

HIGH UNKNOWN LOSSES CAUSED BY ENTRAINMENT DURING EVAPORATION AND BOILING OF SUGAR CANE JUICE.

By M. VIGER.

Introduction.

The writer wishes to start this address with an apology for the tediousness of elementary theoretical explanations set in this paper. Naturally, a considerable part of the data has been drawn from outside sources, the idea being to give a comprehensive survey of the subject and stress the importance of "Entrainment" in the sugar factory.

Unless one is conversant with the laws or causes which govern entrainment, it is indeed difficult to conceive that such conditions take place inside an evaporator or vacuum pan when it is boiling, even when the height from the top tube plate of the calandria to the vapour exit pipe is some 15 feet high.

What is entrainment? By entrainment we mean the mechanical carrying off of liquid drops caused by the velocity of the vapour current into which they may be projected, depending on the violence of boiling, the velocity and direction of the vapours.

Causes of Entrainment.

Sugar is carried over into the condenser of evaporators or pans through four different causes:—

1. By splashing.
2. By creeping up the sides of the vessels, due to capillarity.
3. By vesicular transference.
4. By flashing or sudden ebullition due to sudden drop in temperature.

By splashing is meant the mechanical projection upward of a drop of liquid; and by vesicular transference the carrying upward of a hollow bubble of liquid. The height to which a drop or vesicle of liquid will reach depends—

1. On their initial velocity.
2. On the pressure exerted on them by the current of steam.
3. On their weight.

A bubble of steam formed at the lower end of a tube travels upward with constantly increasing velocity ($V^2 = 2gH$). This will be greater in vessels having long tubes than those with short tubes.

The graph shown (Fig. 1), indicates the relation $V^2 = 2gH$.

The pressure exerted by the steam on a drop increases with the square of its velocity and also with the pressure under which the steam exists; so with vessels of small diameter and small vapour pipes the tendency to carry forward drops of liquid will be greater than in

vessels of larger diameter and with ample vapour pipes. The weight of a vesicle or bubble of liquid being so much less than that of a drop indicates that it is to vesicular transference that the greater part of entrainment losses are due. Owing to the viscosity of the denser juice in the last body, the tendency to form vesicles is increased at this stage, so that entrainment losses become serious.

Losses due to vesicular transference are much harder to control, since the bubble may be so light that the influence of the current forward of vapour is enough to overcome the force of gravity.

Detection of Entrainment.

There are several methods through which entrainment can be detected:—

1. Testing the tail water from the condensers by one of the usual colour tests, such as *a* naphthol or ammonium molybdate, etc., etc.
2. Polariscope test of the water after concentration, precautions being taken to prevent inversion of the sucrose.
3. By inserting an half-inch pipe in the vapour line between the vessel and condenser. The pipe is led to a suitable vessel, preferably of glass (as aspirator bottle), as this allows easy inspection during sampling.

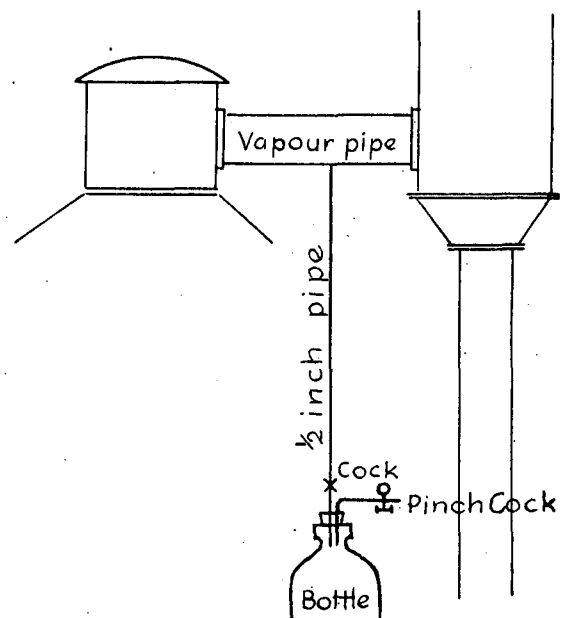
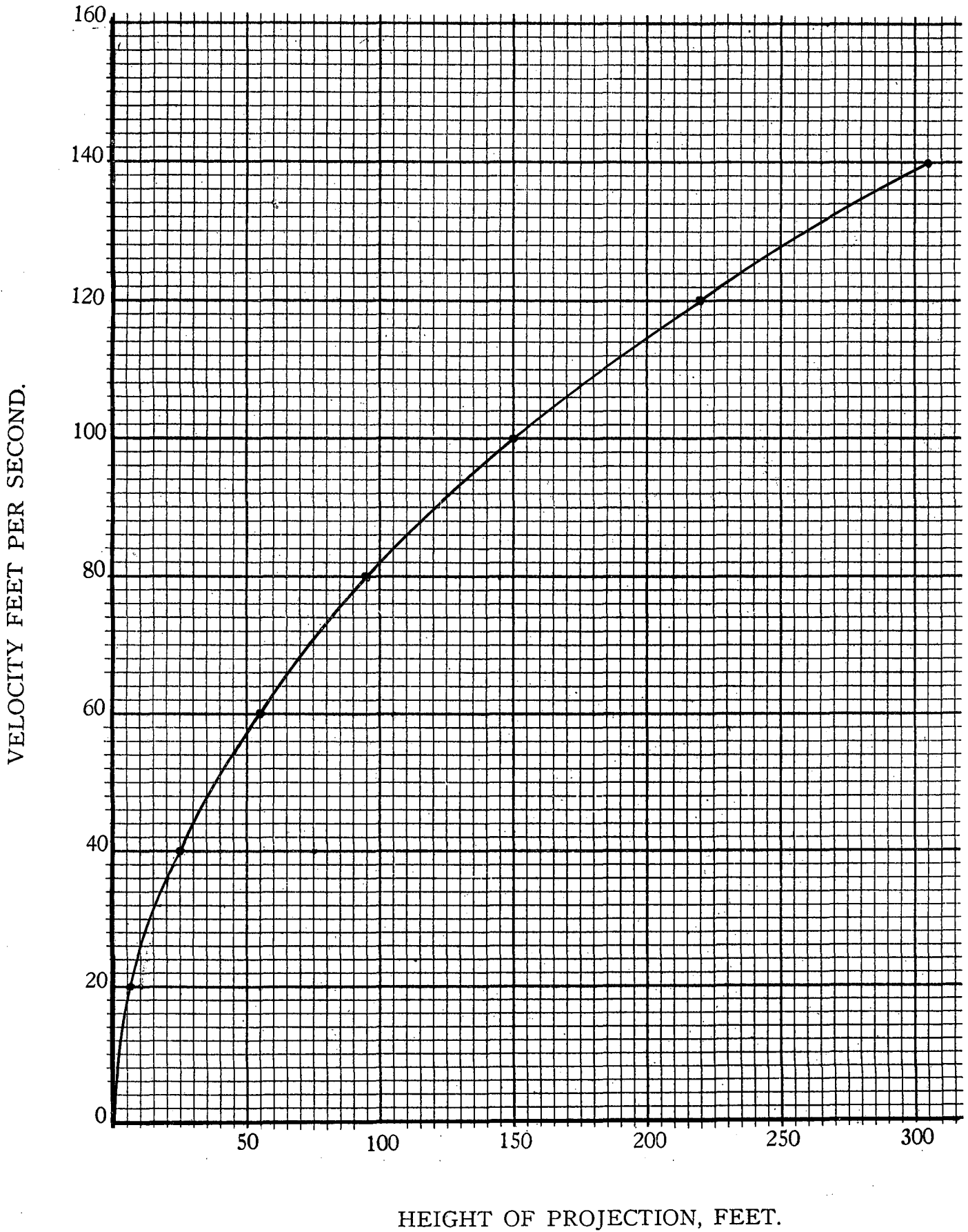


Fig. 2.

GRAPH SHOWING RELATION $V^2 = 2gh$.

(FROM WEBRE).

FIG. 1.



The following figures were obtained during last season and shows the evaporator working under various conditions.

The evaporator is 24,000 sq. ft., the height from the top tube plate to the vapour exit pipe being 24 feet 3 inches.

Table Showing Amount of Entrainment when Evaporator is Working under various Conditions.

Days.	A.		B.		C.	
	Brix.	Amount collected by Sampler.	Brix.	Amount collected by Sampler.	Brix.	Amount collected by Sampler.
		Litres.		Litres.		Litres.
Monday ..	41.2	72	15.0	20	2.2	16
Tuesday ..	48.5	68	23.1	11	3.6	20
Wednesday ..	50.3	66	23.6	13	7.1	16
Thursday ..	49.7	57	27.7	15	3.4	15
Friday ..	49.5	55	23.2	24	4.1	17
Saturday ..	50.0	58	24.1	35	3.3	30
Total	376	..	118	..	114
Average ..	48.0	63	22.7	20	3.9	19

- A.—Evaporator working without entrainment catcher.
- B.—Wire screen (Helmer's) and wooden baffles.
- C.—Stillman installed.

A mill crushing 311,827 tons of cane and producing 37,818 tons of sucrose in the mixed juice for the season; an undetermined loss of 0.2% cane (say, due to entrainment) means a loss of 623 tons of sucrose.

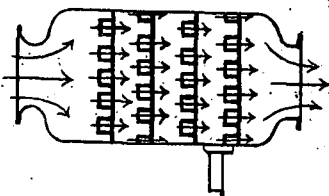
Taking the sucrose recovery at 85.2 and the pol. of sugar at 97.5, the 623 tons of sucrose would yield 545 tons of raw sugar, which at £10 = £5,450—a very substantial sum.

The price of an efficient save-all is about £600. The installation would more than pay for itself in a season, even with a loss of 0.1% cane the equipment would still be worth while.

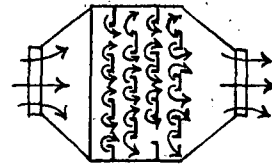
In addition to the monetary gain the recovery figure would be raised by 1.8% or 0.9% according to the loss.

TYPES OF CATCHALLS OR SEPARATORS IN USE WITH EVAPORATORS.

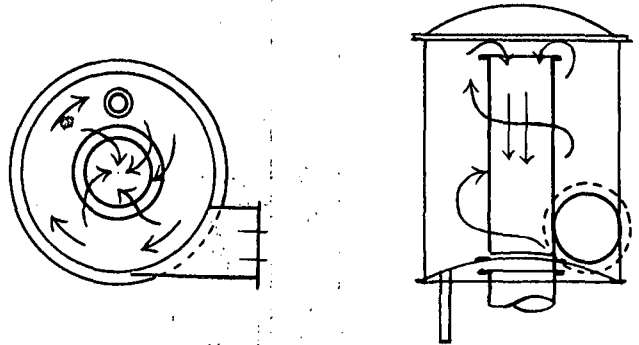
(Sketches taken from Webre and International Sugar Journal.)



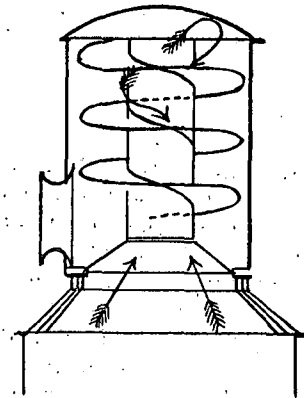
Hodek Separator.—Excellent catchall, but with high friction loss.



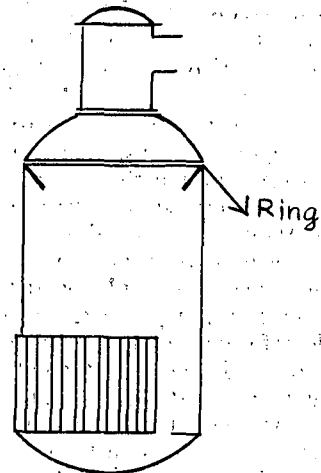
Multiple Channel Catchall.—Weak point, re-entrained spray.



The Webre Centrifugal Separator.—Good for any vapour speeds within the limits of practice.



Honolulu Iron Works Co. Catchall.



Ring device inserted at top of evaporator to stop creeping action.

Sampling the tail water from the condenser (Fig. 3) is not recommended for the following reasons:—

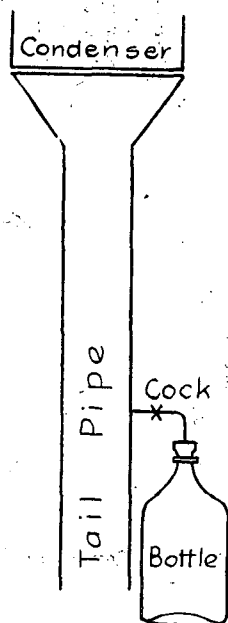


Fig. 3.

Mr. J. S. de Haan, in Java, found that the testing of tail water for entrainment was very unreliable. He was led to this conclusion by the examination of the waste waters when he knew positively that a good deal of entrainment was occurring. Almost invariably only a small loss was indicated and sometimes none at all; and the reason for this was believed to be due to the fact that the spray entering the Torricellian condenser does not mix at all thoroughly with the water, there being insufficient agitation and insufficient time to cause the solution of the dense drops of syrup in the liquid. This point was put to proof in the laboratory, using a glass tube which was provided at the bottom with a small sampling tube, so as to imitate the conditions prevailing in practice as closely as possible. It was concluded that even when a comparatively large sample was continuously taken at the bottom of the column the analytical results showed only a few per cent. of the sugar actually entering at the top with the water. Of course, it may happen now and again that some of the sugar reaches the neighbourhood of the sampling tube; but this must generally escape detection owing to the very small proportion compared with the large amount of water running through the pipe. The writer has experienced very similar results as obtained by Mr. J. S. de Haan. (On several occasions when entrainment was known to be very heavy, the usual routine tests showed a negative result, or at times a very slight trace. The direct tapping of vapour gives more positive and reliable information, and is strongly recommended as a method to detect entrainment. The amount of syrupy liquor collected every hour, and its brix is a useful guide to the operator. This will not by any means show the actual quantity of sucrose lost at the end of a period. The amount of sucrose found in the syrup can be accurately ascertained only by weighing the syrup; so the importance of weighing this material

is obvious, and the cost of such additional equipment as a scale fully pays for itself in a short period of time.

Prevention of Entrainment.

To prevent this loss a number of appliances, with varying degrees of efficiency, have been devised. The original and best known type is the Hodek-Ralentsseur. This apparatus consists of a chamber in which are arranged a number of transverse perforated partitions, the sum of the areas of the perforations being greater than the area of the vapour pipe. Its action is probably twofold—the vesicles on striking the partitions are ruptured, forming drops which are not carried forward but fall down; and, secondly, the sudden change in the area of the pipe reduces the pressure on the vesicles, causing them to burst into drops. Many modifications of the Hodek have been devised, such as the arrangement by Stillman.

According to Horsin-Deon, the best proportions for a save-all are that the diameter be 3 to $3\frac{1}{2}$ times, and the length 6 times the diameter of the vapour pipe in which they are inserted. In principle, a save-all is very much like a steam separator. Other devices which make use of centrifugal force to separate the comparatively heavy particles of juice from the vapour, seem to be simplest and most effective, such as the Webre Centrifugal Separator, and another apparatus made by the Honolulu Iron Works Company.

A very simple type of entrainment catcher, devised by Helmer, is a wire screen inserted at the top in the last vessel of the evaporator. This can be conveniently made of $\frac{1}{4}$ -mesh heavy wire and rendered more efficient by superimposing two screens. Helmer got his idea by watching a spider. "Robert Bruce watched a spider and marvelled at the creature's perseverance. While I am no Bruce, I watched the spider's web on a foggy morning and recognised its moisture consolidating properties."

Another type, also extensively used, is made of wood and in principle very much resembles the screen used by Helmer. The wire screens or the wooden baffles appeal very much on account of cheapness and ease of installation; but they are not as efficient as the Webre Centrifugal Separator, in which fine particles of liquor can be separated even when vapour is moving at the rate of 250 feet per second. With large quantities of liquor going through, the entrainment losses are only 0.02 per cent.

When wire screens are used, great care must be taken to see that the apertures do not clog; in this condition the area through which the vapour travels will be restricted, so an immediate increase in the velocity of the vapour will take place, resulting in heavier entrainment losses.

An important point when installing a save-all, the drain or return connection for the removal of the entrapped liquors should be water-sealed in the evaporator. If this is not done the liquor is blown back and carried away with loss.

A sight cross for observation in the drain pipe is very useful.

CHAIRMAN: Mr. Viger's very valuable paper introduces a subject which really has had very scant consideration in the past. We have known that we have had fairly high undetermined losses in our factories, but owing to the absence, as he points out, of weighing machines for syrup and molasses the Chemist has been unable to apportion those losses into their correct departments. Mr. Viger has taken from the authorities this valuable information together with information which he has been able to obtain at Darnall during the last year, and I think it is a subject well worthy of investigation by every Company.

Mr. H. FOSTER: Mr. Viger seems to have made quite a study of entrainment problems at Darnall. In the course of that study I would like to know whether he has noticed that entrainment appears to be excessive at some portions of the season, or whether he has found it more or less constant throughout the year.

Mr. VIGER: Yes I think it depends on the type of juice. At times for no apparent reason the entrainment is higher.

Mr. BECHARD: On the point of estimating the losses by analysis as against weighing, which we all agree is the best method of estimating losses, Mr. Viger gives us three tables A, B, and C. We had some experience of this entrainment last year at Amatikulu following the line that Darnall had set us. We found he is quite right in what he says about the screens. We put the two screens in, one with a quarter inch mesh and the other a lattice. We found for the first few days it worked beautifully, and after that the entrainment went back to what it was before. We removed the screen and after that we found the lattice by itself was a very effective catch-all. The point is that this screen reduced the brix eventually to 2 brix with about 6 litres per day, showing that definitely the screen had done very useful work. I understand our Company is installing a Webre type catch-all.

Mr. VIGER: We had the same experience at Darnall. After a few weeks' work we found the wire was choked, and mention of it is made in the International Sugar Journal in October or November last year.

Mr. MURRAY: With regard to entrainment in an evaporator, where does it start? Are your tubes too close, making your vessel too small. What is the spacing for your tubes? Mr. Viger mentions about this screening in the tube; that is a very old thing and has been tried many times. But that spacing of tubes is done by manufacturers to get a small vessel, and you get the benefits afterwards! (Laughter).

Mr. WATSON: I think the whole result of this paper should be tied down to this, that all Engineers should acknowledge that entrainment goes on,

and that we have to do something to stop it. I think that is the real idea of Mr. Viger's paper. Any means whereby we can prevent entrainment is surely going to bring money back into the pockets of the manufacturer. Mr. Bechard mentioned that we at Amatikulu are going in for the Webre type. On page 4 of Mr. Viger's paper you will see one called a centrifugal separator. It is a tremendous thing. The actual weight of the one to suit Amatikulu is 20 tons; it is going to extend through the roof of the factory. That 20 tons does not include the weight of the structure for it, nor the extra piping entailed for bringing the vapour in and out of the separator. I have got hopes that it will certainly increase our recovery, but as Mr. Viger said without some definite apparatus for weighing the syrup we are still in the dark. Without weighing the syrup we can't definitely state that there is any loss between clarified juice and syrup, and when we put this thing in this year we are going to endeavour to weigh and analyse the run-off from the separator and probably be able to tell what we are actually getting from putting this thing in. But we will have to wait a year before we can give any definite results.

Mr. WILSON: While in the States in 1924 I investigated the best type of entrainment preventer, and the type recommended by Refinery Managers and Engineers over there was the Webre type. At the Refinery all our vacuum pans and evaporators are equipped with entrainment preventers after the style of this Multiple Channel Catchall. We find them very effective. Mr. Blacklock might be able to give you some figures in connection with that.

Mr. BLACKLOCK: As Mr. Wilson says we have entrainment preventers on our vacuum pans, but while we know there is certainly entrainment to some extent we do not notice it to the extent noticed by Mr. Viger. During the working of the pan the condensed liquor runs down the legs of the cell at the bottom and stands there, and when the pan is taken off discharges through the bottom. We have sampled that and have found anything from 2 to 5 deg. brix, and not very much of it, but on top of that, the stuff we find there is in a very advanced stage of fermentation and is very acid and very highly charged with iron, so instead of using the entrainment preventer as an economic unit we would rather use it as a protector to our condenser water, to prevent sugar getting into the condenser water and getting used again. We run that liquor to waste, we do not think it advisable to mix it with any product we have in the Refinery.

Mr. VIGER: Your tests were made on vacuum pans? We also carried out tests on the vacuum pans and they are in the neighbourhood of 2 to 3 brix, but although it happens at times there is a heavier amount, the general amount is very little. But these figures given here are from the evaporator. The tubes are bigger and the sugar comes rapidly into crystals and circulation is slower.

Mr. B. E. D. PEARCE: I would like to give a word of warning about these catchalls. In Illovo we had no entrainment in any of the vessels except the last body, so we took steps and put a save-all in and stopped it there, but it has started in the third body now!

CHAIRMAN: Some very interesting points have been raised on this matter and I think in the past we have been a good deal in the hands of the manufacturers. The unknown losses the Chemist

has had to explain, and taken the assurance of the Manager; one of the points that may have escaped his attention is that regarding the point raised by Mr. Viger, the testing of tailwater is not sufficient for detecting such losses. The point raised by Mr. Foster is worthy of more consideration and that is the effect of the pols of the juice on entrainment. It is possible that at certain times of the year entrainment is more heavy. I will ask you to accord Mr. Viger a hearty vote of thanks for his paper. (Loud applause).