STUDIES ON FUELS FOR TEA DRIERS—IV.

THE RELATIVE COSTS OF HEATING AIR WITH FIREWOOD, COAL AND OIL

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GENERAL

In previous articles in this series [1] the theoretical and practical considerations involved in the combustion of firewood, coal and oil in tea driers have been dealt with at some length. As a living authority on heat[2] has deduced and pointed out: "when fuel is put in the place provided by the makers for this purpose the drier gets frightfully hot". Apart from this, other advantages may accrue from a reasonable amount of attention to the stoking of tea drier furnaces.

(1). A considerable saving in fuel may be effected.

(2) A steady inlet temperature may be maintained, which will reflect upon both quality of tea made and the cost of firing, since,

(a) A fall of temperature may tend to set up stewing conditions when the drier is loaded for a fixed drying capacity; and

(b) Rise of temperature under similar conditions will result in overfiring and waste of heat.

(3). Increased length of life of costly furnaces will certainly result from their careful use. Furnace distortion which is liable to cause loss of efficiency, to make repairs difficult, and thereby expensive, will also be avoided. The possibility of smoke taints will be obviated. Fire hazard will be definitely reduced.

To an industry faced with the inevitable need for ruthless efficiency, such conditions undoubtedly merit attention.

In this paper it is proposed to enlarge upon Section (1) above, and since the proof of any contention lies in trial, it is pertinent to mention at the outset that trials in St. Coombs Factory dealing with a small crop of 150,000 lbs. have resulted in a saving of Rs. 1,200 for the current year.

Accurate estimates of the relative values of firewood, coal and oil for heating air, particularly for general interpretation, cannot be obtained in a commercial factory working under normal conditions. The reasons for this are not far to seek if we consider the factors involved in the cost of firing a pound of tea:—

(1). Cost of heat units in the fuel used which varies widely with (a) type of fuel, (b) district and (c) accessibility of estate.

(2). Efficiency of stove, and efficiency of (a) oil burner or (b) stoking.

(3). The amount of moisture in the fermented leaf and the extent to which the leaf is dried out during firing.

(4). (a). The cost of lighting up must be separated from the cost of actual firing since the former obviously raises the overall cost per pound much more on a small crop than it does when firing is carried on for a period of, say, 10 hours or more.

(b). The feeding of fermented leaf must be continuous and at an even rate. The firing machine will work most economically when loaded to its maximum capacity. Intervals between sets of dhools introduce errors which are almost impossible to correct if figures are required for comparative purposes.

(c). The cost of hot air required for withering must be separated from the cost of lighting up the stove and the cost of firing tea.

(5). The efficiency of the drying chamber will also affect the cost of firing. If air escapes up the sides of the trays or passes through large gaps between trays without coming into contact with the tea, then it does not perform any useful work and its heat content is wasted.

When the air is all used to the best advantage, the exhaust temperature must be standardised for comparative purposes, since the exhaust temperature indicates the amount of heat in the air which is actually used for drying. Having decided upon the standard exhaust temperature at which to compare fuel costs it must be adhered to as nearly as possible throughout all tests. At the commencement and end of firing and during firing of the big bulk large errors will be made.

(6). The temperature of the outside air will also affect fuel consumption, since if firing is to be carried out at 190°F. it will obviously cost more to raise air at 60°F. to this temperature than it will to raise air from 90°F. *i.e.*, 130°F. of heat against only 100°F. of heat.

The situation created by the above factors is not generally realised, hence the indiscriminate claims put forward from time to time.

It is obviously desirable therefore to use some method of comparing fuels other than by relation of cost of fuel to pounds of tea fired. Fortunately a much more simple and accurate method is available since in the heater of a tea drier we are only concerned with heating a certain quantity of air. The subsequent history of the hot air does not affect the efficiency with which the task of the furnace is carried out. The efficiency of any one furnace will remain reasonably constant, so that measurements of the quantities of different fuels required to heat a fixed amount of air through a given range of temperature will afford the most accurate method of studying fuel economy provided that all tests are carried out on the same heater.

PROCEDURE

(1). The heater used for all the fuel tests was a Davidson's No. 5 Stove. The furnace of this stove did not need any special adaptation for burning firewood or coal.

(2). Each test was run over a period of several hours after the heater had been raised to working temperature.

(3). The temperature of the air flowing from the heater was maintained at 190°F.

(4). The air flow was maintained at a fixed rate. To ensure this (a) the fan was run at constant speed, (b) the fan valve was set at a fixed position after lighting up. This position was such as to allow the same volume of air as normally used in tea drying to pass through the heater.

The following observations were recorded:—

(1). Fan speed (checked every 15 minutes).

(2). Wet and dry bulb temperatures of the intake air and of the air leaving the heater (at frequent intervals).

(3). Flue temperatures, pressures and flue damper adjustments. Carbon-dioxide content of the flue gases.

(4). The volume of air flow as measured by an anemometer. For this purpose the exhaust duct was divided up into 36 sections and a set of readings, one in each section, obtained during each test.

(5). Weight of fuel consumed. In firewood and coal tests the fuel was divided into lots of 10 pounds. In oil tests dip-stick measurements in a calibrated tank were made at the end of lighting up and subsequently at hourly intervals.

(6). At the conclusion of each coal test the weight of coal ash was measured.

The tests carried out may be divided into the following groups:—

1. FIREWOOD

(a) *Red Gum.*—Cost Rs. 3 per yard of 850 lbs.
Moisture content 12·4 per cent.
Calorific value 7,857 B.T.U's. per lb.
Furnace did not need any special adaptation to burn the fuel.

(b). *Toonah.*—Cost Rs. 3 per yard of 535 lbs.
Moisture content 13·5 per cent.
Calorific value 7,471 B.T.U's. per lb.
Furnace as for Red Gum.

2. COAL

Cost Rs. 37 per ton excluding bags which are returnable.
Moisture content 2·6 per cent.
Calorific value 12,573 B.T.U's per pound.
The furnace did not need any special adaptation. A small part of the grate area was bricked up for trial but better results were obtained using the whole grate area.

3. OIL

Cost 31 cents per gallon of 9.4 lbs.
Calorific value 19,000 B.T.U's. per lb.
(Figures supplied by Shell Co. of Ceylon, Ltd.)

(a). *Alcosa No. 5 Burner.*—This burner was of the high pressure type. The furnace was bricked up with ordinary firebricks and broken bricks were placed in the combustion chamber to maintain a steady flame. This burner was originally installed in a similar manner in the firing machine.

(b). *Laidlaw Drew and Wallsend Burners.*—These burners were of low-pressure type employing atomising air at 10-15 inches Water Gauge Pressure.

A special combustion chamber was constructed according to a design supplied by the Shell Company of Ceylon, Ltd. Barakar firebricks were employed in the construction of the chamber; the sides of the furnace and the floor were insulated with Silocel.

Within a period of an hour or so after lighting up the hourly fuel consumption became almost constant.

A large amount of data was collected in these tests and is available for the use of anyone interested. It is not proposed in this paper to go into technical detail.

RESULTS AND DISCUSSION

When considering Table I in relation to other estates it is of the utmost importance to bear in mind the actual cost of the fuel in yards, tons or gallons on the particular estate because the relative values will vary widely with the relative costs. To facilitate comparison, the figures will later be calculated on a unit basis, meanwhile it must be borne in mind that reference is made to costs at St. Coombs Factory.

The outstanding feature of these results in relation to St. Coombs costs is the low figure for firewood in comparison to oil and coal. The variation in the value of different species of firewood

RESULTS.

TABLE I.

Test No.	Fuel		Lighting up (cold stove) Raising temperature of heater to 190°F.				Maintenance of air flow of 2,900 cu. ft. per minute at 190°F.			Notes
	Type.	Cost per lb. at St. Coombs.	Time taken		Weight of fuel	Cost	Temp. of intake air (Av.)	Amount of fuel used per hour.	Cost of fuel per hour.	
		Cts.	hrs.	min.	lbs.	Cts.	°F.	lbs.	Cts.	
1	Red Gum.	0·35	1	20	212	74	70	65	23	
2	Red Gum.	0·35	1	05	215	75	73	77	27	
3	Toonah.	0·56	2	35	250	143	80	82	47	
4	Toonah.	0·56	2	00	250	143	75	100	57	**Test run for one hour only.**
5	Coal.	1·65	1	40	120	198	82	41	68	Ash 20%. This contained a small amount of cinder which can be picked out and used for fuel.
6	Coal.	1·65	2	00	125	206	77	40	66	
7	Oil Alcosa No. 5.	3·30	1	15	47	165	73	31·3	103	
8	Burner	3·30	0	40	37·6	132	78	31·3	103	
9	Oil in Laidlaw	3·30	1	45	61·1	215	77	23·5	78	
10	Drew K.O. Burner.	3·30	1	15	54·1	190	78	22·9	76	
11	Do.	3·30	1	15	49·4	173	—	—	—	**Combustion chamber reconstructed. Lighting up test only.**
12	Oil in Wallsend O.O. Burner.	3·30	1	15	47·0	165	79	22·1	73	**Using the reconstructed combustion chamber.**

explained in Part I of this series, is illustrated by the figures for red gum and toonah showing that at the same price per yard, toonah is twice as expensive a fuel as red gum.

At St. Coombs, the relative costs of firing by oil or coal depend on the length of the day's work. Oil is less expensive than coal to light up on, but costs more for running the heater after it has been raised to working temperature. The reason for this is most probably that coal requires a large draught for proper combustion which cannot be realised until the furnace and stove have been heated. Where induced draught is available this lack may, to some extent, be remedied. Banking coal fires at night as described in Part 2 will also facilitate the raising of the heater to working temperature.

A substantial difference in the cost of oil-firing is shown between the Alcosa high-pressure burner and the low-pressure types. The differences between these burners depend not only on pressure but also size, the Alcosa burner being too large for the particular stove. This disparity has been noted in a considerable number of cases in Ceylon [3].

The tests revealed little difference between the two low-pressure types of oil burner. Tests 9 and 10 have been included in Table I in order to demonstrate the importance of a correctly designed installation. In these two tests trouble was experienced with carbon formation, and was found to be due in the first case to an insufficient supply of atomising air. This was remedied by substitution of the centifugal type of blower by a positive type originally employed with the high-pressure burner. Secondly, the discovery was made that the combustion chamber had not been constructed according to specification and this was remedied by reconstruction. These two faults impaired efficiency considerably and Tests 11 and 12 show the improvement that resulted from correction.

These examples serve to show the necessity for expert advice with oil installations and since this is available, free of charge, to all estates in Ceylon, through the Shell Company, there is little excuse for running oil burners uneconomically.

Apart from the above considerations a modern type of oil burner, properly fitted, is delightfully simple to use and gives scarcely any trouble, whereas a faulty oil burner is liable to be an endless nuisance and to cause damage to the stove.

Similar analogies may drawn from the use of coal, and tests at St. Coombs will serve for illustration.

When coal was first used for these tests, the firing cooly was left to his own devices and, as usually happens, he put far too much fuel into the furnace and attempted to work with a bed of fuel up to twelve inches thick! It is of interest to note that the cooly soon discovered that he got better results under these conditions by leaving the furnace door open. It is essential when burning coal that the cooly be instructed in the art of feeding the fuel and using the slice. The removal of clinker may cause some difficulty at first for until the cooly learns to recognise clinker from fused coal he may waste a good deal of fuel. Two complete tests were carried out before instructing the cooly along the lines given in Part 2. Little difficulty was experienced in the adoption of the recommended method while *the fuel consumption for heating the same amount of air as previously was halved.*

As with oil, the services of experts arranged through the suppliers, are available to all Ceylon estates. In some cases grate area needs reduction when coal is used as a fuel, and in this instance expert advice is most helpful.

Coal, like oil, is easier to burn economically than firewood once the elementary principles underlying its use have been grasped.

SUMMARY

The above results and discussions relate to the conditions appertaining to St. Coombs Estate. The only deviation of importance on other estates will be the actual cost of the various fuels in terms of cubic yards, tons or gallons. In order to facilitate comparison under various conditions it is only necessary to choose a unit and to express the results obtained on St. Coombs in multiples of this unit. Further, to simplify the application of these multiples they have been calculated for a range of fuel prices and the results set out in the following table. Red Gum at Rs. 1·50 per yard has been assigned the value of 100 units and all other costs based on this figure.

TABLE II

Fuel	Cost of Fuel	Cost of heating stove to working temperature	Cost of heating air
RED GUM	Rs. 1-50 per yd.	100 units	100 units
	2-00 ,, ,,	134 ,,	134 ,,
	2-50 ,, ,,	166 ,,	166 ,,
	3-00 ,, ,,	200 ,,	200 ,,
	3-50 ,, ,,	234 ,,	234 ,,
	4-00 ,, ,,	268 ,,	268 ,,
	4-50 ,, ,,	300 ,,	300 ,,
	5-00 ,, ,,	334 ,,	334 ,,
TOONAH	Rs. 1-50 per yd.	194 units	202 units
	2-00 ,, ,,	258 ,,	270 ,,
	2-50 ,, ,,	322 ,,	336 ,,
	3-00 ,, ,,	386 ,,	404 ,,
	3-50 ,, ,,	450 ,,	472 ,,
	4-00 ,, ,,	514 ,,	538 ,,
	4-50 ,, ,,	578 ,,	606 ,,
	5-00 ,, ,,	644 ,,	674 ,,
COAL	Rs. 25-00 per ton	368 units	394 units
Burnt as efficiently	30-00 ,, ,,	442 ,,	472 ,,
as firewood after	35-00 ,, ,,	516 ,,	550 ,,
heating up.	40-00 ,, ,,	590 ,,	628 ,,
	45-00 ,, ,,	664 ,,	708 ,,

Fuel	Cost of Fuel	Cost of heating stove to working temperature	Cost of heating air
OIL	25 cts. per gallon	338 units	512 units
Using a high	27 ,,	366 ,,	552 ,,
efficiency burner.	29 ,,	394 ,,	594 ,,
	31 ,,	420 ,,	636 ,,
	33 ,,	446 ,,	676 ,,
	35 ,,	474 ,,	718 ,,
	37 ,,	502 ,,	758 ,,
	39 ,,	528 ,,	800 ,,
	41 ,,	556 ,,	842 ,,
OIL	25 cts. per gallon	338 units	724 units
Using a burner which	27 ,,	366 ,,	780 ,,
gives the same efficiency	29 ,,	394 ,,	838 ,,
as firewood.	31 ,,	420 ,,	896 ,,
	33 ,,	446 ,,	954 ,,
	35 ,,	474 ,,	1012 ,,
	37 ,,	502 ,,	1070 ,,
	39 ,,	528 ,,	1128 ,,
	41 ,,	556 ,,	1186 ,,

In Part I it was shown under the heading "Firewood Costing" that the relative values of different species of firewood depended largely on the weight of dry matter in a yard. For practical purposes two rough divisions of different species of wood used for fuel could be made as follows:—

1st. Class.	Red Gum
	Blue Gum
Close textured	*Grevillea*
heavy wood.	Acacia
	Up-country jungle firewood.
2nd. Class.	Toonah
Open textured	Albizzia
light wood.	Dadap

An approximate idea of the relative fuel costs using the other firewoods given in the above list can therefore be made by reference to Table II.

Our thanks are due to the Shell Company for allowing Mr. R. Batie, M.Sc., to assist during the test with oil and to Mr. Batie for the able way in which he rendered this assistance.

APPENDIX

In Part I [4] it was pointed out that the fundamental consideration in assessing the value of firewood was the amount of potential heat, expressed in British Thermal Units, in each pound.

The term thermal efficiency expresses the percentage of this potential heat which can be utilised in any system.

It follows therefore that the fundamental factors underlying the cost of heating air in any air heater with any fuel are:—

(1). The cost of the heat units in the fuel.

(2). The thermal efficiency of the stove. If oil fuel is used the thermal efficiency of the oil burner must be taken into account.

The thermal efficiency of a stove is naturally dependent upon the design and upon the efficiency of combustion of the fuel.

During the firing tests described above the thermal efficiency achieved during each test was measured.

The figures are not necessarily the exact efficiency in absolute terms but they serve for the purpose of accurate comparison between any tests of the series. The thermal efficiency figures given below apply only to the process of heating air and are independent of the efficiency of lighting up.

TABLE III

Test	Fuel	Thermal Efficiency,* per cent
1	Red Gum	51
2	Red Gum	43
3	Toonah	39
5	Coal	47
6	Coal	52
7	Oil burnt in over-	42
8	size high pressure	
	burner	42
10	Oil burnt	58
12	in low pressure	58
	burner	

* Value for air flow as measured by Anemometer not corrected for density.

Firewood figures are most variable owing to the difficulty of burning the fuel correctly. Results with coal are much more uniform, while with any one burner very consistent results may be obtained with oil.

Firewood, coal and oil burnt in an unsuitable burner give a thermal efficiency of the same order. Oil burnt in a well-designed installation gives a definitely higher thermal efficiency.

Taking an average of Tests 1 to 8 in Table III and comparing this with Tests 10 and 12, we find an improved efficiency of approximately 13 per cent.

Further improvements may result from the introduction of the Java heater [5] in which combustion is so complete that the gases resulting from it (normally called the flue gases) are drawn directly into the drying chamber. An efficiency approaching 100 per cent. may be obtained with this heater.

At present prices, under St. Coombs conditions, oil can only compete with firewood and coal if the fullest advantage is taken of the possibilities of obtaining higher thermal efficiencies by its use. This point may be illustrated by the actual cost of heat units in the fuels used in the above tests.

Fuel		Cost of 10,000 B.Th.U's. delivered at St. Coombs Factory
Red Gum	...	0·45 cents
Toonah	...	0·76 ,,
Coal	...	1·32 ,,
Oil	...	1·74 ,,

For heating up a tea drier stove it was shown in Table I that oil was a highly efficient fuel. During the running of the air heater, when firewood and coal have attained their maximum efficiency oil has to reach an efficiency 24 per cent higher than its nearest competitor to maintain an equal cost, under conditions at St. Coombs.

Even if imported fuels can be burnt twice as efficiently as firewood, that is to say with maximum possible efficiency, they cannot compete with red gum firewood at Rs. 4 per air-dried yard of 850 lbs.

While local industry can produce red gum or similar firewood at Rs. 4 per yard, or until imported fuels are reduced considerably in price, firewood growing must be a sound economic proposition. The suggestion is ventured that insufficient attention has been given to this aspect of the tea industry and, in view of the closing of Government fuel blocks in many parts of the Island, a thorough revision of the local fuel-growing industry is desirable.

REFERENCES

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The Tea Quarterly 1936, Part II, page 48.
The Tea Quarterly 1936, Part III, page 110.

(2). Souchong Sandy, Planters' Note-Book.

(3). *The Tea Quarterly* 1936, Part III, page 118.

(4). *The Tea Quarterly* 1936, page 17 *et seq.*

(5). Report on a Visit to Java — Forbes and Norris, 1935, page 56.