WIND VELOCITIES NEAR A BUILDING AND THEIR EFFECT ON HEAT LOSS

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THE estimation of the heating requirements of buildings is the most fundamental practice of the heating and ventilating engineer. It has been the subject of continuous study since the heating of buildings became an important branch of the engineering industry. The determination of the heating load of a building requires *first,* knowledge concerning heat transfer and infiltration through the various types of construction involved for a practical range of temperature differences and wind velocities; *second,* knowledge concerning the weather conditions to which the building will be subjected; *third,* knowledge concerning the proper application of the items listed in formulae to give the resultant heat loss from the completed building or room under consideration.

During recent years research has been directed more intensively toward the extension of the available data on heat transfer and infiltration, and as a result, these data are now better understood than the facts concerning the probable temperatures, wind velocities, sun effect, heat capacity, and other environmental conditions and their use in the calculation of the final results. This subject was approved as a major research project by the Committee on Research last summer, and a Technical Advisory Committee under the chairmanship of D. S. Boyden was appointed.

A great deal of consideration has since been given to plans for this study by the Committee, including the collection of data on the over-all heat demands of existing buildings, an analysis of weather bureau data for various localities with a view of determining the combined effect of wind and outside temperature, and more intensive studies of the heat loss from a few individual rooms in existing buildings. It was agreed to concentrate for the present on the third type of study, namely, investigations of individual rooms in existing buildings. Data were collected during the past heating season in buildings in a number of

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geographical locations, including the study here reported, which was made in eight rooms in the Grant Building, Figs. 1 and 2.

The Grant Building is a modern 40-story office building of the set-back skyscraper type built in 1926. The building is normally heated by a differential vapor system using enclosed copper convectors below all windows. Control

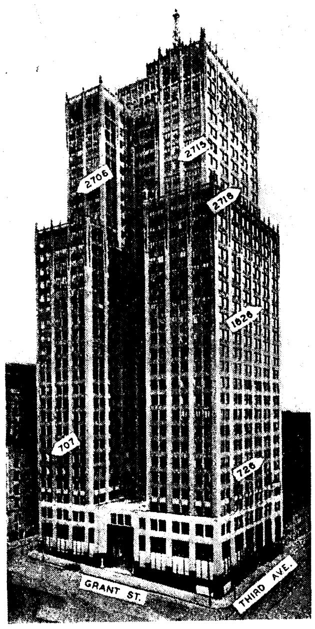

FIG. 1. THE GRANT BUILDING, SHOWING LOCATIONS OF SIX OF THE EIGHT ROOMS USED IN THE STUDY

of heat supply is obtained by varying the pressure of the steam supplied to the system from a small positive pressure in cold weather to the required vacuum in mild weather.

The rooms were chosen so as to give data on the heating demand of the different sides of the building on a given floor as affected by outside weather conditions and data concerning the relation of elevation to heat demand due to exposure to wind and the chimney effect of the building. Three rooms were

chosen on the 7th floor; 726 facing Third Avenue or the southwest, 707 facing Grant Street or the northwest, and 705 facing Fourth Avenue or the northeast. No typical rooms were available for test on the fourth side of the building which was devoted largely to corridors and elevator space. The three rooms on the 7th floor were chosen to represent different exposures in the lower portion of the building, where the heating demands might be affected by other buildings in the vicinity.

Buildings across the streets which may affect wind movement near these rooms and their heights are as follows: Across Third Avenue and opposite room 726 buildings extend to the sixth floor of the Grant Building; across the corner of Third Avenue and Grant Street there is a three-story building; the lot across Grant Street near Third Avenue is vacant; across Grant Street and opposite room 707, across the corner of Grant Street and Fourth Avenue, and across Fourth Avenue and opposite room 705, buildings rise, respectively, to the levels of the 9th, 18th and 14th floors of the Grant Building. Third Avenue, Grant Street and Fouth Avenue, are respectively, 37, 88 and 58 ft wide from building to building.

A single room, 1818, was chosen on the 18th floor facing Third Avenue or the southwest, to represent conditions in the middle or the neutral zone of the building.

Four rooms were chosen on the 27th floor; 2718 facing Third Avenue or southwest, 2715 facing Grant Street or northwest, 2703 facing Fourth Avenue or northeast, and 2706 on the north corner facing both Grant Street and Fourth Avenue. These rooms were chosen to represent the different directions of exposure in the upper portion of the building. With the exception of the corner room, 2706, all rooms had but one exposure, with similarly heated offices on either side as well as above and below. The three rooms facing Third Avenue on the 7th, 18th and 27th floors were similarly located with respect to the plan of the building so as to eliminate the effect of slight variations in location on the floor.

Each room studied was equipped with electrical heaters located directly below the copper steam convector with the cabinet extended downward to 3 in. from the floor so as to enclose the electrical heater. The convection currents of air passed upwards through the steam heating unit and into the room through the same grille which is used when heating the room with steam. The arrangement of the electrical heaters with respect to the convector and its enclosure, the window and other details is shown in Fig. 3, and was observed by the use of smoke to give convection currents of air into the room of the same temperature, velocity and direction as given by normal operation of the steam system.

The electrical heaters were arranged so that a capacity of 2,560 Btu per hour was always controlled by an "on" and "off" thermostat located 36 in. above the floor in the center of the room and shielded from view of the window and convector cabinet. A simple arrangement of switching made it possible to add additional or auxiliary heating capacity in units of 640, 1,280, and 2,560 Btu per hour, according to the heating demand. This gave a very satisfactory and flexible control without the disturbing effect of throwing the entire heating load of the room on and off. Each time upon passing through the rooms

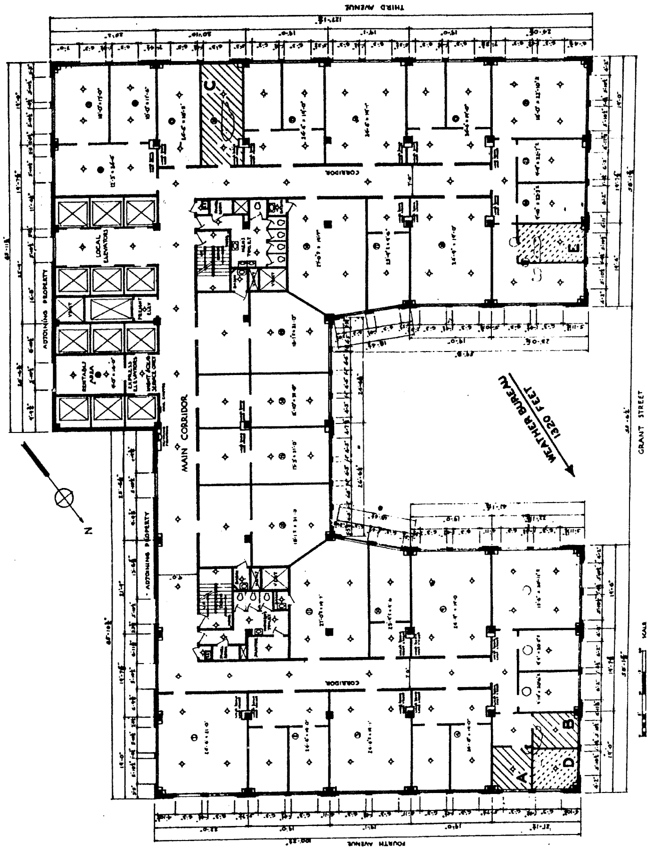

Fig. 2. Plan of Fourth to Twenty-third Floors of Grant Building Showing Rooms *A*, 705; *B*, 707; *C*, 726 and 1826. Rooms 2703, 2706, 2715, and 2718 Are Similarly Situated to *A*, *D*, *E*, and *C*, Respectively, But Set Back from the Building

the attendant adjusted the auxiliary heating capacity in an attempt to make it and that controlled by the thermostat just a little greater than sufficient to maintain the desired room temperature. All current supplied to each room for the heating units, light and other uses passed through an integrating watt-hour meter having dials which could be read to ± 5 watt-hours or 17 Btu.

Temperatures were observed by thermocouples, at various heights between the ceiling and floor in the center of the rooms, at a single location in each of

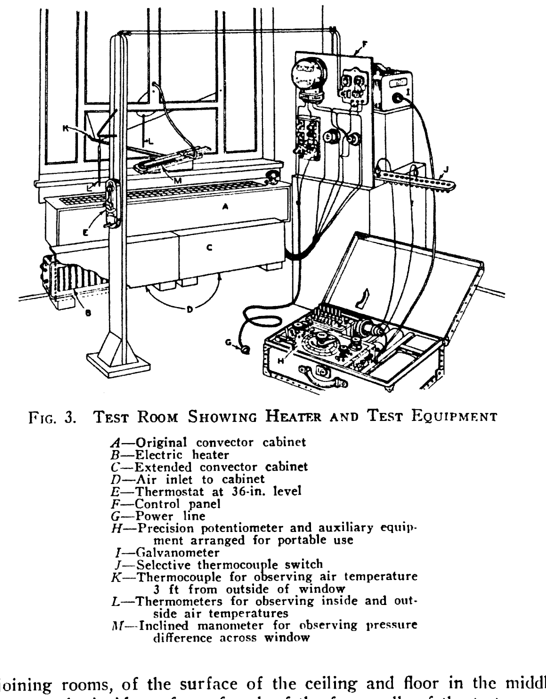

Fig. 3. Test Room Showing Heater and Test Equipment

A—Original convector cabinet
B—Electric heater
C—Extended convector cabinet
D—Air inlet to cabinet
E—Thermostat at 36-in. level
F—Control panel
G—Power line
H—Precision potentiometer and auxiliary equipment arranged for portable use
I—Galvanometer
J—Selective thermocouple switch
K—Thermocouple for observing air temperature 3 ft from outside of window
L—Thermometers for observing inside and outside air temperatures
M—Inclined manometer for observing pressure difference across window

the adjoining rooms, of the surface of the ceiling and floor in the middle of the test room, the inside surface of each of the four walls of the test room, the glass surface, the outside air 3 ft away from the window, and of the outside wall surface of the building. Some of these temperatures were checked by calibrated mercury thermometers. The pressure drop through the window was observed by an inclined manometer.

Wind velocities three feet away from the building wall were observed by an anemometer held out of the window of a room adjoining each of the test

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
		Weather Bureau Data													Data From Room 2703							
		Wind			Temperature Fahrenheit							Heat Flow Btu/Sq Ft/Hour Through Glass								Percentage		
			Velocity-MPH																			
Test Number	Date – 1934	Direction	Average	Maximum	Minimum	Average	Maximum	Minimum During Test Period	Min. From 10:00 PM To Following 10:00 PM	* Precipitation – Inches	Solar Energy on Horizontal Surface – Btu/Sq Ft/Day	Maximum	Time of Max.	Av. Condition	Velocity 3 Ft from Window at Time N – MPH	Outside Air Temperature at Time N – °F	Glass Heat Flow – Btu/Sq Ft/Hour/F – Based on P, Q + 70 F	f_o – Btu/Sq Ft/Hour/F	Glass Heat Flow – Btu/Sq Ft/Hour/F – Based on Q, S + 70 F	$\frac{Q}{M} \times 100$	$\frac{R}{M} \times 100$	$\frac{T}{M} \times 100$
1	Jan. 18	SE	9	12	6	30	38	19	19			58.5	9:00A	46.0								
2	19	W	12	18	4	37	40	32	32	T		46.5	9:00A	39.6								
3	20	W	8	12	2	40	46	28	28		638	44.0	7:30A	33.8								
4	22	SE	16	22	13	47	52	41	40	.01	420	35.0	7:00A	29.3								
5	23	W	22	29	14	38	46	30	30	.01	606	49.3	1:30P	42.3								
6	24	S	8	10	3	40	47	26	26		636	44.3	9:30A	33.8								
7	25	W	16	22	11	42	51	33	33	.01	76	44.3	9:30P	35.5								
8	26	SW	8	12	5.	36	41	29	29		674	45.0	7:30A	38.0								
9	27	SW	12	17	8	43	46	37	35	T	153	39.4	8:30A	32.5								
10	29	W	19	22	15	3	5	1	1	T	802	89.8	9:00A	86.5								
11	30	W	14	18	9	6	9	-1	-1	T	689	88.2	6:30A	79.0								
12	31	SW	15	20	10	28	35	12	9		716	69.8	6:00A	52.2								
13	Feb. 1	SW	12	15	9	31	34	2	23	T	77	58.0	10:00P	46.8	6.0	23.5	44.8	3.16	48.2	80.7	85.9	83.1
14	2	N	9	11	5	19	22	15	15	T	215	65.0	6:30A	58.2	11.0	16.5	63.0			89.5	96.9	
15	3	S	7	11	4	20	27	8	8		393	69.2	6:30A	54.2	6.5	9.0	65.5	1.46	47.5	78.3	94.7	68.6
16	5	NE	10	12	5	27	29	21	21	T	587	57.2	10:30P	50.0	6.0	21.4	52.0	2.21	46.2	77.4	90.9	70.8
17	6	W	9	12	5	21	26	12	12		511	62.0	6:30A	56.2	6.0	14.0	59.5	1.60	45.5	90.6	96.0	73.4
18	7	NW	13	15	11	26	28	20	20	T	471	63.0	10:30P	53.5	5.0	19.8	52.0	2.46	49.2	84.9	82.5	78.1
19	8	N	13	15	10	6	12	-4	-4		770	89.5	10:00P	78.2	0.4	-1.6	61.0	2.47	70.0	87.4	68.2	78.2
20	9	NE	10	12	7	2	9	-11	-11		747	97.6	6:30A	79.2	7.8	-11.0	90.0	1.79	69.0	81.1	92.2	70.7
21	10	SE	8	12	4	24	34	1	-1		713	72.0	7:00A	51.5	2.0	1.0	63.8	1.73	59.0	71.5	88.6	81.9
22	12	SW	13	19	9	31	33	30	30	.05	153	50.0	10:30P	47.5	15.0	32.6	46.5	2.95	39.6	95.0	92.6	79.2
23	13	NW	17	22	8	14	20	10	10	T	629	72.3	2:00P	71.0	11.2	14.0	66.2	3.26	61.5	98.2	91.6	85.1
24	14	S	8	11	4	24	32	7	5		481	64.5	7:30A	51.6	3.0	8.5	59.3	1.92	55.0	80.0	91.9	85.3
25	15	NW	14	17	6	36	43	21	21		667	58.8	10:00P	42.0	1.4	21.0	43.5	1.65	40.5	71.4	79.0	68.9
26	17	SE	5	8	4	28	37	12	12		479	66.0	8:00A	43.7	1.0	15.0	48.0	2.07	50.4	72.8	80.0	84.0
27	19	NW	13	18	10	18	32	7	7	.08	200	73.0	10:00P	63.3	5.1	6.8	65.5	2.52	63.0	84.4	87.3	84.0
28	20	W	13	18	6	12	20	-2	-2		913	85.2	8:00A	70.5	3.0	0.3	67.2	1.88	60.5	82.7	78.9	71.0
29	21	SW	8	12	2	34	42	14	13		903	54.0	6:00A	40.2	0.6	15.5	46.5	1.49	49.0	71.8	83.0	87.5
30	23	W	19	26	12	14	18	9	9	T	640	76.6	3:30P	72.2	10.0	13.5	65.3	2.66	57.0	94.2	85.2	74.4
31	24	W	10	13	5	11	15	3	3	T	730	80.5	8:00A	68.5	2.8	8.2	59.0	1.90	54.0	85.1	73.3	67.1
32	26	NW	17	21	10	14	17	7	7	.06	384	72.2	4:30P	71.2	5.0	16.0	56.0	3.10	58.0	88.6	77.6	70.3
33	27	W	11	12	4	6	12	-3	-3		1015	86.4	8:00A	76.0	3.0	2.0	66.3	2.70	70.0	88.0	76.4	81.0
34	28	S	7	12	3	20	28	-1	-1		339	71.2	8:00A	54.3	1.8	3.5	60.4	2.17	61.5	76.3	84.8	86.4
35	Mar. 1	S	7	11	3	34	39	17	17		371	51.0	7:30A	39.5	1.0	16.8	46.5	2.07	49.0	77.5	91.2	96.1
36	2	SE	10	16	5	45	51	29	29	.02	214	49.8	6:30A	29.1	1.0	28.8	36.0	1.35	30.5	58.4	72.3	61.2
37	5	SW	16	30	7	48	56	39	39	.24	711	45.6	10:30P	27.8	7.0	38.0	35.0	1.34	23.6	51.0	66.8	41.8
38	6	SW	21	30	12	35	39	29	29	.02	852	55.8	2:30P	45.7	14.0	31.0	47.8	1.76	33.0	71.9	75.7	59.1
39	7	W	9	11	8	35	37	31	31	T	441	46.2	10:30P	40.0	1.4	34.4	31.8	1.43	27.0	86.6	68.8	58.4
40	8	W	11	18	5	28	30	23	23	.04	203	56.5	6:30P	44.5	4.5	29.2	42.0	2.91	43.0	87.6	74.3	76.1
41	9	NW	14	18	8	26	29	20	20	T	1010	63.5	6:30A	59.3	5.0	21.0	51.0	2.93	51.8	85.5	80.3	81.6
42	10	N	14	18	9	22	28	15	15	.37	302	67.3	10:30P	59.2	9.0	19.5	57.2	1.97	45.0	88.0	85.0	66.9
43	12	S	13	17	9	28	33	14	14	T	1071	69.8	6:30A	51.3	14.0	13.8	72.2	3.56	63.5	73.5	103.4	91.0
44	13	SW	20	34	9	52	58	42	33		1175	36.0	6:30A	23.5	19.0	42.0	36.0	2.32	27.0	65.3	100.0	75.0
45	14	NW	15	18	7	28	34	23	23	.04	652	56.5	10:30A	52.2	10.0	28.0	49.0	2.90	44.2	92.4	86.7	78.2
46	15	SW	8	9	3	36	42	18	18		1005	52.0	6:30A	38.0	3.8	18.5	51.0			63.1	98.0	
47	16	W	14	18	2	49	54	40	39		1231	38.2	6:30A	25.9	2.0	40.8	27.2	1.70	24.5	57.8	61.2	54.1
48	17	SW	17	23	9	62	70	43	38		1229	30.6	7:30A	10.2	2.0	43.0	25.0	1.96	24.3	33.3	81.7	79.4
49	24	NW	8	12	5	32	37	25	25		316	50.4	9:00A	42.5	4.6	28.5	42.5	2.23	39.5	74.3	84.3	78.4
50	26	SE	11	19	5	48	59	37	33	.27	230	39.2	6:30A	26.0	1.0	37.4	28.4	2.41	31.6	56.3	72.5	80.6
51	27	NW	14	17	3	37	56	28	28	.26	169	52.8	8:00P	40.7	4.2	28.0	43.0	1.63	34.6	77.1	81.4	65.5
52	28	NW	9	10	4	34	42	22	22		1356	54.8	6:00A	41.3	3.5	26.0	49.3	3.21	48.0	75.4	79.0	87.6
53	29	N	4	7	2	50	61	29	29		445	42.7	6:00A	20.0	1.2	34.0	31.8	1.98	32.3	46.8	74.5	75.6
54	31	E	11	17	7	47	51	41	41	.11	385	34.2	8:00A	27.5	9.7	41.0	33.9	2.31	27.8	80.4	89.1	71.3
55	Apr. 5	E	12	18	8	58	68	45	45		1508	29.8	7:30A	14.5	11.0	46.0	28.2	2.75	24.8	48.7	94.6	83.2
Av. All Tests			12	17	7.	30	36	20	19		608	58.6		47.4	5.7	20.8	50.3	2.25	45.8	74.3	83.6	75.4

* T = Trace of Precipitation

TABLE 1. TEST DATA AND RESULTS

rooms. At a distance of 3 ft from the window the component of the wind velocity perpendicular to the building wall and the horizontal and vertical components parallel to the building wall were observed. A cup anemometer was located on the top of the Grant Building and connected to an electrical counter on the 27th floor. Complete Government Weather Bureau data were available from the Pittsburgh station located 1320 ft away in the direction indicated in Fig. 2.

In making a test, the observer entered each room at about 8:00 a. m., turned off the steam heat which had been left on the night before and turned on the electric heating unit controlled by the thermostat and a sufficient number of auxiliary heaters so that the total was a little greater than the heat required to maintain the desired temperature when the thermostat was on. Observation of the room temperature, the temperatures of the surrounding rooms and the watt-hour meter readings were also made on this tour of the eight rooms. Frequent rounds were made of all the test rooms throughout the day, when these observations were repeated and the necessary adjustments to the temperature of the adjoining rooms or to the thermostats in the test rooms were made.

This procedure was continued until 10:00 p. m., when on the last round the observer turned off all electric connections and turned on the steam radiators before leaving for the night, thus allowing the test rooms to float through the night with the same steam heat supply and control as was maintained in the remainder of the building.

Less frequently, additional rounds were made of the test rooms when temperatures given by the thermocouples and thermometers in and about the rooms were read and the wind velocities, 3 ft outside the window, and the pressure drops through the window were observed.

TEST RESULTS AND OBSERVATIONS

Because of the great volume of data collected between January 18, when the tests were started, and April 12, when the last test was made, and because it was impossible to analyze any considerable number of the results while collecting the data, this report will be limited to an analysis and discussion of the results obtained from the weather bureau records, the wind velocities and temperatures observed 3 ft outside of the individual test rooms, and the temperatures of the glass surfaces. Table 1 gives wind velocities and temperatures obtained from the weather bureau records and observed near the Grant Building and results calculated therefrom for the days studied. It will be observed that the minimum daily temperatures for the period of the tests on these days range from −11 to 45 F. The maximum daily wind velocity ranged from 8 to 34 mph. It should be noted that the minimum temperature and maximum wind did not necessarily prevail at the same time.

Column L gives the total solar energy per square foot of horizontal surface for the period from sunrise to sunset as recorded by the weather bureau in Pittsburgh. Column M gives the calculated maximum rate of heat flow through a window from an inside temperature of 70 F and the most severe concurring outside temperature and wind velocity recorded by the weather bureau for the test periods. These calculations were based upon an inside glass surface film conductance coefficient, $f_i = 1.65$, and an outside coefficient, $f_o = 1.65 +$

0.232 V, where V is the wind velocity. This relation between the outside surface coefficient and the wind velocity is in agreement with values determined by the Laboratory in Pittsburgh [1] and by Professor Rowley [2] at the University of Minnesota. Column N gives the time when the maximum calculated rate of heat flow occurred, which was most often in the early forenoon.

Column O gives the average rate of heat flow through the glass based upon the above considerations and the average temperature and wind velocity recorded by the weather bureau for the period of the tests.

Column P gives the wind velocity and Column Q the temperature observed 3 ft outside of the window for room 2703 at the time of the maximum calculated rate of heat flow. Column R gives the calculated rates of heat loss from a 70 F room to the outside air for the observed wind velocities and temperatures given in columns P and Q.

The rate of heat flow, H, through a window may be calculated from the difference between the inside air temperature, t_3, and the glass surface temperature, t_2, if the inside surface film conductance coefficient f_1 is known, by the formula:

$$H = f_1 \, (t_3 - t_2) \tag{1}$$

Likewise, the outside film conductance coefficient f_0 is given by the formula:

$$f_0 = \frac{H}{(t_2 - t_1)} \tag{2}$$

where t_1 = the outside temperature

or

$$f_0 = \frac{f_1 \, (t_3 - t_2)}{(t_2 - t_1)} \tag{3}$$

Column S gives the values for the outside film conductance coefficient based upon the inside room air temperature and the glass surface temperature observed at the time of the maximum calculated rate of heat flow given in column M. Column T gives the rate of heat flow through the glass based on the values of f_0 given in column S, a value of $f_1 = 1.65$, an inside air temperature of 70 F, and the observed outside temperature 3 ft from the window.

Columns U, V and W give the percentages which the rates of heat flow given in columns O, R and T, respectively, are of the maximum rate of heat flow given in column M.

These percentages show that the heat flow through the window from a 70 F room calculated from the observed temperatures and wind velocities outside of the window is considerably lower than that calculated from the weather bureau data. When the rate of heat flow is calculated from the observed relation between the inside air temperature in the center of the room and the glass surface temperature and the accepted inside film conductance coefficient, the discrepancy between this value and that calculated from the weather bureau is

[1] Wind Velocity Gradients Near a Surface and Their Effect on Film Conductance, by F. C. Houghten and Paul McDermott. A.S.H.V.E. TRANSACTIONS, Vol. 37, p. 301.

[2] Surface Conductance as Affected by Air Velocity, Temperature and Character of Surface, by F. B. Rowley, A. B. Algren and J. L. Blackshaw. A.S.H.V.E. TRANSACTIONS, Vol. 36, p. 429.

increased. The average for all tests shows the heat flow calculated from the observed temperatures and wind velocities outside of the window to be 83.6 per cent and the heat flow calculated from the inside film conductance coefficient to be 75.4 per cent of that based upon weather bureau observations. While these facts cannot be accepted as final proof of error in the practice of basing heat loss calculations directly on weather bureau data, they do represent strong evidence of such an error.

Considerable variation in the magnitude and direction of the wind velocity observed 3 ft outside the window was apparent. It was also apparent that these velocities were usually lower than those recorded by the weather bureau. Fig. 4 shows the relation between the weather bureau wind velocities and those observed 3 ft outside of rooms 707, 2706, 2718 and 2715, for all observations

Wind Dir. / Room	North				Northwest				West				Southwest			
	Av. %	Max. %	No. Obs.	No. Obs. Over 50%	Av. %	Max. %	No. Obs.	No. Obs. Over 50%	Av. %	Max. %	No. Obs.	No. Obs. Over 50%	Av. %	Max. %	No. Obs.	No. Obs. Over 50%
705	23.5	39.0	8	0	27.1	60.0	20	1	35.4	88.0	12	3	36.5	95.0	10	2
707	39.9	79.0	9	3	70.2	122.6	17	11	70.6	105.0	6	4	68.4	117.0	12	9
1026	47.0	75.0	9	3	44.3	81.0	18	7	65.0	105.0	7	3	54.6	102.0	16	9
2718	17.0	25.0	7	0	28.5	62.5	19	1	52.2	98.0	10	3	36.5	100.0	15	2
2715	61.6	91.0	6	3	55.0	100.0	17	10	35.5	71.0	13	2	33.2	66.0	16	2
2703	32.7	50.0	7	0	38.0	73.0	22	4	25.9	52.0	10	1	55.4	106.0	17	9
2706	34.1	44.0	3	0	32.6	60.0	16	2	65.6	100.0	10	7	57.7	120.0	18	9
Dir. / Room	South				Southeast				East				Northeast			
705	38.4	62.0	8	1	70.3	91.0	6	5	90.0	90.0	1	1	90.8	114.0	5	4
707	38.5	90.0	11	3									46.0	55.0	3	1
1026	38.2	59.0	6	1	63.5	100.0	8	5	43.0	58.0	2	1	44.5	68.0	7	3
2718	50.1	77.0	7	2	55.0	92.0	9	5	41.0	58.0	3	1	27.4	39.0	7	0
2715	24.1	84.0	8	1	31.4	85.0	10	2	42.8	59.0	4	1	28.4	54.0	7	1
2703	31.7	94.0	9	2	20.5	52.0	10	1	57.0	75.0	6	4	53.0	68.0	5	3
2706	26.4	54.0	9	1	16.1	40.0	10	0	55.0	78.0	3	1	24.0	26.0	2	0

TABLE 2. WIND VELOCITY 3 FT FROM WINDOWS IN PER CENT OF WEATHER BUREAU VELOCITY FOR VARIOUS WIND DIRECTIONS

in all tests when the weather bureau recorded a northwest wind. The values are given by the points of the arrows which indicate the direction in which the wind outside the window was blowing when observed by a person facing out of that particular window. For convenience in comparison, the lines, which represent respectively conditions where the wind velocity outside of the window was 100 per cent and 50 per cent of that recorded by the weather bureau, are drawn. This relationship is better expressed for the eight directions of wind recorded by the weather bureau and for the different windows listed, in Table 2, which gives the average and maximum percentages of all observed velocities outside of each of the seven windows in terms of the concurrent velocity recorded by the weather bureau. This table does not distinguish between direction of the velocities observed outside of the windows. The total number of observations on which the average is based is also given together with the number of observations for any particular window and wind velocity which exceeded 50 per cent of that recorded by the weather bureau.

Table 2 indicates a decided reduction in the observed wind velocities 3 ft from a window below that recorded by the weather bureau, and also a rather definite relationship between this reduction for any window and the direction of the wind. While in all cases the average wind velocity outside of the window is considerably less than that recorded at the weather bureau, certain windows, depending upon the direction of the wind, indicate occasional high velocities. This reduction in observed wind velocity near a building must necessarily be an important factor in reducing the actual heat loss below that

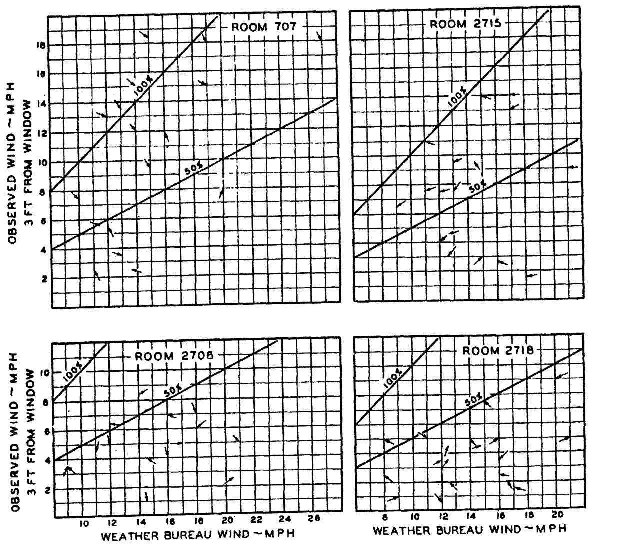

FIG. 4. RELATION BETWEEN OBSERVED WIND 3 FT FROM WINDOW AND WIND RECORDED BY WEATHER BUREAU. ALL DATA FOR A NORTHWEST WIND AT WEATHER BUREAU. ARROW POINTS INDICATE MAGNITUDE AND DIRECTION OF WIND TO OBSERVER FACING WINDOW FROM WITHIN. LINES INDICATE OBSERVED WINDS OF 100 PER CENT AND 50 PER CENT OF WEATHER BUREAU VELOCITIES

estimated from weather bureau data. In this connection it should be pointed out that the velocity a few inches away from the glass or that actually affecting the surface heat transfer may be even a lower percentage of the weather bureau values, because windows are set in several inches from the plane of the outside of the building wall.

The relation between location of a room in a building and the average and maximum winds observed near it as given in Table 2 and Fig. 4 is of special interest. In general, the relation between wind velocity observed near the surface and the weather bureau wind is more or less logical. As an example, when the wind was from the northwest or when it was striking directly into the

broad front of the building it tended to split sideways in each direction, giving high velocities for rooms 707 and 2715 which are near the corners of the building. Most surprising, however, is the fact that the highest velocities were experienced near certain 7th floor rooms where one would have expected shielding due to buildings across the street. As an example, the observed wind velocities were generally highest near room 707, having buildings extending to above this level on the opposite side of the street. Particularly was this true when the weather bureau reported a northwest, west or southwest wind, which seemed to enter Grant Street near Third Avenue and blow in a northeastwardly direction through the canyon formed by the taller buildings on both sides of Grant Street near and beyond Fourth Avenue. These facts do not agree with the frequent practice of assuming a lower wind for sheltered

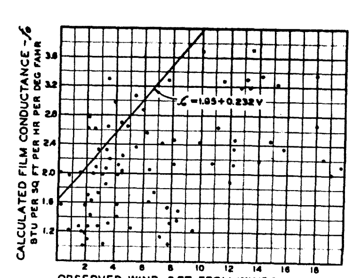

FIG. 5. POINTS SHOWING RELATION BETWEEN CALCULATED f_0 AND OBSERVED WIND VELOCITY 3 FT FROM WINDOW. CURVE GIVING VALUES OF f_0 AS DETERMINED BY FORMULA. DATA FROM ROOM 707

buildings. They seem to lend credence to claims concerning the howling winds through the canyons of New York and other large cities.

Fig. 5 shows the relation between the outside film conductance coefficient, when calculated by formula (3), for all observations on room 707 and the wind velocity observed outside the window. The curve giving values of $f_0 = 1.65 + 0.232\ V$ is drawn for convenience in comparison. It will be observed that most of the values of f_0 calculated from the inside air and glass surface temperatures are considerably lower than those given by the curve for the wind velocity observed 3 ft from the window. Similar data for all other rooms show approximately the same relationship, indicating the probability of a considerably lower actual rate of heat flow through windows than that calculated from wind velocities and temperatures observed 3 ft from the window.

The effect which wind has on the outside film conductance coefficient for a wall or window and therefore its effect on heat transfer is amply demonstrated by the work of the Research Laboratory [1] and Professor Rowley [2] at the University of Minnesota. These laboratory studies, however, gave results for definitely controlled conditions where the wind was parallel to the wall surface. This does not necessarily apply for natural wind around a building.

The effect which wind has on heat loss from a building differs widely according to variations in wall construction and the percentage of wall and window areas in the building. The effect of wind may be negligible for a well insulated wall, while for a single thickness of glass it may become a very important factor.

The exposed walls of the eight rooms studied in the Grant Building contained 42 per cent of glass and metal sash and frame area, and 58 per cent of masonry walls. The masonry walls had a conductance of 0.413. Assuming an inside film conductance coefficient of 1.65 and an outside brick film conductance coefficient of $f_0 = 2.0 + 0.4\,V$, where V is the wind velocity, the heat transmission coefficient for the wall becomes 0.283 and 0.317 Btu per square foot per hour per degree temperature difference for wind velocities of zero and 15 mph. Assuming glass surface film conductance coefficients $f_1 =$ 1.65 and $f_0 = 1.65 + 0.232\,V$, and allowing no resistance to the flow of heat for the glass itself, the heat transfer coefficient for the glass becomes 0.825, and 1.248 Btu for the same wind velocities. The 15 mph wind increases the heat transfer through the glass to 151 per cent of that for still air, which becomes a considerable percentage increase for the total building.

SUMMARY

This report, dealing with wind velocities and temperatures near the windows of several rooms, and their relation to weather bureau observations and heat loss through windows, represents an analysis of a small phase of the study made in the Grant Building during the past heating season. As such it should be considered as a single step in the analysis of a much more comprehensive study. The results suggest reasons for shortcomings in the present methods of estimating heating requirements of buildings based upon improper application of local weather bureau records to conditions in the immediate environment of a building. The findings here presented should not be considered final and conclusive in demonstrating possible errors in the present methods of estimating heat losses. They should be accepted rather as strong evidence of such errors to be considered in relation to other evidence resulting from more complete analysis of the data already collected in the Grant Building and elsewhere and to future studies, which will probably be made in other types of buildings and in other localities.

ACKNOWLEDGMENT

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DISCUSSION

W. C. RANDALL: I am not surprised to learn that the authors of this paper observed that there were no particular relations between wind velocities recorded at the observatory and those found on the face of the building at various locations.

In our investigations, from which data were received for the paper,[3] we noted that the pressure effect of the wind was greater on the lower floors because it apparently was harder for the wind to spill around the buildings and get away and, therefore, build up pressure. As we measured the pressure drop between the outside and the inside of the building higher up in the building we found, generally speaking, that it decreased, and was negative, particularly in the upper stories. We also found that the stack effect caused, in a great many of the openings on the upper floors, this reversal of pressure drop, and that floors midway between might either have outflow or inflow, according to the location, particularly around the side of the building. These observations are confirmed somewhat by the findings of the paper under discussion.

This brings up the thought that the chapter on Infiltration in THE A. S. H. V. E. GUIDE 1934 might logically be changed so it would not infer that there was a definite infiltration of a window for certain wind velocities, but rather indicate that it was a method of computing heating equipment and possible maximum heating loads. In other words, if the cubic feet of air was changed to a heat factor, the method of making a computation would be more simple and the inference, I believe, would be more correct.

G. D. WINANS: It is interesting to note the results obtained by measuring the wind velocities 3 ft from the building. In the experiments for the paper, Influence of Stack Effect on the Heat Loss in Tall Buildings,[4] by Axel Marin, attempts were made to measure the wind velocities close to the building with no satisfactory results due to the swirling effect of the wind at the building surface.

As explained in the aforementioned paper, measurements were made of the pressure difference across the windows of the various rooms by means of draft gages. To determine the direction of the air movement on the outside of the building, large volumes of tobacco smoke were discharged to the outside of the building through the draft gage connections. The movement of the smoke was a rapid upward one parallel with the building wall in all 3 test rooms. This was done while the wind direction was normal to the building wall. The outside connections of the draft gages were about 4 in. from the face of the wall.

W. W. TIMMIS: This paper demonstrates very clearly the necessity for conducting much more of our testing under actual field conditions than has been the practice heretofore. It is becoming increasingly obvious that the standards developed as a result of our laboratory investigations cannot in many cases be successfully applied under actual working conditions.

When we begin to study the operation of heating systems as systems, and to study the system in relation to the building it is called upon to service, we shall begin to find out many things about heating which have not heretofore been apparent.

The matter of proper distribution of heating elements in the various rooms of a building has assumed much greater importance during the past 5 or 6 years because of the development of control systems in which control is obtained by regulating the flow of heating medium at the source, or of dividing the building into a number of zones and controlling each zone by regulating the flow of heating medium at the entrance to each of the zones into which the piping is divided.

[3] Pressure Difference Across Windows in Relation to Wind Velocity, by J. E. Emswiler and W. C. Randall, A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930, p. 83.
[4] A.S.H.V.E. TRANSACTIONS, Vol. 40, p. 377.

In buildings in which this type of control is utilized it is of the utmost importance that the heating elements be properly proportioned to the spaces they are intended to serve. If they are not properly proportioned, the result is that in order to maintain the spaces which are relatively under-radiated at a desirable temperature, it is necessary to overheat the spaces which are correctly proportioned, and to grossly overheat spaces which are over-radiated.

It is incumbent upon all of us who are working with systems of this type to forward such pertinent field data as may be obtained to the Committee and I for one propose to do so.