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Division of Physical Metallurgy
Steel Castings Section

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A STUDY OF METHODS FOR TESTING GELATINIZED CORN FLOUR MOLD AND CORE BINDERS

- Report M-2698 -

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ABSTRACT

Several tests used in the manufacture and testing of gelatinized corn flour binders have been discussed and investigated. Tentative limits for specifications have been suggested where the test seems appropriate. It should be pointed out that as more is learned about these materials it may be necessary to change certain limits and add or eliminate tests.

In using these materials in the foundry the importance of using weight measurements instead of volume measurements cannot be over-emphasized because there are large differences in density between various brands.

Authorization

1. Studies of gelatinized corn flour binders were authorized by Bureau of Ships letter QP/Castings (692-336) to NRL of 28 December 1944.

Statement of Problem

2. Many brands of gelatinized corn flour are marketed for use as binders. in foundry molding sands. The densities of these binders vary between wide limits and other properties also vary considerably from one manufacturer to another. Since foundrymen frequently use such binders on a volume basis and evaluate the quality of the resulting sand mixtures empirically, wide variations in sand performance may be obtained by changing from one corn flour binder to another in the same shop. This fact and a general lack of knowledge by foundrymen of the properties of gelatinized corn flour has led to the practice of specifying these binders by brand-name. Such a practice is satisfactory in commercial foundries but difficulties arise in Naval foundries or similar shops where materials must be purchased on bid.

3. Therefore, the problem was that of determining (1) the causes of variation in the performance of sands bonded with different corn flour binders, (2) what tests are suitable for predicting the performance of corn flour binders in molding sands and (3) within what limits it is necessary to hold the properties as defined by such tests to obtain molding sands with uniform and reproducible characteristics.

Known Facts Bearing on the Problem

4. Very little is known about corn flour binders except for the practical information developed as a result of their use in the foundry over a period of many years. They are used both in molding sands and in core sand mixtures. Variations between various brands of corn flour when used in molding sand are noted as differences in sand texture and in the green and dry compressive strengths of the sand mixtures. The green compressive strength imparted to core sands by the corn flour binders is not known because no machine sensitive enough to make this test has been available in the sand laboratory.

5. As a preliminary step in the study of corn flour binders, the laboratories and plants of two producers, the Corn Products Refining Company at Argo, Illinois and the Illinois Cereal Mills at Paris, Illinois were visisted to obtain information concerning laboratory procedures and product control methods. A report of the findings is included in Appendix A. Appendix B is a description of laboratory procedures employed by the Corn Products Refining Company.

Experimental Work

6. One hundred pounds of each of eight brands of gelatinized corn flour were purchased for tests at NRL. They included:

"Amerikor" - Chas. A. Krause, Milwaukee, Wis.
"Ceres" - Illinois Cereal Mills, Paris, Ill.
"K-B" - Knefler-Bates Co., Indianapolis, Ind.
"M-H" - Miner-Hillard Milling Co., Wilkes Barre, Pa.
"Mogul" - Corn Products Refining Co., Argo, Ill.
"Penco" - Pennsylvania Foundry Supply Co., Philadelphia, Pa.
"Rex" - Patent Cereals Co., Geneva, New York.
"Truscor" - Chas. A. Krause, Milwaukee, Wis.

7. While this list does not include all producers, it represents both heavy and light types of binders and the products are believed to be representative of those of the industry as a whole.

8. All binders were tried in the steel foundry facing sand in use in the NRL foundry and the substitution of the test binder in place of that in regular use was not detected by the molders and no change in results was noticed. The binders were used on a weight basis rather than on a volume basis. This is important because the substitution of a light binder for a heavy binder on a volume basis will produce pronounced changes in sand properties.

9. All binders were subjected to chemical and physical tests. The methods of analysis recommended by Corn Products Refining Co., Appendix B, were used for the chemical tests. The chemical tests were made on the corn flour binders as received. The physical tests were made on a 3,000 gram batch of sand containing 1.0% of the corn flour under test and 99% of No. 80 New Jersey washed silica sand on a dry basis; water was then added to produce a moisture content of 4.0%. The ingredients were mixed one minute dry and five minutes wet in a Simpson 18 inch laboratory muller and transferred to mason jars which were sealed until the tests were made. Dry specimens were baked for two hours at 105°C. to 110°C. (220°F. to 229°F.) in an oven with forced air circulation and were cooled to room temperature in a desiccator before testing. The results of these tests are shown in Table 1.

10. Green strength is one of the most important properties of a corn flour binder, particularly when it is used in core sand mixtures. However, none of the test machines in general use in the foundry sand control laboratories has adequate sensitivity for measuring green strength at very low strength values. For this reason, very little is known about the green strength of cores and, until such machines are made and used it will be impossible to specify green strength of corn flour binders. Mr. Bulfer of the Corn Products Refining Company at Argo, Illinois designed a shot loaded compression testing machine for testing compressive strength at loads from 0.5 to 2 lbs. per square inch. Although the Corn Products Refining people believed that the design of the machine was good, it was said to have insufficient sensitivity for accurate testing. It was sent to the sand laboratory at NRL for trials. Officials of the company stated that any necessary changes in the machine could be made and that the machine could be freely used it if was found to be of value as a sand testing machine.

11. The machine was tried and found to have too much friction in its moving parts, particularly the counterweight arm and the vertical plunger. The counterweight was removed completely and a new method of supporting the vertical plunger was designed. It consists of two V grooved wheels, mounted vertically, one above the other. The vertical plunger is held in the V grooves of these wheels by a third wheel on the opposite side of the plunger. The third wheel has a flat face and is mounted on an eccentric shaft which permits it to be held against the side of the plunger with any desired pressure. The wheels are all made with a tire pressed over an enclosed type ball bearing. This arrangement permits the vertical plunger to move up and down with a minimum of friction but it restricts all lateral movement. One other change was made in raising the plunger support and shot reservoir high enough to permit the specimen and the stripping post to be inserted together. This makes it possible to strip the specimen and place it in the testing machine without touching it by hand. Since some specimens are very weak and fragile this is a great improvement over the original machine. A sketch of the machine is shown as Plate 1. A duplicate of this machine is being made for the sand laboratory at NRL and the original machine, including the improvements will be returned to the Corn Products Refining Company. The machine may be copied by any interested parties and blueprints can be obtained from NRL.

12. In a short test to determine the reproducibility of results and the sensitivity of both the machine furnished by the Corn Products Refining Company and the new machine made at NRL, six tests were made on each machine from the same sand mixture. These tests gave arithmetic mean values of 0.705 and 0.692 pounds per square inch for the old and new machines respectively, with standard deviations of 0.028 and 0.017 pounds per square inch.

13. The original machine with the revisions made at NRL was used for the tests shown in Table 1. The weight of the plunger, cup-support and top compression head was considered as dead or initial load. The cup and the shot contained in it was considered as live load and was weighed after each test. Live and dead load were added and converted to pounds per square inch on a standard two inch specimen by the graph shown on Plate 2.

14. Various discussions have indicated that stress strain measurements might give considerable information regarding the differences in performance of different binders. In order to investigate this possibility the green strength machine was equipped with an Ames dial for measuring strain. The rate of loading of the machine was measured and found to be constant as shown by Plate 3. This made it possible to measure stress by means of the time elapsed after the start of the test. A movie camera was focused on the apparatus during the tests so as to show the specimen, the Ames dial and a stop watch. This is illustrated in Plate 4. Data for stress strain curves were read from the film and one of the curves is shown as Plate 5. Although some differences in the curves were found, no practical interpretation of the results could be made and the strain measurements have been discontinued.

15. Dry strength measurements on sand containing cereal binders are very important but there is considerable confusion over methods of measurement. Tensile tests on briquettes are used as well as bending tests on a 1" square bar 8" long. The values shown in Table 1 are compressive strengths on 2" diameter x 2" long cylinders broken in a Carver laboratory press. The Carver press is of a suitable size and capacity for compressive strength tests on baked sands and cores but it is not as sensitive and accurate as it should be for this purpose. Dietert's Type CP universal sand strength machine, even with the high strength attachment is not strong enough to break the average baked core. Since green and dry sands are tested in compression it is believed that cores should also be tested in compression on the same size of specimen so that results will be comparable. Tests such as bending or tension require specimens which are more difficult to make and have little correlation with compressive strength test results. A sketch of the heads used in the Carver press is shown as Plate 6. The upper head is pivoted so it may rotate to insure axial loading. The bottom head provides a flat surface to hold the specimen and the flanges on the cup serve to catch the sand and broken pieces of the specimen when it fails.

Test Results

16. The significance of the various chemical and physical tests made and the range of the results are discussed below. Where the test is suitable for purposes of specifications, limits are recommended. The values suggested are tentative and may need to be revised after the specification is tried in actual use.

17. A corn flour is used in a molding sand or core mixture for the physical properties it imparts to the aggregate such as green strength, dry strength, and proper texture. Therefore, the chemical and physical properties of the corn flour are useful in a specification primarily to insure constant quality of the product.

18. Moisture content which was in the range of 5.5% to 9.6% for the eight binders tested will also vary with humidity. If the water content is too high the user pays a high price for the usable bond, as purchase is made on a weight basis. High water content may cause hardening or caking and chemical deterioration. A maximum of 10% is recommended.

19. Ash content of the eight binders tested ranged from 0.27% to 2.39% with seven of them containing less than 0.42%. The ash test detects the presence of any earthy or clay materials which may be used as adulterants to increase weight. A maximum of 1.0% is recommended and it seems probable that Binder E can be produced to meet this specification since the others are all well below 1.0%.

20. The soluble material was determined on a dry basis. Values range from 10.2% to 23.9%. This test shows the relative amounts of insoluble starches and soluble components such as dextrines. If the soluble material is high the binder tends to migrate to the surface of a mold or core as it dries which makes the

surface hard and leaves the center relatively soft. If the soluble material is low, dried molds and cores will have about the same hardness all the way through. In many foundries, dextrine is added to the mixture when surface hardness is desired, and, when used with the less soluble corn flour, permits very good control. Limits of 10% to 25% cover all of the binders tested and seem to be adequate for specifications. If a binder with a high soluble content is used the sand mixture may require more corn flour and less dextrine than a binder in which the percentage of soluble material is low.

21. The water absorption test indicates the amount of swelling which takes place in the binder when it is mixed with an excess of water. It is expressed in milliliters per gram and for the binders tested ranged from 8.2 to 11.7 milliliters per gram. The significance of this test is not known, but it may have a bearing on the texture and sponginess of the molding and core sands produced. Some mixtures, especially those high in cereal binder, are known to swell considerably after they are rammed. Limits of 8% to 12% are suggested for specifications.

22. The pH value is determined on a 1 to 20 mixture of binder and water and is used in controlling the manufacturing process but its significance in sand mixtures has not been thoroughly investigated. It is known that Western bentonite, used in molding sand mixtures, is basic and that the addition of acid materials to the molding sand usually tends to reduce the green strength of the material. The binders tested range from 4.1 to 6.3 in pH and limits of 4.0 to 6.5 are suggested as minimum and maximum for specifications.

23. The protein test may be useful as a manufacturing control but its bearing on the use of corn flour in sand is not yet apparent. The binders tested ranged from 6.5 to 8.2% protein. The test may be useful, however, in controlling the reproducibility of physical properties of the sand mixtures and limits of 5 to 10% are suggested.

24. Density of corn flour binders varies over wide limits depending on the brand and on the method of measurement. In the loose or unpacked condition the values range from 0.1632 grams per milliliter to 0.5160 grams per milliliter. These data were obtained by passing the corn flour through a 6 mesh sieve and a funnel into a 100 milliliter graduate. If the corn flour is packed by tapping the bottom of the graduate on the top of a table until no more compaction appears to take place, the range increases to 0.2983 grams per milliliter and 0.8130 grams per milliliter, or nearly twice the original values. Table 1 shows the average density of loose and packed binders as well as the weight in pounds per cubic foot corresponding to the average density.

25. Since the variation in density is so large and since all of the products which were tested seemed to be satisfactory in the foundry tests, it is believed that density should not be a criterion for accepting or rejecting a corn flour binder. If specifications for this property are desired they should range from a minimum of 0.220 to a maximum of 0.700 grams per milliliter for the average density. These correspond approximately to 14 and 44 pounds per cubic foot respectively.

26. A "paste test" is sometimes used to indicate the quality of gelatinized corn flours. When 20 grams of the corn flour is mixed with 160 milliliters of water the resulting paste will vary in consistency from thin to very thick. The thick pastes appear to be thixotropic and will support a glass stirring rod in a vertical position almost indefinitely. An effort was made to obtain some quantitative measurement of the consistency of the paste with the slump test and with the Gardner Mobilometer but the results have not been very satisfactory. Pastes made from the eight binders tested ranged from thin to thick but no correlations could be found between the paste and the strength developed in sand mixtures.

27. Green compressive strength values, determined with the machine described above, ranged from 0.781 to 1.012 pounds per square inch. Although equipment for measuring this property is not now generally available and the test cannot yet be used in specifications, it is very important and should be included as soon as the necessary machines can be made. Since green strength is necessary in a core to hold it together during handling and drying and to promote clean drawing of core boxes and since the organic material in the core should be kept as low as possible to avoid excessive formation of gas, it is obvious that binders of reasonably high green strength should be used. A minimum value of 0.75 pounds per square inch is recommended as a tentative specification and it may be possible to raise this value after the test has been in use.

28. Dry compressive strength values were determined on the Carver laboratory press as described above and cover the range from 225 to 465 pounds per square inch. Dry strength is instrumental in maintaining dimensional stability and in preventing erosion of the sand by the molten metal. Here again, high strength is to be desired in order to produce adequate dry strength with a minimum of organic or gas forming materials. A minimum of 225 pounds per square inch is recommended as a tentative specification.

Conclusions and Recommendations

29. Density of a gelatinized corn flour is not an indication of its quality as a molding sand binder. However, to obtain consistent performance of molding sands bonded with various brands of gelatinized corn flours, mixtures must be compounded on a weight basis.

30. The usefulness of gelatinized corn flour binders is not impaired by a considerable variation in their properties as determined by known methods of chemical testing. (Limits of these properties are suggested in the body of this report).

31. Green compressive strength and dry compressive strength of simple sand and gelatinized corn flour mixtures can be measured with sufficient accuracy and reproducibility to determine the effective bonding capacity of such binders.

32. It is recommended that tentative specifications for the purchase of gelatinized corn flour binders be prepared on the basis of chemical tests which

define the limits of certain properties as established by the experimental work described in this report. Green and dry compressive strength tests are recommended for inclusion in such specifications as soon as the necessary machines can be made or obtained.

33. It is further recommended that emphatic instructions be given to the users of gelatinized corn flour binders purchased under Naval specifications regarding the importance of compounding molding sand mixtures by weight rather than by volume.

34. Although No. 80 New Jersey sand was used for the tests described in this report, it is recommended that AFA standard sand be used for acceptance testing in order to keep the test conditions constant and make the results of different laboratories comparable.

APPENDIX A

MANUFACTURING PROCEDURES AND CONTROL METHODS EMPLOYED FOR THE PRODUCTION OF GELATINIZED CORN FLOUR BINDERS

1. The plants and laboratories of the Corn Products Refining Company at Argo, Illinois, and the Illinois Cereal Mills at Paris, Illinois, were visited to observe plant operation and methods and to discuss tests which might reveal the quality and suitability of various corn flours for use as foundry sand binders.

2. The Corn Products Refining Company produce a wide variety of starch and dextrine products. Their foundry corn flour, called "Mogul", is only one of the products derived from the whole corn grain and its properties are affected by the fact that the plant is run on the "wet process". This means that the corn grains are soaked or "steeped" in a one percent sulphur dioxide solution as the initial step in the refining process. The grains are then coarse ground and passed through a separation chamber where the germ floats to the top and the starchy part of the grain sinks to the bottom. The germ is subsequently separated into corn oil and a pulpy residue high in protein which is used as feed for farm animals. The corn oil is purified and forms cooking oils such as "Mazola" and is also used in other products.

3. The starchy part of the grain is ground slightly finer and passed through silk screens which remove the hulls. The starch is then filtered to remove water and dried in a large rotating dryer from which it emerges with a water content of 38 to 42 percent. This material is then fed into a gelatinizing apparatus which consists of a pair of large steel rolls, about three feet in diameter and four feet long, mounted horizontally and at the same level. They are heated with steam. The rolls move downward at the point of contact, squeezing a layer of paste over both rolls. This paste is dried from 38 percent to approximately 8 percent water by the heat of the roll and, as the roll revolves, the paste is scraped from it by a stationary knife. Each pair of rolls produces about 500 pounds per hour of the dried material which is in the form of large sheets. This material is then ground and passed through a hammer mill from which it emerges as the finished product. At this point it is put in bags and weighed.

4. A blender is used to mix the corn flour with any desired amount of dextrine as required by some customers on special orders. Blending is done on only a small percentage of the orders.

5. The process outlined above is shown very briefly as a flow diagram in Plate 7.

6. Mr. W. J. Lauterback, Chief Chemist at Corn Products Refining Company, presented most of the members of his staff including Mr. Valentine who acted as guide for a tour of the plant and the control laboratory.

7. Tests made at the laboratory with recommended values are:

Moisture	11% maximum
Soluble	8-13%
Ash	.35% maximum
pH	4-5
Protein	5-10%
Absorption	10% minimum
Weight per cu. ft.	37 lbs. minimum
Green Compression	0.50 P.S.I.
Dry Bond	9 lb. load in special transverse testing machine

8. Recommended methods of analysis as practiced by the Corn Products Refining Company are included as Appendix B. Although the procedure for determining moisture outlined therein specifies vacuum drying for four hours at 120°C. (248°F.), Mr. Lauterbach stated that very nearly identical results can be obtained by atmospheric drying at 110°C. (229°F.) for four hours or at 155°C. (311°F.) for fifteen minutes. For the ash determination, the procedure has been changed slightly from that given in Appendix B. The platinum crucible containing the sample is placed directly in an electric furnace at 700°C.(1292°F.). Mr. Lauterback believes that gradual raising of the temperature is not necessary.

9. High density distinguishes Mogul from most of the competitive products. It weighs 38 to 43 pounds per cubic foot while most other corn flours weigh from 18 to 22 pounds per cubic foot. A test for density in grams per milliliter made by sieving the corn flour into a container of specified dimensions, striking off level with the top and weighing, would be very desirable.

10. Green compression tests are made on specimens prepared from a mixture of sand, binder, and water. Three thousand grams of graded Ottawa sand are used, with 32 grams of corn flour and 120 milliliters of water. The sand and corn flour are mixed dry in a Simpson 18 inch laboratory muller for 30 seconds. The water is then added and mixing is continued for four additional minutes. The mixture is then discharged into a metal container which is sealed and allowed to stand for 30 minutes before testing is started. Three 2 inch by 2 inch cylindrical specimens were tested during the inspection. A very old spring type sand testing machine was used and values of 0.55, 0.55 and 0.55 were obtained. Mr. Lauterback thought that the values were expressed as pounds per square inch. The machine is not believed to be sensitive enough for testing sands of such low strength.

11. The dry bond test is performed on 1- x 1- x 8- inch bars made in an aluminum core box from the sand mixture described above. The core box and hopper are filled level full and rammed with ten blows of the standard rammer. The hopper is removed, the top is struck off, the core box is removed so that the cores are supported on small plates. They are oven dried for two hours at 105°C. to 110°C. (221°F. to 229°F.) after which they are air cooled one hour

and stored in a desiccator one hour. The cores are then broken in a bending machine on 6 inch centers. This machine is shot loaded and is believed to be a type made about 25 years ago by Campbell or Grubb. The lever arms involved are not known and the beam formula is not used so the unit stress at the breaking point cannot be calculated. The values reported are simply the weight of the shot and receiving cup which, for three tests made during the visit were 13.8, 13.3 and 15.8 pounds. A more modern test giving compressive or tensile strength in pounds per square inch or even a bending test in which the results are computed to stress in pounds per square inch would be much more desirable.

12. The one to eight pastes test is used and is believed to be an index of the amount of gelatinization that has occurred. It was indicated that a good binder for foundry sands should make a medium to thick paste when 20 grams of the binder is mixed with 160 milliliters of water. The paste is mixed in an ordinary water glass with a glass rod. A thick paste was described as one in which the rod will be held erect by the paste and a thin paste is one in which a collar of water is visible at the top of the paste after it has been allowed to stand. All intermediate stages were described as medium pastes. This test appears to be a good index of the condition of the binder and if worked out as a viscosity or slump test might be useful.

13. The Illinois Cereal Mills, Inc. at Paris, Illinois, is a smaller plant and grinds about 30,000 bushels of corn per day compared with 93,000 bushels per day at the Argo plant of the Corn Products Refining Co. A larger proportion of the grind, however, goes into "Ceres", the corn flour binder made at Paris, so the amounts of corn flour binder produced at the two plants are of the same order.

14. The Illinois Cereal Mills use the so-called "dry process". The shelled corn is cleaned with air and then "tempered" to a water content of about 23 percent. The moist corn is heated to drive the moisture into the grains after which it is cracked in a machine consisting of a fixed cone with a rotating cone inside. As the grains are caught between the teeth of the two cones they are cracked and the germ is split from the starchy part. The germs are separated by sieving and are put through a hot press to remove the corn oil. The remaining pulp is used in cattle food and the oil is filtered and sold to other manufacturers.

15. The starchy part of the grain is ground and gelatinized on hot rolls as at the Argo Plant. At Paris, however, there are several differences in equipment and process. The corn enters the rolls at a water content of about 19 percent (compared with 38 to 40 percent at Argo). The rolls are small (about 24 x 30 inches long) and travel at a higher speed. They are heated with gas instead of steam. The roll temperature is about 600°F. and the pressure between the rolls is about 18 tons. At this plant, therefore, gelatinization is produced by a shorter, hotter process from a dryer starting mixture than that used at Argo. The resulting product has a water content of about 8 percent. It is ground, put through a hammer mill, bagged and weighed as before. Ceres has a density of about 22 pounds per cubic foot compared with 38 to 43 for Mogul.

16. Test equipment at the control laboratory of this plant is not very extensive. There are two rapid moisture testers, a glass for the paste test, a small balance, a rotap sieve shaker and a small set of testing sieves. Moisture tests at various steps in the operation is the principal method of checking the operation of the plant.

17. The company has a small research laboratory operated by Dr. William F. Henry. He uses methods and tests very similar to those in use at Argo. He uses a funnel in measuring the viscosity of corn flour pastes. The time in seconds required for 50 milliliters of paste to pass thru the funnel into a graduate is taken as a measure of viscosity.

18. No sand tests are made at this plant. Some Dietert sand testing equipment was on order but had not been received at the time of the visit. Occasional samples are sent to Dietert for tests.

19. Dr. Henry discussed various properties of corn flour binders and suggested the following limits to be reasonable for such materials:

Moisture (115° for 3 hrs.)	4 to 5 percent minimum; $8\frac{1}{2}$ to 9 percent maximum.
Ash content	0.5 percent maximum
pH	4 to 6
Protein	6 to 10 percent
Solubility (Dry basis 25°C.)	8 to 20 percent
Weight	210 to 250 grams per quart

20. The process is shown as a flow diagram in Plate 8.

APPENDIX B

METHODS OF ANALYSIS FOR GELATINIZED ROLL PRODUCTS

MOISTURE

Weigh 5 grams into a tared aluminum moisture dish and dry for four hours at 120°C. (248°F.) and 26 inch vacuum. Remove the dish from oven and cover tightly; cool to room temperature in a desiccator and reweigh.

% Moisture = Gram loss in weight x 20.

SOLUBLE

Determine % dry substance on sample according to procedure for determining moisture.

Weigh 2 grams of sample, transfer to a 200 milliliter Kohlrausch flask containing about 25 milliliter of water at 25°C. (77°F.) and fill flask with water at 25°C. (77°F.) to about milliliter of mark. Shake gently for one hour while flask is submerged in a water bath at 25°C. (77°F.). Fill flask to mark and shake until thoroughly mixed. Filter at once through a double thickness of $18\frac{1}{2}$ centimeter #588 S & S filter paper. Measure 50 milliliters of the filtrate and transfer to a weighed evaporating dish. Evaporate to dryness on a steam bath and dry in vacuum oven for one hour at 100°C. (212°F.). Cool and weigh.

Calculation

$$\text{Soluble (Dry Basis)} = \frac{(\text{Gram Residue})\ (100)}{\frac{(50\ \text{ml})}{200\ \text{ml}}\ (2\ \text{gm sample})\ \frac{(\%\ \text{D. S.})}{100}} =$$

$$= \frac{(\text{Gm Residue})\ (20{,}000)}{\%.\ \text{D. S.}}$$

ASH

Weigh 10 grams of sample into a weighed platinum or silica dish. Place in muffle (ignite while charring to prevent loss of sample) at 550°C. (1022°F.) for two hours. Cool and weigh.

$$\%\ \text{Ash} = \frac{(\text{Gram of ash})\quad (100)}{10\ \text{gram sample}}$$

pH

Weigh 10 grams of sample, stir into 200 milliliters of water, and shake 30 minutes. Determine pH by electrometric method, (Leeds and Northrup) or colorimeteric method.

PROTEIN

Weigh accurately 5 grams of material and transfer to dry Kjeldahl flask. Add 10 grams of K_2SO_4 and 0.3 grams Cu $SO_4 \cdot 5H_2O$. Wash down any particles adhering to neck of flask with 50 milliliters H_2SO_4. Mix and digest two hours with occasional agitation. Cool completely, add about 300 milliliters of water, phenolphthalein indicator and a small amount of granular zinc to prevent lumping. Connect flask to distillation until. Immerse end of delivery tube into a measured quantity . (50 milliliters) of N/10 H_2SO_4 contained in a 500 milliliter Erlenmeyer receiving flask, adding a small amount of water if necessary. Add enough 40° Beaume NaOH to Kjeldahl flask through the funnel tube to make contents strongly alkaline, and mix gently. Stopper end of funnel tube and distil at a moderate rate until about 250 milliliters have passed over.

Titrate excess acid in receiving flask with N/10 NaOH using Methyl Red indicator. Determine a blank on reagents substituting pure cane sugar for the sample and deduct from acid titre.

Calculation:

% Protein in corn products = (6.25) (% Nitrogen)

$$\% \text{ Protein} = \frac{\text{ml N/10 } H_2SO_4 - \text{Blank titre}) (.00875)(100)}{\text{Gram Sample}}$$

ABSORPTION

Measure 100 milliliters of water and pour about half of it into a beaker. Weigh 5 grams of sample - transfer to beaker containing water and stir to smooth paste. Wash the mixture into a 100 milliliter graduated cylinder with the remainder of the water and shake thoroughly. Let stand overnight. Note the volume of supernatant liquid.

Absorption in milliliter per gram =

$$\frac{(100 \text{ ml Water} - \text{ml supernatant liquid})}{5 \text{ gram sample}}$$

WEIGHT PER CUBIC FOOT

Carefully fill a weighed 100 milliliter graduated cylinder to the 100 milliliter mark with the sample, and determine weight. Now pack contents of cylinder as much as possible by tapping cylinder up and down on a table top, adding sample to keep volume at the 100 milliliter mark after thoroughly tapping. Determine weight of content.

Calculation:

$$\text{Pounds per cu.ft.} = \frac{(\text{Gm sample loose} + \text{Gm sample packed}) \quad (62.43 \text{ Lb.CuFt.})}{(2) \quad (100 \text{ milliliter sample})}$$

PASTE TEST

Transfer 20 grams of sample to a glass tumbler containing 160 milliliters of water, add the sample slowly and stir to make a smooth paste. A paste which spreads out immediately is reported "Thin", A paste which appears granular and doughy when stirred is reported "Thick".

A paste which is smooth, but retains its form when stirred, is reported "Satisfactory".

TABLE I

PROPERTIES OF EIGHT GELATINIZED CORN FLOUR BINDERS

WITH PROPOSED LIMITS FOR SPECIFICATIONS

Property	BINDERS								Proposed Limits
	A	B	C	D	E	F	G	H	
Moisture %	6.9	6.7	5.5	9.6	6.7	9.0	9.4	9.4	10% Max.
Ash %	0.33	0.27	0.31	0.34	2.39	0.36	0.41	0.38	1% Max.
Soluble (Dry Basis)	10.7	11.3	23.9	18.0	11.7	15.5	10.2	17.8	10% to 25%
Water Absorption	11.7	10.0	11.0	10.5	11.0	9.8	8.2	10.3	8% to 12%
pH	4.1	5.1	4.7	6.3	5.5	6.1	6.1	6.2	4 to 6.5
Protein	6.5	8.0	8.2	7.9	7.2	7.7	7.9	7.9	5% to 10%
Green Strength	0.781	0.930	0.988	0.978	0.906	0.955	1.012	0.938	0.750 psi Min.*
Dry Strength	329	402	465	329	362	430	225	285	225 psi. Min.
Density loose gm/ml	.4886	.2105	.1632	.2412	.3358	.2363	.5160	.2396	
Density packed	.6781	.3725	.2983	.4310	.6068	.4110	.8130	.4147	
Density Average	.5834	.2915	.2308	.3361	.4713	.3236	.6645	.3272	**
Density-lb./cu.ft.	36.4	18.2	14.4	21.0	29.4	20.2	41.5	20.4	

* This is a tentative value for use when suitable testing machines are available.

** No limits are recommended for density unless proof can be developed to show that very high or very low densities are accompanied by poor results when such a corn flour is used in foundry molding sands or cores.

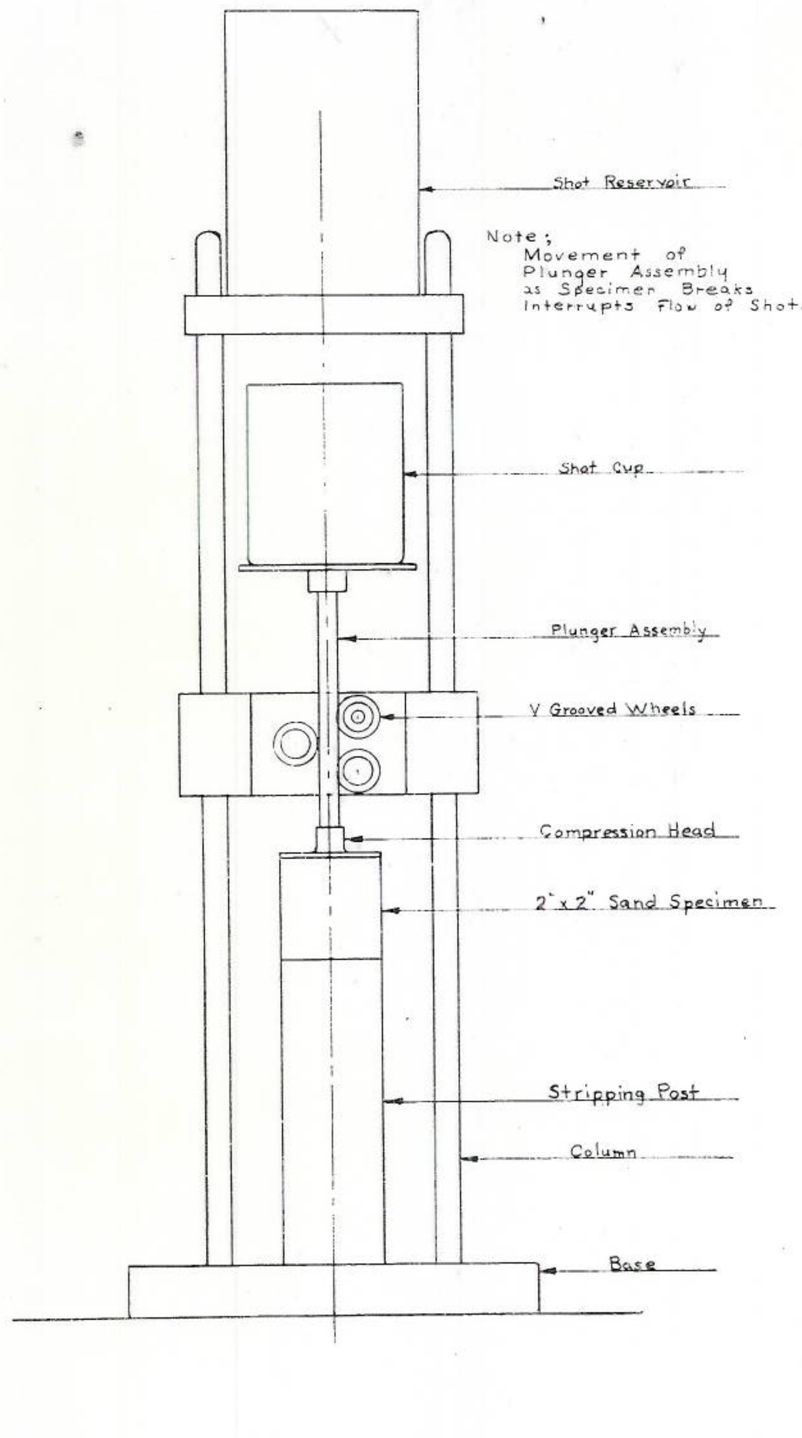
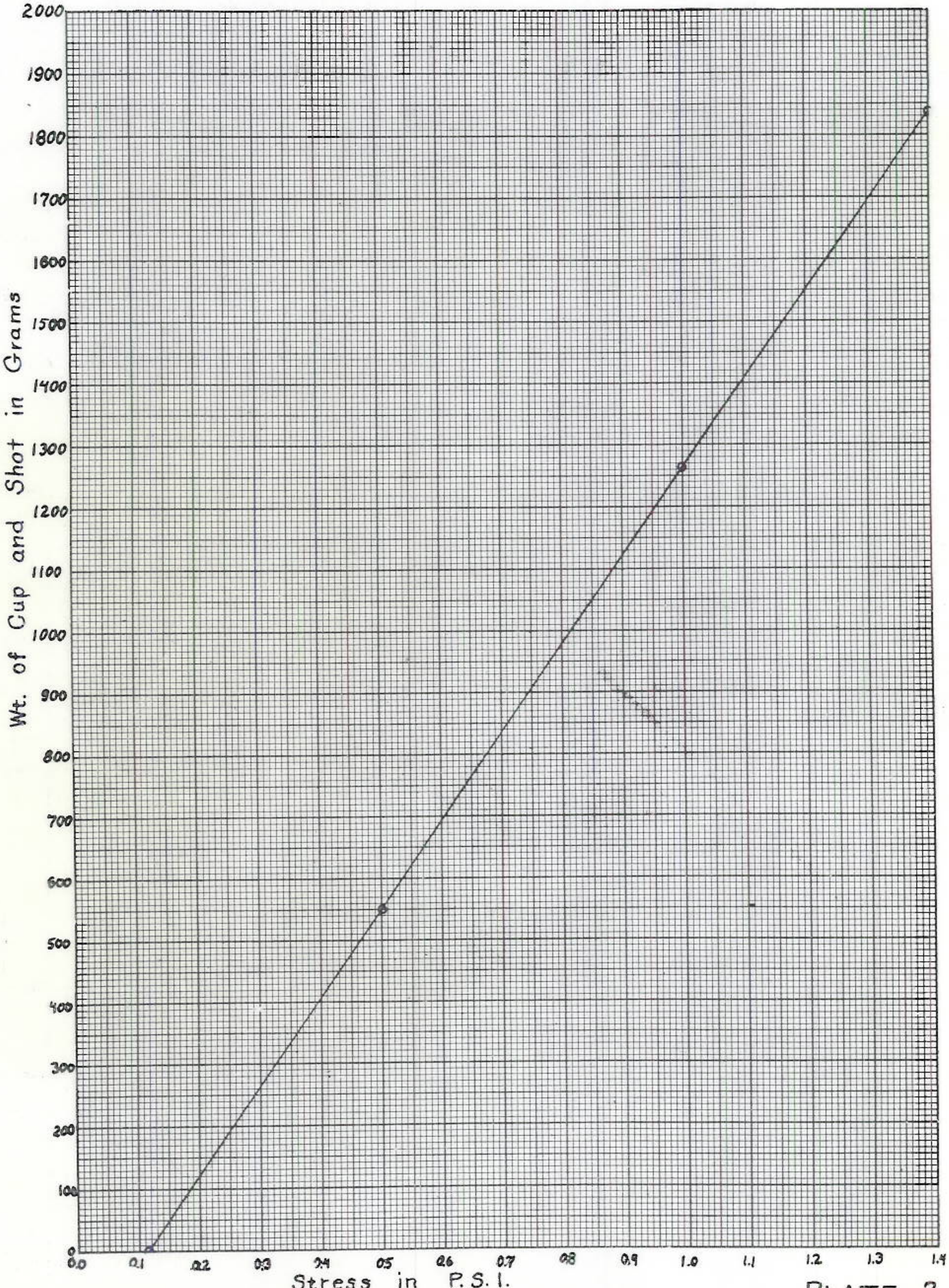

Shot Reservoir
Note;
Movement of
Plunger Assembly
as Specimen Breaks
Interrupts Flow of Shot.
Shot Cup
Plunger Assembly
V Grooved Wheels
Compression Head
2" x 2" Sand Specimen
Stripping Post
Column
Base

PLATE I



Wt. of Cup and Shot in Grams
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
Stress in P.S.I.

PLATE 2

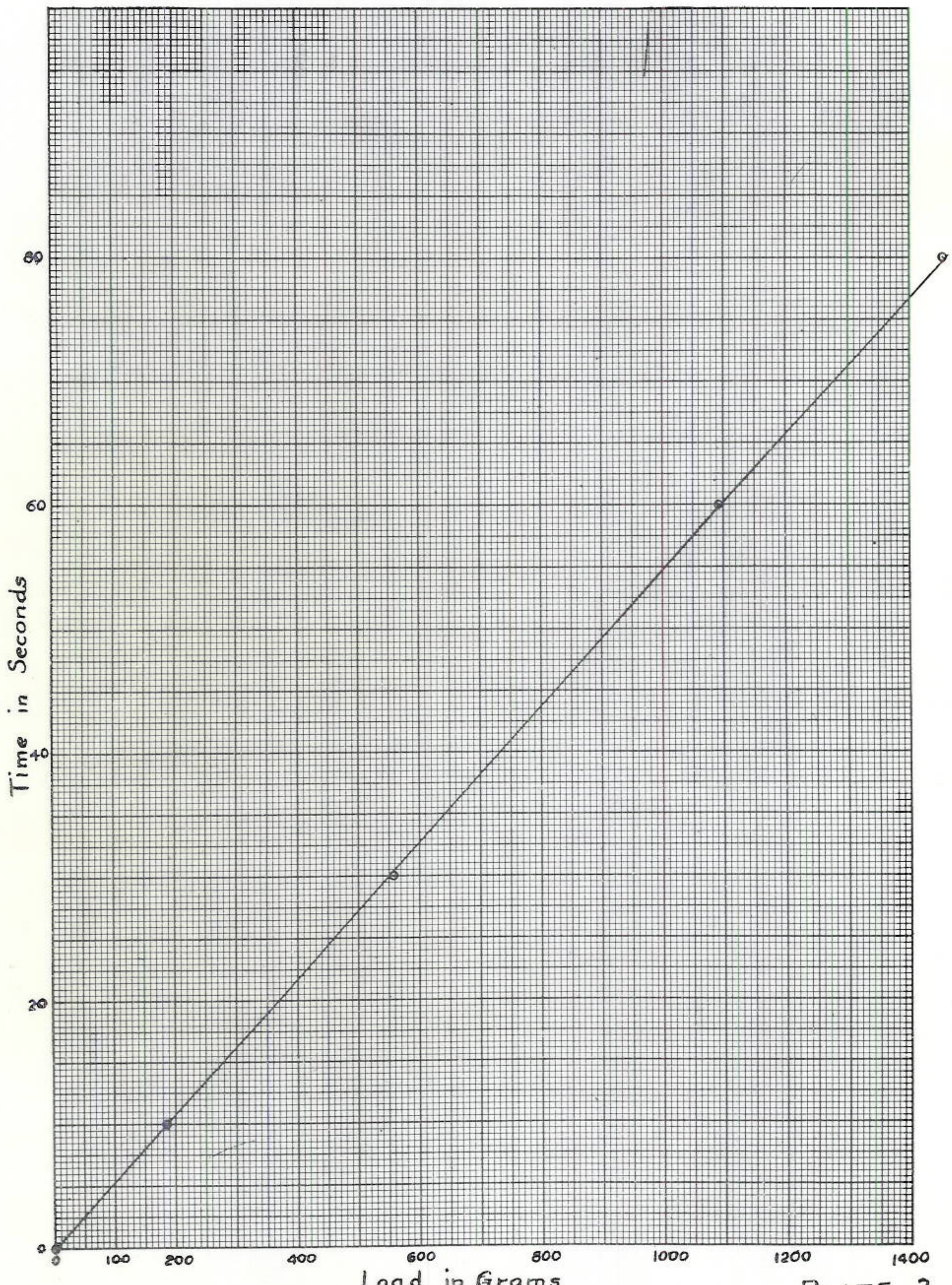
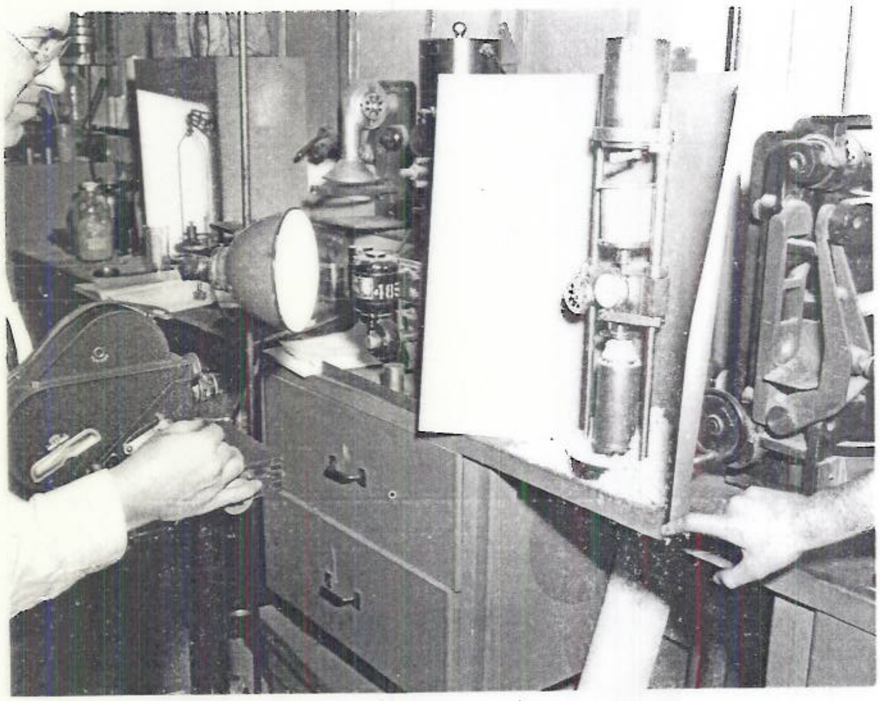

80
60
40
20
0
Time in Seconds
0
100
200
400
600
800
1000
1200
1400
Load in Grams

PLATE 3



GREEN COMPRESSIVE STRENGTH TESTING MACHINE
WITH AMES DIAL, WATCH AND CAMERA
SET UP TO MEASURE STRAIN

PLATE 4

STRESS STRAIN CURVE FOR A SAND MIXTURE
CONTAINING A GELATINIZED CORN FLOUR BINDER

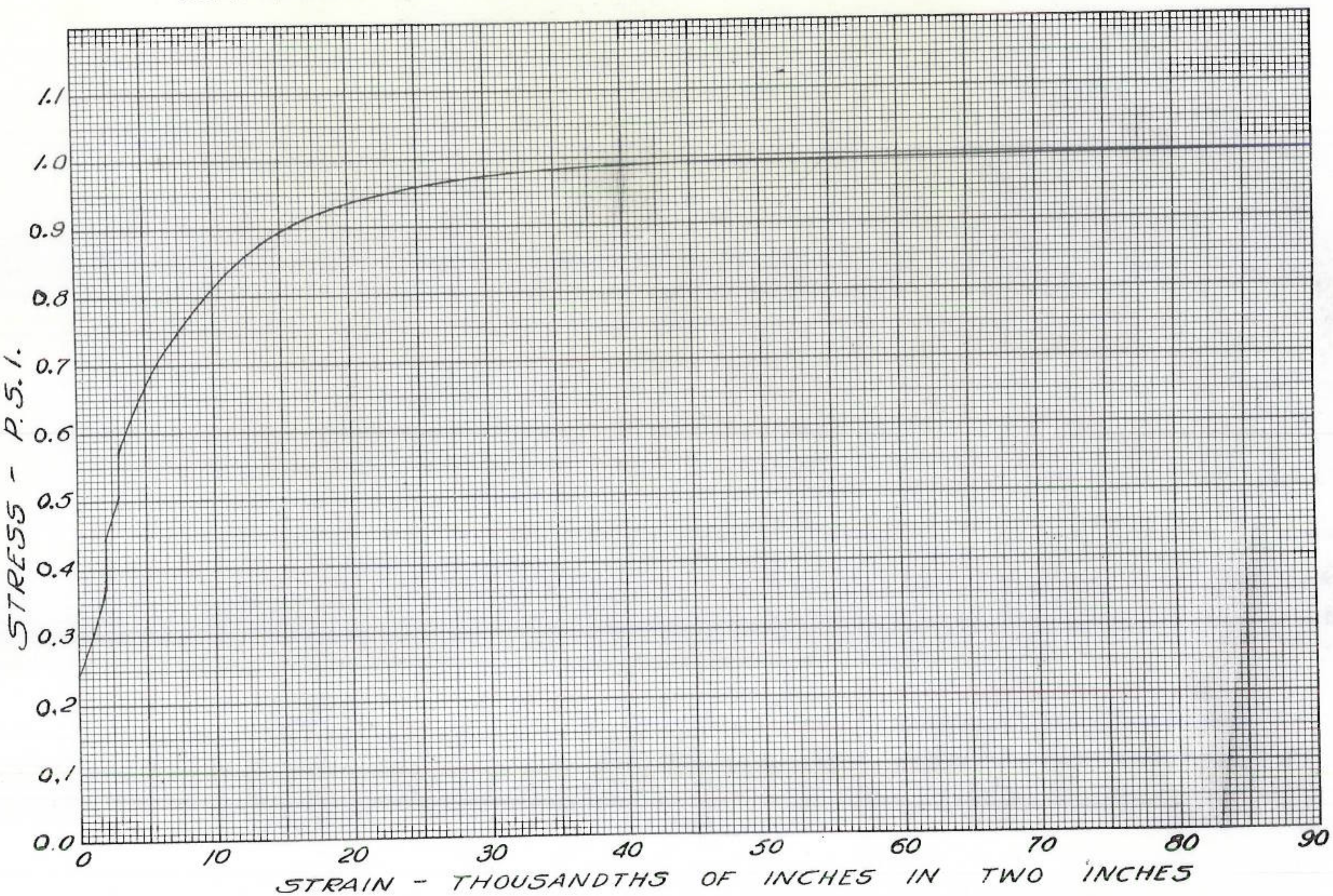
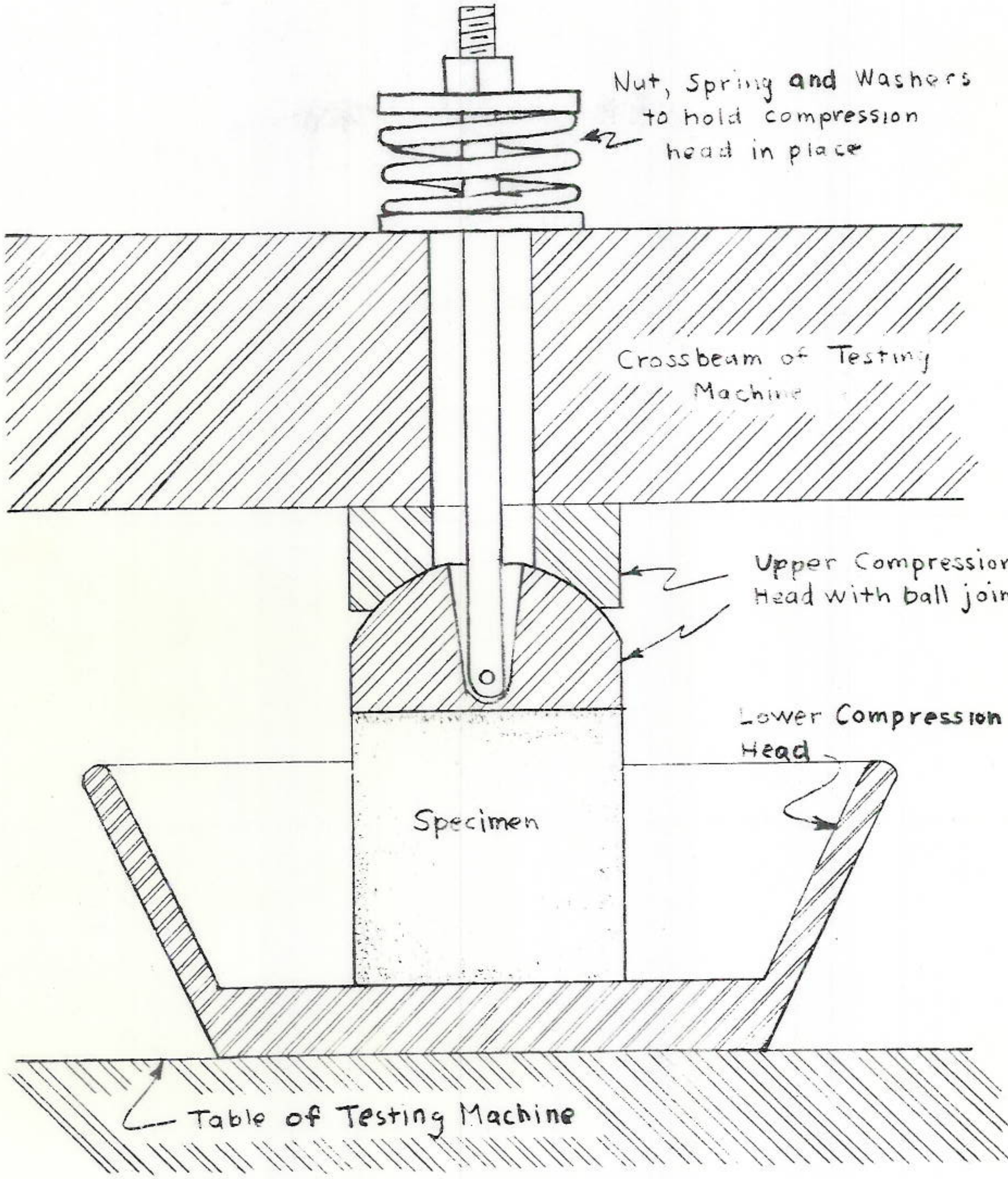
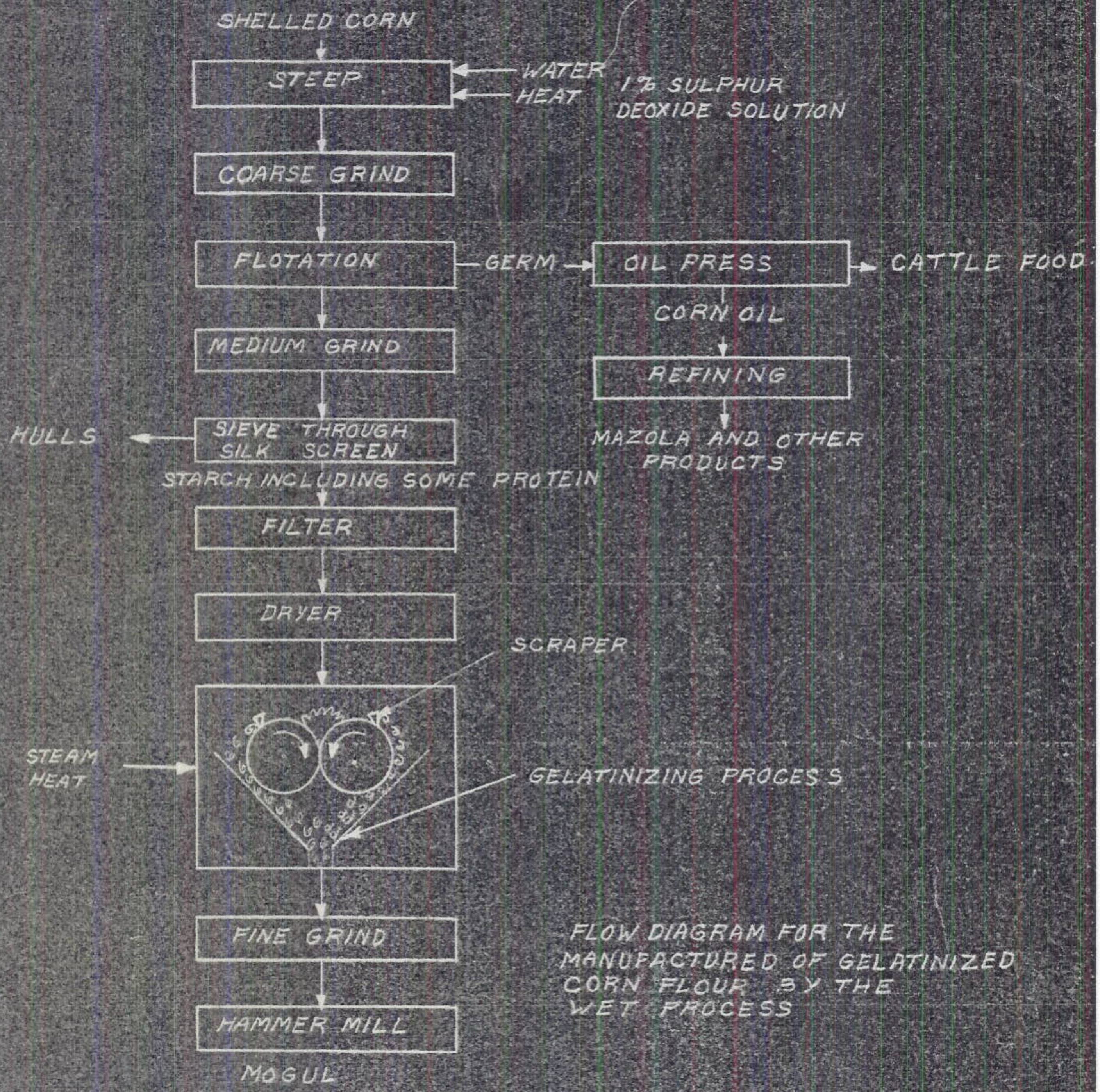


PLATE 5



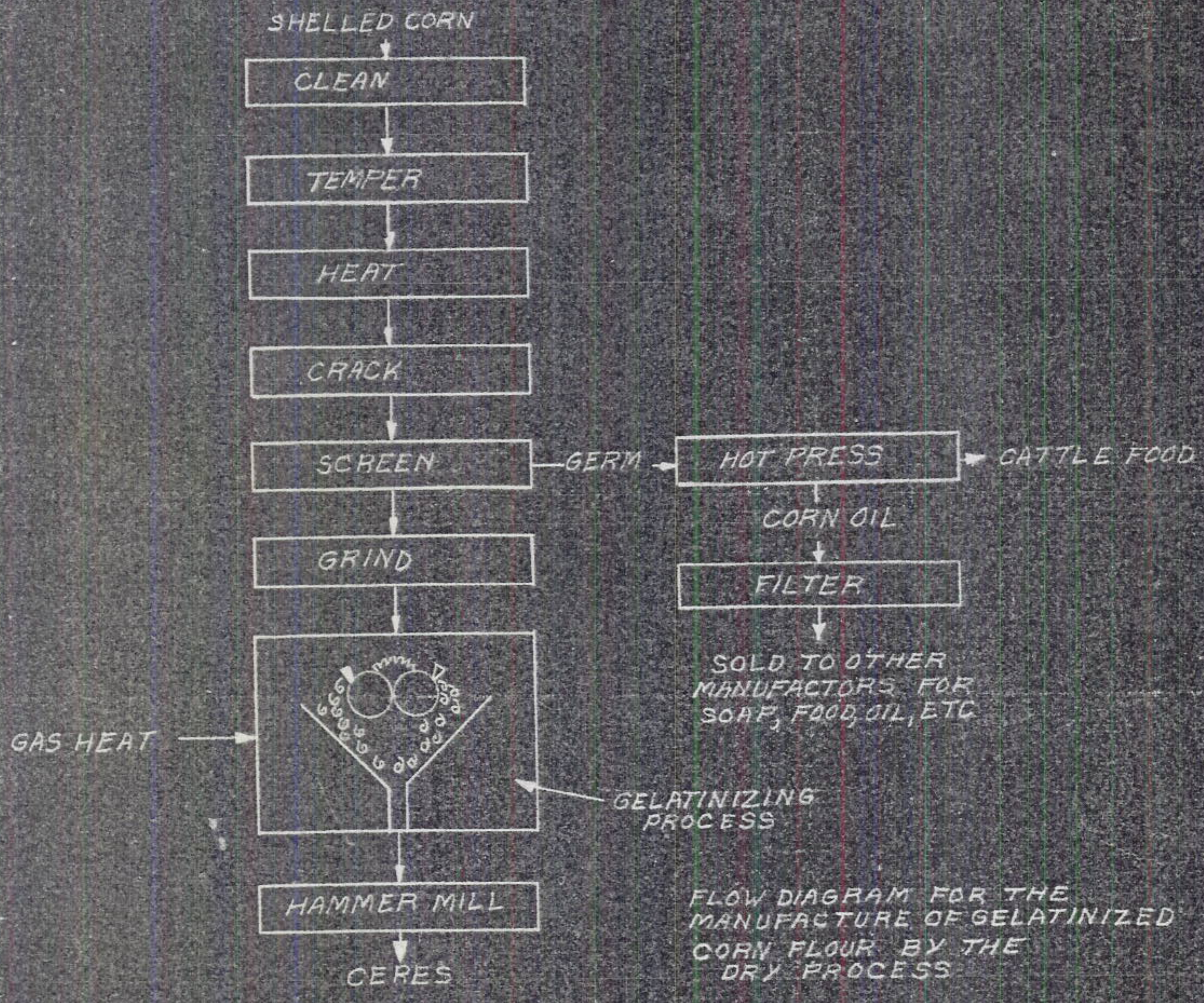
Compression Heads Used in Carver
Laboratory Press

Plate 6



FLOW DIAGRAM FOR THE MANUFACTURED OF GELATINIZED CORN FLOUR BY THE WET PROCESS

PLATE 7



FLOW DIAGRAM FOR THE MANUFACTURE OF GELATINIZED CORN FLOUR BY THE DRY PROCESS

PLATE 8

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