CLAIMS

1. A high-temperature die casting apparatus comprising:

a die casting die including at least a first die plate and a second die plate defining a recess for receiving and solidifying molten metal into a metal casting, the recess including gating in fluid communication with a main cavity; and

an in situ zone refining apparatus comprising:

a chiller including at least a first fluid sprayer and a second fluid sprayer each movable in a first longitudinal direction relative to the die casting die, or vice versa, the first fluid sprayer directed toward a first lateral side of the die casting die and a second fluid sprayer directed toward a second opposing lateral side of the die casting die; and

a heat source disposed ahead of the chiller and movable in the first longitudinal direction relative to the die casting die, or vice versa;

wherein the heat source selectively cooperates with the chiller to directionally apply a localized thermal gradient through an exterior surface of at least one of the first and second die plates to the die casting die recess, the localized thermal gradient applied along the first longitudinal direction from the first end to the second end of the die casting die across at least the main cavity via relative movement of the in situ zone refining apparatus from the first end of the die casting die to the second end;

wherein the localized thermal gradient induces a movable solidification front in the molten metal received in the main cavity such that the in situ zone refining apparatus is configured to maintain a portion of the metal above the solidification front above a γ/γ' solvus temperature of the metal as the localized thermal gradient is directionally applied.

2. The high-temperature die casting apparatus of claim **1**, wherein the gating in the die casting die includes a grain selector.

3. The high-temperature die casting die apparatus of claim **1**, wherein a grain selector configured as a seed crystal is disposed in the main cavity.

4. The high-temperature die casting die apparatus of claim **1**, wherein the first die plate and the second die plate comprise an insulating material sufficient to allow the first and second die plates to maintain the portion of metal above the solidification front and ahead of the thermal gradient in a molten state, the molten metal having a melting temperature of at least 1500° F., and the insulating material selected from a group consisting of: a ceramic, a metal matrix composite, a ceramic matrix composite, a refractory metal, and combinations thereof.

5. The high-temperature die casting die apparatus of claim **4**, wherein the first die plate and the second die plate further comprise at least one thermally conductive pathway extending through the insulating material, between the in situ zone refining apparatus and the recess, to maintain the solidification front, and while maintaining the portion of the metal above the solidification front above the γ/γ' solvus temperature of the metal.

6. A method of die casting a molten metal having a melting temperature of at least 1500° F. (815° C.), the method comprising the steps of:

injecting the molten metal into gating and a main cavity of a die casting die, the main cavity and gating forming at least a part of a recess defined by at least a first die plate and a second die plate;

operating an in situ zone refining apparatus to directionally apply a first localized thermal gradient to the molten metal through an exterior surface of at least one of the first and second die plates to the die casting die recess, the in situ zone refining apparatus and the die plates movable relative to each other so as to apply the first localized thermal gradient along a first longitudinal direction along the main cavity from a first end to a second end;

wherein operating the in situ zone refining apparatus comprises:

operating a chiller to direct a first fluid spray from a first fluid sprayer toward a first lateral side of the die casting die, and to direct a second fluid spray from a second fluid sprayer toward a second opposing lateral side of the die casting die, and moving the first and second fluid sprayers in the first longitudinal direction relative to the die casting die, or vice versa; and

operating a heat source disposed ahead of the chiller, wherein the heat source is movable relative to the die casting die, or vice versa, the heat source selectively cooperating with the chiller such that the first localized thermal gradient is applied through the exterior surface of the at least one of the first and second die plates, and along the first longitudinal direction across at least the main cavity;

wherein the step of directionally applying a first localized thermal gradient induces a movable solidification front in the molten metal disposed in the main part cavity such that a portion of the metal above the solidification front remains above a γ/γ' solvus temperature of the metal as the first localized thermal gradient is directionally applied, thereby solidifying the molten metal in the main part cavity to form a casting.

7. The method of claim **6**, wherein the solidifying step comprises performing the first directional applying step on the molten metal injected into the die casting die to solidify the molten metal directly into a casting having a first grain orientation.

8. The method of claim **7**, wherein a grain selector is disposed in the main part cavity or as part of the gating, and wherein the first directional applying step comprises first directionally applying the localized thermal gradient through a portion of the molten metal proximate the grain selector, and then through a remainder of the molten metal to solidify the molten metal directly into a single crystal.

9. The method of claim **8**, further comprising:

removing the casting from the die casting die;

directionally applying a second localized thermal gradient directly in the casting, which results in zone refining of the casting.

10. The method of claim **6**, wherein the metal has a predominant element selected from the group: iron, nickel, cobalt, and titanium.

11. The method of claim **10**, wherein the metal has a predominant element of nickel.