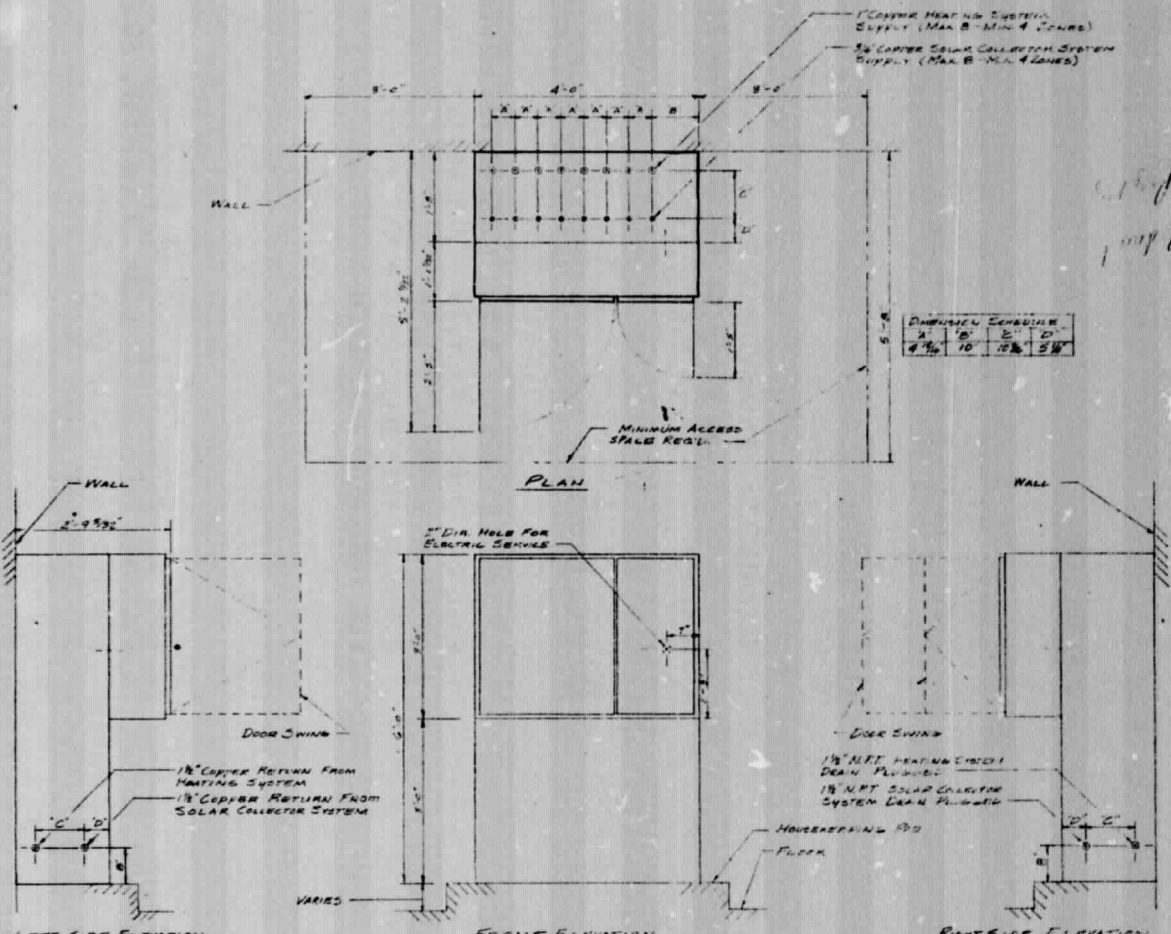
RISING THRESHOLD: 9.2 - 15.5 Volts
FALLING THRESHOLD: 1.75 - 7.3 Volts
INPUT IMPEDANCE: 1.5K
STATE DEFINITION: OPEN = GND = OFF
LED INDICATOR WITH EACH INPUT

DIGITAL OUTPUT

CURRENT CAPABILITY: 100 mA sink max.
VOLTAGE: Clamped to +24V, -0.3V
LED INDICATOR WITH EACH OUTPUT

VOLTAGES (AVAILABLE FOR USER)

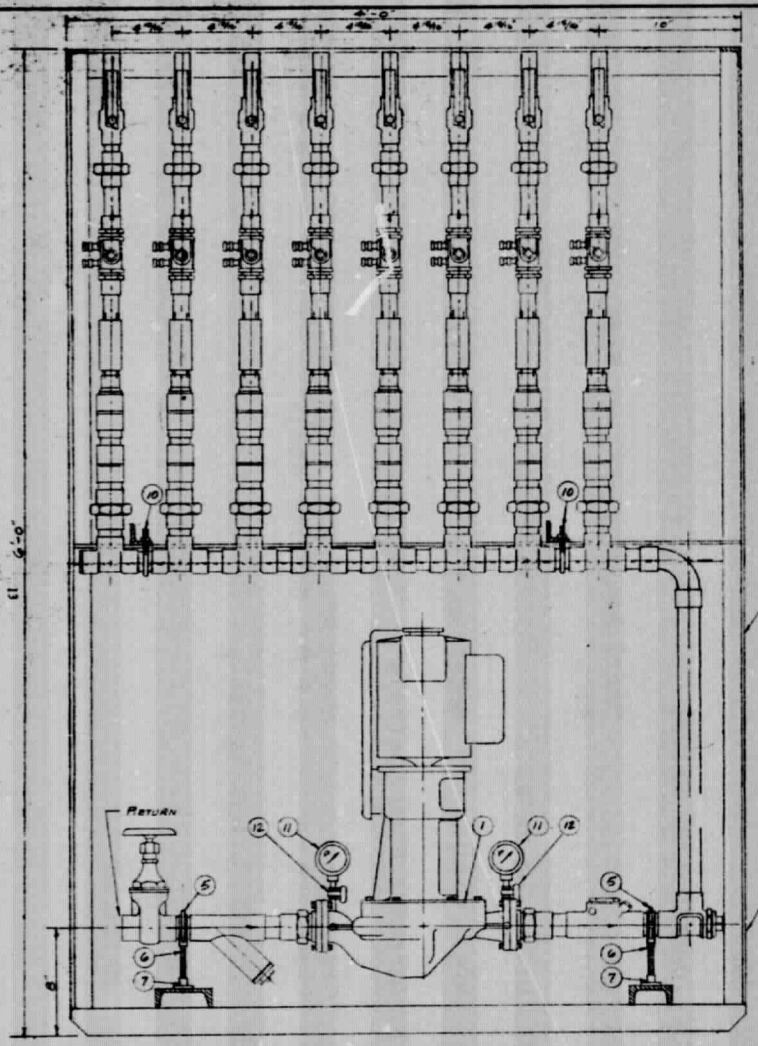
+5, +8, +24, +12 Volts Available On Connectors @ 250 mA Max. Each



Installation Notes

1. Install piping connections with bends or offsets to minimize expansion forces.
2. Approximate operating weight 900 l.b.
3. Electrical Data: Max. 2 - 1 Hp motors 115-230 V., 1 Phase, 60 Hertz.
4. Provide floor drain adjacent to IFRCH for draining spigot.

Sunkeeper Control Corp. P.O. Box - 34 Andover	Shawsheen Village Sta. Massachusetts 01810
Scale:	Dwn. TAK
Date: 6-21-87	Chkd.
National Space Flight Center NAS "B" Mechanical Sub-System	
IFRCH Installation Dimensions	1061-000



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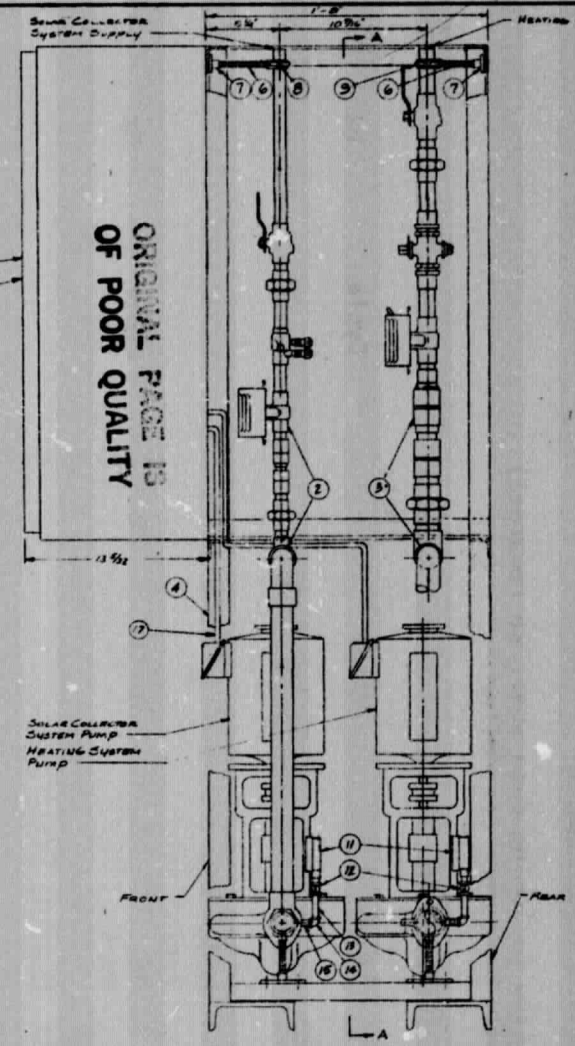


RIGHT END VIEW

BILL OF MATERIALS

Part No.	Quan	Description
1	2	Pump Assembly - Ref Dwg. 1054-000
2	1	Solar Collector Manifold - Ref Dwg. 1158-000
3	1	Heating Supply Manifold - Ref Dwg. 257-000
4	1	Frame - Ref. Dwg. 1056-000
5	4	Extension Split Pipe Clamp - 1¼ Copper
6	10	⅜" Threaded Rod - Cut to Fit
7	20	⅜" Rod Threaded Flange
8	8	Extension Split Pipe Clamp - ¾" Copper
9	8	Extension Split Pipe Clamp - 1" Copper
10	4	¼" Threaded U-Bolt - 1¼ Copper
11	4	2½" Dia. Pressure Gage 0-100 PSI
12	4	⅛" N.P.T. Gage Cock - Brass
13	4	⅛" Brass Nipple x 2" Lg.
14	4	⅛" N.P.T. 90° Elbow - Brass
15	4	⅛" Brass Nipple x 1" Lg.
16	1	Sunkeeper Control Cabinet - Ref Dwg. 1059-000
17	2	Flexible Electrical Conduit
18	AR	Low Voltage Wire - Ref. Dwg.

HYDRONIC DAT

Solar Collector System
18 G.P.M. @ 10 Ft. Max. External T.D.H.
Min. - 4 Zones - 4.5 G.P.M. Ea.
Max. - 8 Zones - 1.875 G.P.M. Ea.

Heating System
40 G.P.M. @ 80 Ft. Max. External T.D.H.
Min. - 6 Zones - 10 G.P.M. Ea.
Max. - 8 Zones - 5 G.P.M. Ea.

GENERAL NOTES

1. For Next Highest Assembly Refer to Dwg. No. 1061-000

Rev.	Date	Description	By
1	6-77	Notes Added	TM

SUNKEEPER CONTROL CORP.
P.O. BOX 86 SHAWSHEEN VILLAGE STA.
ANDOVER MASSACHUSETTS 01810

Drawn	TM
Date	5-13-77
Checked	
Date	

MARSHALL SPACE FLIGHT CENTER NASA-MSFC
MECHANICAL SUB-SYSTEM

1 PER'N ASSEMBLY — 1060-000

GRAPHIC SCALE

774

DATA REQUIREMENT NO. 505-13
Contract No. NAS8-32257

QUALIFICATION & ACCEPTANCE
TEST PROCEDURES

I. ITEMS TO BE TESTED

(The following data shall be recorded)

A) Sunkeeper Controller

Model No.		Volts		A.C.
Serial No.		Phase		
Power	Watts		Cycle	Hz

B) Solar Collector System Pump

Mfg.				
Model No.				
Serial No.				
HP	Volts	PH	Cycle	Hz
Amps				

C) Heating System Pump

Mfg.				
Model No.				
Serial No.				
HP	Volts	PH	Cycle	Hz
Amps				

D) Zone Control Valves

Mfg.	Model No.	Size	
Volts	Amps	Cycle Hz	PH

E) Balancing Valve

Mfg.	Model No.	Size

F) Constant Flow Controls

Mfg.	Model No.	Size	
Flow Rate	G.P.M., Control Range		P.S.I.D.

G) I.P.E.C.H. Sub-Assembly

Mfg.	
Model No.	
Serial No.	

II. TEST OBJECTIVES

The object of these tests shall be to simulate operating conditions specified for the I.P.E.C.H. Sub-Assembly. These performance specifications shall be as listed in "Subsystem Performance Specifications" of Prototype Design Review Data Article No. 505-8. In addition, data accumulated during these tests shall be used to support responses to Performance Requirements listed in the Verification Cross Reference Matrix.

III. LOCATION & SCHEDULE OF TESTING

All testing shall be performed at Sunkeeper Control Corporation's manufacturing facilities in Andover, Massachusetts. Testing of the first article is planned to commence during the last week of August 1977.

IV. TEST PREREQUISITES FOR PASSING OR FAILING

All incoming materials shall be inspected for damage and compliance with Sunkeeper Control Corporation's procurement specifications. Damaged materials or those not in compliance shall be rejected and replaced.

During assembly of the Sunkeeper Controller, all P.C. boards and sub-assemblies are inspected for compliance with drawings and specifications. Diagnostic tests are performed during assembly to verify proper function of all circuitry. All circuitry that fails diagnostic tests are replaced prior to final assembly.

After all components have been inspected and tested, the I.P.E.C.H. package shall be assembled and wired. Operational test shall then be performed. The I.P.E.C.H. package shall operate within specified limits. Failure to do so shall result in rejection of the package. Repair, replacement of components or redesign as required until package operates within specified limits. Operation within specified limits shall result in acceptance.

V. TEST PROCEDURE

A) Sunkeeper Controller

The Sunkeeper Controller is subjected to five tests for acceptance. Three of the tests are analytical circuitry checks. One test verifies interface checks. One test exposes the controller to the specificd environment to determine that the controller will function properly.

The Power-On Test checks that the proper voltages are available at various locations in the circuitry. The lower Random Access Memory (RAM) test is used to verify proper function of memory bits and addressing function. The upper Random Access Memory (RAM) test verifies proper function of upper RAM by using a preprogrammed PROM to exercise this memory. In addition it verifies that memory is retained during power "off" periods.

The hardware interface test is used to check all inputs and output functions by using a test box to simulate actual operating conditions. The environmental test verifies controller operation in the specified environment. A simple program is entered into the controller. The controller is installed in a test chamber. Power is turned "on" and "off" randomly while program function is observed. Controller must process the program during environmental extremes and not lose the program during power "off" periods, thus verifying proper function of battery back-up.

I) Power "On" Test: Techtronics 465 Oscilliscope

A. With FB-1 - 4 & R - 89, 116, 117 not installed
B. Location FB-1 Measure +12VDC
C. Location FB-2 Measure +5VDC — Inductor
D. Location FB-3 Measure -5VDC
E. Location FB-4 Measure -12VDC
F. Location R-89 Measure +8VDC
G. Location R-116 Measure +24VDC — Resistor
H. Location R-117 Measure +4VDC
I. Install FB1-4, & R-89, 116, 117.
J. Location U-118 Pin 7 Measure +2VDC — Integrated Circuit
(Trim with R-192) — Resistor
K. Check all again
L. Check voltage indicator LED's "ON" at following locations: +24, +12, +5, -5, -12, 5V O.K., AC O.K.
M. If all good readings, power test acceptable

II) Lower Random Access Memory Test

A. Power "OFF"
B. Insert Programmable Read Only Memory (PROM) in F.C. address socket
C. Connect Lear Siegler Inc. ADM-3A video terminal
D. Apply Power "ON"
E. Audible signal bell "ON" - "OFF"
F. Terminal display
Zero bits test complete
Ones bits test complete
Odd bits test complete
Even bits test complete
Addressing test complete
Continue above test loop if passed until power "OFF"
G. If any of the first four tests failed terminal displays:
ERROR!!! trigger analyzer at FC-51.

H. If addressing test failed terminal displays: ERROR!!! Trigger analyzer at FC80.
I. If any test failed, troubleshoot with Hewlett-Packard 1611A logic state analyzer. Remove or replace or repair components as required. Repeat test until all complete.

III) Upper Random Access Memory Test

A. Power "OFF"
B. Remove PROM from F.C. address socket
C. Install PROM identified "H" bug in F.C. address socket
D. Install memory test PROMs E0 in address socket, F0 in address socket.
E. Power "ON"
F. Audible signal "ON" - "OFF"
Terminal displays asterisk
G. Open appropriate memory addresses, input upper and lower memory test limits, close addresses.
H. Initiate RAM test through terminal unit. Terminal unit displays less than ( ) symbol when ready.
I. Run following test by inputing at terminal unit:
"AT" - Addressing test
"PP" - Ping pong test (odd/even bit)
"RT" - Random pattern test
"RP" - Repeat Pong Test
Power "OFF"
Allow 30 seconds minimum power "ON"
Reinitiate memory test
"VP" - Verify pong test
J. If test passed, terminal displays "ADDRESS IS", "SHOULD BE" and "E.O.T." End of Test.
K. If test failed, terminal will display that address that failed, what the data "is" at that address, and what it "should be".
L. Troubleshoot RAM with H.P. 1611A analyzer. Remove or replace or repair faulty components.
M. Terminate memory test.

IV) Hardware Interface Test

A. Connect hardware simulator test box
B. Power "ON"
C. Terminal Connected
D. Turn "ON" all digital outputs through terminal. LEDs in Sunkeeper and simulator should light. Print drivers through terminal. Terminal should display PD 1-32. Turn digital outputs "OFF", LEDs should be unlit. Print drivers, terminal should display "PD".
E. Switch all digital inputs at simulator to "ON". LEDs in Sunkeeper should light. Print inputs through terminal. Terminal should display "PI 1-32". Switch all "OFF". LEDs unlit, print inputs, terminal displays P.I.

F. Turn all analog value pots on simulator all the way to the left. Print analogs through terminal. Terminal should display the number "64" for analogs 1 - 24 and "224" for analogs 25 - 32. Turn all pots all the way to the right. Print analogs, terminal should display the number "224" for analogs 1 - 24 and "64" for analogs 25 - 32.

G. If any of above tests failed, troubleshoot and repair as required until all tests pass.

V) Environmental Tests

A. Power "ON"
B. Terminal connected
C. Enter program to sequence digital output "ON" and "OFF"
D. Remove terminal
E. Power "OFF"
F. Install Sunkeeper in test chamber and apply power "ON"
G. Set thermostat and humidity control to maintain specified limits.
H. Set time-clock to randomly turn power to Sunkeeper "ON" and "OFF"
I. Leave Sunkeeper in test chamber for 48 hours. Record date, time, off test start and finish. Record temperature and humidity.
J. Remove Sunkeeper from test chamber
K. Test shall have been passed if program entered in "C" above has been retained as verified by observation of output LEDs when power "ON" is applied to Sunkeeper outside the test chamber.

B) Collector Circulation System

Design: 15 G.P.M. @ 20 ft. max. external T.D.H.
Min. 4 Zones - 4.25 G.P.M. ea.
Max. 8 Zones - 1.875 G.P.M. ea.
Max. Operating Temp. 240°F
Max. Operating Pressure 30PSIG

Hydrostatic Test:
(Refer to Hydronic Test Set-Up Diagram)

1. Open Valves V-1, 2, 3, 7, 10 & 12. Close Valve V-14.
2. Fill system with water and vent through air vent V-16. Close city water fill.
3. Close Valves V-12 to array and open by-pass Valve V-12. Close Valves V-12 on electric water heater 13.
4. Start compressor and set pressure regulator to 45 P.S.I.G.
5. When compressor storage tank is charged, open Valve V-14 to pressurize system. Observe pressure gauges 6 & 8. Adjust compressor regulator as required to obtain 45 P.S.I.G. static pressure.
6. Close Valve V-7 and Valves V-1, zones 1-8. Observe piping for leaks. If no leaks, allow system to remain as is for one hour and record following data:

Date:
Start Time:
Reading Press. Gauge 6 Pump Inlet P.S.I.G.
Reading Press. Gauge 6 Pump Disch. P.S.I.G.
Finish Time:
Reading Press. Gauge 6 Pump Inlet P.S.I.G.
Reading Press. Gauge 6 Pump Disch. P.S.I.G.

7. Open Valves V-7 & V-1, Zone 1-8. Close gauge cocks on pressure gauges 6. Adjust compressor regulator to obtain 125 P.S.I.G. static pressure. Observe piping for leaks. Record following data:

Data:
Date:
Time:
Reading Press. Gauge 8 at Inlet P.S.I.G.
Reading Press. Gauge 8 at Disch. P.S.I.G.

8. Close Valve V-14, open Vent V-16 to relieve static pressure to 30 P.S.I.G. and close. Open gauge cocks on pressure gauges 6.
9. If leaks are found, repair and re-test until no leakage occurs.

Hydrodynamic Test:
(Refer to Hydronic Test Set-Up Diagram)

1. Open Valves V-1, 2, 3, 7, 10 & 12. Close Valve V-14.

2. Start compressor and adjust regulator for 30 P.S.I.G. When compressor tank charged, open V-14 and adjust regulator to obtain 30 P.S.I.G. static pressure on system. Record following:

Date:	
Time:	
Press. Gauge 6 Inlet to Pump	P.S.I.G.
Press. Gauge 6 Disch. from Pump	P.S.I.G.

3. Preset zone balancing Valves V-2 for desired flow rate. Close by-pass Valve V-12 to solar array. Close Valve V-14.

4. Operate pump 5 and observe pressure gauge readings at gauges 6 on inlet and discharge of pump. From pump curve determine flow rate for pressure drop across pump.

5. Adjust balancing valve 10 to obtain design external pressure drop by observing readings of pressure gauge 8 at inlet and discharge from I.P.E.C.H. sub-assembly. Determine flow rate as described in "4" above. Take preliminary flow readings at zone balancing valves V-2. Check these against flow rate determined for Pump 5, and adjust as required. Continue to make adjustments to Valves V-2 and V-12 until design flow rates across Pump 5 and in each of 8 zones are established with the specified external pressure drop.

6. When design flow rates and pressure drops have been established, allow system to run continuously through the solar array. Add supplemental heat with electric water heater 13 until water temperature reaches 240°F . Check flow rates and pressure drops and adjust as required.

7. Record the following data:

   A) Inlet pressure to pump
   B) Outlet pressure from pump
   C) Inlet pressure to I.P.E.C.H.
   D) Inlet temperature to I.P.E.C.H.
   E) Outlet pressure from I.P.E.C.H.
   F) Outlet temperature from I.P.E.C.H.
   G) Flow rate at balancing valves V-2 for each of eight zones

8. Close Valves V-3 of zones 1, 2, 3 & 4 in sequence. After each zone Valve V-3 has been closed, record data listed in "7" above. Open Valves V-3 of Zones 1, 2, 3, & 4. Close valves V-3 of zones 5, 6, 7, & 8 in sequence. After each zone valve V-3 has been closed, record data listed in "7" above.

9. Review data recorded in item "7" above. If recorded data is within specified limits, tested sub-assembly shall be accepted.

If not tested sub-assembly shall be rejected. Determine cause of failure to comply and correct. Re-test sub-assembly until performance complies with specifications.

10. The purpose of procedure described in Item "8" above shall be to insure that flow in individual zones shall not increase substantially when zone valves V-3 are closed. The object shall be to maintain constant zone flow rate regardless of the number of zones that are open.

C. Zone Water System

Design: 40 GPM @ 30 ft. Max. External T.D.H.
Min. 4 Zones 10 G.P.M. ea.
Max. 8 Zones 5 G.P.M. ea.
Max. operating Temp. 240°F
Max. operating Press. 30 P.S.I.

Hydrostatic Test:
(Refer to Hydronic Test Set-Up Diagram)

1. Repeat Items 1 through 9 for hydrostatic test in Item "B" above.

Hydrodynamic Test:
(Refer to Hydronic Test Set-Up Diagram)

1. Repeat Items 1 through 10 for hydrodynamic test in Item "B" above.

DATA SHEET NO. 1

1. Sunkeeper Controller

   Model No. Volts AC; Power Watts
   Serial No. Phase ; Cycles Hz

2. Solar Collector System Pump

   Manufacturer
   Serial No. ; Model No.
   H.P. ; Volts AC; Phase ; Cycles Hz.
   Amperes

3. Heating System Pump

   Manufacturer
   Serial No. ; Model No.
   H.P. ; Volts AC; Phase ; Cycles Hz.
   Amperes

4. Zone Control Valves

   Manufacturer
   Volts AC; Phase ; Cycles Hz.; Amps
   Solar System: Model No. ; Size
   Heating System; Model No. ; Size

5. Zone Balancing Valves

   Manufacturer
   Solar System: Model No. ; Size
   Heating System: Model No. ; Size

6. Constant Flow Controls

   Manufacturer
   Solar System: Model No. ; Size
   G.P.M. ; Control Range P.S.I.D.
   Heating System: Model No. ; Size
   G.P.M. ; Control Range P.S.I.D.

7. I.P.E.C.H. Sub-Assembly

   Manufacturer: SUNKEEPER CONTROL CORPORATION
   Model No. :
   Serial No. :

DATA SHEET NO. 2

A. SOLAR COLLECTOR SYSTEM TEST

Hydrostatic Test 45 P.S.I.G. Date:
Start Time: ; Rdg. Gauge 6 Inlet PSIG; Disch. PSIG
Finish Time: ; Rdg. Gauge 6 Inlet PSIG; Disch. PSIG

Hydrostatic Test 125 PSIG
Date: ; Time: ;
Rdg. Gauge 8 Inlet PSIG; Outlet PSIG,

Hydrodynamic Test:
Date: ; Time: ;
Rdg. Gauge 6 Inlet PSIG; Disch. PSIG;

DATA	DESIGN	INITIAL	ZONE VALVES CLOSED							
			1	1-2	1-3	1-4	5	5-6	5-7	5-8
Rdg. Gauge 6 Inlet PSIG										
Rdg. Gauge 6 Disch. PSIG										
Rdg. Gauge 8 Inlet IPECH PSIG										
Rdg. Guage 8 Outlet IPECH PSIG										
Rdg. Therm. 7 Inlet IPECH °F										
Rdg. Therm. 7 Outlet IPECH °F										
Flow Rate G.P.M.										
Zone 1										
2										
3										
4										
5										
6										
7										
8										

Accepted Rejected
Date: By:

DATA SHEET NO. 3

B. ZONE WATER SYSTEM TEST

Hydrostatic Test 45 P.S.I.G. Date:
Start Time: ; Rdg. Gauge 6 Inlet PSIG; Disch. PSIG
Finish Time: ; Rdg. Gauge 6 Inlet PSIG; Disch. PSIG

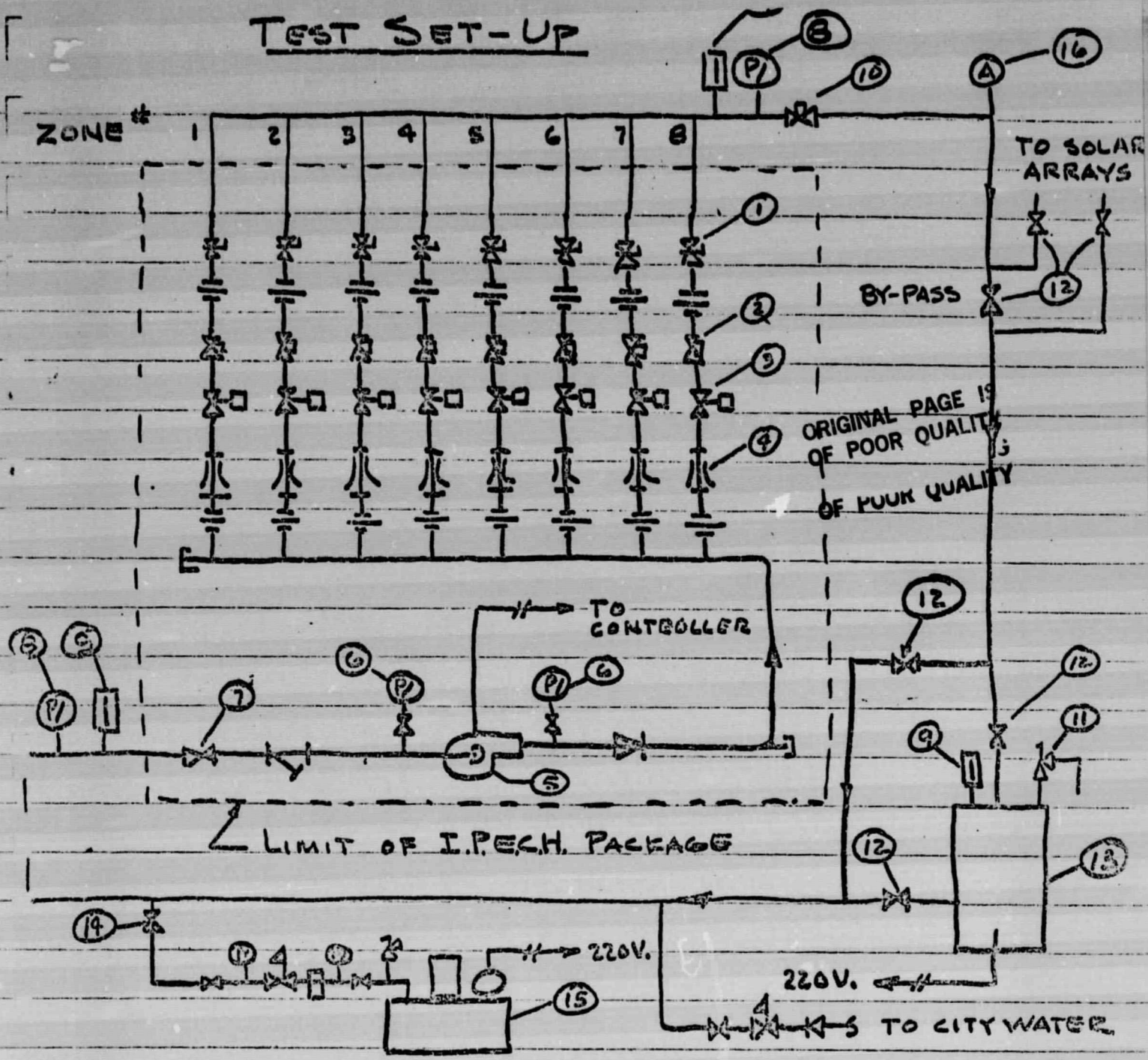
Hydrostatic Test 125 PSIG
Date: ; Time: ;
Rdg. Gauge 8 Inlet PSIG; Outlet PSIG,

Hydrodynamic Test:
Date: ; Time: ;
Rdg. Gauge 6 Inlet PSIG; Disch. PSIG;

DATA	DESIGN	INITIAL	ZONE VALVES CLOSED							
			1	1-2	1-3	1-4	5	5-6	5-7	5-8
Rdg. Gauge 6 Inlet PSIG										
Rdg. Gauge 6 Disch. PSIG										
Rdg. Gauge 8 Inlet IPECH PSIG										
Rdg. Guage 8 Outlet IPECH PSIG										
Rdg. Therm. 7 Inlet IPECH °F										
Rdg. Therm. 7 Outlet IPECH °F										
Flow Rate G.P.M.										
Zone 1										
2										
3										
4										
5										
6										
7										
8										

Accepted Rejected
Date: By:

TEST SET-UP



LEGEND

1. BALL VALVE
2. B&G. CIRCUIT SETTER
3. B.&G. ZONE VALVE
4. GRISWOLD FLOW CONTROL
5. B.&G. PUMP
6. PRESS. GAGE 0-100 PSI
7. GATE VALVE
8. PRESS GAGE 0-150 PSI
9. THERMOMETER 0-300°F
10. BALANCING VALVE - 1 1/2"
11. RELIEF VALVE SET 30 PSI
12. GATE VALVE - 1 1/2"
13. ELECTRIC WATER HEATER
14. GATE VALVE
15. AIR COMPRESSOR, DRYER, & REDUCING STATION
16. AIR VENT