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Machine Variables in Basis Weight Control

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MACHINE VARIABLES
IN
BASIS WEIGHT CONTROL

by

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ABSTRACT

The purpose of this study was to determine the significance of machine variables as they affect the scan average basis weight readings obtained from the Industrial Nucleonics basis weight gauge on the fourdrinier paper machine of the Department of Paper Science and Engineering at Western Michigan University. The variables used in this study were machine speed, machine chest and tray white water consistencies, tray white water flow, flow to the headbox, stock valve position and head on the stock valve. Each of the above variables was sampled every ten minutes.

There were definite correlations between basis weight variation and machine speed, machine chest consistency and head levels. A smoothing out of these process variations would give a more uniform sheet and better basis weight control.

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INTRODUCTION

The control of basis weight is a very important aspect of the papermaking process. The lack of a good material control system can result in the manufacture of off specification paper. The production of off specification paper creates a misuse of raw materials and poor utilization of machine time.

The control of basis weight on the pilot fourdrinier paper machine at Western Michigan University is accomplished by an Industrial Nucleonics AccuRay Basis Weight Control System. The system uses radiation transmission techniques to measure the mass of material per unit area in the web on the paper machine. There is some question as to the reliability and sufficient response time given by this system to control basis weight of the pilot paper machine.

In order to study the question raised, several variables that may affect basis weight and subsequent automatic control of basis weight were explored.

LITERATURE REVIEW

Basis weight is the mass of material per unit area. In today's market paper is sold in several ways. It can be bought by weight or by the area. In each case the manufacturer depends on accurate basis weight control. If he sells on a weight basis, he will want to have his basis weight on the heavy end of the estimated specifications. On the other hand if he sells by area, he would like to keep his sheet light to produce more square feet of paper. Either way he must be able to closely control his sheet basis weight.

Bossen (1) gives some substantial economic reasons for good weight control. The first of these reasons is increased good production and improved throughput. On a dryer limited machine the production of a flat sheet in both the machine and cross machine directions permits uniform loading of the dryers. This can produce a savings in steam and more uniform moisture profile. Machine speeds can also increase about one to three percent. A second benefit is better machine utilization. This can be shown in decreased start-up and grade change times. The time savings, due to a good basis weight control system, can amount to fifty to sixty percent. This is a great improvement for a mill that makes many different grades. Bossen estimates that savings between $30,000 and $100,000 per year may be realized from the use of a good weight control system.

Historically, the control of basis weight has been a slow, manual procedure. Most of the adjustments made as corrections to a varying sheet weight were made manually. These corrections consisted of slice opening, stock flow, and machine speed adjustments. The corrections were made only after a reel had been turned up. At this point a tearout was taken to test the physical properties and basis weight of the sheet. Any corrections made for weight variations were performed by the operator from his past experiences with the machine.

Presently, the most common method of weight control is a system composed of on-line weight measurement instrumentation, automatic controller, magnetic flowmeter, and a remotely controlled stock flow valve.

Landesman (2) gives several process variables which can cause basis weight variations. These are stock flow rates, stock retention, and machine speed. Basis weight depends largely upon the delivery of a constant net weight of fiber to the wire. A control of the volumetric flow rate to the process at a constant consistency is required to give a desired weight. Flow rates may change for a number of reasons including stock chest consistency, and stock pump and valve surges. Machine speed is important to the discussion in that the flow of stock to the wire may be excellent, but if the machine speed varys significantly, the basis weight will be off target.

Variables in stock retention can result in more or less fiber on the wire. These variables consist in part of retention aids, stock refining, and pH and temperature variations.

Nelson (3) states that to have basis weight uniformity, stock consistency must be maintained at a constant level. Factors that affect a stable consistency are stock agitation in the chests and dilution water flow and consistency. Stratification of the stock can occur in chests due to lack of sufficient agitation. The fibers of higher specific gravity will tend toward the bottom of the tank and consistencies will be greater there becoming increasingly dilute as the tank is pumped empty. Stock refining is also an important variable. If drainage rate or freeness of the stock changes, the basis weight of the sheet could change because of more or less retention of fibers. Shorter fiber stocks could give less retention on the wire and a lower basis weight.

The variables mentioned in the literature review will be the foundation for the study of basis weight stability on the pilot machine.

BACKGROUND

The stock control system on the pilot machine is the AccuRay Basis Weight Control System manufactured by the Industrial Nucleonics Corporation. The system consists of a beta ray transmission gauge for measurement, sufficient electronic circuitry to receive and analyze signals from the gauge, and a remotely controlled Fisher Vee-Ball stock valve. In addition, two recorders are available for visual presentation of basis weight variations in both machine and cross machine direction. Control is accomplished by using the error signal (difference between order weight and average weight of the sheet) to regulate the stock flow through the stock flow valve to the fan pump.

The automatic controller of the AccuRay regulates a stock flow valve located between the machine chest and the fan pump. Automatic corrections can be made when the average basis weight varies more than one-half pound on either side of the target weight. There is one-quarter pound dead band around the target to avoid "hunting" by the controller.

In the daily operation of the pilot paper machine and resulting use of the basis weight gauge there is a definite lack of confidence in this instrument. The automatic mode of control is rarely used for several reasons. First, the operator feels that sufficient control may be maintained by manual controller operation. Secondly, the lag time of the system is much too long for some research runs. The reason for a longer lag time is the lack of cascade control in the correction of basis weight.

In cascade control the controller makes corrections on a flowmeter set point instead of directly upon the stock flow valve. This reduces time lag in that a change in flow to the flowmeter will be corrected by a corrective signal from the flowmeter to the stock flow valve. This can smooth out surges due to pump variations or stock chest variations and can give quicker more exact, basis weight changes. Under the present pilot plant conditions, the weight controller affects only the stock valve, and is not sufficiently fast to correct for rapid weight changes. This discrepancy is expected because the system is set up to run on a continuous basis with few basis weight changes.

A trial run made on November 26, 1972 to evaluate the performance of the fourdrinier machine and its effect on basis weight as indicated by the weight control system. The conditions were ideal for good basis weight control. The stock used was free of additives and at a constant freeness of 500 CFS. A basis weight target of 50 pounds per 3000 square feet was used at a machine speed of 80 feet per minute. Several observations were made. There was definite drift of weight from high to low covering a range of 2 pounds. Unexplainable offsets of 1-2 pounds were randomly observed. Lastly, a large change in basis weight of about 7-10 pounds occurred each time the machine chest was refilled. Consistency measurements were taken to determine whether the consistency of the machine chest was changing as the chest emptied. The results show a decrease in the two percent consistency of about 0.15 percent as the stock level decreased.

STATEMENT OF OBJECTIVES

The study of the process variables is not a piece of original work. Yet from a single trial run on the pilot machine it is felt that a study of this scope is needed.

The pilot machine, being a research tool of the industry, should be able to closely duplicate the variables and production quality of actual mill operation. Reliance upon trials made on this machine is heavy, and many important theories and products can be proven or disproven by the results of the test runs.

The use of the pilot machine and the variations noted in this report established a need for **further** study of the cause and effect relationship between basis weight control and pilot machine operations. This is to be done in the interest of better production and the more efficient use of the AccuRay Basis Weight Gauge.

The objectives of the study are to determine whether the variations noted are due to process variables peculiar to the pilot machine or whether the basis weight control system, in its present configuration, is inadequate for research oriented production on a small scale machine.

EXPERIMENTAL DESIGN & PROCEDURE

The pilot fourdrinier machine at the Department of Paper Science and Engineering is the object and source of information gathered for this study. The AccuRay Basis Weight System was used, through the use of the average recorder readings, to assess the major machine process variables. A Hewlett Packard dual channel strip chart recorder has been used to evaluate stock valve movement with respect to recorded basis weight changes.

A machine run was made monitoring the following variables.

1. Machine speed: Wire speed of the fourdrinier was recorded through the use of the Dynapar Digital speed indicator.
2. Stock flow rate to the headbox: Magnetic flowmeter located just before headbox was monitored.
3. White water flow rate: One white water tray was dammed with a triangular wier to indicate any change in flow from wire.
4. Stock retention from the wire: Two white water trays were sampled for consistency fluctuation.
5. Machine chest consistency: Samples were removed from stuff box over machine chest.
6. Head level changes on stock pump: Stuff box head changes monitored by measuring head as chest level decreased.

7. Basis weight variations: These were taken from average basis weight scans recorded by AccuRay Basis Weight Gauge.

Due to the scope of the project only one machine speed, basis weight, and stock type was used. A system block flow diagram can be referred to in the Appendix, Figure 8.

DATA DISCUSSION

The data for the trial machine run are presented in Tables I and II in the Appendix. There was one trial run which consisted of running the pilot fourdrinier paper machine at a speed of seventy feet per minute at a basis weight of forty pounds per three thousand square feet. The basis weight control system was placed in the manual mode and on average basis weight scanning position. Samples of those variables mentioned in the experimental procedure portion of this report were sampled every ten minutes.

Figure 1 gives the relationship of machine speed with time and basis weight. The long term change of machine speed resulted in a neglegible difference from the target speed of seventy feet per minute. Short term variation showed good correlation between speed and weight. On three occasions the weight decreased from three to five percent. Increases in machine speed accounts for forty five percent of this decrease in weight. This correlation accounts for some of the sudden offsets seen in basis weight.

The stock flow rate to the headbox began at 75 gallons per minute and remain unchanged throughout the run. This fact eliminates any pump surges from the fan pump as related to flow to the headbox and basis weight variations.

The tray white water consistencies and flow show a definite correlation with basis weight. Over the total run the weight decreased, and therefore the thickness of the filter media on the wire decreased.

This would increase the flow through the early portion of the wire and possibly increased the fiber content of the tray white water. Figure 2, 3, and 4 show the pattern expected. In Figure 2, tray no. 2 white water flow decreases over the total run time due to the decreased filter mat and introduces the possibility of more of the drainage taking place in the first tray. The two tray consistencies increased slightly owing to a decreased mass per unit area of wire allowing more fiber to escape with the water.

This drop in weight and corresponding increases and decreases in tray water flow and consistency could be caused by several variables. Drainage rate through the wire can be increased or inhibited by pH, temperature and stock refining. Stock refining was controlled for this run and it is felt that the stock was uniform. The temperature and pH were uncontrolled during the run and no attempt was made to measure them. Either of these two variables could account for the floccuations in retention and basis weight.

There were some erratic swings in the consistencies and flow of the tray water. These could be due to an error in gathering of data, but some are most definitely tied to the changing of machine speed as seen in Figure 1. It can be concluded that when the speed increased, the drainage to the first tray increased and the consistencies increased due to a thinner mat on the wire. Tray 2 flow decreased to more drainage earlier on the wire.

Machine chest consistencies increased 1.7% as the chest was filled thus causing increases in basis weight of 4% corresponding to filling the chest. This can be seen in Figure 7. As the chest level fell the consistency dropped off 0.07 percent causing a 2.0 percent decrease in basis weight. Again over the length of the trial run the tray consistencies had a net increase and the basis weight a net decrease. These discrepancies show a possible lack of good agitation in stock chests.

The stock flow valve position in the trial remained unchanged by the operator. The graph in Figure 6 shows a distinct drift in the direction of opening the valve. The valve opened eight tenths of one percent which offset the downward trend of the basis weight. If the valve had not come open during operation the sheet weight would have dropped an additional eight tenths percent.

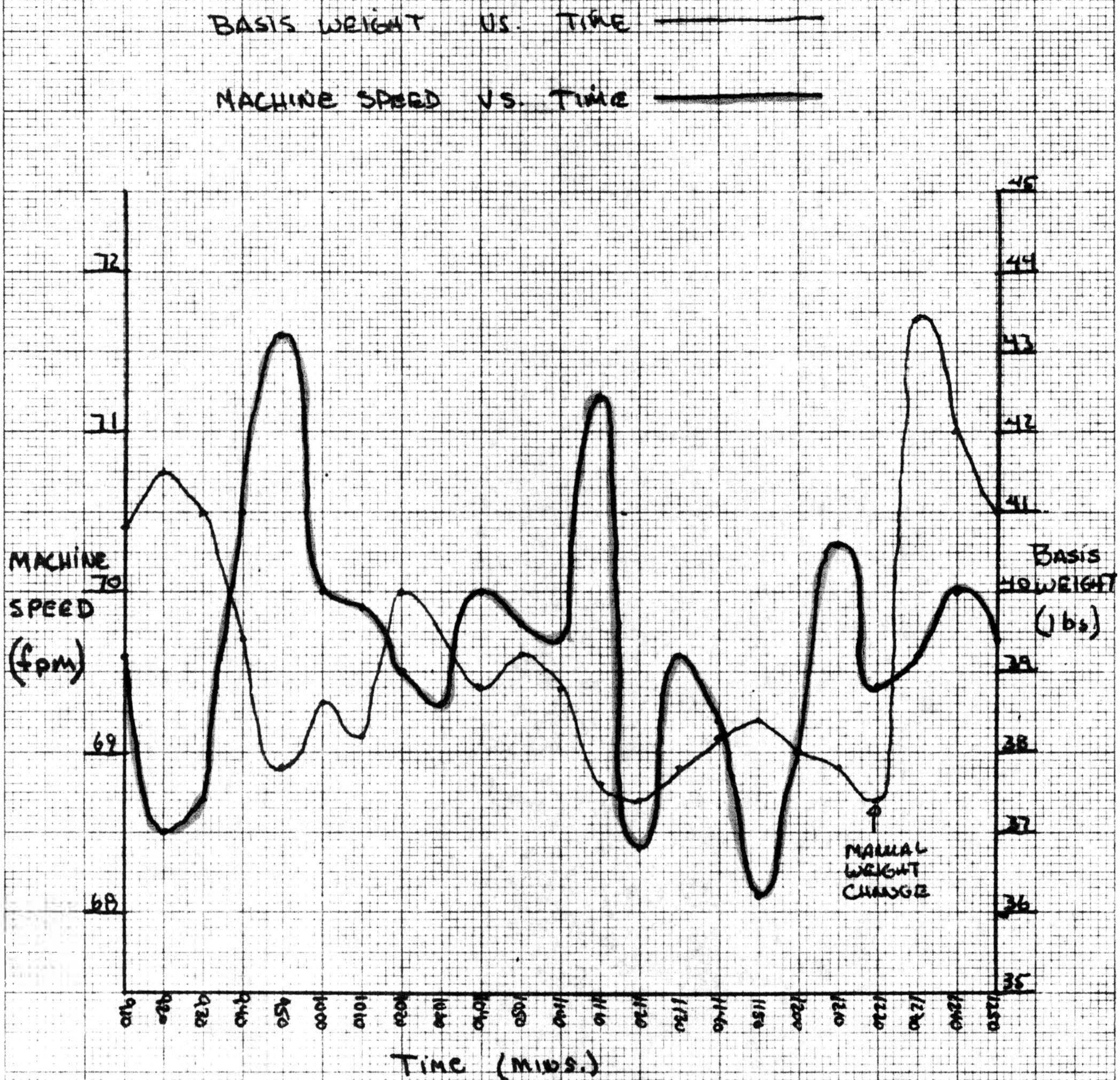
The head on the stock flow valve to the fan pump was found to have changed during operation. The head was actually measured on the pump preceding the stock valve, but it was assumed that a constant head was developed by the pump, and differences in head measured at the stuff box were actually differences of head on the stock valve. As the stock chest level decreased, the stuff box level decreased by one percent. Figure 7 shows this correlation and is described as the head on the valve as explained above. The basis weight follows very closely the decreasing head on the stock pump and valve as the stock chest empties and is subsequently filled. This is one of the clearest indications of why the basis weight varies.

At no time were any large unexplainable offsets in basis weight noted that could have been caused by stock plugging the stock flow valve.

Lastly, the basis weight average data followed the actual weight as determined by random hand samples taken by the operator. Some problems did occur with the average recording device when the average reading fell far below (i.e. 2-3 lbs.) the set point. Each thirty minutes the basis weight control system would standardize itself, and at no time was any discrepency noted that would indicate any recorder malfunction.

FIGURE 1

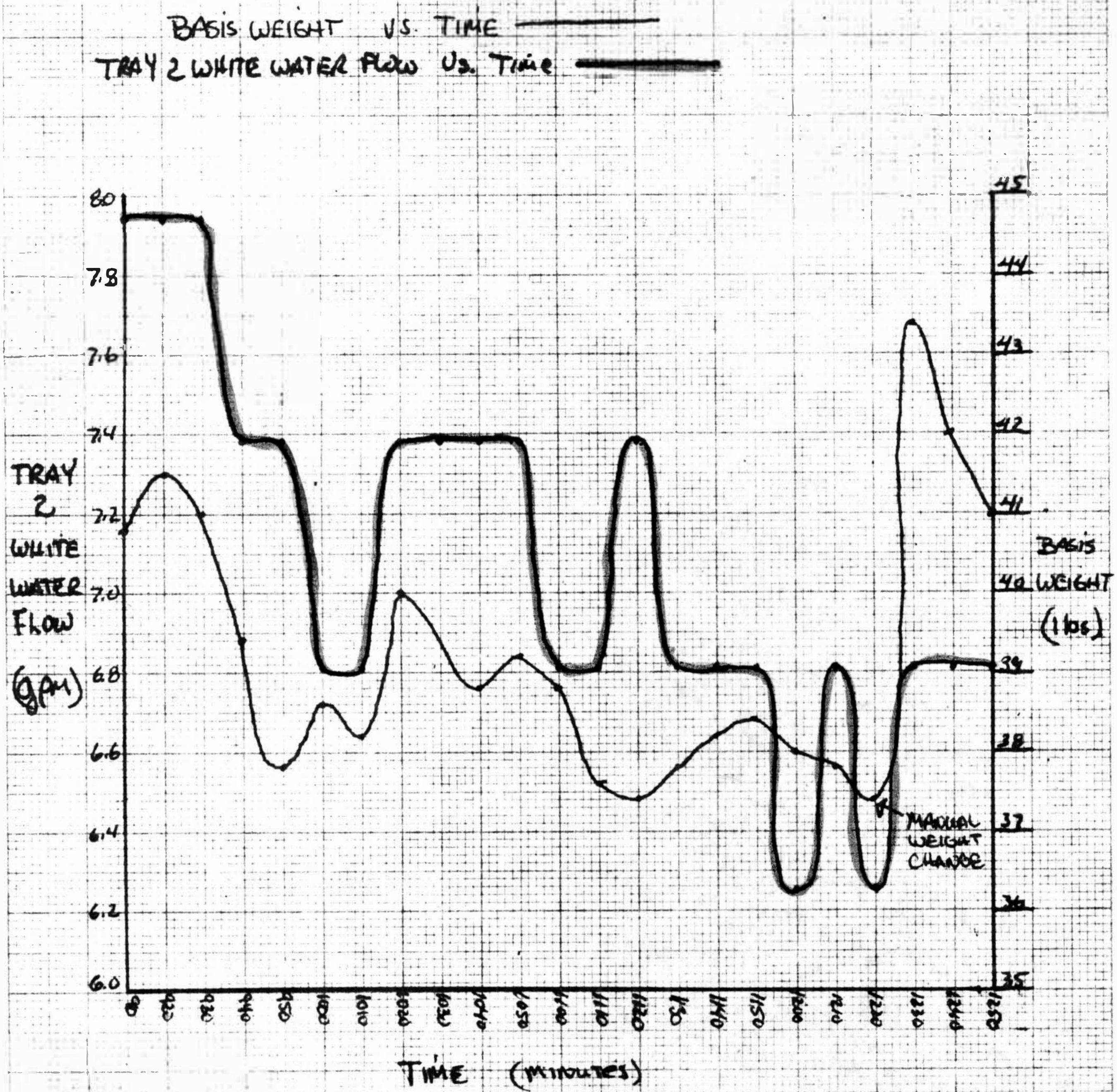
BASIS WEIGHT VS. MACHINE SPEED



· SAMPLED EVERY 10 minutes

FIGURE 2

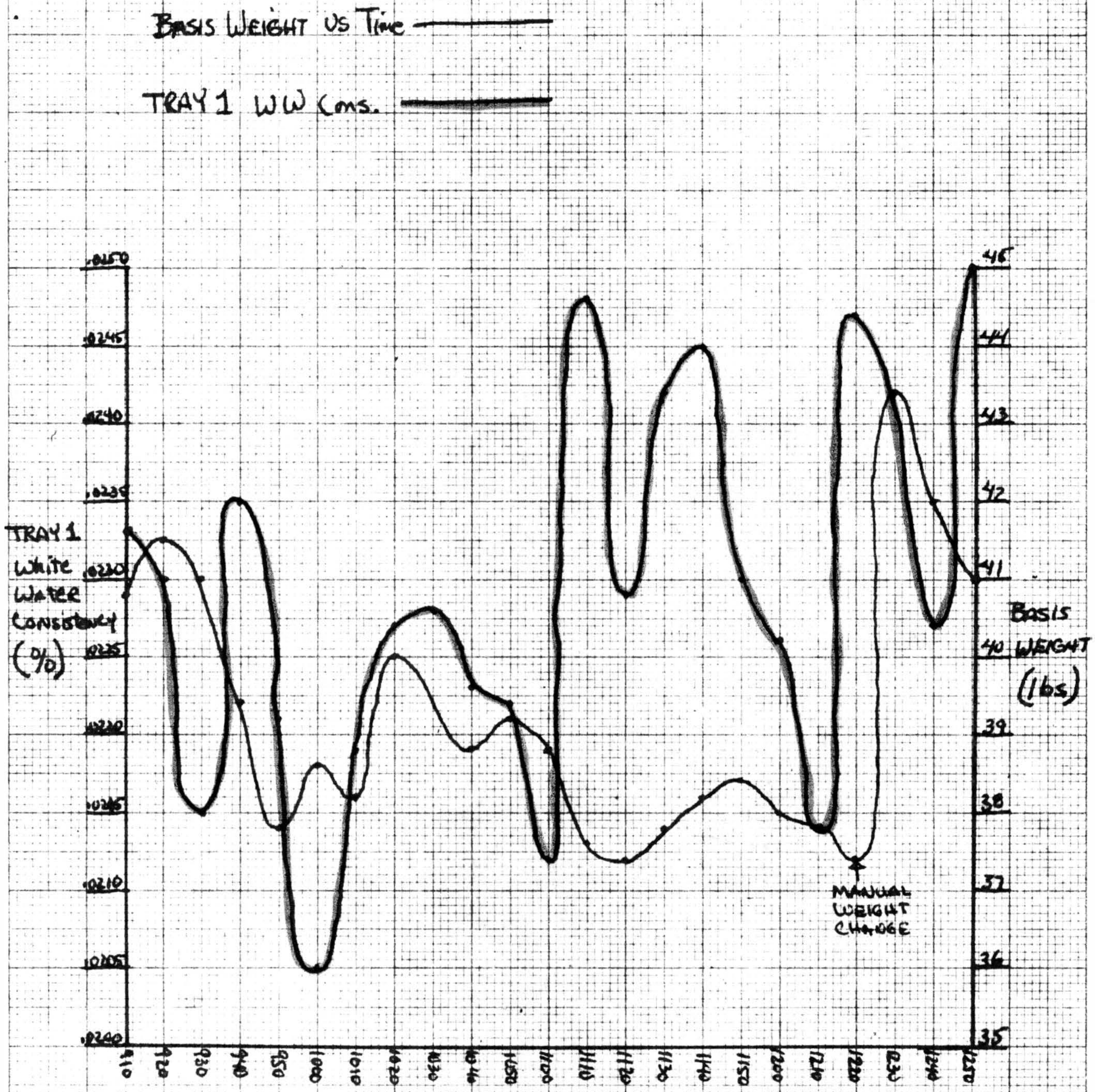
BASIS WEIGHT VS. TRAY 2 WHITE WATER FLOW



· SAMPLED EVERY 10 minutes.

FIGURE 3

BASIS WEIGHT VS. TRAY 1 WW CONSISTENCY

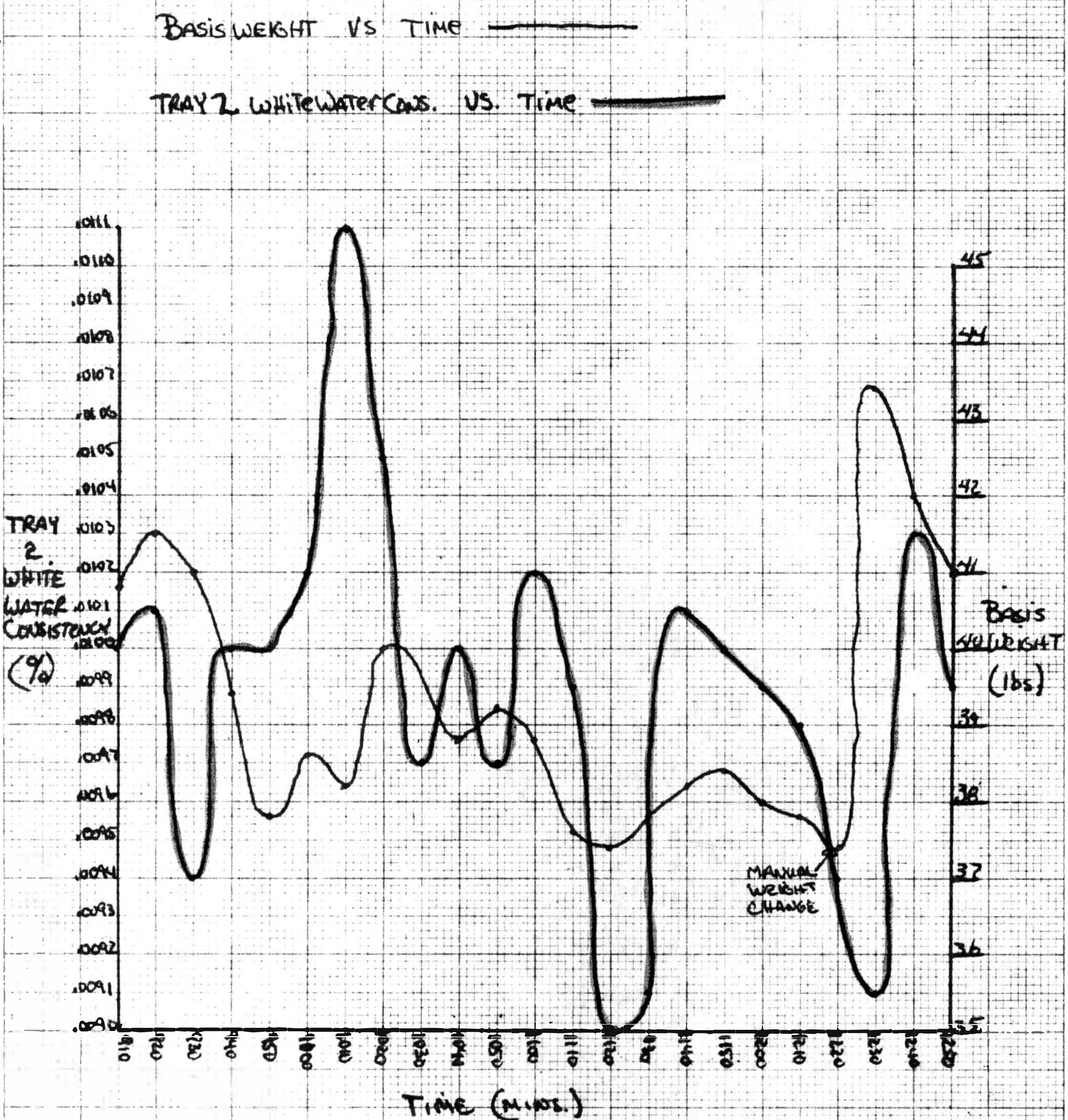


TIME (MINUTES)

SAMPLED EVERY 10 MINUTES

FIGURE 4

BASIS WEIGHT VS. TRAY 2 WHITE WATER CONSISTENCY



SAMPLED EVERY 10 minutes

FIGURE 5

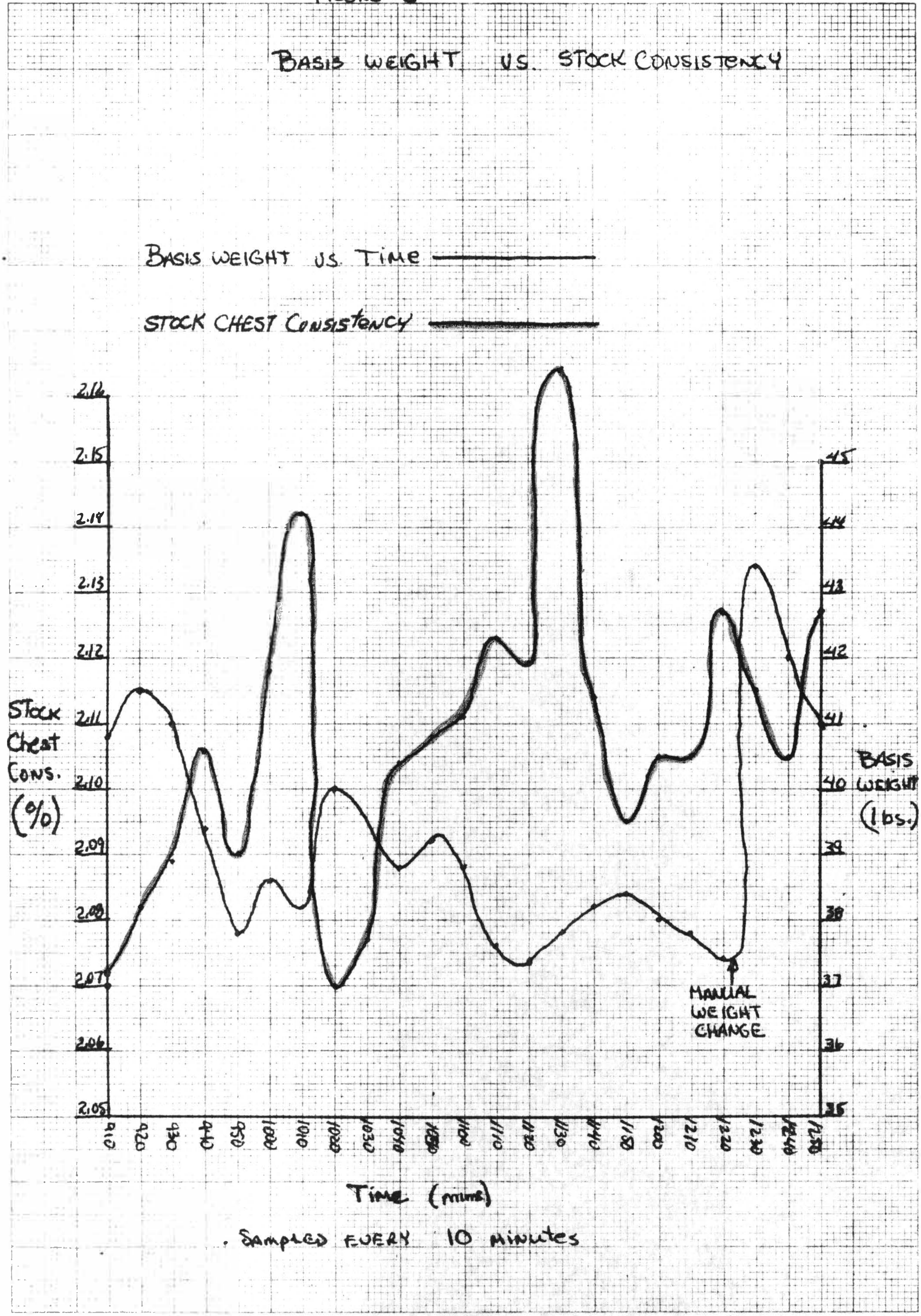

BASIS WEIGHT VS. STOCK CONSISTENCY
BASIS WEIGHT VS. TIME
STOCK CHEST CONSISTENCY
STOCK CHEST CONS. (%)
BASIS WEIGHT (lbs.)
2.05
2.06
2.07
2.08
2.09
2.10
2.11
2.12
2.13
2.14
2.15
2.16
35
36
37
38
39
40
41
42
43
44
45
910
920
930
940
950
1000
1010
1020
1030
1040
1050
1100
1110
1120
1130
1140
1150
1200
1210
1220
1230
1240
1250
MANUAL WEIGHT CHANGE
TIME (mins)
SAMPLED EVERY 10 minutes

FIGURE 6

BASIS WEIGHT VS. STOCK FLOW VALVE POSITION

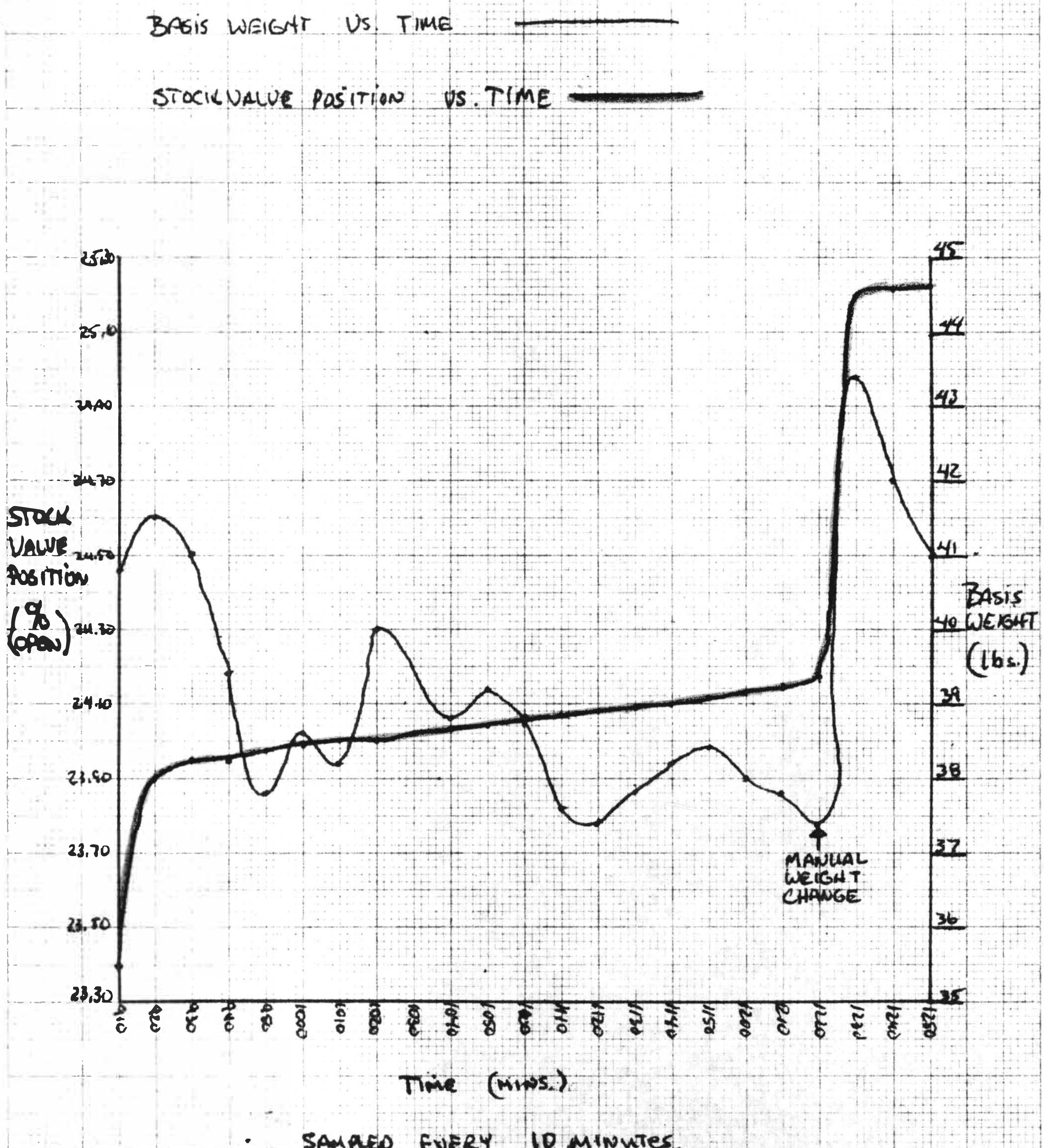
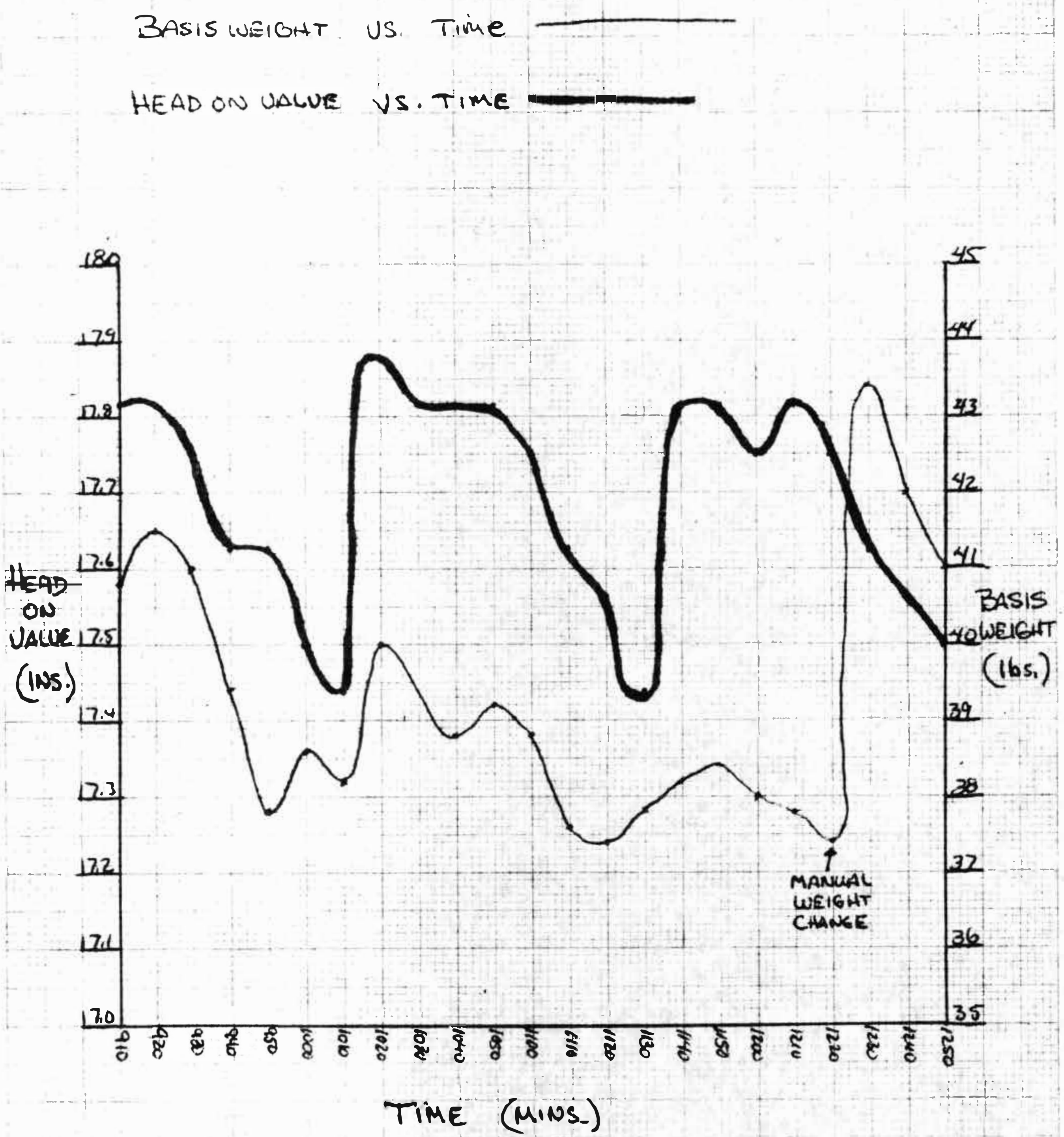


FIGURE 7.

BASIS WEIGHT VS. HEAD ON VALVE



SAMPLED EVERY 10 MINUTES

CONCLUSIONS

Basis weight variations on the pilot fourdrinier machine are caused by two major and one minor problem areas.

With a constant jet velocity from the head box, the changes in wire speed are causing significant jumps in basis weight. These are short term offsets, but of sufficient duration to cause the AccuRay control system to attempt a correction. These corrections can lead to a seeming unreliability of the central system.

The head level changes on stock pump and valve show through as being sufficient enough to be triggering weight profile changes that are undesirable. These changes are producing weight drifts on the average basis weight recorder of the AccuRay System.

Secondary in importance is the variation in stock consistency to the headbox. It is possible that large offsets observed in previous trials, though not this trial, could be caused by the combination of large increases in stock consistency and increases in head level as the stock chest is filled.

Stock preparation had no variations that affected the basis weight readings.

In general the trial run bears out much of what is predicted in the literature. With regards to the accuracy and reliability of the AccuRay Basis Weight Control System there seems to be no flaw in its operation other than that noted previously. The offsets here referred to seem to be a problem of system adjustment.

RECOMMENDATIONS

The results from this machine run lead to four possible recommendations:

1. The installation of a flowmeter and controller in the stock line ahead of the fan pump would help smooth out any increased or decreased flows due to head changes on the flow valve.
2. A consistency regulator which could be tied into the weight control system would afford much better control. Possible placement could be in the line between the machine chest and stock flow valve.
3. The problem of machine speed changes should be investigated. A possible replacement of speed regulator control on the operators panel could help.
4. The AccuRay System should be serviced to correct the difficiencies as pointed out in the last paragraph of Discussion section of this report.

LITERATURE CITED

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APPENDIX

Formula

This formula was used to calculate flow over a weir according to Shaw and Loomis (7).

$$Q = (C)\ 4/15\ (L)\ (H)\ \ 2gH$$

$$Q = 1.4076\ H^{5/2} \quad \text{for a } 60^{o} \text{ V-notch weir}$$

where: Q = flow of water in cubic feet per second.

L = width of notch in feet at H distance above apex.

H = head of water above apex of notch in feet.

C = constant, varying with conditions, .57 used.

TABLE I

Trial Run Data

Time	(lbs.) Basic Weight	(fpm) Machine Speed	(%) Stock Chest Consistency	(%) Tray 1 WW Consistency
9:10	40.8	69.6	2.072	.0233
9:20	41.5	68.5	2.082	.0230
9:30	41.0	68.7	2.089	.0215
9:40	39.4	70.5	2.106	.0235
9:50	37.8	71.6	2.090	.0221
10:00	38.6	70.0	2.118	.0205
10:10	38.2	69.9	2.142	.0219
10:20	40.0	69.5	2.070	.0227
10:30	*	69.3	2.077	.0228
10:40	38.8	70.0	2.104	.0223.
10:50	39.2	69.8	2.108	.0222
11:00	38.8	69.7	2.111	.0212
11:10	37.6	71.2	2.123	.0248
11:20	37.4	68.4	2.119	.0229
11:30	37.8	69.6	2.164	.0242
11:40	38.2	69.2	2.114	.0245
11:50	38.4	68.1	2.095	.0230
12:00	38.0	69.0	2.105	.0226
12:10	37.8	70.3	2.105	.0214
12:20	37.4	69.4	2.127	.0247
12:30	43.4*	69.6	2.115	.0242
12:40	42.0	70.0	2.105	.0227
12:50	41.0	69.7	2.127	.0250

TABLE II

Time	(%) Tray 11 WW Consistency	(GPM) Tray 11 WW Flow	(%) open Stock Flow Valve Position	(in.) Head on Valve
9:10	.0100	7.94	23.40	17 13/16
9:20	.0101	7.94	23.90	17 13/16
9:30	.0094	7.94	23.95	17 12/16
9:40	.0100	7.38	23.95	17 10/16
9:50	.0100	7.38	23.97	17 10/16
10:00	.0102	6.81	23.99	17 8/16
10:10	.0111	6.81	24.00	17 7/16
10:20	.0105	7.38	24.00	17 14/16
10:30	.0097	7.38	24.02	17 13/16
10:40	.0100	7.38	24.03	17 13/16
10:50	.0097	7.38	24.04	17 13/16
11:00	.0102	6.81	24.05	17 12/16
11:10	.0099	6.81	24.07	17 10/16
11:20	.0090	7.38	24.08	17 9/16
11:30	.0091	6.81	24.09	17 7/16
11:40	.0101	6.81	24.10	17 13/16
11:50	.0100	6.81	24.12	17 12/16
12:00	.0099	6.25	24.13	17 13/16
12:10	.0098	6.81	24.15	17 13/16
12:20	.0094	6.25	24.17	17 12/16
12:30	.0091	6.81	25.20	17 10/16
12:40	.0103	6.81	25.21	17 9/16
12:50	.0099	6.81	25.22	17 8/16

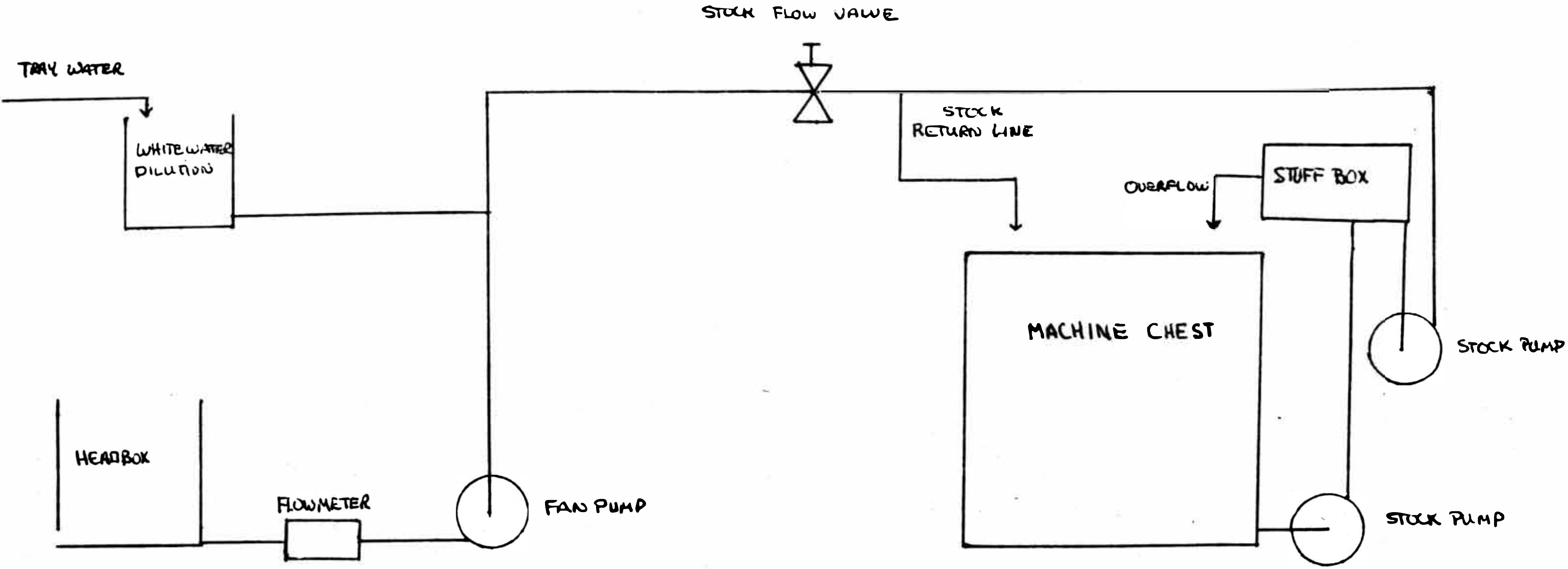

Figure 8

System Flow Diagram