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FOREIGN DOCUMENTS OR RADIO BROADCASTS

REPORT

CD NO.

50X1-HUM

COUNTRY	USSR	DATE OF INFORMATION	1950
SUBJECT	Scientific - Fuel, flameless combustion		
HOW PUBLISHED	Monthly periodical	DATE DIST.	27 Jul 1950
WHERE PUBLISHED	Moscow	NO. OF PAGES	3
DATE PUBLISHED	Feb 1950		
LANGUAGE	Russian	SUPPLEMENT TO REPORT NO.	

THIS IS UNEVALUATED INFORMATION

SOURCE Vestnik Akademii Nauk SSSR, No 2, 1950

SOVIET WORK ON FLAMELESS COMBUSTION

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Complete combustion of fuel and very high temperatures may be attained without any visible flame. This factor offers the possibility of eliminating large, bulky furnaces and of constructing smaller and more efficient heating equipment. Flue gases from the flameless combustion process do not contain any products of incomplete combustion and may be utilized in industry and agriculture as a free source of carbon dioxide and inert gases.

Coal and oil are two fuels which have been widely used up to the present. But coal, since it requires bulky equipment, is inconvenient for many technological processes. Liquid petroleum fuel is much more convenient and produces higher temperatures. However, its limited availability restricts its use. Meanwhile, consumption of liquid motor fuel by aircraft, automobiles, and tractors is growing rapidly, and the petroleum industry will be able to release fewer products for use as furnace and boiler fuels.

Gas, as a substitute for oil, is gaining in importance. The current (1946 - 1950) Five-Year Plan provides for large-scale development of a new gas industry designed to raise the production of gas from coal and shale to 1.9 billion cubic meters and the extraction of natural gas to 8.4 billion cubic meters. According to plans, underground gasification must yield annually 920 million cubic meters. The wide utilization of coke gas and blast-furnace gas is also proposed. Production and application of several other gas fuels (from liquefied gases with heating value about 25,000 calories per cubic meter to low-calorie gases with heating value of 700 calories per cubic meter) have been organized.

Adequate supply of gas fuel for industry has to be combined with improved technology since the intensification of gas heating equipment operations gives great possibilities for increasing the efficiency of equipment without additional investment. However, ordinary methods of gas combustion cannot secure the highest efficiency.

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New and entirely different methods have been developed recently. The combustion process proceeds with high speed and without any visible flame if gas mixed with air is being burned near a surface of incandescent refractories; for example, in chamotte tunnels, in the space filled with fireproof checkered brickwork or in a layer of crushed refractory material. High-combustion speed, much higher than the speed of the usual methods of combustion, contributes to the possibility of decreasing the furnace size approximately 100 times and also makes possible the construction of a new type of compact "furnaceless" heating equipment. The flameless method permits the burning of gas with a minimun excess of air. This factor provides for the highest temperatures, lower fuel consumption, and lower loss of heated material. The stimulating effect of incandescent refractory surfaces is especially great with the combustion of two essential types of gas fuel, namely, low-calorie gases with comparatively low combustion temperature and natural gases with a high content of low-reactive methane.

Numerous experiments in the combustion of various gas fuels, conducted by the Power Engineering Institute of the Academy of Sciences USSR, have definitely established the stimulating action of incandescent refractory surfaces on the combustion process. For example, only 75 percent of oxyhydrogen gas reacted during a 30-minute period in an empty quartz tube at 900 degrees centigrade with an initial one millimeter vacuum in the system. After filling the tube with crushed chamotte, 100 percent of the gas reacted in 5 minutes under similar conditions. Laboratory experiments have established a possibility for further intensification of the combustion process by using catalytically active refractory surfaces.

Gas fuel is used intensively for water-heating boilers in heating systems for houses and factories. However, the efficiency factor of these boilers is only 45-55 percent and in the best cases it reaches only 70-80 percent, whereas a new type of boiler with flameless combustion designed by the Power Engineering Institute shows an efficiency of 92-95 percent. City utility gas, with a heating value from 5,030 to 7,770 calories per cubic meter, was burned with four flameless burners in chamotte tunnels. The air-gas mixture, which failed to burn entirely in the tunnels, was burned completely in the small space between the boiler brickwork and lower water-coil pipe. Over-all dimensions of the boiler, including refractory lining and metal jacket, are as follows: length, 1.88 meters; width, 0.65 meter; height, 0.5 meter; volume of refractory tunnels, 5 liters, volume of free space under the coil pipes, only 50 liters.

The boiler was used to heat production plant buildings encompassing several tens of thousands of cubic meters. The maximum thermal load of the boiler reached 240,000 calories per hour and the rate of heat liberation reached 4.5 million calories per cubic meter per hour, which value surpasses by 10-15 times the rate of flame furnaces. Heat liberation of the refractory tunnels was 48 million calories per cubic meter per hour and could be raised to 90 millions. The combustion process proceeded with ideal completeness and at minimum air excess. The oxygen content was maintained at an 0.6-0.8 percent level which corresponds to an air excess coefficient of 1.03-1.04. The metal used in constructing a flameless boiler with a productive capacity of one million calories per hour amounts to only 1.5 tons, whereas metal requirements for ordinary boilers of similar capacity vary from 6 to 25 tons for various systems. Boilers of the type described were tested successfully in large Moscow plants.

The Power Engineering Institute designed two other types of flameless combustion boilers, ENIN-2 and ENIN-4, with still higher efficiency factors. The ENIN-4 is designed for use in combination with low-temperature furnaces and driers.

Along with the construction of new types of efficient heating equipment, good results have been achieved by converting some old equipment to the flameless

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process -- a procedure which has cut fuel consumption almost in half. Especially high economy may be attained in certain cases by replacing electric furnaces with flameless combustion furnaces operating on natural gas.

Wide application of the flameless combustion method has been hampered until recently by some erroneous suppositions. For example, it has been assumed that a pressure of not less than 0.8 atmosphere and even 1.4 atmospheres should be maintained for the combustion of natural gas. However, such a pressure is not always available in many industrial establishments. Research conducted in the Power Engineering Institute and under industrial conditions permitted elimination of this limitation. Flameless burners are operated satisfactorily with a natural gas pressure of 0.1 atmosphere.

Another obstacle to maximum efficiency in the combustion of gas fuel was the fear of combining the operation of premixing flameless burners with high-temperature preheating of gas and air. This fear was based on a supposed danger of explosion caused by penetration of a combustion zone into a mixing gas pipe. Again, investigations at the Power Engineering Institute established the groundlessness of this apprehension and proved the possibility of operating flameless burners with air preheated to 500-600 degrees.

In addition to conserving fuel and intensifying the heating process, the flameless combustion method permits the utilization of the waste products of combustion -- flue gases. The gases, being extremely pure and free of carbon monoxide, may be used as a carbon dioxide fertilizer for green houses. Many USSR cities are planning to use the flameless combustion method for economical heating of green houses with simultaneous utilization of waste gases as a free carbon dioxide fertilizer. Pure waste gases also may be used for storage of perishable products in an atmosphere enriched with carbon dioxide: a great many foodstuffs may be stored over long periods of time without refrigeration.

It should be noted that the flameless method may also be applied in the combustion of some liquid and solid fuels.

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