Consistency Measurement: The Foundation For Accurate Dilution Control

At all levels throughout the pulp and paper making process

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ABSTRACT

Keeping stock consistency constant - at different levels for different steps in the pulp and paper making process - has always been, and will remain, one of the most important control functions.

No consistency control loop can ever be better than the sensor that measures the fiber content in a moving pulp slurry. The signal we get from consistency sensors depends on the relation between certain pulp properties and the dry fiber content per volume unit of the suspension. The best correlation with true consistency is usually found in the fiber network strength and the optical characteristics of a given pulp. Most in-line consistency sensors are designed to work on these principles. They are either rotating or stationary mechanical sensors for shear force measurement, or electro-optical sensors for the measurement of light reflection. These pulp properties vary with consistency, but unfortunately, they also change with process variables which are not consistency dependent, e.g. flow variations, variations in filler contents, and blend changes.

Due to the great economic significance of accurate consistency control, it is essential to fully understand the possibilities and limits of the various applications.

This paper will concentrate on the practical aspects of dilution, and discuss the benefits of different sensors.

KEYWORDS:

Consistency
Shear Force
Optical
Fibre Network
Dilution
Control Loop

GENERAL

In order to evaluate the performance of a specific consistency transmitter, one has to consider the complete control loop. The consistency transmitter is only one of several components, which all have to work together for good overall control results. We also have to consider the importance of controllers, DCS systems, dilution valves, installation points, sample taking and testing, type of stock, flows, etc. Any one of the above can destroy an otherwise good control loop. Then there are, as mentioned earlier, different types of consistency transmitters, and special care has to be taken for proper selection.

THE SYSTEM

The most common system today is illustrated in Figure 1. This arrangement offers a very short physical time lag, with dilution water (8) before the pump and mixing through the pump with the consistency transmitter only three to five feet downstream. A transportation time of less than one second from dilution point to measuring point is obtainable. Most pumps presently used in these types of applications are capable of adequate mixing action.

Should a pump not be available, or if it is not suitable for the mixing needed, an approach like Figure 2 is recommended. Here, a dedicated mixer is installed. The dilution water is added on the opposite side of the pipe into the turning mixerhead, and ensures good mixing of water and fibers. Comparing Fig. 1 and Fig. 2 as far as the overall control loop, we can see that they are the same, i.e. the signal from the transmitter, in most cases 4 - 20 mA, is fed into a controller (4), where it is compared to a set point, and the difference is transmitted to the actuator (6) on the dilution valve for dilution water adjustment.

Figure 1

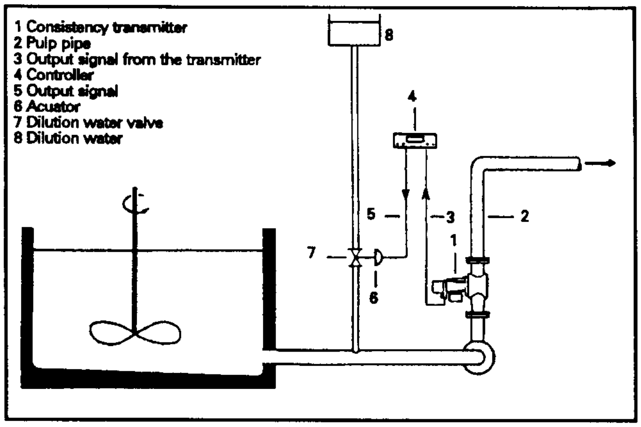
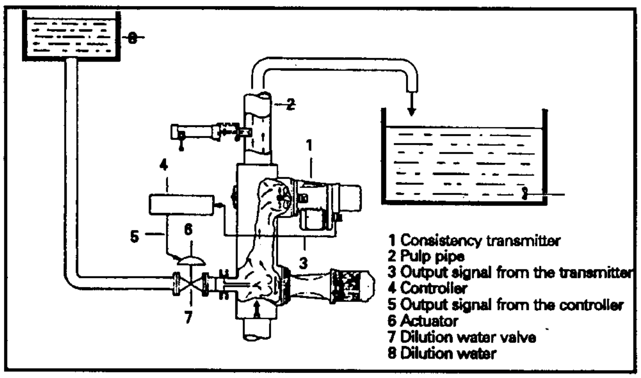


Figure 2



CONTROL CONSIDERATIONS

Once the most suitable sensor is selected, the other components need to be chosen, sized and installed. The control valve must be properly sized for optimum control. An oversized valve will decrease the responsiveness of the loop, while a valve that is too small simply will not be able to handle the high peaks. As a rule of thumb, at least 30 - 50% of the total pressure drop ought to be across the dilution valve to ensure proper operation.

In applications with large swings in either consistency or stock flows, two valves can be used: a coarse (major) valve for the "base load" and a trim valve for fine adjustments. The major valve can be adjusted manually or ratioed with the trim. When tuning the loop, it is important that good balance between transmitter span and controller gain is obtained (Fig. 3).

The transmitter is normally set to approximately a 2% consistency span. However, in stock flow with reasonably smooth consistency, the span can be narrowed. Should the measuring span be too narrow, loop stability can only be achieved by low gain values in the controller. The controller is then too slow to respond to the highly responsive transmitter output. A well balanced control loop will generally result in a controller gain of 0.75 to 1.0 with a reset value appropriate to the loop dynamics.

Sensor location must also be optimized. Typically, the transport lag time should not exceed 10 seconds between the dilution point and the measuring point. Beyond the 10 second mark, the risk of oscillation in the loop increases rapidly (Fig. 4).

Figure 3

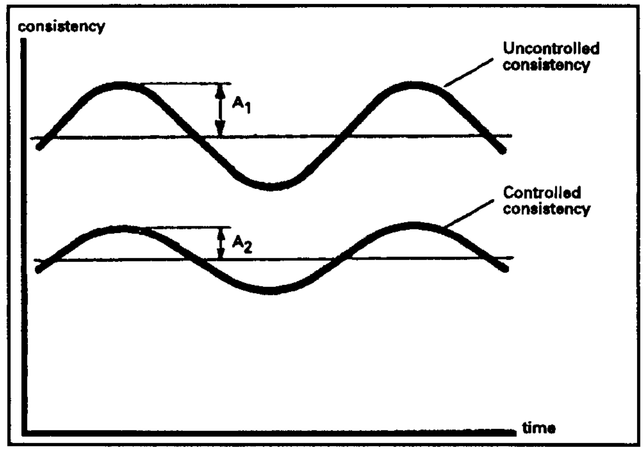
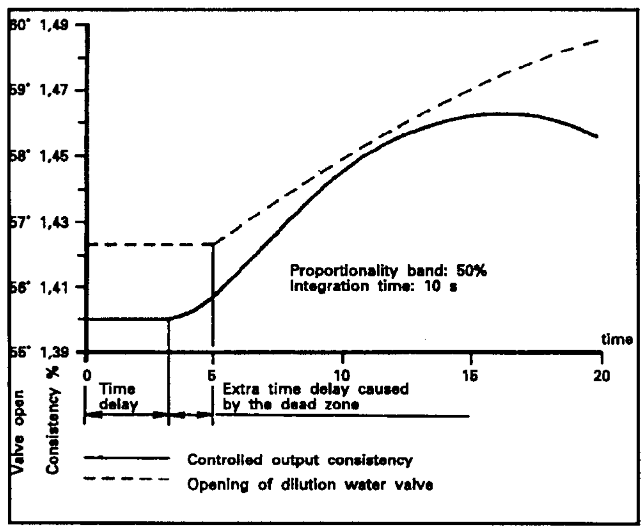


Figure 4



THE TRANSMITTER

In order to be able to select the most suitable transmitter for any given application, it is important to understand how the different types work and what their short- comings and strengths are. We will describe rotating, stationary blade, moving blade and optical type transmitters, and look at where to use or not use any given type and why.

For any sensor we can state that it is important for the sensor to see as large a representative sample volume as possible. This will statistically increase the validity of the measurement. Furthermore, it should not be sensitive to anything but changes in fibre concentration.

The optical consistency transmitter is normally inserted into the main pulp line through a ball valve. Optical units installed this way mostly work on a back scattered light principle. An LED emits a tightly defined infrared light beam through a quartz window into the pulp stream. The backscattered light is received by two photodetectors at different angles, indirect and direct. The indirect is used for intensity control of the LED and the direct is the actual measurement. By ratioing the two signals, compensation for contamination build-up on the sensor window is achieved. The total measuring range is 0.5% to 7%.

Other optical consistency transmitters work on a light transmission principle. They are normally installed in a sample line or bypass line. Since all optical sensors are sensitive to more than just pulp consistency, great care has to be taken when analyzing a potential application. The unit is not sensitive to flow changes, but changes in furnish such as hardwood or softwood, sawdust or groundwood can affect the measurement. There can also be influences from additives, fillers, TIO_2 and clay.

The advantage offered by an in-line optical sensor is accurate, repeatable measurements in suitable applications. Also, ease of installation, calibration, operation and overall maintenance are very favorable.

Some recommended applications for in-line optical transmitters:

- High Density Storage, Washed Stock
- Low Density Storage, Washed Stock
- Pulp Machine Application
- Brown Stock to Bleach Plant
- TMP and CTMP, Single Freeness Range
- Stone Groundwood
- Kraft and Sulfite Stock, Bleached-Unbleached

The stationary blade is generally a simple, inexpensive solution to applications with lower accuracy requirements. The working range is smaller, 1.5% - 8% theoretically, 2% - 6% practically. Mounted in-line where the stock flow creates a "drag" force directly on the blade, these types of sensors are known to be sensitive to flow changes. This flow dependency has almost been eliminated on the newest version, a moving blade type transmitter. This transmitter is protected by a deflector that forces the pulp stock on to the sides of the blade, which strokes and creates a shear force as it moves through the fiber network. The higher the consistency the longer the stroke time. The stroke time is measured optically. Flow changes within 1-15 ft/s have little or no effect. Like the optical type, the blade shows some sensitivity to changes in fiber length, freeness and solids content, but to a much lesser degree.

Recommended applications are:

- High Density Storage
- Low Density Storage
- Broke
- Repulpers
- Brown Stock to Bleach Plants

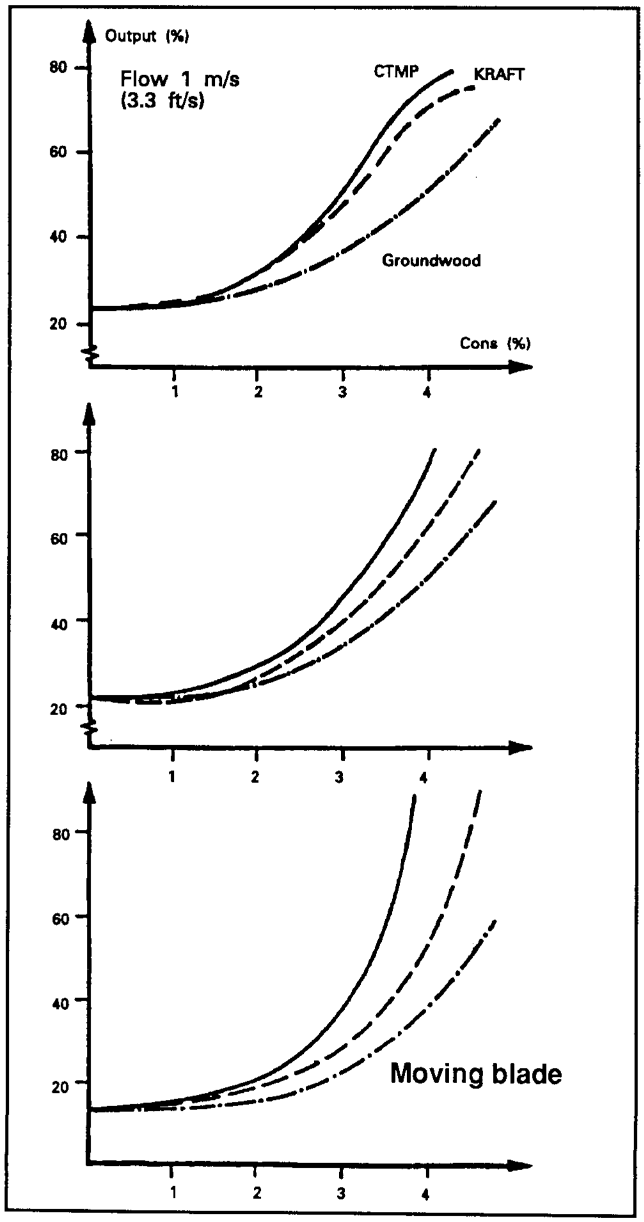
Finally, the most versatile consistency transmitter is the rotating transmitter. With a total range of 0.1% - 16%, which includes almost any application in a pulp & paper mill, this unit is a safe choice wherever used. Although mounted in-line, it's sensing element is slightly off to the side of the main flow. The rotating sensing element is connected to a "stock pump" through a flexible coupling. This "stock pump" pulls stock from the main flow across the sensor, thereby creating a fixed flow pattern. This makes the transmitter insensitive to flow changes and turbulence in the pipe. The shear force torque, created as the sensor cuts through the fiber network, is transferred to the transducer section and converted to an electrical output signal.

The mechanical/electrical consistency transmitter works on the forced balance principle. By changing the sensing element, the transmitter can handle any application from the blow line all the way through to the paper machine.

APPLICATION CONSIDERATIONS

The ideal consistency transmitter has a very wide working range, from low to high consistencies. The signal response is linear and is sensitive only to fiber concentration. However, with existing technologies and methods, we have to make

Figure 5



compromises. All existing consistency transmitters are more or less sensitive to the installation configuration and the characteristics of the pulp. Sample taking and lab test procedures are also very important factors for maximum results.

In an effort to throw some light on some of the variables that we need to be knowledgeable about, we will go through a number of graphs showing some of the dependencies and how they affect the different instruments.

If we start by looking at flow dependency, we will notice that as we stated earlier, stationary blades are the most sensitive. In Figure 5, two stationary blades (two top graphs) are compared to a moving blade (bottom graph) under a fixed flow of 3.3 ft/s. The stocks measured are CTMP, kraft and groundwood. We can see that all three sensors give a good response from approximately 2% consistency and up.

The same type comparison is repeated between the rotating and optical transmitters (fig. 6). Both are working well, as expected. One other observation from these two graphs regards the optical transmitter's response to different furnishes compared with a mechanical sensor. Groundwood pulp is optically seen as a more dense pulp due to its short fibers, with a higher light reflectance and increased output.

For the rotating transmitter, it's the CTMP pulp with its high fiber network strength that gives the highest output due to a higher shear force.

Figure 6

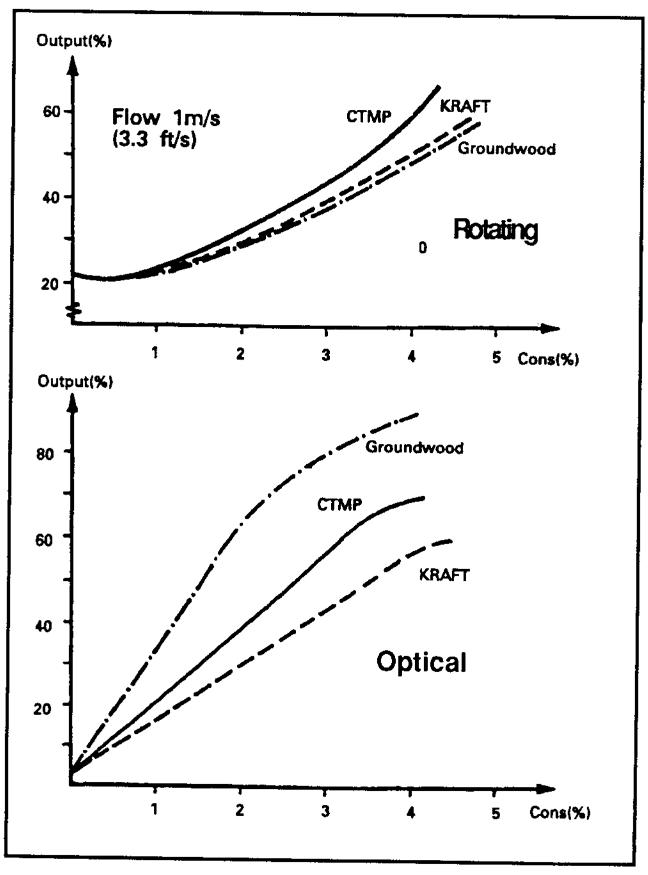
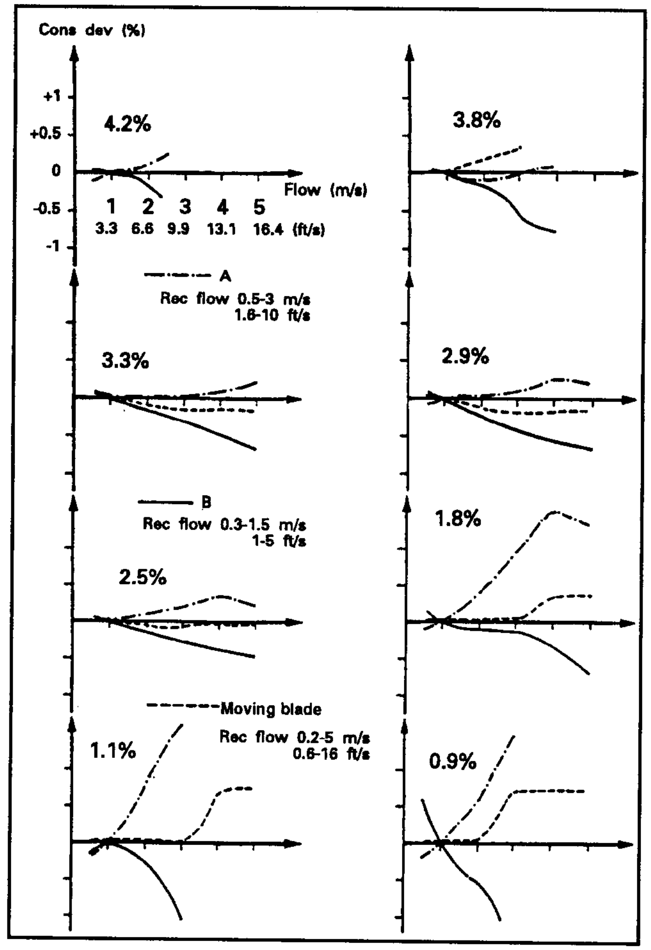


Figure 7



Figures 7 and 8 show the same transmitters compared on CTMP pulp at different consistencies and varying flow. The total flow range is between 1.5 ft/s to 15 ft/s. Generally, the moving blade transmitter gives a better signal than the stationary blades, although both are subject to a loss of accuracy fairly fast below the 2% mark. On the other hand, the rotating and the optical transmitters show practically no flow sensitivity at all.

In groundwood (figs. 9 and 10), we can see that the moving blade transmitter is much more accurate than the stationary blade type. The reason is that the fiber network strength is lower, and the flow change has more effect than a consistency change. The moving blade type, meanwhile, strokes and cuts through the pulp, creating a shear force rather than a "drag" on the sensor. Thereby, it keeps the ratio of consistency/flow strength on the consistency side.

Again, the rotating and optical transmitters show little or no effect from flow.

The effect of freeness changes (Figure 11), is decreasing with an increase in refining, with its highest influence in the 15 - 40° SR range. The test was done on kraft with a rotating transmitter.

Figure 8

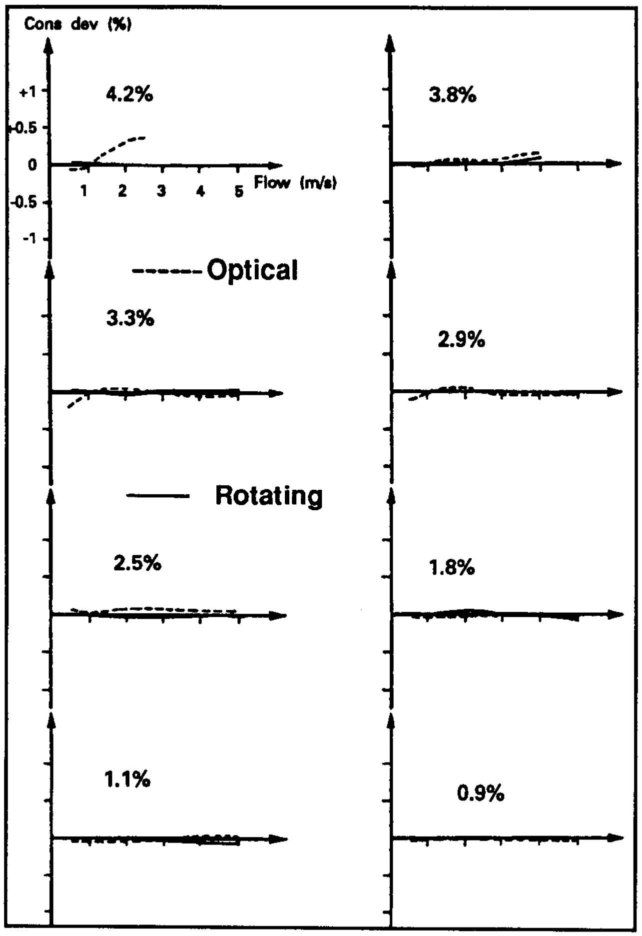


Figure 9

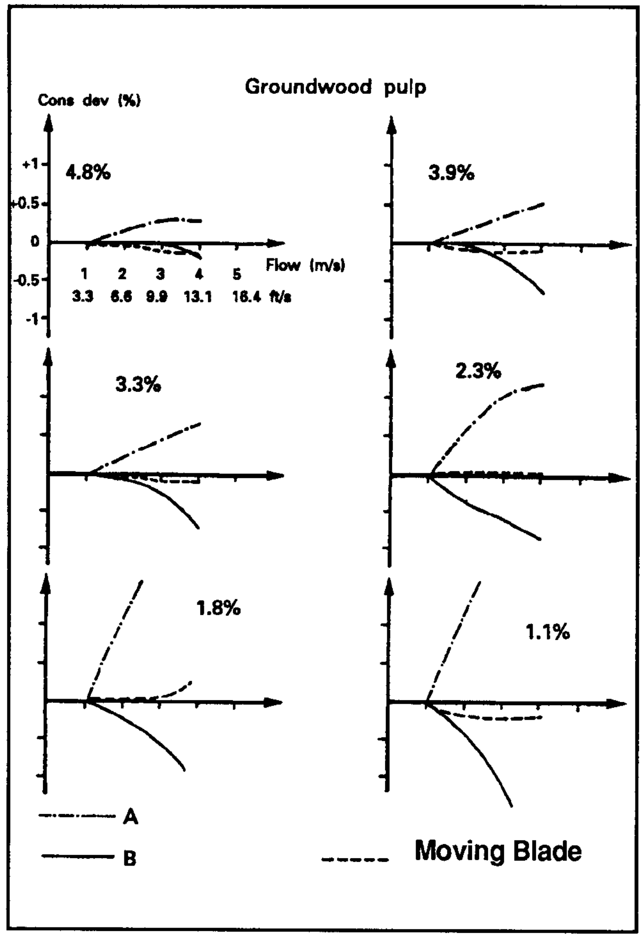


Figure 10

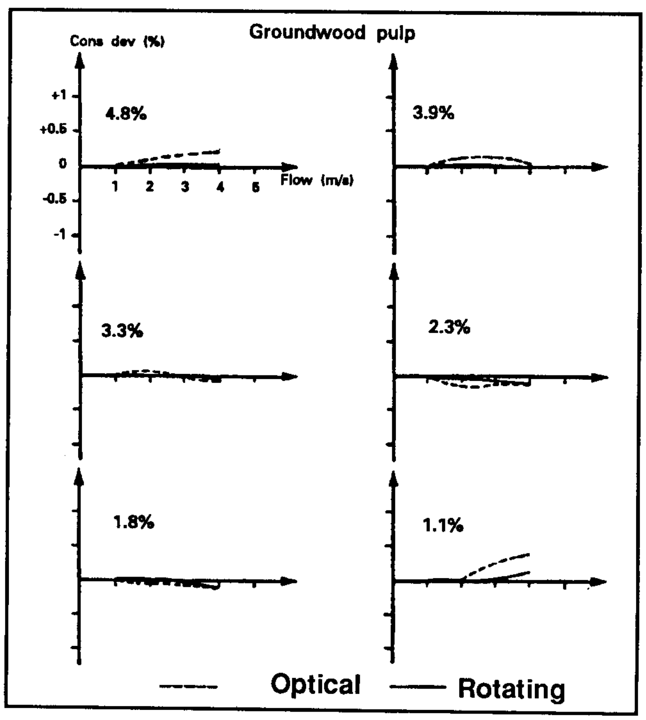


Figure 11

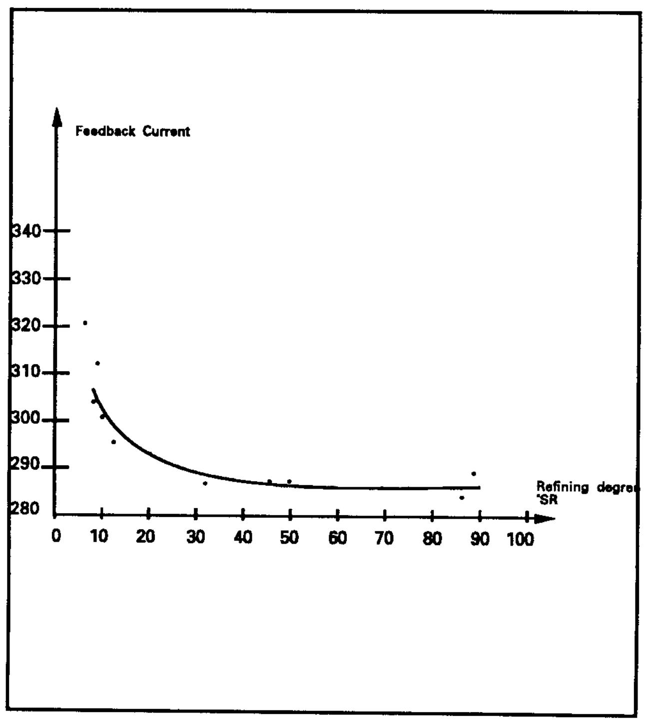


Figure 12

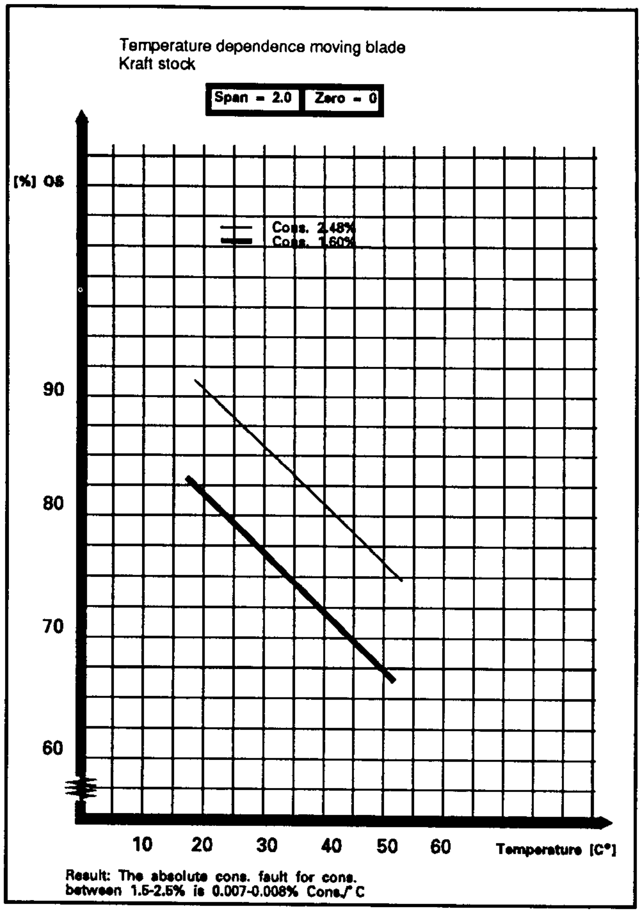


Figure 13

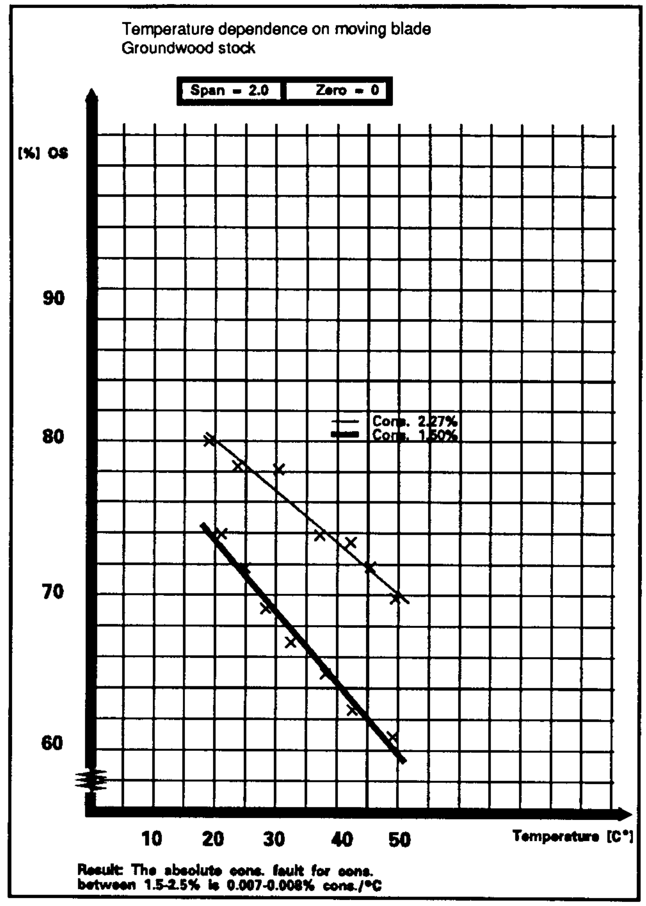


Figure 14

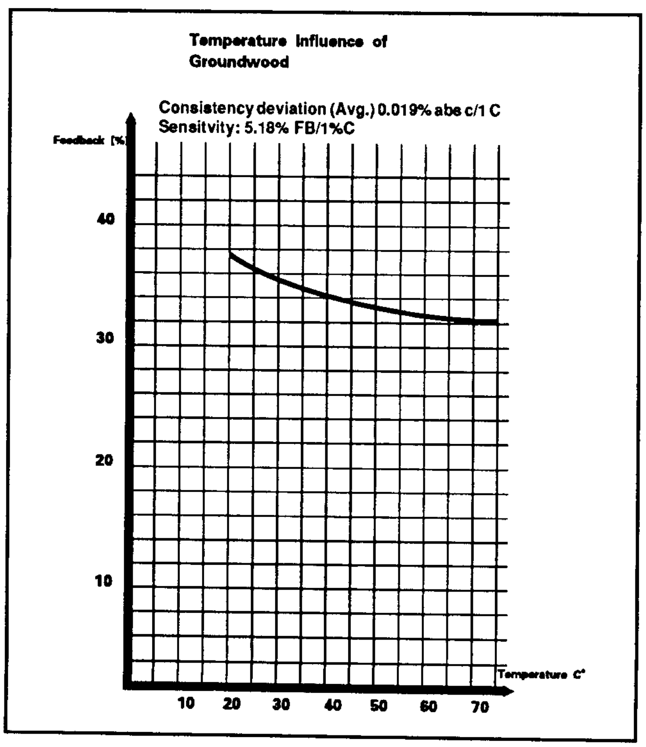


Figure 15

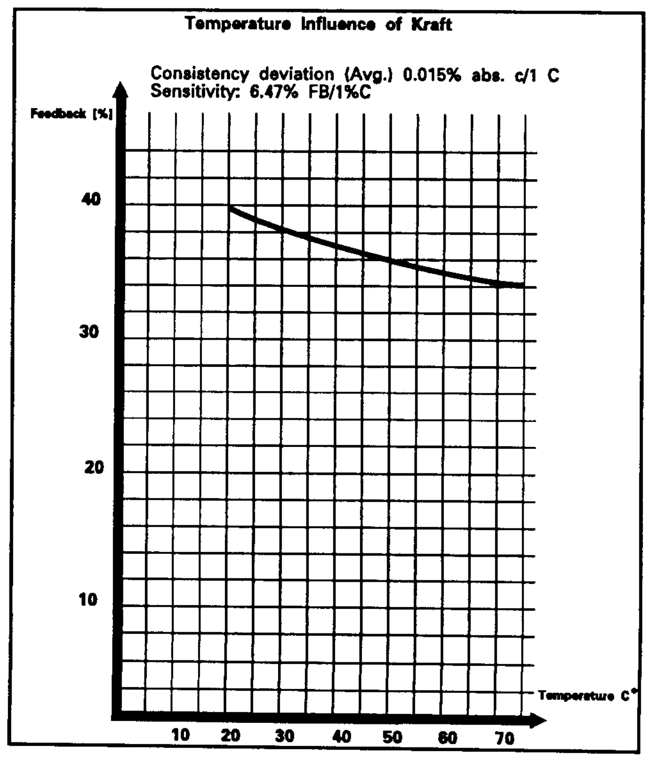


Figure 16

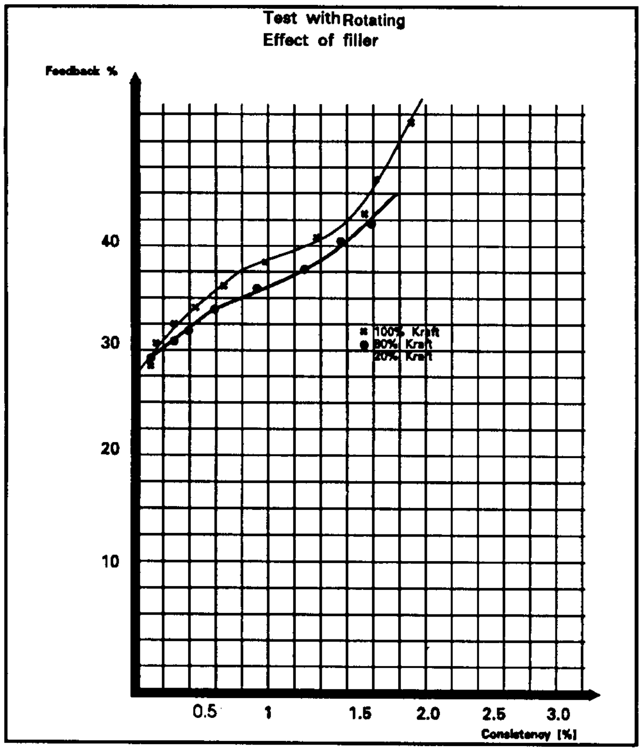


Figure 17

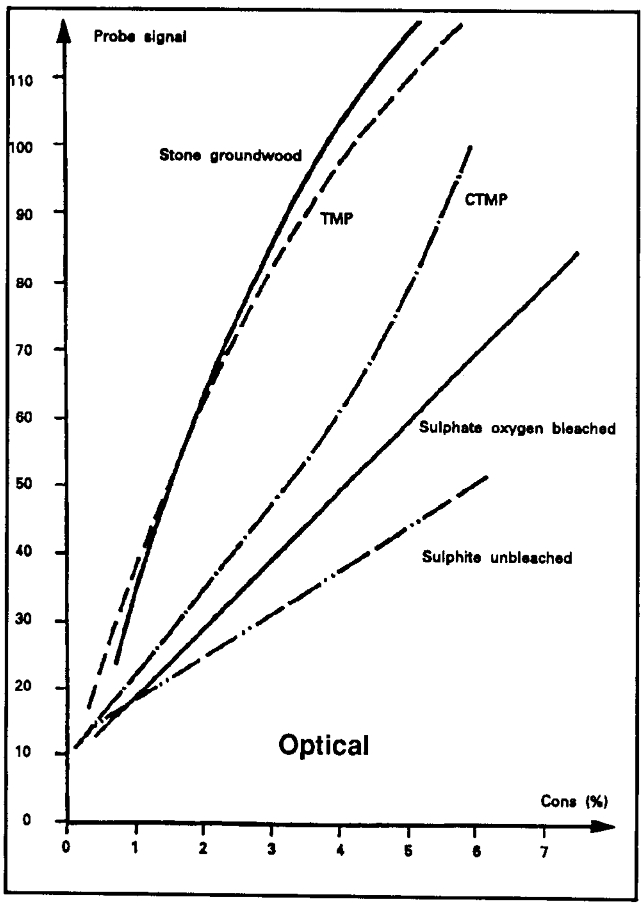


Figure 18

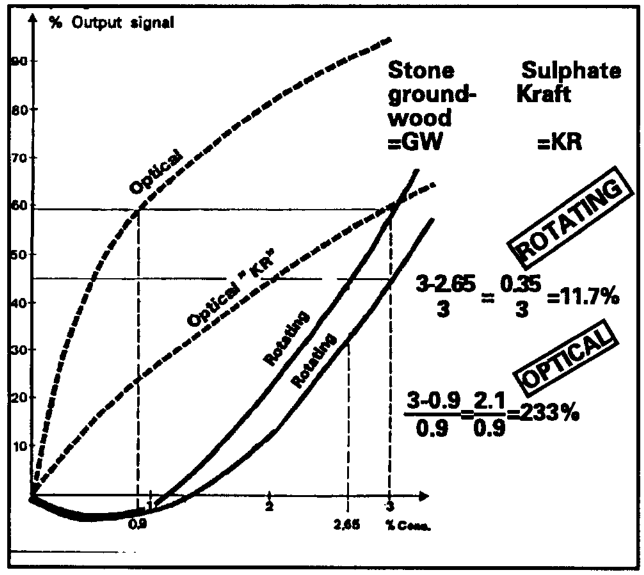
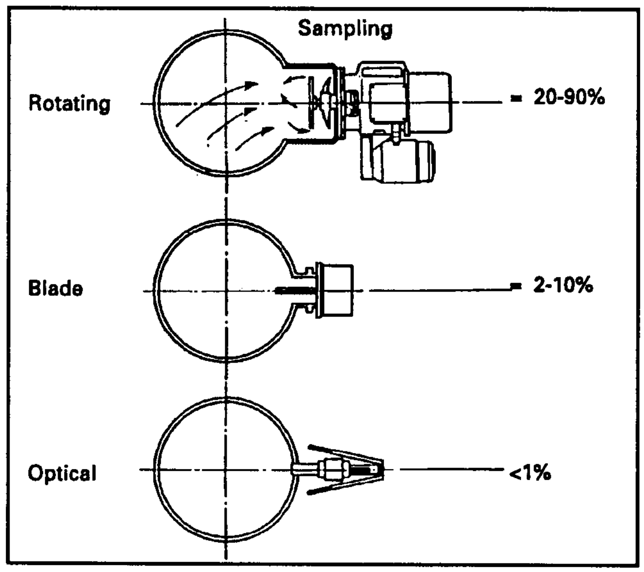


Figure 19



Several tests were performed on how temperature can affect the consistency measurement (Figures 12 and 13). Visually, the graphs seem to indicate a great temperature dependency. However, when the actual consistency change is divided over the actual temperature change, it becomes clear that the temperature influence is negligible in most practical applications (Figures 14 and 15). The influence of filler in kraft was tested using a rotating transmitter (Figure 16). As the filler is added, the shear force decreases slightly. Of course, an optical sensor would have responded more drastically.

Figure 20

All existing consistency transmitters are more or less sensitive to installation configuration and variations and properties in the pulp suspension. A simple listing of various transmitter properties can be made in the following way.

5 represents good and 1 poor performance.

	MEK-2000	MBT-100	Stationary Blade	Stationary Blade	Optioon
Sampling	5	2	2	2	1
Velocity changes	4-5	2-4	1-3	1-2	4
Sensitivity	4-5	2-3	2	2-3	4-5
Consistency range	5	3	3	3	4
Linearity	4	2	2	2	5
Grade change	4-5	2-3	3	3	1
Freeness	4-5	2-3	2-3	2-3	1
Colour	5	5	5	5	3
Brightness	5	5	5	5	3
Fillers content	4-5	2-3	2-3	2-3	1
Fines content	5	5	5	5	1
Temperature	3	3	3	3	3
Black liquor content	5	5	5	5	1

In Figure 17, we can see that the optical transmitter has a good linear response to the different furnishes. However, there is a drastic difference from grade to grade. The darker, longer fiber type pulps absorb more light and thereby reduce the reflectance, thus causing a decrease in response. While on stone groundwood, which is not so dark and has short fibers, the response is quite different. By comparing the optical behavior with the mechanical (Figure 18), it is clear that the choice of transmitters is dependent on the specific application. Figure 18 shows an optical transmitter applied at 3% consistency kraft, which gives a certain output. If we keep the same consistency, 3%, but change the furnish to groundwood, the instrument shows the same output for a consistency as low as 0.9%. The rotating on the other hand, shows a very small dependence on the same drastic furnish change.

In conclusion, it is clear that sensitivity to consistency changes varies with different types of sensors, as does sensitivity to other undesirable variables present in the pulp stream. Sampling, both by the instrument and the lab tester, is important. Figure 19 illustrates how much of the actual stock flow the specific sensors generally sample. The larger the sample the better.

Many other variables influence consistency measurement to some degree, but there is simply not enough time to discuss them all in detail. Therefore, we have created a summary (Figure 20), which can be used as a general guide for selection of the proper instrument.