HEAT IN RELATION TO MANUFACTURING PROCESSES

D. W. FINLEY, B.A., B. Sc. (Oxon.) A.M.I.B.E.

Factory Superintendent,

Kirkoswald Estate, Bogawantalawa.

When Dr. Norris asked me to speak to you this afternoon, he suggested that the subject should be as general as possible, and that technicalities should be avoided. I make no apology, therefore, for generalities.

One underlying principle behind three of the important processes of tea manufacture concerns the use of heat. That "heat is the enemy of quality" has always been quoted as one of the most important sign-posts to the goal of good manufacture; in addition it is a saying that has stood the test of time. And yet the more that is understood about withering, fermenting, and firing, the more it is realised that heat — this so-called enemy — must be present for successful manufacture.

Throughout this paper a careful differentiation is made between 'heat' and 'temperature.' However loosely these terms may be employed colloquially, in scientific parlance they have quite distinct meanings. Heat is a quantity and temperature is a quality. It is the difference between a bucket of red paint (which is enough to cover a given area) and the colour red which is simply an abstract quality, and may exist in different degrees such as scarlet, crimson or maroon.

* The Institute does not necessarily endorse the views expressed in papers contributed by persons other than members of the Staff.

Temperature — the quality — is measured by degrees, but heat is measured by the British Thermal Unit, (or B.T.U.) the quantity of heat required to raise one pound of water through one Fahrenheit degree of temperature. Nowadays we are familiar with the term 'calorie' in connection with various forms of diet. 250 medical calories are approximately equivalent to one B.T.U.

It must always be remembered when considering the measurement of temperature, that withering leaf and fermenting leaf, both containing moisture, will 'feel' a lower temperature than the temperature of the air. In practice this resembles the wet bulb temperature of a hygrometer, particularly in the case of moist fermenting leaf.

WITHERING

Turning from the general consideration, we can now consider how these effect the various processes of manufacture. Most factories in Ceylon employ fans for withering, at any rate during part of the year. But in any case, whether a fan wither or a natural wither is being used, heat is actually necessary. In order to remove water either by boiling or by a process of slow evaporation at a lower temperature than boiling, heat must be supplied to the container of the water.

In the case of withering leaf, a definite amount of heat will have to be supplied in the lofts to allow the evaporation that takes place there to be completed. Heat must therefore be applied continuously, over about 17 hours.

The change of state from liquid water to water-vapour requires a tremendous amount of heat. In fact it takes about 1,000 times as much heat to evaporate one pound of water as it does to raise it through one degree Fahrenheit, say 200°-201°F. In the case of a fan wither this heat is supplied by means of the driers, using hot air as the medium. In the case of a natural wither, the heat is also supplied by means of the atmosphere, in the sense that the air is cooled down. In both cases the heat is probably supplied indirectly The leaf supplies the heat for the evaporation and as soon as the leaf has cooled sufficiently it will reabsorb heat from the atmosphere. This means that when equilibrium is reached, the leaf will always be a little below the temperature of the air.

It may be that this is the explanation of the curiously accurate 'teamaker's judgment,' a judgment which is so much a matter of experience that few teamakers can explain it. Merely by running their hands over withered leaf on the tats, they can estimate the moisture content of the leaf surprisingly accurately. It is a noticeable thing that withering occurs more rapidly at first, and slows down as soon as about 56 per cent moisture content is reached. Heat is being taken from the leaf more slowly after that point, consequently the leaf cools down less noticeably. Leaf that is withering rapidly feels very fresh and cold, but when the wither slows down it feels warmer.

There is a second effect — the effect of the rate of wither on the distribution of moisture in the leaf itself. Both before and after withering, the stalk contains about 10 per cent more moisture than either the leaves or the bud.

These are typical figures for leaf from a field about 2 years old.

	Before withering	After withering for 17 hours
Stalk ...	84.5% water	65.2% water
Bud ...	80.1%	50.8%
First leaf ...	75.3%	49.3%
Second leaf ...	75.6%	51.9%
Average of flush ...	78.1%	53.6%

These figures show that the stalk acts as a reservoir, a conclusion that can be confirmed as follows. If, before withering takes place, the flush is separated by breaking off the first leaf and bud, leaving the stalk and second leaf, it will be found that the stalk has acted as a reservoir for the bud and leaves, and that evaporation occurs mainly through the leaves. This has a very important effect on withering. If the hygrometer difference rises too high in the lofts, evaporation can take place so quickly that the leaves are often shrivelled up at the edges although the stalk is still definitely underwithered. In this case withering has occurred so rapidly that the minute capillary veins that are used to feed the sap from the stalk to the leaves are dried up, and water is virtually trapped in the stalk.

To effect a wither in a given time, say 17-18 hours, a given amount of heat must be supplied. If the wither is not quick enough, either the hygrometer difference can be raised or more air must be passed through the lofts. Either methods increase the quantity of heat available in a given time. There is a popular impression in Ceylon that a hygrometer difference of about 6°F is necessary for a fan wither. It is possible to wither at 2° or 3°F in 18 hours by using more air than is normal, say about 35,000 cubic feet of air per minute in each loft. The latter method has the advantage that if a change in the weather conditions occurs and is not noticed by the night staff, harmful hygrometer differences are rarely reached.

The rate of withering is controlled by the rate of supply of heat. As the air takes up moisture, heat is taken from the air so that the air is cooled down. The relationship between moisture contents and actual water evaporated per 100 lbs. of green leaf is given in the the following table:—

	Total	Dry matter	Water	Moisture contents	Evaporation
Green leaf	100 lbs.	22 lbs.	78 lbs.	78%	—
Withered leaf	(47.8)	22 lbs.	25.8 lbs.	54%	52.2 lbs. (withering)
Made tea	(23.9)	22 lbs.	(1.9) lbs.	4%	23.9 lbs. (firing)

In the second column of this table, it is assumed that the weight of dry matter is not changed by withering or firing, an assumption that is very nearly true. The total weight is calculated after considering the average moisture contents; and the number of pounds of water evaporated obtained by subtraction.

Taking average figures, for every 100 lbs. of green leaf, 52 lbs. of water are evaporated by withering. In one test the incoming air was at 73°F with a hygrometer difference of 6°F and the air exhausted from the lofts was at 70°F with a difference of 3°F. By looking up the appropriate hygrometer tables, it is found that the air has gained (correcting for altitude), about three-fourths-of-a grain of water per cubic foot before leaving the loft. Since about 20,000 cubic feet of air were passing per minute, the air would remove about 125 lbs. of water per hour. The leaf spread had about 1,250 lbs. of water to be evaporated. If a uniform rate of withering had been maintained the leaf would have been ready in about 10 hours. Actually the rate of withering decreases.

Air leaves the lofts containing only 60-70 per cent of the maximum possible amount of water. Some recent Java experiments have shown that both growing and withering tea leaves are surrounded by an atmosphere of moisture. It is probable that this fact contains the explanation of the inefficiency of withering. There is a tension in this atmosphere rather like surface tension — the skin effect on the surface of water. This is strong enough to float a needle. The vapour tension round tea leaf can be broken down and partially dispersed by warming the leaf, so that at a higher temperature withering is easier. If the leaf is spread thickly, it is even more difficult than usual to disperse the film of water vapour and the Java experiments have shown that the unevenness in different individual specimens of apparently evenly withered leaf is in fact due largely to the position of the leaf on the tats. They found by statistical analysis that only about 10 per cent of leaf has a really good chance of withering evenly and 25 per cent was definitely badly placed on the tats. I am not aware if this work has been followed up with open woven hessian, but in theory the freer the air movements the more readily will the skin of water vapour surrounding the leaf be broken down.

ROLLING AND FERMENTING

Dr. Norris has already dealt with several points in this connection. The important point is that the rollers generally employed in Ceylon combine two processes: twisting up of the leaf and the starting off of fermentation by the exposure of the tea juices to the air. Unfortunately in the present type of roller the starting off of fermentation tends to be progressive instead of simultaneous. Consequently the brokers are constantly reminding us that we have 'some greenish leaf.' This simply means that some part of some dhools have not been fully fermented. As Mr. Lamb has told us, the best way to overcome this with the *existing* rollers is to choose for the first rolls, a type which will allow very heavy rolling with a very small dhool out-turn. This depends largely on the battens. A type of roller recently put on the market allows a pressure of up to 1,000 lbs. without turning out more than 12 or 13 per cent first dhools, and is ideal for first rolls. On the other hand, the same spring on a popular type of roller produced over 50 per cent first dhool. The difference was simply a matter of batten type — the first type being a 'twisting type' and the second a 'cutting type' of batten.

It seems generally agreed that the Clivemeare roller, although it may have some disadvantages because of the appearance of the made tea, has always effected a marked improvement in the evenness of infusion. This is due to the simultaneous initiation of fermentation. The leaf can afterwards be put through the ordinary roller to twist it. On the other hand there are two methods of 'cold-rolling' which in effect allows the disintegration of the leaf without starting fermentation. By both these means the processes of starting of fermentation and twisting up of the leaf can be separated. At St. Coombs, some leaf was on one occasion kept for about 8 hours without appreciable fermentation. A very vital objection to fermenting on metal trays is that during early morning manufacture the generation of heat by fermentation is greatly delayed.

In the case of fermentation therefore, heat is required. The requirements are better known and understood than in the case of withering, where the ideal requirements are almost a matter of guesswork. For fermentation recent authorities favour the range 65°-75°F., and there is a marked preference for 70°-72°F. using air as nearly saturated as is practical. Fortunately for most up-country factories, the temperature of the fermenting room so rarely exceeds 70°F. that in practice cooling would never be necessary. This would make such a scheme quite reasonably cheap, and no doubt one of the most important immediate steps in factory control will be along this line. Obviously there can only be one *ideal* temperature for fermentation and, after this is found by experiment, it should be maintained. An even time of fermentation would follow, with considerable assistance to organisation.

FIRING

Firing is the second important process of evaporation. It is worth while stressing this point most strongly, because of the persistence of the fallacy that the hourly out-turn of a drier in lbs. of made tea is directly related to the performance of the drier. The out-turn is affected from day to day by several factors, particularly the moisture contents of the dhools fed. But the pounds of water evaporated per gallon (or pound) of fuel used, should be constant for the same conditions of inlet and outlet temperatures, irrespective of varying moisture contents. In just the same way as moisture content of withered leaf is the figure now coming into general use, instead of the meaningless figure of percentage wither, so the evaporating capacity of a drier should be used rather than the out-turn in pounds of made tea.

A table is given showing how moisture content affects the out-turn.

Made tea out-turn for different evaporating capacities of driers at different moisture contents.

Made Tea % on withered leaf	Equivalent moisture contents of withered leaf	Pounds evaporated per hour				
		150	175	200	225	250
50	50%	150 lbs.	175	200	225	250
48	52%	139 ,,	162	185	208	231
46	54%	128 ,,	149	171	192	213
44	56%	118 ,,	138	157	177	197
42	58%	109 ,,	127	145	163	181
40	60%	100 ,,	117	133	150	167

The process of firing is not a particularly efficient one in practice. Not only are there losses up the chimney between 12 and 15 per cent, but there are losses in the drier itself because the air leaving the drier is generally at about 115°-120°F. and is rarely much more than 40 per cent saturated on a pressure type of drier. At the same time it seems to be well established that the exhaust temperature should always exceed 110°F to avoid 'stewing' teas. Consequently the air can never be very highly saturated, even if the design of the driers is changed.

With liquid fuel the production of a steady flame is quite simple and the best possible combustion is easily obtained from the fuel. But with coal and firewood a tremendous amount of heat may be lost through bad stoking and incomplete combustion. Various factors affect the results. With the usual 36 in. logs of firewood a big draught has to be maintained to overcome the damping effect to the fire when stoking. If the logs are cut to half or third lengths, the draught can be cut down considerably, regulating by means of the ventilators situated under the furnace doors. Cutting to 12 in. lengths, stoking is so easy that I have known a saving of over 40 per cent although the corresponding saving with 18 in. lengths was not so great. With red gum the output was increased to about 1,200 lbs. of made tea to the yard of firewood.

Induced draught is of great assistance in maintaining an even furnace temperature and in saving fuel. Generally induced draught is supplied with too big a suction, partly to cope with the cold stove and chimney when lighting up. For normal running the fan should be closed as far as possible consistent with good combustion. With liquid fuel too big a draught causes the flame to flicker and jump, and also causes the flame to tail off into a series of sparks. Low pressure burners are economical, and require a very small amount of air. It is a common mistake of coolies to have the small inspection doors and the door underneath the burner fully open. The latter door is for directing the flame. By admitting air, the flame can be lifted. Any excess air required should be admitted by the circular louvres round the burner. The makers of the Wallsend low pressure burners recommend that the flame should be such that smoke can just be seen from the chimney. After a long series of experiments I found that the most economical flame is one with which the least reduction of draught causes smoke.

With either wood or coal, a shallow even fire is the most economical. Although furnaces are often bricked up too much, it must be realised that if carelessly used, after the removal of some of the bricks, a larger grate area allows more waste than a small area, and the draught associated with the larger area must be particularly carefully supervised.

Superintendents are often asked to revise estimates for firing costs when a conversion is made from one kind of fuel to another. This can be done reasonably accurately since all fuel has a definite "calorific value." That is to say a fixed weight of wood or liquid fuel or coal will produce a definite amount of heat. In practice the heat produced by a given fuel is below the theoretical value, and this particularly applies to damp firewood and to coal used with bad conditions of stoking, draught, or dampness. It cannot be too strongly emphasised that a rough firewood store shed is a very much worth while proposition to the estate. The out-turn per yard can be calculated from the following tables, which show the average weight of wood to a yard, and the cost per pound of made tea. The table assumes continuous firing, that the firewood is stored under rough cover, and that it is well stacked and well cut.

Weight per yard		Approx. cost per lb. of made tea			
		(a)	(b)	(c)	(d)
Red Gum	1000 lbs	0.46 cts.	0.40	0.37	0.25
Blue Gum	925	0.50	0.43	0.40	0.27
Rubber	800	0.58	0.50	0.47	0.31
Grevillea	750	0.62	0.53	0.50	0.33
Toonah	675	0.68	0.59	0.55	0.37
Acacia	650	0.71	0.62	0.58	0.38
Jungle wood	650-850	0.71-.54	0.62-.47	0.58-.44	0.38-.29
Albizzia	500	0.92	0.80	0.75	0.60

Notes.—All costs are worked out at a charge of Rs. 3/- to a yard of firewood, and for a modern type of drier stove. They are based on the fact that continuous firing with any firewood under a given set of conditions, will show a given out-turn in pounds of made tea to a *pound* of firewood.

(a) Without induced draught, and firewood 36 in. lengths, out turn 0.65 lbs. tea/lbs. firewood.

(b) Without induced draught, and firewood 12 in. lengths, out-turn 0.75 lbs. tea/lbs. firewood.

(c) With induced draught, and firewood 36 in. lengths, out-turn 0.80 lbs. tea/lbs. firewood.

(d) With induced draught, and firewood 12 in. lengths, out-turn 1.20 lbs. tea/lbs. firewood.

Whilst some of these figures are theoretical calculations, they all correspond closely to actual figures from my own records, and others produced by Messrs. Davidson & Co. Of course the costs will be proportional for different costs of firewood, and for different out-turns of made tea to a pound of firewood.

If the conversion from wood to liquid fuel or coal is contemplated, the following figures, supplied by the Shell Co. may help.

	Liquid fuel	Equivalent coal	Equivalent firewood
Natural draught	1 gallon	22.95 lbs.	65.4 lbs.
Induced draught	1 gallon	18.18 lbs.	52.7 lbs.
			30 lbs for 12 in lengths

From these figures new costs can be worked out. For example, with red gum weighing 1,000 lbs. per yard, one yard will be equivalent to $\frac{1,000}{52.7}$ gallons of liquid fuel, *i.e.*, about 19 gallons.

If one yard of gum costs Rs. 3.00 and liquid fuel costs 30 cents per gallon the cost of firing will rise to about Rs. 5-70 for the same weight of fired tea.

On the other hand one yard of the same firewood will be equivalent to about 345 lbs. of coal, which at Rs. 37-50 per ton costs Rs. 5.77. In both cases induced draught is considered.

The last point I should like to make is this. The best firewood is a heavy firewood like red gum. According to Mr. H. C. King in *The Tea Quarterly*, 1935, planting gums at 6 × 6 feet (approximately 1,000-1,200 per acre) and felling every 12 years, 50 acres of gums are required to supply fuel for 500 acres of tea in bearing. This figure is based on 400 yards to an acre. I believe personally that the yield per acre is a little higher than this in many cases, and the required acreage of fuel block lower than is mentioned. Shade trees often account for a good many thousand trees.

In conclusion, I would like to express my thanks to the Directors of the Bogawantalawa District Co., to the Tea Research Institute, to Messrs. Davidson & Co., and the Shell Co. of Ceylon all of whom have been of great assistance in the matter of collecting data for this paper.

DISCUSSION

Mr. C. W. Newton said it had been suggested that teas made by the Clivemeare rolling process did not keep well and asked if there were any proof of this.

Dr. Norris in reply said he did not think there was any real evidence in regard to their keeping qualities, though statements of a general nature had been made. The only commercial invoices sent to London were the two experimental invoices he had referred to. Of the numerous small samples which had been sent to London some, at any rate, had been preserved for a considerable time and had kept well.

Mr. Morford said he had had the opportunity of using both the Clivemeare roller and the Legge cutter. Dr. Norris had referred to the possibility of some major modifications in tea manufacture and the thing that had struck him when using the latter machine was the advantage of eliminating withering. Due to this, teas made in the Legge machine were ready to leave the factory by 1 p.m. on the day the 10 o'clock leaf was plucked. After a little experience had been gained, all these teas were reported on as being very brisk and very bright and they had sold above the market average. Legge manufacture was not continued, however, since the blenders found that the type of tea produced caused difficulty in packing and the purchase of large quantities would involve drastic alterations to their packeting machines.

There were two major difficulties about this type of manufacture. The moisture content of the leaf at the time it went to the drier was probably about 70-75 per cent. It was impossible for the existing type of driers to deal satisfactorily with such leaf, particularly as the out-turn of the cutter was in the region of 1,000 lbs. per hour. Again, the cut tea fermented within 20-25 minutes and it was impossible to complete drying quickly enough, with the result that some of the tea was overfermented by at least half-an-hour.

Mr. Morford said he referred to these experiments as they provided some indication that withering might not be as important as sometimes thought. It was possible to obtain good teas without withering and this could be an important point in factory construction. Elimination of withering also removed one possible source of bacterial infection and Mr. Benton had attributed the success of the "no wither" system in the Dooars very largely to this cause.

Mr. Wilfred Rettie said that Dr. Norris in his address had referred to the question of drying at lower temperatures and he thought this was extremely important. It might be of interest therefore if he described an experiment carried out on an estate in which he was interested during the monsoon. The experiment made, using a 3 feet E.C.P. drier, was really a repetition of one carried out 20 years before but modern drier fitments made it more accurate.

Two firing temperatures had been employed, namely the normal firing temperature of 185° and a temperature of 165°. In the former case the tea was put through the machine in 20½ minutes, in the latter in 31 minutes.

Identical leaf had been used in each case and two comparative invoices manufactured for sale in London. Samples were examined in Colombo and the verdict given in favour of the normally fired tea. He had himself been in London when the teas reached home and had tested the samples with the brokers. Again everyone was unanimous that the normally fired teas were the better. By the time the teas were sold, however, about six weeks later, the position had been reversed and the teas fired at 165° secured three-farthings a pound more than those fired at 185°. This would suggest that the firing temperature had had an influence on the way in which the tea matured.

MR. RETTIE went on to say there were two or three points arising from Mr. Finley's interesting paper to which he wished to refer. Mr. Finley had stated that for many years one of the main signposts to successful manufacture had been labelled "Heat is the enemy of quality." This statement appeared to indicate rather a lack of discernment on the part of planters. He presumed Mr. Finley really meant unnecessary heat.

Secondly, Mr. Finley had stated that in the case of natural withers the heat of evaporation was taken from the leaf itself. Was this correct? If the leaf provided its own heat for evaporation, it would freeze long before it became withered. He suggested the air used in natural withers provided the heat just the same as in artificial withers.

Again, Mr. Finley had said that the improvement in fermentation so clearly produced by the Clivemeare roller was due to the sub-division of the leaf particles and the rapid initiation of fermentation by the exposure of the tea juices to the air, only the latter process requiring heat.

He wished to ask if it was necessarily a good thing if fermentation throughout a batch of leaf started simultaneously — the batch could not be fired simultaneously.

Lastly, Mr. Finley had referred to the persistence of the "fallacy" that the out-turn in pounds of a drier was directly related to the performance of the machine.

He (Mr. Rettie) did not quite see where the fallacy arose. It was well-known that the greater the moisture the less the dry leaf, but there were standards in Ceylon and so long as one had to deliver so many pounds of dry tea to the market so long would a drier be required to turn out so many pounds of dry tea per hour.

Mr. Finley in reply said that in regard to the first point raised he entirely agreed with Mr Rettie and he was sorry he had not made the point clear. Heat was rather like electricity — dangerous when uncontrolled. It was certainly more correct to say "*Unnecessary* heat is the enemy of quality."* Without this qualification the phrase was misleading.

On the second question also his meaning was exactly what Mr. Rettie had stated. In both fan and natural withers enormous quantities of heat were required to effect the necessary evaporation. In both cases the water evaporated at the leaf surface. The leaf thereby cooled down and reabsorbed heat from the air. In this way a state of equilibrium was reached which explained why the leaf was always a few degrees cooler than the air itself. That the air was cooled could easily be seen by taking the temperatures of the incoming and outgoing air in the loft. In both a natural and a fan wither the leaf was cooled. Such cooling was less marked in the case of a natural wither, probably due to the greater quantity of air flowing through the loft.

With regard to fermentation, he appreciated Mr. Rettie's point. Rollers of the type of the Clivemeare and McKercher greatly improved infusions. Whether this was entirely due to the rapid and simultaneous setting up of fermentation he was unable to say. Even with the Clivemeare roller however progressive dhools were taken. Moreover, recent work at St. Coombs suggested that different parts of the flush had different enzymic activity and consequently the rate of fermentation would not be uniform. It was, he believed, a common factory experience that the wiry leaf took longer to ferment than the first dhools, *i.e.*, longer to reach the teamaker's standard of evenness in fermentation. Possibly Dr. Norris would be able to give more detailed figures.

In connection with drier out-turns he merely wished to stress the point that it would, in his opinion, be advantageous if the drier were referred to in terms of the number of pounds of moisture it could evaporate per hour instead of the number of pounds of made tea it could turn out. The former figure was a constant for a given machine over widely varying conditions, the latter would vary from factory to factory under each set of conditions, particularly with changes in the moisture content of the dhools. Mr. Finley referred to the case of a new drier recently put on the market where the

* Mr. Finley wishes to make an acknowledgment to Messrs. Elliott and Whitehead's book *Tea Planting in Ceylon* where this important distinction was first drawn.—Ed.

makers stated the capacity of the machine in terms of the pounds of moisture that could be evaporated but related this to the number of pounds of dry tea obtained for a given moisture content of the leaf.

MR. HUNTLEY-WILKINSON said it would be interesting to know in a normal rolling programme of 2½ to 3 hours, what proportion of the leaf was fermented in the rollers.

DR. NORRIS said it was not possible to give exact figures. The dhool out-turn and the time required to complete fermentation of each dhool would however give an approximate indication. In the later dhools probably at least 80 per cent of the fermentation had taken place in the roller.

It seemed probable that better results would be obtained if fermentation could be carried out under fixed and constant conditions. This could not be achieved with a normal roller and by no means completely with a roller such as the Clivemeare. Fermentation was set up more nearly simultaneously in the latter type, but there still remained the difference due to the different portions of the leaf which, as Mr. Finley had pointed out, did not necessarily ferment at the same rate.

MR. S. F. H. PERERA asked whether the quality of low-grown and mid-grown tea could be improved by the installation of air-conditioning plants in factories.

DR. NORRIS said an experiment had been carried out at St. Coombs where leaf brought up from a low-country estate had been manufactured and compared with tea from a portion of the same batch of leaf manufactured in the estate factory. The tea manufactured at St. Coombs was considerably the better of the two. A similar result had been obtained in an estate experiment on similar lines. He had no reason to think that anything except the different temperature conditions contributed to these results. There was, therefore, some reason to think that air-conditioning in factories at low elevations might result in an improvement to the tea made. It was impossible at the moment to indicate how the right conditions could be economically achieved. As had been pointed out in a recent article in *The Tea Quarterly* (1938, Vol. XI, pp. 151-154) conditioning of separate fermenting rooms presented no special difficulty; rollers could also be cooled, but withering was a much more serious problem. The Institute was in touch with firms interested in air-conditioning in the hope of obtaining further data on the subject.

MR. E. C. CAMERON asked Mr. Finley if he were right in deducing from the figures given that firing by liquid fuel was slightly cheaper than the use of coal.

Mr. Finley replied that if the prices quoted were accepted, namely liquid fuel at 30 cents per gallon and coal at Rs. 37.50 per ton, the firing costs given in his paper would be found approximately correct.

In further reply to Mr. Cameron who asked if these calculations were worked out on theoretical considerations or practical tests, Mr Finley said that they were based on theoretical grounds but had been confirmed by a large number of experiments carried out both at St. Coombs and by engineering firms.