Rice drying and storage in Louisiana.

W G. Taggart
RICE DRYING AND STORAGE IN LOUISIANA

During the past few years labor conditions have changed materially in the Louisiana rice territory. The binder and thresher are being gradually replaced by the combine. The shorter labor supply and the combine have made it more desirable to handle and store rice in bulk instead of by the conventional sack method.

Rice when combined generally contains from 2 to 17 per cent more moisture than rice that has been threshed. Normally, threshed rice contains from 13 to 17 per cent moisture and can be stored satisfactorily in sacks and bulk. A moisture content of 14 per cent or less is generally considered necessary for safe bulk storage; hence, the need for drying equipment to insure safe storage.

The conventional sack-storage structures are large sprawling buildings with raised floors that do not readily lend themselves to conversion into bulk storage. The following material is presented as a guide for the farmer in securing a better drier and storage structure.

Description and Characteristics of Rough Rice

Rough rice, also known as “paddy,” “paddy rice,” and “uncleaned rice,” is threshed rice with the hulls on as it comes from the farm. Commercially, the term rough rice is used to designate the threshed rice when marketed for milling.

The seeds of the most common variety, Blue Rose, average 8.7 millimeters long and 3.4 millimeters in thickness, and 1,000 average kernels weigh 29.67 grams. The glumes are pale yellow and have smooth margins. The hull loosely encloses the kernel and is yellow and thick. Its surface has a burlap appearance and is thinly covered with long white hairs which are longer and more numerous toward the tip.

Rough rice with a moisture content of 14 per cent weighs on an average about 36.2 pounds per cubic foot. Some of the long grain varieties weigh slightly more but seldom exceed 38.6 pounds per cubic foot.

Respiration

A factor of considerable importance where rice is stored in bulk is respiration, which may be defined as the release of energy through biochemical oxidation of organic compounds. Respiration is continuous as long as life remains in the kernel. Carbon dioxide and water are the chemical end products, and in addition heat is liberated. Since rice itself
is a poor conductor of heat, it follows that the heat released through respiration accumulates in the mass in proportion to its bulk, and the increase in temperature may reach a dangerous level.

The rate of respiration of rice at different moisture contents was determined at the University of Minnesota with samples of threshed rice obtained from a mill at Crowley, Louisiana. The results were as shown in the following table:

**Respiration of Paddy Incubated at 37.8 Degrees Centigrade For Four Days.**

<table>
<thead>
<tr>
<th>Moisture</th>
<th>CO₂ respired per 24 hours for each 100 grams of dry matter.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.37%</td>
<td>0.27 mg.</td>
</tr>
<tr>
<td>12.15</td>
<td>0.32</td>
</tr>
<tr>
<td>13.22</td>
<td>0.51</td>
</tr>
<tr>
<td>14.12</td>
<td>1.01</td>
</tr>
<tr>
<td>14.93</td>
<td>2.20</td>
</tr>
<tr>
<td>16.11</td>
<td>8.22</td>
</tr>
</tbody>
</table>


These data indicate that where rice is stored in bulk in any considerable quantity and for a considerable period of time, it should not have a moisture content greater than 14 per cent.

**Moisture Content**

To obtain data on the equilibrium moisture content of rice under South Louisiana conditions a sample of combined and artificially dried Blue Rose rice was obtained from a large bin of the Louisiana State Rice Mill at Lake Charles, Louisiana, in November, 1943. Its moisture content as it came from the bin was 14.1 per cent. It was stored in a burlap sack in the Agricultural Engineering laboratory at Louisiana State University, where it was exposed to atmospheric temperatures and humidities but was protected from direct contact with moisture. By March, 1944, its moisture content had dropped to 12.6 per cent, which indicates that under South Louisiana conditions, rice does not have a tendency to absorb moisture from the atmosphere in excess of the maximum of 14 per cent generally considered safe for bulk storage, as shown in the preceding table.

Rice that has been artificially dried is usually placed in storage at temperatures of from 10 to 40 degrees above that of the prevailing outside atmosphere. Under these conditions there is a tendency for moisture to transfer from certain parts of the bin and to accumulate at or near the top center of the mass. This same tendency has been observed with soybeans.

Angle of Repose

The angle of repose for rice, or the coefficient of friction of rice on rice ($\mu$), was measured by filling a light wooden frame, mounted on a tilting top drafting table, with rice. The table top was then tilted until a part of the rice spilled over the lower edge of the frame, leaving an inclined surface which was the angle of repose for that particular sample. The inclined surface was measured by means of a plumb bob and protractor. The angle of repose was determined for the most common variety of rice, Blue Rose, and also for Rexoro, which is typical of the long grain rices.

It was found that angle of repose is greatly influenced by moisture content, especially when it exceeds 16 to 17 per cent. At higher moisture, it increases very rapidly. The values given in the following table are for rice with 14 per cent moisture.

The results obtained were very consistent and for the same sample seldom varied more than plus or minus one per cent from the mean.

### Angle of Repose for Rice

<table>
<thead>
<tr>
<th>Variety</th>
<th>Angle of Repose, Degrees</th>
<th>Coeff. of Friction of rice on rice (tan. of angle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Rose</td>
<td>36</td>
<td>0.727</td>
</tr>
<tr>
<td>Rexoro</td>
<td>34</td>
<td>0.675</td>
</tr>
</tbody>
</table>

### Coefficient of Friction

The coefficient of friction ($\mu'$) of rice on various bin materials is of particular importance to the bin designer because of its influence on bin pressures, and also on the required slope for hopper bottoms and any spouting to and from the bin proper.

The method used to determine the coefficient of friction was essentially the same as that for determining the angle of repose, except that a sample of the bin material to be tested was first placed between the wooden frame and the tilting table top. The bin material was fixed to the table top but the frame and contents were left free. The rice was carefully poured into the frame and leveled even with the top edges. The table was tilted until the angle was reached at which gravity overcame the frictional force between the rice and bin material, and movement began down the slope.

It was found that additional weight placed on the top surface of the rice had no significant effect on the angle at which movement began. This is to be expected, as the coefficient of friction is independent, within reasonable limits, of pressure per unit area.
<table>
<thead>
<tr>
<th>Material</th>
<th>Blue Rose</th>
<th>Rexoro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice on flat galvanized iron</td>
<td>0.402-0.414</td>
<td>0.447-0.449</td>
</tr>
<tr>
<td>Rice on concrete (smooth finish)</td>
<td>0.516-0.531</td>
<td>0.461-0.473</td>
</tr>
<tr>
<td>Rice on wood (plywood, across grain)</td>
<td>0.495-0.500</td>
<td>0.530-0.542</td>
</tr>
<tr>
<td>Rice on wood (plywood, with grain)</td>
<td>0.435-0.440</td>
<td>0.500-0.506</td>
</tr>
<tr>
<td>Rice on wood (cribbed wall)</td>
<td>0.583-0.613</td>
<td></td>
</tr>
</tbody>
</table>

**Ratio of Lateral to Vertical Pressures**

The ratio of lateral to vertical pressure ($k$) for rice was determined with a small model bin two feet deep and one square foot in cross-sectional area. The bin was equipped with hydraulic-type pressure gauges at the side and bottom. When vertical pressure was applied at the top surface of the rice, the resultant pressure at the bottom and side could be determined by measuring the increased height of the water columns connected to the respective gauges.

A series of tests was made using gradually increased loadings up to a maximum of 868 pounds, which was the practical limit with the equipment being used. Figure 1 shows that $k$ increases very rapidly at low pressures, but soon reaches and maintains a constant level for the remainder of the range of pressure applied.

In examining the graph shown in Figure 1 it is noted that only about 27 per cent of the total vertical load was transmitted through the two-foot column of rice to the bottom gauge. This surprising result was verified by several tests in which the walls of the bin were supported separ-
ately from the floor, while the bin bottom only rested on a platform scale. This experiment also checked the accuracy of the pressure gauge, in that the pressure indicated by the water column checked very closely with the actual pressure as shown by the platform scale.

**General Requirements of Rough Rice Storage Bins**

A bulk storage system for rice must have a sufficient number of bins to store each variety separately. Since the average rice grower will ordinarily grow as many as four different varieties, to spread his harvesting season over a longer period, a minimum of four bins is required in the most simple system. Where an artificial drier is used, additional work bins are needed for storage of partially dried rice. As a general rule from ten to fourteen bins should be provided where the total capacity does not exceed 10,000 barrels.

The most popular rice combines now in use have a maximum daily harvesting capacity of about 250 to 300 barrels. Combined rice must be artificially dried, and it is common practice to dry the rice from two to four separate times on consecutive days. It is believed that one combine will have sufficient capacity for the average rice grower in Louisiana. Where this is the case four working bins should be provided, each of about 250 to 300 barrels capacity.

The commercial rice driers now available require a space about 16 feet by 22 feet by 40 feet high. To accommodate a drier of this height the work house (part of structure in which drier and elevators are located) must be about 50 feet in height. Where a work house of this height is used, it is economical to construct the storage bins a minimum of 30 feet deep rather than of less depth and greater cross-section, thus simplifying to some extent the conveying system.

Since the rice must be frequently moved the labor required for this should be reduced to a minimum. All bins should be hopped at the bottom so they will empty entirely by gravity. For dry rice a 45 degree slope is satisfactory where the valley angle is lined with smooth tin. For bins which will handle damp rice, such as the working bins, the hopper slope should be increased to 60 degrees.

Rice is a granular material. The pressures exerted by it when stored within a bin do not follow the laws of fluid pressure. In order to check the laboratory analysis, gauges were installed in the bulk storage plant of the Louisiana State Rice Mill at Lake Charles, where there are rice bins 65 feet deep. The test bins were filled 52 feet deep with Blue Rose five times and Rexoro three times. The rice was all of good quality and had a moisture content ranging from 13.9 to 14.2 per cent. The result of these tests indicated that the walls were carrying 87.2 per cent of the total weight of the contents, while only 12.8 per cent was carried by the bottom of the bins.

**Handling and Conveying Equipment**

The conveying and elevating equipment for a bulk handling plant is very important and deserves careful study. This equipment receives a
great deal of use and in any case should have a capacity equal to that of the drier. For a small bulk storage an 8" x 5" cup with a 9" auger is about the minimum size. In most installations where a drier is used a minimum of three elevators is desirable — one for moving rice from the unloading pit to drier or bin, one from the drier to bins, and another from bin to drier or bin to bin. With this arrangement it is possible to unload rice from the combine at the same time other rice is being dried. Where a double row of bins which are individually hopped on at the center is used, a fourth elevator is desirable, which will permit "loading out" rice into trucks or box cars at the same time other operations are going on.

To prevent undue mixing of rice varieties, all elevator boots and conveyors should be made readily accessible for cleaning. Experienced rice buyers can readily detect if there is even a small amount of another variety mixed in the rice they are buying, and usually they discriminate rather severely against it.

An unloading pit should be provided for rice coming in for storage. A concrete pit with a ramp leading toward and away from it makes a good arrangement. It can be covered with a grating and provided with some type of hoist for dumping the rice from truck or trailer. The slope of the hopper bottom should be a minimum of 60 degrees. Where a pit is used, care must be taken during construction to insure a waterproof job.

Combined rice often contains considerable foreign matter with a high moisture content, such as short lengths of straw and pieces of green leaves and berries from weeds. This, if allowed to remain, may give trouble by preventing a uniform flow of rice through the drier and, later, by tending to cause heating in storage. It is advisable to use some type of cleaning device for removing this material. A machine such as No. 6 Monitor Cleaner is of about the right size for the smaller storage plants.

Fundamentals of Rice Drying

Combined rice normally contains about 14 pounds of excess water per barrel, which must be removed before the rice can be satisfactorily stored or milled. This excess water could be removed as a liquid by means of a very powerful press, but this would obviously be impractical. A more practical method is to evaporate the excess moisture and remove it as a vapor.

Evaporation requires energy in the form of heat. To evaporate one pound of water from rice requires, in round numbers, about 1,000 BTU of heat, or the total heat required to dry one barrel of combined rice is equal to that required to raise the temperature of about 14,000 pounds of water one degree Fahrenheit. Nature supplies this same amount of heat to rice dried naturally in the shock in the field from the vast amount of energy supplied by the sun.

The most practical method for artificially removing the excess moisture is to pass warm air through the damp rice. The heat from the air supplies the energy for evaporation and at the same time tends to main-
tain a greater vapor pressure within the rice grain than exists on the exterior. This difference in vapor pressure largely governs the rate at which moisture will move from the interior to the exterior of a rice grain.

Another important function of the warm air is to provide a medium for carrying away the water vapor liberated by evaporation. The amount of water vapor which air can hold or transport is governed by its temperature. A pound of air which is saturated at ordinary atmospheric temperature can be made to carry an additional amount of vapor equal to what it already has by raising its temperature 25 to 30 degrees Fahrenheit.

The humidity of the air in South Louisiana is usually high. About 2,000 cubic feet of warm air are required to absorb and carry away one pound of water vapor, or about 28,000 cubic feet are needed to dry one barrel of rice.

There are a number of factors which govern the rate at which water can be evaporated from rice. Surface moisture which is present when the moisture content is high is very easily removed as the evaporation takes place from a free water surface. Internal moisture is more difficult to remove, as the diffusion of moisture to the surface is relatively slow, owing to the dense kernel and somewhat impervious hull of the rice grain. The deviation of the drying rate from the rate of free evaporation will depend upon the time required to bring the moisture to the surface. Diffusion of moisture to the surface will be quite rapid at first, but as drying advances, the process becomes slower until a condition of equilibrium is reached and further evaporation ceases. The ultimate rate of drying is thus governed by the rate of both evaporation and diffusion.

To reduce the total time for drying to a minimum and thereby increase the capacity of the drier, it is good practice to expose rice to drying air at intervals. After the surface moisture has been evaporated the rice is placed in storage for a time until the moisture has again become evenly distributed throughout the grain. It is then again exposed to the drying air.

Since heat is needed in drying, both to supply energy for evaporation and to maintain a difference in vapor pressure which causes internal moisture to diffuse to the surface, the drying air temperature should be as high as possible without damaging the rice. The upper safe limit for this temperature is probably about 130 degrees Fahrenheit.

Warm air, which supplies heat for drying and carries away moisture, should be supplied at the rate of 350 to 400 cubic feet per minute for each barrel of rice being dried. The practical limit for the relative humidity of the air leaving the drier is about 75 per cent. To obtain uniform distribution of air throughout the drier without excessive static pressure, it is important that the lineal velocity of the air in the ducts does not exceed 2,000 feet per minute. When this precaution is observed, the static air pressure at the blower need not exceed ¾ inch water pressure.
Evaporation requires heat. Where the heat is largely supplied by warm air passing through the rice, the greater the rate of evaporation, the greater the drop of temperature between the inlet and outlet air. The temperature of the air will drop approximately $8\frac{1}{2}$ degrees Fahrenheit for each grain of moisture absorbed per cubic foot of air measured at 70 degrees, or 0.64 of a degree for each grain absorbed per pound of air, where no heat has been lost to the rice or drier itself. As the drying rate decreases, there is less cooling of the rice by evaporation and finally the temperature of the rice and the outlet air will increase and gradually approach the temperature of the inlet air. These temperatures are the best indication of what is actually happening to the rice in the drier and should be closely observed by the drier operator.

It is recommended that the temperature of the rice should not be allowed to exceed 110 degrees Fahrenheit for best drying results. This temperature can be determined by catching a sample of the rice from the drier in a container and inserting the bulb of an ordinary laboratory thermometer into the interior of the sample.

**Rice Drying Instructions**

A. Start with good quality rice.
   1. Rice should not be chalky, pecky, etc.
   2. Rice should be of uniform ripeness. Overripe grains usually are uncheckered.
   3. Rice should be well combined and have a minimum of hulled grains.
   4. Rice should be combined at 22 to 26 per cent moisture content.

B. First drying.
   1. Begin within six hours after combining.
   2. Dry for 30-45 minutes at 130 degrees Fahrenheit.

C. Second drying.
   1. Begin 6 to 12 hours after completion of first drying.
   2. Dry for 20-30 minutes at 130 degrees Fahrenheit.

D. Third drying and additional dryings required to reduce the moisture to 14½ per cent.
   1. Begin 6 to 12 hours after completion of previous dryings.
   2. Dry for 20 minutes at 130 degrees Fahrenheit.

E. Last drying.
   1. Begin within 24 hours after previous drying.
   2. Dry without artificial heat unless atmospheric humidity is above 75 per cent.
   3. Dry until rice temperature is as low as the atmospheric temperature.

**Low Yield of Head Rice**

Occasionally a lot of artificially dried rice is received at the mills which yields fewer pounds of head rice than is normal for that variety.
Investigation of the reasons for the low milling yield usually reveals one or two causes. The rice kernel may be fractured in the drier either by too rapid drying with excessive heat or by too rapid cooling. In most cases, however, where a sample of the original rice that was dried naturally is available for comparison, it is found that the quality of the rice was poor when it first reached the drier.

The common complaint is that the rice has been stack burned by the drier. Stack burning is occasionally found in artificially dried rice but does not occur in the drier. Experimental work conducted by research workers at the University of Minnesota* and others shows that certain molds, bacteria, and fungi are almost invariably present on normal rice grains even though the rice has been grown and harvested under ideal conditions. Their presence is entirely harmless as long as conditions are unfavorable for their growth. When the moisture content exceeds the minimum for the reproduction of these organisms and the temperature conditions are suitable, abundant growth is produced. This condition prevails when the relative humidity of the air surrounding the rice grains reaches or exceeds about 75 per cent at a minimum temperature of about 77 degrees. Growing organisms produce moisture and heat as end products of their respiration and also excrete powerful digestive ferments which act on the starches, proteins, and fats, which are readily available near the bran layer of the rice grain.

The occurrence of stackburn can best be prevented by limiting the length of time between dryings. The practice of allowing the temperature of rice to rise in the bin is not recommended. The temperature of dried rice should be reduced to atmospheric temperature before it is placed in final storage.

**Weight Loss Due to Drying**

When rough rice is dried artificially or naturally in the shock in the field, there is always a loss of weight. The loss of weight is due to the removal of moisture, and the percentage of loss of weight due to drying is always greater than the reduction in the percentage of moisture. This difference exists because as the rice is being dried there is a constant change of base in making the moisture test.

The algebraic calculations for the final weight of a barrel of rice, after drying, may be made as follows:

\[
\text{Final wt.} = \text{original wt.} - \text{wt. lost due to drying} \quad (1) \\
\text{Wt. lost due to drying} = (\text{original wt.} \times \text{original \% moisture}) - (\text{final wt.} \times \text{final \% moisture}) \quad (2)
\]

As an example, assume 162 pounds of rice are dried from 24 per cent to 14 per cent. Transposing these values into equation (2) and then in turn into equation (1), we have:

Final wt. = 162 lbs. — (162 lbs. x 0.24 — final wt. x 0.14)  
Final wt. = 162 lbs. — 38.88 + 0.14 final wt.  
Final wt. = 162 - 38.88 = 143.16 pounds.

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* Max Milner, Minnesota Agricultural Experiment Station.
Note that in this case the reduction in moisture is 10 per cent while the reduction in weight due to drying is 11.63 per cent.

Another form of the same equation which is more easily remembered is as follows:

\[
\text{Final wt.} = \frac{\text{original wt. x original \% dry matter}}{\text{final \% dry matter}}
\]

\[
\text{Final wt.} = \frac{162 \text{ lbs. x (100\% - 24\%)} = 162 \times 76\% = 143.16 \text{ lbs.}}{(100\% - 14\%)}\]

In addition to the weight lost due to drying there is usually some loss due to the blowing out of small particles of broken grains, dust, and hulls. Where the rice is cleaned during the drying process additional straw, weed seeds, and foreign material are removed and the total weight loss may be as much as 2 per cent for each per cent of moisture removed by the drier. The average weight loss on over 69,000 barrels of rice dried at the Crowley Rice Drier Co-op., Inc., Crowley, Louisiana, during the 1945 drying season was 9\% per cent.

**Cleaning Combined Rice Before Drying**

Combined rice usually contains varying amounts of straw, grass, weed seeds, etc., which add considerably to the total moisture of the sample. As an example, moisture tests made on an exceptionally dirty lot of rice showed the average moisture to be 37\% per cent. The rice only was then removed by hand from the same sample and it was found to contain only 22 per cent moisture. The wet foreign material in combined rice not only cuts down on the capacity of the drier, but also interferes with the uniform flow of the rice in the drier, bins, and conveying system.

Combined rice which has not been dried is difficult to clean. Many of the weed seeds will pass through the same size screen opening as rice, and when wet are too heavy to be removed by air. One of the greatest problems is to obtain sufficient cleaning capacity in barrels per hour without excessive cost for cleaning equipment.

A coarse screen is probably the best for removing the larger pieces of straw and other material which interfere with the uniform flow of rice. One of the best commercial cleaners observed uses a revolving screen cylinder for removing the larger pieces and an air blast for the smaller and lighter dust, chaff, hulls, etc.

When rice is artificially dried, a great deal of dust is produced. This is because the rice hulls and other foreign matter are more porous or smaller than the rice kernel itself and become very dry and brittle. The transferring of rice from bin to drier and return causes these brittle pieces to break up into smaller pieces. Some varieties of rice such as Blue Rose have a fuzz on their hull which when dry is easily rubbed off.
Screen Analysis of Dust Obtained at the Crowley Rice Drier
Co-op., Inc., Crowley, La.

Sample A. Settled dust from ledges near drier.
Sample B. Settled dust deposited by air currents only.

<table>
<thead>
<tr>
<th>Screen Analysis (Mesh)</th>
<th>Sample A</th>
<th>Sample B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through 325 mesh</td>
<td>25.3%</td>
<td>49.7%</td>
</tr>
<tr>
<td>325 - 200 mesh</td>
<td>18.9%</td>
<td>23.3%</td>
</tr>
<tr>
<td>200 - 100 mesh</td>
<td>7.2%</td>
<td>18.4%</td>
</tr>
<tr>
<td>100 - 65 mesh</td>
<td>9.4%</td>
<td>4.0%</td>
</tr>
<tr>
<td>Under 65 mesh</td>
<td>39.2%</td>
<td>4.6%</td>
</tr>
</tbody>
</table>

Dust Control in the Drying Plant

To avoid much of the annoyance and inconvenience of dust, it is recommended that all driers be enclosed. The drier enclosure should be large enough to act as a settling chamber to remove the heavier particles of dust from the air stream. The exhaust opening from the drier enclosure should always have an area at least equal to the total area of the blower outlets leading into the enclosure. This is necessary to avoid back pressure on the blower.

Where better separation of dust from the drier air is necessary than is possible with a simple settling chamber, an air washer is recommended. The greatest factor in the elimination of dust in an air washer is a properly designed scrubbing surface wetted and washed down with low pressure water sprays. The air flowing through the washer should be divided by the scrubbing plates into as narrow layers as practical in order that as great a contact surface as possible may be secured, and so that the dust particles in the air will have a relatively small distance to travel before coming in contact with a wetted surface. In addition to the scrubbing plates, it is advisable to provide a chamber with water spray so arranged that the spray is directed toward the plates and in the direction of the air flow. The water should be supplied with a settling tank, through which the spray water is recirculated to remove dust particles. Provision should be made for quickly draining and refilling the settling tank, as this must be done periodically. A centrifugal pump is used to circulate the spray water.

A source of much of the dust in a drying plant is the elevator discharge of partially dried rice into the receiving hopper of the drier. Most of this dust and larger foreign material such as dry straw can be removed here by passing the rice through an aspirator.

Another source of dust is at the discharge of the drier. This dust is produced by the movement of the rice in passing through the drier. Since it is very dry and consists mostly of very small particles it is easily removed by air. In most cases a suction applied to the discharge spout leading from the drier to the elevator will be sufficient.

Where dust is systematically removed from the rice at the locations mentioned, it does not have a chance to accumulate. By placing covers on the conveyors most of the remaining dust is prevented from escaping.
Where complete dust control is necessary or desired the recommendations given in U. S. D. A. Department Bulletin 1373, "Dust Control in Grain Elevators," will be found very helpful.

Another very good reference on dust control is Engineering Service Department Bulletin No. DC-200A, which can be obtained from the Mill Mutual Fire Prevention Bureau, 400 West Madison Street, Chicago, Illinois.

Those interested in the explosive properties of rice dust are referred to U. S. D. A. Technical Bulletin No. 490, "Explosibility of Agricultural and Other Dusts as Indicated by Maximum Pressure and Rates of Pressure Rise," or they may obtain more recent information by writing direct to Mr. Hylton R. Brown, Senior Engineer, U. S. Department of Interior, Bureau of Mines, Eastern Experiment Station, College Park, Maryland.

**Moisture Testers**

The principal advantage of the electric type testers is in the rapidity with which tests can be made. For this reason they are very popular with rice drier operators, who need to know at all times the approximate moisture content of each lot of rice. These testers have been calibrated with clean rice of uniform moisture content, and when testing such rice are very accurate. Wet combined rice is seldom uniform in moisture content and usually contains varying amounts of weed seed of high moisture content, which makes it very difficult to obtain a true average moisture reading. Rice which has just passed through a drier is not of uniform moisture throughout the entire grain, and unless allowance for this is made the true moisture is not obtained. For this reason some drier operators have been led to believe that moisture content of rice changes appreciably while in the bin between dryings.

The Brown-Duvel tester, if properly operated, will give the true moisture of a sample of rice regardless of foreign matter, temperature of the rice, or uniformity of drying. The principal disadvantage of this tester is that about 30 minutes is required to complete a moisture test. Complete instructions for the operation of this tester are given in U. S. D. A. Bulletin No. 1375D, "The Brown-Duvel Moisture Tester and How to Operate It."

All types of moisture testers are calibrated and checked by oven drying a part of the sample being tested. This method is extremely accurate and is standard for all types of moisture tests, but requires considerable time. Information on the procedure for making this type of test is given in U. S. D. A. Agricultural Marketing Service, Service and Regulatory Announcement No. 147, "Air-oven and Water-oven Methods Specified in the Official Grain Standards of the United States for Determining the Moisture Content of Grain."

**Seed Rice Drying**

Seed rice may be dried artificially without damage to the germination. Very good results have been obtained in experimental work by
continually rotating the seed rice from bin to drier and then to another bin until dry. An inlet air temperature of 120 degrees Fahrenheit and a 20-minute drying period were used. This method of drying reduces the capacity of the drier somewhat but eliminates the possibility of mold or fungus attacking the germ of warm damp rice while in the bin between drying periods.

Before drying a lot of seed rice it is extremely important that the drier, bins, and conveying system be thoroughly cleaned in order that there will be no mixing with other varieties. The seed rice drier should be of a self-cleaning type. The bins should be free of projections or ledges on the interior, and the elevator boots easily cleaned. Screw conveyors can be cleaned with a small portable electrically driven hand blower. The dust covers are removed, and with the conveyor running, cleaning is started at the receiving end and proceeds to the discharge end. As rice is piled up by the blast of the blower, the next conveyor flight picks it up and carries it to the discharge end.

Heat Supply For Drier

The amount of heat required for warming the air used by a rice drier depends upon the initial temperature and moisture content of the air. The approximate quantity of heat required to raise the temperature of one pound of air and its moisture one degree Fahrenheit is about 0.246 BTU per pound of the mixture, or about 18.1 BTU per 1000 cubic feet of air.

The average mean temperature in the Crowley, La., area during August, September, and October is about 77 degrees Fahrenheit. Assuming 77 degrees Fahrenheit initial temperature, 130 degrees maximum temperature, and with no heat loss, a total of about one BTU of heat is required per minute for each cubic foot of air used by the drier.

To take care of lower initial air temperature, heat losses, and periods of above average humidity, it is recommended that enough heating capacity be provided to supply about two BTU per minute for each cubic foot of air used.

The most satisfactory source of heat for a rice drier is natural gas or butane gas. Gas burners are relatively inexpensive and are easily regulated to maintain a desired air temperature. Because a clean flame is produced, the burner can be directed toward the inlet to the blower and the products of combustion allowed to pass through the drier.

Gross Heating Value of Various Fuels

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Gross Heating Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>1,000 BTU per cu. ft.</td>
</tr>
<tr>
<td>Commercial butane</td>
<td>21,180 BTU per pound</td>
</tr>
<tr>
<td></td>
<td>102,600 BTU per gallon</td>
</tr>
<tr>
<td>Commercial propane</td>
<td>21,560 BTU per pound</td>
</tr>
<tr>
<td></td>
<td>91,500 BTU per gallon</td>
</tr>
<tr>
<td>Gasoline</td>
<td>21,050 BTU per pound</td>
</tr>
<tr>
<td></td>
<td>129,000 BTU per gallon</td>
</tr>
</tbody>
</table>
Kerosene .................................. 20,000 BTU per pound
                                       135,000 BTU per gallon

As a safety precaution each burner installation should be equipped with a solenoid valve in the gas line. During normal operation the solenoid valve is held open by electrical energy from the same circuit which drives the blower motor. It should be wired so that in case of current failure the valve is automatically closed and remains closed until manually opened by the drier operator.

**Experimental Work on Drying Plants**

Preliminary work on the requirements of an inexpensive individual type farm rice drier was begun during the 1943 rice harvest season. At that time experiments were conducted and data collected, on a full season's drying results, at an existing plant owned and operated by Webster Todd and Donald Todd near Holmwood, Louisiana. The results of the first season's research provided valuable information on the drying conditions which must be maintained in a drier to ensure a maximum yield of head rice.

Following the 1943 harvest season, work on the design of a drier was begun. The following principles were kept in mind:

1. With optimum drying conditions known and maintained in the drier, each grain of rice should, as far as is mechanically practical, be uniformly exposed to those same drying conditions.

2. The drier should be easy to fabricate with standard types and sizes of materials most readily available.

3. The drier should be easily constructed without an elaborate set of tools and equipment.

4. The drier should be entirely self-cleaning, making it suitable for the drying of seed rice.

5. The drier should be of a size suited to the needs of the small grower.

The first experimental drier was built during the summer of 1944. The construction of the drier is best shown by referring to Figure 2, a picture of a one-fourth-scale model of the drier, and to Figures 3 and 4. During the early part of the 1944 harvest season, it was installed on the farm of John Baker and Floyd Baker near Gueydan, Louisiana. The picture of the scale model shows one side of the inlet air duct constructed from transparent plastic material. In the large model this was replaced with ¾-inch plywood.

Four 300-barrel-capacity round tanks of light gauge steel construction were used for working bins. A receiving hopper for wet rice, two elevators, and necessary screw conveyors were provided. Heat for the drier was supplied by a homemade burner using natural gas. A 7½ H.P. electric motor supplied all of the power for the elevators and conveyors.
About 10,000 barrels of rice were dried that season at a cost of 18 cents per barrel. The total cost of the plant was estimated at $5,500.

As a result of the research at Gueydan, a second drying plant was erected the following year by Remy Robert and Bros. at Burnside, Louisiana, as shown in Figure 5. The drier is of the same design shown in Figures 3 and 4, except that it is larger and of steel construction. Plans
Figure 3. — Exploded isometric view of rice drier.
Figure 4. — Section views of rice drier.
Figure 5. — Rice drier and storage of Remy P. Robert and Bros., Burnside, La.

for the drier, elevators, conveying system, bins, and layout of the complete plant were supplied by the Experiment Station. In order to test out the feasibility of using steel bins for storage of rice, a test was made in cooperation with Remy P. Robert.

Approximately 200 barrels of Blue Rose rice were combined, dried and put into a round cylindrical steel bin 11 feet 4 inches in diameter with a conical-shaped hopper on November 28, 1945. This rice was not
disturbed during the storage period and was in good condition when removed on April 15, 1946. Results of this test indicate that steel bins are satisfactory for the storage of rice, as shown by data in the following table.

### Temperature and Moisture Data on Rice Stored in Steel Bin

<table>
<thead>
<tr>
<th>Thermocouple Location</th>
<th>1945</th>
<th>1946</th>
<th>1945</th>
<th>1946</th>
<th>1945</th>
<th>1946</th>
<th>1945</th>
<th>1946</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11-28</td>
<td>12-10</td>
<td>12-18</td>
<td>1-4</td>
<td>1-17</td>
<td>2-1</td>
<td>2-19</td>
<td>3-8</td>
</tr>
<tr>
<td>Temperature in degrees F.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Center, 6 ft. below surface</td>
<td>100</td>
<td>69</td>
<td>64</td>
<td>58</td>
<td>54</td>
<td>54</td>
<td>52</td>
<td>55</td>
</tr>
<tr>
<td>Center, 3 ft. below surface</td>
<td>96</td>
<td>71</td>
<td>66</td>
<td>58</td>
<td>56</td>
<td>55</td>
<td>53</td>
<td>54</td>
</tr>
<tr>
<td>Center, 3 in. below surface</td>
<td>91</td>
<td>70</td>
<td>58</td>
<td>44</td>
<td>49</td>
<td>55</td>
<td>61</td>
<td>68</td>
</tr>
<tr>
<td>4 ft. from side, 3 in. below surface</td>
<td>77</td>
<td>79</td>
<td>58</td>
<td>47</td>
<td>54</td>
<td>63</td>
<td>64</td>
<td>71</td>
</tr>
<tr>
<td>3 in. from side, 3 in. below surface</td>
<td>95</td>
<td>57</td>
<td>47</td>
<td>56</td>
<td>52</td>
<td>57</td>
<td>65</td>
<td>64</td>
</tr>
<tr>
<td>Air, 6 ft. above rice</td>
<td>81</td>
<td>50</td>
<td>57</td>
<td>68</td>
<td>53</td>
<td>60</td>
<td>64</td>
<td>74</td>
</tr>
<tr>
<td>Sample Moisture in per cent determined by oven drying</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Center, 3 in. below surface</td>
<td>17.47</td>
<td>16.82</td>
<td>15.68</td>
<td>15.30</td>
<td>15.56</td>
<td>14.78</td>
<td>14.31</td>
<td></td>
</tr>
<tr>
<td>3 in. from side, 3 in. below surface</td>
<td>17.12</td>
<td>16.72</td>
<td>16.15</td>
<td>15.63</td>
<td>15.68</td>
<td>14.99</td>
<td>14.54</td>
<td></td>
</tr>
<tr>
<td>3 in. from side, 36 to 48 in. below surface</td>
<td>16.02</td>
<td>15.80</td>
<td>14.63</td>
<td>14.78</td>
<td>14.15</td>
<td>14.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom outlet gate</td>
<td>13.80</td>
<td>13.02</td>
<td>13.48</td>
<td>12.80</td>
<td>12.70</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The following bill of material gives the materials from which a farmer can fabricate the drier easiest. If plywood is not available, tongue and grooved dressed lumber can be substituted. The entire drier can be and has been built of sheet iron, angles, rods, and piping; its construction, however, requires tools and machine for working steel not found on many farms.

### Bill of Material for Building Small Grain Drier

- **7 sheets**—4' x 8' plywood, ¾” thick, 5-ply, for ends and sides
- **24 pcs.**—dressed lumber, 1" x 10" x 12', for inverted sections
- **8 pcs.**—dressed lumber, 1" x 4" x 12', for supporting ends of inverted sections
- **1 pc.**—dressed lumber, 1" x 10" x 12', for supporting lower row of inverted sections
- **2 pcs.**—dressed lumber, 1" x 3" x 12', for braces
- **4 sheets**—4' x 8', 20 gauge galvanized sheet metal, for air duct from blower to drier
- **8 ft.**—¾" x 1" strap iron, for attaching metal air duct to blower
- **6**—round rods ¾" x 4'6", threaded at each end and with nuts and washers
6 sheets—4′ x 10′, 28 gauge galvanized sheet metal, for covering inverted sections (Use leftovers to cover boards in discharge feed roller section)

**Receiving Hopper**

4 sheets—4′ x 8′ plywood, ⅜” thick, 5-ply
36 ft. —⅛” x 1” strap iron, for reinforcing hopper and attaching to drier

**Discharge Feed Roll Section**

1 pc. —dressed lumber, 4” x 8” x 8′
1 pc. —dressed lumber, 1” x 8” x 12′
1 pc. —dressed lumber, 1” x 4” x 12′
3 pcs. —pipe, 60” long, 1” outside diameter
18 —iron straps, ⅛” x 1⅛” x 4′0”
6 —washers, 1⅛” size
4 —sprockets, 5” diameter, 1” bore
96 in. —chain for sprockets
2 pcs. —sheet iron, ⅛” x 5⅛” x 4′6”

**Discharge Hopper**

2 sheets—3′ x 8′, 20 gauge galvanized metal
100. —stove bolt and nuts, 3/16” x ½”

**Base of Drier**

3 pcs. —dressed lumber, 6” x 6” x 12′, for legs of base and horizontal supporting members
4 pcs. —dressed lumber, 2” x 6” x 12′, for braces

**Miscellaneous Items**

200 —wood screws, No. 15, 3”
100 —wood screws, No. 10, 1½”
100 —wood screws, No. 8, ⅜”
5 lbs. —small nails, for tacking sheet metal to inverted sections
75 —lag screws, ⅛” x 4”
1 —blower, similar to Type BC-40 manufactured by ILG Electric Company, 304 Natchez Bldg., New Orleans, Louisiana
1 —electric motor, 2 H.P., 1750 RPM, for blower
1 —electric motor, ½ H. P., 1750 RPM, for speed reducer
1 —butane tank, 100 gallon size or larger
1 —old 55 gal. oil drum, open at ends. Use as duct for heated air at inlet to blower. Do not attach to blower.
2 —thermometers, 20-220°F. range

* This list gives material of standard sizes. In some cases, it will have to be dressed down to conform to the sizes called for in the blueprints.
ACKNOWLEDGMENTS

Acknowledgment is due the following for their valuable assistance in conducting this research on rice drying: Webster Todd and Donald Todd of Holmwood, La.; John Baker and Floyd Baker of Gueydan, La.; Remy P. Robert and Bros. of Burnside, La.; Crowley Rice Drier Co-op., Inc., Crowley, La.; Jos. A. Heinen of Branch, La., whose broad knowledge of the rice industry was of inestimable value in keeping this research on a practical basis; and to Ned J. Bond, Jr., for work in making detailed drawings of drier developed by Harold A. Kramer.