Bulletin 393 August, 1932

THERMOSTATICALLY CONTROLLED MASTER VALVES AS HEAT CONTROLLERS FOR BUILDINGS

By F. E. Goetz

Colorado Agricultural College
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Fort Collins

The Colorado Agricultural College

FORT COLLINS, COLORADO

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ACKNOWLEDGMENT

The author wishes to express his appreciation to the Public Service Company of Colorado for the loan of measuring equipment, to Col. Chas. Larsen for suggestions and helpful advice, to Prof. J. H. Scofield and Miss Lois Hopkirk for assistance in collecting data, and to all others who in any way assisted, either by action or consent, in making this study and report possible.

THERMOSTATICALLY CONTROLLED MASTER VALVES AS HEAT CONTROLLERS FOR BUILDINGS

By F. E. Goetz

Introduction

Purpose.—The purpose of this investigation was to study the action of thermostatically controlled master valves in order to ascertain their value as a means of controlling temperatures in buildings. While the idea of controlling temperature thermostatically was not new, control of an entire building thru one thermostat and one valve gave promise of considerable saving in heating costs and the study was made with a view to economizing on fuel as well as bringing about more comfortable and healthful living conditions for the workers occupying the buildings.

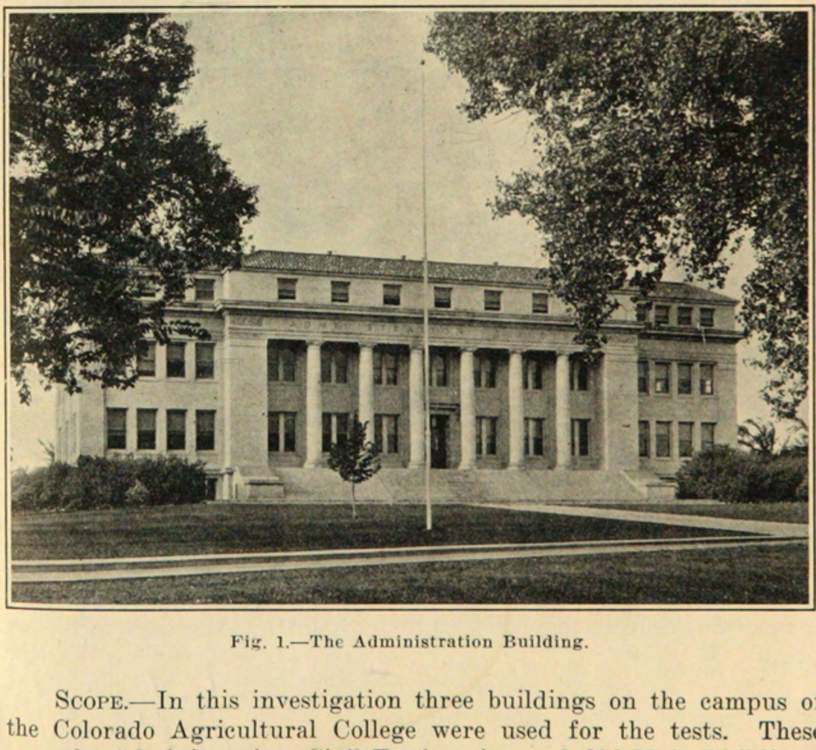

Fig. 1.—The Administration Building.

Scope.—In this investigation three buildings on the campus of the Colorado Agricultural College were used for the tests. These were the Administration, Civil Engineering and Old Main Buildings.

Each was equipped with one thermostat and one valve on the steam main leading to that building from the central heating plant. Metering apparatus was installed on two of the buildings, the Administration and Civil Engineering. Fuel consumption was taken from the records kept in the building superintendent's office and weather conditions taken from the records of the Meteorological Station at the college.

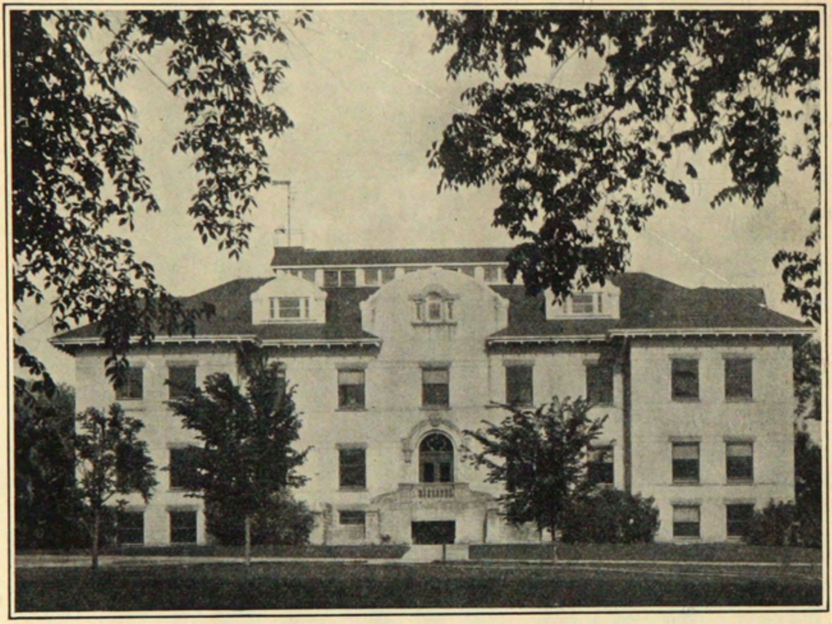

Fig. 2.—The Civil Engineering Building.

FACTORS AFFECTING THE CONTROL OF TEMPERATURE IN THE BUILDINGS

LAYOUT OF THE BUILDING.— The layout of a building has a good deal to do with the control of temperatures in that building. In general the more compact a building the easier it will be to control the temperatures. Of the three buildings tested, two were of the compact type and one, the Old Main Building, was rather badly cut up due to several additions to the original building, some of which were rather isolated. This caused a greater variation in temperature among the rooms in this building than in either of the other two.

RADIATION.—Radiation may affect temperature control in several ways. Experience has shown that the two-pipe system is easier to control than the one-pipe system. With the two-pipe system the amount of steam flowing to each radiator can be controlled by means of the

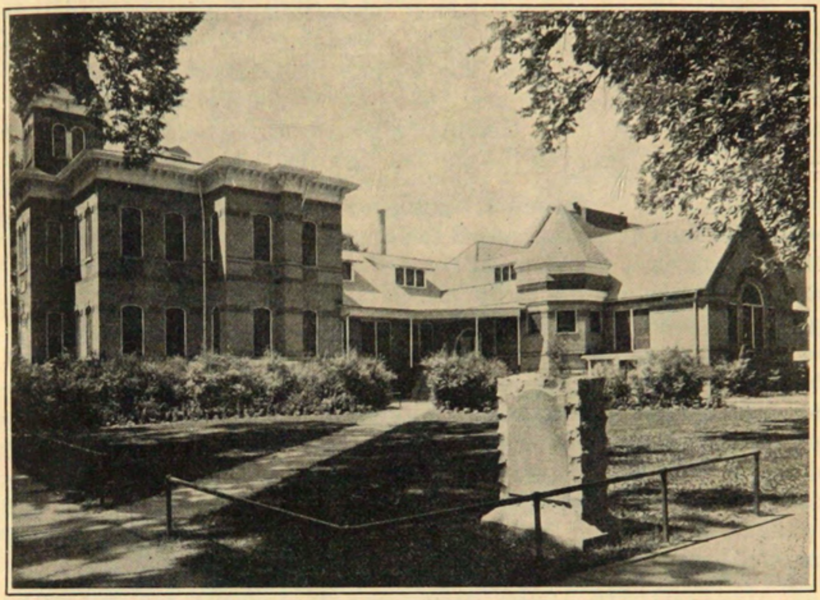

Fig. 3.—The Old Main Building.

radiator valve. This cannot be done with a one-pipe system or water-logging will result. Consequently a more even distribution of heat can be obtained with a two-pipe system thru adjustment. This, however, should not be meant to make up for an improper amount of radiation but only as a control to counteract other conditions, particularly weather. If the radiation in a building is sufficient and well distributed, even tho it is a one-pipe system, the temperature can be satisfactorily controlled. The Old Main and Civil Engineering Buildings are buildings with a one-pipe heating system. The Administration Building has a two-pipe system thruout.

KINDS OF WORK CARRIED ON.—If the work carried on in any particular building is the same thruout, the different parts of the building can all be run at the same temperature. When more than one kind of work is carried on, then adjustments must be made in the heating system to take care of the difference in heat required, whether more or less. To have more than one kind of work carried on in the same room is not a satisfactory arrangement as some of the occupants will either be too hot or too cold. Such a condition existed in the printing room in the basement of the Administration Building where printing, type-setting and office work were all being carried on in the same room. The office workers were always too cold when the printers were comfortable. Separation of the different kinds of work is essential to the success of a master control system.

OUTSIDE TEMPERATURES.—Only low extremes of outside temperatures affect temperature control in a building. Thermostats must be placed in a location where low outside temperatures at night will cause them to turn on the heat before any damage is done to the contents of a building thru freezing or temperatures become too low to be returned to normal in the allotted time the following morning.

WIND.—Of all factors affecting the control of heat in buildings, wind was the one which caused the greatest upset. In this section of the country it is not unusual for rather high winds to descend suddenly from the mountains during certain seasons of the year. These winds cause heat to be moved from the windward side to the leeward side of the buildings, thereby causing above-normal temperatures to leeward and below normal temperatures to windward. The only thing which can be done to minimize the effect of wind is to weatherproof the buildings as much as possible by weather-stripping the windows and closing as tightly as possible all other openings thru which air might move freely. This was tried as an experiment on two offices in the Administration Buildings resulting in these offices holding their normal temperatures much better.

HUMIDITY.—Humidity affects control of temperature only thru raising and lowering the comfort temperature. During the winter months the relative humidity in the buildings often runs below 20 percent. This means that comfort temperatures of from 72°F. to 75°F. must be maintained and thermostats must be set accordingly. A change in relative humidity of the air may therefore make the rooms too hot or too cold, even with the same thermostat setting, thru raising or lowering of the comfort temperature.

VENTILATION.—Some ventilation is necessary in all buildings where people are at work. Excess ventilation, however, is not only unnecessary but is one of the major sources of heat loss and one of the hardest factors to control, since it is left to each individual person to ventilate as he sees fit. Experience has shown that unless discomfort is caused, no control of ventilation to avoid excess heat loss will be exercised by those occupying the offices.

THE HUMAN FACTOR.—The mere thought that the temperature in a building is to be controlled and that the occupants of the buildings are to have no part in the control leads most people to become antagonistic to any scheme for control because they fear that their personal liberties are being encroached upon. If humans were capable of looking after themselves in the manner in which they think they are able, no controls would be necessary. Experience has shown that in most cases the occupants of a room will open the windows in order to regulate the room temperature before they will regulate the source of heat even tho the temperature may go to 80°F. or above. On the other hand sound engineering practice states that temperatures above 76°F., for this climate, are absolutely unnecessary, except in very special cases; that they are a waste of fuel, and that health is impaired and mental capacities hindered by temperatures above that figure in closed rooms. Since this is the case, controls are desirable but care must be exercised in their setting so that comfortable conditions are maintained, taking into account as much as possible the health, individuality and time that the occupants are on duty as well as being as economical as practicable under the circumstances.

TEST APPARATUS

BUILDINGS.—Three buildings—Administration, Civil Engineering and Old Main were used for the tests. These three buildings were chosen because each was of a different type. Old Main and Civil Engineering had one-pipe heating systems while Administration had a two-pipe system. Different kinds of work were carried on in different portions of the buildings but there was sufficient duplication for comparisons. Steam was supplied to each building from the central heating plant thru low-pressure mains.

VALVES.—The valves used in these tests were remote-control, motor-operated balanced valves. These valves were installed on the steam mains where they entered each building so that all steam en-

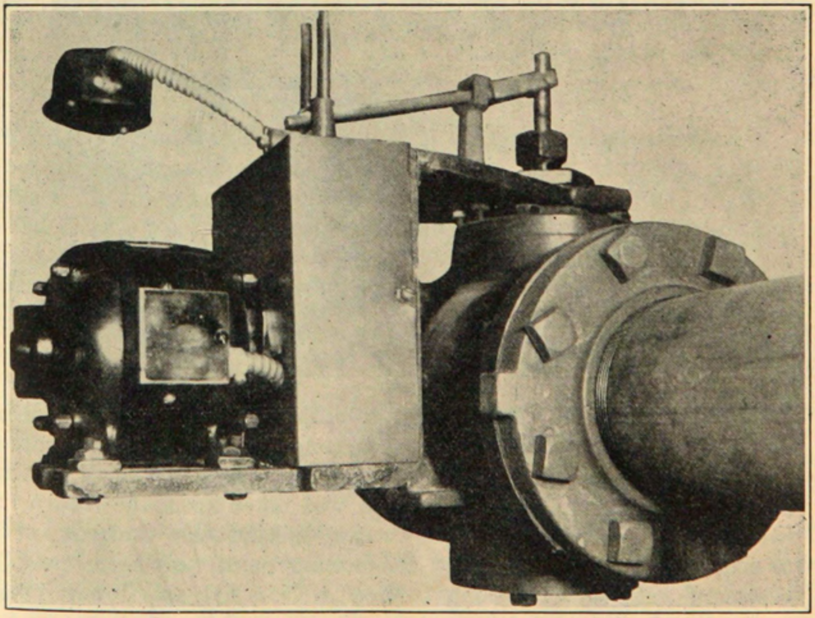

Fig. 4.—One of the master valves used in the test.

tering that building passed thru the thermostatically controlled valve.

THERMOSTATS.—The remote controls to the valves were 8-day clock-thermostats. The thermostats in Old Main and Civil Engineering were located on the first floor while the thermostat in the Administration Building was located on the second floor. These locations were selected because of their being subjected to most of the variations in temperature to which the buildings in general were exposed.

THERMOMETERS.—Thermometers were installed in all rooms in the three buildings under test. A recording thermometer, using a 24-hour chart, was mounted on a stand to make it portable and used to record temperatures in the different rooms. All thermometers were calibrated before being placed for use.

CONDENSATION METERS.—Steam consumptions for the buildings under test were measured by means of condensation meters placed in the return lines leading from the buildings. Meters used were condensation meters of the gravity, atmospheric-pressure type. Measurement of the water thru these meters was by weight, not volume.

TRAPS.—Since the return lines from the buildings were kept under vacuum, it was necessary to use steam traps which would hold both steam pressure and vacuum. For this purpose inverted bucket-type traps were chosen. Radiators on the two-pipe system in the Administration Building were equipped with traps.

RECORDING GAGES.—The time during which steam was being fed to the buildings was measured by means of a recording pressure-vacuum gage. This gage could be moved from building to building and was placed on the building side of the master valve, so that the gage recorded pressures only when steam was flowing to that building. Another recording gage connected to the high-pressure steam header at the heating plant recorded the steam pressures on the boiler side of the pressure reducer.

ARRANGEMENT OF MEASURING APPARATUS.—Apparatus for measuring the steam consumption was arranged as shown in Figure 5. This was the assembly used on the one-pipe system in the Civil Engineering Building. The condensation was taken from the return line thru a trap, thence thru the water coil in the tank, in order to cool the condensation below the boiling point, to the meter. The basement return was brought thru a No. 4 trap (lower right) to the line leading into the meter. This caused the basement line to operate on the flooded principle but it was entirely satisfactory.

From the meter the condensation returned thru another trap (extreme lower right) to the return line to the heating plant. Valves were arranged so as to change the course of the condensation from the main to the meter at will. The measuring apparatus used on two-pipe systems, such as the Administration Building, was similar except that the cooling tank and the first trap were unnecessary because each radiator was trapped separately and the condensation cooled below the boiling point of water, at atmospheric pressure, before it reached the meter.

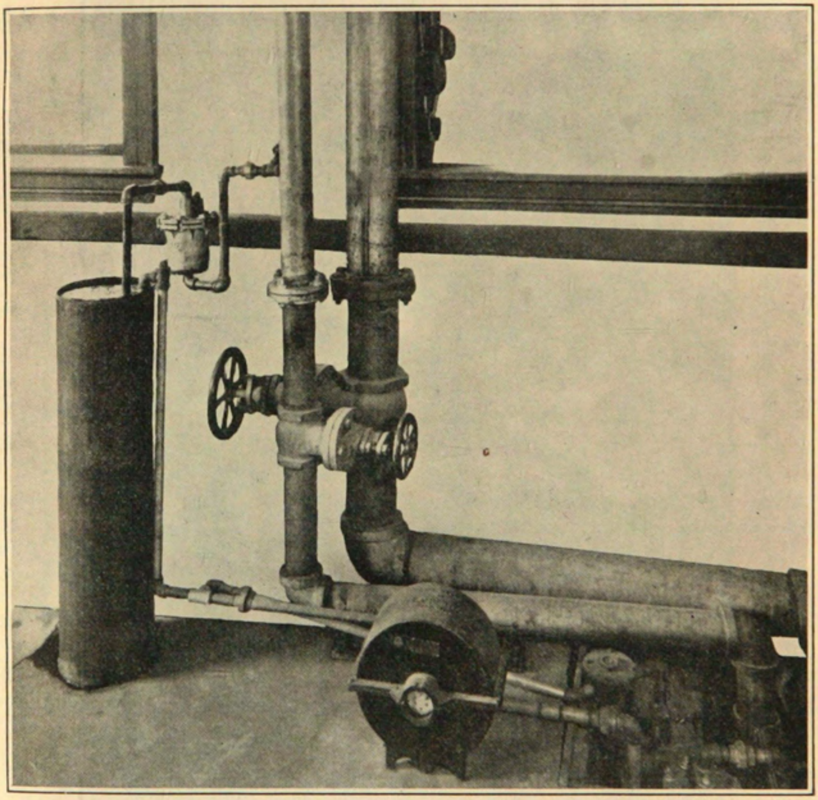

Fig. 5.—Apparatus for measuring the steam consumption in the Civil Engineering Building.

METHOD OF CONDUCTING TESTS

CONDITIONS OF THE TESTS.—The master valves were installed about the middle of September, 1931, and were put in operation a few days later. The tests continued until April 1, 1932.

The buildings under test were in normal use for the entire time of

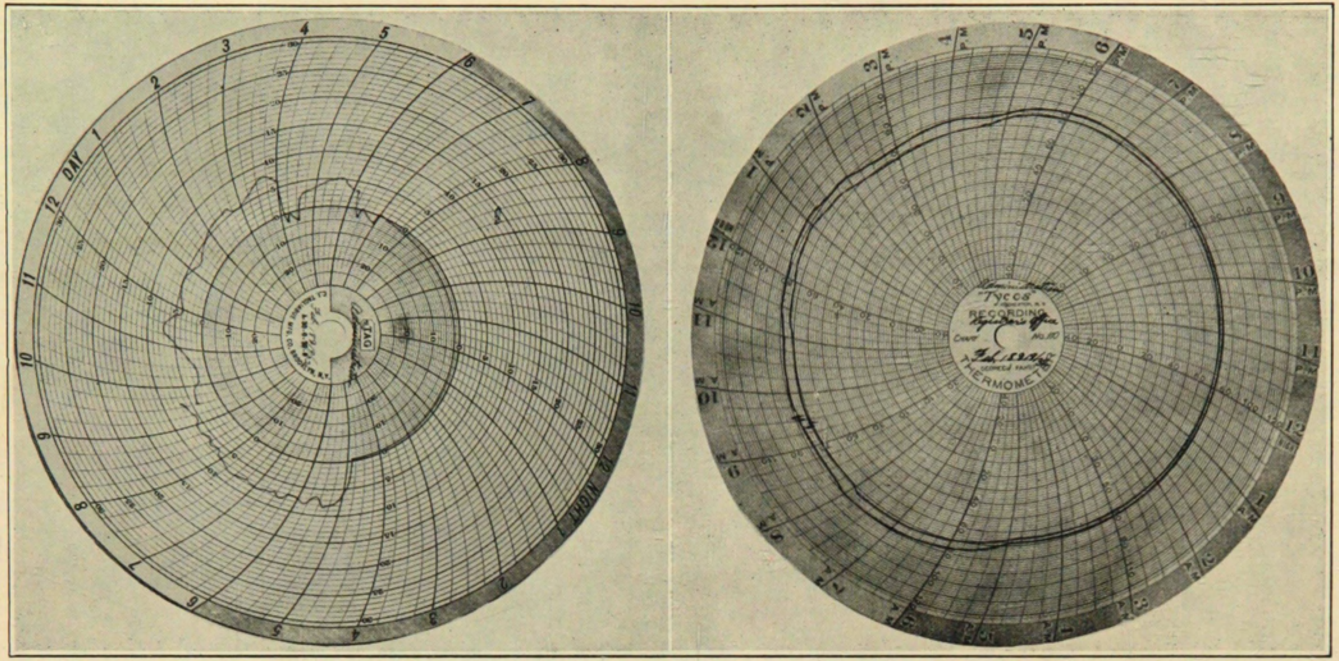

Fig. 6.—Pressure and Temperature Charts made with the control in operation.

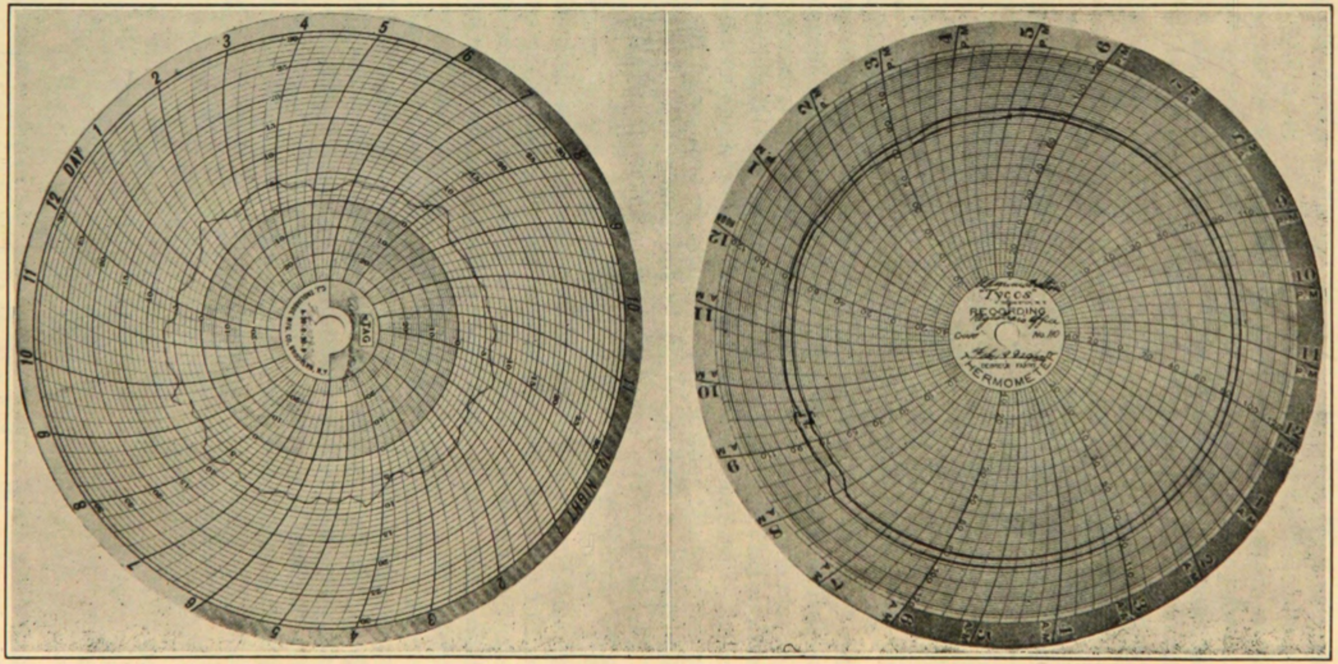

Fig. 7.—Pressure and Temperature Charts made without the control.

the test. During the daytime the control of the radiators was entirely in the hands of those using the offices. At night the janitors set the radiators so as to have the rooms above 70°F. the following morning when the workers came on duty at 8 o'clock. This assured the rooms of being as evenly heated as possible in the mornings, especially in the Administration Building with its two-pipe system.

The thermostats were set to hold a temperature of 60°F. from 6 o'clock in the evening till 5 o'clock the following morning when they automatically returned to the day setting. The day setting for the Administration Building was 73°, for the Civil Engineering Building 71°, and for Old Main Building 70°. These settings gave comfortable day temperatures in the coldest places in the respective buildings. Visits were made to each of the buildings every day and for part of the time three times per day. This gave opportunity for studying the conditions in each building very thoroly.

TEST PERIODS.—Apparatus for measuring the steam consumption was put in operation the second week in February, 1932, and daily readings taken until April 1. Two tests each were run on the Administration Building and the Civil Engineering Building during this period. These tests were made with the buildings operated without the thermostatic control and as nearly as possible in the manner in which they had been operated in previous years. The data obtained during these two test periods were taken as a basis for estimating the saving in steam consumption.

RECORDS KEPT.—Condensation meters were read daily and records kept of the time when the steam was being fed to the buildings. The recording thermometer was moved from place to place and records made of the temperatures in the different rooms in the buildings.

RESULTS AND CALCULATIONS

BUILDING TEMPERATURES.—The recording thermometer was set near the thermostats and the sensitivity found to be about 1°F. This sensitivity was sufficient to maintain even temperatures thruout the buildings during the daytime. Charts taken with the recording gage showed that the heat was very seldom on at night. Windy weather was usually the cause for the heat being on. Furthermore, comparison with the temperature chart revealed the fact that the buildings could always be heated to day temperature in less than 3 hours. Temperatures in the buildings generally averaged 3° to 5° lower when the control was in operation than when it was not. This difference however would have been much greater if excess ventilation had not removed much of the heat when the control was not in operation.

Controlling the temperature reduced the excess ventilation considerably because discomfort was caused if the ventilation was not restricted. By supplying more radiation or an auxiliary source of heat in the cold places in the buildings it was possible to reduce the temperatures in the buildings to the point where no discomfort was caused in any portions of them due either to excess or lack of heat. The net result was not only more comfortable and healthful conditions, free of extremes, in the buildings but also a considerable saving in the amount of steam required to heat the buildings. Figures 6 and 7 show steam pressure and temperature charts taken on two succeeding days in the Administration Building. On the temperature charts the inner line was the temperature at 4 feet above the floor, while the outer line was the temperature 7 feet above the floor. Figure 6 was made with the thermostatic control on and shows a normal cycle of operation. Temperatures during the night dropped to about 65°, but rose immediately when the steam came on and were amply high when the room was opened at 8 a. m. The variations in temperatures during the daytime were due only to ventilation. Figure 7 shows charts taken the next day with the heat control shut off. Temperatures averaged considerably higher during the entire 24 hours in spite of the excessive ventilation employed by those using the office in an endeavor to maintain comfortable temperatures. The waste of heat under these conditions is very apparent.

STEAM CONSUMPTION.—Steam consumptions during the time that the Civil Engineering and Administration Buildings were under test are shown in Tables I and II respectively. The first column in each table shows the actual steam consumption as measured by the meter while the second column shows the estimated consumption, when this was either desirable or necessary, as sometimes occurred. Both of the first two columns give data taken with the thermostatic control in operation. The third column in each table shows the actual steam consumption as measured by the meter and the fourth column the estimated consumption when it was either desirable or necessary, both of these two columns being with the thermostatic control shut off and the buildings operated as they had been before the controls were installed. The data given in these two tables are shown graphically in Figure 8. Examination of the tables and graphs will show at once the economy in steam consumption effected by thermostatic control.

Tables III and IV show daily mean temperatures and daily mean wind velocities, respectively, as recorded by the Meteorological Station at Fort Collins. These data are also shown graphically in Figure 9. A comparison of the steam consumptions of the two buildings with the weather conditions shows that the steam consumption varied almost inversely as the outside temperature and directly as the wind velocity. Since this relation exists, the graphs give a fairly reliable source from which to estimate savings effected thru the use of the thermostatic control.

Table I.—Civil Engineering Building steam consumption.

	Thermostat On		Thermostat Off		
Date	Actual Steam Consumption in Lbs.	Estimated Steam Consumption in Lbs.	Actual Steam Consumption in Lbs.	Estimated Steam Consumption in Lbs.	Remarks
Feb. 8					
9					
10					
11	6600				
12	11700				
13	6700				
14	7600				
15	8700				
16	7700				
17	8500				
18	8100				
19	7800				
20		6000	15400		
21		5000	11500		
22		4300	13200		
23		3300	4300		
24		3200	8400		
25		3300	8300		
26		3000	2200		
27	2600				
28	1600				
29	2600				
Mar. 1	3000				
2	6700				
3	5000				
4	7800				
5	8800				
6	8100				
7	10800				
8	12300				
9	15700				
10	14900				
11	14600				
12		14000	21700		
13		12000	19500		
14		9000	18000		
15		5300	7500		
16		5000	7200		
17		3000	7100		
18		6000	7900		
19	100	3000			
20	2100				
21	5300				
22	5700				
23	4700				
24	3800				
25	6900				
26	5900				
27	4300				
28	4500				
29	2500				
30	5700				
31	3200				

Table II.—Administration Building steam consumption.

	Thermostat On		Thermostat Off		
Date	Actual Steam Consumption in Lbs.	Estimated Steam Consumption in Lbs.	Actual Steam Consumption in Lbs.	Estimated Steam Consumption in Lbs.	Remarks
Feb. 8	7400				
9	10200				
10	8000				
11	8500				
12	12200				
13	11000				
14	12800				
15	12400				
16	12400				
17	12800				
18	11700				
19	11900				
20		10500	19400		
21		10100	14100		
22		9000	14200		
23		7000	11000		
24		6700	10300		
25		6700	10600		
26		6600	10800		
27	3700	6000			Feb. 28
28		4000			Trap outlet lock-
29		6000			ed and flooded
Mar. 1		6500			meter
2	9300				Mar. 2
3	9500				Trap repaired
4	10700				and again in
5	13800				service
6	11200				
7	10700				
8	13400				Mar. 12 frozen
9	16600				return line pre-
10	15200				vented measure-
11	13600				ment of conden-
12		13000			sation.
13		12800	24500		Mar. 15 Trap
14		11000	20100		outlet locked
15		9000		14000	and flooded meter.
16	2900	8000			Mar. 16 Repaired
17	6300				and in service
18	9000				
19	6600				
20	5300				
21	8100				
22	10800				
23	9600				
24	8200				
25	7700				
26	8900				
27	8400				
28	9800				
29	3200				
30	8100				
31	8100				

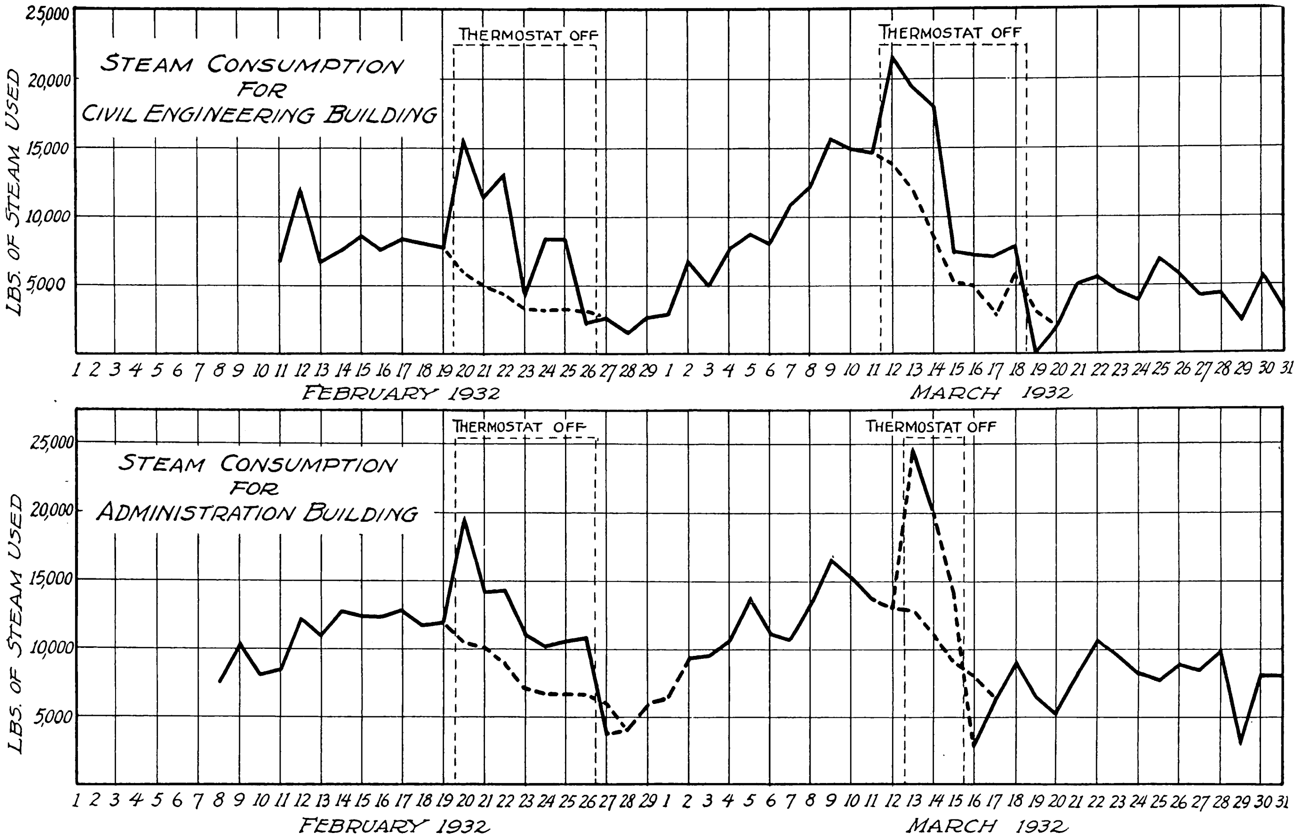

Fig. 8.—Graphs of steam consumptions for the two buildings under test.

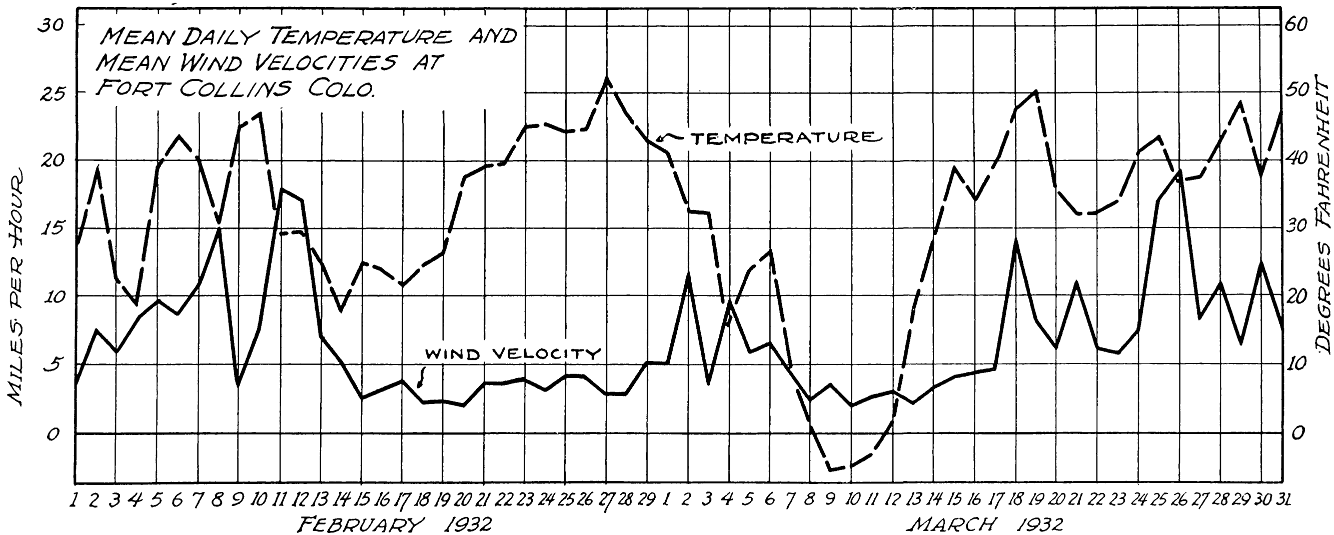

Fig. 9.—Graph of mean daliy temperatures and mean daily wind velocities during the test period.

Table III.—Daily mean temperatures at Fort Collins, February and March, 1932.

Date	Maximum Degrees F.	Minimum Degrees F.	Mean Degrees F.
Feb. 1	54.2	0.2	27.20
2	51.0	25.0	38.00
3	29.9	15.2	22.55
4	43.0	-6.9	18.05
5	49.0	27.9	38.45
6	57.4	29.1	43.25
7	49.0	31.0	40.00
8	41.6	19.4	30.50
9	62.0	27.2	44.60
10	60.2	33.2	46.70
11	36.1	21.8	28.95
12	36.2	22.0	29.10
13	34.2	15.0	24.60
14	20.8	14.4	17.60
15	31.0	17.8	24.40
16	27.4	20.4	23.90
17	42.8	0.4	21.60
18	38.4	10.7	24.55
19	43.0	9.8	26.40
20	58.8	16.2	37.50
21	57.0	21.2	39.10
22	59.6	19.6	39.60
23	62.0	27.6	44.80
24	65.3	25.1	45.20
25	60.3	28.2	44.25
26	66.6	22.0	44.30
27	74.2	29.6	51.90
28	64.1	28.9	46.50
29	55.0	30.2	42.60
Mar. 1	51.4	30.2	40.80
2	48.3	16.6	32.45
3	49.0	15.3	32.15
4	26.7	7.8	17.25
5	39.0	8.8	23.90
6	43.6	11.2	27.40
7	13.3	6.4	9.85
8	8.9	-7.2	0.85
9	16.0	-27.5	-5.75
10	9.8	-19.6	-4.90
11	12.1	-18.7	-3.30
12	27.2	-24.4	1.40
13	38.5	-2.8	17.85
14	45.2	13.0	29.10
15	53.0	25.2	39.10
16	46.0	22.0	34.00
17	49.5	30.2	39.85
18	57.7	37.5	47.60
19	63.0	38.2	50.60
20	46.2	26.0	36.10
21	40.6	23.7	32.15
22	41.6	22.8	32.20
23	49.4	18.2	33.80
24	58.0	24.4	41.20
25	52.1	35.2	43.65
26	46.1	27.7	36.90
27	55.4	19.2	37.30
28	64.5	21.2	42.85
29	61.0	36.1	48.55
30	59.1	16.1	37.60
31	65.3	29.3	47.30

Table IV.—Daily mean wind velocities at Fort Collins, February and March, 1932.

Date	Maximum Miles per hour	Minimum Miles per hour	Mean Miles per hour
Feb. 1	7	0	3.29
2	17	2	7.46
3	14	1	5.88
4	26	1	8.33
5	29	2	9.62
6	23	2	8.79
7	25	3	11.00
8	38	2	14.90
9	7	1	3.54
10	20	2	7.62
11	31	8	18.00
12	36	1	17.08
13	13	2	6.96
14	9	2	5.25
15	5	1	2.42
16	8	1	3.04
17	8	1	3.79
18	4	0	2.29
19	4	0	2.38
20	4	0	2.04
21	6	1	3.62
22	7	1	3.71
23	8	1	3.92
24	8	1	3.12
25	8	1	4.08
26	6	2	4.04
27	7	0	2.92
28	6	0	2.79
29	13	0	5.17
Mar. 1	14	1	5.17
2	31	1	11.58
3	8	1	3.75
4	22	2	9.54
5	12	0	5.92
6	12	1	6.67
7	9	0	4.79
8	6	0	2.54
9	7	1	3.62
10	4	1	2.00
11	6	0	2.75
12	6	1	3.08
13	4	1	2.17
14	6	2	3.38
15	13	1	4.25
16	17	1	4.54
17	11	2	4.67
18	34	4	14.08
19	19	3	8.29
20	16	2	6.29
21	14	5	11.00
22	13	1	6.21
23	10	2	5.79
24	20	1	7.50
25	54	3	16.96
26	35	1	19.25
27	23	2	8.29
28	32	1	10.96
29	14	2	6.58
30	35	2	12.46
31	22	1	7.50

Two test runs, without the thermostatic control, were made on each building, the results of which are given in Tables I and II. These two test periods together with the actual and estimated steam consumptions are also shown in the graph, Figure 8. Actual steam consumptions as metered are shown in solid lines on the graph while those estimated from records and experience gained in using the thermostatic control are shown in dotted lines.

Compilation of the figures given in Table I for the period February 20 to February 26 shows an actual steam consumption, in the Civil Engineering Building, of 63,300 pounds of steam, with the control shut off. The estimated consumption, during this same period with the control amounted to 28,100 pounds of steam. The indicated saving was therefore 35,200 pounds of steam or about 55.6 percent. For the period March 12 to March 18 the actual consumption, without the control was 88,900 pounds of steam, the estimated consumption with the control 54,300 pounds of steam, the indicated saving 34,600 pounds of steam and the saving 38.9 percent. This gives an average indicated saving for the two test periods of 47.2 percent.

The figures for the Administration Building, when compiled from Table II give somewhat similar results. For the period February 20 to February 26 an actual consumption, without the control, of 90,400 pounds of steam was shown. The estimated consumption, with the control, for the same period, amounts to 56,600 pounds of steam. The indicated saving is therefore 33,800 pounds of steam which is about 37.4 percent. For the period March 13 to March 15 the actual and estimated consumption without the control amounts to 58,600 pounds of steam, the estimated consumption with the control, 32,800 pounds of steam. The indicated saving therefore amounted to 25,800 pounds of steam which is 44.0 percent. This gives an average indicated saving for this building of about 40.7 percent. The second run on this building was, unfortunately, cut short by trouble with some of the apparatus but the results obtained appeared to be of value so were included in the data given.

Averaging the results for the two buildings, a saving of 44 percent is indicated.

COAL CONSUMPTION.—The records of the coal consumption at the central heating plant for the seasons 1930-31 and 1931-32, to April 1 in each case, show that during 1930-31 the coal consumption amounted to 5,453 tons while during 1931-32 it amounted to only 4,796 tons. This is a saving of 657 tons which amounts to 12 percent. At $2.50 per ton the saving is $1,642.50. Since the controls for the three buildings cost about $1000.00 installed, the profit on fuel saved is evident.

These savings in fuel were made under circumstances which ordinarily tend to increase the coal consumption rather than diminish it. The records of the Meteorological Station, given in Table V, show that the season 1931-32 averaged 0.89° colder with much lower minimum temperatures than the season 1930-31. In addition to this, the Horticultural Laboratory, a one-story brick building, size 40 feet by 75 feet, was added to the heating-plant load during 1931-32. In spite of these handicaps the above savings are shown.

Table V.—Monthly mean temperatures at Fort Collins.

		Maximum Degrees F.	Minimum Degrees F.	Mean Degrees F.	Range Degrees F.
1930	Sept.	85.4	26.0	59.28	30.34
	Oct.	76.6	17.2	46.53	28.77
	Nov.	69.9	11.1	37.30	30.72
	Dec.	58.0	3.8	27.69	30.55
1931	Jan.	66.2	2.0	29.92	33.35
	Feb.	61.1	12.2	34.75	26.98
	Mar.	65.8	0.0	34.75	24.25
1930-31	Means for Season			38.60	29.28

		Maximum	Minimum	Mean	Range
1931	Sept.	88.6	33.0	63.31	31.27
	Oct.	79.3	18.4	50.37	28.28
	Nov.	75.4	-1.2	32.83	30.22
	Dec.	59.8	-2.9	29.36	28.56
1932	Jan.	56.6	-3.2	24.40	25.38
	Feb.	74.2	-6.9	34.69	29.24
	Mar.	65.3	-27.5	29.03	28.24
1931-32	Means for Season			37.71	28.74

DISCUSSION OF RESULTS

ACCURACY OF RESULTS.—The savings in steam consumption for the two buildings on which data were taken are estimates only. These estimates were made from the experience gained in using the controls and observations of the amounts of steam used under various weather conditions. Estimated points were plotted on a graph and checked with points made from actual data taken from meter readings. As near as could be determined, these estimates were accurate within a range of about 5 percent.

The saving in coal consumption would undoubtedly have been greater if the conditions of 1930-31 could have been duplicated exactly in 1931-32. This, however, was impossible but the outstanding fact is that a considerable profit was shown even in spite of the handicaps mentioned.

CONCLUSIONS

SUMMARY OF CONCLUSIONS.—Under the conditions of the tests the following conclusions were arrived at:

The master controls maintained comfortable, even temperatures free of extremes at all times except during high winds.

Night temperatures were kept down but never so low but what the buildings could be heated to day temperatures in less than 3 hours.

Excess ventilation was materially reduced, thereby conserving considerable heat which would otherwise have been wasted.

Steam consumption was materially reduced, estimations indicating an average saving of about 44 percent during the two test periods run on the buildings.

A saving in fuel consumption was shown in spite of an increased load on the heating plant and lower average temperature for the season. The fuel saving under these conditions amounted to about 12 percent and not only paid for the entire equipment but showed a considerable profit on the investment.