CLAIMS

1. A system for producing a silicon ingot, the system comprising:

a crystal puller including a hotzone having a plurality of components therein, and in which a silicon ingot may be pulled;

a pyrometer positioned to view a region of interest within the hotzone;

an infrared (IR) camera positioned to view one or more additional regions of interest within the hotzone; and

a controller connected to the crystal puller, pyrometer, and the IR camera, the controller programmed to:

control the crystal puller to introduce a step change to a characteristic of one or more component of the plurality of components; and

one or both of:

receiving temperature data of the region of interest within the hotzone from the pyrometer before, during, and after the step change to the characteristic is introduced; and

receiving IR images of the one or more additional regions of interest from the IR camera before, during, and after the step change to the characteristic is introduced.

2. The system of claim 1, wherein the one or more components in the hotzone comprise a susceptor, a reflector, a crucible, a side heater, a bottom heater, a cooling jacket, and, when a silicon ingot is being produced, a silicon melt within the crucible and a silicon ingot extending from the silicon melt.

3. The system of claim 2, wherein the region of interest within the hotzone comprises a portion of the susceptor or a portion of a surface of the silicon melt.

4. The system of claim 2 or claim 3, wherein the one or more additional regions of interest are selected from a portion of the reflector, a portion of the silicon ingot, and a portion of a surface of the silicon melt.

5. The system of any of claims 2-4, wherein the step change to the characteristic of one or more component comprises one or more of a step change in a position of the crucible, a step change in a position of the susceptor, a step change in a power output of the side heater, a step change in a power output of the bottom heater, a step change in a position of the reflector, a step change in the position of the cooling jacket, and a change in a position of the side heater or the bottom heater.

6. A system for producing a silicon ingot, the system comprising:

a crystal puller including a hotzone having one or more components therein, and in which a silicon ingot may be pulled;

a pyrometer positioned to view a region of interest within the hotzone;

an infrared (IR) camera positioned to view one or more additional regions of interest within the hotzone;

a controller connected to the crystal puller, pyrometer, and the IR camera, the controller programmed to:

control the crystal puller to produce a silicon ingot;

receive temperature data of the region of interest within the hotzone from the pyrometer while producing the silicon ingot; and

receive IR images of the one or more additional regions of interest from the IR camera while producing the silicon ingot; and

a computing device communicatively coupled to the controller, the computing device programmed to:

receive operation data about the operation of the crystal puller to produce the silicon ingot;

receive the temperature data of the region of interest within the hotzone captured while producing the silicon ingot; and

receive the IR images of the one or more additional regions of interest captured while producing the silicon ingot;

extract IR temperature data from the received IR images;

compare the extracted IR temperature data, the received operation data, and the received temperature data to corresponding data used for simulating, by a computing device, production of a silicon ingot;

update the corresponding data based on the comparison to the extracted IR temperature data, the received operation data, and the received temperature data.

7. The system of claim 6, wherein the one or more components in the hotzone comprise a susceptor, a reflector, a crucible, and, when a silicon ingot is being

produced, a silicon melt within the crucible and a silicon ingot extending from the silicon melt.

8. The system of claim 7, wherein the region of interest within the hotzone comprises a portion of the susceptor or a portion of a surface of the silicon melt.

9. The system of claim 7 or claim 8, wherein the one or more additional regions of interest are selected from a portion of the reflector, a portion of the silicon ingot, and a portion of a surface of the silicon melt.

10. The system of any of claims 6-9, wherein the controller is further programmed to:

extract IR temperature data from the received IR images;

compare the extracted IR temperature data, the received operation data, and the received temperature data to corresponding data used for simulating, by a computing device, production of a silicon ingot;

updating the corresponding data based on the comparison to the extracted IR temperature data, the received operation data, and the received temperature data.

11. A method comprising:

positioning a pyrometer to view a region of interest within a hotzone of a crystal puller, the hotzone of the crystal puller having a first configuration including a first plurality of components therein;

positioning an infrared (IR) camera to view one or more additional regions of interest within the hotzone;

controlling the crystal puller to introduce a step change to a characteristic of one or more component of the plurality of components;

performing one or both of:

receiving first temperature data of the region of interest within the hotzone from the pyrometer before, during, and after the step change to the characteristic is introduced; and

receiving first IR images of the one or more additional regions of interest from the IR camera before, during, and after the step change to the characteristic is introduced;

changing at least one component within the hotzone of the crystal puller to produce a second configuration of the hotzone having a second plurality of components;

controlling the crystal puller to reintroduce the step change to the characteristic in the second configuration of the hotzone; and

performing one or both of:

receiving second temperature data of the region of interest within the hotzone from the pyrometer before, during, and after the step change to the characteristic is reintroduced to the second configuration of the hotzone; and

receiving second IR images of the one or more additional regions of interest from the IR camera before, during, and after the step change to the characteristic is reintroduced to the second configuration of the hotzone.

12. The method of claim 11, further comprising, analyzing, using a computing device, the first temperature data and the second temperature data, the first IR images and the second IR images, or the first temperature data, the second temperature data, the first IR images, and the second IR images to compare thermal characteristics of the first configuration of the hotzone and the second configuration of the hotzone.

13. The method of claim 12, further comprising selecting the first configuration of the hotzone or the second configuration of the hotzone as having preferred thermal characteristics.

14. The method of claim 13, further comprising controlling the crystal puller to produce a silicon ingot with the selected one of the first configuration of the hotzone or the second configuration of the hotzone.