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IMPROVED PROCESS FOR OPERATING A FURNACE

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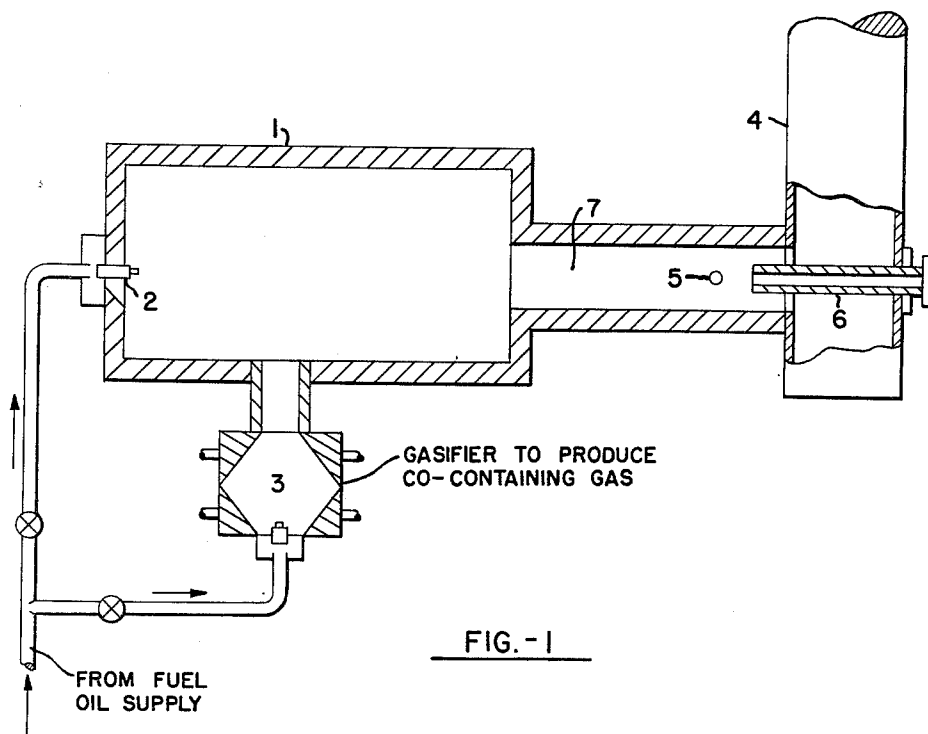


FIG. -1

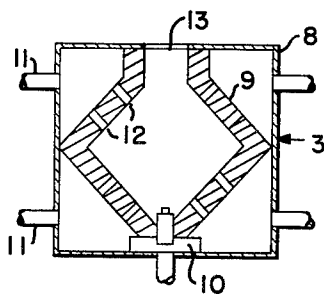


FIG. -2

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1

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IMPROVED PROCESS FOR OPERATING
A FURNACE

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The present invention relates to an improved process for burning fuel oil, and to improved furnace installations.

Mineral fuel oil is widely used in the furnaces of boilers both for inland and marine installations. Usually, residual fuel oils are used, by which term is meant the highest boiling fraction remaining after refinery distillation has been carried out on crude oil. Such residual oil may, however, be cut back with lighter boiling point fractions to give a composition of lower viscosity, and hence improved pumpability. Mineral oil fractions of lower boiling point than residual fuel oils may also be used as fuel oils in boiler installations, e.g. mineral oils having a boiling point above 250° C. It is usual to classify the heavier oils according to their viscosity. Thus, mineral oils having a viscosity between 35 and 6,000 sec. Redwood No. 1 at 100° F. may be used. A commonly used fuel oil for marine use is the so-called "Bunker C" oil which has a viscosity of about 5,000 seconds.

Commercial boiler and furnace installations vary in their efficiency to burn fuel oil completely without the formation of smoke. Smoke formation is undesirable because of fuel wastage, atmospheric pollution, and carbon deposition resulting in inhibition of heat transfer to heat-exchange surfaces, etc. Such efficiency depends on fuel oil quality, burner design, and inherent design factors in the furnace or boiler itself. A 100% efficient installation, a theoretical entity, would be characterised by operating on a stoichiometric quantity of air entering the burning zone, resulting in complete combustion of the fuel. The divergence of installations from 100% efficiency is manifested by the proportion of air which must be supplied to the burning zone in excess of the stoichiometric amount. Thus many installations require up to 25% or more by weight of excess air over that required for stoichiometric combustion to avoid smoke formation.

One of the characteristics of fuel oils used in furnaces and boilers is that they contain sulphur, the proportion of sulphur generally increasing with viscosity. Thus "Bunker C" fuel oil may contain as much as 5% by weight of sulphur. The presence of sulphur in fuel oil has a limiting effect on the efficiency of boilers in which it is burnt. Although it is desirable to use as little excess air as possible, as mentioned above it is common practice to use as much as 25% by weight of excess air in commercial installations. Under stoichiometric conditions, the end products of complete combustion of hydrocarbons are carbon dioxide and steam. Under normal practical conditions of excess air combustion, however, the sulphur dioxide is partially converted into sulphur trioxide. The effect of this is twofold. The presence of sulphur trioxide in the combustion gases firstly encourages fouling of low-temperature heat exchangers and other surfaces, and secondly results in an elevation of the dew-point of the combustion gases so that corrosion takes place of surfaces below the dew-point. Thus, whereas the dew-points of SO₂-containing combustion gases may be as low as 120° F., the dew-point of SO₃-containing combustion gases may be elevated to as much as 350° F. Thus, in order to prevent fouling and corrosion, it is necessary to raise the back end temperature of furnaces and boilers using sulphur-containing fuel oils

2

to above the dew-point. This has the further effect of reducing the thermal efficiency of the installation.

Numerous expedients have been resorted to in an endeavour to reduce the acid dew-point of the effluent gases.

Thus particulate compounds, such as dolomite metal powders or soaps, or nitrogenous gaseous additives, such as ammonia, have been introduced to various parts of the system. Such prior attempts have varied in efficacy and have often been associated with higher operational costs.

The present invention is directed to an improved method of operating an oil-fired furnace (which term includes boilers), and particularly furnaces operating on sulphur-containing fuels, under conditions whereby the combustion is improved. Thus, when operating according to the present invention the amount of excess air required for a given thermal output is reduced without a significant increase in smoke generation, thereby increasing the thermal efficiency of the furnace, and the combustion conditions within the burning zone are such that they approach, or may reach, stoichiometric conditions. A concomitant advantage of these conditions is that, when using sulphur-containing fuel oils, the formation of SO₃ in the fuel gases is inhibited, resulting in a lowering of the dew-point of the effluent gases. A further advantage of the process of this invention is that gas injection does not diminish the turbulence inside the furnace and, in fact, tends to enhance the turbulence, thus improving combustion.

To this end, the present invention provides a process for operating an oil-fired furnace to obtain heat, comprising replacing a portion of the oil fuel with an extraneously-produced reducing gas injected into the burning zone of the furnace. By the term "extraneously produced" is meant that the reducing gas is not generated within the combustion space of the furnace.

The function of the reducing gas is twofold. First it provides part of the fuel requirements in combusting with oxygen in the burning zone and secondly it reduces or eliminates the amount of excess air in the combustion gases, thus inhibiting the formation of SO₃.

The reducing gases used according to the present invention may contain any gas capable of combusting with oxygen, such as hydrogen, methane, and particularly carbon monoxide. In practice, mixtures of such gases may be used, for instance town gas or natural gas, or gas mixtures containing such reducing gases.

In a preferred modification of the present invention, a proportion of the oil fuel normally fed to the furnace is diverted to one or more gasifiers wherein it is converted into a carbon monoxide-containing gas, the gasified products being injected into the burning zone of the furnace.

The hot CO-containing gases emerging from the gasifiers supply the remainder of the final heat output by the furnace by virtue of their intrinsic heat content and their heat of combustion with excess air present in the burning zone. Thus, stoichiometric combustion of the fuel is, in effect, produced.

It is important that the reducing gas be injected into the burning zone of the furnace, i.e. that zone where the oil fuel is undergoing actual combustion. If the reducing gas is injected at too late a stage in the furnace the temperature within the furnace may not reach the ignition temperature of the reducing gas with oxygen, which for carbon monoxide is approximately 600° C.

The proportion of oil-fuel which is replaced by the reducing gas may be varied within limits depending on the efficiency of the furnace. To achieve the full advantages of the present invention, the proportion of fuel replaced by the reducing gases should be equal to the proportion of excess air that would otherwise have been used. Thus, where 20% of excess air is normally recom-

3

mended by the furnace designers, 20% of the fuel requirements are preferably met by the reducing gas according to the present invention. The overall amounts of excess air going into the furnace will be reduced compared with that for conventional operation.

Thus, in the instance outlined above, 120% of total air is conventionally supplied to the furnace. When operating the furnace with gasifiers, according to the preferred form of the present invention, 80% of fuel oil is introduced into the furnace accompanied by 96% of stoichiometric air required for total fuel used. The 20% of the fuel going to the gasifier is accompanied by sub-stoichiometric amounts of air to ensure the production of a reducing gas (i.e. a CO-containing gas). If, for instance, 80% of stoichiometric air is introduced into the gasifiers, this corresponds to 16% of air based on stoichiometric air for total fuel combustion, the total air introduced thus being 112% of stoichiometric requirements. This reduction of excess air over conventional operations for complete combustion means increased thermal efficiency of the boiler and inhibition of SO₃ content of effluent gases when using a sulphur-containing fuel, without any significant increase in smoke generation.

The amount of reducing gas injected into the burning zone should not be greater than that required to combust with the excess air present. However, some excess of reducing gas may be tolerated without losing the advantages of the invention. In practice, the amount of reducing gas actually introduced into the burning zone may conveniently be somewhat below the actual amount required to react with all the excess air present, in order to avoid the effect of surges in the control systems up-setting combustion in the furnace.

Another aspect of the present invention provides apparatus for burning fuel oil having means for injecting a reducing gas into the burning zone, and particularly to such apparatus having means for diverting a proportion of the oil feed to one or more gasifiers, and means for injecting a reducing gas from the gasifiers into the burning zone.

The present invention may be further understood by reference to the following experiments and examples together with the accompanying drawings.

FIGURE 1 of the accompanying drawing illustrates a cross sectional view of a refractory lined furnace. FIGURE 2 of the accompanying drawing illustrates a cross sectional view on a reduced scale of a gasifier for the extraneous production of a reducing gas.

Referring to FIGURE 1 of the accompanying drawing, a refractory lined furnace 1 capable of burning up to 10 gallons of fuel oil per hour has a medium pressure atomising burner 2 and a gasifier 3 set into the side of the wall so that effluent gases from the gasifier impinge into the burning zone of the furnace. A passage 7 leads from the furnace to the base of the stack 4. A sampling point 5 within the said passage is adapted to analyze the combustion products leading from the furnace to the stack, and to determine the smoke points, and a probe 6 within the stack base is adapted to determine the dew-point of the effluent gases.

Metering means allow a proportion of the fuel oil flowing to the burner 2 to be diverted to the gasifier 3.

The gasifier 3 is shown in more detail in FIGURE 2 of the accompanying drawing, wherein a case 8 contains a refractory shell 9, constituting the gasifying zone. A burner 10 leads into the zone, primary air being injected into the burner. Secondary air is lead through the tubes 11 and jets 12 into the interior of the combustion zone. The effluent gases containing carbon monoxide and other reducing gases flow through exhaust 13.

Several experiments were conducted on the above apparatus. Thus the furnace was operated in a normal manner with excess air and without the benefit of the gasifier injecting reducing gases into the burning zone of

4

the furnaces, and finally the furnace was operated using fuel oil, part of which was gasified.

In all instances, measurements were taken of the smoke point, CO₂ and SO₃ content, and the dew-point of the effluent gases.

The smoke point measurements were taken with a Von Brandt continuous recording smoke meter. On this scale, a reading of 1 means no smoke recorded at all, 2 a barely perceptible smoke record and 9 a dense smoke record corresponding to dense smoke appearing at the stack. Dew-point values were determined using the BCURA type water cooled probe, described in the Journal Inst. Fuel, vol. XXV, No. 146, page 246, and SO₃ determinations carried out using a modified Corbett method, described in the Journal Inst. Fuel, vol. XXIV, No. 140, page 247.

The result of these runs are shown in the accompanying table:

Fuel supply (200 seconds Redwood viscosity, 2.8% S content)	Flue gas analysis			Von Brandt Smoke No.
	Percent CO ₂	SO ₃ p.p.m.	Dew-point, °F.	
Through burner only (30% excess air)	11.8	24	300	1
73% by wt. through burner, 27% by wt. through gasifier	15.4	12	260	2
Through burner only (20% excess air)	12.8	28	-----	1
78% by wt. through burner, 22% by wt. through gasifier	15.4	9.8	-----	2

¹ Stoichiometric equivalent.

It will be observed that passing a proportion of the fuel through the gasifier causes complete combustion of the fuel reflected in the high CO₂ content of the combustion gases, without the production of significant smoke, and accompanied by a substantial reduction in the SO₃ content of the effluent gases, and a diminution of the dew-point.

It is to be understood that the invention is particularly applicable to boilers of steam-raising plant, and is not confined to any specific type of gasifier or other generator for producing a reducing gas, nor is it restricted to having the gasifier or gasifiers or other injecting means for reducing gases in any particular position provided they are adapted to inject their effluent gases into the combustion zone, and not to a region in the furnace wherein the reducing gases cannot pass to the combustion zone, but pass out of the furnace unignited.

What I claim is:

1. A process for operating a furnace fired with a sulphur-containing fuel oil by which the formation of sulfur trioxide is inhibited, which process comprises, feeding fuel oil into the combustion zone of the furnace, feeding combustion air into the furnace in an amount in excess of that required to effect stoichiometric combustion of the fuel oil, feeding fuel oil into a gasifier and combusting said oil in said gasifier to produce a carbon-monoxide-containing gas, and injecting said gas into the burning zone of the furnace to combust with excess air therein, whereby hot combustion gases from the fuel oil and the said carbon-monoxide-containing gas, are produced.

2. A process as claimed in claim 1 wherein the total amount of combustible gases produced by the gasifier is not greater than the amount required to combust with the excess air present in the burning zone of the furnace.

3. A process as claimed in claim 1, wherein the proportion of excess air based on the fuel oil fed to the furnace is that required to effect substantially complete combustion when operating the furnace without the gasifier.

4. A process as claimed in claim 1 wherein said gas is injected into a burning zone having a temperature of at least 600° C.

5

5. A process as claimed in claim 1 wherein said fuel oil is Bunker C oil.

6. A process for operating a furnace fired with sulfur-containing fuel oil of from 35 to 6000 seconds Redwood No. 1 viscosity at 100° F. by which the formation of sulfur trioxide is inhibited, which process comprises feeding about 73% by weight of said fuel oil into the combustion zone of said furnace, feeding combustion air into the furnace in an amount in excess of that required to effect a stoichiometric combustion of the fuel oil, feeding about 27% by weight of said fuel oil into a gasifier and combusting said oil in said gasifier to produce a carbon monoxide-containing gas, and injecting said gas into the burning zone of the furnace to combust with the excess air therein, said burning zone having a temperature of at least 600° C., whereby hot combustion gases from the fuel oil and the said carbon monoxide-containing gas are produced.

7. A process for operating a furnace fired with sulfur-containing fuel oil of from 35 to 6000 seconds Redwood No. 1 viscosity at 100° F. by which the formation of sulfur trioxide is inhibited, which process comprises feeding about 78% by weight of said fuel oil into the combustion zone of said furnace, feeding combustion air into the furnace in an amount in excess of that required to effect a stoichiometric combustion of the fuel oil, feeding about 22% by weight of said fuel oil into a gasifier and combusting said oil in said gasifier to produce a carbon monoxide-containing gas, and injecting said gas

6

into the burning zone of the furnace to combust with the excess air therein, said burning zone having a temperature of at least 600° C., whereby hot combustion gases from the fuel oil and the said carbon monoxide-containing gas are produced.

References Cited in the file of this patent

UNITED STATES PATENTS

10	438,872	Wilson et al.	Oct. 21, 1890
	1,987,400	Hillhouse	Jan. 8, 1935
	1,987,401	Hillhouse	Jan. 8, 1935

FOREIGN PATENTS

15	170,465	Great Britain	Oct. 27, 1921
	697,861	Great Britain	Sept. 30, 1953

OTHER REFERENCES

20 Lees, B.: "An Investigation into the Air-heater Corrosion of Oil-fired Boilers," Journal of the Institute of Fuel, London, England, April 1956, pages 171-175. (Copy vol. 29 available in Scientific Library.)

25 Corbett, P.F.: "The SO₂ Content of the Combustion Gases from an Oil-fired Water Tube Boiler," J. Inst. Fuel, August 1953, 26, page 92, pages 102-104. (Vol. 26 in Scientific Library.)

Nelson, W. L.: Petroleum Refinery Engineering Third edition, 1949, McGraw-Hill Book Co., New York, pages 20, 99, 100, 605.