Forté Series 8790/8760 System

Calibration Procedure for Bales of Pulp

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1 INTRODUCTION

The purpose of this manual is to assist the customer in the calibration of the FORTÉ Series 8790 Moisture Measuring System for wood pulp bales. It also includes a brief description of how the FORTÉ System works and why it works.

2 PRINCIPLES OF THE FORTE SYSTEM

In order to appreciate the calibration requirements and the interaction of the units comprising the FORTÉ system, it is necessary to understand how the system functions and why it works. This section gives a brief description of the FORTÉ system.

2.1 BASIC THEORY

The heart of the FORTÉ Moisture Measuring System is a modified Hartley type high frequency oscillator. The resonant frequency of this oscillator is controlled by an LC tank circuit as shown in Equation 1.

$$F_r = k/(LC)^2 \qquad \text{(Equation \#1)}$$

Where F_r = resonant frequency
k = proportional constant
L = tank circuit inductance
C = tank circuit capacitance

With the tank circuit inductance fixed, any change in the resonant frequency must be caused by a change in the tank circuit capacitance. In the FORTÉ system, all capacitance involved in the tank circuit are fixed except the capacitance of the electrode cover plate and the press base. This capacitor therefore controls the change in the resonant frequency.

The value of a capacitor is determined by the relationship shown in Equation 2.

$$C = kA\varepsilon/d \qquad \text{(Equation \#2)}$$

Where k = proportional constant (different from Equation 1)
A = area of smaller plate
d = distance between plates
ε = Dielectric constant

The key to the functioning of the FORTÉ system is the change in the effective dielectric constant of the bale during the press cycle.

2.2 PRACTICAL APPLICATION

Figure 1 is a physical representation of the FORTÉ system press electronics. The FORTÉ photocontrol unit provides two signals that tell the microprocessor to read the frequency. The first signal occurs when the upper light beam is broken. The microprocessor counts the pulses generated by the signal generator for precisely one tenth of a second. When the lower light beam is broken the microprocessor again counts the pulses generated by the signal generator for precisely one tenth of a second. The difference between these two counts is caused by the change in the effective dielectric constant of the bale during the press cycle. We call this difference the FORTÉ number and it correlates with the moisture in the bale.

Figure 2 is a simplified equivalent circuit of the FORTÉ signal generator including the capacitance of the electrode and the press. The inductance and all capacitance except C^b (the bale capacitance) are constant. Hence it is the change in C_b that controls the FORTÉ number.

The resultant capacitance of Figure 2 is equivalent to the C in Equation 1. Since the FORTÉ system is concerned with the change in the resonant frequency and C_b is the only capacitance that changes, then effectively

$$\mathrm{AA}F_r = k/(\mathrm{AA}C_b)^2 \qquad \text{(Equation \#3)}$$

Let us now discuss how C_b changes during the press cycle. A pulp bale is composed of three principal components; air, fiber, and water. The effective dielectric constant of the bale is the sum of the products of each portion of each component multiplied by the component dielectric constant, i.e.

$$\varepsilon_{eff} = \mathrm{Ax}\varepsilon_{air} + \mathrm{Bx}\varepsilon_{fiber} + \mathrm{Cx}\varepsilon_{water}$$

Where A, B, and C = proportion constants of air, fiber and water respectively
ε_{air} = dielectric constant of air
ε_{fiber} = dielectric constant of fiber
ε_{water} = dielectric constant of water

The dielectric constant for air is 1. The dielectric constant for wood pulp fiber is between 2 and 5. And the dielectric constant for water is 80. This high dielectric constant for water is what permits the FORTÉ system to work.

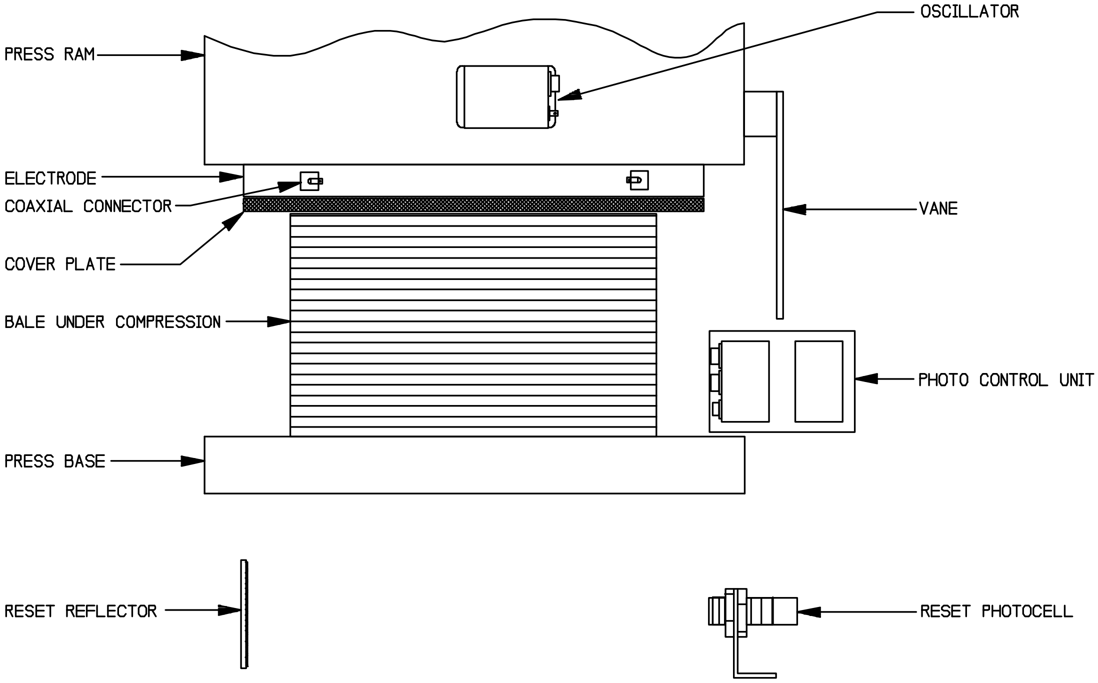
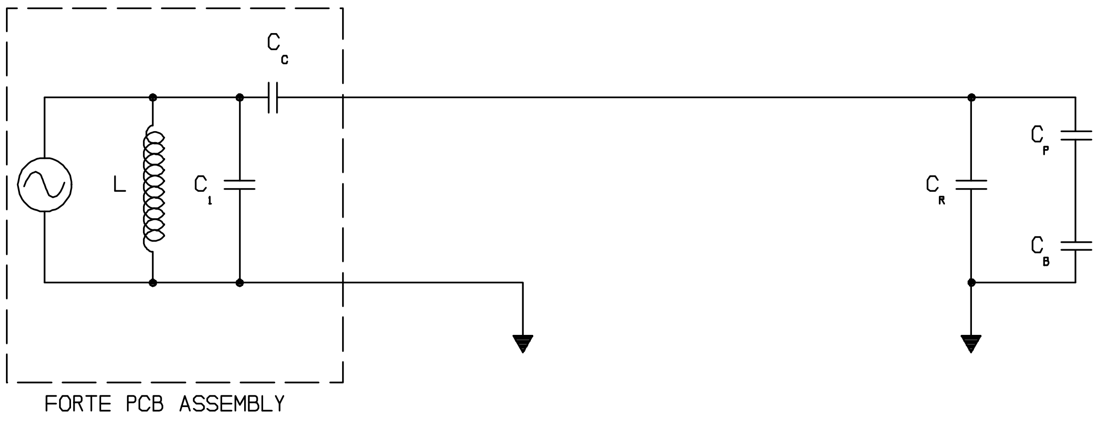


FIGURE 1 : PRESS ELECTRONICS (INTERCONNECTING CABLES OMITTED FOR CLARITY .)



L = TANK CIRCUIT INDUCTOR

C_1 = TANK CIRCUIT CAPACITOR (CONTROLS THE BASIC FREQUENCY OF THE OSCILLATOR)

C_C = COUPLING CAPACITOR (PREVENTS LOADING DOWN THE OSCILLATOR)

C_R = CAPACITANCE BETWEEN THE ELECTRODE AND THE PRESS RAM

C_P = CAPACITANCE BETWEEN THE ELECTRODE AND THE COVER PLATE

C_B = CAPACITANCE BETWEEN THE COVER PLATE AND THE PRESS BASE
THROUGH THE BALE

88295ZAM

FIGURE 2 : BALE PRESS , SIMPLIFIED EQUIVALENT CIRCUIT

For example, let us assume that when the upper light beam in the photocontrol unit is broken, that the bale consists of 50% air, 40% fiber, and 10% water.

$$\begin{aligned}\varepsilon_{eff} &= 0.5\text{x}1 + 0.4\text{x}4 + 0.1\text{x}80\\ &= 0.5 \quad + 1.6 \quad + 8.0\\ &= 10.1\end{aligned}$$

Let us now assume that when the lower light beam of the photocontrol unit is broken, the bale volume has decreased to 80% of the previous volume, i.e. the bale density has increased 25%. This means the new effective dielectric constant becomes

$$\begin{aligned}\varepsilon_{eff} &= 0.375\text{x}1 + 0.5\text{x}4 + 0.125\text{x}80\\ &= 0.375 \quad + 2.0 \quad + 10.0\\ &= 12.375\end{aligned}$$

This means there is an increase in the effective dielectric constant by 2.275 of which 2.0 was the result of the moisture in the bale. This increase in the dielectric constant increases the capacitance as shown in Equation 2 and decreases the resonant frequency as shown in Equation 1.

The change in the resonant frequency (the FORTÉ number) is primarily caused by the moisture in the bale. It must be noted that the heavier the bale (the more material), the greater the change in frequency. For this reason the bale weight must be taken into consideration.

3 PREPARATION FOR TESTING

Before proceeding with the calibration of the FORTÉ System, you must assure that all of the laboratory and FORTÉ equipment is correct and in proper operating condition.

3.1 LABORATORY OVEN

Check oven temperature to assure that it is at 105℃ and is constant during the drying time of samples.

3.2 LABORATORY SCALE (BALANCE)

Using a "Calibrated" set of weights, check the scale to assure that it is correct, especially in the range that the samples of pulp are being weighed. The use of a laboratory scale with a resolution of 0.0001 grams is recommended.

3.3 FORTÉ STABILITY – OSCILLATOR AND PRODUCTION LINE SCALE

Test the stability of the FORTÉ system with the press empty and press platen in the up position. Nothing should be touching the electrode and coverplate assembly. There should be no operators or technicians within 3 feet (1 meter) of the press during the test.

Frequency measurements will vary from system to system based on the following variables:

- the series of FORTÉ oscillator (signal generator) used and the components on the board,
- the model and setup of the press,
- the length of the coaxial cable used to connect the oscillator to the electrode,
- the size of the electrode / coverplate assembly,
- and mounting method used to attach the assembly to the press platen.

The no-load FREQUENCY readings should be in the 3.0 MHz to 3.7 MHz range if the coaxial cable from the electrode/coverplate assembly is disconnected from the BNC connector on the oscillator enclosure.

The base-line FREQUENCY readings should be in the 2.4 MHz to 3.0 MHz range if the coaxial cable from the electrode/coverplate assembly is connected to the BNC connector on the oscillator enclosure.

The Difference (Delta) reading in the last column should be +/- 3 maximum. The Difference reading is calculated from the difference between an initial reference frequency reading that is followed by an additional test reading at a fixed interval.

Stability Tests for various FORTÉ Systems:

Stability Test for FORTÉ Series X585 and X590 Systems:

While on-line, press the "T" on the keyboard to activate the Oscillator Test Command and note the Frequency and Difference measurements that are displayed.

Stability Test for FORTÉ Series X790 System (DOS):

While on-line, select the DIAGNOSTICS Menu or the F2 Test Commands, highlight the Oscillator Test Command in the pop-up menu, and press the "Enter" key on the keyboard to activate the Oscillator Test Command. Note the Frequency and Difference measurements that are displayed. The Difference (Delta) reading in the last column should be +/- 3 maximum.

Stability Test for FORTÉ Series X760 System (Windows XP):

While on-line, select the DEVICES Command from the SETUP Menu. Highlight OSCILLATOR in the device list and press the TEST button. The FORTE (Difference between UPCOUNT and DOWNCOUNT frequencies), UPCOUNT (Initial Reference Frequency), and DOWNCOUNT (Final Test Frequency) will be displayed

Production Line Scale Check:

Since the FORTÉ measurement depends on the both a frequency reading and the weight of the material under test, the operation of the weighing scale must be checked monthly or quarterly by the local "weights and measures" authority, or by a certified scale service company. In addition, the operators should perform regular scale checks by using "calibrated" test weights in the weight range of the material being tested.

The scale display should accurately display the total amount of the calibrated test weights placed on the weigh platform and then return to “zero” (0.000) when the platform is empty.

The Test Command in the FORTÉ DOS and Windows XP-based systems both contain utilities to test communication with the scale.

4 CALIBRATION

Section 2 above describes how the Forte system functions and how the FORTÉ number is obtained. Calibration is the process that correlates the bale weight and the FORTÉ number to the bale moisture. The data needed for calibration includes the bale weight, the associated FORTÉ number, and the laboratory moisture for each sample bale selected. The weights and FORTÉ numbers are readily obtained from production. It requires a considerable effort to obtain valid results in determining the laboratory moisture of the bales. A good initial calibration effort will eliminate the need for any re-calibration.

4.1 BALE SELECTION AND DATA COLLECTION

In order to achieve a satisfactory calibration of the Forte system, the sample bales selected must cover the full moisture range that occurs in normal production. The inclusion of wet bales, normal bales, and dry bales is necessary to minimize the effect of measurement errors, and to eliminate the use of extrapolation in the calculations.

The collection of good raw data, i.e. measured data, is the key to a good calibration. The bale weight and FORTÉ number are easily obtained and are accurate measurements. The wet weights and the dry weights of the bale samples are more difficult to obtain and, because of sample handling, less accurate.

4.1.1 SELECTING SAMPLE BALES

Select sample bales from production at the desired moisture levels and assign a unique bale sample number to each bale. For sheet pulp systems, select the bales at the layboy. Unless edge slitters are used at the dry end, do not use the drop end bales for calibration. The sheet size of these bales may differ from the inside bales.

For flash dried pulp, bales may be selected after the press-cycle provided that the weight and FORTÉ number data are available. The advantage in selecting the bales at this point is the FORTÉ number is known and indicates the moisture level.

4.1.2 SAMPLE BALE DATA

When the selected bale is on the scale conveyor, record the weight. The FORTÉ number is available on the system schematic page when displayed on the monitor. Record the FORTÉ number for the selected bale after it has been pressed.

4.1.3 LABORATORY BALE SAMPLES

Laboratory samples must be collected from each selected bale in order to determine the bale moisture. The method for collecting will vary depending on whether the pulp is flash dried or sheet. If sheet pulp, sample sheets are collected from the layboy. For flash dried pulp, the samples are taken after the bale has been pressed.

For sheet pulp, if a Sunds type layboy is used, samples from the selected bale can be collected during the build-up on the layboy. If the layboy design does not provide for removal of sheets during bale build-up, samples can be taken after pressing as is the case in flash dried pulp.

4.1.3.1 COLLECTING SHEET SAMPLES AT LAYBOY

Samples collected at the layboy must be placed in plastic bags to preserve the moisture. The tare weight of each bag must be recorded on the bag prior to collecting the samples. The sample number, usually the selected bale number plus a dash number for the sample, should also be recorded.

Before collecting samples at the layboy you must have a cutting board, a razor-sharp knife, the plastic bags mentioned above, and elastic bands for sealing. It is recommended that operators be used to remove the sheets during bale build-up, as they are more adept at this task than laboratory personnel. The laboratory personnel can cut the sample strip, place it in the proper plastic bag and seal it.

As the bale build-up is in process, the operator removes a sheet at approximately each 10% of the build-up and hands it to the laboratory personnel. The laboratory person quickly cuts a 3 to 4-inch wide strip from the sheet. The strip should be cut from the sheet perpendicular to the sheet flow direction. The strip should be placed in the appropriate plastic bag, with the excess air removed from the bag. Twist the end of the bag, fold the twisted end, and seal it with the elastic band. Each sample strip should weigh approximately 75 to 125 grams.

This process is repeated until ten (10) sample strips have been collected for each selected bale. This procedure can be accomplished on two or more bales in the same drop, depending on sheet speed and bale build-up time.

4.1.3.2 COLLECTING SHEET SAMPLES AFTER BALE PRESS

The preparation for collecting samples after the bale press is the same as for collecting samples at the layboy, except the cutting board is not required. After the selected bale leaves the press, stop the conveyor line. Remove approximately 10% from the top of the bale. With the razor knife cut a 3 to 4-inch wide strip from the top sheet perpendicular to the sheet flow direction. Place the strip in the appropriate plastic bag, remove the excess air from the bag, twist the end of the bag, fold the twisted end and seal it with the elastic band. Each sample strip should weigh 75 to 125 grams.

Remove another 20% of the bale and repeat the above to collect a second sample strip. Continue removing 20% of the bale and collecting sample strips until at least five have been collected.

The sections of the bale that has been removed may be re-stacked on the conveyor and processed as a production bale or they may be returned to the re-pulper.

4.1.3.3 COLLECTING FLASH DRIED PULP SAMPLES

For flash dried pulp bales, the selected bale is removed from the conveyor line after the bale press. Utilizing the brute force method, hammer and chisel, the bale is broken apart. Samples are taken from each cookie or slab, plus additional samples to total at least five samples per bale. Identified and tared sample plastic bags are prepared ahead of time.

When the selected bale has been removed from the conveyor line, separate the cookies with the hammer and chisel. From each cookie collect a sample of at least 100 grams. Each sample should be taken from a different side of the bale. Place each sample in the appropriate plastic bag, remove the excess air, twist the end, fold the end, and seal it. Take additional samples from each bale at random locations until at least five samples have been collected.

4.1.4 LABORATORY MEASUREMENTS

Take the collected and identified samples to the laboratory for weight measurements. The scale or balance used for measuring the weights should have a resolution of one milligram. The scale used for measuring the sample wet weight must also be used for measuring the sample dry weight. The plastic sample bags must also be tared on the same scale.

4.1.4.1 SHEET PULP SAMPLE STRIP WEIGHTS

Weigh and record the weight of each sample strip in its plastic bag with the elastic band removed. Subtract the tare weight of the bag and record the result as the sample strip wet weight. Once this weight is recorded remove the sample strip from the plastic bag and record the sample number and wet weight directly on the strip. Repeat this process for every sample strip collected.

Accordion-fold each sample strip in preparation for drying. Place the sample strips in a drying oven set at a temperature of 105°C. The sample strips should be positioned to permit the maximum airflow at its surface. The circulating air in the oven must be dry and the oven door must not be opened once the drying cycle starts. Dry the samples for 16 hours, or until there are no measurable weight losses in the samples after drying an additional two hours.

When the drying cycle is complete remove each sample from the oven one at a time, place it in a tared container to minimize convection current effects and weigh the sample. Record the dry weight. Repeat this process for each sample strip.

4.1.4.2 FLASH DRIED SAMPLE WEIGHTS

Prepare a number of metal drying dishes with tare weights and sample numbers corresponding to the samples. One at a time, remove the flash dried pulp sample from the plastic bag, break open the sample and take approximately 25 grams from the center and place it in the appropriate sample drying dish. Immediately weigh and record the weight of the sample and dish. Repeat this procedure for all flash dried pulp samples.

Subtract the drying dish tare from the weight of the drying dish and sample and record this as the sample wet weight.

Place all samples in a drying oven with the temperature set at 105° C allowing the air to flow around the samples without causing any disturbance of the pulp. Once the samples are in the oven and the drying cycle has started do not open the door until the drying cycle is complete. Allow the samples to dry overnight.

In the morning remove the samples from the oven one at a time, weigh the sample and dish, and record this weight. Repeat this procedure for every sample.

Subtract the drying dish tare from the weight of the drying dish and sample and record this as the sample dry weight.

4.2 DETERMINATION OF MOISTURE FOR SELECTED PULP BALES

For each sheet pulp sample strip or each flash dried sample calculate the percent oven dry as follows:

%OD = 100 x sample dry weight / sample wet weight

If percent air dry is used as the measure of moisture, calculate the percent air dry as follows:

%AD = (100/0.9) x sample dry weight / sample wet weight

Determine the mean and standard deviation for all samples collected from each selected bale. Program routines for these calculations are available in most statistical calculators. Consider the mean as the laboratory moisture for the selected bale.

4.3 DETERMINATION OF THE CALIBRATION CONSTANTS

Now that the necessary data for the determination of the calibration constants has been collected, performing a linear regression on the data will determine the calibration constants. The FORTÉ calibration routine will graph the data and determine the calibration constants. The graph is a good indication of the quality of the calibration.

The linear regression can also be done on a number of computer spreadsheet programs. These programs give additional parameters such as the correlation coefficient, the variance or coefficient of determination, and the standard error of Y, which qualify the calibration.

4.4 QUALITY OF THE CALIBRATION

As stated earlier, the selected bales for calibration should cover the range of moistures expected in normal production. The number of bales required for a good calibration is between 10 and 20 bales. However, if the results are not adequate additional bales must be sampled. Some calibrations may take 50 or more bales.

The correlation coefficient, r, is the parameter normally used as the measure of quality of a linear regression analysis. A value of r better than -0.97 is considered a good calibration for pulp. The range of moisture of the sample bales affects the value of r and could affect the interpretation of the correlation coefficient.

The standard error of Y, (S_y), is a better measure of the quality of the linear regression analysis. The units are in percent moisture - the same units as the bale measurements. The value is not affected by the range of moistures of the sample bales. The standard error of Y is the mean of the differences of the measured and calculated values of moistures of the sample bales and represents the standard deviation of those values.

Comparing the standard error of Y with the average standard deviation of the samples for each bale is a very good measure of the quality of the calibration. The average standard deviation of the sample bales represents the error in the laboratory measurement of the bale moisture. The standard error of Y includes this error. If the standard deviation of the sample bales and the standard error of Y are close in value, this means the FORTÉ system is not introducing any measurable error.

Expected values of calibration parameters are correlation coefficients of -0.97 to -0.99, average standard deviations of sample bales of 0.4 to 0.7, and standard errors of Y of 0.4 to 0.7. If the results of your calibration are in these ranges you can consider your calibration as valid.

5 CALIBRATION PARAMETER EQUATIONS

Below are the terms and equations required to statistically determine the calibration constants, the correlation coefficient, the variance or coefficient of determination, and the standard error of Y.

The terms required in the equations include the following:

Σx = sum of the logarithms (F/W)
Σy = sum of the laboratory moistures
Σxy = sum of the products (logarithms x moistures)
Σx^2 = sum of the squares of the logarithms (F/W)
Σy^2 = sum of the squares of the laboratory moistures
N = the number of samples

Slope Constant, $A = (N\Sigma xy - \Sigma x\Sigma y)/[N\Sigma x^2 - (\Sigma x)^2]$

Intercept Constant, $B = (\Sigma y\Sigma x^2 - \Sigma x\Sigma xy)/[N\Sigma x^2 - (\Sigma x)^2]$

Corr Coef, $r = (N\Sigma xy - \Sigma x\Sigma y)/\{[N\Sigma x^2 - (\Sigma x)^2][N\Sigma y^2 - (\Sigma y)^2]\}^{(2)}$

The Variance is equal to the square of the correlation coefficient i.e. r^2.

Standard Error of Y, $S_y = [\Sigma(y - y_c)^2/N]^{(2)}$
where y_c = calculated value of moisture from the regression equation.