ORIGINAL PAPERS AND DISCUSSIONS.

A STUDY OF DRAFT MOVEMENTS IN FLUES.

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Introduction.

In a paper by C. B. Harrop¹ on "The Inadequacy of Static Pressure Draft Gages," he proved beyond question that the ordinary draft gage is apt to be misleading, and that its readings do not indicate the rate of movement of gases in the kiln because the pressure, producing this movement, is entirely different from the static pressure measured by the draft gage. The pressure causing the rate of movement or velocity of flow of gases is called the "velocity pressure" and when added to the static pressure—which is the pressure required to overcome the resistance offered to the flow—gives the total pressure or draft intensity of a stack. The "velocity pressure" is not apt to vary directly with the static pressure and for this reason cannot be equal to it. Therefore, if the static pressure reading, as obtained by a draft gage, is assumed to be the velocity pressure, the results will be erroneous.

As an illustration, Harrop discussed a stack having a grate bar furnace built into its base, and with the internal gases at a temperature of 600° F. If the fire and ash doors were closed, the draft intensity was 0.6 inch (water column). If the ash doors were opened and the friction in the chimney was considered as negligible, a velocity pressure of 0.3 inch was developed. At the same time, the draft gage would show a reading of 0.3 inch over the grates. Assuming a constant stack temperature and a thicker fuel bed offering 50 per cent. more resistance to the passage of the air—only three-fourths as much air would pass through and the corresponding velocity pressure would be less than before. The draft gage

¹ *Trans. Am. Ceram. Soc.*, 18, 223 (1916).

recording the static pressure, or the difference between the total draft intensity and the velocity pressure, would read higher. Thus he pointed out that by thickening the fuel bed and, therefore, by decreasing the volume of gas flowing through the grates, the draft gage gave a higher reading. This higher reading would erroneously indicate a better draft.

Investigation.

It seems that the inconsistency and tendency of the draft gages to mislead is not quite generally known and as there are many in actual use the necessity for a better method for its use is evident. Accordingly, this investigation was undertaken with a view to either finding a way to make the draft gage indicate the rate of movement of the gases or to find some other way of measuring the volume of gas passing through a flue.

The method selected was that suggested by Harrop¹ at the close of his paper and also mentioned in the discussion of his paper. Briefly, the measurement of the static pressure between two points in a flue was taken as a basis—the friction between the two points always being constant with any given velocity of gases.

The apparatus used consisted of static pressure tubes inserted into a flue at the two points and each connected to one end of a U-tube, as used on the draft gage. A differential reading giving the friction between the two points was then taken. As long as no air passes through the flue, there is no friction and consequently the liquid in both tubes would stand at the same level. However, as soon as air passes through, there is friction and this friction would be measured by the differential reading on the gage. It is evident that the differential reading would vary directly as the volume of gas passing through the flue, since the greater the volume the greater the velocity of the gas and the greater, therefore, the resistance offered by the flue. However, since the velocity of the gas in the flue between a kiln and stack is only about 600 feet per minute, the two points in the flue would have to be a great distance apart in order to get an appreciable reading—a straight flue offering but little resistance. In fact, the full length of most kiln

¹ *Trans. Am. Ceram. Soc.*, 18, 223 (1916).

flues would be too short to give sufficient resistance. It was therefore necessary to devise a different method for providing this resistance.

Apparatus.

The use of a diaphragm with an orifice, as used by the Bailey Meter Company and others in their flow meters, used primarily for the measurement of steam and water pressure, was thought especially desirable. There appeared to be no reason why this method could not be made applicable in the measurement of the amount of gas flow in a flue system. It has been found to be extremely accurate by the Bailey Meter Company in their meters and preferable to the Pitot tube.

The Pitot Tube.

The Pitot tube is not suitable for measuring the flow of gases at the low velocities usually found in flues and requires long runs of straight flow before it will give accurate results. It is also difficult to get an average reading with the Pitot tube, especially when the cross section of the flue is irregular. The latter disadvantage would undoubtedly be met in kiln flues, for the flue between kiln and stack is often quite short and since a straight flue is needed on both sides of the tube, this instrument would hardly be practical. Besides, it must be used very carefully in order to get accurate results. Therefore, the use of a diaphragm with orifice in a flue, if it could be made applicable, seemed to be the most practical.

Experimental Flue.

It was considered inadvisable to carry on the experimental work with a flue connected to a stack because no means of controlling the draft and of testing different sized flues were available. An electrically driven fan was therefore connected at its inlet to a wooden flue (Fig. 1) thus producing an induced draft. The wooden flue was 35" $\times$ 35" $\times$ 12' in length and was made as air-tight as possible. It had but three sides, the concrete floor serving as a bottom. A brick flue was not considered necessary—since only the drop in pressure through the orifice was

measured and all other rubbing surfaces would have but little effect.

A brick wall was built about nine feet from the fan inlet in the flue. A greater distance than this was desirable but more space was not available. The orifice in the center of the diaphragm was made square. The brick were laid in cement mortar, and all cracks and openings between the diaphragm and the flue were made air-tight.

FIG. 1.

Orifices of two sizes were tried. The area of the first was equal to about 25 per cent. of the area of the vertical section of the flue. With a velocity of ten feet per second through the flue, the draft gage registered a drop of 0.42 inch W. G. through this orifice. This was considered excessive since the draft would undoubtedly be seriously affected by much added resistance. An orifice having an area of about 50 per cent. of the flue was then constructed. With this orifice, the drop under the same velocity was but 0.13 inch W. G. and at the lowest velocities was about 0.015 inch W. G. An orifice of this size was therefore adopted. The area of the orifice (26" $\times$ 26") was a little larger than one-half (55 per

cent.) the area of the flue. A sketch of the part of the flue containing the diaphragm is shown in Fig. 2.

In order to make the conditions more comparable to those actually found in flues leading from kiln to stack, the end of the flue was partly closed. The obstruction served as the resistance offered to the flow of the gases by the furnaces and kiln, and was made equal to about 0.2 inch W. G. under maximum velocity conditions. It has been found that, for ordinary round kilns, the draft gage reaches a maximum of about 0.2 inch W. G. The

FIG. 2.—Portion of flue showing diaphragm and positions of tubes.

draft gage tube "A" (Fig. 2) between the diaphragm and the end of the flue would therefore register a pressure of 0.2 inch plus the resistance from the end of the flue to the tube, while the draft gage tube "A'" beyond the diaphragm would read this resistance plus the resistance offered by the diaphragm. These gage tubes were placed about three inches from the diaphragm on each side and entered the flue through holes in the center of one side. They projected about one inch into the flue but this distance is not important since the gage reading was not affected by any change.

Measurements.

A Pitot tube was used to measure the velocity of the gas through the orifice for every reading taken on the draft gage. The Pitot tube was practical in this case for we had a straight flow of gas and the velocity through the orifice—400 to 1000 feet per minute—was high enough to assure accuracy. The Pitot tube was inserted just behind the diaphragm (Fig. 2) and through the same opening used for the draft gage tube—the bent end of the Pitot tube reaching just to the center of the wall. The Pitot tube therefore gave the pressures existing in the orifice. Three readings were taken across the orifice, as marked in Fig. 2—the average of these being taken as the average pressure in the orifice.

An inclined manometer, which could be so adjusted that from two to forty inches of slant along the manometer was equivalent to one inch of vertical reading, was used. The forty-inch slope of the manometer assured an accurate reading with low velocities. In converting the manometer readings to inches of water gage, they were multiplied by the specific gravity of the oil used (0.837).

Since one part of the Pitot tube gives total pressure and the other static pressure, the difference being the velocity pressure, if each tube is connected to the ends of the manometer tube, the differential reading will be the velocity pressure. To illustrate, suppose a reading is 3.82 and the manometer is set at a slope of 20 (that is, 20 inches on the manometer being equivalent to one-inch vertical reading). Then $3.82 \div 20 = 0.191$ " vertical reading. Multiplying by 0.837, the specific gravity of the oil, $0.191 \times 0.837 = 0.16$ " W. G. = the velocity pressure. The velocity of the gas is then determined by means of the formula—

$$V = K\sqrt{p},$$

where V = velocity in feet per minute,

p = velocity pressure in inches W. G.,

and K = velocity constant.

The velocity constant K changes with the temperature. At 70° F. it is 4006. A table giving these constants is included later. The photograph (Fig. 1) shows the arrangement of the entire apparatus. The inclined manometer is shown directly above the word "Pitot."

Before making any tests, readings of the Pitot tube were checked against the tubes used with the draft gage for static pressure. The manometer was also checked against the draft gage. Each tube was inserted at the same time, the fan operated, and the following results were obtained:

Draft gage tube.....	{ On draft gage.... 0.587 inch W. G..
	{ On manometer... 0.591 inch W. G.
Pitot tube (static pressure)....	{ On draft gage.... 0.579 inch W. G.
	{ On manometer... 0.582 inch W. G.

The readings of the Pitot tube and draft gage tubes varied less than 0.01, differing but 0.008, and the manometer and draft gage differed but 0.004. This was quite satisfactory and gave us more confidence in the readings of the Pitot tube.

The Tests.

In making the tests, the velocity through the flue was varied—200 feet per minute being the minimum. By partly closing the outlet of the fan, any desired velocity could be obtained.

The results secured with the 35" by 35" flue and 26" by 26" orifice are tabulated as follows:

TABLE I.

Static pressure before diaphragm (Tube A' in Fig. 2).	Differential reading (draft gage).	Manometer.	Slope.	Velocity through orifice in feet per minute.	Remarks.
0.02	0.017	0.4	40	370	Temperature 80° F.
0.048	0.04	1.00	40	587	Specific gravity of oil 0.837
0.065	0.052	1.30	40	668	Formula to figure velocity—
0.085	0.07	1.93	40	815	$V = K\sqrt{p}$.
0.12	0.10	2.45	40	917	K at 80° F. = 4044
0.13	0.107	2.57	40	938	Unrestricted outlet.
0.155	0.116	2.78	40	977	
0.17	0.12	2.90	40	995	
0.19	0.125	3.07	40	1030	

The size of the flue was next reduced to 23½" by 22½" (3.67 square feet). The area of the orifice was made 55 per cent. of that of the flue or 2.02 sq. ft. (17" × 17").

The results for a flue of this size are tabulated as follows:

TABLE 2.

Static pressure before diaphragm.	Differential reading.	Manometer.	Slope.	Velocity through orifice F. P. M.	Remarks.
0.02	0.015	0.18	20	351	Temperature 82° F. K at 82° = 4050
0.027	0.022	0.29	20	446	
0.034	0.028	0.33	20	476	
0.045	0.035	0.40	20	523	
0.057	0.048	0.55	20	614	
0.06	0.05	0.58	20	630	
0.09	0.062	0.88	20	776	
0.13	0.08	1.23	20	918	
0.15	0.11	1.30	20	945	
0.19	0.123	1.55	20	1030	

If the results secured by the use of the two orifices are compared, it will be found that they check very closely. For instance, for 370 feet per minute in the larger flue, a drop of 0.017 inch through the orifice was noted, while for 351 feet per minute in the smaller flue, we noted a drop of 0.015 inch. Again, with 1030 feet per minute in both flues, we noted 0.123 inch drop in one case and 0.125 inch in the other. This appears to indicate that if the ratio of the areas of orifices and flues are kept constant, the same drop in pressure through the orifice occurs with the same velocity—the size of the flue being unimportant.

The accuracy of the readings was tested by the use of the relation, "pressure or resistance varies as the square of the velocity." The average of the two tests was taken from the following condensed results (Table 3) giving only the drop in pressure through the orifice for the corresponding velocity. The higher velocities, 1100 to 1600 feet per minute, which the fan could not produce, were calculated from the pressure-velocity relation (Table 4). Under "ratio" is given the ratio of the first reading of pressure to every other pressure. The second ratio column gives the same for the velocities. Any pressure ratio should, therefore, be theoretically equal to the square of the corresponding velocity ratio.

TABLE 3.

Large flue.		Small flue.	
Pressure drop.	Velocity.	Pressure drop.	Velocity.
0.017	370	0.015	351
0.04	587	0.022	446
0.052	668	0.028	476
0.07	815	0.035	523
0.10	917	0.048	614
0.107	938	0.05	630
0.116	977	0.062	776
0.12	995	0.08	918
0.125	1030	0.11	945
0.150	1100	0.123	1030
0.178	1200	0.147	1100
0.210	1300	0.176	1200
0.243	1400	0.206	1300
0.279	1500	0.238	1400
0.318	1600	0.273	1500
...	..	0.312	1600

TABLE 4.—AVERAGE FOR TEMPERATURE OF 80° F.

Pressure drop.	Ratio.	Velocity through orifice.	Ratio.	Velocity through flue.
0.016	...	360	..	198
0.028	1.75	482	1.34	266
0.044	2.75	600	1.66	330
0.051	3.19	650	1.81	357
0.066	4.12	796	2.21	407
0.09	5.62	918	2.55	473
0.1107	6.92	952	2.64	523
0.115	7.19	970	2.69	533
0.124	7.75	1030	2.86	555
0.1485	9.29	1100	3.06	605
0.177	11.07	1200	3.34	660
0.208	13.0	1300	3.62	715
0.2405	15.03	1400	3.89	770
0.276	17.25	1500	4.17	825
0.315	19.68	1600	4.45	880

These ratios were plotted against each other and checked by drawing the theoretical pressure-velocity curves on the same chart (Fig. 3). With but two exceptions (the pressure drops of 0.066 inch and 0.09 inch) all points fall upon the curve. This appears to indicate that the drop in pressure through an orifice

is an accurate indication of the velocity of the air passing through a flue. The results were put in more convenient form by means of curves so that the velocities could be determined directly from the differential reading, providing the temperature is known

FIG. 3.

and the same ratio of orifice and flue, as used in this investigation, is employed.

The temperature of the gas is an important factor in the pressure developed at a certain velocity. It would appear that, as the temperature increases and the sp. gr. of the gas decreases, the pressure developed at a constant velocity becomes lower. Since the results (Table 4) were taken at a temperature of about 80° F., they cannot be applied to conditions in a flue, the temperature of which may be 1500° F. Results for the different temperatures must therefore be obtained.

A very simple method of converting the pressures from one temperature to that at another temperature was obtained by the use of the following "Table of Constants" (Table 5)¹ giving the velocity constants already mentioned for any temperature.

In Table 5, K represents the velocities of dry air, in feet per minute, required to sustain a column of water one inch in height. This was obtained by using the formula

$$k = \sqrt{\frac{2g \times \text{weight of 1 cu. ft. of water at } 62^{\circ} \text{ F.}}{12 \times \text{weight of 1 cu. ft. of air at temp. stated.}}}$$

Small k in the formula is the velocity in feet per second and is multiplied by 60 to secure the values for K given in the table.
 g = acceleration due to gravity = 32.16.

The ratios given in the table are those between the fan speeds necessary for the various temperatures listed and 70° F. to produce the same water gage indication.

The table is used as follows: To change any pressure, say at 80° F. to that at 200° F. under the same velocity, divide the pressure at 80° F. by the square of the ratio of the velocity constant at 200° F. to the velocity constant at 80° F. For example, suppose we take the differential reading obtained for a velocity of 1600 feet per minute through the orifice or 880 feet per minute through the flue, which is 0.315 inch W. G. at 80° F., the temperature of the experiment. The ratio of the velocity constants at 200° F. and 80° F. would be $\frac{4470}{4044} \cdot \left(\frac{4470}{4044}\right)^2 = 1.22 = \text{the fac-}$

¹ This table was obtained from Mr. L. E. Eisensmith of the American Blower Co.

tor by which all pressures at 80° F. must be divided in order to obtain the pressure at 200° F. $0.315 \div 1.22 = 0.258$. The pressure at 880 feet per minute at a temperature of 200° F. would therefore be 0.258 inch W. G.

TABLE 5.—CONSTANTS.

Figured for dry air at sea level.
Barometer 29.92 inches mercury.

Temperature.	K.	Ratio.	Temperature.	K.	Ratio.
40° F.	3567	0.890	480° F.	5332	1.331
30	3609	0.901	500	5389	1.345
20	3651	0.911	520	5445	1.359
10	3692	0.921	540	5500	1.373
0	3733	0.932	560	5555	1.387
10	3773	0.942	580	5609	1.400
20	3813	0.952	600	5663	1.413
30	3852	0.961	620	5716	1.426
40	3891	0.971	640	5769	1.439
50	3930	0.981	660	5821	1.452
60	3968	0.990	680	5873	1.465
70	4006	1.000	700	5925	1.478
80	4044	1.009	720	5976	1.491
90	4081	1.018	740	6027	1.504
100	4118	1.028	760	6077	1.517
110	4155	1.037	780	6127	1.530
120	4191	1.046	800	6177	1.542
130	4227	1.055	820	6226	1.554
140	4263	1.064	840	6275	1.566
150	4298	1.073	860	6323	1.578
160	4333	1.082	880	6371	1.590
170	4368	1.090	900	6418	1.602
180	4402	1.098	920	6465	1.614
190	4436	1.106	940	6512	1.626
200	4470	1.114	960	6558	1.638
220	4537	1.132	980	6604	1.649
240	4603	1.149	1000	6650	1.660
260	4668	1.165	1020	6695	1.671
280	4732	1.181	1040	6740	1.682
300	4796	1.197	1060	6785	1.693
320	4851	1.213	1080	6829	1.704
340	4921	1.228	1100	6873	1.715
360	4982	1.243	1120	6918	1.726
380	5042	1.258	1140	6962	1.737
400	5101	1.273	1160	7005	1.748
420	5159	1.288	1180	7048	1.759
440	5217	1.303	1200	7090	1.770
460	5275	1.317	..	..	...

In this way the pressures at 80° F. were converted into those at temperatures up to 1500° F. The results for each temperature were plotted as shown in Fig. 4. In plotting, the two velocities corresponding to the two points which were off the pressure-velocity curve were corrected in order to make the final curves

FIG. 4.

more accurate. From these curves, the velocity through the flue at any temperature can be secured from the differential draft gage reading. However, even the velocities may become misleading, since the same velocity at different temperatures does not mean the same weight of gases, and the weight of the gases after all is what we must have in order to determine the rate of combustion we are getting in the fire boxes. A set of velocity weight curves for the different temperatures was therefore drawn directly over the differential draft gage reading curves, and from this double set of curves the weight of the gas may be determined directly from the differential reading on the draft gage. This weight is expressed in pounds per minute per square foot of flue area—since this forms a basis from which the actual weight of gas can be figured for any flue. The weights are based on dry air—since the data in the "Table of Constants" was figured on the same basis. A source of error is introduced here since the weight of the air varies as the relative changes in humidity. However, the most useful part of these curves is from about 300° F. and higher. The relative humidity must become very low as the temperature increases beyond this point and the error should not be great enough to make the results unreliable.

An illustration of the use of the curves is indicated in Fig. 4. Assume a reading of 0.132 inch W. G. at a temperature of 600° F. in the flue. Approximating 600° F. on the solid line curves, we come down until we strike 0.132 on the differential reading scale. If we wish to determine the velocity, we drop to the abscissa and find it to be 800 feet per minute. To get the weight we proceed vertically in the direction of the arrow until we strike the approximate 600° F. curve on the broken line set of weight curves. We then go to the left to the weight scale along the ordinate and find it to be 30.

Conclusions.

Lack of time prevented any additional work. Since the differential readings at the higher temperatures are not very large, it would be interesting to run similar tests with a somewhat smaller orifice in order to determine the relation between the size of the orifice and the differential readings. It is very doubtful whether the orifice should be made smaller since the size used

produced a static pressure drop of somewhat over 0.1 inch W. G. The addition of 0.1 inch W. G. of static pressure to a stack would very likely push it to its limit in order to maintain sufficient velocity pressure to produce the desired draft movement.

It is interesting to note that, with induced draft, the static pressure gives a higher reading than the total pressure. The relation—"total pressure minus static pressure equals velocity pressure"—still holds, however, since in induced draft they are both negative and by subtracting the static from the total pressure we get a positive velocity pressure which is as it should be. For example, if we have a total pressure of 0.4 inch W. G. and a static pressure of 0.6 inch W. G.,

$$\begin{aligned} \text{then T. P.} - \text{S. P.} &= \text{V. P.} \\ -0.4 - (-0.6) &= +0.2. \end{aligned}$$

With this, a possible method of using the draft gage to measure velocities and weights in a flue has been found. However, the work is merely experimental and should be tried out under actual conditions in order to determine its practicability. It shows possibilities and might, with some alterations, be of value in the firing of kilns. Conditions vary at every plant, but there seems to be no reason why any one plant could not prepare a set of readings by this method for use in noting whether or not the burn is progressing satisfactorily.

DISCUSSION.

MR. DAVENPORT: I would like to ask Mr. Harrop whether the minimum static pressure observed in these tests was comparable with the minimum observed in ordinary kiln firing. Although the data presented is interesting from the theoretical standpoint, it has been my experience that the very low draft pressures involved in periodic kiln firing render it exceedingly difficult to secure reliable readings. Mechanical engineers have about given up the problem of trying to read pressure differences amounting to only 0.04" to 0.05" of water.

MR. HARROP: Our method of measuring the pressure involved the use of a manometer similar to that used by the American

Blower Company. This manometer may be set at a very low angle and is very sensitive. I realize that it is very difficult to secure an accurate reading in this way, but to my knowledge this manometer is the most delicate instrument available for use in measuring the velocity pressure by the Pitot tube method. In regard to the pressures employed, the static pressure resulting from the resistance through a kiln at the beginning of a burn was taken as 0.02" and was determined by an actual kiln reading. This static pressure of 0.02" resulted from the resistance of the kiln to the flow of gases. In other words, that static pressure would have shown up on the kiln side of the diaphragm. As the burn continued the static pressure increased to about 0.21" at the highest temperature.

MR. DAVENPORT: I would like to add that this problem of the determination of the amount of air or gas moving through kilns is an important one, but I would also like to emphasize the fact that it is a complex one and one which has for some time baffled the best efforts of mechanical engineers. The Thomas Electric meter seems to offer one practically reliable method of determining the flow of gases at very low velocity pressures; but in my own experience with Pitot tubes I have found, inasmuch as the variation may be as much as 50 per cent. plus or minus, that an endeavor to reduce the results to absolute values below about 0.05" is fruitless. I believe, however, that if work of this kind were undertaken by ceramic engineers and an active demand were created for some means of measuring very low draft pressures, that some good would come of it; but at present the Pitot tube and slant gage are conceded by most authorities to be exceedingly unsatisfactory for the measurement of low velocities.

COMMUNICATED DISCUSSIONS.

ELLIS LOVEJOY: Mr. Fritz has given us a very creditable piece of work and it is to be hoped that it will lead to some improvement in the important burning operations.

I have had no respect for a draft gage for some time and the majority of clay workers are also lacking in respect—if I may judge from the number of gages I have seen entirely out of com-

mission, or running their course of uselessness without any attention. Where records are kept, the firemen have settled down to filling in the spaces in a prefunctory manner without even reading the gages and the data slips are added to the dusty pile in the corner of the kiln house.

A draft gage attached to a chambered continuous kiln compartment will show several tenths minus pressure in the early stages of the compartment's operation. As the fires approach the compartment in question, the pressure will drop back to zero and often go beyond, indicating no draft, in fact a back pressure, yet the operation of the kiln moves along in spite of the readings of the draft gage. The behavior is easily explained and the explanation condemns the draft gage.

A differential gage will, as Mr. Fritz has shown, give us correct draft readings which may be reduced to velocity and to volume of gas moved. The attachment of such a gage to a kiln is a problem in itself.

Consider the chambered continuous kiln for example. The natural location for the gage would be in the long flue connecting the kiln to the stack or fan, but in the modern kiln there are two distinct operations carried on by the fan draft; namely, burning and water-smoking, each under damper control. Draft gage readings beyond these dampers would be of no value and there is no room between the dampers and the kiln as a rule. It would be impracticable to make the connections on opposite sides of the chamber division walls because of the wide difference in temperature.

Down-draft kilns may have wall stacks, outside stacks in close proximity to the kiln, or distant stack or fan. In the first two instances the differential gage could only be attached to the stack with such adjustments as may be necessary for the difference in altitude. The stack, and this is also true of any flue, must be large enough to accommodate a suitable diaphragm having an opening of requisite size for the kiln operation and there will be an essential difference in temperature for which correction must be made.

Besides the difference in temperature on opposite sides of the diaphragm, we must take into consideration the constantly ad-

vancing temperature in the kiln flue and stack, and we must also consider that the stack and flue temperatures, will vary widely at any given stage in successive burns, and it is not safe to assume that, if on the sixth day of one burn we have 0.3 inch water gage draft, this will be the proper draft for the sixth day of any other burn.

The draft gage to be useful to the clay workers is not to tell them what has been done but to direct the work in the future. Its real purpose is to enable the manager to put in the kiln house a diagram showing the burner just what the draft gage should read at every stage in the process to the end of the burn.

How far the draft gage may become useful in kiln operations remains to be seen, but it will, in kiln tests under competent handling, determine proper kiln pressures for various wares in several types of kilns and thus give us the necessary data for better kiln design and construction.

Mr. Fritz states that for ordinary round kilns the draft reaches a maximum of about 0.2 inch water gage.

I have been seeking this data for some time and if he has accurate records along this line I should very much like to have them. Down draft kilns vary widely in the construction of the floor flue system and there is a greater variation in the kiln setting.

A gas burning kiln with a simple floor system set with drain tile or other hollow ware is a very different matter from a closely set face brick kiln with a complicated floor flue system, burned with coal fired in grate bar furnace.

It seems to me that 0.2 inch water gage is too low for a maximum resistance in down draft kilns, and I am inclined not to accept it without further proofs of actual tests under maximum resistance conditions.

C. B. HARROP: Regarding the statement in the impromptu discussion offered by Mr. Davenport, relative to the impracticability of Pitot tube readings under low pressure conditions, attention should be called to two points: First, as the diaphragm orifice (where the Pitot tube was placed) was approximately 50 per cent. of the area of the flue, the velocity through the orifice

was approximately double that through the flue. This gave at all times sufficient velocities to be satisfactorily read with the Pitot tube. Second (as shown in Fig. 3), the relation between velocities determined by the Pitot tube and resistance or pressure drop results in practically a perfect " R varies as V^2 " curve, which in itself proves that the Pitot tube readings were amply accurate for the work.