

COIL AND CALANDRIA VACUUM PANS

By CHS. G. M. PERK.

Since the change-over from coil pans to calandria pans at the Natal factories several years ago, the few coil pans left here have become out-of-date, due to the great progress made in other countries in improving coil pan design. It therefore seems opportune to point out the advantages of the modern coil pan design, and to compare modern coil pans with calandria pans.

THE DEVELOPMENT OF THE COIL PAN.

The oldest pans were coil pans, in shape spherical or lens-shaped. Later, a cylindrical section was inserted between the two semi-globes forming the top and bottom parts of the pan. At the same time the number of coils was increased. The semi-spherical bottom usually was steam-jacketed and formed a principal part of the heating surface in the oldest pans. In modern pans, this steam-jacket, if provided, is no longer considered as part of the heating surface, but as a superior kind of lagging.

In the course of time, the ratio between the height and the diameter of the pan, which was originally 1 : 1, increased considerably. This increasing slenderness of the pans did not assist in maintaining a good boiling performance.

When the use of C sugar magma as a footing for the A and B masseuites had become a universal practice, however, graining the C masseuite on syrup was still adhered to: a tendency was developing to cram as much heating surface as possible into the lower part of the pan in order to be able to make grain for one C strike only, and in the shortest possible e.

In order to provide as much heating surface as possible at such a low level, the lower part of the pan was provided with a so-called double bottom and two banks of double coils. Consequently, the other banks of coils also were placed lower than usual, and this resulted in the full pan level protruding three feet and more above the highest bank of coils. Moreover, the cramming of so much heating surface into the lower half of the pan obstructed the circulation of the masseuite. This type of pan had only one advantage (and it proved to be only a temporary one), viz., it could grain well with a filling of only 25 per cent.—a feature much appreciated in the days when the last strike was still grained on syrup. The introduction of graining on molasses deprived this type of pan of its right of existence, and the practice of cramming too much heating surface into the lower portion of the pan ceased.

At that time, the contrary practice of spreading the heating surface over the whole area of the pan became more general. At the same time the idea that the diameter of the cylindrical portion of the pan should be equal to the height, and that the down-take must be very generous, gained ground.

To be honest, we must confess that as far back as 1912 some pan designers constructed pans, the design of which can at this date be described as modern. In that year, for instance, Maxwell built pans of 600 cubic feet capacity with a diameter of 12 feet, and with the diameter of the free passage in the centre of the pan—the so-called down-take diameter—amounting to 40 per cent. of the pan diameter. The vertical spacing between the coils was so apportioned that the highest bank of coils only became submerged when the pan was filled to seven-eighths of its full capacity. These are all properties which we demand nowadays of a modern pan design.

In the last decade the following new tendencies have evolved:—

- (a) to decrease the ratio between height and diameter of the pan to a greater extent;
- (b) to shorten the length of the coils; and
- (c) to reduce the resistance which the coils exert against the circulatory movement of the masseuite by—
 - (i) using flattened coils,
 - (ii) arranging the coils in concentric circles, and
 - (iii) lessening the obstruction caused by coil clamps, etc.

The shortening of the tubes is achieved in several ways. Thomson of the Java Sugar Experiment Station constructed coils popularly called "carriage-wheels" because of their shape. However, the cross-section of these coils was still circular. H. A. Ditmar Jansse, of Java, constructed two modern coil pans (800 cubic feet pan, 10 feet 9 inches in diameter) with seven banks of coils, each bank consisting of three separate coils, the vertical section of the coils showing an oval with a ratio of height to width of 15 : 8, for Inkerman and Pioneer Mills, Queensland. At Pleystowe and Mulgrave Mills in Queensland, two new pans with seven banks of coils (960 cubic feet pan, 12 feet in diameter), designed by J. L. Halpin, came into use: each bank consisted of 6 by 2 semi-circular shaped coils; the coils having an oval-shaped vertical cross-section with a ratio of 14 : 10. The coils are arranged in concentric circles and connected to radial manifolds.

Finally, Stork re-tubed an old coil pan with six banks of coils of modern design for a Java mill in 1950. Each bank consists of six complete turns of flattened 5-inch coils, the banks being well distributed over the height of the pan. The diameter of the down-take area at the top bank of coils is ± 40 per cent., and at the bottom coils is ± 35 per cent., of the diameter of the pan. As mentioned above, each bank of coils of the new Stork pan consists of six turns of coils arranged in concentric circles. The steam inlets and the condensate outlets of the six turns of each bank are provided for in the form of rectangular, oblong boxes of cast steel, a diaphragm dividing the boxes into upper and lower halves. The steam is introduced into the upper halves of these radial manifolds, and since all the turns begin in these halves the steam divides itself over all the 6×6 turns. The turns end in the lower halves of the manifolds, and thus the condensates of the coils gather here and are piped down through the bottom of the pan to the steam traps.

The advantage of short coils is that this type of coil pan can also be used for boiling with low-pressure steam; for example, with vapour from the first or second cell of the evaporator. Old-fashioned long coils could only work properly with live steam, and coils of medium length with live steam and exhaust steam only, and not with vapour of about atmospheric pressure.

Since these short coils are only provided with flanges at both ends to connect them to the radial manifolds, they oppose minimum obstruction to the circulatory movement of the massecuite and improve circulation.

Flattened coils do not only improve the circulation by reducing the resistance, but they provide, too, the opportunity to enlarge the centre well diameter without reducing the horizontal clearance between the coil turns. In this way they improve the circulation also.

The modern manifold coil pans, besides their suitability for the use of steam of various pressures, have very good boiling qualities, the most essential property in a vacuum pan. Owing to the good distribution of their heating surfaces and their high circulation rate, these pans can boil fast and tight—qualities which are always welcome and effective, whatever massecuite is being boiled.

THE DEVELOPMENT OF THE CALANDRIA PAN.

The gradual increase in the capacity of the pans in the course of years has not benefited those characteristics which make for good boiling performance in calandria pans.

Starting from the almost globe-shaped old pans, the capacity can be increased by increasing (a) the

diameter, (b) the height, or (c) both dimensions. In the case of coil pans, both dimensions are increased, and, in the last decade particularly, the diameter more than the height. In the case of calandria pans, however, the height has increased more than the diameter, resulting in a slender instead of a squat pan shape.

There are, however, exceptions:—

- (a) in Java the cylindrical part of the coil as well as of the calandria pan is kept with a ratio between height and diameter varying between 1 : 1 and 1 : 1.2, and
- (b) the so-called “low head fast boiling” type of calandria pan has a cylindrical part above the upper tube sheet with a very large diameter, markedly larger than the diameter of the calandria.

A type of calandria pan in common use to-day is a pan with 4-inch wide tubes 4 feet in height. If such a pan is boiled up to 6 feet above the upper tube sheet, the graining charge will amount to approximately 40 per cent. of the full pan capacity. However, usually a lower graining percentage is demanded, and in consequence calandria pans are quite often boiled up to 7 to 8 feet above the upper tube sheet. In this way—sustained by a reduction of the space below the under tube sheet by substituting the ordinary 30° bottom with a so-called “saucer bottom”—the graining volume can even be reduced to 28 per cent.

We would draw attention to the fact, however, that it is commonly understood that 5 feet is the maximum height at which we are allowed to boil above the highest point of the heating surface. This height is limited by the gradual increase in boiling temperature, travelling from the top of the massecuite column downwards, which gradual temperature rise results in a like gradual decrease of the degree of supersaturation. About 5 feet down the supersaturation changes to undersaturation, viz. at that *niveau* the crystallization of sucrose has not only stopped but has changed into a redissolving state.

For example, if we boil a pan up to a level of 6 feet above the upper tube sheet, crystallization as described above will only occur from about 2 feet above the upper tube sheet. On the other hand, sucrose will be re-dissolved in the layer just above the upper tube sheet. Thus, the whole crystallization process must take place in these topmost 4 feet of massecuite, i.e. in a relatively small portion of the pan area, and therefore only a small portion of the total crystal area of the pan will be used in the crystallization process. The boiling rate being de-

NOTE.—Illustrations of a modern calandria pan as used in Hawaii, of the Ditmar Jansse, and the Halpin pan at Queensland, are shown in an article on vacuum pans by C. B. Venton (I.S.J. 1950, p. 63).

pendent on the crystal area available, it must of necessity be lower than when the whole pan space is involved in the crystallization process. If this limited boiling rate is exceeded, the formation of false grain will occur.

A recent development in the problem of obtaining a low graining volume without an excessively high massecuite column above the upper tube sheet has provided a solution which has been adopted in Hawaii for modern calandria pan design. In this design not only is the saucer bottom with centre flow arrangement applied to reduce the volume beneath the calandria, but in addition the capacity per foot height above the calandria is increased by fitting a cylindrical portion with a wider diameter on the top of the calandria part of the pan. This type of pan is also called the "low head fast boiling" type.

One of the factors governing the circulation rate of a pan is its shape, i.e. the ratio between the height and the diameter of the pan. Generally speaking, a wide pan increases, and a slender pan diminishes, the circulation. The progress made in coil pan design has improved this most important quality due to better spacing and distribution of the coils throughout the pan and, last but not least, by returning to the squat pan type. On the contrary, however, the above-mentioned tendency to reduce the graining volume of the calandria pan has not improved its circulation at all.

We can prove the above statement by negative demonstration, in pointing out that from the earliest days there have always been calandria pans provided with mechanical stirrers, and this characteristic has not been reduced in latter years. The reverse is the case, because there are calandria pans in use to-day with more highly powered stirrers than ever before.

Improvement of circulation is particularly needed when boiling slowly, i.e. when not enough water evaporates per time unit to provide for natural circulation. In our opinion, it is in such cases particularly that mechanical stirrers can be used to best advantage. In other cases mechanical stirrers are a more or less necessary evil, their necessity being caused by a too tall and narrow pan shape.

This is well demonstrated by the claim that mechanical circulation makes possible the use of low pressure steam (vapour). The squat type of calandria pan, however, has always been, and is still, an excellent pan for boiling with vapours of the first or even of the second vessel. The slender calandria pan lacks this property because its circulation is poor compared with the squat type of calandria pan, and it is necessary to provide the slender pan with stirrers in order to be able to use it with low pressure steam.

The best known pan with mechanical circulation, is the Webre pan. The first description of this pan can be found in the I.S.J. 1933 (p. 228), in which Webre described the results of tests made over a

period of four years, with a pan provided with mechanical circulation. This pan, in which mechanical circulation is promoted with the aid of a more powerful motor than ever before, was subsequently introduced into several countries.

Webre points out (loc. cit.) how, by providing the electromotor with a recording type of ammeter, the current curve obtained can be a very useful element in controlling the boiling process, because the magnitude of the current consumed by the electric motor is inversely proportionate to the fluidity of the mass.

This principle has been developed further, and in a paper presented to the 7th Congress of the I.S.S.C.T. Webre explains how a pan boiling refined sugar can be automatically controlled by regulating the fluidity of the strike in proportion to the power developed by the motor driving the circulator. This is effected by using a wattmeter with an adjustable contacting device, which can be positioned at any desired power consumption. The signal from the wattmeter is first passed through a time delay relay, and from here to an electric pneumatic relay by means of which an air diaphragm feed valve is made to open or close as the load on the motor driving the circulator over-passes or under-reaches the desired set point.

The way in which this auxiliary implement has changed into a process controlling apparatus reminds us of the ammeter of the Gränsdörfer pans being used by the pan men in the first form of boiling control effected by means of conductivity readings. In these Gränsdörfer pans an electric current was passed between two electrodes protruding into the pan in order to stimulate the circulation. An ammeter was provided to check the magnitude of the current going through the mass. After a short time it became routine for the pan men to use the readings of this ammeter to determine the moment of introducing another drink. This was thus the first application of the variations of the conductivity of the mass as a means of determining the supersaturation.

IS THE COIL OR THE CALANDRIA PAN THE BETTER PAN?

From the point of view of pure boiling the coil pan is the better pan, because of its better circulation properties and smaller temperature differences occurring in the different massecuite layers. Due to its ability to start with a very small initial charge the coil pan is more adaptable to different circumstances, e.g. the coil pan can boil and grain a low grade strike as well as a high grade strike, and it can eventually boil just enough grain for one boiling. The calandria pan, on the contrary, can only boil grain for at least two boilings, and in consequence always has to cut over.

However, calandria pans are more commonly used than coil pans the world over, with the exception of certain countries, such as Australia and Java, where the coil pan is predominant.

When asked whence the predominance of the calandria pans in the greatest part of the world originates, the usual answer is that more square feet heating surface per cubic feet of pan capacity can be fitted in a calandria pan than in a coil pan.

In the first place, let us point out that it may not be tacitly assumed that a higher heating surface to capacity ratio is identical with a higher boiling rate or a shorter pan cycle. There are other, more influential factors (circulation properties of the pan, available crystal area, crystal content, viscosity, purity, temperature, supersaturation, etc.) which determine the duration of the pan cycles. Moreover, the increase in boiling rate is ultimately checked by the risk of false grain formation, and of entrainment, and not by the possibility of cramming in more heating surface per cubic foot.

A calandria pan starting with its whole heating surface submerged can use the whole heating surface directly from the beginning of the strike. In contrast, a coil pan usually has only two-fifths to three-sevenths of its banks of coils submerged, when commencing a new strike, and consequently can admit steam into these banks only. This comparison, however, is not quite accurate, the calandria pan usually being forced to start with a higher content than the coil pan so as to ensure that its calandria is submerged. If we assume, however, that both start with the same preliminary filling, i.e. 40 per cent. of the pan capacity, the coil pan will be able to start with about 50 per cent. of its heating surface in action, and the boiling rate at the beginning will be increased accordingly.

However, it is as a consequence of the high starting rate of the calandria pan that the regularity of the steam demand is very badly affected—in particular at the moment when a calandria pan starts concentrating syrup preliminary to graining, when there is an immediate and marked rise in the steam demand. If the syrup is of low density, then this high steam demand will be more prolonged than if syrup of normal density is concentrated. If, moreover, all three massecurtes are boiled on syrup grain these characteristics are experienced several times a day. *It is, therefore, my opinion that there is a very strong relationship between (a) the need for steam accumulators in the Natal mills and (b) the routine of graining on syrup, using calandria pans for this purpose.*

Before the modern designed coil pan was adopted, squat calandria pans received consideration if the pan had to boil with steam (vapour) of approximately atmospheric pressure. However, the modern manifold coil pan, or generally speaking each coil pan with short coils (length of the coil not exceeding 100 times the diameter), can boil with vapours bled from the evaporator, but only if the same provisions are made for the drainage of the condensates and for the venting of non-condensable gases as are routine

arrangements for the second, third, etc., vessels of the evaporator—arrangements which are also necessary if vapour bleeding is used for calandria pans.

Concerning the cost of maintenance, if we compare a fixed calandria type of calandria pan with a modern coil pan the maintenance costs will not differ appreciably, provided that the calandria pan is of all-welded construction with flat steel plate tube sheets. On the contrary, if the calandria is of the floating type, or the fixed calandria still has bolts and nuts joints, the cost of upkeep will be higher than that of a coil pan. In the case of inclined tube sheets of cast bronze, a great deal of expense will be incurred in keeping the joints tight, particularly the lower joint between the tube sheet and the centre well. The more expensive Webre pans have also higher depreciation costs.

Calandria pans will be given precedence when the boiling of high purity strikes is considered, because the starting speed of calandria pans is higher than that of coil pans.

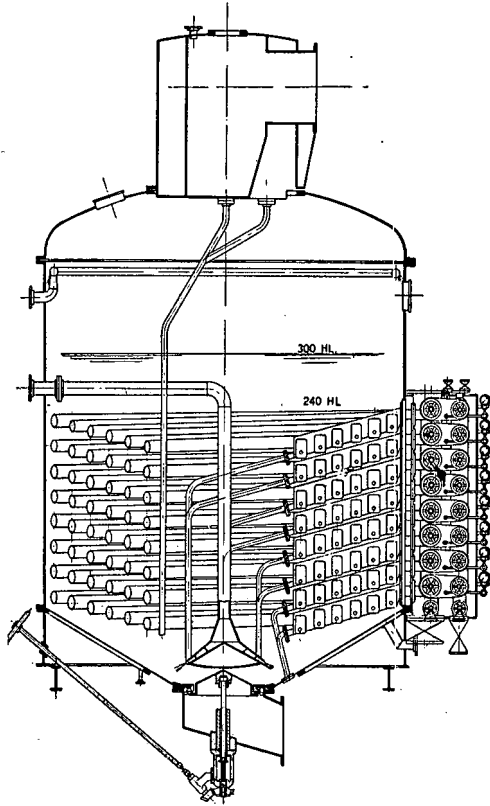
When boiling high-purity strikes the advantage of faster boiling gives calandria pans preponderance, because the number of pans can be decreased as a result of the shorter cycles. However, a high-purity strike can never be heavied up to the same extent in a calandria pan as is possible in a coil pan. Even if the calandria pan is provided with wide (5 inches in diameter) and short ($2\frac{1}{2}$ feet to 3 feet) tubes, the strike will not drop, when we attempt to heavy up a high-purity strike, to the same extent as is possible in a coil pan.

However, the ability to boil at high rates is not always called for. About two-thirds of the exhaustion of the C massecurte, for instance, can be achieved in the pan proper, provided the boiling is slowed down in the closing stages, and the heavying up (after the feed is discontinued) is prolonged to at least an hour.

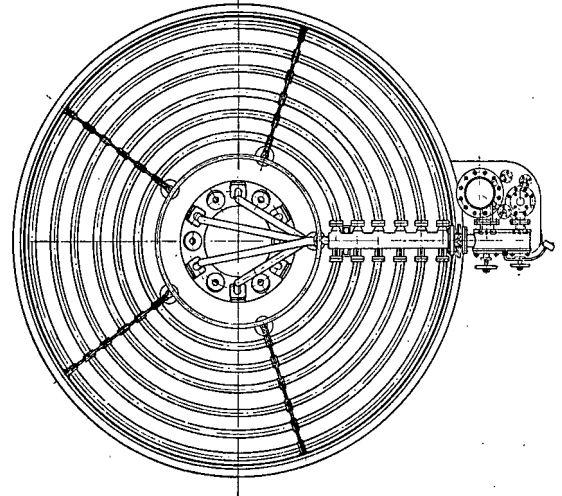
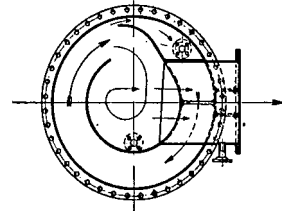
The coil pan is to be preferred when (a) the amount of water to be evaporated is relatively small, (b) the mass is viscous, (c) it is necessary to boil tight during the whole process, and (d) it is necessary to finish off at the highest brix possible.

When a C strike has to be boiled, good circulation and a not too large graining charge in particular are what we require in a vacuum pan. Consequently, C strikes can be better boiled, and are better boiled, in coil pans. Since to obtain a good exhaustion the C strikes are boiled slowly, the ability of the calandria pan to boil fast is of no use. On the contrary, if we want to boil a C strike well in a calandria pan, mechanical circulation is essential to facilitate such slow boiling as is required for a C strike.

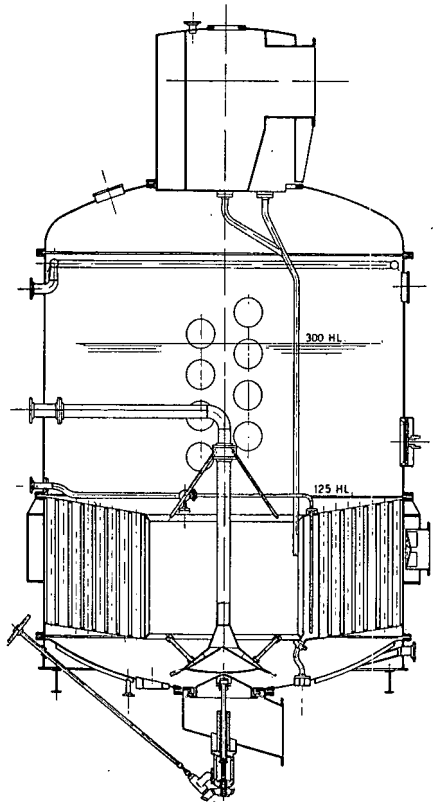
Coil pans are to be preferred for boiling C strikes, or if we want to use à tors & travers calandria pans then calandria pans with mechanical circulation are to be used for this purpose.



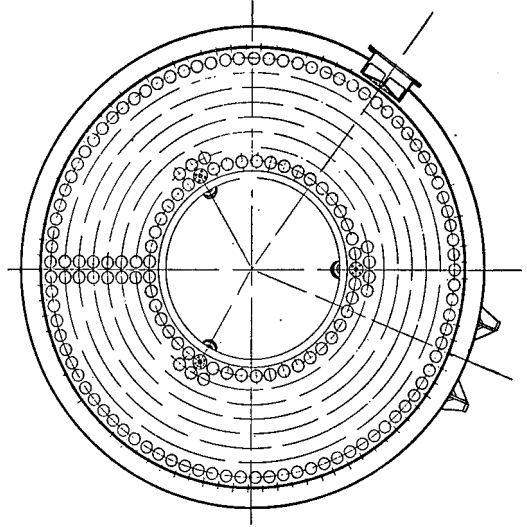
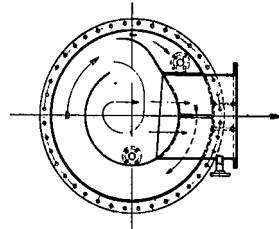
Manifold Coil Pan. Diameter 12 ft. 6 ins. Capacity 1,060 cu. ft.



Manifold Coil Pan. Horizontal cross-section showing safe-all, circular coils and manifold.



Calandria Pan with steam belt. Diameter 12 ft. 6 ins. Capacity 1,060 cu. ft.



Calandria Pan with steam belt. Horizontal cross-section showing safe-all, and calandria with steam belt.

Mr. Elysee said it was a pleasure to hear this paper read by Mr. Perk. It was a well-known fact that efficient circulation in our pans could be given further consideration. Very high pans with small diameter were a complete departure from ideal conditions. He said that, as recommended by Mr. Perk, very wide and squat pans should have had priority consideration by manufacturers long ago, instead of the present trend to construct tall pans. Many pans in present use in our factories were originally coil units, and were somewhat squat in structure. Calandrias were substituted for coils and in addition a band distance piece was added, consequently elongating the pans. This procedure was considered economical at the time because it was an easy way to increase the capacity of the plant to cope with increasing input. Replacing coils with calandrias of greater heating surface did not speed up the heating rate in comparison with the old coil pans, which were considered then as slow boiling units.

He said that it must be mentioned that excellent work was done in those slow-boiling coil pans, and that regularity of grain and crystal yields from the massecuites were as good, if not better, than was found at present. Low purity products from Uba cane was boiled at that time.

Mr. Oliver Pearce asked if Mr. Perk thought it would be possible to boil a pan completely automatically. He said he had visited Mr. Oliver Lyle in England and stated that there was a wide view overseas that it could be done.

Mr. Perk replied that he did not think it was possible for the graining to be done automatically, although filling up of the pan could be and was already being done automatically.

Dr. Douwes Dekker said that in Australia they were studying the subject of automatic boiling. He said that the Colonial Sugar Refinery was working on the subject, but they had not yet found a final solution to the problems involved. They had worked it out in the vacuum pan and used the ammeter, but only after the graining stage.

Mr. Grant asked whether the calandria pan with the increased temperature represented a decided advantage over the coil pan.

Mr. Perk replied that he felt that the view he had expressed was the correct one and illustrated by means of drawings the reasons for his opinion.

Mr. Elysee said that one disadvantage found with coil pans was that the cleaning of the coils was a laborious procedure and could not be done as easily and thoroughly as the vertical calandria tubes. Any leak found in the banks of coils was very difficult to

repair. He said that the new designs recommended in this paper were a definite advancement and should be wholeheartedly supported.

Mr. Perk replied that cases of leaks which he had encountered were caused by lack of steam trap fittings. He again illustrated by means of drawings his version of an ideal arrangement for cleaning coil pans.

Mr. Galbraith referred to the second last paragraph of Mr. Perk's paper and mentioned that when the old type of coil pans were in use at Sezela, it took from 12 to 15 hours to complete a strike of "C" massecuite. The average purity of the molasses from these "C" massecuites was in the vicinity of 48° purity. These pans were then converted to the calandria type and the boiling time was reduced to about five hours, while the molasses from these massecuites were to-day averaging 38°. He asked if Mr. Perk thought that by installing the latest type of coil pan a lower exhaust molasses could be obtained as a result of the longer boiling time taken by the coil pan.

Mr. Perk expressed the view that this was possible. He said it was possible to get better exhaustion in coil pans.

Mr. Walsh said that Mr. Perk had given an excellent comparison between calandria and coil pans. He thought, however, that Mr. Perk was biased in favour of coil pans. In the light of modern practice, he felt that coil pans were fighting a losing battle. In America modern design low-head fast-boiling pans were being widely installed, and he felt there was more future in calandria than in coil pans. There were also new types which had been established in Britain and he felt developments of this type of pan would be interesting.

Mr. Duchenne asked whether the Grensdorf was the original German pan.

Mr. Perk replied that that was the case.

Mr. Duchenne asked whether this type of pan was being adopted by Tate and Lyle.

Mr. Perk said that it was.

Dr. Douwes Dekker said that he was not sure that coil pans were fighting a losing battle in America. For the exhaustion of "C" massecuite it had been found that the coil pan had its advantages.

Mr. Grant referred to Mr. Perk's statement on steam accumulators in Natal mills and expressed the view that this was possibly, in his opinion, not correct.

Mr. Dymond asked members to accord Mr. Perk the usual hearty vote of thanks for his paper.