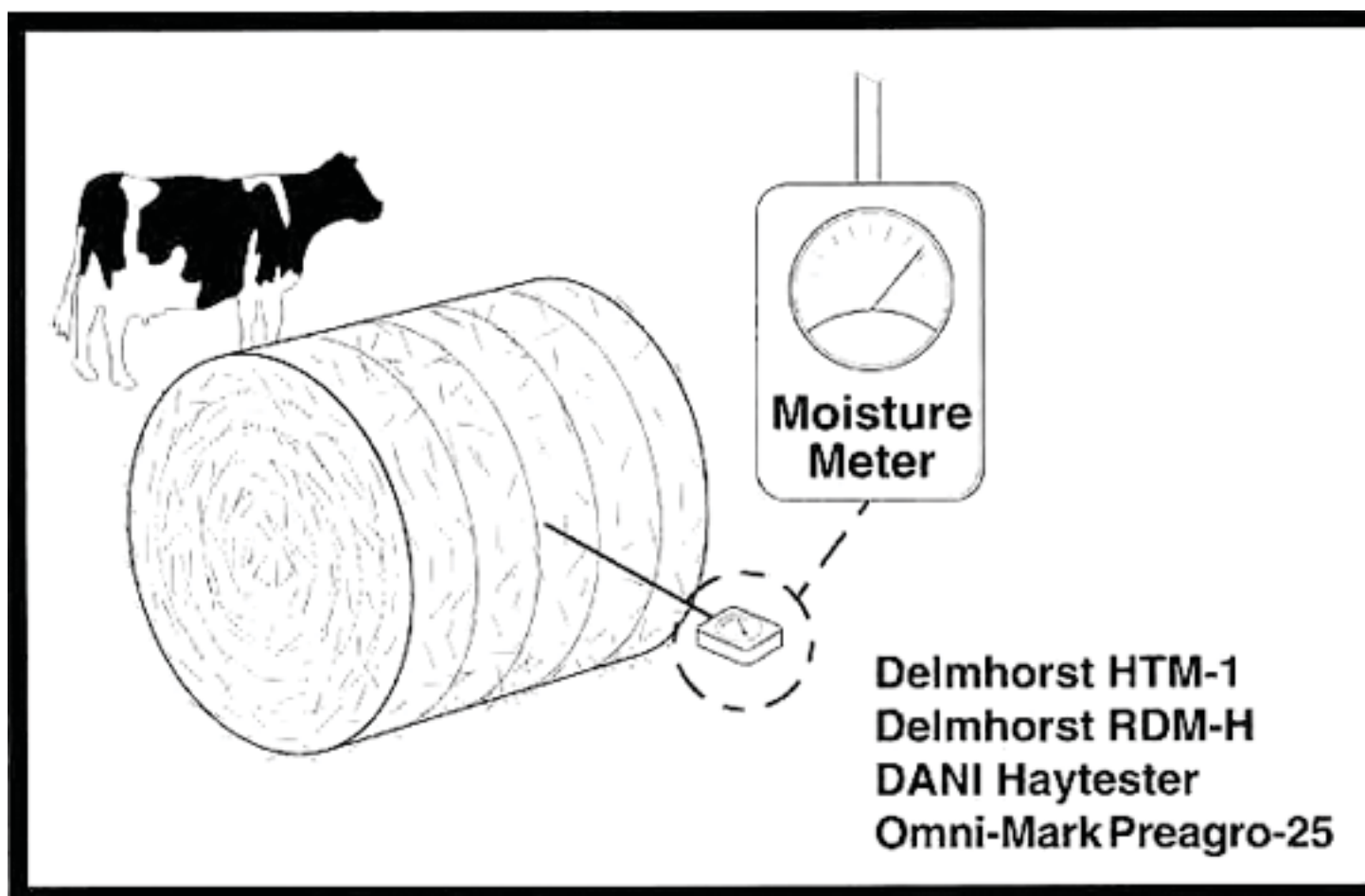


Evaluation Report

700



Hay and Forage Moisture Meters

A Co-operative Program Between



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HAY AND FORAGE MOISTURE METERS

INTRODUCTION TO REPORT CROP VARIABLES

The electrical properties of forage material vary greatly with forage variety, maturity, weathering, and tempering (rewetting), as well as non-uniformity of the forage material (stems, leaves, etc.). A hay moisture meter is an attempt to accurately represent the average moisture levels for one or several hay varieties. To accurately predict the dielectric properties and corresponding moisture contents of all varieties of forage grown on the prairies is very difficult. Therefore several samples should be averaged to accurately predict the moisture content of the forage material being tested. The owner should also periodically check the results of the meter by comparing to an oven dry test.

METER PERFORMANCE

To assess hay moisture meter performance, three factors must be considered; accuracy, uncertainty, and repeatability.

Accuracy indicates how close the average meter reading is to the true moisture content and is considered at three points; the upper and lower limits of the meter and at 18% moisture content (within the range for the safe storage of most forage materials as recommended by The Canadian Journal of Plant Science).

Uncertainty is a measure of scatter over the range of moisture contents measured, or how close the readings follow the best-fit line. Uncertainty results from both sample variation and meter repeatability. The shaded belts represent the region in which 95% of the test results can be expected to occur. The narrower the belt, the greater the certainty of the meter.

Repeatability is a measure of how consistently a meter gives the same reading when the same forage sample is measured several times. It indicates how subject the measurement method is to both operator error and instrument error.

SCOPE OF TEST

The moisture meters evaluated by PAMI were configured as described in the General Description and Specifications sections of this report. The manufacturers may have produced different versions of these meters either before or after the PAMI tests. Therefore, when using this report, check to ensure the meter being considered is the same as the one evaluated in this report. If differences are found, PAMI or the manufacturer may be contacted to determine the effect of the changes on performance.

Each of the meters was operated in the field to determine moisture contents of three types of hay forages; alfalfa, brome grass, and a mix of alfalfa-brome grass. Ten readings from each square bale were averaged to determine the moisture content of the hay. Measurements were compared to those obtained using a standard oven method.¹

Hay was square baled at various stages of drying and was measured immediately to determine meter performance. The range of moisture contents considered (specified by the manufacturers) as the meters ranges of measurement spanned from 10 to 70%. Readings were taken by probing the end of the bale at various locations but at a uniform depth with each meter. A wafer or layer of hay at the measurement depth was removed and oven dried for comparison.

All of the moisture contents in the report are expressed on a percent wet-basis. The meters were evaluated for quality of work, ease of operation, and suitability of the operator's manual.

Senior Engineer: B.H. Allen

Project Engineer: D.J. May

Project Assistant: G.A. Bergen

¹American Society of Agricultural Engineers Standard S358.1 Moisture Measurement-Forages.

DELMHORST HTM-1 FORAGE MOISTURE TESTER

MANUFACTURER

Delmhorst Instrument Company
51 Indian Lane East,
P.O. Box 68, Towaco, New Jersey
Ph. (201) 334-2557
Toll Free 1-800-222-0638

DISTRIBUTORS

Transfeeder	Tirol Dehydrators
P.O. Box 2445	P.O. Box 220
Olds, Alberta	Tilley, Alberta
T0M 1P0	T0J 3K0
403-556-6968	403-377-2227

RETAIL PRICE:

\$357.00 (June 1993, f.o.b. Portage la Prairie, MB) with 18 in (456 mm) bale probe.



FIGURE 1. Delmhorst HTM-1 Forage Moisture Tester.

SUMMARY

Portability of the Delmhorst HTM-1 was very good. It was light, compact and had a self-contained power supply. Ease of operating the meter was very good. Moisture and temperature readings were taken by simply pushing the probe into a bale and pressing the appropriate button. The control and display layout on the meter was excellent. Ease of changing the battery was very good, and ease of cleaning the meter was very good.

The range of measurement of the Delmhorst HTM-1 was fair. It would measure moisture contents from 10 - 40%, which was adequate for normal baled hay. Accuracy of the meter was fair at normal bale moisture content. Uncertainty of the HTM-1 was fair in baled hay. Repeatability of the meter was very good in baled hay.

The operator's manual was very good. It was generally easy to read and understand.

RECOMMENDATIONS

It is recommended that the manufacturer consider providing a meter, which displays temperatures in degrees Celsius.

THE MANUFACTURER STATES THAT

With regard to the recommendation:
We do offer a model "HTM-2" which displays temperature in degrees Celsius.

Manufacturer's Additional Comments

With regard to the accuracy of the HTM-1 you indicate that at 15% M.C. the average meter reading was 6 points low. Note that the range of the HTM-1 is 12 - 40%. Indications outside of this range are considered as "no readings". Therefore it may be difficult to determine accuracy at 15% M.C.

We refer to report No. E0678C of June, 1981 on our model F-4. Accuracy findings in baled hay were "6% high at 10% M.C. to 10% low at 30% M.C. with accurate readings at 18%". The HTM-1 incorporates a superior and more reliable primary electrical circuit than the F-4, but the secondary calibrations are virtually identical. These two meters, probing the same mass of material, should read the same electrically. Differences can only be due to the many varying electrical properties of the material, outside of the meter.

GENERAL DESCRIPTION

The Delmhorst HTM-1 is a portable, electronic forage moisture tester. It determines moisture content by measuring electrical resistance. Moisture content may be determined in either round or square bales using the bale probe supplied. By pressing the appropriate button on the meter either moisture content or temperature can be read directly off of the display panel.

The tester operates on one 9V battery.

More details are given in the specifications section, and the meter is shown in FIGURE 1.

SCOPE OF TEST

A total of twenty-three bales were probed with the Delmhorst HTM-1, during which time about 600 readings were taken.

RESULTS AND DISCUSSION

EASE OF OPERATION

Portability: Portability of the Delmhorst HTM-1 was very good. It was very easy to use, light, compact, and had a self-contained power source, making it convenient for field use. The digital display was easy to read. A cable connected the display unit to the sensor probe, allowing it to be held at eye level during measurements.

Operating Procedure: Ease of operating the Delmhorst HTM-1 was very good. It was provided with a bale probe attachment only. Best results were obtained when the probe was inserted perpendicular to the plant stems as instructed in the operator's manual. Moisture and temperature readings were taken by depressing the appropriate button on the instrument face and reading the value on the display panel. Temperature correction was made using a table in the operator's manual. The manual advised taking readings by driving the prod across the slices or layers of the bale, not between slices, to give firmer and more uniform contact. The manufacturer advised the operator to take several readings and to pay specific attention to the high readings.

The force required to push a bale probe into a bale is dependent on the material baled, bale density, bale moisture content and direction of probe insertion in relation to the orientation of the material baled. In general, the Delmhorst bale probe could be easily inserted into a hay bale by an adult of average strength. A single moisture reading could be registered on the meter display in about two seconds after the probe was inserted to the desired depth.

Calibration: There was no provision for the operator to change the calibration of the meter. The meter readings did not appear to drift during the evaluation.

Controls: The control and display panel layout on the Delmhorst HTM-1 was excellent. It had two push buttons for activating the display. One button activated the moisture reading while the second button was for temperature readings. The display panel was easy to read under normal and bright light conditions.

Battery: Ease of changing the battery was very good. A low battery reading on the display panel indicated when the battery needed replacement. The single 9V battery lasted for the duration of the test during which about 600 readings were taken. The access door to the battery was easily removed.

Cleaning: Ease of cleaning the Delmhorst HTM-1 was very good. Its smooth plastic surface stayed relatively clean during the test. The operator's manual recommended periodically cleaning the bale probe with alcohol.

QUALITY OF WORK

Range of Measurement: The range of measurement of the Delmhorst HTM-1 was fair. The meter would give readings up to 40%, after which the display panel would read "HI". The

manufacturer cautioned in the operator's manual that readings over 25% are less accurate due to "variability in moisture distribution", and "a few indications of high moisture content make it imperative that some action be taken to dry the hay to avoid spoilage, or even combustion".

Ensiled forage, which ranges up to 75% was beyond the capability of the meter. However, normal baled hay, which has a moisture content below 30%, was well within the measurement range.

Accuracy: Accuracy of the meter was fair. FIGURE 2 presents results for the Delmhorst HTM-1 in alfalfa bales when using the 18 in (460 mm) bale probe. Each moisture content is determined from an average of ten readings on the same layer of bale. The best fit line gives average results for 23 moisture readings in baled hay from samples taken from a variety of fields around Portage la Prairie.

Average moisture readings varied from 15 to 32%. At 15% moisture content the average meter reading was 6 percentage points low. When the actual moisture content was 18% (within the range for the safe storage of most forage materials), the average meter reading was 13%. At 32% moisture content the average meter reading was 1 percentage point low. An accuracy of 5% (i.e. 0.05 x reading which is about 1 percentage point at 18% moisture) is an acceptable level for most forage operations.

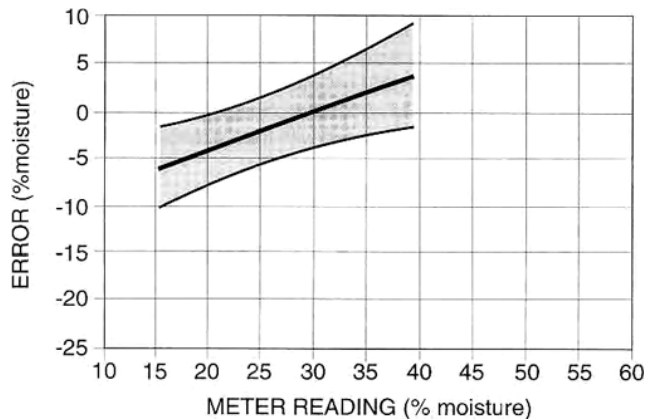


FIGURE 2. Accuracy of the Delmhorst HTM-1 in Baled Alfalfa Using Bale Probe.

Uncertainty: Uncertainty of the Delmhorst HTM-1 was fair in baled hay. Uncertainty is indicated by the 95% confidence limits displayed by the width of the shaded band in FIGURE 2. The manufacturer recommended that several readings be taken per sample, to reduce uncertainty from sample variation. Averaging ten readings in baled hay resulted in an uncertainty of $\pm 3.6\%$ of moisture at 18% moisture content.

This interval of uncertainty shows the importance of averaging a number of readings when determining moisture content. The manufacturer also advised paying close attention to the high readings, as they may indicate a need to turn the windrow for more even drying.

Repeatability: The repeatability of the Delmhorst HTM-1 was very good in baled hay. It indicates how subject the measurement method is to both operator error and instrument error. Sampling repeatability of the Delmhorst HTM-1 averaged 0.32% and ranged no higher than 1.0% in the test.

Temperature Compensation: Temperature corrections had to be applied to meter readings when determining moisture content. The temperature correction table included in the operator's manual presented temperatures in both the Fahrenheit and Centigrade scales. The meter displayed temperature only in the Fahrenheit scale. It is recommended that the manufacturer consider providing a meter, which displays temperatures in degrees Celsius.

An analysis of the data indicated that over a sample temperature range from 60 to 86° F (15 to 30° C) (which this meter was operated in), temperature correction did not significantly improve meter accuracy. The variations of meter readings due to scatter in samples was much more significant than variations due to sample temperature.

Calibration Curve: FIGURE 3 presents a PAMI calibration curve for the Delmhorst HTM-1 in baled alfalfa. This curve is based

on several forage crops in the Portage la Prairie area and are for a sample temperature range of 60 to 86° F (15 to 30° C). The equation for this curve is

$$R = 1.40 \times M - 12.07$$

where R = the meter display reading; M = the moisture content, wet basis, over the specified range of the meter found using the oven method.

The correlation coefficient was 0.81. The confidence belts on this curve shows the expected scatter due to sample variation when readings are based on an average of ten measurements.

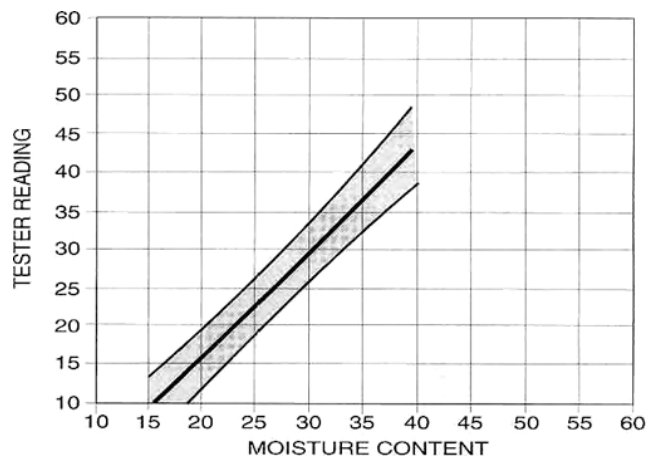


FIGURE 3. PAMI Calibration Curve for the Delmhorst HTM-1.

OPERATOR'S MANUAL

The operator's manual was very good. It was generally easy to read and understand. The manual described the meter as being designed to test moisture in hay over a range of 13 to 40%. It contained comprehensive operating instructions, sampling methods and recommendations, a maintenance procedure and temperature correction tables.

MECHANICAL HISTORY

No mechanical or electronic problems occurred during the test.

SPECIFICATIONS	
MAKE:	Delmhorst
MODEL:	HTM-1
SERIAL NUMBER:	0764
MANUFACTURER:	Delmhorst Instrument Co. 51 Indian Lane East, P.O. Box 68, Towaco, NJ 07082
ELECTRICAL POWER SOURCE:	One 9-volt battery
OVERALL DIMENSIONS:	
-- Meter	
-length	4.8 in (122 mm)
-width	2.8 in (71 mm)
-height	1.5 in (39 mm)
-- Probe	
-length	18 in (456 mm)
-diameter	0.39 in (9.8 mm)
OTHER EQUIPMENT:	
-- cord length	36.8 in (935 mm)
-- probe handle length	6.1 in (154 mm)
TOTAL WEIGHT:	19.4 oz (555 g)
PRINCIPLE OF OPERATION:	Electrical conductance

DELMHORST RDM-H FORAGE MOISTURE TESTER

MANUFACTURER

Delmhorst Instrument Company
51 Indian Lane East,
P.O. Box 68, Towaco, New Jersey
Ph. (201) 334-2557
Toll Free 1-800-222-0638

DISTRIBUTORS

Transfeeder	Tirol Dehydrators
P.O. Box 2445	P.O. Box 220
Olds, Alberta	Tilley, Alberta
TOM 1P0	TOJ 3K0
403-556-6968	403-377-2227

RETAIL PRICE:

\$545.00 (June 1993, f.o.b. Portage la Prairie, MB) with bale sensor and 14 ft (4.3 m) cable.



FIGURE 4. Delmhorst RDM-H Forage Moisture Tester.

SUMMARY AND CONCLUSIONS

Ease of installation of the Delmhorst RDM-H was good. A drilling template to mount the sensor in the bale chamber and all of the required wiring was provided. Ease of operating the RDM-H was very good. The control and display layout of the meter was very good, and ease of cleaning the meter was very good.

Range of measurement of the Delmhorst RDM-H was fair. Accuracy of the RDM-H was fair. Uncertainty of the meter was good. The operator's manual was very good. It was generally easy to read and understand.

RECOMMENDATIONS

No recommendations were made as a result of the evaluation.

MANUFACTURER'S COMMENTS

Periodic field testing and customer input received on an ongoing basis supports our original findings that the continuous monitors generally read an average of approximately 2 - 4 points higher than the bale probe. The sensor in these cases is mounted in a standard small square baler, half way up the side of the chamber, 12 to 18 inches in from the exit. This difference, between the probe and the bale sensor, is often greater when using the continuous monitor on a large square baler, likely due to the increased pressure of the bale coming through the chamber.

When making oven versus bale sensor comparisons it would seem that plant variety plays a larger role in determining "accuracy". The spread between leaf to stem moisture is usually greater in the leafy grass varieties. This difference cannot be easily picked up by a sensor mounted in the chamber. However it is further support for using a multi-pin probe for checking stem moisture in the windrow before and occasionally during baling.

GENERAL DESCRIPTION

The Delmhorst RDM-H is a baler/tractor mounted, electronic forage moisture tester. It determines moisture content by measuring electrical resistance and is suitable for square bales using the sensor supplied. There is an on/off switch to control the power to the meter and two buttons, one to select mode of operation and one for calibration.

Moisture content is determined from the RDM-H display unit mounted in the tractor when it is connected to the bale sensor mounted in the bale chamber. The RDM-H makes five moisture measurements per second and calculates the average and standard deviation of fifteen readings (accumulated in three seconds). It can display the average, standard deviation, highest, and lowest of the last fifteen readings depending on which of the five modes is selected by the operator.

The tester operates on a 12 volt DC system of the tractor or a separate 12 volt system.

More details are given in the specifications section, and the meter is shown in FIGURE 4.

SCOPE OF TEST

The Delmhorst RDM-H was used to determine moisture contents of a variety of crops as they were processed into small square bales. Meter readings were taken as the bales were formed in the chamber. The measurement area consisted of a 1 in (25 mm) wide strip along the left side of each bale. A 2 or 3 in (30 to 40 mm) layer of the bale that had been measured was oven dried as in the case of the probe type meters. A total of twenty-one bales were assessed with the Delmhorst RDM-H.

RESULTS AND DISCUSSION

EASE OF OPERATION

Installation: Installation of the Delmhorst RDM-H was good. A drilling template was provided to install the bale sensor. A stainless steel mounting bracket was supplied for the display unit along with all necessary wiring. The display unit could easily be removed from the mounting bracket for safe storage.

Operating Procedure: Ease of operating the Delmhorst RDM-H was very good. When the meter was turned on, it announced the software version for a few seconds and then displayed the moisture readings. The "Mode" key could then be used to select one of five display modes (default is mode one).

Mode one displayed the average reading and the highest reading, each for 1.5 second intervals. Mode two displayed the average, standard deviation, and highest reading, each for 1 second intervals. Mode three displayed the lowest reading for 3 second intervals. Mode four displayed the average reading for 3 second intervals. Mode five displayed the highest reading for 3 second intervals. Pushing the "Mode" key once displayed the current mode. Pushing the same key again (within 2 seconds) advanced one display mode.

The manufacturer advises that the continuous readings by the RDMH are generally higher than those obtained by a manual probe. The manufacturer recommends a spot check of the windrow and freshly made bales to help establish an appropriate range for baling.

Calibration: To check the meter calibration, the input sensor was disconnected from the meter and the "CAL CHECK" key was pressed. The meter displayed "C 20" ± 1 for 3 seconds, indicating that the meter was in electrical calibration.

Controls: The control and display panel layout on the Delmhorst RDM-H was very good. It had two membrane switch button keys for activating the display. One button activated the moisture reading by selecting the appropriate mode while the second button was for checking calibration. The display panel was easy to read under normal, bright light conditions and in total darkness.

Cleaning: Ease of cleaning the Delmhorst RDM-H was very good. Its smooth plastic surface and the membrane switch buttons stayed relatively clean during the test. The operator's manual gave no cleaning or maintenance instructions.

QUALITY OF WORK

Range of Measurement: The range of measurement of the Delmhorst RDM-H was rated fair. The meter would display

average readings between 10 and 40%. Average values below 10% were displayed as "A LO" and values above 40% were displayed as "A HI". Highest readings between 6 and 80% were displayed. Highest readings below 6% were displayed as "LO H" and those above 80% were displayed as "HI H". The operator's manual noted that a highest reading of 60% (for example) does not necessarily mean 60% moisture content but only indicates that the moisture content is greater than 40% and is beyond the capability of reliable measurement. The lowest readings were displayed in the range of 6 to 40%. Below 6% the meter read "L LO", and above 40% the meter read "L HI".

Ensiled forage, which ranges up to 75% was beyond the capability of the meter. However, normal baled hay, which has a moisture content below 30%, was well within the measurement range.

Accuracy: Accuracy of the meter was fair. FIGURE 5 presents results for the Delmhorst RDM-H in alfalfa bales. Each moisture content is determined from an average of ten readings on the same bale. The best fit line gives average results for 21 moisture readings in baled hay from samples taken from a variety of fields around Portage la Prairie.

Average moisture readings varied from 15 to 32%. At 15% moisture content the average meter reading was 6 percentage points low. At an actual moisture content of 18% (within the range for the safe storage of most forage materials) the average meter reading was 11%. At 32% moisture content the average meter reading was 12 percentage points low. An accuracy of 5% (i.e. 0.05 x reading which is about 1 percentage point at 18% moisture) is an acceptable level for most forage operations.

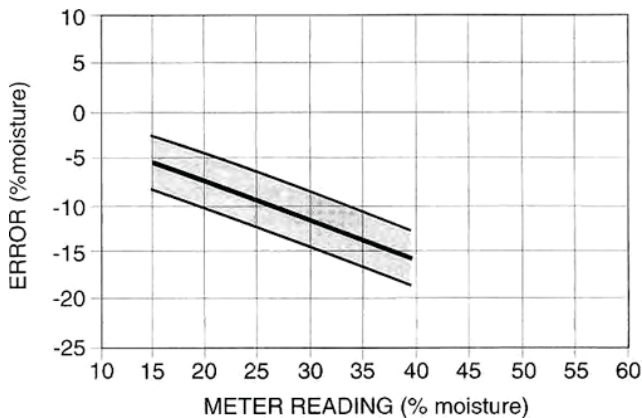


FIGURE 5. Accuracy of the Delmhorst RDM-H in Baled Alfalfa.

Uncertainty: Uncertainty in the Delmhorst RDM-H was rated good. Uncertainty is indicated by the 95% confidence limits displayed by the width of the shaded band in FIGURE 5. Averaging ten readings in baled hay resulted in an uncertainty of $\pm 2.9\%$ of moisture at 18% moisture content.

This interval of uncertainty shows the importance of averaging a number of readings when determining moisture content. The manufacturer also advised paying close attention to the high readings, as they may indicate a need to turn the windrow for more even drying.

Repeatability: The repeatability of the Delmhorst RDM-H was not measured because the sensor was mounted permanently in the baler chamber and only sampled along one surface of the bale.

Temperature Compensation: There was no method of temperature compensation on the Delmhorst RDM-H. Temperature compensation would not have significantly improved the accuracy of the meter.

Calibration Curve: FIGURE 6 presents a PAMI calibration curve for the Delmhorst RDM-H in baled alfalfa. This curve is based on several forage crops in the Portage la Prairie area and are for a sample temperature of 60 to 86° F (15 to 30° C). The equation for this curve is

$$R = 0.59 \times M + 0.74$$

where R = the meter display reading; M = the moisture content, wet basis, over the specified range of the meter found using the oven method. The correlation coefficient was 0.59.

The confidence belts on these curves show the expected scatter due to sample variation when readings are based on an average of ten measurements.

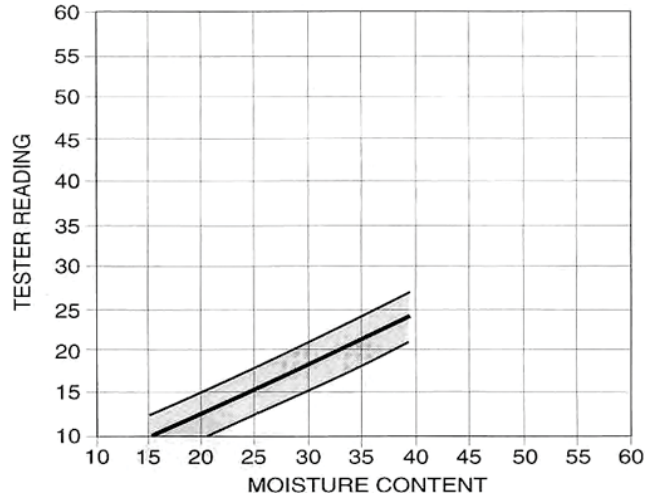


FIGURE 6. PAMI Calibration Curve for the Delmhorst RDM-H.

OPERATOR'S MANUAL

The operator's manual was very good. It was generally easy to read and understand. The manual described the meter as being designed to test moisture in hay over a range of 6 to 40%. It contained comprehensive operating instructions, sampling methods and recommendations, and installation procedure.

MECHANICAL HISTORY

No mechanical or electronic problems occurred during the test.

SPECIFICATIONS	
MAKE:	Delmhorst
MODEL:	RDM-H
SERIAL NUMBER:	310
MANUFACTURER:	Delmhorst Instrument Co. 51 Indian Lane East, P.O. Box 68, Towaco, NJ 07082
ELECTRICAL POWER SOURCE:	12 volt DC system of tractor or a separate 12 volt battery
OVERALL DIMENSIONS:	
-- Meter	
-length	3.5 in (90 mm)
-width	1.0 in (27 mm)
-height	2.0 in (50 mm)
-- Cable	
-length	14 ft (4.3 m)
-diameter	0.2 in (5.1 mm)
OTHER EQUIPMENT:	
-- power cord length	6 ft (1.8 m)
TOTAL WEIGHT:	26.3 oz (755 g)
PRINCIPLE OF OPERATION:	Electrical conductance

DANI HAYTESTER FORAGE MOISTURE TESTER

MANUFACTURER

Farmex, Inc.
130 Lena Drive
Aurora, Ohio 44202

DISTRIBUTOR

DANI Farm Supply Ltd.
R.R. #3, Site 4,
P.O. Box 32, Red Deer, Alberta
T4N 5E3
Ph. (403) 343-6222

RETAIL PRICE:

\$289.00 (June 1993, f.o.b. Portage la Prairie, MB) with 20 in (510 mm) bale probe.



FIGURE 7. DANI Haytester Forage Moisture Tester.

SUMMARY AND CONCLUSIONS

Portability of the DANI Haytester was very good. It was light, compact and had a self-contained power supply. Ease of operating the meter was very good. The control and display panel layout on the DANI was excellent. It had a trigger switch for activating the display. Ease of changing the battery was fair, and ease of cleaning the meter was very good.

Range of measurement of the DANI was fair. Accuracy of the meter was very good. Uncertainty of the DANI was good and repeatability was very good in baled hay.

The operator's manual was very good. It was generally easy to read and understand.

RECOMMENDATIONS

It is recommended that the manufacturer consider providing a meter, which displays temperature in degrees Celsius.

THE MANUFACTURER STATES THAT

With regard to the recommendation:
Farmex will investigate the temperature read out in Celsius.

GENERAL DESCRIPTION

The DANI Haytester is a portable, electronic forage moisture tester. It determines moisture content by measuring electrical resistance. Moisture content may be determined in either round or square bales using the bale probe supplied. By squeezing the trigger switch on the meter either moisture content or temperature can be read directly off of the display panel.

The tester operates on one 9V battery.

More details are given in the specifications section, and the meter is shown in FIGURE 7.

SCOPE OF TEST

A total of twenty-six bales were probed with the DANI Haytester, during which time about 600 readings were taken.

RESULTS AND DISCUSSION

EASE OF OPERATION

Portability: Portability of the DANI Haytester was very good. It was very easy to use, light, compact, and had a self-contained power source, making it convenient for field use.

Operating Procedure: Ease of operating the DANI Haytester was very good. Best results were obtained when the probe was inserted perpendicular to the plant stems. Moisture or temperature readings were taken by setting the rocker switch to the moisture or temperature position and then pulling the trigger switch in the handle. There was no table given nor reference made to temperature correction in the operator's manual. The manufacturer advises the operator to take five readings and to use the highest reading as a guideline. The manual recommends that if one reading is over the recommended moisture content, not to bale and not to average the readings.

The force required to push a bale probe into a bale is dependent on the material baled, bale density, bale moisture content and direction of probe insertion in relation to the orientation of the material baled. In general, the DANI bale probe could be easily inserted into a hay bale by an adult of average strength. A single moisture reading could be registered on the meter display in about one second after the probe was inserted to the desired depth.

Calibration: There was no provision for the operator to change the calibration of the meter. The calibration could be checked by taking the "moisture" reading at room temperature with nothing touching the tip (should be 14.5 ± 1) and by shorting the sensor tip of the probe with aluminum foil (should read 47.0 ± 1).

Controls: The control and display panel layout on the DANI Haytester was excellent. It had a trigger switch for activating the display. A switch was used to select either the moisture reading or the temperature reading. The display panel was easy to read under normal and bright light conditions.

Battery: Ease of changing the battery was fair. The single 9V battery lasted for the duration of the test during which about 600 readings were taken. The battery was replaced by removing two small screws from the access door. After a protective wrapper was removed from the battery, the terminal leads could be snapped off and the battery replaced. The operator's manual cautions not to lose the small screws and to be very careful not to strip the threads. It also recommended removing the battery if the meter would not be used for several months.

Cleaning: Ease of cleaning the DANI Haytester was very good. Its smooth plastic surface stayed relatively clean during the test. The operator's manual recommended wiping the tip clean after each use and cleaning the bale probe with alcohol or mineral spirits from time to time.

QUALITY OF WORK

Range of Measurement: The range of measurement of the DANI Haytester was fair. The meter was designed for readings in the range of 14 to 46%. Moisture contents below 14% would still read 14. The meter continued to give readings above 46% though the operator's manual states that readings over 30% should only be used as a qualitative indication of very high moisture.

Ensiled forage, which ranges up to 75% was beyond the capability of the meter. However, normal baled hay, which has a moisture content below 30%, was well within the measurement range.

Accuracy: Accuracy of the meter was very good. FIGURE 8 presents results for the DANI Haytester in alfalfa bales when using the 20 in (500 mm) bale probe. Each moisture content is determined from an average of ten readings on the same layer of bale. The best fit line gives average results for 26 moisture readings in baled hay from samples taken from a variety of fields around Portage la Prairie.

Average moisture readings varied from 15 to 32%. At 15% moisture content the average meter reading was 2 percentage points low. At 18% moisture content (within the range for the safe storage of most forage materials) the average meter reading was

again 2 percentage points low. At 32% moisture content the average meter reading was 1 percentage point low. An accuracy of 5% (i.e. 0.05 x reading or about 1 percentage point at 18%) is an acceptable level for most forage operations.

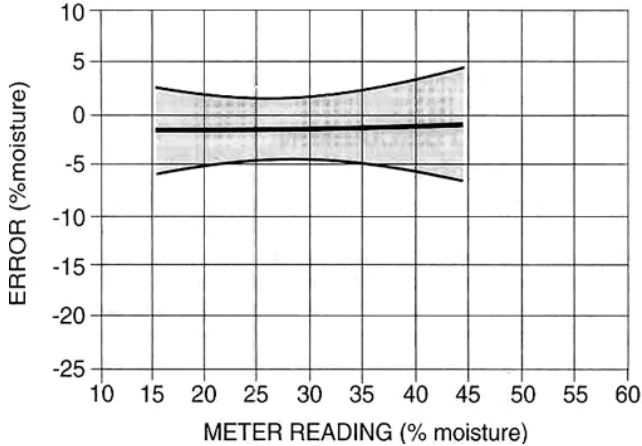


FIGURE 8. Accuracy of the DANI Haytester in Baled Alfalfa with the Bale Probe.

Uncertainty: Uncertainty of the DANI Haytester was good. Uncertainty is indicated by the 95% confidence limits displayed by the width of the shaded band in FIGURE 8. The manufacturer recommended that several readings be taken per sample, to reduce uncertainty from sample variation. Averaging ten readings in baled hay resulted in an uncertainty of $\pm 1.7\%$ of moisture at 18% moisture content.

This interval of uncertainty shows the importance of averaging a number of readings when determining moisture content. The manufacturer also advised paying close attention to the high readings, as they may indicate a need to turn the windrow for more even drying.

Repeatability: The repeatability of the DANI Haytester was very good in baled hay. Sampling repeatability of the Haytester averaged 0.5% and ranged no higher than 1.8% in the test.

Temperature Compensation: No temperature correction instructions were given in the operator's manual so it was assumed that it was not necessary. However, a rocker switch on the back of the meter changed the display to temperature reading in degrees Fahrenheit. It is recommended that the manufacturer consider providing a meter, which displays temperatures in degrees Celsius.

Calibration Curve: FIGURE 9 presents a PAMI calibration curve for the DANI Haytester in baled alfalfa. This curve is based on several forage crops in the Portage la Prairie area and are for a sample temperature of 60 to 86° F (15 to 30° C). The equation for this curve is

$$R = 1.02 \times M - 2.05$$

where R = the meter display reading; M = the moisture content, wet basis, over the specified range of the meter found using the oven method. The correlation coefficient was 0.81.

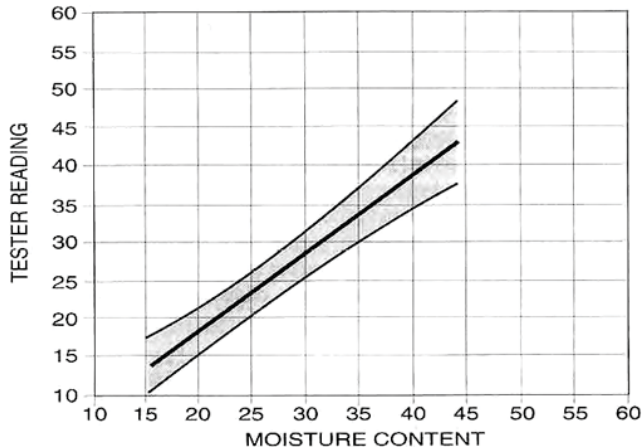


FIGURE 9. PAMI Calibration Curve for the DANI Haytester.

The confidence belts on these curves show the expected scatter due to sample variation when readings are based on an average of ten measurements.

OPERATOR'S MANUAL

The operator's manual was very good. It was generally easy to read and understand. The manual described the meter as being designed to give moisture readings from 14 to 46%. It contained comprehensive operating instructions, testing hints, recommendations, maintenance procedure, and trouble shooting procedure.

MECHANICAL HISTORY

No mechanical or electronic problems occurred during the test.

SPECIFICATIONS	
MAKE:	DANI
MODEL:	07200 Haytester
SERIAL NUMBER:	2-00151
MANUFACTURER:	Farmex, Inc. 130 Lena Drive Aurora, Ohio 44202
ELECTRICAL POWER SOURCE:	One 9-volt battery
OVERALL DIMENSIONS:	
-- Meter (not including handle)	
-length	6.25 in (159 mm)
-width	3.5 in (90 mm)
-height	1.4 in (35 mm)
-- Probe	
-length	19.6 in (498 mm)
-diameter	0.38 in (9.7 mm)
TOTAL WEIGHT:	18.8 oz (534 g)
PRINCIPLE OF OPERATION:	Electrical conductance

OMNI-MARK PREAGRO-25 FORAGE MOISTURE TESTER

MANUFACTURER & DISTRIBUTOR

Omni-Mark Inc., a subsidiary of Blue Shark Electronics Inc.
1120 8th St., Kirkland, WA 98033
Ph. (206) 822-7800
FAX (206) 828-9499

RETAIL PRICE:

\$475.00 (June, 1993, f.o.b. Portage la Prairie, MB) with 18 in (510 mm) bale probe and 10 in (250 mm) silage probe.



FIGURE 10. Omni-Mark Preagro-25 Forage Moisture Tester.

SUMMARY AND CONCLUSIONS

Portability of the Omni-Mark Preagro-25 was very good. It was light, compact and had a self-contained power source. Ease of operating the meter was good. The control and display panel layout on the Omni-Mark was excellent. Ease of changing the battery was fair and ease of cleaning the meter was very good.

Range of measurement of the Omni-Mark was very good. It would give readings in the range of 13 to 70% moisture content. Accuracy of the meter was good. Uncertainty of the Omni-Mark was very good and repeatability was very good in baled hay.

The operator's manual was very good. It was generally easy to read and understand.

RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Modifications to the meter, which would make the readings stabilize quicker.
2. Modifications to the bale probe, which would make it more durable.
3. Describing the recommended bale probing technique in the operator's manual.

THE MANUFACTURER STATES THAT

With regard to recommendation number:

1, 2 & 3. The PAMI suggestions for the Preagro 25 hay and silage moisture tester have been taken under consideration by Omni-Mark for future development.

GENERAL DESCRIPTION

The Omni-Mark Preagro-25 is a portable, electronic forage moisture tester. It determines moisture content by measuring electrical capacitance. Moisture content may be determined in either round or square bales using the bale probe supplied. By pressing the power button on the meter the moisture content could be read directly off of the display panel.

The tester operates on one 9V battery. More details are given in the specifications section, and the meter is shown in FIGURE 10.

SCOPE OF TEST

A total of thirteen bales were probed with the Omni-Mark Preagro-25, during which time about 600 readings were taken.

RESULTS AND DISCUSSION

EASE OF OPERATION

Portability: Portability of the Omni-Mark Preagro-25 was very good. It was very easy to use, light, compact, and had a self-contained power source, making it convenient for field use.

Operating Procedure: Ease of operating the Omni-Mark Preagro-25 was good. It was necessary to first calculate the bale density. The operator's manual gave good examples on how to do this calculation. The probe was inserted perpendicular to the plant stems. The operator's manual did not make a recommendation as to which orientation the probe should be inserted into the bale. It is recommended that the manufacturer consider describing the recommended bale probing technique in the operator's manual.

The power button had to be pressed continuously for several seconds to take a reading. The first thing to appear on the screen was the probe indicator number (0, 1, 2, or 3). For use of the 18 in (510 mm) probe, number 1 was selected. This was done by pressing the function key to scroll through the three options. If no buttons were pressed for approximately 2 seconds the next number to appear was the density of the bale, which could be selected by scrolling through the options with the function key. If the function key was not pressed, the number would remain on the screen for 6 seconds and then the moisture content would appear. Whatever selections made with the function key remained in memory until such time as different settings were entered. When initial settings were made, a moisture reading would appear after depressing the power button for about 10 seconds. However, it took much longer for the readings to stabilize for a reasonable period of time. It is recommended that the manufacturer consider modifications to the meter, which would make the readings stabilize more quickly.

The force required to push a bale probe into a bale is dependent on the material baled, bale density, bale moisture content and direction of probe insertion in relation to the orientation of the material baled. In general, the Omni-Mark bale probe could be easily inserted into a hay bale by an adult of average strength.

There was no recommendation made for temperature correction in the operator's manual. The manufacturer advises the operator to take several readings from different parts of a field and to average those readings to achieve the most accurate results.

Calibration: There was no provision for the operator to change the calibration of the meter nor was a procedure recommended to check the calibration of the meter. The manual recommended returning the item if recalibration was required.

Controls: The control and display panel layout on the Omni-Mark Preagro-25 was excellent. It had two push button keys for activating the display. One button activated the moisture reading while the second button was for changing the function reading. The display panel was easy to read under normal and bright light conditions.

Battery: Ease of changing the battery was fair. A low battery reading on the display panel indicated when the battery needed replacement. The single 9V battery lasted for the duration of the test during which about 600 readings were taken. The access door to the battery was easily taken off by removing two screws and unclipping the battery.

Cleaning: Ease of cleaning the Omni-Mark Preagro-25 was very good. Its smooth plastic and aluminum surface and membrane switch buttons stayed relatively clean during the test. The operator's manual recommended storing the probe in a dry, dust free environment.

QUALITY OF WORK

Range of Measurement: The range of measurement of the Omni-Mark Preagro-25 was very good. The meter was designed to give readings in the range of 13 to 70%. Below 13% the digital display indicated three dashes for a reading to imply that the hay is sufficiently dry and no reading is necessary. Between 13% and 16% the reading was displayed in a flashing mode, implicating that the hay was in the dry end of the moisture range. Above 50% the reading was also displayed in a flashing mode to indicate that the

hay was above the safe storage limit. The display gave readings above 70%.

The manufacturer cautioned in the operator's manual that readings should be taken from bales in all areas of the field to account for terrain changes and other variations in the field. It also recommends to take the average of several readings to achieve the most accurate results.

Ensiled forage, which ranges up to 75% was within the range of measurement of the meter, although no measurements were carried out to check the accuracy at this moisture content. Normal baled hay, which has a moisture content below 30%, was well within the measurement range.

Accuracy: Accuracy of the meter was good. FIGURE 11 presents results for the Omni-Mark Preagro-25 in alfalfa bales when using the 18 in (460 mm) bale probe. Each moisture content is determined from an average of ten readings on the same layer of bale. The best fit line gives average results for 13 moisture readings in baled hay from samples taken from a variety of fields around Portage la Prairie.

Average moisture readings varied from 13 to 33%. At 13% moisture content the average meter reading was 2 percentage points high. At an actual moisture content of 18% (within the range for the safe storage of most forage materials) the average meter reading was 17%. At 33% moisture content the average meter reading was 8 percentage points low. An accuracy of 5% (i.e. 0.05 x reading) which is about 1 percentage point at 18% moisture) is an acceptable level for most forage operations.

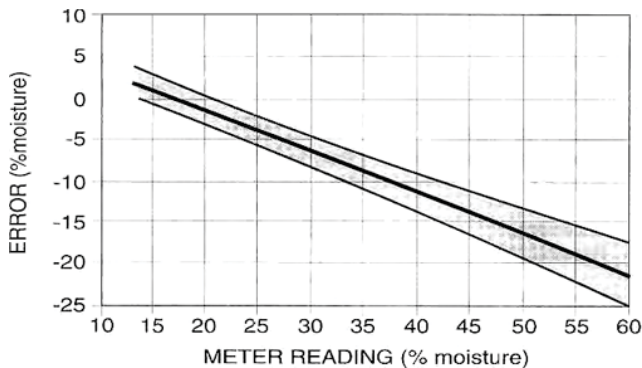


FIGURE 11. Accuracy in Baled Hay with the Bale Probe.

Uncertainty: Uncertainty of the Omni-Mark was very good. Uncertainty is indicated by the 95% confidence limits displayed by the width of the line in FIGURE 11. The manufacturer recommended that several readings be taken per sample, to reduce uncertainty from sample variation. Averaging ten readings in baled hay resulted in an uncertainty of $\pm 0.6\%$ of moisture at 18% moisture content.

This interval of uncertainty shows the importance of averaging a number of readings when determining moisture content. The manufacturer also advised averaging the readings to get an accurate indication of the moisture content and to measure the moisture content of the windrow, as this may indicate a need to turn the windrow for more even drying.

Repeatability: The repeatability of the Omni-Mark Preagro-25 was very good in baled hay. Sampling repeatability of the Preagro-25 averaged 0.8% and ranged no higher than 2.2% in the test.

Temperature Compensation: No temperature correction instructions were given in the operator's manual so it was assumed that it was not necessary. The meter did not have a temperature measurement capability.

Calibration Curve: FIGURE 12 presents a PAMI calibration curve for the Omni-Mark Preagro-25 in baled alfalfa. This curve is based on several forage crops in the Portage la Prairie area and are for a sample temperature of 60 to 86° F (15 to 300 C). The equation for this curve is

$$R = 0.51 \times M + 8.14$$

where: R = the meter display reading; M = the moisture content, wet basis, over the specified range of the meter found using the oven method.

The correlation coefficient was 0.81. The confidence belts on

these curves show the expected scatter due to sample variation when readings are based on an average of ten measurements.

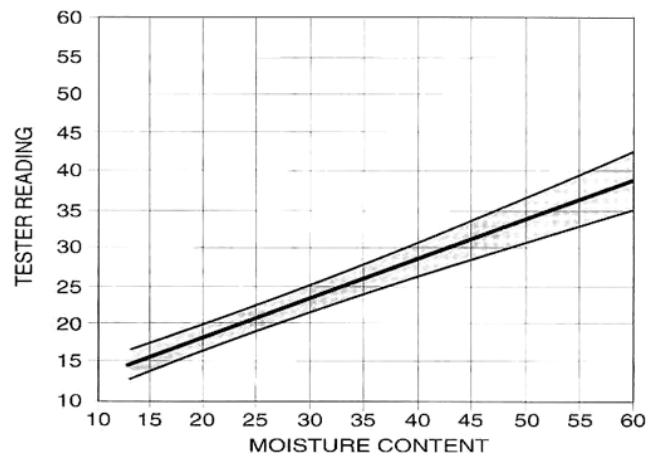


FIGURE 12. PAMI Calibration Curve for the Omni-Mark Preagro-25.

OPERATOR'S MANUAL

The operator's manual was very good. It was generally easy to read and understand. The manual described the meter as being designed to provide forage moisture content information up to 70% when measuring bales of hay or forage in a bucket. It contained comprehensive operating instructions, sampling methods, recommendations, and a maintenance procedure.

MECHANICAL HISTORY

The tip pulled out of the bale probe while probing bales in excess of 30% moisture content. The manufacturer replaced the bale probe. It is recommended that the manufacturer consider modifications to the bale probe, which would make it more durable. No other mechanical or electronic problems occurred during the test.

SPECIFICATIONS	
MAKE:	Omni-Mark
MODEL:	Preagro-25
SERIAL NUMBER:	039252
MANUFACTURER:	Omni-Mark Inc. a subsidiary of Blue Shark Electronics Inc. 1120 8th St., Kirkland, WA 98033
ELECTRICAL POWER SOURCE:	One 9-volt battery
OVERALL DIMENSIONS:	
-- Meter	
-length	5.5 in (140 mm)
-width	3.1 in (80 mm)
-height	2.7 in (68 mm)
-- Probe	
-length	18 in (513 mm)
-diameter	0.3 in (8 mm)
OTHER EQUIPMENT:	
-- Silage probe	
-length	10.0 in (255 mm)
-diameter	6.3 in (160 mm)
TOTAL WEIGHT:	20.7 oz (589 g)
PRINCIPLE OF OPERATION:	Electrical capacitance

APPENDIX I MACHINE RATINGS	
The following rating scale is used in PAMI Evaluation Reports:	
Excellent	Fair
Very Good	Poor
Good	Unsatisfactory

SUMMARY CHART

Delmhorst HTM-1	
RETAIL PRICE:	\$357.00 (June 1993, f.o.b. Portage la Prairie, MB)
EASE OF OPERATION	
Portability	Very Good; light and compact
Operating Procedure	Very Good; easy to use
Calibration	None
Controls	Excellent; two push button keys
Battery	Very Good; easy to change
Cleaning	Very Good; smooth plastic surface
QUALITY OF WORK	
Range of Measurement	Fair; 10 - 40%
Accuracy	Fair; 5 percentage points low at 18%
Uncertainty	Fair; $\pm 3.6\%$ of moisture at 18%
Repeatability	Very Good; less than 1% instrument error
OPERATOR'S MANUAL	Very Good; easy to read and understand
MECHANICAL HISTORY	No problems during the test.

DANI Haytester	
RETAIL PRICE:	\$289.00 (January 1993, f.o.b. Portage la Prairie, MB)
EASE OF OPERATION	
Portability	Very Good; light and compact
Operating Procedure	Very Good; easy to use
Calibration	Calibration check only
Controls	Excellent; trigger switch activated display
Battery	Fair; had to remove two small screws
Cleaning	Very Good; smooth plastic surface
QUALITY OF WORK	
Range of Measurement	Fair; 14 - 46%
Accuracy	Very Good; 2 percentage points low at 18% moisture
Uncertainty	Good; $\pm 1.7\%$ at 18% moisture
Repeatability	Very Good; less than 1.8% instrument error
OPERATOR'S MANUAL	Very Good; easy to read and understand
MECHANICAL HISTORY	No problems during the test.

Delmhorst RDM-H	
RETAIL PRICE:	\$545.00 (June 1993, f.o.b. Portage la Prairie, M B)
EASE OF OPERATION	
Installation	Good; drilling template provided
Operating Procedure	Very Good; easy to use
Calibration	Calibration check only
Controls	Very Good; two push button keys
Cleaning	Very Good; smooth plastic case
QUALITY OF WORK	
Range of Measurement	Fair; 6 - 40%
Accuracy	Fair; 7 percentage points low at 18%
Uncertainty	Good; $\pm 2.9\%$ at 18% moisture
Repeatability	Not Measured
OPERATOR'S MANUAL	Very Good; easy to read and understand
MECHANICAL HISTORY	No problems during the test.

Omni-Mark Preagro-25	
RETAIL PRICE:	\$475.00 (June 1993, f.o.b. Portage la Prairie, MB)
EASE OF OPERATION	
Portability	Very Good; light and compact
Operating Procedure	Good; had to first calculate bale density
Calibration	None
Controls	Excellent; two push button keys
Battery	Fair; had to remove two small screws
Cleaning	Very Good; smooth plastic and aluminum surface
QUALITY OF WORK	
Range of Measurement	Very Good; 13 - 70%
Accuracy	Good; 1 percentage point low at 18%
Uncertainty	Very Good; $\pm 0.6\%$ at 18% moisture
Repeatability	Very Good; less than 2.2% instrument error
OPERATOR'S MANUAL	Very Good; easy to read and understand
MECHANICAL HISTORY	The tip pulled out of the bale probe.



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