D. Heise
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VOLTAGES IN I.R. MOISTURE METERS

1. VOLTAGES LISTED IN I.R. MANUAL

In the process of caliberating the AFRL Infra-red Moisture Meter and setting it up as the "standard meter", the Programmed Infra-red Moisture Meter Manual was consulted to determine the correct voltages that should be applied to the lamps through the four heating cycles. Of course, the voltages depend on the setting of the variable transformer, but the manual indicates what setting to: use. "Correct voltages are applied to the drying lamps when the meter reads half of full scale deflection. (Middle of the red zone)" Part I, page 3. This is a meter setting of 0.5.

Through the four heating cycles, 215V, 195V 170V, and 140V AC are successively applied to the I.R. lamps. This is the set of voltages indicated in Part IV A page 2, Part IV B page 7, and on the circuit diagram of the Control Unit. However, in Part IV B page 8 a different set of voltages is listed. The manual indicates there that permanent tappings have been provided at –

366 turns for 235 volts
331 turns for 212 volts
289 turns for 195 volts
238 turns for 150 volts

The manual then indicates the setting of a variable transformer for achieving these voltages. "The above voltages are obtained when 240V A.C. is applied via the moving brush to 409 turns".

The manual has indicated elsewhere that the correct voltages are obtained at a meter setting of 0.5, so now the question arises as to how this relates to the 409 turns mentioned here. If the 409 turns represent a higher meter setting, then perhaps the higher set of voltages are not inconsistent with the set of voltages given elsewhere. Unfortunately, this is not so. If volts are plotted against turns, a straight line should be obtained, but this is certainly not so for the voltages listed on page 8, Part IV B. Possibly in recognition of this, or of the fact that those voltages could never be obtained on a meter, a revised set of voltages has been written in beside the others in the manual, probably from actual measurement. The revised set of voltages is 235V, 215V, 187V, 150V.

Unfortunately, even when these values are plotted, the voltage on the line of best fit at 409 turns is not 240V but 265V. The fact is that the set of voltages beginning with 235V is completely in error. Plotting the lower set of voltages (beginning with 215V), a straight line is obtained which passes through 240 volts at 409 turns.

In checking with Dr Draper about these voltages, it was found that the set of voltages beginning with 235V was incorrect. It was also learned that moisture meters can be compared only at a setting of 0.5 on the meter. The meter can be adjusted so that when the correct voltages are being applied to the lamps, the meter reads half of full scale deflection or 0.5. Because of the circuitry in the meter itself, although meters can be adjusted to read the same voltages at a setting of 0.5, the voltages at other settings can differ by as much as 20%. This casts doubt on the usefulness of doing moisture determinations at settings other than 0.5. The original intention of the variable transformer was to correct for variations in the A.C. mains voltage. It was never intended to be used to vary the amount of heat that was applied. This was to be done through variations in the heating time, and the number of cycles.

2. VOLTAGE READINGS ON METERS IN AFRL AND COORANBONG FACTORY

Because of these deviations from origional intentions, it was decided to take voltage measurements through the four heating cycles at different voltage settings on the four moisture meters in the Cooranbong factory and AFRL.

The purpose was to observe the effect on voltage of settings other than 0.5, and to find the particular set of voltages being used on the meters at a setting of 0.5. Four meters were measured - AFRL meter, Cooranbong Laboratory meter, Weet-Bix make machine meter, and Rice floor meter. Measurements were taken in July using a dial multi-meter. Further readings were taken on 3.8.76 using a digital multi-meter. Additional readings were taken on the AFRL meter only, over several days, after making some adjustments to the meter.

3. COMPUTER ANALYSIS OF VOLTAGE DATA

The computer was used to find a function that fitted the overall data for each set of measurements on a moisture meter. The function could then be used to find deviations from the expected values, and also to determine the effect of settings other than 0.5 on the voltage.

At a given setting, the voltage is proportional to the number of turns. This would imply that the function would be V = aT. However the line may fit the data better if it is not forced to go through the origin. In this case the line would be V = a+bT. The setting acts as a scaling factor. Since a setting of zero on the meter does not imply a zero voltage, the scaling factor would have to be c+dS. So the function to fit voltage at various settings and cycles should be V = (a+bT)(c+dS)
= ac+bcT+adS+bdST

In doing the correlations, it was found that the term "adS" contributed nothing to the accuracy of the expression, so it was deleted. Renaming the other coefficients, the function to find in each case is therefore V = a+bT+cST
This can also be written as V = a+(cS+b)T

Each of the coefficients a, b and c is useful in describing some characteristic of the meter.

Coefficient "a" should be close to zero for all meters. If it is not it probably indicates that there is some deviation from the manual in the number of turns on the variable transformer for each heating cycle. The set of values for "number of turns that best fit the data has been estimated for each meter, and this can be compared with the values shown in the manual.

Coefficient "b" measures the effect on voltage of the number of turns on the variable transformer, and this should be much the same from meter to meter.

Coefficient "c" measures the scaling effect of the variable transformer. Because of the circuitry in the voltage meter, voltages at settings other than 0.5 can vary from meter to meter. On some meters, the voltage varies faster as the setting changes than it does on others, and this will be reflected in coefficient "c". This will vary from meter to meter, and will be larger on moisture meters where there is a greater scaling effect in the voltage meter.

4. DISCUSSION

Number of Turns on Variable Transformer

Table 2 shows the number of turns estimated from the voltage data for each of the four moisture meters tested. There is some deviation from the numbers specified in the manual, although in the case of the Rice meter this is negligible. The AFRL meter shows the widest variation, and this may be due at least in part to the fact that it is more or less a prototype.

The estimated values in Table 2 were based on the fact that voltage is proportional to the number of turns. The voltages for each cycle were summed over all the settings used in table I, then these voltages were scaled so that their sum was equal to the sum of the turns specified in the manual (1224).

The equations using these estimated turns rather than the specified turns had smaller standard errors of the estimate, and coefficient "a" was closer to zero, except for the Rice meter. (See Table 3) The smaller standard error of the estimate means that the equation using calculated turns is more accurate for predicting voltage given the setting and the number of turns than the equation using the specified number of turns. Since voltage is proportional to turns we would expect that for zero turns the voltage would be zero, so coefficient "a” should be close to zero. This was true for the equations using the calculated number of turns, coefficient "a" became further from zero as the estimated number of turns became further from specified set of values.

The estimated number of turns are really the "effective" number of turns.. If the actual number of turns on the transformer were counted, it may Le found to agree with the values specified in the manual, but because eof some variations in the meters, the voltage varies according to the estimated number of turns in Table 2.

Equations $V = a + bT + cST$

In Table 3, the coefficients, a,b and c are listed, calculated from both the specified number of turns, and the estimated number of turns. As has been pointed out already, coefficient "a" is closer to zero and the standard error of the estimate is smaller when using the estimated values for number of turns.

Coefficient "b", which indicates the effect of the number of turns, is much the same for all meters, although it is larger for meters with estimated turns closer to specified number of turns.

Coefficient "c" bears out Dr Draper's statement that meters are comparable at only one setting, which is chosen to be 0.5. The Rice meter has the lowest scaling effect, while the Weet-Bix meter has the highest. Voltage moves much more rapidly on the Weet-Bix meter as the setting is changed than it does on the Rice meter. This is clearly seen in the data in Table 1. While the meters read similar voltages at a setting of 0.5, at a setting of 0.1 the Weet-Bix meter has voltages almost 20V lower than the Rice meter.

Voltage Meter Settings

The AFRL meter has been adjusted to give readings as close as possible to those specified in the Manual when set on 0.5 (215, 195, 170, 140\1). The other three meters would have to be adjusted to give those voltages at 0.5. Table 4 shows voltages predicted by the equations using estimated turns, at a setting of 0.5. Table 5 Shows the meter setting required to obtain the specified voltages with the present meter adjustment. Table 6 shows the voltages obtained at those settings.

CONCLUSION

Voltages

The voltages being used in I.R. Moisture Meters are not the ones originally intended. The ammended set of values in Part IV B .page 8 of the Manual are not consistent with the numbers of turns for the permanent tappings, although as we have seen, there is some variation between meters in this respect. Since operators are familiar with using the moisture readings obtained with the current voltage settings, the manual has been corrected to read 235, 213, 186, 153.

Methods of Varing the Amount of Heat

Some of our Standard Methods of Analysis specify meter settings other than 0.5. Because there can be such a large difference between meters at settings other than 0.5, it is recommended that another approach be found to varying the amount of heat. This could be done by using different numbers of cycles (2,3 or 4) or by varying the length of the cycles. There is some reluctance to alter the time setting because 1 minute 37½ seconds has become fixed as a standard which operators must not alter. If the time setting is to be variable, depending on the analysis, then there is the danger that operators may be tempted to use the time setting to obtain more desirable results. Some would also feel that the timer is not accurate enough to use at different settings, but that it should be set in the correct position and left there. However, results so far show that variations in the time setting are small, and do not contribute significantly to experimental error.

Another possibility is to modify all the meters so that all meters read the same voltages at all settings, rather than just at 0.5. All the voltage meters would have to be returned and the diodes replaced with hand-picked diodes all having the same value

Unless these diodes are replaced, it is not possible to compare moisture analyses done by different meters at other than a 0.5 setting, Because the set up proceedure of any meter is such that it would not necessarily give the same moistures when set on 0.5, when compared to another meter, it has been decided to view any moisture value produced by the I.R. Moisture Meters as a purely relative value, and with this in mind, continue using other than 0.5 settings.

It should be recognized however that this relative moisture value on any meter will vary in relation to absolute moisture values in a different manner for different products using the different proceedures outlined in the manual as well as varying between meters and age of lamps etc.

TABLE 1.

VOLTAGE READINGS

Setting	Cycle	AFRL	SHF Lab	Weet-Bix	Rice
.1	1		207	216	
	2		la6	196	
	3		161	170	
	4		132	140	
.2	1	197	213	206	222
	2	178	192	186	201
	3	153	167	161	175
	4	124	137	130	144
.3	1	204	21a	216	226
	2	184	197	195	205
	3	158	171	169	179
	4	127	140	136	148
.4	1	211	225	225	231
	2	190	202	203	210
	3	164	175	176	182
	4	131	144	142	150
.5	1	218	229	235	235
	2	197	206	213	215
	3	169	180	184	18Ei
	4	136	147	149	154
.6	1	226	235	246	240
	2	203	212	223	218
	3	175	184	193	190
	4	141	150	155	157
.7	1	232	240	255	
	2	210	217	232	
	3	180	188	200	
	4	145	154	161	

TABLE 2.

Number of Turns, estimated from voltage data

Cycle	Specified	AFRL	SHF Lab	Weet-Bix	Rice
1	366	371	368	368	365
2	331	334	332	334	332
3	289	288	288	289	289
4	238	231	236	233	238

TABLE 3.

Equations V = a + LT + cST

(calculated from both specified and estimated number of turns)

Where V = voltage s.e. = standard error of the estimate
T = turns
S = setting

	AFRL		SHF Lab		Weet-Bix		Rice	
	Spec.	Est.	Spec.	Est.	Spec.	Est	Spec.	Est.
a	-16.3	.472	-6.30	-.225	-12.3	-.269	.338	-.391
b	.547	.492	.560	.548	.545	.505	.577	.580
c	.190	.190	.152	.151	.268	.268	.133	.133
s.e.	.65	.48	.54	.53	.88	.57	.69	.57

TABLE 4.

Predicted Voltages at a Setting of 0.5

Cycle	AFRL	SHF Lab	Weet-Bix	Rice
1	218	229	236	236
2	197	207	213	214
3	170	179	184	186
4	136	147	149	153

TABLE 5.

Settings Required for Correct voltage

.498	.270	.311	.074

TABLE 6.

Voltages obtained at those Settings

Cycle	Specified	AFRL	SHF Lab	Weet-Bix	Rice
1	215	218	217	217	215
2	195	196	195	196	195
3	170	169	169	170	170
4	140	136	138	137	140