TESTS ON AN AUTOMATIC RADIATOR VALVE

by

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CHAPTERS:

INTRODUCTION

This thesis deals with some tests on an automatic radiator valve that is manufactured by the Fulton Sylphon Company of Knoxville, Tennessee. The details of design and manufacture are not dealt with at all. Other valves made by various companies could well be given the same tests regardless of the interior details. Since only one valve was used no effort was made to compare it with others based on the same theory of operation. The whole purpose was to investigate and devise tests that would prove or disprove the suitability of the valve for the purpose for which it is made.

The writer acknowledges the help given him by the Fulton Sylphon Company. The experimental department had a large amount of apparatus already assembled. Their permission to use this saved the writer much time that would have been consumed in setting up the various devises. Mr. Barnes of this same department rendered some valuable advice before the start of the tests. He was instrumental in obtaining the use of the above mentioned equipment.

GENERAL THEORY

An automatic radiator valve is designed to be placed on the radiator, connecting it with the steam riser. In this position it is supposed to control the flow of steam into the radiator in such a way that the temperature of the air for a distance of several feet from the valve is held constant. This control is maintained as follows:

The valve may contain as an integral part a spring, a bellows containing a liquid which vaporizes at low temperature, or some other expanding device. This device is connected to the valve stem in such a way that the expansion closes the valve. Now high temperatures cause the valve to be closed and low temperatures tend to open it. Consequently, a cold room opens the valve and permits more steam to flow into the radiator. This additional steam warms the room, causing the valve to close before too much steam is admitted to the radiator. Thus it can be seen that if the valve is made and adjusted properly it should prevent a very great change of temperature within the room.

The valve may be given three kinds of tests, namely: control tests, steam flow tests, and tests for sensitivity or valve opening. The first two mentioned are most important.

The whole idea of the valve is temperature control. The control tests should show just how near constant temperature a room may be kept by use of the valve. A recording thermometer in the room should give sufficient data for this.

The steam flow test is not so simple as the first mentioned one. It may be desired to know whether or not the valve will pass enough steam to supply the required amount of radiation. It may be desired to know what steam pressure will be required to supply steam for a certain amount of radiation. If the valve be kept at a constant temperature, and steam passed through it at different pressures and the condensate weighed each time, a certain amount of flow will be determined for each pressure. If now the same procedure be followed for two other temperatures there will be three flows for each pressure. The results can be represented by separate curves for each pressure, plotted with temperature against flow per hour. Remembering that one pound of steam is equivalent to four square feet of radiation there is suffient data for determining the desired information.

The sensitivity test is not so important but may be interesting. It may be desired to know just how much the valve opens per degree rise in temperature or at what temperature the valve is completly closed. If it requires too much of a temperature change to open or close the valve the control will not be good. Of course the control test itself is the best test of operation that can be given; but the sensitivity may interest the designer. If the valve has its temperature gradually raised as steam is allowed to pass through it, a point will be reached finally where no steam will flow. Of course the valve is closed at that corresponding temperature. If a dial gage or some other device similar to an extensometer be connected between the frame and valve stem it will show the amount of opening at any particular temperature difference. The dial gage readings may be plotted against temperatures to give a curve that will show where closing begins as well as the valve movement per degree.

GENERAL SURVEY OF THE FIELD

The Fulton Sylphon Company has run steam flow and control tests on one of their $\frac{1}{2}''$ automatic valves. They have also tested the bellows of the valve for fatigue. But this fatigue test isn't directly related to the operation of the valve. They had no data on the relation of temperature to valve opening.

The Direct Control Valve Company at Chicago, Illinois, permitted their valve to be tested by the Committee of Architects and Engineers. The committee sought to determine the comparitive steam saving and efficiency in the heating of a building between Direct Control Valve System, a hand controlled system, and a pneumatic controlled system. The tests were all conducted on commercial installations. The steam supply for the heating system was metered and daily readings taken during the entire heating season.

The Sterling Engineering Company at Milwaukee, Wisconsin, manufacture the "Thermotrol". They submerge the assembled apparatus consecutively in two barrels of water, one of which is of a temperature two degrees higher than the other. When the "Thermotrol" is submerged in the water of higher temperature the valve is supposed to be completely closed, and in the colder water it is completely open; so that in actual practice the valve is expected to maintain the room temperature within a range of one degree either way from the point at which it is set.

Some control tests were run on the "Thermotrol" at the University of Pennsylvania

There are some other companies making automatic radiator valves, but the ones mentioned are the leaders in the field. It would seem that the tests given the Fulton valve No."875" are the ones that involve a real steam flow and valve movement test as is herein to be described.

STATEMENT OF PURPOSE

The purpose of this undertaking is to give a Fulton $\frac{3}{4}$" No. 875 automatic radiator valve a series of tests for performance. and secure data that would help one to use it properly. It is also desired to study the subject as the work is carried on.

APPARATUS

I. For Control Test.

1. Recording thermometer of 24 hour range.

2. A Fulton $\frac{3}{4}$" No.875 automatic radiator valve.

3. An office built in one corner of a steam laboratory. The laboratory was about 60 feet long and 30 feet wide. The two built-in walls of the office did not extend to the ceiling of the larger room. The ceiling was about twelve feet above the floor.

4. The radiator consisted of several steam pipes lapped back and forth throughout the whole length of one side of the laboratory and office.

II. For Steam Flow Test.

Figure 1 shows the general set-up for this test. Steam enters at B at a higher pressure than is desirable or suitable for the purpose at hand. The reducing valve C cuts the pressure down to about 18 lbs. per sq. in. as shown by the gage D. The other reducing valve F has a lever and sliding weight which enables it to be varied from zero pressure up to about 15 lbs. The pressure changes were all made by manipulating F. The tank I collects the moisture in the steam and passes it out at the bottom. The dry steam flows on to the valve which is being tested. When valve O is open it can pass upward to the right and into the condensing tubes J. The steam condenses and flows into the weighing tank L.

Tap water is supplied to the condenser through pipe A. Water flows from the condensing tank through N.

Rubber tubes connect, one on the intake side and one on the exit side of the valve O. These same tubes connect to the mercury U-gage and cause it to show the pressure drop through the valve O. The pressure at the exit of O is very little, if any, above atmosphere. The pressure drop is regulated by F.

The crock H contains water up to the top of the bellows of the valve. A rubber tube acts as a siphon extends from this crock. A pinchcock on this tube makes it possible to run water from the crock at will. Crock E contains ice-water and is placed above H. Water can be siphoned from it to H at will through another rubber tube.

Two other small can be seen extending into H. One connects to the tap water and the other to the steam supply. They are used with a larger vessel than the crock when working with higher temperatures. This vessel is a galvanized iron box with a capacity of about 1 cubic foot. Its side is slotted so water cannot rise above the bellows. The slot serves as an overflow.

Timing is done with an ordinary watch.

The water in H is stirred with a small wooden paddle.

III. Apparatus For Valve Opening Study.

A dial gage is placed on the frame of the valve with its plunger extending downward against a brass strip soldered on the bellows. This strip moves with the bellows which in turn move with the valve stem. The strip is on the end of the bellows next to the valve stem.

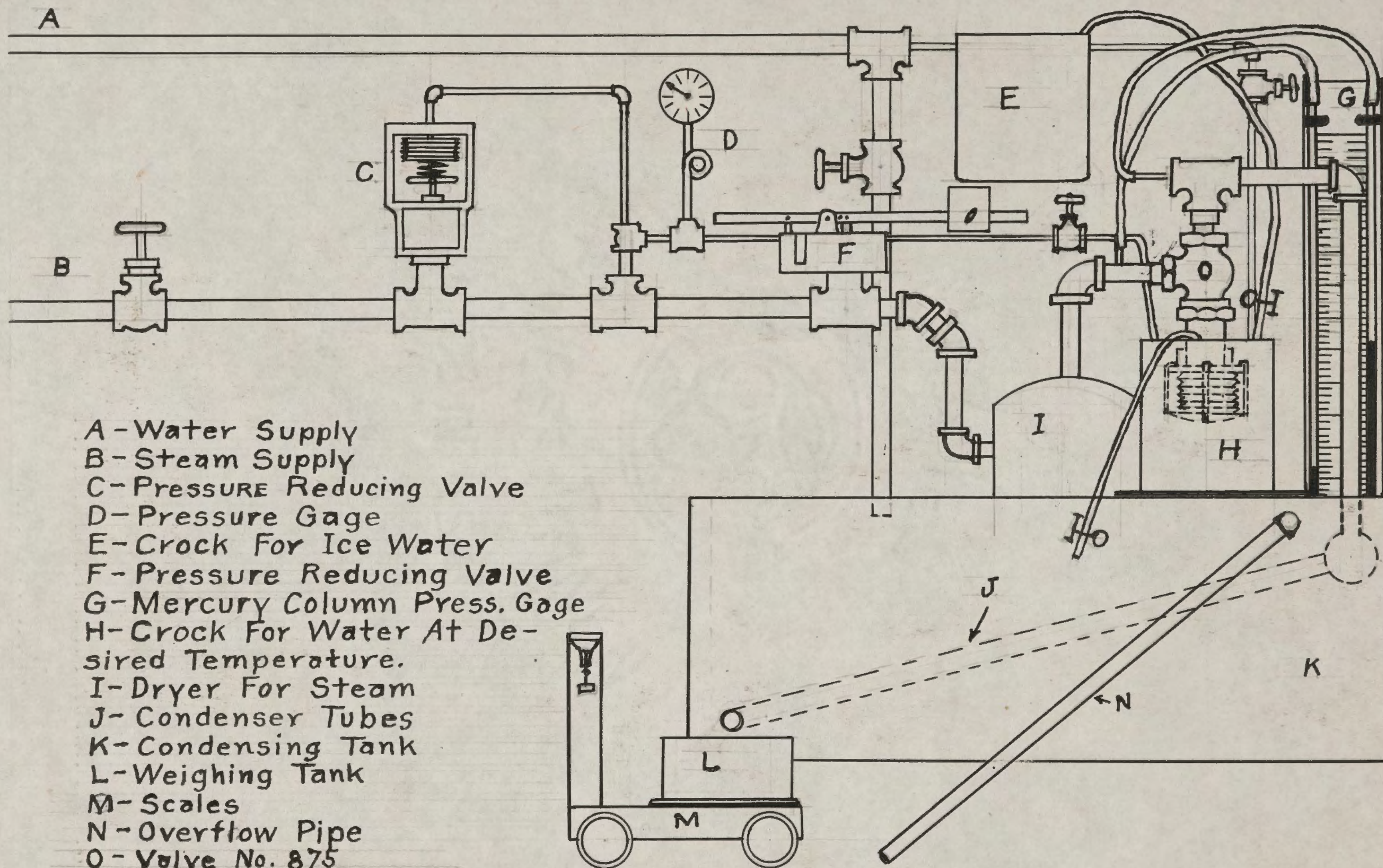


Fig. 1 - GENERAL SET-UP OF APPARATUS

PERFORMANCE

1. The Control Test.

The valve was placed on the radiator and connected to the steam supply or riser. It was adjusted to about three fourths of the way between the "Med" setting and "Hot". A recording thermometer was placed upon a table about five feet from the valve, set at the existing room temperature and time after an hour or so and allowed to run. Neither the valve or thermometer were touched for approximately 24 hours. At the end of that time the chart was taken from the thermometer.

Two separate control tests were run.

The actual charts are shown in figures 2 and 3. The existing outdoor temperatures were obtained from the Knoxville office of the weather bureau and plotted on the charts.

II. The Steam Flow Test.

The valve has three settings on it. The are "Cold", "Med" and "Hot". Consequently it was deemed advisable to run a separate test for each setting.

The first work was done with the value set at "Hot". The apparatus was set up as in figure 1 except that the galvanized iron box was used instead of the crock H. Crock E was not used either. A Fahrenheit thermometer was kept suspended in the vessel containing the water and bellows.

The water was first adjusted at 60° F. by letting in steam if too cold, and tap water if too hot. By careful manipulation this temperature was obtained. The excess water flowed through the slot in the box. Valve F was now adjusted until the V-gage showed a pressure difference of $\frac{1}{4}$ pound at 80° the value was open and steam began to flow through finally coming out as water into tank L. Tank L was now emptied and put back on the scales wet but not under the condensate. The scale arm was balanced. Attention was now given to see if the temperature in the iron or "tin" box was still at 80°. If not it was made so again. The pressure was also made constant at $\frac{1}{4}$ pound. Now the tank L was quickly shoved under the condensate to catch it, and the time noted to seconds. Attention was now given to keeping the temperature constant. At the end of the desired time interval the tank L was quickly drawn from under the flow and weighed. The difference in times gave the time of collecting the now known discharge. The steam flow per hour at 80° F and $\frac{1}{4}$ pound pressure could now be determined. This same procedure was followed up to 10 pounds pressure; then the temperature was lowered to 75°F and the work and notation repeated. Finally a run was made at 70°F. This gave in the end three temperatures and three steam flows for every pressure studied, which made enough points to draw curves like those mentioned under "General Theory".

The valve was now set at "Med" and the two crocks arranged as shown in figure 1. It was necessary to use ice-water here to get low enough temperatures. The valve was started out at 70°F; the next temperature taken was 65°F; the final was 60°F. Outside of the temperature control the procedure was exactly the same as when the valve was set at "Hot". The temperature was controlled by letting ice-water from E to H or by admitting steam to H as the occasion demanded. Overflow was taken care of by the tube and

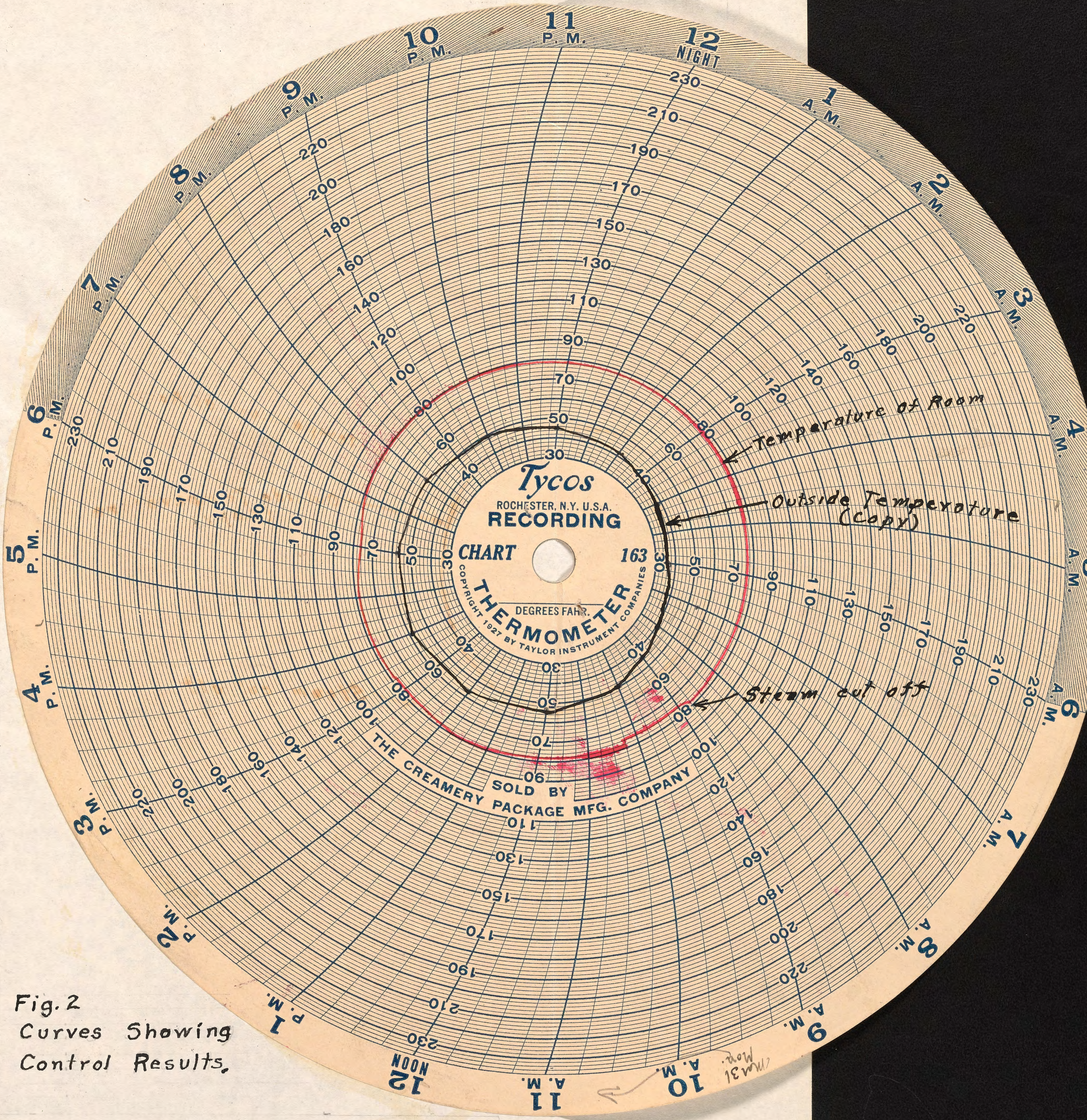


Fig. 2
Curves Showing
Control Results.

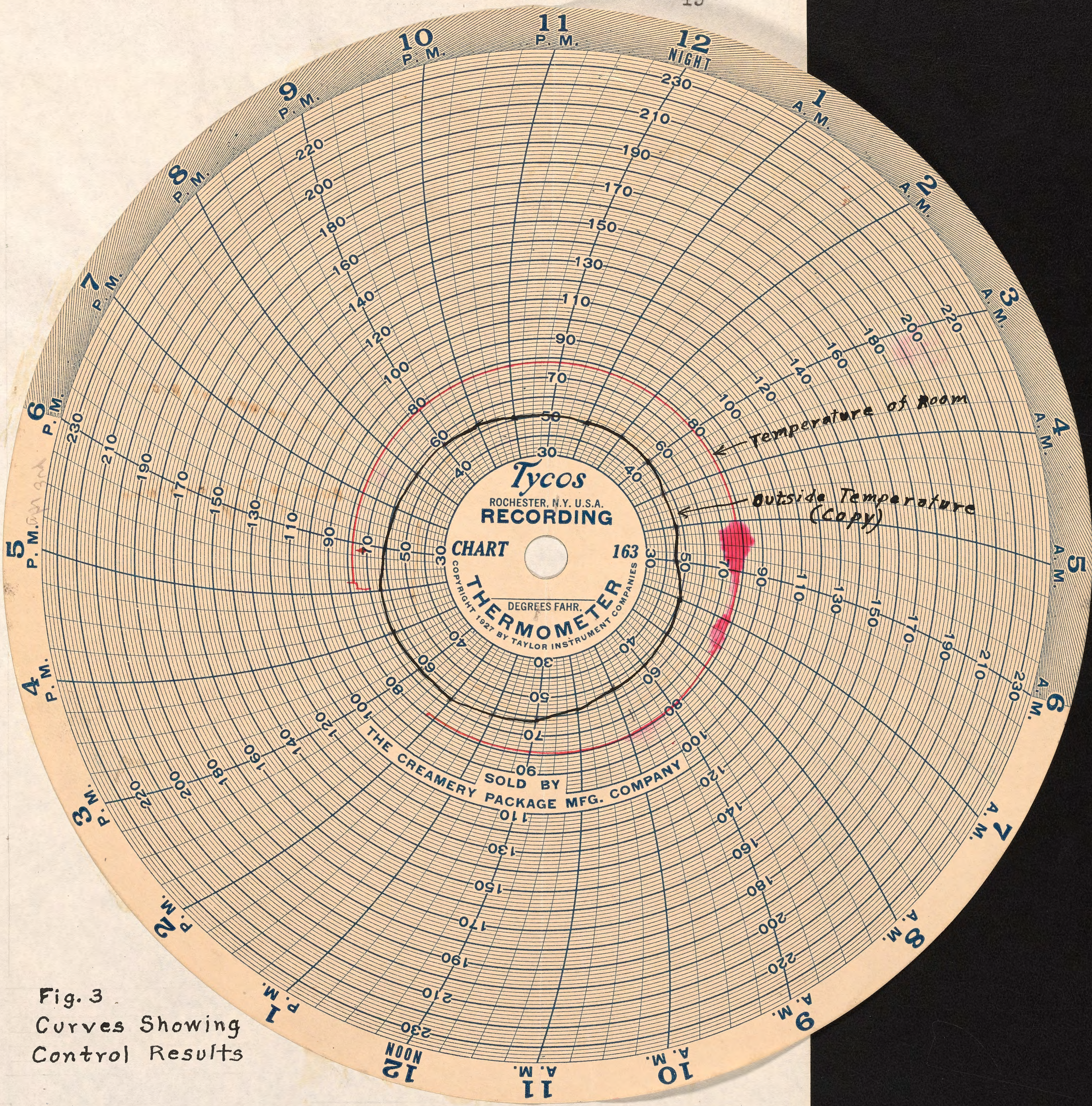
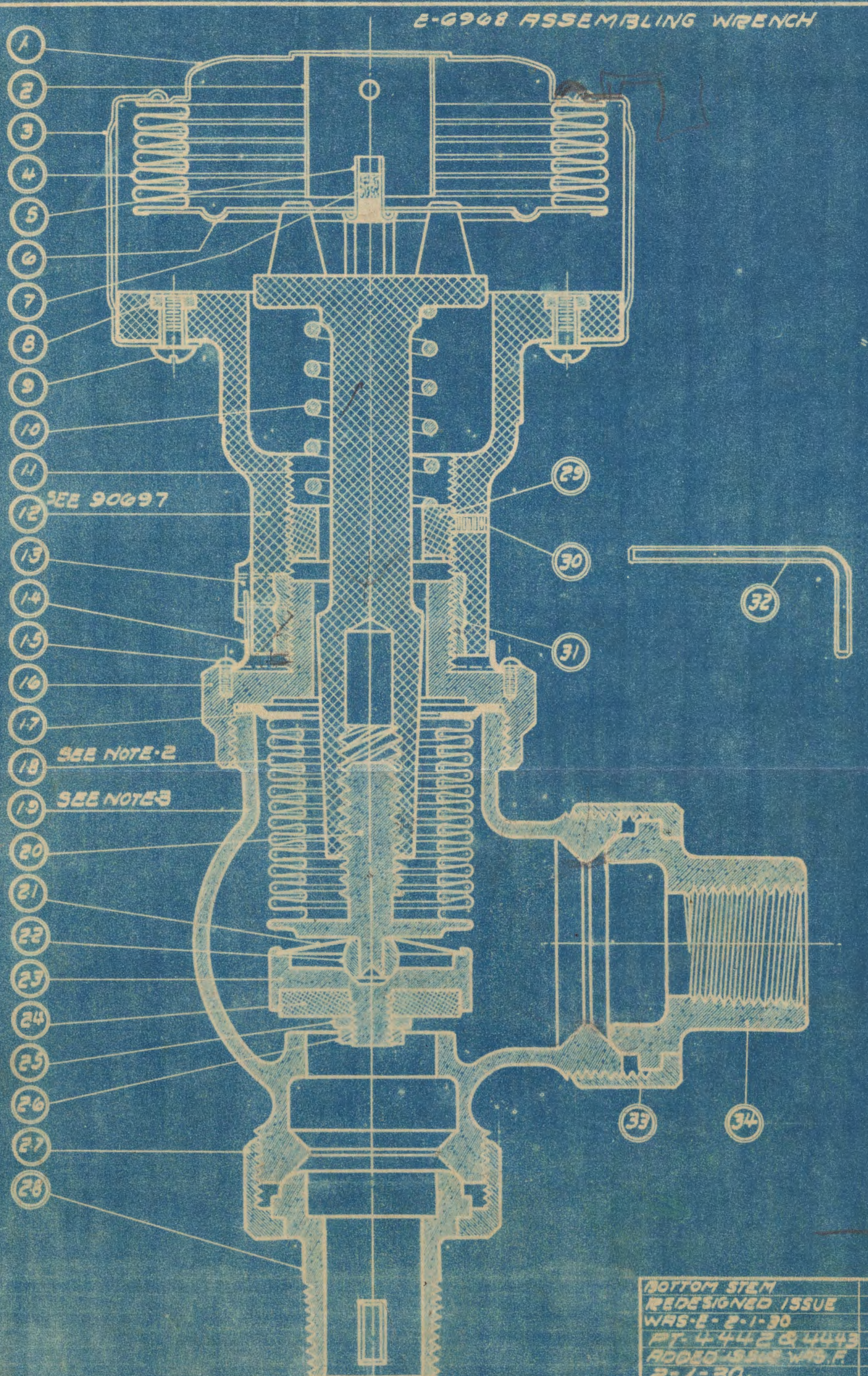


Fig. 3
Curves Showing
Control Results



NOTE-1- TEMPERATURE RANGE 60° TO 80° MAX. STROKE 1/4"

NOTE-2- WHEN ASSEMBLING SEE THAT FREE LENGTH OF SYLPHON 90201-14R IS ENOUGH TO BRING VALVE DISC 2493 IN CONTACT WITH VALVE SEAT WHEN RING HEAD 2270 RESTS ON TOP OF VALVE BODY.

NOTE-3- CAST BRASS ELBOW 4669 CAN BE USED WITH TAIL PIPES AND TAIL NUTS SHOWN HERE TO REPLACE #875 FOR SUPPLYING TEMPORARY HEAT WHEN #875 IS REMOVED FOR ANY REASON AFTER INSTALLATION.

		DET. Nº	Nº REQ'D	DESCRIPTION	SIZE OF VALVE 1/2	3/4	1
D	A	1	1	BELLOWS HEAD	1113	1113	1113
D	A	2	1	BELLOWS STOP	4431	4431	4431
	D	3	1	SPIDER	4432	4432	4432
D	A	4	1	SYLPHON BELLOWS	162-6	162-6	162-6
D	A	5	1	FILLING TUBE	1720	1720	1720
D	A	6	1	BELLOWS HEAD	4433	4433	4433
	D	7	1	SEALING CORK	658	658	658
D	C	8	4	Nº 10-24 HEX NUT (PURCHASED IN SUBASSEM 90697)	1586	1586	1586
	D	9	4	Nº 10-24 X 3/8 ROUND HD. SCR.	2262	2262	2262
		10	1	LOADING SPRING	4434	4434	4434
	D	11	1	THERMOSTAT TRI-POD 90774	~~4435~~	~~4435~~	~~4435~~
D	C	12	1	THERMOSTAT BASE (SEE 90697)	4436	4436	4436
		13	1	LOCK SCREW 1/4-20 X 3/8 ALLEN HD. SET. SCR.	4446	4446	4446
		14	1	STOP	4437	4437	4437
		15	2	Nº 6-32 X 3/16 ROUND HD. SCR.	2289	2289	2289
		16	1	CAP NUT	4438	4438	4438
	B	17	1	BELLOWS HEAD	2270	2270	2270
	B	18	1	SYLPHON BELLOWS	90201-14R	90201-14R	90201-14R
		19	1	VALVE BODY	4439	4439	4439
B	E	20	1	STEM HEAD	4817	4817	4817
B	E	21	1	ANCHOR	4816	4816	4816
B	E	22	1	SWIVEL JOINT BALL	4818	4818	4818
B	E	23	1	DISC HOLDER	4819	4819	4819
	B	24	1	VALVE DISC	2493	2493	2493
	B	25	1	DISC WASHER	1492	1492	1492
	B	26	1	DISC NUT	1501	1501	1501
		27	1	TAIL NUT	1472	1472	1472
		28	1	TAIL PIPE	4547	4548	4596
		29	1	SPRING SEAT	4445	4445	4445
		30	1	Nº 6-32 X 1/4 HEADLESS STL. SET SCR.	4602	4602	4602
D	C	31	1	REINFORCING RING	4748	4748	4748
		32	1	KEY FOR LOCK SCR.	4444	4444	4444
		33	1	TAIL NUT	1473	1473	1473
		34	1	TAIL PIPE	4441	4442	4443

A	90694	162-6, 1113, 4433, 4431, 1720
B	90695	1492, 1501, 2270, 2493, 90749, 90201-14R
C	90697	1586, 4436, 4748
D	90736	658, 2262, 4432, 4435, 90694, 90697
E	90749	4816, 4817, 4818, 4819

ALLOWABLE VARIATION ON DIMENSIONS LOCATING FINISHED SURFACES IS + OR - .015 UNLESS OTHERWISE SPECIFIED.

BOTTOM STEM REDESIGNED ISSUE WAS E-2-1-30
PT. 4442 & 4443 ADDED ISSUE WAS F
2-1-30

DRAWN
TRACED
CHECKED J.W.H.
DATE 2-1-30
SCALE 12" = 1 FT.

THE FULTON SYLPHON CO.
SYLPHON PATENTS

X-510

RADIATOR CONTROL VALVE #875

DRAWING No. | ISSUE F G

13

pinchcock extending from H.

The procedure with the setting at "Cold" was the same as that at "Med".

Figures 5, 6, and 7 show the results of the steam flow procedure. The observed data is shown on the pages immediately preceding the curves.

III. The Valve Opening Study

As in the steam flow work three sets of datas had to be collected, due to the three different settings.

Here ice-water was put into crock H, and the temperature permitted to rise with an occasional check so as to get a dial gage reading. Time had to be given the valve to reach the temperature shown by the themometer at each reading.

The pressure was left at about 1 pound throughout the whole test.

Where the temperature rise was too slow between points to be read steam was admitted to H to speed up the rise.

The tabulations show dial gage readings and corresponding temperatures. The dial gage was set arbitrarily to start with. The study in each case was made over the temperature range for that setting. Resulting curves are shown in figures 8, 9, and 10.

TABLE I

Data From Steam Flow Test

$\frac{3}{4}$" Valve No. 875 Set At "Hot"

Temp. of Valve Deg. F.	Steam Press Lbs. Per Sq. In.	Condensate Lbs.	Time Interval Min.	Lbs. Steam Per Hour
80	$\frac{1}{4}$	2.17	20	6.51
80	$\frac{1}{2}$	2.23	15	8.92
80	$\frac{3}{4}$	2.70	15	10.80
80	1	1.88	10	11.28
80	2	1.53	6	15.30
80	3	1.54	5	18.48
80	4	1.75	5	21.00
80	5	2.15	5	25.80
80	6	2.24	5	26.84
80	7	2.65	5	31.80
80	8	3.12	5	37.40
80	9	4.00	5	48.00
80	10	4.16	5	49.85
75	$\frac{1}{4}$	3.33	10	20.00
75	$\frac{1}{2}$	2.28	5	27.38
75	$\frac{3}{4}$	2.68	5	32.80
75	1	3.31	5	39.70
75	2	4.48	5	53.75
75	3	5.60	5	67.20
75	4	6.61	5	79.25
75	5	9.00	6	90.00
75	6	8.25	5	99.0
75	7	9.27	5	111.1
75	8	12.00	6	120.0
75	9	10.89	5	130.80
75	10	11.74	5	140.4
70	$\frac{1}{2}$	5.33	10	32.0
70	$\frac{1}{2}$	4.30	6	43.0
70	$\frac{3}{4}$	4.40	5	52.8
70	1	5.28	5	63.4
70	2	8.82	6	88.2
70	3	9.17	5	111.0
70	4	11.12	5	133.0
70	5	12.31	5	147.7
70	6	13.46	5	161.5
70	7	14.90	5	179.0
70	8	19.37	6	193.7
70	9	17.10	5	205.0
70	10	18.24	5	219.0

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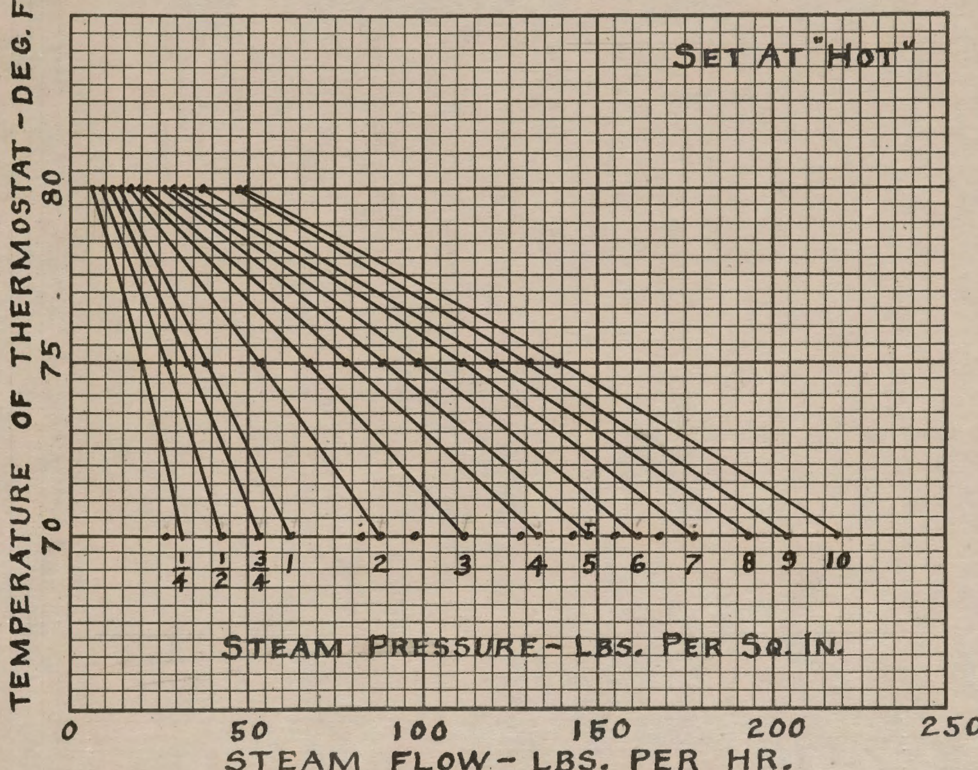

FIG. NO. 5

TITLE:- Curves Showing The Relation of Steam Flow to Pressure and Temperature.

INTERPRETATION OF CURVES - Since 1 lb. of steam gives 4 sq. ft. of radiation the abscissae represent four sq. ft. of radiation per unit lb. of steam. By reading upward to the desired steam pressure line and to the left the available temperature can be found.

If the temperature and radiation is assumed, where the two cordinates cross will give the steam pressure required.

TABLE II

Data From Steam Flow Test (Cont'd)

¾" Valve No. 875 Set At "Med"

Temp. of Valve Deg. F.	Steam Press Lbs. Per Sq. In	Con- densate Lbs.	Time Interval Min.	Lbs. Steam Per Hour
70	¼	.67	10	4.02
70	½	.86	10	5.14
70	¾	.69	5	8.30
70	1	.83	5	10.00
70	2	1.37	5	16.5
70	3	1.84	5	22.1
70	4	2.17	5	26.0
70	5	2.52	5	30.2
70	6	2.79	5	33.5
70	7	3.06	5	36.8
70	8	3.42	5	41.0
70	9	3.61	5	43.2
70	10	6.15	8	46.1
65	¼	2.20	7	18.84
65	½	2.20	5	26.40
65	¾	2.57	5	30.81
65	1	2.97	5	35.60
65	2	5.34	6	53.40
65	3	5.70	5	68.40
65	4	6.48	5	77.75
65	5	7.56	5	90.70
65	6	8.24	5	99.0
65	7	9.20	5	110.3
65	8	9.75	5	117.0
65	9	10.44	5	625.2
65	10	27.05	12	135.2
60	¼	1.88	5	22.56
60	½	3.27	5	39.22
60	¾	4.73	6	47.30
60	1	4.59	5	55.10
60	2	7.00	5	84.0
60	3	8.70	5	104.3
60	4	10.02	5	120.0
60	5	13.85	6	138.5
60	6	12.43	5	149.2
60	7	13.69	5	164.2
60	8	14.74	5	177.0
60	9	15.92	5	191.0
60	10	33.13	10	200.0

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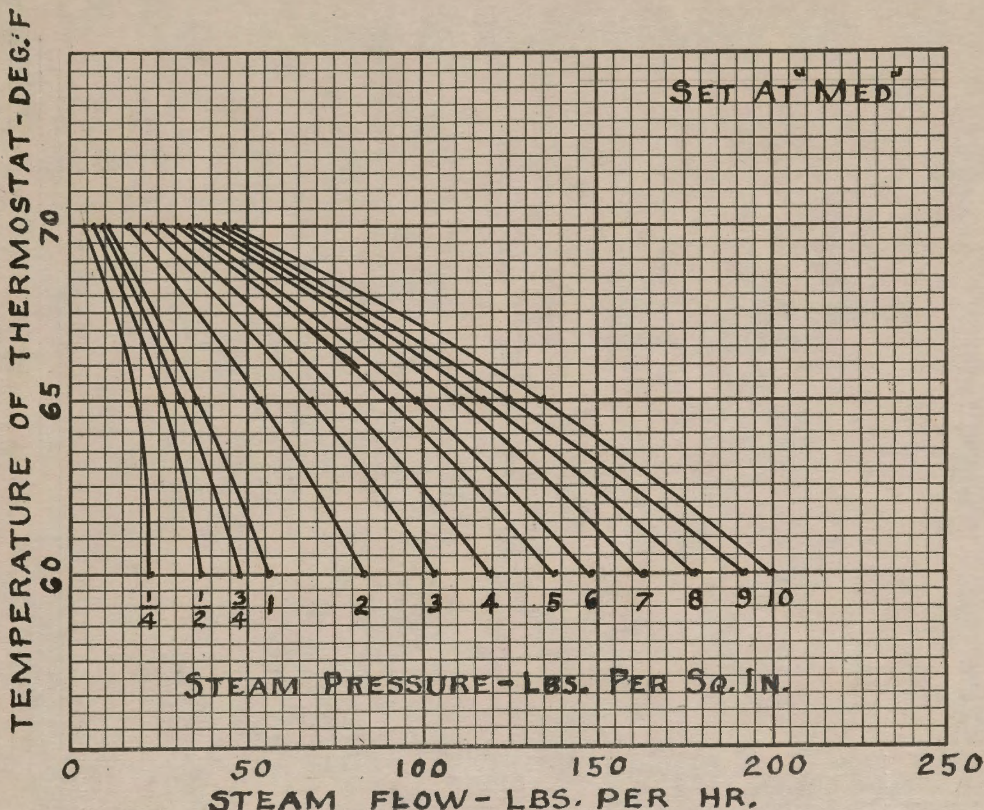

FIG. NO. 6

TITLE:- Curves Showing The Relation of Steam Flow to Pressure and Temperature.

INTERPRETATION OF CURVES - Same as for setting at "Hot" except that here some less steam flows for the same pressure, due to the lower temperatures.

TABLE III

Data From Steam Flow Test (Cont'd)

¾" Valve No. 875 Set At "Cold"

Temp. of Valve Deg. F.	Steam Press Lbs. Per Sq. In.	Con-densate Lbs.	Time Interval Min.	Lbs. Steam Per Hour
60	¼	0	10	0
60	½	.208	10	1.25
60	¾	.209	5	2.51
60	1	.334	5	4.20
60	2	.417	5	5.20
60	3	.625	5	7.51
60	4	.855	5	10.25
60	5	1.19	5	14.37
60	6	1.54	5	20.50
60	7	1.77	5	22.56
60	8	2.20	5	24.35
60	9	2.25	5	29.05
60	10	2.92	6	31.60
55	¼	.47	5	5.65
55	½	.20	5	8.40
55	¾	.87	5	10.60
55	1	1.27	5	15.25
55	2	2.05	6	20.50
55	3	2.06	5	24.75
55	4	2.44	5	29.33
55	5	2.68	5	32.11
55	6	2.88	5	34.5
55	7	3.71	6	37.1
55	8	3.20	5	38.4
55	9	3.35	5	40.2
55	10	3.52	5	42.25
50	¼	.88	6	8.80
50	½	1.02	5	12.25
50	¾	1.19	5	14.30
50	1	1.56	5	18.70
50	2	2.03	5	24.40
50	3	2.45	5	29.40
50	4	2.84	5	33.83
50	5	3.21	5	37.24
50	6	3.33	5	40.00
50	7	3.47	5	41.60
50	8	3.76	5	45.10
50	9	3.96	5	47.50
50	10	4.13	5	49.64

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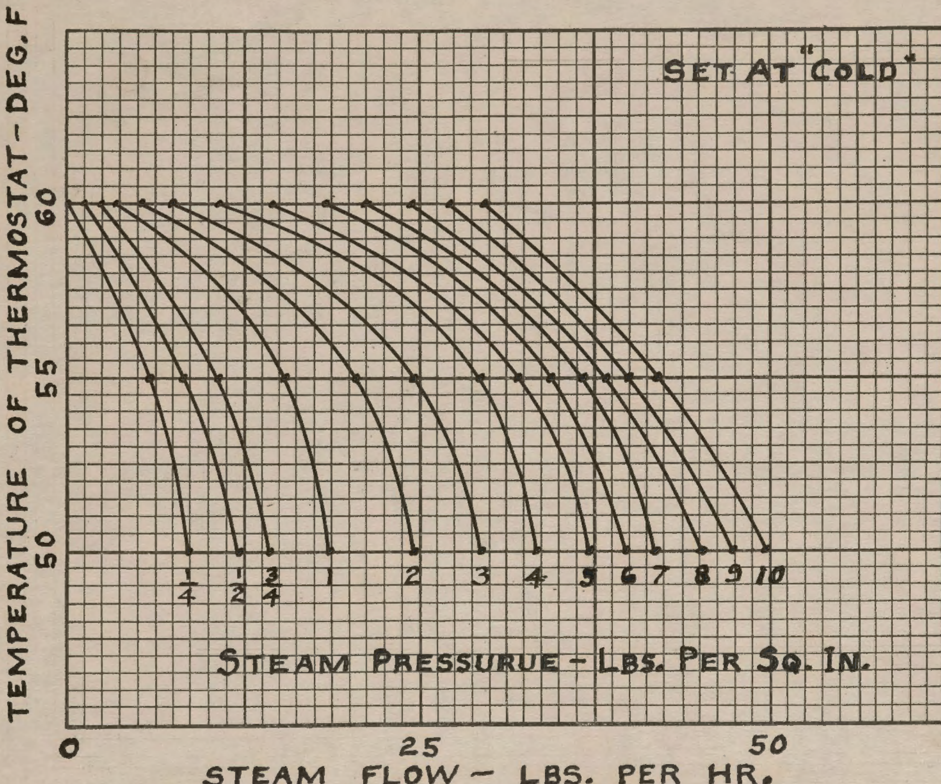

FIG. NO. 7

TITLE:- Curves Showing Th Relation of Steam Flow to Pressure and Temperature.

INTERPRETATION OF CURVES - Same as others but with a much lower steam consumption. A temperature above 60_0F cannot well be reached with valve set at "Cold".

TABLE IV

Data From Valve Opening Study

Temp. of Valve Deg. F.	Dialgage Reading Inches	Remarks	Temp. of Valve Deg. F.	Dialgage Reading Inches	Remarks
Valve Set At "Cold"					
45	.0368		62	.0531	
50	.0392		63	.0537	
55	.0429		64	.0542	Slow drip
60	.0468		65	.0548	
61	.0495		66	.0561	No flow
Valve Set At "Med"					
55	.070		73	.1250	
60	.076		74	.1265	
65	.0945		75	.1294	
68	.1057		76	.1325	Slow drip
70	.1110		77	.1330	
71	.1196		78	.1339	
72	.1216		80	.1350	No flow
Valve Set At "Hot"					
65	.0043		84	.0797	
70	.0277		86	.0828	Fast drip
75	.0500		88	.0842	
80	.0720		90	.0875	
82	.760		92	.0896	Slow drip

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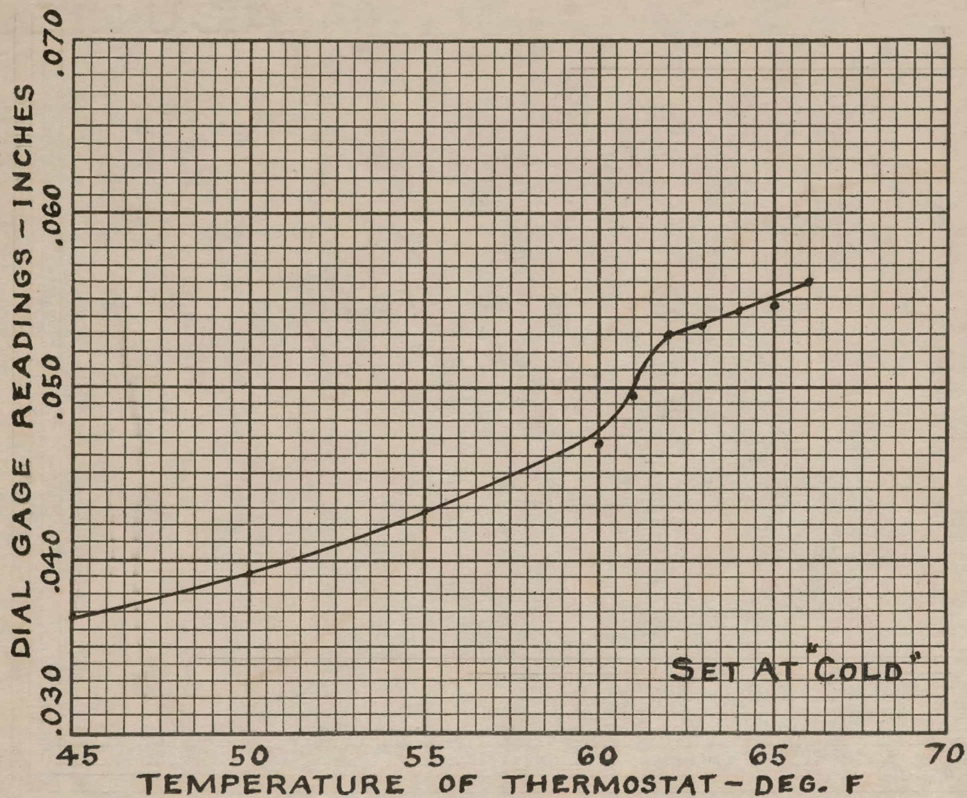

FIG. NO. 8

TITLE:- Curve Showing Variation of Valve Opening With Temperature.

INTERPRETATION OF CURVES - The gradual curve between 45° and 60° shows tht the valve opening is very nearly proportional to the temperature change within these limits. The abrupt change of direction at about 60° shows that the valve is beginning to close. The smaller slope now shows that the closing is gradual and no absolute closing temperature can be found.

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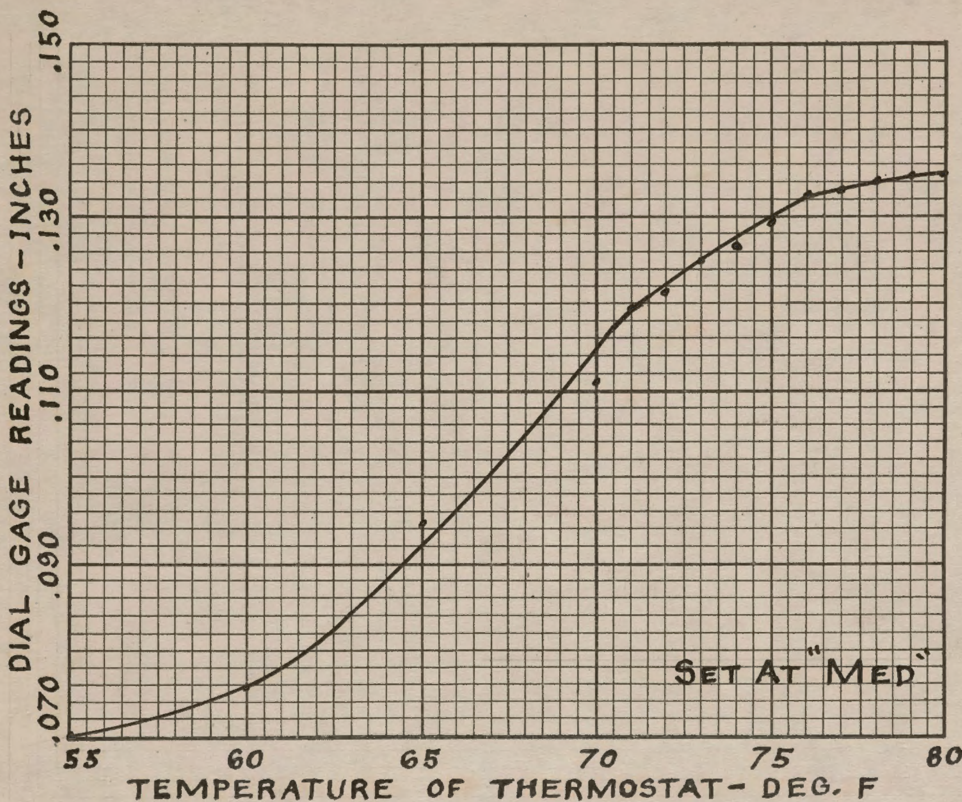

FIG. NO. 9

TITLE:- Curve Showing The Relation Between Valve Opening and Temperature Change.

INTERPRETATION OF CURVES - Practically the same in general as the preceding curve. Here however the valve comes in contact with its seat at about 71°. Some irregularity in the seat may have caused steam to flow until nearly 80° was reached.

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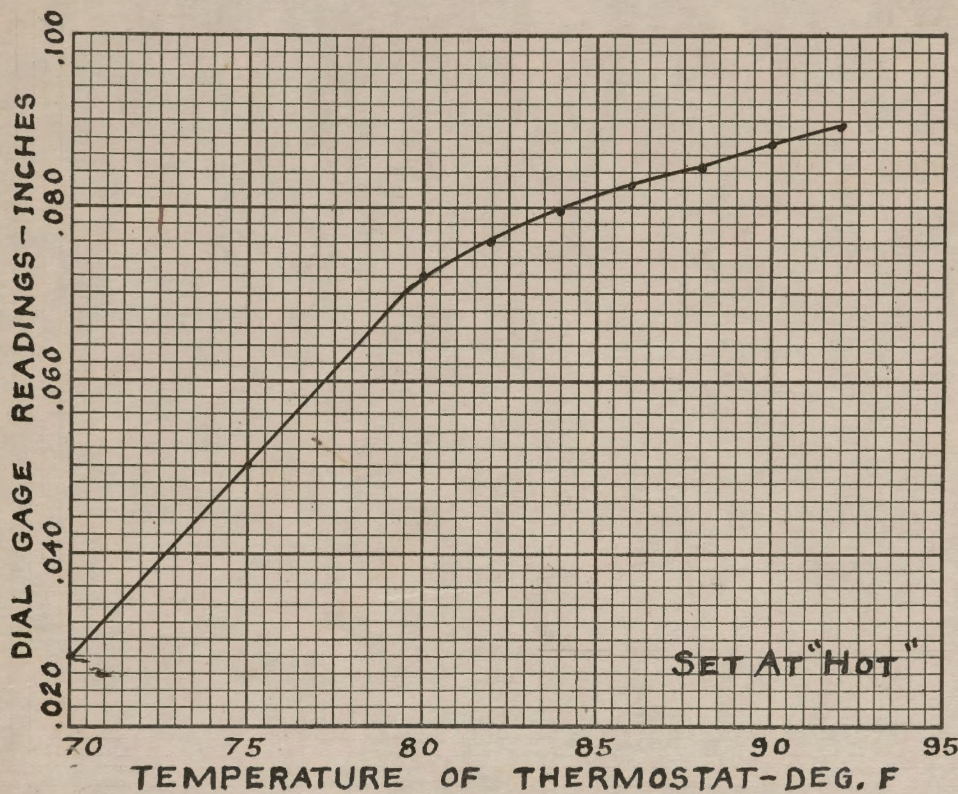

FIG. NO. 10

TITLE:- Curve Showing The Relation of Valve Opening to Temperature Change.

INTERPRETATION OF CURVES - This time the valve apparently starts seating at about 80°. Its actual closing is rather indefinite as shown by the curve.

CONCLUSION

From the results of the tests it appears that the valve studied will perform in a very creditable manner. The temperature control is particularly good. The variation was not more than a half degree above or below the temperature at which the room was to be held.

While the study of the valve closing would seem to indicate that the valve was not sensitive to small temperature changes, the control test refutes this indication. It was noticed that the valve seated slowly as the temperature increased. But even before it was fully closed it ceased to admit enough steam for appreciable heating. The sensitivity then, is not necessarily dependent upon the suddenness with which the valve completely closes.

The steam flow tests show the capacity of the valve at ordinary heating pressures of $\frac{1}{4}$ lb. to 10 lbs. with room temperatures from 50° to 80°.

APPROVAL.

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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