

A REVIEW OF INSTRUMENTS DEVELOPED BY SMRI FOR FACTORY MEASUREMENTS

MA GOOCH, VC STONE AND RWH VON FINTEL

Sugar Milling Research Institute, Durban, South Africa

Abstract

Over the past 10 years the SMRI has developed a number of instruments for making process measurements in factories. In most cases the instruments were developed because commercial instruments were unavailable or unsuitable for use in the harsh environment of sugar factories. This paper describes equipment developed by the SMRI for torque measurement, conductivity tracer testing, volumetric measurement on a conveyor, measurement of total suspended solids in a mud mixer, measurement of mud consistency from a clarifier, evaporator scaling, Preparation Index, mill lift, juice clarity, clarifier mud level and pressure in pressure feeder chutes. A brief description of each instrument or method, and some application examples, are given.

Introduction

The instruments reviewed in this paper fall into the following categories.

- Consulting tools, viz. tools used mainly for once-off measurements in consulting work. They comprise torque measurement and conductivity tracer testing equipment. The former was built to overcome problems experienced when using older, commercially available equipment. The latter was developed to assist in fault finding and the optimisation of diffusers and clarifiers.
- On-line instrumentation for measuring:
 - volumes on conveyor belts
 - suspended solids in a mud mixer
 - consistency of mud from a clarifier
 - fouling of evaporator tubes
 - mill lift
 - pressure in feeder chutes
 - signals from strain gauges
 - clarity of juice
 - level of mud in clarifiers.
- Preparation index of prepared cane.

Torque measurement equipment

In recent years the Hottinger Baldwin Messtechnik (HBM) MD 3555 receiver and the HBM MT 2555A transmitter were used for torque measurements. This equipment used a capacitive link to transfer data from the transmitter on the rotating shaft to the receiver. This type of installation required an

elaborate aerial and was prone to electrical interference and failure due to moisture around the aerial and the receiver. A new instrument was developed to overcome these difficulties. The new equipment (von Fintel, 1999) makes use of a radio link between the transmitter and receiver and has the following advantages:

- simple aerial configuration
- receiving equipment can be installed far away from hazardous areas (a distance of 70 m was used in a recent trial)
- data transmission is not affected by welding, switching of electrical drives or variable AC drives
- battery life has been increased, allowing longer continuous measurements to be made (up to 11 days).

Tracer testing equipment

A six channel conductivity meter was developed to measure and log six conductivity channels simultaneously because there was no suitable instrument available commercially for this purpose. The six channel conductivity meter shown in Figure 1 was designed and built at the SMRI. All conductivity channels are isolated to enable them to be used in earthed vessels in a factory environment. This instrument is used by the SMRI as a consulting tool to determine the residence time distribution in diffusers or clarifiers.

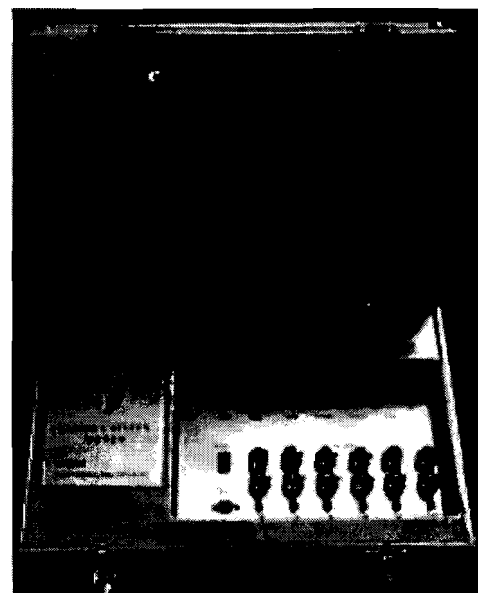


Figure 1. Six channel conductivity meter.

Volumetric measurements on a conveyor belt

The SMRI was asked to investigate whether there was an alternative method of measuring the volume of cane and bagasse on conveyor belts because the belt weighers that were commercially available infer the volume from mass. The result was an instrument that was designed and built to measure the volume of bagasse conveyed on a belt by means of 'fingers' sensing the height of the material on the conveyor belt. The first prototype was installed at the old Illovo mill site on the chopped cane conveyor so that the measurements could be compared with the readings of a belt weigher further down the line. Although the prototype worked in principle, it failed mechanically due to all the moving parts becoming coated with juice. The juice and dust caused failure of the lubrication, leading to seizure of the mechanical parts.

A new design based on the same principle, having no rotating or sliding bearings, was built. The number of 'fingers' was reduced to five and they were spring mounted on a horizontal bar running across the conveyor. Rubber bushes supported the horizontal bar, eliminating the need for lubricating the bearings. As the volume on the conveyor increased, the 'fingers' were raised. This led to a torque being applied to the horizontal bar, with each finger linearly adding to the torque. Thus the horizontal bar acted as a summing device from which a torque measurement could be read. The torque signal, measured by means of a load cell attached to the horizontal bar, is proportional to the cross sectional area of the volume on the conveyor belt. Cross sectional area multiplied by the belt speed results in a volumetric measurement of the material on the belt.

The new instrument was installed at Illovo and operated satisfactorily, but was later relocated to the Mount Edgecombe sugar mill where it was installed on the conveyor belt leading into the bagasse shed. A second machine was installed on

the conveyor exiting the bagasse shed. Figure 2 shows typical data obtained. During these tests the mill was operating with a varying supply of cane and the graph shows that during the first 90 minutes more bagasse was drawn from the bagasse stores than was produced. After this period, it can be seen that the bagasse drawn from the stores decreased. These measurements can provide a useful on-line stock-take of the bagasse stores.

Measurement of the total suspended solids in a mud mixer

To control the rotating Oliver filters efficiently it is necessary to ensure that the consistency of the mud and bagacillo mixture in the mud mixer is maintained within set limits. Because there was no consistency meter available commercially for this environment, three different methods were tried in order to measure the consistency of mud in the mud mixer. The first approach of measuring the power drawn by the mud mixer motor showed no suitable change as the consistency of mud changed. The second approach to measure the drag on one of the mud mixer paddles failed because of the difficulty of sealing the strain gauges on the paddle. The third approach, which proved successful, is described below.

A consistency probe as shown in Figure 3 was designed to be installed into the side of a mud mixer, with the probe protruding between the paddles. This instrument measured the drag caused by the fluid being rotated by the paddles of the mixer. Assuming that the mixer rotates at a constant speed, the drag force exerted by the rotating mud has been shown to be proportional to the consistency measured as a percentage of total solids. This drag acting on the end of the probe deflects it and the deflection is converted to a 4-20 mA signal (see results in Figure 4). This instrument has worked reliably at Noodsberg mill in controlling the quantity of bagacillo added to the mud mixer.

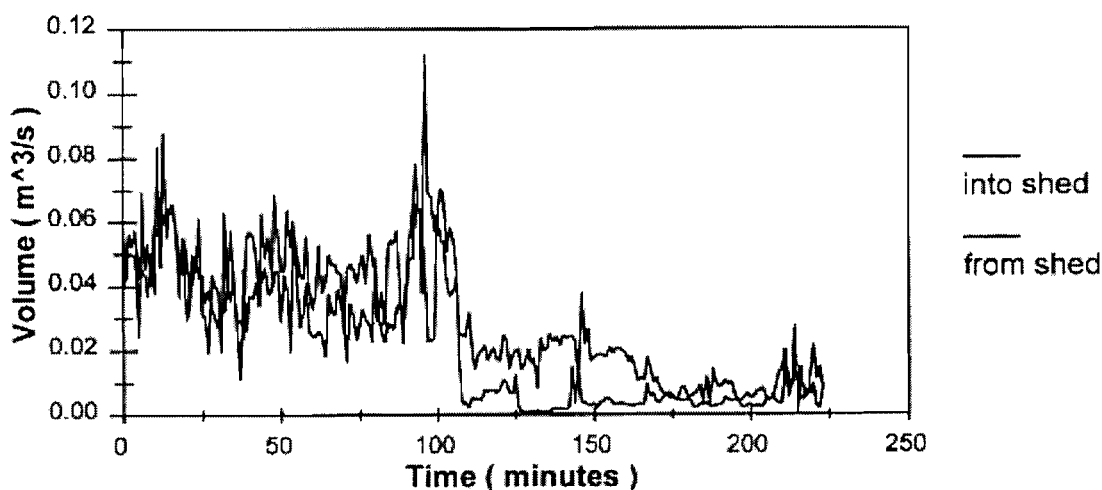


Figure 2. Results of volumetric flow meter.



Figure 3. Mud consistency probe.

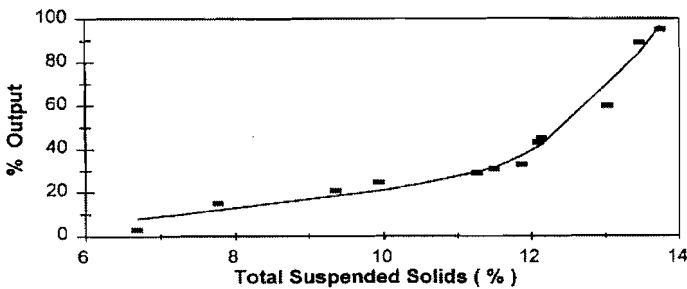


Figure 4. Results as measured by mud consistency probe.

Measurement of mud consistency from a clarifier

When the consistency of mud from the clarifier changes, the ratio of bagacillo to mud in the mud mixer should be adjusted to ensure good operation of the rotating Oliver filters. This has resulted in the need to measure this consistency.

Equipment for measuring the consistency of mud from a clarifier, shown in Figure 5, was constructed and tested. The apparatus makes use of the fact that, for a steady pressure head the velocity of flow of a liquid through a pipe, at a constant temperature, is inversely proportional to consistency measured as a percentage of suspended solids (Gooch,

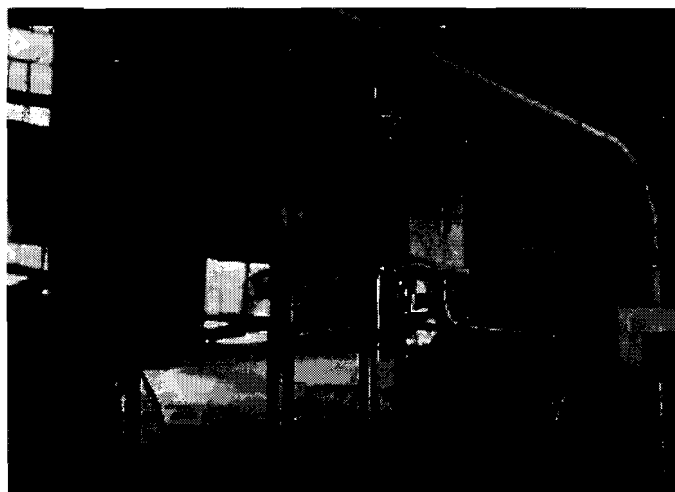


Figure 5. Header tank and venturi installed at Mount Edgecombe mill.

1994). A header tank maintained a constant head height of the mud from a clarifier and a venturi was used to measure the velocity of this mud. Figure 6 shows some results relating the differential pressure output to the percentage of suspended solids obtained when the venturi was installed at the Mount Edgecombe mill.

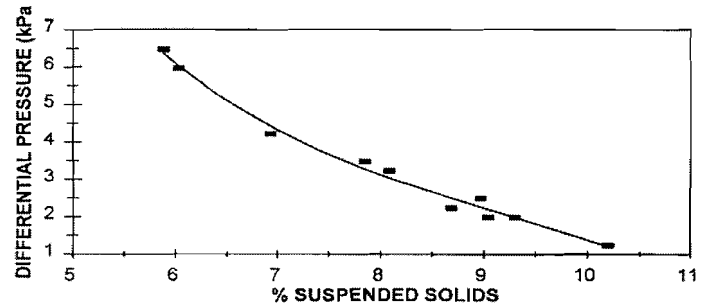


Figure 6. Differential pressure versus % suspended solids.

Scaling probe

A probe has been developed to measure the amount of scaling or, conversely, the effect of chemical cleaning, in evaporators. This instrument has undergone many changes to overcome problems experienced in the field. The original design consisted of an electrically heated stainless steel tube, which was maintained at the temperature of the input steam and immersed in the syrup in the evaporator. Thermocouples were used to measure the tube temperature and a power meter was used to measure the power input to the heater. Knowing the heat input and the temperature difference between the tube and the syrup, the heat transfer coefficient (HTC) could be calculated.

The design was simplified further by applying a constant power of 750 W to a heater inside a stainless steel tube which gave a power density of 15 kW/m² on the tube surface. The temperature differential between the tube and the syrup was measured and the HTC calculated using the fixed input power. This eliminated the expense and complexity of building a controller to drive the heater, and a power meter to measure this power. Figure 7 shows a picture of this instrument and Figure 8 shows a graph of typical results obtained while the probe was installed at Felixton sugar mill. Unfortunately, chemical cleaning was terminated towards the end of last season before the probe could be tested as a monitor of the progress of cleaning.



Figure 7. Final model of the scaling probe.

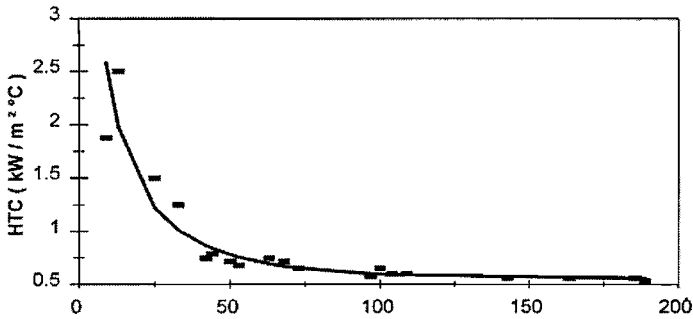


Figure 8. HTC results measured by the scaling probe.

Mill lift transmitter

The SMRI was asked to design an instrument to replace the old mechanical devices used to measure mill roll lift. Figure 9 shows a picture of the mill lift transmitter that was designed and manufactured at the SMRI. In order to survive the harsh environment the electronics were housed in a rugged waterproof aluminum casing. The transmitter is mounted in a vertical position with the shaft downwards. A thin, stranded steel cable connects the transmitter to the bearing cap of the mill roll to be measured. The output from the instrument is a 4-20 mA signal which is proportional to the amount of mill roll lift.

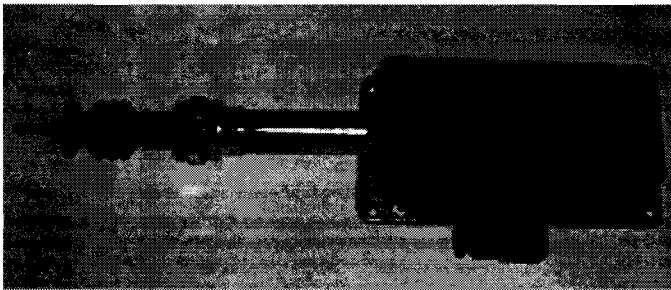


Figure 9. Mill lift transmitter.

Pressure feeder chute transducer

The pressure feeder transducer, as the name implies, measured the pressure in the feeder chute of the mill (Wienese and Reid, 1985). This was a circular disk of 300 mm diameter and 10 mm thickness with the inside 200 mm diameter of the disk machined down to 5 mm thickness. Strain gauges were mounted on this plate and sealed with silicone sealer. The output from the strain gauges was proportional to the forces on the plate. This plate was installed in the pressure feeder chute of the mill. The aim of the instrument was to prevent overloading of the pressure chute, thereby reducing mill down-time due to burst chutes. The instrument became unreliable after about six months due to the ineffective sealing qualities of the silicone sealer. A modification of this instrument was introduced at the Maidstone mill. A load cell was mounted behind the plate such that the force exerted on the plate was transferred to the load cell. The modification overcame the previous disadvantages of the strain gauges and it proved reliable.

Strain gauge amplifier

The strain gauge amplifier was designed to be used in measuring the output from the pressure feeder chute transducer. This amplifier had an isolated 4-20 mA output and switch selectable time constants and was housed in a diecast aluminum box with an analogue local display. The instrument provided a stabilised excitation voltage to the strain gauge bridge and amplified the bridge output. The amplified voltage was converted to a 4-20 mA signal for recording or remote display. This amplifier has now become redundant due to the availability of low cost commercial units.

Juice clarity machine

The sugar industry identified the need to measure carry-over in clear juice and hence the four channel juice clarity machine was developed. (Stone, 1994). The results obtained with the juice clarity machine measuring turbidity of clear juice showed that the instrument in Figure 10 could detect poor operation of the clarifier long before any carry-over occurred.

The commercial version of the juice clarity machine has been modified to a single channel device with a local LCD display. This was brought about with improvements to the optical system and changes to the electronics which made it economically feasible to have one controller and optical cell per machine. The cell has also been changed, eliminating the necessity for a fan. The LED light source has been changed from a 640 nm wavelength to an 880 nm wavelength, which eliminates the effect of colour on the measurement of turbidity. The output of the instrument is an isolated 4-20 mA signal and an alarm relay. The voltage supply to the instrument is 24 V DC. A normal instrumentation air supply to drive the valve actuator and a condensate or drinking water supply for self calibration of the instrument are required.

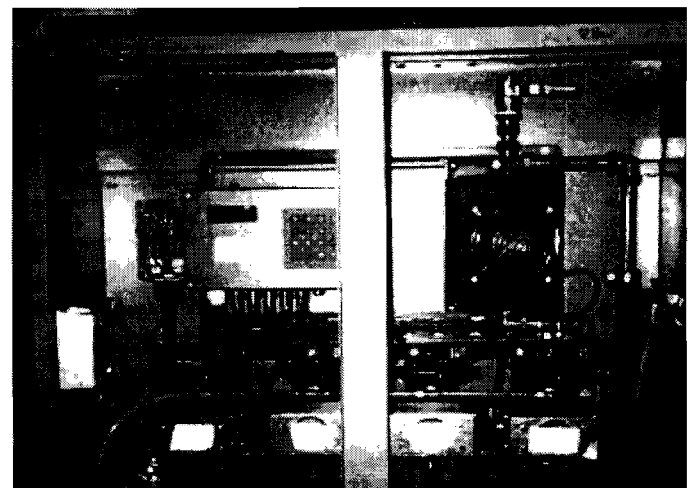


Figure 10. Juice clarity machine.

Clarifier mud level

The SMRI was asked to investigate the possibility of measuring the level of mud in a clarifier, and the multi-channel transmissometer was constructed for this purpose. Continuous samples of juice were drawn from the top, middle and bottom of the normal mud level sampling points and passed through the instrument where the light transmission of the juice was measured. Under normal operation a transmission reading across the sampling points of about 10 to 20% was observed. As soon as mud particles were present, the transmission dropped to 1%. This instrument has been replaced by the single channel juice clarity machine which can be used in this application.

Preparation Index (PI) apparatus

The PI machine has undergone several changes since details of it were published by Reid and Hastie (1994). The machine was completely redesigned and tested to produce a more compact instrument that can be manufactured commercially. Water is pumped through a sample of the prepared cane and the conductivity of the solution is measured as it circulates. The PI is calculated from the shape of the conductivity curve. From the limited set of results obtained it appears that the new PI machine gives appreciably less scatter than the tumbler machine. The new machine is also far less complex to operate and a PI reading can be obtained within 10 minutes of placing the sample in the container. The output is displayed on an LCD and, should there be any uncertainty in the result, no PI value will be displayed. Figure 11 shows the PI machine and Figure 12 compares data between the PI machine and the tumbler method.

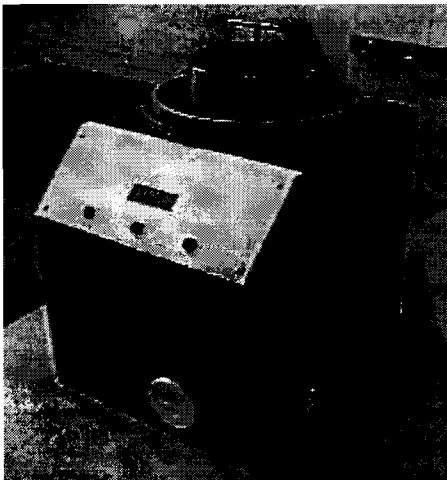


Figure 11. PI machine.

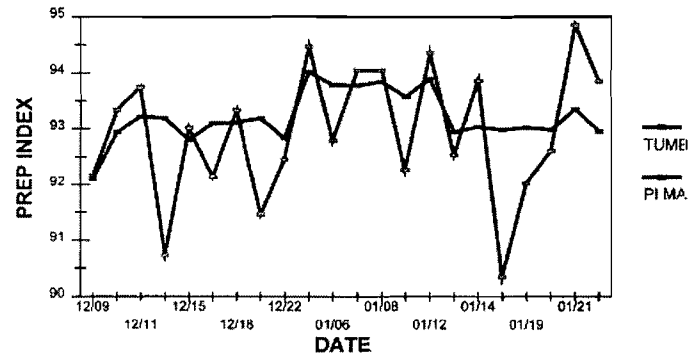


Figure 12. Comparison of PI machine and tumbler method.

Acknowledgments

The authors would like to express their gratitude to the staff at the SMRI and the various sugar mills where research was done. Special thanks go to the workshop staff at the SMRI for building and installing some of the instruments.

REFERENCES

- Gooch, MA (1994). The development of a method to measure clarifier mud consistency. *Proc S Afr Sug Technol Ass* 68: 87-90.
- Reid, MJ and Hastie, A (1994). A method of measuring cane preparation index using a computer. *Proc S Afr Sug Technol Ass* 68: 133-136.
- Stone, VC (1994). The development of an instrument to measure the optical density of juice from a clarifier. *Proc S Afr Sug Technol Ass* 68: 83-86.
- von Fintel, RWH (1999). Torque measurement equipment. Sugar Milling Research Institute Technical Note No. 3/99. 3 pp.
- Wienese, A and Reid, MJ (1985). The use of strain gauges in the measurement of pressure feeder torque and internal chute pressure. *Proc S Afr Sug Technol Ass* 59: 83-87.