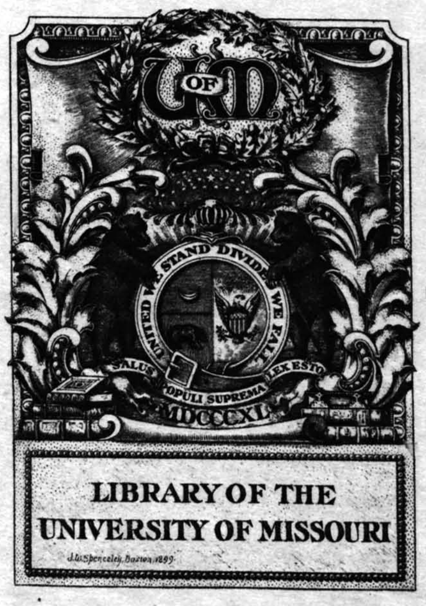
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SILAGE INVESTIGATION

by

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CONTENTS.

SILAGE INVESTIGATION.

INTRODUCTION.

More than one hundred years ago people began the practice of preserving green feed in silos. In this country the first silo above ground was built in 1875, in Michigan. From this beginning the use of the silo has spread rapidly until today it may be considered a well-established feature in American farm economy, not only in dairy sections, but in general, where any kind of live-stock farming is practiced.

While silos and silage have been in general use for a number of years there are several important questions that do not seem to be fully and satisfactorily answered. For example:

1. What is the importance of temperature in silage? Is it uniform thruout? Does the material used in the construction of the silo exert any influence on the temperature in the silo?

2. What is the relation of the percent of acidity and moisture to the keeping qualities of silage? What are the factors operative in the production of a desirable quantity of acid?

3. What is the percentage of loss in the silo? How much is unavoidable?

4. Is there a possibility of making silage from shock corn fodder and legumes?

5. What does silage weigh per cubic foot at different depths in the silo?

6. What is the effect of the kind of material used in the construction of different kinds of silos upon the composition of silage, especially near the wall?

7. Of what significance are moulds in silage?

8. With a need of experimental work in silage there arises the question of the reliability of small silos for experimental purposes.

With these questions in mind a series of experiments were carried on by the Dairy Department of the Missouri Agricultural College during the winters of 1913-1914 and 1914-1915. The work for 1913-1914 was carried on by D. G. Magruder and the results may be found in his thesis for that year. The work for this thesis is a continuation of that started by Magruder, but includes other problems which were not taken up in his experiments.

LITERATURE.

About 1880 Fry advanced the view that the heating of silage was due to the respiration of the cut vegetable tissues, but his ideas did not meet with acceptance and have since that time, until quite recently, been entirely neglected in the prevailing tendency to explain all fermentative effects as due to microbic action.

At present there are two views held as to silage fermentation; one that it is due to bacterial action, the other that the cellular activities are the causative agents. Pernot of the Oregan Experiment Station,[1] and Esten and Mason of the Storrs Experiment Station[2] support the former view; while Hart,[3] Babcock and Russell of the Wisconsin Experiment Station,[4] and E. J. Russell[5] of the Rothamstead Experiment Station in England hold that the changes are due to the intromolecular respiration of the plant cells. The larger mass of evidence seems to be in favor of the intromolecular theory.

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1. Annual Rpt. 1902, pp. 68-69.
2. Bul. No. 70, pp. 12-14, 1912.
3. Jour. Amer. Chem. Soc., 34 (1912), No. 11, pp. 1619-1625.
4. Annual Rpt. 1900, pp. 123-141.
5. Jour. Agr. Sci., (1908) 2, No. 4, pp. 395-410.

Temperature.

Short of the Wisconsin Experiment Station[1] in the fall of 1888, using experimental silos and taking the temperature with maximum thermometers in pipes placed in the silos at filling time; reports that on the second day of filling, August 31, the temperature registered 123 degrees F. And it continued to rise for a week when the maximum was reached at 163 degrees F. then slowly fell to 105 degrees F. on November 13. Good silage was produced with an acid content of 1.26 per cent calculated as acetic acid.

A temperature of 80 degrees F. is reported by Cooke of Vermont Experiment Station,[2] on the second day after filling, August 30, then a gradual decline to 60 degrees F. on September 21 when the silo was opened; as is shown in the following table:

Date	Temperature
Aug. 29	78° F.
" 30	80° F.
" 31	80° F.
Sept. 1	77° F.
" 4	72° F.
" 10	71° F.
" 17	70° F.
" 21	60° F.

1. Bul. No. 19.
2. Annual Rpt. 1889, p. 96.

The silos used were circular wooden tanks, three feet high and two feet in diameter.

Lamson of the New Hampshire Experiment Station[1] took temperatures with an electrical apparatus,- based on the same principle as the apparatus used by the Missouri Experiment Station at the present time. The electrode was a narrow glass tube filled with a salt solution. The silos which he used in this experiment were made of double matched boards, and were 13 x 14 x 30 feet deep. The silos were in the barn. Two electrodes (1 & 2) were placed in one silo, and three electrodes (3, 4 & 5) in the other. The silage was made of nearly mature corn, and the silos were filled as rapidly as possible and received very little packing - one or two men to keep the surface level. A silage of good quality was produced, being barely moist, olive brown in color, and slightly acid with a pleasant aromatic odor.

Electrode No. 1 was placed between eight and nine feet from the bottom of the silo. The first reading two days afterwards was 118 degrees F. which was the maximum. The temperature fell rapidly during the first ten days to 108 degrees F., then very gradually and uniformly until uncovered February 17, - when it registered 71 degrees F.

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1. Bul. No. 79, pp. 29-33, 1900.

Electrode No. 2 was placed about ten feet above No. 1 and deeply covered. Within two days the temperature rose to 84 degrees F. then gradually rose to the maximum, 105 degrees F. twenty-six days after filling, then gradually declined to 85 degrees F. January 14, when it was uncovered.

Electrode No. 3 was placed about three and one-half feet from the bottom of silo No. 2. The maximum temperature, 100 degrees F. was reached three days after filling. From this it fell very slowly until February 17, when it was 70 degrees F.

Electrode No. 4 was placed about thirteen feet from the bottom of the silo. There was a gradual rise from 77 degrees F. the next day after filling, to the maximum of 103 degrees F. forty-three days after filling, then a very slow fall to 98 degrees F., February 17.

Electrode No. 5 was placed in the silo about four and one-half feet above No. 4 and one and one-half feet below the surface of the silage. The surface remained uncovered for several days then was covered with about one foot of litter. There was a rapid rise to a maximum of 127 degrees five days after filling. Then a gradual but irregular decline

to 97 degrees F. January 14. This electrode was probably influenced by external factors, being so close to the surface.

According to Babcock and Russell of the Wisconsin Experiment Station[1] the large amount of heat developed in silage may, under normal conditions, be attributed to the intromolecular respiration of the ensiled material. They also demonstrated; by using vessels ranging in size from a pint to several gallons, and controlling the temperature; that when other conditions are natural just as good silage can be made in small containers at room temperature (60 degrees - 70 degrees) as in large silos where the heat is much higher. "Showing that the accumulation of heat which naturally occurs in a silo when large masses of fodder are ensiled, is not at all essential for the production of good silage".

The work on temperature changes in the silo was continued by Babcock and Russell[2] during the next year with much the same results. Galvanized iron receptacles one and one-half feet in diameter and four feet high were used as silos. These cans were filled with field corn of an average state

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1. Annual Rpt. 1900, pp. 123-141.
2. Annual Rpt. 1901, pp. 177-184.

of maturity and hermetically sealed. The temperature was taken by thermometers in large glass tubes sealed at the lower end and inserted thru the cover. The initial maximum temperature was recorded on the first day. There was a gradual decline to the temperature of the room on about the twelfth day, then the temperature of the cans fluctuated with the temperature of the room. The cans were opened on the twenty-fifth day. There was no spoiled silage and it appeared normal in every way. The silos were then left uncovered to note the effect of the bacterial and mould development on the temperature. There was no striking rise until about the third day (the thermometer was placed about four inches below the surface); then the rise was rapid and continued for about ten days, reaching a maximum of 122 degrees F. After this period the temperature again declined but not as low as the room temperature.

Pernot of the Oregan Experiment Station[1] reports temperatures in three experimental silos, 12 x 5 feet, as follows:

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1. Annual Report 1902, pp. 68-69.

	Maximum temperature	Days after filling	30 days after filling
Silo No. 1:	76°F.	13	64°F.
Silo No. 2:	80°F.	7	62°F.
Silo No. 3:	66°F.	5	62°F.

These temperatures were taken at the center of the silo.

Temperature observations covering a period of five years were reported by Esten and Mason of the Storrs Experiment Station[1]. The highest temperature of 126 degrees F. was found at the surface of the silage where the silage was exposed to the air. The highest temperature found within the silage mass did not exceed 86 degrees F. During the filling of the silo in 1910 five maximum thermometers were buried in the silage. All were placed about half way between the center and the wall of the silo; with about twenty tons of silage between each thermometer, and about forty tons above the first thermometer. At the time this work was reported only two thermometers had been recovered and they registered 80.6 degrees and 80.4 degrees F. respectively. The authors report the best

1. Bul. No. 70, pp. 22-30, 1912.

temperature for silage formation to be 75 degrees to 85 degrees F. They state that a temperature above 100 degrees F. means silage destruction, and below 65 degrees F. during fermentation a poor quality of silage is produced.

Neidig of the Iowa Experiment Station[1] reports temperatures in a wooden stave, a hollow tile, and a concrete silo for a period from the middle of September to the second week in October. Temperatures were taken at the center, two feet from the center, two feet from the wall, and at the wall in each silo. They were taken with an electrical apparatus of a type similar to the one used at this Station, that is resistance bulbs were placed in pipes in the silo and the wires carried to the top of the silage, where the temperature was read directly by means of an indicator box. All three silos showed about the same characteristics where the thermometers were not affected by outside influences. The time during which the temperatures were taken was very short and the data just shows that when silage is put up right no high temperatures are obtained during the period of silage formation. The maximum in this case

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1. Res. Bul. No. 16, pp. 8 - 13, 1914.

being 91 degrees F. in both the concrete (18 days after filling) and the hollow tile silo (9 days after filling) and 86 degrees F. in the stave silo (21 days after filling).

Magruder[1] in his thesis work took temperatures with electrical thermometers in pipes in the silos. The highest temperature, 130 degrees F., was reported near the surface of the silage. Within the mass of silage the temperature rose slightly to about 100 degrees F. in the iron and concrete silos. Higher temperatures were reported in the Gurler and stave silos, but they are thought to be due to the fact that the silage was drier and not packed so well. There was very little difference at different depths in the silo. In all cases there was a sharp rise to the maximum temperature in about two weeks after filling, then a slow and quite uniform decline.

Moisture and Acidity.

Short of the Wisconsin Experiment Station[2] presents data to show that the per cent of acid varies with the percent of moisture in silage.

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1. Thesis for A.M. degree, University of Missouri, 1914.
2. Bul. No. 19, p. 22.

Percent of Moisture	Percent of Acid
54.43	1.34
38.13	0.43
80.00	1.64
74.60	1.30

The following table taken from Michigan Bulletin No. 68 (1890), shows the relation of acidity to the percent of moisture in silage.

Date of Cutting	Percent dry matter in Silage	Percent acid in silage as acetic acid	Percent dry matter in corn at cutting.
August 10	10.00	1.26	13.90
August 16	12.70	.84	15.13
August 22	15.60	.76	17.46
August 28	18.00	.72	19.50
September 3	21.40	.72	22.56
September 9	24.27	.72	25.39
September14	29.90	.70	30.80

The Massachusetts Experiment Station[1] reports the percent of moisture and acidity in six samples of silage as follows:

Sample	Percent of moisture	Percent of acid
1	76.38	3.68
2	70.01	2.12
3	82.87	1.98
4	75.36	2.69
5	78.84	1.26
6	71.65	1.13

It is thought by King of the Wisconsin Experiment Station[2] that too much water tends to increase the acidity of the product. Where the corn is put in the silo in too immature condition, an over sour and lower quality of silage will be obtained. In an experiment to determine the factors operative in the formation of sweet and sour silage, Griffeths[3] found that silage produced below a temperature of 90 degrees F. had 1.66 percent of acid (methods not given);

1. Bulletin No. 36, 1890.
2. Annual Report 1893, pp. 201-227.
3. Chem. News, 70 (1894), pp. 273-275.

between 90 degrees F. and 120 degrees F. the silage had 1.50 percent acid; and between 133 degrees and 158 degrees F. a sweet silage was produced with only 0.08 percent of acid, which was mostly valeric with a trace of lactic acid. This silage also contained four percent of sugar.

The author states that the two varieties of silage, acid or sweet, which are produced in silage formation are determined by the temperature at which the fermentation takes place within the mass of silage; "and the silage is acid or sweet according to the presence or absence of certain acids belonging to the fatty series. A temperature of 140 degrees to 158 degrees F. favors the production of sweet silage."

Babcock and Russell of the Wisconsin Experiment Station[1] are of the opinion that the acidity of silage is a product of the intromolecular respiration of the plant tissues, and the amount of acid developed is due to the length of the cellular activities. The cellular activities take place for a longer time in the immature and succulent plant than in the more mature fodder, therefore the greater amount of acid. Carbon dioxide plays an important part in the develop-

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1. Chem. News. 70 (1894), pp. 273-275.

ment of acid, as it kills the plant tissues and consequently stops the development of acid.

In silage made from corn when the kernels were in the dough stage, Withycombe of the Oregan Experiment Station[1] found 80 percent of moisture and 1.94 percent of acid as acetic acid. With clover silage in three different silos there was quite a variation, as is shown in the following table:

Silo	Percent of Moisture	Percent of Acid
1	74.7	0.80
2	77.2	1.16
3	77.3	1.06

Water was added to silo No. 2 and silo No. 3 at the rate of one gallon of water to 100 pounds of material.

Morse of the New Hampshire Experiment Station[2] conducted a series of experiments covering two years to determine the acidity in silage. There was quite a variation between the two years. In 1895 the acidity varied from 0.67 percent to 1.33 percent. One sample one year old had 1.54 percent. In 1896 it varied from 1.47 percent to 1.95 percent. There was

1. Bul. No. 67, p. 104, 1901.
2. Bul. No. 96, pp. 115-117, 1902.

no regularity in the amounts of acid occuring. The acidity at the surface was always lower than six inches below the surface.

Hart and Willaman of the Wisconsin Experiment Station[1] express the belief that the acid produced in silage is formed within the tissues by anaerobic respiration of the living cells, rather than by means of foreigh organisms; due to the fact that grinding the tissues very fine in a food grinder liberates more acid than simply chopping with a knife.

For a period covering five years work, the Storrs Experiment Station[2] gives the average percent of acid in corn silage as 1.5 percent. However, it varied from 1.0 percent to 2.0 percent.

Magruder in his thesis shows that the percent of acid increases with the moisture. The percent of acid and moisture varies with the maturity of the corn. He reports a lower percent of acid at the wall than at the center of the silo, while the percent of dry matter is practically the same.

Dox and Neidig of the Iowa Experiment Station[3] performed an experiment to determine the amount

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1. Jour. Amer. Chem. Soc., 34(1912), No. 11, pp. 1619-1625.
2. Bul. No. 70, 1912.
3. Res. Bul. No. 10, 1913.

of lactic acid in silage and its rate of development. Samples were taken every day for the first fourteen days. They were taken with a two inch soil auger thru a hole in the door of the silo. They found that the rate of formation of lactic and volatile acids was greatest in the first three days. The formation of the volatile acids was about twice as rapid as the formation of the lactic. The average ratio of the lactic to the volatile acids was 1.0 : 0.75.

Losses in Silage.

"The fermentation of an organic body is always accompanied by a loss of substance."[1]

In 1889 the Arkansas Experiment Station[2] reported a loss of 62 percent with corn, and 56 percent with sorghum from ensiling these two crops. However, the loss included the spoiled silage; and also this was before the advent of the round silo.

Armsby[3] reports a loss of 22.9 percent, 37.6 percent and 23.1 percent respectively in three experimental silos. No. 1 was filled with corn shredded,

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1. Wis. Bul. No. 19.
2. Annual Report 1889, p. 4.
3. Penn. Report, 1890, pp. 69-79.

well packed, and covered and weighted. For No. 2 the corn was cut one inch long; the sides and corners were tramped but the middle was left go. After settling the silage was covered. For No. 3 the corn was cut in two inch lengths, otherwise it was treated the same as No. 2. He thinks that some of the losses were due to fermentation; but a large percent was due to the moulding and spoiling which took place at the sides.

Smith of the Michigan Experiment Station[1] reports a loss of 8.32 percent as an average of four tests from putting corn in the silo. Some other tests varied from 14.57 percent to 20.36 percent.

Woll of the Wisconsin Experiment Station[2] weighed the corn into the silo and weighed the silage out. He reports a loss of 10.3 percent in dry matter from putting 65 tons into the silo. 3012 pounds of spoiled silage was counted in the loss.

An experiment was carried on by Collier of the New York Experiment Station[3] in which bags containing 50 pounds each of the green material were buried in the silo at filling time. This material was analyzed at the time of filling and then at the time the bags

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1. Bul. No. 191, 1901.
2. Annual Report 1891, pp. 227-231.
3. Annual Report 1892, pp. 162-173.

were taken from the silo. There was a loss of 12.6 percent of dry matter, 18.5 percent of albuminoids, and 26.6 percent of sugars and starches. An increase of 3.7 percent of amide nitrogen, and an apparent increase of 45.4 percent in crude fat, - due to the increased solubility of the ether extract thru the fermentation in the silo.

In 1894, for a period covering six years, the Kansas Experiment Station[1] reported an average of 77.2 percent of good silage, 10.5 percent of rotten silage, and 12.3 percent of loss. Of several plans tried for the saving of silage, they obtained the best results when the surface of the silage was covered with a layer of green grass that would be six inches thick after it had settled, and then covered this with earth. Very little silage spoiled.

As a result of a series of experiments in 1893 - 1894, King of the Wisconsin Experiment Station[2] found the losses in silage to be considerable less than 10 percent; as low as 5 percent to 6 percent. According to Babcock and Russell of the same Station[3] the unavoidable losses in silage are due to the forma-

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1. Bul. No. 48, pp. 33-40.
2. Annual Rpt 1895, pp. 273-278.
3. Annual Rpt. 1900, pp. 123-141.

tion of water, carbon dioxide gas, and volatile organic acids, as a result of the intromolecular respiratory processes of the ensiled tissues. King[1] also performed an experiment to determine the influence of close packing of corn in the silo upon the unavoidable losses in silage. Two samples of silage of the same weight and composition were taken. One sample was packed in a pint milk bottle, the other was put into a quart milk bottle. Both bottles were then sealed. The covering contained a mercury valve which permitted the escape of gases but did not let air in. The amount of loss in each is shown in the following table:

	1st pair		2d pair	
	1 pt. gms	1 qt. gms.	1 pt. gms.	1 qt. gms.
Weight of corn at start	323.7	318.7	299.6	299.7
Loss of silage after 33 da.	1.0	7.6	3.8	8.5
Percent of loss after 33 da.	.31	2.38	1.27	2.91
Loss of silage after 303 da.	2.40	10.4	5.6	12.0
Percent of loss after 303 da.	.74	3.26	1.80	4.11

1. Annual Report 1901, pp. 200-209.

The loosely packed sustained a loss nearly three times as great as that which was closely packed; 3.68 percent for the loose, and 1.27 percent for the close packed one (the average of two bottles in each case).

A comparison of green fodder with the silage made from that fodder is given by Morse of the New Hampshire Experiment Station[1]. The greatest and most important changes were in the carbohydrates; mainly sugars and fiber. A loss of sugar and an increase of fiber. He states that the losses in silage are confined almost exclusively to the sugars.

Table showing the loss of sugar in silage:

	1898-1899		1899-1900		1900-1901	
	fodder %	silage %	fodder %	silage %	fodder %	silage %
Dry matter	19.50	18.25	18.86	16.38	20.05	19.52
Sugar in dry matter	7.75	0.20	20.89	0.51	8.24	0.55

Apparently the starch was not affected. The sugar content of the corn plant is most abundant during the early stages of ear development. As the plant matures the sugar changes to starch. The least loss of carbohydrates will therefore take place the nearer the corn is to maturity and yet make good silage; since the

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1. Bul. No. 92, 1902.

sugar is almost all destroyed in the silo.

Cooke of the Colorado Experiment Station[1] reports the following losses in an experimental silo ten feet square: 9997 pounds of fodder corn put in and 8997 pounds taken out, - a loss of 10 percent. 9721 pounds put in and 9409 pounds taken out, making a loss of 3 percent.

WEIGHTS IN SILAGE.

King of the Wisconsin Experiment Station[2] reports the weight of a cubic foot of silage at filling time, from several Stations, to be as follows:

Station	Wt. per cubic foot	Depth of silage in silo.
	Lbs.	ft.
Wisconsin	24.75	13
Wisconsin	27.90	12
North Carolina	26.00	14
North Carolina	34.00	31.5
New York	25.90	14
New York	25.70	14
Missouri	30.00	16
Kansas	34.00	20
C.E.King, White-water, Wis	44.60	27

These weights are based upon the weights of the green

1. Bul. No. 57, 1900.
2. Annual Rpt. 1891, pp. 241-244.

material put into the silo, and are an average for the whole silo.

In Mr. King's work the weight per cubic foot was calculated from the weight of the silage put into the silo. He assumes the mean weight of a cubic foot of silage made from well glazed corn to be 42 pounds in a silo twenty-seven feet deep and slowly filled; the upper thirteen feet to average 26 pounds; and 45 pounds as the weight of a cubic foot thirteen feet below the surface. Also assume that below this thirteen foot level there is a uniform increase until 63 pounds is reached. From this he computes the weight of a cubic foot at different depths in the silo (no methods given). In his table he obtains the maximum weight (63 pounds) at a depth of twenty-three feet in the silage, and below this depth he considers the weight uniform for succeeding depths. King[1] has since gotten out a table in which he has calculated the weight of a cubic foot of silage from a depth of one to thirty-six feet. He shows a fairly uniform increase from 18.7 pounds to 61.0 pounds.

King[2] also reports the results of an ex-

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1. Annual Rpt. 1893, p. 207.
2. Annual Rpt. 1891, pp.249-254.

periment to determine the latteral pressure in the silo; by means of pressure plates. In general, it was found that below a depth of three feet the presure increased at a rate of nearly 11 pounds for each foot of depth. King[1] reports two incidents where the silo had burned, and in both cases the silage maintained the form of the space in which it had been stored; showing that after silage has once settled there is very little latteral pressure (A. D. Rice's silo burned October 20. C. E. King's silo burned four days after filling).

Cooke of the Colorado Experiment Station[2] divided an experimental silo ten feet square into three layers with boards to separate the layers, and rods extending from the boards to the surface so that the amount of settling could be recorded. The final weight for each layer is given in the following table:

	Lbs. of Silage	Thickness of layer inches	Lbs. Pressure	Da. of settling	Lbs. per cu.ft.
Botton layer	6588	15.5	323	90	50.7
Middle layer	9721	47.0	244	77	33.3
Top layer	9997	39.0	145	8	31.5

1. Annual Rpt. 1894, p. 289.
2. Bul. No. 57, 1900.

When the cover and the top were removed down to the first layer, the top of this layer rose two and one-half inches. This includes the expansion for the whole mass. The first and third layers expanded one inch each and the middle layer one-half inch.

SHOCK-CORN FODDER IN THE SILO.

The report of the Utah Experiment Station for 1892 (pp. 40-49), gives a short reference to the placing of fodder in the silo, comparing the keeping qualities in the silo as against the mow. The fodder was put thru the silage cutter before being placed in the silo. The fodder contained 58 percent moisture. No water was added. As far as could be determined there was no loss. The fodder seemed to be softer, and quoting from the author, "It was eaten better than I have ever known corn fodder to be eaten, fully as well as hay is usually eaten."

The Delaware Experiment Station[1] reports some trials with shock corn fodder as silage. Rectangular silos 7 x 8 x 28 feet were used. February 26 and 27, 1903, about 9,000 pounds of dry fodder were

1. Annual Report 1903, pp. 38-41.

placed in a silo; February 27, 2025 pounds of well water, at a temperature of 52 degrees were put on the silage. On March 2, 3070 pounds of water additional were added; this mass then had 27.5 percent of dry matter. On this same date iron pipes five feet long were driven down into the silage; also pipes were driven thru the side walls of the silo into the center of the silage. Temperatures were taken by means of chemical thermometers. The following temperatures were reported:

Ft. below surface	March 2	March 3	March 4
5	149°F.	122°F.	140°F.
12	125°F.	140°F.	140°F.
18	77°F.	122°F.	131°F.

Beach of the Vermont Experiment Station[1] shredded about 8 tons of dry corn fodder with 60 percent of dry matter, into a stave silo; and at the same time added 3 tons of water. Within the next two weeks enough water was added to reduce the dry matter to approximately 25 percent. A sweet silage

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1. Bul. No. 70.

was produced. It seems that not enough water was added at the time of filling as portions "fire fanged".

Magruder in his thesis found that when water is added to corn fodder at the rate of one pound of water to one pound of fodder at time of filling a good silage is produced with a moisture content about typical of normal silage.

LEGUMES FOR SILAGE.

The Maryland Experiment Station[1] reports a trial of soybeans and corn for silage (proportions not given). The silage was in good condition at the time the silo was opened. However, upon exposure to the air the soy beans quickly changed, developing an undesirable odor and were refused by the cattle.

The Wisconsin Experiment Station[2] reports good success with clover as a silage crop. The points they emphasize are:- use fairly mature clover; and cut it when the dew is off. By following these suggestions a bright, sweet, and palatable silage can be produced, and it will have an aromatic odor.

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1. Annual Rpt. 1891, p. 349.
2. Bulletin No. 19, p. 27.

Alfalfa was made into silage on a small scale by Cooke of the Colorado Experiment Station[1]. Alfalfa both whole and cut was tried in the silo, but better success was secured with cut alfalfa. With the cut alfalfa there was 7.3 percent of spoiled silage, and about 10 percent loss in dry matter. However, excellent silage was produced.

It is generally believed by farmers that the legumes, alfalfa, clover, cowpeas, etc., may be made into silage; but that corn is a better silage crop, and where possible the silo should be filled with corn, and the legumes made into hay.

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1. Bul. No. 57, 1900.

DESCRIPTION OF SILOS.

The silos used are situated in and about Columbia. They are as follows:

South Concrete Silo.
North Concrete Silo.
Iron Silo.
Miller's Stave Silo.
Reid's East Stave Silo.
Reid's West Stave Silo.
Gurler Silo.
Tile Silo.
Estes' Concrete Silo.
Dorsey's Concrete Silo.
Six Experimental Silos.
Six Experimental Cans.

The South and North Concrete Silos are situated at the dairy barn on the University Farm. They are of the monolithic type, 33 feet high and 16 feet in diameter with concrete floors and set 5 feet in the ground.

The South Concrete Silo was filled September 2 - 5. The corn was somewhat greener than that which is usually used for silage purposes,

most of it had not yet passed the glazed stage, so no water was added. The corn was cut quite fine, and the silage was well tramped, especially the surface after the silo had been filled; and one-half barrel of common salt was spread over the south half.

The North Concrete Silo was filled Septemper 22 and 23. The silage was well tramped and after filling operations had ceased the north half of the surface was covered with tarred paper, the edges overlapping about two inches, then a load of cowpeas was run thru the silage cutter and put on top of this paper.

The Iron Silo is situated at the University cattle feeding sheds, and is 26 feet high, 12 feet in diameter, and sets about 4 ½ feet in the ground. The part above ground is made of iron bands two and one-half feet in width and rivited together. This silo was filled August 29 - 31. The silage was well tramped and no water was added. About 18 days after filling the surface was leveled and tramped down, and a quantity of common salt sprinkled all over the surface.

The Tile Silo is situated on a farm southeast of Columbia, and is 42 feet high and 14 feet in diameter. It is made of glazed hollow tile cemented together, and sets 2 feet in the ground. It was filled September 2 to 4. The corn was cut rather coarse and was not tramped very much.

All of the stave silos are typical. They are situated on farms east of Columbia. Miller's Stave Silo is 37 feet high, 16 feet in diameter, and sets 5 feet in the ground. It was filled September 12 to 15.

Reid's East Stave Silo is 32 feet high, 16 feet in diameter and sets 4 feet in the ground. Reid's West Stave Silo is 36 feet high, 14 feet in diameter, and sets 4 feet in the ground. They were filled August 29 to September 1.

The Gurler Silo is located on a farm northeast of Columbia, and is 30 feet high and 14 feet in diameter. It has been used several years and the plastering has cracked in places. It was filled August 25 and 26.

Estes' Concrete Silo and Dorsey's Concrete Silo are located on farms southeast of Columbia, and

are of the monolithic type. The former is 52 feet high and 16 feet in diameter. The latter is 52 feet high and 14 feet in diameter.

Six circular water tanks six feet high and three feet in diameter, and made of two-inch cypress were used as experimental silos. They contained a bottom, and tops were made that would settle down in the silo as the silage settled. They were placed in the loft of the dairy barn for protection from the cold. They are designated as experimental silos No. 1, No. 2, No. 3, etc.,

Each time an experimental silo was filled a wire screen which would fit loosely in the silo was placed so that about one foot of silage was above the screen when the filling was completed. The weights of the amount of silage both below and above this screen were taken when put in and again when removed. The object in using this screen was to make it possible to distinguish between the loss of nutrients due to the fermentation of the silage and the loss on top that occurs from exposure to the air.

The Experimental Cans were 20 inches high and 12½ inches in diameter, and held about ten gallons.

DESCRIPTION OF METHODS USED.

Temperature Observations -- Temperature readings were obtained by means of Leeds and Northrup Resistance Thermometers with balance type Indicator.(The Leeds and Northrup Company). This apparatus consisted of a portable indicator and resistance thermometers. These thermometers were placed in half inch gas pipes, and the wires carried from the thermometers thru the pipe to the surface of the silage. The pipe was placed against the wall, extending from the top of the silo to the desired depth and from the lower end of this pipe a similar pipe extended to the center of the silo. One thermometer was placed at the lower end of the perpendicular pipe to give the temperature at the wall, and one at the inside end of the horizontal pipe to give the temperature at the center of the silo. When readings were desired the thermometers was connected with the indicator box and on passing and electrical current thru the apparatus, the temperatures were read directly in degrees Fahrenheit on the indicator scale.

Moisture Determinations -- A sample of the silage was taken when desired and weighed. The

silage was then spread in a mouse tight case and thoroly dried at room temperature. The dried silage was then weighed and the percent of air dry matter in the fresh silage calculated.

Acidity Test -- Samples for the acidity test were taken in two-quart fruit jars. About one cubic centimeter of chloroform was added to preserve the sample until the acidity could be determined. The sample for acidity was a part of the sample taken for moisture. The sample was run thru a small feed cutter to chop the silage up fine, and then thoroly mixed and two 100 gram portions taken for the acidity test. These portions were washed with distilled water and the washings titrated against a standard alkali until the last washing titrated the same as the blank which had been run on the distilled water. Four washings were usualy required; about 1000 c.c. for the first one and 500 c.c. each for the succeeding ones. Twenty-four hours or longer intervened between washings. Each washing was decanted into a suction filter, and the filtrate made up to 500 c.c. and 100 c.c portions titrated immediately. Where the washings were unusually cloudy they were washed over animal

charcoal to remove the color. An average molecular weight of 80 was used for the mixture of acids, this being the molecular weight used by the Storrs Experiment Station.

Method of Taking Weights -- The weight of silage per cubic foot at different depths in the silo was taken by means of an apparatus devised by Reed of the Kansas Experiment Station. This is an iron frame which can be driven into the silage to enclose a cubic foot. This frame is a foot square on the outside and eighteen inches high. The upper six inches of the frame are braced for strength and to this upper part sharp pointed rods are welded, one on each corner and one in the middle of each side. (See Plate 1.) The silage was cut around the outside of the frame with a hay knife, and the silage taken out of the frame to a depth of one foot and weighed for the weight of a cubic foot at that depth. These weights were taken as the silage was fed out.

PLATE I.

"Kansas Apparatus"

TEMPERATURES IN SILAGE.

Object.

The object of this experiment is to obtain definite knowledge as to:-

1. The importance of temperature in its relation to the fermentation of silage.

2. The factors affecting temperatures.

   (a) Material used in the construction of the silo.

   (b) The effect of air in silage.

Plan of Experiment.

High Temperature as Compared with Low --The six experimental cans were filled with silage from the South Concrete Silo at the time it was being filled, and a sample was taken for analyses. The silage was thoroly packed in the cans and the tops put on, then the cans were placed in the cheese press and heavy pressure applied. The tops were fastened on with wire, and melted paraffin was poured around the edges to seal the cans air tight. The weight of the silage in each can was taken both at the time of

filling and when the cans were opened.

Two cans were placed in the refrigerator at 50 degrees F.

Two cans were placed in a room at 68 degrees F.

Two cans were placed in a special box arranged in the basement and heated by an electrical oven, set to maintain the temperature at about 100 degrees F.

One can from each place was opened three weeks after filling, and the remaining three were opened about two months after filling. Samples were taken for acidity and chemical analyses.

<u>Temperature in the Large Silos</u> -- Temperatures were taken at the wall and center of the two Concrete Silos, the Iron Silo, the Tile Silo, the Gurler Silo, and the two Stave Silos; to gather data on the relation of the material used in the construction of the silo to the temperature of the silage.

<u>Air in Silage</u> -- Two experimental silos were filled with nommal silage taken from the South Concrete Silo at the time it was being filled. The silage was thrown loose into one of these silos and

no weight applied, while it was well tramped into the other and 1500 pounds of weight applied.

Two experimental silos were also filled with shock corn fodder in the same way as the two preceeding silos.

A resistance thermometer was placed in each silo so that the temperature could be taken at the center of the silo. Samples for analyses were taken from all silos.

DISCUSSION OF DATA.

Experimental Cans -- Temperature readings were taken daily (Sundays excepted) thruout this experiment. The temperature of the refrigerator was the most difficult to controll; the range of temperature was from 44 degrees F. to 57 degrees F. With four exceptions the range of temperature was within four degrees of 50. The temperature of the cheese curing room was the most constant, the extremes were 64 degrees F. and 71 degrees F. There were only three exceptions to a range of two degrees each side of 68. With the exception of eleven days (September 23 to October 2, when the electricity

was turned off) the temperature of the special box was also quite uniform. The range of temperature was from 92 degrees F. to 103 degrees F., and with but four exceptions the range was within three degrees of 99.

When the cans were opened the silage was compared as to appearance, odor, taste; and samples were taken for acidity and moisture. Small amounts of mold were found in some of the cans, indicating that some air had gained entrance.

Twenty-three days after filling, one can from each lot was opened.

The silage held at 50 degrees F. had 1.94 percent of acid, and sustained a loss in weight of 1.26 percent. The silage in this can had not changed much in color from that of green corn. However, it had a disagreeable taste and odor. The odor resembled that of alcoholic fermentation, with some putrefaction. There were a few spots of mold in this silage, next to the seams of the can, but not enough to affect the general results.

The silage held at 68 degrees F. had an acidity of 2.20 percent, and showed a loss in weight of only 0.27 percent. This silage was darker than that which had been held at 50 degrees F. It was

very sour to taste and had a pleasant acid odor. It also had an odor somewhat characteristic of freshly cut corn.

The silage held at 99 degrees F. had 1.45 percent of acid, and sustained a loss in weight of 2.74 percent. This silage was the darkest in color of the three samples and was very similar to that of normal silage. The odor was also very much like that of normal silage, with the possibility of a greater amount of alcoholic fermentation. This silage did not taste as strongly acid as that which had been held at 68 degrees F. There was some mold present, but not enough to affect the general results.

The three remaining cans were opened 58 days after filling.

The silage held at 50 degrees F. had 1.56 percent of acid. It had a much greener color than the silage in the other two cans. Also it was greener than the silage which was taken from the South Concrete Silo at this time. The silage had a sharp acid taste, and not an unpleasant odor; altho it was not as pleasing as that in the other two cans, however, it would pass for good silage.

The evidence of alcoholic fermentation, or putrefaction which was present in the other silage held at 50 degrees F. was lacking in this silage.

The silage held at 68 degrees F. had an acidity of 2.19 percent, and showed a loss in weight of 1.72 percent, however there was no evidence of spoiled silage. The silage was darker in color than that in the preceeding can, but not as dark as that which was taken from the South Concrete Silo at this time. It had a sharp acid taste about like that in the preceeding can, but a more pleasant odor. When this can was first opened it had an odor resembling that of swill, but it soon disappeared, and this silage would pass for good normal silage.

The silage held at 99 degrees F. had 1.82 percent of acid. It was very nearly of the same color as that which was taken from the South Concrete Silo; and more like it in odor and taste than the silage in either of the other cans. This silage did not taste as sour as that in the other two cans, and appeared to be the best lot of silage.

TABLE 1.

Comparing the Effect of High and Low Temperature Upon the Formation of Silage.

Can No.	Temperature	Percent of acid	Percent of dry matter (air dry)	Percent of loss in weight	Days after filling
1	50°F.	1.94	30.40	1.26	23
2	50°F.	1.56	32.27	----*	58
3	68°F.	2.20	30.49	0.27	23
4	68°F.	2.19	30.11	1.72	58
5	99°F.	1.45	29.18	2.74	23
6	99°F.	1.82	31.66	----*	58

*There was an apparent gain in Nos. 2 and 6; probably due to an error.

The percent of acid in the different lots show no uniformity with the appearance, odor, and taste. At the end of three weeks the acidity of the silage held at a low temperature was greater than that of the silage held at a high temperature, while at the end of two months this conditinn was reversed. There was a loss of acidity in No. 2 as compared with No. 1, while No. 6 showed an increase over No. 5.

The silage which had been held at 50 degrees F. for twenty-three days was the poorest of all the

lots and was considered to be very poor silage, while all remaining lots, including the one held at 50 degrees for 58 days would have passed for normal silage.

These data indicate that the temperatures ordinarily obtained in the silo (70 degrees F. to 100 degrees F.) play an unimportant part in silage formation. It is probable that 70 degrees F. is not the lower limit of temperature at which good silage can be made.

This conclusion is in accord with the results obtained by Babcock and Russell of the Wisconsin Experiment Station[1], and Esten and Mason of the Storrs Experiment Station[2].

Babcock and Russell report that when other conditions are natural just as good silage can be made in small containers at a temperature of 60 to 70 degrees F. as in large silos where higher temperatures are obtained. "Showing that the accumulation of heat which naturally occurs in a silo when large masses of silage are ensiled, is not at all essential for the production of good silage."

Esten and Mason state that a temperature

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1. Annual Report 1900, pp. 123-141.
2. Bul. No. 70, pp. 12-14, 1912.

of 70 degrees F. favors the production of lactic and acetic acids, while 50 degrees F. favors the production of the stronger aromatic acids - propionic and butyric. The silage held at 70 degrees F. did not have so strong an odor as that held at 50 degrees F., but it had more of a silage odor. They hold that a temperature of 100 degrees F. or over means silage destruction, and a temperature below 65 degrees F. during fermentation results in the production of silage of poor quality.

All the data available show that no very low temperatures, 60 to 70 degrees F. or lower, are attained in the silage thruout this region during silage formation.

We may conclude that if silage is properly put up the temperature factor will not enter in, as the range of variation at filling time is within the limits considered to be essential for the production of good silage.

Temperature Readings in Silos -- The temperature readings taken in the large silos are given in the following tables:-

TABLE 2.

TEMPFRATURE READINGS* - SOUTH CONCRETE SILO.

Filled September 2 - 5, 1914.

Date of Reading	Time of Reading	Reading of Thermometers Placed				Mean Temperature of Atmosphere
		At Wall	Two ft. from Wall	Three ft. from Center	At Center	
		Degrees F.				
Sept. 7	9:45 A.M.	89	90	96	93	74
" 8	4:00 P.M.	80	91	93	93	66
" 9	4:15 P.M.	78	89	93	92	64
" 14	5:00 P.M.	82	90	95	92	78
" 15	3:30 P.M.	80	91	94	94	72
" 18	4:45 P.M.	81	89	94	94	72
" 19	3:45 P.M.	84	90	94	94	75
" 23	4:30 P.M.	76	89	94	93	57
Oct. 2	3:45 P.M.	76	86	92	94	66
" 9	3:00 P.M.	73	84	91	93	67
" 23	4:00 P.M.	81	79	89	91	65
Nov. 14	9:45 A.M.	57	73	84	88	59
Dec. 12	2:15 P.M.	37	62	77	84	26
Jan. 1	2:30 P.M.	31	50	52	79	36
" 15	3:00 P.M.	39	49	52	74	50

*Resistance thermometers were placed 17 ft. from top of silage.

TABLE 3.

TEMPERATURE READINGS* - NORTH CONCRETE SILO.

Filled September 22 - 23, 1914.

Date of Reading	Time of Reading	Reading of Thermometers Placed At Wall Degrees F.	Reading of Thermometers Placed At Center Degrees F.	Mean Temperature of Atmosphere Degrees F.
Sept. 24	2:30 P.M.	68	65	62
" 26	3:45 P.M.	72	72	60
" 28	10:15 A.M.	72	74	64
" 29	1;45 P.M.	76	76	64
Oct. 1	4:30 P.M.	78	78	68
" 2	3:45 P.M.	77	77	66
" 5	2:45 P.M.	77	78	71
" 9	3:15 P.M.	73	78	67
" 23	1:45 P.M.	71	79	65
Nov. 14	10:00 A.M.	61	79	59
Dec. 12	3:15 P.M.	39	78	26
Jan. 1	2:15 P.M.	34	74	36
" 15	2:30 P.M.	65	71	50
" 29	2:45 P.M.	--	69	16
Feb. 2	2:00 P.M.	47	67	28
" 23	2:45 P.M.	67	63	40
Mch. 13	3:15 P.M.	50	60	40
" 26	9:00 A.M.	55	58	34
Apr. 10	1:30 P.M.	58	58	60
" 19	10:45 A.M.	73	61	70

*Resistance thermometers were placed 7 ft. 6 in. from top of silage.

TABLE 4.

TEMPERATURE READINGS* - IRON SILO.

Filled August 29-31, 1914.

Date of Reading	Time of Reading	Reading of Thermometers Placed		Mean Temperature of Atmosphere
		At Wall Degrees F.	At Center Degrees F.	Degrees F.
Sept. 4	3:45 P.M.	98	97	71
" 5	2:30 P.M.	98	99	79
" 7	4:45 P.M.	78	99	74
" 8	4:15 P.M.	85	100	66
" 9	4:30 P.M.	71	102	64
" 15	3:15 P.M.	84	101	72
" 18	4:30 P.M.	95	100	72
" 19	3:15 P.M.	98	101	75
" 23	4:45 P.M.	86	100	57
Oct. 2	4:00 P.M.	94	101	66
" 9	2:45 P.M.	72	97	67
" 23	1:30 P.M.	70	93	65
Nov. 14	9:30 A.M.	61	85	59
Dec. 12	1:45 P.M.	32	76	26
Jan. 1	2:00 P.M.	53	68	36
" 15	3:15 P.M.	74	61	50
" 29	2:30 P.M.	--	59	16
Feb. 2	1:45 P.M.	42	58	28
" 23	2:45 P.M.	44	52	40
Mch. 13	3:00 P.M.	60	50	40
" 26	9:15 A.M.	--	48	34
Apr. 10	1:15 P.M.	--	48	60
" 19	10.45 A.M.	95	48	70

* Resistance thermometers were placed approximately 16 feet from top of silage.

TABLE 5.

TEMPERATURE READINGS* - MILLER'S STAVE SILO.

Filled September 12 -15, 1914.

Date of Reading	Time of Reading	Reading of Thermometers Placed: At Wall	Two ft. from Wall	3½ ft. from Center	At Center	Mean Temperature of Atmosphere
		Degrees F.				
Sept. 29	4:30 P.M.	86	95	96	96	64
Oct. 24	10:30 A.M.	71	82	91	91	54
Dec. 12	10:30 A.M.	43	63	80	*80 ~~73~~	26
Jan. 16	11:00 A.M.	52	60	71	72 ~~67~~	40
" 26	10:30 A.M.	34	56	~~84~~	72 ~~67~~	21
Feb. 5	1:00 P.M.	42	55	68	69 ~~64~~	30
" 18	10:30 A.M.	50	60	69	68 ~~63~~	45
" 25	10:45 A.M.	43	55	67	68 ~~63~~	34
Mch. 9	11:30 A.M.	41	60	64	66 ~~61~~	32
" 18	11:15 A.M.	43	57	64	66 ~~61~~	36
" 25	11:30 A.M.	37	56	63	64 ~~59~~	41
Apr. 6	9:45 A.M.	58	59	62	62 ~~57~~	64
" 15	9:45 A.M.	57	62	62	58 ~~55~~	64
" 29	9:30 A.M.	73	70	64	59	

* Resistance thermometers were placed approximately 20 feet from top of silage.

* When this bulb was taken from the silo it was found to read seven degrees too low between 70°-80°F. and five degrees too low between 60°-70°F.

TABLE 6.

TEMPERATURE READINGS* - TILE SILO.

Filled September 2 - 4, 1914.

Date of Reading	Time of Reading	Reading of Thermometers Placed: At Wall Degrees F.	Reading of Thermometers Placed: At Center Degrees F.	Mean Temperature of Atmosphere Degrees F.
Sept. 15	11:00 A.M.	79	92	72
Oct. 20	3:00 P. M.	64	89	64
Dec. 8	3:15 P.M.	49	81	38
Jan. 9	10:45 A.M.	39	77	36
" 23	11:00 A. M.	33	74	3
Feb. 8	11:30 A.M.	24	73	28
" 16	10:45 A.M.	30	71	37
Mch. 2	11:15 A.M.	44	68	35
" 16	10:45 A.M.	47	70	39
" 30	11:15 A.M.	50	65	37
Apr. 13	10:45 A.M.	71	65	50

* Resistance thermometers were placed approximately 22 feet from top of silage.

Due to accidents only a few temperature readings were obtained in Reid's Stave Silo, and in the Gurler Silo. However, they substantiate the readings obtained in the other silos.

These temperature readings are given in the following table:-

TABLE 7.

REID'S EAST STAVE SILO.

Date of Reading	Time of Reading	Reading of Thermometers Placed: At Wall Degrees F.	Reading of Thermometers Placed: At Center Degrees F.	Mean Temperature of Atmosphere Degrees F.
Sept. 9	11:45 A.M.	--*	71	64
Jan. 16	12:15 P.M.	---*	68	40
" 26	11:15 A. M.	--*	67	21
Feb. 5	2:30 P.M.	--*	66	30
GURLER SILO.				
Sept. 16	3:00 P.M.	94	114	77
" 27	12:00 N.	87	108	64
Oct. 18	3:00 P.M.	79	---**	60
Nov. 22	3:00 P.M.	70	---**	38

*Short Circuit.

**One thermometer pulled out and the other pulled to the wall.

The silage in the Gurler Silo was very dry and more or less moldy thruout.

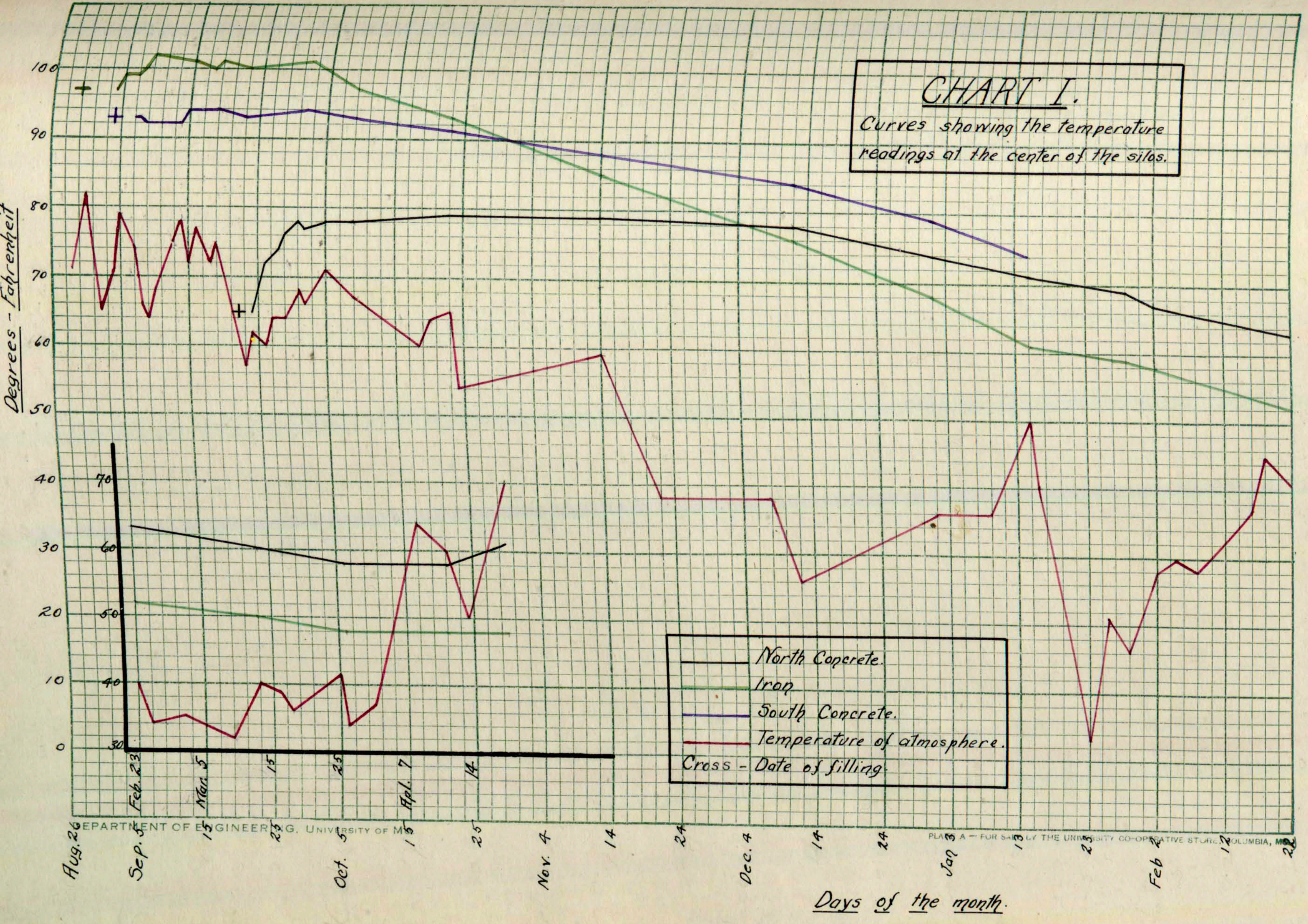
CHART I.
Curves showing the temperature readings at the center of the silos.
North Concrete.
Iron
South Concrete.
Temperature of atmosphere.
Cross - Date of filling.
Degrees - Fahrenheit
Days of the month.
Aug. 26
Sep. 5
Oct. 5
Nov. 4
Dec. 4
Jan 3
Feb 2
Feb. 23
Mar. 5
Apl. 7
DEPARTMENT OF ENGINEERING, UNIVERSITY OF MO.
PLATE A — FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

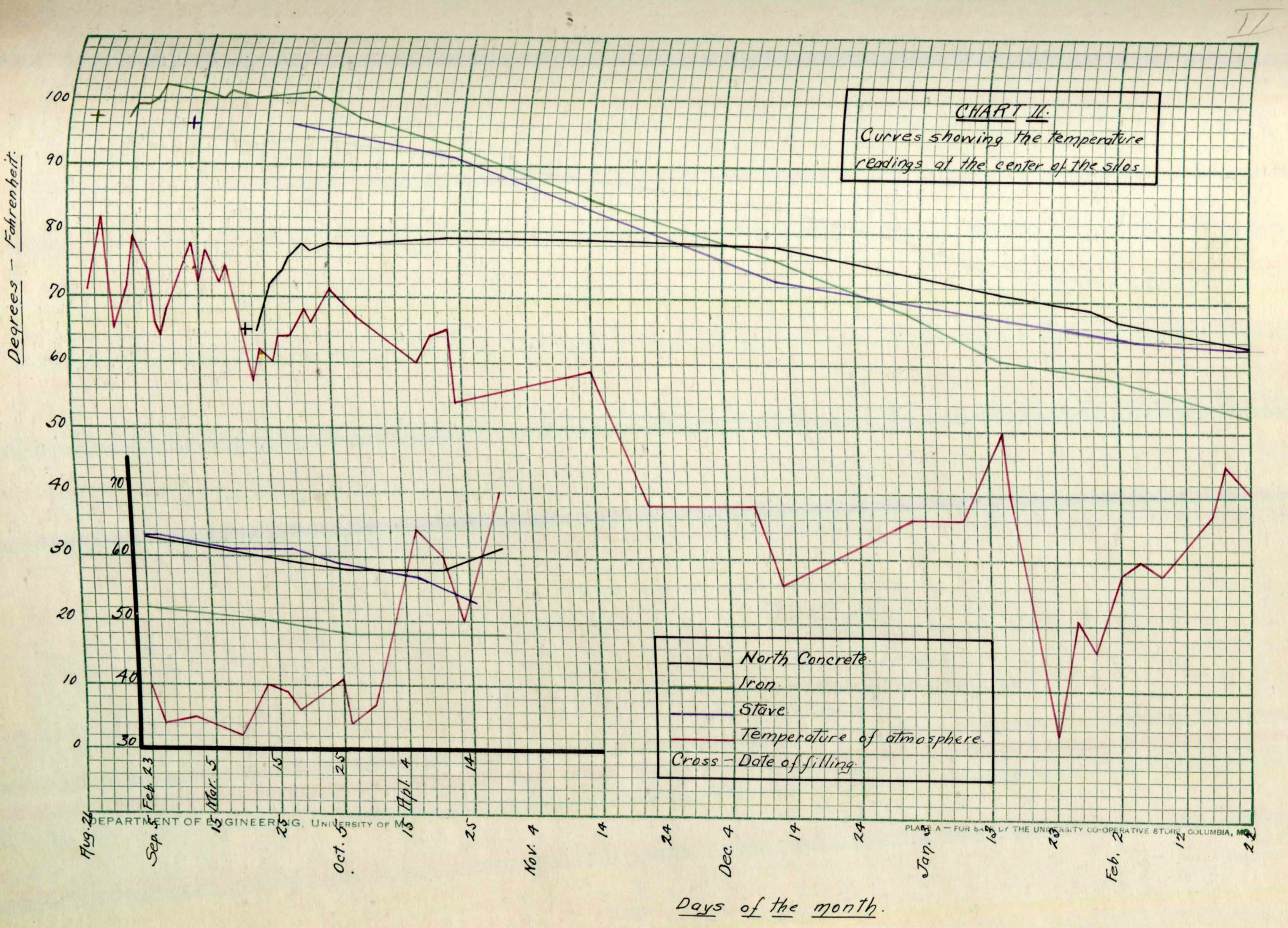
II
CHART II.
Curves showing the temperature readings at the center of the silos
North Concrete
Iron
Stave
Temperature of atmosphere
Cross - Date of filling
Degrees - Fahrenheit.
100
90
80
70
60
50
40
30
20
10
0
70
60
50
40
30
Feb. 23
Mar. 5
15
25
Apl. 4
14
Aug. 26
Sep. 5
15
25
Oct. 5
15
25
Nov. 4
14
24
Dec. 4
14
24
Jan. 3
13
23
Feb. 2
12
22
Days of the month.
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CHART III.
Curves showing the temperature readings at the center of the silo
Temperature of the atmosphere
South Concrete
Tile
Cross - Date of filling.
Degrees — Fahrenheit.
Days of the month.
0
10
20
30
40
50
60
70
80
90
100
Aug. 26
Sep. 5
15
25
Oct. 5
15
25
Nov. 4
14
24
Dec. 4
14
24
Jan. 3
13
23
Feb. 2
12
22
30
40
50
60
70
Feb. 23
Mar. 5
15
25
Apl. 4
14
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PLATE A — FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

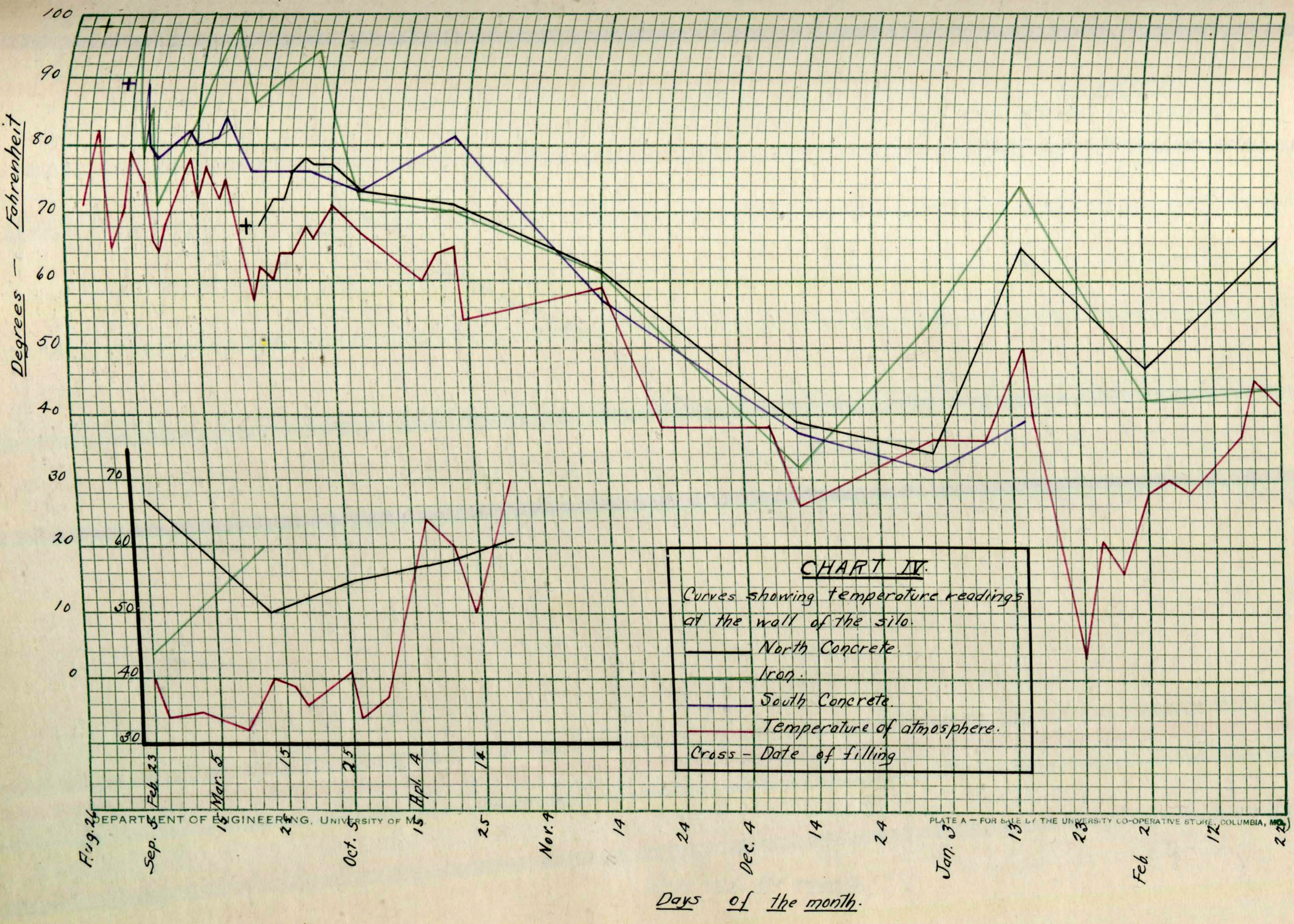
CHART IV.
Curves showing temperature readings at the wall of the silo.
North Concrete.
Iron.
South Concrete.
Temperature of atmosphere.
Cross - Date of filling
Degrees — Fahrenheit
100
90
80
70
60
50
40
30
20
10
0
Days of the month.
Aug. 26
Sep. 5
15
25
Oct. 5
15
25
Nov. 4
14
24
Dec. 4
14
24
Jan. 3
13
23
Feb. 2
12
22
Feb. 23
Mar. 5
15
25
Apl. 4
14
DEPARTMENT OF ENGINEERING, UNIVERSITY OF MO.
PLATE A — FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

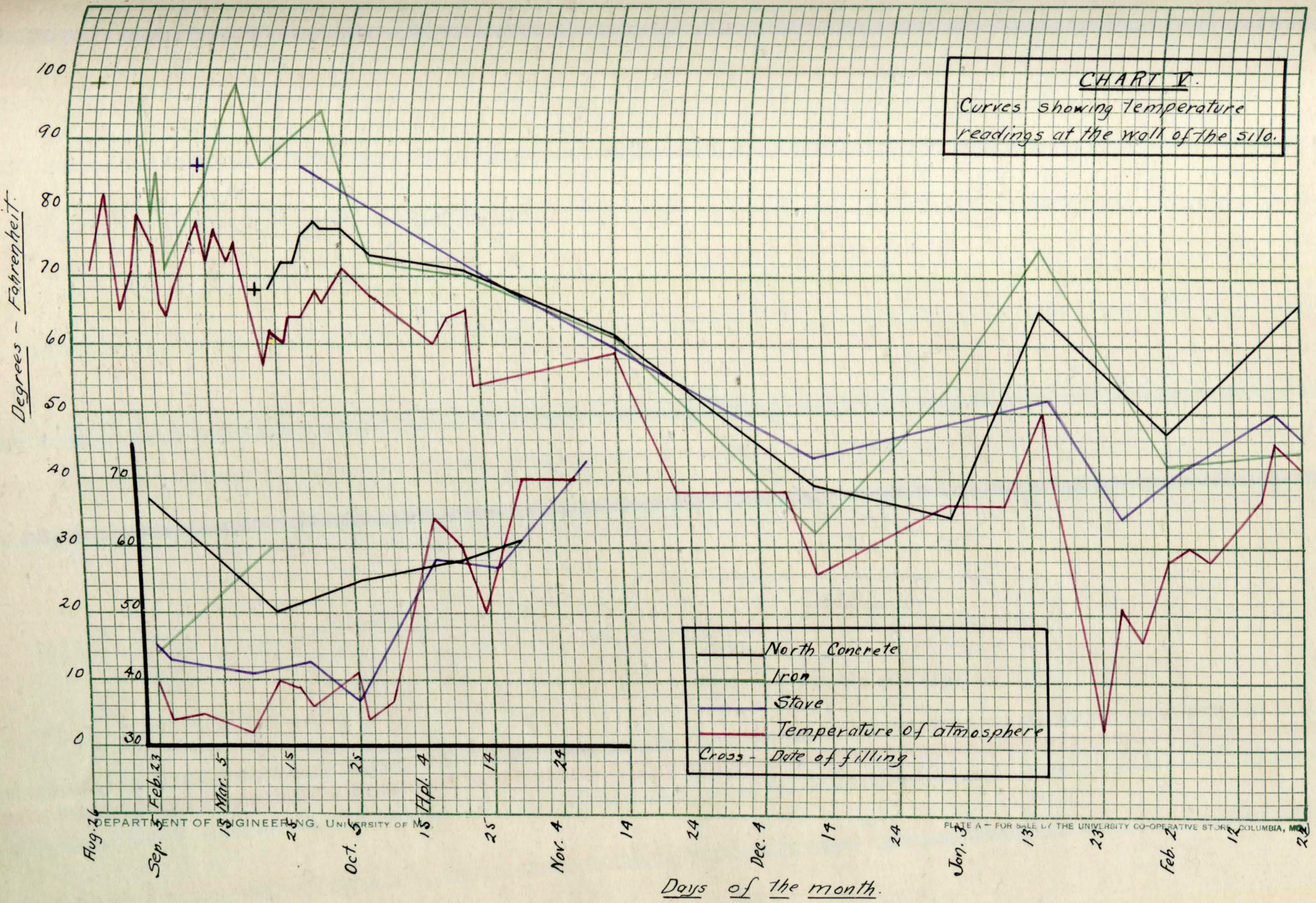

CHART V.
Curves showing Temperature readings at the wall of the silo.
North Concrete
Iron
Stave
Temperature of atmosphere
Cross - Date of filling.
Degrees - Fahrenheit.
Days of the month.
100
90
80
70
60
50
40
30
20
10
0
Aug. 26
Sep. 5
15
25
Oct. 5
15
25
Nov. 4
14
24
Dec. 4
14
24
Jan. 3
13
23
Feb. 2
12
22
Feb. 23
Mar. 5
Apl. 4
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PLATE A — FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

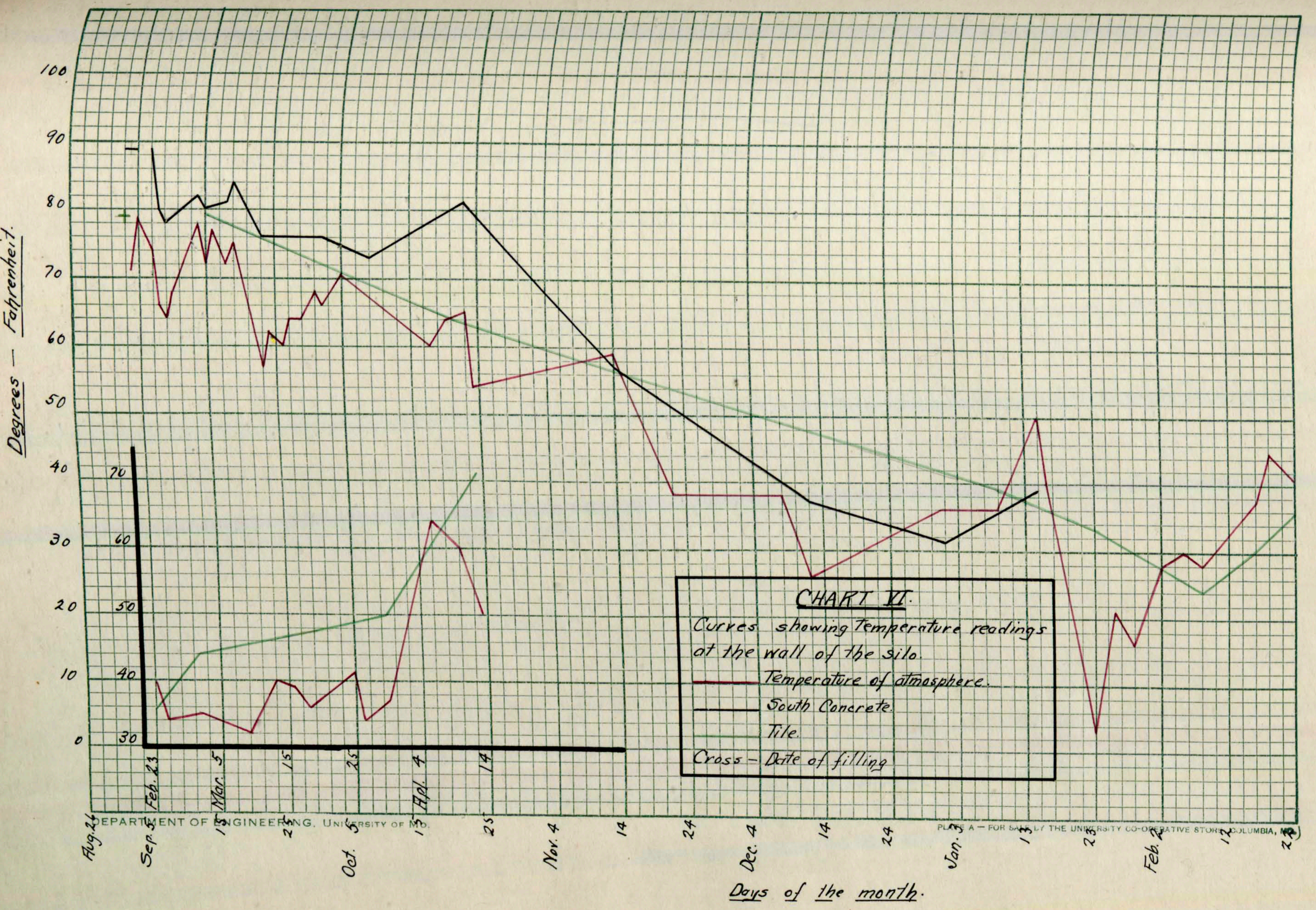
CHART VI.
Curves showing Temperature readings at the wall of the silo.
Temperature of atmosphere.
South Concrete.
Tile.
Cross - Date of filling
Degrees — Fahrenheit.
Days of the month.
Aug. 24
Sep. 5
Oct. 5
Nov. 4
Dec. 4
Jan. 3
Feb. 2
Feb. 23
Mar. 5
Apl. 4
DEPARTMENT OF ENGINEERING, UNIVERSITY OF MO.
PLATE A — FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

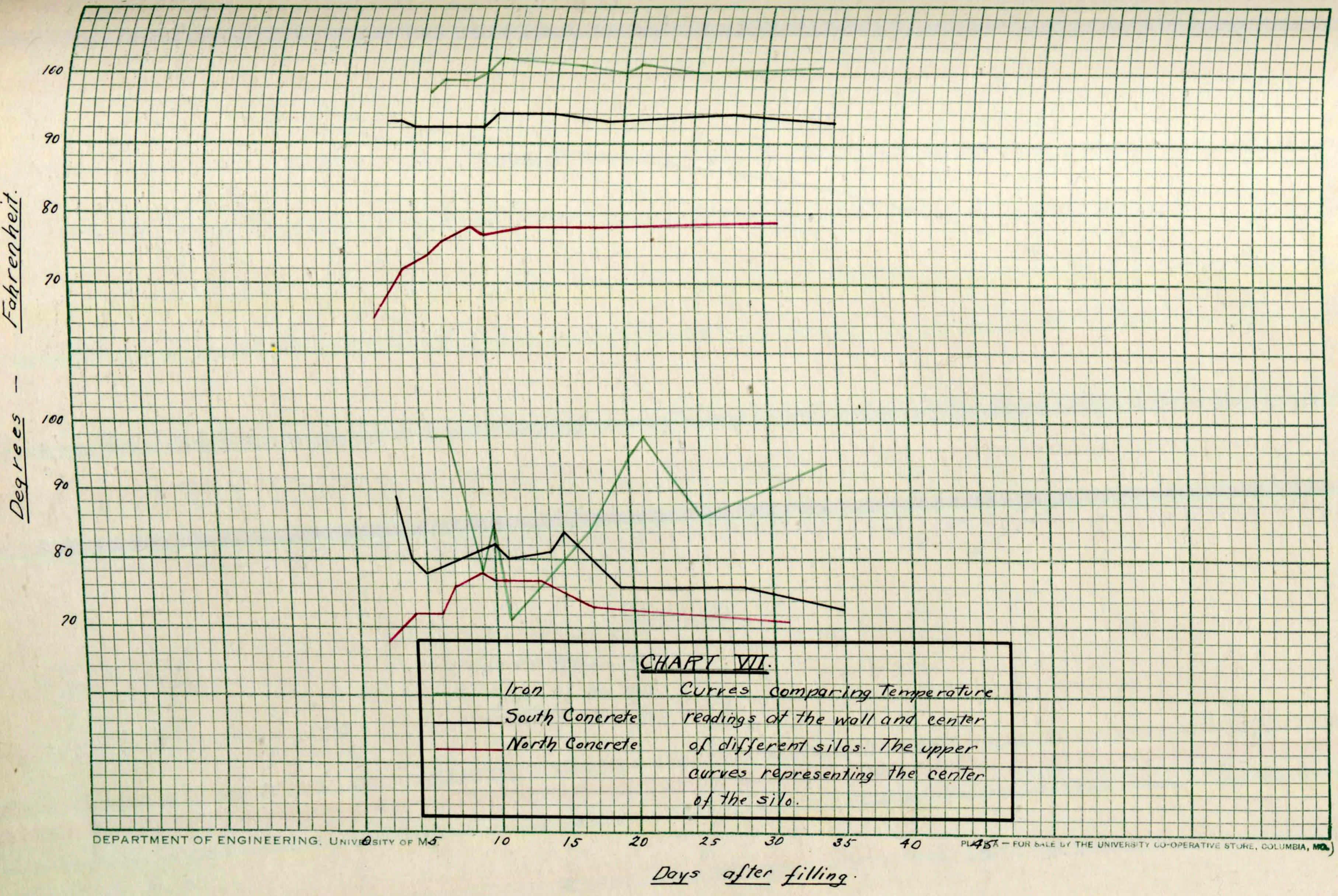
CHART VII.
Iron
South Concrete
North Concrete
Curves comparing Temperature readings at the wall and center of different silos. The upper curves representing the center of the silo.
Degrees - Fahrenheit.
100
90
80
70
0
5
10
15
20
25
30
35
40
45
Days after filling.
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PL 45A — FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

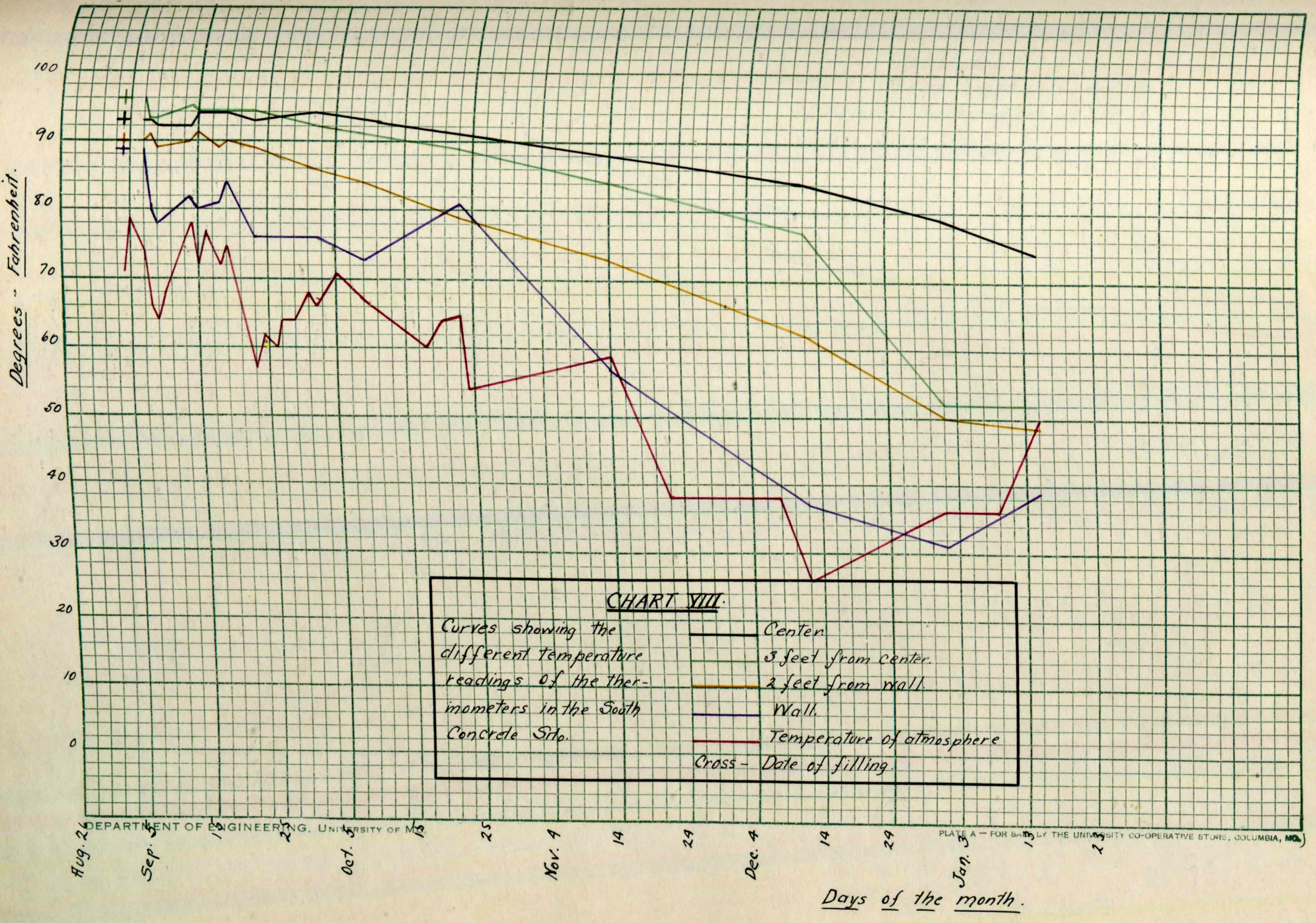
CHART VIII.
Curves showing the different temperature readings of the thermometers in the South Concrete Silo.
Center.
3 feet from center.
2 feet from wall.
Wall.
Temperature of atmosphere
Cross - Date of filling.
Degrees - Fahrenheit.
100
90
80
70
60
50
40
30
20
10
0
Aug. 26
Sep.
Oct.
25
Nov. 4
14
24
Dec. 4
14
24
Jan.
Days of the month.

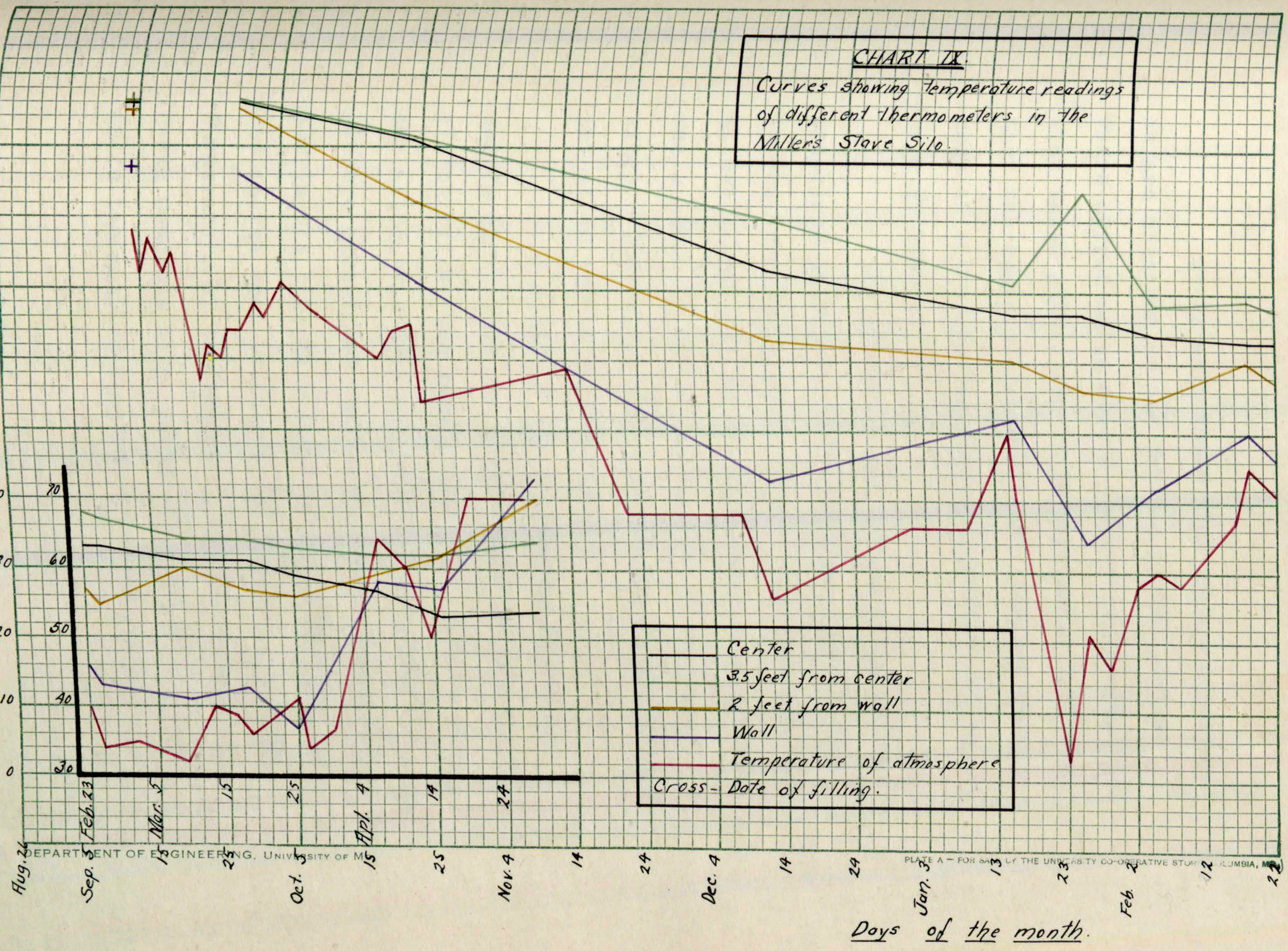
CHART IX.
Curves showing temperature readings of different thermometers in the Miller's Stave Silo.
Center
3.5 feet from center
2 feet from wall
Wall
Temperature of atmosphere
Cross - Date of filling.
Degrees Fahrenheit.
Days of the month.
Aug. 26
Sep. 5
15
25
Oct. 5
15
25
Nov. 4
14
24
Dec. 4
14
24
Jan. 3
13
23
Feb. 2
12
22
Feb. 23
Mar. 5
15
25
Apl. 4
14
24
100
90
80
70
60
50
40
30
20
10
0
70
60
50
40
30
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PLATE A — FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

It is well known that high temperatures are obtained at the surface of the silage where oxygen gains access and partial decomposition takes place, and it is popularily believed that the temperatures which are attained in the mass of silage during silage formation are as high or higher.

The silage in all of the silos was in excellent condition, with the exception of that in the Tile and Gurler silos. The Tile Silo contained a quantity of red mold thruout, and there was a large amount of white mold in the Gurler silo. Therefore, the temperatures in the different silos should be comparable.

A study of the preceeding tables and charts shows that the temperatures at the center of the silos were fairly uniform. And in only two silos, the Iron and Gurler Silos, did the temperature exceed 100 degrees F., the maximum being 102 in the Iron Silo ten days after filling, and 114 in the case of the Gurler Silo. A maximum temperature of 94 degrees F. was obtained in the South Concrete Silo, eleven days after filling; while the maximum temperature of 79 degrees F. in

the North Concrete Silo was not obtained until thirty days after filling.

Exceedingly high temperatures, 120 to 145 degrees F., were obtained only at the surface where air gained access; and these high temperatures were obtained in all of the silos.

The data show that there was a rather sharp rise in the temperature for the first two or three weeks, and then a gradual and quite uniform decline during the entire winter.

The temperature at the walls of the different silos fluctuated, following closely that of the atmosphere. The Iron Silo showed the greatest variability.

Charts No. VIII and No. IX show that for the first few weeks a small amount of heat may be developed by fermentation in the silage, but after this there is a gradual cooling of the mass of silage from the wall to the center of the silo; and that in time the temperature of the silage will become the same as that of the atmosphere.

Magruder[1] reports a maximum temperature of 110 and 120 degrees F. with two thermometers in

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1. Magruder's Thesis, 1914.

Conley's Stave Silo, one and two days respectively after filling; and 112 and 111 degrees F. with two thermometers in the Gurler Silo, three and five days respectively after filling. A temperature of 114 degrees F. was also obtained during the past winter in the Gurler Silo. Some mold was present thruout the silage in these silos.

All these facts indicate the presence of air in silage; and the conclusion that these high temperatures are due to the dry condition of the silage and insufficient packing is supported by the data obtained in Experimental Silos Nos. 1 and 2, and Nos. 7 and 8, which shows that free air in the silage resulted in high temperatures. These data are discussed on page 59 .

In the fall of 1913 Magruder reports a maximum temperature slightly above 100 degrees F. in the two concrete silos, which is higher than the temperatures obtained in these two silos during the fall of 1914. These higher temperatures are accounted for by the higher temperature of the atmosphere in the fall of 1913 during the time the silos were being filled, than the temperatures at

the time the silos were filled in the fall of 1914.

As a possible explanation of the difference in the temperatures in the different silos during the first few weeks, we offer the suggestion that it may be due to the temperature of the atmosphere during the time the silo was being filled.

The results on all of the silos indicate that the temperature in the silage is influenced to a very slight degree, if at all, by the material used in the construction of the silo. The only apparent exception to this conclusion is the Iron Silo. However, there are three possible explanations of why the temperature declined the fastest in the Iron Silo:-

1. The thin walls of the silo would permit faster radiation of heat from the silo.

2. The silo is only 12 feet in diameter, therefore there is a greater area per given mass of silage exposed to the walls of the silo.

3. The temperature of the atmosphere was much higher at the time this silo was filled than at the time of filling the other silos. The temperature in all of the silos at filling time was higher than the average mean temperature of the at-

mosphere at that time. The difference between the temperature in the Iron Silo and the average mean temperature of the atmosphere was greater than in the case of the other silos, therefore, the temperature would have a tendency to decline faster.

Temperatures in Experimental Silos -- As outlined in the plan of the experiment two Experimental Silos were filled with corn from the South Concrete Silo at the time it was being filled.

The corn was thrown loose into No. 1 and no weight was applied, while that of No. 2 was well tramped and 1500 pounds of weight applied.

Both silos were opened January 15, 1915.

The silage below the screen in No. 2 was normal in every way.

No. 1 contained a large amount of spoiled silage below the screen. However, the silage in the bottom of the silo was normal. This was probably due to the fact that the silage contained such a high percent of moisture that it packed itself to some extent and forced the air out.

Temperature observations on these two silos are given in Table 8.

The Effect of Air Upon Temperatures In Shock Corn Silage -- January 2 Experimental Silos No. 7 and No. 8 were filled with shock corn fodder. The fodder was brought directly from the field and run thru the silage cutter. Water was added to this fodder in the ratio of one pound of water to one pound of fodder, by sprinkling as the fodder was put in the silo.

The fodder was thoroly tramped in Silo No. 7 and 1500 pounds of weight applied. The temperature of the water used was 37 degrees F.

The fodder was thrown loose into silo No. 8 and no weight was applied. The water had a temperature of 33 degrees F.

Both silos were opened February 12, 41 days after filling. There was no evidence that any fermentation had taken place; the silage had the appearance of wet corn fodder.

There was no mold below the screen in silo No. 7, while there was a large quantity of white mold thruout the silage in silo No. 8.

Temperature readings in these two silos are given in Table 9.

TABLE 8.

TEMPERATURE READINGS - EXPERIMENTAL SILOS.

Filled September 3, 1914.

Date of Reading	Time of Reading	Experimental Silos No. 1 Degrees F.	Experimental Silos No. 2 Degrees F.
Sept. 4	3:15 P.M.	95	79
" 5	2:30 P.M.	110	87
" 7	4:30 P.M.	102	83
" 8	3:45 P.M.	96	84
" 9	4:00 P.M.	92	87
" 10	3:00 P.M.	89	87
" 14	4:45 P.M.	79	74
" 15	3:15 P.M.	81	75
" 17	4:45 P.M.	83	75
" 18	4:30 P.M.	84	76
" 19	3:30 P.M.	85	76
" 22	3:15 P.M.	86	77
" 23	4:15 P.M.	83	76
" 24	2:15 P.M.	80	74
" 28	10:00 A.M.	77	68
Oct. 2	3:30 P.M.	78	68
" 8	4:15 P.M.	80	70
" 13	3:45 P.M.	73	67
" 23	2:15 P.M.	73	63
Nov. 14	10:00 A.M.	63	58
Dec. 5	10:45 A.M.	56	48
Jan. 1	2:45 P.M.	32	31
" 15	8:30 A.M.	42	39

TABLE 9.

TEMPERATURE READINGS - SHOCK CORN SILAGE.

Filled January 2, 1915.

Date of Reading	Time of Reading	Experimental Silos No. 7 Degrees F.	Experimental Silos No. 8 Degrees F.	Temperature in barn loft Degrees F.
Jan. 4	9:45 A. M.	36	48	---
" 5	2:45 P.M.	38	76	--
" 6	9:45 A.M.	39	84	--
" 7	1:30 P.M.	40	74	--
" 8	1:15 P.M.	40	65	42
" 9	2:45 P.M.	41	59	48
" 11	4:30 P.M.	42	54	43
" 12	1:15 P.M.	41	51	42
" 13	4:15 P.M.	42	51	50
" 15	2:30 P.M.	43	53	56
" 18	2:30 P.M.	45	52	35
" 21	2:45 P.M.	38	46	30
" 23	2:30 P.M.	35	43	26
" 25	2:15 P.M.	33	39	30
" 29	2:45 P.M.	31	37	29
Feb. 2	2:00 P.M.	32	50	39
" 12	1:45 P.M.	55	43	64

Due to the small size of the Experimental Silos the temperature was influenced to some extent by the temperature of the atmosphere.

The temperature of the silage in Silo No. 7, Table 9, showed a gradual and quite uniform rise from 36 degrees F. on January 4 to 45 degrees F. on January 18.

The temperature in the other lots of silage showed a sharp rise to the maximum within three or four days, then a gradual but irregular decline, being influenced somewhat by the temperature of the atmosphere.

Higher temperatures were obtained at all times in the silage that had not been packed, and therefore contained an excess of air, as compared with the silage that had been packed. Undoubtedly some oxidation must have taken place to maintain these higher temperatures.

The high temperatures which are sometimes obtained in a silo indicate that the silage contained an excess of air. This may be due to a low moisture content; or insufficient packing. A certain percent of moisture is necessary to fill the

air spaces in the silage. Just what percent is essential to produce silage of the highest quality has not been determined.

The object of adding water to the silage is to aid in forcing the air out and thus increase the keeping qualities of the silage. Also silage with a high percent of moisture will keep better with the same amount of tramping than silage with a lower percent of moisture.

The fact that higher temperatures were obtained thruout this experiment in the silage which contained a large amount of entangled air as compared with that which was well packed and weighted to exclude the air indicates that free air must be considered as a factor affecting the temperature in silage.

MOISTURE, ACIDITY AND AIR IN SILAGE.

Object.

The object of this experiment is to determine:

1. The factors affecting the percent of moisture and acid in silage.

   (a) Material used in the construction of the silo.

   (b) Air in the silage.

   (c) The kind of silage.

2. The relation of the percent of moisture to the percent of acid in silage.

Plan of Experiment.

Large Silos -- Moisture and acidity tests were made of samples taken at the wall and near the center of the South Concrete Silo, the Iron Silo, the Tile Silo, Miller's Stave Silo, and Reid's East Stave Silo.

Air in the Silage -- Moisture and acidity tests were made of the silage in Experimental Silos Nos. 1, 2, 7, and 8.

The Kind of Silage -- Moisture and acidity tests were made of corn silage, cowpea silage, soybean silage, alfalfa silage, silage made of oats and field peas, and shock corn silage.

Discussion of Data.

The Large Silos -- Samples for moisture and acidity determinations were taken within the four inches directly in contact with the east wall, and near the center of each silo. These samples were taken at a depth from the surface of the silage sufficient to exclude the possibility of obtaining any spoiled silage.

Table 10 gives the percent of air dry matter and acidity at the wall and center of the different silos.

TABLE 10.

MOISTURE AND ACIDITY IN THE LARGE SILOS.

Name of Silo	Percent of Acid		Percent of Air Dry Matter	
	Wall	Center	Wall	Center
South Concrete Silo	2.02	2.73	32.27	28.85
Iron Silo	1.16	1.88	28.37	28.24
Tile Silo	1.45	2.20	37.08	38.21
Miller's Stave Silo	2.32	2.34	38.10	39.93
Reid's East Stave Silo	2.22	2.37	31.47	31.93

The percent of acid at the wall was uniformly lower than that at the center of the silo, however, there was very little difference in the case of the two stave silos. In all cases the difference was not sufficient to interfere with the keeping or feeding qualities of the silage.

Excepting the South Concrete Silo there was no very great difference in the percent of air dry matter at the wall as compared with the center of the silo. In the South Concrete Silo it was perceptably higher at the wall than at the center of the silo, but the difference was not enough to be considered.

We may conclude that a small amount of acid

is lost at the wall, but that there is practically no change in the percent of moisture.

Table 11 taken from Magruder's thesis supports this conclusion.

TABLE 11.

MOISTURE AND ACIDITY AT WALL AND IN CENTER OF SILOS.

Name of Silo	Percent of Acid		Percent of air dry matter	
	Wall	Center	Wall	Center
South Concrete Silo				
Near top of silage	1.64	1.83	30.7	30.60
13 ft. from top of silo	2.20	2.62	31.3	30.90
18 ft. from top of silo	1.52	2.20	31.56	32.11
23 ft. from top of silo	1.86	2.01	34.04	27.90
Stave Silo	1.49	2.27	34.38	35.40

Air in the Silage -- Experimental Silos Nos. 1 and 2 were filled with corn taken from the South Concrete Silo at the time it was being filled.

The corn was thrown loose into No. 1, and no weight was applied, while it was thoroly packed in No. 2 and 1500 pounds of weight were applied, as has previously been described under "Temperatures in Experimental Silos" (Page 55)

Experimental Silos Nos. 7 and 8 were filled

with shock corn fodder as described under "Temperatures in Shock Corn Silage" (page 56).

Table 12 gives the percent of acid and air dry matter in these silos.

TABLE 12.

No. of Exp. Silos	Percent of Acid	Percent of air dry matter
1	1.89	23.80
2	2.58	25.59
7	0.89	39.91
8	0.46	44.28
Gurler Silo*	1.03*	40.48*

*Magruder's thesis, 1914.

The percent of acid in the two silos which contained a large amount of entangled air (Nos.1 and 8) was lower than that of the two silos in which the silage was thoroly packed.

The silage was very dry in the Gurler Silo, and the fact that high temperatures were obtained (110 degrees F. to 114 degrees F.), and mold developed in spots in the silage indicates that a considerable amount of air was present.

The fact that there was uniformly a lower percent of acid in the silage containing an excessive amount of air indicates that air must be considered as a factor affecting the acidity in silage.

The Kind of Silage -- Moisture and acidity tests were made of different kinds of silage.

Table 13 shows that the nature of the silage crop affects the percent of acid in the silage; and the one which contains the greatest amount of soluble carbohydrates has the highest percent of acid.

TABLE 13.

No. of Exp. silo	Kind of Silage	Percent of Acid	Percent of air dry mat.	Days after filling
2	Corn	2.58	25.59	134
3	Soy Beans	0.68	26.60	57
4	Soy Beans	1.00	25.75	158
5	Dry Corn*	1.74	42.08	70
6	Cow Peas	0.40	15.52	69
7	Corn Fodder	0.89	39.91	41
A	Oats and Peas	1.82	33.05	42
B	Alfalfa	2.05	47.77	53

*Allowed to dry in the field until badly in need of water. to make normal silage.

The development of acid in the legume silage must be due changes other than the changes which take

place in the sugar content, since it is well known that the legumes contain a very small amount of sugar.

Relation of Moisture To Acidity in Silage -- Table 14 gives a comparison of the percent of acid to the percent of moisture in silage.

TABLE 14.

Percent of moisture compared with percent of acid		Percent of acid compared with percent of moisture	
Percent of Acid	Percent of moisture (Air Dry)	Percent of moisture (Air Dry)	Percent of Acid
2.73	71.15	72.10	2.01*
2.62	69.10	71.76	1.88
2.37	68.07	71.15	2.73
2.27	64.60	69.10	2.62
2.20*	67.89	68.07	2.37
2.20	61.79	67.89	2.20*
2.01*	72.10	64.60	2.27
1.88	71.76	61.79	2.20

*Water Added.

The data given in this table show very little relation between the percent of acid and

the percent of moisture in silage.

There is a variation of 32.9 percent between the extremes in the percent of acid, and only 16.6 percent between the extremes in the percent of moisture. Moreover the extremes in the percent of acid do not follow the extremes in the percent of moisture. The difference in the percent of moisture with the highest and lowest percent of acid is only 2.4 percent.

The highest percent of acid, 2.73 percent, was obtained with a high percent of moisture; however, the silage with the highest percent of moisture, 72.10 percent and to which water had been added, contained only 2.01 percent of acid.

The question arises:-- Is the acidity of silage influenced by the moisture in the silage, or is the acidity affected more by the maturity of the plant at the time of ensiling?.

It is a recognized fact that the percent of moisture and sugar is influenced by the maturity of the plant. The higher percent of moisture and sugar being found in the more immature plant. And the sugar of the plant is considered to be the main source of acid in silage. As the plant ma-

tures the sugar changes to starch; therefore there is less sugar available to be converted into acid.

Therefore it appears to us that the maturity of the plant should be a greater factor in the formation of acid in silage than the percent of moisture; as water is quite frequently added to silage; and it is difficult to conceive that the addition of water should increase the acidity of silage.

But if the acidity is affected by the maturity of the plant at the time of ensiling there should be a direct relation between the percent of moisture in the plant and the percent of acid in the silage. However, the data given in Table 14 does not bear out this statement, and the facts available indicate that there is very little relation, if any at all, between the percent of moisture and the percent of acid in the silage.

LOSSES IN SILAGE.

Object.

It is generally believed that there is a considerable loss in weight of silage in the silo. But some work which was done at the Wisconsin Experiment Station[1] indicates that the losses may be less than 10 percent.

The object of this experiment is to obtain additional data on this point.

Plan of Experiment.

Each time an experimental silo was filled a record was kept of the amount of the silage put into the silo. A wire screen was placed so that there would be about one foot of silage above it when the silo was filled. The object in using this screen was to make a clear division between the loss of nutrients due to the fermentation of the silage and the loss at the surface that occurs from exposure to air. The silage both below and above the screen was carefully weighed, and samples for analyses were taken both at the time of filling

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1. Annual Rpt. 1895, pp. 273-278.

the silo, and again when the silo was emptied. A moisture test was made of the silage crop; and moisture and acidity tests were made of the silage when the silos were emptied. All calculations are based upon the amount of silage below the screen.

Discussion of Data.

It was hoped that the chemical analyses of some of these samples would be available so that the loss of nutrients in silage could be taken up. As it is only the losses in weight will be discussed.

A record of the Experimental Silos for the winter 1914 - 1915 is given in Table 15.

The data in this table are based upon the weights and analyses of the silage below the screen.

The table shows that there is uniformly a slight decrease in the percent of air dry matter in all of the silos. There was no great loss in weight. The corn fodder silage showed an actual gain of 1.25 percent; this is accounted for by the settling of water from the silage above the screen;

Table XV

No. of Silo	Kind of Silage	Pounds weighed in	Pounds weighed out	Pounds of loss in weight	Percent of loss in weight	Percent of air dry matter when put in	Percent of air dry matter when taken out	Percent of loss in air dry matter	Percent of acid	Days after filling
I	Peas and Oats	652.0	630.0	22.0	3.37	33.70	33.10	5.09	1.82	42
II	Corn	792.5	773.0	19.5	2.46		25.59		2.58	134
III	Soybeans	830.0	818.0	12.0	1.44	26.83	26.60	6.78	0.68	57
*IV	Soybeans	892.0	824.75	67.25	7.53	26.83	25.75	11.28	0.99	158
V	Partially Dried Corn	579.0	551.0	28.0	4.83	45.93	42.08	12.82	1.74	70
VII	Corn Fodder	600.0	607.5	7.5	1.25	40.87	39.91	1.14	0.89	41

* This silo leaked some moisture.

however, there was a loss of 1.14 percent in air dry matter.

The silage made from corn which was allowed to dry (Silo No. 5) in small shocks in the field until it was considered to be badly in need of water to make normal silage showed the greatest loss in weight, not-with-standing the fact that it was extraordinarily well tramped into the silo and 1500 pounds of weight applied. The fact that there was a small amount of mold around the edge of the bottom of this silo indicates that all of the air was not excluded, consequently the losses would be greater.

All of the silos showed a greater percent of loss in air dry matter than in weight, the greatest loss being in silo No. 5.

The first five silos in Table 15 show an average loss of 3.92 percent. While Magruder reports a loss in weight of 3.93 percent, as an average of five lots during the winter 1913 - 1914.

<u>Losses at the Surface of the Silage</u> -- After filling operations had ceased one-half barrel of common salt was spread over half of the surface of the silage in the South Concrete Silo.

One-half of the surface of the silage in the North Concrete Silo was covered with tarred paper, the edges overlapping about two inches, then a load of cowpeas was run thru the silage cutter and put on top of this paper.

The object in both cases was to determine whether there is any special treatment which will decrease the losses at the surface of the silage.

The South Concrete Silo was opened October 15,. So far as could be noted there was no difference in the amount of spoiled silage between the salted and unsalted portions of the surface. However, on the half that had been salted, about three inches of the surface was much wetter than where no salt had been applied.

The North Concrete Silo was opened March 26, 1915. There was only about six inches of spoiled silage on the part covered with tarred paper and cowpeas, and about 16 to 18 inches of spoiled silage on the part untreated. The layer of silage in contact with the under side of the tarred paper was quite wet.

It is interesting to note that the good silage under the tarred paper was cold, while the good silage under the surface that had not been treated was warm to the touch, indicating that oxidation was still taking place.

SHOCK CORN SILAGE.

Object.

The data available indicates that fairly good silage can be made from shock corn fodder by adding water as the fodder is put into the silo. However, since shock corn fodder is not usually put into the silo before cold weather, and likewise the water is cold; the question naturally arose as to the effect of the temperature of the water upon the quality of the silage.

Therefore, the object of this experiment was to determine the effect of the temperature of the water added upon the quality of the silage produced.

Plan of Experiment.

On January 2, Experimental Silo No. 7, and two experimental cans were filled with shock corn fodder. Water was sprinkled on the fodder in the ratio of 1 : 1 as it was put into the silo.

The fodder was well packed into Silo No. 7 and 1500 pounds of weight applied. The temperature of the water used was 37 degrees F. A resis-

tance thermometer was placed in the center of the silo.

The fodder was well tramped into the cans, the tops put on, then heavy pressure was applied with a cheese-press. The tops were wired on and the cans sealed with paraffin. The water used had a temperature of 55 degrees F. These cans were first placed in the refrigerator, but the temperature became too cold so they were changed January 23, to a room with a temperature of 54 degrees F.

The silo and cans were opened February 12, 41 days after filling.

Discussion of Data.

In the experimental silo the temperature rose from 36 degrees F. on January 4 to 45 degrees F. on January 18, then declined to 32 on February 2. When opened on February 12 the silage had a temperature of 55 degrees F.

The temperature of the room in which the cans were kept varied from 38 to 67 degrees F., the average being 53. With six exceptions the range was within five degrees of 53.

So far as could be noted there was no evidence that any fermentation had taken place; the silage had the appearance of wet corn fodder.

There was no mold below the screen in the experimental silo. About four inches of silage in the bottom of the silo was very wet, due to the settling of some water. This silage was not very sour to taste.

There was some mold around the bottom of the cans, and thruout the surface of the silage, due to the cans admitting air.

A summary of the results is given in Table 16.

TABLE 16.

Silo No.	Percent of loss in weight	Percent of loss in air dry matter	Percent of acid*	Temperature of water degrees F.	Days after filling
7	+1.25	1.14	0.87	37	41
1	7.45	11.12	1.20	55	41
2	11.11	14.68	1.20	55	41

*The dry fodder contained 0.66 percent of acid at time of siloing.

Both cans showed a greater loss than the silo. However, they both leaked some water, and

the fact that some mold was present indicates that some destructive processes were taking place.

The silage at the higher temperature developed more acid than that in the silo at a lower temperature.

As far as could be determined by appearance, the silage in the cans was identical with that in the silo.

If temperature is a factor in the production of silage from shock corn fodder, it is evident that we must have a temperature higher than those used in this experiment.

LEGUMES FOR SILAGE.

Object.

The object of this experiment was to determine the character of the silage produced from legumes.

Plan of Experiment.

Experimental silos were filled as follows:-

One was filled with peas and oats, June 24, 1914.

One was filled with alfalfa, July 9, 1914.

Two were filled with soy beans, September 21, 1914.

One was filled with cowpeas, October 3, 1914.

A record was kept of the amount put into each silo, and of the amount of silage weighed out. Samples were taken for analyses, both at the time of filling the silo, and again when the silo was emptied.

Discussion of Data.

All of the crops were put into the silo as soon after cutting as possible.

Peas and Oats -- The oats were somewhat immature, but the peas were beginning to dry out; however, the crop shows a normal percent of air dry matter.

There was a loss of only 3.37 percent in the weight and 5.09 percent in air dry matter, and the silage contained 1.82 percent of acid. The silage was in good condition when taken out of the silo. It had a pleasant odor and taste, and there was no mold visible.

The bottom three or four inches of silage were very much wetter and had a very bad rotten odor. This condition was possibly due to a small amount of water left in the silo at the time of filling. This water was used for wetting the sides of the silo.

The cows did not eat the silage as readily at first as corn silage, but they ate the third feed greedily.

Alfalfa -- The second cutting of alfalfa

was used, and most of it was in bloom. On account of the dry weather the dry matter was probably considerably higher than normal for alfalfa of this stage.

The silage had 2.05 percent of acid and was in excellent condition when taken out of the silo, altho it seemed quite dry. There was some mold below the screen on account of not having enough alfalfa above it. There was a very little dry mold around the edge of the bottom. The cows ate the silage readily.

Soy Beans -- Two experimental silos were filled with soy beans that were well seeded and at about the proper stage for making hay.

Fifty-seven days after filling, the silage was taken out of the first silo. It sustained a loss of only 1.44 percent in weight and 6.78 percent in air dry matter, and had only 0.68 percent of acid. The silage had a very disagreeable odor and a bitter taste. No acid could be detected by taste. Some moisture had settled in the silo, and water could be wrung out of the bottom two or three inches of silage. Most of the cows refused the silage, and those that did eat it, ate very sparingly.

The second silo was opened 158 days after filling. This silage sustained a loss of 7.53 percent in weight and 11.28 percent in air dry matter.as compared with 1.44 percent and 5.09 percent respectively in the first silo. However, this silo leaked moisture for some little time before being opened. The silage had 0.99 percent of acid.

None of the silage above the screen appeared to have spoiled. In a few places next to the wall and just below the screen there was a very small amount of white mold. Also around the edge of the bottom there was a small amount of rotten silage. Otherwise, the silage seemed to have kept perfectly. It was very dark thruout, and had a disagreeable odor; but it did not have a bitter taste, however, it was not very palatable. No acid could be detected by taste.

<u>Cowpeas</u> -- The cowpeas had not yet begun to bloom, and were not mature enough for hay, as is shown by the fact that they had only 13.14 percent of air dry matter. However due to the probability of a killing frost they had to be cut.

This silo leaked so much water that the data collected on this silage is of little value. Only 0.40 percent of acid developed.

The silage was very wet, and had a somewhat disagreeable odor and taste. No acid could be detected by taste. The silage in the bottom of the silo was slightly wetter than that at the top. The cows ate this silage readily.

A comparison of the losses in the different kinds of silage is given in Table 17.

From this experiment we may conclude that it is quite practical to ensile peas and oats, and alfalfa.

We also believe that if the soy beans and cowpeas had been allowed to dry out somewhat before being ensiled, that a fair quality of silage could have been produced.

However, corn is a better silage crop, and where possible the silo should be filled with corn, and the legumes made into hay.

Table XVII

Kind of Silage	Pounds weighed in	Pounds weighed out	Pounds of loss in weight	Percent of loss in weight	Percent of air dry matter when ensiled	Percent of air dry matter when taken out	Percent of loss in air dry matter	Per-cent of acid	Days after filling
Peas and Oats	652.0	630.0	22.0	3.37	33.7	33.1	5.09	1.82	42
Alfalfa	639.0**	805.0	----	----	45.7	47.77	----	2.05	53
Soybeans	830.0	818.0	12.0	1.44	26.83	26.60	6.78	0.68	57
Soybeans*	892.0	824.75	67.25	7.53	26.83	25.75	11.28	0.99	158
Cowpeas*	945.0	732.0	213.0	22.54	13.14	15.52	19.5	0.40	69

**Probably an error in the weight.

*Silos leaked some moisture.

CAPACITY OF SILOS.

Object.

We could find no information concerning the capacity of silos, other than that based upon the results of Prof. King's work at the Wisconsin Experiment Station in 1892. His figures were based upon the weights of the green material put into the silo, and are averages for the whole silo. According to his own statement his work was not sufficiently extensive to furnish a safe basis. It is certain that the ordinary figures are too high.

This experiment was planned to obtain definite knowledge as to the capacity of silos, and to obtain the weight per cubic foot at different depths in the silage.

Plan of Experiment.

All of the corn was weighed into the concrete silos at the dairy barn on the University Farm. Three markers of burlap sacks were put in the South Concrete Silo at different depths in the silage, during the time of filling.

Weights Per Cubic Foot at Different Depths in the Silo -- The weight per cubic foot at different depths in the silage was taken with the "Kansas Apparatus" in the following silos:

South Concrete
North Concrete
Iron
Tile
Dorsey's Concrete
Estes' Concrete
Miller's Stave
Reid's East Stave
Reid's West Stave.

Discussion of Data.

A total of 47.8 tons of corn were put in the North Concrete Silo, with no markers. The silage settled four and one-half feet, which made a layer of silage twelve feet, seven inches thick, six months after filling.

A total of 124.7 tons of corn was put in the South Concrete Silo, and three markers were put in at different depths as the silo was filled. This

silo was opened 42 days after filling and the silage had settled five feet, and the markers were recovered at the following depths from the surface as the silage was fed out:-

15 feet, 2 inches; 17 feet, 11 inches; and 21 feet, 11 inches respectively. Thus we had four layers of silage as follows:-

The first one was 15 feet, 2 inches thick.
The second one was 2 feet, 9 inches thick.
The third one was 4 feet thick.
The fourth one was 5 feet, 4 inches thick.

It was not considered practical to weigh the silage as it was fed out, for undoubtedly some one would forget to weigh a cart load occasionally; which would seriously interfere with the results. Therefore, all of the calculations are based upon the weights of the green corn weighed into the silo.

The weight for each section, the average weight per foot of depth, and the average weight per cubic foot is given in Table 18.

TABLE 18.

Silo	No. of Section from top	Feet and inches in Section	Tons in Section	Av. Wt. per ft. of depth Tons	Av. wt. per cubic foot Pounds
North Concrete	---	12'-7"	47.88	3.80	37.85
South	1	15'-2"	57.60	3.79	37.78
Concrete	2	2'-9"	10.50	3.81	38.28
	3	4'-0"	24.60	6.15	61.28
	4	5'-4"	26.90	5.04	50.26
Total for: Silo		27'-3"	124.70	4.57	43.71

The weight per foot of depth, and the average weight per cubic foot in the North Concrete Silo were identical with those of the first layer in the South Concrete Silo.

There is very little difference in the weight per foot of depth between the first and second layers of silage in the South Concrete Silo. But there is an increase in the third layer over the second of 61.9 percent. The fourth layer was one ton lighter per foot of depth than the third layer. The total depth of silage in the South Concrete Silo averaged 4.57 tons per foot of depth.

The table shows an average of 3.8 tons

per foot for the upper 18 feet, and an average of 5.59 tons for the lower 9 feet.

Weights Per Cubic Foot at Different Depths in the Silo -- It has been suggested that silage expands as the weight is removed from above, and therefore the weights as taken with the "Kansas Apparatus" would not be accurate.

In the fall of 1913 when the experimental silos were filled a screw press was arranged to compress the silage. After compressing the silage as tight as possible, it was then allowed to remain for two or three hours, and at that time the screw could be turned with ease; showing that the upward pressure had disappeared. It appears that the settling of silage is due to the air being forced out, and not to the elasticity of the material put in the silo.

There were 1500 pounds of weight applied to the surface of the silage in an experimental silo at filling time. Four and one-half months later when the silo was opened, the distance from the top of the silo to the lid just before removing the weight was the same as that after the weight had been removed.

There were 103,151 pounds of green corn weighed into the two lower sections of the South Concrete Silo, and it was estimated from the average of the weights of a cubic foot as taken by the "Kansas Apparatus" in these sections that 110,150 pounds were taken out, which is a difference of only 6.78 percent and could easily be made by the methods used. No allowance was made for the losses that naturally occur in the silo. These weights do not support the supposition that silage expands when the weight is removed, because from these figures there was more silage taken out than was weighed in.

If the silage in the lower part of the silo expanded when the weight above was removed, it would be expected that the silage would pull away from the wall. This was not observed to be the case.

From these observations we believe that the silage does not expand when the weight above is removed; therefore the weight of a cubic foot of silage as taken with the "Kansas Apparatus" is considered to be quite accurate.

All of the weights taken were reduced to the air dry basis for the purpose of comparison.

The weights per cubic foot of silage at different depths in all of the silos are given in Tables 19 to 26 inclusive.

The distance, from the top of the silage before opening, to the surface of the silage at which the cubic foot was taken, was used as the depth from the surface of the silage at which the weight of the cubic foot was taken.

There is very little uniformity between the weights at the same depth in the different silos.

All of the tables show that there is an increase in the weight per cubic foot of the fresh silage, for the first nine to twelve feet of depth, and below this the weights are fairly constant for succeeding depths. The weights for the air dry silage do not show this same variation in all of the silos. Reid's two stave silos show very little if any increase in weight at the succeeding depths.

The South Concrete Silo showed an increase of 50 percent in the air dry matter between the first and last weights, while there was an increase

of only 30 percent in the weights of the fresh silage. This difference may be accounted for by the difference in the maturity of the corn. The last of the filling was entirely too green to make the best of silage. However, there was no uniformity between the increase of the fresh and the air dry silage in each silo, and in the different silos.

Dorsey's Concrete Silo when compared with the Tile Silo shows about the same weight per cubic foot for the fresh silage, but it has a much higher percent of air dry matter, therefore the weight of the air dry silage per cubic foot is much greater. This difference is accounted for by the fact that the silage in Dorsey's Concrete Silo was packed very much better, forcing out more of the air; therefore it has a greater weight of air dry matter.

At the beginning of the experiment it was thought that by reducing the weights to the air dry basis we would eliminate most of the variations; but such was not the case.

The question then arose:- How are we to account for these wide variations in the different silos?

If we choose the weight of a cubic foot of silage in one silo and compare it with the weight of a cubic foot at a corresponding depth in any other silo, we find a wide variation, even if the amount of air dry matter weighs the same.

If we assume that a cubic foot of silage free from air weighs the same as a cubic foot of water, we can explain this difference in weight by the difference in the amount of air in the silage. This is clearly shown in the following diagrams:

The weights used in these diagrams are checked in Tables 19 and 25.

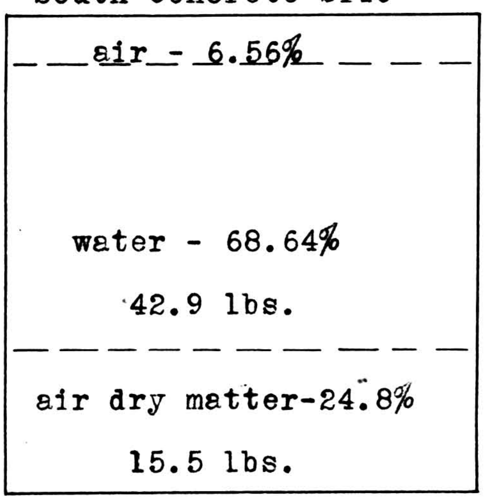
It appears that silage reaches a limit of compressibility at about 9 to 12 feet, and below this point the increased pressure will not force out any more air. The only means of forcing out the rest of the air is to add water.

From the diagrams we may conclude that the addition of water to silage aids in forcing out the air and increases the weight of the fresh silage per cubic foot, but does not materially increase the weight of the air dry matter.

In addition to the amount of water added it is probable that there are several other factors

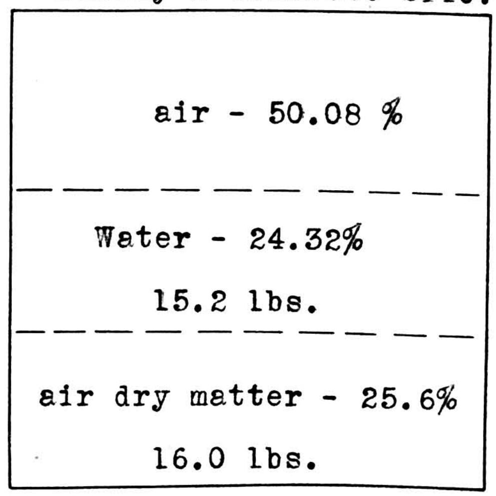
Diagrams showing the relative amounts of air dry matter, water, and air in a cubic foot of silage.

South Concrete Silo



The cubic foot in the South Concrete Silo was taken 23'-4" from the surface and weighed 58.4 pounds, and contained 26.55 percent of air dry matter.

Dorsey's Concrete Silo.



The cubic foot in Dorsey's Concrete Silo was taken 23'ft. from the surface and weighed 31.2 pounds, and contained 51.25 percent of air dry matter.

which affect the weight of silage per cubic foot, among which are the following:-

The maturity of the corn plant.

The fineness of cutting.

The proportion of grain to fodder.

The amount of packing at the time of filling.

The amount of pressure.

The depth of the silage.

Possibly the diameter of the silo.

Every silo is a complication of these factors.

TABLE 19.

WEIGHTS OF SILAGE - SOUTH CONCRETE SILO.

Date		Distance from top of silage: Feet	Inches	Pounds per cubic foot fresh	Percent air dry Matter	Pounds per cubic foot Air dry
Oct.	17	1	6	44.7	24.41	10.9
"	23	2	7	45.0	24.57	11.0
Nov.	3	4	5	47.0	25.23	11.8
"	14	5	8	48.0	24.00	11.5
"	23	7	9	52.0	25.95	13.5
Dec.	5	9	2	53.0	24.56	13.0
"	15	10	11	54.0	25.41	13.7
Jan	4	14	2	60.5	28.12	17.0
"	22	16	10	58.0	25.69	14.9
Feb.	2	18	9	60.0	28.85	17.2
Mch.	1	21	8	58.5	27.78	16.2
"	15	23	4	58.4	26.55	15.5*

TABLE 20.

WEIGHTS OF SILAGE --- TILE SILO.

Date	Distance from top of silage: Feet	Distance from top of silage: Inches	Pounds per cubic ft. Fresh	Percent air dry Matter	Pounds per cubic foot air dry
Dec. 18	2	1	34.0	29.27	9.9
Jan. 9	7	3	36.9	39.12	14.4
" 23	9	4	37.1	37.15	13.8
Feb. 8	12	1	39.2	38.21	14.9
" 16	13	4	43.0	34.21	14.7
Mch. 2	15	4	40.0	35.00	14.0
" 16	17	2	39.2	34.29	13.5
" 30	19	6	36.7	34.13	12.5
Apr. 14	20	9	39.2	34.86	13.6

TABLE 21.

WEIGHTS OF SILAGE - MILLER'S STAVE SILO.

Date	Distance from top of silage: Feet	Distance from top of silage: Inches	Pounds per cubic ft. Fresh	Percent air dry Matter	Pounds per cubic foot air dry
Feb. 18	2	4	26.5	41.58	11.0
" 25	4	2	27.5	43.23	11.8
Mch. 9	6	6	28.7	39.31	11.3
" 18	8	0	31.3	39.93	12.5
" 25	9	5	33.6	38.95	13.1
Apr. 6	11	1	38.9	29.68	11.5
" 15	13	6	37.7	37.31	14.0
" 29	15	2	41.4	40.13	16.61

TABLE 22.

WEIGHTS OF SILAGE - REID'S EAST STAVE SILO.

Date	Distance from top of silage: Feet	Inches	Pounds per cubic ft. fresh	Percent air dry matter	Pounds per cubic foot air dry
Jan. 16	13	2	47.4	31.40	14.9
" 26	15	8	42.5	32.79	13.9
Feb. 5	17	9	49.1	31.93	15.6
" 18	20	7	48.9	28.54	13.9
" 25	22	4	51.7	31.09	16.0

TABLE 23.

WEIGHTS OF SILAGE - REID'S WEST STAVE SILO.

Date	Distance from top of silage: Feet	Inches	Pounds per cubic ft fresh	Percent air dry matter	Pounds per cubic foot air dry
Mch. 18	6	5	30.9	44.07	13.6
" 25	9	10	31.7	49.63	15.7
Apr. 6	14	7	34.2	37.15	12.7
" 15	18	1	32.5	47.29	13.7

TABLE 24.

WEIGHTS OF SILAGE - IRON SILO.

Date	Distance from top of silage: Feet	Inches	Pounds per cubic ft. fresh	Percent air dry matter	Pounds per cubic ft. air dry
Mch. 15	4	0	30.9	35.66	11.0
Apr. 1	7	2	44.2	28.24	12.5
" 14	8	6	39.1	34.07	13.3
" 29	10	4	42.4	27.64	11.7

TABLE 25

WEIGHTS OF SILAGE - DORSEY'S CONCRETE SILO.

Date		Distance from top of silage: Feet	Inches	Pounds per cubic ft. fresh	Percent air dry matter	Pounds per cubic ft. air dry
Feb.	16	10	6	34.2	37.29	12.7
Mch.	2	16	10	28.4	47.39	13.4
"	16	23	0	31.2	51.25	16.0*
"	30	28	6	42.1	37.90	15.9
Apr.	13	32	6	40.3	44.69	18.0
"	27	34	9	39.3	42.08	16.5

TABLE 26.

WEIGHTS OF SILAGE -- ESTES' CONCRETE SILO.

Date		Distance from top of silage: Feet	Inches	Pounds per cubic ft. fresh	Percent air dry matter	Pounds per cubic ft. air dry
Mch.	2	6	0	28.0	40.48	11.3
"	16	9	8	37.2	33.53	12.4
"	30	14	0	36.4	40.53	14.7
Apr.	13	18	6	41.2	35.37	14.5
"	27	22	0	38.8	40.16	15.6


CHART X.
Curves showing the weights per cubic foot at different depths in the silos.
South Concrete - Fresh silage.
South Concrete - Air dry silage.
Dorsey' Concrete - Fresh silage.
Dorsey's Concrete - Air dry silage.
Estes' Concrete - Fresh silage.
Estes' Concrete - Air dry silage.
Weight in Pounds.
60
55
50
45
40
35
30
25
20
15
10
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30
32.5
35
Depth in feet.
DEPARTMENT OF ENGINEERING, UNIVERSITY OF MO.
FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

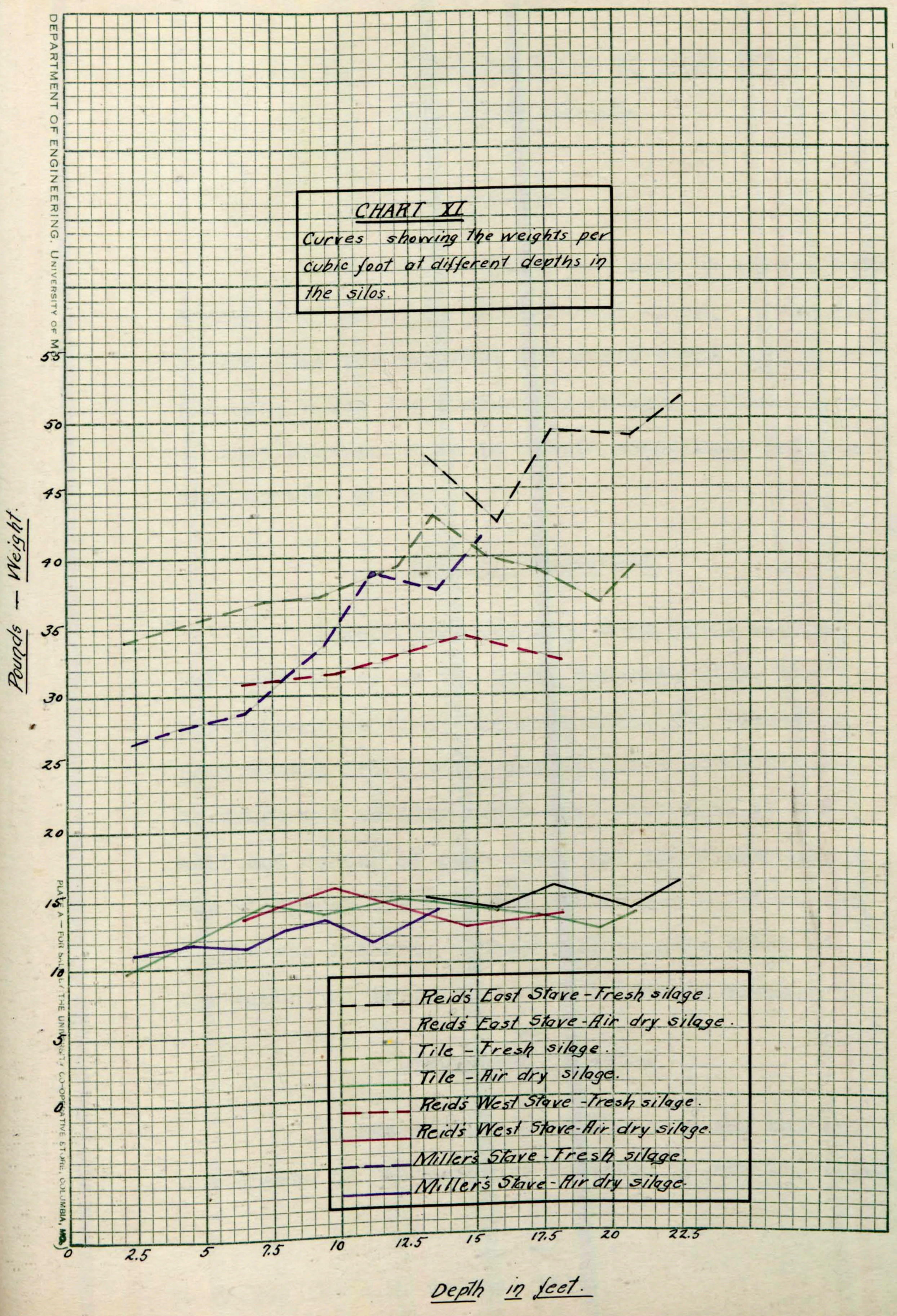


CHART XI
Curves showing the weights per cubic foot at different depths in the silos.
Pounds - Weight.
55
50
45
40
35
30
25
20
15
10
5
0
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
Depth in feet.
Reid's East Stave - Fresh silage.
Reid's East Stave - Air dry silage.
Tile - Fresh silage.
Tile - Air dry silage.
Reid's West Stave - Fresh silage.
Reid's West Stave - Air dry silage.
Miller's Stave - Fresh silage.
Miller's Stave - Air dry silage.
DEPARTMENT OF ENGINEERING, UNIVERSITY OF M

VALUE OF DIFFERENT KINDS OF SILOS FOR PRESERVING SILAGE.

Object.

Conflicting claims are made by silo agents concerning the value of different silos. Magruder[1] showed that the concrete and stave silos have about the same value for preserving silage. The object of this experiment is to obtain additional information on this point.

Plan of Experiment.

Temperature readings were taken at the wall and center of the South Concrete Silo, the North Concrete Silo, the Iron Silo, the Tile Silo, Reid's East Stave Silo, and Miller's Stave Silo. Moisture and acidity tests were also made at the wall and center of each silo, and the appearance of the silage at the wall and center was noted as the silage was fed out. Observations were taken of the amount of freezing in the different silos.

Discussion of Data.

As has already been shown in the tables and charts on "Temperature Readings in Silos", there

1. Thesis for A.M. degree, 1914.

was no great variation in the temperature at the wall in one silo as compared with another; moreover, the variations were within the limits between which normal silage is produced.

In every silo the percent of acid was lower at the wall than at the center, and in some of the silos this difference was quite marked; however, there was sufficient acid in all cases to preserve the silage. There was practically no difference in the percent of moisture at the wall as compared with the center.

So far as could be noted from appearance the silage at the wall kept as well as that at the center of the silo. There was considerable mold thruout the silage in the Tile Silo, but it is thought to be due to the fact that the silage was quite dry and very poorly packed.

No difference was noted in the amount of freezing in one kind of silo as compared with another.

Since the period of silage formation only extends over three weeks to a month, and occurs at that time of year when the weather is never exceedingly cold, we may conclude that no one type of silo has any particular advantage over others as

affects the fermentation of silage.

Therefore, the only factor to be considered in erecting a silo is to have the walls air tight, and strong enough to withstand the latteral pressure.

SMALL SILOS FOR EXPERIMENTAL PURPOSES.

Object.

The data taken during the winter 1913 - 1914 and reported in Magruder's thesis, seems to show conclusively that the small silos are reliable for experimental purposes except in the case of temperatures.

The object of this experiment was to obtain additional data on this point.

Plan of Experiment.

During the time of filling the South Concrete Silo enough corn was taken out to fill an experimental silo, and the place marked. When the silage was fed out to this marker the experimental silo was opened. Samples were taken for analyses from the experimental silo and from the South Concrete Silo, both at time of filling and again when the small silo was emptied.

Discussion of Data.

The chemical analysis of these samples was not available, therefore only a comparison of

the acidity and the appearance of the silage will be taken up.

The silage in the small silo contained 2.58 percent of acid and 25.59 percent of air dry matter as compared with 2.31 percent of acid and 27.01 percent of air dry matter in the South Concrete Silo.

So far as could be noted from appearance the silage in the small silo was identical in every way with that in the large silo.

These data substantiate the conclusion given by Magruder; which is, that silos three feet in diameter and six feet high, and made of two inch material, are reliable for experimental purposes except in temperatures.

SUMMARY AND CONCLUSIONS.

At the beginning of this paper several leading questions were asked.

The summary is given in the form of answers to these questions.

Temperature

1. The temperature in large silos is not an important factor in silage fermentation, for if the silage crop is properly ensiled, the range of variation in the temperature at this time will be within the limits considered to be essential for the production of good silage.

2. The results on all of the silos show that the temperature in the silage is influenced to a very slight degree, if at all, by the material used in the construction of the silo.

3. The data show that for the first few weeks a small amount of heat may be developed by fermentation in the silage, but after this there is a gradual cooling of the mass of silage from the wall to the center of the silo; and that in time the temperature of the silage will become the same as that of the atmosphere.

4. The fact that higher temperatures were obtained at all times in the silage which contained a large amount of entangled air as compared with that which was well packed to exclude the air indicates that free air must be considered as a factor affecting the temperature in silage.

5. The temperatures which are obtained in the silage are influenced in a large degree by the temperature of the atmosphere at the time of filling the silo.

Moisture and Acidity.

6. There was a smaller amount of acid at the wall as compared with the center of the silo.

7. The fact that there was uniformly a lower percent of acid in the silage containing an excessive amount of air indicates that air must be considered as a factor affecting the acidity of silage.

8. The percent of acid is affected by the nature of the silage crop; the one which contains the greatest amount of soluble sugar has the highest percent of acid.

9. The percent of moisture at the wall

was practically the same as that at the center of the silo.

10. The facts available indicate that there is very little relation, if any at all, between the percent of moisture and the percent of acid in silage.

Losses in Silage.

11. The silage in five experimental silos showed an average loss in weight of 3.92 percent.

12. There was a loss of only six inches of silage at the surface which was covered with tarred paper and cowpeas, as compared with 16 to 18 inches on the part untreated.

13. So far as could be noted there was no difference in the amount of spoiled silage between the salted and unsalted portions of the surface.

Shock Corn Fodder as Silage.

14. So far as could be determined from appearance the silage made from shock corn fodder

at a temperature of 53 degrees F. was identical with that at a temperature of 39 degrees F. However, as judged from appearance there was no evidence that any fermentation had taken place in either silage; since it had the appearance of wet corn fodder.

Legumes for Silage.

15. Good silage was made from peas and oats, and alfalfa.

16. We believe that a fair quality of silage can be made from soy beans and cowpeas, if they are allowed to dry out somewhat before being ensiled.

Weight of Silage.

17. Weights based upon the amount of green corn weighed into two concrete silos, 16 feet in diameter, show an average weight of 3.8 tons per foot of depth for the upper 18 feet, and an average of 5.59 tons for the lower 9 feet.

18. From a study of the weights of a cubic foot of silage as taken with the "Kansas Apparatus", it appears that silage reaches a limit

of compressibility at about 9 to 12 feet, and below this point the increased pressure will not force out any more air.

19. The addition of water to silage simply serves to force out the air and increases the weight of the fresh silage per cubic foot, but does not materially increase the weight of the air dry matter.

20. There was a great deal of variation in the weights of a cubic foot of silage in the different silos. Undoubtedly the weights are affected by factors other than the amount of water added.

Kind of Silo.

21. Since the period of silage formation extends over three weeks to a month, and occurs at that time of year when the weather is never exceedingly cold, we may conclude that no one type of silo has any particular advantage over others as affects the fermentation of silage.

Experimental Silos.

22. Silos three feet in diameter and six feet high are reliable for experimental purposes, except in the case of temperatures.

ACKNOWLEDGMENT

The writer wishes to express his appreciation to C. H. Eckles, Professor of Dairy Husbandry, University of Missouri, for his helpful suggestions in the preparation of this paper.

UNIVERSITY OF MISSOURI
COLUMBIA

COLLEGE OF AGRICULTURE
DEPARTMENT OF FARM MANAGEMENT

May 20, 1915.

Dr. Walter Miller,
Chairman, Graduate Committee,
Academic Hall.

Dear Sir:

I am returning to you today the thesis of Mr. O. I. Oshel. I have gone over this thesis pretty carefully. It seems to me to represent more work, if anything, than is given to the average thesis for a Master's degree. While the results of the experimental work do not show that anything new has been discovered, yet the results of the investigation are of considerable value in that they agree in most respects with previous work which has been done along this line. The work is of a great deal of value in that previous work has not covered enough cases to prove conclusively the points made. I believe the work adds considerable in that way.

I do not take up any of the details of the work as I do not know that you wish to have me do this in a letter. If you wish more detail,

in regard to the various parts of the thesis, I will be glad to furnish it.

Trusting that this will be of help to the committee, I am

Very truly yours,

O. R. Johnson

Assistant Professor of

Farm Management

ORJ/MR

DUE	RETURNED
MU MAR 15 2013	

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