Reliable consistency measurement without rebuilding your pulp mill—a mill experience

PHILIP PRICE AND JIMMY LEE

ABSTRACT

Consistency measurement is infinitely more an art than a science; most instrument technicians would say it is more like a dart game! There are several different instrument manufacturers, with a variety of measurement methods, and all claim to be able to measure and produce repeatable measurements of consistency. (Most have a disclaimer stating the application must have adequate installation conditions to maintain laminar flow and low flow velocities.)

This paper addresses the trials run on an existing hardwood unbleached medium-consistency (3–4.5%) kraft pulp stock line with high flow velocities and turbulent flow. The consistency was measured with a blade-style sensor, and the process was unable to be run on automatic-consistency control.

Results of the trial showed that repeatable manual-consistency samples could be obtained (an average repeatability of 2.9% was measured over 1 year of sampling). It was also shown that compensation curves can be created in the distributed control system to give a reliable, compensated continuous consistency measurement for dependable automatic-consistency control (the loop was able to be put on automatic control).

Application:

Reliable consistency measurement of medium-consistency kraft pulp can be achieved without expensive instrumentation or Utopian installation conditions.

THERE HAVE BEEN NUMEROUS papers written over the past several years addressing the difficulty of measuring and controlling pulp consistency. Most "successful" consistency meter installations are qualified by disclaimers that proper installation conditions and good lab tests for calibrating the meter must be present. There have also been several papers written about the fact that these "optimum" installation conditions are rarely met and that achieving satisfactory, repeatable consistency lab tests is almost impossible. This paper documents the findings of a successful series of trials run on a hardwood unbleached stock line with a blade-style consistency meter in a less-than-optimum installation.

The goal of the trials was to achieve acceptable repeatability of consistency lab tests in order to model the relationship between lab tests and meter readings accurately enough so that the meter could be used to automatically control consistency in the process line.

TRIAL CONDITIONS

A consistency loop on the feed of unbleached hardwood kraft stock (3–4.5%) to the first stage of a DcEopD bleach plant was chosen for the trials. The process line was installed in the fall of 1991 at the Fort James Naheola, AL, mill. Due to space limitations, the blade-type consistency meter was installed in a straight run of pipe with only a 5-pipe-diam upstream "stilling" section and less than a 2-pipe-diam downstream stilling section. (The average recommended stilling sections are 10 pipe diameters upstream and 5 pipe diameters downstream.) The sample valve used for manual-consistency testing was a 1.5-in. Struhman "screw-out"–type valve.

The process was chosen because we wanted to take a worst-case application and be able to achieve reliable automatic consistency control without changing the meter or other equipment/piping. Since the startup of this process line in 1991, the consistency loop had to be run in manual mode because the loop could not be stabilized. Lab tests also repeatedly showed much higher consistencies than did the meter, even after re-zeroing the meter based on lab tests. Different brands of blade-type meters were tried in the loop, but none could provide reliable measurements because of high turbulence in the line.

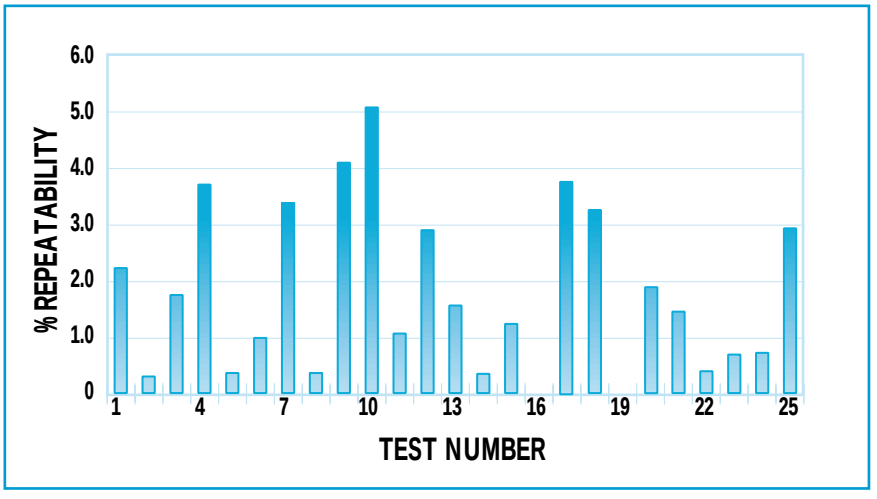
TRIAL PROCESS

Sampling

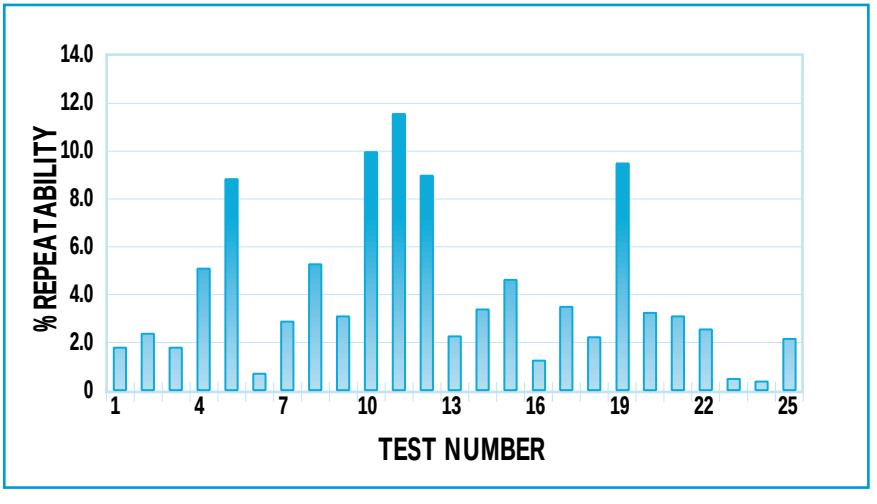
We decided that the best way to get reliable control using the meter was to model the meter readings vs. lab results and "build" a compensated curve in the distributed control system (DCS) to provide automatic consistency control. The first step in achieving this was to prove that the lab tests were repeatable.

The test procedure used is shown in the appendix; it closely follows TAPPI Test Method T 240 om-93.[1] The T 240 method predicts a repeatability of 10%. This is usually not acceptable for proper zeroing of the consistency meter. Seventy-five trials were conducted over a 1-year period with a resulting 2.9% average repeatability and a 0.07% consistency standard deviation (see **Figs. 1–3**). These results were considered

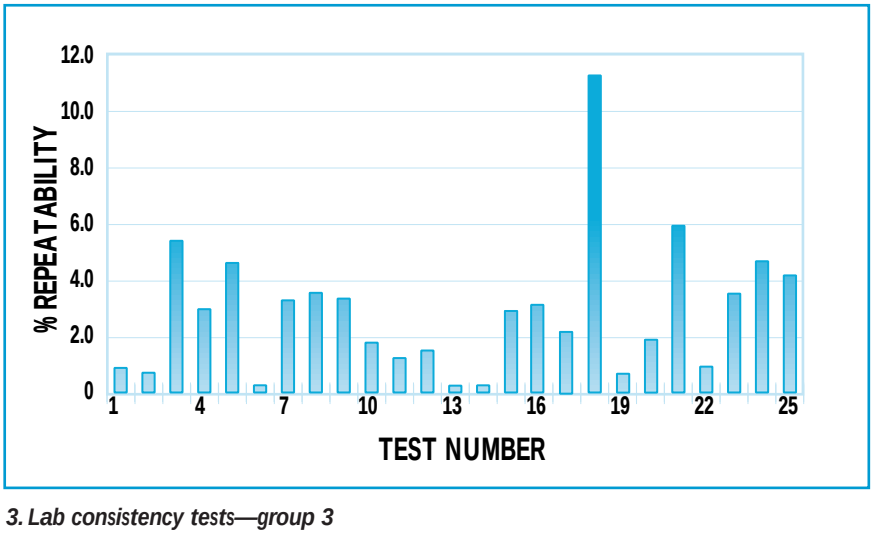
[1]TAPPI T 240 om-93, "Consistency (concentration) of pulp suspensions."



1. Lab consistency tests—group 1



2. Lab consistency tests—group 2



3. Lab consistency tests—group 3

acceptable for use in modeling the meter readings to actual consistency. Figs. 1–3 show the 75 trials of mainly two samples, each in three groups.

TAPPI Test Method T 1206 rp-91[2] defines *repeatability* as "a limit within which agreement may be expected 95% of the time between two test results obtained under essentially the same conditions and from the same homogeneous sample of material."The first few trials were done using three samples from the same sample flow. Since the repeatability of these trials was so good, we decided that the mill standard test procedure of catching two samples per trial would be sufficient.

The equation for calculating percent repeatability was taken directly from TAPPI T 1206:

$$\text{Repeatability, \%} = \frac{100(2.77\, s_e)}{\bar{x} m^{0.5}} \quad (1)$$

where

s_e = standard deviation
$\bar{x}$ = average
m = number of test specimens.

For these trials, m = 2, since two samples were taken from the same sample flow for each test.

The equation for calculating the test standard deviation is from the analysis of variance (ANOVA) equation:

$$\text{Test } s_e = \sqrt{\frac{\sum_{P=1}^{75}\sum_{t=1}^{2}(y_t - \bar{y}_p)^2}{\text{DF}}} \quad (2)$$

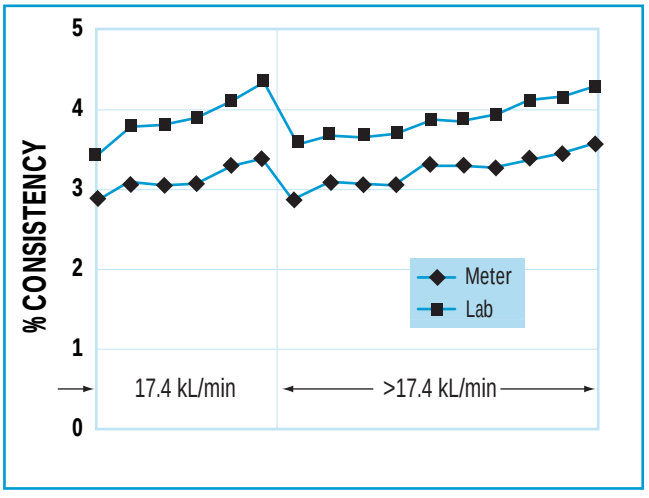
where

DF = degrees of freedom.

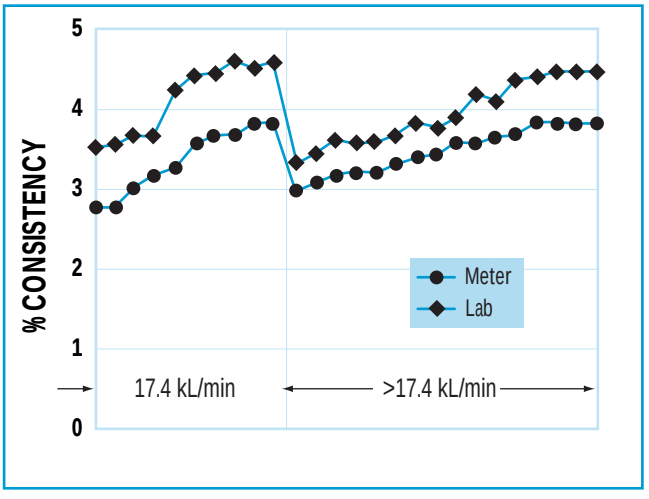
Modeling lab vs. meter

Once confidence in the repeatability of the lab tests was achieved, consistency samples were gathered at varying consistencies and over a wide range of process flows. (The mill where these trials were conducted is fully integrated, and the process

[2]TAPPI T 1206 rp-91,"Precision statement for test methods."



4. Meter 1 vs. lab for all flows



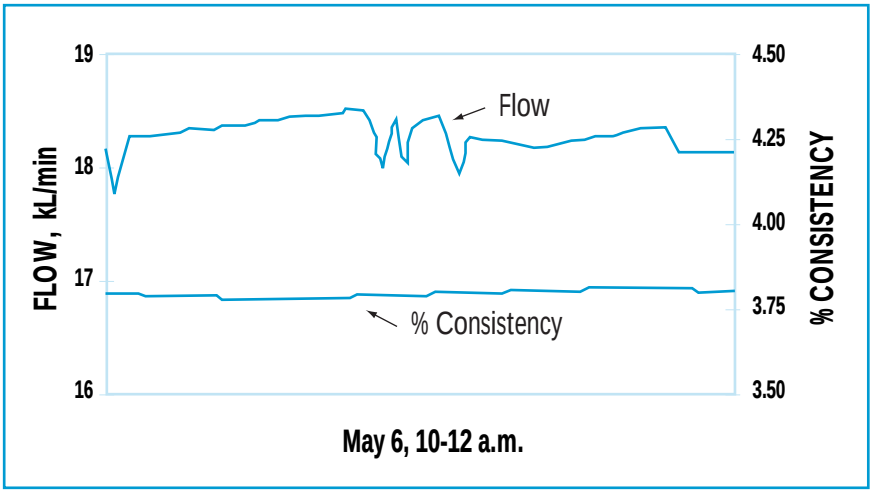
5. Meter 2 vs. lab for all flows

being testing frequently experiences rate changes as the paper machines' loads change.)

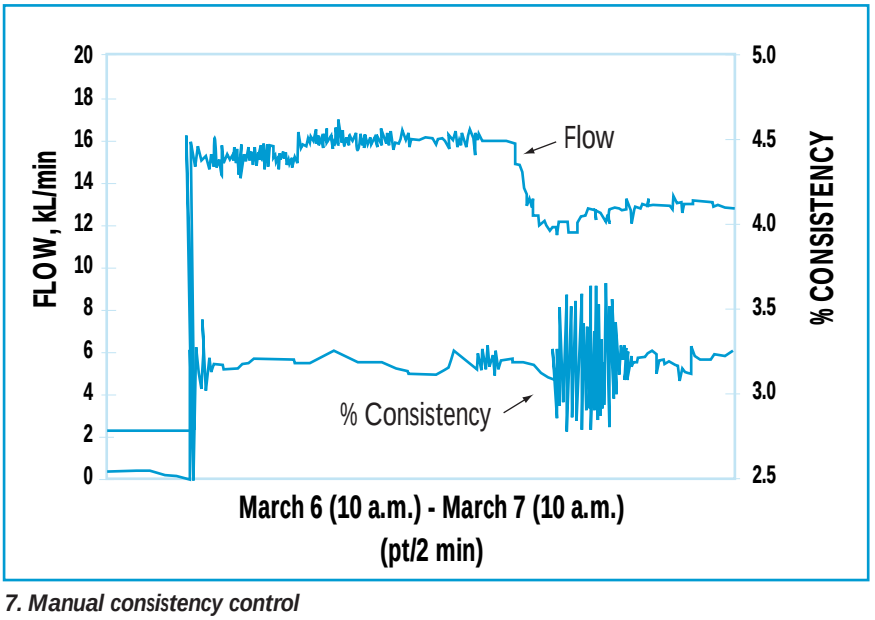
Data gathered over a 2-month period showed direct correlation between meter readings and lab tests. We noted that the meter had different "curves" over two stock flow ranges. As **Fig. 4** shows, the meter had a different curve for stock flows ≤ 17.4 kL/min (4600 gal/min) than for stock flows > 17.4 kL/min. Meter 1 was struck by a stock plug and over-ranged, so a new meter (Meter 2) of the same brand and model was installed and used for the remainder of the trials. **Figure 5** shows similar meter/lab/flow relationships.

The data from trials run on Meter 2 (shown in **Fig. 5**) were used as inputs into a neural-network program. The neural-network program was then used to "learn" the relationship between meter readings and actual consistencies (lab test data) while compensating for stock flow variations.

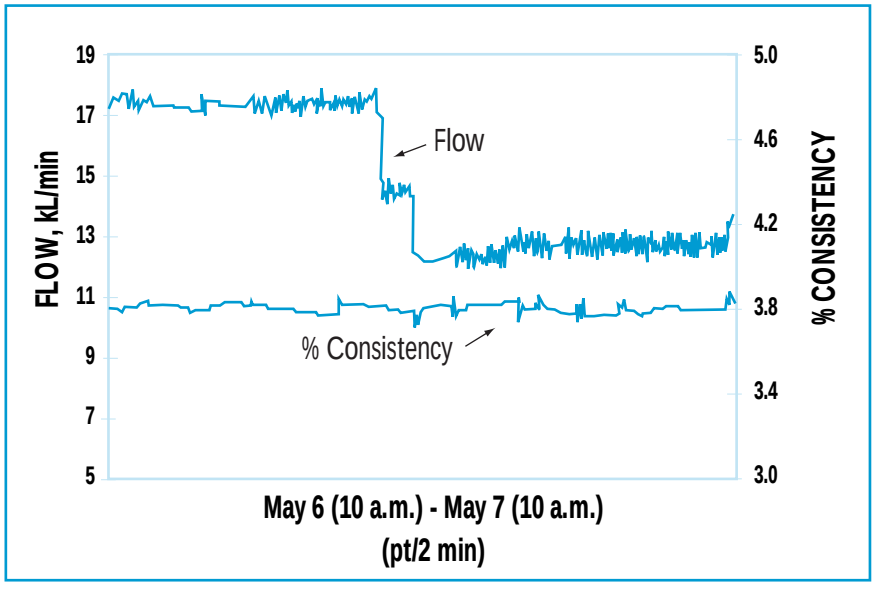
The generated model was then loaded into the DCS. The model used the continuous meter and stock flow inputs to the DCS to generate a "compensated consistency" value. This value was then used as the process variable for the consistency control loop.



6. Automatic consistency control (compensated curve)



7. Manual consistency control



8. Automatic consistency control (compensated curve)

Implementation of the model

After some testing, the consistency loop was placed in automatic-control mode using the DCS-compensated consistency. **Figure 6** shows the satisfactory results.

The process was run on automatic-consistency control for a 2-month period and continues to function well. **Figures 7 and 8** compare the stock flow and consistency readings on manual- and automatic-compensated control over a 48-hour period, respectively. We noted that process flow rate step changes did not affect the consistency control when in automatic-compensated mode.

SUMMARY AND RECOMMENDATIONS

The following points summarize our results:

- Because greater variation exists in manual sampling than in electronic meter readings, acceptable lab repeatability must be achieved first before accurate modeling of the process can be achieved. Reliable consistency sampling and lab tests can be achieved with proper procedures and qualified lab personnel. These trials showed that a 2.9% repeatability of lab tests is achievable.
- Blade-type consistency meters without the new electronics that offer "one-point calibration" can still provide reliable representation of process consistencies in medium-consistency (3–4.5%) hardwood unbleached stock, even in less-than-desirable installation conditions.
- This method would probably not be practical for applications where a blend of species and/or fillers is present, as multiple models would be required.

TJ

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APPENDIX

SOP: BROWNSTOCK CONSISTENCIES

Date issued: 8/7/95

Equipment needed

The following equipment is needed:

- Mill radio
- 500-mL Nalgene bottles
- Buchner funnel for 18.5-cm Whatman filter paper
- 4000-mL Pyrex filtration flask w/vacuum hose
- 1000-mL plastic beaker
- Drying oven at 105°C.

PROCEDURE

The following procedure should be followed:

1. Take mill radio with you to each sample point, and prior to or during sample collection, contact control room for readings from Honeywell and record on worksheet.
2. Open sample lines, and allow a free flow of stock before catching in 500-mL Nalgene bottles. When catching sample, try to catch about half a bottle. This is done by quickly running the mouth of the bottle under the stock flow stream.
3. Catch duplicate samples, and quickly cap bottles after catching. Label samples A and B.
4. Wash bottles and area after sampling, and return to lab for testing.

5. Weigh bottles with sample, and record weight on worksheet.
6. Pour entire sample from bottle into 1000-mL beaker, and dilute with water to make filtration easier.
7. Pour diluted sample onto filter paper in Buchner funnel/filtration flask setup, and begin vacuum filtration (water filtration setup or vacuum pump setup). Note: Rinse sample well to ensure that no stock remains on the side of the funnel, and when removing pulp pad formed, be sure to get all stock from the filtration funnel.
8. Place pulp pads into 105°C drying oven for 1.25 hours.
9. After removing dried pulp pads from oven, allow them to acclimate in a desiccator for 15 min.
10. Reweigh empty bottles, and record on worksheet as tare weights to be subtracted from bottle and wet sample weights.
11. Record weights of dried pulp pads on worksheet.

CALCULATION

Use the following calculation to determine percent consistency:

Dry weight × 100/Wet weight = % Consistency

Samples A and B are averaged to obtain the percent consistency reported on each sample.

SAFETY CONSIDERATIONS

Wear all required safety gear for sampling area (hard hat, safety glasses, and escape respirator). Use insulated rubber gloves to collect samples, and take care when opening valve lines since stock is hot and caustic black liquor is present. Be aware of safety shower locations and their operation.