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Group 7a

Evaluation Report 701

Calc-U-Dri Combine Moisture Meter

A Co-operative Program Between

ALBERTA FARM MACHINERY RESEARCH CENTRE

PAMI
PRAIRIE AGRICULTURAL MACHINERY INSTITUTE

DMC CALC-U-DRI MOISTURE METER

MANUFACTURER:

David Manufacturing Company (DMC)
1600-12th Street N.E.
Mason City, Iowa 50401
U.S.A.
Telephone: (515) 423-6182

RETAIL PRICE:

$1,095.00 (July 1993, f.o.b. Humboldt, Saskatchewan).

SUMMARY AND CONCLUSIONS

The range of measurement of the Calc-U-Dri was excellent. The meter was capable of detecting moisture beyond the ranges of concern.

In barley, accuracy was fair, repeatability was very good and uncertainty was good. In canola, accuracy was fair while repeatability and uncertainty were very good. In wheat, accuracy was good while repeatability and uncertainty were very good. The Calc-U-Dri had a linear response to changes in crop moisture. However, the deviation from actual moisture increased as the moisture content departed from the calibration point. This deviation was greatest in canola.

Temperature compensation was good. This occurred automatically, but the reading varied somewhat with temperature changes.

Ease of installing the Calc-U-Dri was good. Installation took one person 8 hours and required modification to the grain tank loading auger. The controls and display were very good. The controls were easy to use and the display was easy to see in all conditions. Ease of performing adjustments was very good. The switches and dials were well spaced and sized to allow easy on-the-go adjustments. Field operation was good. The Calc-U-Dri responded quickly to changes in grain moisture and provided the operator with a continuous display of grain moisture and temperature of grain flowing into the grain tank. Calibration was very good. Calibration was easy to perform and took little time. However, accurate calibration required proper technique and a reputable moisture meter.

The were no apparent safety hazards associated with the Calc-U-Dri. However, caution was required when retrieving samples from the grain tank for calibration.

The operator's manual was very good. Information was easy to find and understand. However, an update to the circuit board moved the offsets away from those suggested in the manual. No mechanical problems occurred during the 41 hours of operation.

RECOMMENDATIONS

It is recommended that the manufacturer consider:

1. Modifications to better correlate offset to display change.

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THE MANUFACTURER STATES THAT:

1. DMC has modified the sensor and circuitry to better correlate the offset and display through a full range of possible moistures that may be encountered.

Manufacturer's Additional Comments:

We also make a combine Calc-U-Dri with Averaging for $1,310.00.

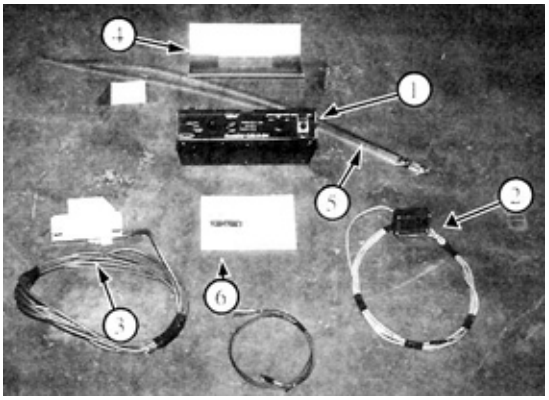

FIGURE 1. DMC Calc-U-Dri Moisture Meter (1)Control Module, (2) Digital Display, (3) Sensor, (4) Sensor Template, (5) Mounting Straps and (6) Operator's Manual.

GENERAL DESCRIPTION

The DMC Calc-U-Dri is a moisture meter that monitors the moisture content and temperature of grain flowing into the combine grain tank.

The system consists of a sensor, control module and digital display. The sensor is mounted in the combine grain tank loading auger, while the control module and digital display are located in the cab. Wires connect the sensor and display to the control module.

The meter uses the capacitance principle to determine moisture content. This principle is based on the change in the dielectric properties of grain with changes in moisture content. Temperature is detected using a solid state temperature transducer.

As grain flows over the sensor, the measured grain moisture content is continuously updated and displayed. Grain temperature is also displayed by depressing and holding a switch. Weighing is not required and temperature compensation is performed automatically. An alarm could be set to signal grain moisture above a pre-set point.

The meter operates on the combine 12 volt negative ground system.

Detailed specifications are found in APPENDIX I.

SCOPE OF TEST

The meter evaluated by PAMI was configured as described in the General Description, FIGURE 1 and Specifications sections of this report. The manufacturer may have built different configurations of this machine before or after PAMI tests. Therefore, when using this report, check that the machine under consideration is the same as the one reported here. If differences exist, assistance can be obtained from PAMI or the manufacturer to determine changes in performance.

The main purpose of the test was to determine the ability of the Calc-U-Dri to detect grain moisture and temperature and to assess functional performance in the field. The testing was done in two stages; 1) lab tests and 2) field operation.

Lab testing assessed the quality of moisture and temperature detection. Temperature compensation was also assessed in the lab. Field testing evaluated the moisture meter for ease of operation and adjustment, calibration, operator safety and the suitability of the operators manual.

Lab testing was performed by recirculating approximately 1.25 bu (0.045 m^3) of grain in a test stand. This stand consisted of a Case IH grain tank loading auger that was driven hydraulically. The loading auger was modified to allow the grain to circulate from the discharge into the inlet.

During the lab testing, the meter was calibrated using samples at 68°F (20°C), and near the upper dry limit moisture content for the three crops (barley, canola and wheat). After calibration, samples ranging in moisture were circulated in the stand and the Calc-U-Dri reading recorded. A second test was performed by cooling the same samples to near 45°F (7°C) and using the 68°F (20°C) sample calibration, the Calc-U-Dri reading was recorded. All the Calc-U-Dri readings were compared to oven dry moisture of each of the samples. Further testing was performed to determine the effect when calibrating at lower and higher moistures.

Temperature performance was assessed in two ways. The first compared the actual temperature of the grain in the test stand to the Calc-U-Dri reading. The second test consisted of placing the sensor in a controlled environment and comparing the air temperature to the Calc-U-Dri reading.

Field testing was performed with the Calc-U-Dri moisture meter mounted in a John Deere 7720 Titan II combine. It was operated in conditions shown in TABLE 1 for about 41 hours.

Table 1. Operating Conditions.

Crop	Yield Range		Grain Harvested		Hours	Field Area	
	bu/ac	(t/ha)	bu	(tonnes)		ac	(ha)
Canola	12 - 22	(0.7 - 1.2)	1,525	(34.5)	15.7	103	(43)
Fall Rye	26 - 66	(1.6 - 4.1)	2,850	(72.4)	13.3	76	(31)
Wheat	24 - 30	(1.6 - 2.0)	1,270	(34.6)	11.7	48	(19)
				Totals	40.7	227	(93)

RESULTS AND DISCUSSION

QUALITY OF WORK

Measurement Range: The range of measurement of the Calc-U-Dri was excellent for barley, canola and wheat.

The range of moisture content of greatest concern is between 12 and 20% for cereal grain and between 8 and 15% for canola. These ranges include dry, tough and damp stages.

The Calc-U-Dri was evaluated using samples ranging from 8 to 16% for canola, 12 to 23% for barley and 8 to 23% for wheat. The Calc-U-Dri was capable of measuring moisture outside these ranges.

Meter Performance (Accuracy, Uncertainty and Repeatability): To assess meter performance, three factors; accuracy, uncertainty and repeatability, should be considered. Accuracy indicates how close the average meter reading is to true moisture content. Uncertainty is a measure of scatter over a range of moisture content measured or how close the reading follows a best fit line. The shaded belts in FIGURES 2 to 4 can be used as a measure of meter uncertainty since they represent a region in which 95% ofthe test results can be expected to occur. A wide belt indicates a wide scatter and measurement uncertainty, whereas a narrow belt shows better meter certainty. Repeatability is a measure of how consistent a meter gives the same reading when the same sample is tested several times. During the lab testing the same sample was recirculated. In this situation, the range of meter fluctuation was used to assess repeatability.

FIGURE 2 shows the performance ofthe Calc-U-Dri in barley. In this crop, accuracy was fair, repeatability was very good and uncertainty was good. The Cal-U-Dri displayed higher moisture contents for grain with moisture above the calibration point and displayed lower moisture contents for grain with moisture below the calibration point. With this response, operators would think they were harvesting crop at higher than actual moisture for grain moisture above the calibration point. When the actual moisture dropped below the calibration point, operators would be inclined to believe they were harvesting crop drier than actual.

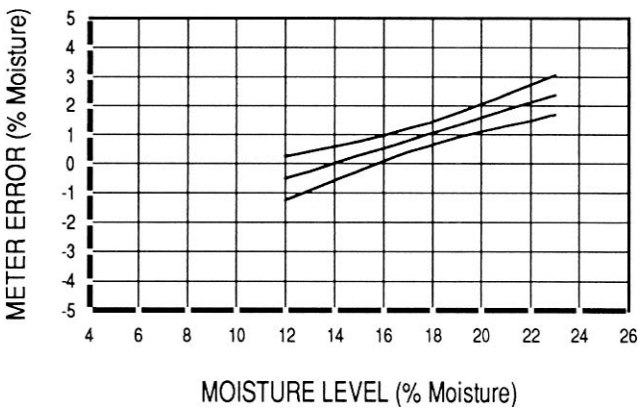

FIGURE 2. Accuracy of Calc-U-Dri in Barley.

FIGURE 3 shows the performance of the Calc-U-Dri in canola. In this crop, accuracy was fair while repeatability and uncertainty were very good. As with barley, the Calc-U-Dri displayed higher moisture for grain with moisture above the calibration point and displayed lower moisture for grain below the calibration point.

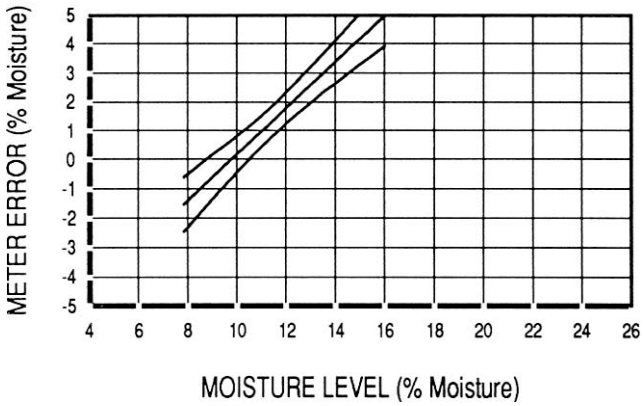

FIGURE 3. Accuracy of Calc-U-Dri in Canola.

FIGURE 4 shows the performance ofthe Calc-U-Dri in wheat. In this crop, accuracy was good while repeatability and uncertainty were very good. In this crop the meter responded the opposite to that of barley and canola. For grain above the calibration point, the meter displayed slightly lower than actual moisture and displayed slightly higher moisture for grain below the calibration point.

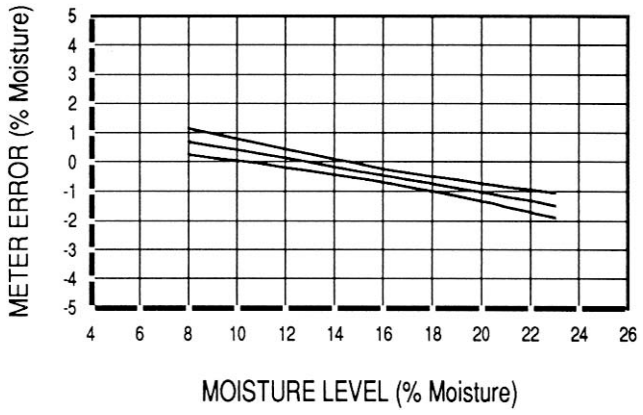

FIGURE 4. Accuracy of Calc-U-Dri in Wheat.

Temperature Compensation: Temperature compensation was good.

Temperature compensation is important on the Canadian Prairies. Temperature from midday until night could easily vary from 86°F (30°C) to 50°F (10°C) or lower during harvest time. The manufacturer claims that the Calc-U-Dri is temperature compensated.

In a stable environment the Calc-U-Dri gave accurate temperature readings from 36 to 104°F (2 to 40°C). However, in a test when the grain was cooled to 45°F (7°C) and the exterior of the sensor was exposed to room temperature air, the Calc-U-Dri read approximately 7°F (4°C) higher. Conditions like this occur regularly when harvesting windrowed crop as temperature of grain harvested from a windrow can lag air temperature by a significant amount. It is important that operators realize that slight errors in moisture may occur when the air temperature is different from grain temperature. Also, when temperature varied, the meter response to the change was slow and could take considerable time. This could affect readings for the first while when starting to fill the tank if the filling auger was at outside temperatures and the grain temperature was lagging air temperature. The effect on this displayed number would depend on the amount of temperature difference. It was important that the operator was aware of these characteristics when reading the display.

Errors From Crop Variables: The dielectric properties of grain vary with grain variety, kernel size, geographic location, maturity, weathering, artificial or natural drying, tempering (whether or not a dry windrow was re-wetted with rain) and other factors depending on the year the grain was harvested.

The Calc-U-Dri requires calibration for each crop and variety. During calibration, the operator adjusts the display by varying the offset. This offset should be recorded for future use in the same crop. The offset number varies for crop and variety. It is therefore recommended that the owner systematically check the results of his moisture meter against the one used by their grain buyer. This procedure is good practice and common for all moisture meters as variations between moisture meters are common. It is important to use your grain buyer as variations between buyers meters also exist.

During the test season, some low lying areas in the same field were damaged by frost. Grain harvested in these areas of the field had lower bushel weights and resulted in the Calc-U-Dri displaying lower moisture than actual.

EASE OF OPERATION AND ADJUSTMENT

Installation: Ease of installation was good.

Installation took one person about 8 hours. A torch, jig saw, drill and hand tools were needed to install the Calc-U-Dri.

The control module was located in the cab roof using 4 screws. The display was placed on the steering console using double sided adhesive tape. The sensor was mounted in the grain tank loading auger (FIGURE 5). This required the most time and care. To assist sensor installation, the grain tank loading auger was removed from the combine. Once removed the auger was modified to accept the sensor. This required cutting a hole in the auger tube, using a template supplied with the sensor, and removing a section of the flighting.

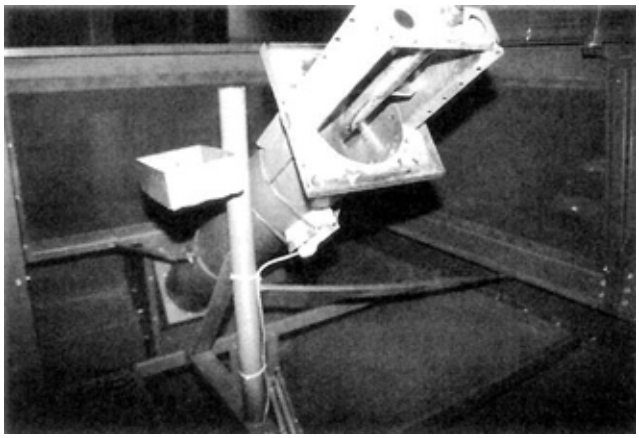

FIGURE 5. Sensor Location.

Controls and Display: The controls and display were very good.

The controls were easy to use and well placed. The control unit had two switches, three dials and an offset scale. Both the switches and dials were easy to identify and could be easily adjusted while operating the combine.

One switch turned the meter on. This switch had two positions; *on* without moisture limit detection and *on* with moisture limit detection. The other switch self centered and had three positions. The *center* position selected grain moisture content, the *top* position selected grain temperature and the *bottom* position was used to set the moisture limit alarm. One of the dials was used to set the moisture limit alarm and the other two were used to adjust offset when calibrating.

The display was connected to the control unit by a cable. This, along with it's light weight and size, allowed it to be placed in a number of locations for easy viewing. The digital display and moisture limit light were easy to see in all conditions. The display was continuously backlit for easy night viewing. Moisture content was displayed in percent wet basis. Temperature on the tested model was displayed in degrees Fahrenheit. The manufacturer also provides a model that displays temperature in degrees Celcius.

Adjustments: Ease of performing adjustments was very good.

The switches and dials were well spaced and sized to allow easy on-the-go adjustments and selection. Calibration and moisture limit adjustment were the only adjustments.

Calibration offset was performed by dialing the offset potentiometer to the desired value then positioning another dial to the "add or subtract" position. This changed the display readout by adding or subtracting the offset change to the display.

Moisture limit was adjusted by holding the self centering switch to the moisture limit position and turning the dial until the digital display was at the desired set point. This adjustment did not require grain to be over the sensor. The limit could be set from 0.01% to 25.4%. When the Calc-U-Dri detected moisture higher than the set point, an audible alarm triggered for 3 seconds and a light below the center of the display illuminated until the Calc-U-Dri detected moisture lower than the set point. This feature was very useful if the operator did not want to harvest grain above a predetermined moisture.

Field Operation: Field operation was good.

Many factors associated with harvesting affected the moisture displayed by the Calc-U-Dri. However, the Calc-U-Dri was very useful in showing the operator grain moisture changes. This feature was valuable since the operator could continue harvesting while monitoring grain moisture without stopping. When the Calc-U-Dri displayed moisture near a limit of concern, the operator could then stop to check the grain. It is important that the operator realize the moisture shown by the Calc-U-Dri could vary from moisture detected by a grain buyer's meter.

The Calc-U-Dri responded quickly to changes in grain moisture. The sensor did not restrict grain flow into the grain tank and did not require cleaning during the test.

Calibration: Calibration was very good.

Calibration was easy to perform and took little time. Calibration was performed by observing the Calc-U-Dri display and obtaining a grain sample that correlated to the display readout. The sample was placed in another moisture meter. Once the moisture of the sample was known, the operator adjusted the offset by the difference of the Calc-U-Dri display minus the actual moisture content. A space in the operator's manual was provided to record the offset numbers for various crops. This was helpful to quickly calibrate the meter when returning to the same crop. TABLE 2 shows the offsets used by PAMI.

Table 2. Calibration Offsets.

Crop	Offset
Barley	+ 0.60
Canola	- 0.68
Wheat	- 0.75

Numerous factors such as crop dielectric properties, sample quality, supply voltage, temperature, grain flow rate, etc., can affect a moisture meter's accuracy. For optimum performance, the meter calibration should be performed under typical and stable conditions, such as when the grain flow is steady and the moisture is not changing rapidly. Calibration should also be performed at or near the moisture content of most concern, since the meter's accuracy is best near that point.

Calibration instructions indicated that changes to the offset would change the moisture content readout by the same amount. However, in canola and wheat, offset changes at different moisture contents did not vary the readout by the same amount. This discrepancy would cause different meter performance when calibrated at high, medium or low moisture. It is recommended that the manufacturer consider modifications to better correlate offset to display change.

OPERATOR SAFETY

No safety hazards on the Calc-U-Dri were apparent. However, normal safety precautions were required when retrieving grain samples for calibration. These included disengaging the separator and stopping the engine. Before entering the grain tank, the operator should ensure that the machine's components have come to a complete stop.

OPERATOR'S MANUAL

The operator's manual was very good.

Information in the manual was easy to find and understand. The operator's manual was small and compact, and contained sections on safety, operation, parts, installation, trouble shooting and calibration. A space above the control unit PrOvided a excellent spot for storage of the manual.

An update to the circuit board resulted in a different offset than suggested in the manual. The manufacturer indicated that all subsequent manuals will contain updated offset guidelines.

MECHANICAL HISTORY

The intent of the test was evaluation of functional performance. Extended durability testing was not conducted. The wrong sensor was supplied at the start of the test. This sensor was returned and replaced with the correct sensor. No mechanical problems occurred during the remaining 41 hours of operation.

APPENDIX I
SPECIFICATIONS

Make:	Calc-U-Dri
Serial Number:	CUD-91-0517
Manufacturer:	David Manufacturing Company (DMC) Mason City, Iowa
Power Source:	Combine 12 volt D.C. negative ground
Allowable Range:	10 to 15 volt D.C.
Dimensions:	
Control Unit:	
Length:	12 in (303 mm)
Width:	8 in (202 mm)
Height:	2.75 in (70 mm)
Weight:	4.6 lb (2.1 kg)
Display:	
Length:	3.2 in (82 mm)
Width:	1.2 in (30 mm)
Height:	2.0 in (52 mm)
Weight:	0.17 lb (0.08 kg)
Sensor:	
Length:	6.1 in (155 mm)
Width:	2.3 in (58 mm)
Height:	4.5 in (155 mm)
Weight:	0.96 lb (0.44 kg)
Principle of Operation:	Capacitance

APPENDIX II
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 4 of the 68°F (20°C) samples.

In the following table M = the reading in percent moisture, wet basis, while T = the moisture of the sample in percent moisture determined by oven drying. Sample size refers to number of grain samples used.

Grain Type and Moisture Range	Figure Number	Regression Formula	Correlation Coefficient	Standard Estimate of Error	Sample Size
Barley 12 - 23% m.c.	2	M = 1.26 x T - 3.62	0.795	0.548	5
Canola 8 - 16% m.c.	3	M = 1.80 x T - 7.77	0.907	0.723	5
Wheat 8 - 23% m.c.	4	M = 0.85 x T + 1.86	0.812	0.367	6

APPENDIX III

MACHINE RATINGS

The following rating scale is used in PAMI Evaluation Reports:

Excellent	Fair
Very Good	Poor
Good	Unsatisfactory

SUMMARY CHART

DMC CALC-U-DRI COMBINE MOISTURE METER

RETAIL PRICE	$1,095.00 (July, 1993, f.o.b. Humboldt, Saskatchewan)		
QUALITY OF WORK			
Meter Range	**Excellent;** detected moisture beyond required range		
Meter Performance	CANOLA	BARLEY	WHEAT
Accuracy	**Fair**	**Fair**	**Good**
Repeatability	**Very Good**	**Very Good**	**Very Good**
Uncertainty	**Good**	**Very Good**	**Very Good**
Temperature Compensation	**Good;** occurred automatically; cool grain temperature still affected meter response somewhat		
EASE OF OPERATION AND ADJUSTMENT			
Installation	**Good;** requires tools and modifications to grain loading auger		
Controls And Display	**Very Good;** controls well sized and placed, display easy to see in all conditions		
Adjustments	**Very Good;** easily made		
Field Operation	**Good;** quick response to changing moisture		
Calibration	**Very Good;** easy to perform and took little time, requires another moisture meter		
OPERATOR SAFETY	No apparent safety hazards		
OPERATOR'S MANUAL	**Very Good;** information was easy to find and understand		
MECHANICAL HISTORY	No mechanical problems occurred		

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