FINAL REPORT

PHASE I

PARAMETRIC STUDY OF ROCK PILE THERMAL STORAGE FOR SOLAR HEATING AND COOLING

October 1977

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Prepared For

National Aeronautics and Space Administration

George C. Marshall Space Flight Center

Technical Monitor: Dr. W. R. Humphries

Grant No. NSG-8041

Alabama Agricultural and Mechanical University

SCHOOL OF TECHNOLOGY

HUNTSVILLE, ALABAMA

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FOREWORD

This report describes the work done for the NASA/MSFC Grant No. NSG-8041, "Parametric Study of Rockpile Thermal Storage for Solar Heating and Cooling." This report includes literature survey, design of a rock pile thermal storage test bed with test instrumentation plan, a test plan for the parametric study of a pile of tin cans filled with water as thermal storage medium, and some test data with an analysis of the data.

The deviation from the original plan of testing rocks is due to MSFC's immediate need of heat transfer characteristics of metal containers of different shapes filled with liquid. The parametric study of rockpile will be continued after the completion of the present plan.

This research program contributed extensively to improve faculty and student-research capability-at the Alabama A & M University and this support by NASA/MSFC is greatly appreciated. The author appreciates the help received from the school of Technology faculty and staff (the Dean Dr. J. R. Jenkins, Mr. Lee Roy Byrd and others).

The author wishes to acknowledge the helpful assistance and advice received from NASA specialists--Dr. W. R. Humphries, Mr. Sam E. Clonts, Mr. Fred Zur Burg, and his associates, Mr. Juan E. Maldonado, Mr. Olin K. Duren, and Mr. Joe E. Zimmerman and his associates. The author would also like to express his appreciation to Mr. Marion I. Kent, Assistant Director for University Affairs, NASA/MSFC, for his effort in making this grant possible.

PARAMETRIC STUDY OF ROCK PILE THERMAL STORAGE

FOR SOLAR HEATING AND COOLING

ABSTRACT

The primary objective of this investigation is to present the test data and an analysis of the heat transfer characteristics of a solar thermal energy storage bed utilizing water filled cans as the energy storage medium. The intent is to optimize such aspects as can size, can arrangement, and bed flow rates by experimental and analytical means. This type of storage medium, liquid filled cans, utilizes the benefits of both solids like rocks and liquids like water. This combination of solid and liquid mediums shows unique heat transfer and heat content characteristics and will be well suited for use with solar air systems for space and hot water heating. The literature survey revealed that there was a need for experimental data on heat transfer characteristics of solar thermal storage mediums. For this purpose of an extensive parametric study of heat transfer characteristics of rocks, of other solids, and of solid containers filled with liquids—of different shapes and sizes, a multy flow cycle storage test facility was designed. The trends of the test results acquired thus far, are representative of the test bed characteristics while operating in the various modes.

INTRODUCTION

Direct trapping and utilization of solar radiation is probably the aspect of solar energy which holds the most immediate promise of widespread utility.

Solar heat is wanted most during the hours when the sun is not shining, so it is necessary to store this heat for when it is needed. This can be accomplished by using a large insulated vessel filled with rocks or other solids. During the day, the hot air from the solar panels heats one of these reservoirs. At night or in a cloudy day, when the heat is needed, air flows through the reservoir and is heated. Properly designed rock/solid beds have performance comparable to liquid cooled collector/water heat storage systems. Although a rock/solid bed has higher volume than a water tank of equal heat capacity, the container is cheaper and is more easily built with conventional construction techniques and materials. A rock/solid bed is also an efficient heat transfer device. The heat storage capacity of a rock/solid bed can be improved by using fluid filled cans as the energy storage medium.

To make the rock/solid storage bins efficient heat storage and heat transfer devices it is important to know the influences of the various parameters, such as, size and types of solid medium, area and height of the storage unit, flow rate, pressure drop across the test bed, inlet and outlet temperature of air, and temperature distribution in the test bed - on the performance of the beds.

The experimental data available on this subject at this time are not satisfactory. Therefore, the primary objective of this experimental study is to investigate the heat transfer characteristics and energy storage capability of a solar energy storage bed utilizing water filled metal cans or rocks as the energy storage medium. The intent of the test series is to optimize and parameterize such aspects as bed and can size, can arrangement, bed flow rates, and pressure drop. A similar parametric study will be conducted with rocks as storage medium during the 2nd phase of this project. An ultimate goal would be to develop and formulate mathematical models that can be utilized for performance evaluation of these types of storage systems.

According to the current literature survey it is apparent that this experimental research is unique in its type and highly desired by the solar energy users at this time.

This report contains the following items:

a) An up-to-date literature survey of rock pile and other solid medium heat storage systems experimental and theoretical studies.

b) Description of the thermal storage medium, the design of the multy-flow cycle test facility, and instrumentation.

c) Test plan

d) Preliminary results and discussion of the results with metal cans filled with water.

e) Description of the experimental study and analysis during the phase II of this project.

f) General comments.

LITERATURE SURVEY

The use of rock pile heat storage systems has been considered for different solar energy applications [1-6]. Experimental data for the heat transfer corfficient between air and rocks of irregular shape are scarce. Lof and Hawley [8] have obtained experimental results for the type of rock beds most commonly used in solar energy storage. Kays and London [9] have correlated data for packed beds from different sources. Dunkle and Ellul [10] have proposed the use of the equation obtained by Kays and London [9] for the design of randomly-packed beds. The reference [11] presents some test results of rock pile heat transfer coefficients. The measurement of heat transfer coefficient is performed by means of a transient method where a temperature step is applied to the bed, and the obtained time-temperature relations for the fluid at different points in the pile are compared with the theoritical curves calculated by Schumann [12] and by Furnas [13]. Mr. Dennis Jones at the National Bureau of Standards, Gaithersburg, Maryland has shown me some test data of rock pile heat transfer measurements at NBS which will be published soon. Mumma and Marvin [7] have given a computerized method of simulating the performance of a pebble bed thermal energy storage and recovery system. A new type of thermal storage medium, pint glass jars filled with water, is used in LASL Solar Mobile/Modular Home Project [14].

TEST FACILITY

For the purpose of an extensive parametric study of heat transfer characteristics of rocks, of other solids, and of solid containers filled with fluid-of different shapes and sizes, a multy-flow cycle storage test facility is designed. The design specifications satisfy the following requirements [Fig. 1]:

Three temperature controllers regulate the three resistance heating elements of 5 KW each respectively. The electric blower with variable speeds can reach an air mass flow rate of 800-1600 cfm for a 1.0 inch of water pressure drop. The inlet temperature range to the test-section is 70^{o}-200^{o}F. The storage test section height will be variable from 2 ft. to 8 ft. Integration of the above using ducts, turning vanes, dampers, intake and outlet valves, etc., into an air tight and thermally insulated system as shown in the diagram [Fig. 1]. This design enables four different types of charge and discharge flow cycles [Fig. 2,3,4,&5].

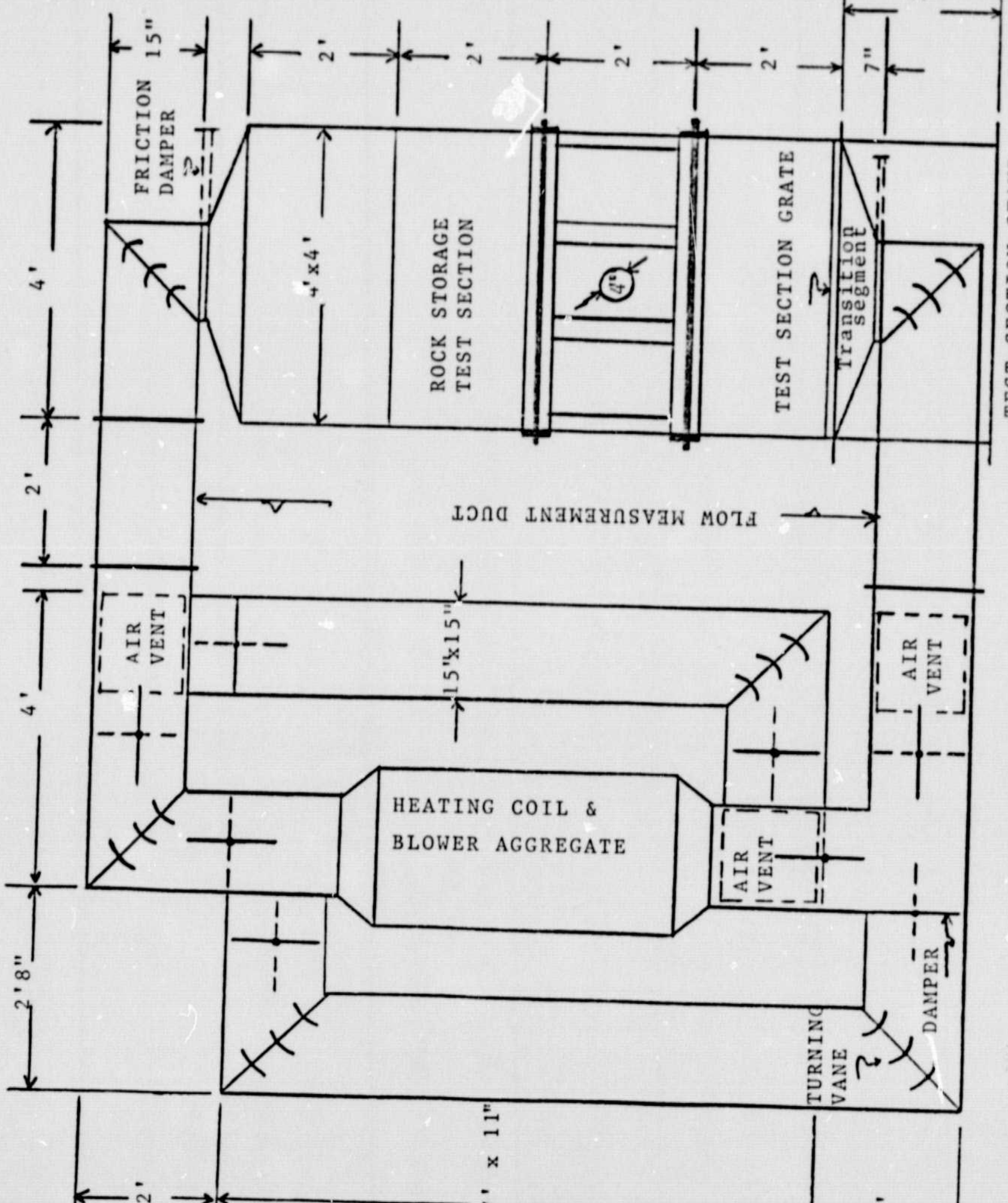


FIG. 1 ROCK STORAGE TEST FACILITY

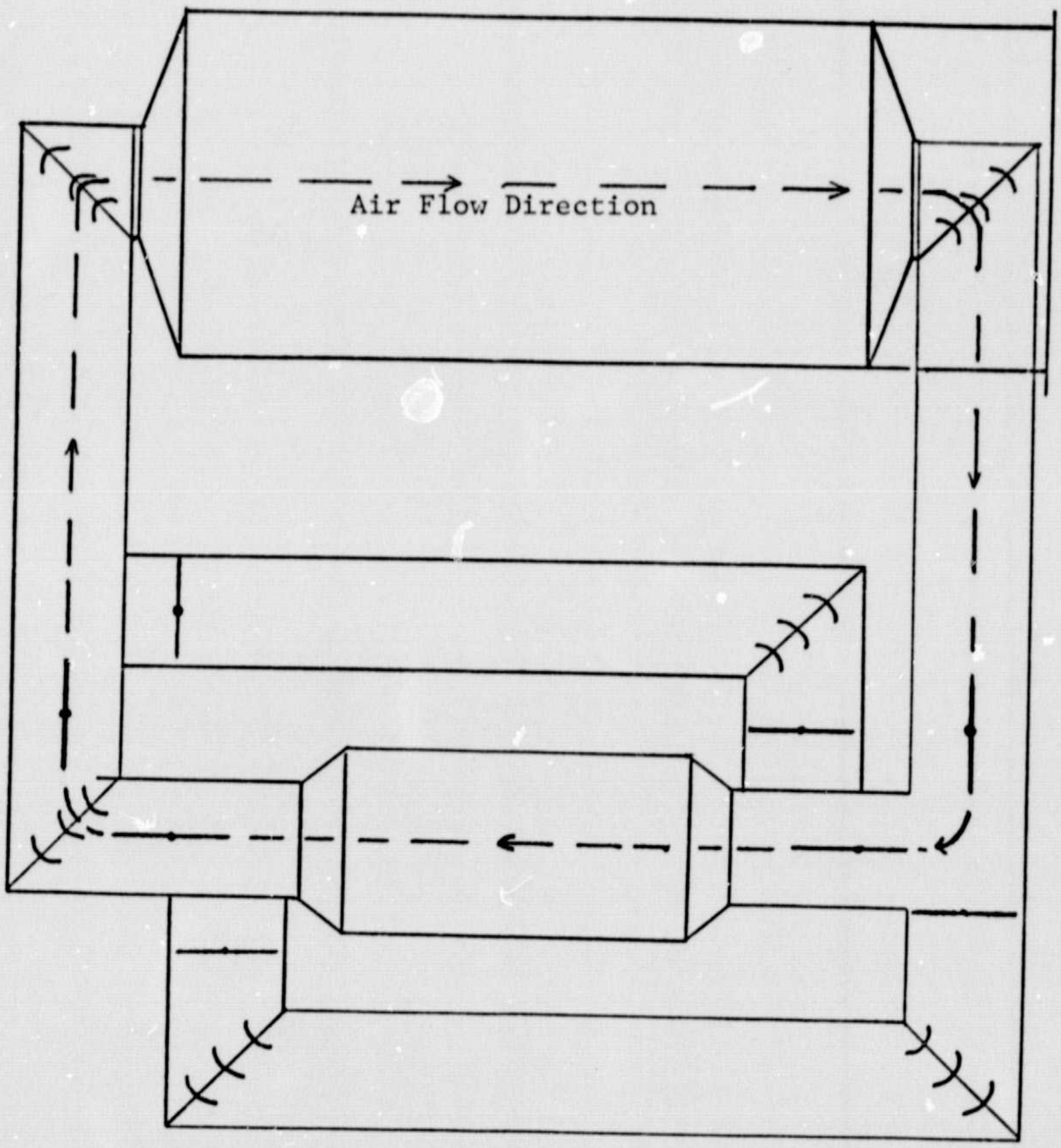


FIG. 2 CHARGING MODE 1

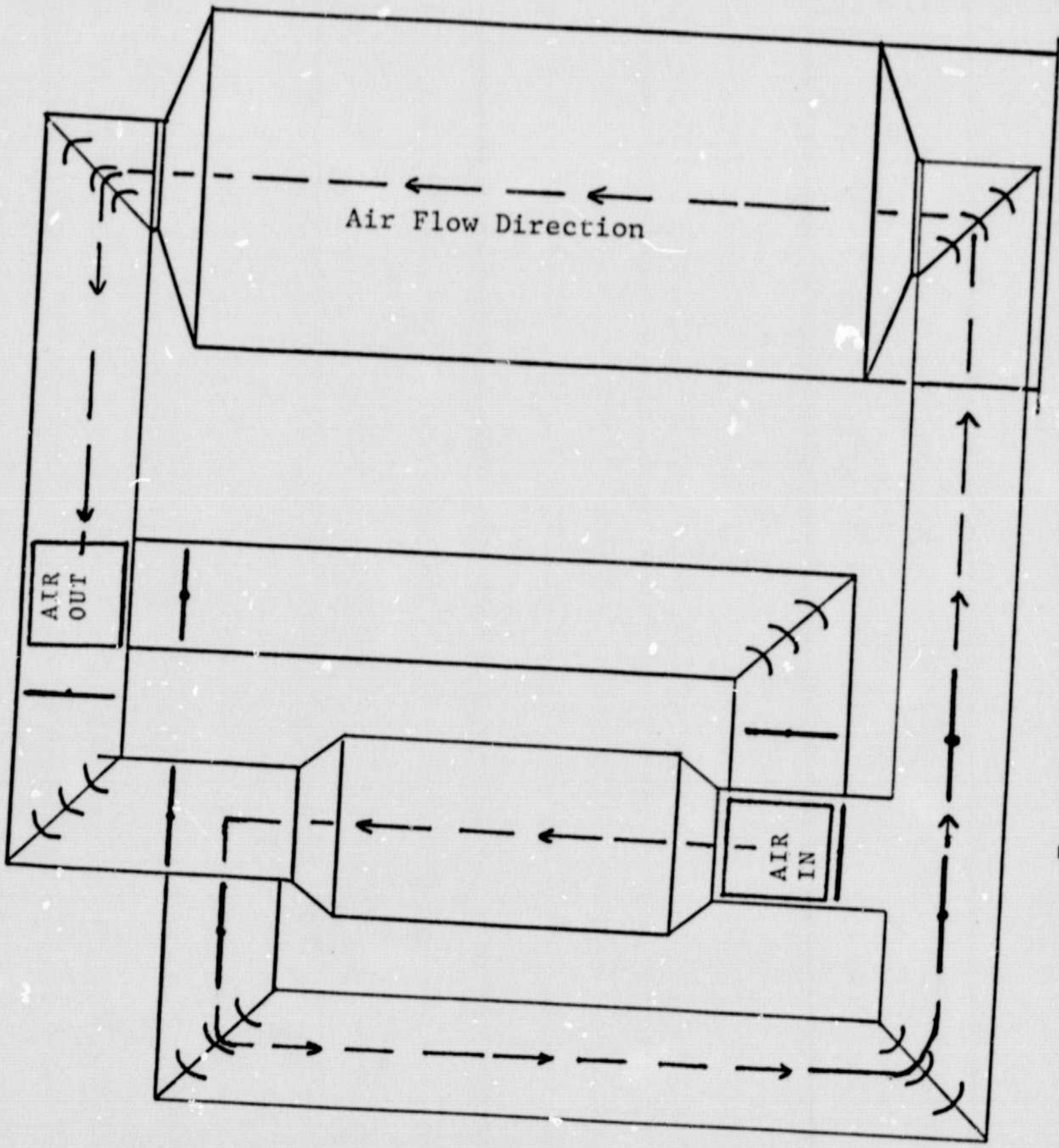


FIG. 3 DISCHARGING MODEL

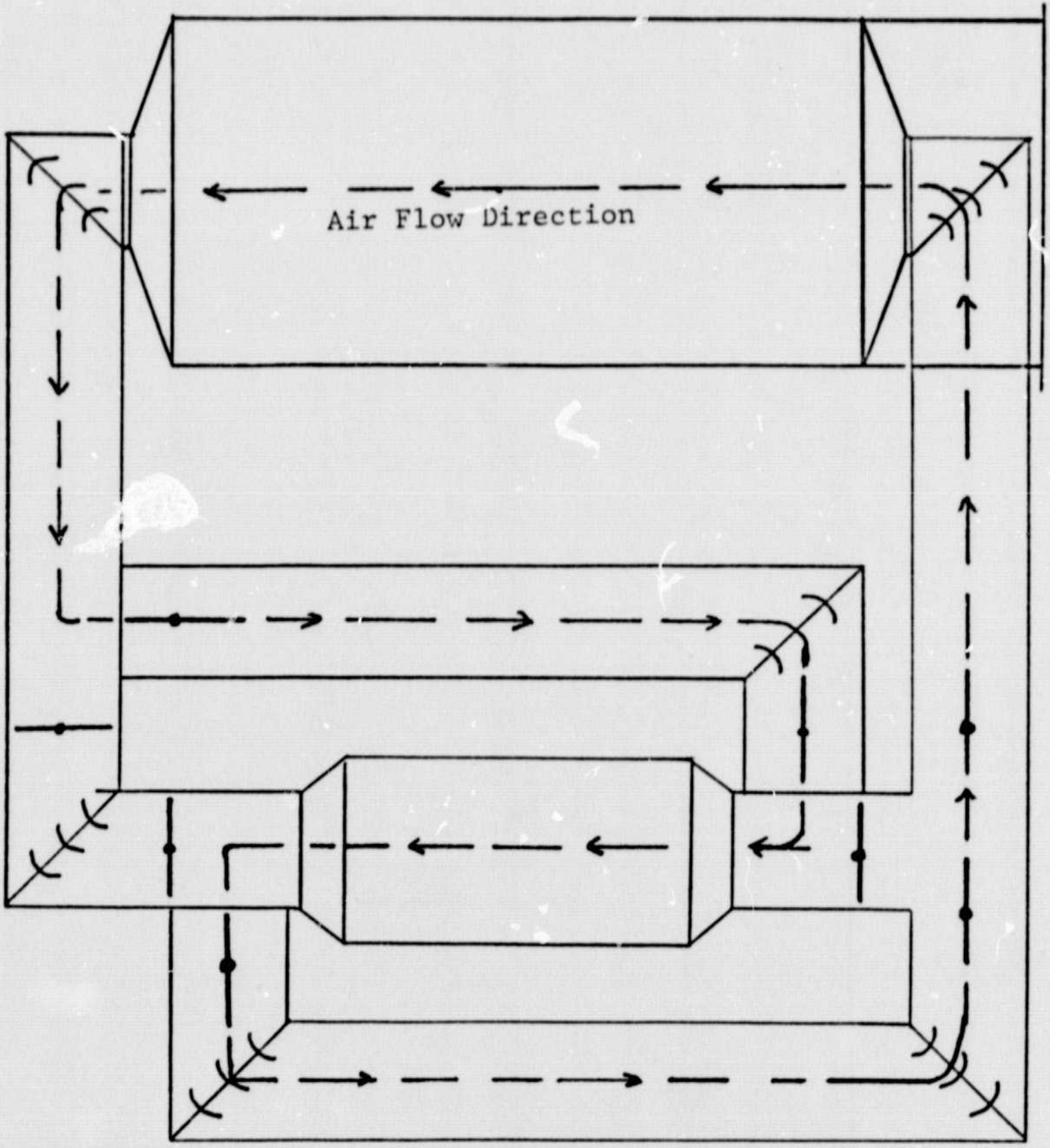


FIG. 4 CHARGING MODE 2

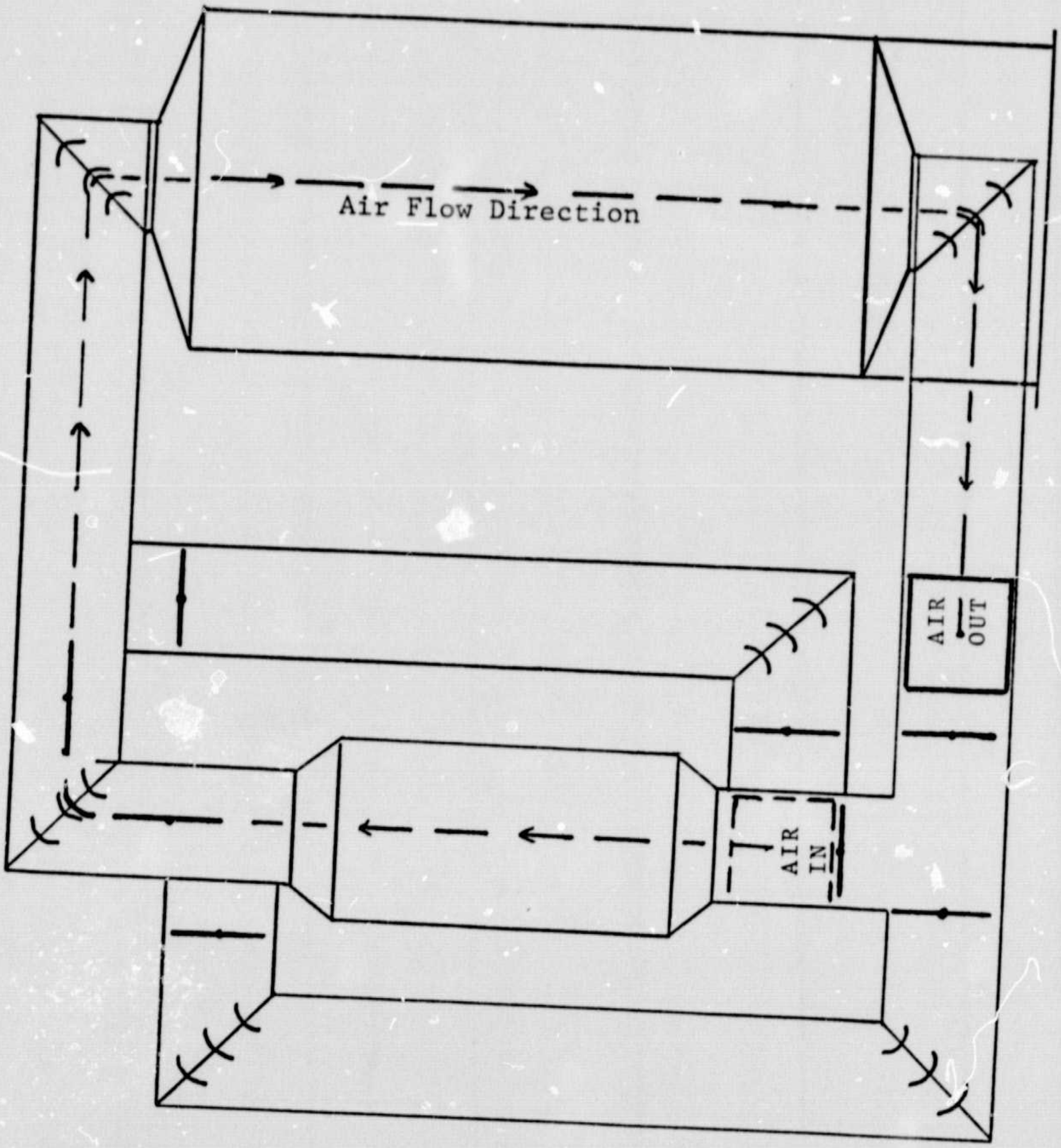


FIG. 5 DISCHARGING MODE 2

Detailed Description of the subsystems [Fig.1]

1. Rock Storage Test Section

   This section consists of four segments each of 4'x 4'x 2' ft.[3] in dimension. Each is constructed by using angle iron frame with galvanized iron sheet covering the inside. Each segment will have two 4" diameter peep holes covered with glass on opposite sides. Each test segment is insulated by 3 inches of compressed fiberglass silverlined sheets of one inch thickness. The angle iron frames are attached to each other by gasket and bolts. This will allow the total height of the test section to vary from 2 ft. to 8 ft. The angle iron frame is strong enough to hold 11,000 lbs. of rocks. Six holes of 1/8" diameter with steel tubes are used for temperature measurement devices in each segment.

2. Hot Air Handling Ducts

   The ducts are all 15" x 15" square, made out of galvanized iron sheet of lengths as given in the diagram. The total ducting is insulated by 2 layers of 1" thick compressed fiber-glass silverlined sheets.

3. Replacement Air Handling Ducts

   To replace a test segment as described in item 1) a 15" x 15" duct is used to vary the test section height without varying the total configuration. Three of these replacement ducts will be required.

4. Flow Measurement Ducts

   Two 2 ft. long removable ducts are provided as shown in the diagram for flow measurement instrumentation.

5. Test Section Grate

   A 4' x 4" steel grate of 1 inch mash size capable of holding 11,000 lbs. of rock is placed at the bottom of the lowest test segment which rests on a stand.

6. Test Section Stand

   A supporting stand made of heavy steel channels should be capable of holding the rocks and the test segments.

7. Transition Segments

   Two segments connect the 4' x 4' test segments to 15" x 15" with one each friction dampers to disconnect the airflow between the test section and the ducts.

8. Inlet & Outlet Air Vents

   Two exhausts and one inlet air vents of 15" x 15" square will be manually opened and closed for air flow.

9. Dampers and Turning Vanes

   Manually operated dampers as shown in diagram will allow the appropriate flow cycle. Industrial fixed turning vanes will reduce the pressure drop.

10. Heating Coil & Blower Aggregate

    This will house the heating coil and the blower. An in line Bell Driven Blower, catalog No. REX 14B Penn Centrex Fan CFM operating range 800/1600 cfm for 1" of water pressure drop with a Dayto Electric 1½ H.P. motor and assortment of pulleys for the operating range above, is used to generate the required air flow.

An industrial resistence heating aggrigate with three 5 KW each heating elements is used to regulate the appropriate inlet temperature.

Instrumentation

The following measurements of temperature, pressure, and flow velocity at different locations of the test system are considered for testing water filled cans as thermal storage medium [Fig.6].

1. Temperature Measurements

Copper-Constantan thermocouples (Type T) are used to measure temperature of air, water, and surfaces according to the following scheme. A multipoint Data Logging System, Doric Scientific Corp. Model 210-60-05-kl, SN 14965 with a thermocouple reference Junction, Pace Engineering Model BRJR 185-60PP-1401 is used to measure and record the temperature in milivolt equivalent form.

a. Air temperature probes will be placed at the following system coordinates:

(1) Top (0,1,0), (1.5,1,0) (-1.5,1,0)
(0,1,1.5),(0,1,-1.5)

(2) Center (0,0,0), (1.5,0,0), (-1.5,0,0)
(0,0,1.5), (0,0,-1.5)

(3) Bottom (0,-1,0), (1.5, -1,0), (-1.5,-1,0)
(0,-1,1.5), (0,-1,-1.5)

(4) Duct to bed

(a) Inlet (0,2,0)

(b) Outlet (0,-2,0)

(5) Plenum

(a) (0,1.5,1)

(b) (0,-1.5,1)

(6) Outside and Inside wall cermperature @ (2,0,0)

b. Can Surface temperatures at the following system coordinates:

Location	Coordinate
Top can, top outside surface	(0,1,0)
Top can, inside surface	(0,1,1)
Top can, bottom outside surface	(0,1,0)
Bottom can, top outside surface	(0,-1,0)
Bottom can, bottom outside surface	(0,-1,0)
Bottom can, bottom lid inside surface	(0,-1,1)

c. H_2O inside can temperatures at the following system coordinates:

(1) Top	(0,1,0), (1.5,1,0)
(2) Center	(0,0,0) [Can center inside surface, 1/4 can diameter, 1/2 can diameter], (1.5,0,0)
(3) Bottom	(0,-1,0), (1.5,-1,0)

d. Room air temperature

e. Electric heat strip on-time.

2. Pressure Difference Measurement

Two average pressure drops, one across the test bed and the other across heater-blower unit are measured using two inclined nanometers, Dwyer model 1227 Dual-Range Flex Tube Manometer.

3. Inlet and Outlet air velocities are measured by a flow-meter of 2% accuracy, Alnor 6000 AP velometer.

Thermal Storage Medium

Two types of thermal storage mediums will be tested.

a. Water filled metal cans.

Soup cans with noncorrosive inner lining of the following measurements and quantity have been acquired from Sweet Sue Kitchens:

5280 of 2.75" dia. x 3.00" length, L/D = 1.09
3960 of 2.75" dia. x 4.00" length, L/D = 1.45
2340 of 4.4" dia. x 3.55" length, L/D = 0.807
1080 of 4.4" dia. x 7.0" length, L/D = 1.59

b. Rocks.

Five different types of rocks of 1"-2" of average diameter with following properties will be used:

Solids	Specific Gravity	Thermal Conductivity [Btu/hr.ft.^{o}F]	Average Density [lb/ft^{3}]	Specific Heat [Btu/lb^{o}F]
Granite	2.65-2.8	1.08-2.33	165-172	0.19-0.22
Lime stone	2.7	0.33-0.75	167-171	0.2-0.22
Dolomite	2.7-2.8			0.2-0.22
Traprock	2.8-3.15			0.19-0.22
Sandstone		0.67-1.33	134-147	0.17-0.22

TEST PLAN

The test conditions and plan for water filled cans are given below:

1. Bed heights - Tests are to be conducted with three heights within the test bed; these are 2,3, and 4 feet. The tests start with a bed heights of 2 feet, than incrementing the bed with a 2-foot section to reach 4 feet.

2. Test will be conducted with can diameters of 2.75 inches, 4.4 inches with L/D ratios of 1.45, and 1.59 for the 2.75 inch cans and 0.807 and 1.09 for the 4.4 inch diameter cans, respectively.

3. Bed loading (i.e., longitudinal can dimensional orientation)

a. Random Placement of Cans

b. Close Packed Vertical Placement of Cans

c. Close packed Horizontal Placement of Cans

4. Storage Charging Tests

The following is a list of required tests with associated bed configuration and thermal/flow input requirements.

Test No.	Can Orientation	Can Size Dia. (in)	L/D	Total Bed Flowrate (CFM)	Bed Entering Air Temp. (^oF)
1	Random	2.75	1.45	800	90
2	Random	2.75	1.45	800	110
3	Random	4.4	1.59	800	110
4	Random	4.4	.807	800	110
5	Random	2.75	1.09	800	110

6	Vertical	2.75	1.45	800	110
7	Horizontal	2.75	1.45	800	110
8	Random	2.75	1.45	800	110
9	Random	2.75	1.45	800	150
10	Random	2.75	1.45	1200	90
11	Random	2.75	1.45	1200	110
12	Random	4.4	1.59	1200	110
13	Random	4.4	.807	1200	110
14	Random	2.75	1.09	1200	110
15	Vertical	2.75	1.45	1200	110
16	Horizontal	2.75	1.45	1200	110
17	Random	2.75	1.45	1200	110
18	Random	2.75	1.45	1200	150
19	Random	2.75	1.44	1600	90
20	Random	2.75	1145	1600	110
21	Random	4.4	1.59	1600	110
22	Random	4.4	.807	1600	110
23	Random	2.75	1.09	1600	110
24	Vertical	2.75	1.45	1600	110
25	Horizontal	2.75	1.45	1600	110
26	Random	2.75	1.45	1600	130
27	Random	2.75	1.45	1600	150

5. Storage Heat Loss Tests

At the conclusion of storage charging test noted below, when the bed has become fully charged and stabilized at 150° F, temperature measurements will be made at a constant inlet temperature and flowrate to determine the overall heat transfer coefficient-area product, UA, of the bed.

Test No.	Initial Storage Charging Test No.
28	9
29	18
30	27
30A	3
30B	12
30C	21

6. Storage Discharge Test (i.e. Removing Heat from Bed)

At the conclusion of the indicated charging tests the following discharge tests will be conducted using ambient air as bed inlet media.

Test No.	Initial Storage Charging Test No.
31	1
32	6
33	7
34	11
35	15
36	16
37	24
38	25
39	26
40	3
41	12
42	21
43	4
44	13
45	22
46	5
47	14
48	23

7. General Test Requirements

a. Both the storage charging and discharge tests will conclude when the bed outlet temperature gradient is equal to or less then $1^{o}F$ per hour.

b. As a result of initial test evaluations, other test may become necessary during the course of this test program. These requirements will be determined in real time.

8. Test Sequence

The following test sequence will be followed for the solar energy storage via liquid filled cans.

Test Schedule for Each of the Bed Heights: 2',3', & 4'.

Can Size	Can Arrangement		
Dia. (in) L/D	Random	Vertical	Horizontal
2.75/1.45	1,31;	6,32;	7,33
	2;	15,35:	16,36
	8;		
	9,28;	24,37;	25,33
	10;		
	11,34;		
	17;		
	18,29;		
	19;		
	20;		
	26,39;		
	27,30;		
4.4/1.59	3;40,30A		
	12;41,30B		
	21;42,30C		
4.4/0.807	4; 43		
	13; 44		
	22; 45		
2.75/1.09	5; 46		
	14; 47		
	23' 48		

PRELIMINARY TEST RESULTS

The test facility became operational from the beginning of June 1977. Since then several runs were taken to check-out the test facility and the test procedure. Finally, several test runs were taken according to the test schedule. These test covered the charging, storage, and discharge operating modes, and was conducted for various combinations of inlet flow temperature and mass flow rate using 2.75-in. dia. by 4-in. long water filled cans randomly oriented in a 2-feet height by 4x4 feet square storage bed and the following detailed description:

Storage bed height = 2 [ft.],

Storage bed and plenum volume = 40 [ft^3]

Storage bed Surface Area = 64 [ft^2]

Storage medium = Water filled cans of 2.75 [in.] dia. by 4 [in.] long; L/D = 1.45,

Can Orientation = Random

Can surface Area=46.42 [$in.^2$] = 0.322 [ft^2]

Weight of H_2O in a can = 0.6438 [lb.]

Empty weight of each can = 56 [grams] = 0.12348[lb.]

Volume of a can = 23.758 [in^3] = 0.013748 [ft^3]

H_2O mass/surface Area = 1.9964 [lb/ft^2]

Total number of cans = 1310

Total weight of empty cans = 161.758 [lb.] Mcan

Total weight of H_2O in cans = 843.378 [lb] = M H_2O

Total weight of h_2O + cans = 1005.136 [lb]

Void Fraction = (1-Total Volume of cans/Total Volume of Bed)

= 0.4372 [Void]

Specific heat of H_2O = 1.0 [Btu/lb^oF] = Cp_{H_2O}

Specific heat of metal can = 0.11 [Btu/lb^oF] = Cp_{can}

Apparent Specific heat of storage medium =

$$= (Cp_{H_2O}\, MH_2O + Cp_{can} M_{can}) / (M_{H_2O} + M_{can})$$

$$= 0.8567 \quad [Btu/16^oF]$$

The energy supplied to the system is through 15 KW electric heat strip.

a. The Figures 7 through 13 represent parametrically the system's reaction during a charging mode with thermostat set to maintain a maximum bed inlet temperature of 142^o F and a mass flowrate of - 1075 CFM with a pressure drop across bed of 0.06 in. of water. From these graphs it is evident that:

1. When the H_2O mass within the bed has reached a maximum temperature as determined by the air inlet set point temperature (142^{o}F) there is only 3^{o}F vertical stratification across the H_2O mass within the bed.

2. The maximum usable energy stored in the bed is Q total = $\bar{C}p_{H_2O+can} M_{H_2O+can} \Delta T_{H_2O} \sim 5.08 \times 10^4$ Btu. This occurred at the end of 2 hr 10 min charging period with a total of 1005 lbs of storage medium.

3. Figure 9 represents the horizontal temperature gradient between the air flow and the water in a can located at the center of the storage bed. The inside can film coefficient (h_i) for the center can using this experimental data was found to be $\sim$ 57 (Btu/hr-ft^2 ^oF).

4. The apparent vertical average air temperature gradient across the bed was ∿ 33 °F up to ∿ 45 minutes into the run, then as the air and water temperature began to converge, this value decreased to ∿ 15 °F at completion of the run.

5. An apparent U-value derived using experimental data for this configurational mode is ∿ 12 (Btu/hr.-ft^2°F). This was derived using the total energy stored in the bed per unit time ($Q=MC_p\Delta T$) and the U-value was then derived using can surface area, ΔT's, film coefficients ho and hi between the air stream, can surface, and inside can H_2O temperature. U= (1/(1/ho + 1/hi)), where ho and hi are the outside and inside can film coefficients respectively.

b. Figures 14 through 17 represent parametrically the system's reaction when the system is charged up with all dampers closed off (the storage mode) and allowed to sit for ∿ 68 hours. From these graphs the following data is evident:

1. The average bed temperature dropped ∿ 37°F.

2. The bed energy drop corresponding to the temperature drop is 3.18×10^4 Btu's.

c. Figures 18 through 20 show the applicable parameters for bed discharge mode with constant temperature ∿ 82.5 [°F] room air as inlet fluid and a flowrate of ∿ 520 CFM at 0.04 in. of water pressure drop across bed, The time required to discharge the bed from ∿ 105 °F to ambient temperature (∿82.5°F) is ∿ 3 hours. The trends presented from this test are representative of the test bed characteristics while operating in the various modes.

It is recognized that the data utilized to derive these curves contain abnormalities resulting from equipment and personnel recordings. Future tests, however, will be conducted with improved recording equipment and additional instrumentation that will minimize the error margins and, thus, produce data of greater reliability. Data from this test will be used in comparison with future tests to select the best can size, orientation, to develop bed parameterization and to check the effectiveness of this type against the performance of other competitive storage systems.

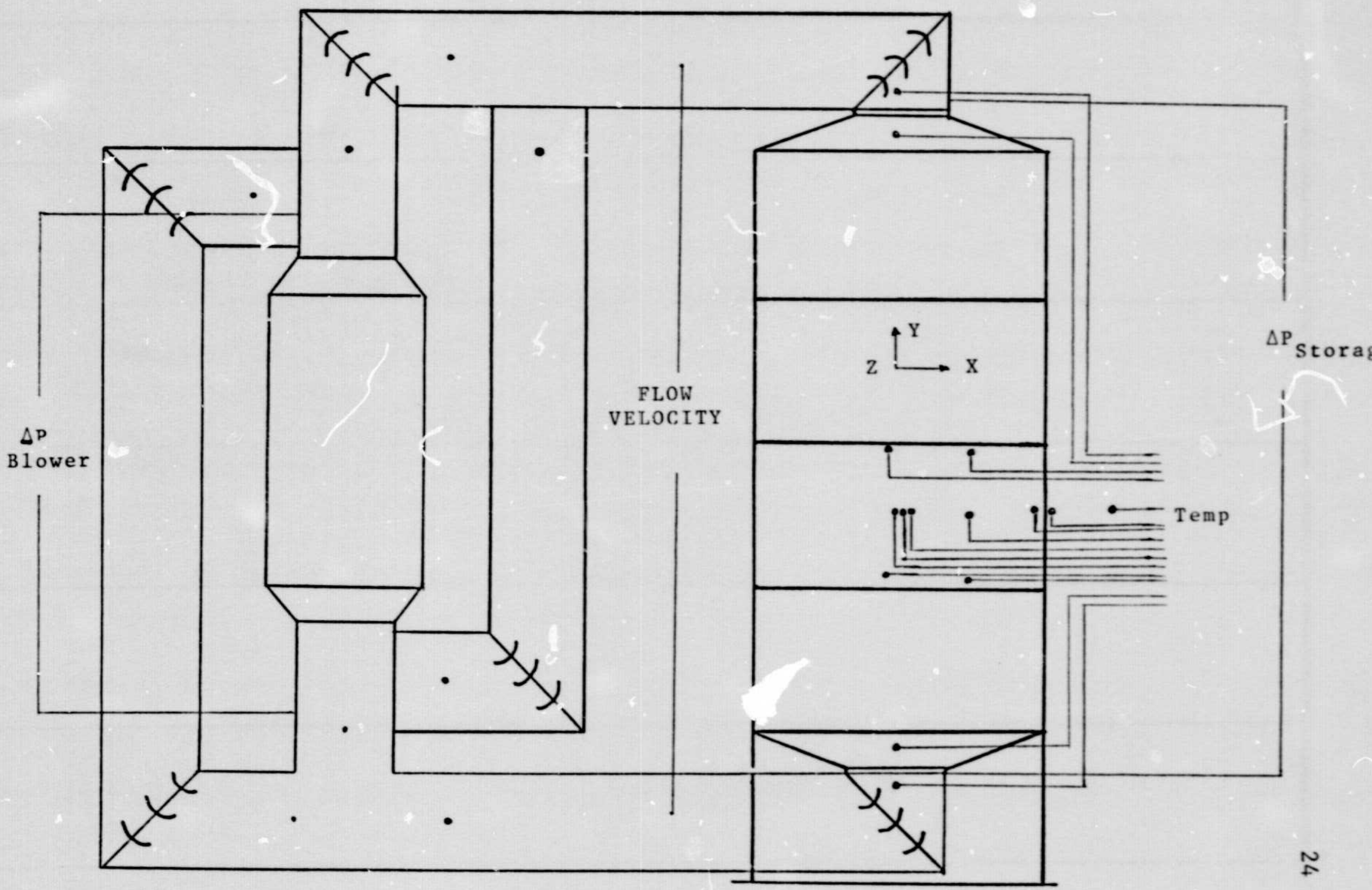
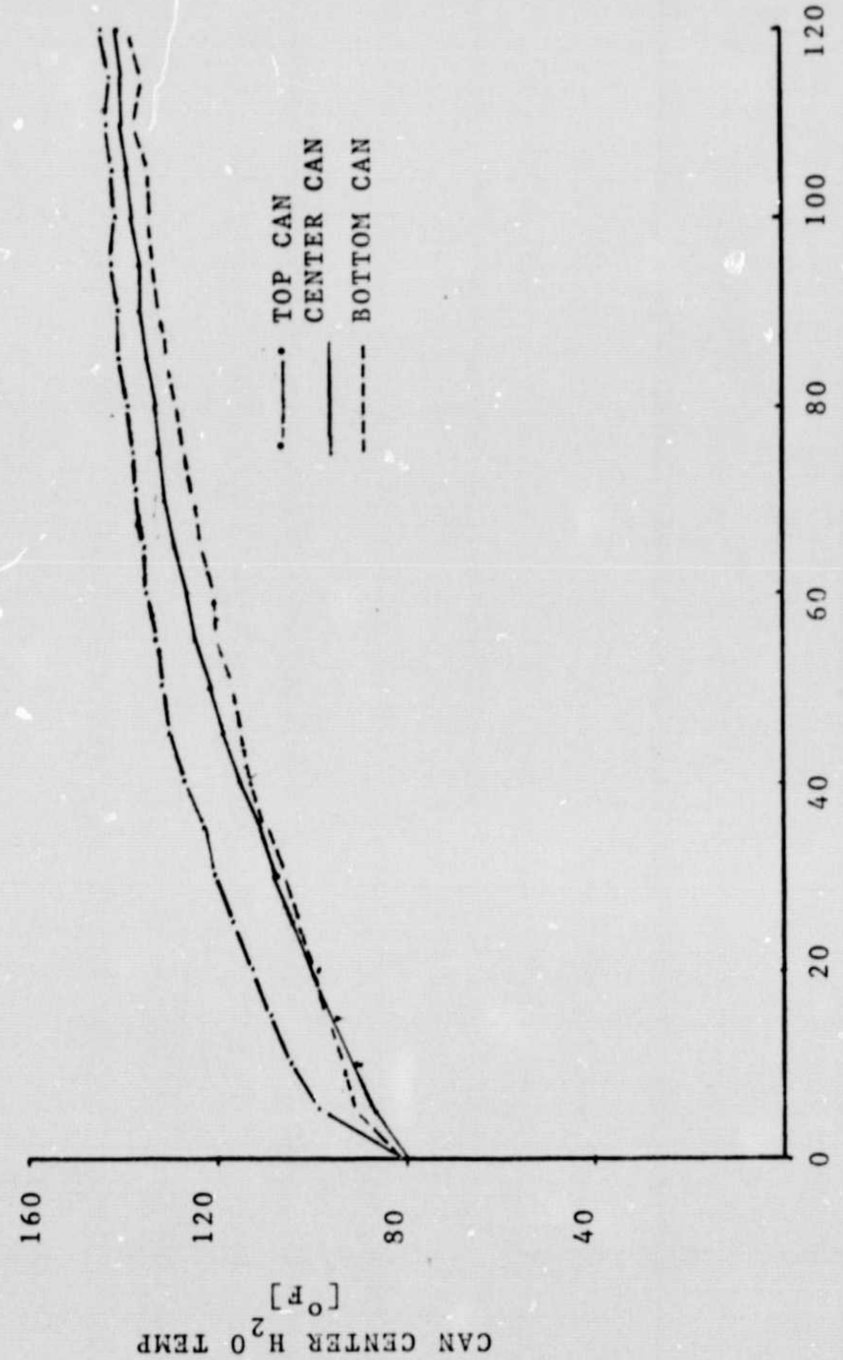


FIG. 6. GENERAL INSTRUMENTATION

Fig. 7 H_2O TEMP AT CAN CENTERS WITH TIME, CHARGING MODE



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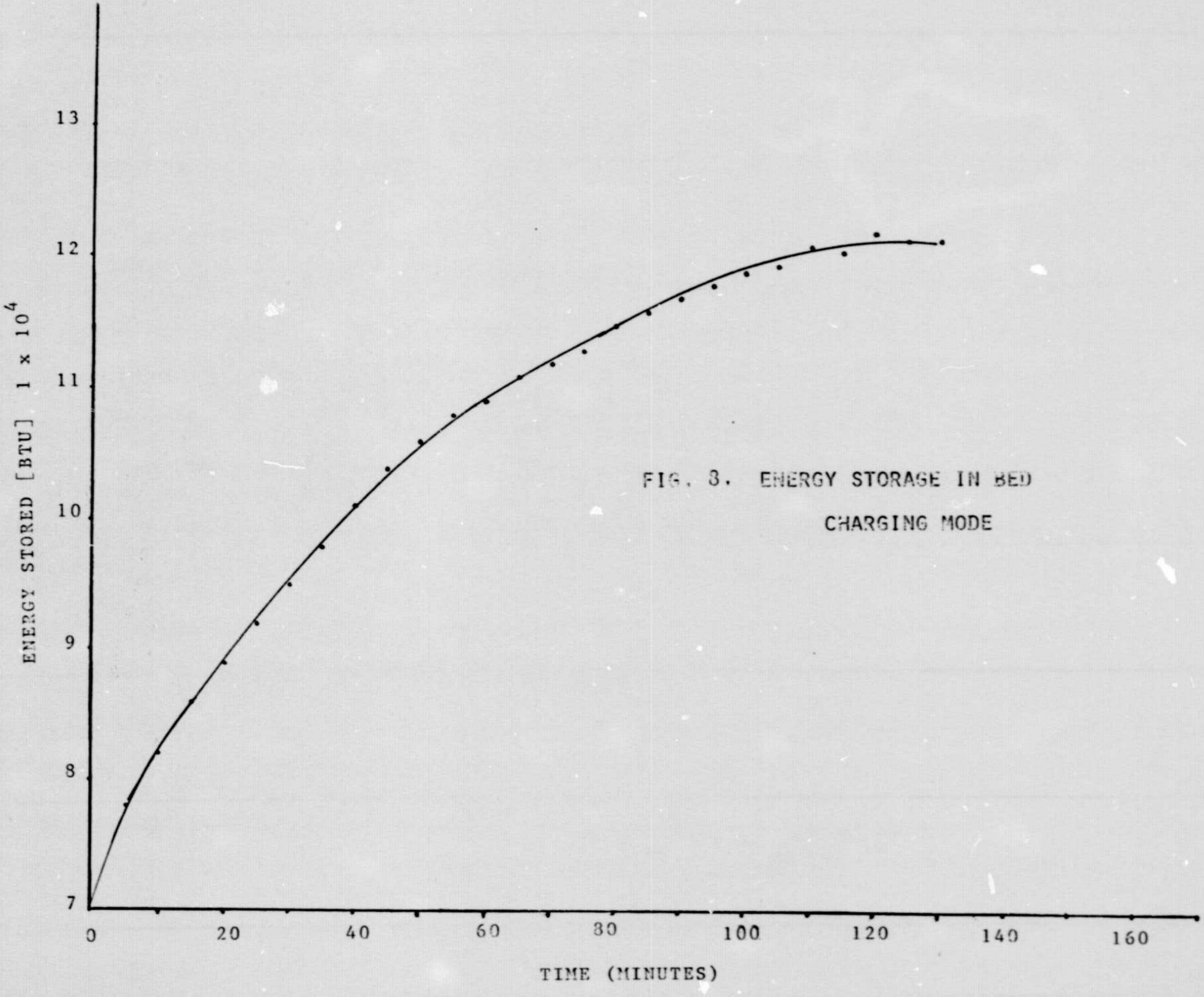


FIG. 8. ENERGY STORAGE IN BED
CHARGING MODE

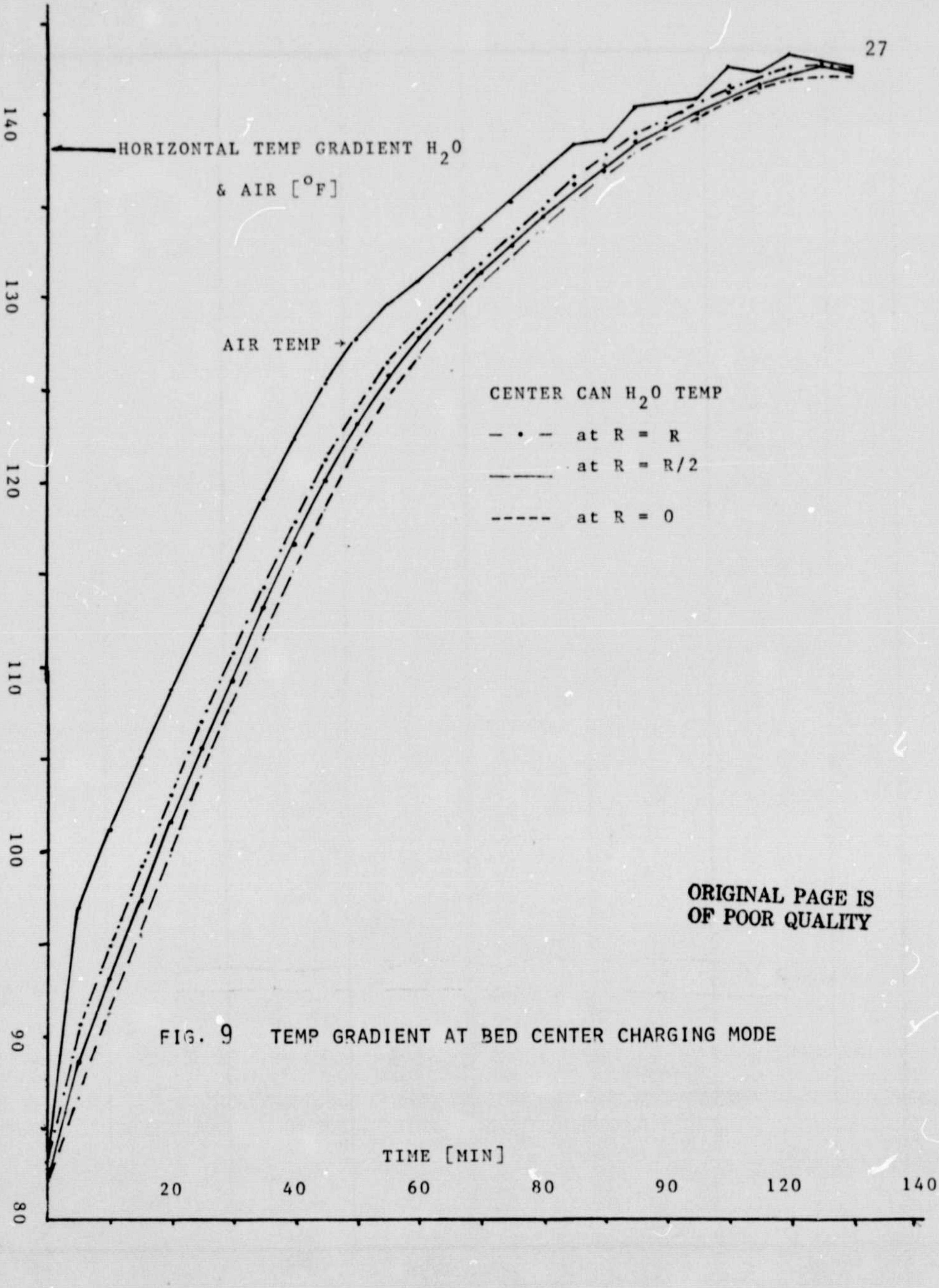
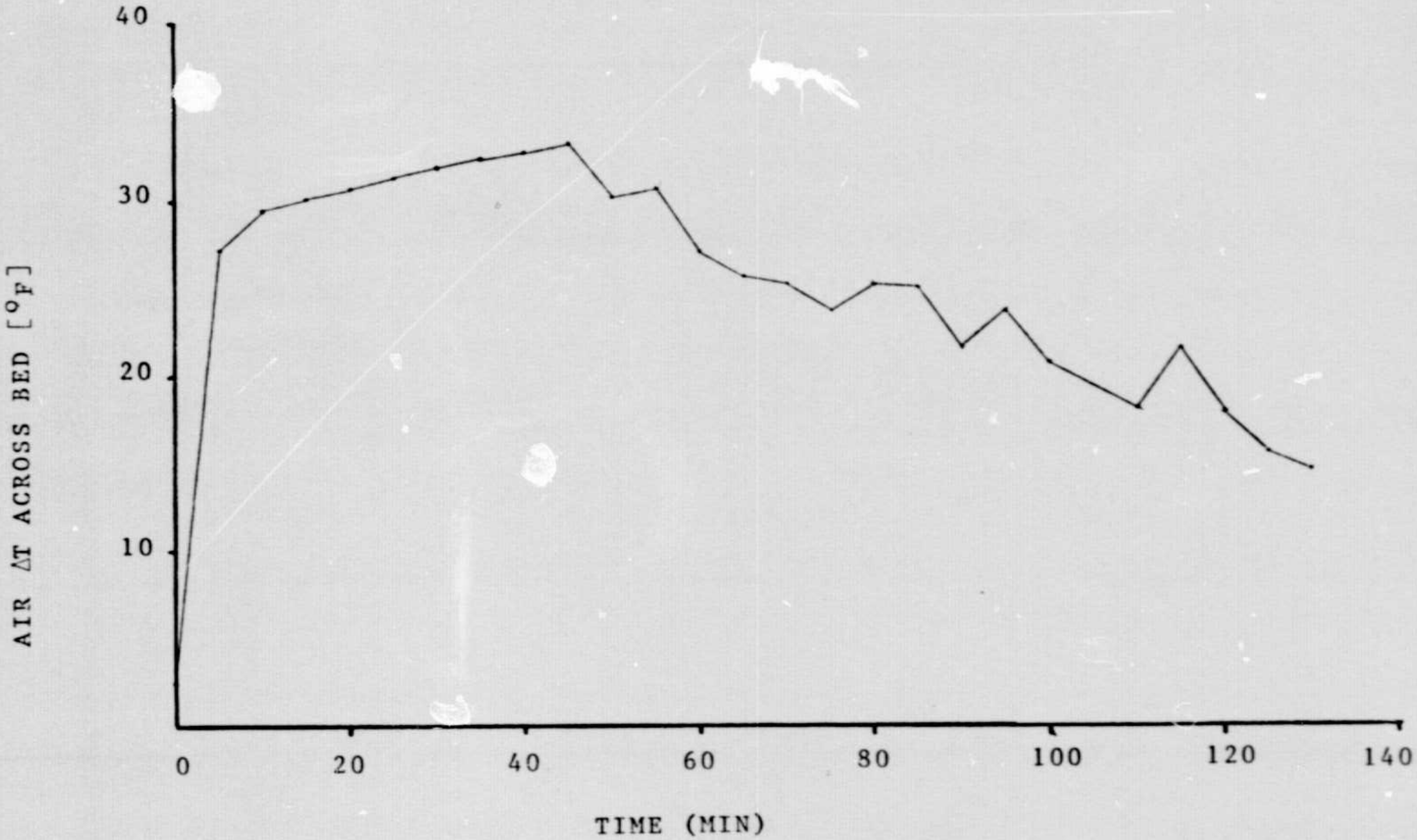


FIG. 9 TEMP GRADIENT AT BED CENTER CHARGING MODE

Fig. 10 VERTICAL AIR TEMPERATURE GRADIENT ACROSS BED
CHARGING MODE



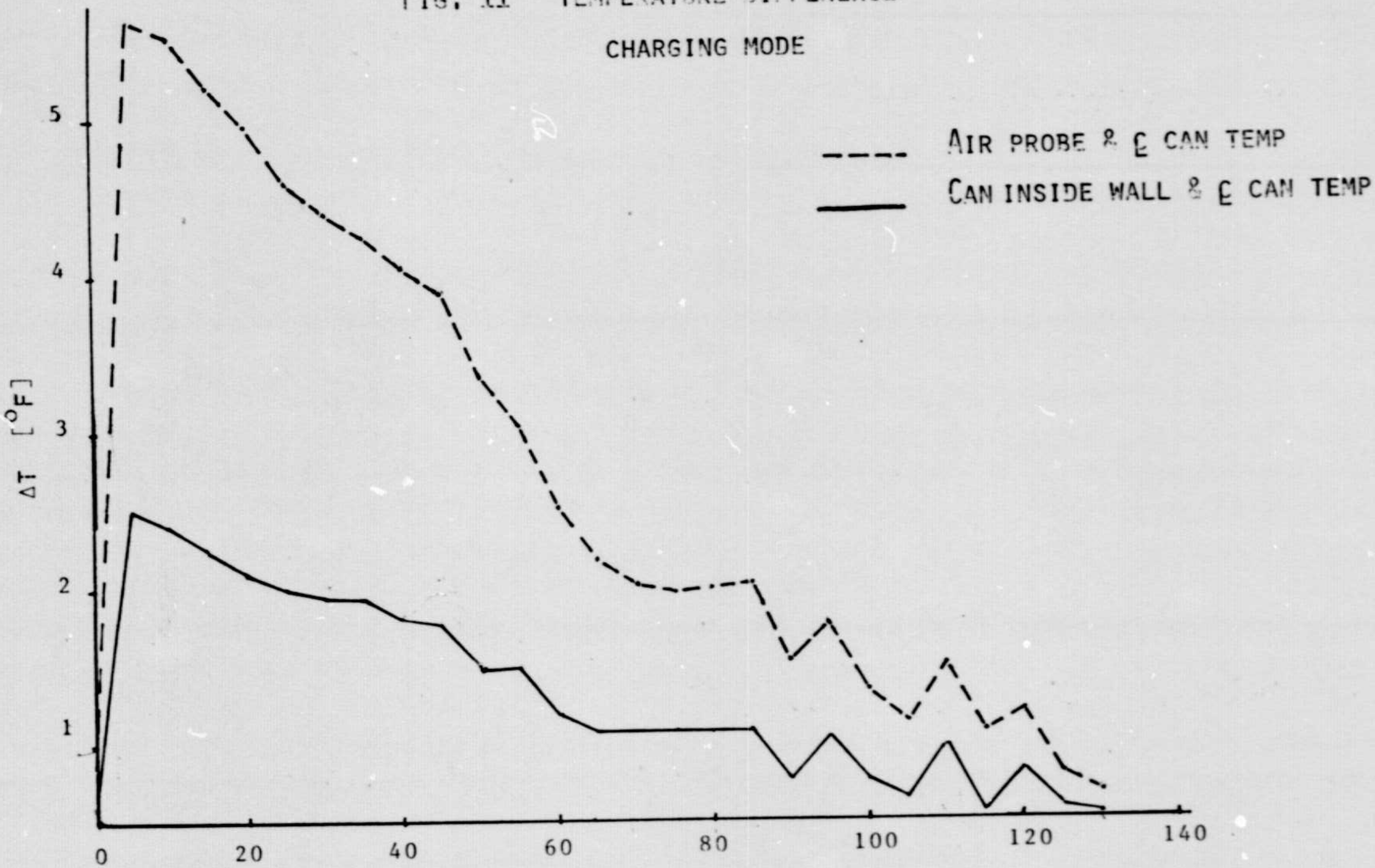


FIG. 11 TEMPERATURE DIFFERENCE

CHARGING MODE

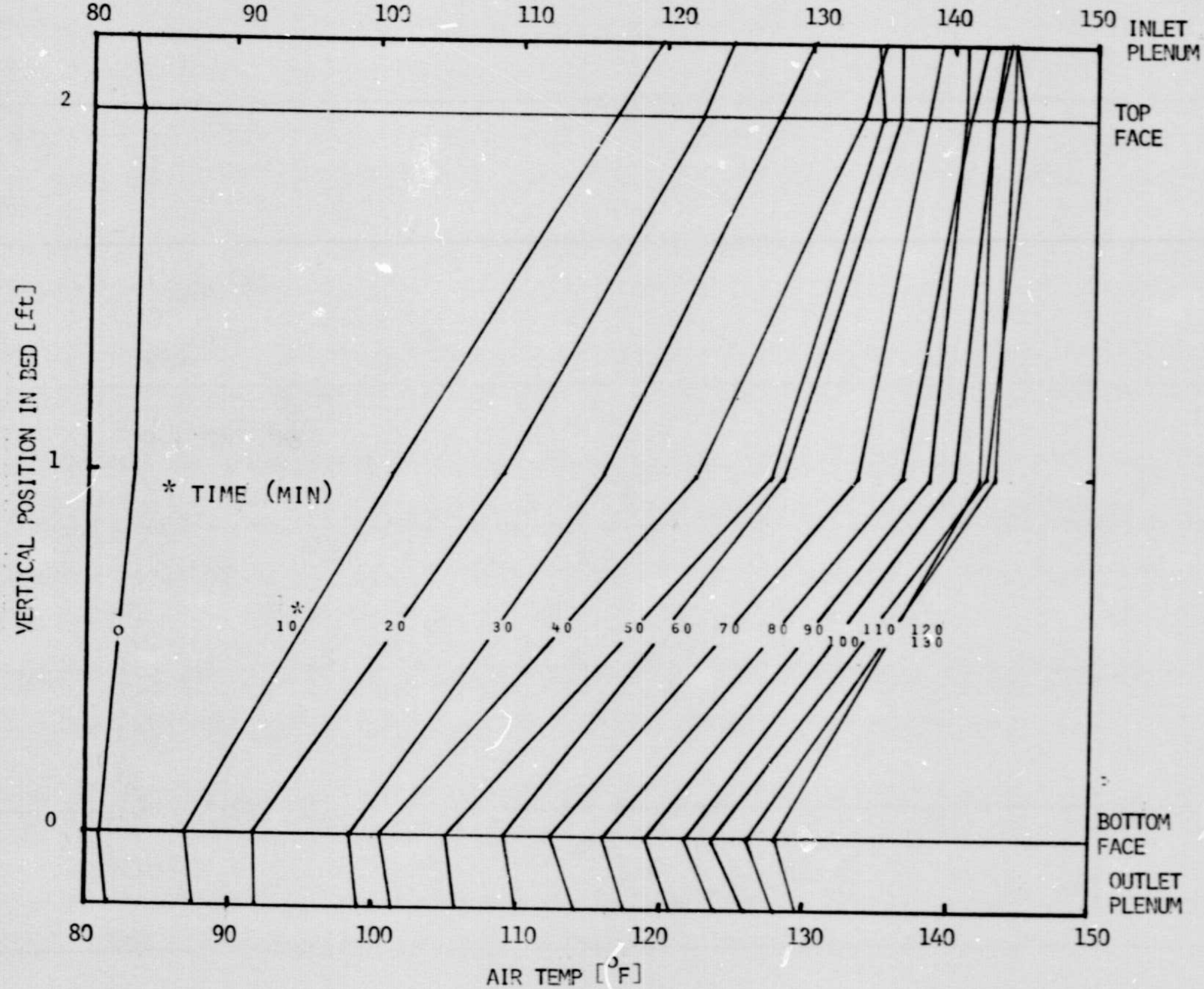


FIG. 12. AIR TEMPERATURE PROFILE IN BED, CHARGING MODE

FIG. 13. ΔT ACROSS CAN SURFACE

CHARGING MODE

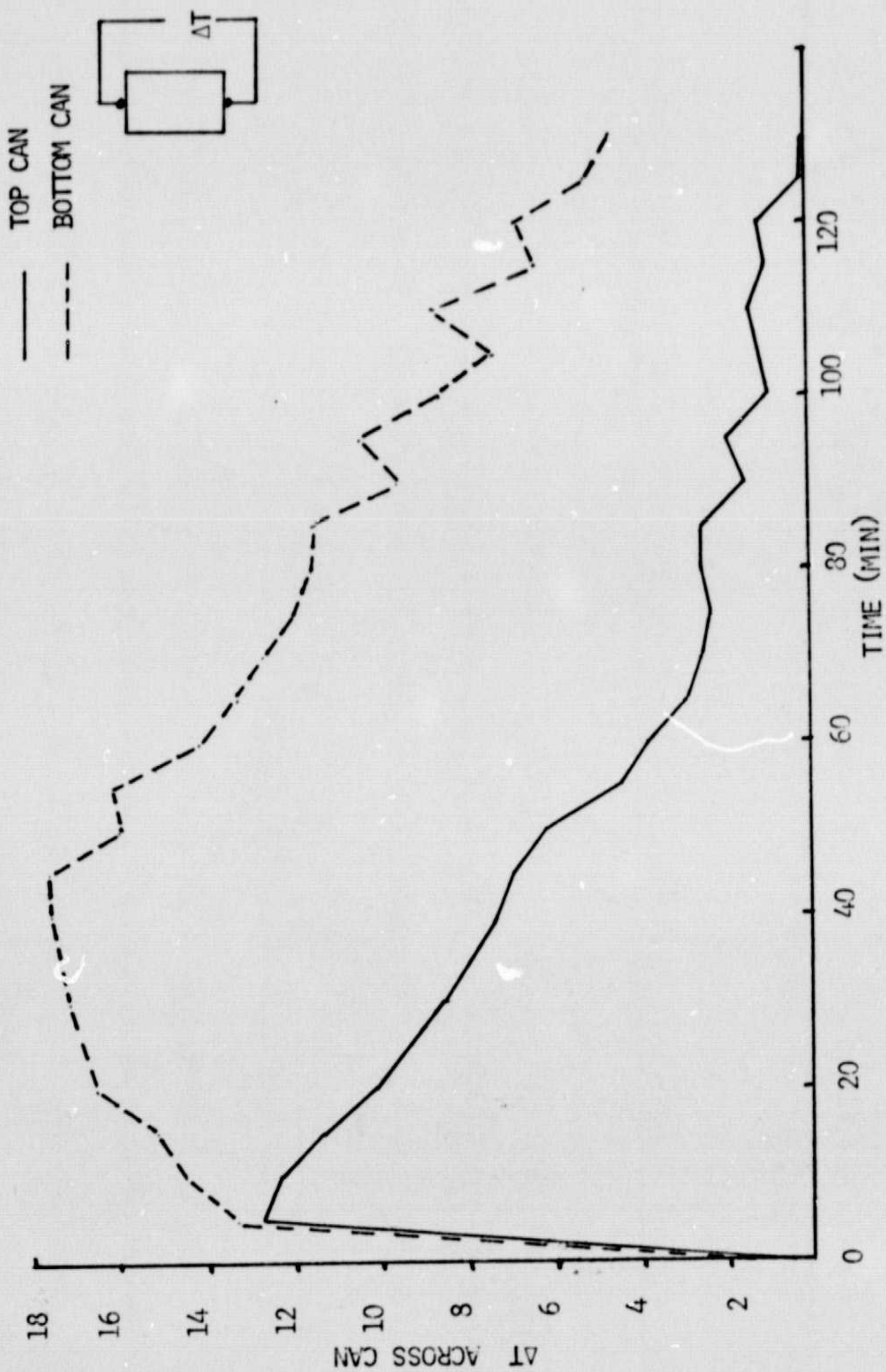
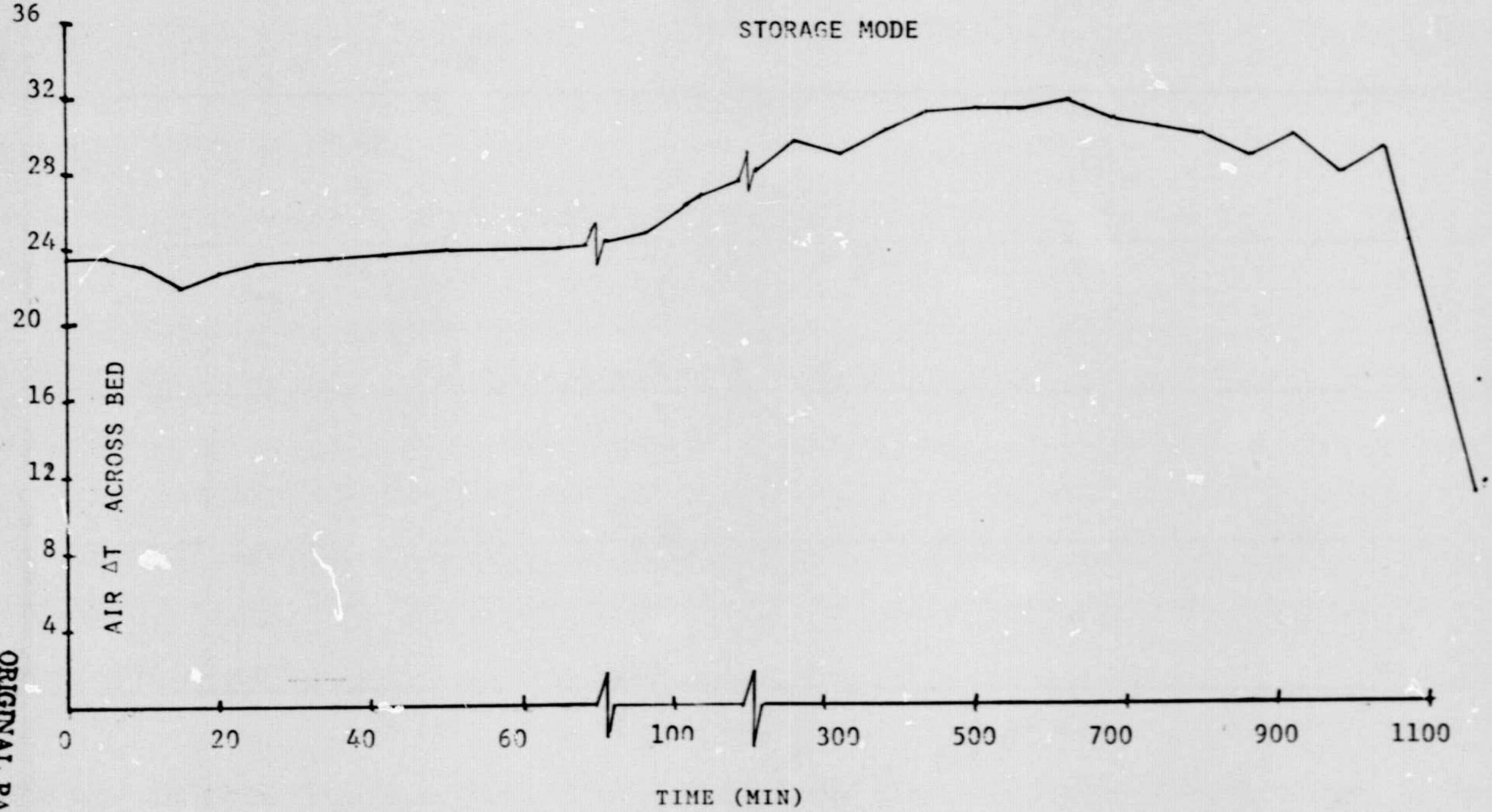


FIG. 14. VERTICAL AIR TEMPERATURE GRADIENT ACROSS BED

STORAGE MODE



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OF POOR QUALITY

FIG. 15. CAN ℄ H_2O TEMPERATURE

STORAGE MODE

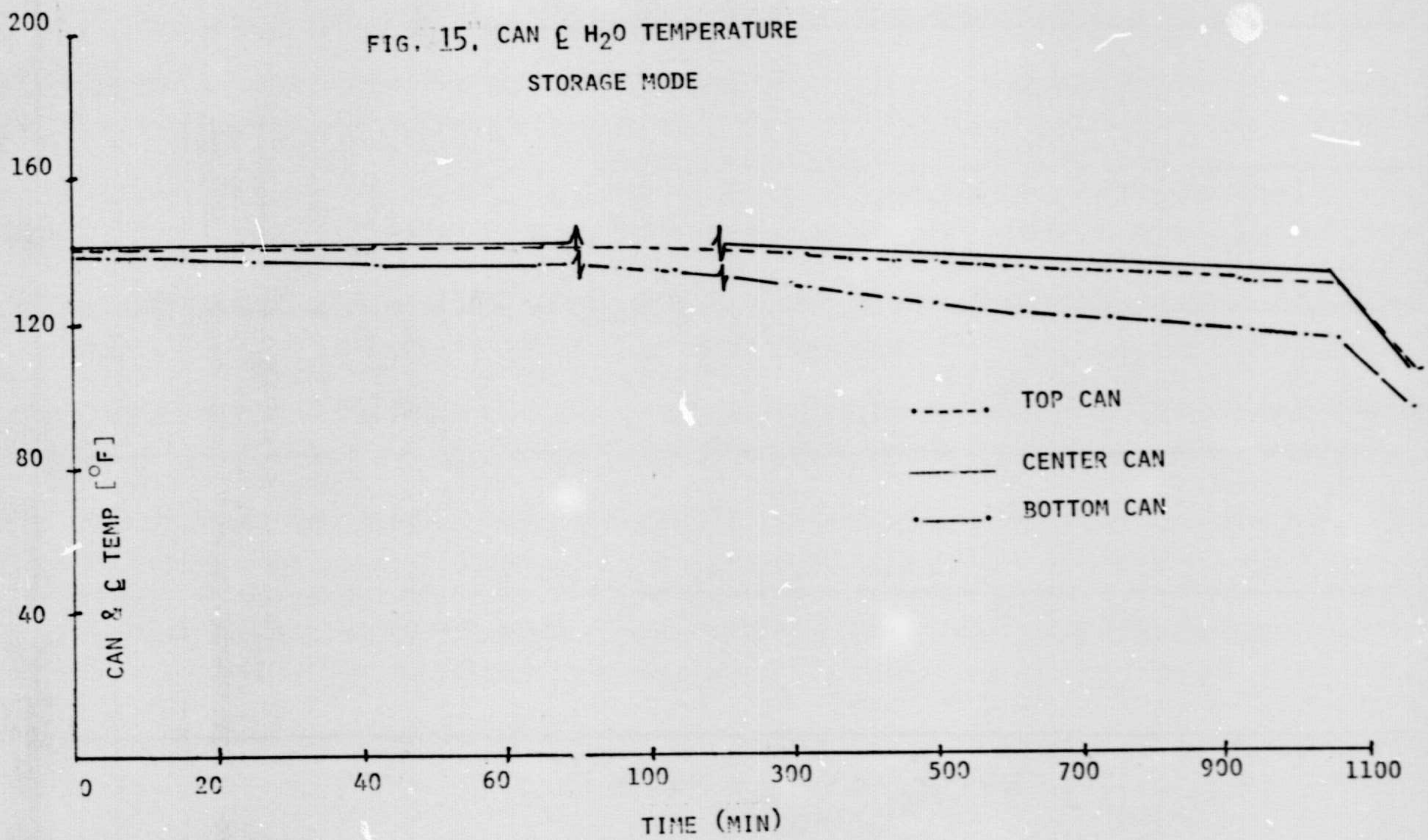
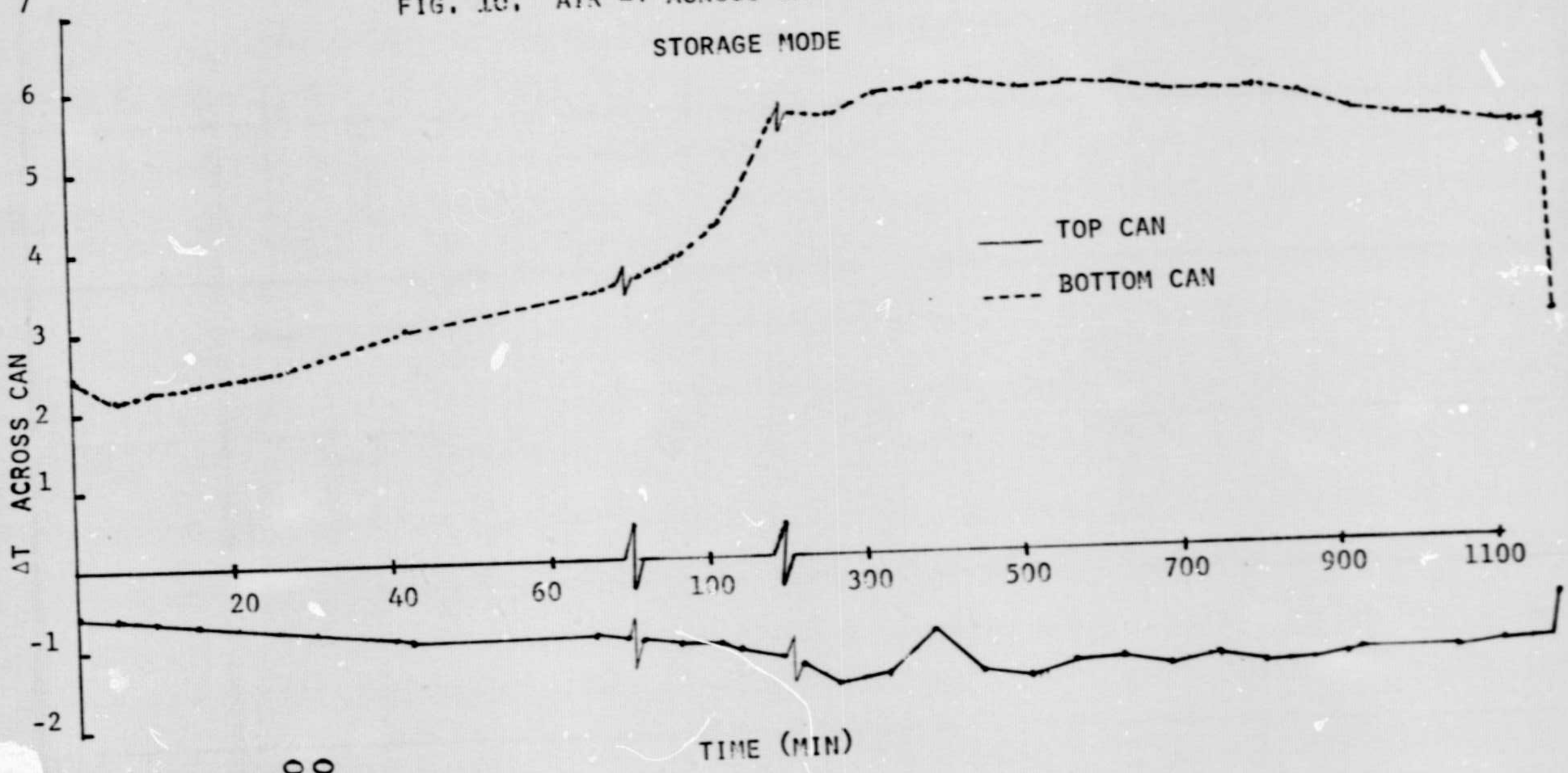


FIG. 16. AIR ΔT ACROSS CAN SURFACE

STORAGE MODE



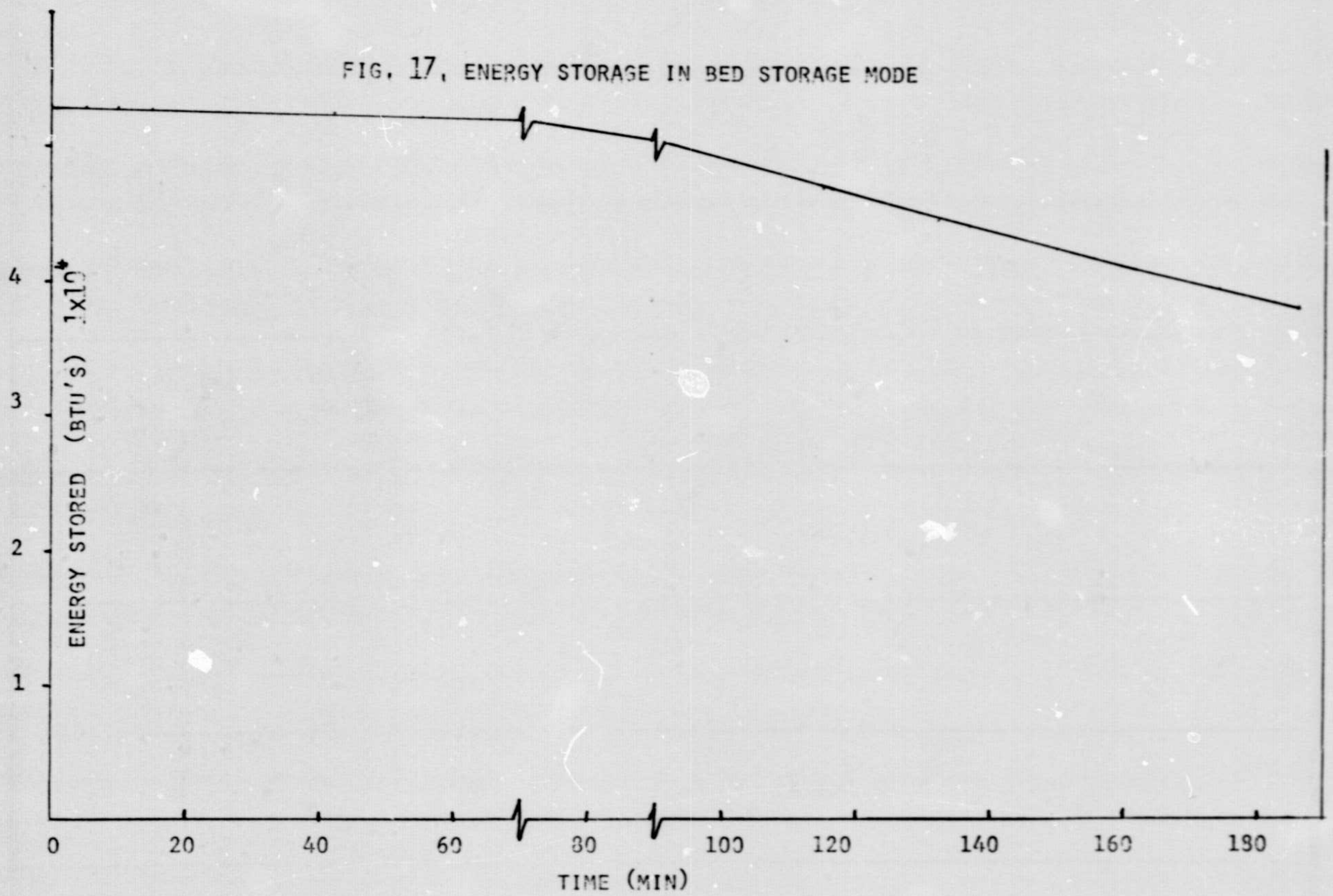


FIG. 17. ENERGY STORAGE IN BED STORAGE MODE

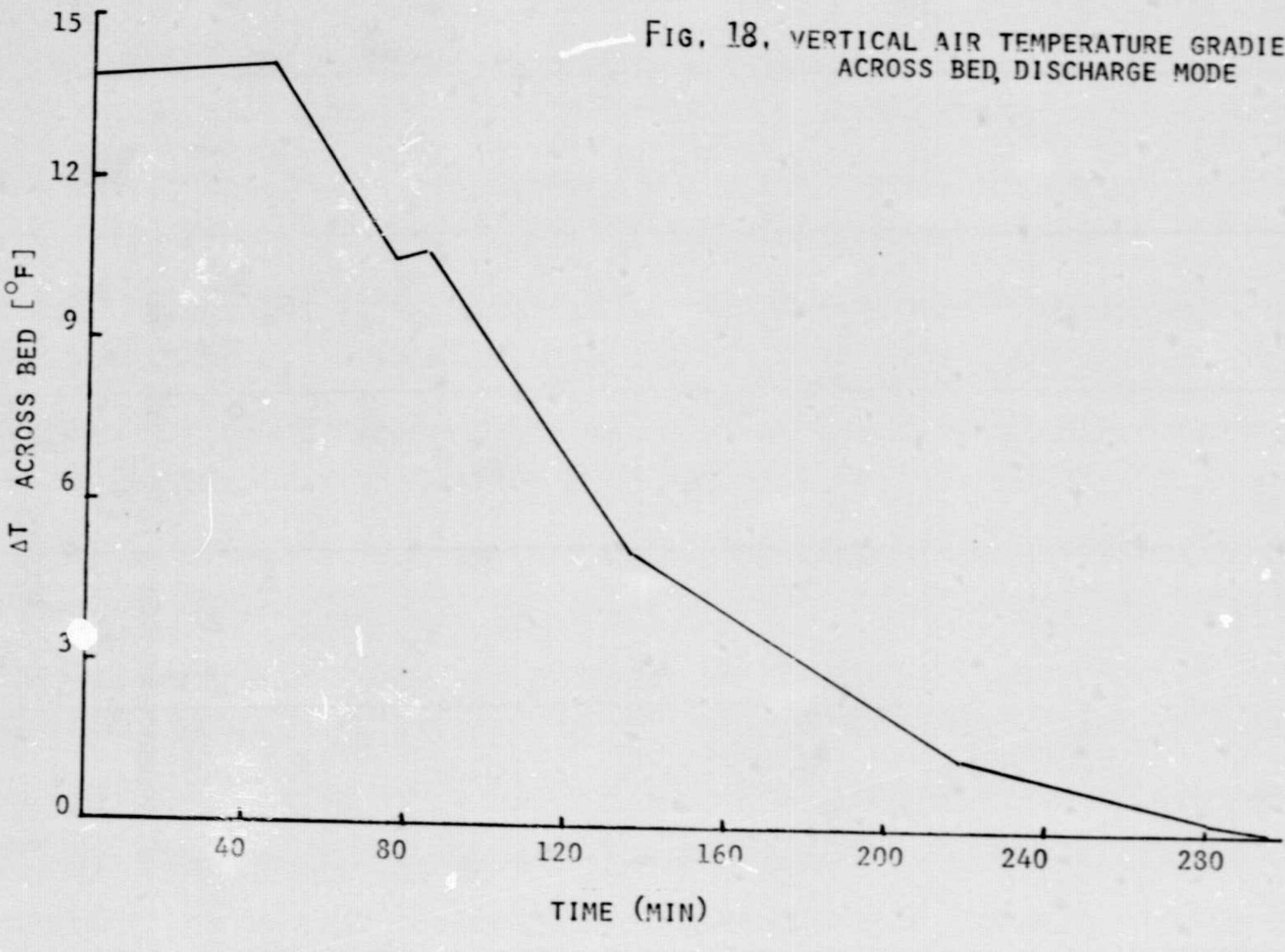
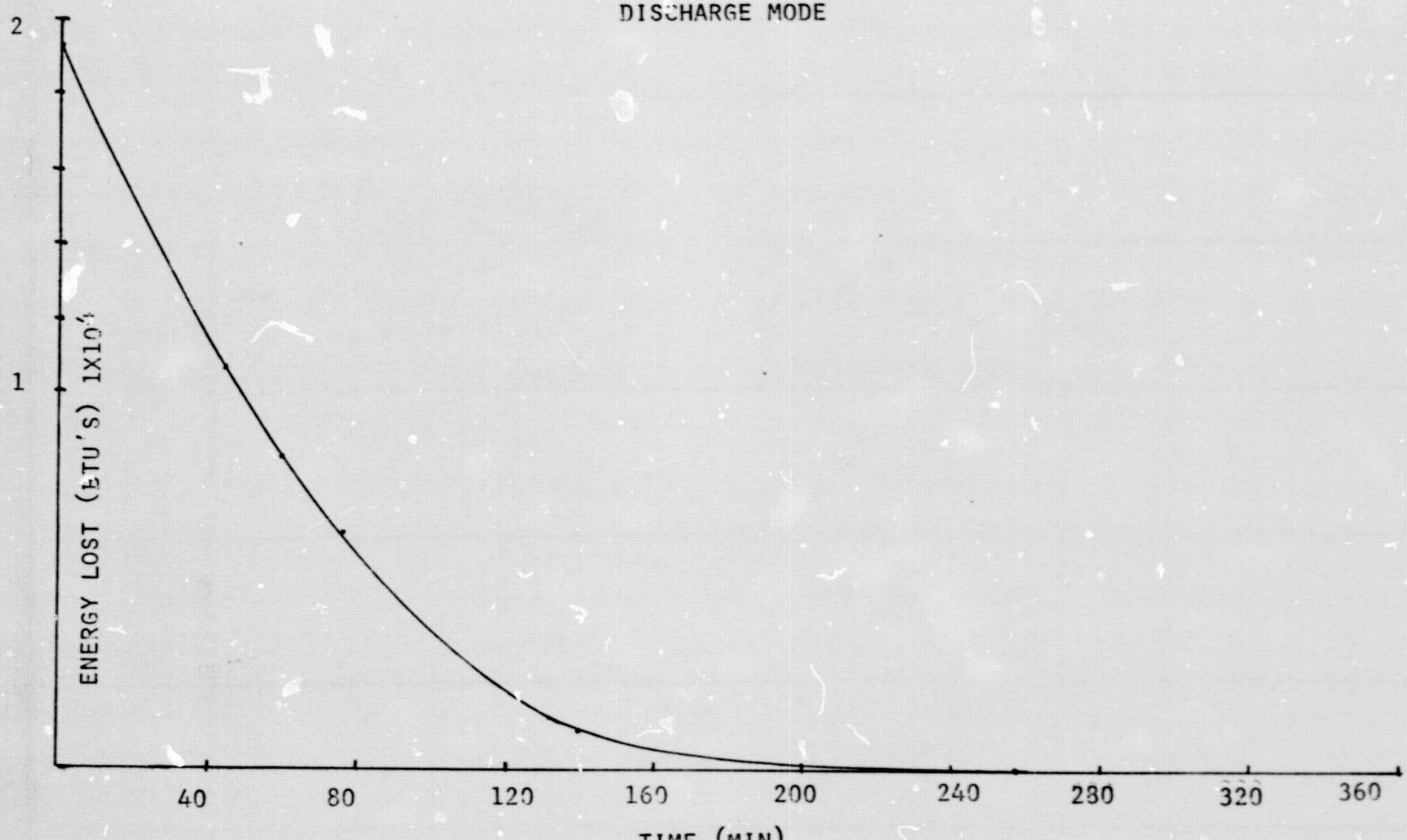


FIG. 18. VERTICAL AIR TEMPERATURE GRADIENT ACROSS BED, DISCHARGE MODE

FIG, 19 ENERGY DISCHARGE RATE VS, TIME

DISCHARGE MODE



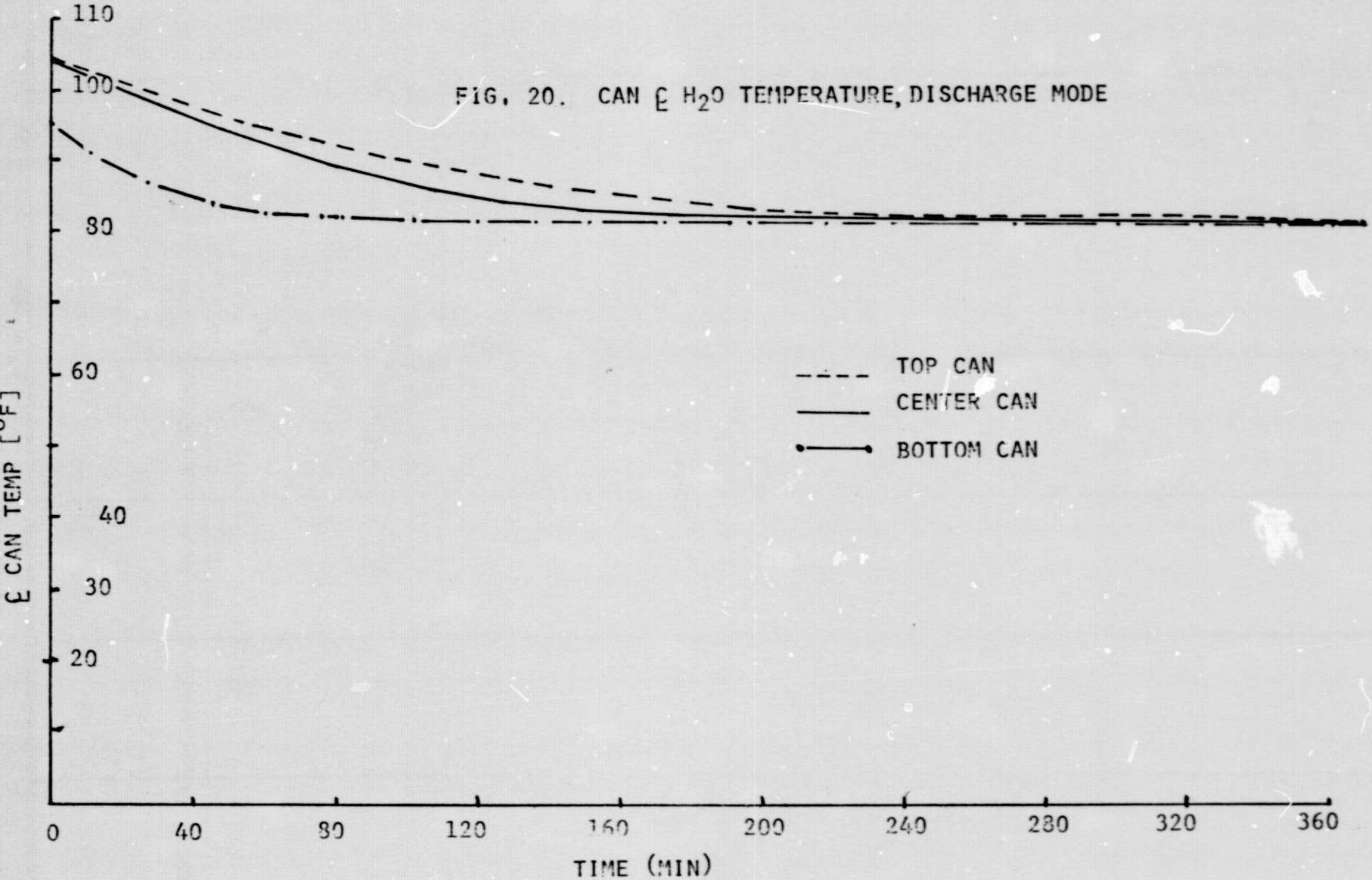


FIG. 20. CAN ℄ H_2O TEMPERATURE, DISCHARGE MODE

EXPERIMENTAL AND ANALYTICAL STUDY

PHASE II

During the phase II of this experimental research project, the remaining tests, as shown in the test plan, for three different bed heights (2,3, and 4 feet) with four different sizes of cans packed in three different (Vertical, Random, & Horizontal) ways will be conducted. For each set of tests the mass flow rate and bed inlet air temperature will be varied. The following information will be derived from these tests.

a. "UA" of storage bed in each configuration.
b. Temperature profile of H_2O and air across bed during charging, storage, and discharge modes.
c. Amount of energy stored in bed versus the time required to store this energy and bed efficiency.
d. Amount of energy that can be removed from bed and the time required to do this.
e. Mass flow rate through the bed during charging and discharging.
f. ΔP across bed-charging and discharging.
g. Determine heat transfer coefficienct for water filled cans.
h. Emperical equations and mathematical models for the test bed characteristics curves for extrapolation to predict the performance of other bed and can demensions for these type of storage systems.

i. A relationship between H_2O mass to can heat transfer surface area and energy storage and discharge rate.

These results will be ducumented in a final report to reflect the primary objective - to investigate the heat transfer characteristics and energy storage capability of a solar energy storage bed utilizing water filled cans as the energy storage medium.

A similar study will be made with rocks as storage medium at the conclusion of the above tests.

COMMENTS

The author had the opportunity to discuss the initial results of this experiment with solar energy storage experts in seminars and international energy conferences. Their comments about this new innovation in combining the benefits of H_2O and metal as storage mediums are very encouraging. The author feels that this type of storage medium will be quite useful for solar air surface heating systems.

A few improvements of the test and data acquisition system will be required for fast and accurate data generation:

a. A power controlled temperature regulator to keep the bed inlet air temperature within half a degree of the set temperature is a necessity.

b. An automatic data acquisition system to directly convert and store the data on tape for computer data processing will reduce a lot of human errors and labor.

Due to the lack of funds these items were not available during the phase I of this project. The technical advisiors at NASA/MSFC have been contacted for help and advice with respects to these improvements.

The most recent literature survey shows that there is a need for experimental data on the following types of storage mediums:

a. Metal cans filled with different types of fused salts with relatively high heat of fusion, suitable melting point, appropriate solidification characteristics, low toxicity and inexpensive.

b. A mixture of a particular type of liquid (oil) and rocks for high temperature storage required for heating, cooling, and power generation.

The present test facility is designed such that these above mentioned tests can be conducted here without much alteration and expense.

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