

GROUP DISCUSSION ON THE PREVENTION OF ENTRAINMENT AND THE CONSTRUCTION OF SAVE-ALLS

Mr. W. H. Walsh initiated the discussion by reading the following resume:

You will, I think, all agree the subject chosen for the group discussion is a very suitable one as it is a subject which at one time or another has given every sugar factory manager, engineer and chemist a good deal of worry and anxiety. Why this subject is particularly appropriate at the moment is answered quite simply from the opening paragraph of a memorandum on the subject prepared by a manufacturer of sugar machinery:

For some unknown reason, perhaps because of an improvement in supervision, from all over the world we seem to be hearing more about entrainment troubles, and although a variety of head boxes have been designed, we do not seem to be making much headway with the problem.

Various new designs have been installed here and there and the installer has immediately claimed to have solved the problem, but in many instances, after a year or two, we have learnt that the trouble is still being experienced with entrainment. It is an unfortunate fact that no one has devoted the time necessary to making a complete study of the problem. No one can tell us whether the entrainment is continuous at a more or less uniform rate, or whether it is intermittent. With regard to vacuum pans, we have never been told whether the entrainment takes place in the early stages or in the late stages when the pan is nearly full or over-full, or whether it is continuous throughout the boiling of the pan. We know from our own observation that in many cases the entrainment in evaporators is irregular and it can be traced to rapid and severe fluctuations of steam pressures and vapour pressures, but in other cases it is continuous.

While we are limiting our discussion to evaporators and vacuum pans in sugar factories, we might, at a later stage, if time permits, compare the apparatus and technique used with that now being applied in boiler plant and other apparatus used in industry generally.

The causes of entrainment as such have been elaborated very fully by authorities such as Webre and Husbrand particularly and, nearer home, we have all read with interest very complete articles by Mr. C. G. M. Perk published in the *S.A. Sugar Journal* in 1953.

We can, therefore, very safely confine our discussions to the practical aspects of the subject and particularly to our own experience in this country and to observations which have been made and tests carried out in our factories. You will be doing a valuable service to the industry and to the records of this Association if you will recall your own observations and relate the particular circumstances under which you feel you may have some particular angle which may assist in solving the problem before us.

May we accept that under normal conditions entrainment is periodic and not continuous, and, in the case of an evaporator, is primarily due to irregular

operation, and one cannot stress too strongly the desirability of maintaining—

- (1) a regular juice supply at a regular inlet temperature;
- (2) a regular steam supply at a regular pressure and consequent temperature;
- (3) a regular vacuum maintained within reasonably close limits.

Now, these three conditions are not easily maintained in a sugar factory and we are also faced with a further condition which, when coupled with changing conditions in the above, can be the cause of considerable entrainment. Evaporating plants today are being operated at considerably higher evaporative rates than previously and resulting violent ebullition has emphasised certain weaknesses in design at one or two points. The definition of the term "ebullition" describes exactly what can be observed at certain times in an evaporator: boiling, effervescence, sudden outburst.

It can be confidently stated that the higher evaporative rates are the result of a very careful study of steam distribution, condensate removal, feed distribution, and more careful level control between vessels.

One cannot say the same care has been devoted to the design of save-alls for the same apparatus and one wonders whether this is due to the inadequate reports which have been collated and the scarcity of complete tests carried out in recent years on evaporating plant. One feels that if users called for acceptance tests, as in the case of boiler plants, a good deal of valuable information would be collected by the makers on their own apparatus and some valuable knowledge would also be gained as to how this apparatus is operated under average sugar factory conditions.

Before we leave this section, it would be interesting to have observations as to the effect on entrainment of the degree of clarity of juices, varying pH, and low purity juices.

It will also be most interesting to know how this problem compares from country to country where cane is grown under different climatic conditions and whether the same problems occur to the same extent in the beet sugar industry as in the cane sugar industry.

On these two latter points, our visitors may be able to give us some interesting observations.

Vacuum Pans

It is evident that considerable thought has been given to improvements in the design of vacuum pans and the improvements in circulation and evaporative rates are quite considerable.

These later designs, however, are much more responsive to changing conditions, particularly as regards steam pressure and feed temperatures, and neglect of this factor can undoubtedly produce conditions under which entrainment can take place.

Anyone who has witnessed the foaming which can take place under certain conditions, say on a Sunday night after a long week-end stop, will realize the danger and the manner in which excessive entrainment can take place.

Save-alls

We now come to the very vexed question of save-alls and on this subject it does appear the fashion changes almost yearly and one can imagine the position of the manufacturer who has developed a 1957 model of evaporating plant for South Africa, which is not acceptable to Australia, the West Indies, or the beet sugar industry, because each has its own particular fancy on entrainment prevention.

In this country we have seen such types as the Yaryan, Raschig, Heckman, Arnold, Wishart, Webre, and Stillman, amongst others, and it would be interesting to know if there are really sound reasons why we should discard some of the designs, particularly of external save-alls, which have been giving good service for the past few years.

Another thought which strikes me is that we should compare how separation is effected in other apparatus and here we are led to believe that ribbon separation and scrubbing is the most successful and unit cells of small individual capacity are the present trend.

One example is the method adopted for separation of moisture and dirt particles in water tube steam boilers by means of the Tracey separator and this apparatus has also been very successfully applied on steam pressure pipe lines in this industry. Reports on tests were submitted to this Association many years ago as a result of tests carried out by Dr. Hedley.

The subject is an intriguing one and could be enlarged upon considerably. One feels the present evaporating plant is largely a compromise and that if the design of an evaporator was further examined from a purely theoretical point of view, one might see some quite radical changes. With automatic control in the foreseeable future, we may hear more of this subject.

If, from our own experience in the factories, we can record our personal observations on the subject of entrainment prevention, this group discussion will have served a good purpose.

Mr. Rault (Chairman) stated that in some years past, his factory had experienced very high undetermined losses, a great part of which was entrainment at the evaporator and in a lesser degree at the pan boiling stage.

It was thought that the high evaporative rate of $8\frac{1}{2}$ lb. per sq. ft. per hour, demanded from an under-capacity evaporator, was the factor leading to entrainment, although opinions vary on the standard of efficiency to be expected from a quadruple effect. When a larger capacity evaporator replaced the old smaller one, undetermined losses were considerably reduced, to the benefit of boiling house recovery.

However, in the course of time, with higher crushing rates, the balance was again lost between cane and evaporation surface, and it became necessary to install save-alls. These were of the Webre type fitted between the pots, but not inside them. It was possible to measure that quantity of juice returned from each vessel, and this amount is an appreciable one. The estimation of entrainment in the last vessel by concentrating the condensate water in the laboratory seems to fall short of the real loss at that stage.

Mr. Walsh enquired what tests had been carried out with different entrainment apparatuses.

Mr. Rault replied that these save-alls were fitted outside the evaporators and the juice collected by them, represented an appreciable amount of sugar returned to process. The amount returned was measured in his factory.

Mr. Antonowitz said that one thing about entrainment which seemed to be generally missed was the nature of the juice being evaporated and agitation by boiling. This was similar to the flotation process in some ways and he felt there was room for a considerable amount of research on the subject.

Mr. Rijkeusch stated that in Tanganyika they do have trouble with entrainment in the evaporators, but they experience still more in entrainment through the vacuum filters.

Mr. Ashe mentioned that he had seen articles in sugar journals about a particular type of pad separator and he wondered if any of the local people had had any experience of this.

Mr. Walsh stated that this was called a mist extractor and took the form of a stainless steel mattress which caught small particles of entrained sugar juice. This, however, has not been used as yet in this country and he really wanted to know the experiences of the local industry with existing save-alls.

Mr. Scott stated that most of the existing save-alls consisted of metallic surfaces which could collect liquids only, but there had been no attempt to trap the vapour itself.

Mr. Walsh said that we should watch what is going on in other industries from which we might learn much.

Mr. McGregor stated that thirty years ago entrainment was heard of, but not to the same extent as today. He said that one fault was that we asked the manufacturer to supply us with apparatus of a certain heating surface and not to do a specific job, with the result that in some cases the pitch of the tubes had been reduced to get more heating surface in, thereby keeping down the diameter of the vessel. With the wider-pitched tubes there was not so much entrainment

Mr. Main said that entrainment was caused through two reasons. One was chemical frothing and the other was mechanical. Experience with the De Haan carbonation process taught us how to control frothing. He pointed out that a firm in Holland had produced an evaporator from which entrainment was entirely eliminated. The juice was introduced into this evaporator so as to cause a swirl or vortex and in the case of this apparatus entrainment was very small or negligible. The calandrias were placed outside the vessels and the juice forced through them into the vessel where it circulated in a tangential manner. By this means the evaporation rate was enormously increased. He agreed with Mr. Antonowitz that while the chemical problem was important, the mechanical problem was still more important.

Mr. Antonowitz questioned if there was less entrainment in the past. Even today it was difficult to know if we had calculated undetermined losses properly. He considered that only by weighing the syrup could we come to a positive solution.

Mr. Elysee said that this subject had been discussed before. He had no doubt that at Amatikulu there was considerable entrainment. The save-all was only just a large vessel into which the vapour was introduced tangentially and from this apparatus juice was flowing through an inch pipe, full bore. With the introduction of the defecation process they were now putting through one hundred and forty tons of juice per hour where before the same apparatus could not take ninety tons per hour. This was due to increased imbibition. The undetermined losses had now reached 3 per cent. on sucrose per per cent. cane. He said that entrainment consisted largely of small particles of juice and he was horrified to know that in the second and third vessels of the quad at Amatikulu there was no baffle plate. On testing, he had found quite a considerable amount of sucrose in the second and third vessels. He said that it was not possible to assess the correct amount of sucrose lost by entrainment. He also said it might be possible for hydrolysis of small quantities of entrained sucrose in the large quantities of condensate to take place. There was no doubt that

entrainment took place, but it was impossible to assess the quantity of sucrose lost in this way.

Mr. Grant said that he could not give a definite figure but gave his experience at Darnall with a quadruple effect fitted with a Heckman fitted in the last vessel and a Stillman fitted on the vapour pipe before the condenser. Any adjustment to the Heckman made no difference whatsoever and a considerable amount of scale was found in the head of the vessel. With the Stillman fitted with four baffle plates a large deposit of scale was found on the first two baffles, but the second pair were found to be reasonably clean, which indicated that there was a considerable saving through the Stillman. A centrifugal-type save-all designed by the S.M.R.I. was fitted in the vapour space of the third vessel. Prior to its installation heavy incrustation took place in the head of the vessel but after a full season's work (approximately nine months) with this device installed there was no incrustation whatsoever, which indicates that it was eliminating entrainment entirely.

Mr. Rault asked if Mr. Perk could tell us something about the Kestner apparatus which had long tubes of very restricted diameter. Was a lot of sugar entrained through the higher evaporation or had this difficulty been overcome.

Mr. Perk stated that the Kestner save-all was probably the most efficient. He demonstrated the construction and operation of the Kestner apparatus and its save-all on the blackboard and said he did not know why this apparatus was not used more. However, the principle of the Kestner save-all was incorporated in the save-alls designed by the S.M.R.I. He followed this explanation with a demonstration of the semi-Kestner apparatus.

Mr. Dick referred to experience with a Kestner multiple-effect in a sugar factory-cum-refinery in India. This was not used in the raw sugar house but for concentrating the sweetening-off water from bone char filters.

The Kestner, when used on raw sugar house juice concentration, did have troublesome entrainment losses, possibly as a result of the juice frothing.

One other trouble was difficulty in cleaning scale from tubes effectively on account of the tubes being twenty to twenty-two feet long.

Kestner evaporators were used in one tanning extract factory in Natal, here again entrainment losses were experienced as a result of frothing, and tube cleaning was found to be most difficult. Two such evaporators were replaced about eight years ago by another make.

Mr. Walsh said though while it was obvious that the high evaporator rates now required increased the amount of entrainment there was no doubt that the

engineers and chemists through fitting save-alls have been able to reduce entrainment considerably.

Mr. Boyes said that no-one had come forward to suggest how losses due to entrainment at the evaporator could be properly assessed. He suggested that this might be done by recording the temperatures of the cooling water in and out of the condenser, together with the temperature of the condensing vapour. The evaporation rate for the evaporator could be calculated from the brix and juice feed figures. A thermal balance over the condenser, ignoring the heat lost by the incondensable gases, would give the flow of condenser water per hour. Samples could be collected from the tail pipe at regular intervals and analysed by the Luff-School method. Each sample would be concentrated from say 1000 ccs. to 100 cc. and completely inverted with HCl., the invert sugar present being determined by means of the Luff-School method and sucrose determined by using the inversion factor of 0.95. This method gets round the rapid inversion that takes place in the tail pipe sample.

Since entrainment is usually intermittent, peaks will be observed when test-runs are continued for an extended period. The exact magnitude of these peaks can be assessed.

Mr. Elysee pointed out that one of the difficulties in assessing the loss was the fact that it was not continuous, but rather intermittent. It was quite obvious that one could calculate the amount of evaporation but to determine the actual sucrose loss was another matter.

Mr. Fourmond stated that at the factory at which he was engaged they had a first vessel which was twice the size of the following three. In other words these were being forced. He found that a $\frac{1}{8}$ -inch pipe connected to the vapour pipe gave them a Winchester quart of juice in a few minutes in spite of the S.M.R.I. save-all. The evaporator was originally intended for bleeding for feeding the juice heaters, but owing to bad arrangement of the incondensable gas piping and the lack of a pump for extracting condensed water from the juice heaters this could not be done. He was of the opinion that entrainment was really mechanical. Bad juice would cause entrainment in the first, but not in the last vessel. He considered that weighing the syrup would be the best method of measuring entrainment. He found that by slowing down the rate of evaporation the undetermined losses could be reduced by about three per cent.

Mr. Alexander asked if anybody in the industry were using anti-foaming agents and wondered if this could be an economical proposition.

Mr. Hendry said that when required, it was intended to use condensate from the second, third and fourth vessels for the boilers in this coming season. That there was entrainment in the fourth vessel was

obvious as one could see it being returned by a thief pipe from the save-all. He was of opinion that not much sucrose was lost as shown by the condition of the river.

Mr. Walsh said that on the older pans and evaporators they fitted what they called "buttercups" which allowed a certain amount of oil to flow into the vessel, but as entrainment was intermittent these were not of great value. He wished to know if any difference in the evaporation, entrainment, or things of that nature, were noticeable, more so now since the introduction of the defecation process.

Mr. Perk endorsed Mr. Walsh's remarks that steady working would reduce entrainment. Save-alls may reduce entrainment losses, but since prevention is better than cure, we should start by reducing the tendency to entrain. This can be done by steadying working conditions, as steady vacuum, uniform juice flow rate, steady exhaust steam pressure, etc.

As far as weighing of syrup is concerned, he said that although syrup weighing might measure the losses between mixed juice and syrup, it did not reduce them. Moreover, not all the losses between mixed juice and syrup weighing were due to entrainment.

Dr. Van der Pol said that an evaporator's function was to evaporate, and if, through supplanting the sulphitation process with the defecation process, one could evaporate more, then the obvious solution was to instal a larger save-all. He noticed that at some factories there was no liquid seal between the save-all and the drain to the pan or the evaporator. As there was a slight pressure drop between the vessel and the save-all the liquid tended to go away to the condenser instead of returning to the vessel. He agreed it was most difficult to try to assess the actual loss by entrainment; because this was largely intermittent. Unless one sampled condensate at the same rate at which it was evaporated, the calculation became quite unreliable. He considered that the entrainment problem was not insoluble but he felt that more attention should be devoted to the design of the save-alls rather than looking at it from a point of view of the construction of the evaporator.

Mr. Ken Pearce said that they had fitted Metex save-alls at Illovo, these being of the internal mist collector type. The one on the pan was not successful, being too low and it became filled with sugar. It was difficult to estimate the worth of the others as external save-alls were also in operation on the vessels to which they were fitted.

Mr. Leclezio stated that there were two distinct aspects to this problem of entrainment. The first was the creation of entrainment and the second the recovery of the entrained juice. Considering the first point, it had been found in Mauritius that poor condenser design was often responsible for high

entrainment losses. In some condensers the gases could not easily escape, built up, and then were suddenly released, thereby causing a surge in vacuum and producing entrainment. As far as save-alls were concerned, the centrifugal type advocated by Mr. Perk had been used with great success in Mauritius. Also a locally-designed type, subjecting the vapours to two successive vertex motions in opposite directions, had proved very efficient, and its use was widespread. Where losses previously had been very high they were now reduced to less than 75 p.p.m. in the condenser water. He pointed out that in the construction of save-alls it was important to pay attention to every detail, such as the liquid seal mentioned by Dr. Van der Pol.

Mr. Walsh said he thought it would be agreed that the S.M.R.I. save-all was developed from the centrifugal save-all constructed many years ago. One of the problems of the manufacturer was to know what type of save-all to install in his plant and therefore reports or discussions such as this would be of great value to him. The modern evaporator was designed for high evaporating rates and as many of them were now being fitted with S.M.R.I. save-alls it would be interesting to see how effective they would be with the new type of apparatus. Many of these apparatuses were followed by the Stillman which was very efficient although it had a high frictional loss. He asked if anybody could give experience of how they overcame the loss through condensers on the vacuum filters.

Mr. Thumann stated that most of these losses were due to air leaks. He said this was overcome to a large extent by fitting plastic piping instead of brass or copper tubing inside the vacuum filters.

Mr. Hendry asked if water was used in the barometric column of a vacuum filter. It was quite sufficient just to seal the downpipe into a drum.

Mr. Scott said that some years ago they used a pump with Saunders valves to return the filtrates but this resulted in an accumulation in the receiver. The pump picked up and delivered the juice with a tremendous surge resulting in much going into the condenser.

Mr. Munro stated that he had watched boys on the Oliver filters sometimes scrape off a sticky patch on the screen, but this patch was under vacuum which caused a tremendous surge of air into the system.

Mr. Antonowitz said that the fact that there were sticky patches on the filter pointed to poor chemical clarification and supply of adequate bagacillo.

Mr. Rault asked if Mr. Walsh would specify a certain evaporating rate for an evaporator which should not be exceeded in order to avoid entrainment.

Mr. Walsh said that in the past $4\frac{1}{2}$ lb./sq. ft. was considered sufficient. This had now risen to 8 lb. or so, but whatever the manufacturer recommended would always be exceeded by the factories.

Mr. Thumann wondered what problems were met in other industries which used evaporators, such as the oil industry. They must have had experience and designed apparatus to avoid entrainment. The same thing applied to the operation of filters. He considered it would be of value to obtain some discussion by an outsider connected to, say, the oil or other industry using such apparatus.

Mr. Walsh stated that, as he had mentioned in his notes, the present evaporator was just a compromise, but had it been tackled from a purely theoretical point of view, we might have obtained a much more efficient apparatus.