



1. A method of melting glass forming material in a glass melting furnace, said furnace having a back wall, breast walls above sidewalls, and a downstream front wall connected to a roof, wherein at least one batch charger for charging glass forming batch material is contained in at least one of the back wall and the sidewall, comprising:

providing at least one oxy-fuel burner in the roof of said furnace over said batch material, wherein said at least one oxy-fuel burner is adapted for staged combustion;

providing a flow of fuel to said at least one oxy-fuel burner;

providing a flow of gaseous oxidant in association with said at least one oxy-fuel burner;

injecting the fuel and the oxidant into the furnace, wherein the fuel jet comprises one of a substantially fuel only jet and a fuel rich fuel-oxidant mixture, and wherein the oxidant jet comprises one of a substantially oxidant only jet and a fuel lean fuel-oxidant mixture, wherein the injected fuel jet and the injected oxidant jet are separated, and are optionally angled with respect to the other, by an amount sufficient to cause the respective flows to converge proximate to or at the surface of the glass forming material, preferably wherein the fuel jet and oxidant jet are separated and angled with respect to each other from 0° to about 90°; and,

combusting said fuel from at least said one oxy-fuel burner such that at least a portion of combustion is effected in the vicinity of said glass forming material to enhance convective and radiative transfer of heat to said glass forming material without substantially disturbing said glass forming material;

optionally wherein the mixing of said fuel and said oxidant is delayed to localize combustion proximate to or at the surface of said glass forming material, optionally including staging the flow of fuel from the oxy-fuel burner, and further optionally including fully combusting reactive intermediate species proximate to or at the glass forming material surface.

2. The method of claim 1, including at least one of the following:



(i) wherein the oxidant is selected from the group consisting of oxygen-enriched air, non-pure oxygen and "industrially" pure oxygen;

(ii) wherein the fuel is a gas selected from the group consisting of methane, natural gas, liquefied natural gas, propane, liquefied propane gas, butane, low BTU gases, town gas, producer gas and mixtures thereof;

(iii) wherein the fuel is a liquid selected from the group consisting of heavy fuel oil, medium fuel oil, light fuel oil, kerosene and diesel.

3. A method of melting glass forming material in a glass melting furnace, said furnace having a back wall, breast walls above sidewalls, and a downstream front wall connected to a roof, wherein at least one batch charger for charging glass forming batch material is contained in at least one of the back wall and the sidewall, comprising:

providing at least one oxy-fuel burner adapted for staged combustion in the roof of said furnace over said batch material;

providing a flow of liquid fuel to said at least one oxy-fuel burner;

providing a flow of gaseous oxidant in association with said at least one oxy-fuel burner;

injecting the fuel and the gaseous oxidant into the furnace, including injecting a majority of oxidant set apart from and substantially surrounding the liquid fuel flow to a point beyond the initial non visible combustion zone; and,

combusting said fuel such that at least a portion of combustion is effected in the vicinity of said glass forming material to enhance convective and radiative transfer of heat to said glass forming material without substantially disturbing said glass forming material;

optionally including at least one of the following:

(i) angling the injected fuel and the injected oxidant about 45° to about 101° from the horizontal;

(ii) injecting the remainder of the oxidant adjacent to and concentric to the injected fuel;

(iii) staging the flow of fuel from the oxy-fuel burner;

(iv) injecting the remainder of the oxidant by tertiary injection into the furnace;

(v) wherein the oxidant is selected from the group consisting of oxygen-enriched air, non-pure oxygen and "industrially" pure oxygen; and,

5 (vi) wherein the liquid fuel is selected from the group consisting of heavy fuel oil, medium fuel oil, light fuel oil, kerosene and diesel.

4. The method of claim 3 including one of the following:

10 (a) wherein the injected liquid fuel has a droplet size of greater than about 100 microns;

(b) atomizing the liquid fuel to produce droplets in the range of about 5 microns to about 50 microns, optionally including one of (i) through (iii):

15 (i) rapidly mixing the droplets with an atomizing medium in the initial burner region to form a substantially homogeneous mixture;

(ii) atomizing the liquid fuel with an oxidizing atomizing medium to produce a partially pre-combusted mixture;

20 (iii) atomizing the liquid fuel with an atomizing medium selected from the group consisting of air, oxygen, steam, natural gas and hydrogen or mixtures thereof to reduce the C:H ratio in the fuel/atomizing medium mixture.

5. The method of any preceding claim, wherein said providing a flow of gaseous oxidant comprises at least one of:

25 (i) wherein the oxy-fuel burner is contained in a burner block, providing integral staging of said oxidant via injection from the same oxy-fuel burner block;

30 (ii) wherein the oxy-fuel burner is contained in a burner block, providing external staging of said oxidant via injection separate from the oxy-fuel burner block;

(iii) providing at least one secondary oxidant injector in the roof of said furnace to provide additional oxidant for completing combustion

proximate to or at the surface of said glass forming material, optionally including injecting from 0 to 90% of stoichiometric oxidant through the oxy-fuel burner block and injecting from 100% to about 10% stoichiometric oxidant via at least one secondary oxidant injector separate from the oxy-fuel burner block; and,

(iv) bubbling oxidant from beneath the glass forming material surface.

6. The method of any preceding claim wherein the glass forming material enters the furnace through at least one charger, including providing the at least one oxy-fuel burner in the roof of the furnace proximate to the at least one charger above the glass forming material.

7. The method of any preceding claim wherein the burner is mounted from an orientation substantially perpendicular to the surface of the glass forming material to an orientation up to 45 degrees away from the perpendicular and toward the downstream front wall of the furnace.

8. The method of any preceding claim, including at least one of the following:

(i) wherein at least one oxy-fuel burner is provided in the roof proximate the downstream front wall;

(ii) providing all furnace burners as oxy-fuel burners;

(iii) providing all furnace burners as roof mounted burners;

(iv) operating at least one said roof mounted oxy-fuel burner in a fuel rich mode and at least one said roof mounted oxy-fuel burner in a fuel lean mode.

9. A method of melting glass forming material in a glass melting furnace, said furnace having a back wall, breast walls above sidewalls, and a downstream end front wall connected to a roof, wherein at least one batch charger for charging glass forming batch material is contained in at least one of the back wall and the sidewall, comprising:

providing at least one oxy-fuel burner in the roof of said furnace over said batch material, wherein said at least one oxy-fuel burner is adapted for fuel staged combustion and contains at least one outer oxidant injector and two inner fuel injectors, the innermost fuel injector being adapted for high velocity fuel injection and the other fuel injector, disposed between the innermost fuel injector and the outer oxidant injector, being adapted for lower velocity fuel injection;

providing a flow of fuel to said at least one oxy-fuel burner, wherein the flow of fuel through the innermost fuel injector has a higher momentum than the flow of fuel through the other fuel injector;

providing a flow of gaseous oxidant to the outer oxidant injector, having a lower momentum than the flow of fuel through the innermost fuel injector;

combusting said fuel from at least said one oxy-fuel burner such that at least a portion of combustion is effected in the vicinity of said glass forming material to enhance convective and radiative transfer of heat to said glass forming material without substantially disturbing said glass forming material;

optionally wherein (a) about 10% to about 90% of the fuel flow is utilized by the innermost fuel injector, or (b) a liquid fuel is provided to the innermost fuel injector, and a gaseous fuel is provided to the other fuel injector, wherein the liquid fuel is selected from the group consisting of heavy fuel oil, medium fuel oil, light fuel oil, kerosene and diesel and the gaseous fuel is selected from the group consisting of methane, natural gas, liquefied natural gas, propane, liquefied propane gas, butane, low BTU gases, town gas, producer gas and mixtures thereof.

10. An oxy-fuel burner comprising at least one outer oxidant injector and two inner fuel injectors, the innermost fuel injector being adapted for high velocity fuel injection and the other fuel injector being adapted for lower velocity fuel injection; optionally wherein the innermost fuel injector is adapted to provide a central high pressure fuel jet comprising at least one of a gaseous fuel and a liquid fuel, the other fuel injector is adapted to provide a

substantially annular lower pressure fuel shroud comprising a gaseous fuel outwardly concentric to the central fuel jet, and the oxidant injector is adapted to provide a substantially annular oxidant stream outwardly concentric to the fuel shroud, the oxidant stream being provided with a lower momentum than the central fuel jet.