JUICE FLOW STABILIZATION SYSTEM

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ABSTRACT

The clarification process is much improved if the juice flow from the weighed juice tank is stabilized. This is required because of the intermittent operation of the juice weighing scale/s. A flow stabilization system is described here which utilizes the principle of "floating inventory control". Because the material balance is closed around the weighed juice tank, this system gives better results. The heart of the system is the electronic modifier developed by the authors. This unit and the microprocessor-based controller in the system are responsible for better performance. Once tuned, the system automatically takes care of the crushing rate variations without being re-adjusted.

INTRODUCTION

Use of batch scales to weigh incoming mixed juice is still the standard method in most countries. This method, being intermittent, complicates subsequent control of juice pH and temperature and disturbs clarifier operation. When the incoming juice is measured in batch scales, the level in the weighed juice receiving tank fluctuates and any attempt to control it conventionally propagates the flow variations through the heater and clarifier. A uniform flow of mixed juice from the weighed juice receiving tank to the boiling house greatly simplifies the control of the juice pH and its temperature and results in better juice clarification. Because batch scales are used in all factories, fluctuating juice flow from the weighed juice receiving tank is a situation common to most of the factories in India.

The basic intention of Juice Flow Stabilization (JFS) system is to reduce fluctuations in the flow of juice which is pumped to the process. The fluctuations are created mainly due to following reasons:

1) Use of batch weighing scales which intermittently dump into the weighed juice receiving tank.
ii) The raw juice pumps always have excess capacity than needed. So, after every dump of the scale in the weighed juice receiving tank, the pump, if its suction and delivery valves are not throttled correctly, delivers the dumped juice within a time interval shorter than that between two successive dumps. Obviously, the pump generally runs empty for some time in every cycle. Thus, the flow fluctuations are 0 to 100% in each cycle.

iii) The instantaneous rate of crushing cannot be kept constant. It means that quantity of juice coming to the weighing scale varies and subsequently, scale dump intervals vary.

iv) The filtrate returns from rotary vacuum filter and other drains to the weighed juice receiving tank are irregular.

The JFS system is designed to achieve the following requirements:

i) Bringing down the flow fluctuations of juice from the weighed juice receiving tank to such a level that they can easily be tolerated in juice heating and clarification stages.

ii) Avoiding empty running of the raw juice pumps (air-locking) as well as overflowing of the receiving tank.

iii) Automatically taking care of varying filtrate returns, varying crushing rate and making full use of the available volume of the receiving tank to adjust the flow rate to the process.

It should be borne in mind that any system designed to keep the outgoing flow of juice constant from the weighed juice tank, irrespective of the crushing rate, is bound to create problems while actually working in the factory. The third requirement stated above will not be met. That is why, the juice flow is not kept constant by this system, but it is stabilized to suit the present crushing rate.

DESCRIPTION OF SYSTEM

The “theory” behind Shinskey's statement that “material flows from a source through a series of process units...each of which needs its material balances closed. If inflow and outflow are not matched, there must be accumulation. Then the difference between inflow and outflow is sensed and controlled in the accumulation of inventory. ...open vessels can accommodate substantial inventory, which is sensed as the liquid level within them.”
Shinskey further states that "... any difference between inflow and outflow will cause inventory to either rise or fall. A steady state can be achieved only by applying a controller. ... These processes, therefore, cannot be left unattended in manual control because eventually the controlled variable will surpass allowable limits."

St. Clair states that "If inflow varies rapidly, tight level control will pass these variations on to the outflow which could be undesirable for subsequent process. A goal could be to absorb as much of these inflow variations as possible in the holdup of the vessel. This is called averaging level control."

Again, Shinskey states that "when there is no need to control inventory precisely to protect equipment, but rather the capacity is provided for smoothing. ... inventory should be allowed to float with load in such a way that disturbances are attenuated as much as possible." This is the principle of floating inventory control.

It will be seen that this is almost the description of the weighed juice receiving tank considered as a unit operation. The JFS system described here is based on the material balance across the weighed juice receiving tank. The rate of flow of juice going out to the process is automatically adjusted equal to the average rate of the juice coming into the weighed juice receiving tank such that the equation,

\[ \text{Flow of juice going out to process} = \text{Average flow of juice coming in}, \]

is satisfied. This equation is the heart of the system. It makes the system very simple to operate. In fact, no adjustments in the system are required to be done once it starts operating, even if there are changes in crushing rate. The principle of operation also makes the system independent of the daily crushing capacity and the weighed juice tank size which varies from factory to factory. The weighed juice tank size reflects only on the variations in the stabilized flow. Smaller the size, more are the variations, naturally!

**The system**

The main process equipment for this system is the juice receiving tank. In India, these receiving tanks are generally rectangular in shape although circular tanks can also be found. The weighing scale capacity is usually 4 to 6.5 tons of juice per dump. The mixed juice pumps are of 150 m³/h capacity with 60 m head up to 3,500 TCD plant capacity.
Mukherji states that the juice receiving tank capacity should be 3 to 5 min and 10 min is ideal. Above 10 min retention, microbiological problems may start cropping up. He also suggests a circular tank for the same reason.

With these considerations, the tank volume is about 15 m³, out of which about 12.25 m³ is the working volume. This gives a retention of about 8 min at 2500 TCD and about 5 min at 3,500 TCD.

The control system is shown schematically in Figure 1a, and its wiring diagram is shown in Figure 1b. As there are two pumps installed (one working as stand-by), their deliveries are made common and the control valve is installed on the common delivery line going to the juice heaters.

**FIGURE 1a. Schematic of Juice Flow Stabilization (JFS) system.**
SYSTEM COMPONENTS

1. Control valve: This is a butterfly type control valve with a pneumatic actuator. A standard 0.2 to 1 kg/cm² pneumatic signal actuates the valve from full open to full close positions. A valve positioner is provided so that accurate positioning is possible under actual working conditions. As the mixed juice contains a lot of soil and bagacillo, a butterfly valve with "open" construction is chosen.

2. Electronic controller: This is a microprocessor-based controller with programming facility. Apart from the usual PID and set point settings, other useful parameters can also be programmed in it, such as the output limits, alarms, etc.

FIGURE 1b. Wiring diagram of Juice Flow Stabilization (JFS) system.
3. Electronic modifier: Level signal from the transmitter and tank dump signal from the proximity switch installed at the weighing scale come to this modifier. From the output of this instrument, the controller essentially learns about the inventory of juice in the tank and the rate at which it is coming from the mill station. This instrument is the heart of the system.

4. Sensing system: There are two sensings in the system; a) level of juice in the weighed juice tank, and b) weighing scale dump.

   a) Level: Level of juice in the tank is sensed by purging air through a vertical pipe installed in the tank. An oil separator, pressure regulator, purge rotameter and a bubbler are installed in this air line. The back pressure is sensed with the help of an electronic-pressure transmitter which gives standard 4 to 20 mA current signal to the electronic modifier. The back pressure is proportional to the level of juice in the tank.

   As the cross section of the tank is constant throughout its height, the level signal is essentially the volume signal which is calibrated for the working volume for individual factory.

   b) Scale dump signal: A proximity switch is installed at the weighing scale. Every time the scale dumps juice in the receiving tank, the arm of the scale comes in front of the switch and gives a pulse to the modifier.

   Both these units are powered by the modifier itself.

5. Current-to-pressure converter: As the controller is electronic and the control valve is pneumatically operated, the current output (4 to 20 mA) of the controller is converted into pneumatic (0.2 to 1 kg/cm²) signal using the current-to-pressure converter.

**WORKING OF THE SYSTEM**

As and when the tank of the weighing scale is filled up, the juice is dumped into the receiving tank below. The electronic transmitter with the help of back pressure from the air purging system gives current signal to the modifier. The transmitter is calibrated for the working height of the receiving tank before installation. The modifier shows this signal as level in % of the working height. The scale dump sensing proximity switch is also connected to the modifier. When the scale dumps, an LED lamp on the modifier glows and the value of the level signal is given out to the controller from the modifier.
The controller settings depend upon the tank volume. A set point of about 25 to 35% of the working volume is generally chosen to start with and fine tuned when the system starts working. The controller gives out signal to the I/P converter which converts it into proportional pneumatic signal. The control valve is air-to-close type, so that if the air supply fails, the valve opens completely and subsequent tank overflow is avoided. Thus, as tank inventory increases, the output from the controller diminishes thereby reducing the air signal to the control valve.

RESULTS AND DISCUSSION

The graph of juice flow, measured with magflometer (Figure 2) shows both flow patterns, with and without stabilization on the same circular chart for comparison. Without stabilization, the variations in flow are 100% while they are extensively reduced to about 5% with the control system working. This is the effectiveness of the system.

FIGURE 2. Magflometer record showing juice flow with and without JFS system.
Figure 3 shows motor current of the raw juice pump and the juice flow measured with magflometer on the same graph, when the stabilization system is working. The pattern of variations is identical for both these parameters. As the two pens are on opposite sides on the recorder, the plots are displaced 180° with respect to each other.

As the motor current truly reflects the flow variations from the raw juice pump, we have standardized on recording motor current instead of actual juice flow for all subsequent installations. Figure 4 shows such a plot. Note that all the circular plots are for 24 h.

FIGURE 3. Record of juice flow with magflometer (outer) and motor current (inner) with JFS system.
We tried this system first with a simple electronic PID controller. We later changed to microprocessor-based programmable controller. The juice flow regulation improved with this controller. This is attributed to greater tuning flexibility of the controller and we have now standardized on microprocessor-based controller in our systems. Figure 5 shows plot of motor current with a microprocessor-based controller. Note that the thickness of the line is reduced as compared to that of all earlier plots.

Figure 6 shows installation of the stabilization system for two weighing scales dumping juice in one receiving tank. This, generally, is the case of expanded factories. We have designed the electronic modifier to accept signals from two scales instead of one. The system works equally well in this situation too. In fact, the plot in Figure 5 is from such an installation.

![Diagram](image_url)

**FIGURE 4.** Record of motor current with JFS system.
Sloane, et al., have described a sampled-data controller (HSPA controller) earlier. Present system is more organized and simple. Also, it gives more flexibility and better performance. For example, settings like the minimum dump interval are to be matched with process characteristics in the sampled-data controller. The settings of controller in this present system are virtually free of process characteristics. Again, the bias in the HSPA system is understood to be adjusted for average juice flow. This present system, once tuned will adjust itself to varying crushing rates. This is due to the use of the electronic modifier.

FIGURE 5. Record of motor current with microprocessor-based controller. For other captions, refer to diagram. [390.41]
With this system working, the downstream process of clarification is greatly improved. Figure 7 shows a plot of sulfured juice pH with and without juice flow stabilization. The pH is automatically controlled in both the cases. The improvement seen is mainly due to juice flow stabilization system.

Chinnaswamy et al have described the integrated juice clarification system. This present system was part of that integrated system.

CONCLUSIONS

The present juice flow stabilization system is now better matched to the process. It is flexible, easy-to-use and gives better performance. It is suitable for all practical situations encountered in the sugar industry. It is proved that an integrated system for juice clarification, of which this present system is a part, gives good results. Shinskey has described a controller with arrange-
FIGURE 7. Record of pH with and without JFS system.
RESUME

Les résultats obtenus en clarification sont meilleurs quand le debit de jus est stable. Ce control est necessaire parce que la pesee est une operation discontinue. La stabilisation du debit de jus utilise un principe appele "control d'inventaire flottant". On a trouvè que ce system fonctionne bien. Au centre du system on trouve un appareil electronique develope par l'auteur. Cette unite et le micro ordinateur employe donnent de bons resultats. Une fois regle le system corrige automatiquement les effets des variations de tonnage aux moulins.

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SISTEMA PARA LA ESTABILIZACION DE EL CAUDAL DE JUGO

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RESUMEN

El proceso de clarificación puede ser mejorado si el caudal de jugo de la tanque de pesada es estabilizado. Esto es necesario debido a la operación intermitente de las pesas de jugo. Se describe aquí un sistema para la estabilización del caudal de jugo, utilizando el principio de "control de inventario flotante". Debido a que el balance de materiales es cerrado alrededor de la pesa de jugo, el sistema produce mejores resultados. El corazón del sistema es un modificador electrónico desarrollado por los autores. Esta unidad y un controlador basado en microprocesador que se emplean en el sistema son los responsables por los mejores resultados. Una vez estabilizado el sistema compensa por las variaciones de la molienda sin requerir otros ajustes.

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