A LOOK AT TRACER TESTING IN THE SUGAR INDUSTRY

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Abstract

The application of tracer techniques to the sugar industry is reviewed. This includes the investigation of residence time distribution in clarifiers, evaporators, continuous pans, crystallizers and fluidized bed dryers; the flow split in diffusers and evaporator vessels; leak detection; measurement of entrainment in vacuum pans and determination of system volumes such as cooling water ponds.

Introduction

In most continuous process vessels used in the sugar industry, backmixing, channelling of the fluid and the creation of stagnant regions result in a lowering of the performance of the unit. The flow pattern in these vessels can be analysed using tracer techniques, and often, as a result, remedial action can be taken.

Tracer techniques can also be applied to the measurement of flow rates and flow splits in situations where conventional flow meters cannot be used.

This paper looks at some investigations that have been done in the sugar industry using tracers with particular reference to some recent applications in South Africa.

Residence Time Distribution

Tracer tests are based on the stimulus-response technique. The stimulus is the input of the tracer into the material entering the system, and the response is a time record of the concentration of the tracer flowing past the measuring point at the outlet, which gives the residence time distribution curve, RTD, for the system.

Several models have been used to interpret the RTD curves obtained from tracer tests in sugar factories. The most frequently used are the dispersion model (Levenspiel[11]), the tanks-in-series model[11], and the model of Wolf and Resnik[25].

To date a large number of residence time determinations have been carried out in the sugar industry to investigate, amongst others, the performance of diffusers, carifiers, evaporators, continuous pans, crystallizers and fluidized bed dryers.

Diffusers

The flow pattern in a pilot plant diffuser was investigated by Love and Rein[15] using sodium chloride. They applied the dispersion model to the RTD curves, and showed that the dispersion increased with increasing percolation velocity. This study was extended to a full scale diffuser at Amatikulu and a continuous measure was obtained by using conductivity recorders.

Clarifiers

Tests using radioactive isotopes as a tracer were done by Wramstedt[26] in Sweden on sugar beet clarifiers and Ellis and Brain[7] in Queensland on a Bach subsider. Both investigations indicated that considerable mixing takes place in the clarifiers. In both experiments, errors in measurement resulted from background radiation.

Love[14] in South Africa did a number of tracer tests on Rapidorr and Dorr 444 clarifiers first using sodium chloride and later lithium chloride, since base line drift was experienced with sodium chloride. The conclusions drawn from these tests were that the mean residence time was shorter than the nominal residence time and that short circuiting of juice takes place.

A number of similar tests have been carried out by the SMRI (Munsamy[19]) during the past two years on Rapidorr, Dorr 444 and SRI clarifiers, also using lithium chloride. Residence time distribution curves obtained are shown in Figure 1 for the juice and Figure 2 for the mud.

As can be seen in every case the mean residence is shorter than the nominal residence time.

Evaporators

The RTD of juice and syrup in multiple effect evaporators has been measured in Taiwan (Chen *et al*[5]) using radioactive iodine as a tracer, and in Germany using sorbitol (Mosich[18]).

Tests have also been done in South Africa at Tongaat (Vanis[24]) and Illovo (Allan[1]) using sodium chloride. The mean residence times in the vessels of the Tongaat evaporator are shown in Table 1.

Continuous Pans

The flow through one cell of a continuous low grade pan was studied by Wright and Broadfoot[27] using lithium chloride as a tracer. The results were analysed by means of the model of Wolf and Resnik[25] and the tanks-in-series model. Perfect mixing was found to take place.

TABLE 1
Mean residence times in multiple effect evaporators at Tongaat in 1977

Kestner	3,5 min	No. 2 ..	6,5 min
Pre-evaporator	4,5 min	No. 3 ..	7,5 min
Vessel No. 1 ..	6,0 min		

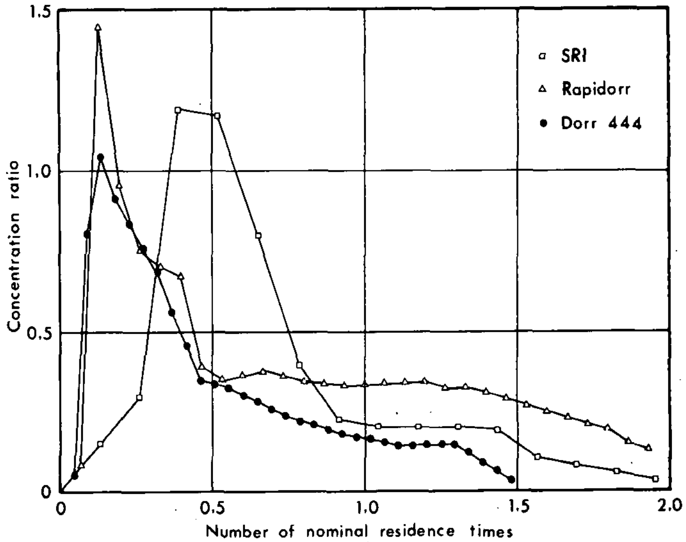

FIGURE 1 *Residence time distribution of juice in clarifiers.*

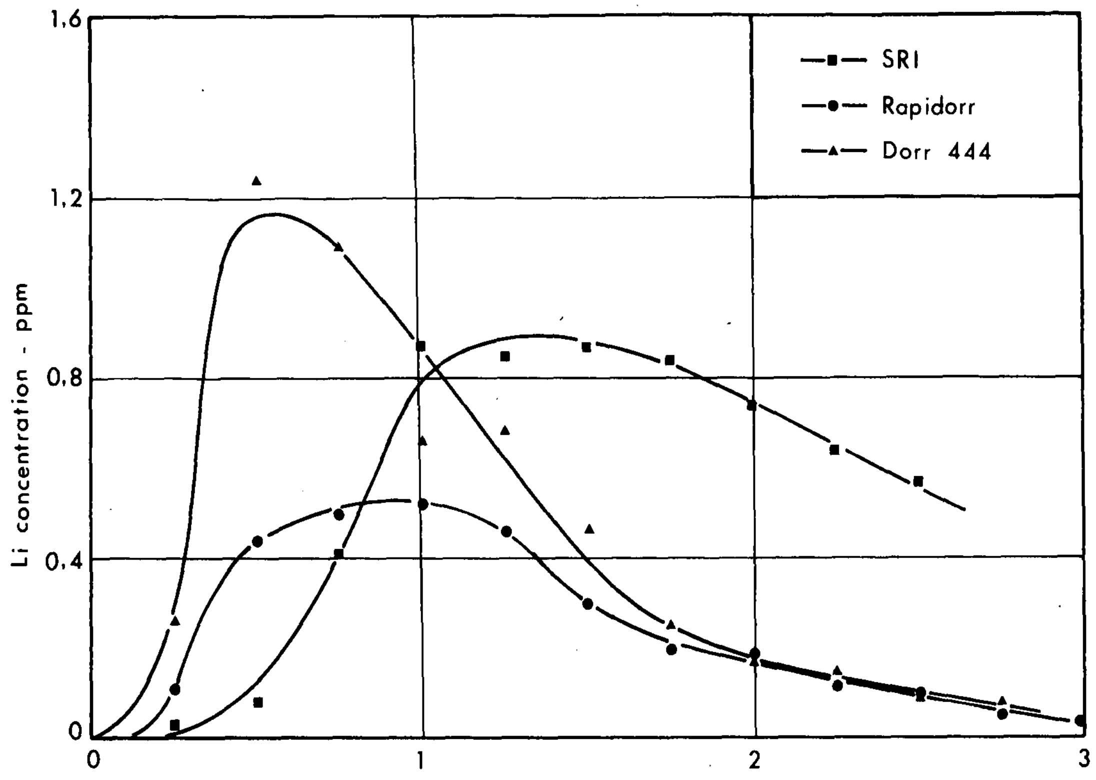

FIGURE 2 Residence time distribution of mud in clarifiers.

Bonnenfant and Vicaigne[2] used the same tracer and model to study low grade and high grade pans in the beet sugar industry. They observed that a closer approach to plug flow was achieved by increasing the number of compartments in a high grade pan from five to twelve.

During the past season tracer tests were done on two Fives Cail Babcock C-pans at Tongaat and Gledhow by Jullienne and Munsamy[9]. Lithium chloride was used as a tracer. The mean residence times were found to be 9,5 and 16,7 hours respectively. The reason for the big difference is that the Gledhow pan was operating well below its design capacity at the time of the test.

Crystallizers

In crytallizer operation, plug flow is desired in the axial direction combined with complete mixing in the radial direction. Any short circuiting or mixing in the axial direction reduces the residence time, and thus the extent of crystallization. Because of the economic importance of good molasses exhaustion, the crystallizer station is the part of the factory that has been most thoroughly investigated by means of tracer tests.

However, in crystallizers, massecuite enters and leaves in laminar flow, and the velocity profile is not flat. Under these conditions different methods of introducing the tracer or measuring the concentration at the exit will give different tracer curves and a different mean residence time (Levenspiel and Turner[12]).

Broadfoot[3] used lithium chloride as a tracer which was mixed with some massecuite and introduced as a slug in the inlet stream. The tests were done on three different installations consisting of (a) a Werkspoor, (b) two Werkspoor in parallel followed by two Blanchard in parallel and (c) six crystallizers in series each fitted with a central underflow baffle. This last system gave the residence time distribution which came closest to plug flow.

Chen, Cheng and Tong[4] used radioactive iodine mixed with massecuite to study the flow through the third crystallizer in a set of eight. As there was no massecuite receiver in the system, a correction was applied to adjust for the variable flow rate.

An installation consisting of two crystallizers each fitted with three vertical baffles was studied by Wright and Broadfoot[27] using lithium chloride. They analyzed the results by applying the tanks-in-series model and that of Wolf and Resnick[25].

In South Africa, Smith, Basson and Smith[21] used radioactive iodine to investigate the behaviour of three low grade crystallizers, two of which had reciprocating stirrers and one a rotating element. The dispersion model was used to interpret the results. It was shown that a rotating agitator gave more intense mixing but resulted in a larger dead volume.

The residence time distribution obtained with different types of crystallizers was studied by Strickland, White and Kirby[22]. The crystallizers investigated were the Werkspoor, coil and eccentric coil types. The study was done in scaled down units of 5,5 litres capacity filled with glucose syrup and the tracer consisted of 1 mm dia. black PVC particles of the same density as the syrup. The tanks-in-series model was applied to the results. The conclusions were that more by-passing occurred with the concentric coil than with the eccentric coil.

The previous study was extended by Kirby and White[10] to cover crystallizers fitted with extended arm elements, reciprocating elements and eccentric coil elements, but using coils with a more open pitch than in the previous study. They found that better plug flow was obtained with the extended arm stirrer followed by the coil and reciprocating elements in that order.

Madsen and Nielsen[15] used magnesium or lithium salts to compare six crystallizers in series with a DDS vertical crystallizer, all operating on beet massecuite. They applied the tanks-in-series model and found that the deviation form plug flow was acceptable in both cases.

Again in South Africa, Rein[20] reported on tests carried out at Amatikulu using radioactive iodine. The installation consisted of 13 crystallizers in series. The dispersion model was applied to the results. It showed that the dead volume ranged from 85 to 10% along the intallation.

Fluidized Bed Dryer

By-passing in a fluidized bed dryer at Gledhow was studied by Fitzgerald, Taylor and Bestwick[8] using fluorescein coated sugar as the input signal, while the response was measured by optical means. The tests were done before and after the introduction of a baffle system to eliminate short circuiting. The results were assessed by applying the dispersion model and the Wolf and Resnik model. In both cases a change of the coefficients in the right direction showed a closer approach to plug flow when baffles were installed.

Flow Measurement

Injection of tracer in a flow system has been used successfully in determining the flow split between the cells of diffusers and between multiple effect vaporators in parallel.

Diffusers

In South Africa sodium chloride was used as a tracer to investigate percolation rates and percolation angles in diffusers (Matthesius[17]). The tracer was introduced as a pulse into the hopper feeding the juice circulation pump and sampling was done at the stage in which the tracer was introduced and at the upstream and downstream stage. These tests showed that the percolation angles were shallower than those allowed in the design of the diffuser, and that as a result half of the juice ended up in the downstream stage and was recirculated. The conclusion reached was that diffusers should have fewer but longer stages.

Evaporators

The flow split between two vessels working in parallel and forming the first effect of a quadruple effect evaporator at Empangeni was measured by a tracer injection using lithium chloride (Taylor[23]). The tracer was injected on a continuous basis as a step signal using a metering pump. The arrangement of the injection and sampling points is shown in Figure 3. The tracer concentration is expressed as a mass ratio of Li/Bx and the values obtained during the test are shown in Figure 4 and in Table 2. The flow split was calculated from the equation :

$$\frac{C_3}{C_1} = \frac{q_1}{q_1 + q_2}$$

where C_1 = concentration in branch flow.
C_3 = concentration in combined flow.
q_1 = volumetric flow rate in branch 1.
q_2 = volumetric flow rate in branch 2.

Leak Detection

Tracer methods can be used for detecting leaks in pipelines and in process vessels. Measurement of entrainment from evaporators could be classified as leak detection.

The measurement of entrainment from vacuum pans has always presented a problem because the background level of sucrose in recirculating condenser water tends to mask the entrained sucrose. Hence, any method which could overcome this deficiency would be of considerable value. Measurements have recently been done at the SMRI (Lionnet[18])

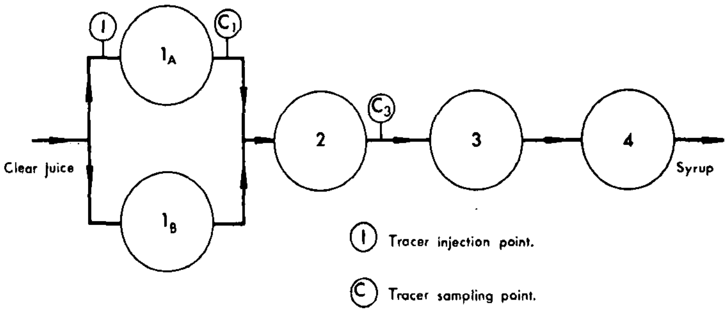

FIGURE 3 Layout of evaporator vessels and injection and sampling points in flow split determination.

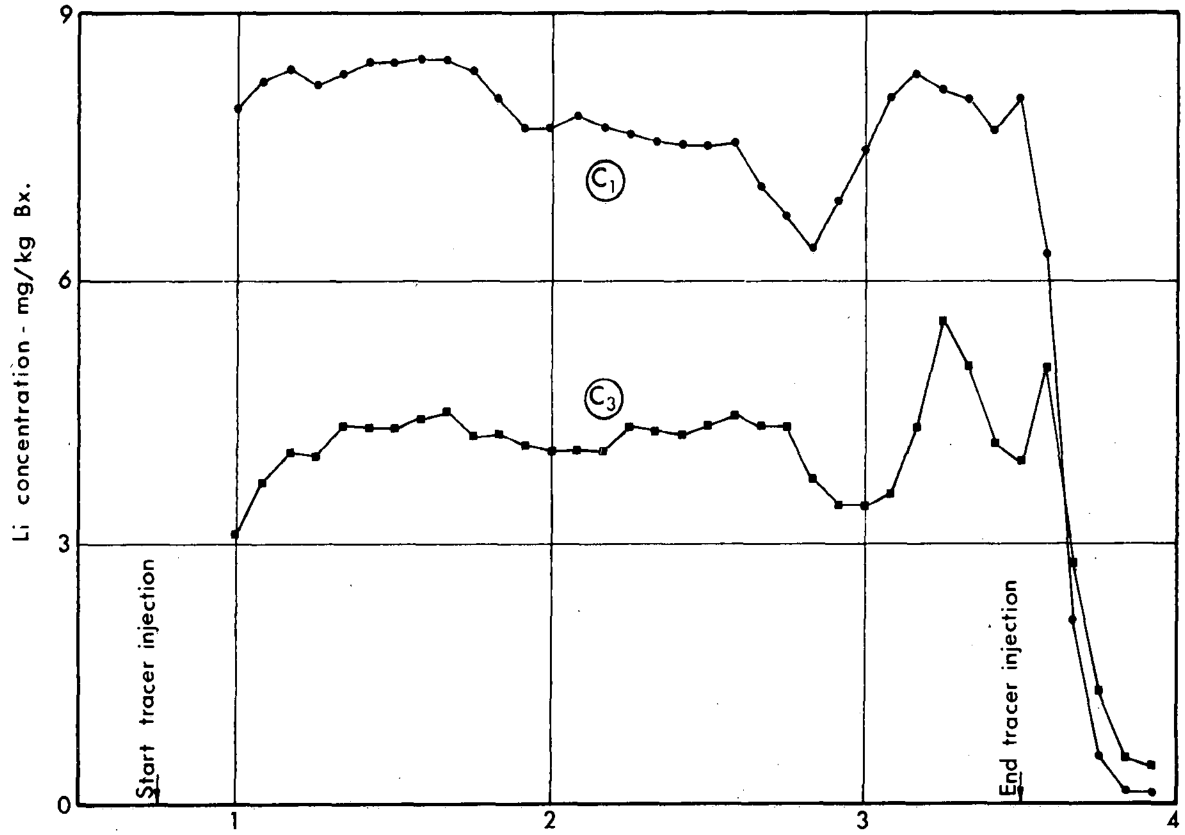

FIGURE 4 Tracer concentrations in flow split determination.

TABLE 2

Tracer Concentrations in Flow Split Determination

Time (h)	Brix %		Density (kg/l)		Li + (mg/l)		Li +/Bx (mg/kg)		$100 \times q_1$
	1	3	1	3	1	3	C_1	C_3	$q_1 + q_2$
1-2	15,2	21,8	1,062	1,091	1,33	0,99	8,24	4,16	50,5
2-3	14,2	19,1	1,057	1,079	1,10	0,85	7,33	4,12	56,2
3-3,5	13,1	17,8	1,053	1,073	1,12	0,85	8,12	4,45	54,8

by introducing a pulse of lithium chloride in the pan at the start of the strike and measuring the lithium concentration in the condenser tail pipe. Initial indications are that the level of entrainment was directly related to the evaporation rate. Further work is being done in this area.

Determination of System Volume

A tracer injection was used at the Huletts Refinery to determine the volume of water in their cooling system (Cox[6]). A mass of lithium chloride, equivalent to 0,38 kg of lithium was added to the system. Sampling was done continuously from the condenser water line. The results are shown in Figure 5. It appears that it took four hours for the tracer to be evenly dispersed in the system. A constant concentration was not obtained from this point onwards. This was attributed to loss of tracer through system overflow or wind carry-over. The drifting base line was extrapolated to the starting time to give a concentration of 0,18 mg/l at injection time. From this the system volume was calculated to be 2 100 m³.

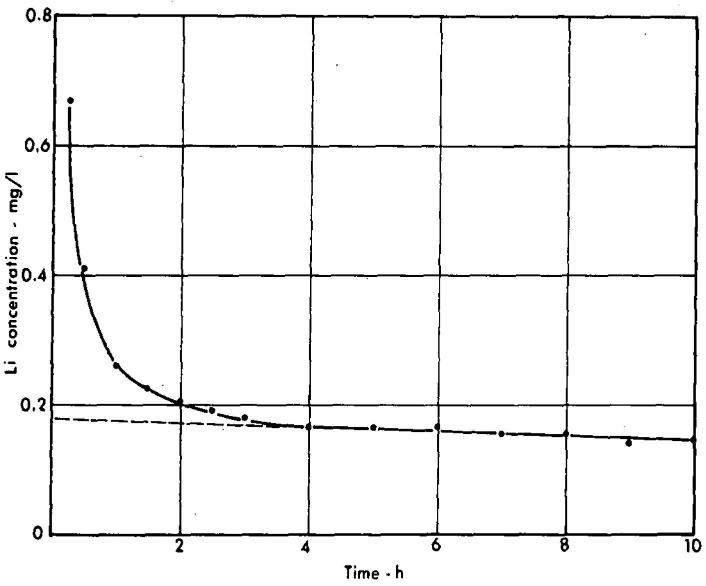

FIGURE 5 Tracer concentrations in determination of volume of cooling system.

Conclusions

The examples described in this paper illustrate the many different ways in which tracers can be applied. With tracers it is not only possible to evaluate existing equipment or assess the improvements brought about by modifications, but also to obtain information on flow systems by means of relatively simple tests. While most factory managers are aware of tracer techniques for residence time distribution, few realise that there are other applications which may be useful in improving the operating efficiency.

It is a field of activity which is growing with the increasing scope of techniques, and the increasing realisation of the benefits that can be derived from it.

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