AN OXYGEN-ACETYLENE HIGH-TEMPERATURE FURNACE¹

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ABSTRACT

A detailed description, with drawing, is given to show the use of oxy-acetylene gas in a small furnace for using refractory cones. The advantages claimed, are (1) simplicity of construction, operation and repair; (2) ease of control; (3) high temperatures obtainable; (4) oxidizing atmosphere; (5) comfortable working conditions, owing to the small volume of hot combustion gases; and (6) portable character of the furnace, fuel and firing apparatus, permitting its use in localities where gas or electricity can not be obtained, such as in the field or at the mine. The following change is suggested in the Ceramic Society's specified rate of heating for cone fusion tests. "The rate of heating shall not exceed that corresponding to one-half a cone (approximately 10 degrees C) per minute within a range of ten cones below that of the final fusion cone and this rate shall preferably be decreased to one cone per five minutes within two cones of the final cone of fusion."

With the recent development of the apparatus and commercial use of the gases, oxygen and acetylene, for rapid welding and cutting of metals, it is natural that these high-temperature flames should be used in the fusion tests of fire clays and other refractories. Washburn and Libman² have shown that the oxy-acetylene flame can be used for high temperature ceramic work.

This is not the description of a "paper" furnace but of one which has given good service in the Ceramics laboratory of the College of Mines, University of Washington, in the fusion of over 500 clay samples from the State of Washington, ranging from cone 2 to cone 35.

The furnace shown in the accompanying sketch is similar to the fusion furnaces used where natural gas of high calorific value can be obtained. As the volume of the oxygen-acetylene gas

¹ Received August 6, 1921. By permission of the Director, U. S. Bureau of Mines.

² Washburn, Edward W., and Libman, Earl E., *THIS JOURNAL*, 3, 634-640 (1920).

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and its products of combustion is small and the temperature of the flame is very high, the size of the furnace is relatively small. The one described can be carried in the arms.

Burners and Flame.—Two small “lead-burning” torches, placed on opposite sides of the furnace, direct the flames

tangentially to the circumference of the circular chamber.¹ The combustion gases follow the usual spiral path around the cone pedestal and out at the top. This center stand is high enough to keep the cones out of the direct blast of the flame. Uniform temperatures can be produced on all sides of the cone plaque by adjusting the burners to supply the proper amounts of oxy-acetylene and by preserving a symmetrical interior design of the fire chamber together with the centering of the cone plaque. A projecting portion of the furnace wall or a fallen particle may so deflect the flame that a local hot spot may be produced.

Lining.—For fire-clay fusion temperatures we have successfully used alundum, magnesia, and an alundum-magnesia mixture. We have had poor results with zirkite (early fusion), pure china clay (early fusion), carborundum (early fusion, accompanied by blistering and bubbling), combinations of clay and magnesia, and a clay-carborundum mixture.

For a magnesia lining, a good grade of brick may be cut and fitted into the circular jacket, or the lining may be made in the following manner. We press a prepared, calcined ferro-magnesia mixture in a mold and fire the resulting shape. This is then backed with fire clay or an insulating material and packed into a suitable container, which may be an empty can of suitable dimensions. We prepare the calcined magnesia by crushing a good grade of magnesia brick to pass a 20-mesh sieve and adding enough gum or dextrine and a small amount of water to make the mass plastic. This can be packed into position for either the original lining or for repairs. It derives its dried strength from the gum, while the fired strength may be obtained directly by heating with the oxy-acetylene flame. One magnesite brick will provide a number of cone plaque stands. After cutting to approximate size with a hammer, the stands can be rounded to dimension on an emery wheel. A thin layer of iron chromate must be daubed on the top of the stand to prevent violent reaction between the clay and magnesia above 1600°C.

Cone Plaques.—We mix raw English china clay with an equal weight of English china clay, calcined to cone 15, and ground to

¹ R. T. Stull: "New Type of Laboratory Test Kiln," *Trans. Am. Ceram. Soc.*, 12, 127 (1910).

pass a 20-mesh sieve. The plastic mass is rolled out on a table to an approximate thickness of $\frac{3}{8}$ inch, and a small rectangular indentation formed by pressing with a suitable wooden core. The plaque is then cut to dimensions, dried, and fired to cones 2 to 4 so that it will possess sufficient strength to permit easy mounting of the cones and will stand placing in a hot furnace without disruption.

Mounting Cones.—Plastic china clay mixture is pressed into the rectangular shaped opening of the cone plaque. It is best to undercut the edges slightly so that this plastic mass will not pull out easily. Triangular holes are cut in the clay and the cones inserted with additional clay packed around them. The plaque is marked and placed in the top of the furnace, just over the flame, to dry before placing in the hot furnace. Calcined cones or cones made of calcined materials and gum arabic, and plaques made as above, can be placed in a furnace at a temperature corresponding to cones 20 or 23 without bursting or breaking. Placed as shown in the sketch, we have two duplicate unknown cones with a series of four Orton cones. These are not spaced as recommended in the specifications of the American Society for Testing Materials, but are placed as close together as possible. With calcined materials and good packing, the tendency of the cones to fall on each other is eliminated, and one is more certain of the exact cone deformation, compared with that of the standard Orton cones. By preparing cones and plaques ahead of time and preheating them on the top of the furnace, we can replace plaques of cones in the hot furnace in the minimum time.

Cost of Oxy-Acetylene Apparatus.—The familiar welding torch, pressure gauges and regulator valves so widely used for welding metals, are used. The oxygen and acetylene are shipped in tanks from the factories to any express or freight station. The oxygen tanks are loaned free of charge, while a 300-cubic foot tank for acetylene may be leased for about \$75.00. The valves, gauges, regulators, hose connections, and two small lead burning torches cost approximately \$105.00. A single large welding torch with the same necessary equipment costs about \$140.00 and can be used in place of the two smaller torches, by cutting only a single flame entrance and placing the cone plaque on

a bridge of magnesite. In this case, the flame shoots under the bridge and rises on both sides. Oxygen costs \$2.00 per hundred cubic feet and acetylene gas, \$3.35. The initial outlay including 300 cubic feet of each gas, will be about \$200.00. However, nearly all of the essentials for this equipment will be found in the average well-equipped machine shop or factory and may be used for this purpose.

Gas Consumption.—The following is a typical 5-hour run.

Laboratory number	Cone fused	Oxygen reading, cu. ft.	Acetylene reading, cu. ft.	Time, p. m.
Start	.....	150	226	1:10
806	31-32	125	210	2:25
807	31+	117	205	2:45
808	30	110	200	3:10
809	31	105	195	3:30
810	31-32	99	190	3:48
806	31-32	93	185	4:10
807	31+	88	180	4:30
808	30	80	172	4:45
809	31	71	165	5:10
810	31-32	59	163	5:37
KW	28	52.0	160	5:56
11 Heats	Cone 30.8 average	98 cu. ft.	66 cu. ft.	4 hours 46 minutes

Total cost of gas..... \$4.17

Cost of gas per heat..... 0.38

The cost can be cut almost in two by running two *different* unknown cones on the same plaque, a procedure which is warranted when temperatures are uniform and check runs are made.

A speed test run was made, starting with a cold furnace. Cone 26 was deformed in 35 minutes with the consumption of 20 cubic feet of oxygen and 8 cubic feet of acetylene. Cone 32 was deformed five minutes later with a total gas consumption of 28 and 10 cubic feet of oxygen and acetylene, respectively. Greater economy is obtained if a number of tests are run immediately after the original heating.

The average cost of gas used in fusing 300 samples in a period from August 10, 1920 to April 9, 1921, including the experimentation and development of the furnace, was 47 cents per sample.

Time of Heating.—The specifications of the Standard Committee of the American Ceramic Society call for a rate above 800 degrees C not to exceed 10 degrees C per minute. This means about a 76-minute run to the fusion point of cone 28 in addition to the time required to reach 800 degrees C. After carefully comparing the results of first heats which approximate this specified rate, with heats made with a hot furnace, we believe that it is unnecessary to spend this much time at the lower temperatures and that the period where the slow rate of heating is essential, is within two or three cones of the final cones of fusion. If we could revise the specifications, we would consider the following an improvement.

"The rate of heating shall not exceed that corresponding to one-half a cone (approximately 10 degrees C) per minute within a range of ten cones below that of the final fusion cone and this rate shall preferably be decreased to one cone per five minutes within two cones of the final cone of fusion."

Advantages of the Oxy-Acetylene Fusion Furnace

(1) **Simplicity.**—This type has the advantage of the simple construction common to all gas or oil-heated furnaces in contrast to the carbon resistance electric furnace. In the latter type, we found difficulty in maintaining an expensive crucible protection for the cones; also, the electrical contact between the resistor and metal leads was by no means uniform or dependable after a little use. The cone plaque-stand in the gas-fired furnaces can be replaced and any holes in the walls patched while the furnace is hot. Very little time is lost for repairs.

(2) **Ease of Control.**—With a flame which can be thrown in any direction to any part of the furnace and also raised in temperature to a point above 3,000 degrees C, uniform conditions can be maintained around the cones and the temperatures held or varied at will from below cone 10 to cone 42.

(3) **High Temperatures.**—High temperatures which would be impossible with the ordinary gases or fuels of low calorific value can be produced. Studies can be made with the super-refractories.¹

¹ Washburn and Libman

(4) **Oxidizing Conditions.**—Our best results in terms of clean colors with white, buff, and dark-burning clays have been obtained with the oxygen-acetylene flame. The use of air with its large content of nitrogen makes reducing conditions unavoidable with natural gas flames at the higher temperatures. With oxygen gas in place of the air mixture, the high temperatures can be maintained with the minimum content of reducing gases. With the carbon resistance furnaces it was impossible to keep the high-carbon gases from passing through the crucible and blackening both cones and plaque.

(5) **Comfortable Working Conditions.**—With the small volume of combustion gases rising from the furnace, it is possible to watch the cones deform with the eye at a distance of 15 to 24 inches from the top. This is impossible where the volume of the hot gases is large. In that case it is necessary to take short-time observations from behind insulating screens. With the personal discomfort removed one can maintain the firing conditions with a greater degree of nicety.

(6) **Portable Character.**—The firing equipment, fuel, and even the furnace itself, can be shipped to almost any out-of-the-way locality, factory, or mine. In prospecting a new area for fire clays or running control tests at the mine, this apparatus can be used to save time and expense. Shipments of inferior refractory material can be stopped at the clay bank or mine instead of at the distant factory. The mine foreman can tell within two hours whether a sudden change in the fire-clay seam is for better or worse without sending a sample to a distant testing laboratory.

Other Possibilities.—Hydrogen gas can be used with oxygen to produce a maximum flame temperature of 3,191 degrees C (Richards)¹ and is somewhat cheaper than acetylene and almost as universally obtainable.

Compressed artificial or natural gas fired with oxygen will give higher temperatures than air and the gas, as well as greater ease of handling. The ordinary city gas pressures are too low for high temperature work with the concentrated oxygen.

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¹ Richards, Joseph W., "Metallurgical Calculations," p. 52.