STUDIES ON FUELS FOR TEA DRIERS.—II.

STOVE DESIGNS AND THE STOKING OF WOOD AND COAL

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GENERAL

Before discussing details apertaining to the individual uses of firewood, coal and liquid fuel, it is of interest to consider the general problems involved in air heaters.

The main object is to raise a sufficient quantity of air to a suitable temperature without contaminating it with undesirable products of combustion. For this purpose it is generally found necessary to transfer heat from the furnace through metal tubes or a gilled plate to fresh air drawn through the stove by a fan and thus obviate admixture of air and flue gases. In almost all modern driers cast iron tubes are used. In machines such as Farbridge, Marshall's and Walker's driers the hot gases from the furnace pass over the outside of the tubes while the air is drawn through the tubes. The opposite takes place in Davidson's machines in which the flue gases pass through the inside of the tubes.

As much of the heat of the flue gases as possible should be transferred to the air, but practical considerations limit the abstraction of heat from these gases. For one thing the products of combustion include water which passes off in the flue gases as steam.

FUEL +	AIR =	CARBON DIOXIDE +	WATER + HEAT.
(Carbon + Oxygen + Hydrogen)	(Extra oxygen)	(CO_2)	H_2O

If the flue gases are cooled down too much the water vapour from combustion condenses to liquid water. This often occurs when driers are first lit up, excessive cooling taking place as the flue gases pass over or through a succession of cold tubes. In this case water may be seen dripping from the stove during lighting up.

Condensation is more serious when it continues beyond the period of lighting up which may happen if the circulation of the flue gases is faulty, resulting in stagnant areas around the outside tubes where excessive cooling takes place. The serious aspects of this problem of condensation is that the water condensed out of flue gases is liable to contain acids, such as pyroligneous acid, which attack the tubes and cause rapid corrosion.

Analysis of liquid collected from a stove giving this trouble showed the liquid to be acid and to contain 4·2 per cent solids, mainly iron salts (probably iron acetate). Scale removed from corroded areas gave the following analysis:—

Loss on ignition (Soot, moisture, etc.)	...	21 per cent
Iron ...	...	25 ,, ,,
Iron calculated as iron acetate		79 ,, ,,

It is often said that condensation is due to excessive moisture in firewood used for fuel. Such an opinion is not very well supported by a closer examination of the problem.

The limit to the amount of heat which can be extracted from the gas is imposed by the water which arises from combustion since it is not practicable to cool the gases below the point where the steam begins to condense to water. The amount of water formed by the combustion reaction alone is usually very much greater than the amount of water originally present in the fuel. Kemp [1] gives the average composition of dry wood as 49·5 per cent Carbon, 6 per cent Hydrogen and 44 per cent Oxygen. Since every pound of hydrogen in the fuel will give rise to 9 pounds water, every 100 pounds of dry wood will give rise to 54 pounds of water in the flue gasses when properly burnt.

In Part I, page 20, of this series of articles [2] it is shown that 15 per cent moisture means that only 2 per cent of the total heat is lost in evaporating the moisture and expelling it from the firewood in the form of steam. 100 pounds of such fuel will contain 85 pounds dry wood and 15 pounds of water. The 85 pounds of dry matter will, on combustion, give rise to $\frac{85}{100} \times 54 = 46$ pounds water which causes a loss of 6 per cent of the total heat in the fuel in the form of steam; the total heat losses of this nature amounting to 8 per cent. In this case $46 + 15 = 61$ pounds water pass off in the gases from 100 pounds fuel compared to 54 lbs. from completely dry fuel; an increase of only 7 lbs. per 100 lbs. fuel. Only at 35 per cent moisture content does the moisture content in the fuel equal the water formed by combustion, and this amount causes a further 6 per cent loss, making a total loss of heat in the form of steam of 12 per cent of the total heat, assuming complete combustion. Unless wood is burnt too green or stored very badly (see Part I) such a high moisture content as 35 per cent is unlikely and, even in this case, under proper condition of burning, condensation should not take place if the stove is properly designed. Investigation of a number of cases of condensation has revealed that this may take place when firewood is well stored and up to standard in every way. In such cases it is the stove itself which is at fault and not the fuel.

Another problem is superimposed upon this, however, since a certain amount of heat is necessary to maintain the draught. If an air heater contains a large number of tubes and more than a certain proportion of the heat is extracted from the flue gases, then the gases will not rise up to the chimney. In this case a fan is necessary to boost the gases up the chimney. The introduction of a fan means that additional appliances and additional work (the drive of the fan) are necessary to extract the larger fraction of the available heat. Whether this is an economical proposition has not been definitely settled, but another consideration must be taken into account. Induced draught fans may be fitted where natural draught will suffice with the object of controlling the draught. In both cases the whole process of combustion is greatly simplified. It should be understood that induced draught does not necessarily mean better or more economical combustion, always provided that adequate control is exercised over natural draught. Induced draught does mean, however, that economical burning of all fuel is greatly facilitated, but whether the saving which accrues from this facility is commensurate with the extra capital and power required is a question which demands investigation.

Before passing on to the actual stoking operations we must consider the controls available on the various types of air heaters and the best use to which they can be put. The stove of every air heater has a characteristic thermal efficiency which is the maximum percentage of heat which can be transferred from the fuel to the air under the best working conditions. In order to maintain the conditions, adequate control must be exercised over the feeding of the fuel and over the draught. Only the general principles of draught control will be considered in this section since later sections will deal with the details apertaining to the individual fuels. In the case of liquid fuel special conditions are necessary since a considerable fraction of the air is supplied through the atomiser. With firewood and coal the main object is to cause the air to pass through the firebars directly into the bed of burning fuel. A certain amount of air above the fuel may be necessary and this may be introduced through the door of the stove. The total amount of air passing through the furnace is controlled by the chimney damper and this regulates the rate of combustion.

The temperature of the heated air leaving the stove, that is to say the inlet temperature of the drier, is best regulated by the use of this damper.

A roaring draught will cause a higher rate of generation of heat from the fuel than is necessary and a great deal of this heat is carried away up the chimney. The rate of passage of flue gases through the stove is too high to allow a proper interchange of heat to take place. Such a condition is indicated by the base of the chimney becoming too hot. At this point the temperature should not exceed 400°F. and it should be possible to touch the chimney quickly with the flat of the hand. A roaring draught is also liable to lead to a vicious circle since the hotter the chimney becomes, the greater the draught induced by the heat and the higher the rate of combustion.

A sufficient body of fuel in the furnace is essential for avoidance of the necessity for very rapid combustion in order to keep the temperature of the heated air up to the required level, but it is a great mistake to have too much fuel in the furnace since smoke will result from efforts to damp the draught down. It is equally important that the firebars should be completely covered by the fuel. Under all circumstances the firebars must be kept cleared so that the passage of air through these are not interrupted. Small and frequent additions of fuel are necessary in order to keep a "level" fire, which expression means that a constant amount of fuel is kept in the furnace. With firewood it is a great advantage to have the fuel cut into small pieces rather than large logs, otherwise it is difficult to keep a level fire.

In addition to maintaining a constant capital of fuel in the furnace bed (level fire) it is necessary to have a slightly thicker bed of fuel in the front of the stove so that the fire bed tapers to the back end. The reason for having a thinner fire at the back end of the furnace is to allow a slight excess of air through the bars at the back of the furnace, in order to ensure combustion of volatile products mixed with the flue gases. Only a part of the heat is actually liberated in the bed of the fire. The rest results from burning gases passing towards the bridge and on to the flue. If sufficient air for the combustion of these useful gases is not available, they may pass up the chimney unburnt and result in a very considerable loss of heat. These latter remarks apply more particularly to coal than to firewood. In addition to sloping the fire bed it may be necessary, particularly with coal, to allow a certain amount of secondary air in through the fire door. The criterion of this necessity is excessive smoke. Air may be forced to enter through the fire door by closing down the dampers on the ashpit doors. Secondary air will generally only be necessary for a short time after the addition of a fresh charge of fuel. The opening of the door to admit the charge is usually sufficient if the door is not closed too quickly after charging. If it is found necessary to continue admitting a secondary supply of air in order to overcome a tendency to smoke, then it is almost certain that the firebars are blocked and these should be cleared immediately. Too much secondary air must be avoided since it will waste a great deal of heat if admitted unnecessarily. The major part of the draught must pass through the firebars.

These principles may be summarised as follows and are easily grasped by a cooly:—

(a) Inlet temperature must be controlled by the flue damper.

(b) Fuel additions must be little and often and designed to maintain a constant amount of fuel in the furnace.

(c) The fire should be thicker in the front than the back, but never so thick in either place that air cannot pass through freely.

(d) Most of the air should pass through the firebars which must be kept clear, but if the fire becomes smoky then a little air may be admitted through the door.

A cooly who has been taught these four points soon becomes an expert artiste at the adjustment of the various factors.

The efficiency and ease of running an air heater is ensured by regular attention to cleaning of the tubes in order to avoid these being blocked by soot and dust, to the cleaning of flues and spark arrestors, and occasional examination of the chimney in case the latter is partially blocked by soot, although this should not happen if combustion has been properly regulated.

FIREWOOD FOR TEA FIRING

[In this section it is proposed to give practical details relevant to the stoking of firewood. Certain points may already have been mentioned above, but for the sake of completeness they are recapitulated under this heading.]

The firewood drawn from the stock as described in Part I is best cut into as small pieces as possible. For this purpose a circular saw is very useful. Small pieces of firewood enable a level fire to be maintained and help considerably in avoiding smoke and in keeping the inlet temperature of the drier at a constant figure. The depth of the fire will depend to some extent on the nature of the wood as, for instance, heavy dense red gum will be better burnt in a thinner fire than a bulky light wood like *Albizzia* or *Toona*. The best depth can be easily found by trial, and should be sufficient to maintain a steady inlet temperature without too frequent adjustments of the chimney damper. Small additions at frequent intervals are essential and under no circumstances must the furnace be piled up with large logs. Small additions at frequent intervals mean that a constant amount of fuel is kept in the furnace and that a constant amount of combustion takes place. Under these circumstances comparatively little adjustment of the flue damper will be necessary after the temperature of the air supply to the drying chamber has been raised to working level. During lighting up the flue damper should be left full open, and thereafter it should be closed down to the working position which must be found by trial. If the inlet temperature falls the damper should be opened a little, and when the temperature rises too much the damper should be closed down, taking care to avoid over-adjustment which may cause the fire to smoke.

Periodically the firebars must be cleared of ash in order to allow a free flow of air through the bed of fuel from the ashpit, and for this purpose the ashpit must be reasonably clear, with the ashpit doors open to a sufficient extent. When burning firewood it is hardly ever necessary to admit extra secondary air through the door of the furnace.

MIXING FIREWOOD

Consideration of the above principles and facts does not support the practice of deliberately mixing various species of firewood. Where the firewood comes to the factory in a mixed condition it is not worth while sorting out the different kinds of wood, but apart from this there is every reason for burning one kind of fuel at a time. Where the object is to maintain an even rate of burning it is surely better to avoid complication by using fuel of uneven composition.

Albizzia is sometimes said to burn quickly and is on that account mixed with other wood. Albizzia gives the impression of burning quickly because of its large bulk for a given weight of combustible matter. Where gum may weigh up to 1,000 lbs. per yard, Albizzia may only weigh 450 lbs. per yard, which means that over two yards of Albizzia must be burnt to raise the same amount of heat as one yard of gum.

The complaint that any particular wood burns "too hot" simply means that the firing cooly has paid insufficient attention to draught control. It not infrequently happens that the chimney damper is left wide open and never touched from one year's end to the next. Under such circumstances a roaring draught will result which makes the chimney hot and induces an even bigger draught. This state of affairs may lead to serious consequences if the stove is badly stoked.

The firing cooly is inclined to fill the furnace as full as possible in order to save the trouble of frequent attention. With a dense fuel like old red gum a large weight of combustible material can be packed into a furnace, and if this is subject to a roaring draught it will give a very intense heat. When the inlet temperature gets too high the cooly will probably open the cold air inlets which simply means that the tubes are starved of air when they most need it. Burnt out tubes, burnt firebars, and distorted furnaces are a result of these malpractices.

REFERENCES.

(1). Engineers' Year-Book, 36th Edition, p. 2199.

(2). *The Tea Quarterly*, 1936, Vol. IX, Pt. I, p. 20.