ADAPTING PANEL HEATING TO SUMMER COOLING.

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By

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ADAPTING PANEL HEATING TO SUMMER COOLING

INTRODUCTION

The science of controlling the atmosphere within a building for the benefit of human comfort has been developed until it is now possible to provide nearly any type of desired atmospheric condition. Comfort in the winter heating season has come to be accepted as an essential feature of structures in most areas. Although the advantages of summer comfort in our industrial and business activities have been pointed out by many investigators, as yet, summer comfort systems have not been utilized to the same degree as winter comfort systems. Every residence has provision for winter heating, relatively few a summer cooling system. The reason this situation exists may be traced primarily to the relatively high cost of the summer cooling systems; such a system usually includes a rather expensive refrigeration plant to provide for cooling and dehumidifying of air. The installation of a summer comfort system in a business is generally considered to be economically desirable. The additional income which normally results may be used to pay for the increased overhead of the business resulting from the added cost of the summer cooling system. In the construction of homes it is not easy to justify an increased investmant based on increased income due to the summer cooling system, therefore, the high cost of the normal summer cooling system curtails its broad acceptance in residential construction. It is the purpose of this investigation to determine, from an engineering and economic standpoint the feasibility of adapting panel heating to summer cooling of residences.

A panel heating system consists essentially of pipe coils, through which hot water is circulated. These are built into the walls, ceiling or floors of the residence. The adaption of these pipe coils, to the circulation of cool water for providing summer comfort is to be investigated. Since the refrigeration equipment is the most expensive part of the normal summer cooling system, it is further proposed, that the cool water circulated through the pipe coils, be cooled by evaporative cooling in a cooling tower.

The following method was used in making the investigation: A typical section of a frame building wall including a pipe coil as normally used in panel heating systems was constructed. This wall was tested by the "guarded hot box" in which any desired summer temperature could be simulated. Since the temperature of water available from a cooling tower is a function of the outside air wet bulb temperature, it was found necessary to make tests with variable water temperatures in order to predict the overall performance of the cooling coils on the basis of outside wet bulb temperatures.

The tests furnished data giving the inside wall surface temperatures for various cooling water temperatures. This wall surface temperature data was used in calculating the probable effect on human comfort in a building.

CONSTRUCTION OF EQUIPMENT

After a study of the construction of the panels used in panel heating systems, it was decided to use a panel with a coil made of three quarter inch inside diameter copper tubing on six inches spacing. The construction of the wall section and the mounting of the coils is shown in Figure 1. The heat transmission coefficient of 0.077 Btu/hr/sq. ft./°F, was determined from the ASHVE Guide.[1] It was desired in the testing of this panel that the maximum cooling load be used. The panel used contains a coil, the surface of which approximates the maximum surface generally found in such panel heating systems.

Data taken from Radiant Heating by Adlam, gives the following values for total heat emission from a panel used during the winter heating system:[2]

Difference between water and surface temp.	°F	10°	15°	20°
Total heat emission Btu sq. ft. per hour		42	64	84

The range of temperature differences between water circulated through the coil and the wall surface (10° to 30°) for winter heating systems is much greater than could be maintained to advantage for summer cooling. Therefore, in compensating for the small temperature difference, the panel must have a large surface area in order to be effective for a summer cooling application which uses water cooled in a cooling tower.

The "guarded hot box" which was used in conducting the tests of the wall panel section is shown in figures 2, 3, 4 and 5. This item of labor-

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1. ASHVE Guide 1948, pp 124-125, tables 5 and 6.

2. T. Napier Adlam, Radiant Heating, p. 483, figure 330

atory equipment, normally used to determine the heat transmission coefficients of building walls, was adapted to this particular test without any physical changes. The testing procedure, however, was modified slightly to meet the needs of this investigation.

In lieu of a cooling tower and by means of mixing valves, the water temperature for the tests was controlled by mixing water from the city mains with water from a coil cooled by the laboratory refrigeration plant.

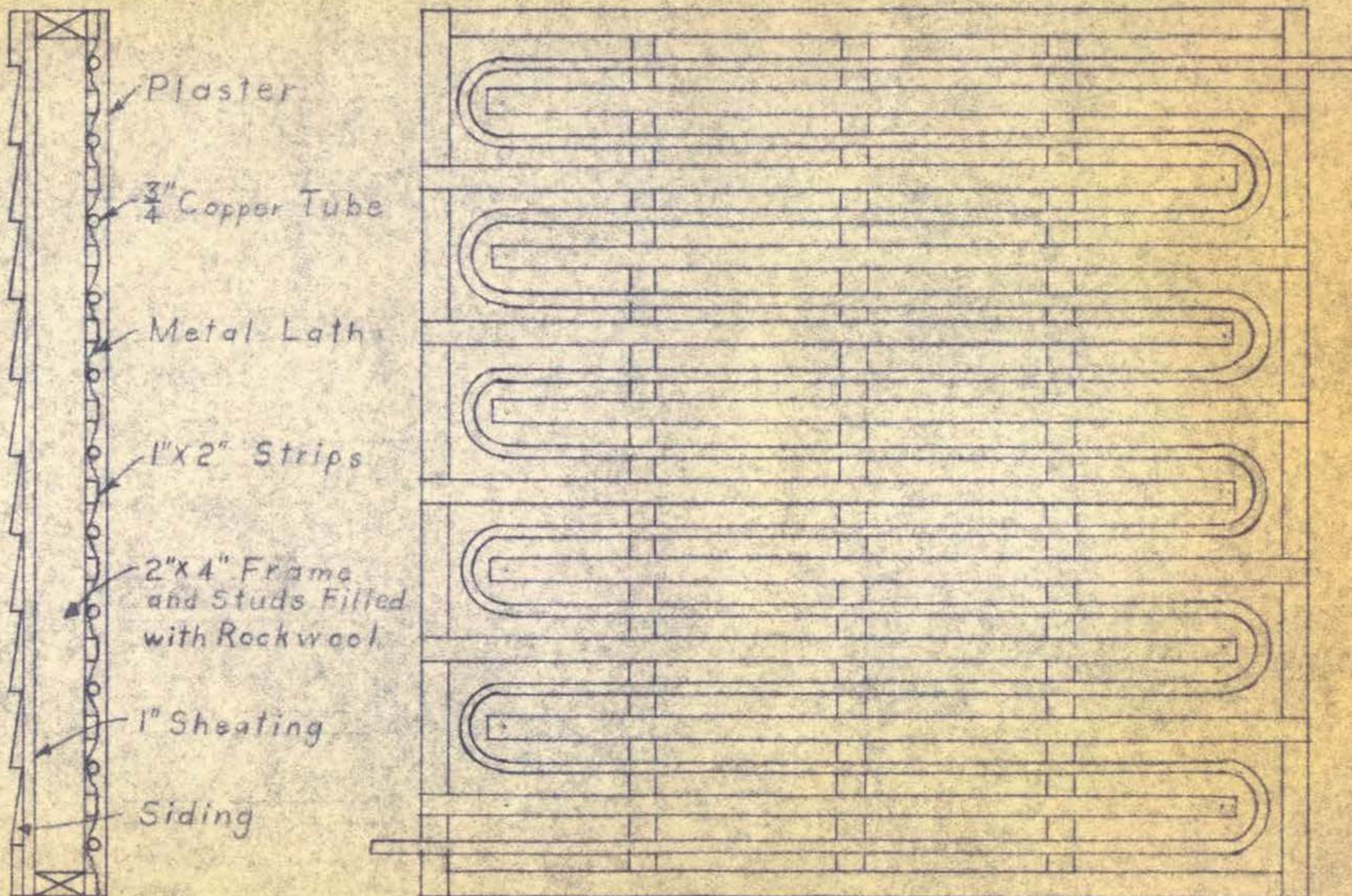

Figure 1. Construction of Wall Section

Figure 2 - TEST WALL SECTION

The numbered parts of test equipment are as follows:

1. Weather side of test wall section
2. Pipe coil entering test wall
3. Valves for mixing water from city mains and laboratory refrigeration plant cooling coil
4. Guard around thermometer well

Figure 3 - TEST WALL AND GUARDED HOT BOX

The numbered parts of test equipment are as follows:

1. Plastered or room side of test wall section
2. Exterior of guarded hot box
3. Thermometer well inside guard
4. Clamps to hold test wall section to guarded hot box
5. Fan motors
6. Watt hour meter for measuring electrical imput to heating element in inner box of guarded hot box
7. Thermostat regulating knobs

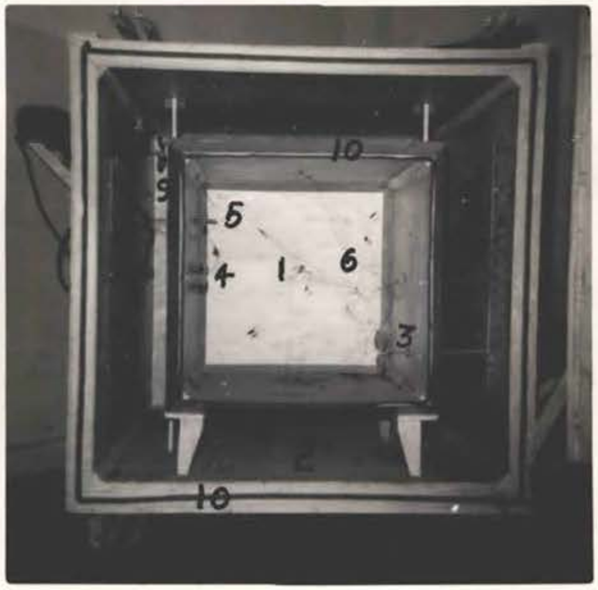

Figure 4 - INTERIOR OF GUARDED HOT BOX

The numbered parts of test equipment are as follows:

1. Interior of inner box of guarded hot box
2. Interior of outer box of guarded hot box
3. Fan in inner box
4. Heating element in inner box
5. Thermostat bulb in inner box
6. Thermocouples and wires
7. Fan in outer box
8. Heating element in outer box
9. Thermostat bulb in outer box
10. Gaskets against which test wall section is clamped.

Figure 5 - TEST INSTRUMENTS OF GUARDED HOT BOX

The numbered parts of test equipment are as follows:

1. Potentiometer
2. Thermocouple selector switch
3. Ice water jug containing thermocouple cold junction
4. Exterior of guarded hot box
5. Fan motor

TESTING PROCEDURE

Investigations, involving the heat flow through materials having large thermal storage capacity, require that thermal equilibrium be established before starting the test. For the test equipment used, it required from twenty-four to thirty-six hours to establish the desired stable conditions. The establishment of equilibrium conditions was indicated by obtaining constant air temperatures throughout the interior of the guarded hot box. Air and surface temperatures were measured by means of numerous thermocouples and a potentiometer. Temperature of the water flowing through the coil was measured by thermometers inserted in thermometer wells of the piping system.

The attainment of a condition of absolute thermal equilibrium was hindered by a number of operating difficulties, but it was found possible to bring the temperatures in the inner and outer boxes to within two or three degrees of each other, which was close enough for all practical purposes. There were no difficulties encountered in maintaining temperatures within the respective boxes, constant within the limits of accuracy of the testing equipment. After much preliminary investigation concerning the difficulty of obtaining constant temperature in the inner and outer boxes of the guarded hot box, it was concluded that the energy input to the fan motor in the inner box was sufficient to cause the inner box to maintain a temperature some two or three degrees higher than the temperature of the outer box. The fan was arranged for continuous operation during the test with the heating elements controlled by a thermostat. It was found that after the guarded hot box attained the desired testing temperature, adjustment of the thermostat in the inner box for a lower temperature did not result in any temperature change. The thermostat was replaced with the same operating results. It then became apparent that the only source of heat to cause the temperature differential as noted above was due to the fan motor.

Since the summer condition to be simulated in the guarded hot box must include the effect of solar radiation, the application of the concept of sol-air temperature as defined in the ASHVE Guide was used in setting the conditions of this test.[3] Sol-air temperature is the temperature of air which in contact with the weather side of a wall that was receiving no solar or sky radiation, would give the same instantaneous rate of heat entry into that surface as exists with the actual combination of incident solar and sky radiation and temperature of the outdoor air. From the same authority we find that the probable maximum sol-air temperature encountered for a wall such as was used for the test is 158°F. The guarded hot box was maintained at this approximate temperature during the test runs.

The temperature of the water to be circulated through the coil from a cooling tower is a function of cooling tower designs and the outside air wet bulb temperature. A study of data on commercial cooling tower operation shows that a design is practical in which water can be cooled to within 3°F of the wet bulb temperature. Since the maximum design, wet bulb temperature, for this part of Oklahoma is 77°F the maximum water temperature to be used in the test would necessarily be about 80°F.

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3. ASHVE Guide, op. cit., p. 267 and table 11, p. 268

TEST DATA

The observed data obtained from the test is given in tables 1 to 8, inclusive. This observed data has been plotted on graphs and is presented in figures 5 to 12, inclusive. In this graphic presentation of data the various temperatures are plotted as a function of time.

The following legend has been used for the curves plotted in the graphs of figures 6 to 13, inclusive.

A - Average temperature of inside box.
B - Temperature of wall surface on weather side.
C - Temperature of room air.
D - Temperature of wall surface on plastered side.
E - Temperature of water entering panel coil.
F - Temperature of water leaving panel coil.

OBSERVED DATA

Table 1 Date June 16, 1949

Time of reading	8:00	8:30	9:00	9:30	10:00	10:30	1:45	2:45	3:45
Millivolts inside box sta. 4	3.54	3.52	3.52	3.52	3.52	3.49	3.47	3.53	3.50
Millivolts inside box sta. 13	3.51	3.50	3.50	3.50	3.51	3.52	3.48	3.48	3.48
Average temp. inside box	153.3	152.7	152.7	152.7	152.7	151.7	151	153	152
Millivolts outside box sta. 8	3.38	3.33	3.30	3.32	3.31	3.33	3.33	3.28	3.33
Millivolts outside box sta. 14	3.33	3.33	3.30	3.29	3.29	3.30	3.25	3.32	3.31
Millivolts inside wall surface	3/35	3.38	3.38	3.37	3.38	3.3.37	3.34	3.33	3.33
Temp. inside wall surface	147	148	148	147.6	148	147.6	146.6	146.2	146.2
Millivolts outside wall surface	1.56	1.56	1.41	1.42	1.39	1.37	1.46	1.46	1.48
Temp. outside wall surface	86	86	80.8	81	80	79.5	82.4	82.4	83.2
Millivolts room air	1.35	1.36	1.35	1.39	1.39	1.46	1.55	1.62	1.85
Temp. room air	78.8	79	78.8	80	80	82.4	85.5	88	96
Temp. water entering coil			78	77.8	78		78.5	79	80.8
Temp. water leaving coil			78.5	78.5	78.6		80	80	79.8
Time, minutes for flow of 200 lbs. water		12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.25
Flow rate of water, lbs/min.		16.33	16.33	16.33	16.33	16.33	16.33	16.33	16.33

OBSERVED DATA

Table 2 Date June 17, 1949

Time of reading	8:00	9:00	10:00	11:00	2:00	3:00	4:00
Millivolts inside box sta. 4	3.50	3.51	3.51	3.50	3.48	3.50	3.50
Millivolts inside box sta. 13	3.49	3.51	3.50	3.50	3.47	3.50	3.50
Average temp. inside box	152	152.3	152.3	152	151.3	152	152
Millivolts outside box sta. 8	3.33	3.36	3.35	3.32	3.37	3.32	3.33
Millivolts outside box sta. 14	3.29	3.33	3.30	3.32	3.34	3.32	3.33
Millivolts inside wall surface	3.37	3.38	3.37	3.34	3.37	3.35	3.35
Temp. inside wall surface	147.6	148	147.6	146.6	147.6	147	147
Millivolts outside wall surface	1.38	1.37	1.40	1.35	1.47	1.47	1.46
Temp. outside wall surface	79.7	79.5	80.5	78.8	82.8	82.8	82.4
Millivolts room air	1.38	1.39	1.47	1.49	1.62	1.73	1.74
Temp. room air	79.7	80	82.8	83.5	88	92	92.2
Temp. water entering coil	78.6	78.7	77.6	77.5	78	78	78.3
Temp. water leaving coil	79	79.2	78	78.1	78.9	78.9	79.1
Time, minutes for flow of 200 lbs. water	21.5	21.5	7.16	7.16	7.16	7.16	7.16
Flow rate of water, lbs/min.	9.3	9.3	27.9	27.9	27.9	27.9	27.9

OBSERVED DATA

Table 3 Date June 22, 1949

Time of reading	8:00	9:30	10:00	11:00	11:30	1:00	4:30
Millivolts inside box sta. 4	3.58	3.55	3.57	3.53	3.53	3.55	3.51
Millivolts inside box sta. 13	3.59	3.53	3.55	3.55	3.52	3.53	3.50
Average temp. inside box	154.6	153.7	154.3	153	153	153.7	152.3
Millivolts outside box sta. 8	3.37	3.39	3.37	3.32	3.36	3.40	3.35
Millivolts outside box sta. 14	3.34	3.36	3.37	3.37	3.33	3.34	3.33
Millivolts inside wall surface	3.48	3.45	3.46	3.45	3.44	3.43	3.42
Temp. inside wall surface	151.2	150.2	150.5	150.2	150	149.6	149.3
Millivolts outside wall surface	1.90	1.53	1.56	1.56	1.53	1.55	1.58
Temp. outside wall surface	98	85	86	86	85	85.6	86.7
Millivolts room air	1.68	1.67	1.70	1.80	1.78	1.82	2.03
Temp. room air	90	89.8	91	94.3	93.7	95	102.3
Temp. water entering coil			80.5		80.3		81.3
Temp. water leaving coil			81.2		81		82
Time, minutes for flow of 200 lbs. water			4.5		4.5		4.5
Flow rate of water, lbs/min.			44.4		44.4		44.4

OBSERVED DATA

Table 4 Date June 23, 1949

Time of reading	9:00	10:00	11:00	11:45	12:55	3:00
Millivolts inside box sta. 4	3.58	3.56	3.55	3.58	3.57	3.54
Millivolts inside box sta. 13	3.57	3.57	3.56	3.55	3.54	3.51
Average temp. inside box	154.6	154	153.7	154	154.3	153.2
Millivolts outside box sta. 8	3.35	3.35	3.39	3.35	3.38	3.40
Millivolts outside box sta. 14	3.32	3.33	3.36	3.33	3.37	3.37
Millivolts inside wall surface	3.44	3.40	3.41	3.42	3.38	3.43
Temp. inside wall surface	150	148.6	149	149.3	148	149.6
Millivolts outside wall surface	1.71	1.56	1.56	1.56	1.50	1.60
Temp. outside wall surface	91.2	86	86	86	84	87.4
Millivolts room air	1.53	1.53	1.60	1.61	1.64	1.78
Temp. room air	85	85	87.4	87.8	88.8	93.7
Temp. water entering coil		81.6	81.2		81.6	82.1
Temp. water leaving coil		82.1	81.9		82	82.8
Time, minutes for flow of 200 lbs water	4.83	4.83	4.75		4.75	4.75
Flow rate of water, lbs/min.	41.4	41.4	42.2		42.2	42.2

OBSERVED DATA

Table 5 June 28, 1949

Time of reading	9:50	11:20	1:20	2:30	3:30	4:30
Millivolts inside box sta. 4	3.53	3.54	3.50	3.50	3.50	3.45
Millivolts inside box sta. 13	3.54	3.53	3.51	3.51	3.48	3.45
Average temp. inside box	153	153.2	152	152	152	150.2
Millivolts outside box sta. 8	3.38	3.36	3.38	3.38	3.37	3.37
Millivolts outside box sta. 14	3.38	3.36	3.35	3.35	3.35	3.34
Millivolts inside wall surface	3.41	3.38	3.35	3.38	3.37	3.28
Temp. inside wall surface	149	148	147	148	147.7	144.5
Millivolts outside wall surface	1.59	1.14	1.27	1.28	1.27	1.30
Temp. outside wall surface	87	70.5	76	76.3	76	77
Millivolts room air	1.41	1.44	1.53	1.62	1.70	1.72
Temp. room air	80.8	81.8	85	88	91	91.6
Temp. water entering coil		60.8	69.8	68.3	67.1	66.8
Temp. water leaving coil		63.0	71	69.8	68.8	68.5
Time, minutes for flow of 200 lbs water		7.5	7.5	7.5	7.5	7.5
Flow rate of water, lbs/min.		26.7	26.7	26.7	26.7	26.7

OBSERVED DATA

Table 6 Date July 13, 1949

Time of reading	9:20	2:00	2:30	3:00	3:30	4:00
Millivolts inside box sta. 4	3.52	3.52	3.54	3.54	3.52	3.54
Millivolts inside box sta. 13	3.53	3.50	3.55	3.51	3.49	3.52
Average temp. inside box	152.7	152.7	153.3	153.3	152.7	153.3
Millivolts outside box sta. 8	3.38	3.37	3.40	3.42	3.37	3.43
Millivolts outside box sta. 14	3.32	3.37	3.40	3.33	3.35	3.38
Millivolts inside wall surface	3.43	3.42	3.43	3.44	3.42	3.42
Temp. inside wall surface	149.6	149.3	149.6	150	149.3	149.3
Millivolts outside wall surface	1.57	1.61	1.57	1.42	1.38	1.38
Temp. outside wall surface	86.3	87 .8	86.3	81	79.8	79.8
Millivolts room air	1.43	1.55	1.55	1.57	1.60	1.67
Temp. room air	81.4	85.6	85.6	86.3	87.4	89.8
Temp. water entering coil			71	71.8	72	72.2
Temp. water leaving coil			72.7	72.8	73	73
Time, minutes for flow of 200 lbs water			7.3	7.3	7.3	7.3
Flow rate of water, lbs/min.			27.3	27.3	27.3	27.3

OBSERVED DATA

Table 7 — Date July 14, 1949

Time of reading	9:00	9:30	10:00	10:30	11:00
Millivolts inside box sta. 4	3.53	3.54	3.55	3.53	3.55
Millivolts inside box sta. 13	3.56	3.56	3.54	3.53	3.52
Average temp. inside box	153	153.3	153.8	153	153.8
Millivolts outside box sta. 8	3.34	3.39	3.36	3.38	3.37
Millivolts outside box sta. 14	3.35	3.35	3.35	3.35	3.35
Millivolts inside wall surface	3.45	3.45	3.43	3.42	3.42
Temp. inside wall surface	150.2	150.2	149.6	149.3	149.3
Millivolts outside wall surface	1.62	1.56	1.47	1.42	1.37
Temp. outside wall surface	88	86	83	81	79.3
Millivolts room air	1.53	1.54	1.54	1.61	1.63
Temp. room air	85	85.2	85.2	87.8	88.4
Temp. water entering coil		78.2	76	75.2	74.2
Temp. water leaving coil		78.8	76.5	75.8	75
Time, minutes for flow of 200 lbs. water		6.5	6.5	6.5	6.5
Flow rate of water, lbs/min.		30.7	30.7	30.7	30.7

OBSERVED DATA

Table 8 Date July 15, 1949

Time of reading	9:00	9:30	10:00	10:30	11:00	11:30	1:10	2:00	3:00	3:30	4:00
Millivolts inside box sta. 4	3.58	3.58	3.57	3.58	3.57	3.56	3.57	3.57	3.53	3.55	3.55
Millivolts inside box sta. 13	3.57	3.57	3.56	3.57	3.56	3.56	3.57	3.58	3.52	3.52	3.55
Average temp. inside box	154.7	154.3	154.3	154.7	154.3	154	154.3	154.3	153	153.8	153.8
Millivolts outside box sta. 8	3.38	3.39	3.36	3.43	3.40	3.42	3.40	3.44	3.42	3.40	3.38
Millivolts outside box sta. 14	3.37	3.36	3.36	3.40	3.38	3.39	3.40	3.40	3.40	3.40	3.38
Millivolts inside wall surface	3.50	3.51	3.51	3.50	3.50	3.48	3.44	3.44	3.43	3.41	3.45
Temp. inside wall surface	152	152.3	152.3	152	152	151.2	150	150	149.6	149	150.2
Millivolts outside wall surface	1.72	1.61	1.51	1.45	1.35	1.35	1.35	1.47	1.40	1.36	1.37
Temp. outside wall surface	91.5	87.8	84.3	82	78.7	78.7	83	83	80.3	79	79.3
Millivolts room air	1.54	1.54	1.53	1.53	1.60	1.58	1.58	1.60	1.63	1.63	1.71
Temp. room air	85.2	85.2	85	85	87.4	86.8	86.8	87.4	88.4	88.4	91.2
Temp. water entering coil		79	76.5	74.6	73.5	73.2	79.2	73.3	70.8	70.8	73.7
Temp. water leaving coil		79.9	77	75	73.9	73.7	79.5	74	71.6	71.7	74
Time, minutes for flow of 200 lbs water		5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83
Flow rate of water, lbs/min.		34.3	34.3	34.3	34.3	34.3	34.3	34.3	34.3	34.3	34.3

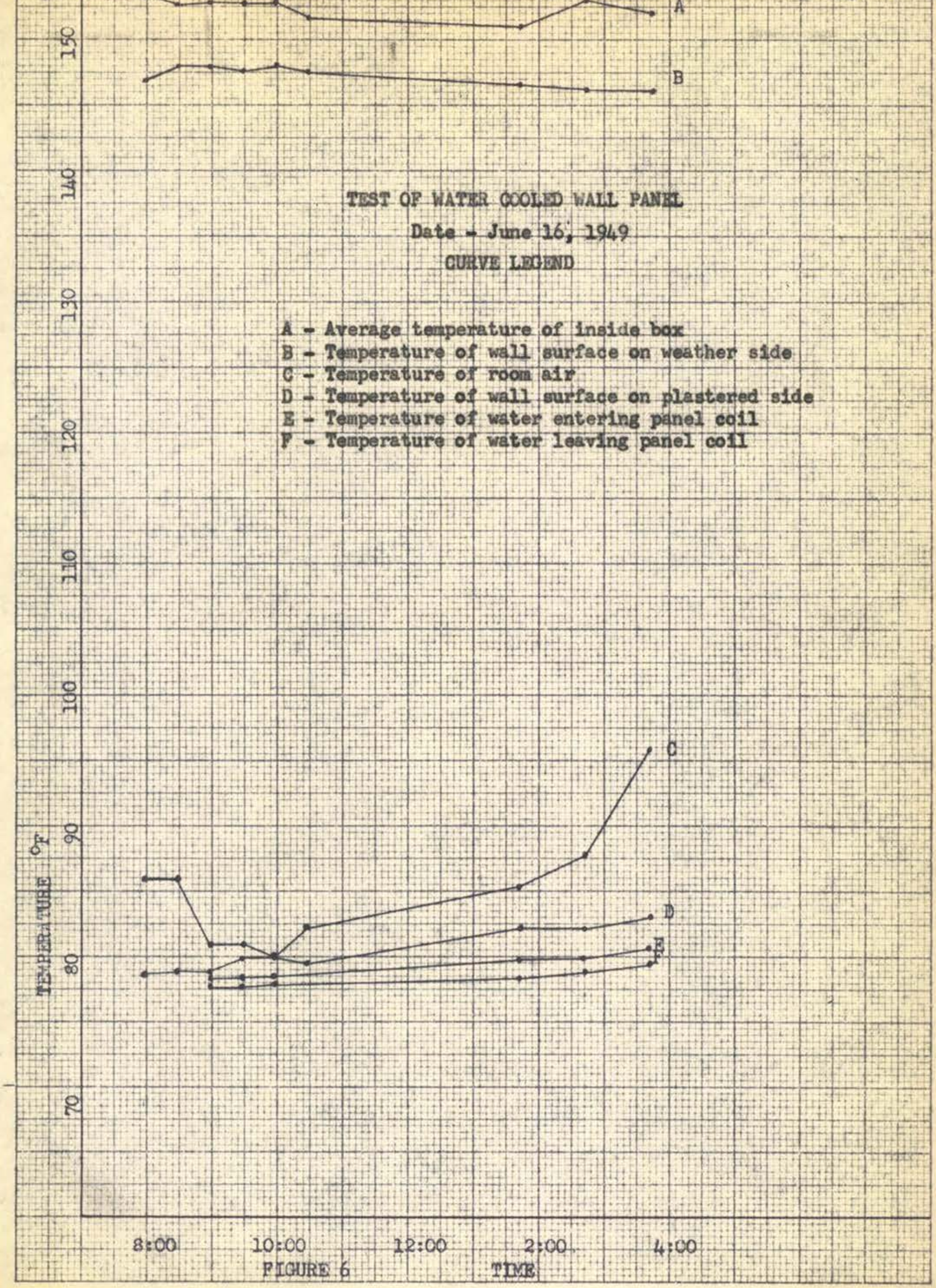
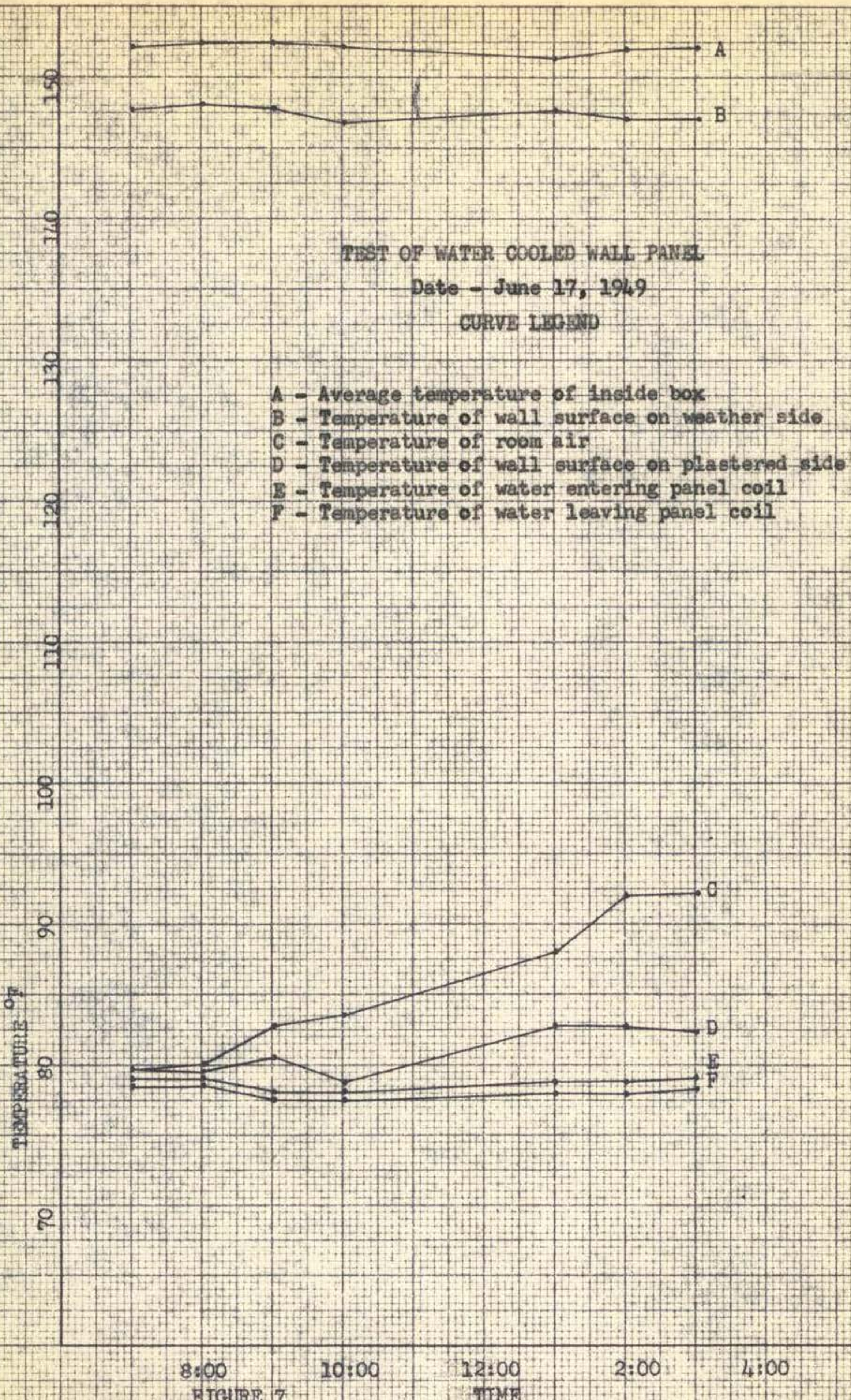

TEST OF WATER COOLED WALL PANEL
Date - June 16, 1949
CURVE LEGEND
A - Average temperature of inside box
B - Temperature of wall surface on weather side
C - Temperature of room air
D - Temperature of wall surface on plastered side
E - Temperature of water entering panel coil
F - Temperature of water leaving panel coil
A
B
C
D
E
150
140
130
120
110
100
90
80
70
TEMPERATURE °F
8:00
10:00
12:00
2:00
4:00
TIME

FIGURE 6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A
B
C
D
E
F
150
140
130
120
110
100
90
80
70
TEMPERATURE °F
8:00
10:00
12:00
2:00
4:00
TIME

FIGURE 7

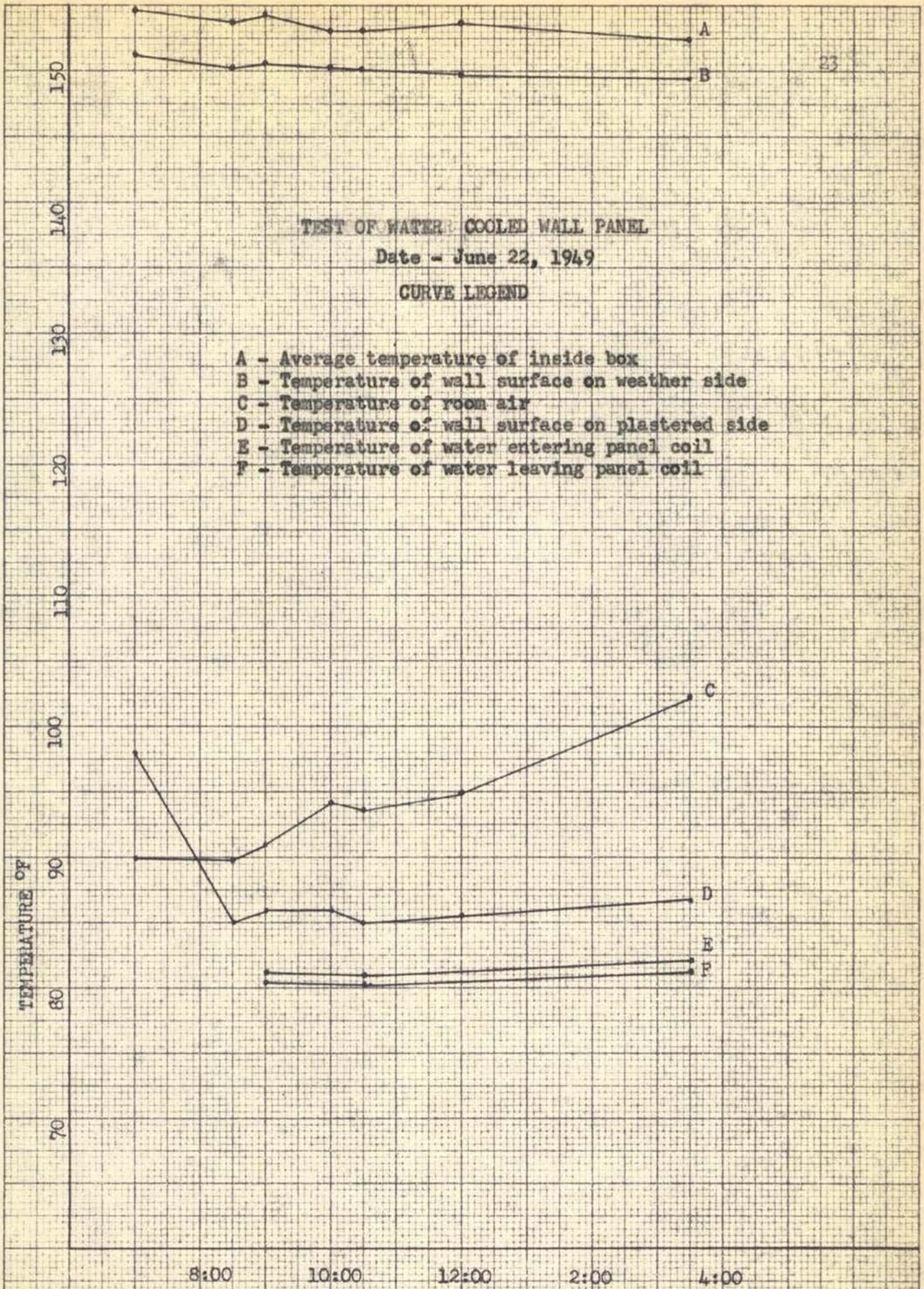
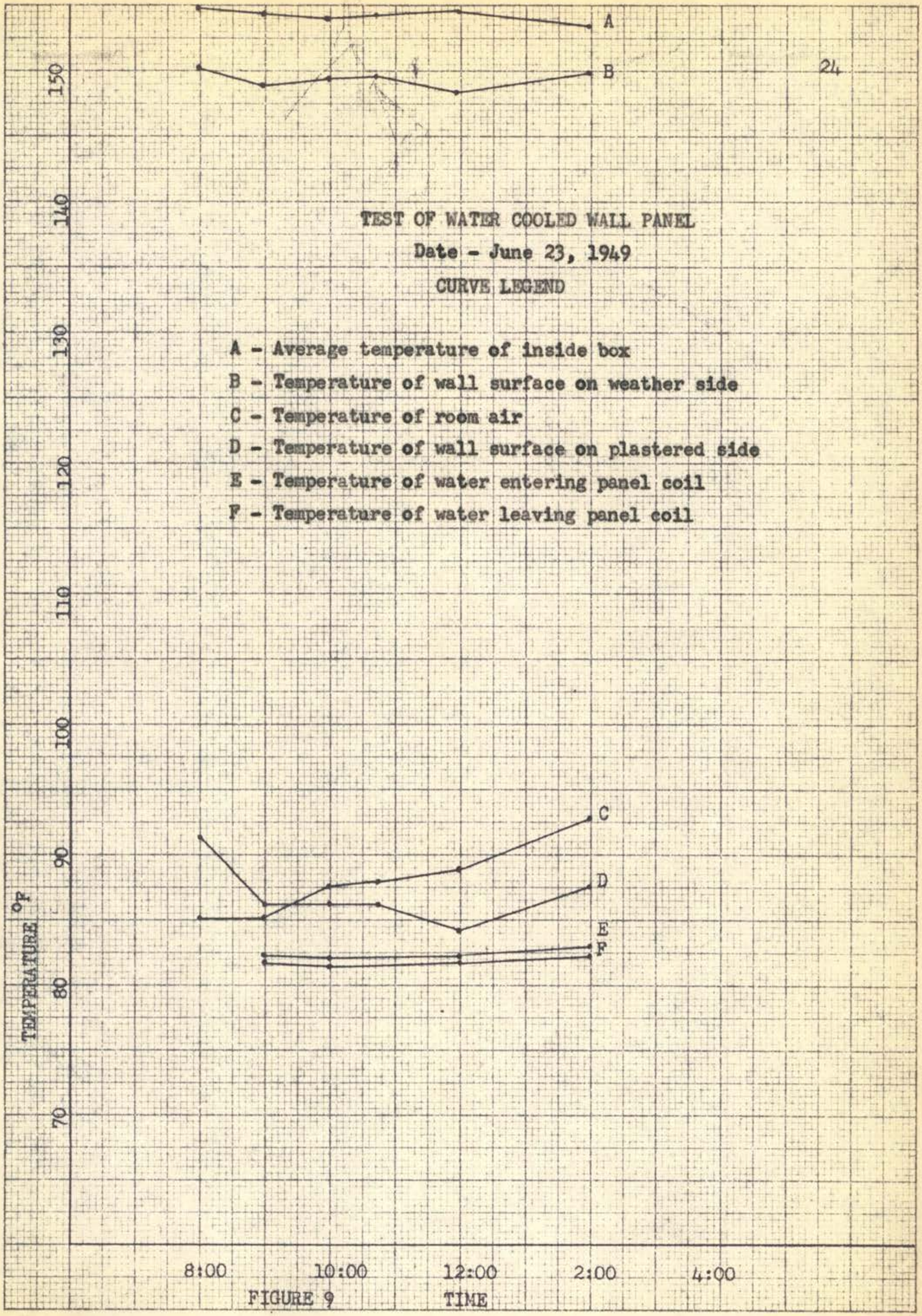

TEST OF WATER COOLED WALL PANEL
Date - June 22, 1949
CURVE LEGEND
A - Average temperature of inside box
B - Temperature of wall surface on weather side
C - Temperature of room air
D - Temperature of wall surface on plastered side
E - Temperature of water entering panel coil
F - Temperature of water leaving panel coil
A
B
C
D
E
F
150
140
130
120
110
100
90
80
70
TEMPERATURE °F
8:00
10:00
12:00
2:00
4:00
TIME

FIGURE 8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Date - June 23, 1949
CURVE LEGEND
A - Average temperature of inside box
B - Temperature of wall surface on weather side
C - Temperature of room air
D - Temperature of wall surface on plastered side
E - Temperature of water entering panel coil
F - Temperature of water leaving panel coil
A
B
C
D
E
F
150
140
130
120
110
100
90
80
70
TEMPERATURE °F
8:00
10:00
12:00
2:00
4:00
TIME

FIGURE 9

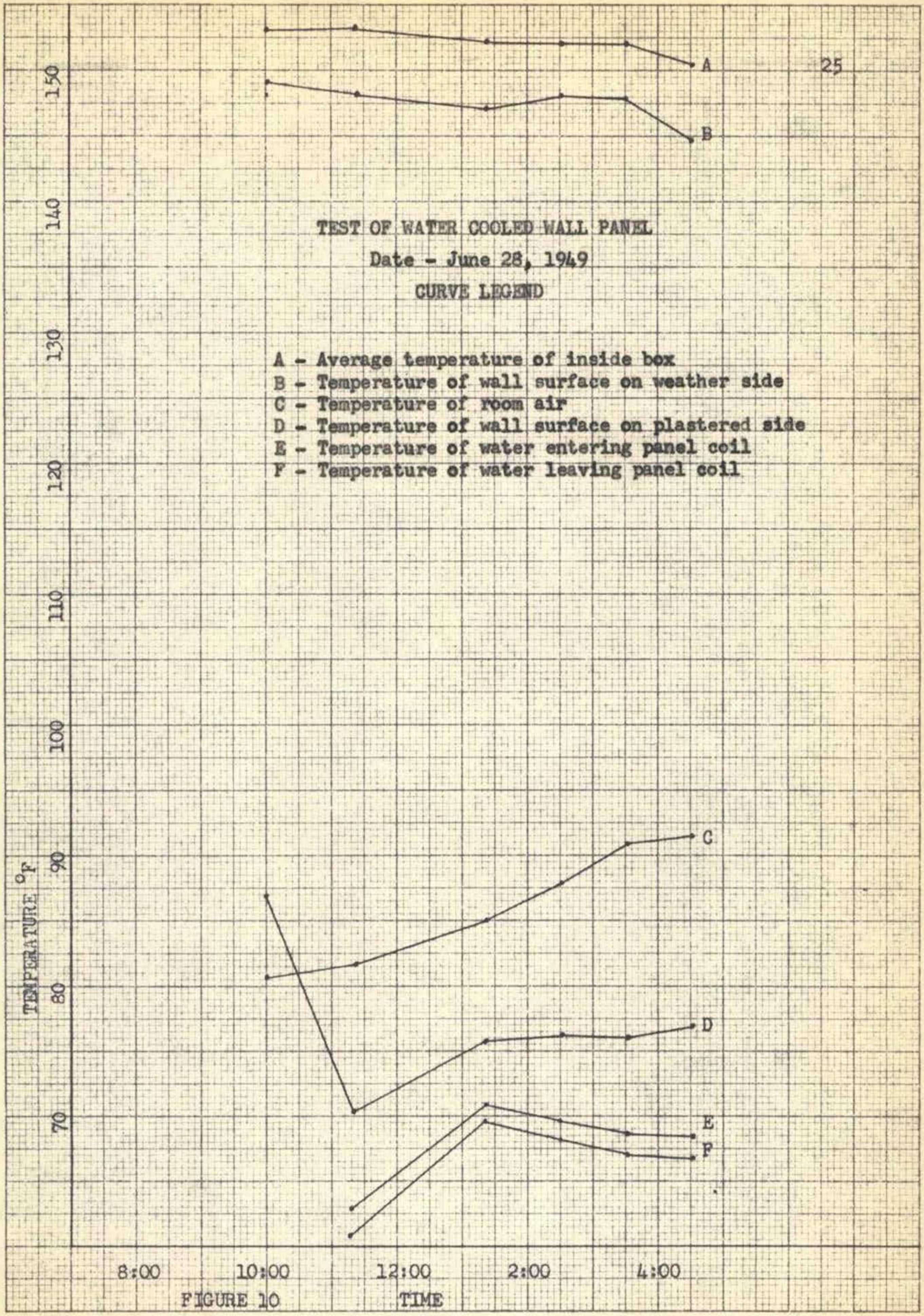
TEST OF WATER COOLED WALL PANEL
Date - June 28, 1949
CURVE LEGEND
A - Average temperature of inside box
B - Temperature of wall surface on weather side
C - Temperature of room air
D - Temperature of wall surface on plastered side
E - Temperature of water entering panel coil
F - Temperature of water leaving panel coil
A
B
C
D
E
F
150
140
130
120
110
100
90
80
70
TEMPERATURE °F
8:00
10:00
12:00
2:00
4:00
TIME

FIGURE 10

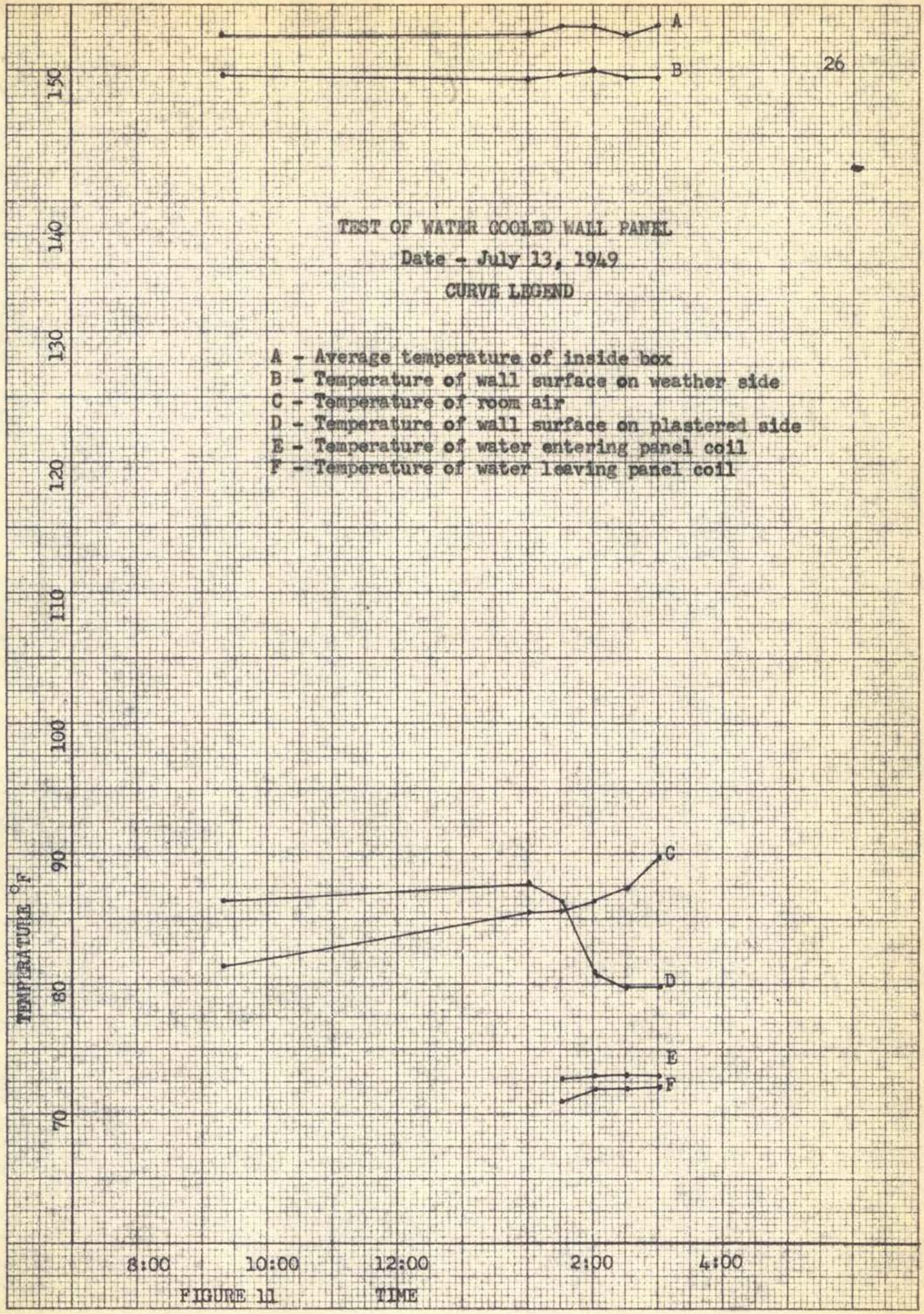
TEST OF WATER COOLED WALL PANEL
Date - July 13, 1949
CURVE LEGEND
A - Average temperature of inside box
B - Temperature of wall surface on weather side
C - Temperature of room air
D - Temperature of wall surface on plastered side
E - Temperature of water entering panel coil
F - Temperature of water leaving panel coil
A
B
C
D
E
F
TEMPERATURE °F
150
140
130
120
110
100
90
80
70
8:00
10:00
12:00
2:00
4:00
TIME

FIGURE 11

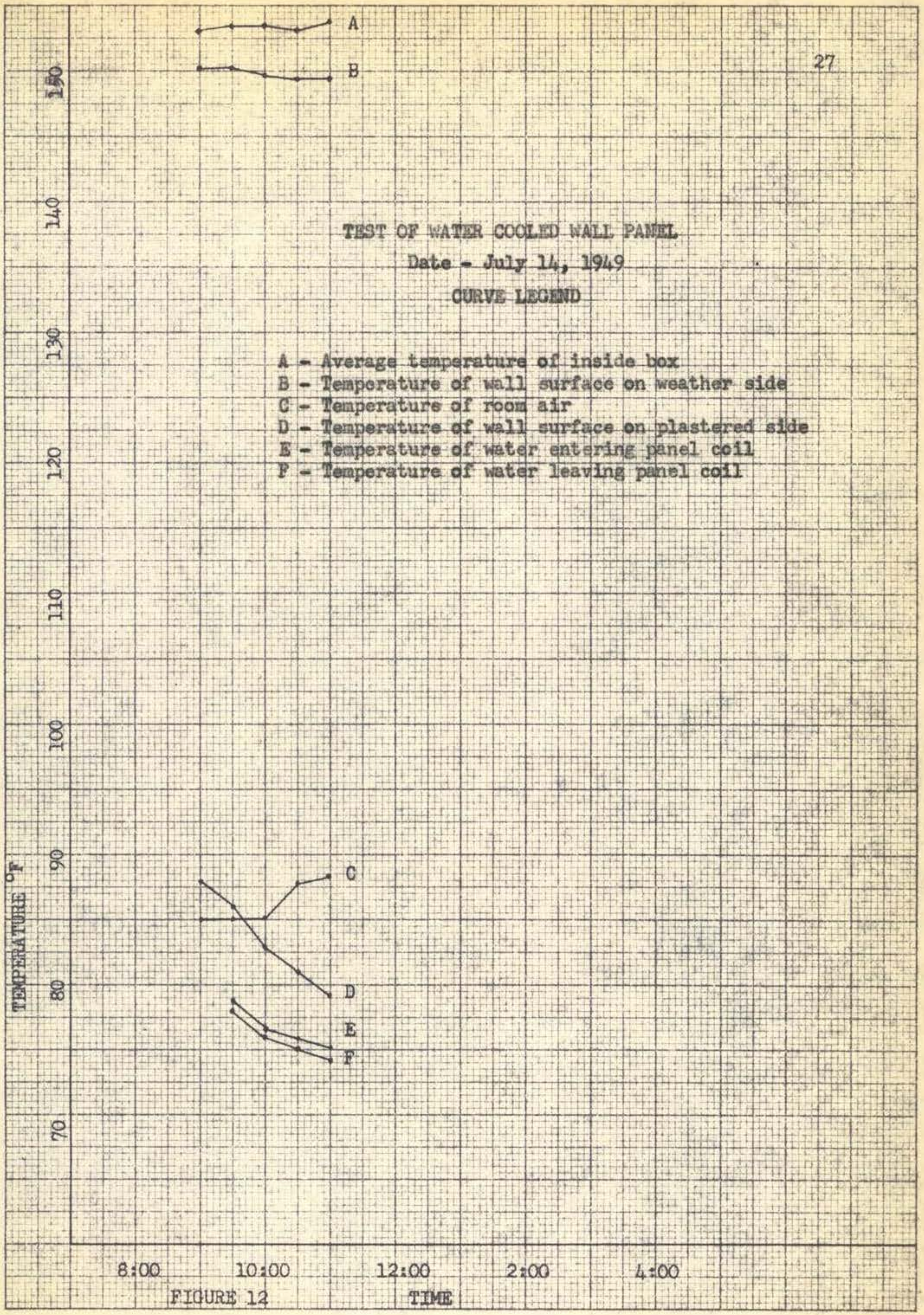
TEST OF WATER COOLED WALL PANEL
Date - July 14, 1949
CURVE LEGEND
A - Average temperature of inside box
B - Temperature of wall surface on weather side
C - Temperature of room air
D - Temperature of wall surface on plastered side
E - Temperature of water entering panel coil
F - Temperature of water leaving panel coil
A
B
C
D
E
F
150
140
130
120
110
100
90
80
70
TEMPERATURE °F
8:00
10:00
12:00
2:00
4:00
TIME

FIGURE 12

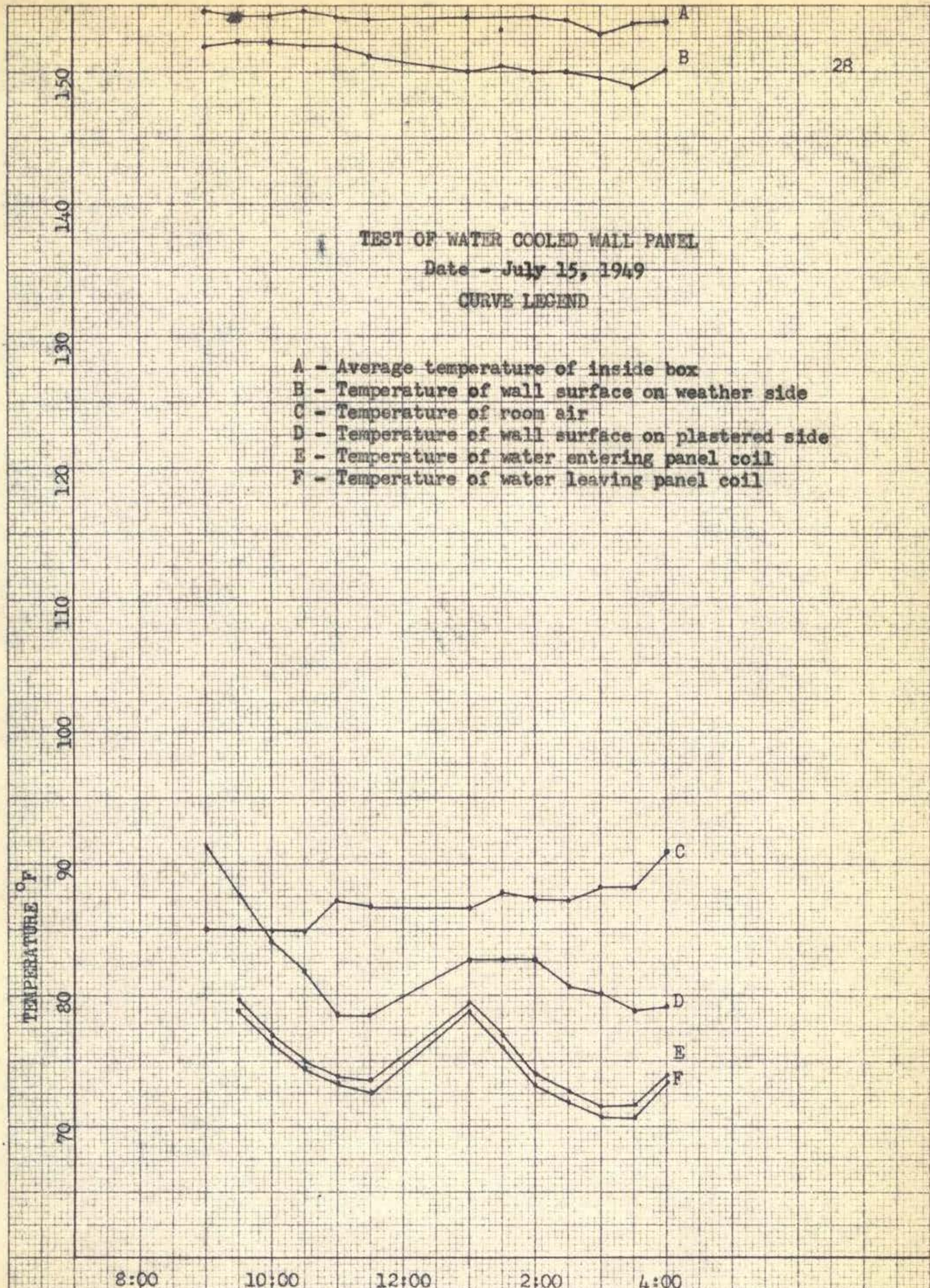
TEST OF WATER COOLED WALL PANEL
Date - July 15, 1949
CURVE LEGEND
A - Average temperature of inside box
B - Temperature of wall surface on weather side
C - Temperature of room air
D - Temperature of wall surface on plastered side
E - Temperature of water entering panel coil
F - Temperature of water leaving panel coil
A
B
C
D
E
F
150
140
130
120
110
100
90
80
70
TEMPERATURE °F
8:00
10:00
12:00
2:00
4:00
TIME

FIGURE 13

DISCUSSION OF RESULTS

The graphs plotted from observed data show the comparative effect of the thermal storage capacity of the test wall section to the temperature variation of the wall surface. It will be noted, that the surface temperature of the test wall changes slowly with changes in room air temperature and temperature of the water flowing through the coil. The ASHVE Guide indicates that this construction of wall section would have a time lag, in heat flow, of about four hours.[4] Such a time lag indicates that the change in heat flow through the wall section, due to large variation in outside air or cooling water temperature, will have a time effect on room comfort.

A study of the data, also shows the direction and the relative quantity of heat flow during the cycle. The air temperatures adjacent to each wall surface are greater than the wall surface temperatures, respectively. This indicates that heat is entering the wall from both sides and is being removed by the cooling water circulating through the coil. Such a condition indicates that the cooling coil is successfully absorbing the heat entering the weather side wall surface and is preventing it from flowing into the room, and that it is also removing some heat from the room. At the window and door areas no panel coils are possible, therefore, it would be desirable to remove the heat entering the room through these areas by means of the cooling coil.

The relative quantities of heat entering the test wall from the

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4. ASHVE Guide, op. cit., table 12, p. 270

weather side and room side wall surfaces may be evaluated in terms of the coefficients of heat transmission and temperature differentials from the coil to the respective wall surfaces. Noting from figure 1 that the coil is located just under three-fourths inch of plaster and that the overall heat transmission coefficient from page 3, is 0.077; the respective coefficients from coil to wall surfaces are : coil to plastered room surface 1.0 Btu/hr/sq. ft./°F, coil to weather side wall surface 0.0833 Btu/hr/sq./ft./°F. The respective temperature differences from figure 6 are: coil to plastered room surface 6°F, coil to weather side wall surface 72°F. The ratio of these products 0.0833 x 72/1x6 equals one. This result indicates that for the test condition considered,equal quantities of heat were entering the wall from each side of the wall section tested and was being absorbed by the panel cooling coil.

Consideration next was given to the possible comfort resulting from the relative equal quantities of heat flow as deducted in the preceding discussions. For this consideration, let the following example be offered: A room 10 feet x 12 feet with 8 foot ceiling having two exposed walls and four $2\frac{1}{2}$ foot by 5 foot windows with double glazing. Coefficients of heat transmissions are: windows, 0.57, walls and ceiling, 0.077. The net wall and ceiling area is 250 sq. ft. and window area 50 sq. ft. giving a ratio of window area to wall and ceiling area of 1:5. The ratio of heat transmission coefficient through the window area to the heat transmission coefficient through the wall and ceiling areas is 7.4:1. Combining the heat transmission ratio and area ratio gives a ratio of the heat flow through the window area to the heat flow through the wall and the ceiling areas of 1.5:1.

The preceding calculation indicates that more heat enters the room through the windows than is removed from the room by the cooling coil in the wall. However, only one-fifth as much heat would be added to the room with the use of cooling coil panels as would be added to a room without such panels.

Another factor affecting the body comfort of people is the heat loss by radiation. The ASHVE Guide indicates that approximately half of the human body heat loss takes place by radiation. [5] It follows then that if the room wall surface temperatures are lowered by a cooling coil, comfort conditions will be provided that are equivalent to a lower room air temperature with a higher room wall surface temperature.

This investigation indicates that a panel heating system adapted to use for summer cooling by using water cooled in a cooling tower is practical, from an engineering standpoint. The economies of cooling water in a cooling tower are well known. Based on both the engineering and economic factors it seems reasonable to recommend the adopting of panel heating systems to summer cooling of residences.

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5. ASHVE Guide, Op. cit., figure 2, p. 202

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