

Evaluation Report

216



Delmhorst F-4 Forage Moisture Tester

A Co-operative Program Between



DELMHORST F-4 FORAGE MOISTURE TESTER

MANUFACTURER:

Delmhorst Instrument Company
607 Cedar Street
Boonton, New Jersey 07005
U.S.A.

DISTRIBUTOR:

M.H. Western Agribusiness Ltd.
1400 - 8th Street
Nisku, Alberta
T0C 2G0

RETAIL PRICE:

\$255.00 (June 1981, f.o.b. Nisku with bale probe, short-pin probe and case)



FIGURE 1. Delmhorst F-4 Moisture Tester.

SUMMARY AND CONCLUSIONS

Functional performance of the Delmhorst forage moisture tester was very good in low moisture chopped alfalfa and fair in baled hay. It was not capable of moisture measurements above 50%.

Recalibrating, for prairie forage crops, was necessary to correctly read moisture content. In chopped alfalfa, the meter indicated moisture contents, which varied from 3% high (at 20% moisture content) to 1% low (at 37% moisture content), with accurate readings at 32% moisture content. In baled alfalfa, the meter indicated moisture contents varying from 7% high (at 19% moisture content) to 10% low (at 30% moisture content) with accurate readings at 18%. Accuracy of the short pin prod was not evaluated in windrowed hay.

It was best to average measurements from several samples in each forage batch to reduce errors from moisture variation within the forage samples. The errors were reduced from an average of $\pm 9.6\%$ in chopped alfalfa and $\pm 7.5\%$ in baled alfalfa for single sample measurements to an average of $\pm 2.4\%$ and $\pm 1.6\%$ respectively by averaging several measurements. Meter repeatability was fair in chopped alfalfa and good in baled alfalfa.

Operating ease was excellent. The Delmhorst F-4 was convenient to use in the field. Best results with the bale probe were

obtained by piercing the bale perpendicular to the stems. A single moisture determination took less than one minute.

Corrections for sample temperature, indicated by the manufacturer, were found to have little significance due to the large variations found among individual forage samples.

The batteries lasted the duration of the test.

RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Providing a second scale on the meter suitable for measuring moisture content in baled hay.
2. Providing a protective cap for the short pin prod.
3. Providing a temperature correction table in SI units.

Chief Engineer -- E.O. Nyborg

Senior Engineer -- J.C. Thauberger

Project Engineer -- R.R. Hochstein

THE MANUFACTURER STATES THAT

With regard to recommendation number:

1. We note the recommendation, however such a scale may not readily apply to all types of baled hay. Differences occur in grass-hay, when compared to alfalfa-hay, and differences often exist in meter readings between first-cut and second-cut hay.
2. We plan to provide a protective cap for the short pin prod and to ship the prod with the points slightly blunted. This will minimize the possibility of injury, without any change in functional capability. We also offer an optional protective carrying case, for the meter, which can be used to safely store the short pin prod.
3. We plan to provide temperature correction tables in Celsius as well as Fahrenheit degrees, in future.

Manufacturer's Additional Comments

Due to variations in meter readings, as a result of the variability of hay moisture, we stress the importance of taking several tests to determine an average moisture and reduce the possibility of sampling a high moisture pocket. A principle advantage of a probe type instrument, when used in hay, is the ability to determine the degree of conditioning of the product, as well as the average moisture content. Since many readings can be taken in a very short time, the F-4 is very useful to determine the overall condition of the hay, even when average moisture readings may vary up to 2%.

Note: This report has been prepared using SI units of measurement. A conversion table is given in APPENDIX III.

GENERAL DESCRIPTION

The Delmhorst F-4 is a portable, electronic forage moisture tester. It determines moisture content by measuring electrical conductivity. Moisture content may be determined in the windrow or in chopped hay, using a short pin prod, or in the bale, using a bale probe. Moisture content is determined by reading it directly off the meter.

The tester operates on two 9V transistor batteries.

Detailed specifications are given in APPENDIX I.

SCOPE OF TEST

The Delmhorst was used to determine moisture contents of a variety of chopped alfalfa forages and bales. Meter readings were compared to moisture contents obtained using a standard oven method¹. Forage samples were collected from a large number of fields at various stages of crop maturity and from several alfalfa and hay bales. The moisture contents of four representative samples were measured from each large sample or bale. In total, more than 250 forage and hay samples were tested with the Delmhorst.

The Delmhorst was evaluated for ease of operation, quality of work and suitability of the operator manual.

¹PAMI T7830 Detailed Test Procedures for Forage Moisture Testing Devices.

RESULTS AND DISCUSSIONS

EASE OF OPERATION

Portability: The Delmhorst was easy to use. It was light and portable, with a self-contained power source, making it convenient for field use. No levelling was required since sample weight was not needed.

Sample Selection: One of the major problems in forage moisture measurement is obtaining a representative sample. The operator manual clearly detailed instructions for selecting a suitable sample out of a windrow or from chopped forage. It also recommended that several readings be taken from different parts of a forage sample or a hay bale to arrive at an average moisture content.

Operating Procedure: The Delmhorst was provided with attachments for measuring the moisture content of chopped hay and windrowed or baled hay. A short pin prod was used for chopped or windrowed hay, while a probe attachment was used for bales. Since a force of 120 to 130 N (27 to 30 lb) had to be applied with the palm of the hand when using the pin prod, it was best to place samples in a bucket for moisture measurement. Proper force was indicated when the retaining screw in the plunger centre contacted the palm of the hand. With the bale probe, best results were obtained when the probe was inserted perpendicular to the plant stems. Moisture readings were taken by depressing a key on the instrument face and noting the position of the pointer on the scale. Temperature correction was made using a table in the operator manual.

Calibrating the instrument and checking the battery was done by depressing the adjust key and adjusting the pointer to correspond to the appropriate mark on the meter scale. When this could no longer be done, the battery needed replacing. It took less than one minute to make a single moisture measurement.

Controls: The Delmhorst had two push button keys for activating the display. One button was for calibrating and checking battery voltage while the second was for moisture readings. The meter was easy to read.

Battery: The two batteries lasted for the duration of the test during which about 250 samples were measured. Battery replacement was convenient.

Cleaning: The Delmhorst F-4 stayed clean throughout the test. The operator manual recommended periodic cleaning of the bale probe with alcohol and cleaning of the short pin prod with hot water.

QUALITY OF WORK

General: Chopped forage is a non-uniform material. As detailed in the operator manual, it was important to obtain a representative sample of forage for moisture determination. Since large variations in moisture content occur in a field, samples should be taken from several locations within a batch of forage to get a good indication of the average moisture content.

The electrical conductivity of similar forages may also vary due to many uncontrollable factors such as crop variety, geographical location, maturity and weathering. Since the meter scale is an attempt to represent average properties for many crops, variations can be expected due to uncontrollable crop differences.

Range of measurement: The scale on the Delmhorst indicated that it was capable of measuring moisture contents from 0 to 50% irrespective of crop type. The Delmhorst was evaluated with chopped alfalfa samples ranging from 12 to 37% moisture content and with baled alfalfa ranging from 10 to 30% moisture content. The moisture content of ensiled forage, which ranged up to 75%, was beyond the capability of the Delmhorst. However, baled alfalfa, which had a moisture content below 30%, was well within the measurement range. The narrow measurement range of the Delmhorst makes it unsuitable for high moisture silage measurement.

Accuracy: FIGURE 2 presents results for the Delmhorst in chopped alfalfa when using the short pin prod in a bucket of forage. Each moisture content is determined from an average of four readings on the same batch. The best fit line gives average results for 32 moisture readings in chopped alfalfa from samples taken from a variety of fields around Portage la Prairie.

Average moisture readings varied from 3% high (at 20% moisture content) to 1% low (at 37% moisture content). Accurate results occurred at about 32% moisture content.

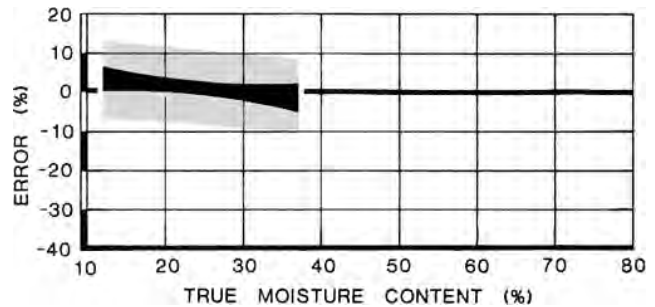


FIGURE 2. Accuracy in Chopped Alfalfa using Short Pin Prod.

FIGURE 3 similarly shows the accuracy of the Delmhorst in baled alfalfa when using the bale probe. This best fit line gives average results for 108 readings. Average moisture readings varied from 6% high (at 10% moisture content) to 10% low (at 30% moisture content). Accurate readings occurred at about 18% moisture content.

An accuracy of 5% is an acceptable level for most forage operations. It is recommended that the manufacturer consider providing a second scale on the meter to measure moisture content in baled hay.

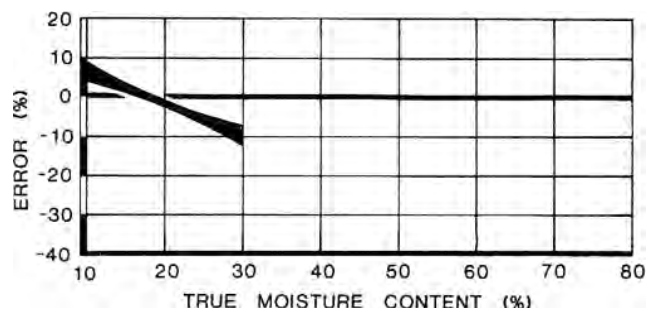


FIGURE 3. Accuracy in Baled Alfalfa using Bale Probe.

Uncertainty: Uncertainty is indicated by the 95% confidence limits displayed by the width of the line in FIGURES 2 and 3. This uncertainty results from both sample variation and meter repeatability.

The light shaded area (scatter) indicated in FIGURE 2 shows the effect sample variation will have on the meter reading when only single measurements from a forage batch are taken. The manufacturer recommended that several readings be taken per sample, to reduce uncertainty from sample variation. Averaging four readings in chopped alfalfa reduced this uncertainty from $\pm 9.7\%$ for single meter readings down to a scatter varying from $\pm 1.7\%$ to $\pm 3.0\%$ when averaging four readings. Similarly, in baled hay, the uncertainty was reduced from $\pm 7.5\%$ for single meter readings down to a scatter varying from $\pm 0.7\%$ to $\pm 2.4\%$.

This difference in the scatter shows the importance of averaging a number of readings when determining moisture content.

Repeatability: Meter repeatability (APPENDIX II) is a measure of how consistently a meter gives the same reading if the same sample is measured several times. It indicates how subject the measurement method is to both operator error and instrument error. The repeatability of the Delmhorst F-4 was fair in chopped alfalfa and good in baled hay.

Temperature Compensation: Temperature corrections had to be applied to meter readings when determining moisture content. The temperature correction table included in the operator manual presented temperatures in only the Fahrenheit scale. It is recommended that a table in degrees Celsius be provided. An analysis of the data indicated that over a sample temperature range from 10 to 30°C, temperature correction did not significantly improve meter accuracy. The variations of meter readings due to the scatter in samples was much more significant than variations due to sample temperature.

Calibration Curves: FIGURES 4 and 5 (APPENDIX II), present PAMI calibration curves for the Delmhorst in chopped and baled alfalfa respectively. These curves are based on a wide variety of alfalfa crops in the Portage la Prairie area and are for a

sample temperature of 20°C. Errors were insignificant when these curves were used for sample temperatures from 10 to 30°C. The confidence belts on these curves show the expected scatter due to sample variation when readings are based on an average of four measurements.

Since significant errors resulted from using the manufacturer's moisture indication scale for prairie forage crops, it is recommended that the manufacturer supply charts or calibration curves more suitable for these crops.

OPERATOR MANUAL

The operator manual was easy to read and understand. It contained comprehensive operating instructions, sample selection recommendations and contained temperature correction tables. As discussed previously, Celsius temperature correction tables were not provided.

APPENDIX I SPECIFICATIONS	
Make:	Delmhorst
Model No.:	F-4
Serial No.:	820937 13553
Electrical Power Requirements:	2 - 9V Batteries (NEMA Type 1604)
Overall Dimensions:	
-- meter	
-length	130 mm
-width	45 mm
-height	70 mm
-- bale probe	
-length	240 mm
-diameter	8 mm
-- short pin prod	
-height	190 mm
-diameter	60 mm
Weight:	700 g
Principle of Operation:	electrical conductivity

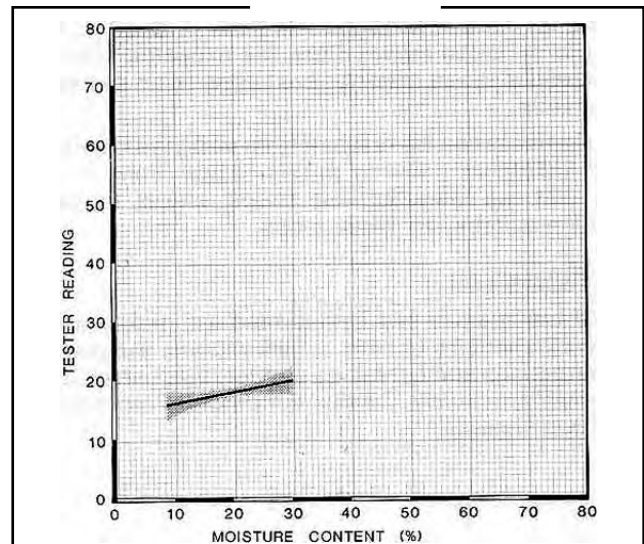
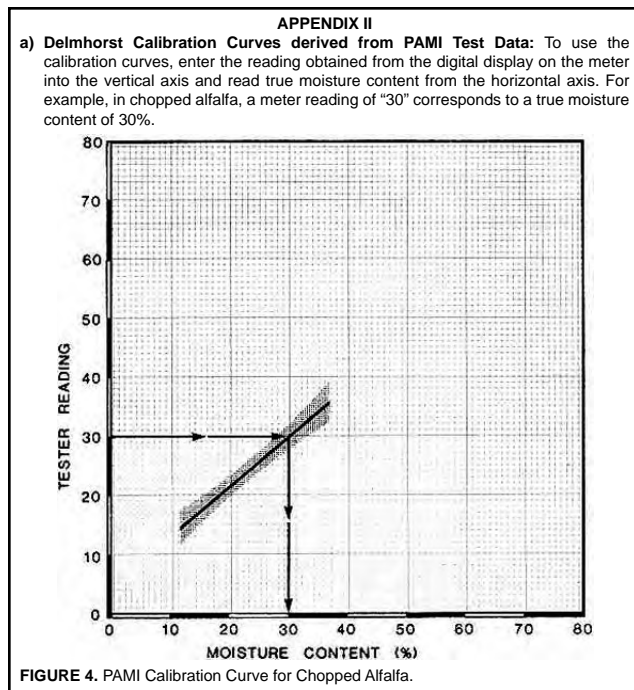


FIGURE 5. PAMI Calibration Curve for Baled Alfalfa.

b) **Regression Equations:** TABLE 1 presents regression equations for the Delmhorst in chopped alfalfa and baled hay. In the table, R = the meter display reading; M = the moisture content, percent wet basis, over the ranges specified in FIGURES 4 and 5.

Crop	Figure Number	Regression Equation	Correlation Coefficient
Chopped Alfalfa	4	$R = 0.85 M + 4.79$	0.83
Baled Hay	5	$R = 0.19 M + 14.33$	0.18

c) **Meter Repeatability:** To eliminate the effect of sample variation, moisture meter repeatability was determined by relating the coefficient of variation (CV) of the meter to that of the oven drying method. The coefficients of variation were determined by expressing the standard deviation as a percent of the mean for each of the four samples taken from each forage batch. The values, 6.7% in chopped alfalfa and 4.9% in baled hay for the meter and 3.0% in chopped alfalfa and 2.2% in baled hay by the method, are the average coefficients of variation for all samples. The equation used to determine the meter repeatability was:

d)

$$\text{Repeatability} = \frac{[(CV \text{ meter})^2 - (CV \text{ oven})^2]^{1/2}}{2}$$

Repeatability for the Delmhorst was 6.0% in chopped alfalfa and 4.4% in baled alfalfa.

**APPENDIX III
Conversion Table:**

1 millimetre (mm)	= 0.04 inches (in)
1 kilogram (kg)	= 2.2 pounds mass (lb)

**APPENDIX IV
Machine Ratings:**

The following rating scale is used in PAMI Evaluation Reports:

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