DESIGN AND PERFORMANCE OF AN IN LINE TURBIDITY METER FOR CLARIFICATION CONTROL

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Introduction

Mud solids entrained in clarified juice have an adverse effect on subsequent sugar curing and may retard refinery filtration rates if occluded in raw sugar crystals. Entrainment may be caused by refractory juices or instability of process control and may itself lead to unstable processing rates due to retarded curing rates and molasses recirculation. The adverse effects may therefore be quite prolonged.

Instruments for the continuous monitoring of turbidity are readily available and may be constructed cheaply. It is therefore surprising that factories rely solely on visual checks when a continuous in line turbidity recorder would provide a constant check on turbidity of juice actually entering the evaporators and a means of correlating entrainment with cane quality or other process variables. This would indicate the direct cause of entrainment and probably facilitate more rapid and positive corrective action.

A simple in line turbidity meter has been developed and tested by the S.M.R.I. for the purpose of providing a continuous indication of suspended matter in clarifier cane juice. This paper describes the design and application of the instrument.

Basis of Design

The instrument was designed on the basis of intensive laboratory tests during which it was shown that, within the normal range, variation in colour of cane juice had no significant effect on absorption of light from a tungsten lamp. This avoided the necessity of measuring scattered light which, for particles greater than the light wavelength, is an extremely complicated function of particle size, scattering angle, etc. and would therefore not provide any predictable quantitative measure of suspended solids. On the other hand light extinction by transmission through suspended particles follows an exponential relationship which may be corrected to a linear output and therefore facilitate callibration.[1]

Exact quantitative relationships between turbidity and suspended matter are however not possible since, for particles smaller than the wavelength, extinction is dependent on the sixth power of their radius, the fourth power for particles near the wavelength and the second power for large particles.[1] Fig. 1 shows the range of turbidity (arbitrary units) recorded after the progressive addition of small amounts of mud to clear juice. The variation in turbidity for the same suspended solids concentration may be attributed mainly to different particle size characteristics. In practice, entrainment caused by process instabilities would probably fall within a more restricted size range since it represents a size group with a settling velocity close to liquid velocity.

On the basis of this theory and background work an in line turbidity meter was designed bearing in mind the above limitations, mainly for detecting abnormal entrainment in clarifiers.

Description of Turbidity Meter

The electrical circuitry of the turbidity meter is shown in Fig. 2. The detecting element is a light-dependent resistor (l.d.r.) which forms one arm of a resistance bridge. A variable resistance is placed in an opposite arm of the bridge to facilitate zero adjustments (usually on water). A stabilised power supply is fed to the bridge, the main element being a cadmium cell. A 4 volt projector lamp is powered from the same source. The turbidity cell is constructed from standard ½ in. pipe fittings, the main item being a standard cross fitted with two nipples, one being connected to a tee and the other to a reducer. The l.d.r. is secured firmly within the reducer by means of a shaped nylon bush and the lamp is fixed within the tee, its filament being aligned along the axis of the cross. The vertical limb of the cross is fitted with a concentric ¼" i.d. Pyrex glass tube, sealed at each end with nylon bushes, so that liquid may pass through the vertical limb of the cross without entering the horizontal one. This arrangement is shown on the left. The lamp circuit is equipped with two relays which prevent overcharging of the battery when the lamp filament fails and draining of the battery power when mains supply fails. A millivolt recorder is connected across the bridge with suitable matching to provide for measurement over the normal range of juice turbidities. Apart from the recorder, the most expensive item is the cadmium cell and the other items add very little more to the total cost.

Conclusion

The turbidity meter has been installed at several factories and has given reliable service. It has provided useful information on the causes of intermittent entrainment. Temperature and feed rate fluctuations have been found to coincide with adverse clarification performance. Since the cost of the actual detector is very low it may form the basis for automatic clarifier operation. The instrument is robust and requires no maintenance under normal process conditions apart from cleaning the glass tube at the end of each week.

Acknowledgements

The author wishes to thank the managements of Tongaat Sugar Co., Hulett's, Darnall and Noodsberg Sugar Co. for providing facilities for testing prototypes and the final model turbidity meter. The author gratefully acknowledges the co-operation of Mr. Bruijn in the development of a prototype model and for design of the circuitry of the final model which was constructed by Mr. N. I. Bowes of the S.M.R.I.

Summary

An in line turbidity meter suitable for recording the turbidity of clarified juice is described. It is mainly intended for indicating periods of entrainment so that corresponding instability in other process variables may be correlated. Preliminary tests indicated that colour of juice had no significant effect on the turbidity and the instrument was therefore designed to measure the intensity of transmitted light using a light dependent resistor. The meter has been successfully applied to "trouble shooting" in several clarification plants.

Reference

[1] Orr, C. Jr., and Dallovalle, J. M. "Fine Particle Measurement," 1st Ed., 1959, 101-5, MacMillan Co., N.Y.

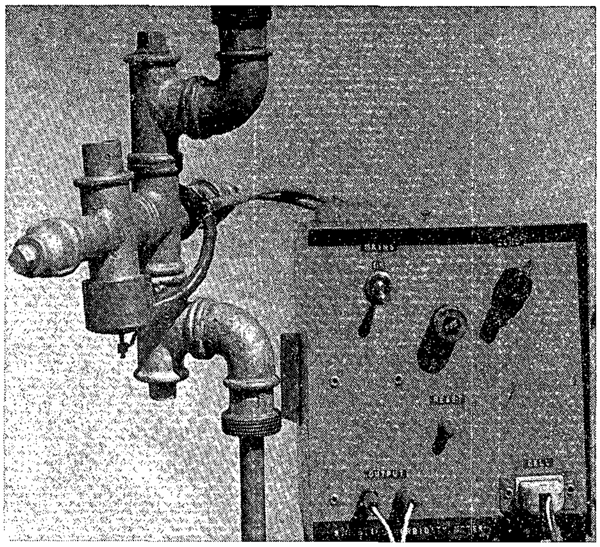

PLATE I: Photograph showing turbidity cell and housing for stabilised power supply

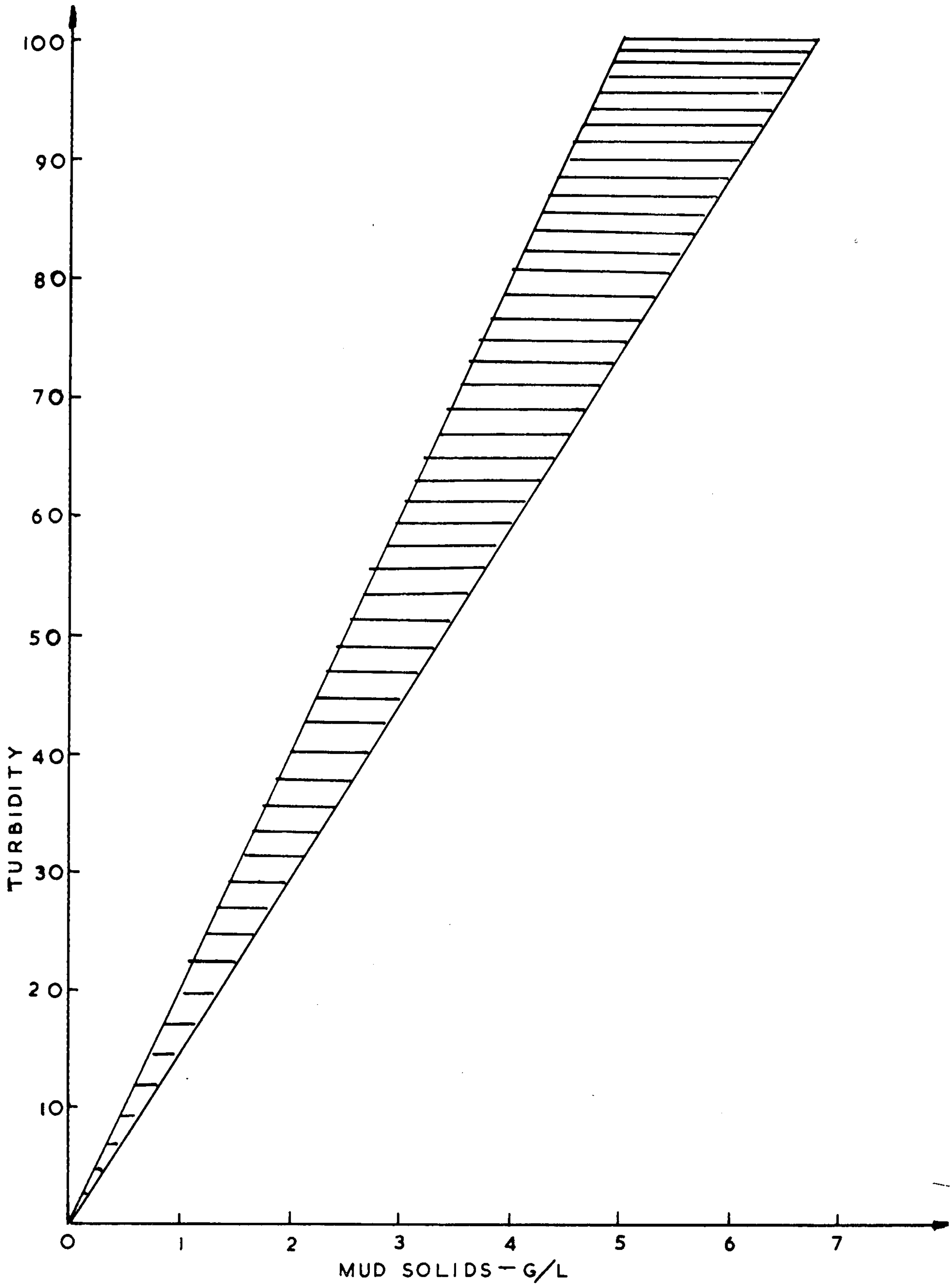

FIGURE 1: Graph showing turbidity range for various concentrations of mud added to clarified juice

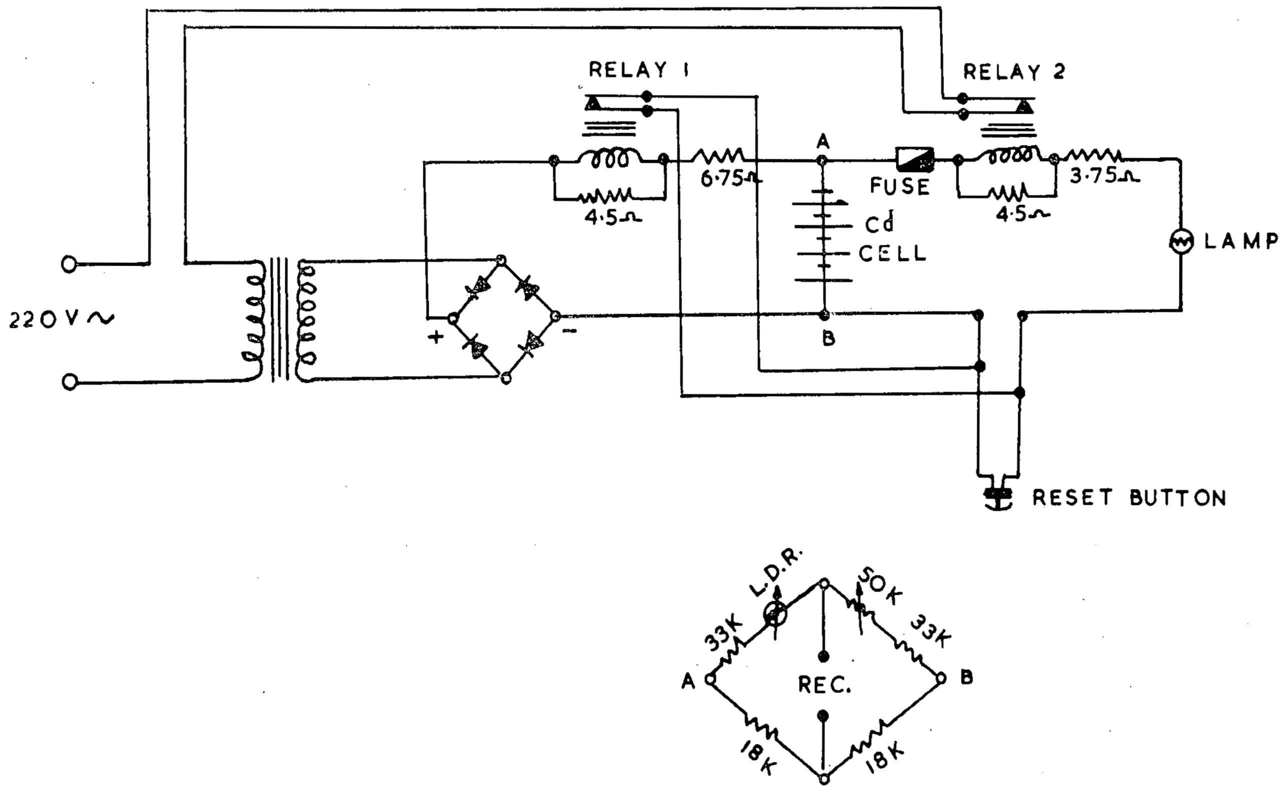

FIGURE 2: Circuit diagram for turbidity meter, stabilized power supply and resistance bridge

Discussion

Mr. Bentley (in the chair): The industry has needed an instrument like this for a long time, particularly as it is reliable and inexpensive. In the past we have trusted to the human element to control the clarification station, and this is likely to be unreliable, particularly in the small hours of the morning.

Mr. Rabe stated earlier that the turbidity of the clarified juice was an indication of its starch content and this meter will therefore indicate the starch content of juice coming from the clarifiers. I am surprised that the glass tube only requires cleaning once a week as I would have expected it to discolour rapidly and require frequent cleaning.

Mr. Renton: At Darnall we had to clean the tube daily to get consistent readings.

Mr. Buchanan: We operated the meter at Jaagbaan for two months and even if the tube was left uncleaned for longer than a week effects on readings were negligible. Possibly the flow rate of the juice through the meter was much faster at Darnall.

Mr. Robinson: We could get readings after a week at Darnall but sensitivity was lost so we arranged to clean it every day.

Mr. Buchanan: When the instrument was used at Darnall it was in its earlier stages of development and had not been set to its final sensitivity. After it was used at Darnall we reduced its sensitivity, which we found had previously been higher than was required, and this probably reduced the significance of scaling.

The instrument is easily cleaned by removing two plugs and using a bottle brush.