RETENTION TIME IN ROTARY KILNS-
CONSIDERATION OF FLIGHT DESIGN

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RETENTION TIME IN ROTARY KILNS- CONSIDERATION OF FLIGHT DESIGN

SUMMARY

This work was undertaken with the intention of extending previous investigations of the various effects which influence the time of passage of solids through rotary kilns. As far as could be ascertained, no previous consideration had been given the effect of flights in rotary kilns, and it was proposed to develop an equation which would express the results imposed by this condition.

The relation of slope, speed, and angle of repose of the material to the retention time was investigated in a simple, unobstructed kiln (length - 9 ft., diameter - 1 ft.) in the Chemical Engineering Laboratory of the University of Tennessee. An equation giving retention time in terms of these variables was derived from the data. The equation was $t = \frac{1.71\ L\ \theta^{0.503}}{p\ d\ n}$. The average deviation of retention time calculated by this equation from that observed was 4.9 percent. A similar equation, $t = \frac{1.77\ L\ \theta}{p\ d\ n}$, derived from more extensive data by the Bureau of Mines (3) was found to express the retention time within 4.3 percent of the observed. Five longitudinal flights were installed

in the kiln, and the determinations were repeated. An equation expressing the retention time within 5.4 percent of the observed was developed. This equation was $t = \frac{0.105\ L\ \theta^{1.38}}{p\ d\ n}$. In these equations, t is retention time in minutes, L is the length of the kiln in feet, θ is the angle of repose of the material, p is the pitch or slope of the kiln in degrees, d is the diameter of the kiln in feet, and n is the rate of rotation in r.p.m.

It should be possible to develop empirical relations for kilns having other types of flights using the method of study and interpretation employed in this work. A scale model of a particular flight design could be constructed, three or more runs using different materials made, and an equation developed upon which construction of full-scale apparatus might be based. A set of equations corresponding to the several types of flights in use would be of extreme utility. Other modifying conditions, the most important of which is gas velocity, should be investigated.

RETENTION TIME IN ROTARY KILNS-
CONSIDERATION OF FLIGHT DESIGN

INTRODUCTION

Rotary kilns and driers find application in such processes as calcining, drying, nodulizing, and roasting. Briefly, a rotary kiln is a cylinder, the length of which is several times the diameter, placed with its longitudinal axis inclined a few degrees from the horizontal. Crushed material or slurry is fed into the upper end and heated as the rotation of the kiln causes it to advance toward the lower end. Several successful and accepted methods of supplying heat to the kiln are in general use. A discussion of these is not in order here. This type of equipment is indispensable in the portland cement and lime industries, and many lesser known but equally useful applications have been made.

It is evident that, for a desired result of the heating operation, the material must be in contact with the heating medium (usually hot gases) for a definite length of time. While, in general, an excessive time of contact has not proved injurious to many materials, it is economically desirable that the retention time be kept to a minimum consistent with the requirements of the product. Kiln design and operation have been largely governed by empirical rules, and little effort has been made to establish a theoretical basis for analysis of the process.

In 1927, a paper published by the U.S. Mines Bureau (3) related the time of retention to the length of the kiln, the diameter, the slope or pitch, the speed of rotation, and the angle of repose of the material. These variables were assembled into an equation explicit in retention time, which is applicable to a simple, unobstructed kiln. The equation was modified after further experimental work to enable one to consider the effect of "nose rings" or constrictions. As far as could be ascertained, no investigation of the effect of flights has been undertaken. In a recent discussion by Gibbs, (2) an empirical equation giving the optimum rate of production of rotary kilns was presented. Although this equation may be useful as a rule of thumb, the meed for general relations which can be used in design persists. "As far as is known, the only formulas for passage time of material through rotary kilns that have attained widespread use are the four empirical equations published by the U.S. Bureau of Mines in 1927. Except for the simplest case where a kiln of uniform diameter without rings or other obstructions is to be investigated, these equations are quite complex....." (1)

The present work was undertaken for the purpose of investigating the reliability of the relation developed by the Bureau of Mines, with the additional intention of developing an equation which would take into account the effect of longitudinal flights in the kiln. Only crushed, dry materials were passed through the experimental apparatus since it was felt that less reproducible results would be obtained with wet feed. No attempt was made to investigate the effects of heating or

gas velocity. It should be stated, however, that results determined under these rather ideal conditions were found by Bureau of Mines investigators to be directly applicable to commercial kiln operation. Even though chemical changes occur and angle of repose is not constant in a material undergoing a drying process, the unobstructed kiln equation was found to give results within 7.9 percent of the actual retention times for four commercial installations.

The equation developed by the Bureau of Mines for a simple, unobstructed kiln is $t = \frac{1.77\ L\sqrt{\theta}}{p\ d\ n}$

where
- t = time of stay of the material in the kiln, min.
- L = length of the kiln, ft.
- θ = angle of repose of the material, deg.
- p = pitch or slope of the kiln, deg.
- d = diameter of the kiln, ft.
- n = speed of rotation, r.p.m.

Of these terms, perhaps only the angle of repose needs clarification. It is common experience that a mass of solid particles in a horizontal drum or cylinder will be carried a certain distance up the side when the cylinder is rotated. In the kiln, the particles advance toward the lower end at the same time, so that the path of an average particle is helical. The angle to which the mass of particles will be carried up the side before they start to slide back down is defined as the angle of repose of the material.

DESCRIPTION OF EQUIPMENT AND MATERIALS

General:

The rotary kiln used was constructed of a nine-foot section of 12-in. pipe mounted on rollers and provided with a sprocket chain drive, powered by a one-third horsepower electric motor. The kiln was equipped with five equally spaced longitudinal flights, the flights being bolt attached and easily removed. For a sketch of the equipment, see Figure 1.

Longitudinal Flights:

The individual flights consisted of two, nine foot strips of one-eighth inch sheet steel, a strip of one inch width was welded at an angle of 135 degrees to a strip of one and one-half inch width. The one and one-half inch strip was attached to the shell at an angle of 20 degrees from the center line, as shown in Figure 1, so that the one inch strip was roughly parallel to the inside surface of the shell.

Rotating Mechanism:

A one-third horsepower electric motor and a gear box (200 to 1 speed reduction) were mounted above the kiln. Four speeds were provided by a four-step cone pulley.

Feeding Mechanism:

A small vibrating feeder (JT - 104, Jeffrey Mfg. Co., Columbus, Ohio) was used to feed the materials into the kiln. Electrically induced vibrations moved the material from the hopper into the kiln at constant rates of feed.

Supporting Jacks:

Adjustable supporting jacks were used to vary the slope (inclination from the horizontal) of the kiln.

Materials:

Sand (60 - 80 mesh), cedar sawdust (oversized), and limestone gravel were used as obtained in the Chemical Engineering Laboratory. The coal (stoker size) was borrowed from the University Power Plant.

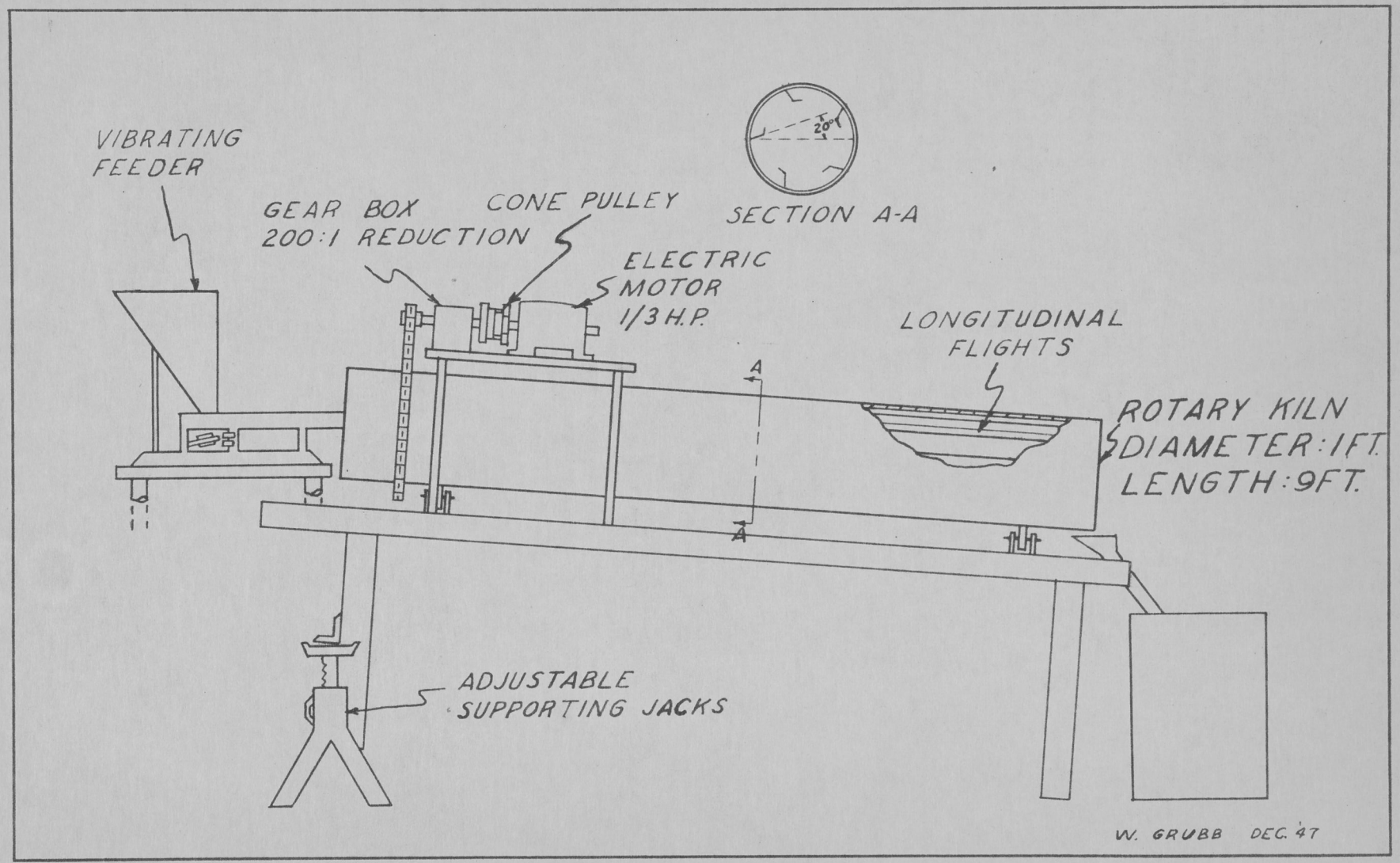


FIGURE 1
EXPERIMENTAL ROTARY KILN

PROCEDURE

It was proposed to investigate the effect of the variables, angle of repose, pitch, and speed, by changing each one individually while the others were held constant. Since only one kiln was available for use, the effect of changing the length and diameter could not be investigated.

Of the materials used, sand, limestone gravel, and cedar sawdust were fed by a small vibrating feeder. Stoker coal was fed by hand. After steady operation was attained, the material discharged in a measured interval (usually 15 to 20 minutes) was collected and weighed. The feeder and kiln were stopped at the end of this time, and the material remaining in the kiln was discharged and weighed. The time of retention was, then, the weight of material remaining in the kiln divided by the weight of material collected, times the duration of the run. In order to obtain equilibrium conditions, the apparatus was operated for 15 to 20 minutes before measured collection of the discharge was begun.

The angle of repose used in describing the behavior of solids in a kiln is defined as the angle to which the mass of particles will be carried up the side before slumping. It follows that this angle may be evaluated only by indirect means. The following steps comprise this determination: Material sufficient to give a bed of 3 to 4 inches depth was put in a 55 gallon drum which had been placed in a horizontal position on a flat surface. The drum was rotated until the material

slumped and came to rest. The angle between the surface of the material and the reference surface was measured with a bevel protractor. The drum was rotated until the material had slumped twenty times. The angle between the horizontal and the surface of the material was measured after each slump. The distance that a point on the lip of the drum had moved was measured, and the angle through which the drum had been rotated was calculated. The average angle between the surface of the material and the horizontal was calculated. The angle through which the drum rotated was divided by the number of measurements taken. The sum of the results of these two operations was the angle of repose of the material.

The experimental work may conveniently be divided into two parts. The first eighteen experimental runs were concerned with the operation of a simple, unobstructed kiln. Then five longitudinal flights were installed in the kiln, and the remaining twelve runs were made.

Since the Bureau of Mines formula indicates that rate of feed is not a variable, it was first necessary to determine if such were actually the case. Sand (60 - 80 mesh) was introduced into the kiln at several different rates, with the slope being held at 4.3 degrees, and the speed, at 2.23 r.p.m. The angle of repose of the sand was 36.6 degrees. The particular values of slope and speed used were chosen because they most nearly represented a mean of the ranges which would subsequently be employed.

The effect of rate of rotation of the kiln was investigated next.

Speeds of 0.80, 1.07, 1.54, and 2.23 r.p.m. were employed, and the slope of the kiln was held at 4.3 degrees. The 60 - 80 mesh sand was used.

The pitch or slope of the kiln was then varied from 1.65 degrees to 6.70 degrees, using increments of 1.0 to 1.5 degrees, with the speed being held at 1.54 r.p.m. Sand was the material tested.

Different materials were passed through the kiln to determine the effect of angle of repose of the material on the retention time. Cedar sawdust having an angle of repose of 44.4 degrees, stoker coal having an angle of repose of 27.0 degrees, and limestone gravel having an angle of repose of 40.2 degrees were employed in addition to the sand. Speed was 1.54 r.p.m., and the slope of the kiln was 4.4 degrees.

The longitudinal flights were installed at the completion of the eighteenth run, and essentially the same determinations were repeated.

RESULTS

For the simple unobstructed kiln the equation, $t = \frac{1.71\ L\ \theta^{0.503}}{p\ d\ n}$, was derived from data tabulated in Table I and plotted in Figures 2, 3, and 4. A comparison of observed retention times with those calculated from this equation and from the Bureau of Mines equation is given in Table II.

For the kiln with longitudinal flights the equation, $t = \frac{0.105\ L\ \theta^{1.38}}{p\ d\ n}$, was derived from data tabulated in Table III and plotted in Figures 5, 6, and 7. Table IV gives a comparison of observed retention times with those calculated using this equation.

TABLE I

DATA USED TO DEVELOP UNOBSTRUCTED KILN EQUATION

Relation of Retention Time and Speed, Figure 2

Run No.	Observed Retention Time, min.	Speed, r.p.m.	1 / Speed
2	10.6	2.23	0.448
9	15.3	1.54	0.650
10	20.7	1.07	0.935
8	28.3	0.80	1.250

Relation of Retention Time and Slope, Figure 3

Run No.	Observed Retention Time, min.	Slope, degrees	1 / Slope
11	9.9	6.7	0.149
12	10.7	5.8	0.173
13	13.1	4.9	0.204
14	20.4	3.0	0.333
15	36.7	1.65	0.606

Log K vs. Log Angle of Repose, Figure 4

Run No.	Material	Angle of Repose, θ	Log θ	K, (txpxm)	Log K
1-15	Sand	36.6	1.564	97.4	1.988
16	Sawdust	44.4	1.647	97.7	1.990
17	Coal	27.0	1.432	76.5	1.884
18	Gravel	40.2	1.604	105.0	2.020

TABLE II

RETENTION TIMES IN UNOBSTRUCTED KILN

Run No.	Observed Retention Time, min.	Retention Time by Derived Equation, min.	Deviation from Observed Time, %	Retention Time by Bureau of Mines Equation, min.	Deviation from Observed Time, %
1	9.5	9.8	3.2	10.1	5.0
2	10.6	9.8	7.5	10.1	4.7
3	8.1	9.8	21.0	10.1	24.7
4	10.3	9.8	4.8	10.1	1.9
5	11.1	9.8	11.7	10.1	9.0
6	11.0	9.8	10.9	10.1	8.2
7	7.5	9.8	30.7	10.1	34.7
8	28.3	27.3	3.5	28.0	1.1
9	15.3	14.2	7.2	14.6	2.6
10	20.7	20.4	1.4	20.9	1.0
11	9.4	9.1	2.7	9.9	6.2
12	10.7	10.5	1.9	10.4	2.8
13	13.1	12.4	5.3	12.8	2.3
14	20.4	20.3	0.5	20.9	2.5
15	36.7	37.0	1.0	37.8	3.0
16	14.4	15.3	6.2	15.6	8.3
17	11.3	11.9	5.3	12.2	8.0
18	15.5	14.6	5.8	14.9	3.9

TABLE III

DATA USED TO DEVELOP EQUATION FOR KILN

WITH LONGITUDINAL FLIGHTS

Relation of Retention Time and Speed, Figure 5

Run No.	Observed Retention time, min.	Speed, r.p.m.	1 / Speed
23	13.2	2.25	0.445
25	17.0	1.54	0.650
26	23.3	1.07	0.935
27	33.5	0.77	1.300

Relation of Retention Time and Slope, Figure 6

Run No.	Observed Retention Time min.	Slope degrees	1 / Slope
21	16.0	4.40	0.227
22	8.9	6.85	0.131
23	13.2	5.40	0.185
24	22.5	2.95	0.339

Log K vs. Log Angle of Repose, Figure 7

Run No.	Material	Angle of Repose, θ	Log θ	K, (t x p x n)	log k
25	Sand	36.6	1.564	141.2	2.150
28	Sawdust	44.4	1.647	180.5	2.256
29	Coal	38.5	1.585	141.2	2.150
30	Gravel	40.2	1.604	150.0	2.176

TABLE IV

RETENTION TIMES IN KILN WITH LONGITUDINAL FLIGHTS

Run No.	Observed retention time, min.	Retention time by derived formula, min.	Deviation from observed time, %
19	15.4	14.3	7.1
20	15.7	14.3	8.9
21	16.0	14.3	10.6
22	8.9	8.9	0.0
23	13.2	11.3	14.4
24	22.5	20.6	8.5
25	17.0	16.4	3.5
26	23.3	23.6	1.3
27	33.5	32.9	1.8
28	21.7	21.4	1.4
29	17.0	17.6	3.5
30	18.0	18.7	3.9

Average Deviation = 5.4%

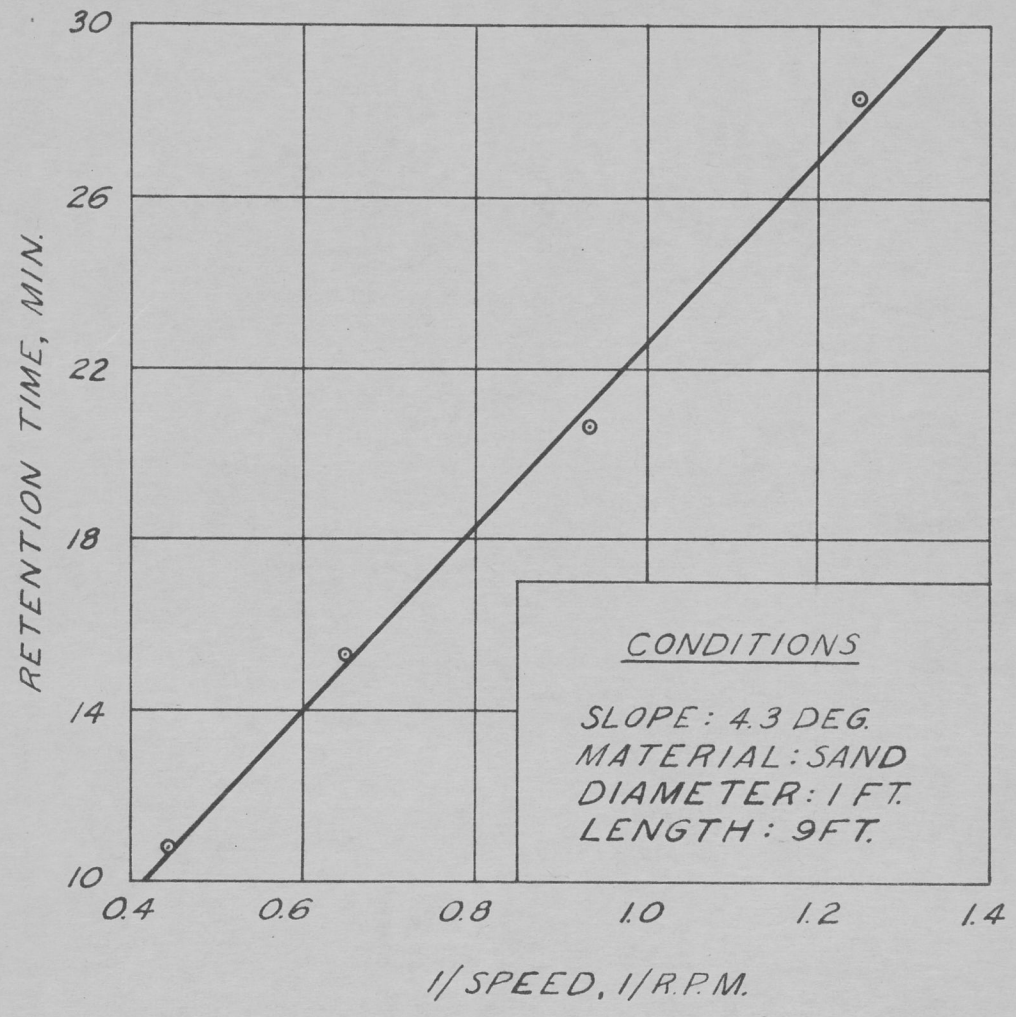


FIGURE 2
RELATION OF RETENTION TIME AND SPEED IN UNOBSTRUCTED KILN

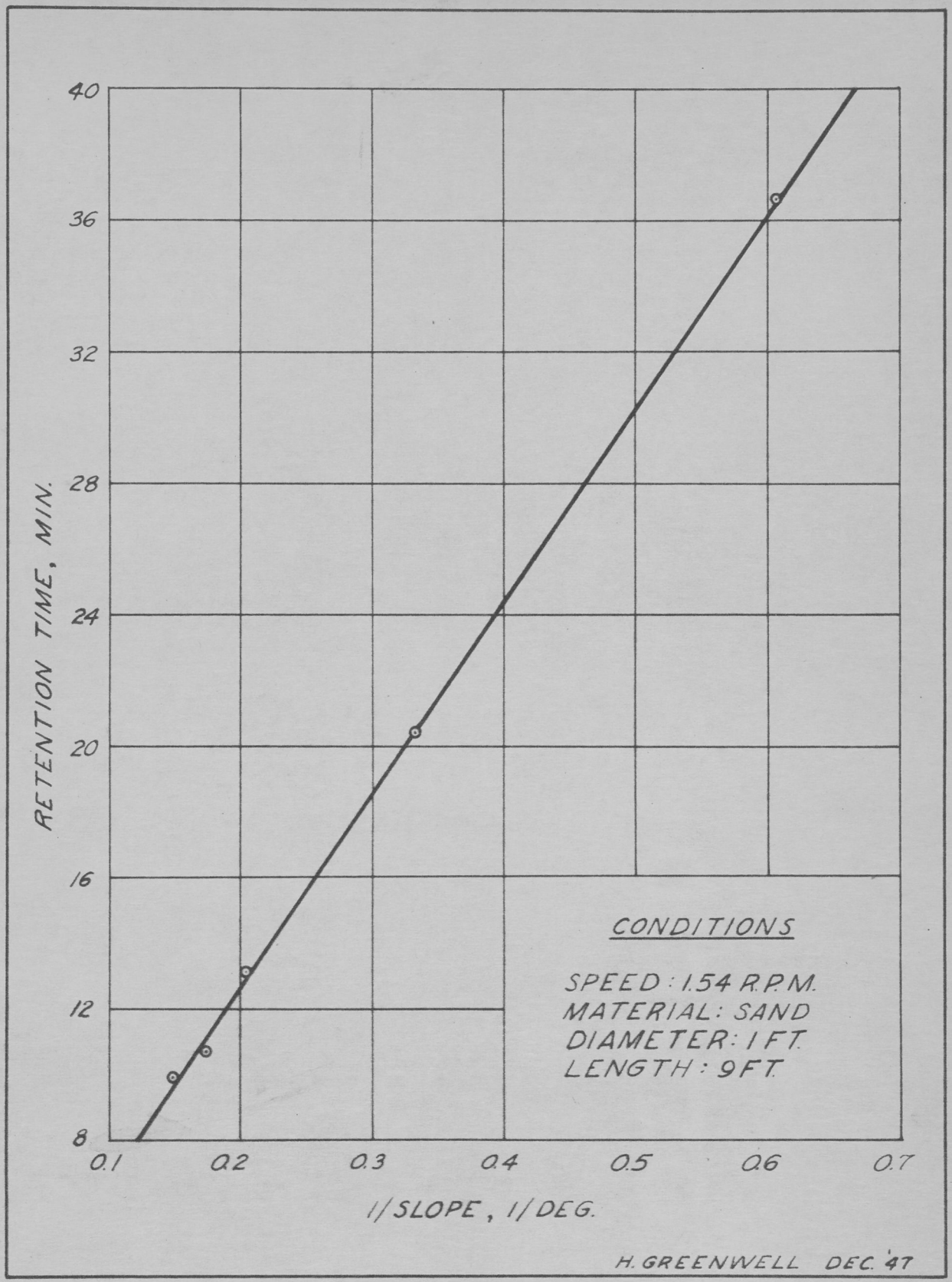


FIGURE 3
RELATION OF RETENTION TIME AND SLOPE IN UNOBSTRUCTED KILN

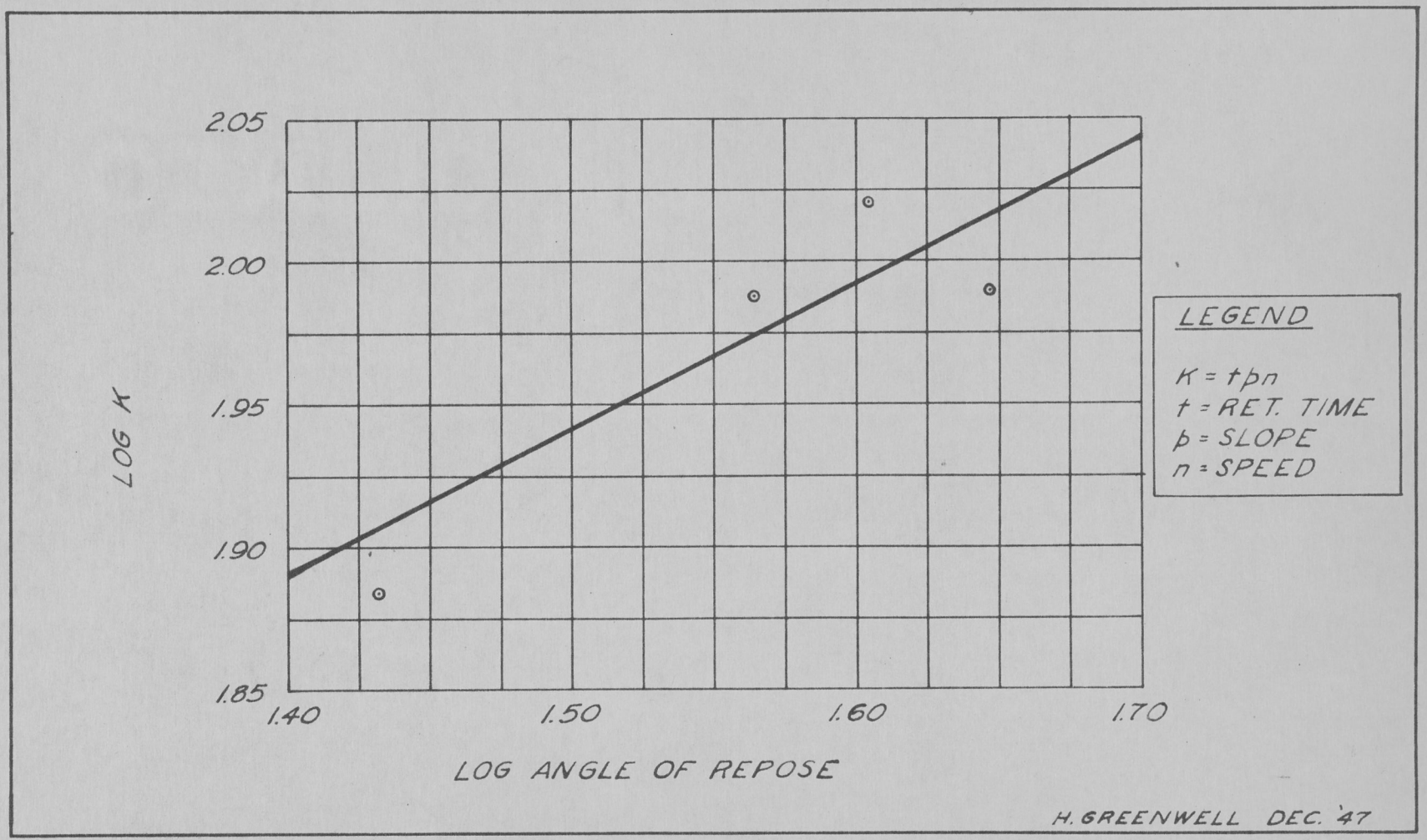


FIGURE 4

LOG K VS. LOG ANGLE OF REPOSE FOR UNOBSTRUCTED KILN

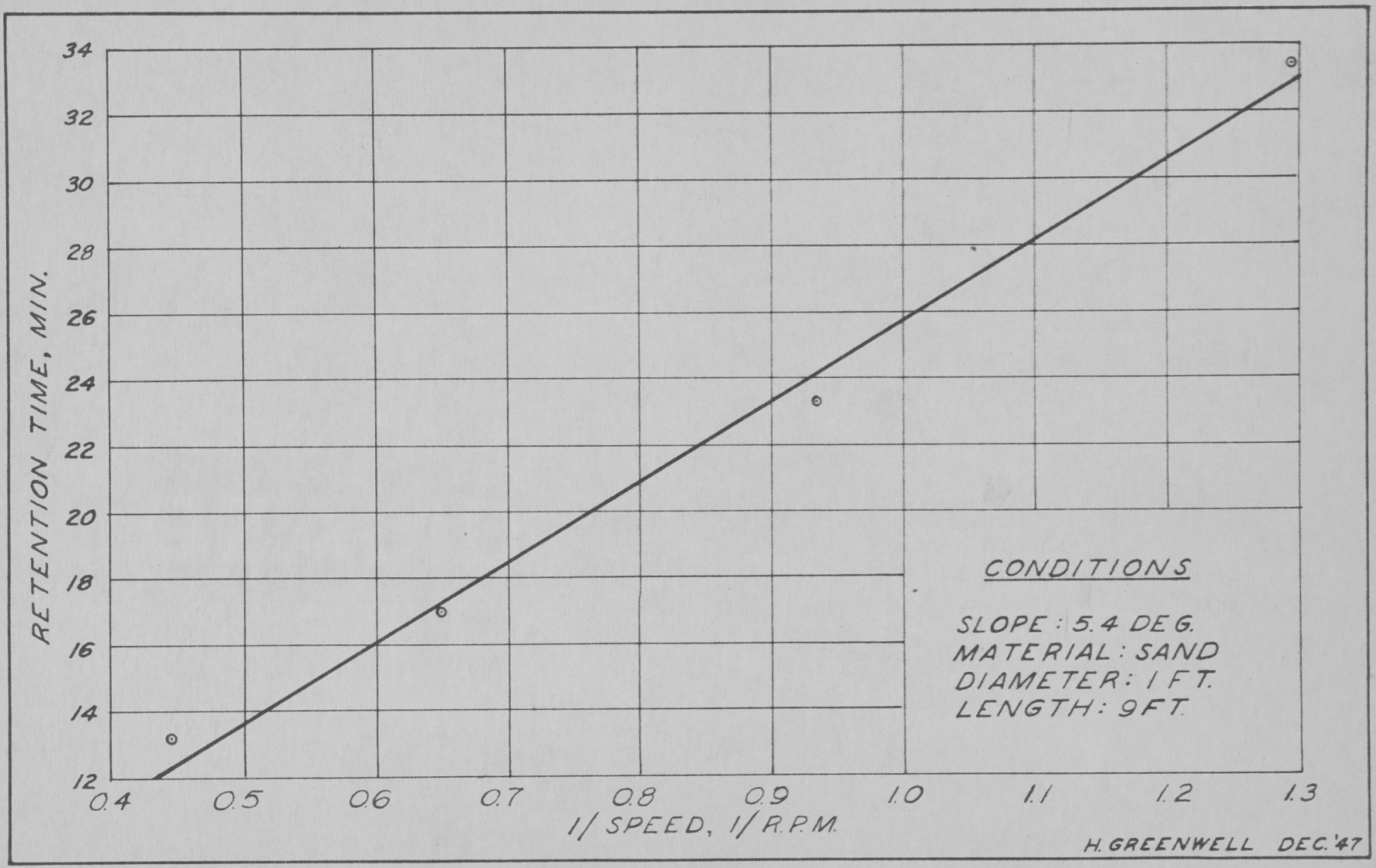


FIGURE 5

RELATION OF RETENTION TIME AND SPEED IN KILN WITH FLIGHTS

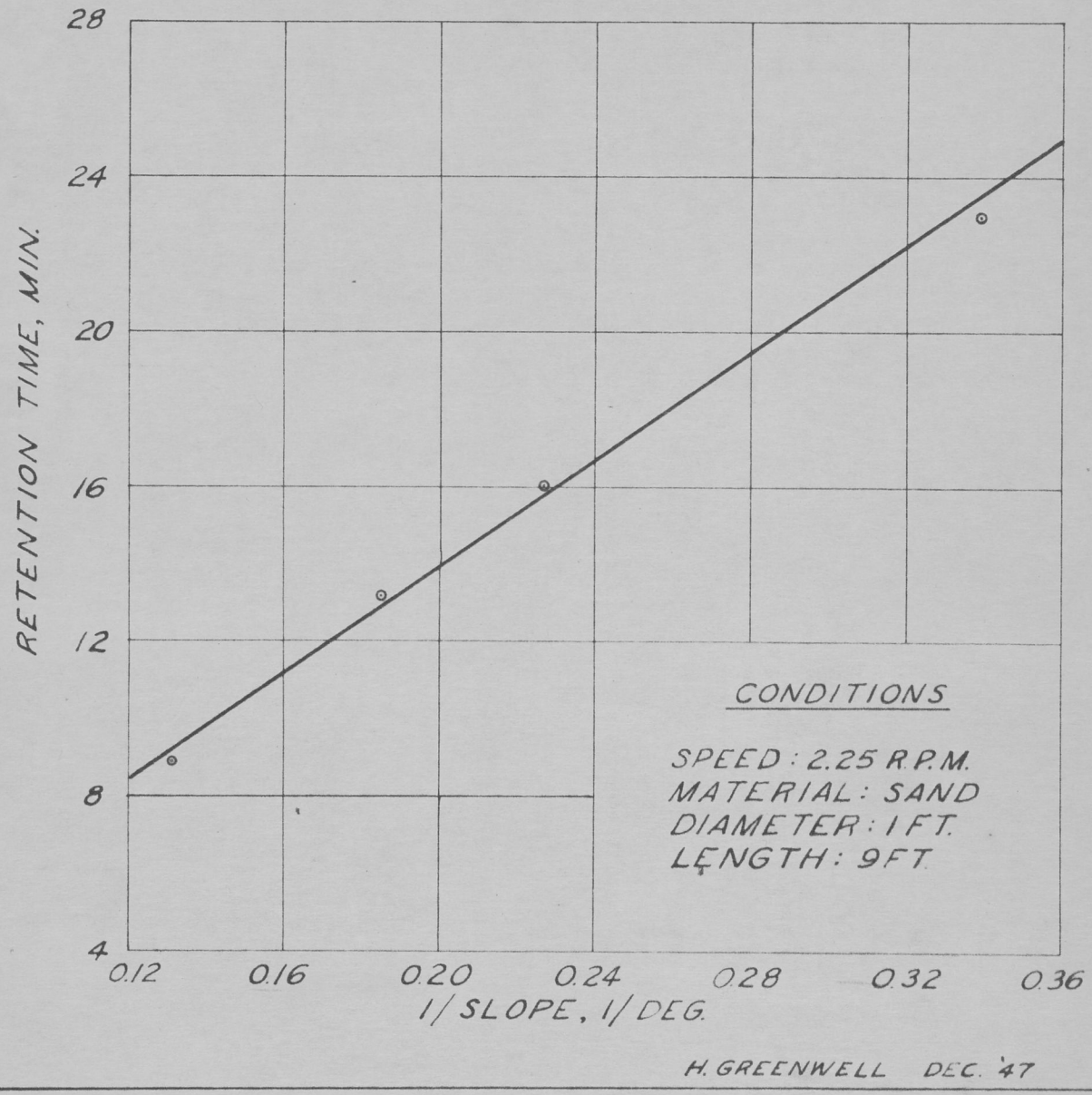


FIGURE 6
RELATION OF RETENTION TIME AND SLOPE IN KILN WITH FLIGHTS

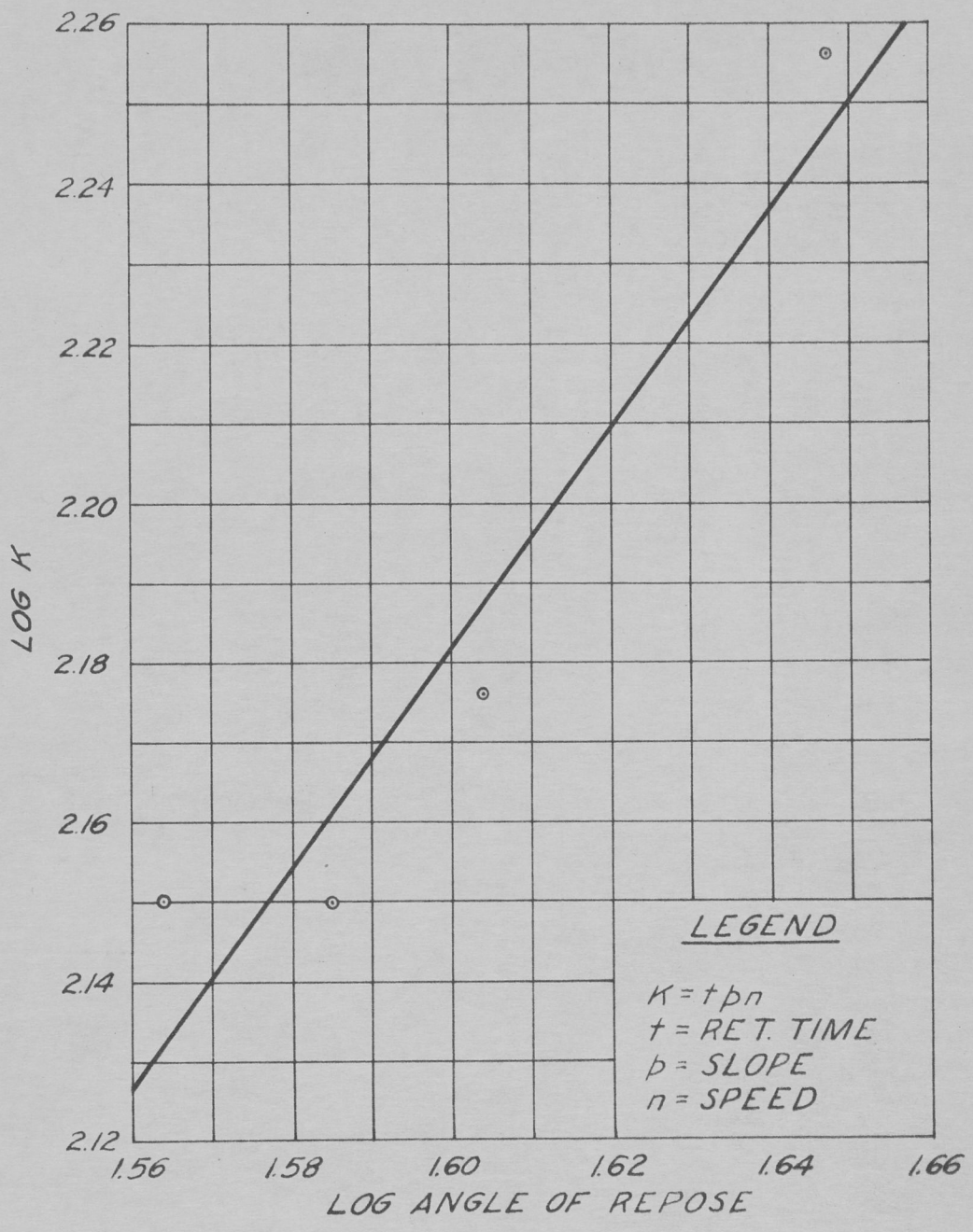


FIGURE 7
LOG K VS. LOG ANGLE OF REPOSE FOR KILN WITH FLIGHTS.

DISCUSSION OF RESULTS

The time of retention as calculated by the Bureau of Mines equation for the simple, unobstructed kiln was found to have an average deviation of 4.3 percent from the observed time. Use of a similar formula derived for illustrative purposes from the data on the unobstructed kiln resulted in an average deviation of 4.9 percent from the observed times. That the derived formula does not represent the data as well as the Bureau of Mines formula can be ascribed to the limited number of materials employed. This will be given further consideration in a discussion of angle of repose.

For the kiln with longitudinal flights, observed times of retention were compared with those calculated from a derived formula. The average deviation was 5.4 percent.

Rate of Feed:

Variation of the rate of feed over rather wide limits demonstrated that the retention time is independent of the rate of feed. Data supporting this conclusion are shown in Table II (Runs 1 through 7). Increasing the rate of feed served only to make the bed of material in the kiln deeper.

Speed:

Investigation of the effect of rate of rotation on the time of retention showed that the time is inversely proportional to the speed of rotation. This condition is depicted in Figure 2.

Slope:

Variation of the slope from 1.65 to 6.70 degrees demonstrated that the time of retention is inversely proportional to the slope. The range of slopes studied probably includes most slopes encountered in practice. In expressing this proportionality, the slope is given in degrees. Angular measure is more convenient to use when dealing with the relatively small angles employed. The choice between angular and trigonometric measure can be made freely, since the equation to be developed is dimensionally independent of the units used. Figure 3 shows graphically the relation of slope to retention time.

Diameter and Length:

The effects of diameter and length were not investigated. The Bureau of Mines investigation showed that the time of retention varies inversely as the diameter of the kiln, other conditions being constant. With certain exceptions noted as "End Effects", the effect of length on retention time is self-evident.

End Effects:

Heavy feed in a kiln having a slight slope results in a "piling up" effect at the upper end. This increases the slope and causes the time of retention to be less than would be anticipated. This effect becomes less significant with decreasing rates of feed and increasing slope. There is a "dropping off" effect at the discharge end of a kiln. It is obvious that a uniform bed of material will not extend all the way to the end of the kiln. The "dropping off" effect is of

more consequence when the bed is deep. Abnormalities at either or both ends of a kiln the length of which is several times the diameter would hardly be discernable. Conversely, in a relatively short kiln, the retention time would not be absolutely proportional to the length.

Angle of Repose and its Relation to the Other Variables:

It has been shown that retention time is inversely proportional to the slope and the speed, and is independent of rate of feed. If these variables are assembled into an equation, we have $t = k/pn$ or $k = t\ p\ n$ where k is a constant of proportionality. However, it was found that the time of passage also varies with the angle of repose of the material. The constant, k, was calculated for each run. It was found that when log k was plotted against log θ (angle of repose), a straight line resulted (Figure 4). The equation of this line was, then, $k = a\ \theta^n$. The constants a and n were evaluated in the usual manner, and k was found to equal $15.4\ \theta^{0.503}$. Therefore, $t = \frac{15.4\ \theta^{0.503}}{p\ n}$, for a simple unobstructed kiln. Introducing length and diameter, $t = \frac{1.71\ L\ \theta^{0.503}}{p\ d\ n}$. It should be noted that only four materials were used in the investigation, and the accuracy of the equation probably could be improved by extending this part of the experiment. It has been demonstrated that a reasonably reliable equation may be derived using a limited amount of experimental data.

Effect of Flights:

Investigation of the variables for the kiln with longitudinal flights showed that rate of feed, speed, and slope had the same effect

as in the simple kiln. It is reasonable to assume that length and diameter exert the same influence on time of passage. End effects should not be appreciably changed, although a better distribution of the material in the kiln was obtained with flights. It would appear that the effect of flights can be thought of as an increased angle of repose. On this assumption, the installation of flights could be expected to result only in a different numerical constant and a different exponent of θ in the kiln equation.

The variables, slope, speed, and time were assembled into the equation $k = t\ p\ n$. Log k was plotted against log θ (Figure 7) as for the simple kiln, and k was found to equal $0.949\ \theta^{1.38}$. Therefore, $t = \frac{0.949\ \theta^{1.38}}{p\ n}$. Introducing length and diameter, $t = \frac{0.105\ L\ \theta^{1.38}}{p\ d\ n}$. This equation was found to express the results of the experiment within 5.4 percent.

CONCLUSIONS

The Bureau of Mines formula for the simple, unobstructed kiln has been reproduced within reasonable limits from the data of the present work. It has been found that the method by which this formula was derived is equally applicable to the conditions imposed by the installation of longitudinal flights. Accuracy comparable to that obtained with the Bureau of Mines formula may be assumed, i.e. five to seven percent. It is felt that the method of investigation and interpretation of the relative influence of each of the variables can be applied to kilns containing other types of flights. Formulas obtained by the method shown should be useful in the development of full scale equipment. In other words, for a particular flight design in question, a scale model could be constructed, three or more runs made using different materials, and a formula could be developed upon which construction of full-scale apparatus might be based.

RECOMMENDATIONS

The effect of gas velocity, which is an important factor in most commercial installations, should be evaluated. The attendent problem of dusting could be given attention at the same time. In regard to other types of flights, the validity of the methods employed in the present work should be tested. A set of formulas corresponding to the several types of flights in use would be of extreme utility. A more complete and extensive range of angles of repose should be investigated.

BIBLIOGRAPHY

(1) Bayard, R. A., "New Formula Developed for Kiln Time", Chem. and Met., 52:100-2 (Mr., '45).

(2) Gibbs, R., "Estimating Best Output and Fuel Rates of Dry Feed Lime Kilns", Chem. and Met., 53:99-101 (Apr. '46).

(3) U.S. Mines Bureau, Time of Passage of Solid Particles through Rotary Cylindrical Kilns, Technical Paper 384.

APPENDIX

TABLE V

Experimental Data

Unobstructed Kiln Operation

Run No.	Material Tested	Angle of Repose, deg.	Slope, deg.	Speed, r.p.m.	Duration of Run, min.	Material Discharged, lb.	Hold-up Material, lb.
1	Sand	36.6	4.3	2.23	15	57.4	36.4
2	Sand	36.6	4.3	2.23	15	36.8	26.0
3	Sand	36.6	4.3	2.23	15	12.6	6.8
4	Sand	36.6	4.3	2.23	15	75.4	51.6
5	Sand	36.6	4.3	2.23	15	30.4	22.5
6	Sand	36.6	4.3	2.23	15	21.8	16.0
7	Sand	36.6	4.3	2.23	15	8.0	4.0
8	Sand	36.6	4.3	0.80	30	36.4	34.4
9	Sand	36.6	4.3	1.54	16	42.9	41.0
10	Sand	36.6	4.3	1.07	20	30.0	31.0
11	Sand	36.6	6.7	1.54	10	47.9	45.7
12	Sand	36.6	5.8	1.54	10	45.5	51.5
13	Sand	36.6	4.9	1.54	15	38.8	34.0
14	Sand	36.6	3.0	1.54	20	26.4	26.9
15	Sand	36.6	1.65	1.54	20	17.6	32.2
16	Sawdust	44.4	4.4	1.54	25	12.0	6.8
17	Coal	27.0	4.4	1.54	15	30.2	22.7
18	Gravel	40.2	4.4	1.54	10	29.3	45.3

Operation of Kiln with Longitudinal Flights

Run No.	Material Tested	Angle of Repose, deg.	Slope, deg.	Speed, r.p.m.	Duration of Run, min.	Material Discharged, lb.	Hold-up Material, lb.
19	Sand	36.6	4.3	2.25	15	36.1	37.0
20	Sand	36.6	4.3	2.25	15	20.5	21.5
21	Sand	36.6	4.3	2.25	16	41.8	41.8
22	Sand	36.6	6.85	2.25	13	30.8	21.0
23	Sand	36.6	5.4	2.25	10	16.1	21.3
24	Sand	36.6	2.95	2.25	15	20.3	30.5
25	Sand	36.6	5.4	1.54	18	29.9	28.2
26	Sand	36.6	5.4	1.07	16	26.7	39.0
27	Sand	36.6	5.4	0.77	12	17.1	47.7
28	Sawdust	44.4	5.4	1.54	20	6.9	7.5
29	Coal	38.5	5.4	1.54	15	27.2	30.8
30	Gravel	40.2	5.4	1.54	15	29.5	35.4

APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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