THESIS

DESIGN OF A HEATING AND LIGHTING SYSTEM

M. M. BABCOCK L. W. DOUGHERTY

1910

This thesis was contributed by

Mr. L. W. Dougherty

under the date indicated by the department stamp, to replace the original which was destroyed in the fire of March 5, 1916.

PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.
MAY BE RECALLED with earlier due date if requested.

DATE DUE	DATE DUE	DATE DUE
AUG 2 2 2009		

THESIS

---oooOOO$OOOooo---

DESIGN OF

A

HEATING AND LIGHTING SYSTEM

FOR

REMODELLED BUILDING OF THE UNION LITERARY SOCIETY

---oooOOO$OOOooo---

MICHIGAN AGRICULTURAL COLLEGE

--ooO$Ooo--

1910

By

M.M.Babcock, L.W.Dougherty.

THESIS

12-4-51

(8)

DESIGN OF A HEATING AND LIGHTING SYSTEM
FOR
REMODELLED BUILDING OF THE UNION LITERARY SOCIETY.

It is the purpose of this thesis to investigate the methods commonly in use by Heating and Lighting Engineers for determining the amount of radiation required to heat a building, and also for determining the amount of light that should be supplied to a room in order to give satisfactory illumination. For this reason we chose to figure on a building that was to be constructed, and benefit ourselves by being able to see the actual results. The building for which we have designed heating and lighting systems is that belonging to the Union Literary Society of the Michigan Agricultural College, located at East Lansing, Michigan.

As the art of heating buildings has been studied for many years, we were able to find considerable data on the subject; and arrived at quite satisfactory results by several methods, which agreed with each other within reasonable limits. However the reverse is true conwerning illumination, almost no data being available at this time; in fact authorities differ very widely as to the desired result. Naturally illumination may be said to be an inexact science. Expreience seems to be the basis of figuring. Therefore we took the advice of an engineer who had had more or less experience along this line, andit was by his methods that we made our calculations for lighting. The rule may be said to be sort of "rule of thumb" method but it seems to be a good one, and gives quite satisfactory results.

The rule is, for ordinary heights of ceiling, (from 9 to 15 ft.) allow one 16 candle power lamp for every 36 square feet of floor.

The heating and lighting system as planned in this thesis are to be used in the remodelling of the building of the Union Literary Society, with few minor changes, and it may be of some interest to note the results.

A word might be said with regard to the piping as is shown by plans. One must bear in mind that this is not a new installation and it was desired to use as much of the old system as was consistent toward securing satisfactory results, and at the same time keep down expense. The lighting system is to be entirely new, none of the old wiring being used.

Methods of determining the radiation required.

(1) By the wall losses. (See tables)

---

(2) Carpenter's Method #1

$\left(\frac{CN}{55} + \frac{W}{4} + G \right) d =$ losses in B.T.U.

or $\frac{1}{250} \left(\frac{CN}{55} + \frac{W}{4} + G \right) d =$ Sq. ft. of radiation surface

Where

$C =$ Volume in cubic feet.

$W =$ Wall surface in square feet.

$G =$ Glass surface in square feet.

$d =$ difference in temperature on wall.

$N =$ 1 for ordinary rooms.
1.5 for corridors -- depending on tightness of room.
2 to 3 for vestibules.

---

(3) Carpenter's Method #2

$\left(\frac{W}{4} + G \right) dn$ - Square feet of radiation required.

---

(4) American Radiator Company's Method.

$R = \frac{G}{2} + \frac{W}{20} + \frac{C}{200} =$ Square feet of radiation required.

---

(5) Volumetric Method.

$R =$ Volume divided by a constant K, which is 40 for ordinary exposure, and is 38 for rooms having a severe north or west exposure.

---

(6) See tables showing a comparison of the different methods.

WALL LOSSES

A single wall having a thickness X is exposed on the inside to room temperature t_1 and on the outside to the temperature t_o which is less than t_1 . (See fig. 1). There are two other temperatures to be considered t_1' and t_o' of the inside and the outside of the wall respectively.

The following relations exist.

$$t_1 > t_1' > t_o' > t_o \tag{1}$$

otherwise heat does not flow across the system.

Let a_1 and a_o be respectively the constant which multiplied by the temperature differences $(t_1 - t_1')$ and $(t_o' - t_o)$ will give the B.T.U. transmitted per hour per sq. ft. of wall surface.

Evidently, $$a_1(t_1 - t_1') - a_o(t_o' - t_o) \tag{2}$$

The coefficient of conductivety "e" is the B.T.U. which a wall of 1 inch thickness will transmit by conductor per hour per sq. ft. of exposed surface per degree difference of temperature.

Evidently, $$\frac{e}{X}(t_1' - t_o') = a_1(t_1 - t_1') = a_o(t_o' - t_o) \tag{3}$$

A double wall of thickness X with air space and temperature conditions as shown on fig. 2; by a similar reasoning we get equations (4), (5) and (6).

$$t_1 > t_1' > t_2' > t_2'' > t_o' > t_o \tag{4}$$

$$a_1 (t_1 - t_1') = a_2'(t_2' - t_2) = a_2''(t_2 - t_2') = a_o(t_o' - t_o) \tag{5}$$

$$a_1 (t_1 - t_1') = \frac{e}{X}{}'(t_1' - t_2') = \frac{e}{X}{}_2(t_2'' - t_2') \tag{6}$$

<u>A compound wall</u> composed of two materials as in fig. 3 may be considered as a special case of case 2, in which the air space is zero. By analogy,

$$\frac{e_1}{x_1}(t_1' - t_2) = \frac{e_2}{x_2}(t_2 - t_o') = a_1(t_1 - t_1') = a_o(t_o' - t_o) \qquad (7)$$

$$t = \frac{\frac{e' t_1'}{x_1} \quad \frac{e_2 t_o'}{x_2}}{\frac{e_1}{x_1} \quad \frac{e_2}{x_2}} \qquad (8)$$

For convenience it is desirable to have a formula for any combination design of the form $K(t_1 - t_o)$ in which K is the B.T.U. per hour per square foot per degree difference in temperature.

Therefore in case 1, $$K = \frac{1}{\frac{1}{a_1} + \frac{1}{a_o} + \frac{x}{e}} \qquad (9)$$

In case 2, $$K = \frac{1}{\frac{1}{a_1} + \frac{1}{a_1'} + \frac{1}{a_o'} + \frac{1}{a_o} + \frac{x}{e_1} + \frac{x_2}{e_2}} \qquad (10)$$

In case 3, $$K = \frac{1}{\frac{1}{a_1} + \frac{1}{a_o} + \frac{x}{e_1} + \frac{x}{e_2}} \qquad (11)$$

These values of K have been worked out by experiment and otherwise by a greatmany experimenters, and these values were used im computations; except for the wall itself, in which case we solved equation (10) for a value.

<u>VALUES OF K USED IN COMPUTATIONS.</u>

For outside wall -------------K = .25

For ceiling ----------------K = .10

For glass windows ------------K = 1.03

For Door -------------------K = .41

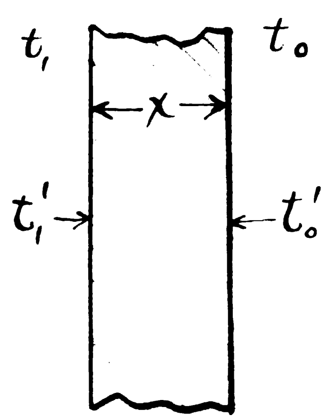

Fig. 1.

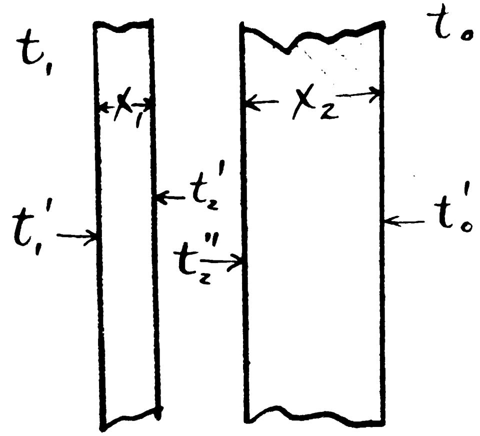

Fig. 2.

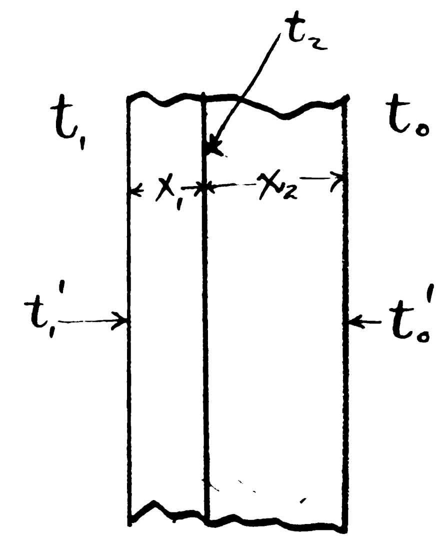

Fig. 3.

For <u>two column radiator of cast iron</u> we find, that <u>unit radiation</u> ≤ 1.66 when the temperature difference 155

$225^\circ - 70^\circ = 155^\circ$

1.66 x 225 257 B.T.U. per square foot of radiation per hour. <u>250</u> was used in computations.

Leakage correction was applied for all rooms.

$$L - \frac{nc}{55}(t_n - t_o)$$

Where n number of changes of air per hour by leakage. (n - 1 for ordinary houses)

c volume of room.

t_n inside temperature 70°.

t_o outside temperature 0°.

<u>Allowance for north and west exposure</u>

10% of the corresponding losses additional.

In ball-room an <u>allowance</u> was made for high <u>ceiling</u> being 14 feet high.

$t_m = t \quad .015\ (h - 10)t$

t_r = head high temperature.

t_m = mean temperature of room.

h = height of ceiling.

Allowance was not made for intermittant service as heat is supplied day and night.

Determination of K for wall.

$$K \quad \frac{1}{\frac{1}{a_1}+\frac{1}{a_1'}+\frac{1}{a_o'}+\frac{1}{a_o}+\frac{x_1}{e_1}+\frac{x_2}{e_2}}$$

(See Fig. 4)

$$a_1 = c + d + \frac{(4c + 3d)\,T}{1000}$$

$$= 1.23 + .74 + \frac{(4 \times 1.23 + 3 \times .74)\,14.4}{1000} = 2.0728$$

$$a_1' = .82 + .74 + \frac{(4 \times .82 + 3 \times .74)\,14.4}{1000} = 1.64$$

$$a_o' = .82 + .74 + \frac{(4 \times .82 + 3 \times .74)\,1.8}{1000} = 1.59$$

$$a_o = 1.03 + .74 + \frac{(4 \times 1.03 + 3 \times .74)}{1000} = 1.78$$

$$K = \frac{1}{\frac{1}{2.07}+\frac{1}{1.64}+\frac{1}{1.57}+\frac{1}{1.78}+\frac{1}{5.6}+\frac{1}{.76}} = .2458$$

WALL LOSSES

Ball-room, Parlor and lower hall.

No	Exposure	Surface	Dimensions	Area in Sq. feet	$t_1 - t_o$ F°	K	$K(t_1 - t_o)$	B.T.U.	Sq. feet Radiation
1	S	Wall	48'x 14'	576	74.2	.25	18.5	10670.	
2	S	4Windows	8 x 3	96	"	1.03	76.4	7340.	
3	E	Wall	28 x 14	320	"	.25	18.5	5920.	
4	E	3Windows	8 x 3	72	"	1.03	76.4	5510.	
5	W	Wall	28 x 14	320	"	.25	18.5	5920.	
6	W	3Windows	8 x 3	72	"	1.03	76.4	5510.	
7	N	Wall	19 x 14	242	"	.25	18.5	4475.	
8	N	1Window	8 x 3	24	"	1.03	76.4	1835.	
9				10% of N. and W. Exposures				1774.	
10				Leakage				23940.	
11				Total Losses				72894.	
12				Square feet of radiation					290.
1	W	Wall	12 x 10	120.	70	.25	17.5	2100.	
2	E	Wall	12 x 10	100.5	"	.25	17.5	1752.	
3	E	1 Window	6½x 3	19.5	"	1.03	72.1	1406.	
4	N	Wall	20 x 10	161.	"	.25	17.5	2817.	
5	N	2 Window	6½x 3	39.	"	1.03	72.1	2812.	
6				10% of N. and W. Exposures				773.	
7				10% for fireplace				1167.	
8				Leakage				3360.	
9				Total Losses				16194.	
10				Square feet of radiation					65.
1	W	Wall	7½ x 10	51.	70	.25	17.5	892.5	
2	W	Window	8 x 3	24.	"	1.03	72.1	1730.4	
3	E	Wall	7½ x 10	67.	"	.25	17.5	1172.5	
4	E	Window	4 x 2	8.	"	1.03	72.1	576.8	
5	N	Door	5 x 8	40.	"	.41	28.7	1148.0	
6				10% of N. and W. Exposures				377.1	
7				Leakage				2910.0	
8				Total Losses				8807.3	
9				Square feet of radiation					35.
10				Total radiation required					390.

WALL LOSSES

Upper hall, library and den.

.Exposure		Surface	Dimensions	Area in Sq.Feet	$t_1 - t_0$ F°	K	$K(t_1 - t_0)$	B.T.U.	Sq. Feet Radiation
W		Wall	7½ x 7½	36.7	70	.25	17.5	642.3	
W	1	Window	3 x 6½	19.5	70	1.03	72.1	1405.9	
		Ceiling	18 x 7½	135.	30	.10	3.0	405.0	
				10% of west exposure				204.8	
				Leakage				1546.3	
				Total Losses				4204.3	
				Square Feet of Radiation					17.
		Ceiling	11 x 6½ 17 x 9	224.	30	.10	3.0	672.6	
				Leakage				2575.0	
				Total Losses				3247.6	
				Square Feet of Radiation					13.
E		Wall	28 x 7½	151.5	70	.25	17.5	2651.3	
E	3	Windows	3 x 6½	58.5	"	1.03	72.1	4217.8	
S		Wall	19 x 7½	94.5	"	.25	17.5	1653.7	
S	2	Windows	(3 x 6½ 9 x 7½)	39.0	"	1.03	72.1	2811.9	
N		Wall	9 x 7½	48.0	"	.25	17.5	840.0	
N	1	Window	3 x 6½	19.5	"	1.03	72.1	1405.9	
		Ceiling	19 x 28	532.0	30	.10	3.0	1596.0	
				10% of north exposure				224.6	
				Leakage				6710.0	
				Total Losses				22161.2	
				Sq.Ft. of radiation					90.
E		Wall	13 x 5	65.	70	.25	17.5	2137.5	
N		Wall	20 x 9	141.	"	.25	17.5	2467.5	
N	2	Windows	3 x 6½	39.	"	1.03	72.1	2811.9	
W		Wall	13 x 5	57.	"	.25	17.5	997.5	
W	1	Window	2 x 4	8.	"	1.03	72.1	580.0	
		Ceiling	20 x 13	260.	30	.10	3.0	780.0	
				10% N. & W. Exposure				685.7	
				Leakage				2978.0	
				Total losses				13438.1	
				Sq. Feet of Radiation					59.
				Total Radiation required					179.

WALL LOSSES

Three Dressing rooms, and lavatory.

Exposure	Surface	Dimensions	Area in Sq. Feet	$t_1 - t_o$ F°	K	$K(t_1 - t_o)$	B.T.U.	Sq. Feet Radiation
	Ceiling	14½ x 10¼	149.	30	.10	3.0	447.	
N	Wall	7½ x 10	55.5	70	.25	17.5	971.3	
N	Window	3 x 6½	19.5	70	1.03	72.1	1405.9	
W	Wall	10¼ x 7½	57.	70	.25	17.5	997.5	
W	Window	3 x 6½	19.5	70	1.03	72.1	1405.9	
	LowCeiling	4½ x 10¼	46.1	30	.10	3.0	138.3	
			10% of N. and W. Exposure				478.1	
			Leakage				1705.0	
			Total Losses				7549.0	
			Square feet of Radiation					30.
S	Wall	12½ x 7½	74.2	70	.25	17.5	1298.5	
S	Window	3 x 6½	19.5	70	1.03	72.1	1405.9	
	Ceiling	12½ x 10¼	128.0	30	.10	3.0	364.0	
	Wall	7½ x 3	22.5	70	.25	17.5	394.0	
	Low Ceiling	3 x 5	15.0	30	.10	3.0	45.0	
			Leakage				1459.0	
			Total Losses				4976.4	
			Square Feet of Radiation					20.
W	Wall	10¼ x 7½	59.2	70	.25	17.5	1036.0	
W	Window	3 x 6½	19.5	70	1.03	72.1	1405.9	
S	Wall	12½ x 7½	74.2	70	.25	17.5	1298.5	
S	Window	3 x 6½	19.5	70	1.03	72.1	1405.9	
	Ceiling	12½ x 10¼	128.0	30	.10	3.0	348.0	
	Ceiling	3 x 5	15.0	30	.10	3.0	45.0	
			10% of west exposure				270.5	
			Total Losses				7314.8	
			Square Feet of Radiation					30.
W	Wall	6½ x 7½	29.0	70	.25	17.5	507.5	
W	Window	3 x 6½	19.5	70	1.03	72.1	1405.9	
	Ceiling	6½ x 8½	48.7	30	.10	3.0	146.1	
			10% of west Exposure				191.4	
			Leakage				632.5	
			Total Losses				2883.4	
			Square feet of Radiation					15.
			Total Radiation (Square feet)					95.

Table showing comparison of results by different methods.

Square feet of radiation required.

Method		#1	#2	#3	#4	#5	Used
Ball-Room	1	290	270	264	300	470	350
Parlor	2	65	55	45	60	65	65
Hall	3	65	65	75	80	85	35
Library	4	90	80	55	100	125	125
Den	5	60	45	30	50	60	65
Dressing room	6	30	30	20	35	45	30
Lavatory	7	15	10	10	15	15	15
Dressing room	8	30	30	20	30	30	30
Dressing Room	9	20	20	15	20	30	30
Total		665	605	534	690	925	745

Table showing the required illumination.

No	Room	Size	Area	C.P. reqd.	Watts reqd. for Tungsten lamps	Tungsten Lamps No-Size	Tungsten Lamps Watts	Carbon lamps Watts	Total Watts
1	Ball Room	48-28-14	1344	598	747	12-70	840	224	1064
2	Parlor	20-12-10	240	107	134	2-70	140		140
3	Hall 1st	7½-30½-10	229	101	126	1-45	45		45
3	Hall 2nd	7½-18-9	135	60	75	1-45	45		45
3	Hall 2nd	9-17-9 11-6½-9	868	386	482	1-70	70		70
4	Library	28-19-9	532	236	295	4-70	280	112	392
5	Den	20-13-9	260	115	144	2-70	142	112	252
6	Dressing room	14½-10¼-9	148	66	83			112	112
7	Lavatory	8½-6½-9	55	24	30			56	56
8	Dressing Room	12½-10¼-9	128	57	71			56	56
9	Dressing room	12½-10¼-9	128	57	71			56	56
	Toilet (by 6)	4-6-9	24					28	28
	Porch Lights							112	112
	Piano Lamp							56	56
								Total Watts	2484

Estimated Cost of Illumination.

Room	Estimated hours used per week.	K.W. used per week.
1	10	10.640
2	3	4.200
3	20	.900
3	6	.270
3	6	.420
4	5	1.960
5	15	3.780
6	1	.112
7	10	.660
8	6	.280
9	30	1.680
toilet	2	.056
porch	3	.336

K.W. Hours per week 12.194

At 10 cents per K.W.hour the cost per week would be $1.22,

Cost per month (30 days) $5.24

Method of calculating the necessary illumination.

Allow one 16 C.P. lamp for every 36 square feet floor space.

Candle power needed $= \frac{\text{Area} \times 16}{36}$

Tungsten lamps use about 1.25 watts per candle power.

Carbon lamps use about 3.5 watts per candle power.

COST ESTIMATE.

Fixtures.				
3 - 4 light chandeliers	@	$8.50	$25.50	
8 - 1 light wall brackets	@	.90	7.20	
1 - 2 light chandelier	@	6.00	6.00	
2 - 1 Light ceiling globe	@	.60	1.20	
6 - 1 light den brackets	@	.50	3.00	
2 - 1 light wall brackets	@	2.00	4.00	
3 - 1 light sockets & wire	@	.50	1.50	
1 - 1 light wall bracket	@	.90	.90	
1 - 1 piano lamp	@	3.00	3.00	
				$ 52.30
Glassware for fixtures				
9 - 6" globes	@	.20	1.80	
3 - 7" globes	@	.30	.90	
8 shades	@	.30	2.40	
2 - 6" Ceiling globes	@	.20	.40	
6 shades	@	.30	1.80	
2 shades	@	.50	1.00	
				$ 8.30
Lamps.				
20 - 70 Watt tungsten lamps	@	$1.10	22.00	
2 - 45 " " "	@	.70	1.40	
12 - 16 C.P. Carbon lamps	@	.17	2.04	
8 - 8 C.P. " "	@	.15	1.20	
				$ 26.64
Switches etc.				
10 - Push button switches	@	1.00	10.00	
3 - Snap switches	@	.25	.75	
1 - Socket or receptacle	@	1.00	1.00	
				$ 11.75
Fuses, distribution panel and wire.				
14 - Fuses & plugs	@	.15	2.10	
1100 feet #14 DRC wire	@	.02	22.00	
200 feet #10 DRC wire	@	.02	4.00	
8 - outlet, fuse box	@	8.00	8.00	
Labor of wiring			20.00	
				$ 66.10
Tubes			5.00	
Knobs			5.00	
Loom			3.00	
Tape			1.00	
Solder			.25	
				$ 14.25
Total Cost ------				$179.34

Pocket