

MONITORING OF ENTRAINMENT BY VAPOUR SAMPLING AND THE USE OF A FLAME PHOTOMETER

By T. B. DALE* and J. P. LAMUSSE

Sugar Milling Research Institute

Abstract

A flame photometer has been used to monitor entrainment from evaporator vessels and pans. A special probe is used to obtain a sample from the vapour line going to the condenser. The vapour is condensed and the potassium level in the condensate is recorded continuously. A predetermined ratio of sucrose to potassium is used to estimate entrainment. A typical application of the instrument is described.

Introduction

The use of a flame photometer to control the sugar content of condensates has been reported by Verhaat and De Visser.¹ This technique is based on analysing the condensate for potassium and estimating the amount of sugar by means of a known ratio of sucrose to potassium in the condensate.

A flame photometer made by Marius (Utrecht) was designed specifically for this purpose and has been used in the beet sugar industry.

One of these instruments was acquired by the SMRI and used to monitor vacuum pans and evaporator condensates. The flame photometer was initially operated on condensates in parallel with an auto-analyser the results of which confirmed the sensitivity of the instrument and provided data on the sucrose to potassium relationship.

Potentially, the most dangerous source of loss by entrainment in sugar factories is not in condensates but in barometric condensers. Because of the large volume of water circulating in the condensers, any entrainment is diluted and difficult to detect. An entrainment detection procedure was therefore developed which was based on monitoring potassium in a sample of vapour from the evaporator or pan after its condensation in a small surface condenser.

Theory

Since entrainment consists of fine drops of syrup carried over with the vapour from the last vessel of an evaporator, it can be assumed that the entrained droplets have the same chemical composition as the syrup. Therefore the ratio of sucrose to potassium in the vapour is the same as in syrup.

If S_j = Sucrose concentration in syrup
 K_j = Potassium concentration in syrup
 S_c = Sucrose concentration in vapour
 K_c = Potassium concentration in vapour.

Then $\frac{S_j}{K_j} = \frac{S_c}{K_c}$
 and $S_c = \frac{S_j}{K_j} \times K_c$

For routine tests the ratio of sucrose to potassium has been assumed to be 100 : 1 but analyses have shown that it varies from 85 : 1 to 100 : 1.

The above reasoning is based on entrainment of syrup but will also apply to entrainment from a pan. The ratio of sucrose to potassium will vary depending on the massecuite boiled and is determined on the feed to the pan. As sugar crystallizes

out during boiling this ratio will change but has been assumed to be fixed in the tests carried out so far because an accurate quantitative measurement of entrainment was not required. Typical sucrose to potassium ratios are 32 : 1 for A molasses and 14 : 1 for B molasses.

Vapour sampling

Theoretically the analysis for potassium should be carried out on a representative sample. However the layout of vapour piping between evaporator or pans and their condensers is such that it is generally virtually impossible to obtain an isokinetic sample. In order to simplify operation, and because absolute values are not required, a sampler which has the advantage of simplicity and low cost has been developed.

Equipment

1. Sampling equipment (Figure 1)

The sampler consists of a hollow brass probe 1 m long and 25 mm external diameter equipped with positioning handles. At the handle end there is a hose connection through which the vapour passes on its way to the condenser. The other end of the tube is blocked off and has a 12,5 mm hole drilled in the side through which vapour enters the probe. The probe is inserted into the vapour line through a 38 mm gate valve and is held in position by means of a positioning collar with the sample hole facing upstream. It can be pushed in and out thus allowing the sample to be taken at any point along the diameter of the pipe.

SAMPLE PROBE

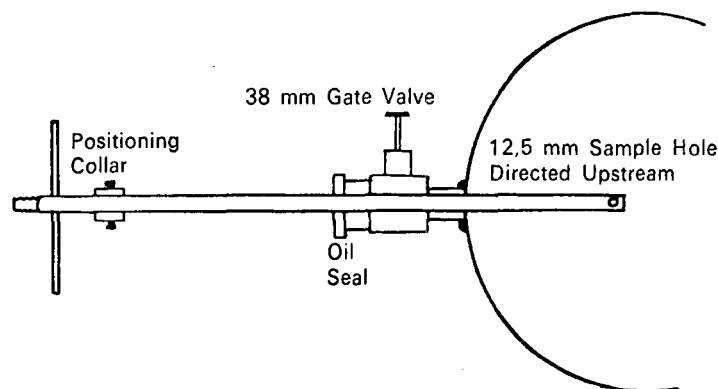


FIGURE 1

2. The Condenser (Figure 2)

This is a simple condenser made of two concentric brass tubes with cooling water running in the jacket between the tubes. The inner tube of the condenser is connected to a vacuum pump capable of producing a higher vacuum than that in the vapour pipe which is being sampled. The condensed

* Present address, Pongola Sugar Mill.

vapour drains into a barometric leg made of 6 mm O.D. nylon tubing.

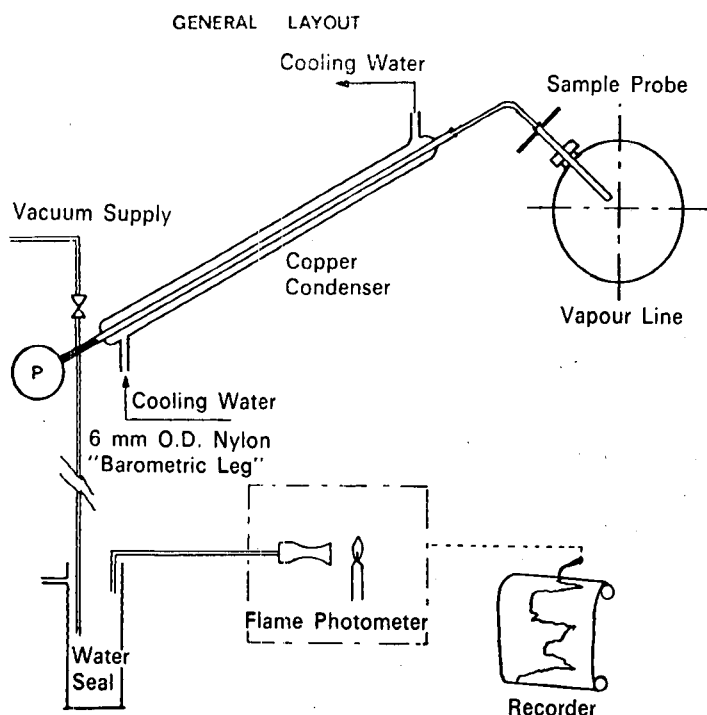


FIGURE 2

3. The Flame Photometer (Figure 3)

The flame photometer unit consists of:

- (a) The flame photometer proper and an amplifier.
- (b) A propane gas cylinder equipped with a constant pressure regulator.
- (c) An air pump or compressed air supply at constant pressure.

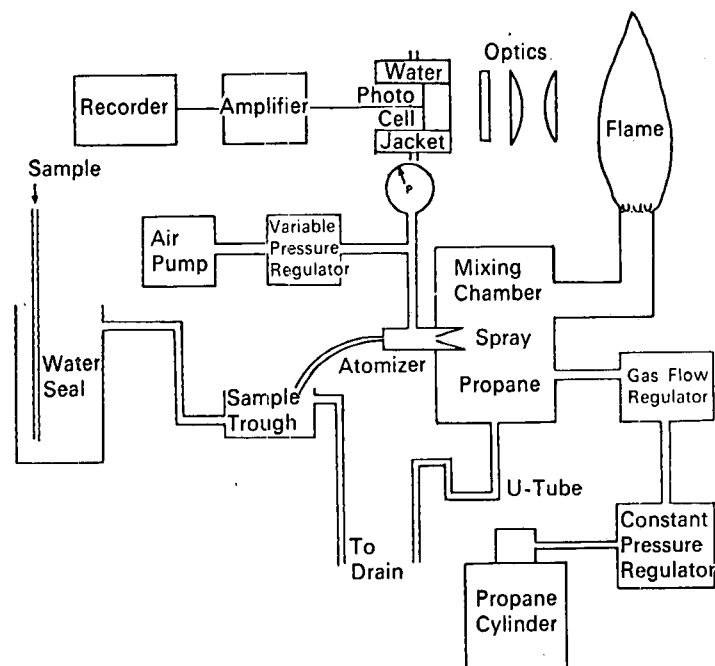


FIGURE 3

The condensate in the sample trough is sucked into the atomizer (Fig. 4) through a 0,7 mm diameter capillary tube. In the atomizer the sample is mixed with compressed air at 1,3

bar absolute pressure and a fine spray or "mist" of sample is discharged into the mixing chamber where it is mixed with propane gas and led to the burner. A constant air pressure is essential and the instrument must be calibrated at operating pressure. Only the smaller droplets in the sample spray actually reach the flame. The rest flows out of the mixing chamber through the U-tube which serves as a seal to prevent any propane escaping. The light of the flame passes through an optical condenser and a 768 mm wavelength light filter before falling onto a water cooled photoresistor.

The conductivity of the resistor is proportional to the intensity of the light and consequently the current flowing to the amplifier is proportional to the concentration of potassium in the flame.

The current reaching the amplifier is displayed on a microammeter. The amplifier may be connected to an alarm system and/or a recorder.

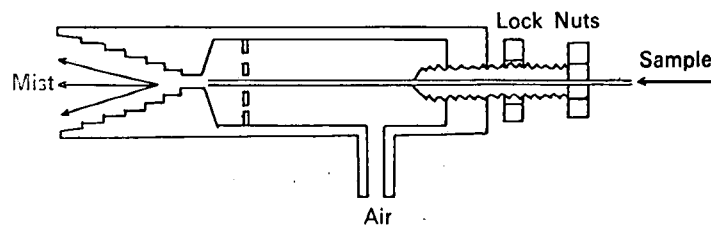


FIGURE 4

Application

The equipment described above has been used since 1971 to monitor entrainment from evaporators and, in a few cases, from vacuum pans in several factories. The main difficulties experienced were due to fluctuating vacuum wherever a factory vacuum pump was used as the source of high vacuum. The flame photometer used consisted of separate units which were assembled on site in a cabinet.

This combination was not dust or moisture proof and has led to repeated instrument failures in factories in which environmental conditions were poor. A new instrument more suited for factory work is on order.

Use of the equipment is best illustrated by the following typical application:

During part of the 1975/76 season undetermined losses at GH were high and there was evidence of sporadic entrainment from an evaporator which had undergone extensive modifications, including the commissioning of new effects, during the previous off season. It was therefore decided to monitor systematically all possible sources of entrainment from the evaporator as follows:

- (1) Condensate from the first vessels to check for the possibility of leaks. Results were negative.
- (2) Condensate from the second vessel and condensate from juice heaters on VI. This run lasted a week and showed very low losses, usually less than 50 ppm sucrose.
- (3) The instrument then ran on combined condensate from vessels 3 and 4 (i.e. V_2 and V_3) for about 3 weeks. Entrainment was low averaging between 0 and 75 ppm sucrose and only twice peaking to 500 ppm. One of these peaks is shown in Fig. 5.
- (4) Injection water was then tested. Problems were encountered due to blocking of the instrument's capillary by suspended matter in the water. Both inlet and outlet water were monitored and the chart (Fig. 6) shows that K^+ level in the outlet was higher than in the inlet and that the amount of potassium present in water was high. The instrument had been calibrated to read

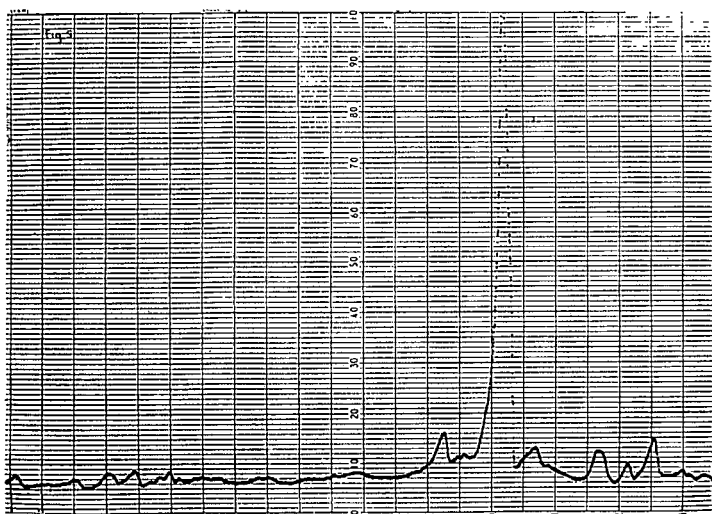


FIGURE 5

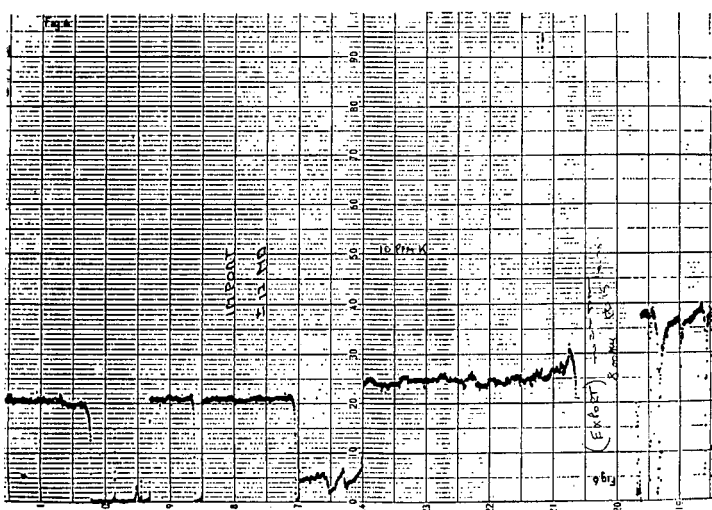


FIGURE 6

10 ppm K^+ at 50% f.s. With a sucrose to potassium ratio of 100 to 1 this would be equivalent to 1 000 ppm sucrose. The difference in K^+ between inlet and outlet water was approximately 0,66 ppm equivalent to 66 ppm sucrose. Assuming a condensing water to vapour ratio of 40:1 in the condensers the sucrose concentration of vapour from the evaporator would be 2 640 ppm.

- (5) This high sucrose concentration was confirmed when the instrument was used to monitor combined vapour from the two fourth effects. The results (Fig. 7) show

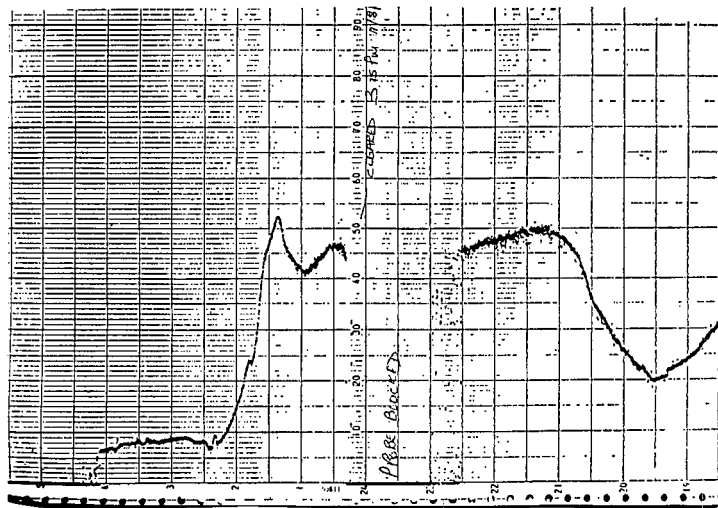


FIGURE 7

entrainment peaks of between 4 000 and 5 000 ppm with the instrument probe sometimes becoming blocked by sugar which crystallized out. Further tests carried out on vapour from effect 4A showed that it was this vessel that was responsible for entrainment. The continuous recording of entrainment also indicated that massive entrainment occurred whenever there were fluctuations in exhaust steam pressure to the evaporator.

Corrective action has since been taken and in fact GH has since purchased a flame photometer of this type for continuous monitoring of boiler feed water.

In another application of vapour sampling at UC it was found that entrainment occurred only late during the night and in the early morning and this was traced to the higher vacuum produced by colder injection water during this period.

These examples indicate how monitoring of sucrose in vapour to the condensers can be used to pinpoint sources of entrainment.

A continuous installation on each condenser of a sugar mill could not be justified but a portable photometer can be used when entrainment is suspected provided the vapour pipes are fitted with valves through which the sample probe can be introduced. In view of the fact that a portable instrument is available at the SMRI all mills should have sample valves on evaporator and pan vapour lines.

REFERENCES

1. Verhaat, M. L. A. and de Visser, N. H. M. (1966). Flame photometer for detecting sugar in boiler feed water. *Zucker* 1966, 19, 509-510.