FERMENTATION IN THE MILLING TRAIN: ITS EVOLUTION, DEVELOPMENT AND INFLUENCE ON RECOVERIES

By J. ANTONOWITZ

In a S.A.S.T.A. publication entitled "Cane Testing with Particular Reference to the use of the Java Ratio in Natal" written by W. O. Christianson, reference is made to "much circumstantial evidence pointing to the loss of sucrose in the milling plant." In the Proceedings of the 13th Ann. Conf. Asoc. Tecnicos Azucareros Cuba, 1939, J. G. Salinas claimed that where compound imbibition is used, the dilute juices are exposed to the action of micro-organisms for such a length of time that destruction of sugar and other inconveniences tend to nullify the theoretical advantages of compound imbibition. As a contrast, on page 6, "The Microbiology of Sugars, Syrup, and Molasses," William M. Owen states: "Under conditions of raw sugar manufacture it is still a debatable question as to whether any significant losses of sucrose may be attributed to microbial action. The time interval between the extraction of the juice and its exposure to high temperatures of clarification reduces opportunities for microbial development to very short intervals, and there have been few reported instances where detectable losses of sugar have occurred during this interval . . . McCleery reported a considerable reduction in the drop of purity between crusher and mill juices, as a result of mill sanitation and frequent mill cleaning and the use of steam at frequent intervals. This would indicate that the loss of sucrose during milling is of considerable significance, if some precautions are not taken to maintain sanitary conditions in the main mill."

Viewing sucrose losses from a different angle, the same writer (Sugar Journal, Feb. 1952) states: "The behaviour of micro-organisms in the presence of finely divided colloidal material such as boneblack, activated carbon or baggacillio is a phenomenon that has long been known, but has only recently been appraised with reference to its relation to the undetermined losses in sugar manufacture . . . The difficulty of accurately appraising these losses when the drop in purities is at a consistently low level of one or more tenths of a degree, and when the lack of laboratory methods that are sufficiently sensitive to measure infallibly such differences, makes estimates all the more uncertain of the percentage of the total of these losses that is contributed by the activities of micro-organisms."

In the present writer's opinion the short time interval between the extraction of the juice and its exposure to high temperatures is no justification for the contention that the loss of sucrose during this time interval is not of much significance. The period of time during which the maximum amount, and the most rapid destruction, of sugars occurs, is during the imbibition cycle on the milling train. The time interval for the juice passage from crusher to juice heaters is not the time interval during which the destruction occurs.

The microbial population of a cane juice is most heterogenous; individual types of micro-organisms subsist on specific groups or collections of nutrients, e.g. some do not adsorb sucrose or related disaccharides and other complex carbohydrates, but readily live on glucose and other monosaccharides. Other micro-organisms again, break down the complex carbohydrates such as starches and gums, etc., releasing monosaccharides; that is, a simbiotic situation develops. Therefore if a cane juice in the process of being extracted from a cane by milling is passing through an environment heavily populated by a variegated collection of micro-organisms, it is reasonably possible to postulate that this juice, having a given ratio of invert sugar to sucrose (R.S.R.), in normal juice, can retain this R.S.R even if the mixed microbial population has most drastically reduced the total sugars content of the juice. The relatively high buffer capacity of the cane juice masks a great deal of acidic fermentation, consequently a very small drop in pH of the juice in its passage through the milling train can actually represent a relatively high destruction of sugars.

Apropos the behaviour of micro-organisms in the presence of bagacillio, it is pertinent at this point to refer to a paper entitled "The Resistance to Inversion of Sucrose in Harvested Sugar Cane" by Lauritzen, Balch, *et al.*, printed in the I.S.S.C.T. Proceedings of the Sixth Congress, 1938. In this paper the presence of naturally occurring invertase in the cane is shown to be responsible for much inversion of sucrose in harvested cane. In the assessment of the enzymatic activity, the fineness of the bagasse is very important.

When it is considered that the sucrose content of the cane is appraised so largely by the sucrose content of the mixed juice, it is evident that even if a great deal of the sucrose originally present in the cane is lost due to microbial activity during its passage through the milling train, this loss can never show itself in the usual chemical control, except possibly, in lowering the Java Ratio.

Referring again to Christianson's correlation of decreasing Java Ratio with increasing atmospheric temperature, it should be evident that wide fluctuations in Java Ratio values on similar qualities of cane crushed should bear further scrutiny, particularly on hot humid days. To elaborate on this point,

Sucrose % Cane ÷ Sucrose % Crusher Juice = Java Ratio;

and

$$\text{Sucrose \% Cane} = \frac{\text{Tons Suc. Mx. Ju.} + \text{Tons Suc. Bag.}}{\text{Tons Cane}} \times \frac{100}{1}$$

Assume that the sucrose per cent. crusher juice remains constant, but for some reason the tons sucrose in mixed juice varies. The Java Ratio will then vary. The lower the total quantity of sucrose in the mixed juice is, the lower will the Java Ratio become. If the absolute juice per cent. cane also remains constant, but variations occur in the mixed juice, variable quantities of sucrose must be getting lost somewhere between the crusher and the mixed juice scales. The absolute juice per cent. cane figure is affected by discrepancies in mixed juice weights in the same way as is the computation of bagasse per cent. cane; therefore if the absolute juice per cent. cane figure is consistently regular, faulty juice weights can be ruled out. If losses of sucrose due to juice wastage between crusher and juice scales do not exist, or rather cannot be located, sucrose must be getting lost by destruction in the milling train, if the Java Ratio continues to decrease, but the sucrose per cent. crusher juice remains constant. Further aspects will be considered later.

Continuous industrial fermentations, as distinct from the age-old batch processes, are a relatively new concept in industry; and it is only under the highly specialised conditions obtaining in continuous fermentation processes that one can get a true idea of the unsuspectedly large amounts of sugars destroyed by adventitious microbial activity. It is therefore necessary to examine such a process in some detail.

When a solution of suitable sugars (nutrients), is used in a continuous fermentation process, a given amount of sugar will give a specific amount of product, provided the culture used is a "pure strain" and the environmental conditions do not alter. If the environmental conditions are changed, say by increasing the concentration of sugars fed, all the sugar is not taken up, some goes to waste, and some is used in side-reactions. This results in more sugar being used to secure a given quantity of product. To eliminate this wastage, sugar determinations are made on the fermented waste liquid. Frequently, fermentation conditions, such as feed, aeration, etc., apparently remaining constant, the amount of product obtained for a given quantity of sugar fed is greatly reduced. In many cases in the writer's experience, a given quantity of sugar gave only half the normal amount of product, but the concentration of the sugars going to waste in the fermented liquid was identical to that under normal conditions. That is, a quantity of sugar A, gives a quantity B of product, plus a waste containing a quantity of sugar C, under normal conditions. Under unfavourable conditions the quantity of sugar A gives only the quantity B/2 of product plus the same quantity C of sugar in the waste.

Whenever this happened, it was consistently found that foreign micro-organisms or "bacteria" had established themselves in the fermentation process, (i.e. a heterogenous population had grown or evolved). The point to be stressed here is the fact that, judging from the analysis of the juices entering or leaving the fermenter or "process," nothing was being wasted, whereas in actual fact the efficiency of the process has decreased by 50 per cent.

Looking at this from a cane milling point of view, all the above appears to be rather irrelevant, because the milling of cane is not a fermentation process, and strictly speaking, the milling process is not supposed to function as a fermentation process. If any micro-organisms occur in the juices from the cane, then the milling process unfortunately becomes an adventitious "continuous fermentation process." The above very readily explains the consistent discrepancy between sucrose content of cane, determined under most exacting laboratory conditions on hand samples of cane from a given consignment and the sugar content of the same consignment after milling. (W. O. Christianson gives illuminating figures in the paper referred to above.)

Once the essentials of a "Continuous Fermentation Process" are grasped, the rather startling analogy between the continuous fermentation process and a milling train working with compound imbibition becomes very apparent. Briefly any specific micro-organism, given the proper stable environmental conditions will multiply at a constant rate. That is, a given population of micro-organisms will double itself in a given time. If a vessel (environment), is provided in which the micro-organisms are required to propagate themselves, these micro-organisms can be made to reproduce themselves indefinitely—and in constant quantity—if a volume of nutrients in the proper relative concentrations is fed to the vessel, proportional to the growth rate of the micro-organisms, while at the same time an equivalent volume of liquid containing the micro-organisms is drawn off from the propagating vessel.

If the volume of nutrients (juice), fed to the propagating vessel is such that it is small in proportion to the volume of the microbial population, the nutrient content of the juice will be exhausted, while the density of the microbial population will reach a limit, depending on the amount of nutrient available. If the volume of nutrient (juice), fed to and removed from the propagating vessel is large in proportion to the density and growth rate of the microbial populationtherein, a large proportion of the microbial population will be removed from the propagating vessel; that is, there will be a tendency for the population to diminish, while the nutrient content of the waste or surplus feed will tend to be relatively high. The main point to be emphasised here is that the density of the microbial population is conditioned by the volume of liquid entering or leaving the vessel in relation to the total volume of the liquid in the vessel.

Consider the volume of imbibition water entering the milling train in one hour in relation to the volume of diluted juice and bagasse passing through the entire milling train under imbibition during that hour. As this water and juice is recycled several times, the effective volume on the milling train is very large in proportion to the volume of water and undiluted juice entering the milling train, or the diluted secondary juice leaving the mills.

If the propagation rate of the heterogenous microbial population of the juice is fairly rapid, the recycling period of the imbibition water and juices is conducive to the building up of a very heavy microbial population. The point to be stressed here is that a microbial population of a certain density is built up and *thereafter retains that density*. In other words, the milling train, volume of water, bagasse and juice constitutes the "environment" or "fermenting vessel."

Dilute nutrient solutions (juices) favour microbial activity, hence the imbibition water entering the last mill speeds up their activities. Increases in temperature also speeds up microbial activity, an increase of 1°C in temperature brings about a tenfold increase in activity (multiplication). This activity is dormant at 0°C, and at its maximum between 30-40°C, depending on the type of micro-organism. Hence the use of hot imbibition water favours the multiplication of the microbial population.

Relatively concentrated juices slow down the reproductive rates, but the presence of bagacillio, nullifies this retardation. Bagasse as a substrate to speed up the fermentation of *aspergillus niger* in the fermentation of citric acid is the basis of many patents.

Consideration of the above aspects convinces the writer that it is the milling train as a whole and the compound imbibition cycle which constitutes the principal environment for the sugar-destroying micro-organisms, and that dead ends, etc., are serious contributors by being sources of infection. Even if all superficial signs of spoilage are removed by what is accepted as standard mill sanitation procedure, the losses of sucrose on the milling train are still considerable. The principal factor is the density of the microbial population is the "environment," and once it has established itself, it will maintain its equilibrium density even if subsequently completely aseptic cane and water is applied to the mill.

It is here that the time in which the micro-organisms are in contact with the substrate loses much of its significance. Practical examples, often given to indicate that sucrose losses on the milling train cannot be very high, make the contention that if a sample of infected mixed juice is taken, analysed and allowed to stand for several hours, the loss in sucrose on subsequent analysis is never very great. Therefore if the time of contact of the juice with insanitary conditions amounts to only twenty minutes, significant losses must be very small. The essential point overlooked here is the fact that the juice sample under observation has been divorced from the fermenting environment, viz. the milling train. The rapidity with which sterile sugar solutions can be taken up by microbial activity under favourable conditions, can be illustrated by the fact that on innumerable occasions within the writer's experience, over ninety-five per cent. of the available sugars have been used up in a contact period of only thirty-five minutes. The speed with which the sugars are taken up is limited only by the microbial population density and the available nutrient accessories. According to Owen (*ibid.*, p. 30), "It is obvious from the composition of normal juice with reference to its nutrient content, its reaction, and the presence of growth factors, that it is almost an ideal substrate for a wide variety of organisms."

Sterilization with Chlorine

From the above it follows that completely sterile conditions must be obtained if sucrose losses on the milling train are to be obviated entirely. This can be accomplished very readily by the application of a saturated solution of chlorine in water to the milling train, in such concentration that incubation tests on the juices shew complete sterility. Practical results obtained by the writer, using a chlorine dispenser of limited capacity, shewed that, even though not nearly enough chlorine is added to the milling train, appreciable savings of sucrose could be effected. This is vividly illustrated by Graph No. 1 and Table No. 1 wherein the rise or fall of the Java Ratio coincides with the periods wherein chlorine was applied, or not applied, to the milling train. The average Java Ratio is higher by approximately two per cent. when chlorine is applied than when no chlorine is applied.

Referring to Graph No. 1, it will be noted that the daily fluctuations in Java Ratio in general follow the fluctuations in mixed juice temperature. On the same graph it is also apparent that the drop in purity from crusher juice to mixed juice ties up with these same fluctuations. The same remarks apply to the "Kopke" clarity.

During the period 20th-25th August, the daily Java Ratio decreased as the temperature increased. On the 28th, the Java Ratio reached an exceptionally high level. On this day, in addition to the fact that a cold spell was experienced, the chlorination dispensing apparatus was first put into operation. The following day the chlorination was stopped, and even though the average day temperature decreased, the Java Ratio decreased. On the following day when chlorine was again applied, the Java Ratio increased.

The application of chlorine to the milling train was continued without interruption until the 11th of September. During this period it will be noted that the daily fluctuations in the Java Ratio fluctuated as did the average daily mixed juice temperature, but while chlorination was in progress, the average Java Ratio was much higher than any of the periods during which chlorine was not applied. For the period graphed, the mean Java Ratio was 80.19 when no chlorine was used, but while chlorinating the mean Java Ratio was 82.05. Whenever the chlorine apparatus was closed off for a day, the Java Ratio for that day dropped considerably. Whenever the chlorine apparatus was restarted, the Java Ratio for that day increased.

The relative differences in Java Ratio are tabulated hereunder: (28th August to 22nd October);

TABLE 1

Java Ratio With Chlorine	Java Ratio Without Chlorine	Increase in Java Ratio	Java Ratio With Chlorine	Java Ratio Without Chlorine	Increase in Java Ratio
83.37	80.01	3.36	82.74	80.40	2:34
82.67	81.72	0.92	83.56	81.17	2.39
82.47	78.67	3.80	82.34	81.40	1.94
81.56	80.20	1.36	83.59	80.99	2.60
84.02	77.64	6.38	82.25	80.39	1.86
81.29	77.64	3.61	82.25	80.58	1.67
82.52	81.41	1.12			
82.26	81.41	0.85		*Averages:*	
83.46	81.86	1.50	82.50	80.52	1.98
82.23	81.86	0.37			
81.96	80·40	1.56	*Mean Difference:*		2.213

Influence on Factory Working

Apart from the not insignificant saving in sucrose that can be effected by sanitary milling conditions, another equally if not more important aspect is the influence of the residual products of decomposition which are introduced into the mixed juice by fermentation. Many of the micro-organisms present in cane juices, viz. *aspergillus* and related genera, secrete amylolytic enzymes. Many of these enzymes are used extensively commercially for the liquefaction of starch, the oxidation of glucose to gluconic acid, the production of tannin materials and to hydrolyse sugar syrups so that they will not crystallise even at very high density. In the presence of complex carbohydrates, such as starch, etc., many of these enzymes exhibit a marked activity over a wide range of temperature, even as high as 95;C. A remarkable property is that in the presence of starch and at a pH of between 7 and 8, it is almost impossible to inactivate the enzymes even by boiling. It would appear that the so-called inversions occurring in juice stored in continuous subsiders during shut-downs, could be explained in this way if the temperature of the contents of the subsiders does not fall below 85°C.

The naturally-occurring vegetative enzymes in sugar cane juice mentioned earlier, are generally inactivated at 60°C. It is therefore reasonable to suppose that if enzymic activity does occur in continuous subsiders, the enzymes are probably of an amylolytic nature, originating as side products or secreted during fermentation in the milling train. Another fermentation product, viz. dextran, introduced into the juice by leuconostoc, causes, according to W. L. Owens, "Immeasurable losses and unsurmountable obstacles to juice clarification."

From the clarification point of view, two very simple, well-known purely chemical aspects are overlooked entirely by most authorities on juice clarification problems. I refer to the natural phosphate content of the juices. The principal clarificant, as is well known, is the precipitate formed by the naturally-occurring phosphate content of the juice and the lime added in the clarification process. One of the essential growth factors for microbial multiplication is the presence of phosphates. Cane juices contain significant amounts of phosphate, which, if microbial activity is present, is taken up proportional to the metabolic requirements of the microbial population. The greater the density of the microbial population, the smaller the quantity of phosphate remaining available in the juice to carry the reaction with the added lime to completion.

The other significant factor is the solubility of the calcium phosphate precipitate in the presence of significant amounts of citric, lactic, and related organic acids and various glucosides. If fermentation has occurred in the milling train, the juice becomes "refractory" and will not respond to the usual method of treatment.

According to E. R. Behne (Tech. Communication No. 4, Bureau of Sugar Experiment Stations, Queensland) the presence of the chloride in a solution containing phosphates encourages the formation of the tricalcium phosphate precipitate if lime is added. Therefore apart from the beneficial action of the presence of chlorine in inhibiting the production of organic compounds which interfere with or upset the normal clarification procedure, the chlorine ion very materially assists in the chemistry of the clarification by carrying the phosphate reaction rapidly to completion.

It is to be noted that at the Umfolozi factory, using the usual clarification procedure, the scaling up of the quadruples was much reduced so long as chlorine was being applied to the milling train, but rapid scaling-up occurred if the chlorine dispensing apparatus was out of commission for any appreciable length of time. Graph No. II was prepared indicating, the dependance of boiling house recovery on the clarity of the clarified juice. Wide fluctuations in the clarity of the clear juice coincide very markedly with periods when the application of chlorine to the milling train was stopped or started.

A further graph (Graph No. III) is shewn, indicating the dependance of the clarity on the difference between the crusher purity and the mixed juice purity. As long as chlorine was applied to the milling train, the drop in purity from crusher to mixed juice remained small, but the fluctuations in turbidity of the clear juice did *not* coincide with the fluctuation in the purity differences. When chlorine was not applied to the milling train the difference between the crusher and mixed juice purities was very much greater. The greater the difference in purity, the greater the turbidity of the clear juice.

Summary

To sum up, low recoveries are due to poor clarification of juices. Refractory juices which do not clarify readily are often the result of the action of residual by-products and secretions of fermentations which occur in the milling train. This fermentation is inherent in the compound imbibition and milling process as such, and can only be eliminated by complete sterilization with chlorine.

By eliminating unaccounted-for losses in the milling train, by sterilization with chlorine, both the miller and the planter obtain higher returns. Once the significance of the action of micro-organisms on canes, burnt, cut, trashed, fermented or otherwise spoiled, is appreciated, a host of apparently most conflicting data is resolved and integrated.

The President said Mr. Antonowitz had given us a paper which many of us had thought about and discussed for many years, but had been reticent to put on paper. He was grateful that the subject had now been brought forward as it was of such great importance. He referred to his own paper, published in 1931, on electrolytic chlorine as a disinfectant, wherein he shewed that the application of E.C. affected the brix of the juice, and, therefore, gave false purity readings.

Mr. Antonowitz referred to Mr. Dymond's use of E.C. and said that chlorine was the only disinfectant which did not leave a residual product in the juice. He maintained that chlorine in water had no brix density to speak of.

Dr. Douwes Dekker said that the subject had been discussed by authors in nearly all sugar-producing countries of the world. In some mills the sanitary conditions were very bad and gave rise to losses in sucrose. He said that although it was difficult to believe that there could be considerable losses in certain factories, it was not a question of what one believed but rather of what figures showed. He only knew of one case where a thorough investigation into the quantity of sucrose lost was done and this was in Java many years ago. There no large loss was found. It was only a very small mill train which was kept scrupulously clean. Nowadays the mill trains are larger, imbibition is compound and there are other things which might cause loss, in particular there are quite a lot of things about milling trains in many factories which are not kept clean at all, both here and in other countries. He said that he thought that if the mills were kept scrupulously clean, losses would be insignificant. In conclusion he said it was safe to say that there are losses in mill trains, and the amount of them depends upon the way in which the mill train is kept clean. It might be that we have to use chlorine, or we might not have to use chlorine, and while Mr. Antonowitz showed important savings by using chlorine, he did not think that to rely upon the Java Ratio figure alone was safe, especially over a short period. A number of figures would be required, which would have to be dealt with statistically before we could come to any definite conclusion. He thought that a proper investigation should be carried out to study the effects of chlorination on sucrose losses and on the quality of the clarified juice. The Sugar Milling Research Institute hoped to carry out such an investigation at Umfolozi during the coming season. It would then probably be possible to obtain more definite information about the quantity of the loss due to fermentation.

The President said that he was glad to hear that such an investigation would be carried out by the S.M.R.I. There were other matters, such as the determination of sucrose in cane in a laboratory mill at Gledhow in 1935, and there it was noticeable that there was a definite difference between the sucrose determined on the hand samples as compared with the sucrose measured in the factory.

Mr. Davies said that he was interested to see that Mr. Antonowitz drew conclusions about the effect of clarity on recovery. On reducing the clarity of the juice by reducing chemicals, he found that the recovery was not affected and he was not sure now what effect turbidity had on the recovery.

Mr. Du Toit agreed with Mr. Dymond that it was noticeable that when hand samples were tested, the figures were invariably higher than those obtained in a factory. It had been contended, with regard to tests done at the Experiment Station, when the cane was clean and no dead sticks were included, results were too high, but even allowing for the clean cane the difference between these tests and mill results was not explained. He thought that although using the Java Ratio was not a perfect method of assessing the loss, it did indicate when the losses were excessive. He thought that the absolute juice sucrose ratio, i.e. the ratio of the sucrose per cent. absolute juice to the sucrose per cent. crusher juice, might be taken into account in the forthcoming investigation. On investigating factory figures he found that they were much lower than those figures obtained in a laboratory mill as far as the absolute juice factor was concerned.

Mr. Antonowitz thought that if one had always completely sterile cane entering the factory, the ordinary methods of mill sanitation would be sufficient, but with varying degrees of infection he felt that chlorine was essential. If one started off with a very high concentration of microbiological population this soon became very much greater in the milling train.

Mr. Elysee said that at Amatikulu he had tried various disinfectants, but he had not found any improvement in any of the figures. In a big factory like Amatikulu, the use of even small quantities of chlorine such as five or ten parts per million would be extremely expensive and would not yield an adequate financial return.

The President said that if ordinary cheap common salt were used to generate E.C. and only a small rise in purity were effected, this would be profitable.

Mr. Antonowitz said that there had been indications that they were saving five tons of sucrose per day and in saving five tons of sucrose per day, the cost of the chlorine was negligible as compared with the gain.

Mr. Rault said that by thinking along the lines of his previous experience in yeast manufacture, the author had put up a challenging case when he asserted that unsuspected sugar losses took place during the treatment of canes in the long milling trains through the action of micro-organisms. Such losses, but on a smaller scale, were accepted in the beet industry, with its slower diffusion process on a material already over-exposed before processing.

Undertermined losses are only accounted for in the cane industry after the juice scales and are the concern of the manufacturer. In Mr. Antonowitz's mind other previous undertermined losses exist which are predudicial to manufacturers as well as growers. The similitude between a continuous fermentation process and that of the operation of the juice circulation system of the long milling train is very ingenious, but it seems that the time factor is somewhat lacking in the latter case.

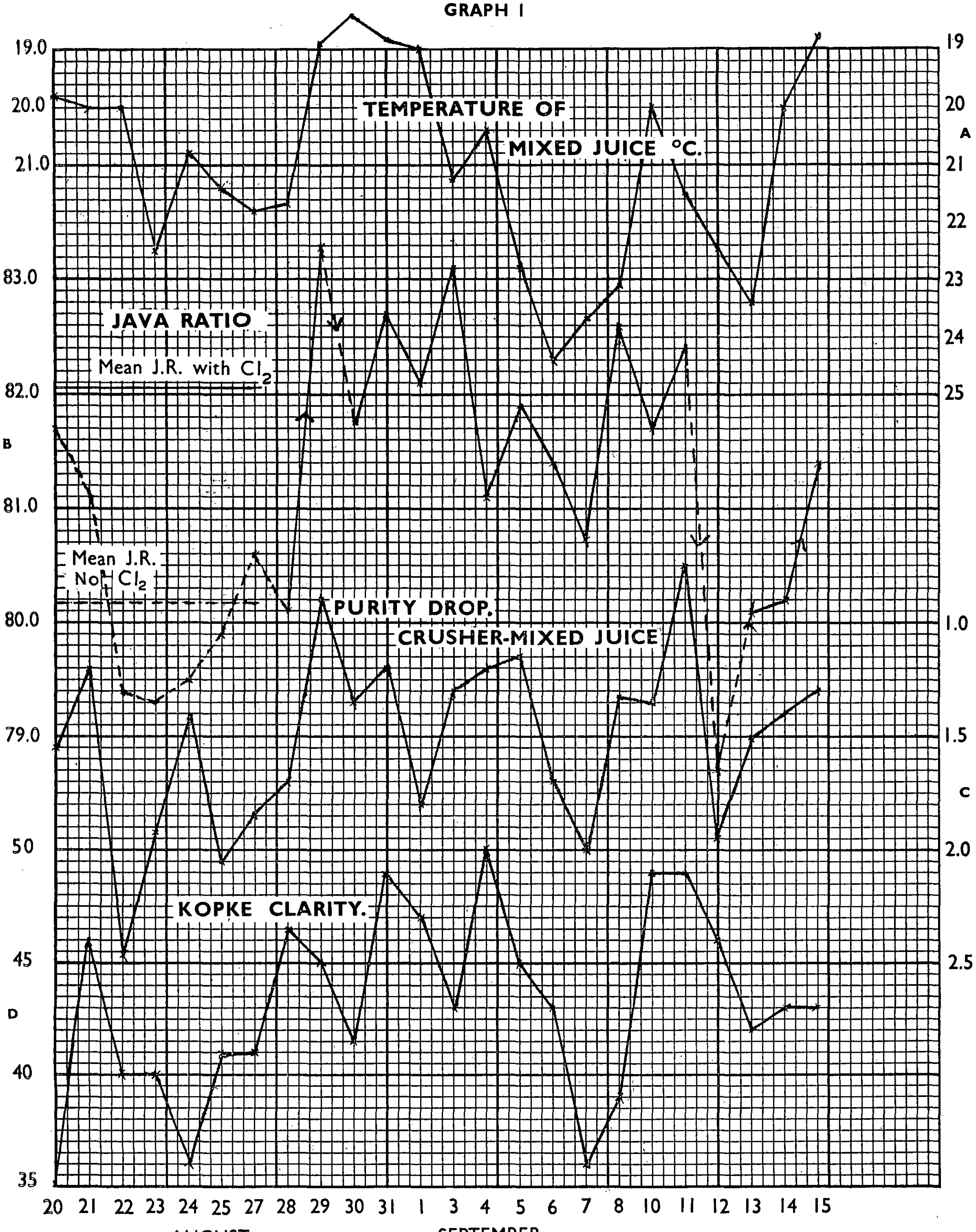
Nevertheless the few figures quoted on the Java Ratio issue are very startling, and if proved statistically correct would have serious repercussions, inasmuch as the avoidance of such conditions, accepted as genuine losses, would entail a gain of sugar material equivalent in bulk to the additional duty of a fifth mill or the further exhaustion of final molasses by a matter of five degrees in purity. The additional return would outbalance the initial and running cost of the chlorination plant suggested, but he wondered whether the geographical position of Umfolosi factory and the extension of the crushing season there during the hot summer months were not unique in the industry, so that conditions there were non-existent in the other South African factories situated in the colder regions and which completed the season before Christmas.

Mr. Elysee enquired what concentration of chlorine should be used. He maintained that there would always be a considerable loss of chlorine.

Mr. Antonowitz replied that very heavy applications of chlorine were necessary for complete sterility and one would have to have free "free" chlorine in the mixed juice before one could feel confident that microbial activity had been completely suppressed; one would have to gauge one's requirements by that point.

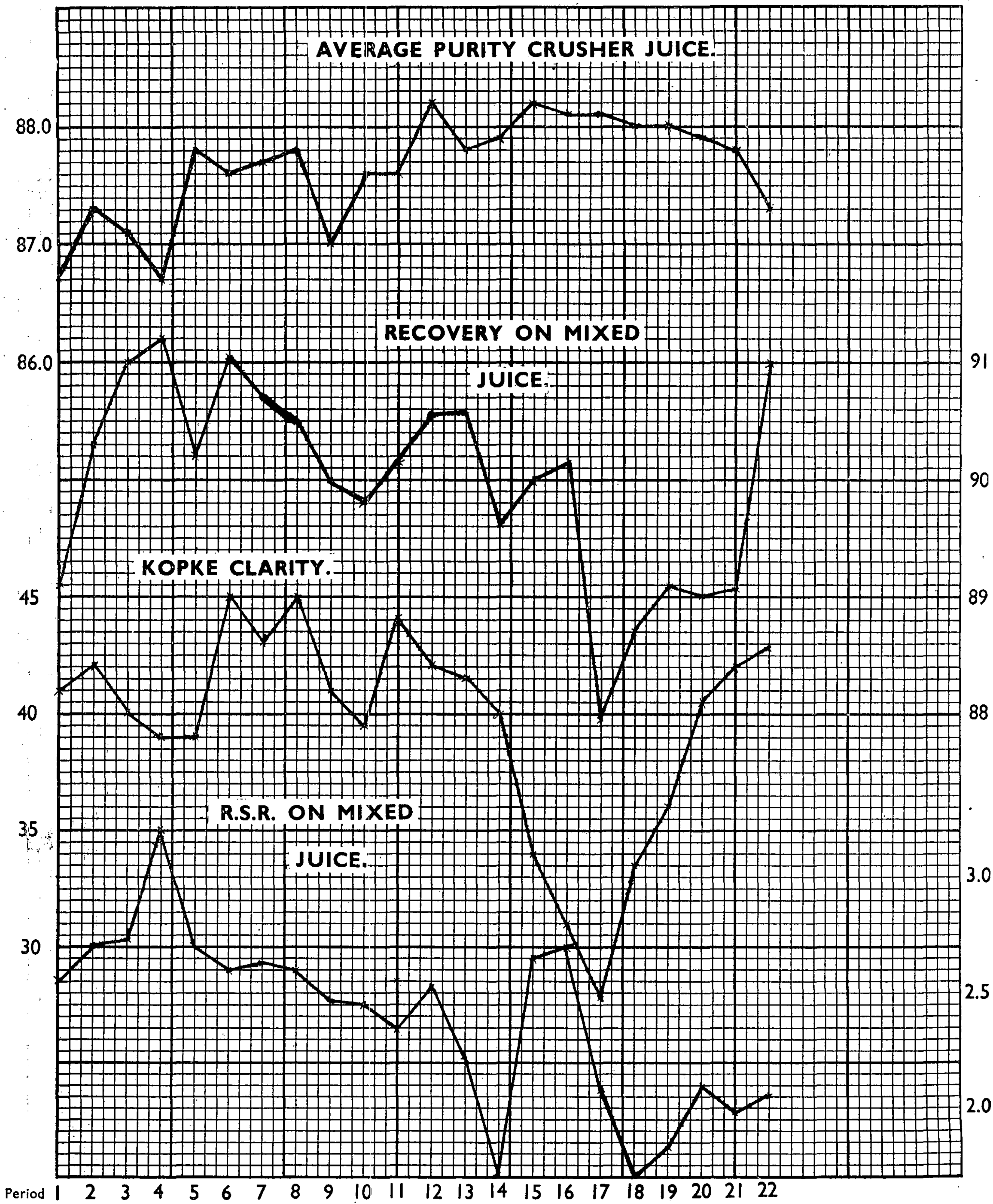
Mr. Bechard said that this paper was long overdue. Mr. Antonowitz had laid stress on the microbiological population of the cane entering the factory and he was amazed that the milling companies delayed the delivery of cane into the factory. He had seen cases where cane had taken two weeks to get to the mill for no real reason. Such cane was paid for at too high a rate because of our present methods of sucrose determination. Although the Java Ratio was a convenient method of distributing sucrose, the results were very inaccurate. Some years ago he did a statistical examination of the effect of fibre on Java Ratio. From a regression equation he found that each degree of fibre affected the Java Ratio inversely by 0.69. He said there were other factors involved. With our present Java Ratio there was a premium attached to delivering old, dried-out cane. This should not be so.

GRAPH I



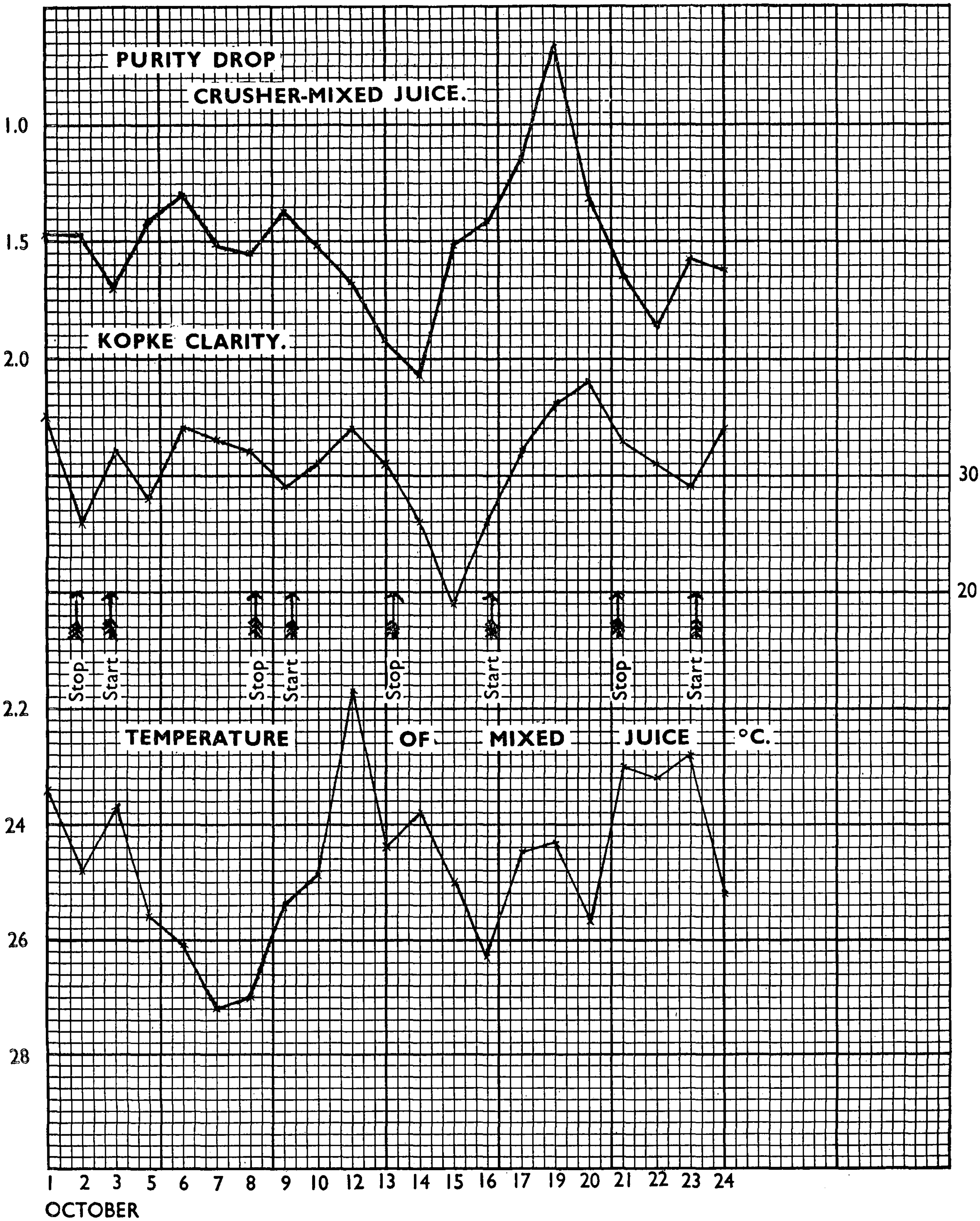
A.—Temperature of Mixed Juice °C. **B.**—Javo Ratio. **C.**—Purity Drop Crushed-Mixed Juice. **D.**—Kopke Clarity.
Arrowheads on curve B (Java Ratio) indicates start or stop of Chlorinating Apparatus.

GRAPH 2



AVERAGE PURITY CRUSHER JUICE.
RECOVERY ON MIXED JUICE.
KOPKE CLARITY.
R.S.R. ON MIXED JUICE.
88.0
87.0
86.0
45
40
35
30
91
90
89
88
3.0
2.5
2.0
Period 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

GRAPH 3



Arrows indicate periods when Chlorine Apparatus was stopped or restarted.