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FLUX-FORMING FUEL AND PROCESS
FOR THERMALLY WORKING MINERALS
THEREWITHCharles J. Burch, Plainfield, N. J., assignor to The
Linde Air Products Company, a corporation of
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This invention relates to a comminuted flux-forming fuel, and to a process using the same for thermally working meltable minerals and like materials, such as concrete and hard Sudan iron ore (hematite).

In my Patent No. 2,327,496, issued August 24, 1943 and entitled "Method of and apparatus for working mineral materials and the like," there are disclosed a novel process and an apparatus for thermomechanically working mineral materials with a diffusion type oxy-fuel gas flame, as by piercing in them holes for blasting. In the aforementioned process, an intense oxy-fuel flame from a long tubular blowpipe melts off material and leaves a hole into which the blowpipe is advanced continuously. The molten material or slag separated from the mass by the flame flows from the melting zone in the fluid state, after which it is quenched within the hole by water discharged from the blowpipe and is mechanically crushed or disintegrated into small solid particles, as by rotating teeth carried on the blowpipe. The resulting small solid particles of slag thereafter are removed from the hole by water, steam formed within the hole, and the gaseous products of combustion.

Usually, a continuous stream of an unbonded comminuted metallic flux-forming fuel is carried by the fuel gas into the melting zone where it burns, providing intense heat and forming oxides. The metallic oxides combine with the molten mineral material or slag to increase its fluidity and to form a slag composition which, when quenched, may be easily crushed and disintegrated mechanically.

Another procedure for piercing minerals involves complete removal of the slag from the hole in the fluid condition, without a quench followed by mechanical disintegration. Such a process is described in Patents 2,286,191 and 2,286,192 of R. B. Aitchison, et al.; and typical apparatus is shown in application Serial No. 470,839 filed December 31, 1942 by V. C. Williams which application is a continuation-in-part of Patent No. 2,327,482, issued August 24, 1943.

An object of the present invention is the provision of a novel comminuted flux-forming fuel having particular value for rapidly and economically thermally working masses of meltable mineral materials and the like. Another object is the provision of such a novel flux-forming fuel which, when oxidized, forms with molten mineral material a highly fluid slag which may be easily crushed and disintegrated after quenching. Another object is the provision of such a

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novel flux-forming fuel containing iron, manganese, zirconium, silicon, and aluminum associated together in intimate relationship. Still another object is the provision of a novel process for thermally working meltable mineral materials, using the novel flux-forming fuel of the invention.

The above and other objects, and the novel features of the invention, will become apparent from the following description.

By the term "comminuted unbonded composition" used herein is meant a free-flowing powder wherein the individual particles are discrete, that is, not coalesced into a large mass, as opposed to a bonded composition such as a briquet wherein the particles are coalesced.

The novel flux-forming fuel of the present invention comprises a comminuted unbonded composition containing in intimate relationship, by weight, 4% to 36% iron, 28% to 63% manganese, 3% to 19% silicon, 4% to 50% aluminum, and 1% to 13% of at least one substance selected from the group consisting of zirconium and calcium. One convenient way of forming this composition is to mix intimately together ferromanganese, zirconium-silicon alloy, and aluminum, all in finely-divided form and in suitable proportions. Proportions which have been found suitable to give the desired composition are, 40% to 70% ferromanganese (70% to 90% manganese, 10% to 30% iron, balance chiefly silicon), 10% to 26% zirconium-silicon alloy (10% to 50% zirconium, 30% to 60% silicon, and 5% to 55% iron), and 4% to 50% aluminum. With these constituents, the ranges of iron, manganese, zirconium, and aluminum are as above, but the range of silicon is 3% to 16%. It is desirable that the particles in the mixture be between 200 and 300 mesh (Tyler) in size, but the fineness of the particles is not particularly critical.

Pulverulent calcium-silicon alloy may be substituted for all or part of the zirconium-silicon alloy, the calcium-silicon alloy comprising, by weight, 20% to 40% calcium, 50% to 70% silicon, and 1% to 10% iron. Good results in thermally working mineral and like materials, notably Sudan iron ore, have been obtained with such a comminuted unbonded flux-forming fuel containing, by weight, 4% to 24% iron, 28% to 63% manganese, 5% to 19% silicon, 4% to 50% aluminum, and 2% to 11% calcium.

One specific flux-forming fuel which has been found particularly advantageous for thermally working mineral and like materials comprises a

comminuted unbonded composition containing, by weight, about 9% iron, 37% manganese, 9% silicon, 38% aluminum, and 7% zirconium. This fuel may be conveniently formed by mixing together in the pulverulent state 45% of ferromanganese (82% manganese, 17% iron, 1% silicon), 17% of zirconium-silicon alloy (40% zirconium, 51% silicon, 9% iron), and 38% of aluminum.

Another specific comminuted unbonded flux-forming fuel composition which has been found particularly useful is that containing, by weight, about 14% iron, 55% manganese, 14% silicon, 7% aluminum, and 10% zirconium. This flux-forming fuel may be formed by mixing intimately together in the pulverulent state 67% of ferromanganese (82% manganese, 17% iron, 1% silicon), 26% of zirconium-silicon alloy (40% zirconium, 51% silicon, 9% iron), and 7% of aluminum.

Although the flux-forming fuels of the invention have been described as conveniently compounded from ferromanganese, zirconium-silicon alloy and/or calcium-silicon alloy, and aluminum, it is to be understood that the various components in their elemental form, or in the form of other alloys, may be used with satisfactory results.

It has been found that the comminuted flux-forming fuels described in the preceding paragraphs, when burned in gaseous oxygen, provide large quantities of heat at high temperatures; and that the resulting metallic oxides unite with mineral and like materials, such as normally viscous concrete and iron ore slags, to modify the slag compositions. The resulting modified slags have greatly increased fluidity, and may be mechanically crushed and disintegrated easily after quenching.

The novel process for working meltable mineral masses and the like, according to the present invention, comprises separating and removing material from such a mass and leaving a hole therein by applying an intense oxy-fuel flame from a blowpipe against a portion of the mass, while introducing into the flame and against the portion of the mass in the melting zone a flowing stream of the novel comminuted unbonded flux-forming fuel previously described herein.

The highly fluid slag produced by the heating action of the flame, and by the fluxing action of the metallic oxides formed by combustion of the comminuted fuel, is removed from the melting zone in the liquid state by the pressure of the gaseous products of combustion. Thereafter, the slag may be completely removed from the hole in the liquid state by the gaseous products of combustion, often assisted by an auxiliary ejection fluid such as compressed air; or, preferably, the slag may be quenched within the hole by water from the blowpipe, after which it may be disintegrated mechanically, as by rotating teeth carried by the blowpipe, and the small solid particles removed by the gaseous products of combustion, water, and any steam formed within the hole. Suitable apparatus for performing the former procedure is disclosed in the aforementioned Patents 2,286,191 and 2,286,192, and in the aforementioned application Serial No. 470,839. Suitable apparatus for performing the latter thermomechanical procedure is fully disclosed in my previously mentioned Patent 2,327,496.

The process of the invention is particularly applicable to the piercing of deep blasting holes of circular cross-section extending straight into a mass of mineral material. However, the princi-

ples of the process of the invention also may be applied to the production of other holes in the nature of grooves or cuts.

In a typical example of the thermal working of mineral and like materials by the process of the invention, a hole 60 inches deep and 1½ inches in diameter was thermomechanically drilled in Sudan iron ore at an average speed of 2½ inches per minute using a flame from a long oxy-acetylene blowpipe and an acetylene conveyed comminuted flux-forming fuel mixture, previously described, containing about 45% of ferromanganese alloy, 17% of zirconium-silicon alloy, and 38% of aluminum. Using the same flux-forming fuel on Sudan iron ore, a total of 91 feet of holes was thermomechanically drilled at an average speed of 1.94 inches per minute. These figures far surpass the average drilling rate of 4.67 inch per minute obtained with pneumatic drills in Sudan iron ore, as disclosed in U. S. Bureau of Mines Circular 6911.

In a second example of the process of the invention, a total of 185 feet of blasting holes was thermomechanically drilled in Sudan iron ore at an average rate of 1.31 inches per minute using a flame from a long oxy-acetylene blowpipe, and an acetylene conveyed flux-forming fuel mixture, previously described, containing about 7% of aluminum, 67% of ferromanganese, and 26% of zirconium-silicon alloy.

Holes also have been successfully drilled in Sudan iron ore using the previously described flux-forming fuel containing about 67% ferromanganese, 26% calcium-silicon alloy, and 7% aluminum. Slag produced when piercing iron ore with this fuel was somewhat more easily disintegrated after quenching than was the slag obtained with zirconium-silicon alloy, although the drilling rate was somewhat lower and more fumes and dust were produced.

What is claimed is:

1. A flux-forming fuel comprising a comminuted composition containing, by weight, 4% to 36% iron, 28% to 63% manganese, 3% to 19% silicon, 4% to 50% aluminum, and 1% to 13% of at least one substance selected from the group consisting of zirconium and calcium.

2. A flux-forming fuel comprising a comminuted composition containing, by weight, 4% to 36% iron, 28% to 63% manganese, 3% to 16% silicon, 4% to 50% aluminum, and 1% to 13% zirconium.

3. A flux-forming fuel comprising a comminuted composition containing, by weight, 4% to 24% iron, 28% to 63% manganese, 5% to 19% silicon, 4% to 50% aluminum, and 2% to 11% calcium.

4. A flux-forming fuel comprising a comminuted composition containing, by weight, about 9% iron, 37% manganese, 9% silicon, 38% aluminum, and 7% zirconium.

5. A flux-forming fuel comprising a comminuted composition containing, by weight, about 14% iron, 55% manganese, 14% silicon, 7% aluminum, and 10% zirconium.

6. A flux-forming fuel comprising a comminuted composition containing, by weight, 40% to 70% ferromanganese, 4% to 50% aluminum, and 10% to 26% of at least one substance selected from the group consisting of zirconium-silicon alloy and calcium-silicon alloy; said ferromanganese containing 70% to 90% manganese and 10% to 30% iron; said zirconium-silicon alloy containing 10% to 50% zirconium, 30% to 60%

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silicon; said calcium-silicon alloy, containing 20% to 40% calcium, 50% to 70% silicon.

7. In a process for thermally working mineral and like masses comprising separating and removing material from such a mass by applying an oxy-fuel flame to a portion thereof while introducing into such flame a comminuted flux-forming fuel, the improvement which consists in introducing said flux-forming fuel as a flowing stream of a comminuted composition containing, by weight, 4% to 36% iron, 28% to 63% manganese, 3% to 19% silicon, 4% to 50% aluminum, and 1% to 13% of at least one substance selected from the group consisting of zirconium and calcium.

8. In a process for thermally working mineral and like masses comprising separating and removing material from such a mass by applying an oxy-fuel flame to a portion thereof while introducing into such flame a comminuted flux-forming fuel, the improvement which consists in introducing said flux-forming fuel as a flowing stream of a comminuted composition containing, by weight, 4% to 36% iron, 28% to 63% manganese, 3% to 16% silicon, 4% to 50% aluminum, and 1% to 13% zirconium.

9. In a process for thermally working mineral and like masses comprising separating and removing material from such a mass by applying an oxy-fuel flame to a portion thereof while introducing into such flame a comminuted flux-forming fuel, the improvement which consists in introducing said flux-forming fuel as a flowing stream of a comminuted composition containing, by weight, 4% to 24% iron, 28% to 63% manganese, 5% to 19% silicon, 4% to 50% aluminum, and 2% to 11% calcium.

10. In a process for thermally working mineral and like masses comprising separating and removing material from such a mass by applying an oxy-fuel flame to a portion thereof while introducing into such flame a comminuted flux-forming fuel, the improvement which consists in introducing said flux-forming fuel as a flowing stream of a comminuted composition containing, by weight, about 9% iron, 37% manganese, 9% silicon, 38% aluminum, and 7% zirconium.

11. In a process for thermally working mineral and like masses comprising separating and removing material from such a mass by applying an oxy-fuel flame to a portion thereof while introducing into such flame a comminuted flux-forming fuel, the improvement which consists in

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introducing said flux-forming fuel as a flowing stream of a comminuted composition containing, by weight, about 14% iron, 55% manganese, 14% silicon, 7% aluminum, and 10% zirconium.

12. In a process for thermally working mineral and like masses comprising separating and removing material from such a mass by applying an oxy-fuel flame to a portion thereof while introducing into such flame a comminuted flux-forming fuel, the improvement which consists in introducing said flux-forming fuel as a flowing stream of a comminuted composition containing, by weight, 40% to 70% ferromanganese, 4% to 50% aluminum, and 10% to 26% of at least one substance selected from the group consisting of zirconium-silicon alloy and calcium-silicon alloy; said ferromanganese containing 70% to 90% manganese and 10% to 30% iron; said zirconium-silicon alloy containing 10% to 50% zirconium and 30% to 60% silicon; said calcium-silicon alloy containing 20% to 40% calcium and 50% to 70% silicon.

13. In a process for thermally working mineral and like masses comprising melting off material from such a mass and forming a molten slag by applying an oxy-fuel flame to a portion thereof while introducing into such flame a comminuted flux-forming fuel, and removing such slag from the mass in the molten condition, the improvement which consists in introducing said flux-forming fuel as a flowing stream of a comminuted composition containing, by weight, 4% to 36% iron, 28% to 63% manganese, 3% to 19% silicon, 4% to 50% aluminum, and 1% to 13% of at least one substance selected from the group consisting of zirconium and calcium.

14. In a process for thermally working mineral and like masses comprising melting off material from such a mass and forming a molten slag by applying an oxy-fuel flame to a portion thereof while introducing into such flame a comminuted flux-forming fuel, quenching and disintegrating said molten slag, and removing the slag from such mass in the solid condition, the improvement which consists in introducing said flux-forming fuel as a flowing stream of a comminuted composition containing, by weight, 4% to 36% iron, 28% to 63% manganese, 3% to 19% silicon, 4% to 50% aluminum, and 1% to 13% of at least one substance selected from the group consisting of zirconium and calcium.

CHARLES J. BURCH.