4-1971

Performance Evaluation of the Moistron and Inframike Moisture Gauges on the Pilot Paper Machine

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"PERFORMANCE EVALUATION OF THE MOISTRON AND INFRAMIKE MOISTURE GAUGES ON THE PILOT PAPER MACHINE"

by

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A Thesis submitted to the

Faculty of the Department of Paper Technology

in partial fulfillment

of the

Degree of Bachelor of Science

Western Michigan University
Kalamazoo, Michigan

April, 1971

Abstract

The following work pertains to the correlation of the Industrial Nucleonics Moistron moisture meter and the General Electric Inframike. The readings from these two devices were compared to each other and to moisture on an oven dry basis. The moisture readings were taken on a furnish of a 50-50 hardwood, softwood mixture which had various additives added by means of metering pumps. The basis weights of the furnishes were varied for each of the additives.

The readings on the Moistron were not taken from the machine chart but rather from a calibration tape placed below said chart. The General Electric Inframike readings were taken on the basis of a rough standardization with the CENCO moisture determining device (an infrared drying lamp).

The readings of the two meters correlated quite closely in that the amount of the change from one furnish to another was about the same. The readings of the Moistron and that of the oven dry moisture were quite close; whereas, the readings on the Inframike varied from the oven dry moisture by about two per cent moisture. As the amount of additives and the basis weight increase, the readings of the meters vary more across the sheet. This is also shown in the oven dry readings as they also varied. The heavier basis weight oven dry readings were a little farther from the Inframike than those of the Moistron. This can be expected for the Inframike and could also be expected with the Moistron.

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INTRODUCTION

There have been many on-line moisture sensing devices developed in the past decade or so. Claims have been made that these devices are quite accurate in their determination of the per cent moisture in a sheet. The pilot plant at Western Michigan University's Department of Paper Technology has two such devices on its pilot paper machine. This thesis tried to show the relative merits of each of these machines and the correlation of the readings obtained by the use of these machines..

One meter was an infrared backscatter moisture determining device. This meter goes under the trade name of Inframike and was developed by the General Electric Company. The other meter was a transmittance type of moisture determining device which employs the use of A.C. conductivity. This meter goes under the name of Moistron and was developed by the Industrial Nucleonics Corportion.

The machines have been said to be affected by certain paper machine variables and furnish variables. This paper tried to find if these claims are accurate and to what extent the machines show their accuracy to one another. The furnish had different additives which were used in sheets at varying basis weights.

The readings of the machines were compared to each other by the use of moisture measurement by oven drying. The machine readings were taken as an error against the oven dry moisture and plotted on graphs as deviations.

HISTORICAL BACKGROUND AND DEVELOPMENT OF THE PROBLEM

The G.E. Inframike Moisture Meter

The Inframike was a development by the General Electric Company as a moisture measuring device. This was accomplished by measuring the amount of infrared radiation backscattered from a sheet of paper passing through the path of the Inframike. General Electric is one of the leading developers of this type moisture gage.

Claims have been made that the instrument is independent of electrolyte, fillers and coatings. The speed or amount of static electricity is also supposed to affect the readings very little.

The principle behind the operation of this device is that infrared radiation can be selectively absorbed by the water molecule. By passing the correct frequency of I.R. radiation (a range of approximately 1.93 microns to 1.94 microns) through the paper and comparing this with a reference wavelength (usually about 1.80 microns) that is just outside of this selective absorbency. The band which the water absorbs is referred to as the "resonant frequency".(1) The frequency that is just outside this absorbency range is referred to as the "reference wavelength".(2) These ranges are true for most paper ranges.

A description of the machine is that it consists of a scanning head which could be fixed over the sheet to give a single point reading or by mounting the gage on a traversing device which will give a sheet profile measurement. The gage head is about 7.5 inches in diameter and 9.0 inches tall. With fittings added to the gage, the height increases an additional 6.0 inches.

The system is designed for non-contacting operation but can be operated with the sheet in contact, provided a self-cleaning window is employed. A set of stainless steel skis may be used when the web flutter is large enough to cause the readings to be greatly effected. These skis are attached to the sensing head.

A necessary evil of the device is that the control cabinet must be located within 100 feet of the sensing head.

Basis weight must be compensated for in the use of this device. Without doing this, the readings obtained would be inaccurate because the moisture varies as the weight of the sheet increases.

The figures on the performance of this gage are as follows:

1) Moisture range: 0-12% on a basis weight of 6-70 lbs. per 3300 square feet. % moisture = (100)((w+s)-s/w+s) where w=weight of water and s=dry weight sample.

2) Moisture sensitivity: senses total moisture of the linear basis weight range 6-70 lbs. per 3300 square feet. The maximum sensitivity is approximately .001 mg water per cm^2. The sensitivity is defined as being equivalent to the noise observed on a recorder with a time constant of one second.

3) Accuracy: according to the article, the accuracy was determined by gravimetric analysis. This accuracy was a 2-sigma confidence limit of 0.45%.

4) Precision: measurements on an individual sheet were reproducible to the width of the pen of a null-balance recorder or better than ± 0.1%. This was on a 40 lb per 3300 square feet sheet in the 5% moisture range.

5) Sensitivity to paper variables: the device is insensitive to almost all paper variables with the exception of a heavily coated sheet, on the order of larger than 70 lb. per 3300 square feet. The explaination for this was moisture contained in the coating added to that of the moisture in the sheet.

6) Basis weight range: the range on this instrument is almost a straight line calibration of basis weight. The range is from 6-70 lbs. per 3300 square feet. A non-linear calibration for basis weight occurs beyond this range. At a basis weight above 150 lb. per 3300 square feet the gage is no longer insensitive to the basis weight. A consideration of moisture distribution must be used if the gage is used for greater basis weight measurements.

7) Response time: the time constant for the gage is approximately one second for a water change in the gage's range. The recorder or controller that is provided has a time constant which can be varied from .25-6.0 seconds.

8) Backround effects: the slope of the calibration curve will change when a non-moving reflecting surface is

less than an inch from the paper. Light changes of no longer than one second will have no effect on the readings. Noise will be caused when a moving non-uniform reflecting surface is at a distance of less than an inch.

9) Paper-to-gage-head spacing: the gage will operate three different ways. These are: non-contacting; contacting the stainless steel runners but not with the quartz window; contact with the quartz window. The normal gage head window to paper distance is about .125 inches.(3)

An illustration of the principle of operation behind the Inframike is in figure 6 of the appendix.

The Industrial Nucleonics Moistron Moisture Meter

In the Moistron moisture meter, the measurement of the paper moisture is done by a device which comes in contact with the paper. This moisture probe sends an A.C. voltage of a given frequency through the paper. A detecting element is then used to sense the resulting current which flows through the paper. The magnitude of the current is a measure of the impedence of the paper which can be used to figure out the moisture. The basis weight affects the measurement greatly and to a lesser extent so does the sheet temperature and the furnish. Calibration and computational techniques are used to make these variables negligible.

The Moistron measuring device employs a dual frequency technique which makes changes in paper thickness and basis weight of no effect. This technique uses two radio frequencies applied through the moisture probe and obtaining a unique signal which is related to moisture content at each frequency. When the basis weight varies, so does the impedence in the same proportion at each frequency. Because of this, when the ratio of the impedences is taken, the basis weight will cancel out and leave the ratio proportional to the moisture content.

The calibration of the moisture meter is done by using paper samples of varying moisture contents as measured by the oven dry method. The sheet temperature to impedence an furnish to impedence coefficients are determined for paper grades associated with the applications. The operating frequencies are chosen with consideration of these calibrations and so that the desired moisture span can be attained.

Some of the advantages and disadvantages for taking moisture with the moisture gages that use A.C. conductivity are as follows:

Advantages

1) Not affected by static electricity
2) Insensitive to contact pressure
3) Calibrated directly to % moisture
4) High sensitivity to moisture, i.e. moisture change by factor of five for each 1% moisture
5) Insensitive to basis weight variations
6) Contact from one side only

Disadvantages

1) Temperature affects measurement
2) Effected by pH variations and additives of electrolyte nature
3) Maximum range of operations 12% as limited by the resistance of various furnishes
4) Unit limited to operations on fourdrinier or single cylinder machines(4)

This unit for measuring moisture is a modular type of construction. Because of this type of construction, the device may be serviced easily and will decrease the amount of downtime greatly. This construction also makes the amount of space taken up less, thus allowing the unit greater useability at various places. The most common positions for using the moisture meter are: dry end, ahead of the size press; dry end, before or after the calender stacks; at the reel.

The use of sheet guides must be employed if the sheet flutter is greater than ± 0.5 inches. The pass line of the sheet should also be determined to assure proper operation.

The machine takes into account many grade variations. A grade parameter, such as the percentage ash, will cause the ratio to shift. Variations in temperature will cause a similar shift.

The moisture probe of this unit is essentially a parallel plate capacitor which is specially guarded. The use of the probe guards are that they are arranged in such a manner so that a voltage supplied to the driven elements creates an electrostatic field which will extend outward intercepting the sheet. The four standard probes that may be used are:

Element spacing	Sensitivity requirements
.75 inches	Low
.375 inches	Medium
.1875 inches	Average
.09375 inches	High(5)

The accuracy of the Moistron as compared to the oven dry moisture can be made very small. If the instrument is calibrated properly, the difference between the Moistron and the oven dry moisture will be about ± o.5 per cent or less. The machine should be recalibrated if the deviation is greater than five per cent.

This system with its built in electronic controls provides an automatic system of programmed calibration.

This will insure periodic standardization of the instrument with no need for manual attention. This system also provides for itself becoming incapable of self calibration. This is done by a warning light coming on which will indicate the need for servicing by the maintainence personnel.

The introduction of this type system was made in 1957. The industry has since then come to accept this type of moisture measuring device greatly.

By the use of these devices and other such instruments like them, the industry has been able to make an on-line check of moisture thus allowing better control of drier heat. These methods eliminate the old type off-line measurement of moisture and will therefore do away with the time necessary for this measuring. By this means operations can be made faster and more accurate.

An illustration of the principle of operation behind the Moistron is in figure 7 of the appendix.

The Development of the Problem

The method of comparison between the instruments was by an off-line moisture determination. The oven-dry technique gave the accurate measurement.

After the moisture was determined, it was plotted against the reading on the Moistron and the Inframike. The difference from the off-line reading and these readings gave the plot for the relation between the two devices.

At a given time the sheet passed between the transmission devices for each of the meters. The readings were taken and the samples taken as it left the reel so that the moisture could be measured by oven drying.

The readings were taken for the Moistron, Inframike, and the oven drying. They were related to each other in the following manner:

Moistron

$$\frac{\text{oven dry reading - Moistron reading}}{\text{oven dry reading}} \times 100 = \%\ \text{difference}$$

Inframike

$$\frac{\text{oven dry reading - Inframike reading}}{\text{oven dry reading}} \times 100 = \%\ \text{difference}$$

These readings were plotted on a cartesian graph as a relation between the per cent difference and the per cent moisture on the oven dry reading for the given basis weights and furnishes.

Various basis weights, furnishes, and filler content variations were measured and illustrated by these graphs to show how the meters will measure. This gave an idea of how well the machine will function for different type sheets.

The changes in the sheet furnishes was made by altering the basis weights, adding clay or titanium dioxide to the sheet without rosin and alum sizing, and adding clay or titanium dioxide with rosin and alum sizing.

After the sample was taken from the machine, it was placed in a plastic bag until it was run for moisture content by oven drying. The readings on the machine were as a point reading rather than an overall scan average.

EXPERIMENTAL SECTION

The Preparation of Clay and TiO_2

The clay and titanium dioxide were prepared on the following basis: a 50-50 mixture of hardwood and softwood at a CSF of 375. The pounds of additives per minute were determined in the following manner:

Basis weight:	40 lb	60 lb	80 lb
	107 lb/hr 60 fpm 1.78 lb/min	109 lb/hr 45 fpm 1.81 lb/min	107 lb/hr 33 fpm 1.78 lb/min
Clay used to give 6% ash on the reel (500 cc/min)	.2132 lb/min .0004 lb/cc	.2172 lb/min .0004 lb/cc	.2136 lb/min .0004 lb/cc
TiO_2 used to give 4% ash on the reel (500 cc/min)	.1424 lb/min .0002 lb/cc	.1448 lb/min .0002 lb/cc	.1424 lb/min .0002 lb/cc

The clay mixtures were prepared by mixing 4 gallons of water with 6.04 pounds of clay(beater clay). The TiO_2 mixtures were prepared by mixing 4 gallons of water with 3.03 pounds of TiO_2.

Without the addition of alum and rosin sizing, the ash content of the sheet would be about 6% clay or 4% TiO_2 at the reel. With the alum and rosin sizing, the ash content would be about twice the amount for each of the additives (clay or TiO_2).

The Preparation of the Samples for Oven Drying

The samples were prepared by removing them from their storage bags and cut into one inch square sheets. They were then palced into aluminum weighing pans and a weight was taken of both the sample and the pan. The weight of the pan that was used for each of the samples was taken previous to the use of the pan. The pan and its contents were then taken to the drying oven and placed inside and allowed to dry for two hours and at a temperature of between 105 to 115 degrees C.

The number of the samples taken from each of the runs was five. This was to insure a random number of readings which would allow for fluctuations in the moisture content of the sheet. These readings could then be averaged to give and average reading for the sample. This reading can then be compared to the readings of each of the machines. This also gave an idea of how the moisture varies along the sheet and how the moisture sensing device measures merely an average moisture in the sheet.

TABLE I

The Per Cent Readings of the Moistron

Basis weight:	40 lb	60 lb	80 lb
No additives	6.5	6.5-7.0	7.0
Clay(no sizing)	6.75	7.0-7.2	7.0-7.2
3% alum, 1% rosin	6.8	6.8-7.0	6.8-7.0
Clay(sized)	6.8	6.8	6.0-6.2
TiO_2(sized)	6.8-7.0	6.8	6.2-6.5

The pH of the sized sheets moust be controlled in order to insure proper sizing. The pH of the sheet while the size was in the sheet was 4.5-5.0.

TABLE II

The Per Cent Readings of the Inframike

Basis weight:	40 lb	60 lb	80 lb
No additives	3.8	4.0-4.4	4.2-4.4
Clay(no sizing)	3.8-4.0	4.0-4.2	5.0-5.4
3% alum, 1% rosin	3.8-4.0	4.0-4.8	5.0-5.4
Clay(sized)	4.2	4.8	5.0-5.2
TiO_2(sized)	4.6	4.8-5.0	4.8-5.0

The pH of the sized sheets must be controlled in order to insure proper sizing. The pH of the sheet while the size was in the sheet was 4.5-5.0.

The settings on the instrument were: output compensator zero - 50.0, slope - 20.0; Inframike calibrate - 42.8, high - 27.6, low - 50.1.

TABLE III

The Per Cent Readings of the Oven Drying

Basis weight:	40 lb	60 lb	80 lb
No additives			
Sample I	6.81	6.77	3.84
Sample II	7.66	7.00	6.19
Sample III	7.50	6.78	5.61
Sample IV	6.56	6.56	5.64
Sample V	6.32	6.15	5.99
Average	6.97	6.65	5.45
Clay(no sizing)			
Sample I	6.54	6.25	4.30
Sample II	6.82	6.91	5.92
Sample III	6.77	6.58	6.42
Sample IV	7.56	6.53	6.09
Sample V	6.22	5.42	5.17
Average	6.78	6.34	5.58
3% alum,1% rosin			
Sample I	8.10	5.57	7.92
Sample II	6.95	5.59	7.12
Sample III	6.34	6.09	6.59
Sample IV	6.39	4.42	6.53
Sample V	5.98	6.75	6.77
Average	6.75	5.62	6.99
Clay(sized)			
Sample I	7.81	5.82	6.41
Sample II	6.25	6.48	4.79
Sample III	6.78	5.61	4.90
Sample IV	6.77	5.89	6.27
Sample V	5.69	4.28	6.07
Average	6.66	5.62	5.69
TiO_2(sized)			
Sample I	7.80	6.54	6.41
Sample II	6.11	6.36	6.46
Sample III	6.12	6.11	6.48
Sample IV	6.88	6.53	6.22
Sample V	7.15	6.48	5.34
Average	6.81	6.41	6.18

TABLE IV

The Per Cent Difference in Oven Dry Readings and Machine Readings

40 lb Basis weight	Moistron	Inframike
No additives	+6.7	+46.0
Clay(no sizing)	+0.44	+44.0
3% alum,1% rosin	-0.74	+43.7
Clay(sized)	-2.1	+36.9
TiO_2(sized)	+0.14	+32.4
60 lb Basis weight		
No additives	+ 2.2	+39.8
Clay(no sizing)	-10.4	+36.8
3% alum,1% rosin	-19.7	+29.6
Clay(sized)	-20.8	+14.6
TiO_2(sized)	- 6.1	+25.1
80 lb Basis weight		
No additives	-28.4	+22.8
Clay(no sizing)	-25.4	+10.4
3% alum,1% rosin	+ 2.7	+28.5
Clay(sized)	- 5.4	+12.1
TiO_2(sized)	- 0.3	+22.3

FIGURE 1
COMPARISON OF MOISTURE READINGS ON
A SHEET WITH NO ADDITIVES IN FURNISH

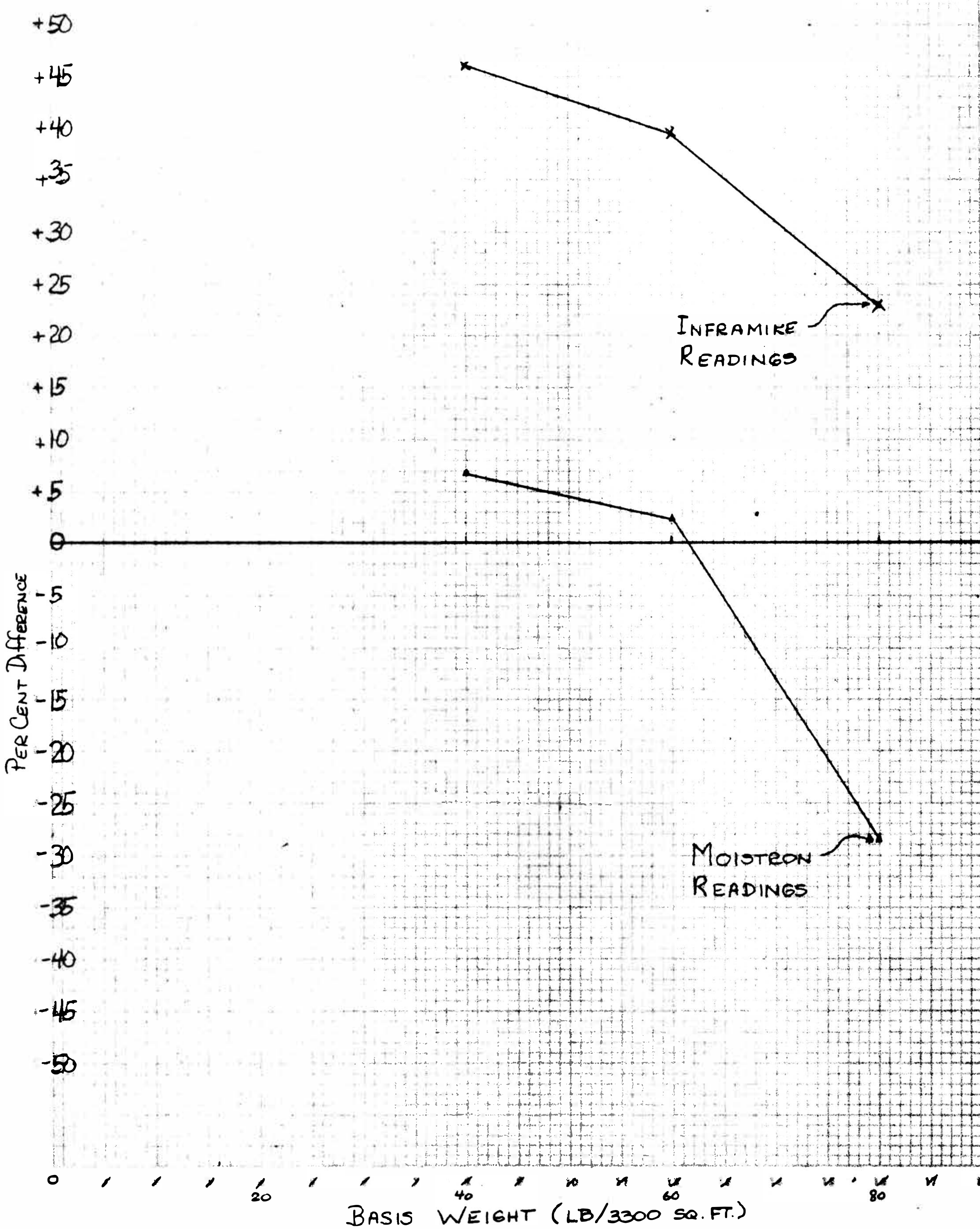


FIGURE 2

COMPARISON OF MOISTURE READINGS ON A SHEET WITH CLAY (NO SIZING) IN FURNISH

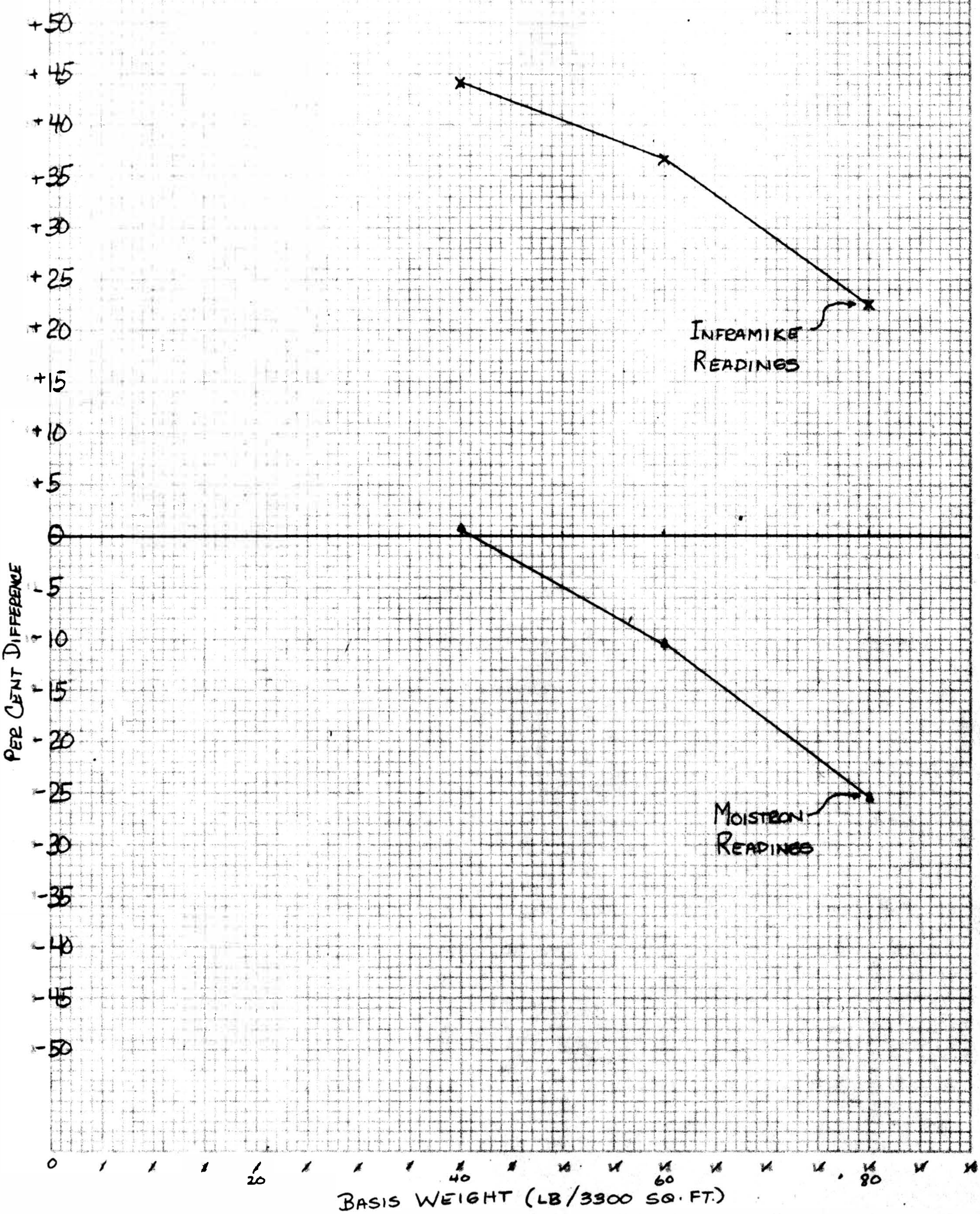


FIGURE 3

COMPARISON OF MOISTURE READINGS ON
A SHEET WITH 3% alum, 1% rosin IN FURNISH

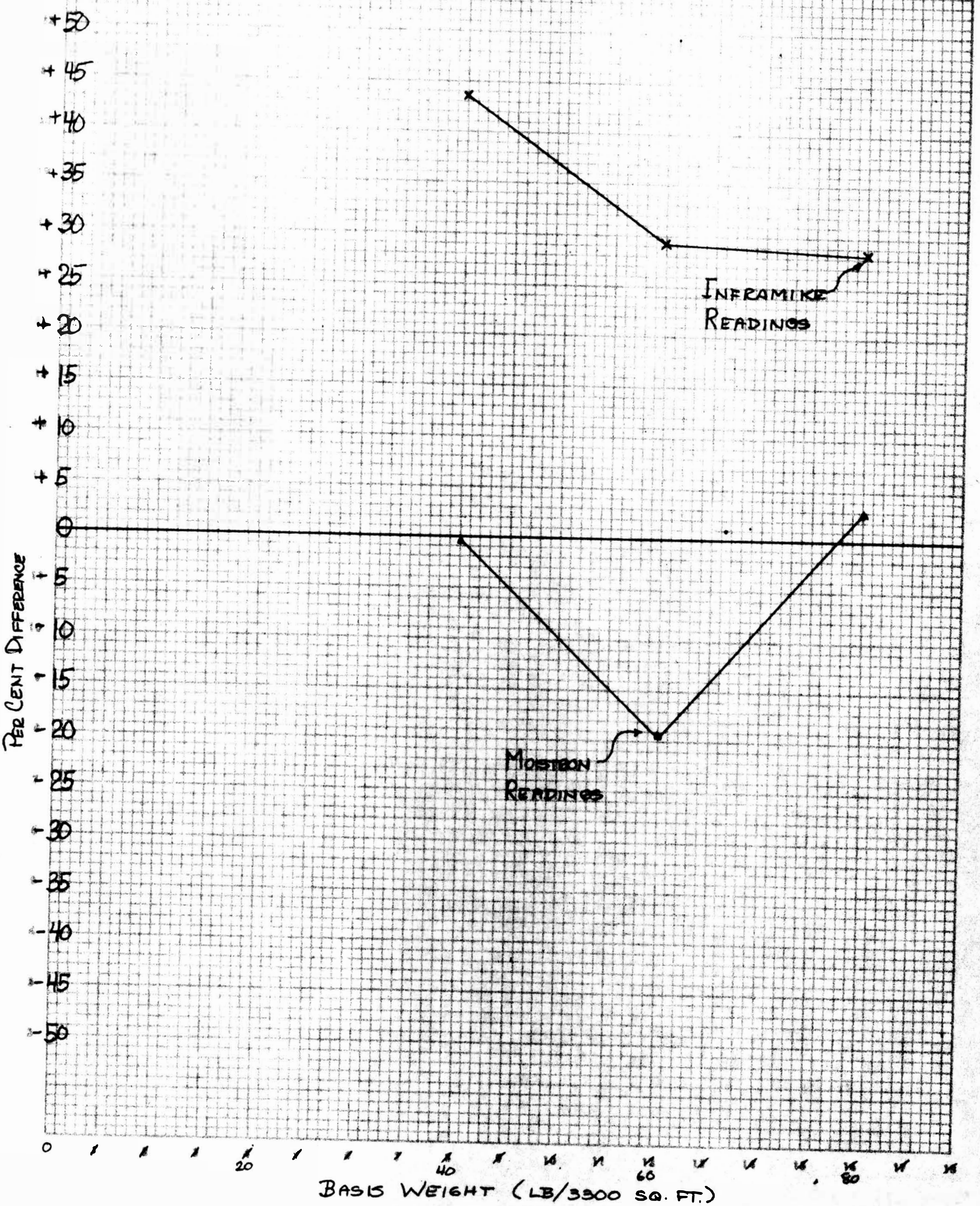


FIGURE 4

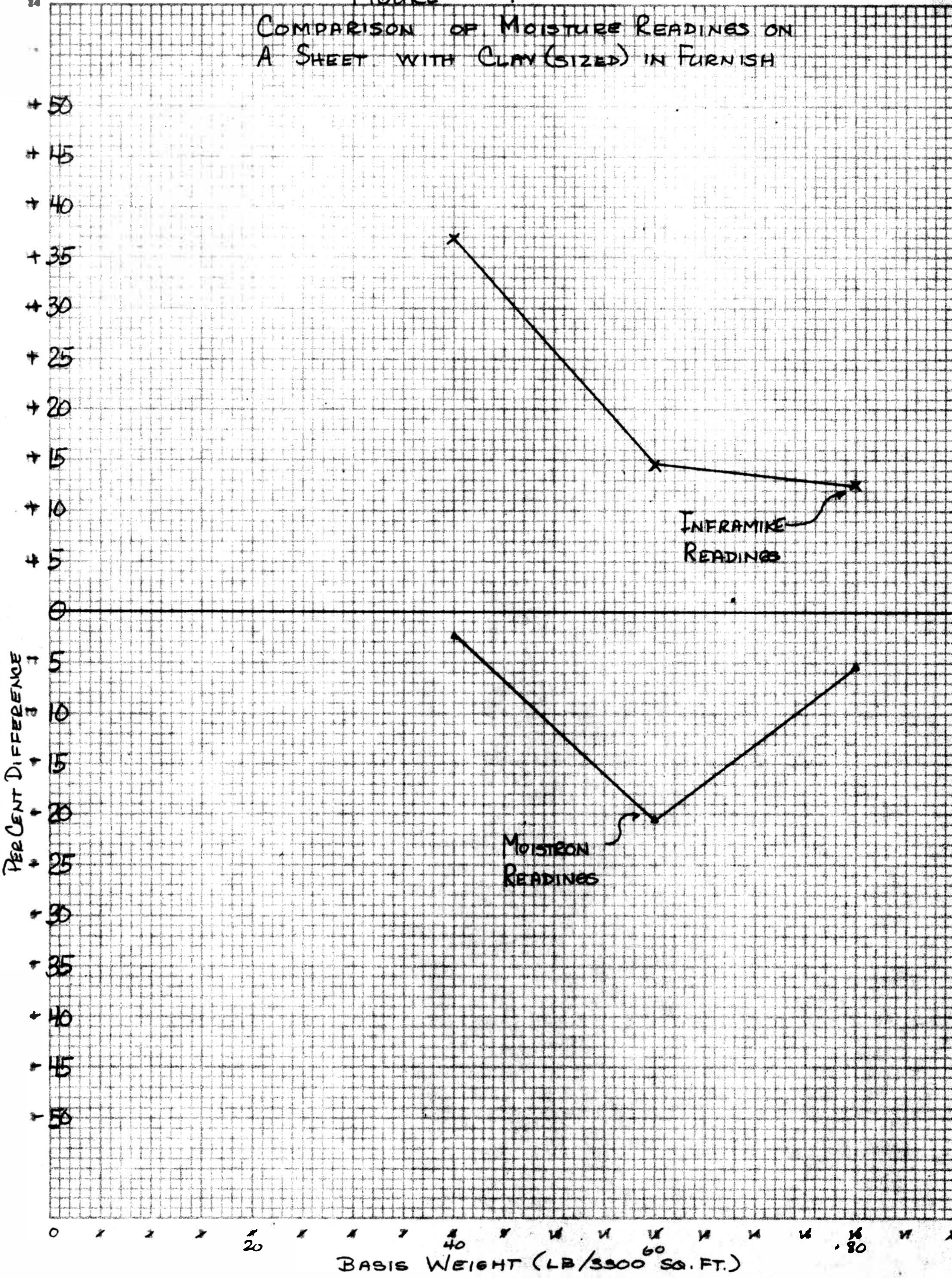
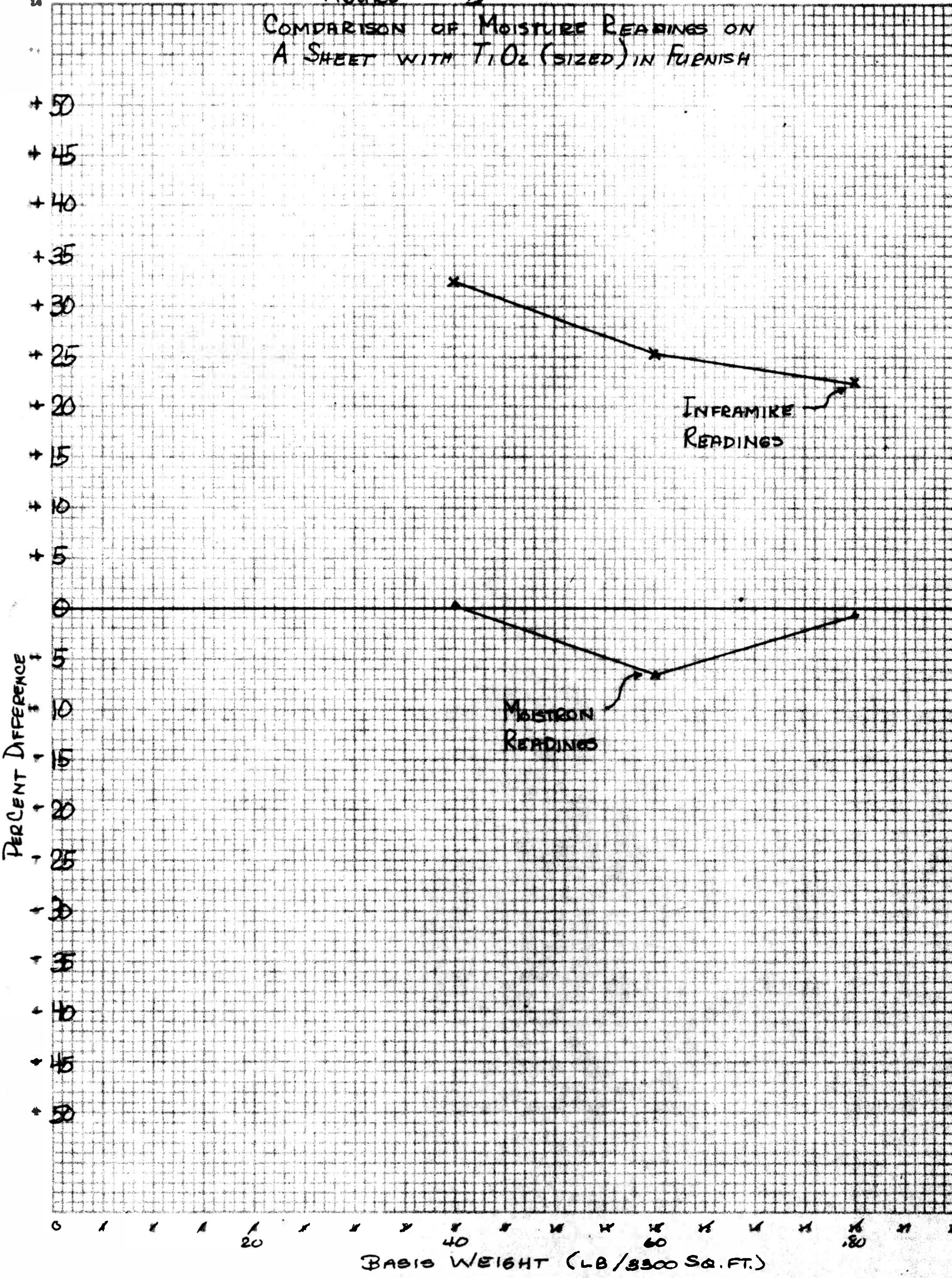

COMPARISON OF MOISTURE READINGS ON
A SHEET WITH CLAY (SIZED) IN FURNISH
+50
+45
+40
+35
+30
+25
+20
+15
+10
+5
0
5
10
15
20
25
30
35
40
45
50
PER CENT DIFFERENCE
INFRAMIKE READINGS
MOISTRON READINGS
0
20
40
60
80
BASIS WEIGHT (LB/3300 SQ. FT.)

FIGURE 5


COMPARISON OF MOISTURE READINGS ON
A SHEET WITH TiO_2 (SIZED) IN FURNISH
+50
+45
+40
+35
+30
+25
+20
+15
+10
+5
0
5
10
15
20
25
30
35
40
45
50
PERCENT DIFFERENCE
INFRAMIKE READINGS
MOISTRON READINGS
20
40
60
80
BASIS WEIGHT (LB/3300 SQ. FT.)

DISCUSSION

The readings on the machines give an indication of the manner in which the moisture in the sheet is distributed and to what extent the moisture tends to fluctuate. The Moistron readings tend to decrease in accuracy with the unsized sheets and show a decrease in accuracy at 60 lbs. and then a rise back up at 80 lbs. with the sized sheets. The Inframike has readings which tend to increase with accuracy as basis weight increases.

The readings of the moisture on the Moistron were taken from a strip of tape above the actual chart reading on the machine. The reason for taking the readings from this strip of tape is that this is a closer calibration on the machine to the paper machine it is being used on.

The Inframike readings were quite far off. The only possible reason for this to have occurred is that the machine was not properly calibrated to the trials being run on the paper machine at the time. The readings tended to vary as the sheet furnish was altered because the machine wasn't recalibrated for the furnish changes.

When the pH of the stock was changed to compensate for the addition of the sizing, the Moistron showed a difference in the accuracy of its readings more at the 60 lb. basis weight. The Inframike, on the other hand, did not show as marked a fluctuation at this basis weight when the pH was adjusted to compensate for the sizing.

The readings of the two moisture meters showed an opposite effect in the unsized sheets in the sense that when the Moistron decreased in accuracy, the Inframike increased in accuracy. In the sized sheets, the Moistron decreased at 60 lbs. and then increased at the 80 lb.; whereas, the Inframike's accuracy increased constantly. The magnitude of the fluctuations were about the same for each of the moisture maters.

The addition of fillers to the furnish appeared to have a marked effect on the readings of both the moisture meters. The Moistron should possibly have had such a deviation but the Inframike should not have registered such a deviation in the moisture readings.

CONCLUSIONS

The Moistron moisture meter does tend to be effected by the fluctuations in the basis weight as does the Inframike.

The Moistron moisture meter would be a better type of moisture gage to use when the basis weight gets to be above the 70 lb. range.

The Inframike moisture meter would be the better of the two meters to use when there was a possibility that the pH would tend to vary quite a bit through the running of a certain sheet, if it were around the 55-65 lb. per 3300 square feet.

The varying of the filler in the sheet would allow the usage of either of the two type moisture meters in the on-line determination of the moisture.

The Inframike type of moisture sensing device would tend to limit the type of operation that it could be usec in due to the fact that the control console must be located so close to the sensing head. The Moistron, on the other hand, would be capable of a variety of uses due to the fact that the instrument panel can be located quite a distance from the sensing head without haveing to sacrifice accuracy.

The Moistron measuring device would be more adaptable to being used with conputer control in that it can standardize itself and that it is of modular design. Most of the Moistron's controls would be very easy to control by the use of the computer on a Direct Digital Control basis.

The Inframike could also be hooked up on such a system and provide similar control. The Inframike doesn't have a chart to give a moisture profile like the Moistron does. This would be of somewhat more benefit if such a system could be set up. The Moistron would be the better of the two devices for getting a idea of the moisture profile because of the chart. This would allow for better control of the machine.

The transmission type moisture sensing device seems to be more accurate in the measurement of the moisture the sheet contains throughout because it measures through the sheet rather than by a backscatter from the sheet.

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1. Buetler, Arthur J., _Tappi_ 48 (9): 490 (1965).
2. Ibid: 491.
3. Ibid: 492-3.
4. Smith, Bruce W., _Tappi_ 43 (3): 228 (1960).
5. Industrial Nucleonics Corporation, _Accuray Mark II Moistron System Manual._

APPENDIX

Figure 6

Diagram of the Inframike Operation

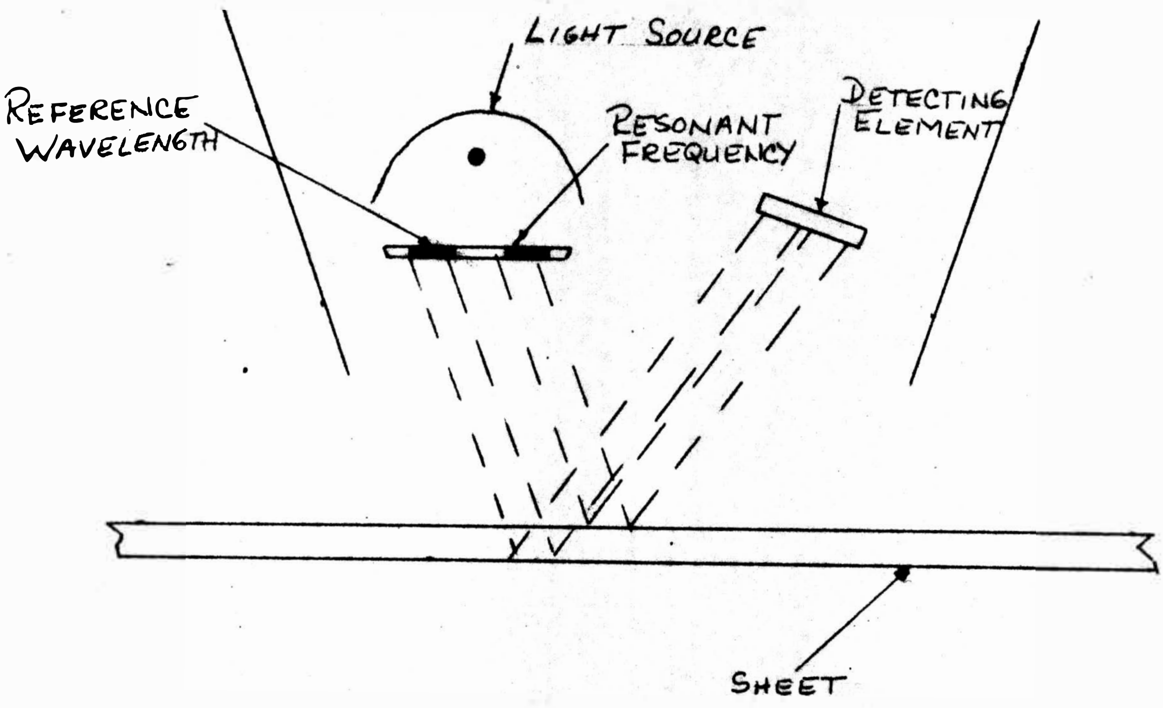

Figure 7

Diagram of the Moistron Operation