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Evaluation Report 5

Dole 400 (PB-70-11) Moisture Tester

A Co-operative Program Between
ALBERTA FARM MACHINERY RESEARCH CENTRE
PAMI
PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

Dole 400 (PB-70-11) Moisture Tester

Manufacturer:
Eaton Control Products
191 East North Avenue
Carol Stream, Illinois 60187
U.S.A.

Distributors:
Allied Farm Equipment
Calgary, Edmonton, Regina, Winnipeg

Frank Flaman Wholesale Ltd.
Southey, Saskatchewan

Retail Price:
$230.00 (January 1977, fio.b. Lethbridge)

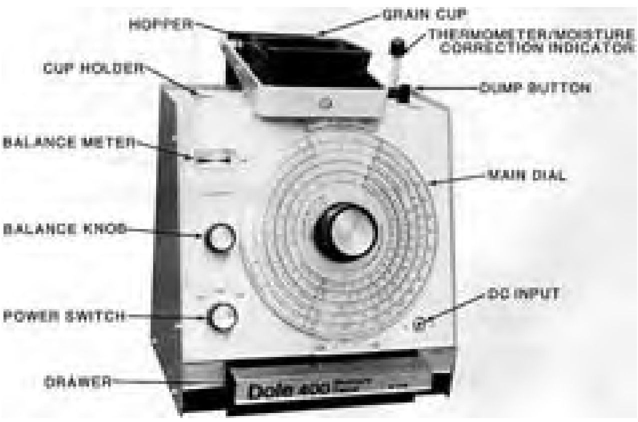

Figure 1. Detailed View of Dole 400 Grain Moisture Tester.

Summary and Conclusions

Accuracy of the Dole 400 moisture tester was excellent in wheat, good in barley, and fair in oats and rapeseed. Meter accuracy could be greatly improved by modification of the calibration charts in rapeseed.

Meter repeatability was excellent in wheat, oats and rapeseed and very good in barley.

Meter readings varied from 0.1% low to accurate in wheat, from 0.2 to 1.1% low in barley, from 1.1% high to 1.7% low in oats and from 1.4 to 1.6% high in rapeseed, over the range of moisture contents from 12 to 20% for cereal grains and 8 to 15% for rapeseed.

Meter readings were dependent upon grain variety, geographic location in which a grain was grown and many other variables. It is recommended that a user annually check a few samples against the meter used by his local grain elevator to determine a suitable correction factor.

The meter was durable and easily transported in its carrying case for field use. The instruction manual was clear and concise.

Recommendations

It is recommended that the manufacturer consider:

1. Improving sample weighing accuracy by placing a mark on the hopper front to indicate balanced position of the weighing system.
2. Making the moisture correction scale on the thermometer easier to use by graduating it in the same increments as used on the main dial.
3. Modifying the calibration chart for rapeseed to improve meter accuracy.
4. Modifying the instruction manual and meter main dial by inclusion of S.I. units and supplying a metric thermometer, to be consistent with the Canadian metric conversion program.

Chief Engineer -- E.O. Nyborg
Senior Engineer -- E.H. Wiens
Project Engineer -- D.R. Stafford

The Manufacturer States That:

1. The scale accuracy is within 0.1% when floating between stops. A balance mark on the hopper front would make weighing extremely difficult when testing large kernel size grain, such as corn, where the addition of a single kernel would take the scale past an arbitrary balance point.
2. Identical increments on the thermometer/temperature correction indicator will be considered. The temperature correction scale, like the grain curves, is an average, therefore, errors caused by the coarse increments is minimal.
3. Calibration charts for specific grain commodities may be obtained by submitting samples to Eaton Corporation along with a letter requesting a curve check. The repeatability of this instrument allows a full field correction factor to be used by comparing readings on several samples to the local elevator tester. An average of the differences may then be used as a field correction factor. By adding or subtracting the average field correction factor, the user will maintain a close relationship with his local elevator.
4. The use of S.I. units will be included in the near future to comply with the U.S. metrification program.

General Description

The Dole 400 moisture tester determines grain moisture content using the capacitance principle. Moisture content for wheat, oats, barley, rye, corn, sorghum and soybeans can be read directly from the main dial. Moisture charts for 36 additional grains are supplied in the instruction manual.

A grain sample of 141.8 g (5 oz) is weighed on an externally mounted grain cup and balance. The meter must be placed on a reasonably level surface for sample weighing.

A thermometer, graduated both in °F and in percent moisture to be added or subtracted, is supplied with the meter to correct for sample temperature.

The meter operates on a 9 volt transistor battery or may be equipped with an optional AC-DC converter for use with 110 volt power.

A sturdy plastic carrying case is supplied with the meter.

Complete specifications are found in Appendix I.

Scope of Test

The Dole 400 was used to determine moisture contents in wheat, oats, barley and rapeseed. Meter readings were compared to moisture contents obtained using the Canadian Grain Commission Research Laboratory oven method. All moisture contents were expressed on a percent wet weight basis.

For each grain, samples of several different varieties, grown in several locations, were used to determine meter characteristics. The meter was used with artificially tempered grain (dry grain which was moistened in the laboratory and allowed to stabilize before moisture measurement) and with naturally tempered grain (originally dry windrows which had been rained upon and were being dried naturally). It was also used with field samples of several grain varieties at various stages of maturity, which had not been subjected to rain after windrowing.

The moisture content of each grain sample was measured five times with the meter. In total, over 500 measurements were made with the Dole 400.

The meter was evaluated for ease of operation, accuracy, repeatability, durability and portability.

Results and Discussion

EASE OF OPERATION

The Dole 400 was easy to operate. The meter was instant on, requiring no warm-up. Less than one minute was needed to weigh a sample and make a moisture measurement. The meter had to be mounted on a reasonably level surface for sample weighing.

The thermometer for temperature correction was graduated in 0.25% moisture divisions to be added or subtracted from the main dial reading. The thermometer scale would have been easier to use if it were graduated in 0.2% divisions to correspond with the graduations on the main dial. The thermometer was also graduated in °F for use with the charts in the instruction manual for more accurate moisture determinations.

The meter was electronically zeroed using the balance knob. This was quickly done and had to be repeated only periodically to ensure accurate readings.

Moisture content was easily read to the nearest 0.1% on the main dial. The error due to reading the meter from an angle (parallax) was insignificant.

The power switch was spring loaded and had to be held during readings. This prevented accidental battery failure as it was impossible to leave the meter turned on. The same battery was used throughout the test for over 500 moisture measurements. The battery was easily replaced and readily obtainable.

ACCURACY

Sample Weight: The balance for measuring sample weight gave differences of 2 g from lift-off to overbalance. Sample weight differences of 2 g resulted in a difference in moisture content of only 0.2%. If grain were poured into the balance at a steady rate, an overfill of over 10 g was possible due to scale reaction time and operator error. Each 10 g overfill would cause moisture content readings to be in error by 1%. It is suggested that to overcome this possibility, a mark should be placed on the hopper to indicate the point of balance. Operating instructions should stress that accurate weighing is necessary.

Moisture Content: Charts and main dial graduations supplied with the Dole 400 indicated that it was capable of measuring moisture contents varying from 6.0 to 26.0% in wheat, 6.0 to 25.0% in barley, 8.4 to 23.4% in oats and 6.6 to 16.3% in rapeseed. The Dole 400 was evaluated with samples ranging in moisture content from 9.5 to 25.9% in wheat, 10.0 to 30.5% in barley, 11.1 to 27.8% in oats and 6.5 to 15.5% in rapeseed. The range of moisture contents of greatest concern for cereal grains varies from about 12 to 20%, and for rapeseed from 8 to 15%. These ranges include dry, tough and damp grains.

Figure 2 presents results for the Dole 400 in wheat. It shows the deviation of meter readings from true moisture content over a range of moisture contents. The best-fit line gives the average results for 25 samples of certified Neepawa wheat which had been artificially tempered (moisture added and samples stabilized in the laboratory) together with 20 samples of naturally tempered Neepawa wheat from a field at Humboldt, Saskatchewan (originally dry windrows which had been rained upon) and 12 samples of several varieties of spring wheat from fields at Lethbridge, Alberta which were maturing in the windrow and had received no rain. The difference between meter readings and true moisture content were insignificant since meter readings varied from 0.1% low at 12% moisture content to accurate at 20%. Data showing statistical significance of the best-fit line are presented in Appendix II.

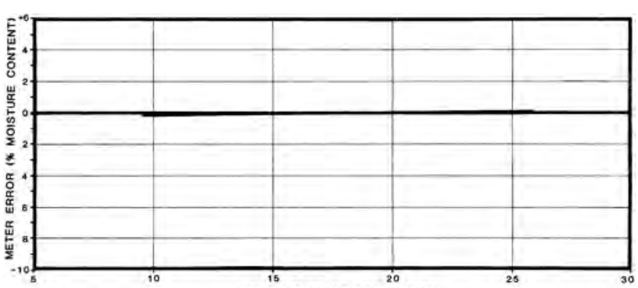

Figure 2. Deviations of Meter Readings for Dole 400 in Wheat.

Figure 3 presents the best-fit line for the Dole 400 in barley. It gives the average results for 13 samples of tempered Betzes barley and 10 samples from four barley fields at Lethbridge, which were maturing in the windrow and had received no rain. Meter readings varied from 0.2% low at 12% moisture content to 1.1% low at 20% moisture content. Data showing statistical significance of the best-fit line are given in Appendix II.

The best-fit line for the Dole 400 in oats is given in Figure 4. This figure gives the average results for six samples of tempered Sioux oats and eight samples of oats from three fields at Lethbridge, which were maturing in the windrow and received no rain. Meter readings varied from 1.1% high at 12% to 1.7% low at 20% moisture content. Meter readings corresponded with true moisture content at 15%. The statistical significance of the best-fit line is given in Appendix II.

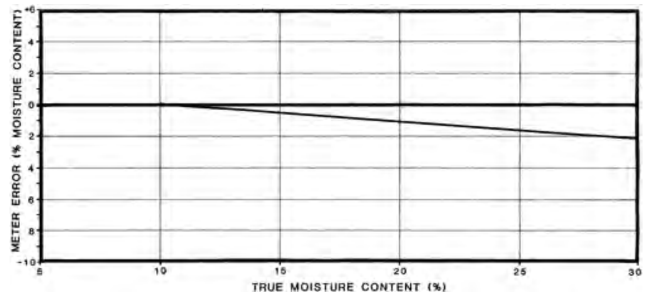

Figure 3. Deviations of Meter Readings for Dole 400 in Barley.

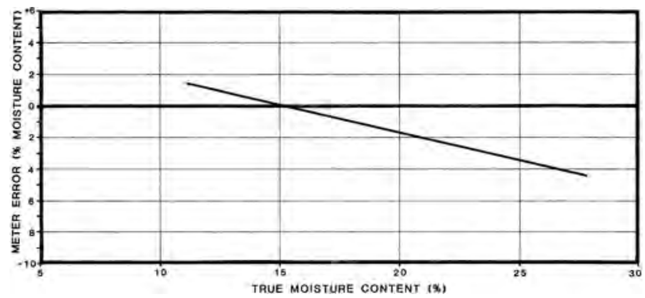

Figure 4. Deviations of Meter Readings for Dole 400 in Oats.

The best-fit line for the Dole 400 in rapeseed is given in Figure 5. The line shows the average results for samples of several varieties from 10 fields, which had received no rain after windrowing. The meter readings ranged from 1.4 to 1.6% high over the range of moisture contents from 8 to 15%. Statistical data are presented in Appendix II. Results could be significantly improved by preparation of a new moisture chart for rapeseed. For example, subtracting 1.5% from the meter reading would make the meter accurate at 12% and in error by less than 0.2% at other moisture contents. Because heating of moist rapeseed is a problem, accurate readings are desirable in the region around 10%, which represents the borderline between dry and tough rapeseed.

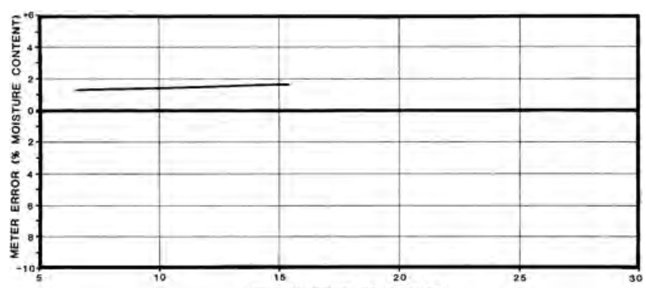

Figure 5. Deviations of Meter Readings for Dole 400 in Rapeseed.

Sources of Error: The Following precautions must be taken to ensure accurate moisture content readings:

1. Making sure that the sample is poured into the hopper at a constant rate and as quickly as possible. The rate at which the grain is poured changes the packing density and could result in moisture content error up to 0.5%.
2. Correctly setting the balance meter to its mechanical zero (null position). The mechanical zero or null position does not necessarily coincide with the center of the circle on the balance meter scale. Failure to use the null position as the mechanical zero could result in errors in the moisture content readings.

Effect of Variables: The dielectric properties of grain with respect to moisture content can vary due to grain variety, kernel size, geographic location, maturity, weathering, artificial or natural drying, tempering (whether or not a dry windrow was rewetted with rain) and other factors depending on the year the grain was harvested. The manufacturer's charts and tables are an attempt to represent the average properties accurately for one sample of one variety. It is difficult to try to accurately predict the dielectric properties of all varieties of spring wheat grown in North America and to prepare an appropriate calibration chart.

To illustrate this point, Figure 2 shows good results for the Dole 400 in wheat. Figure 2 is the average best-fit line for three different types of spring wheat. Figure 6 presents best-fit lines for each of these wheat types. The upper line is for samples from a field of Neepawa wheat at Humboldt, Saskatchewan in 1976. The windrows received rain during combining (naturally tempered) and samples were taken as the wheat dried in the field, very similar to what a farmer would do under the same situation. Meter readings varied from 0.5 to 0.8% high over the range of moisture contents tested. One of the lower lines is for Neepawa wheat, which was harvested a year earlier at Lethbridge, Alberta and which was artificially tempered in the laboratory. Meter readings for this wheat varied from 0.4 to 0.9% low. The third best-fit line is for samples of several varieties of spring wheat from Lethbridge, Alberta in 1976. These samples were maturing in the windrow and had received no rain. In this case, meter results varied from 0.1% high to 0.9% low over the range. Data showing statistical significance of these best-fit lines are presented in Appendix II.

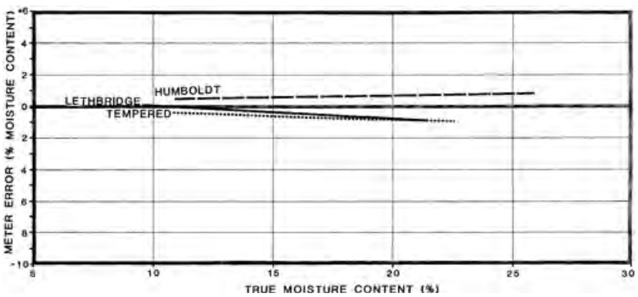

Figure 6. Deviation of Meter Readings for Dole 400 in Three Different Types of Spring Wheat.

It is nearly impossible for a manufacturer to prepare a calibration chart with suitable correction factors to suit all the possible combinations for one type of grain. The measurements involved would be difficult and time consuming and would really defeat the purpose of a portable grain moisture meter. It is, therefore, recommended that the owner annually check the results of his moisture meter against the moisture meter used by his local grain elevator agent. Comparing only a few samples should give enough information to determine how much to add to or subtract from the meter reading.

Only one Dole 400 tester was evaluated. This does not guarantee that results from all Dole 400 meters will be the same as presented in this report.

REPEATABILITY

Repeatability is a measure of how closely a meter gives the same reading when the same sample of grain is tested several times. If a meter is designed so that chances of human error or instrument error are high, then the repeatability would be poor. Conversely, if chances of human error or instrument error are low, repeatability would be good. The coefficient of variation (defined in Appendix II) is a measure of meter repeatability. A low coefficient of variation indicates good meter repeatability while a high coefficient of variation indicates poor repeatability.

Table 1 gives the coefficients of variation for the Dole 400 in wheat, barley, oats and rapeseed. These results show that the repeatability of the Dole 400 was excellent in wheat, oats and rapeseed and very good in barley. The greater variation in barley was due to barley beards resulting in slightly different cell loading for each sample.

Table 1. Coefficients of Variation for the Dole 400

Wheat	Barley	Oats	Rapeseed
0.42%	0.99%	0.30%	0.23%

DURABILITY AND PORTABILITY

The Dole 400 was well constructed and could be used for moisture measurement in the field. A reasonably level surface was required for accurate sample weighing and moisture measurements. A strong plastic case was provided to protect the meter during transport.

INSTRUCTION MANUAL

The instruction manual was easy to read and understand. In addition to specifications, parts identification, operating and maintenance instructions, it contained moisture and temperature correction charts for 36 grains. Most charts and tables used English units of measurement, not consistent with the Canadian metric conversion program.

ACKNOWLEDGEMENTS

The assistance of the Canadian Grain Commission Research Laboratory, Winnipeg, in developing test procedures and laboratory techniques is gratefully acknowledged.

Appreciation and thanks is also extended to Lethbridge area farmers and the Agriculture Canada Research Station, Lethbridge for assistance in collecting grain samples.

APPENDIX I
SPECIFICATIONS

Model Number:	Dole 400 (PB-70-11)
Serial Number:	104021
Electrical Power Requirements:	9 V transistor battery (NEDA Type 1604)
Overall Height:	291 mm (11.5 in)
Overall Depth:	159 mm (6.3 in)
Overall Width:	244 mm (9.6 in)
Total Weight (in carrying case):	6.26 kg (13.8 lb)
Principle of Operation:	capacitance
Weight of Grain Sample:	(low moisture content) 141.8 g (5 oz) (high moisture content) 851. g (3 oz)
Optional Equipment:	AC-DC converter (105 - 125 V, 50 Hz, 0.75 W)

APPENDIX II
STATISTICAL INFORMATION

(a) Statistical Significance of Moisture Meter Results

The following data are presented to illustrate the statistical significance of the moisture meter results shown in Figures 2 to 6. This information is intended for use by those who may wish to check results in greater detail. Sufficient information is presented to permit calculation of confidence belts.

In the following table, M = the reading of the Dole 400 in percent moisture, wet basis, while T = the moisture content of the sample in percent moisture, wet basis, as determined by the Canadian Grain Commission Research Laboratory oven method. Sample size refers to the number of grain samples used. Each meter sample represents the mean of five replicates (five meter readings) on that sample.

Grain Type	Fig. No.	Regression Equation	Simple Correlation Coefficient	Standard Error of Estimate	Residual Mean Square	Sample Size	Sample Mean
Wheat	2	M=1.01T-0.19	0.98	0.78	0.53	57	15.71
Barley	3	M=0.89T+1.08	0.97	1.23	1.78	23	15.84
Oats	4	M=0.65T+5.30	0.88	1.63	4.82	14	15.71
Rapeseed	5	M=1.03T+1.15	0.99	0.48	0.21	10	12.58
Wheat Humboldt	6	M=0.98T+1.01	0.99	0.44	0.20	20	17.93
Wheat Lethbridge	6	M=0.91T+0.99	0.98	0.37	0.32	12	13.32
Wheat Tempered	6	M=0.98T-0.22	0.99	0.51	0.26	25	15.17

(b) Meter Repeatability

Moisture meter repeatability (Table 1) was determined using the coefficient of variation. The coefficient of variation was determined by expressing the standard deviation as a percent of the mean for each of the five replicates taken on each sample.

The values presented in Table 1 are the average coefficients of variation for all samples.

APPENDIX III
MACHINE RATINGS

The following rating scale is used in PAMI Evaluation Reports:

(a) excellent
(b) very good
(c) good
(d) fair
(e) poor
(f) unsatisfactory

ALBERTA FARM MACHINERY RESEARCH CENTRE

3000 College Drive South
Lethbridge, Alberta, Canada T1K 1L6
Telephone: (403) 329-1212
FAX: (403) 329-5562
http://www.agric.gov.ab.ca/navigation/engineering/afmrc/index.html

Prairie Agricultural Machinery Institute
Head Office: P.O. Box 1900, Humboldt, Saskatchewan, Canada S0K 2A0
Telephone: (306) 682-2555

Test Stations:
P.O. Box 1060
Portage la Prairie, Manitoba, Canada R1N 3C5
Telephone: (204) 239-5445
Fax: (204) 239-7124

P.O. Box 1150
Humboldt, Saskatchewan, Canada S0K 2A0
Telephone: (306) 682-5033
Fax: (306) 682-5080