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Performance of the Ottawa Electronic Recording 10 g Dough Mixer

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SUMMARY

Critical performance aspects of a commercial version of the Ottawa electronic recording 10g dough mixer were examined. The torque recording system was found to be accurate with 0.3%, and mixing speed was controlled within 0.8%. Friction in the torque recording system totalled less than 0.15% of the reading. The hoses supplying water to the bowl water jacket introduce a 1% error in recorded torque which can be tared for each sample. The two bowls supplied with the mixer are interchangeable within 5% with respect to torque (i.e. dough strength) readings, but differences in the time to reach the peak are up to 12.4%. A primary source of variation in the readings was found attributable to taking data off the torque time curves which required a degree of interpretation. The greatest effect of interpretation was in estimating the time to the peak. Because this measurement is a sensitive index of wheat quality, it was concluded that further research is needed to manipulate curve shape and improve interpretation techniques in establishing the peak time.

ACKNOWLEDGEMENT

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PERFORMANCE OF THE OTTAWA ELECTRONIC RECORDING 10 g DOUGH MIXER

1.0 Introduction

Development of the Ottawa Electronic Recording 10 g Dough Mixer was described in detail in previous publications (see list of references). An existing dough test instrument, the Mixograph, was redesigned so that smaller flour samples could be tested to examine the quality of breeders' samples at an early selection stage. The sample bowl size was reduced from a 35 g to a 10 g flour sample. The original mechanical dynamometer was replaced by an electronic system to achieve greater resolution, sensitivity and accuracy of mixing torque measurement and recording. Additional advantages such as constant rate of strain etc. are discussed extensively in the references given.

The 10 g mixer is now available commercially (Queensboro Instruments, 645 Brierwood Ave., Ottawa) and units have been purchased by several research establishments. The purpose of the work reported here was to evaluate critical performance aspects of a commercially produced instrument purchased for the Cereal Laboratory of the Winnipeg Research Station.

2.0 Description and Operation

The mixing head and bowl are constructed to the dimensions given in ERS Bulletin 6208. The arrangement of the equipment incorporates a number of design improvements that have evolved since the new mixer was first reported (Voisey, et.al. 1966). An improved torque transducer and bowl pivot (Voisey, et al. 1969) (Figure 4) and an improved bowl clamp (Figure 4) are the most evident features. Redesign of the mixer framework (Figure 2), mixing head (Figure 6), mixing head counterbalance spring (Figure 2,7) and numerous other mechanical improvements have also also been made based on previous operating experience, particularly those incorporated in the 5 g version of the mixer that was developed.

Access to the transducer is provided by a cover held in place by two thumb screws at the front and below the bowl support platform (Figure 2,4). The mechanisms at the rear of the mixer are enclosed by a sheet metal cover held on with screws (Figure 7).

The electric power for the mixer is controlled by a switch at the lower front and a red light indicates when the mixer is on. The mixing motor is started automatically when the mixing head is lowered to the mixing position by a microswitch inside the rear cover (Figure 7).

The electronic recording system (Figure 1) is the same as used previously except that a different make of recorder is used. The torque transducer is connected to this system via an extension cord between a plug at the rear of the mixer (Figure 7) and a plug at the front of the recorder console, (transducer) (Figure 1). This connects the transducer to a Daytronic Model 300D-91 strain gage amplifier which is connected to a potentiometric type strip chart recorder. The recording system is calibrated and operated as described in instruction manuals that were issued previously (see file 6510) with the following differences introduced by the new recorder.

a. The recorder has a normal full-scale response time of less than 1.0 sec which is too fast to record the average of the rapidly fluctuating mixing torque. A special filter has been added to increase the response time to about 10 sec. The filter is selected by a switch adjacent to the recorder range switch. This switch must be in the "filter in" position whenever the mixer is connected to the system. For other applications (e.g. an electronic recording extensigraph) the recorder can be used with the filter off to record signals changing at rates up to about 3 sec full-scale.

b. A range of metric chart speeds from 75 mm/hr to 480 mm/min are selectable.

c. The recorder has a zero control, a range switch and a variable sensitivity control. These duplicate the functions of the controls that are on the strain gage amplifier. Thus, during calibration and operation the amplifier controls are used to adjust the system approximately (i.e. coarse controls) and final adjustments are made more conveniently at the recorder controls. It should be noted that for the variable sensitivity control on the recorder to operate the variable/fixed (VAR./FIX) switch on the recorder must be in the variable (VAR) position. Sufficient information is given in the test results to select recorder and amplifier range switch settings for different full-scale torque calibrations.

d. Experience has shown that in a controlled environment laboratory that a costly controlled environment cabinet for the mixer is unnecessary. The mixer design, cost and operation is simplified by eliminating the cabinet and using water jacketed bowls. Therefore, a cabinet is not provided, but the mixer uses water jacketed bowls. The jacket water supply is connected by hoses on the bowl which plug in at quick disconnects on the left hand side of the mixer. Controlled temperature water supply and a return are connected to the quick disconnects at stand pipes on the LH side of the mixer. The hoses on the bowl are soft rubber and made longer than necessary to minimize the effect of the hoses on recorded torque. (Figure 2, 3)

e. Two water jacketed bowls each with a pair of mixing pins and top bowl cover are provided. The bowls are numbered (1 & 2) and the corresponding mixing pins are identified by 1 or 2 rings machined at the top.

f. The attachment installed in place of the bowl to calibrate the torque transducer has a top disc held in place by a screw at the center (Figure 5). Removing this disc reveals holes that can be used to check the alignment of the mixing head pins. When the calibration attachment is installed, a lever stored at the right hand side of the mixer (Figure 6) is released by a thumbscrew, swung forward, and reclamped. This places a pulley at 10 cm radius from the centerline of the transducer (Figure 6). A cord connected from the calibration lever is passed over this pulley to suspend weights and apply a force at exactly 10 cm radius (Figure 6). Thus, the calibration torque T cm g applied by a weight Wg:

$$T = 10\ W\ \text{cm g}$$

g. The clamp mechanism that holds the bowl in the platform on top of the torque transducer (Figure 4) is an over center device and may require adjustment as wear occurs. Slacken the 3 screws that hold the front pivot bracket of the over center linkage on top of the platform. A screw in the front edge of the platform just below this bracket is then turned clockwise about 1/8th turn and the 3 bracket screws are retightened. Continue this procedure until the cup is firmly clamped in position, but the over center linkage is not too difficult to operate.

h. The motor driving the mixing head has a rated speed of 1725 RPM. This is reduced by an integral gearbox (having a ratio of 18 to 1) to 95.83 RPM. The motor output shaft drives the mixing head via a pair of gears that increase the speed by a ratio of 42 to 40 to a nominal speed of 100.625 RPM. Thus, the over-all ratio between the motor and mixing head is 17.143 to 1.

3.0 Tests and Results

3.1 Mixing Speed

The mixing speed was measured by a digital tachometer recording the speed of the motor shaft to within 0.1 RPM. The speed determined was the average speed over a 10 sec period. This was monitored for 7.0 min (the usual Mixograph test time) without a sample and then with samples of hard and soft flour. Thus, the variation in average speed over 10 sec for 7.0 min or 42 readings was obtained in each test.

Under no load the speed was virtually constant at 103.7 RPM changing only 0.026% in 7.0 min (Table 1). The mixing speed was higher than expected because the motor ran at 1778 instead of the 1725 RPM specified.

In testing hard and soft flour the speed dropped as the mixing torque increased. The maximum speed change observed was 0.79%. Thus, it can be assumed that the power input to the dough, which is directly proportional to RPM was affected. Indicated mixing torque would also be affected since the forces generated by the dough in resisting mixing are theoretically some function of speed. However, resistance of viscoelastic materials is not directly proportional to speed. The average speed during mixing was 103.3 RPM. Thus, a speed change of 0.79% equals an error of 0.82 revolutions in a minute or 5.7 revolutions in a 7.0 minute mixing period. This represents a maximum error of 0.79% in the total number of revolutions and, therefore, energy input into the dough.

The rated torque output of the motor is specified as 4.8 in lb. The maximum torque observed in mixing hard flour doughs was less than 0.2 in lb. Assuming that the efficiency of the motor gearbox and motor to mixing head gears combined was 25%, the theoretical mechanical advantage was still 6 to 1. Thus, overloading of the motor was not the cause of the speed variation.

3.2 Torque Transducer Calibration

It was found possible to calibrate the recording system to give full-scale torque recording sensitivities ranging from 50 cm g to 50,000 cm g. However, since the mixing torque normally does not exceed 2,000 cm g, only the ranges up to 10,000 cm g were examined in detail. First the system was calibrated to give the selected range and checked at zero and full-scale. Torque was then applied in 10% increments increasing up to the maximum and returning to zero to determine non-linearity and hysterisis in the relationship between torque and chart reading.

The results (Table 2) showed that at ranges from 200 to 10,000 cm g the maximum deviation from a linear relationship did not exceed 0.3%. Thus, it can be assumed that torque was indicated with an accuracy of 0.3%. There are several sources of these small errors:

a) Friction in the transducer bearings was measured and found to be 0.5 cm g.
b) Friction in the transducer bearings plus the effect of the string and pulley used for the calibration which was 1.2 cm g.
c) As in b above plus the damping effect of the rubber hoses connecting the water supply between the mixer frame and bowl jacket which was 2.8 cm g.

These errors are negligible at the range normally used to test flours (0 to 2000 cm g) since they total less than 0.15% of full scale.

It was observed that when the water jacket hoses were connected to the mixer frame that a small torque was applied shifting zero by 20 cm g. It was found that this could be tared with the recorder zero control and remained constant during a test providing the hoses were not touched. If taring is not used for each sample, the hoses introduce an error of 1% of full scale.

3.3 Mixing Tests

Commercial soft and hard flours were used to test the mixer under operating conditions. Twelve replicates of each flour were tested in each of the two bowls (No. 1 and No. 2). The water jacket and water added to the flour were maintained at 25°C. The optimum sensitivity of the torque recording system found and used for these tests was 2000 cm g. A chart speed of 10 mm min^{-1} was also found suitable.

Typical results are shown in figures 8 and 9. A summary of the results (Table 3) showed that differences in torque readings for each bowl were less than 4%. Bowl 2 generally gave lower readings than bowl 1. Differences in the torque at 7.5 min were less than 1% for both the flours tested. Differences in peak torque were 2.2% for soft flour and 4.0% for hard flour. A careful check of the bowl dimensions did not reveal any reason for the differences in torque readings. The differences may be partly attributed to the degree of interpretation required in estimating the maximum torque from the curves. This, for example would explain why the difference between bowls was less for the soft flour than for the hard flour (compare figures 8 and 9). Thus, the results indicate that with respect to torque readings the two bowls were interchangeable within better than 5%.

The differences between bowls in the time to reach the peak were much greater (4.9% soft and 12.4% hard).

These differences between bowls should be recognized when using the two bowls to test flours and minimize the experimental time by cleaning one bowl as the other is in operation. The sources of differences between bowls must be attributed to the following parameters which are difficult to separate experimentally.

a. Differences in dimensions of the bowls and mixing head such as pin spacing and orientation etc. Because the mixing bowl dimensions are reduced to handle 10 g flour samples (instead of 35 g normally used in the Mixograph) the clearance between the fixed pins in the bowl and the moving pins in the mixing head are reduced. Thus, any differences in dimensions will have a greater effect on the clearances between pins which will affect the intensity of the stresses imposed on a mixing dough. The bowls were dimensionally the same within about 0.0002 inches which is about the best practical limits that can be achieved in manufacturing them.

b. The variability within the flour samples used to test the bowls.

c. Variations in the controlled temperature water supply of about $\pm 1.5^{\circ}C$.

d. Finally interpretation of the curves which requires estimating the peak torque and the time taken to reach this point. The curves produced by the flour samples did not have distinct sharp peaks so that the errors in reading the peak and particularly the time to the peak could easily account for the differences. For example, the time to the peak was about 2.0 minutes or 2.0 cm of chart length. Thus, an error in judgement of 2 mm in marking the peak point on the curve would produce an error of 10%. The effect of interpretation was examined by having a second operator read the same curves. A summary of these results (Table 3, Operator 2) showed significant changes, both in sign and magnitude, of the differences between bowls. Variation among readings was also different for each operator. There were significant differences in average readings obtained by each operator, particularly in the time to reach the peak (Table 4) which ranged from 17 to 46%. This clearly demonstrates that interpretation of the curves is a factor that must be recognized in evaluating the results. The results given are based on only two flours. Different results may be obtained with a wider spectrum of flour quality, as the curve shape (and width) will influence interpretation. The peak, for example is easier to identify on curves for some flours than others. It is indeed inconvenient that the time to the peak, a sensitive index of wheat quality (De La Roche and Fowler, 1975), exhibits such high variability within flours and is influenced so markedly by operator interpretation.

e. There is, in addition, the fact that the torque time curve is the result of a random mixing test in which the orientation of the dough and the quantity undergoing stress at any given point is not controlled mechanically as the dough is free to move relative to the bowl and pins.

4.0 Conclusion

The commercial version of the 10 g Ottawa Electronic Recording Dough Mixer performs as well as or better than the experimental units constructed during the instrument development. It must be recognized that interpretation of the curves and interchangeability of the bowls may affect the readings obtained.

Aspects such as increasing the sample size to accentuate the peak torque should be investigated to simplify curve interpretation.

5.0 Equipment Supplied

The following were supplied by the manufacturer

1 10 g Electronic recording mixer complete with electronic recording system. Serial No. 75-100.

2 Water jacketed bowls complete with hoses and quick disconnects.

2 Sets mixing pins.

2 Mixing bowl cover discs.

1 Calibration attachment with cord.

Record pens, ink and fuses etc.

The following have been supplied by E.R.S.

Hoses to connect controlled temperature water supply to mixer.

Spare soft hose for water supply connection between bowl and mixer.

5 Spare fuses (4 amp sloblo) for mixer.

6 Rolls chart paper.

Charts are available from

B. H. McGregor,
P.O. Box 156,
Station H,
Toronto.

Order Riken Denshi Chart No. SP5.

6.0 References

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Table 1. Variation in average mixing speed (10 sec) over 7 minutes based on 42 readings.

Sample	Motor Speed RPM Maximum	Motor Speed RPM Minimum	Mixing Head Speed RPM Maximum	Mixing Head Speed RPM Minimum	Difference[1] %
None	1778.3	1777.8	103.73	103.71	0.026
Hard flour	1770.9	1764.6	103.30	102.94	0.350
Hard flour	1775.0	1762.8	103.54	102.83	0.685
Hard flour	1774.4	1760.4	103.50	102.69	0.790
Soft flour	1772.2	1768.2	103.67	103.15	0.506
Mean[2]			103.31		

[1] $\frac{\text{Maximum-Minimum}}{\text{Maximum}} \times 100\%$

[2] Of maximum and minimum

Table 2. Typical calibrations of torque transducer (recorder gain at variable) showing maximum non-linearity and hysterisis.

Torque Range cm g	Recorder Range mV	Amplifier Range %	Maximum Error % of Full Scale
10,000	10	100	±0.25
5,000	10	50	±0.20
2,000	10	20	±0.30
1,000	10	10	±0.30
500	5	10	±0.10
200	1	20	±0.20*
100	1	5	±0.10*
50	1	5	-

*Checked at ½ scale only.

Table 3. Summary of data for 12 replicates of two flours tested in each of the 2 available bowls and interpreted by 2 operators.

Operator 1

Flour		Soft			Hard		
Measurement		Peak torque[1]	Time to peak[1]	Torque at 7.5 min[1]	Peak torque[1]	Time to peak[1]	Torque at 7.5 min[1]
		cm g	min	cm g	cm g	min	cm g
$Bowl_1$	Mean	1053	1.63	769	1044	2.42	920
	C.V. %	5.5	25.1	4.9	3.0	11.7	2.6
$Bowl_2$	Mean	1076	1.71	779	1086	2.12	912
	C.V. %	7.5	24.5	8.7	4.3	19.1	6.0
Difference %[2]		-2.2	-4.9	-0.8	-4.0	+12.4	+0.8

Operator 2

Flour		Soft			Hard		
Measurement		Peak torque[1]	Time to peak[1]	Torque at 7.5 min[1]	Peak torque[1]	Time to peak[1]	Torque at 7.5 min[1]
		cm g	min	cm g	cm g	min	cm g
$Bowl_1$	Mean	1063	2.2	923	1075	1.3	772
	C.V. %	2.5	21.4	3.2	4.0	26.9	4.7
$Bowl_2$	Mean	1083	2.0	913	1078	1.4	778
	C.V. %	4.8	31.3	6.1	7.1	46.8	6.7
Difference %[2]		-1.9	+9.1	+1.1	+0.3	-7.7	-0.8

[1]Means of 12 readings

[2]Difference = $\frac{Bowl_1 - Bowl_2}{Bowl_1} \times 100\%$

Table 4. Differences[1] in readings (%) due to operator interpretation.

Flour		Soft			Hard		
Measurement		Peak torque	Time to peak	Torque at 7.5 min	Peak torque	Time to peak	Torque at 75 min
$Bowl_1$	Mean	- 0.95	-34.97	-20.03	- 2.97	+ 46.28	+16.09
	C.V. %	+54.55	+14.74	+34.69	-33.33	-129.9	-80.77
$Bowl_2$	Mean	- 0.93	-16.96	-17.20	+ 0.74	+ 33.96	+14.69
	C.V. %	+36.00	-27.76	+29.89	-65.12	+145.03	-11.67

[1] $\frac{\text{Operator 1 - Operator 2}}{\text{Operator 1}} \times 100\%$

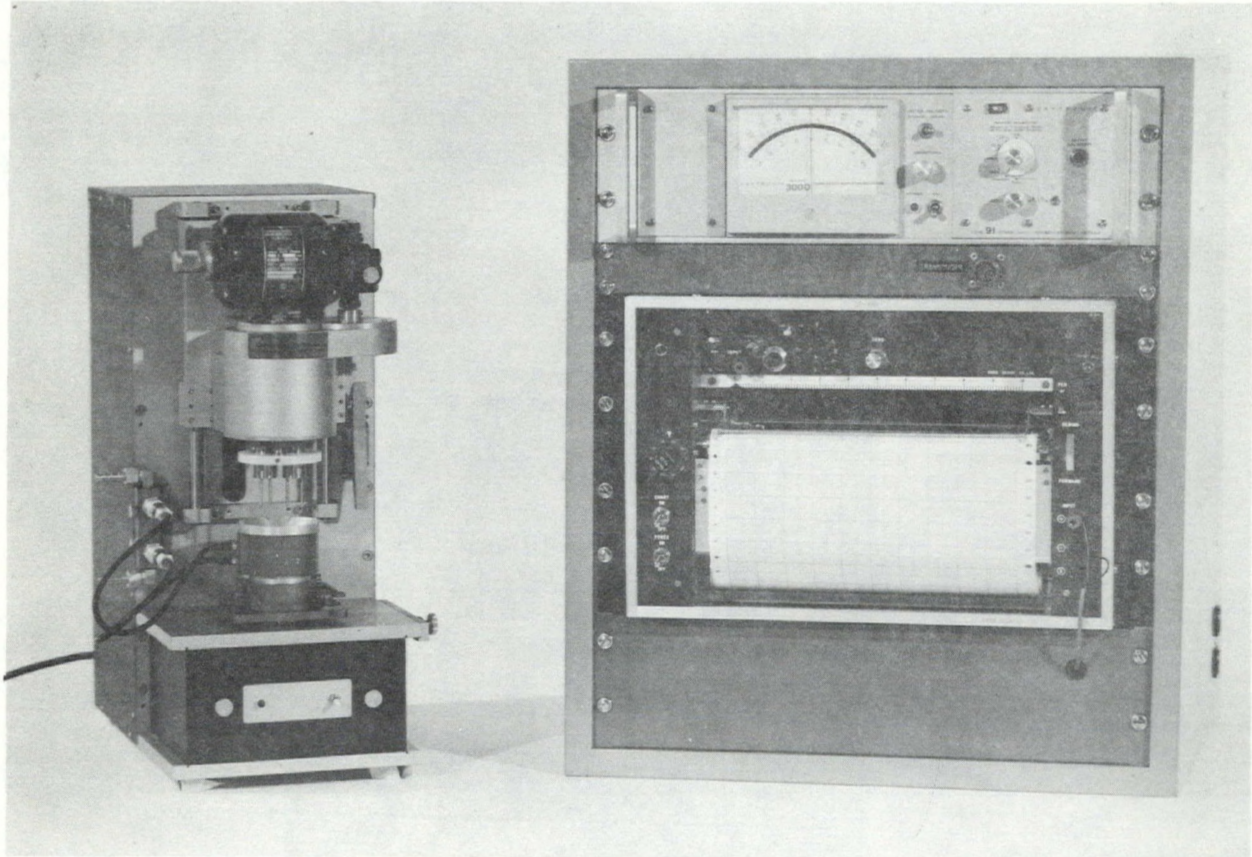

Figure 1. The 10 g mixer and recording system.

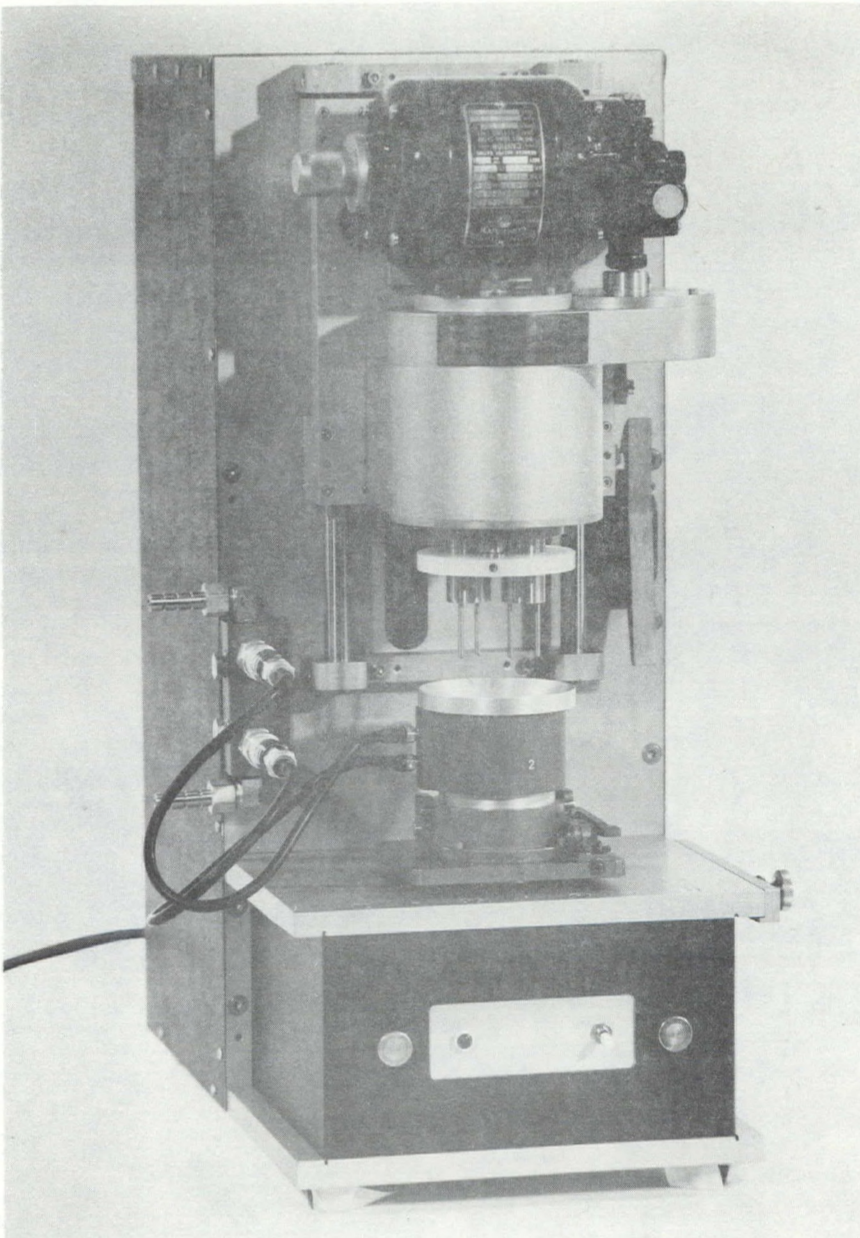

Figure 2. The 10 g mixer with a bowl in position and the water jacket connected to the outlets at the L.H. side. The mixing head is in the raised position.

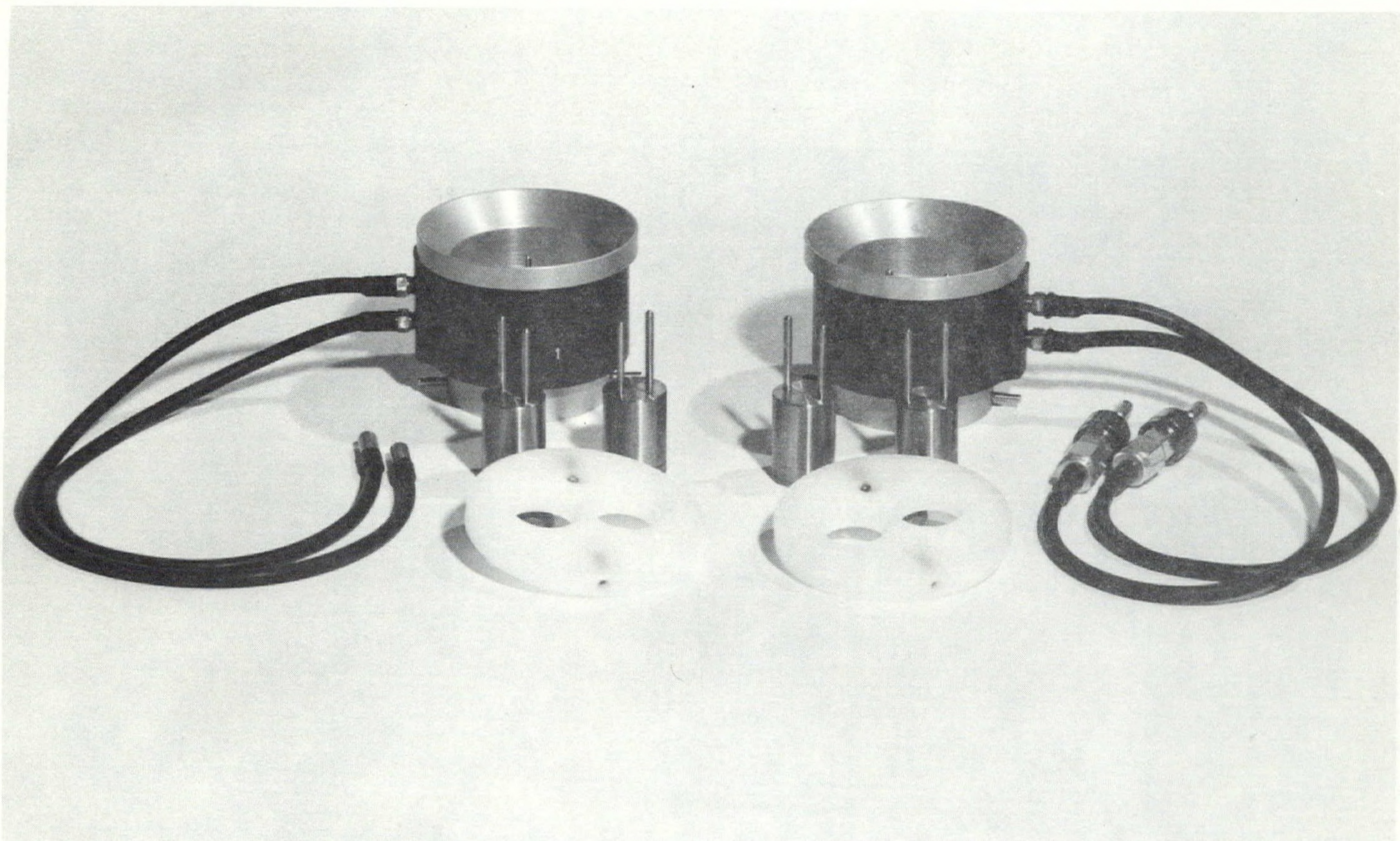

Figure 3. The mixing bowls, pins for the mixing head and the discs that prevent dough escaping from the bowl.

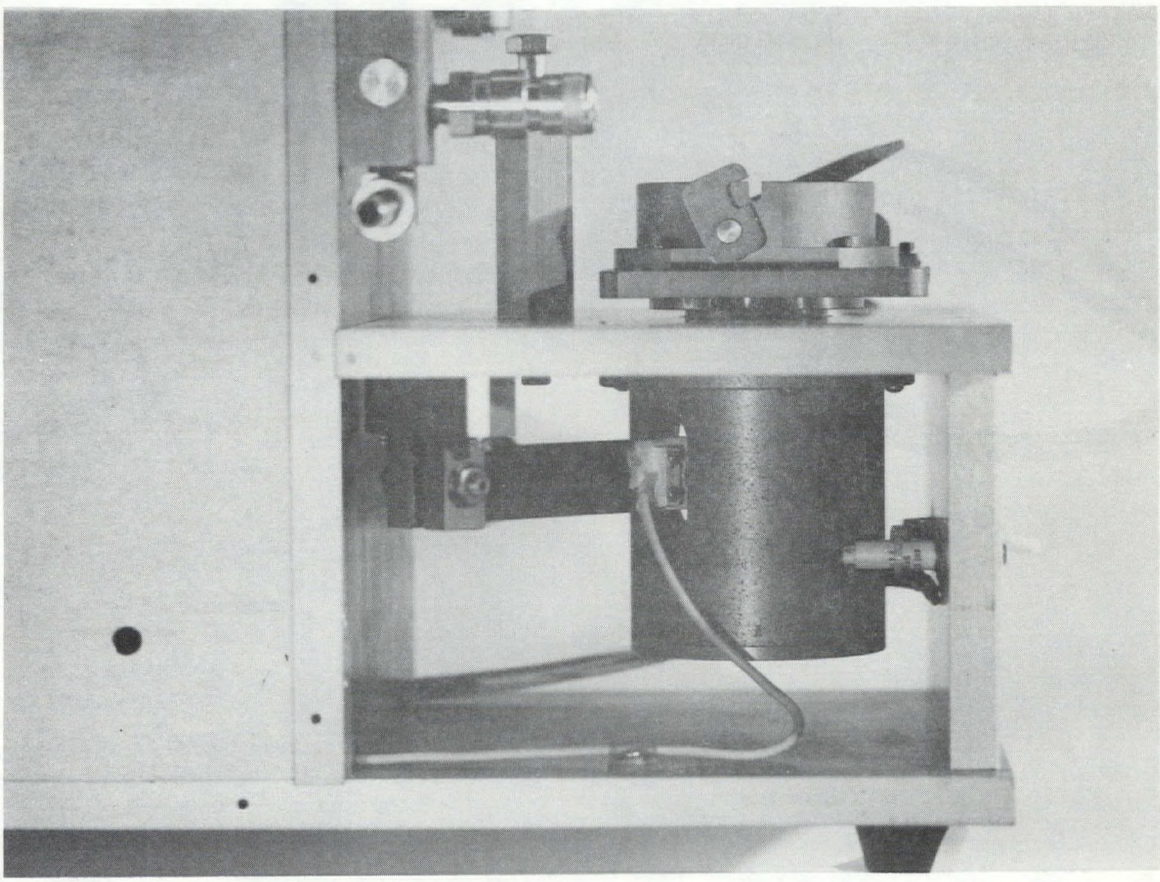

Figure 4. View with cover removed showing torque transducer installation.

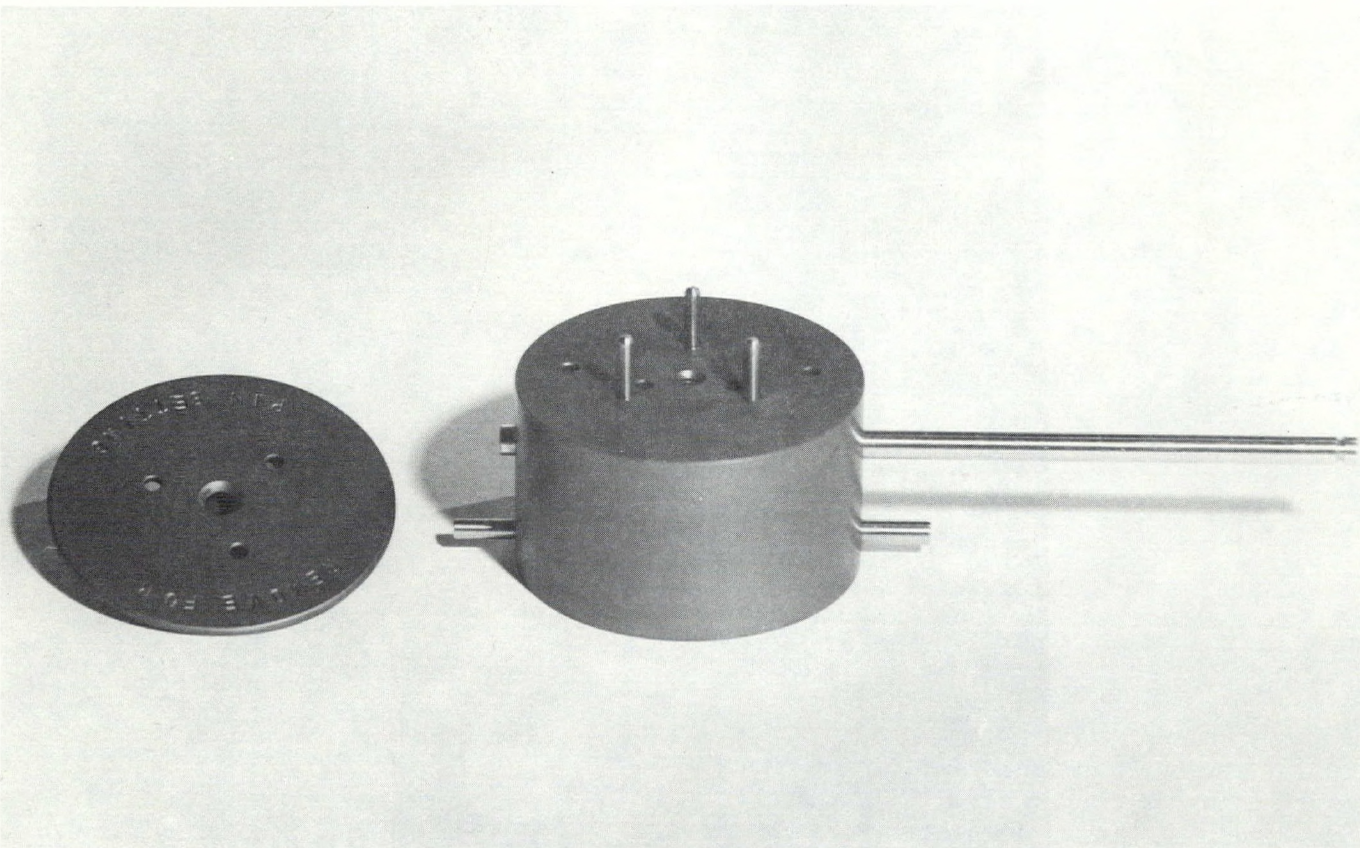

Figure 5. Calibration attachment with cover removed.

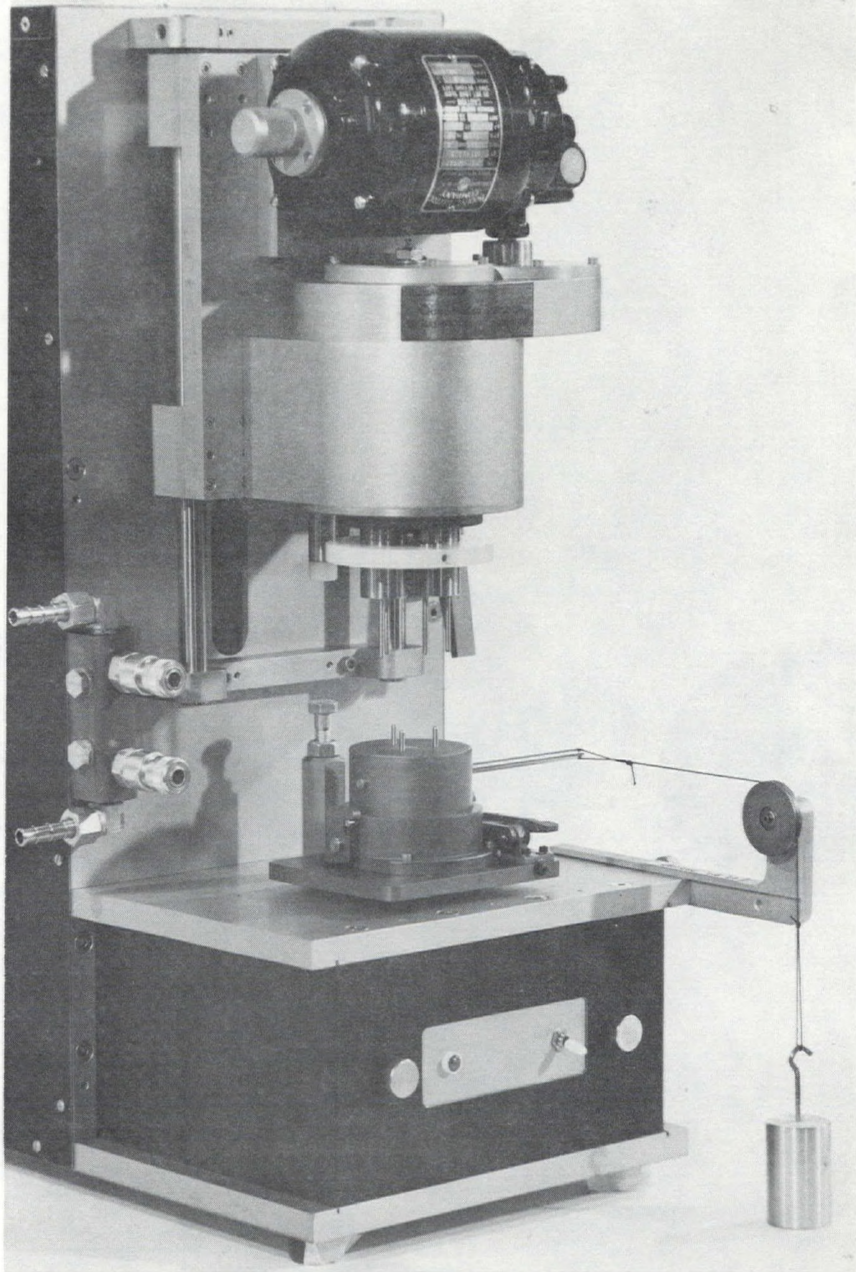

Figure 6. Calibrating the torque transducer.

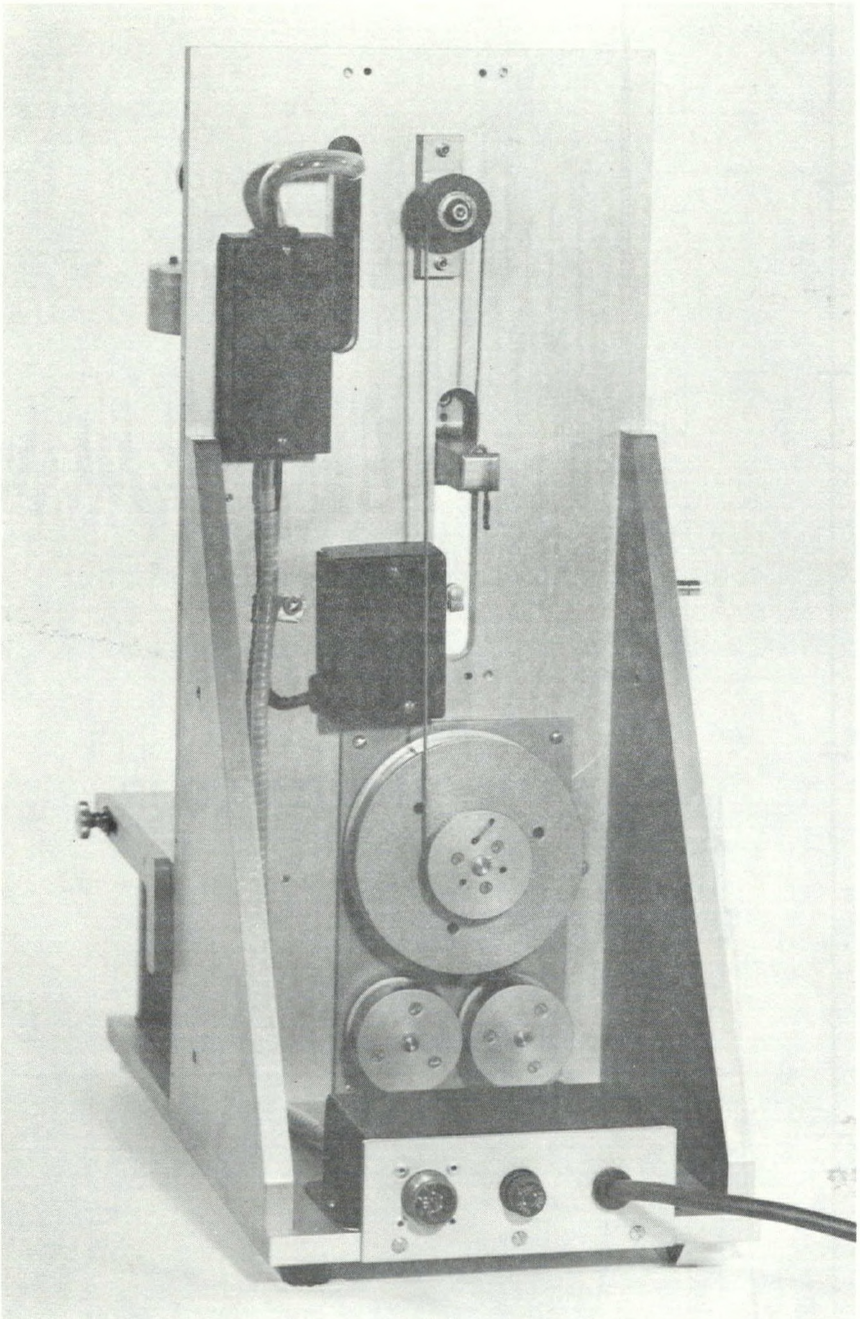

Figure 7. Rear view with cover removed showing counter balance mechanism and switch (at center) that controls the motor.

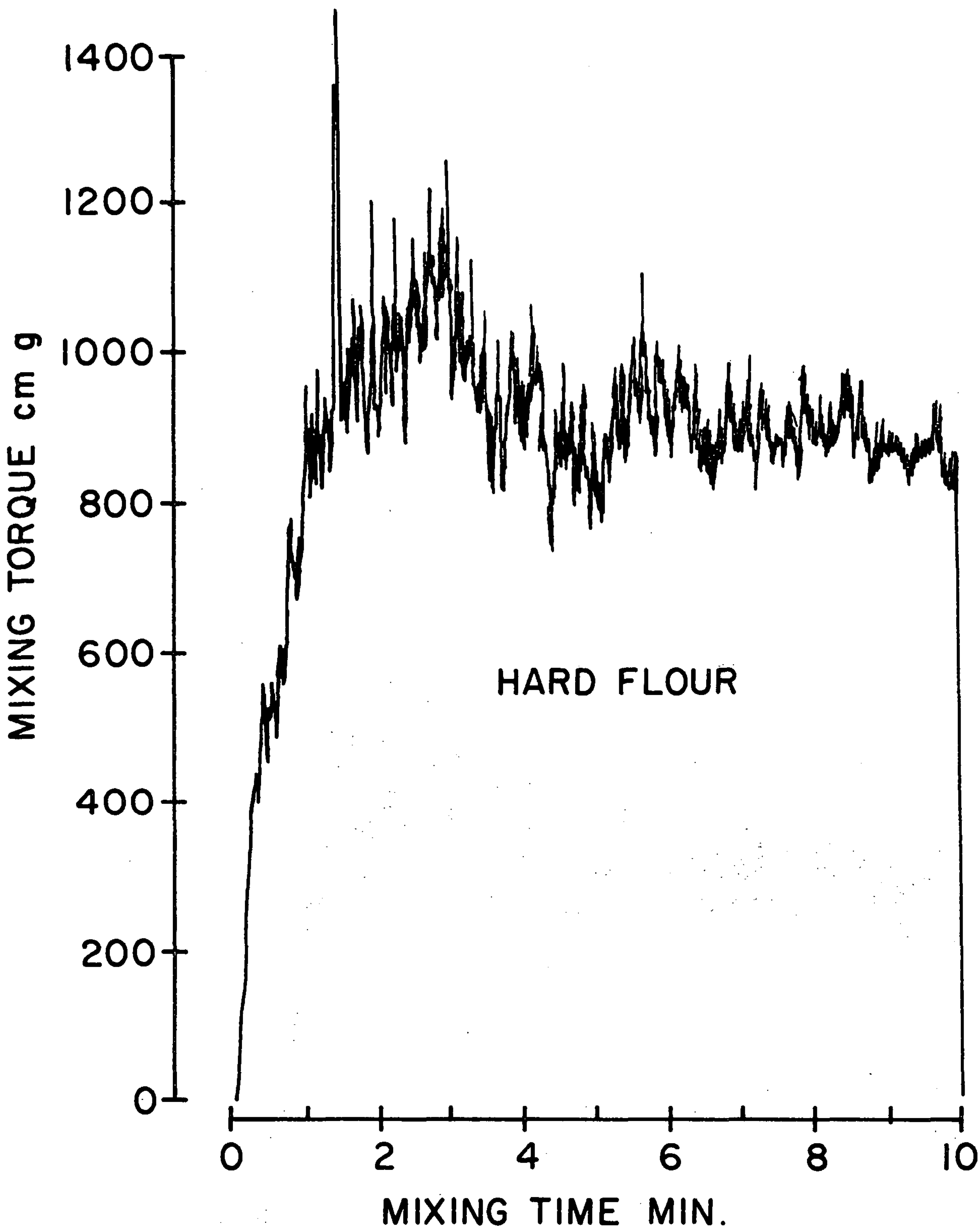

Figure 8. Typical record - hard flour.

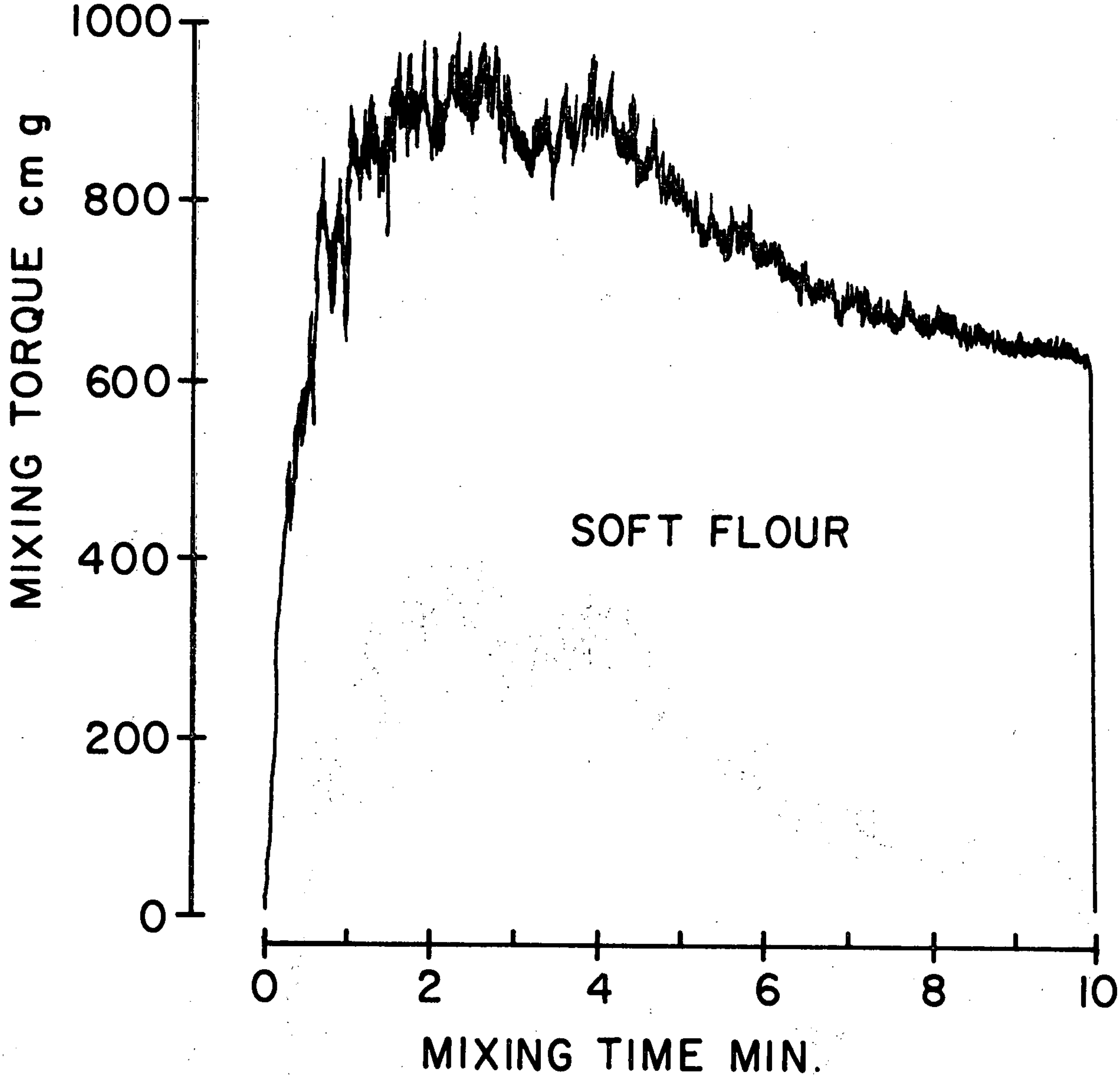

Figure 9. Typical record - soft flour.