LIQUID FUEL FOR TEA FIRING*

(CONTRIBUTED BY THE SHELL CO. OF CEYLON, LIMITED)

INSTALLATION OF OIL TANKS ON ESTATES

Before discussing the installation of storage tanks for oil on estates, there is one point which should be emphasised. The oil used for oil engines and for tea firing is extraordinarily safe from the point of view of fire hazard — much safer than most people realise.

The fuel oil marketed in Ceylon has a flash point of 175°F and over, and therefore does not come within the scope of the strict regulations of the Petroleum Ordinance which refer to comparatively volatile oils, with a very low flash point.

(1). *Siting of Tanks.*—Liquid fuel storage tanks should, if possible, be erected in such a position that oil will flow by gravity from the storage tanks to the service tanks in the factory, thus avoiding the necessity for pumping.

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

As the storage tanks are usually placed in the open, they should be installed in such a way as to prevent the ingress of water or foreign matter.

It is not necessary to fit heating coils in the oil storage tanks in Ceylon.

(2). *Tank Construction and Installation.*—Storage tanks may be built of steel or reinforced concrete. Reinforced concrete tanks have proved perfectly satisfactory for this purpose, provided that the inside is lined with a rendering of water-proofing material, such as "Colemanoid", "Ironite" or "Waterex", all of which are obtainable in Ceylon.

Steel tanks may be welded or close rivetted and tested to a pressure of not less than 15 lbs. per square inch. The plate thickness should be in accordance with the capacity of the tank, the minimum thickness of a tank of 250 gallons capacity being $\frac{1}{8}$ in. and up to 1,250 gallons, the minimum thickness $\frac{3}{16}$ in. The tanks should be supported on strongly constructed brick or concrete cradles and should have a slight slope downwards ($\frac{1}{4}$ to $\frac{1}{2}$ in. per foot of the length) from the outlet towards the drain.

(3). *Manhole.*—A manhole should be fitted on the top of each tank, not less than 16 ins. internal diameter, to enable a workman to enter the tanks for the purpose of cleaning them. Manhole covers should be properly jointed and bolted down. Asbestos cloth, oiled canvas or thick cardboard make excellent jointing for manhole covers.

(4). *Filling Pipe.*—Filling pipes should be as short as possible, free from sharp bends and not less than $2\frac{1}{2}$ inches diameter. The line should terminate in a $2\frac{1}{2}$ inches valve and fitting to take the hose pipe of the tank lorry. When this connection is not in use it should be protected by means of a cap.

It is advisable to have the lorry discharge point above the tanks in order that the oil may be discharged by gravity. If this is not possible and the tank lorry is not provided with a pump, it will be necessary to instal a semi-rotary pump in the pipeline.

(5). *Vent Pipe.*—A vent pipe should be fitted to the top of the tank, which should not be smaller in diameter than the filling pipe and should be free from sharp bends. It must terminate in a goose neck, fitted with a wire cage for protective purposes. *Gauzes* should never be used for the latter purpose, as they are liable to choke.

(6). *Draw-off Connection and Piping.*—In order to provide dead-space for the settlement of water and residue, the bottom of the draw-off connection should be not less than 3 inches above the tank bottom. The draw-off connection and piping should be large enough to allow of an easy flow and should not be less than $1\frac{1}{4}$ inch diameter. A valve or gland cock should be placed in this line as close as possible to the tank (plug cocks should not be used).

(7). *Drain Cock.*—A 1-inch diameter valve or gland cock should be fitted on the underside of the tank at its lowest point, and it should be readily accessible with a clear space below to facilitate its use. This valve should be opened prior to the reception of each load of oil and any water or residue run off. In any case, the valve should be opened once a week to ensure that no water or sludge is left in the tank.

Storage tanks should be emptied and cleaned internally with gunny bags or cloth once a year. Cotton waste or materials containing loose fibre should not be used.

(8). *Oil Level Indicator.*—A dip stick is recommended as a cheap and reliable form of oil level indicator. A dipping hole with a protective cap should be provided as near as possible in the centre of the top of the tank.

(9). *The Reason for Erecting*—tanks and pipelines in this manner is to avoid all risk of water or foreign matter contaminating the oil, as these substances cause a tremendous amount of trouble and inconvenience, entirely disproportionate to the amount present.

The drain valves on storage tanks are essential, as all fuel oils tend to collect a small percentage of sludge over a period, and water is deposited, due to condensation on the internal tank sides.

(10). *Capacity of Storage Tanks.*—The capacity of storage tanks is a question of individual requirements, depending upon the reliability of transport between the bulk depôt and the factory. For conditions in Ceylon we recommend that the minimum storage capacity should be 10 days' supply, and we recommend 20 days' supply as being normal storage.

It is advisable to have two storage tanks interconnected, as this will allow the oil to settle in one tank, whilst the other is in use.

(11). *Service Tanks.*—Service tanks should be installed in the factory, and in no circumstances should supplies be taken direct from the main storage tanks to engines or liquid fuel burners. We strongly recommend that the engine room and each drier should be provided with separate service tanks, to enable the consumption of liquid fuel to be correctly allocated. The capacity of these service tanks should be sufficient for one full day's work, but in no case should it exceed 100 gallons.

Service tanks for tea drier burners should be placed at least 10 feet above the burner and some little distance away from the drier. The supply pipe from the storage tanks should be permanently connected to the top of the service tank and should be fitted with a valve adjacent to the service tank.

The top of the tank should be completely enclosed to prevent the ingress of tea fluff and foreign substance. The vent pipe should be fitted to the top of the tank, and be at least $\frac{3}{4}$ inch diameter. It should be led outside the factory with as few bends as possible to prevent it being choked with tea fluff. It should terminate in a downward direction. If the vent pipe cannot be carried outside the factory, the end of the vent pipe should be provided with a screw-on funnel fitted with gauze; the funnel should be of such size that the area through the mesh is equivalent to at least twice the diameter of the pipe. It is *essential* that this gauze should be removed weekly, cleaned and replaced. The outlet from the service tank should be at least 1 inch diameter and placed 3 inches above the bottom of the tank. A drain pipe should be fitted, as on the main storage tank, and both these should be fitted with full-way valves.

(12). *Pipelines.*—Steam quality black piping should be used on all new installations, and not galvanized piping. Running joints formed with sockets and jam nuts should be avoided, as this type of joint is always unsatisfactory. It is much better to fit unions, as tight joints can be made, and, if necessary, the piping can be disconnected and reconnected easily.

If possible, the piping should have a continuous fall from the storage tanks to the service tanks.

The pipeline should also have a continuous fall to the burner; sharp bends should be avoided.

(13). *Strainers.*—It is advisable to fit strainers or filters in pipelines. They should be large enough to permit easy flow of oil and should be easily accessible for cleaning, which should be carried out at regular intervals. We suggest the strainers should be cleaned weekly.

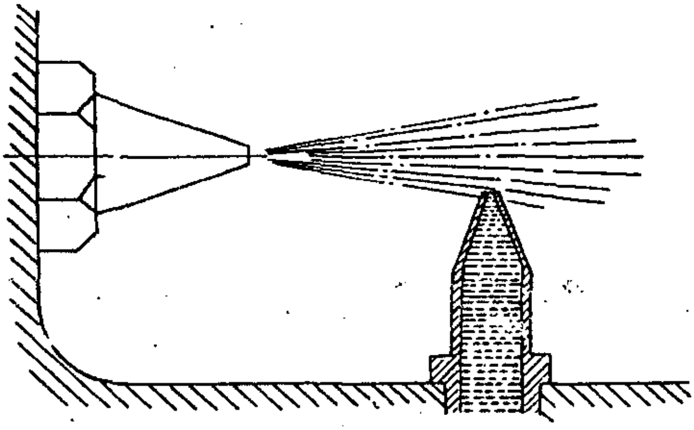
LIQUID FUEL BURNERS

There are a great many different makes of liquid fuel burner, but there are only four methods of burning oil, which reduced to their simplest form are:—

(1). Hot plate or vapourising burners.
(2) Rotary or Centrifugal atomising burners.
(3). Injector burners.
(4). Pressure jet or mechanically atomising burners.

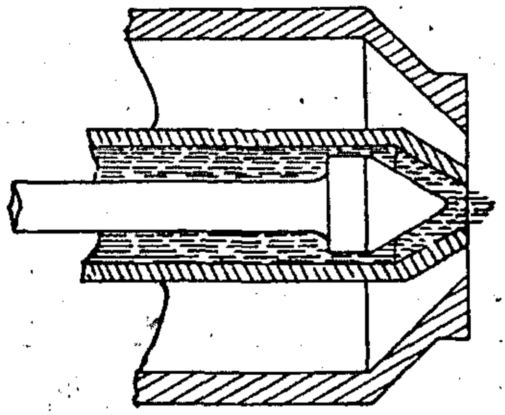
In Ceylon the type of liquid fuel burner usually found on tea driers is of the injector type.

There are many different kinds of injector type burners, nevertheless they all have one feature in common. A high velocity stream of air impinges upon a comparatively slow flow of oil and not only imparts considerable momentum to the mixture of oil and air but tears the oil stream into a finely atomised mist. It is usual with these burners for the oil to be delivered to the burner by gravity, the head required being sufficient to overcome the friction in the supply pipe and in the passages of the burner itself under conditions of maximum flow. The flow of oil is then adjusted by means of a valve in the burner or in the pipeline. In some of these burners, however, the air besides serving to atomise the oil, also acts as an injector and sucks up the oil from a constant level free surface at a fixed distance below the centre line of the burner. Three types of burner are illustrated below:—



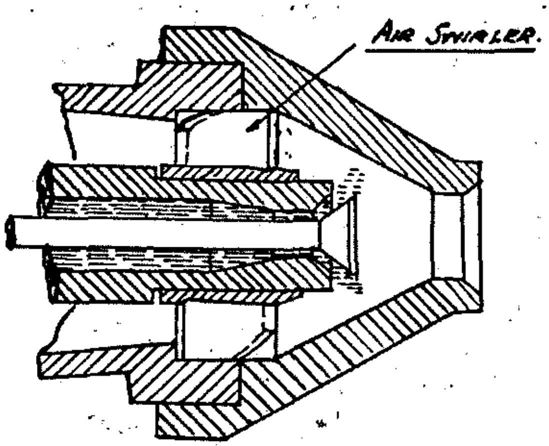
(A)

(A)—is the crudest form of oil burner, and is of the simple scent spray type. It is rather uneconomical with regard to the amount of primary air required. Furthermore, the atomization tends to be rather coarse, so that normally a considerable quantity of refractory material is required to keep a stable flame.



(B)

(B)—is the commonest type of burner, and is of the simple injector form. Oil flows through the inner tube under a low head sufficient to deliver the quantity of oil through the burner. Air is passed through the annular space surrounding the oil tube at pressure ranging from 2½ lbs. per square inch to, say, 30 lbs. per square inch according to the size of the annular orifice and the oil consumption. Where high pressure air is used, probably 5 cubic feet of free air per lb. of oil will be adequate for this burner, but there is a class of medium air pressure burner frequently used which takes 6 to 10 cubic feet of free air per lb. of oil, at pressure ranging from 2½ to 5 lbs. per square inch, delivered by a rotary compressor. If the annular air space is enlarged still further, it is possible to use a correspondingly larger volume of low pressure air delivered from a centrifugal fan at a pressure ranging from 9-inch water gauge, that is, 0·325 lb. per square inch up to as high as 20 inches water gauge, or 0·722 lb. per square inch. From 25 per cent up to 100 per cent air for combustion must go through the burner itself according to the requirements of local conditions. When air pressures in the neighbourhood of say, 16 inches or 20 inches water gauge are used, the proportion of air passing through the burner can be reduced as low as 20 per cent.



(C)

(C).—This is a typical low-pressure oil burner of good design. The oil flows through the inner piping and the amount is regulated by the central spindle valve. The low-pressure air flows round the annular passage and is given a rotary motion by the fixed swirler shown in the block.

For the purpose of this article it is not necessary to go into details of the other types of burner.

It is impossible to exaggerate the importance of the type of burner and the method of atomization in choosing oil firing equipment for any installation.

In most burners fitted to tea driers it is necessary to arrange for the service tank to be erected in such a position that there is at least a 10 feet head of oil above the centre line of the burner to ensure that the oil flows freely from the burner nozzle.

When installing liquid fuel burners they should be rigidly fixed in position, as movement of the burner may cause damage to the stove due to localised heating, or considerable waste of fuel due to the flame formation being disturbed.

It is most desirable that an automatic cut-off should be fitted in the fuel supply line as close to the burner as possible. This is a safety device which cuts off the supply of oil should the air supply fail for any reason, and can be obtained in Ceylon.

In visiting tea factories it has been noted that a considerable number of driers have been fitted with liquid fuel burners which are much too big for the machine, with the result that much more liquid fuel is burnt than is necessary. When a larger burner than is necessary is installed, experience shows that if the supply of oil is reduced below the minimum rating of the burner it is not always possible to reduce the amount of air proportionately, as a definite quantity of air is always required to give efficient atomization. If the air supply is reduced below the quantity required for efficient atomization, there is a tendency for the flame to flicker and go out and under these conditions the efficiency of combustion is greatly reduced. If the air is not reduced in proportion to the fuel oil then there are heat losses due to the presence of excess air and reduction in flame temperature. This will be dealt with more fully. It has usually been found that the small capacity burners can be regulated to give all the heat that is required for fairly large stoves, and at the same time give economical results in smaller stoves. Before dealing with the actual handling of liquid fuel burners, it is necessary to deal briefly with the theory of combustion.

Liquid fuel like any other fuel requires a definite amount of oxygen for combustion, and this is provided by an adequate supply of air. The quantity of air *theoretically* required for complete combustion depends upon the ultimate analysis of the fuel; a typical example being as under:—

	Fuel Analysis		Lbs. Oxygen		Weight of Products lbs.	At 32°F Volume per lb.	Volume of Product cubic feet
Carbon	85·3	combines with	227·5	to form	312·8 CO_2	8·15	2,549·3
Hydrogen	12·8	,,	102.4	,,	115·2 H_2O	19·6	2,257·9
Sulphur	1·6	,,	1·6	,,	3·2 SO	5·59	17·9
Oxygen	0·3						
Nitrogen	—		1,110·0 N		1,110·0 N	12·77	14,174·7

Fuel 100 lbs. combines with 1,441·5 lbs. air to form 1,541 lbs. flue gas.

Volume Dry· 16,742 cubic feet

Wet: 19,000 cubic feet.

Therefore 1-lb. fuel needs 14·4 lbs. or 178·4 cubic feet air for complete combustion.

(with 30 per cent excess air, 1-lb. oil requires 246 cubic feet of free air at 60°F).

Maximum theoretical CO_2 = 15·2 per cent of the dry flue gases (by volume).

1-lb. of fuel oil (calorific value, say, 19,000 B.T.U.) forms 190 cubic feet flue gas.

Therefore volume of flue gas per 100 B.T.U. = 1 cu. ft.

In practice it is not possible to effect complete combustion with either solid or liquid fuel by giving the net amount of air *theoretically* required for complete combustion. The amount of excess air in addition to the minimum theoretical quantity depends on the fuel. Solid fuels usually require at least 50 per cent of excess air, while liquid fuel can be satisfactorily burnt with as little as 20 per cent of excess air. The less the amount of excess air used the greater is the efficiency, as higher flame temperatures can be obtained and lower heat losses in flue gases.

We give below the theoretical flame temperatures for varying quantities of excess air:—

Excess Air		Flame Temperature
0 per cent	...	2100°C
20 ,,	...	1750°C
40 ,,	...	1620°C
80 ,,	...	1400°C

The above figures are theoretical only, and in actual practice the flame temperature can be taken as approximately 200°C less for temperatures over 1700°C and 150°C less in lower temperatures. When burning, oil fuel gives a brilliantly radiant flame, the size and shape of which depends upon the quantity of oil being burnt, the type of burner used and the design of the furnace itself. A great deal of its heat, however, is transmitted from this bright flame radiation in the combustion chamber. A great quantity of excess air results as shown above in a large reduction in the flame temperature and this prevents the user from taking full advantage of the powerful radiant effect of an oil flame. It is impossible to over-emphasise this point.

We have stated above that excess air increases the heat loss up the chimney, and this is clearly illustrated in the table given below.

FLUE GAS ANALYSIS

% Excess Air	% Volume of Dry Flue Gases		Heat carried away by Wet Flue Gases above 60°F.			
	CO_2	O_2	at 300°F %	400°F %	500°F %	600°F %
0	15·2	0	11·46	13·52	15·61	17·67
10	13·75	2·0	11·89	14·13	16·40	18·62
20	12·55	3·66	12·32	14·74	17·19	19·61
30	11·55	5·04	12·76	15·36	17·99	20·39
40	10·68	6·22	13·19	15·97	18·78	21·56
50	9·93	7·53	13·62	16·58	19·57	22·53
75	8·45	9·25	14·70	18·11	21·55	24·96
100	7·38	10·73	15·78	19·64	23·53	27·4
150	5·86	12·81	17·94	22·70	27·49	32·25
200	4·88	14·22	20·10	25·75	31·45	37·11

Having shown the reason for keeping the excess air down to a minimum, we can proceed with the general handling of liquid fuel.

To get the burner working properly using a reasonable quantity of excess air, the atomising air to the burner should be cut down to the minimum required for proper atomization, and the air director should be slowly shut in until a faint haze is just visible at the top of the chimney. Under these conditions the flame is not a brilliant dazzling white colour but of a distinctly yellow hue with tinges of orange at the end of the flame. It is commonly supposed that a flame of dazzling white appearance is giving good results, when actually such a flame is often the result of a considerable quantity of excess air.

It is not necessary to preheat the atomising air for liquid fuel burners for tea driers. Preheating the air will only serve to raise the flame temperature, which might be the opposite of what is required; also, preheating is only obtained at the expense of a furnace heat, which would otherwise be used for heating the drying air.

The quantity and condition of the air drawn through the drier for the purpose of firing the teas has a direct bearing on the fuel consumption, and, speaking generally, the greater the quantity of air the higher the fuel consumption. The fuel consumption in a drier is directly affected by the temperature of the atmosphere, the initial firing temperature, the quantity of heated air put through the drier and the moisture content of the fermented leaf. Assuming that the temperature of the atmosphere is 70°F and the drying temperature is 200°F, then the air drawn through the drier must be heated through 130°F. If the air temperature is 80°F and the firing temperature is 190°F, then the air has only to be heated through 110F. If there were no change in the quantity of air flowing through the drier, then the fuel consumption will be reduced in the ratio of 130 to 110. If the quantity of the air going through the drier is lowered slightly to give lower drier exhaust temperature, then the fuel consumption is lowered proportionately to the weight of air going through the drier. If the moisture content of the leaf is low, then the rate of spreading leaf can be raised and the same consumption of fuel will give a higher output of tea per hour. Because one factory is able to fire tea on a fuel consumption of say $2\frac{1}{2}$ gallons per hour with an out-turn of 120 lbs. of tea, it does not necessarily mean that the next estate can obtain the same fuel consumption, as leaf conditions, firing temperature and quantity of air passing through the drier may be entirely different.

To sum up, in order to get the best results with liquid fuel, the following points should be observed:—

(1). Fit the smallest size of burner which will burn oil at a sufficient rate for satisfactory lighting up. This burner will then be working well within the range for normal firing.

(2). Keep the excess air down to a minimum.

(3). Cut down the fuel supply to the minimum required to maintain an even temperature.

(4). Keep the drier fan speed at the minimum laid down by the makers.