LIQUID FUEL: ITS APPLICATION, USES AND ADVANTAGES.

By E. H. G. Morris.

Under the term "liquid fuel" may be included all substances which are combustible and can be made liquid without serious difficulty. Taking these in seven sections, we have—

1. Animal oils and fats—neatsfoot, whale, tallow, etc.
2. Fish oils—shark, cod, herring, etc.
3. Vegetable oils—linseed, rape, cotton, etc.
4. The whole class of spirituous liquors distilled from fermenting starchy substances, such as potatoes, spirit manufactured in this way being largely used in Germany for industrial and motor car purposes.
5. Vegetable essential oils—eucalyptus, turpentine, and other distillation products of wood.
6. Coal gas tars, creosote, coke oven tars, blast furnace tars.
7. Petroleum and other mineral oils found liquid in nature or distilled from bituminous shales.

The first five sections may be at once rejected, not so much on account of unsuitability as fuel, but by reason of price, therefore we shall only consider petroleum and coal products.

**Petroleum Residue**, which comprises the bulk of the liquid fuel in use. The crude, as it comes from the wells, is subjected to the topping process, which is a distillation extracting the lighter fractions of petrol and kerosene, leaving a product of high calorific value having a high flash point, and known as "furnace fuel." Some crude oils containing little, if any, of the lighter fractions, are used direct from the wells.

**Shale Oil**, which is obtained by the distillation of shale, seams of which are found throughout the world.

**Crude Coal Tar**, obtained by the distillation of coal used in the production of coal gas and from coke ovens; this fuel requires a high temperature for efficient burning.

**Creosote**, obtained by distilling tar; it is therefore lighter, and makes a good liquid fuel.
I do not intend to go deeply into the analysis of liquid fuels; it is sufficient to state that we gain our calorific value from the carbon, hydrogen and sulphur content, nitrogen and oxygen forming the other parts. The percentages vary considerably with different fuels, and, in consequence, there is a marked variation in the calorific value, specific gravity, flash point and viscosity. The following is an approximate analysis of some of the fuels marketed:

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<thead>
<tr>
<th></th>
<th>Carbon</th>
<th>Hydrogen</th>
<th>Sulphur</th>
<th>Calorific Value</th>
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<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>B.T.U.'s</td>
</tr>
<tr>
<td>Coal Gas</td>
<td>77.5 to</td>
<td>6.33 to</td>
<td>.43 to</td>
<td>16,000 to</td>
</tr>
<tr>
<td>Tar</td>
<td>85.3</td>
<td>7.33</td>
<td>.61</td>
<td>16,500</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>83.5 to</td>
<td>10.7 to</td>
<td>.03 to</td>
<td>18,759 to</td>
</tr>
<tr>
<td></td>
<td>87</td>
<td>12.3</td>
<td>3.27</td>
<td>19,300</td>
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The history of the early experiments in the burning of liquid fuel need hardly be mentioned, for it is of slight value unless to confirm the accepted opinion of to-day that to burn it successfully it must be atomised. One of the first papers on this subject was read before the American Society of Civil Engineers in the year 1878. Suffice it to say that this paper raised a discussion so full of error and misconception that it is of no value except to show what had been done to burn liquid fuel prior to the system of atomising.

As I have to cover such a vast field, there being practically no industry where liquid fuel is not being used, it will be necessary to abbreviate my description of the application to each industry.

The system of atomising in general practice to-day is grouped under five headings, namely—

- Pressure jet oil burning.
- Steam jet oil burning.
- High pressure air burning.
- Low pressure air burning.
- Hot plate or vapour burners.

In the pressure jet oil burning the oil is projected under pressure into the furnace in the form of a finely atomised conical spray, the pressure varying from 60 to 200 lbs., depending on the viscosity and heat of the fuel and the design of the burner. A pump discharges the fuel through a heater, where its temperature and corresponding viscosity are brought to those necessary for complete atomisation, the air necessary to bring about complete combustion being supplied either by natural or forced draught. The incoming air required for combustion is
heated by circulation round tubes in the uptakes or by circulation over the furnace front plate, thus producing a higher initial flame temperature, with early combustion, both of which ensure increased efficiency. In the smaller vessels in the Navy it is the adopted practice to have totally enclosed stokeholds under pressure of approximately 8 in. This system will recover 80 to 83 per cent of the theoretical calorific value of the fuel.

In the steam jet system the fuel is atomised by steam, and the burner is of the simplest design. The oil enters the burner, and has a whirling motion imparted to it by means of a spiral guide down the oil passage. The steam enters round the oil passage, thus steam jacketing the fuel and raising it to a temperature which will bring about easy atomisation at the end of the burner with early combustion. Some makes of steam jet burners make provision for extra air to be drawn through an outer cone by the inductive action of the steam. The range of adjustment in this type is large, and, in consequence, the burner can be used in a wide range of work. This system will recover from 5 to 80 per cent of the calorific value of the fuel. About 3 per cent of the total steam raised is required by the burner for atomising. The oil in this instance is fed to the burner by pumping or gravity.

High pressure burners are mostly of the same design as the steam jet burners already mentioned, but some burner manufacturers, in installing this system, have the liquid fuel at the burner slightly higher in pressure than the air. This, in most cases, is done by putting the fuel service tank under air pressure.

In the low pressure system the liquid fuel is atomised by low pressure air supplied by a fan at from 3 in. to 28 in. water gauge. The design of low pressure burners varies considerably. Before discussing various types of these burners, it is necessary to emphasise that, although 1 lb. of oil requires, for satisfactory combustion, approximately 240 cub. ft. of air, it is not by any means necessary to take all this air through the burner. Some burners are designed to take all the air required for combustion, but there are others again which require as little as 30 per cent; this air is usually known as “primary air” and the remainder as “secondary.” There are so many designs of burners which come under this category that it would be impossible to describe them all. It is sufficient to say that in all types high velocity air impinges upon a comparatively slow flow of oil. If time permits, with the aid of sketches, I shall describe eight of the different kinds of burners.

With the hot plate or vapour burner, the oil impinges against a surface heated by radiation of the flame, which throws it into
LIQUID FUEL

a vapour. It is then forced through a jet, and gains its extra air for combustion by a funnel draught.

USES AND ADVANTAGES.

The uses of liquid fuel are many and various, from manufacturing steam for power purposes on a battleship to making bread. Prominent on the list must be placed its application to marine engineering, as for this work it represents a concentrated form of fuel. The ease of its manipulation, its flexibility, and the freedom from difficulty in maintaining steam over a lengthy period, the total absence of smoke and ashes—these features alone make it invaluable for warships. In the merchant ships the use of liquid fuel is rapidly extending. To-day we have only one mailboat calling in Australia which is using coal, and she is making her last trip. Some of the many advantages gained by the use of liquid fuel on board ship are as follows:

Less space occupied for bunkers. Weight for weight, liquid fuel occupies only five-eighths of the space required for coal, a ton of liquid fuel occupying 38, and a ton of coal 45 cub. ft. Coal actually occupies more than this when you take into consideration the bunker space lost through its being impossible to trim the bunkers to their full capacity.

Reduction in engine room staff. To state a case in point, the Cunard S.S. "Aquitania," which has been converted to an oil burner from coal, to-day carries a complement of 42 men as engine room staff against 320 when burning coal, and it will be seen that the saving of wages, victualling and insurance of 278 men becomes a big factor.

Bunkering can be accomplished either at sea or in port with a minimum of time and labour, together with an entire absence of dirt and noise. Many hundreds of tons of oil can be taken on board in an hour, and this oil can be stowed in portions of the ship which could not be used for coal. It is usually stored in the double-bottom tanks, these tanks being used in coal-burning ships as ballast tanks, and being usually kept full of salt water. As water ballast is usually 10 per cent of the tonnage of a vessel, a big saving in carrying capacity is obtained by utilising the fuel oil as ballast.

There is definitely less wear and tear on boilers using liquid fuel, as the temperature in the furnace is always maintained constant, with no variation in steam pressure, no cold air being permitted to enter the fire box. This is certainly not the case in coal-burning ships, as constant cleaning of fires is necessary, the pressure of steam and temperature of furnace dropping
considerably during this work, which entails the removal of all ashes from the firebars and the replacing of same with green coal. During this process a considerable amount of cold air passes through the boilers, and subjects the landings, rivets, etc., to severe strain. Then the fires are forced to their greatest extremity to raise the steam again to the required pressure, over-heating stay-nuts, etc. The replacement of firebars, back plates, bridges, stokehold plates and furnace fronts, and the renewal of firing tools are a large item of expenditure in the coal-burning ship, furnace fronts and stokehold plates being a very expensive proposition, owing to the fact that they are subjected to intense heat whilst fires are being cleaned. This, and the action of salt water, which is used for cooling the ashes when they are drawn from the fires, necessitates the constant renewal of these parts. In the oil-burning ship the boiler fronts are painted white, and replacements are unknown.

There is also one other main feature I should like to mention before leaving the sea, and that is stand-by losses. When one considers that a ship of 10,000 horse power requires twelve tons of coal to cover the firebars before an attempt is made to raise steam, and the same amount remains in the furnace when the vessel is berthed and steam is finished with, this, taken over a trip, would amount to a large tonnage, taking the run of an Australian passenger vessel as calling at ten ports in 26 days. With liquid fuel the valves on the boilers are immediately shut down with the "Finished with Engine" signal.

On land many boilers have been converted from solid fuel to liquid fuel. In the textile industry the first installations were merely a supplementary measure to meet the peak period, the burners being lighted to cope with the sudden demand for steam. The success obtained by this means and the necessity for extending the works, due to the growth of this industry in Victoria, occasioned a total conversion. This enabled the factory to handle the increased output without installing extra boilers, the efficiency of the steam plant being raised from approximately 50 to 75 per cent. Part of the steam raised in these factories is used for obtaining an even temperature at all times in the machine rooms. This is a comparatively steady load, but the processing, dyeing and pressing rooms occasion the heaviest demand. This load is very intermittent, and in consequence the flexibility of liquid fuel is very apparent in meeting this fluctuation. The other advantages, such as cleanliness, stowage, and reduction in handling and firing costs, all tend to the making of liquid fuel an ideal medium for boiler firing in this industry. In the modern textile factory, using steam in every department,
with boiler room situated in the centre of the works, so as to avoid long steam pipe lines, which would mean high radiation losses, the use of liquid fuel becomes a big consideration. The fuel storage tanks can be placed underground away from the works altogether, only requiring a pump to feed the service tanks in the boiler room, and this is certainly a feature where cleanliness is of great importance and space is valuable.

Time will not allow me to describe other industrial plants which are now burning liquid fuel, but, in passing, I would mention the fields of industry where steam boilers are installed which have benefited—clothing factories, dry-cleaning works, tyre-retreading works, dairies, laundries, butchers' shops, etc. In most of these works the boiler is located in the same room as the rest of the equipment. Steam must be available in as short a time as possible, and the boiler must be able to meet every varying load. Cleanliness is essential, and human supervision must be cut out almost entirely, as labour cost is a very big factor in small factories, the saving of one man's wages in many instances amounting to more than the total fuel bill for the week. Many of these factories have increased their output since the boiler was originally installed, and, if they had not been able to increase their boiler efficiency, this would have meant the purchase of a larger boiler. Before passing to the metallurgical field, I would mention one industry which has benefited to the fullest extent, and that is the manufacture of photographic materials, the bugbear—dirt, ashes, and smoke—having been entirely eliminated. This industry was one of the first to adopt the use of liquid fuel, if for no other reason than to eradicate this evil. No other means of steam raising met with success.

**Metallurgical Field.**

Oil firing for all classes of metallurgical and industrial furnaces is finding increasing application, as its use enables a greater output to be obtained, whilst the ease with which the oil and air supply can be regulated enables the temperature and the nature of the flame, either oxidising, reducing or neutral, to be controlled within a fine margin. The heating of a furnace to the required temperature from cold can be brought about in half the time, and with considerably less wear and tear. In a great number of conversions very little alteration is necessary to the existing furnaces to make them suitable for liquid fuel firing. When the furnace is shut down, the fuel is simply closed off, and, as the furnace can be made comparatively airtight, no quick reduction of temperature takes place, thus saving most of the general upkeep of refractory material, and practically
eliminating stand-by losses. I would mention some of the many branches of this field where liquid fuel is being used—

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<td>Annealing</td>
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<td>Assay furnaces</td>
<td>Ladle heating</td>
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<td>Billet heating</td>
<td>Metal smelting</td>
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<tr>
<td>Bolt and nut manufacture</td>
<td>Pipe bending</td>
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<tr>
<td>Boiler making</td>
<td>Plate heating</td>
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<tr>
<td>Brazing</td>
<td>Refining of copper, silver, etc.</td>
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<td>Canister making</td>
<td>Rivet making and heating</td>
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<td>Case hardening</td>
<td>Smithy work</td>
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<td>Core drying</td>
<td>Spring manufacture</td>
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<td>Drop forging</td>
<td>Tinning</td>
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<tr>
<td>Enamelling</td>
<td>Tool making</td>
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<tr>
<td>Frit manufacture</td>
<td>Tube welding, etc.</td>
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<td>Galvanising</td>
<td>Welding</td>
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*Steel Foundry.*—A short description of one of Melbourne’s steel foundries. This foundry uses liquid fuel throughout. The cupola, after being charged with hard coke, metal, and limestone, is then heated. This is done with a portable burner. The coke then brings the metal to the required temperature, approx. 1560°C. During this period the converter is being heated in readiness to receive the metal from the cupola, the large ladle used to convey the smelted metal to the converter also being heated, both with portable burners. Liquid fuel hand torches are used to dry out all moulds. The smaller ladles, used for casting, are heated over a grid furnace. A crucible furnace, designed to take two pots, is used for the smelting of the ferro manganese, this and the annealing furnace and core stove being operated with stationary burners. The actual process of smelting, casting and annealing is carried out in this foundry, as the required amount of molten metal is removed from the cupola to the converter. The metal is then blown with air at a pressure of 3 lbs. to remove all impurities, such as manganese, phosphorus, silicon, and carbon. Ferro manganese in a molten state is then added, and then silicon and aluminium in a wet pack, the percentages varying in accordance with the required formula. The metal is then ready to cast.

In the annealing process low carbon steel castings are treated at a temperature of 950°C for one hour per inch of thickness, and are then allowed to cool slowly. High carbon steel is treated at 900°C. It is then quenched in water, then reheated to 650°C, and allowed to cool off slowly. Manganese steel is treated at 1050°C and quenched in water.

My object in describing a steel foundry is to point out the various temperatures required and the length of time annealing
furnaces must be kept at a constant temperature. Steel manufacturers appreciate the ease with which liquid fuel meets these demands with low fuel and labour cost, and without dirt or inconvenience.

**Cast Iron and Malleable Iron Foundry.**—The whole process is now being carried out with liquid fuel, the smelting furnaces being either of the reverberatory or rotary type. As a high heat transfer is required, a luminous flame is a great advantage. On this account, liquid fuel is an ideal fuel, because of the ease with which it may be handled and the degree of radiation from its flame, and also the possibility of liberating heat at a high rate per cub. ft. of combustion space. High combustion rate simplifies the attainment of high temperatures, and so increases the output of the furnace. The preheating of the combustion air is carried out with some form of recuperator. In this connection it must be remembered that the exhaust gases must leave the furnace at a temperature above the heat of the metal. For this reason, it is clear that much heat must of necessity leave the actual furnace, but if proper provision is made a large percentage can be recovered and returned to the furnace in the combustion air by means of the recuperator. Rapid heating also influences contamination; the shorter the time the metal is in the furnace, the less opportunity there is for it to pick up impurities. As furnaces can be heated with liquid fuel in half the time taken with any other fuel, and a temperature of 1700 °C. can be maintained for any period, it is not necessary to go into any further details to show the advantages over any other method of firing.

Passing to forging and heat treatment, I give a description of one of our largest forging and heat treatment shops, where liquid fuel is now used throughout. In the forging shop the furnace is rectangular, built with two chambers side by side, the burner firing into a combustion chamber at the side formed by a bag wall, which reaches within 9 in. of the top. The products of combustion, passing over, are drawn to flues formed at the bottom of the bag wall, and then pass underneath the hearth of both chambers to the stack. As the wall between the chambers is one brick in thickness, the heat from the main chamber, which is maintained at 1100 °C., by radiation keeps a heat of 600 °C. in the preheating chamber. As alloy steel has to be treated with fairly low temperatures during the early stages of heating, this chamber is essential. The walls of this furnace are 19 in. thick, and so prevent any loss of radiation. The heat treatment furnace is of a similar design, and is maintained at a temperature of 830 °C. in the main chamber and 300 °C. in preheat. After being quenched in oil, the steel is
immersed in a two-ton lead bath, which is maintained at a temperature of 600° C.; it is then quenched in water. This bath is covered with charcoal to save oxidisation. There are also two case-hardening furnaces and a cyanide pot in operation. The burners in use in these furnaces are of the primary and secondary air type. In the design of all furnaces in this factory the full value of the heat and the waste gases has been taken into consideration, and, as they are fitted with burners supplying primary and secondary air, there is perfect control of combustion, no cold air being admitted. A slight reducing flame is at all times maintained. A saving of 30 per cent in the cost of production has been effected.

Another factory in Melbourne dealing mainly with high speed steel has three furnaces installed, one a vertical round semi-muffled, fitted with two burners so placed as to cause a swirl under the hearth, the second a vertical semi-muffled double-decker, the top deck being used as a preheat and the lower deck as the main heat chamber, and the third a rectangular semi-muffled. The temperatures maintained in these furnaces range from 1200° C. down to 650° C. All temperatures must be maintained over lengthy periods. The management claim a saving of 60 per cent on fuel costs alone.

**Metal Smelting.**—Brass, Aluminium, Copper, Lead, Tin, Silver, etc. The field is very extensive in this industry, embracing practically every application of liquid fuel. A number of types of furnace are being used in this work. We have the crucible, reverberatory, open hearth, tilting and rotary furnaces, all giving excellent results in their particular field. One company in Victoria, using liquid fuel throughout, have installed a reverberatory furnace for smelting brass, muntz metal, etc., to run into ingots for their hydraulic press for the manufacture of all sizes of pressed wire and rods; this furnace is maintained at a temperature of 1950° F. They then use an open hearth furnace for heating the ingots for the press. Their aluminium and brass casting furnaces are tilting furnaces, which are maintained at 1950° F. for 24 hours. The capacity of the reverberatory furnace is 6 tons 3 cwt., the fuel consumption being 137 gallons, thus making a cost of approximately 4½d. per cwt. smelted. The open hearth, which is also continuous, is maintained at a temperature of 1480° F., at a cost of 4½d. per 200 lbs. of metal heated. The tilting furnaces have a capacity of 600 lbs. each, twelve charges being smelted in 24 hours, at a cost of 4.7d. per 100 lbs. One of the main features in the conversion to liquid fuel from coke is the fact that the life of the crucible has been increased from 70 to 165 heats. Since each metal and operation must be considered on its own merits,
together with reduction of metal losses, etc., every consideration must be given to the type of furnace to be installed for satisfactory work.

*Canister Manufacture.*—The first experiments with liquid fuel in this work were carried out in 1929. Since then great progress has been made in this industry. To-day we have one of the largest canister manufacturers operating all processes with liquid fuel. The plant consists of a body (auto) former furnace, a top and bottom automatic soldering plant, two soldering glory holes (one with four operators and the other with sixteen), three smelting pots, a stoving lithographing tinplate oven and a drying oven. The management claim that they have increased their output considerably, and show a saving of 60 per cent on fuel cost.

*Industrial Work*

This includes—

- Air heating
- Bakers' ovens
- Bitumen heating
- Central heating
- Cooking
- Ceramic industry (which includes cement, bricks, lime, pottery, and tiles).
- Drying of sand, dust and road metal
- Gas enriching
- Glass manufacture
- Hot water supply
- Pre-mixing
- Roasting of malt, cocoa, coffee, etc.
- Varnish making
- Vulcanising, etc.

As I shall not have time to deal with each of these industries and processes, I propose briefly to discuss some of the main ones.

*Ceramic Industry.*—In this field it is interesting to note that the most conservative of industries has made considerable advancement in the adoption of liquid fuel firing and in the technique of its use. This advancement, we may modestly claim, has not been behind the progress made overseas.

In small pottery production liquid fuel fired muffles had been in practical use for some time, but it was not until 1929 that this fuel was adopted in the production of cheap, heavy clayware, constant strikes in the coal fields being a strong factor in bringing about the first conversion.

The burning of ceramic kilns calls for quite a technique different from that demanded in most other furnace work. Kilns vary very considerably in design and method of operation, but the fundamentals of burning are practically the same
throughout. In the early stages of firing there is a period of low temperature, called steaming, to evacuate carefully, without cracking the ware, the hygroscopic water and the water of manufacture. This period naturally varies with the type of ware and method of production. When all the moisture has been cleared from the kiln, the temperature is then raised until the goods attain an even, dull red; then a period of oxidation must be allowed, as many clays contain organic matter which, if not oxidised before the surface sealing, remain to cause serious bloating, etc., when the ware is raised to higher temperatures. This period varies from nil with purified clay to hours where big masses of carbonaceous clayware are involved. During this period a considerable volume of excess air must enter the kiln.

When the combustion or oxidation of the organic matter has been completed, the temperature can be raised rapidly towards the finishing point. Then a period of soaking is required to even up conditions throughout the kiln. Then again, with some classes of goods, such as those made from the red burning clays —roofing tiles, facing bricks, etc.—it is necessary to have large volumes of excess air to develop the greatest degree of oxidation of the iron content, on which the finished colour depends. By being able to manipulate the secondary air, any condition can be obtained in the kiln from strongly oxidising to heavily reducing; thus many colours can be developed. In other types of ware the soaking period vitrifies the body, developing the surface glaze employed for decoration purposes.

The flexibility of liquid fuel meets any of these required conditions easily.

Victoria's first large conversion took place in 1929, when Wunderlich Ltd. converted four of their down-draught rectangular kilns, the size of these kilns being 49 ft. long, 11 ft. high, and 11 ft. wide, capacity 18,000 tiles, equivalent to 72 tons of clayware. Previous to conversion, the average time of firing with best Maitland coal was 100 hours, with a consumption of 14 to 15 tons. With liquid fuel, the time was reduced to 60 hours, with a consumption of $7\frac{1}{2}$ tons, and the production of excellent ware.

Shortly after this conversion took place, a battery of muffle kilns at the Sunshine Terra Cotta Factory of the same company was equipped for liquid fuel burning, and here results were even more satisfactory. In addition to reduction of firing time and actual cost of burning, it was found possible to eliminate the costly interior muffle and burn the delicate glaze colour in the open, the perfect control of the product of combustion allowing this to be done. This provided considerable additional kiln capacity, and, despite the present-day coal prices, production is
definitely being carried out at an advantage with regard to fuel cost basis, without taking the other advantages into consideration.

In the first conversions little alteration was made to the fire-boxes except to remove fire bars and close the mouths of the boxes. Later, a special design was developed to suit the particular conditions incidental to the greatest economy, so in the building of their new kilns at Vermont a number of somewhat novel features have been incorporated. Chief among these innovations is the setting of fire-boxes at a tangent to the kiln circumference, instead of square on. These boxes provide far better circulation of the hot gases around the kiln, promoting a much better draught and flame control, and doing away with any likelihood of hot spots.

Since local heating of the fire-boxes to high temperatures is, in a greater or less degree, incidental to liquid fuel burning, considerable thought has to be devoted to the refractories used for arches and fire-box linings. Modern refractories have kept pace with modern high temperature demands, and to-day we have a choice of super refractories. Among these is the silicon carbide refractory, with its great temperature resistance and its extraordinarily high value in heat transference. Local enterprise has not been lacking in this field, and a wide range of bricks, shapes or tiles is available.

Also, it is a positive advantage to insulate kiln walls and crown scientifically with low heat-conductivity bricks. This is just as important as the lagging of a boiler.

The drying is one of the most delicate and important phases of clayware production. Various clays have vastly different drying characteristics, but again the fundamentals are similar. Steam is used to provide the heat in the humidity dryers, where the drying commences with a relative humidity of nearly 100 per cent, and gradually reduces until drying is eventually completed in clean, almost dry, air. This process permits of the evacuation of all moisture from the interior of the clay mass. Rapid local drying would occasion case hardening of the surface, thus closing the capillary ducts and imprisoning the moisture. This would set up strains and stresses, involving cracking, etc., during the burning in the kiln.

Automatic burners are used in generating steam for these dryers, as constant temperature is imperative.

Glass Manufacture.—In glass manufacture fuel oil is used to a very great extent, producer gas being its only rival. The tank furnaces, which are so largely used in connection with bottle and lamp glass making, are easily convertible to liquid
fuel without any drastic alteration, as tank furnaces which are solely constructed for using fuel oil vary slightly from the producer gas furnace, practically the only difference being that the crown of the furnace does not require the height from the glass. This is due to the fact that with liquid fuel we can feed more B.T.U.'s per cubic foot of combustion space and obtain higher temperatures. I shall give two illustrations of an actual conversion from producer gas to liquid fuel.

Apart from the glass tank itself, great progress has been made with the use of liquid fuel in the annealing lehrs and also in the finishing of the articles. Even in works still using producer gas for founding, all the rest of the process is carried out with liquid fuel. In glass tanks the full value of the waste gases is made use of, and recuperators are always installed. The effect of this on the fuel consumption is very considerable. This economy is effected by a large proportion of the sensible heat in the waste gases being transferred to the secondary air, and so used again in the furnace. A further gain is due to the improvement in the combustion obtained with hot air, the decrease in the amount of excess air required reducing the volume of waste heat lost in the stack. In order to obtain the maximum benefit from this heat recovery, the quantity of secondary air should be as large as possible, and heated to as high a temperature as procurable. The design of the recuperator therefore plays a big part, the type of the burner also being a definite feature, especially as, with low pressure, fan-blown burners, the primary air necessary for atomisation varies from 60 to 90 per cent of the total air required for combustion, so that the amount of heat which can be recovered in the recuperator is almost negligible. In the medium and high pressure burners only 5 to 10 per cent of the air or steam is required for atomisation; the remaining 90 to 95 per cent of the air may be heated to the highest possible temperature.

Melting rates with liquid fuel have been, in some cases, phenomenal, up to five tons of glass per ton of oil having been established. It does not follow that all glass tanks are operated under such forced conditions. The life of the refractory material in the furnace has to be given due consideration. Still, it is definitely possible to maintain $3\frac{1}{2}$ tons of glass per ton of oil. The average consumption in a well-designed lehr is four to five gallons per ton of glass annealed.

*Enamelling and Enamel Manufacture.*—Liquid fuel is now recognised in Victoria as the only heat medium in this industry. I give a brief description of one of our Victorian factories manufacturing their own frit and enamelling all classes of material. The plant consists of two muffle furnaces, the general arrange-
ment of the flues being one at each side, running from the front end to the back and returning, then passing in a zigzag track under the hearth to the stack situated at the back of the furnace. Two burners, one at each flue, are installed. A recuperator is placed in the stack, and the waste heat is used to give hot air for drying sprayed colours in their process. Temperatures from 900° to 1000° C. are maintained, depending on the material being treated. Each of these furnaces is capable of treating twenty 6 ft. porcelain baths, 2 cwt. in weight, and coated with 14 lbs. of enamel, per shift of 7½ hours, the actual cost per bath for fuel being 9d. When light plate or small castings are being coated the cost per lb. of enamel coating is considerably less. These furnaces have been in operation for five years, at a 50 per cent saving over solid fuel, and have cost less for maintenance in that time than a coal-fired muffle did for six months.

In their frit or enamel manufacture three rotary tipping furnaces, with electric drive, are in use, each furnace being used for a different colour. The capacity of each of these furnaces from cold for a 7½-hour shift, actual weight of charge, is 13 cwt., producing 11 cwt. 2 qrs. of surfacing enamel at an actual cost of 14d. per cwt. for fuel. When lead enamel is being smelted, this cost is reduced to 1/- or 9d. The maintenance of these furnaces is practically nil. The raw batch is quickly charged into the preheated furnace through the end. The furnace is then rotated to put the charge on an angle of approximately 35°. As soon as the burner is lighted, the batch commences to fuse, and flows down the inclined surface to the bottom of the furnace, forming a bath, and leaving a fresh surface of the raw batch constantly exposed to the heat. By this process we gain two definite advantages: The melted enamel is in no danger of being burnt, for it is being constantly kept at the fusing temperature of the charge, any excessive heat being absorbed by the raw batch as it fuses and runs down. The furnace is rotated slightly to keep the raw batch at this angle until the entire charge is fused, and then it is allowed to rotate continuously. This continuous rotation of the fused bath quickly increases the temperature, and the entire charge is matured in a very short period. Samples of the batch can be taken from the furnace whilst in operation. When ready, the furnace is tilted to discharge the smelted enamel into water. The sudden quenching causes crystallisation, and the crystals are then ground to fine powder.

The rotary motion of the furnace gives a uniform wear in the first instance to the brick lining, and the action of the enamel in passing over the entire surface leaves a thin coating which prevents any further wear; also the continual washing of the
enamel, which absorbs the heat from the exposed surface, reduces its temperature, which in turn prolongs its life.

For the correct smelting of enamel, the operator must at all times have complete control. Any flame, whether oxidising, neutral, or reducing, must be obtained and maintained if the frit is to be free from contamination. With liquid fuel, the ease with which the fire is perfectly controlled, together with the view of the entire process which is obtained, eliminates any possible danger of improper combustion.

**Bitumen Heating, Pre-mixing, Drying of Sand, Dust and Road Metal.**—With the development of modern road making, particularly in pre-mixing, asphaltling, etc., involving the extensive use of machinery for preparing the materials and heating appliances for drying dust and metal and melting bitumen, another field for the application of liquid fuel was opened. This process demands a uniform temperature in the rotary drying furnaces, and also in the bitumen or mixing kettles. Tests of fuel consumption carried out with identical plants, one using solid fuel and the other liquid fuel, gave the following results:

With coal—400 galls. of bitumen premix cost 18/4 to bring to the right temperature.

With liquid fuel—400 galls. of bitumen premix cost 6/7½ to bring to the right temperature.

As the burners required practically no attention whilst burning liquid fuel, the fireman was employed as depot attendant in charge of the weighbridge during the liquid fuel test.

**Gas Enriching.**—Liquid fuel is now used to a great extent in the gas industry; in fact, few realise that one-sixth of the fuel oil consumed in the domestic market in Great Britain last year was used for gas enriching. The water gas plant, as it is known, consists of three units—the generator, the carburettor, and the superheater. The generator is worked intermittently. It is filled with coke and blown for 50 seconds with air to bring the coke to incandescence. This period is called "the blow." The blow gases have the composition of a producer gas, and pass through the carburettor and superheater, where secondary air is admitted, and the combustion of these gases serves to heat up this apparatus. The products of combustion then pass through the waste heat boiler to the stack. This boiler generates all the steam necessary for the return blow. The air is then shut off, and steam is turned on for the run, or gas making period, the gas then produced, which is known as "blue water gas," having a calorific value of approximately 300 B.T.U. Theses. These cycles of
run and blow alternate continuously. The reactions which take place are as follows:

\[
\begin{align*}
\text{Blow} & \quad 2C + O_2 \rightarrow 2CO \\
\text{Carbon & Oxygen} & \quad \text{Carbon monoxide} \\
\text{Run} & \quad C + H_2O \rightarrow H_2 + CO \\
\text{Carbon & Steam} & \quad \text{Hydrogen & Carbon monoxide}
\end{align*}
\]

About 1000 cubic feet of water gas are produced from 35 lbs. of coke. In order to increase the heating value of this gas, oil is admitted to the carburettor during the run period, and, with the aid of the temperature existing in the carburettor and superheater, is cracked to gas, the resultant calorific value of the gas increasing with the quantity of oil sprayed into the carburettor. Modern water gas plants are automatic, the coke being automatically fed and the ash removed by rotating grates. All controls in changes of cycle are also automatic.

From this short description of the water gas plant you will see the benefit which has been derived by the gas industry from the introduction of fuel oil. To-day inferior coal can be used, if necessary, without any loss of B.T.U.'s to the consumer, as it is possible to produce 80 cubic feet of 1200 B.T.U. gas per gallon of fuel oil carburetted.

Another interesting development in the use of liquid fuel is the hot-air furnace for direct drying, heating, processing, baking, etc. In this furnace the combustion of the fuel is arranged to take place with the correct amount of air for combustion, and the gases are then lowered to the required temperature by the admission of extra air through ports so arranged that the air will not interfere with the process of combustion itself, and yet mix perfectly. Very careful tests have proved that these gases do not affect any material with which they come in contact. Cereal foods and all other foodstuffs are now being baked by this system, and it has also been adopted for the drying of printing, the lithographing and drying out of tins, phosphates, ores, and many chemical processes, temperatures up to 1100°F. being necessary in some of this work. In the meat industry hot water is replacing steam as a drying medium in the boiling-down works. Flock and waste mills are also installing this type of drying medium.

To give one instance of the saving effected by the installation of a hot-air furnace in a soap factory—the heat was required for boiling and maintaining soap at a temperature of 250°F. for two hours, the vat containing 17 cwt. of sand soap. The fuel consumed during this period amounted to four gallons, at a cost of 4.9d. per gallon, or 1.1d. per cwt. treated. This firm claims that by the direct application of heat, instead of the
previous system of steam coils, they obtain a saving of £479/15/- per annum.

In the quarrying industry hot air is being used to dry and clean toppings and metal, the metal being blown whilst passing from the screens to the bins, the air being maintained at a temperature of 300° to 400°, according to atmospheric conditions. This system has definitely improved the product.

*Baking Ovens—Bread, Pastry, Cakes, etc.*—Liquid fuel has been successfully applied to all types of ovens—steam tube, Scotch, semi-Scotch, and Baker Perkins hot-air tube ovens, with the following advantages:

- Elimination of dust and ashes.
- Reduction in the time necessary to heat up the ovens.
- Considerably increased production.
- Reduction of labour costs and maintenance, the actual cost per bag of flour baked being 5d., which shows a saving over any other fuel.

*Cooking.*—With the advent of the Diesel motor ship and the oil-burning vessel, coal was then carried for the galley only. It naturally followed that it would not be long before liquid fuel would be successfully applied to ranges, grillers, toasters and boilers in the larger passenger liners. So to-day, with the modern development of oil burners to assist its application, it has proved a most satisfactory fuel for this purpose, for, when its advantages are considered, it will be seen that it meets every demand, its only disadvantage being that it is slightly more costly than coal on a heat basis. When you consider, however, that the burner has a much higher efficiency than the ordinary grate, and when no longer wanted it can be shut off as quickly as lighted, this disadvantage is quickly overcome. The actual fuel cost of a four-oven island type of range approx. 6 ft. 0 in. by 4 ft. 0 in. by 2 ft. 6 in., which is in use for a period of seven hours per day, is 1/8 per day. This range has a central combustion chamber the full width, the heat passing from the back of the chamber over the top of the ovens to the centre of the range and then down the sides of the ovens to flues at bottom, the waste gases then passing to the funnel. Liquid fuel is being used extensively to-day in military camps, hospitals, colleges, etc., for all cooking purposes where the cost of other heat mediums has warranted its use.

*Central Heating.*—During the last ten years liquid fuel has to a great extent replaced solid fuel in hot-water services and central heating. We find that all our large buildings have been converted or specially constructed to utilise liquid fuel.
The change, though slow at first, has been rapid during the past five years. I need hardly state the many recognised advantages which have occasioned this swing over, but undoubtedly the elimination of smoke, cleanliness of boiler room, and ease of delivery of fuel have played a big part. This change has necessitated radical alterations in burner design, and to-day we have full automatic control burners with various means of atomisation. These come under three types—Pressure jet or mechanical atomisation, medium pressure air burners, and rotaries. In the rotaries we again have three types—Air-spun horizontal cup, mechanically-spun horizontal cup, and mechanically-spun vertical cup. The term "automatic" implies a burner which lights itself and shuts itself off as the load demands, working intermittently at a steady, fixed rate. The methods employed for ignition vary with the makes of burner—Fixed gas jet; expanding gas jet and pilot jet; electric spark functioning during starting-up period; constant electric spark functioning the whole time the burner is running; electric spark to light a gas jet, the gas jet then lighting the oil; and lastly, the employment of expanding gas jet and the electric spark. The spark lights the pilot jet, which in turn lights the larger jet. This system saves a considerable amount of gas. The types of automatic control vary considerably, some being of much simpler design than others. The burner is started and stopped by making or breaking the current to the electric motor which drives the fans, pumps or compressors, according to the type of burner employed. A thermostat set to a predetermined temperature governs the starting and stopping. Some systems employ the mercury glass tube switch, which makes or breaks the actual motor and ignition current. In other systems relays are employed so that the controls carry only a low voltage current. A safety device is also embodied in the circuit. Time does not allow me to go more fully into the details of central heating systems.

The high cost of liquid fuel for a given number of heat units makes it imperative that efficient means be employed to secure the utmost value from the fuel. Whilst this may add to the first cost of the plant, the saving for the additional outlay will be easily repaid. The secret of economical firing depends, not only on the burner, but on its successful combination with a well-designed plant. The designing of a satisfactory furnace is far more difficult than manufacturers appreciate, so, when a possible installation is being considered, it must be borne in mind that the choice of a system of firing, the design of the furnace, and the refractory material to be used for the combustion chamber must all be given due consideration. In many instances the fuel may represent only a small fraction of the
cost of production, incidental savings, such as increased rate of production, better quality, etc., representing a sum much higher than the total cost of the fuel. So, in considering liquid fuel as a heat medium, we should depend solely on the economy which can be shown in the process as a whole.

*Power Production in Diesel Engines for Marine and Land Installations.*—This subject alone warrants a separate paper, so I must necessarily eliminate this important application.

There is also a large field where the heat value of liquid fuel does not play a part, and in which the engineering profession does not interest itself. Still, in passing, I think it will be of interest to mention that a large gallonage is used for sundry purposes. These include—Dust laying, fruit spray manufacture, ink manufacture, road dressing, rust prevention, sanitary purposes, swabbing poultry pens, timber preservation, weed killing, etc.
DISCUSSION

The President said Mr. Morris had given a very interesting paper on the uses of fuel oil, and its many applications, which were very little known. The paper suggested that fuel oil was definitely the heating medium of the future.

Mr. A. C. Mitchell said the paper had covered a very wide range. He referred to several cases that had come to his notice where serious corrosion had occurred in fuel oil tanks in vessels where the tanks were at other times filled with sea water as ballast. There had been serious corrosion of the rivets, suggesting electrolytic action, and in places the heads of the rivets had completely disappeared.

Mr. Morris said that probably some action had been set up as a result of the combined action of the residue of oil and the sea water. The tanks should have been cleaned out thoroughly. The fact remained that the oil was a rust remover, and the between-decks of many ships were painted with fuel oil.

Mr. S. N. Rodda said that in metallurgical work fuel oil was creeping in, and was doing the work very satisfactorily. He had seen a number of plants converted to oil fuel during the past few years, and had known of its use in connection with steel and glass manufacture and other classes of work, where it appeared to be eminently reliable.

Mr. O. A. Ternes, Superintendent, West Melbourne Gas Works, said Mr. Morris was to be congratulated on his paper in that he had supported his statements by figures that should prove useful to members. Fuel oil had come to the assistance of the gas industry, which was now using large quantities of oil for enriching the gas. Without fuel oil, the water gas could not be blended with coal gas without impoverishing the mixture. With the advent of modern oil-consuming plant, quite a large proportion of tar could now be sold as fuel. He was interested to hear that one-sixth of the oil on the British domestic market was used for enriching water gas.

Mr. W. R. Pollock mentioned that tar was consumed under boilers over thirty years ago by the old Melbourne Tramway Company, using a very crude type of burner.

Mr. R. J. Bennie complimented the author on the scope and lucidity of his paper, which he looked forward to reading subsequently with great care. Although the author rejected certain oils as unsuitable for fuel on account of their high cost, it did
not follow that the products of modern coal treatment and other synthetic fuels would not some day have a competing price.

The President said the use of liquid fuel covered a very great field, and he would like to see representatives from every industry at the next meeting, so that there might be an interesting discussion. They had heard much about gas and fuel oil, each of which had played an important part in its own sphere. In the glass industry they found in use both solid and liquid fuel; and in some cases coal was cheaper than fuel oil, but fuel oil was cleaner. In America all glass works close to the oil wells were using oil, but away from the oil fields coal was in almost universal use, producer gas being the actual heating medium. He believed that when oil was discovered in Australia it would become the universal industrial heating medium, leaving gas for domestic purposes.

The discussion was adjourned, and at 10.10 p.m. the meeting terminated.
LIQUID FUEL: ITS APPLICATION, USES, AND ADVANTAGES.

Paper by Mr. E. H. G. Morris.

Mr. W. R. Pollock said that probably the first to use liquid fuel in Victoria was the Melbourne Tramways and Omnibus Co. In 1893 the Gas Company had large stocks of surplus tar, which at that time was very cheap, and the late Mr. James Turnbull caused three cable tramway power houses to be equipped with simple steam-operated tar burners. These operated for about eight years, and roughly two million gallons of tar were consumed. The burners gave no trouble apart from the usual problems accompanying any innovation, and only the advancing price of tar caused the company to cease using it. One of these burners was exhibited at the meeting. There had been no trouble from smoke after the first few days of adjustment. They had two filters, and used them alternately, cleaning one every day.

Mr. G. E. Gamble said it was interesting to note from an examination of the burner exhibited that there had been very little improvement in design since 1893. Its extreme simplicity no doubt accounted for its efficiency. He thought the great drawback of liquid fuel was its cost, which was roughly double that of slack coal. For an intermittent load, oil was excellent; but for constant load, coal was superior.

Mr. R. J. Bennie said that the Australian Gaslight Company of Sydney for many years had been steam raising by consuming tar oils. But the increasing value of all tar products was gradually rendering this practice uneconomical.

Mr. J. W. Williams said that some six years ago his investigations of the relative costs of tar and coal as boiler fuel had shown a balance in favour of coal. Since then his firm had become large users of coke, with which oil compared still more unfavourably.

The discussion was adjourned.