DESIGN AND DEVELOPMENT OF A MICRO FLOUR MILL

P. K. Turnquist, Jay G. Porterfield
D. C. Abbott

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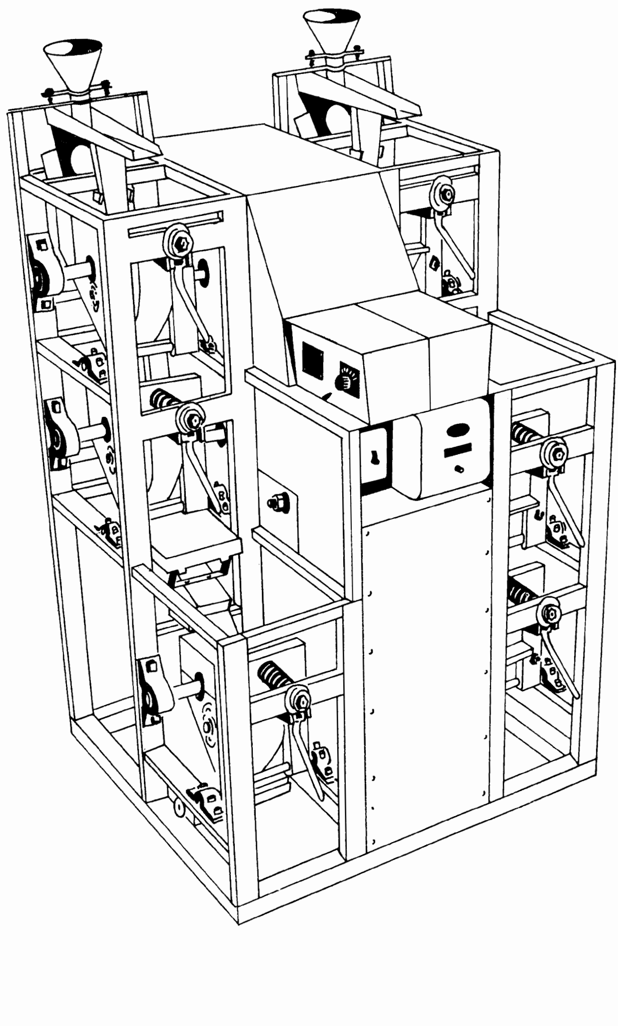

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Design and Development of a Micro Flour Mill

P. K. Turnquist, Jay G. Porterfield, and D. C. Abbott*

Milling properties of wheat and flour quality can be determined from small samples if the proper milling equipment is available. Milling wheat samples of limited size has been difficult because of the lack of proper equipment.

This bulletin reports results of a study to design and develop a micro mill capable of milling wheat samples as small as 100 to 150 grams.

Preliminary Design and Evaluation

A basic unit consisting of a pair of smooth reduction rolls and two sifting units was designed and constructed as shown in Figure 1. Outside dimensions were 30¼ inches long, 20½ inches high and 12 inches wide. The rolls, 6 inches in diameter and 2 inches wide, were powered by a fractional horsepower electric motor.

Stock entered the rolls from a metering device. After grinding, the material was discharged into a small, continuous flow wire screen sifter. "Overs" of the wire screen were bran and shorts. "Throughs" of the screen passed into a second sifter containing a silk flour cloth. "Throughs" of the silk cloth were collected as flour. "Overs" of the cloth could be reprocessed or discarded.

Vibratory motion with a frequency of 5 cps and amplitude of ⅛ inch in a horizontal plane was imparted to the sifting units. The sifting screen was fastened to a carriage mounted on small ball bearing wheels. The core of a solenoid was attached to the carriage and when energized caused motion in one direction. When de-energized, a spring returned the carriage against a rubber stop. A motor driven cam operated a

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* Former Assistant Professor and Professor, respectively, Agricultural Engineering department and Assistant Professor, Biochemistry department.

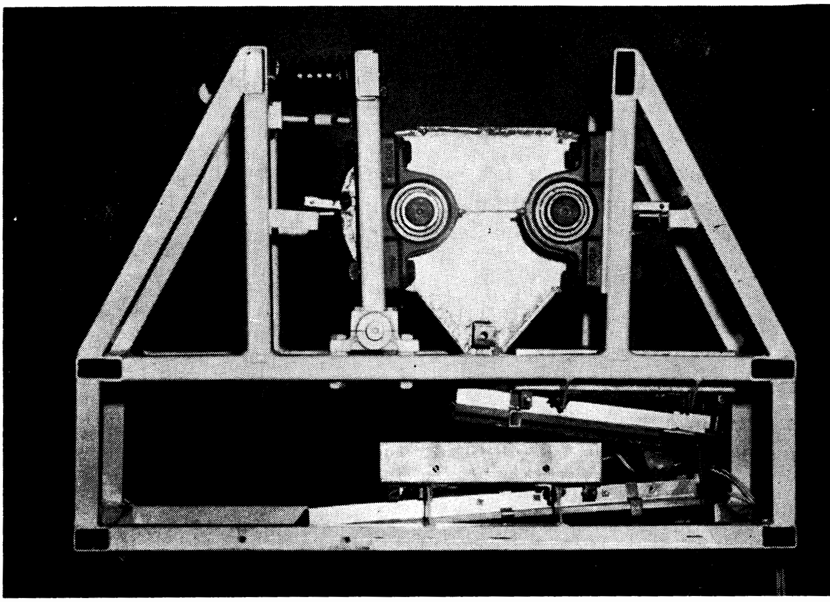

Figure 1. Micro flour mill basic unit consisting of a pair of rolls and two sifting units.

roller micro switch which supplied current to the solenoid at the required frequency.

The unit was first evaluated using material equivalent to that which would normally go to the first reduction rolls in a Buhler mill. A minimum flow rate of 10 grams per minute was established. Factors evaluated in the tests were: (1) amount of material lost; (2) degree of self-cleanout and ease of manual cleaning between samples; (3) quantity of flour produced for various flow rates and roll spacings: and (4) performance of the sifting screens.

Results indicated that screen capacity rather than roll capacity determined the acceptable flow rate. When using a flow rate of approximately 15 grams per minute, 95 percent of the material was recovered. Material passing through the first sifting unit (wire screen) was separated quite effectively. Material delivered to the silk cloth contained an average of 31.05 grams of flour of which 25.38 grams passed through. The unit was cleaned manually quickly and conveniently by directing an airstream into the roll housing and sifting units. A linear relationship was established between roll spacing and the amount of flour produced. For a mean flow of 11.14 grams per minute, $\hat{Y} = 49.94 - .43X$, where $\hat{Y}$ is the percent of flour produced and X the dial setting (roll spacing) in degrees. X varied from 0° to 30°. For a mean flow of 15.45 grams per minute the regression equation was $\hat{Y} = 49.34 - .41X$. Some flaking occurred at the close roll spacings.

A second series of tests were made to simulate a three reduction system in order to: (1) evaluation reduction flour for two varieties of wheat; (2) estimate total flour yield; and (3) to estimate the recovery of products.

Two varieties of wheat, Kanking and Triumph, were used for the tests. Kanking is normally considered more difficult to mill than Triumph. A given sample was run through the unit three times with the roll spacing being decreased after the first and second passes. The total flour obtained for a given combination of three roll spacings was analyzed for ash content, protein and sedimentation. Flour obtained from a Buhler mill in accordance with good milling techniques was used as a comparison standard.

A mean flow rate of 19.36 grams per minute was used. Protein and ash contents of milled Kanking were comparable from both the micro mill and Buhler. Sedimentation was higher for the Buhler flour. This may be attributed to a finer grind.

Protein and sedimentation of Triumph flour were comparable for the micro mill and the Buhler. The micro mill product did have a lower ash content due, perhaps, to a lower flour yield.

Average flour yield from middlings for 3 passes was approximately 78 percent.

Mean recovery rate from middlings was 93.91 percent. This was used as an estimate of losses to be expected in the reduction side of the micro mill. This does not include any losses which might occur in the tubes used to transfer mill stock from one set of rolls to another.

A micro mill consisting of six basic units was constructed on the basis of information learned from the performance of the basic unit. This mill consisted of three units with corrugated rolls forming the break side and three units with smooth rolls forming the reduction side. The flow pattern selected is shown in Figure 2. Gravity flow was used and a manual transfer of middlings from break side to reduction

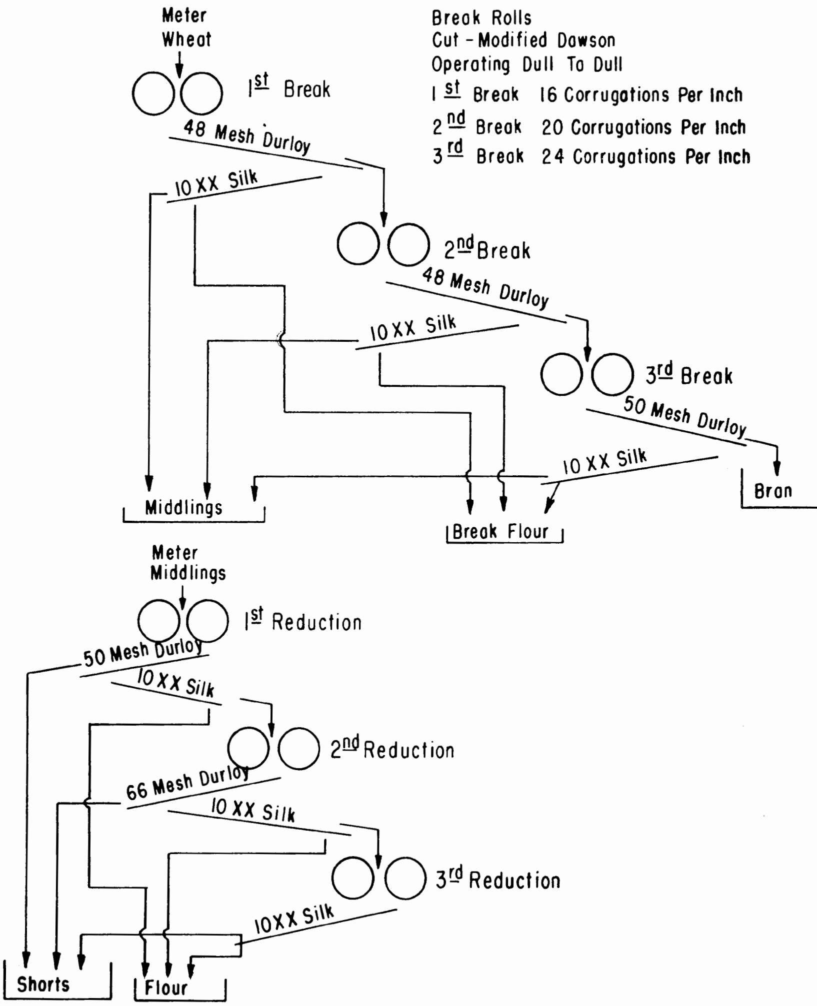

Figure 2. Flow path of prototype micro flour mill.

side was required. The break and reduction banks were positioned parallel with a 1-foot space between the banks for housing the roll drive. Overall dimensions of the micro mill were 36 inches wide, 44⅜ inches deep, and 67½ inches high.

Preliminary runs were made to test the separating effectiveness of wire screen and flour screen sifting units, degree of self-cleanout and recovery of products, time for milling a given sample, and flour yield.

Tempered wheat was fed into the first break rolls at approximately 50 grams per minute. Of nine samples run, eight were 200 grams and one was 300 grams. Separating effectiveness of all wire screens was acceptable. Cleanout of "overs" from all wire screens was acceptable. Cleanout of "throughs" (wire screens) was not as good as desired. The main objection was time required to clean out "throughs" from the sifting unit. The "trailing out" effect necessary to achieve acceptable recovery increased the milling time significantly.

Separating effectiveness of flour cloths did not meet desired standards. Considerable "riding over" of flour was observed. This was tolerable on the break side but on the reduction side significant quantities of flour terminated in the shorts tray. Average flour yield was 61.7 percent. Sifting the flour from shorts in a laboratory sifter increased the mean flour yield to 65.4 percent. In addition to the "ride over", excessive time was required to process middlings through the reduction side. It required 20 to 25 minutes to mill one sample. Given enough time, recovery of products was acceptable. Average recovery of products for the preliminary tests was 96.6 percent.

Due to unsatisfactory performance of the flour cloths, all sifting units were removed and a temporary procedure was devised using the rolls and a separate laboratory sifter. This arrangement was used to mill 184 wheat samples (100-150 grams each) in 1960.

Modifications were made prior to milling the 1961 samples. Wire screens were reinstated on the mill and the flow path used is shown in Figure 3. A small laboratory batch sifter was used in conjunction with the mill. Flour attributes evaluated from approximately 175 samples milled in 1961 were acceptable and representative of the wheat being milled.

Present Design

Flow Pattern and Fraction Separations

The modified flow pattern (Figure 3) used in 1961 was satisfactory in terms of flour attributes. Since the configuration of the mill was for the flow path shown in Figure 2, it was decided to redesign the micro mill. The new design incorporated greater compactness, improvements in roll drive, roll adjustment, roll enclosures, and metering of stock. The original concept of total sifting on the mill was abandoned. Instead, a laboratory batch sifter was used for final

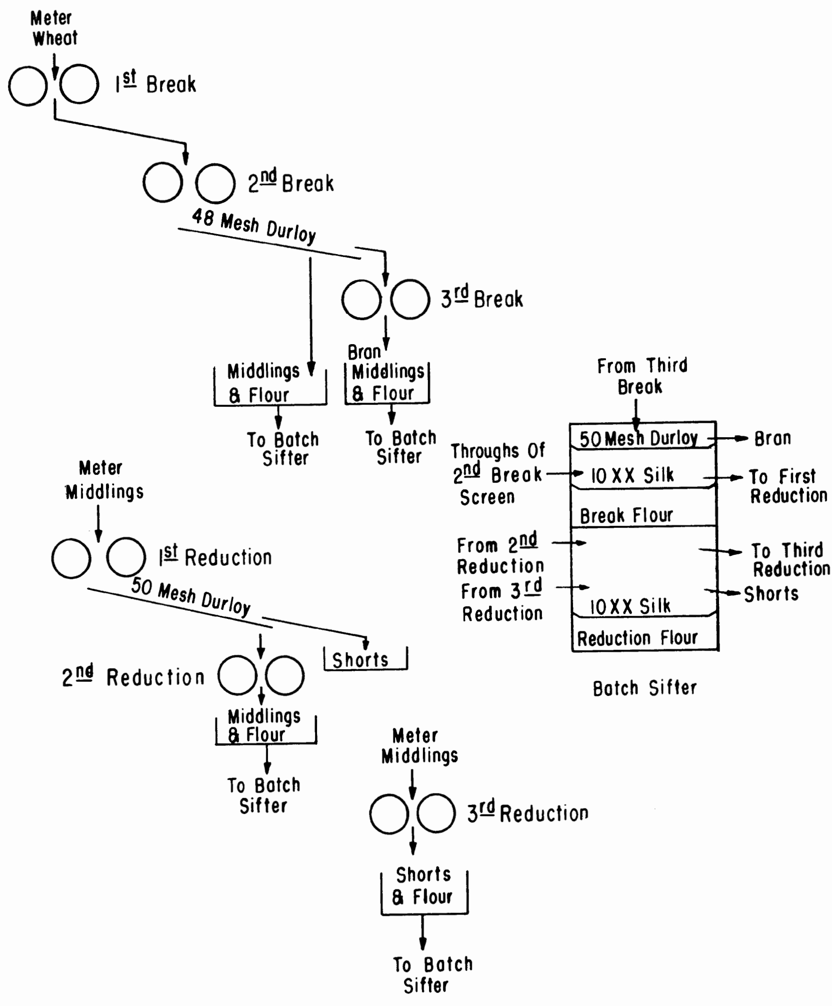

Figure 3. Flow path of modified micro mill and batch sifter.

sifting. Unacceptable performance of the continuous flow flour sifting units prompted the change. The flow pattern of the redesigned mill is shown in Figure 4. The main difference between the previous (modified) and present flow patterns is the geometrical arrangement of rolls.

Wheat passes through first and second break rolls and discharges into a wire screen. "Overs" of the screen pass into the third break rolls.

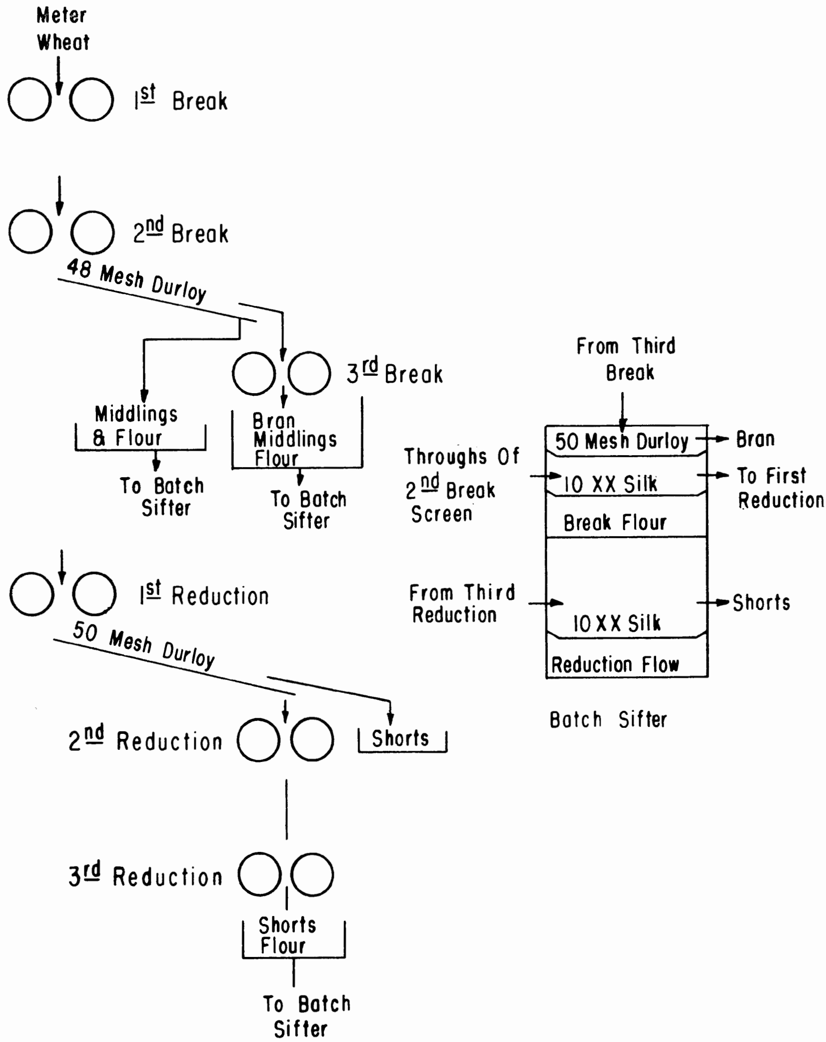

Figure 4. Flow path of redesigned micro flour mill and batch sifter.

"Throughs", containing middling and break flour, are collected in a tray. Material passing through the third break is collected in another tray. Contents of the first tray are placed on the flour cloth in the batch sifter. Contents from the second tray are placed on a wire screen directly above the flour cloth. Operating the sifter separates the stock into bran, middling, and break flour. The middlings are then metered into the first reduction rolls. After the first reduction, stock feeds into a wire screen. "Overs", consisting of bran particles and shorts, discharge into a container. "Throughs" of the wire screen, middlings and flour, flow through the second and third reductions and discharge into a container. This material is then sifted in the batch sifter to recover the reduction flour. If desired, middlings and shorts can be rerun through the reduction side without altering the roll spacings. In some cases, this increased flour yield.

With this flow pattern, break stock of Sample B was sifted at the same time as reduction stock of Sample A in the batch sifter. To use this sifting method the nesting arrangement of screen shown in Figure 5 was used.

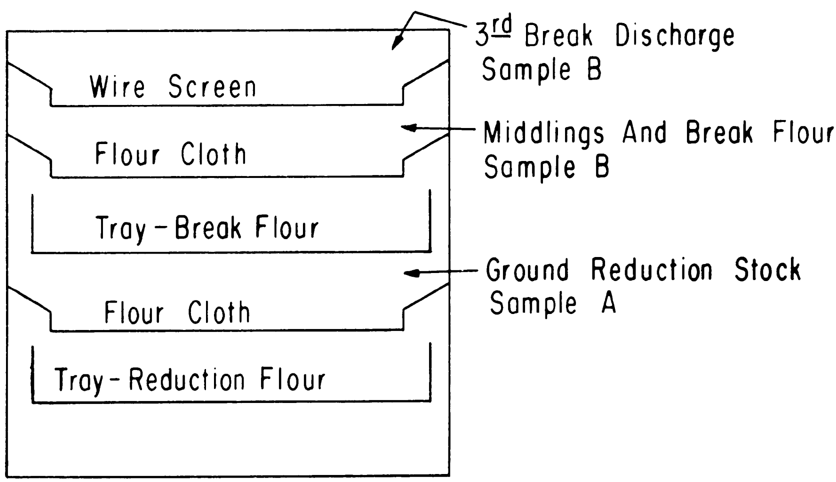

Figure 5. Screen arrangement in laboratory batch sifter for concurrent sifting of two samples.

Framework

The main frame for supporting components was constructed from hot rolled electric welded steel tubing (See Figure 6). Use of the tubing as a structural form insured adequate rigidity, desirable surface for component attachment, and attractive appearance. Various frame members were welded to form a box structure. Pieces were securely clamped in place before welding to minimize warping and distortion. The entire frame was tacked together before completing the welds. Outside frame dimensions were 36 inches wide, 32¼ inches deep, and

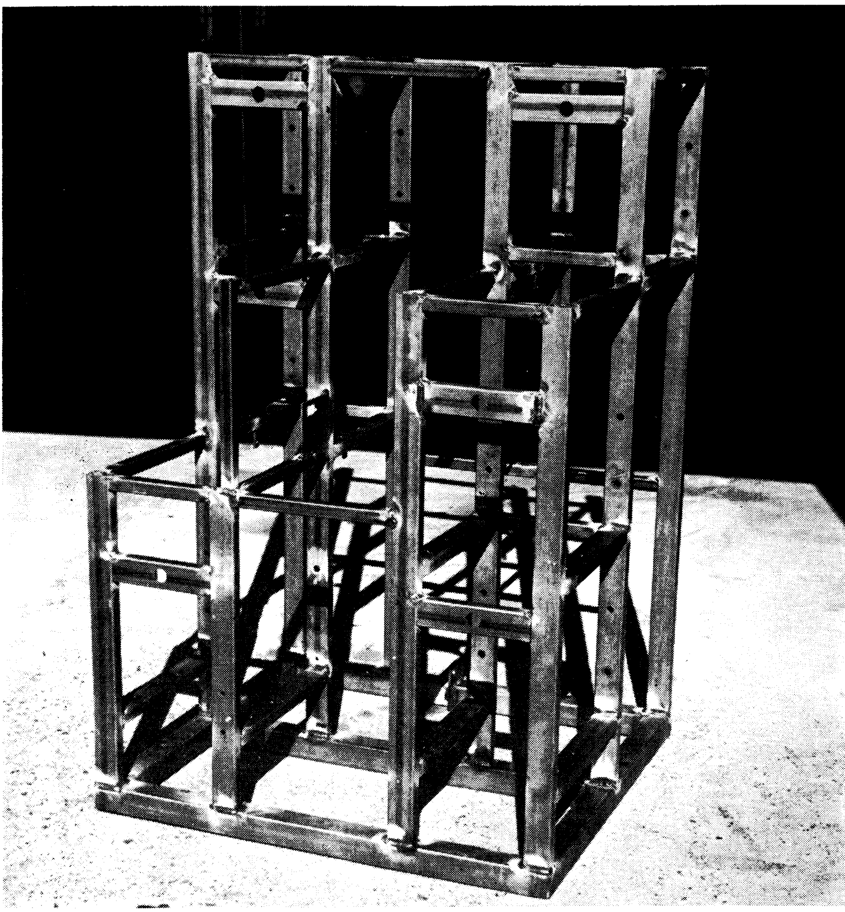

Figure 6. Steel tubing was used in the construction of the main frame.

54 inches high. With all components, the micro mill was 36 inches wide, 36¼ inches deep and 63⅛ inches high.

Sub Assemblies

ROLL ENCLOSURES Roll enclosures (Figures 7 and 8) were designed to provide: Easy acess to all rolls and to roll brushes on the reduction side; sufficient tightness to minimize stock losses; smooth interior surfaces for optimum cleanout; and easy cleaning between samples.

An enclosure, made in two parts, consisted of a lower half attached to the frame and an upper half consisting of a lock-in cover. The cover was easily removed without the use of tools.

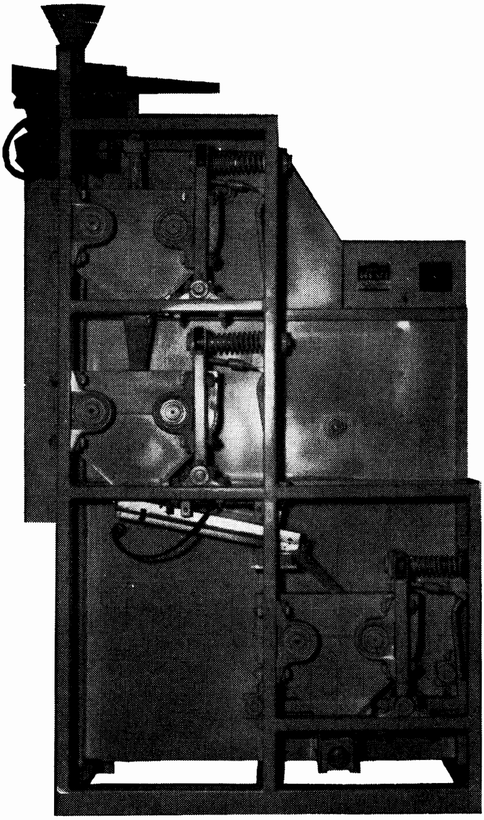

Figure 7. Left side of micro flour mill showing first, second, and third breaks.

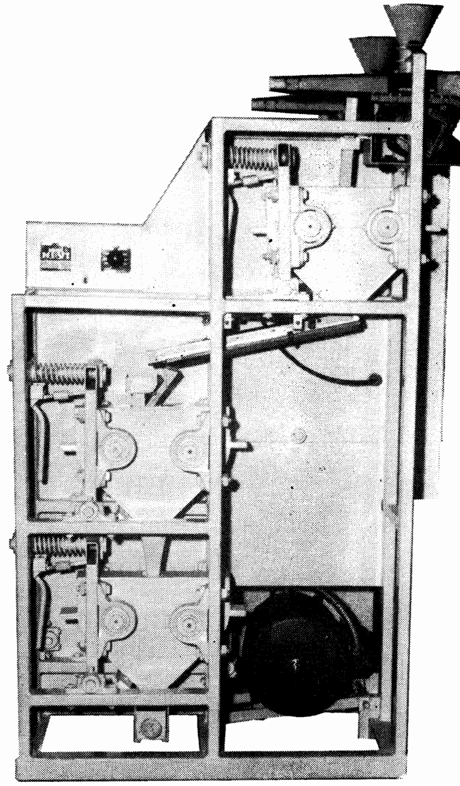

Figure 8. Right side of micro flour mill showing first, second, and third reductions.

Spouts leading to and from the roll enclosures can be quickly removed. A nylon bristle brush for each roll can be inserted through the enclosures on the reduction side. In operation, it was found that one brush on the back roll was adequate to keep both rolls clean.

Vents were provided to allow cleaning with compressed air after each sample had been milled.

Enclosures were made from 24 B.W. gage galvanized sheet. Interiors are smooth and must be thoroughly cleaned before installation. It was necessary to use soap and water for the final cleaning.

ROLL ADJUSTMENT The back roll of a given pair was mounted in sealed ball bearing pillow blocks bolted to the frame. The front roll was mounted in pillow blocks bolted to a spring loaded pivoting member (Figures 7 and 8). Movement of this member was necessary for adjustment of roll spacing and releasing of rolls.

The pivoting member, rectangular in shape, and oriented vertically, rests in two split cast-iron pillow blocks. At the top, a single adjusting screw prevents movement rearward of the front roll. A compression spring offers resistance to forward movement. This resistance is overcome if an undesirable object enters the rolls or if the roll release mechanism is actuated.

A circular stationary reference dial was marked in 15 degree increments and mounted on the frame. A circular disk having one mark was fastened to the adjusting screw. Fifteen degrees of screw rotation changed roll spacing approximately 0.000985 inches. Experience indicated that roll setting must be based on stock evaluation, rather than distance between rolls. A compression spring, independent of the one mentioned previously, was used in place of a lock nut to hold the adjusting screw in position. Use of the spring prevented changes in spacing which might occur if a nut were tightened or loosened. Elimination of the nut simplified the adjustment.

The pair of rolls was properly aligned when installed. The individual rolls were leveled horizontally with shaft centerlines parallel. Slots in the ball bearing pillow blocks and the split cast iron blocks provided adequate adjustment for roll alignment. The initial alignment was made during construction and second alignment was made after permanent installation of the mill. Alignment checks were made periodically, starting at the beginning of a milling season.

ROLL RELEASE Each set of rolls has an over center locking mechanism for releasing and holding the rolls open. The linkage was positioned below the compression spring which enclosed the adjusting screw (Figures 7 and 8). With rolls in operating position approximately 70 pounds of force was exerted on the pivoting member by the compression spring. It required a horizontal force of 148 pounds applied at shaft centerline to initially separate the rolls. Link dimensions were such that the spring was compressed an additional 3/16 to ¼ inch when the rolls were open, thus, increasing the spring load to about 100 pounds. Rolls can be separated when running or stationary.

POWER TRANSMISSION Power requirements for the mill are for sifter oscillation and rotation of the rolls.

SIFTING UNITS Vibratory motion of the sifting units was described in the section on preliminary design and evaluation; however, some additional details will be discussed. The two screens used in the mill were wire mesh. The 48-mesh Durloy screen under the second break was 2⅞ inches wide and 13 inches long. The screen under the first reduction was a 50-mesh Durloy 2⅞ inches wide and 15½ inches long. Slope on both screens was 12½°. The units can handle up to 50 grams per minute of break or reduction stock with satisfactory separation of particles. The shells housing the screens were constructed from aluminum to minimize magnitude of the oscillating mass.

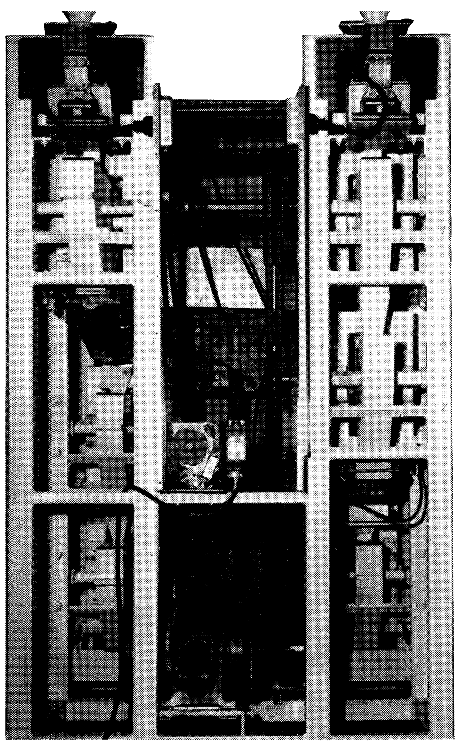

Figure 9. Rear view of micro flour mill with drive enclosure cover removed.

ROLL DRIVE Power was supplied to rolls through a double V-belt from an electric motor to the shaft of the back roll of the first break.

This shaft was connected with a flexible coupling to the back roll of the first reduction (Figure 9). An A.S.A. No. 41 roller chain for each

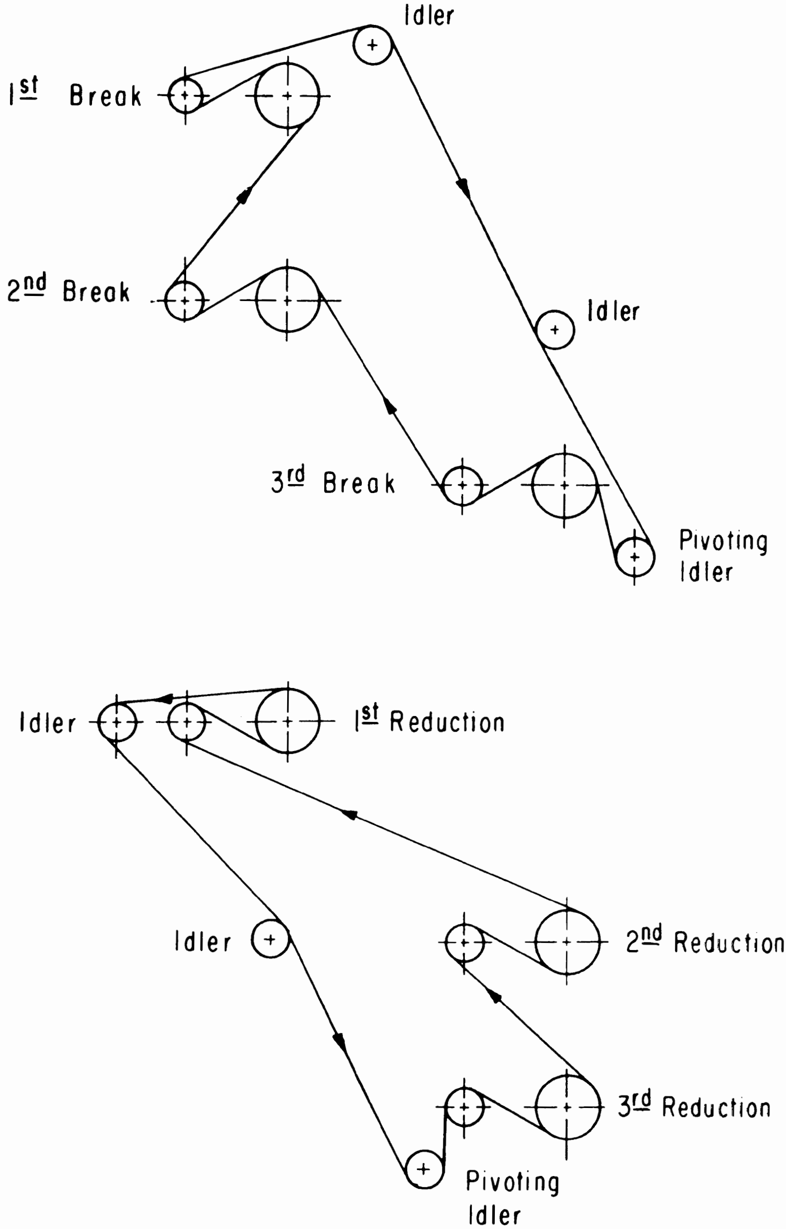

Figure 10. Schematic diagram of roller chain drive.

bank drives the rolls as shown in Figure 10. Motor speed was 1200 RPM. The double-Vee A section belt reduces the speed to 534 RPM which was the speed of all back rolls. Back rolls have 17 tooth sprockets. Front rolls have 32 tooth sprockets which turn at 284 RPM.

The drive on each bank had two 20 tooth idler sprockets mounted in sealed ball bearings. A third pivoting idler compensated for changes in roll spacing due to releasing and/or adjusting. A sketch of the pivoting idler is shown in Figure 11. The idler frame was mounted in 2 split cast-iron pillow blocks bolted to the main frame. At the outer end, a 4¾ pound weight was attached to maintain proper chain ten-

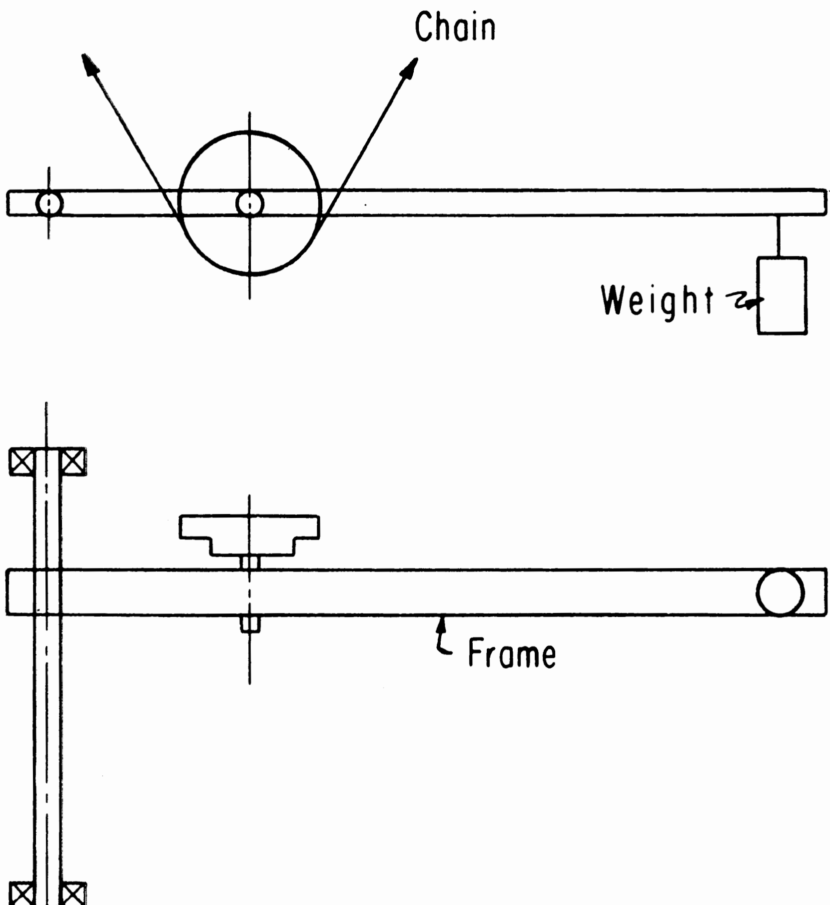

Figure 11. Schematic diagram of pivoting idler.

sion. A desirable feature of using a weight was that constant chain tension was maintained at all times.

Metering of Fractions to Break and Reduction Side

Figure 3 shows that wheat was metered into the first break rolls and middlings into the first reduction rolls. Flow rates set at the

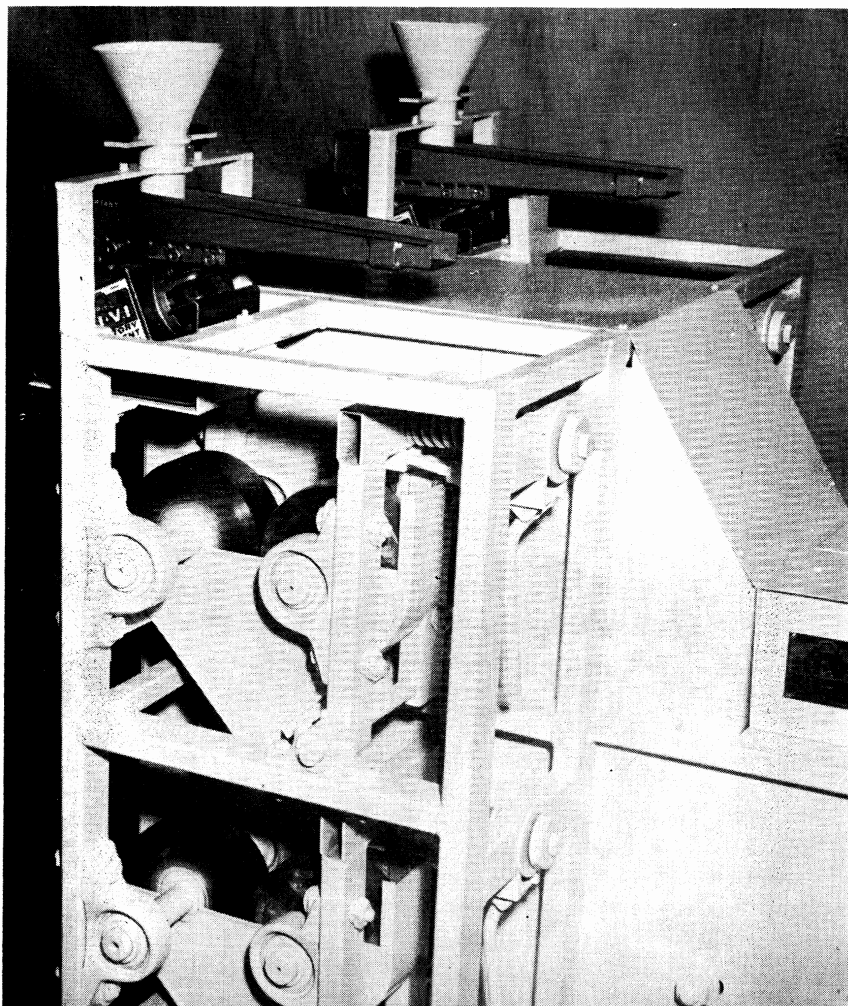

Figure 12. Break side of micro flour mill with roll covers and discharge spouts removed.

entry of each bank of rolls established rates to all subsequent rolls in the bank.

A metering unit must have a convenient adjustment for feed rate and must be reliable. Components used in the system were a funnel feeder placed above a vibrating tray, the vibrating tray, and a discharge spout into the roll housing cover. (Figure 12). The space between the bottom of the funnel and the horizontal tray could be adjusted by a screw arrangement. Normally this adjustment would be made infrequently. The vibratory feeder was a commercial unit having an electro-permanent magnetic drive equipped with a 2 inch by 6 inch horizontal tray. The discharge point of the tray was altered by cutting a slit in the bottom. This allowed desirable orientation of the feeder with respect to other parts in the mill. A control box housing a potentiometer was used to adjust the amplitude of the vibrating tray. Voltage could be varied from 0 to 120 by a control provided on the housing. This gave a wide range of flow rates. The discharge spout was designed for quick removal which allowed the roll cover to be removed for roll inspection.

Mill Clean Out

It was essential that the mill be thoroughly cleaned between samples. To insure high recovery of products for a given sample the roll enclosures should be tapped lightly immediately after the last stock has passed through. The break side could be cleaned independent of the reduction side. Trays containing stock should be removed and emptied. Using an air hose and nozzle (40-60 psi) each set of rolls and connecting tubes could be cleaned easily. Cleaning should proceed in the same order as stock moves through the mill. Either side of the mill can be thoroughly cleaned in 20 to 25 seconds.

Operating Procedure

Separation of break and reduction sides permits milling two different samples simultaneously. After preliminary samples have been run to adjust roll spacings and metering rates the following procedure should be followed:

1. Place wheat sample in funnel feeder on break side.
2. Start rolls and sifting units.
3. Turn feed switch on.
4. Tap each roll housing after stock has passed through.
5. Remove tray containing break flour and middlings and place contents on flour cloth in laboratory batch sifter.

6. Remove tray containing bran, middlings and break flour and place contents on wire screen in batch sifter, (See Figure 4).
7. Turn on lab sifter (operating time approximately 3 minutes.)
8. Clean break side with compressed air and replace trays.
9. Remove separated fraction from lab sifter and place middlings in funnel feeder on reduction side.
10. Start feeder on reduction side.
11. Start second sample through break side.
12. Tap each roll housing after stock has passed.
13. Remove tray from under third reduction and place contents on a second flour cloth (See Figure 4).
14. Remove tray containing shorts.
15. Repeat steps 5 - 7.
16. Clean break and reduction sides with compressed air and replace trays.
17. Continue with step 9.

Samples of Test Milling Runs

After installing the micro mill at the milling and baking laboratory, roll alignments were checked and roll spacings set. A limited number of samples were milled to check yields of known varieties. These tests were conducted prior to milling the samples harvested in 1962. Results of the tests are presented in Table I. The tabulated values are the means This initial evaluation compared favorably with results obtained during the 1961 milling season.

Summary

A micro mill capable of milling small samples of wheat and flour was designed, constructed and tested. Three phases of development included a basic unit consisting of one pair of rolls and sifting units; six basic units combined to form a prototype unit; and the presen· or completed unit.

The present micro mill consists of three break and three reduction rolls and is capable of properly milling 100 to 150 gram samples of wheat.

TABLE I—150 Gram Wheat Samples

Variety	Bran %	Shorts %	Flour %	Losses %	Ash %
Triumph	23.78	7.11	67.78	1.33	0.33
Wichita	23.00	7.00	69.00	1.00	0.39
Kanking	22.33	8.33	67.67	1.67	0.36

Oklahoma's Wealth in Agriculture

Agriculture is Oklahoma's number one industry. It has more capital invested and employs more people than any other industry in the state. Farms and ranches alone represent a capital investment of four billion dollars—three billion in land and buildings, one-half billion in machinery and one-half billion in livestock.

Farm income currently amounts to more than $700,000,000 annually. The value added by manufacture of farm products adds another $130,000,000 annually.

Some 175,000 Oklahomans manage and operate its nearly 100,000 farms and ranches. Another 14,000 workers are required to keep farmers supplied with production items. Approximately 300,000 full-time employees are engaged by the firms that market and process Oklahoma farm products.

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