A REPORT ON DIRECT-FIRED AIR HEATERS

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In the *Tea Quarterly* (1940), XIII, p 73, the Shell Co. of Ceylon and R. C. Scott published details of "A New Type of Direct-Fired Air Heater for Drying Tea" which had been in use at Ottery Estate for two years. This heater is still in daily use and the cost of upkeep has been negligible over a period of seven years. The simple construction of this Direct Fired (D.F.) heater; illustrated and explained in the article referred to, makes it obviously less costly to build than a tubular stove, whilst the theoretical possibility of high efficiency is borne out by figures shewing a cost of operation relatively low for drying by liquid fuel. These three factors, namely :—

(a) Low cost of construction
(b) Low cost of upkeep.
(c) High thermal efficiency.

are the most important factors in the costing of air heater operations and are therefore major considerations in the cost of drying tea.

It will probably strike the reader that factor (c) would have been more neatly expressed as "Low cost of operation." Unfortunately, however, high thermal efficiency does not result in a correspondingly low cost of operation unless the cost per heat unit in the fuel employed is comparatively low. Obviously a heater operating on, say, Liqueur Brandy would be expensive to run however high the thermal efficiency (it is now necessary to add qualifications about atomic energy).

For many years the Tea Research Institute has emphasised the relative cheapness of heat units grown on the estate in the form of fuel trees planted in clearings, swamps, ravines, etc., and has practised on St. Coombs Estate what it has preached in the *Tea Quarterly*. We have also pointed out the possibilities for a local fuel industry with much less effect.

During the war the supply of estate grown fuel was not sufficient to keep prices down and many contractors were quick to start what was virtually a "Black Market" in firewood. Fortunately, the oil companies, despite shipping difficulties and risk to life and limb, were able to supply adequate quantities of fuel oil at a very reasonable cost. It is fitting therefore to pay a tribute to the oil companies for the way in which our liquid fuel supplies were maintained at reasonable cost through the war. The relative costs of heat units in contractors' firewood and in oil reached parity early in the war years and there has actually been a marked change-over to imported fuel during this time. The coal supply, owing to transport and world shortage, has been very difficult, and oil is becoming, or has become, the tea industry's principal source of heat apart from home grown firewood. The cost of home grown firewood being intimately bound up with labour and transport cost has also risen and is unlikely to revert to former levels or to increase in availability. The low costs of construction and upkeep of a D. F. Heater, coupled with a high efficiency which ensures very economical use of liquid fuel, therefore makes *Direct* Firing worth careful consideration under present conditions.

At the beginning of 1945 a D. F. heater was installed in St. Coombs factory in parallel with a tubular stove of high thermal efficiency in such a way that accurate comparison could be made between the two alternative methods of heating the air supply for a common drying chamber. A number of carefully controlled tests were carried out after which the D.F. heater was put into daily use on the commercial side of the factory, operated by ordinary factory labour, and supervised by the teamaker

TESTS

The results of comparable tests on the two different types of heater are shewn in Table I. The heaters were, as already mentioned, both connected to the same drying chamber. In referring to Table I the following points should be noted :—

1. *Time taken to raise temperature.*— The test results shew the times for the thermometers to reach 190°F. In actual practice, when the direct-fired heater is in use, leaf can be charged into the machine five or ten minutes after lighting up, as it takes 20 minutes to fill the drying chamber and the duty is therefore light for the first 20 minutes. When the indirect heater, *i.e.*, the tubular stove, is in use, again it is not necessary to wait until the exact working temperature is reached, but since the large amount of metal in the tubular stove has to be raised to working temperature, the temperature of the air drawn over it rises slowly and must be closely approaching the working degree before the feeding of leaf is commenced. In the case of the direct fired heater, the air is at working temperature almost at once but it takes sometime for the drying chamber, and therefore the inlet thermometer, to record the working temperature. There is no capital of heat locked up in a D.F. heater as there in a tubular stove.

2. *Total weight of leaf fired and moisture content of fermented leaf.*—It will be noted that both from the duration of the test and the moisture to be evaporated per pound of tea fired, conditions were slightly in favour of the tubular heater.

3. *Made Tea.*—The leaf fired per gallon of fuel used, would therefore, as pointed out in para 2, have been even higher in the case of the D.F. heater had the moisture content of the fermented leaf been exactly equal in the two tests.

4. *Fuel used.*—The most exact comparison may be made on the oil consumption figures, especially in the hot air tests. It will be noted that both heaters were heating the same amount of air (Datum 24) to the same temperature (Data 10 and 11) over the same temperature range. They were both performing practically exactly equal tasks but one was consuming 3.3 gallons of fuel per hour and the other 4.5 gallons per hour (Datum 21). The consumption rate was steady but in the tubular heater some of the heat is unavoidably lost in the flue gases which pass up the chimney. The particular tubular heater used in these tests is of comparatively high thermal efficiency. The air from the tubular heater is to a slight extent drier than the air from the D. F. heater which contains the water of combustion* of the fuel, which at 3.3 gallons consumption of oil per hour means the formation of approximately 34.4 lb. of water During the tests in which leaf was dried. 157 lb. of water per hour were evaporated by the D.F. heater as against 143 by the

* Liquid fuel plus Oxygen = Carbon Dioxide plus water

TABLE I

	Direct Heating		Indirect Heating	
	Hot air only	With leaf	Hot air only	With leaf
1. Time to raise temperature ...	25 min.	25 min.	60 min.	45 min.
2a. Duration of test after raising temperature ...	420 ,,	480 ,,	360 ,,	231 ,,
2b. Total time of feeding or discharging ...	—	460 ,,	—	211 ,,
3. Total duration of test ...	445 ,,	505 ,,	420 ,,	276 ,,
Fuel used				
4. To raise temperature ...	1.7 gals.	1·25 gals.	4·25 gals.	4·0 gals.
5. For duration of test after raising temperature ..	23.3 ,,	27·00 ,,	26·75 ,,	16·25 ,,
6. For total duration of test ...	25.0 ,,	28·25 ,,	31·00 ,,	20·25 ,,
Firing				
7. Total wt. of fermented leaf ...	—	2501 lb.	—	1150 lb.
8. ,, ,, ,, made tea ...	—	1297 ,,	—	648 ,,
9. ,, ,, ,, moisture evaporated	—	1204 ,,	—	502 ,,
Mean Temperature °F				
10. Air Intake (outside air) ...	79°	78°	74°	73°
11. Inlet ...	192°	192°	191°	191°
12. Exhaust ...	—	128°	—	131°
Mean percentage moisture contents				
13. Withered leaf ...	—	53	—	53
14. Fermented leaf ...	—	49	—	44
15. Made tea ...	—	3·1	—	3·8
AVERAGES				
16. Fermented leaf fed per hour ...	—	326 lb.	—	327 lb.
17. Made tea discharged per hour ...	—	169 ,,	—	184 ,,
17. ,, ,, per gallon of fuel :—				
(a) Excluding amount to raise temperature ...	—	48 ,,	—	40 ,,
(b) Including amount to raise temperature ...	—	46 ,,	—	32 ,,
19. Moisture evaporated per hour ...	—	157 ,,	—	143 ,,
20. ,, ,, per gallon of fuel :—				
(a) Excluding amount to raise temperature ...	—	45 ,,	—	31 ,,
(b) Including amount to raise temperature ...	—	43 ,,	—	25 ,,
21. Fuel used per hour excluding amount to raise temperature ...	3·3 gals.	3·4 gals.	4.5 gals.	4·2 gals.
22. Fuel used per hour including amount to raise temperature ...	3.4 ,,	3·4 ,,	4·4 ,,	4·4 ,,
Miscellaneous Data				
23. Fan speed r.p.m. ...	590	590	590	590
24. Volume of air at exhaust in cubic ft. per min. (cold air reading) ...	5985	—	6090	—

(Fan valve adjusted to give constant volume of air-flow in all tests)

Indirect method (Datum 19), the fuel consumption in one case being 3.4 gallons and in the other 4.2 gallons. On the basis of equal moisture evaporation, therefore, the ratio is 3.4 to 4.6 and so for all practical purposes the moisture of combustion is negligible in its effect on drying capacity, as the ratio of fuel consumption is practically the same in both tests. The air leaving a tea dryer is still far from saturation point with respect to moisture, and this is the reason for the negligible effect of the moisture of combustion on the drying capacity of the air in a D.F. heater.

COMMERCIAL OPERATION OF D. F. HEATER

The D.F. heater installed in St. Coombs factory has been in daily use for almost a year. It has been operated and maintained by ordinary factory labour and supervised by the tea maker. Through the courtesy of Mr. R. C. Scott we have also been afforded every facility for examining the installation at Ottery Estate and the records of its use. We are from this experience satisfied that a Direct Fired heater is a practical proposition and suitable for use under ordinary estate conditions.

We are, however, bound to point out that since, in the D.F. heater the products of combustion are drawn through the leaf in the drying chamber, it is *possible* to taint leaf more easily than it is in a tubular heater. In the first place, the heater must be properly designed and constructed. The Shell Co. of Ceylon should be consulted in this matter. Secondly, the oil burning equipment must be suitable for the purpose for which it is employed and properly installed. Some types of oil burner are *not* suitable for direct fired heaters and responsible and efficient opinion must be sought on this matter. There are also several technical safeguards which must be incorporated *in the installation.*

Under the conditions specified, little short of gross neglect can lead to any mishap, but it must be realised that against this personal factor of gross negligence there is at the moment no possible technical safeguard. Mechanical troubles are bound to occur from time to time and taints arising from such troubles are largely safeguarded against by a cutout device which shuts off the oil supply as soon as the atomising air supply fails. A fall in atomising air pressure due to partial failure (for instance severe belt slip) would be indicated by the pressure gauge. *If by any* unfortunate combination of circumstances a smoky flame results from mechanical defect, it should be obvious to any normal labourer and immediate steps may be taken to minimize the effect by isolating the leaf in the machine at the time, and by getting tea tasters' advice before bulking the leaf with the rest of the teas fired. Only the grossest neglect could lead to a D.F. heater being operated with a smoky flame for sufficient time to taint any considerable quantity of tea. However, in the past, furnaces fed with firewood have fairly commonly been neglected and maltreated and it is necessary to make it perfectly clear to estate staffs that if a D.F. heater is installed, reasonable interest must be taken in care and maintenance. Technical knowledge is not required but merely a modicum of common-sense and awareness.

In seven years at Ottery Estate and one year at St. Coombs there has not been a pound of tea spoiled by commercial operation of D.F. heaters, and there is no reason why the heaters should not be installed in any factory where supervision is normal.

SPECIAL NOTES ON OPERATION

The normal sulphur content of liquid fuel makes it necessary to specify certain conditions for operation which should be recorded and displayed prominently for the benefit of the factory labour concerned with the operation of a D.F. heater. The sulphur in liquid fuel, which amounts to about 0.9 per cent of its weight, burns to sulphur dioxide which is a pungent gas familiar to all who strike Ceylon matches. It is also alleged to be a prominent constituent of the vapours of the lower world. Sulphur dioxide gas is used at comparatively high concentration for preserving dried fruits and especially concentrated fruit drinks, such as passion fruit juice. The concentration in the air blown through the dryer is very low and its effect on tea leaf negligible. The presence of sulphur dioxide in the withering lofts, especially if a D.F. heater is being used for withering, may cause comment but it is quite harmless. The effect of sulphur dioxide on the ironwork of the dryer is *not*, however, entirely negligible.

Sulphur dioxide attacks iron vigorously at very high temperatures, the rate diminishing with temperature and become slow at tea dryer furnace temperatures. At 190°F. the rate of attack is negligible but below 140°F. it again increases and may eventually have undesirable indirect effects on the fired tea. The actual amount of iron attacked is very small indeed but the product of the attack, namely ferric sulphate, may find its way into the leaf and cause occasional trouble with very dark liquors. Particles of ferric sulphate become detached from the ironwork, and if included in dry leaf when cupped out will give an almost black liquor. This trouble is not of any very great importance and may be entirely avoided by running the dryer above 140°F. As a matter of fact considerable corrosion also occurs in tubular heaters through running them below 140°F. for withering.

It should therefore be an invariable rule in every tea factory never to operate any machine for withering at an inlet temperature below 140°F. In the case of a D.F. heater written instructions in English and Tamil should be attached to the heater and the dryer. Recording thermometers are very useful for ensuring that this rule is obeyed. The first sign of a breach of this rule is a sticky deposit on the trays of the dryer and if this is noted at any time the drying chamber should be cleaned out.

In remote parts of the factory where condensation is liable to form in wet weather, unprotected, *i.e.*, ungalvanised or unpainted iron may "grow" white "whiskers" of ferric sulphate but it is not considered to be of any practical importance and will probably pass unnoticed in most cases.

SUMMARY AND CONCLUSIONS

1. Direct-Fired heaters have been found to have the following advantages :—

(a) Relatively low cost of construction.

(b) A very low cost of maintenance compared to tubular stoves.

(c) A high efficiency resulting in a 25 per cent saving of liquid fuel on a 3 ft. dryer in comparison to a tubular stove of high efficiency.

2. They have been found reliable in operation and easily maintained and supervised by an ordinary factory staff.

3 The following precautions are essential :—

A D.F. heater installation *must be* :—

(a) Properly designed and installed by a responsible engineering firm in consultation with the Shell Co. of Ceylon.

(b) Carefully supervised by a tea-maker who takes an interest in his job and who is reasonably alert. No special technical knowledge but only common-sense is required. The estate superintendent should also satisfy *himself that the* installation is properly maintained. It is emphasised that the gross negligence often allowed with firewood cannot be tolerated with a D. F. heater.

(c) Even when withering, the temperature of the air passing through and out of the drying chamber must be maintained above 140°F.