Thermal conductivity and surface treatment of silo walls

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Thermal Conductivity and Surface Treatment of Silo Walls

BY HENRY GIESE

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IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS
R. M. HUGHES, Acting Director

AGRICULTURAL ENGINEERING SECTION

AMES, IOWA
SUMMARY AND CONCLUSIONS

1. Temperatures taken inside the north wall on concrete, hollow block and wooden stave silos, follow outdoor temperatures rather closely and show little advantage in favor of any one material.

2. Temperatures taken near the center of the silo are higher than and fluctuate less than those near the wall surface.

3. Under most conditions, silage itself is a good insulator. Much heat may be lost through open doors, or out of the top of an unroofed silo. Exposure to cold winds is an important factor. Any of these or a combination of them may have more influence upon the amount of frozen silage than the construction of the wall.

4. All of the materials tested in connection with the study of wall surface treatments gave complete protection for a limited time only.

5. Cement plaster gave the best protection in rendering a clay block silo wall air-tight, but considerable difficulty was experienced in securing a satisfactory bond with the tile.

6. Bituminous coatings have proved satisfactory on tile silos and are easily applied. A high grade roofing cement containing asbestos fibers in asphalt, will stay in place better than asphalt alone. At least the first coat of this cement should be thinned with gasoline to a consistency which will permit application with a brush and so that it may be used cold. Hot applications of asphalt chill quickly upon contact with the cold silo wall, harden at once and fail to bond.

7. The apparent necessity for wall treatment on concrete stave silos has been to stop, or at least retard, the corrosive action of silage acids. Several of the materials accomplished this purpose fairly well. Difficulty was experienced with all specimens due to the sealing of the original cement wash. For this reason, if the wall has been coated with a cement wash, treatment should be deferred until all traces of the original wash are gone. It may appear necessary to act at once to preserve the interior surface of the silo. This corrosive action, however, is not as serious as it may seem at first, and the results will well repay one for waiting. Any treatment applied following a cement wash is likely to fail because of imperfect bond between the wash and the stave.
Thermal Conductivity and Surface Treatment of Silo Walls

By Henry Giese

The work reported in this bulletin deals with two problems in connection with the use of the silo. The first part relates to the thermal conductivity of the wall and its influence on the amount of frozen silage. The second part reports observations on a number of surface treatments which gave promise of rendering the wall air and water-tight and also of reducing the erosion of the wall due to the silage acids.

THERMAL CONDUCTIVITY TESTS

The kind of material used in building a silo does not make much difference in the extent to which the silage freezes.

This is the conclusion reached by the Iowa Agricultural Experiment Station as a result of tests covering several years in which the thermal conductivity of various types of walls was studied. A good deal has been said about the alleged advantages or disadvantages of various construction materials.

The Station tests, made with concrete, hollow clay block and wooden stave silos, show that the heat conductivity of these materials should not be a major consideration in the selection of a silo. Original cost, length of life and freedom from need of repair are more important points to consider.

FIRST OBSERVATIONS MADE IN 1912

The first observations on the amount of freezing were made by the Station in March, 1912. Emil Y. Cable reported the conditions found in 13 silos (table I). More silage froze that year than in the average winter. The geographical location, the kind of material used in the silo wall, thickness of the silo wall and the amount of frozen silage are shown in table I.

In these early observations the amount of frozen silage varied a great deal. Some of the causes suggested for these differences are:

1. Condition of corn when put in the silo. Mature dry corn freezes much less than corn cut in a greener state.
2. Location of silo with reference to barn or other protection.
3. Method of removing silage.
4. Heat loss through poorly constructed roof, chute and open doors.
5. Thickness of wall.
6. Material used in walls.

One stave silo south of Waterloo was reported frozen entirely over so that none except frozen silage could be removed.
### TABLE I. FROZEN SILAGE IN IOWA SILOS

<table>
<thead>
<tr>
<th>Location</th>
<th>Wall Material</th>
<th>Thickness inches</th>
<th>Frozen silage, inches</th>
<th>Direction from barn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ames Wood</td>
<td>2</td>
<td>24</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>Waterloo Wood</td>
<td>3</td>
<td>26</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>Waterloo Wood</td>
<td>2</td>
<td>42</td>
<td>S</td>
</tr>
<tr>
<td>4</td>
<td>Waterloo Wood</td>
<td>2</td>
<td>12</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>Plymouth Wood</td>
<td>2</td>
<td>12-18</td>
<td>SW</td>
</tr>
<tr>
<td>6</td>
<td>Waterloo Brick</td>
<td>8</td>
<td>28</td>
<td>S</td>
</tr>
<tr>
<td>7</td>
<td>Waterloo Clayblock</td>
<td>4</td>
<td>8-12</td>
<td>S</td>
</tr>
<tr>
<td>8</td>
<td>Waterloo Clayblock</td>
<td>4</td>
<td>6-12</td>
<td>S</td>
</tr>
<tr>
<td>9</td>
<td>Northwood Clayblock</td>
<td>4</td>
<td>12-30</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>Ames Clayblock</td>
<td>5</td>
<td>24-30</td>
<td>N</td>
</tr>
<tr>
<td>11</td>
<td>Waterloo Clayblock</td>
<td>8</td>
<td>8</td>
<td>S</td>
</tr>
<tr>
<td>12</td>
<td>Mason City Clayblock</td>
<td>8</td>
<td>8-16</td>
<td>E</td>
</tr>
<tr>
<td>13</td>
<td>Mason City Clayblock</td>
<td>8</td>
<td>8-13</td>
<td>N</td>
</tr>
</tbody>
</table>

Some farmers stated that even during this extreme winter they could have kept the amount of frozen silage down to a minimum if they had removed the outside each day thereby keeping the top of the silage level. Once this was neglected, the thickness of frozen silage around the outside increased each day.
Beginning in the fall of 1913, a more systematic comparison was made, using three silos on the Iowa State College farm. These silos, as shown in figs. 1, 2 and 3, were constructed of monolithic concrete, hollow clay blocks (the original "Iowa silo") and wooden staves. Each year of the tests the silos were filled at approximately the same time and under similar conditions.

In the first tests (in the winter of 1913-14) electric resistance thermometers were used to take temperature readings at various points in the silo. With some variation the same plan was followed in the winter of 1914-15. In neither winter were the tests satisfactory, because the cable coverings deteriorated rapidly when exposed to the silage acids. Moisture reached the resistance coils causing short circuits and erroneous readings. Accordingly, in the following year mercury thermometers were suspended in 1-inch pipes. The thermometers were placed in glass tubes partially filled with alcohol to maintain a uniform temperature while the tubes were pulled to the surface for reading.

Three pipes were imbedded in the silage, one near the north wall, one at the center of the silo and the third half way between the other two. In each pipe one thermometer was placed just below the surface of the silage, another halfway down and a third at the bottom of the pipe, as shown in fig. 4. The thermometers were placed and the readings begun Oct. 9. As the surface of the silage was lowered, the thermometers were also lowered, but were kept in the same relative positions.

Figure 5 shows the daily fluctuations of temperature at the mid-point (from top to bottom) of the silo, (thermometer No. 2 in fig. 4). These temperature readings are for all three silos during November, 1915. Temperatures averaged by 10-day periods are shown in figs. 6 and 7.
OBSERVATIONS IN 1916-17

For the 1916-17 tests mercury thermometers were placed in the silos in the same way as in 1915-16. The silos were filled about the middle of September and readings were begun Sept. 25. They were taken both morning and evening between the hours of 5 and 6.

As the silage was lowered the surface thermometers were lowered until they reached the midway thermometers. The surface ones were then removed and the midway thermometers were lowered with the silage. (Between Dec. 3 and 7 the center pipe thermometer of the stave silo was caught in the pipe and it was impossible to obtain readings.)

In fig. 8 is plotted a comparison of temperatures averaged in 10-day periods as with the 1915-16 data (figs. 6 and 7). This figure shows that just inside the north wall the temperature of the silage followed closely that of the temperature outside the silo, but there was no large nor significant difference in the temperature of the silage in the concrete, clay block and
Fig. 5. Daily temperatures for November, 1915; thermometer No. 2.
Fig. 6. Comparison of north wall temperatures, 1915-1916.
Fig. 7. Comparison of silage temperatures, 1915-1916.
Fig. 8. Comparison of north wall temperatures, 1916-1917.
Fig. 9. Comparison of silage temperatures, 1916-1917.
wooden stave silos. In fig. 9 is shown the average of the readings of the thermometers at the center of the silo and midway between the center and north wall. As in the previous figure, the temperatures shown in fig. 9 indicate that the type of material used in the wall construction had no significant effect on the temperature of the silage—or, in other words, on the amount of frozen silage.

If one examines fig. 9 carefully, he will find that the temperature in the center of the silo is just a trifle above that of the silage midway between the center and north wall. He will further note that the temperature of the silage decidedly increases from the bottom to the top of the silo.

**TREATMENT TO MAKE SILO WALLS IMPERVIOUS**

If silo walls are not air-tight a good deal of silage spoils. One of the problems encountered in the clay block Iowa silo is to make the walls tight.

Various materials were tried in order to find one that would make the walls air and water-tight. From these tests and various other observations it was concluded that a bituminous compound was most satisfactory if it could be protected from abrasion.

Cement plaster also proved very satisfactory in preventing the spoilage of silage, but the plaster did not adhere to the walls too well.

Other tests were made in attempts to find a satisfactory coating for the walls of a cement stave silo. The problem here is not only to make the walls air tight, but also to prevent erosion by silage acids. Various commercial products were tried as well as such home-prepared products as cement washes and linseed oil and turpentine. Out of these tests the various products were classified as to their effectiveness.

**TESTS WITH CLAY BLOCK SILO**

The first tests to make silo walls impervious were on the hollow block silo on the C. F. Curtiss farm near the College. This silo is 16 feet in diameter, 30 feet above grade and is constructed of 4 by 8 by 12-inch straight blocks. Because the blocks are straight, the outside joints are rather wide, averaging about an inch. Many of the joints are open, perhaps due both to difficulty in making so wide a vertical joint tight and to carelessness by the masons in laying the wall. During heavy rains water beats into these joints and enters the silo. The inside wall was not finished smoothly, and in places large pieces of mortar adhered to the joints.

The inside wall in August, 1914, was divided into five strips of equal width as shown in fig. 10. One strip (No. 5) was thoroughly cleaned with a wire brush and left untreated as a
check. Each of the others was treated with one of the following:

1. A wash made of cement and water mixed to the consistency of paint. The silo wall was very dry and the wash dried before it could set properly. It was therefore of little value.

2. A Sylvester solution. This treatment consisted first of a coat of boiling soap solution made by dissolving \( \frac{3}{4} \) pound of castile soap per gallon of water, and second a solution of 1 pound alum to 8 gallons of water applied after the soap solution had dried. The entire operation was repeated. This treatment made no apparent difference in the character of the wall.

3. A ½ inch coating of asphalt heated to 250 degrees F. and applied with a brush. Much trouble was experienced in finding a brush which would withstand the action of the hot asphalt. The asphalt coating did not harden sufficiently in the silo and the silage adhered badly. Near the surface, where the temperature became high soon after filling, the asphalt was melted.

4. A cement plaster coating. This consisted of 1 part cement, 2 parts fine sand and a little lime to increase the adhesiveness. These were mixed with water to a quaky consistency.

Of these only the cement plaster was at all satisfactory. The plaster prevented spoilage of silage next to it, but it did not adhere to the wall in many places. It was put on during hot weather and set too quickly for satisfactory results.

Since the first treatments were generally unsatisfactory, in the fall of 1915 the materials used were all cleaned off, except the cement plaster, and the wall was divided into seven strips as shown in fig. 11. These were treated as follows:

1. Black silo paint. This was obtained from the Glidden Varnish Company, Cleveland, Ohio, and was a bituminous product thinned with a petroleum distillate. A strip 5 feet wide
and extending to the top of the silo was painted with two coats
of this material, allowing 24 hours between coats. This treat­
ment gave a hard, black, shiny surface.

2. Cement plaster with ceresit waterproofing. This strip
was the same width as the first. The wall was covered with
$\frac{1}{4}$ inch of a plaster made of 1 part cement and 2 parts sand.
Ceresit, a product manufactured by the Ceresit Waterproofing
Company, of Chicago, was added to the mixing water at the
rate of 1 part to 12 parts water.

3. Colorless waterproofing. This strip, 6 feet in width,
was given one coat of colorless waterproofing manufactured by
the Glidden Varnish Company.

4. Liquid rubber. This strip, 7 feet wide, was first treated
with "liquid rubber," an asphaltic product obtained from the
Glidden Varnish Company. It was reduced with turpentine
to the consistency of thick paint. This was covered with ap­
proximately $\frac{1}{2}$ inch of a cement plaster comprising 1 part ce­
ment to 2 parts sand.

5. Cement plaster. This strip, treated with cement plaster
in July 1914, was not changed.

6. Cement plaster with Impervite waterproofing. This strip
was given two coats of cement plaster comprising 1 part ce­
ment, 2 parts sand and 1/5 part Impervite. The Impervite
was reduced to a paste by the addition of water and then mixed
with the mortar.

7. Check strip. A strip about 3 feet in width was left as
a check.

As in the previous year's tests, the cement plaster appeared
to be the best of all these treatments. The observations of
these various test strips up to 1923 are given in table II.

In 1922, the lower 28 feet in the silo of strips 1, 2, 3, 4 and 7
were given a thick coat of a bitumen thinned with gasoline
(Desmo's compound). The condition of the various strips in June, 1924, and Sep­
tember, 1926, seemed almost identical with that reported in
September, 1923. Panels 5 and 6 were in fair condition, but
in general the plaster on number 5 looked better than on num­
ber 6. The plaster of number 6, however, was almost entirely
intact, while portions of number 5 had broken off in several
places.

The bituminous coating applied in 1922 apparently had little
beneficial effect upon any of the panels. The only remaining
evidences of the earlier attempts to waterproof were the plas­
tered sections, 5 and 6. While these strips appeared in fair con­
dition to the casual observer, it was discovered that the plaster
of neither was bonded to the wall, but remained in position be­
cause of its inherent strength and shape. Large areas were
# Table II. Wall Surface Treatment—Clay Block Silo

<table>
<thead>
<tr>
<th>Strip No.</th>
<th>Wall Treatment</th>
<th>Condition when inspected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Black silo paint</td>
<td>Badly peeled, no apparent protection</td>
</tr>
<tr>
<td>2</td>
<td>Cement plaster ceresit waterproofing</td>
<td>Surface good, but hollow sound when tapped indicated poor bond in places</td>
</tr>
<tr>
<td>3</td>
<td>Colorless waterproofing</td>
<td>Apparently of no value</td>
</tr>
<tr>
<td>4</td>
<td>Liquid rubber cement plaster</td>
<td>In good condition; adjacent silage good</td>
</tr>
<tr>
<td>5</td>
<td>Cement plaster applied July 1914</td>
<td>Condition same as No. 2</td>
</tr>
<tr>
<td>6</td>
<td>Cement plaster impervite waterproofing</td>
<td>Condition same as No. 2</td>
</tr>
<tr>
<td>7</td>
<td>Check strip</td>
<td>Good mortar joints except white scale as noted on plaster strip</td>
</tr>
</tbody>
</table>

Giese: Thermal conductivity and surface treatment of silo walls

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released and dropped when a thin, flat iron was slid between the plaster and silo wall.

In September, 1926, the plaster was entirely removed, the interior wall of the silo was cleaned with wire brushes and then painted with a bituminous roofing paint thinned with gasoline to a consistency that would permit application with a brush. This appeared to bond well, especially at the mortar joints.

In May, 1927, it was noted that there had been some tendency for the silage to stick to the bitumen, especially near the bottom of the silo, although this may have been due to the fact that the silo was filled very soon after it was painted. The silage kept very well through the winter.

**TESTS ON CONCRETE STAVE SILO***

Twenty-six different materials or combinations of materials were used in treating the walls of the concrete stave silo on the Roach Brothers farm, 1 1/4 mile west of Irma and 4 miles south of Plainfield, Iowa. These tests were continued over a 4-year period, from 1927 to 1931.

As a result of these tests, the following materials were found to give protection as follows:

<table>
<thead>
<tr>
<th>Protection Level</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Protection</td>
<td>Agatex, Aridol, Cement wash, 50 percent iron filings, Cement wash, 50 percent iron filings, sal ammoniac, Ledgerwood paint, Linseed oil and turpentine</td>
</tr>
<tr>
<td>Fair Protection</td>
<td>Cement wash, 25 percent iron filings, Cement wash, 25 percent iron filings, sal ammoniac, Inertol</td>
</tr>
<tr>
<td>Poor Protection</td>
<td>Bay State, Beaver paint, Bondex, Cement wash, Cement wash, lye and alum, Valdura</td>
</tr>
<tr>
<td>No Apparent Protection</td>
<td>Cement wash with Alkagel E, Elastikote, Sodium Silicate</td>
</tr>
</tbody>
</table>

The silo used in the tests was built in 1920. It is 16 feet in diameter, 45 feet high. Tamped, interlocking staves were used in its construction. In addition to the wash applied by the builder to the inside walls at the time of construction in 1920, a second wash was applied by the owner in 1925 and a

*The writer acknowledges the cooperation of the Waterloo Concrete Corporation and the Portland Cement Association in these tests.*
third by the Waterloo Concrete Corporation in 1926. When the tests described in this bulletin were begun in July, 1927, about 50 percent of the three preceding cement washes had come off. The silo contained about 5 feet of silage at that time.

As will be noted in fig. 12, the silo had no roof. It was, therefore, covered with a tarpaulin during the application and curing of the washes. This prevented rapid evaporation in the interior. So much moisture was present that there was considerable condensation on the surfaces treated with bituminous paints. The interior surface was thoroughly cleaned by wire brushing and by chiseling off scaly portions. The various materials were then applied as described in the following pages. The numbers of the treatments correspond to the numbers shown in fig. 13 and table III.

Treatments numbers 1 to 9, inclusive, were applied to dry walls, and treatments 9 to 15, inclusive, to dampened surfaces. Strips 1 to 8 were 3 staves wide (30 inches), 9, 10, 11, 12 and 13 were 4 staves wide (40 inches) while strips 14 and 15 were 6 staves wide (60 inches).
Wall Treatments

1. Intertol. Intertol Company, Inc., New York City—classed by manufacturer as a bituminous compound (coal tar). Applied in accordance with manufacturer’s recommendations in two coats. Brushed on readily with 4-inch paintbrush. Three quarts of Intertol covered 100 sq. ft. first coat; 1½ gallons covered 100 sq. ft. two coats. First coat dried in 15 hours.


4. Bay State Brick and Cement Coating. (Normandy Gray No. 238). Devoe and Reynolds Company, Chicago. To first coat was added 1 pint “Reducer” to 1 gallon of Bay State. Second coat applied full strength. Went on readily with 8-inch brush. Three quarts covered 100 sq. ft. first coat. Two quarts covered 100 sq. ft. on second coat.


6. Linseed oil and spirits of turpentine. First coat equal parts raw linseed oil and spirits of turpentine. Second coat full strength linseed oil. Applied with 4-inch paintbrush. Two quarts covered 100 sq. ft. first coat; 1½ quarts covered 100 sq. ft. second coat.

7. Beaver Paint. The Beaver Products Company, Buffalo, N. Y. A bituminous paint which applied readily with 4-inch paintbrush, 3 qts. covered 100 sq. ft. one coat work.


9. Cement wash with iron filings. Twenty-five percent by weight of cement. Belmont Smelting and Refining Works, Inc., Brooklyn, N. Y. To 20 pounds of Portland Cement added 5 pounds of No. 126 iron filings and 9 pounds of water. Applied with brush to wall surface previously dampened. 4½ lbs. water, 10 lbs. cement and 2½ lbs. iron filings covered 110 sq. ft. one coat. This material settled rapidly, requiring frequent stirring.
10. Same as 9 except amount of No. 126 iron filings increased to 10 pounds for 20 pounds of cement. Mixture of 4 1/2 lbs. of water, 10 lbs. cement and 5 lbs. filings covered 100 sq. ft. one coat. Wash settled even more rapidly than 9.

11. Same as 9 except No. 126 iron filings; contained Sal Ammoniac. Required 4 1/2 lbs. water, 10 lbs. of cement and 2 1/2 lbs. iron filings plus sal ammoniac to cover 110 sq. ft. Strong odor of ammonia. Settled out rapidly.

12. Same as 11, except double the amount of iron filings and sal ammoniac. Required 4 1/2 lbs. water, 10 lbs. cement and

| Table III. WALL SURFACE TREATMENT—CONCRETE STAVE SILO |
|-----------------|-----------------|-----------------|
| Strip No. | Material | June, 1927 | July, 1929 | June, 1931 |
| 1 | Inertol | Varies from good at top to 50% gone on lower 3 feet | About 50% gone; remainder very soft | No noticeable change since 1929 |
| 2 | Agatex | Excellent condition; surface apparently well hardened | Surface hard and in good condition | No noticeable change since 1929 |
| 3 | Valdura paint | Upper half—good condition; lower half—peeling to old wash | Adhering well where applied over clean surface | Coating practically all gone |
| 4 | Bay state | Upper half good, varying to 10% scaling at bottom | Scaling badly from top to bottom | Coating practically all gone |
| 5 | Ledger-wood paint | Surface readily scratched, hence apparently softened | Condition good | Condition good; adhering well over etched surfaces |
| 6 | Linseed oil and turpentine | Excellent condition; surface apparently hardened | Condition good | No noticeable change since 1929 |
| 7 | Beaver paint | 50% scaled off; silage sticking to remainder | 75% gone; remainder in poor condition | Coating practically all gone |
| 8 | Aridol | Excellent condition; surface apparently hardened | Surface hard and in good condition | Surface somewhat softened; still offers protection |
| 9 | Cement wash 25% iron filings | Condition good; slightly scaling in lower 3 feet; color buff to reddish brown | Condition good except where applied over old wash | Condition fair; some scaling |
| 10 | Cement wash 50% iron filings | Condition similar to No. 9; color—dark brown | Condition similar to No. 9 | Condition good except some scaling |
| 11 | Cement wash 25% iron filings Sal ammoniac | Condition and color similar to No. 9 | Condition similar to No. 9 | Condition similar to No. 10 |
| 12 | Cement wash 50% iron filings Sal ammoniac | Condition similar to No. 9; color—dark brown | Condition excellent except where applied over old wash | Condition similar to No. 9 |
| 13 | Bondex | 50% of lower half scaled off; coating easily removed | Coating practically all gone | Condition similar to No. 10 |
| 14 | Cement wash with lye and alum | Condition good, especially where original cement wash was gone | Practically all gone; remainder soft and lifeless | Condition similar to No. 10 |
| 15 | Cement wash | Condition similar to No. 14 | Condition similar to No. 14 | Condition similar to No. 10 |
5 lbs. iron filings containing sal ammoniac to cover 110 sq. ft. Very strong odor of ammonia. Required frequent and thorough stirring to keep in solution.

13. Bondex. The Reardon Company, 2200 North Second street, St. Louis, Mo. To each 10 lbs. Bondex 2½ quarts of water were slowly added, stirring until mixture was smooth and free from lumps. Then added 1½ more qts. water and restirred until mixture was ready for application. Required about 5 lbs. Bondex to cover 110 sq. ft. Went on very smoothly. Solution held its consistency with little stirring.

14. Cement wash with lye and alum. Used about 15 lbs. cement plus 1/6 can lye alum solution to cover 150 sq. ft. Solution made with 1 lb. lye and 1 lb. alum in 1/2 gallon of water.

15. Plain cement wash. Required about 15 lbs. cement to cover 150 sq. ft.

In June, 1928, about a year after the first treatments had been made, the panels were inspected. The observations made are recorded in table III. At that time a second series of treatments (lower 6 feet of the wall was re-divided into 11 panels, numbered 16 to 26) was made to try out several variations of those materials which appeared the most promising the first year. It was also desired to test the value of muriatic acid in treating the surface preparatory to applying the various materials. In this second series of tests, applications were made to the lower 6 feet of the wall on July 18, 1928.

To prepare the wall surface for the treatments it was gone over with wire brushes. Where the old wash was partially loose but could not be brushed off, it was removed with chisels and a small trowel. Strips 17, 18, 19, 20, 21, 22, 23 and 26 were scrubbed with a 1 to 4 solution of muriatic acid and water. All strips except 23, 24 and 25 were damp when the treatments were applied. The numbering of the strips is shown in fig. 14.

Wall Treatments (Second Series)

16. Cement wash on wire-brushed surface. Wall was dampened prior to application of wash which was put on with an 8-inch calcimine brush.

17. Cement wash on surface which had been cleaned with muriatic acid in addition to being wire-brushed.

18. Cement wash on acid treated surface. After standing 3 hours the surface was painted with "Agatex" (full strength). This material went on readily with a 4-inch paintbrush.

19. Same as 18 except surface was painted with "Aridol."

20. Cement wash on acid-treated surface. "Agatex" used as an admixture by adding it to the water used in mixing the wash. One-half pint of "Agatex" was used in each gallon of mixing water.
### Table IV. Wall Surface Treatment—Concrete Stave Silo

<table>
<thead>
<tr>
<th>Strip No.</th>
<th>Material applied July, 1928</th>
<th>Condition when inspected</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Cement wash on wirebrushed surface</td>
<td>Condition good except over old wash</td>
</tr>
<tr>
<td>17</td>
<td>Cement wash on brushed and acid cleaned surface</td>
<td>Scaling badly</td>
</tr>
<tr>
<td>18</td>
<td>Cement wash on acid treated surface; Agatex after 3 hours</td>
<td>Condition very good except over old wash</td>
</tr>
<tr>
<td>19</td>
<td>Cement wash on acid treated surface; Aridol after 3 hours</td>
<td>Condition fair where applied to etched surface; scaling over old wash</td>
</tr>
<tr>
<td>20</td>
<td>Cement and Agatex on acid treated surface</td>
<td>Condition excellent except over old wash</td>
</tr>
<tr>
<td>21</td>
<td>Cement and Aridol on acid treated surface</td>
<td>Considerable scaling and rather soft</td>
</tr>
<tr>
<td>22</td>
<td>Cement wash with iron filings on acid-treated surface</td>
<td>Condition excellent except over old wash</td>
</tr>
<tr>
<td>23</td>
<td>Linseed oil and turpentine</td>
<td>Condition fair</td>
</tr>
<tr>
<td>24</td>
<td>Elastikote</td>
<td>Coating practically all scaled off</td>
</tr>
<tr>
<td>25</td>
<td>Sodium silicate</td>
<td>Surface considerably hardened by treatment</td>
</tr>
<tr>
<td>26</td>
<td>Cement wash with Alkagel E</td>
<td>Coating practically all scaled off</td>
</tr>
</tbody>
</table>

21. Identical with strip 20 except that “Aridol” was used as admixture and included in the mixing water.

22. Cement wash on acid treated surface using an admixture of powdered iron No. 126. Proportion of iron to cement: 1 to 4 by weight.

23. Acid-treated surface painted with raw linseed oil to which turpentine was added in the ratio of 1 part turpentine to 3 parts linseed oil.

24. Wire brushed surface treated in a dry condition with “Elastikote,” a bituminous waterproof paint.

25. Wire-brushed surface painted when dry with a saturated sodium silicate solution using a 4-inch paintbrush.

26. Cement wash including “Alkagel E” as an admixture. One part “Alkagel E” dissolved in fourteen parts water and used in mixing the wash. This surface was acid-treated. This wash was somewhat grainy in character and some difficulty was encountered in getting a smooth finish.

The results of the inspection of both the first and second series of treatments are shown in tables III and IV. In 1928 the lower part of the silo was filled with rather immature corn, while the upper part was filled with corn that had reached the desired stage of maturity. The green corn silage reached approximately the same height in the silo as treatments 16 to 26.
and, therefore, these strips were probably subjected to more severe acid conditions than the upper portion of the silo where the acidity of the silage was about normal.

It was found that when powdered iron was used in cement washes that the oxidized iron penetrated into the silo wall under the wash coating. It also penetrated the old cement wash when applied over such areas.

In June, 1929, when this silo was inspected, about 3 feet of silage remained. No inspection was made in 1930 because the silo remained about half full throughout the summer.

In general the condition of the interior wall in June, 1931, was better than in 1927 when the first experimental coatings were applied. The surface appeared to be harder, denser and more acid resistant than before the tests were started. The surface, however, was very dry due to extreme heat and lack of precipitation in the vicinity of the silo for several weeks prior to this inspection. Weather of this kind would tend to harden the surface. Tables III and IV show the condition of the various panels.