THE HEATING AND VENTILATING SYSTEM

of

THROOP COLLEGE OF TECHNOLOGY.

THESIS CLASS 1913.

THROOP COLLEGE OF TECHNOLOGY.

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The object of this thesis was to make a report upon the existing conditions of the heating and ventilating system at Throop College of Technology. The method of procedure consisted in making and recording various tests and observations of the steam power plant and ventilating system in the main building. The work was carried on through the months of February, March and April, at the end of which the weather was such as to allow the heating to be discontinued except for an occasional day. The following notes, drawings and data were compiled from the observations and experiments.

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LAYOUT AND FEATURES.

The steam power plant is used for heating the main building and for running the apparatus in the steam laboratory. The steam power plant is situated about one hundred and fifty feet from the main building and is equipped with a Scotch Marine boiler rated at one hundred and fifty boiler horse power. The boiler has, for auxiliaries, the necessary feed pump and air pump for forcing the oil fuel feed. Oil fuel is used, fed by a Cyclone burner. Steam or air may be used as an atomizing medium. Steam is kept at an average pressure of sixty pounds gage under ordinary working conditions. An eight inch steam line carries steam from the steam plant to the main building manifolds, where the incoming air is heated as necessary. The steam manifolds are made up of one-inch pipe, there being eight sections, two rows of coils in each section, and exposing a total heating surface of 2900 square feet. The steam pressure on the manifolds is kept at fourteen pounds gage and all condensed steam flows back by gravity through a four inch line to the hot well. The condensed steam enters the hot well at a temperature of two hundred and eight degrees fahrenheit. A drawing of the layout of the steam power plant and connections to the manifolds is given on Plate I. The boiler is used seven months during the year, averaging three hours a day during October, November, April, and May, and seven hours a day during December, January, February and March.

The heating and ventilating system is of the indirect type. Air is taken in at the basement floor beneath the front steps by means of a twelve foot fan driven by a three phase, seven and one-half horse power alternating current motor. The air flows in at the rate of 44,700 cubic feet per minute and passes through a humidifying wall of dampened coke. The air is then forced through the heating manifolds into the hot air tunnel, or into the cold air tunnel, or into both, depending upon the conditions existing at the time. The hot air tunnel is situated directly above the cold air tunnel, both running the length of the main building directly below the basement hall floor. From these air tunnels the flues lead up to the rooms, each room having one or more flues, depending upon its size. The tunnels are also used for conduits for the steam, water, and gas mains, electric light and power wires, and sewer pipes. The rooms have as many outlet flues for the foul air as they have inlet flues for the hot air. The amount of air entering each flue is regulated by means of an automatic damper which in turn is governed by a thermostat situated in each room. (A more detailed description of this system of governing is given on page 4 .) The air in the hot air tunnel is kept at an average temperature of 145° fahrenheit, while the air in the cold air tunnel remains at approximately outside temperature. A Plan of the Fan Room and Tunnels is given on Plate II.

In addition to the action of this large fan in the basement, the ventilation of the Chemistry Department on the upper floor is assisted by four smaller fans. The small fans are used when the work in the laboratories is in progress. Two of these fans are four feet in diameter. Each is driven by a three and one-half horse-power, three phase, alternating current motor. They take the foul air from the laboratories and exhaust directly to the outside through a stack on the roof. The remaining two fans are small wall fans used for ventilating the hoods in the laboratories and exhaust directly to the outside. A Plan of the Chemistry Department is given on Plate III.

The main air outlets from the building are as follows: two on the west side of the roof, one on either side of the dome; two between the ceiling of the second-floor hall and chemistry-laboratory floor, one at the north and the other at the south end of the building; two on the east side of the roof, one on either side of the dome, which are used for the chemistry laboratories and pipe ducts.

The pressure within the building is kept greater than atmospheric pressure and there is a constant escape of foul air from the building to the outside. The incoming air is forced up to the rooms in round sheet-iron flues and enters through rectangular steel gratings situated ten feet above the floor. The outlet for the foul air is a similar opening placed at the floor level and leads directly into the dead air space between the walls, which serves as a flue to the top of the building. There is a large space under the roof of the building where the foul air collects from these flues and from here it passes through the outlets on the roof to the outside.

AUTOMATIC TEMPERATURE GOVERNING.

The Thermostat

The thermostat, shown on Plate IV. is made and operates as follows:- The thermostatic tube (A) is vulcanized rubber, a change in the length of which produces action in the valve lever (O) by means of the plug (H) and the connecting rod (K) pressing on the seat (L). This valve is permitted to open the port (G) under increased pressure on (K) by the flexure of the plate spring (N) and when this pressure is relieved, the spring (N) causes the valve to close. Air under 15 pounds pressure is supplied by the pipe (C). The air must pass through the filter (P) and port (G) into the thermostat. It then passes through the passage (W) to the atmosphere.

The adjustment of the thermostat for different temperatures is provided for by means of the screw (J) acting through the top plug and the indicating disk (X). The air supply is taken from the air main through a small needle-valve or restrictor, which restricts the quantity of air passing through it. This air then flows through the pipe (C) to the thermostat and a branch is taken from (C) and run to the diaphragm operating the damper-motor. When the temperature of a room has fallen so as to produce pressure on the rod (K) through the contraction of the thermostatic tube (A), the port (G) will be opened by the valve lever (O), allowing the air which is fed through the restrictor to flow out of the port (G) into the thermostat and through the passage (W) to the atmosphere. This operation releases the air pressure on the damper-motor diaphragm and causes the springs to pull the diaphragm in, and at the same time shifts the dampers, allowing the warm air to flow into the flue. As soon as the room becomes warm the thermostatic tube expands and relieves the pressure on the rod (K). The valve lever (O) then closes the port (G) and permits no air to escape. The air is then forced through the pipe to the damper-motor and causes the diaphragm to expand, at the same time shifting the dampers and shutting off the hot air. The amount of air released through the port (g) by the valve lever (O) varies the pressure on the damper-motor diaphragm and causes the graduated action desired. The amount of air released through (G) can be regulated by turning the indicating disc. In this way the proper amounts of cold and hot air are allowed to pass into the flue and give the desired temperature in the room.

BUILDING MEASUREMENTS TO DETERMINE RADIATION LOSS.

BASEMENT FLOOR

Room Number	Height	Length of Surface	Number of Windows	Panes per Window	Size of Pane	Total Surface	Net Wall Surface	Net Glass Surface
2	15'	12'-3"	1	12	2'x1'-10"	159.25	115.25	44.
(a)	15	16- 0	1	8	23" x 24"	240.00	198.75	41.25
(b)	15	17'-6"		4	19" x 20"	263.50	263.50	
(c)	15	8'-0				120.00	120.00	
4	15	46'-3"	6	8	24" x 29"	693.00	538.3	154.7
10	15	9'-0"	1	12	21" x 24"	135.00	93.00	42.0
12	11	10'-10"	2	6	21" x 22"	119.20	80.7	38.50
16	11	11'-0	1	12	21" x 22"	121.00	82.5	38.50
(a)	15	32'-0	1	12	21" x 24"	480.00	283 .0	197.0
(b)			2	8	29" x 24"			
20	15	14'-10"	2	8	29" x 24"	222.5	67.5	155.0
22	15	15'-0	2	8	29" x 24"	225.0	70.0	155.0
24	15	21'-0	1	8	23" x 24"	315.0	273.75	41.25
(a)	15	29'-0	1	12	21" x 23"	435.0	394.75	40.25
(b)	15	8'-0		4	19" x 20"			
25	15	15'-6"	Door	1	39" x 29"	232.5	219.9	12.60
			"	1	36" x 19"			
(a)	15	29'-0	1	12	21" x 23"	435.0	393.75	41.25
(b)	15	18'-0		4	19" x 20"	270.0	259.45	10.55
21	15	61'-6"	3	12	23" x 24"	922.5	784.50	138.00
(a)	15	23'-5"	2	6	20" x 19-1/2	351.25	318.75	32.50
9	15	37'-4"	2	6	20" x 19-1/2	559.50	527.00	32.50
(a)	15	15'-6"	1	12	23" x 24"	232.50	186.50	46.00
3	15	30'-0	2	12	23" x 24"	450.00	358.00	92.00
1	15	33'-5"	2	2	19" x 20"	501.25	490.75	10.50
(a)	15	20'-6"	1	12	23" x 21"	307.50	267.25	40.25

BUILDING MEASUREMENTS TO DETERMINE RADIATION LOSS
(Continued)

FIRST FLOOR.

Room Number	Height	Length of Surface	Number of Windows	Panes per Window	Size of panes	Total Surface	Net Wall Surface	Net Glass Surface
122	16	7' -6"	1	15	23"x28"	120.00	52.90	67.10
(a)	16	26'-6"	2	3	12"x18"	424.00	415.00	9.00
(b)	16	18'-0"	1	8	23"x27"	288.00	253.50	34.50
119	16	8'-3"	Door	1	29"x39"	132.00	119.60	7.90
				1	18"x36"			4.50
(a)	16	26'-6"	1	15	23"x29"	424.00	354.40	69.60
(b)	16	11'-0	2	3	12"x18"	176.00	171.50	4.50
120	16	15'-0	2	8	29"x27"	240.00	153.30	86.70
118	16	14'-6"	2	8	29"x27"	232.00	145.30	86.70
Dean's Office	10	25'-6"	4	4	21"x31"	255.00	182.80	72.20
110	16	60'-0	6	12	29"x27"	960.00	568.00	392.00
101	16	15'-0	1	15	23"x29"	240.00	158.00	69.60
			Door		29"x39"			
					18"x36"			12.40
(a)	16	24'-0	1	3	12"x18"	384.00	379.50	4.50
103	16	25'-0	1	15	29"x24"	400.00	323.00	72.50
			1	3	12"x18"			4.50
105	16	60'-0	2	30	29"x24"	960.00	820.50	145.00
				3	12"x18"			4.50
(a)	16	12'-0	1	16	22"x24"	192.00	133.30	58.70
113	16	13'-0	1	3	12"x18"	208.00	203.50	4.50
(a)	16	18'-6"	1	16	22"x24"	296.00	237.30	58.70
115	16	31'-0	2	15	23"x29"	496.00	357.00	139.00
119	16	21'-4	1	15	23"x29"	340.00	270.50	69.50
102	16	24'-0	1	15	23"x29"	384.00	314.50	69.50
(a)	16	23'-0	2	8	27"x29"	368.00	281.00	87.00
(b)	16	15'-0	Door		29"x39"			
					18"x36"	240.00	227.60	12.40

BUILDING MEASUREMENTS TO DETERMINE RADIATION LOSS
(Continued)

SECOND FLOOR.

Room Number	Height	Length of Surface	Number of Windows	Panes per Window	Size of Panes	Total Surface	Net Wall Surface	Net Glass Surface
224	14	35'-0"	2	15	14"x15"	490.00	437.20	43.8
				2	18 x 36			9.0
(a)	14	33'-6"	2	12	18 x 16	470.00	404.50	48.0
				12	14 x 15			17.50
222	14	15'-0"	2	12	16 x 18	210.00	162.00	48.00
218	14	34'-6"	2	12	(16 x 18)	483.00	406.00	48.00
				9	(21 x 22)			29.00
210	14	9'-6"	1	9	21 x 22	133.00	104.00	29.00
208	14	10'-0"	1	12	16 x 18	140.00	116.00	24.00
206	14	54'-6"	5	12	(16 x 18)	764.00	635.00	120.00
				2	(18 x 36)			9.00
(a)	14	34'-0	2	15	15 x 15	476.00	410.40	47.00
				12	14 x 16			18.60
205	14	26'-0	2	15	15 x 15	364.00	308.10	55.90
				2	18 x 36			
(a)	14	35'-0	3	12	16 x 18	490.00	418.00	72.00
(b)	14	7'-6"	1	12	16 x 18	105.00	81.00	24.00
207	14	43'-6"	3	12	16 x 18	609.00	516.50	92.50
				1	4 x 4			
217	14	36'-0"	2	12	16 x 18	504.00	435.50	68.50
				1	4 x 4			
221	14	15'-0"	2	12	16 x 18	210.00	162.00	48.00
223	14	15'-0"	2	12	16 x 18	210.00	162.00	48.00
225	14	8'-0"	Door	1	39 x 29	112.00	99.60	12.40
					19 x 36			
	14	19'-0"	1	12	16 x 18	266.00	237.50	28.50
	14	26'-0"	2	15	15 x 15	364.00	317.20	46.80
215	11	29'-0"	2		6-1/2x9'	319.00	212.00	107.00
	20	11'-0"	1	12	16 x 18	220.00	196.00	24.00
Ceiling		13x40	Sky light		48 sq. ft			
						520.00	472.00	48.00

BUILDING MEASUREMENTS TO DETERMINE RADIATION LOSS
(Continued)

SECOND FLOOR

Room Number	Height	Length of Surface	Number of Windows	Panes per Window	Size of Panes	Total Surface	Net Wall Surface	Net Glass Surface
216	10	27'-0	2	4	21"x22"	270.00	217.50	52.50
				8	21 x 31			
(a)	10	11'-6"	2	4	21 x 31	115.00	88.20	26.80

THIRD FLOOR
Chemistry Department

Room Number	Height	Length of Surface	Number of Windows	Panes per Window	Size of Panes	Total Surface	Net Wall Surface	Net Glass Surface
302	12.6	78'-0				975.00	975.00	
(a) Ceiling		12-1/2'x61		4	7-1/2'x12'	762.50	402.50	360.00
(b) End		8-1/2 x45				382.00	382.00	
(c) Office ceiling		12-1/2'x18		1	7-1/2'x12'	225.00	135.00	90.00
300	Same as 302						1894.50	450.00

FOURTH FLOOR
Library

Walls -	Diameter 37' - Height 9'-6"			1100.00.	
	Diameter 31' - Height 11'-7"	(20-2-1/2'-5')	1127	877.00	250.00
Dome	Radius 18' - Height 11'			11370.00	

Total sq. ft. of radiation surface:

To Outside - Walls = 36,815 sq. ft.
Glass = 5,490 sq. ft.

BUILDING MEASUREMENTS TO DETERMINE RADIATION LOSS

HALL RADIATING SURFACE

The surface radiating to the halls was calculated from the previous tables. In most cases each room has as much hall radiation surface as it has outside radiating surface. With this thought in view, each room was considered and corrections were made for any corner or irregular rooms. Doors were considered the same as ordinary wall space. The following is the total hall radiating surface for each floor:

Basement Floor -	3,766 sq. ft.
First Floor	4,310 sq. ft.
Second Floor	3,946 sq. ft.
Third Floor	2,000 sq. ft.
	14,022 sq. ft.

RADIATION LOSS OF HEAT

In order to determine the heat lost by radiation, each room was inspected and the exposed radiating wall-surface measured and tabulated as given. Calculations were based upon the following assumptions:-

1. Room temperature = 70° Fahr.
2. Outside " = 40° "
3. Hall " = 60° "
4. Radiation coefficient for walls = .25
5. " " " glass = 1.0

Formula

$$H = K W (t_1 - t_o) = \text{B. T. U. lost per hour}$$

K = Radiation coefficient

W = Sq. ft. of radiation surface

t_1 = Temperature of room ° Fahr.

t_o = Outside temperature ° Fahr.

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HEAT REQUIRED FOR VENTILATING AIR

In order to find the amount of heat required to ventilate the building comfortably, the total ventilated volume was taken directly from the building specifications, and substituted in the following formula:

$$H = (.02 \times CV) \ (t_1 - t_o) = \text{B. T. U. per hour}$$

C = No. of air changes per hr.

V = Total ventilated volume.

t_1 = Temperature of room ° Fahr.

t_o = Outside Temperature ° Fahr.

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HEAT REQUIREMENTS BASED ON THEORETICAL CONDITIONS

Radiation Loss of Heat:

56,815 = sq. ft. wall surface to outside

5,490 = sq. ft. glass " " "

14,022 = sq. ft. wall " " halls

Heat Requirements Based on Theoretical Conditions
(Continued)

$H = K\,W\,(t_i - t_o)$

Outside Walls

H = .25 x 36,815 x 30° = 276,120 B. T. U. per hr.

Glass

H = 1. x 5,490 x 30° = 165,000 B. T. U. Per hr.

Halls

H = .25 x 14,022 x 10° = 35,055 B. T. U. per hr.

Total = 476,175 B. T. U. lost per hour by radiation.

Heat Required for Ventilating Air

375,918 cu. ft. = total ventilated volume of building

44,700 cu. ft. of air per minute entering building

$\frac{375,918}{44,700}$ = 8.42 Min. = time to change air in building

$\frac{60}{8.42}$ = 7.13 = number of changes per hour

H = $(.02 \times CV)(t_i - t_o)$ = B. T. U. per hour

H = .02 x 7.13 x 375,918 x 30 = 1,610,000. B. T. U. per hour needed for air change.

DATA ON VARIATION OF ROOM TEMPERATURES

Week from March 17 - 21, 1913.

Room Number	Time	Monday Thm.	Monday Thatt	Tuesday Thm.	Tuesday Thatt	Wednesday Thm.	Wednesday Thatt	Thursday Thm.	Thursday Thatt	Friday Thm.	Friday Thatt.
1	8.00	63.5	----	64.	64.5	----	----	67.	67.	63.5	63.5
	12.00	66.	67.5	68.	69.	65.	67.	68.	68.	67.5	68.5
10	8.00	66.	----	66.8	68.	66.	68.	64.	69.	63.	66.0
	12 .00	66.	66.	68.	69.	64.	67.5	66.	71	66.	70.0
15	8.00	61.	----	62.	62.5	65.	68.	63.	65.	63.	65.0
	12.00	62.8	63.5	67.	68.	65.	66.	69.	67.5	67.5	69.0
22	8.00	67.	----	63.	66.	64.	71.	65.	69.	62.5	66.0
	12.00	65.	67.5	69.	70.	65.	67.	70.	71.5	68.	71.0
Office	8.00	64.5	----	66.	67.	66.	66.5	67.	70.	69.	71.0
	12.00	66.	66.	68.	71.	67.	----	68.	68.	68.5	69.0
110	8.00	72.3	----	72.	72.	65.3	66.	69.	71.	69.	70.0
	12.00	68.	69.	66.	67.	69.	----	67.	70.	67.	68.5
120	8.00	70.	----	----	----	65.5	66.	72.	73.	66.5	67.5
	12.00	66.4	66.5	68.5	69.	66.	67.	68.	69.	69.	69.0
205	8.00	64.5	----	70.7	72	64.5	66.	70.5	72.	68.	69.0
	12.00	64.5	68.0	65.8	68.2	64.5	66.	66.5	69.	63.	69.0
208	8.00	64.5	----	69.5	73.	64.4	67.7	68.5	73.	65.1	69.5
	12.00	66.0	69.	64.0	70.	63.1	68.	64.4	70.	64.4	69.0
225	8.00	----	----	----	65.5	----	67.	----	68.	----	65.5
	12.00	----	65.	----	70.	----	68.	----	70.	----	72.0
302	8.00	----	----	----	72.	----	68.	----	68.	----	68.0
	12.00	----	72.	----	69.	----	60.	----	71.	----	68.0
400	8.00	----	----	----	65.5	----	66.	----	67.	----	64.5
	12.00	----	64.	----	68.	----	66.	----	78.	----	68.0
224	8.00	----	----	----	66.	----	63.	----	66.	----	63.0
	12.00	----	65.	----	65.	----	64.5	----	66.	----	64.0
301	8.00	----	----	----	69.5	----	67	----	70.	----	----
	12.00	----	71.	----	72.	----	70.	----	73.	----	70.
Outside	8.00	60.5	----	57.	----	55.5	----	57.5	----	53.	----
	12.00	64.2	----	65.	----	63	----	66.	----	64.	----

VARIATION OF ROOM TEMPERATURES

During the week of March 17th to 21st, a series of thermometer readings were taken in the most important rooms of the building in order to show how the temperature varied from eight o'clock in the morning until noon. Readings of the thermometers on the thermomstats were taken at the same time so as to check their accuracy. In all cases the temperature rose about three degrees, except in those rooms where the sun shone in the early morning. In these rooms the temperature dropped about three degrees during the forenoon. At eight o'clock in the morning the rooms were at an average temperature of 65° Fahr. This low temperature was due to the fact that the fan was not started until seven-fifty in the morning, and the rooms were not heated at eight o'clock. The thermometers on the thermostats checked up faily accuractely with the thermometers used for the test. A curve shown on Plate V shows the results of these readings in graphic form.

AIR MEASUREMENTS

From time to time the amount of air entering and leaving the building per minute was measured by means of an anemometer. In doing this work we took readings over approximately every one and one-half square feet of duct area and obtained a very good average for the velocity in the whole opening. A stop watch was used to take the time of each reading, the method being to record the seconds for one-hundred feet traveled by the air or one revolution of the indicator on the anemometer. Whenever the value of the velocity of the air varied greatly over the opening, the opening was divided into separate areas and the calculations for these areas added.

Formula

$$\frac{60}{(\text{No. of sec. for 1 revolution})} \times 100 = \text{Velocity in feet per minute.}$$

Velocity in ft. per min. x Area of duct in sq. ft. = discharge in cu. ft. per min.

In order to compare the results, the temperature and barometer readings were taken for each set of air measurements and all results reduced to the standard temperature pf 60° Fahr. and twenty-nine and four-tenths barometric pressure.

Results of Air Measurements for Entering Air

Date	Barometer Reading	Average Temperature	Vol. of air in cu. ft. per min. reduced to 60° F and 29.4 Hg.
Feb. 19, 1913	29.2	53.2° F	43,100
Mar. 14, 1913	29.45	65. ° F	46,300
" 17, 1913	29.3	70. ° F.	45,400
Apr. 9, 1913	29.31	73.5° F	45,300

Results of Air Measurements for Outgoing Air

Feb. 17, 1913	29.2	———	16,880
Apr. 9, 1913	29.31		18,100

Charts shown on Plates VI, VII, VIII, IX, X, and XI show the size of openings of inlets and outlets. Plate XII shows the readings that were taken in measuring the incoming and outgoing air. The figures on these charts represent the number of seconds that it took the air to travel 100 ft. or one revolution of the indicator on the anemometer.

EFFICIENCY TESTS OF STEAM POWER PLANT.

Four tests were made upon the steam power plant, one lasting eight hours made upon the entire system, and the other three of approximately three hours each upon the boiler and auxiliaries alone. The object of these tests was to determine the efficiency of the boiler and system, when operating under ordinary conditions. The tests were made in the following months, one in February, one in March, and two in April, thus giving a fair idea of the operation under different conditions of weather. In carrying out the tests the necessary data was recorded as is shown on the log sheets.

All feed water was weighed as it returned from the steam manifolds before putting it into the hot well. In order to simplify calculations the water level in the boiler was kept the same at the beginning and end of each test and any difference in the water level of the hot well noted. A point was made in the shorter tests to completely use up the small tank of oil so as to avoid having to empty remaining oil and measuring it.

In these tests air was used to atomize the oil fuel because of several difficulties encountered at the time in attempting to measure the amount of steam consumed when used as an atomizing medium. The data on page   shows the results of two tests using steam as an atomizing medium, made previous to this work. From these tests we see that steam is much cheaper than air for atomizing purposes. Steam heats the oil to a certain degree when used as an atomizing agent and is better than air. Nevertheless we found air to be a very satisfactory atomiser and it gave good results in all our work. The results of these tests are as follows:

DATA ON PLANT TEST

Log Sheet

February 19, 1913

Time	Gage Pressure lbs. sq. inch	Air Pressure lbs. sq. inch	Temperatures (Degrees Fahr.) Outside	Hot Well	Calor-imeter	Con. Steam	Pump strokes per min.	Stack Draft Reading Inches H_2O
7:55	—	—	40	99.2	—	—	—	—
9:00	81	—	44			—	45	—
9:15	60	—	—	—	—	200	45	.175
9:30	71	69	47	—	211	—	—	.185
9:45	79	85!	—	—	—	190	49	.245
10:00	61	35	50	—	212	190	53	.200
10:15	69	30	—	—	212.4	—	55	.220
10:30	75	30	50	—	—	—	59	.180
10:45	85	30	—	138	212.2	186	62	.260
11:00	71	90!	—	—	211.6	186	51	.230
11:15	65	35	50	—	212.	—	39	—
11:30	75	30	—	—	211.5	—	45	.270
11:45	91	30	51	—	—	186	70	.270
12:00	56	75!	—	—	211.5	184	62	.270
12:15	58	30	49	—	211.7	—	57	**
12:30	85	30	—	—	211.6	184	—	—
12:45	64	40	—	—	211.8	—		—
1.00	75	30	—	—	211.6	—	54	—
1:15	80	25	—	—	211.7	184	58	—
1:30	90	30	48	125	—	—	—	—
1:45	70	35	—	138	211.8	—	48	—
2:00	87	30	49	140	212.1	186	54	—
2:15	70	35	—	139	211.8	—	61	—
2:30	88	30	48	—	212.2	—	63	—
2:45	65	70!	—	142	212.0	184	64	—
3:00	76	30	—	—	—	—	63	—
3:15	74	30	48	142	212.	—	—	—
3:30	75	35	—	—	211.8	184	61	—
3:45	82	84!	—	—	212.3	184	—	—
3:55	70	—	48	142	212.	—	—	—

! Air not in use

** Draft gage out of order

Data on Plant Test

Log Sheet, Con. Feb. 19, 1913.

Time of Burning Oil

Time Start	Time Shut down	Time Running
7:55	9:03	68 min.
9:14	99:43	29 "
9:53-1/2	10:52	58.5"
11:07	11:45	38 "
12:02	12:33	31 "
12:46	1:13	27 "
1:20	1:30	10 "
1:40	2:01	21 "
2:13	2:35	22 "
2:50	3:10	20 "
3:14	3:22	8 "
3:30	3:41	11 "
3:51	3:53	2 "

Time of Running Air Compressor

Time Start	Time Shut down	Time Running	K. W. Used
7:45	9:07	82 min.	
9:14	9:49	35	2.35
99:54	10:59	65	2.
11:08	11:52	44	2.30
12:03	12:37	34	2.20
12:45	1:18	33	2.20
1:20	1:35	15	2.20
1:40	2:07	27	2.20
2:13	2:42	29	2.10
2:50	3:28-1/2	38	2.10
3:35	3:47	12	2.10
3:52	3:53	1	2.10

Total time of burning oil = 5 hours, 45.5 minutes

Total running time of air compressor = 6 hrs. 55 minutes

Power used by air compressor = 2.15 k.w.

Average stack temperature = 440° Fahr.

Weight of make-up water used = 2068 lbs.

Weight of condensed steam returning from maniforlds = 11,226.5 lbs.

Weight of steam condensed in 8" main = 1155 lbs.

Hot well 12-1/2" lower at end than at start.

Boiler level same at beginning as at end.

DATA ON PLANT TEST (Cont.)

Feb. 19, 1913.

Steam Consumption of Feed Pump

We allowed the feed pump to exhaust into a known weight of water for a given time, counting the number of strokes. The increase in the weight of the water gave us the steam consumption of the pump for that length of time.

Length of run, 5 minutes

Weight of tank at beginning, 252 lbs.

" " " " finish 260-3/4 lbs.

Increase in weight 8-3/4 lbs.

Temperature condensing water, beginning = 92° Fahr.

" " " finish = 129° Fahr.

Total number of double stroke = 300

Gage Pressure = 67 lbs.

Pounds of steam consumed per double stroke = .0292

- - -

Barometer Reading 29.2" Hg.

Equivalent Air Pressure 14.25# per sq. in.

Equivalent Boiling Point 210.5° F.

Data

Duration of test	8 hrs.	0 min.
Fan Motor run	6 "	33 "
Compressor motor run	6 "	55 "
Feed pump run	6 "	30 "
Average temperature of outside air	40.5° F.	
" " " air in hot air duct	144.5° F.	

Average temperature of air in cold air duct	53.2° F.
" " " throttling calorimeter	211.84° F.
" " " psychrometer inside dry	47.5 ° F.
" " " " " wet	45.25° F.
" " " " outside dry	48.7 ° F.
" " " " " wet	44.5 ° F.
Humidity of air outside (% of saturation)	76.3 %
" " " inside (" " ")	88. %
Mixture in air (% by weight)	.50 %
Average velocity of air entering building, north grating	470 ft. per min.
Average velocity of air entering building, south grating	432 ft. per min.
" " " " " hot air duct	557 ft. per min.
" " " " " cold " "	598 ft. per min.
Total ventilated volume of building (from (specifications)	375,918 cu. ft.
Total unventilated " " "	143,480 cu. ft.
Total volume of building	519,398 cu. ft.
Average boiler pressure Gage	74 # per sq. cm.
" stack draft at breeching	.226" H_2O
" pressure of air at manifold above atmospheric	.222 in. H_2O
" R. P. M. of fan	60
Diameter of fan	12 ft.
Time of burning oil	5 hrs. 45 min.
Quality of steam	96.3%
Average temperature of condensed steam	185° F.
" " " boiler feed water	125° F.
Weight of steam generated by boiler	13,862#
" " " delivered to building	11,226.5#
" " " condensed in 8" delivery pipe	1,155#
" " " used by feed pump	683#
" " " lost during run	797#
" " make up water	2,068#
" " oil burned	1,470#
Heat value of oil per lb.	18,500 B.T.U.
Power used by fan motor	39.3 Kw. hrs.
" " " compressor motor	14.8 " "

Calculations

Volume of air entering building at 53.2° F.	41,500 cu. ft. per min.
" " " " hot air duct at 53.2° F.	14,700 cu. ft. per min.
" " " " cold " " " " "	26,700 " " " "
Weight of dry air delivered by fan " " "	3,580 lbs. per min.
" " moisture in air delivered " " "	20.3 " " "
" " wet air to hot air duct " " "	1,102 " " "
" " " " " cold " " " " "	2,213 " " "
Heat to hot air duct from manifolds (above 53.2° F.)	25,400 B.T.U. per min.
Heat to cold air duct from manifold (above 53.2° F.)	2,843 B.T.U. per min.

DATA ON PLANT TEST (Cont.)

Total heat added to building air from run	11,099,499 B.T.U.
" " in fuel oil burned for run	27,195,000 B.T.U.
" " " boiler steam for run	15,958,000 B.T.U.
" " " steam reaching manifolds	12,800,000 B.T.U.
Boiler efficiency	58.8 %
Manifold efficiency	86.7 %
Plant efficiency	41.0 %
Percentage of steam reaching manifolds	81.0 %
" " " used by auxiliaries	5.0 %
" " " lost during run	5.85%
Equivalent of evaporation of boiler (From & at 212° F.)	1,835# per hr.
Boiler horse-power developed for run	53.3
Pounds of steam per pound of oil	9.43#
" " " " " " " (from and at 212° F.)	10.0#
Time required to change air in ventilated portion	9.05 min.
Time required to change air in entire building	10.1 min.

Cost of fuel at 90¢ per 42. gal.	3.96
" " water " 15¢ " 100 cu. ft.	.04
" " electric power at 2-1/2¢ per Kw. hr.	1.35
" " labor	2.00
Total cost of day's operation	7.35

CALCULATION FOR HEAT LOSSES

Heat balance based on conditions found in Plant Test of Feb. 19, 1913

Radiation Surface

36,815 sq. ft. of wall surface to outside
5,490 " " "glass " " "
14,022 " " " wall " " halls

$H = K W (t_1 - t_0)$

K = .25 for walls
= 1 " glass

From tests of Feb. 19, 1913
(t_1 = 70° F. room temperature
(t_0 = 48.5° F. outside temp.
t_2 = 60° F. hall temp.

Radiation Loss

$H = .25 \times 36,815 \times 21.5$ = 198,000 B.T.U. per hr. through outside walls
$H = 1 \times 5,490 \times 21.5$ = 118,000 B.T.U. " " " glass
$H = .25 \times 14,022 \times 10$ = 35,050 B.T.U. " " " hall walls

351,050 B.T.U. lost per hr. by radiation

Heat Balance

375,918 cu. ft. = total ventilated volume of building (from specifications)
6.63 changes of air per hr. (from test of Feb. 19, 1913)

$H = (.02 \times c\,V)\quad(t_i - t_o)$

$= .02 \times 6.63 \times 375{,}918 \times 21.5 =$ 1,071,700 B.T.U. per hr. for heating air
351,050 B.T.U. " " " radiation
1,422,750 B.T.U. " " total heat required

1,585,640 B.T.U. Per hr. given up by steam manifolds
1,422,750 B.T.U. " " required for heating and ventilating
162,890 B.T.U. " " in excess

This excess heat is lost in radiation from the hot air tunnel and flues leading to the rooms.

DATA ON BOILER TEST

Log Sheet — March 19, 1913

Barometer 29.2" Hg

Time	Gage Pressure	Air Boiler	Pressure Pump	Temperatures: Outside	Calorimeter	Hot Well	Con. Steam	Pump strokes per minute
7:00	——	——	——	——	——	——	——	——
7:45	45	39	39	——	——	——	——	——
8:00	50	45	48	52	——	——	——	47
8:15	53	47	40	52	——	——	206	50
8:30	65	36	36	——	——	106	204	——
8:45	83	35	35	54	203	112	204	67
9:00	78	36	36	52	207	66	205	——
9:15	78	36	36	56.5	214	146	206	48
9:30	80	36	36	56	214	152	206	35
9:45	85	36	36	56	——	158	206	35
10:00	90	36	36	57	213	160	206	35

Duration of test 3 hrs.
Weight of oil burned 668 lbs.
Time of burning oil 2 hrs. 57 min.
Weight of steam returning from building 3,590 lbs.
Weight of steam condensed in 8" steam main 427 lbs.
Feed pump run 1 hr. 59 min.
Hot well 10-1/4" higher at end than at beginning.
Weight of make up water 1,671.5 lbs.

<u>DATA ON BOILER TEST</u> (Cont.)

Barometer Reading 29.2" Hg.

Equivalent Air Pressure = 14.25 "# per sq. in.

" Boiling point = 210.5° F.

Duration of test	3 hrs.
Feed pump run	1 hr. 59 min.
Compressor run	3 hrs.
Average gage pressure	74.7 lbs.
Absolute pressure	88.95 lbs.
Average outside temperature	54.4° F.
" temperature in calorimeter	212 ° F.
Quality of steam	94.5%
Average temperature of condensed steam	208.5° F.
" " " boiler feed water	128.6° F.
" number of strokes for feed pump	45.3 per min.
Weight of make up water	1,671.5 lbs.
Weight of steam generated by boiler	4,580 lbs.
" " " delivered to building	3,590 lbs.
" " " used by boiler feed pump	157 lbs.
" " " condensed in 8" delivery pipe	427 lbs.
" " " lost during the run	375 lbs.
" " oil burned (time 2:57)	668 lbs.
Heating value of oil per lb.	18,500 B.T.U.
Total heat in oil	12,358,000 B.T.U.
Total heat in steam generated by boiler	5,388,110 B.T.U.
" " put in steam generated by boiler	4,802,980 B.T.U.
Boiler efficiency	38.9%
Per cent of steam used by auxiliaries	3.45%
" " " " lost during run	8.25%
Equivalent evaporation of boiler from and at 212° F.	1,708 lbs. per hr.
Boiler horse-power developed during run	53.6
Pounds of steam per lb. of oil consumed	6.82#
" " " " " " " " from and at 212° F.	7.67#

DATA ON BOILER TEST

Log Sheet April 8, 1913

Barometer 29.3" Hg.

Time	Gage Pressure	Air Pressure Boiler	Air Pressure Pump	Temperature Outside	Temperature Con. Steam	Temperature Hot Well	Temperature Calor.	Pump Strokes per min.
7:00	—	—	—	—	—	—	—	—
7:45	19	36	37	52	87	74	—	37
8:00	24	34	35	—	117	74	—	46
8:15	25	35	36	55	208	75	—	58
8:30	26	35	36	57	208	85	210	58
8:45	32	35	36	58	208	118	210	30
9:00	37	35	36	—	208	149	208	52
9:15	45	35	36	57.5	208	150	210	51
9:30	56	35	36	57.5	208	164	211.5	24
9:45	70	35	36	62	208	164	215	21
10:00	81	35	36	—	208	164	218	61
10:15	85	35	36	63	208	166	210	47
10:20	85	35	36	63	208	166	219	—

Weight of oil burned = 668 lbs.

Duration of test 3 hrs. 20 min.

Feed pump run 3 hrs.

Boiler level same at end as at beginning of test.

Hot well 1 ft. lower at end than at beginning of test.

Weight of steam condensed in 8" main = 510.5 lbs.

Weight of condensed steam returning from building = 4,207 lbs.

Air pump run 3 hrs. 20 min.

Average temperature of stack = 321° F.

DATA ON BOILER TEST (Cont.)

Barometer Reading 29.3" Hg.

Equivalent Air Pressure = 14.4# per sq. in.

Equivalent Boiling temp. = 210.96° F.

Duration of test	3 hrs. 20 min.
Feed Pump run	3 hrs.
Compressor run	3 hrs. 20 min.
Average gage pressure	48.75 lbs.
Absolute pressure	63.15 lbs.
Average outside temp.	58.1° F.
" temp. in calorimeter	213.3° F.
Quality of steam	97.3%
Average temp. of condensed steam	208. ° F.
" " " boiler feed water	129. ° F.
" number of strokes for feed pump	36.8 per min.
Wt. of make up water	
Wt. of steam generated by boiler	4,809 lbs.
" " " delivered to building	4,207 lbs.
" " " used by feed pump	194 lbs.
" " " condensed in 8" delivery pipe	510.5 lbs.
" " " lost during run	91.5 lbs.
" " oil burned (3hrs. 20 min.)	668 lbs.
Heating value of oil per lb.	18,500 B.T.U.
Total heat in oil burned	12,358,000 B.T.U.
Total heat in steam generated by boiler	5,651,483 B.T.U.
" " put in steam by boiler	5,031,122 B.T.U.
Boiler efficiency	40.7%
Per cent. of steam used by auxiliaries	4.03%
" " " " lost during run	1.9 %
Equivalent evaporation of boiler from and at 212° F.	1,610 lbs. per hr.
Boiler house-power developed during run	51.2
Pounds of steam per lb. of oil consumed	7.2
" " " " " " " from and at 212° F.	8.02

DATA ON BOILER TEST

Log Sheet April 9, 1913

Barometer 29.3" Hg.

Time	Gage Pressure	Temperature				Pump Strokes per min.
		Hot Well	Con. Steam	Calorimeter	Outside	
7:00	0	87.5	0	0 ——	55	——
8:00	35	87.5	84	——	60	36
8:15	40	87	79	——	60	40
8:30	45	87	164	208	62	40
8:45	51	98	208	210	63	50
9:00	59	132	208	214	64	40
9:15	66	144	208	216	66	41
9:30	78	156	208	219	67	39
9:45	85	156	208	222	68	39
10:00	94	160	208	224	68	18
10:15	65	164	208	216	71	53
10:28	80	164	208	216	73	48

Oil burned = 668 lbs.

Hot well 7-1/8 inches lower at end than at start

Water level in boiler same at end as at beginning

Weight of condensed steam returning from manifolds = 3,860.5 lbs.

Weight of condensed steam in 8" main = 489.5 lbs.

Feed pump run 2 hrs. 28 min.

Duration of test 3 hrs. 28 min.

Fire burned 3 hrs. 15 min.

DATA ON BOILER TEST (Cont.)

Barometer Reading 29.3" Hg.

Equivalent Air Pressure =14.4# per sq. in.

Equivalent boiling temp * 210.96° F.

Duration of test	3 hrs. 28 min.
Feed pump run	2 hrs. 38 min.
Compressor run	3 hrs. 20 min
Average gage pressure	63.5 lbs.
Absolute pressure	77.9 lbs.
Average outside temperature	64.6 ° F.
" temp. in calorimeter	216.1 ° F.
Quality of steam	96.7%
Average temp. of condensed steam	208. ° F.
" " " boiler feed water	127 ° F.
" number of strokes for feed pump	40.36
Wt. of make up water	0
" " steam generated by boiler	4,706 lbs.
" " " delivered to building	3,860 lbs.
" " " used by feed pump	186 lbs.
" " " condensed in 8" delivery pipe	489.5 lbs.
" " " lost during run	170.5 lbs.
" " oil burned (3 hrs. 15 min.)	668. lbs.
Heating value of oil per lb.	18,500 B.T.U.
Total heat in oil burned	12,358,000 B.T.U.
" " " Steam generated by boiler	5,562,492 B.T.U.
" " put in steam by boiler	4,964,483 B.T.U.
Boiler efficiency	40.2%
Per cent. of steam used by auxiliaries	3.95%
" " " " lost during run	3.61%
Equivalent evaporation of boiler from and at 212°	1,535 lbs. per hr.
Boiler horse-power delivered during run	48.1
Pounds of steam per lb. of oil consumed	7.06
" " " " " " " from and at 212°	7.98

Tests on the Use of Steam and Air

For Atomizing Agents of Fuel Oil.

Dtae of test		March 15, 1912	Feb. 19, 1913
Time of run	8 hrs. 15 min.	8 hrs.	8 hrs.
Atomizing agent	steam	steam	air
Average boiler pressure (gauge)	71.5#	92#	74#
Quality of steam	96.9%	---	96.3%
Time of compressor run	2.57 hrs.	4.35 hrs.	6.92 hrs.
Wattmeter reading	3.3 Kw.	3. Kw.	2.15 Kw.
Power consumed	8.48 Kw. Hrs.	13.05 Kw. hrs.	10.76 Kw. hrs.
Wt. of steam used for atomizing	439#	574#	---
Wt. of oil burned	1,473.1#	1,418.5#	1,470#
Total wt. of steam generated from and at 212°	15,690#	15,490#	14,680#
Wt. of steam generated per lb. of oil burned	10.65#	10.92#	10#
Wt. of oil per boiler h.p.	3.23#	3.16#	3.45#
Wt. of steam used in atomizing lb. of oil	.298#	.4046	---
Wt. of oil used in atomizing a boiler h.p.	.964#	1.278#	---
Wt. of oil used to generate the steam for atomizing oil to generate a boiler h. p.	.0906#	.117#	---
Cost of oil used to generate the steam for atomizing oil to generate a boiler h.p. at .00269 dollars per lb.	$.000243	$.000315	---

Average power consumption for first and second tests = 10.76 Kw. hrs. which was used for compressing air for oil tank and thermostats.

Power consumed for compressing air for atomizing in third test = 14.8 - 10.76 = 4.04 Kw. hrs.

Cost of power consumed for compressing air for atomzing in third test equals $.101.

$$\frac{\$.101 \times 34.5}{1,470} = \$.00237$$ cost of power for compressing air to atomizing enough oil to generate a boiler horse-power.

COMPARISON OF TESTS ON

STEAM POWER PLANT

The results of these tests are very consistent, especially those of the three shorter runs. The boiler shows a higher efficiency under the longer period of operation, which is to be expected. The efficiency under the shorter runs is about 40%, which is very low and is probably due to the varying of the steam pressure. Under ordinary operations the pressure is allowed to run up to about 90 lbs., then to drop back to about 60 lbs., and then to rise again, giving a very fluctuating pressure. The loss of steam is another important factor, due to leaky joints in the main steam line. It was found that the boiler works at an average of 51 Boiler horse power under an average gage pressure of 60 lbs., thus showing that the 150 Boiler horse power Marine boiler is too large. The Quality of steam for the tests averaged 96%, which was determined by a throttling calorimeter placed just above the gate valve on the boiler outlet. The feed pump has an average steam consumption of 70 pounds of steam per hour, which is very high, due to imperfect valves on the steam end and slip on the water end. The stack draft was about constant and measured 1/4 inch of water. The pressure on the compressed air reservoir was kept at a gage pressure of 36 pounds, a drop of about 1 pound occurring between the reservoir and burner on the boiler.

CONCLUSIONS

The whole Heating and Ventilating System seems to have been installed with no definite scientific study and design. One difficulty in its design lies in the fact that the building may be changed whenever the necessity arises. That is, many curtain walls are used to separate the various rooms and offices, which may be torn down and put in as desired. On account of this, one ventilating flue and one outlet flue has been put into each sixteen foot bay, all flues having been made the same size and no change occurring with different sized rooms.

The faulty design of the fan room on the basement floor greatly decreases the efficiency of the system. The fan is set on an angle to the manifolds in place of being directly in front and parallel. The fan is working under a disadvantage because of the size of the fan room, and a small housing should be placed around it so as to direct the air into the tunnels. At the present time the fan discharges around its circumference and the air is allowed to circulate around the fan room before entering the tunnels. As a result of this much dead air space is left in the room and in places eddy currents are set up. The original plans for the building called for two fans, discharging directly into the tunnels but for some reason this plan was not carried out.

The hot and cold air tunnels have been made the same size throughout while theoretically they should decrease in size according to the amount of air taken off. There are three large holes leading from the cold air tunnel to the hot air tunnel, one at the north end of the building where the eight inch steam line enters the hot air tunnel, two where the eight inch line comes out and goes to the manifolds. These holes allow cold air from the cold air tunnel to enter the hot air tunnel, which is undesirable as it lowers the temperature of the hot air. The temperature of the hot air tunnel has not been brought up to specifications, the average temperature being 145° Fahr., while the specified temperature is 160° Fahr. The cold air tunnel is kept at approximately outside temperature.

The question of outlets for the foul air is another important consideration. The measurements show that about 17,500 cubic feet per minute is the combined flow of all outlets, while 44,700 cubic feet per minute is delivered by the fan to the tunnels. This shows that 40% of the entering air can be accounted for, although a great quantity leaks out around the window and door casements. The velocity of the air at the outlets is high showing that the outlets are too small. The outlets to the chamber between the second floor hall ceiling and chemistry laboratory floor, are only half as large as they might be, one-half of the opening being closed up at the present time. There should be two outlets on the east side of the roof, similar to those already on the west side, because a strong west wind blows the discharging air back and greatly decreases the discharge. With outlets on either side of the roof all may be used or either as occasion may arise, thereby increasing the discharge.

The Library has never been ventilated properly owing to the fact that the pressure in the outlet duct is greater than that in the room and the foul air flows in from the foul air space beneath the roof. This room should have a direct outlet to the atmosphere, which can be easily accomplished by continuing the two present outlet flues to the roof outlets on the west side. As a result of this defect the only way of ventilating the library is to close the outlets and open the windows to the outside.

The Chemistry laboratory is ventilated in a very inefficient manner. There are three inlets to the laboratory and only two outlets both of which are situated at the end of the room, one above the other and exhausting into the same duct. The ventilation can be assisted by starting one of the small fans as mentioned in the layout. At present the only way of ventilating the laboratory when work is in progress is to open the door to the storeroom and allow the foul air from the lower floors to pass through the laboratory and exhaust through the north door to the atmosphere. This is a very undesirable method but seems to be the only one possible under the present circumstances. It is very evident that there are not enough outlets for the laboratories and we suggest that two new outlets exhausting directly to the atmosphere be put in.

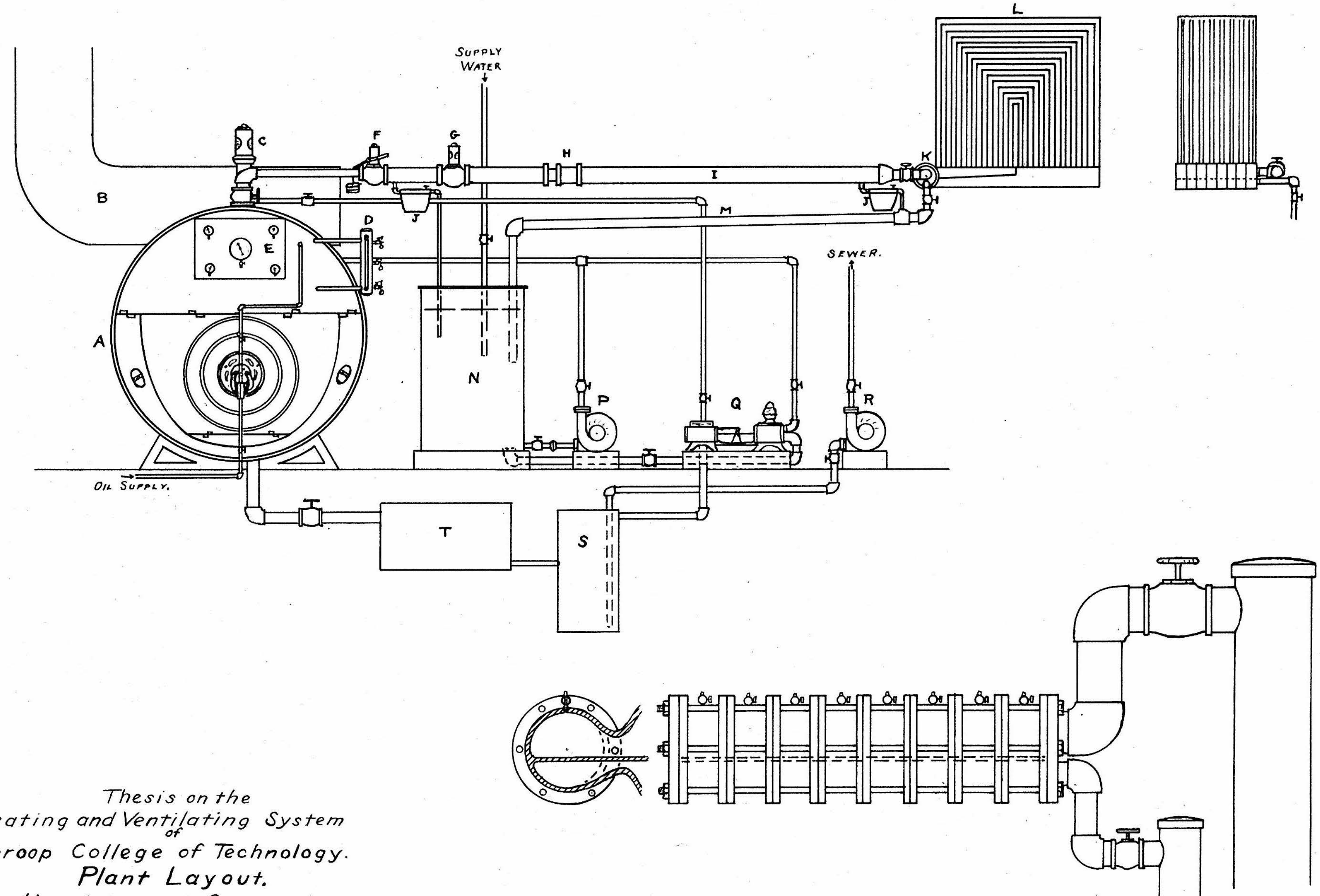
The steam power plant is of ample size to furnish heat for all heating purposes. It is possible to use a smaller boiler and obtain a better efficiency, as the one now in use is too large and cannot be run at rated load, therefore decreasing its efficiency.

Care should be taken about running the fan when no heat is turned in the manifolds as a very disagreeable and chilly feeling is caused in the rooms. This is caused by ventilating with air which is brought directly through the damp coke walls, or humidifier without being slightly tempered afterwards. By reducing the speed of the fan and cutting down its capacity, therefore making the number of air changes about three per hour instead of seven as at present, would remedy this fault considerably.

We think that an advantageous way to ventilate the building in moderate weather would be to open up the windows and shut down the fan. This would give a thorough and even heating and purifying of the whole building.

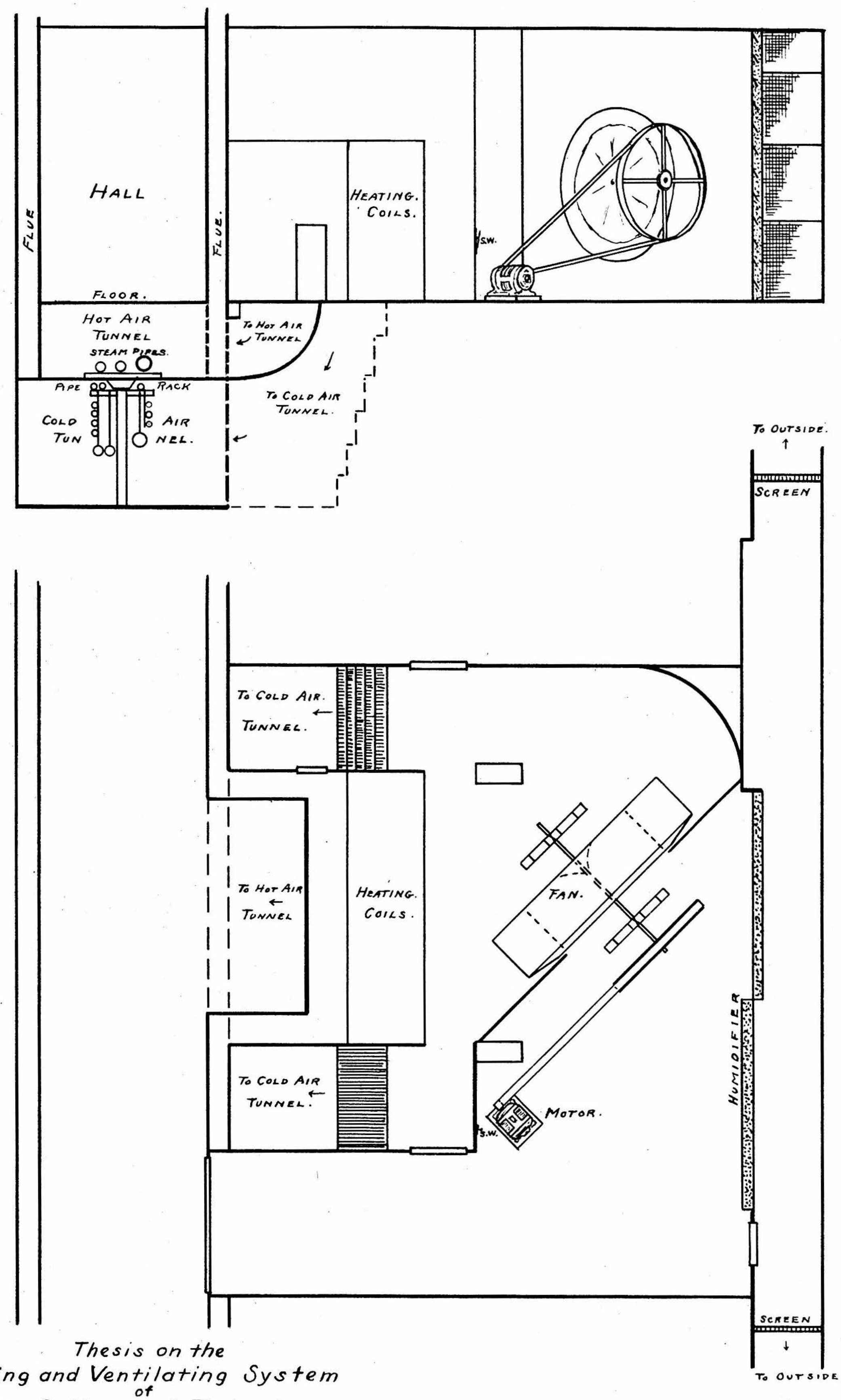
The whole trouble lies in the system of the main building. The fan room, tunnels and ventilating flues have been installed in such a way as to cut down the whole system efficiency.

Plate No 1



Thesis on the
Heating and Ventilating System
of
Throop College of Technology.
Plant Layout.
Header and Connections.

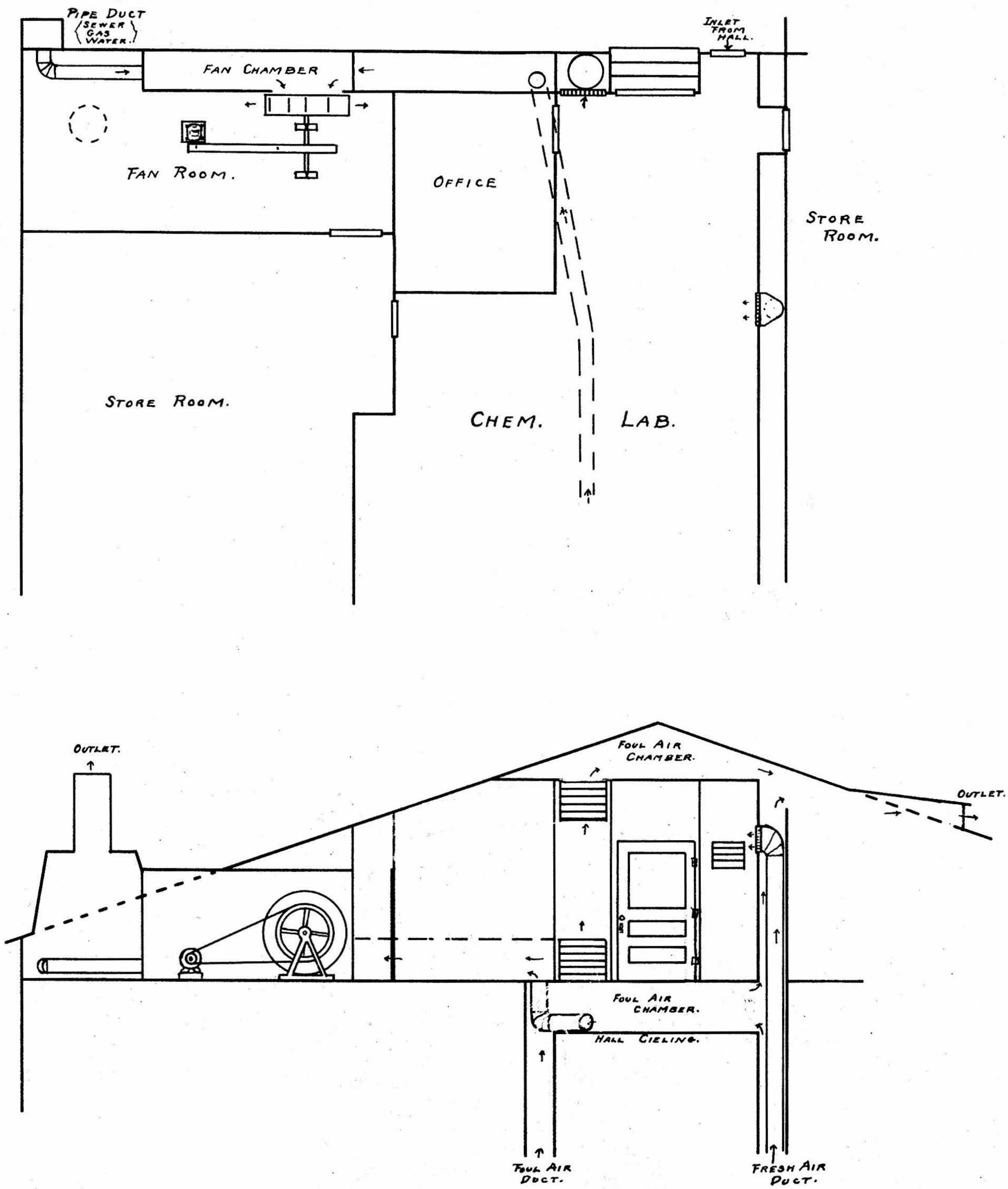
May 5 - 1913. Hovey - Koch.



Thesis on the
Heating and Ventilating System
of
Throop College of Technology
Plan of Fan Room

May 5-1913 Hovey - Koch.

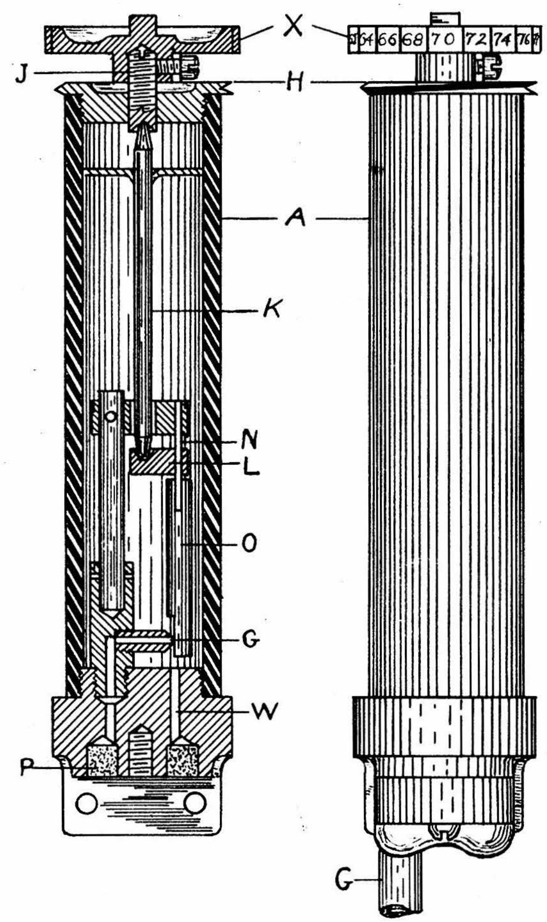
Plate No 3.



Thesis on the
Heating and Ventilating System.
of
Throop College of Technology.
Fan System in Chem. Lab.

MAY 10-1913 Hovey - Koch.

Thesis on the
Heating and Ventilating System.
of
Throop College of Technology.
Thermostat
Thermostat System.
May 5-1913. Hovey – Koch.



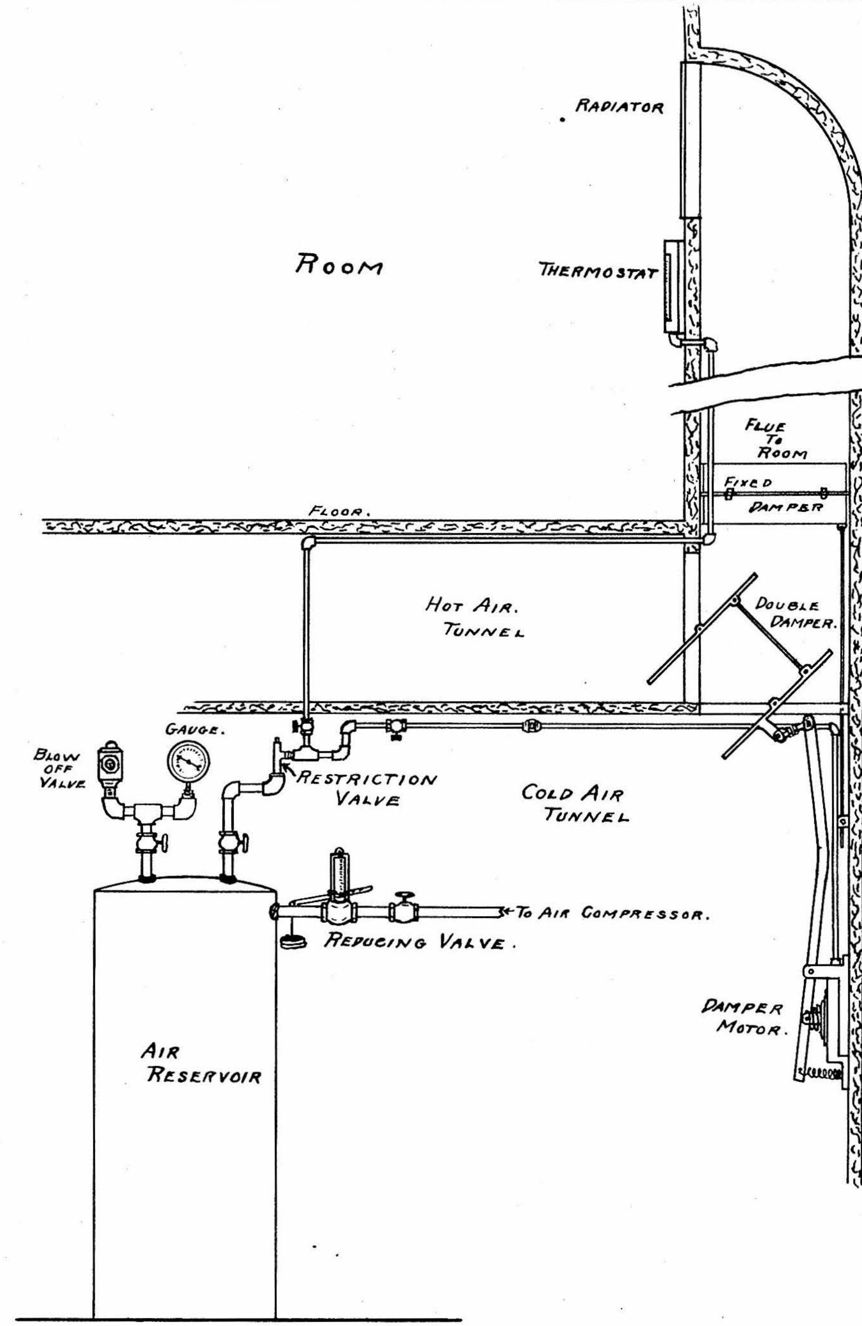
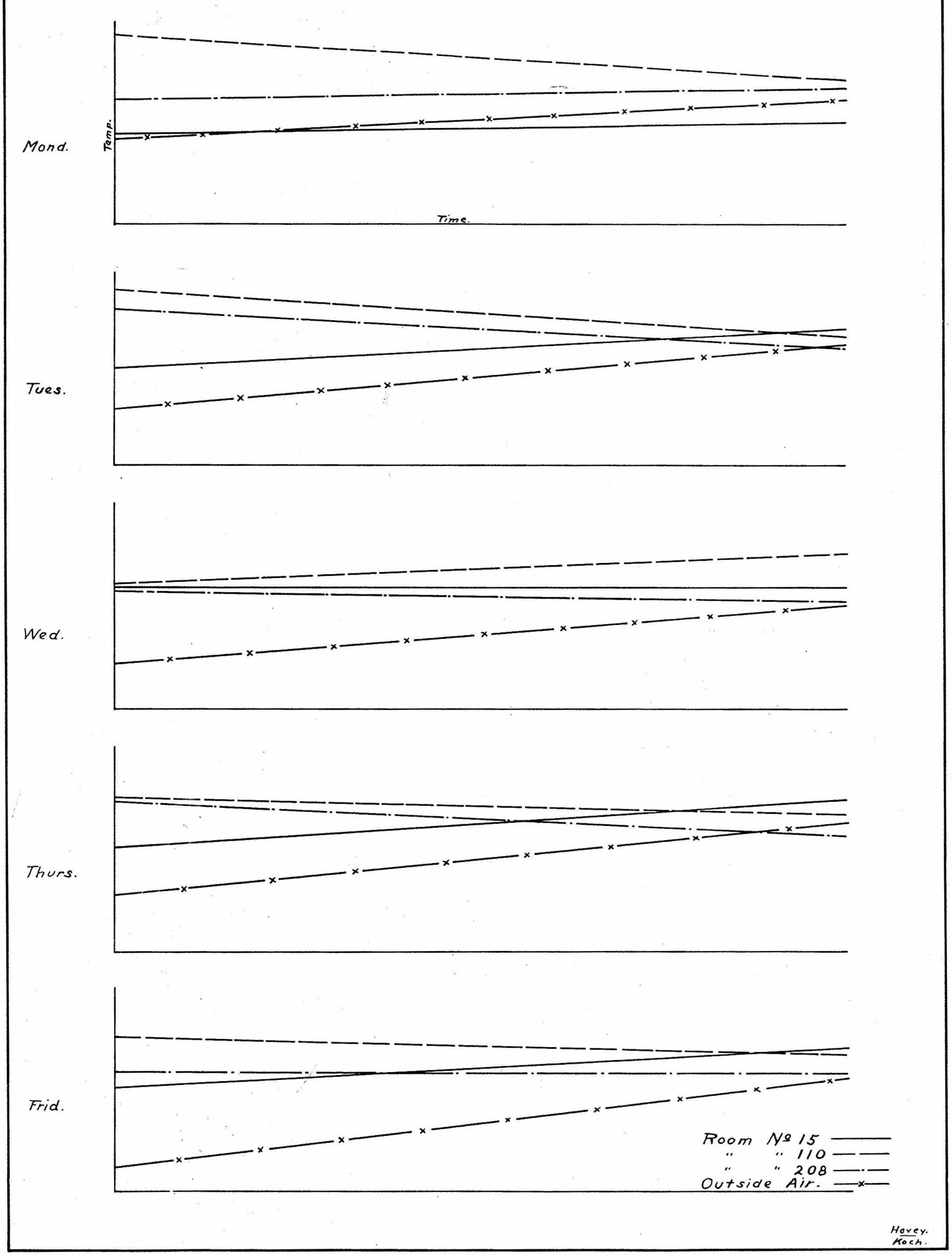
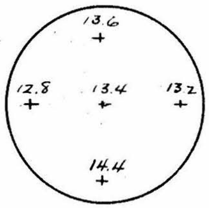


Plate Nº 5.

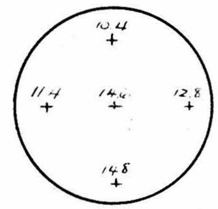
Curves Showing Variation of Temperature in Rooms.



Feb. 17 1913
Barometer 29.2

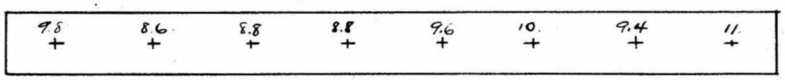


Northeast
Temp. 66°Fah.
Area = 3.14 sq.ft.
Ave. Reading 13.48
$\frac{60}{13.48} \times 100 = 445$ ft. per min.
$445 \times 3.14 = 1400$ cu.ft. per min at 66°F.
$\frac{521}{527} \times 1400 = 1380$ cu.ft. per min at 60°F.



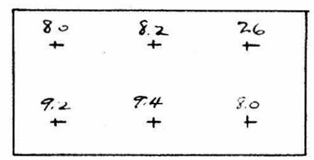
Southeast
Temp = 66°Fah.
Area = 3.14 sq.ft.
Ave. Reading = 12.8
$\frac{60}{12.8} \times 100 = 479$ ft per min.
$479 \times 3.14 = 1470$ cu.ft per min at 66°F.
$\frac{521}{527} \times 1470 = 1450$ cu.ft. per. min at 60°F.

Southwest



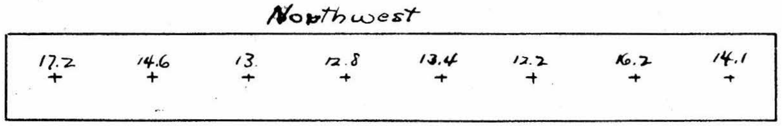
Temp = 64.5°Fah.
Area = 8 sq.ft.
Ave. Reading = 9.5
$\frac{60}{9.5} \times 100 = 632$ ft per min.
$632 \times 8 = 5056$ cu.ft per min at 64.5°F
$\frac{521}{525.5} \times 5056 = 5020$ cu.ft. per min at 60.°F

North End



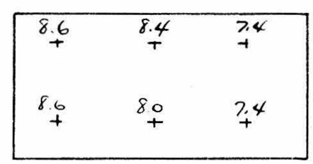
Temp. 67°F.
Area = 4.63 sq.ft.
Ave. Reading = 8.4
$\frac{60}{8.4} \times 100 = 715$ ft. per min.
$4.63 \times 715 = 3320$ cu.ft. per min at 67°F
$\frac{521}{528} \times 3320 = 3280$ cu.ft per min at 60°F

Northwest



Temp = 68°Fah.
Area = 5.8 sq.ft.
Ave. Reading = 14.6
$\frac{60}{14.6} \times 100 = 412$ ft per. min.
$5.8 \times 412 = 2380$ cu.ft per min at 68°F.
$\frac{521}{529} \times 2380 = 2350$ cu.ft. per min at 60°F.

South End



Temp = 69°Fah.
Area = 4.63 sq.ft.
Ave. Reading = 8.06
$\frac{60}{8.06} \times 100 = 745$ ft. per min.
$4.63 \times 745 = 3450$ cu.ft. per min. at 69°F.
$\frac{521}{530} \times 3450 = 3400$ cu.ft. per min. at 60°F

Total Discharge = 16,880 cu.ft. per min at 60° Fah

Horey - Koch.

Feb. 19-1913.
Barometer = 29.2

N. End.

16.4	16.8	16.0
16.0	16.2	16.2
15.4	15.6	14.8
15.0	15.2	14.4
13.8	15.0	14.6
14.2	14.4	13.8
13.2	12.6	12.8
12.6	11.8	10.6
11.2	10.6	10.2
9.6	10.0	11.4

Temp = 53.2°F.

Area = 45.7 Sq. Ft.

Ave. Reading = 13.68

$\frac{60}{13.68} \times 100 = 438$ Ft. per Min.

$45.7 \times 438 = 20,000 \frac{\text{cu. ft.}}{\text{MIN.}}$ @ 53.2°F

$\frac{521}{514.2} \times 20,000 = 20,280 \frac{\text{cu. ft.}}{\text{MIN.}}$ @ 60°F

S. End.

15.8	16.0	15.2
15.4	13.8	16.0
14.0	14.2	15.8
12.4	13.4	14.6
11.0	14.8	12.4
11.2	11.0	10.6
13.0	12.6	12.4
11.6	12.2	11.2
10.2	9.8	9.8
9.4	10.0	10.4

Temp = 53.2°F

Area = 45.7 Sq. Ft.

Ave. Reading = 12.74

$\frac{60}{12.74} \times 100 = 471$ Ft. per Min.

$45.7 \times 471 = 21,500 \frac{\text{cu. ft.}}{\text{MIN}}$ @ 53.2°F

$\frac{521}{514.2} \times 21,500 = 21,820 \frac{\text{cu. ft.}}{\text{MIN}}$ @ 60°F

Total = 42,100 Cu. Ft. per MIN. at 60°F.

Hovey - Koch.

Plate No 8.

Mar. 14-1913.

Barometer = 29.45.

N. End.

12.2	12.0	13.4
12.8	11.4	12.2
12.4	13.0	13.0
14.3	12.6	10.0
11.6	12.6	10.4
10.6	11.4	9.4
10.0	10.8	10.2
10.0	10.9	11.4
10.6	9.8	10.6
12.8	9.4	9.4

Temp. = 64.5° F.

Area = 45.7 Sq. Ft.

Ave. Reading = 11.37

$\frac{60}{11.37} \times 100 = 527.5$ Ft. per Min.

$45.7 \times 527.5 = 24,200 \frac{Cu.Ft}{Min}$ @ 64.5°F.

$\frac{521}{525.5} \times 24,200 = 23,800 \frac{Cu.Ft}{Min}$ @ 60°F.

S. End.

33.8	26.8	25.0
30.0	28.4	22.4
16.8	15.7	15.8
11.0	10.8	13.4
10.2	11.2	10.6
10.0	11.8	11.2
9.6	10.0	10.8
9.2	9.6	9.0
8.6	8.8	9.6
8.8	9.8	9.0

Temp. = 65°F.

Area = 9.12 Sq. Ft.

Ave. Reading = 27.73

$\frac{60}{27.73} \times 100 = 216.5$ Ft. per. Min.

$9.12 \times 216.5 = 1975 \frac{Cu.Ft}{Min}$ @ 65°F.

Area = 4.65 Sq. Ft.

Ave. Reading = 16.1

$\frac{60}{16.1} \times 100 = 373$ Ft. per Min.

$4.65 \times 373 = 1700 \frac{Cu.Ft}{Min}$ @ 65°F.

Area = 18.34 Sq. Ft.

Ave. Reading = 10.88

$\frac{60}{10.88} \times 100 = 552$ Ft. per Min.

$18.34 \times 552 = 10,120 \frac{Cu.Ft}{Min}$ @ 65°F.

Area = 13.68 Sq. Ft.

Ave. Reading = 9.16.

$\frac{60}{9.16} \times 100 = 656$ Ft. per. Min.

$13.68 \times 656 = 8,960 \frac{Cu.Ft}{Min}$ @ 65°F

Total = $22,755 \frac{Cu.Ft}{Min}$ @ 65°F

$\frac{521}{526} \times 22,755 = 22,500 \frac{Cu.Ft}{Min}$ @ 60°F.

Total = 46,300 Cu. Ft. per. Min at 60°F.

Havey - Koch.

Mar. 17-1913.

Barometer = 29.3.

N. End.

10.4	9.6	11.4
10.8	11.8	11.4
13.0	13.2	11.4
11.4	12.8	10.6
12.8	12.0	11.4
12.2	11.8	11.6
10.6	11.8	13.0
10.2	11.0	13.0
12.4	11.6	11.8
13.2	9.8	10.8

Temp. = 70°F.

Area = 45.7 Sq. Ft.

Ave. Reading = 11.95

$\frac{60}{11.95} \times 100 = 502$ Ft. per Min.

$45.7 \times 502 = 23{,}000 \frac{\text{Cu Ft}}{\text{Min.}}$ @ 70°F.

$\frac{521}{531} \times 23{,}000 = 22{,}600 \frac{\text{Cu.Ft.}}{\text{Min}}$ @ 60°F.

S. End.

22.2	20.0	19.8
18.0	17.2	20.1
17.4	18.2	18.6
14.1	13.8	14.4
9.8	10.4	10.6
11.0	10.6	10.8
10.4	9.8	10.0
8.0	8.2	9.6
9.6	9.4	10.2
8.8	8.6	9.0

Temp. = 70°F.

Area = 13.68 Sq. Ft.

Ave. Reading = 19.05

$\frac{60}{19.05} \times 100 = 315$ Ft. per Min.

$13.68 \times 315 = 4310 \frac{\text{Cu Ft}}{\text{Min}}$ @ 70°F.

Area = 4.65 Sq. Ft.

Ave Reading = 14.1

$\frac{60}{14.1} \times 100 = 425$ Ft. per. Min.

$4.65 \times 425 = 1940 \frac{\text{Cu Ft}}{\text{Min}}$ @ 70°F.

Area = 27.46 Sq. Ft.

Ave Reading = 9.71

$\frac{60}{9.71} \times 100 = 618$ Ft. per Min.

$27.46 \times 618 = 16{,}950 \frac{\text{Cu Ft}}{\text{Min.}}$ @ 70°F.

Total = $23{,}200 \frac{\text{Cu Ft}}{\text{Min}}$ @ 70°F.

$\frac{521}{531} \times 23{,}200 = 22{,}800 \frac{\text{Cu Ft}}{\text{Min}}$ @ 60°F.

Total = 45,400 Cu. Ft. per Min at 60°F.

Horey - Koch.

Plate № 10.

Apr. 9-1913.
Barometer = 29.31.

N. End.

11.4	13.4	17.4
15.8	11.4	13.4
10.0	9.4	11.4
11.8	14.4	10.4
10.0	11.4	9.0
18.0	10.0	9.8
16.0	9.8	10.8
18.8	14.8	8.8
14.4	12.2	11.4
13.2	11.8	10.2

Temp. = 74° F.

Area = 45.7 Sq. Ft.

Ave. Reading = 12.69

$\frac{60}{12.69} \times 100 = 482$. Ft. per Min.

$45.7 \times 482 = 22,100 \frac{Cu.Ft}{Min}$ @ 74°F.

$\frac{521}{535} \times 22,100 = 21,600 \frac{Cu.Ft}{Min}$ @ 60°F

S. End.

15.4	20.0	18.0
18.8	19.0	11.8
9.6	11.2	11.6
10.4	13.6	11.8
9.2	9.2	11.6
10.6	16.4	10.4
8.0	8.4	8.8
9.0	9.4	8.8
9.2	8.8	8.4
9.4	9.2	8.6

Temp = 77 °F.

Area = 45.7 Sq. Ft.

Ave. Reading = 11.25

$\frac{60}{11.25} \times 100 = 534$ Ft. per Min.

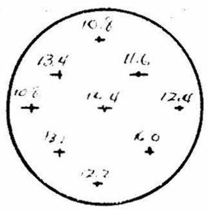
$45.7 \times 534 = 24,400 \frac{Cu.Ft}{Min}$ @ 77°F.

$\frac{521}{538} \times 24,400 = 23,700 \frac{Cu.Ft}{Min}$ @ 60°F.

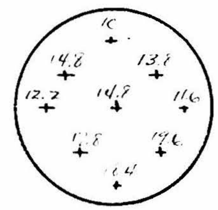
Total = 45,300 Cu. Ft. per Min. at 60°F.

Hovey - Koch.

April 9, 1913
Barometer 29.31

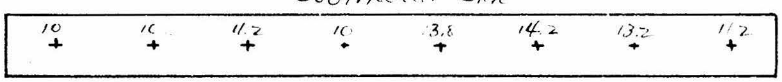


Northeast side.
Temp 71.5 °Fah.
Are Reading 12.75
Area 3.14 sq. ft.
$\frac{60}{12.75} \times 100$ = 481 ft. per min
3.14 × 481 = 1510 cu ft. per min. at 71.5 °F.
$\frac{521}{532.5} \times 1510$ = 1475 cu ft. per min at 60°F

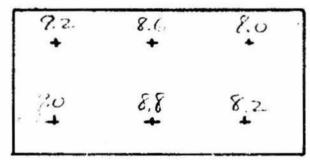


Southeast Side
Temp 73° Fah
Are Reading 14.8
Area 3.14 sq. ft
$\frac{60}{14.8} \times 100$ = 405 ft. per min
3.14 × 405 = 1270 cu ft. per min. at 73° F.
$\frac{531}{534} \times 1270$ = 1240 cu ft. per min. at 60° F.

Southwest Side

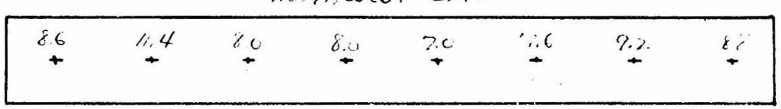


Temp. 71° Fah.
Are. Reading 11.53
Area = 5.8 sq. ft
$\frac{60}{11.53} \times 100$ = 520 ft. per min
520 × 5.8 = 3020 cu ft per min. at 71° Fah
$\frac{521}{532} \times 3020$ = 2956 cu ft per min at 60° Fah

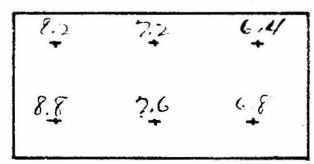


North End
Temp 67½° Fah.
Are. Reading 8.63
Area = 4.63 sq. ft
$\frac{60}{8.63} \times 100$ = 694 cu ft per. min.
694 × 4.63 = 3220 cu ft per min. at 67½°F
$\frac{531}{528.5} \times 3220$ = 3190 cu. ft. per min. at 60°F.

Northwest side.



Temp. 70° Fah.
Area. 8 sq. ft.
Are Reading = 8.43
$\frac{60}{8.43} \times 100$ = 713 ft. per. min.
713 × 8 = 5700 cu. ft. per min. at 70° Fah
$\frac{521}{531} \times 5700$ = 5600 cu. ft. per min. at 60° Fah



South End.
Temp 67½ °Fah.
Area 4.63 sq. ft.
Are. Reading 7.5
$\frac{60}{7.5} \times 100$ = 800 ft. per min.
4.63 × 800 = 3710 cu. ft. per min. at 67½° F.
$\frac{521}{528\frac{1}{2}} \times 3710$ = 3660 cu. ft per min. at 60°F.

Total Discharge at 60° Fah = 18,100 cu. ft. per min.

Harvey Koch

Plate No 12

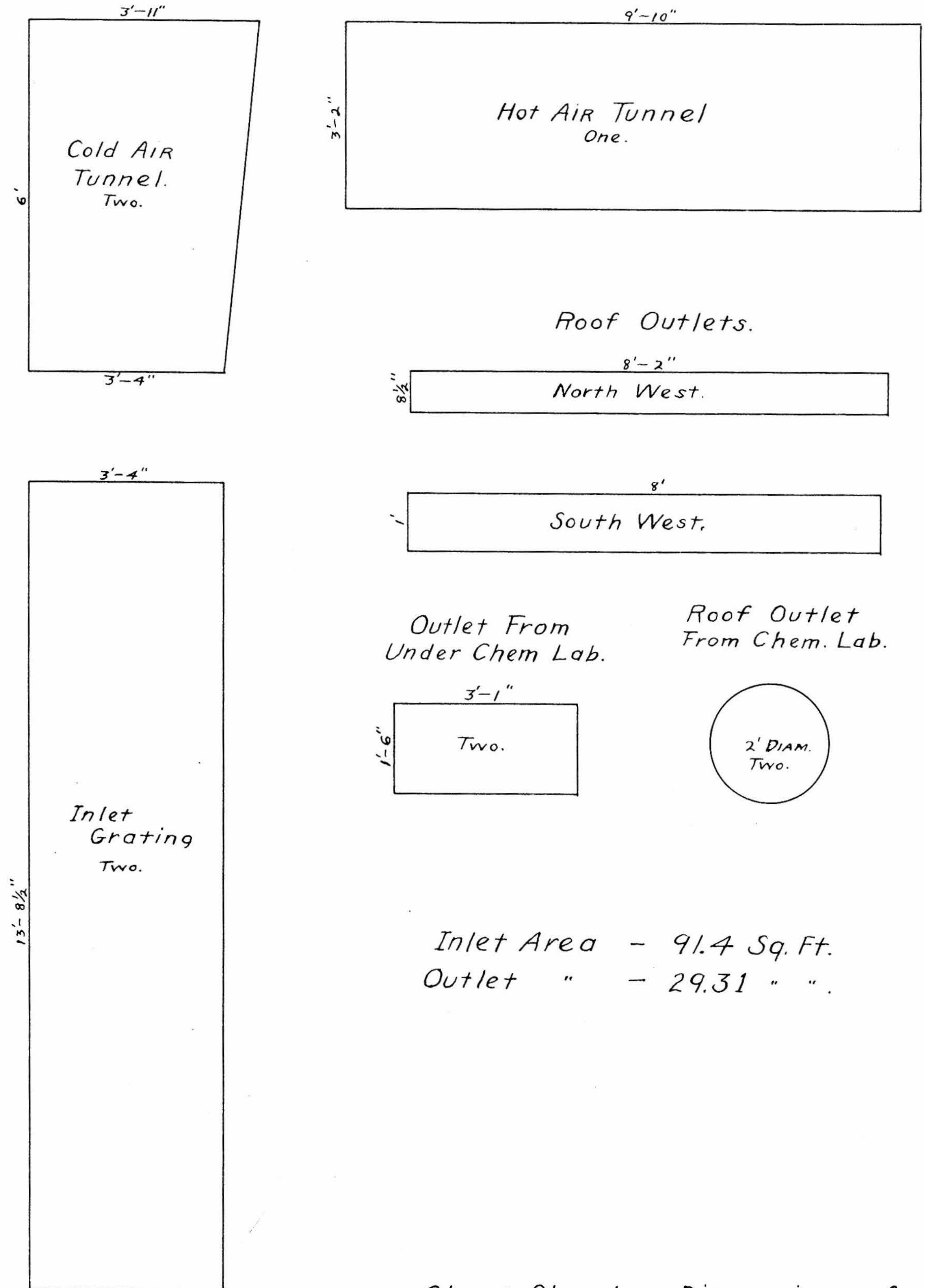


Chart Showing Dimensions of Inlets and Outlets to Building.

Hovey
Koch.