

degree, or fraction of a degree, whereas, the thermo-slide permits constant observation of the starch. The water bath method requires more time for each test and the gelatinizing point cannot be determined with the same accuracy as by the proposed method. Moreover, the total time necessary is very much shorter, as numerous determinations have been made by the thermo-slide method, which required less than five minutes to complete each test.

OKLAHOMA AGRICULTURAL EXPERIMENT STATION
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NOTE ON THE DETERMINATION OF PHOSPHORUS IN PLANT MATERIALS

By A. W. CHRISTIE

Received February 14, 1916

In the course of certain investigations in this laboratory, it became desirable to find a quick and accurate method of oxidizing plant materials in order to determine the total phosphorus. A review of the literature suggested the following methods as being adaptable to this purpose.

Fusion with sodium peroxide¹ can be used in the determination of phosphorus as well as of sulfur but the care and time required by this method makes it undesirable.

Neumann's method is known to give accurate results. A modification,² consisting of digestion with sulfuric acid, 1 g. of potassium sulfate and a drop of mercury, gave fairly rapid oxidation but the subsequent precipitation with molybdate required standing over night to be complete. Digestion with hot fuming nitric acid also suggested itself as a possible method.

Ignition with magnesium nitrate³ was found to be impossible in the case of many plant materials due to excessive deflagration.

The method of ignition with magnesium oxide⁴ has been in use in this laboratory for the oxidation of organic matter in the analysis of phosphorus-containing fertilizers. Hibbard⁵ describes this method but suggests "that some phosphorus may be lost from volatile organic substances containing it, when ignited with magnesia." This method is believed to be the quickest and most convenient of those suggested and hence the following experiment was performed to de-

	MIDDINGS	CASEIN	LECITHIN	Av. Lecithin
Ignition with magnesium oxide	$\left\{ \begin{array}{l} 0.56 \\ 0.56 \\ 0.57 \end{array} \right\}$	$\left\{ \begin{array}{l} 0.87 \\ 0.86 \\ 0.86 \end{array} \right\}$	$\left\{ \begin{array}{l} 3.52 \\ 3.66 \\ 3.56 \end{array} \right\}$	3.58
Fusion with sodium peroxide	$\left\{ \begin{array}{l} 0.57 \\ 0.58 \\ 0.57 \end{array} \right\}$	$\left\{ \begin{array}{l} 0.87 \\ 0.87 \\ 0.86 \end{array} \right\}$	$\left\{ \begin{array}{l} 3.59 \\ 3.70 \\ 3.62 \end{array} \right\}$	3.64
Modified Neumann method	$\left\{ \begin{array}{l} 0.57 \\ 0.58 \\ 0.56 \end{array} \right\}$	$\left\{ \begin{array}{l} 0.85 \\ 0.85 \\ 0.88 \end{array} \right\}$	$\left\{ \begin{array}{l} 3.65 \\ 3.66 \\ 3.51 \end{array} \right\}$	3.61
Fuming nitric acid	$\left\{ \begin{array}{l} 0.37 \\ 0.39 \end{array} \right\}$	$\left\{ \begin{array}{l} 0.64 \\ 0.66 \end{array} \right\}$	$\left\{ \begin{array}{l} 1.56 \\ 1.61 \end{array} \right\}$	1.58

termine the accuracy of the magnesium oxide method as compared with the modified Neumann and peroxide fusion methods.

Three samples, representing substances relatively high in their organic phosphorus content (Merck's

casein, Merck's lecithin and finely ground wheat middlings), were analyzed for total phosphorus by the methods mentioned above. After the preliminary digestion, the phosphorus was precipitated from the solution in the usual manner as ammonium phosphomolybdate and finally weighed as magnesium pyrophosphate. The accompanying table gives the percentages of phosphorus obtained.

The above figures show that ignition with magnesium oxide gives substantially the same results for total phosphorus in the materials analyzed as fusion with sodium peroxide or digestion with sulfuric acid, 1 g. of potassium sulfate and a drop of mercury. The sodium peroxide method has the advantage of furnishing a solution which can also be used for the determination of total sulfur. The modified Neumann method may also be used for the determination of total nitrogen. The use of fuming nitric acid alone is found to be unsatisfactory.

CONCLUSION—Ignition with magnesium oxide is a quick and accurate method of oxidizing plant materials for the determination of total phosphorus.

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SOME EFFECTS OF LITTER ON THE FERMENTATION OF MANURE¹

By W. E. TOTTINGHAM

Received February 14, 1916

Within recent years the increased use of shavings as litter in stables has raised questions regarding the possible effects of such practice upon the value of the manure. One of the most important of these questions concerns the extent of the loss of nitrogen from the manure. Others concern the rate of oxidation of the organic matter and related changes. This paper presents the results of an investigation concerning some of these questions. It is a report of the results of certain chemical changes in a fermenting mixture of manure and shavings as compared with straw-littered manure and unlittered manure.

EXPERIMENTAL

METHODS—A basal manure was prepared by mixing one part by weight of fresh horse manure with two parts of fresh cow manure, each manure having been freed from litter. Four lots of this manure of 25 lbs. weight each were placed in galvanized iron pails with loosely fitting covers. The weighings at this point and subsequently were made on a Fairbanks platform scale sensitive to $\frac{1}{4}$ lb., or to within a possible error of 1.0 per cent for the weights involved. Litters were prepared by sifting finely cut oat straw, oak shavings, and shavings of Georgia pine to uniform size, reserving the material which passed through a sieve of $\frac{5}{16}$ -in. square mesh, but was retained by a similar sieve of $\frac{1}{8}$ -in. mesh. The manure was then treated as follows:

Lot 1 was left untreated to serve as a control. Lot 2 was thoroughly mixed with 2 lbs. of pine shavings. Lot 3 was mixed with 2 lbs. of oak shavings

¹ Published with the permission of the Director of the Wisconsin Experiment Station.

¹ Bur. of Chem., Bull. 107, p. 23.

² Z. landw. Versuchs., 13, 795-802.

³ Bur. of Chem., Bull. 107, p. 2.

⁴ Z. physiol. Chem., 76, 426-32.

⁵ THIS JOURNAL, 5 (1913), 998.

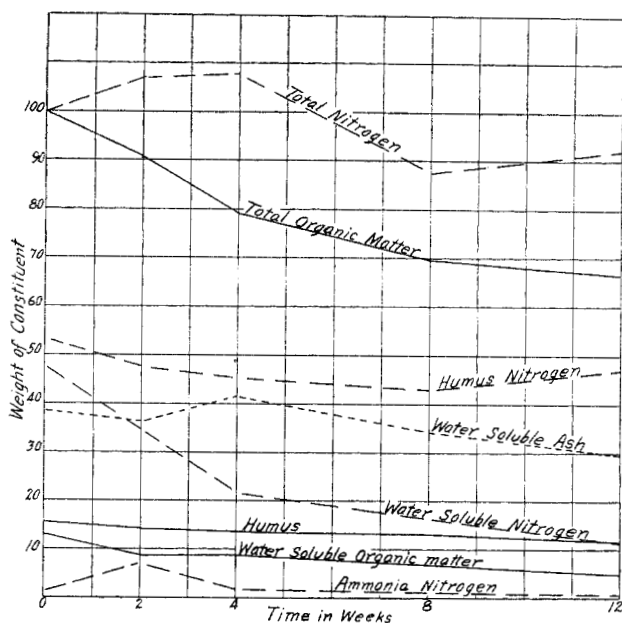


FIG. 1—MANURE ALONE

and Lot 4 was mixed with 2 lbs. of oat straw. At the beginning of the experiment on March 25th, and at two, four, eight, and twelve weeks thereafter the several lots of manure were thoroughly mixed and sampled for chemical analysis and bacterial counts.¹ By weighing the pails before and after sampling it was possible to determine the losses of organic matter and of nitrogen due to fermentation.

The chemical analyses were conducted as follows:

DRY MATTER—One hundred grams of sample were dried to constant weight at a temperature of about 98° C.

TOTAL ASH—The residue from the determination of dry matter was charred, extracted with hot water and the insoluble residue thoroughly ignited. Extract and residue were combined, evaporated and heated in the usual manner.

TOTAL ORGANIC AND VOLATILE MATTER was computed by deducting the per cent of total ash from the per cent of dry matter.

TOTAL NITROGEN was determined by the Gunning modification of the Kjeldahl method, employing 10 g. of the moist manure.

WATER-SOLUBLE NITROGEN was determined by the Gunning modification of the Kjeldahl method, employing 200 cc. of the extract prepared for the determination of total water-soluble matter as subsequently described.

AMMONIA NITROGEN—Five grams of magnesium oxide were added to 200 cc. of the extract employed for determining the total water-soluble matter, and distillation was conducted in the usual manner.

TOTAL WATER-SOLUBLE MATTER—One hundred grams of moist manure were shaken with one liter of distilled water in a motor-driven machine for five hours at room temperature. The extract was then rapidly filtered by suction through a thick layer of paper pulp in a Buchner funnel. After washing the residue with ten portions of distilled water of 75 cc. each the extract and washings were added and made to a volume of two liters. One hundred cc. of the final solution were evaporated and dried to constant weight at about 98° C.

WATER-SOLUBLE ASH—The dried residue from the determination of total water-soluble matter was carefully ignited in a platinum dish heated to dull redness.

¹ For the bacterial counts, which were made upon lactose agar plate cultures, the writer is indebted to Mr. E. E. Eldredge, formerly a member of the staff at this Experiment Station.

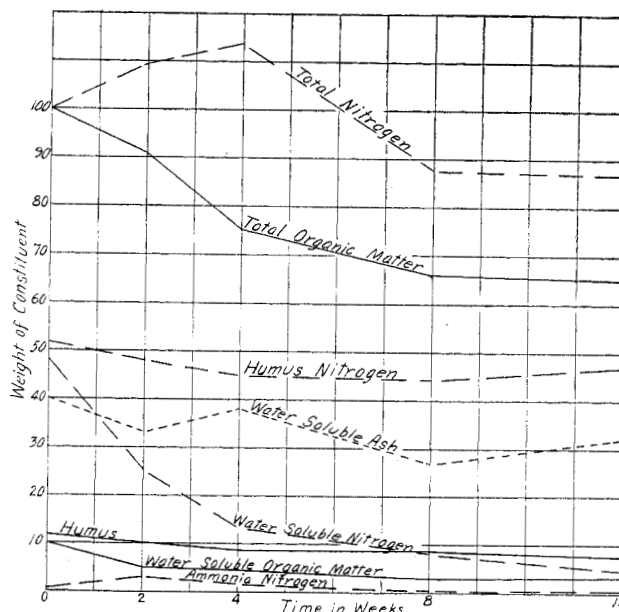


FIG. 2—MANURE + PINE SHAVINGS

WATER-SOLUBLE ORGANIC AND VOLATILE MATTER was computed by deducting the per cent of water-soluble ash from the per cent of total water-soluble matter.

HUMUS—Fifty grams of manure were drained by suction on a layer of asbestos in a Buchner funnel, washed with 1.0 per cent HCl until no more calcium was extracted and finally washed free from HCl by water. The moist residue was digested for 36 hours with 4.0 per cent solution of NH_4OH , employing 50 cc. of solution per gram of original dry matter of the manure. The ammoniacal extract was filtered and its humus content determined by evaporating and igniting in the usual manner.

HUMUS NITROGEN—An extract of the manure was prepared as in the determination of humus, but with the substitution of 4.0 per cent solution of NaOH for the NH_4OH solution. Nitrogen was determined by the Gunning modification of the Kjeldahl method, employing 100 cc. of the filtered extract.

RESULTS—The results of the analyses are presented in Table I, each value being the average derived from duplicate determinations. Attention may be called to the enormous number of bacteria in the straw-littered manure at the third analysis; at this stage it was possible only to estimate the number of organisms; only in this lot of manure was there evidence of the predominance of special types of bacteria. At the third examination an acid-producing organism was especially abundant while at the later stages *streptothrix* formed one-fifth to one-third of the total colonies developed in cultures from the straw-littered manure.

In order to facilitate comparison of the extent of the various changes followed in the different lots of manure the percentages of the total organic matter, total ash, and total nitrogen which existed in various forms have been calculated from the data of Table I and are given in Table II.

It seems probable that the percentages of organic matter in water-soluble and humus forms here bear definite relations to the relative susceptibility of the manures to decomposition in the soil. Similarly, the soluble ash and the various forms of nitrogen may bear direct relations to the relative fertilizing values of the manures.

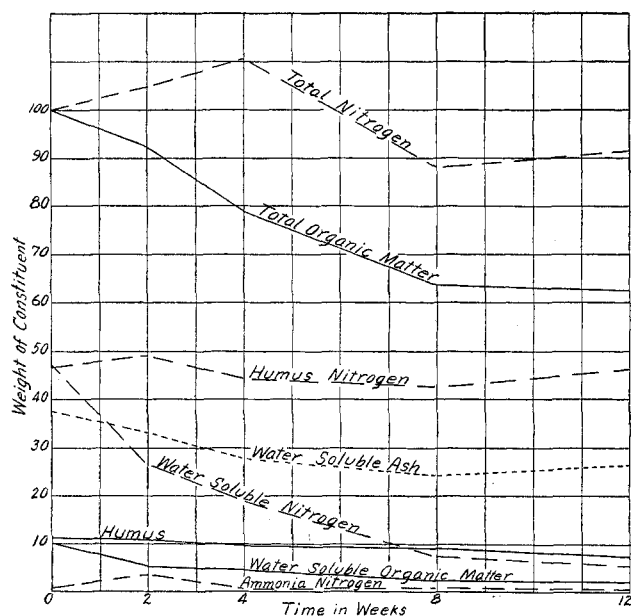


FIG. 3—MANURE + OAK SHAVINGS

The progressive losses of total organic matter in these manures during the four periods covered by the investigation are also presented in Table II. Each value is computed on the basis of the total organic matter present at the beginning of the respective period.

In a similar manner the gains or losses of nitrogen for each period of fermentation have been calculated as percentages of the total amounts of nitrogen pres-

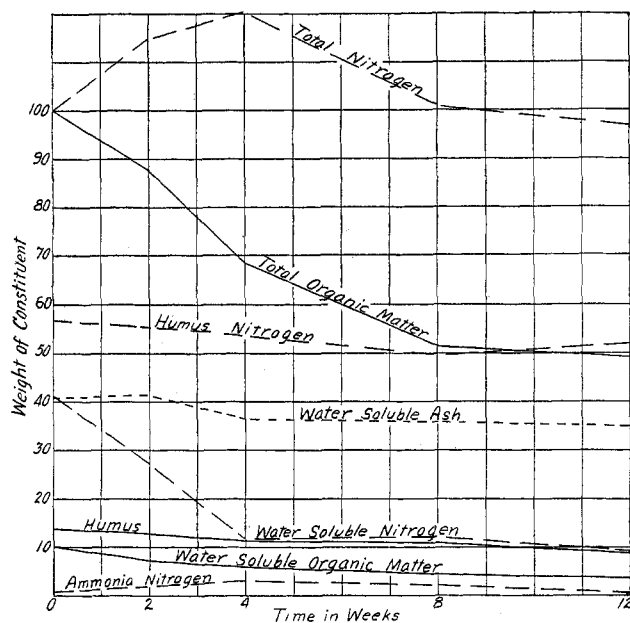


FIG. 4—MANURE + OAT STRAW

ent at the beginning of the respective periods. These data occupy the last column in Table II.

Assigning a value of 100 each to the total organic matter, total ash and total nitrogen of each manure at the beginning of this investigation the relative values of all the other data in Table II have been computed. The resulting values, which express the fluctuations in absolute amounts of the various constituents considered, have been plotted to form the

TABLE I—COMPOSITION OF FERMENTING MANURES

COMPOSITION OF DRY MATTER—RESULTS IN PERCENTAGES OF DRY MATTER

Lot No.	ADDITION TO MANURE	TIME Weeks after starting	DRY MATTER Per cent	Total Organic and Volatile Matter	Total Ash	Total Solids soluble in H ₂ O	Organic Matter soluble in H ₂ O	Ash soluble in H ₂ O	Total N	Soluble N in H ₂ O	N as NH ₃	Humus	Humus N	BACTERIA Millions per Gram of Dry Matter
1	None	0	20.37	88.24	11.76	15.98	11.44	4.54	1.69	0.81	0.020	13.68	0.90	660.0
		2	18.92	87.20	12.80	12.89	8.23	4.66	1.97	0.64	0.130	13.59	0.88	210.0
		4	17.12	85.59	14.41	15.79	9.77	6.02	2.24	0.46	0.036	14.74	0.94	25.0
		8	16.20	83.99	16.01	13.69	8.21	5.48	2.04	0.39	0.028	15.86	1.00	67.0
		12	15.72	83.36	16.64	10.94	6.00	4.94	2.22	0.27	0.020	14.73	1.13	4.1
2	Pine shavings	0	25.97	91.82	8.18	12.47	9.19	3.28	1.26	0.61	0.011	10.78	0.65	212.5
		2	24.12	91.11	8.99	8.01	5.02	2.99	1.50	0.35	0.045	10.26	0.66	250.0
		4	21.52	89.34	10.66	9.48	5.41	4.07	1.85	0.22	0.030	10.49	0.74	61.5
		8	21.00	88.07	11.93	7.11	3.90	3.21	1.37	0.15	0.012	11.68	0.80	57.0
		12	21.62	87.91	12.09	8.55	4.66	3.89	1.53	0.09	0.011	10.38	0.83	4.7
3	Oak shavings	0	26.00	91.31	8.69	12.46	9.20	3.26	1.26	0.59	0.011	10.27	0.59	272.5
		2	24.45	90.67	9.33	8.33	5.23	3.10	1.42	0.36	0.047	10.74	0.68	460.0
		4	21.55	89.24	10.76	8.21	5.22	2.99	1.72	0.29	0.008	11.11	0.69	112.5
		8	18.87	86.99	13.01	6.53	3.36	3.17	1.66	0.14	0.019	12.82	0.81	37.0
		12	18.85	86.80	13.20	6.39	2.87	3.52	1.76	0.10	0.011	10.48	0.90	3.7
4	Oat straw	0	25.25	89.03	10.97	13.56	9.07	4.49	1.36	0.56	0.010	12.23	0.77	530.0
		2	23.22	87.70	12.30	12.50	7.40	5.10	1.75	0.42	0.028	12.95	0.85	38.5
		4	19.52	84.77	15.23	12.91	7.37	5.54	2.28	0.23	0.057	14.00	1.01	10,000(a)
		8	16.65	80.76	19.24	12.66	6.77	5.89	2.42	0.29	0.052	17.15	1.19	30.0
		12	16.50	80.10	19.90	11.99	5.93	6.06	2.39	0.23	0.016	14.37	1.28	12.7

(a) See text.

TABLE II—ANALYSES OF DATA IN TABLE I

Lot No.	ADDITION TO MANURE	TIME Weeks after Starting	PERCENTAGES OF TOTALS PRESENT IN VARIOUS FORMS							PERCENTAGE CHANGES DURING FERMENTATION	
			ORGANIC MATTER		ASH		NITROGEN			Organic Matter	Nitrogen
			Soluble in H ₂ O	As Humus	Soluble in H ₂ O	As Humus	Soluble in H ₂ O	As NH ₃	As Humus		
1	None	0	12.97	15.50	38.61	47.93	1.18	53.25	...	...	...
		2	9.44	15.58	36.41	32.49	6.60	44.67	...	-9.1	+6.9
		4	11.41	17.22	41.78	20.31	1.61	41.96	...	-12.9	+0.9
		8	9.77	18.88	34.23	18.53	1.37	49.02	...	-12.2	-18.5
		12	7.20	17.67	29.69	12.12	0.90	50.90	...	-4.4	+5.1
2	Pine shavings	0	10.01	11.74	40.10	48.41	0.87	51.90	...	...	...
		2	5.51	11.26	33.26	23.33	3.00	44.00	...	-8.9	+9.4
		4	6.06	11.74	38.18	11.90	1.62	39.73	...	-17.3	+4.0
		8	4.43	13.26	26.91	9.36	0.76	50.76	...	-12.5	-23.0
		12	5.30	11.81	32.18	5.67	0.72	54.25	...	-1.5	-3.9
3	Oak shavings	0	10.08	11.25	37.51	47.06	0.87	46.75	...	...	...
		2	5.76	11.84	33.23	25.28	3.31	46.97	...	-7.6	+4.8
		4	5.85	12.45	27.79	17.14	0.47	40.00	...	-14.6	+5.6
		8	3.86	14.74	24.35	8.25	1.14	48.61	...	-19.4	-20.5
		12	3.31	12.07	26.67	5.91	0.63	50.97	...	-1.9	+3.8
4	Oat straw	0	10.18	13.74	40.93	41.40	0.74	56.76	...	...	...
		2	8.44	14.77	41.46	23.89	1.60	48.29	...	-12.4	+14.8
		4	8.69	16.52	36.38	9.87	2.50	44.47	...	-22.1	+4.9
		8	8.38	21.24	30.61	12.02	2.15	49.26	...	-24.5	-16.0
		12	7.40	17.94	30.45	9.50	0.67	53.72	...	-4.0	-4.2

graphs of Figs. 1 to 4 inclusive. These graphs indicate, therefore, the relative changes in the actual amount of each constituent in the different manures as fermentation progressed.

SUMMARY

The results expressed in the accompanying tables and figures may be summarized as follows:

1—The loss of total organic matter during twelve weeks of fermentation ranged from 33 to 51 per cent. It was most rapid and greatest in the straw-littered manure, where bacteria were most numerous.

2—The water-soluble organic matter ranged from 10 to 13 per cent of the total organic matter in the fresh manures. It decreased continuously during twelve weeks of fermentation with the loss of from 60 to 80 per cent of the original amount. In all cases the loss of this constituent was most rapid during the first two weeks.

3—Humus ranged from 11.3 to 15.5 per cent of the total organic matter in the fresh manures. This constituent decreased continuously, but more gradually than the water-soluble organic matter. During twelve weeks it decreased from 26 to 35 per cent. The losses from the littered manures were nearly equal and about one-third greater than from the control manure.

4—The water-soluble ash ranged from 37.5 to 40.9 per cent of the total ash in the fresh manures. This constituent decreased gradually in all of the manures during twelve weeks of fermentation. The decrease ranged from 14 to 30 per cent of the amount originally soluble, being less in the straw-littered manure than in the other lots.

5—The total nitrogen increased in all of the manures until the fourth week of fermentation, the grains ranging from 8 per cent of the original amount in the control manure to 20 per cent in the straw-littered manure. More or less rapid loss of nitrogen occurred from the fourth to the eighth week of fermentation. After twelve weeks a net loss of nitrogen obtained in all of the manures. This net loss ranged from 3 to 13 per cent of the original amount of nitrogen, being less in the straw-littered manure than in the other manures.

6—The water-soluble nitrogen decreased rapidly in all of the manures during the first four weeks. It suffered greater loss than any other constituent investigated, its curve being quite similar to that of the total organic matter. This constituent formed from 41.4 to 48.4 per cent of the total nitrogen at the beginning of the investigation. Losses of the water-soluble nitrogen ranged from 77 to 90 per cent of the original amounts and were somewhat greater in the shavings-littered manures than in the other lots.

7—Humus nitrogen formed from 46.8 to 56.8 per cent of the total nitrogen in the fresh manures. Losses of this constituent ranged from 2 to 10 per cent of the original amounts, being greatest in the control manure. The fluctuation was similar in all of the manures, the humus nitrogen decreasing 10 to 20 per cent during the

first four to eight weeks of fermentation and then gradually increasing.

8—Ammoniacal nitrogen formed only 0.7 to 1.2 per cent of the total nitrogen at the beginning of the experiment. It rose to a maximum value in the control and shavings-littered manures during the first two weeks of fermentation, thereafter rapidly decreasing to about the original value after four weeks. In the straw-littered manure, on the other hand, the maximum production of ammonia was attained and passed gradually at about the fourth week. Ammoniacal nitrogen reached its greatest value in the control manure. In all cases, however, its values, ranging from 0.5 to 6.6 per cent of the total nitrogen, were too low to allow the placing of great importance on its fluctuations.

CONCLUSION

Undoubtedly the gain of nitrogen during the early stages of fermentation is the most important change indicated by the data of this paper. Whether so extensive gains are common is uncertain, but that gains occur has been definitely proved by further work which appears elsewhere.¹ In this work the writer showed that gains of nitrogen occurred in manure treated with wheat straw litter and demonstrated the presence of nitrogen-fixing organisms in the manures. Data from field plots were also presented which showed greater gains from a fermented mixture of manure and straw than from a similar application of fresh manure. For purposes of comparison the latter data are presented in Table III, together with data from shavings-littered manures. The crops referred to were grown on plots of $\frac{1}{20}$ acre in size arranged in three sections for a three-course rotation of corn, barley and clover. Manuring preceded the entrance of the corn crop into the rotation. The writer is indebted to Prof. E. B. Hart of this department for the privilege of using this data. The control yield is the average from two unfertilized plots. Data are averaged from six crops of corn, seven crops of barley and four crops of clover.

TABLE III—COMPARATIVE YIELDS OF CROPS FROM FRESH AND FERMENTED MANURES WITH LITTERS

CROP	UNFERTILIZED CONTROL	FRESH MANURE with		STALL MANURE with	
		Straw	Shavings	Straw	Shavings
Corn-grain	100	106	106	111	100
stover	100	106	109	114	104
Barley-grain	100	100	100	100	100
straw	100	99	100	98	97
Clover hay	100	101	100	96	92

A survey of the data in Table III shows that the effects of the manure are exhausted upon the first crop of the rotation. In the year of application the fresh manure gave the same results whether littered with straw or with shavings. It is only with the stall manure that different effects appear from the use of the different litters. The stall manure was prepared from amounts of the fresh manure equivalent to the direct applications of the latter, but had been given opportunity to ferment to a limited extent while stored in covered boxes during the winter. The data show a decided gain in efficiency of the

¹ W. E. Tottingham, "Increase of Nitrogen in Fermenting Manures," *J. Biol. Chem.*, **24** (1916), 221-225.

straw-littered manure by this process, while the shavings-littered manure shows an actual decrease of efficiency, as compared with the fresh manures. For the values in rounded figures as given here the straw-littered, fermented manure produced about 10 per cent greater yield of both corn grain and stover than did the corresponding shavings-littered manure. This difference is in harmony with the greater gain and

smaller net loss of total nitrogen in the straw-littered manure than in the shavings-littered manures, as shown by the analytical data and graphs of this paper. The results here presented seem to have opened for further investigation questions regarding the comparative value of different litters and the benefits to be derived from controlled fermentation of manure.

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LABORATORY AND PLANT

FLOW OF HEAT FROM SOLIDS TO AIR

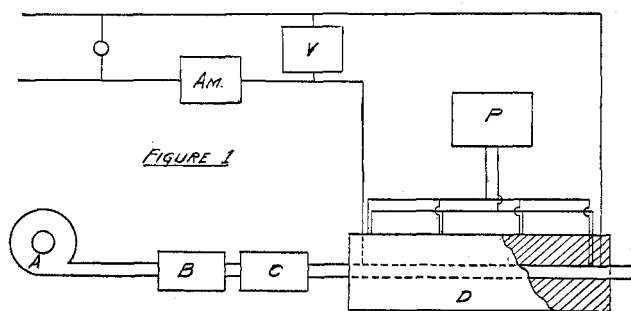
By E. E. SNYDER, C. S. ROBINSON AND W. K. LEWIS

Received May 2, 1916

J. W. Richards¹ makes the statement that the coefficient of heat transfer from solids to air is proportional to the square root of the gas velocity, while Irving Langmuir² states that it is proportional to the cube root of the velocity. Since these statements conflict, and since the experimental data on which they are based are not given in either case, the following investigation was undertaken:

A known weight of air was blown at constant velocity through an electrically heated tube. The temperature of the tube was measured, and the heat picked up by the gas was calculated by subtracting from the total electrical input the heat necessary to maintain the same temperature in the tube when no gas was passing through it.

The apparatus is shown diagrammatically in Fig. 1. A blower, *A*, delivers air through a CaCl_2 drying



tower, *B*, to an orifice, *C*, where the gas is measured. From *C* the air passes to the furnace *D*.

The furnace consists of a brass pipe, $\frac{1}{2}$ in. inside diameter, 27 in. long, fitted with $\frac{1}{2}$ in. \times $1\frac{1}{2}$ in. reducing elbows into which short pipes for air connections are screwed. Four Iron-Ideal thermal-couples are attached symmetrically along the pipe, which is covered with insulating asbestos paper, and wound with No. 19 resistance wire, the winding being closer together near the ends, to even the temperature through the pipe. It is covered with magnesia insulation to a diameter of 5 in. and the whole device enclosed in a galvanized iron can, with suitable openings for lead and thermal-couple wires. The whole furnace was immersed in a water bath of measured temperature.

¹ J. W. Richards, "Metallurgical Calculations," McGraw Publishing Co., New York, 1906, p. 179.

² Irving Langmuir, *Phys. Rev.*, **34** (1912), 401.

Electrical measurements were made with carefully standardized voltmeter and ammeter, and the temperatures along the pipes were measured with the thermal-couples and a Leeds & Northrup Potentiometer Indicator, carefully standardized against metals of known purity. Each run, either blank or constant velocity, was continued until thermal equilibrium was reached. The data obtained are given in Table I, where the column marked *Head* is the differential pressure in inches of water or mercury, as indicated at the orifice, the diameter of which is given in the column marked *Orifice*.

The volts and amperes are those read, and are corrected in Table II. T_2 , T_3 , T_4 , and T_5 are the temperatures measured by the thermal-couples, and T_1 and T_6 are the temperatures of the water bath at opposite ends of the furnace.

The average temperature of the furnace for a given run was found by plotting the temperature gradient against the length of the furnace and determining the average temperature difference by means of a planimeter. For each series of runs at constant velocity the power input was plotted against the average temperature difference between pipe and air. By subtracting the power input for the blank runs the net energy taken up by the gas was obtained. The values of *K* were then calculated and tabulated in Table III, which, however, includes only runs at a velocity of 0.01 lb. per second. The values of *K* at other velocities were calculated in an exactly similar way. The values of *K* for each velocity were plotted against the temperature of the furnace, but it was found that all these curves were practically horizontal straight lines, *i. e.* the value of *K* was independent of the temperature of the furnace. The values of *K* were then plotted against velocity; this plot is shown in Fig. 2. Points were put on this plot for furnace temperatures of 150, 250, and 350° C. and these points as indicated were practically coincident except for a velocity of 0.005. The discrepancy at this point is probably experimental. We may therefore conclude that the value of *K* up to the temperature employed is independent of the temperature and a function of the velocity alone. The equation of this curve is

$$K = \frac{39.6V}{V + 3.67}$$
 wherein *K* is the coefficient of heat transfer from solid to air in B. t. u. per sq. ft. of heating surface per °F. difference in temperature per hour, and *V* is the pounds of air per second flowing