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Rotating collector ring for centrifugal solar receiver

Abstract

A collector ring assembly can capture particles from a centrifugal solar receiver and reduce a speed of the particles. The collector ring assembly can include a collector ring and a stationary shroud. The collector ring can include a plurality of collection members disposed circumferentially around the collector ring. Each collection member can be formed as a shovel. Each shovel can include a front wall, a bottom wall, a rear wall, an angled shield, a lateral lip, and a top wall. The front wall, the bottom wall, and the rear wall of each shovel can form a trough for collecting the particles. The stationary shroud can be disposed around the collector ring. The stationary shroud can receive and funnel particles exiting from the collector ring.

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Background/Summary

INCORPORATION BY REFERENCE TO ANY PRIORITY APPLICATIONS
(1) Any and all applications for which a foreign or domestic priority claim is identified in the Application Data Sheet as filed with the present application are hereby incorporated by reference under 37 CFR 1.57.
BACKGROUND
Field
(2) The present disclosure is directed to a solar receiver, and more particularly to a rotating

collector ring for a centrifugal solar receiver for collecting particles that pass through and are heated in the receiver using solar energy, where the heated particles can thereafter be stored or used (e.g., to provide heat for industrial purposes).

Description of the Related Art

(3) Existing centrifugal solar receivers use stationary collector rings. However, such stationary collector rings result in particle buildup that results in reduction in receiver aperture. Additionally, stationary collector rings are subjected to impacts by the heated particles, creating abrasion of the stationary collector ring that increases wear on the collector ring and attrition of the particles, increasing the operation and maintenance costs of solar receivers with such stationary collector rings.

SUMMARY

(4) In some aspects, the present disclosure provides a collector ring for a centrifugal solar receiver. The collector ring includes a plurality of collection members arranged circumferentially about a central longitudinal axis of the collector ring. The plurality of collection members are configured to capture particles and reduce a speed of the particles.

(5) In some aspects, the plurality of collection members includes a plurality of shovels. Each of the plurality of shovels includes a front wall. a bottom wall extending from the front wall, and a rear wall extending from the bottom wall, wherein the front wall, the bottom wall, and the rear wall define a trough configured to collect particles.

(6) In some aspects, each of the plurality of shovels further include: an angled shield extending from the front wall, the angled shield including an angled surface, wherein the angled shield is configured to direct particles into the trough; a lateral lip extending from the front wall, wherein the lateral lip is configured to capture particles that travel past the angled shield and direct those particles into the trough; and a top wall extending from the front wall.

(7) In some aspects, the rear wall includes a wide portion and a narrow portion.

(8) In some aspects, each of the plurality of shovels is configured to receive particles travelling in a direction from a first end of the shovel to a second end of the shovel, wherein the lateral lip is disposed at the second end of the shovel.

(9) In some aspects, the bottom wall, the top wall, and the lateral lip each extend substantially perpendicular to the front wall.

(10) In some aspects, each of the plurality of shovels is at least partially nested within an adjacent shovel.

(11) In some aspects, the rear wall is angled from the front wall by a tray angle of about 9 degrees.

(12) In some aspects, the top wall is angled from the bottom wall by a mouth angle of about 12.5 degrees.

(13) In some aspects, the plurality of shovels are configured to receive and collect particles from the centrifugal solar receiver when the plurality of shovels are positioned between about 9 o'clock about 4 o'clock along the clockwise rotation cycle of the collector ring, and wherein the plurality of shovels are configured to release particles when the plurality of shovels are positioned between about 6 o'clock and about 9 o'clock along the clockwise rotation cycle of the collector ring

(14) In some aspects, the collector ring further includes a stationary shroud disposed around the collector ring, the stationary shroud configured to collect and funnel particles exiting from the collector ring.

(15) In some aspects, the stationary shroud includes a pointed top shelf and a stepped bottom shelf.

(16) In some aspects, the collector ring is configured to rotate with a rotating inliner drum of the centrifugal solar receiver

(17) In some aspects, the plurality of collection members includes a plurality of curved vanes.

(18) In some aspects, the collector ring further includes an end wall and a front wall defining an opening aligned with an aperture of the centrifugal solar receiver. The front wall is angled towards the central longitudinal axis of the collector ring. The front wall is spaced from an inliner of the

centrifugal solar receiver to form a circumferential gap between the front wall and the inliner via which particles flow from the inliner into the collector ring.
(19) In other aspects, the present disclosure provides a collector ring assembly including a collector ring and a stationary shroud. The collector ring is configured to capture particles from the centrifugal solar receiver and reduce a speed of the particles. The collector ring includes a plurality of shovels arranged circumferentially about a central longitudinal axis of the collector ring. Each of the plurality of shovels includes a front wall, a bottom wall extending from the front wall; a rear wall extending from the bottom wall, wherein the front wall, the bottom wall, and the rear wall define a trough configured to collect particles. The stationary shroud is disposed around the collector ring. The stationary shroud is configured to collect and funnel particles exiting from the collector ring. The stationary shroud includes a pointed top shelf and a stepped bottom shelf.
(20) In some aspects, each of the plurality of shovels further include: an angled shield extending from the front wall, the angled shield including an angled surface, wherein the angled shield is configured to direct particles into the trough; a lateral lip extending from the front wall, wherein the lateral lip is configured to capture particles that travel past the angled shield and direct those particles into the trough; and a top wall extending from the front wall.
(21) In other aspects, the present disclosure provides a collection member of a collector ring for a centrifugal solar receiver. The collection member includes: a front wall; a bottom wall extending from the front wall; a rear wall extending from the bottom wall, the rear wall including a wide portion and a narrow portion, wherein the front wall, the bottom wall, and the rear wall define a trough configured to collect particles; an angled shield extending from the front wall, the angled shield including an angled surface, wherein the angled shield is configured to direct particles into the trough; a lateral lip extending from the front wall, wherein the lateral lip is configured to capture particles that travel past the angled shield and direct those particles into the trough; and a top wall extending from the front wall.
(22) In some aspects, the collection member is configured to receive particles travelling from a first end of the collection member to a second end of the collection member, wherein the lateral lip is disposed at the second end of the collection member.
(23) In some aspects, the bottom wall, the top wall, and the lateral lip each extend substantially perpendicular to the front wall.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a schematic partial cross-sectional view of an inliner for a centrifugal solar receiver and an end view of the inliner with a collector ring.
(2) FIG. **2** is a schematic perspective cross-sectional view of a collector ring for a centrifugal solar receiver.
(3) FIG. **3** is a schematic partial cross-sectional view of the collector ring in FIG. **2**.
(4) FIG. **4** is an image simulating the operation of a centrifugal solar receiver with the collector ring of FIG. **2** in use.
(5) FIG. **5** is a schematic end view of a centrifugal solar receiver with a collector ring assembly coupled to the inliner of the solar receiver.
(6) FIG. **6** is a schematic partial cross-sectional view of the collector ring assembly of FIG. **5**.
(7) FIG. **7**A is a schematic rear view of a shovel of the collector ring assembly in FIG. **5**.
(8) FIG. **7**B is a schematic top view of the shovel in FIG. **7**A.
(9) FIG. **7**C is a schematic side view of the shovel in FIG. **7**A.
(10) FIG. **8** is an image simulating the operation of a centrifugal solar receiver with the collector ring of FIG. **5**.

(11) FIG. **9** depicts a transverse cross-sectional view of a collector ring assembly.
(12) FIG. **10**A depicts a partial perspective view of a collector ring of the collector ring assembly of FIG. **9**.
(13) FIG. **10**B depicts a partial side view of the collector ring of FIG. **10**A.
(14) FIG. **10**C depicts a partial front view of the collector ring of FIG. **10**A.
(15) FIG. **10**D depicts a partial interior view of the collector ring of FIG. **10**A and inliner.
(16) FIG. **11**A depicts a perspective view of a shovel of the collector ring assembly of FIG. **9**.
(17) FIG. **11**B depicts a rear view of the shovel of FIG. **11**A.
(18) FIG. **11**C depicts a first side view of the shovel of FIG. **11**A.
(19) FIG. **11**D depicts a second opposing side view of the shovel of FIG. **11**A.
(20) FIG. **11**E depicts a top view of the shovel of FIG. **11**A.
(21) FIG. **11**F depicts a bottom view of the shovel of FIG. **11**A.
(22) FIG. **12** depicts a transverse cross-sectional view of a shroud of the collector ring assembly of FIG. **9**.
(23) FIG. **13** depicts a partial transverse cross-sectional view of the collector ring within the shroud of FIG. **9**.
(24) FIG. **14** depicts a side view of the collector ring assembly of FIG. **9** coupled to a receiver.
(25) FIGS. **15**A-**20**B show sequential simulation views of particles during operation of the collector ring assembly of FIG. **9**.
(26) FIG. **21** is a schematic view of a receiver tower and heliostats that direct reflected sunlight toward the receiver tower.

DETAILED DESCRIPTION

(27) FIG. **1** is a partial cross-sectional view of a receiver **100** (e.g., centrifugal solar receiver) with an aperture **110** and inliner **120** (e.g., inliner drum), and an end view of a collector ring **200** attached to an inliner **120** of the receiver **100**. The collector ring **200** has a plurality of collection members that are circumferentially arranged about an axis X (of the inliner **120**) and can capture particles P that travel (e.g., slide, slip) along the receiver **100** (e.g., along the inliner of the receiver **100**) toward the aperture **110** while the receiver **100** receives sunlight through the aperture **110** to heat the particles P. As shown in FIG. **1**, in one example each of the plurality of collection members can be formed as a vane **230**. The collector ring vanes **230** are arranged opposing the direction of rotation R so that as the inliner **120** reaches the upward portion of its rotation, gravity helps to slow the particles P so that they fall with much slower velocity. The collector ring **200** is attached to the inliner **120** so that the collector ring **200** rotates R with the inliner **120** (e.g., rotates R at the same rate as the inliner **120** of the receiver **100**).
(28) FIG. **2** shows a perspective view and FIG. **3** shows a partial cross-sectional view of the collector ring **200**. As discussed above, the collector ring **200** couples or attaches to the inliner **120** (e.g., inliner drum) (best shown in FIG. **3**) in a receiver **100** (e.g., centrifugal solar receiver) so that the collector ring **200** rotates with the inliner **120** (e.g., rotates at the same rate as the inliner **120**). The collector ring **200** has an opening **210** that aligns with the aperture **110** of the receiver **100** at the front of the receiver **100**, and via which sunlight can pass (e.g., toward the inliner **120**). The collector ring **200** has an end wall **220** and a front wall **240**, where the front wall **240** defines the opening **210**. In the illustrated example, the front wall **240** is angled toward the axis X (see FIG. **3**) to inhibit (e.g., prevent) particles P from passing through the opening **210** out of the receiver (which could block sunlight coming into the receiver **100**). The collector ring **200** includes multiple vanes **230** circumferentially arranged about and spaced from the front wall **240**. The vanes **230** are spaced from each other to define a channel between adjacent vanes **230** through which the particles P can pass when they exit the collector ring **200** (described further below). The vanes **230** can have a curved shape and are retained between the end wall **220** and a circumferential flange **225** (see FIG. **3**). FIG. **2** shows the end of the inliner **120** that connects to the collector ring **200** (and does not show the circumferential flange **225** in order to show the vanes **230**). A circumferential gap **250**

or channel is defined between the end of the inliner **120** and the front wall **240** via which particles flow from the inliner **120** into the collector ring **200**.
(29) In operation, the particles P move (e.g., slide) from the rear of the receiver **100** (e.g., upper right portion of receiver **100** in FIG. **1**) toward the front of the receiver **100** (e.g., lower left portion of receiver **100** in FIG. **1**) via rotation of the inliner **120** (e.g., inliner drum). As the particles P reach the end of the inliner **120** (e.g., at the top of the rotation of the inliner **120**), the particles P pass via the circumferential gap **250** to the collector ring **200**, where the vanes **230** catch and hold the particles P (e.g., without imparting any acceleration centrifugally or rotational inertia to hold the particles against the collector ring **200**). The vanes **230** hold the particles P until they fall due to gravity (e.g., when the vane is between a 3 o'clock and a 9 o'clock position as the collector ring **200** rotates with the inliner **120** of the receiver **100**), at the bottom of the rotation of the inliner **120**, and pass into an outlet chute.
(30) FIG. **4** shows a simulation of the operation of the collector ring **200** attached to the inliner **120**, rotating counter-clockwise, showing particles P being collected by the vanes **230** of the collector ring **200** (e.g., between about 10 o'clock and 2 o'clock in the image) and show particles P falling due to gravity (e.g., between about 3 o'clock and 9 o'clock in the image).
(31) FIGS. **5-6** show a collector ring **200′** of a receiver **100** (e.g., centrifugal solar receiver). The collector ring **200′** differs from the collector ring **200** in that it has multiple separate collection members that at least partially overlap each other instead of a single monolithic collector ring **200**. In the example shown in FIG. **5**, each of the multiple collection members can be formed as a shovel **230′**. The shovels **230′** are arranged circumferentially about the axis of the inliner **120** of the receiver **100** and each of the shovels **230′** separately couples to the inliner **120** or inliner drum (e.g., each shovel **230′** couples to a separate tile of an inliner **120** (e.g., inliner drum), facilitating individual replacement of shovels **230′** (e.g., without having to replace the whole collector ring **200′**) for ease of maintenance of the collector ring **200′**. Additionally, the individual shovels **230′** can expand (e.g., thermal expansion due to heat) relative to other shovels **230′** in the collector ring **200′** to inhibit (e.g., reduce or prevent) thermal stresses on the shovels **230′** or collector ring **200′**. Further, overlap of the shovels **230′** inhibits (e.g. prevents) particles coming off the drum of the inliner **120** from slipping through any gaps between the shovels **230′**. As discussed above, the collector ring **200′** rotates with the inliner **120** (e.g., rotates at the same rate as the inliner **120**).
(32) The collector ring **200′** has an opening **210′** that aligns with the aperture **110** of the receiver **100** at the front of the receiver **100**, and via which sunlight can pass (e.g., toward the inliner **120** to heat the particles as they move or slip through the inliner **120** toward the front end of the receiver **100**). The collector ring **200′** has a front wall **240′** formed by individual front walls **232′** of each of the shovels **230′**, where the front wall **240′** defines the opening **210′**. In one example, the front wall **240′** is angled (e.g., the individual front walls **232′** of the shovels **230′** are angled) toward the axis to inhibit (e.g., prevent) particles from passing through the opening **210′** out of the receiver (which could block sunlight coming into the receiver **100**). A circumferential gap **250′** or channel is defined between the end of the inliner **120** and the front wall **240′** via which particles flow from the inliner **120** into the collector ring **200′**. The shovels **230′** can be made of sheet metal (e.g., by bending sheet metal). Advantageously, the collector ring **200′** does not reduce the aperture **110** of the receiver **100** (e.g., centrifugal solar receiver) substantially, and provides an improved aperture size as compared with a stationary collector ring. In one example, the collector ring **200′** can have an opening **210′** of about 2.9 to 3 m in diameter, whereas a stationary collector ring may have an opening diameter of 2.6 m, so the collector ring **200′** advantageously provides about 25% increase in area for the aperture **110**.
(33) FIGS. **7**A, **7**B and **7**C show a front, top and side view, respectively of a shovel **230′**. The shovel **230′** has the front wall **232′**, a bottom wall **234′** that extends from the front wall **232′** to a rear wall **236′**. The rear wall **236′** can be angled toward the front wall **232′**. Also, as best shown in FIG. **7**C, the bottom wall **234′** can be angled up toward the distal edge of the shovel **230′**, which

allows the shovel **230′** to retain the particles as the inliner **120** rotates to that the particles travel (e.g., slide, slip) toward the distal edge before falling off the shovel **230′** under gravity into a shroud **130** (see FIG. **5**), where particles and move (e.g., roll) in to an outlet chute **135** in communication with the shroud **130**. The shroud **130** can be stationary (e.g., does not rotate with the inliner **120**).
(34) In operation, the particles P move (e.g., slide) from the rear of the receiver **100** toward the front of the receiver via rotation of the inliner **120**. As the particles P reach the end of the inliner **120** (at the top of the rotation of the inliner **120**), the particles P pass via the circumferential gap **250′** to the collector ring **200′**, where the shovels **230′** catch and hold the particles P (e.g., without imparting any acceleration centrifugally or rotational inertia to hold the particles against the collector ring **200′**). The shovels **230′** contain the particles as they continue to spin with the inliner **120**, allowing the particles P to slide on the shovel surface (e.g., on the bottom wall **234′**) towards the end of the shovel **230′**. When the particles P reach the end of the shovels **230′**, the particles P begin to slide off the edge of the shovels **230′** due to rotational momentum and gravity direction relative to the shovel surface. The shovels **230′** hold the particles P until they fall due to gravity (e.g., when the vane is between a 3 o'clock and a 9 o'clock position as the collector ring **200′** rotates with the inliner **120** of the receiver **100**), at the bottom of the rotation of the inliner **120**, and pass into the outlet chute **135** via the shroud **130**.
(35) FIG. **8** shows a simulation of the operation of the collector ring **200′** attached to the inliner **120**, showing particles P being collected by the shovels **230′** of the collector ring **200′** (e.g., between about 2 o'clock and 9 o'clock in the image) and show particles P falling due to gravity (e.g., between about 3 o'clock and 9 o'clock in the image) as the inliner **120** and shovels **230′** rotate clockwise in the shown orientation.
(36) FIGS. **9-20**B depict various aspects of an example collector ring assembly **150″** for a receiver **100** (e.g., centrifugal solar receiver). The collector ring assembly **150″** can be coupled to an end of the inliner **120** of the receiver **100**. The collector ring assembly **150″** can collect (e.g., capture) particles P from the inliner **120** (e.g., inliner drum) and reduce a speed of the particles P. The collector ring assembly **150″** can direct the particles P out of the collector ring assembly **150″** for storage in a thermal energy storage or for use in one or more industrial processes (e.g., to generate electricity, generate steam, facilitate calcination, facilitate a chemical process, etc.).
(37) FIG. **9** depicts a transverse cross-sectional view of the collector ring assembly **150″**. As shown in FIG. **9**, the collector ring assembly **150″** can include a collector ring **200″** and a shroud **130″** (e.g., disposed about the collector ring assembly **150″**). The collector ring **200″** can rotate with the inliner **120** (e.g., rotate at the same rate as the inliner **120**). The collector ring **200″** can include an opening **210″** that aligns with the aperture **110** of the receiver **100** at the front of the receiver **100**, and via which sunlight can pass (e.g., toward the inliner **120** to heat the particles P as they move or slip through the inliner **120** toward the front end of the receiver **100**). The collector ring **200″** can include a plurality of collection members. Each of the plurality of collection members can be formed as a shovel **230″**. The plurality of shovels **230″** can be arranged circumferentially about the central longitudinal axis X of the inliner **120** of the receiver **100**. As shown in FIG. **9**, the plurality of shovels **230″** can collectively form a substantially annular shape. Each of the shovels **230″** can be separately coupled to the collector ring assembly **150″** or to the inliner **120** (e.g., each shovel **230″** can be coupled to a separate tile of an inliner **120**), facilitating individual replacement of shovels **230″** (e.g., without having to replace the whole collector ring **200″**) for ease of maintenance of the collector ring **200″**.
(38) FIG. **10**A depicts a partial perspective view of the collector ring **200″** with the shroud **130″** removed for clarity. FIG. **10**B depicts a partial side view of the collector ring **200″** with the shroud **130″** removed for clarity. FIG. **10**C depicts a partial front view of the collector ring **200″** with the shroud **130″** removed for clarity. FIG. **10**D depicts a partial interior view of the collector ring **200″** of FIG. **10**A and inliner **120** (e.g., inliner drum). As shown in FIGS. **10**A-**10**D, the plurality of

shovels **230**″ can at least partially overlap each other (e.g., each shovel **230**″ can be at least partially nested within an adjacent shovel **230**″). Overlap of the shovels **230**″ can inhibit (e.g. prevent) particles P coming off the drum of the inliner **120** from slipping through any gaps between the shovels **230**″. Additionally, each shovel **230**″ can expand (e.g., thermally expand due to heat) relative to other shovels **230**″ in the collector ring **200**″ to inhibit (e.g., reduce or prevent) thermal stresses on the shovels **230**″ or collector ring **200**″. Referring to FIG. **10**D, the collector ring **200**″ can be sized and positioned such that top wall **238**″ of each shovel **230**″ is spaced radially inwardly from the inliner **120**. Accordingly, a radial circumferential gap **260**″ or channel can be defined between the inner surface of the inliner **120** and a top wall **238**″ of each shovel **230**″. Particles P can flow from the inliner **120** into the collector ring **200**″ via the radial circumferential gap **260**″. The shovels **230**″ can be made of sheet metal (e.g., by bending sheet metal). In other examples, the shovels **230**″ can be made of any suitable material, including but not limited to metal, metal alloys, composite materials, or the like. The shovels **230**″ can retain the particles P as the inliner **120** rotates so that the particles P travel (e.g., slide, slip) toward the distal edge (e.g., second end **248**″, shown in FIGS. **11**A-**11**B) before falling off the shovel **230**″ under gravity into a shroud **130**″ (see FIG. **12**), where particles P can move (e.g., roll or slide) into an outlet chute **135** in communication with the shroud **130**″.

(39) FIGS. **11**A-**11**F depicts various views of a shovel **230**″ of the collector ring assembly **150**″ of FIG. **9**. FIG. **11**A depicts a perspective view of a shovel **230**″. FIG. **11**B depicts a rear view of the shovel **230**″ of FIG. **11**A. FIG. **11**C depicts a first side view of the shovel **230**″ of FIG. **11**A. FIG. **11**D depicts a second opposing side view of the shovel **230**″ of FIG. **11**A. FIG. **11**E depicts a top view of the shovel **230**″ of FIG. **11**A. FIG. **11**F depicts a bottom view of the shovel **230**″ of FIG. **11**A. Each of plurality of shovels **230**″ can extend from a first end **246**″ to an opposing second end **248**″. Each of the plurality of shovels **230**″ can include a front wall **232**″, a bottom wall **234**″, a top wall **238**″, a rear wall **240**″, a lateral lip **242**″, and an angled shield **244**″. The front wall **232**″ can extend from the bottom wall **234**″ to the top wall **238**″. The bottom wall **234**″ can extend from the front wall **232**″ to the rear wall **240**″. The front wall **232**″ can extend substantially perpendicular to the bottom wall **234**″, the top wall **238**″, and the lateral lip **242**″. The lateral lip **242**″ can extend from the front wall **232**″ towards the rear wall **240**″. The lateral lip **242**″ can extend perpendicularly from a second end **248**″ of the front wall **232**″. The lateral lip **242**″ can inhibit (e.g., prevent) particles P from sliding off the shovel **230**″ before first resting on the bottom wall **234**″, which can help to delay particles P on the shovel **230**″ until they are desired to slip out. The rear wall **240**″ can extend from the bottom wall **234**″. The rear wall **240**″ can extend substantially perpendicular to the bottom wall **234**″. As shown in **11**A, the rear wall **240**″ can include a wide portion **252**″ and a narrow portion **250**″. The wide portion **252**″ can extend from a first end **246**″ of the shovel **230**″ to a position that is substantially aligned with the angled shield **244**″. The narrow portion **250**″ can extend from the wide portion **252**″ to the second end **248**‴ of the shovel **230**″. The size of the rear wall **240**″ can be maximized to prevent particles P from spilling over the shovel **230**″ in the rearward direction. The stepped shape of the rear wall **240**″ formed by the wide portion **252**″ and the narrow portion **250**″ can enable interlocking of the shovels **230**″.

(40) The front wall **232**″, the bottom wall **234**″, and the rear wall **240**″ can form a trough **254**″. As shown in FIGS. **11**C-**11**D, the trough **254**″ can have a substantially U-shaped channel for containing particles P. In operation, particles P can collect and build up in the trough **254**″ as the collector ring **200**″ rotates. As shown in FIG. **11**F, the width of the bottom wall **234**″ of the trough **254**″ can increase (e.g., linearly) from the first end **246**″ to the second end **248**″. Accordingly, the front wall **232**″ can be angled from the rear wall **240**″ by a tray angle θ. The trapezoidal shape of the trough **254**″ resulting from the tray angle θ can enable the shovels **230**″ to be interlocking while also maximizing the amount of particles P that can be held in the trough **254**″ during a rotation of the collector ring **200**″. In some examples, the tray angle θ can be about 9 degrees. In other examples, the tray angle θ can be more than about 9 degrees or less than about 9 degrees. As shown

in FIG. **11**B, the trough **254**‴ can extend beyond the lateral lip **242**″ at the second end **248**″ of the shovel **230**″. This arrangement can enable the trough **254**″ to collect and delay any particles P that are caught by the lateral lip **242**″. The bottom wall **234**″ (and accordingly the trough **254**″) can be angled from the top wall **238**″ by a mouth angle α. The mouth angle α of the trough **254**″ can be tuned to optimize the friction of particles P on the trough **254**″ so that particles P collect during the down-swing of the collector ring **200**″ rotation, and particles P clear during the upswing the collector ring **200**″ rotation with only a thin residual layer of particles P on the trough **254**″ to protect from impact erosion. In some examples, the mouth angle α can be about 12.5 degrees. In other examples, mouth angle α can be more than about 12.5 degrees or less than about 12.5 degrees.

(41) The angled shield **244**″ can function to direct or redirect particles P into the trough **254**″. As shown in FIG. **11**B, the angled shield **244**″ can extend from the front wall **232**″ towards the rear wall **240**″. The angled shield **244**″ can be disposed between the top wall **238**″ and the bottom wall **234**″ such that a first gap exists between the angled shield **244**″ and the top wall **238**″, and a second gap exists between the angled shield **244**″ and the bottom wall **234**″. In some examples, the angled shield **244**″ can be positioned substantially centrally on the front wall **232**″. The angled shield **244**″ can include an angled surface **256**″. The angled surface **256**″ can face towards the top wall **238**″ and the first end **246**″ of the shovel **230**″. In some examples, the angled shield **244**″ can be integrally formed with the shovel **230**″ (e.g., as a monolithic or unitary, seamless piece). In other examples, the angled shield **244**″ can be a separate component that is coupled to or positioned adjacent to the shovel **230**″.

(42) FIG. **12** depicts a transverse cross-sectional view of the shroud **130**″. The shroud **130**″ can enclose (e.g., be disposed around) the collector ring **200**″. The shroud **130**″ can remain stationary as the collector ring **200**″ and the inliner **120** (e.g., inliner drum) rotate. Accordingly, the collector ring **200**″ can rotate within the shroud **130**″ while the shroud **130**″ remains stationary. The shroud **130**″ can function to collect and funnel particles P exiting from the collector ring **200**″. The shroud **130**″ can include an inner sidewall **261**″, an outer sidewall **262**″, a bottom shelf **264**″, a top shelf **266**″, a central opening **268**″, and an exit opening **270**″. The inner sidewall **261**″ can define the central opening **268**″. The central opening **268**″ can be aligned with the opening **210**″ of the collector ring **200**″ and the aperture **110** of the receiver **100**. The outer sidewall **262**″ can be radially spaced outward from the inner sidewall **261**″. The collector ring **200**″ can be disposed between the inner sidewall **261**″ and the outer sidewall **262**″. The top shelf **266**″ can extend from the inner sidewall **261**″ at the top region of the inner sidewall **261**″. The top shelf **266**″ can prevent a build-up of particles P on the top region of the inner sidewall **261**″. As shown in FIG. **12**, the top shelf **266**″ can be shaped such that it narrows to a point (e.g., pointed edge). In some examples, the top shelf **266**″ can have a substantially triangular shape. The pointed edge can be aligned with a center of the shroud **130**″. The shape of the top shelf **266**″ can cause any particles P that land on the top shelf **266**″ to be directed to either side of the pointed edge and slide off the top shelf **266**″ due to gravitational pull. The side surface of the top shelf **266**″ can be angled at a sufficient angle to prevent particle build-up. For example, in some examples, an angle of about 70 degrees can be formed between the side surfaces of the top shelf **266**″.

(43) The bottom shelf **264**″ can funnel particles P to a thermal storage device, exit chute, or other collection receptacle. As shown in FIG. **12**, the bottom shelf **264**″ can extend from the outer sidewall **262**″. As shown in FIG. **12**, the shroud **130**″ can include at least two opposing sloped surfaces that converge to an exit opening **270**″. The exit opening **270**″ can be disposed substantially centrally. In other examples, the shroud **130**″ can include only one or more than one sloped surface. Additionally, in other examples, the exit opening **270**″ can be offset from the center of the shroud **130**″ or positioned at any suitable location on the shroud **130**″. As shown in FIG. **12**, the bottom shelf **264**″ can include one or more steps. The steps can function to inhibit (e.g., prevent) a large build-up of particles P on the bottom shelf **264**″. The steps can segment the sloped surfaces to

reduce the size of any continuous flat surfaces. Reducing the size of continuous flat surfaces can reduce the size of particle piles on that surface. Specifically, the steps can be sized to optimize the size of particle piles that build-up on the bottom shelf **264**″. The size of the steps can be optimized to minimize the total dead mass of particle held on the bottom shelf **264**″ while still allowing a pile of a certain size to accumulate to help damp any particles P flung downward onto the bottom shelf **264**″. The particle build-up on the bottom shelf **264**″ can further reduce erosion of the bottom shelf **264**″ caused by particle impacts. In other examples, the bottom shelf **264**″ can include one, two, three, or any other number of steps.

(44) FIG. **13** depicts a partial transverse cross-sectional view a collector ring **200**‴ within the shroud **130**″. As shown in FIG. **13**, the shroud **130**″ can be disposed adjacent to the front wall **232**″ of each shovel **230**″. Each shovel **230**″ can be sized such that the bottom wall **234**″ of each shovel **230**″ extends radially outward from the top shelf **266**″ so that particles P can exit the collector ring **200**″ at a position that is radially outward from the top shelf **266**″. An axial gap **280**″ can be formed between the top shelf **266**″ and the collector ring **200**″ (e.g., front wall **232**″ of each shovel **230**″). In some examples, the axial gap **280**″ can be about 1 cm. In other examples, the axial gap **280**″ can be less than 1 cm or greater than 1 cm. The axial gap **280**″ can inhibit (e.g., prevent) impact between the collector ring **200**″ and the shroud **130**″. Additionally, the axial gap **280**″ can enable looser tolerances in manufacturing and assembly of the collector ring assembly **150**″. In some examples, it can be preferable to minimize the size of the axial gap **280**″ to limit the amount of particles P that slip through the axial gap **280**″. As shown in FIG. **13**, a support structure **272**″ can secure the collector ring **200**″ to the inliner (e.g., inliner drum) of the receiver **100**. The support structure **272**″ can be a beam, bracket, rod, arm, or other structure capable of supporting the collector ring **200**″.

(45) FIG. **14** depicts a side view of a collector ring assembly **150**″ coupled to a receiver **100**. During operation, the receiver **100** can be oriented at an angle (e.g., 45-degree angle). As shown in FIG. **14**, the bottom shelf **264**″ of the shroud **130**″ can be angled such that the bottom shelf **264**″ is oriented substantially horizontal (e.g., perpendicular to gravity) when the receiver **100** is configured in its operational orientation.

(46) In operation of the collector ring assembly **150**″, the particles P move (e.g., slide) from the rear of the receiver **100** toward the front of the receiver **100** via rotation of the inliner **120**. As the particles P reach the end of the inliner **120** (at the top of the rotation of the inliner drum), the particles P pass to the collector ring **200**″, where the shovels **230**″ catch and hold the particles P (e.g., without imparting any acceleration centrifugally or rotational inertia to hold the particles P against the collector ring **200**″). The shovels **230**″ contain the particles P as they continue to spin with the inliner **120**, allowing the particles P to slide on the shovel surface (e.g., on the bottom wall **234**″) towards the second end **248**″ of the shovel **230**″. When the particles P reach the second end **248**″ of the shovels **230**″, the particles P begin to slide off the edge of the shovels **230**″ due to rotational momentum and gravity direction relative to the shovel surface. The shovels **230**″ hold the particles P until they fall due to gravity and pass into the outlet chute **135** or exit opening **270**″ via the shroud **130**″.

(47) FIGS. **15**A-**20**B show sequential simulation views of the operation of the collector ring assembly **150**″ attached to the inliner **120** as particles P are collected by the shovels **230**″ and deposited into the shroud **130**″. FIGS. **15**B, **16**B, **17**B, **18**B, **19**B, and **20**B are enlarged views of regions within FIGS. **15**A, **16**A, **17**A, **18**A, **19**A, and **20**A, respectively. FIGS. **15**A-**20**B depict a simulation corresponding to clockwise rotation of the receiver **100** and the collector ring **200**″. In other examples, the receiver **100** and collector ring **200**″ can rotate in a counterclockwise direction.

(48) FIGS. **15**A-**15**B depict particles P between the 9 o'clock to 10 o'clock position along the rotation cycle of the collector ring **200**″. As shown in FIGS. **15**A-**15**B, particles P exit from the inliner **120** and are subsequently collected by the shovels **230**″ of the collector ring **200**″ within the zone Z**1**. The zone Z**1** can extend between about 9 o'clock to about 4 o'clock in a clockwise

direction (e.g., between about 10 o'clock and about 3 o'clock). Some of the particles P can rest on the bottom wall **234**″ of the shovels **230**″ (e.g., trough **254**″), whereas other particles P can slide off the end of the trough **254**″.

(49) FIGS. **16**A-**16**B depict particles P between the 12 o'clock to 1 o'clock position along the rotation cycle of the collector ring **200**″. FIGS. **16**A-**16**B show travels paths of particles P entering the shovels **230**″. As shown in FIG. **16**B, some particles P (e.g., a majority of particles P) impact the angled shield **244**″ and are directed to the angled side (e.g., left side in FIG. **16**B) of the angled shield **244**″ before subsequently falling into the trough **254**″. Particles P directed to the angled side of the angled shield **244**″ fall into a middle portion of the trough **254**″ (e.g., at a location closer to the first end **246**″ of the shovel **230**″). The angled shield **244**″ can function to decelerate (e.g., change a travel direction) of the particles P and reduce their impact velocity on the trough **254**″. Additionally, the angled shield **244**″ can function to encourage a larger build of particles P within the portion of the trough **254**″ having a wide portion **252**″ of rear wall **240**″. Some particles P (e.g., a minority of particle) pass over the angled shield **244**″ and travel to the opposing side (e.g., right side in FIG. **16**B) of the angled shield **244**″. Particles P passing to the opposing side of the angled shield **244**″ impact the lateral lip **242**″, which directs those particles P into the trough **254**″. Particles P that impact the lateral lip **242**″ are directed into a portion of the trough **254**″ that is closer to the second end **248**″ of the trough **254**″. Some particles P slip out of the trough **254**″ against the direction of rotation. Particles P that slip out of the trough **254**″ have a lower speed and have been translated further out radially so that they land on top of the top shelf **266**″ of the shroud **130**″.

(50) FIGS. **17**A-**17**B depict particles P between the 2 o'clock to 3 o'clock position along the rotation cycle of the collector ring **200**″. As shown in FIGS. **17**A-**17**B, particles P continue to collect in the trough **254**″. A larger pile of particles P can form in the region of the trough **254**″ that is disposed to the left (as shown in FIG. **17**B) of the angled shield **244**″ (e.g., the portion of the trough **254**″ with a wide portion **252**″ of the rear wall **240**″). At this position along the rotation cycle, flow of particles P off the inliner **120** into the collector ring **200**″ has decreased (e.g., mostly stopped).

(51) FIGS. **18**A-**18**B depict particles P between the 6 o'clock to 7 o'clock position along the rotation cycle of the collector ring **200**″. As shown in FIGS. **18**A-**18**B, at this portion of the rotation cycle particles P remain collected in the trough **254**″ and continue to build up. In some examples, the particles P can accumulate in each trough **254**″ such that each pile of particles P increases in height from the rear wall **240**″ to the front wall **232**″. In some examples, each pile of particles P can have a height at the front wall **232**″ that is equal to or greater than the height of the wide portion **252**″ of the rear wall **240**″. At this position along the rotation cycle, flow of particles P off the inliner into the collector ring **200**″ remains decreased (e.g., has mostly stopped).

(52) FIGS. **19**A-**19**B depict particles P between the 7 o'clock to 8 o'clock position along the rotation cycle of the collector ring **200**″. As the shovels **230**″ start swinging upwards, gravity pulls the particles P down and starts pulling particles P out of the shovel **230**″. Crucially, these particles P have a lower speed than when they exited from the inliner **120** and will continue to decelerate as they continue to move against gravity. As shown in FIGS. **19**A-**19**B, the pile of particles P can start to diminish in size as particle leave the shovel **230**″.

(53) FIGS. **20**A-**20**B depict particles P after completing a full rotation cycle and returning to the 9 o'clock to 10 o'clock position of the rotation cycle of the collector ring **200**″. As shown in FIGS. **20**A-**20**B, after completing a full rotation cycle of the collector ring **200**″, the original particles P have been mostly cleared from the shovel **230**″ as new particles P start flowing in. The mouth angle α of the trough **254**″ is tuned so that a small layer of particles P remains on the trough **254**″. The remaining layer of particles P can function to damp the impact of incoming particles P and reduce wear on the shovels **230**″. As shown in FIGS. **15**A-**20**B, particles P can exit (e.g., be released from or fall out of the shovels **230**″ between about 6 o'clock and about 9 o'clock along the rotation cycle

of the collector ring **200**″. Particles P exiting from the shovels **230**″ of the collector ring **200**″ can be captured by the shroud **130**″ and funneled to the exit opening **270**″.
(54) Advantageously, the collector ring **200**, **200**′, **200**″ can function to slow down particles P exiting from the receiver **100**, and reduce their impact velocities. The collector ring **200**, **200**′, **200**″ can utilize gravity and drag to slow down particles. Advantageously, a reduction in impact velocities of the particles can reduce wear and tear on the collector ring **200**, **200**′, **200**″ and attrition of the particles, thereby reducing operation and maintenance cost. Further, the particles can be preferentially deposited off of the vanes **230** or shovels **230**′, **230**″ onto a mound of particles, eliminating wear on the walls of the shroud **130**, **130**″. Additionally, the collector ring **200**, **200**′, **200**″ reduces (e.g., minimizes) particle buildup, which allows for the reduction in the size of the collector ring **200**, **200**′, **200**″, which can in turn allow for an increased size of the aperture **110** of the receiver **100**.
(55) In operation, the inliner **120** can rotate about the central longitudinal axis X of the receiver **100** and be oriented at an angle (e.g., 45 degree angle). Particles (e.g., carbo-ceramic particles, such as sintered bauxite, coated sand particles) are introduced proximate an upper end of the receiver and onto the inliner **120** (e.g., onto inliner panels). Centrifugal force holds the particles against the inliner panels and the surface features inhibit rolling of the particles on the inliner panels. The particles slide relative to each other as sunlight is directed to the receiver, causing the particles to heat to temperatures of 600-900° C. or higher (e.g., 1000° C. or higher). The heated particles exit the receiver via the inliner into the collector ring **200**, **200**′, **200**″ as described above. Once the particles P are collected via the outlet chute **135**, the particles can in one example be directed to a thermal storage location (e.g., a thermal storage tank), where the heated particles can be stored for use in various industrial applications.
(56) A receiver system, such as the receiver **100** with the collector ring **200**, **200**′, **200**″, can be located on a roof of a building or top of a tower and exposed to sunlight (e.g., reflected sunlight) directed from below the receiver system (e.g., in a manner that captures 80-90% of sunlight onto the receiver **100** of the receiver system). FIG. **21** shows one example of a concentrated solar power (CSP) system that can be used with the receiver system disclosed herein. The CSP system can include a heliostat field HF with one or more heliostats H supported on shafts or frames S**1**. Each heliostat H can have a tracking controller TC and an actuator A and a mirror M. The mirrors M can reflect sunlight to one or more receiver apertures RE (e.g., similar to apertures **110** of the receiver **100**) in a tower T. The tower T can have a housing H at the top thereof that houses the receiver system. A controller C can control the heliostat field HF (e.g., control the heliostats H).
(57) While certain examples of the inventions have been described, these examples have been presented by way of example only, and are not intended to limit the scope of the disclosure. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms. Furthermore, various omissions, substitutions and changes in the systems and methods described herein may be made without departing from the spirit of the disclosure. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the disclosure. Accordingly, the scope of the present inventions is defined only by reference to the appended claims.
(58) Features, materials, characteristics, or groups described in conjunction with a particular aspect or example are to be understood to be applicable to any other aspect or example described in this section or elsewhere in this specification unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. The protection is not restricted to the details of any foregoing examples. The protection extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of

the steps of any method or process so disclosed.
(59) Furthermore, certain features that are described in this disclosure in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations, one or more features from a claimed combination can, in some cases, be excised from the combination, and the combination may be claimed as a subcombination or variation of a subcombination.
(60) Moreover, while operations may be depicted in the drawings or described in the specification in a particular order, such operations need not be performed in the particular order shown or in sequential order, or that all operations be performed, to achieve desirable results. Other operations that are not depicted or described can be incorporated in the example methods and processes. For example, one or more additional operations can be performed before, after, simultaneously, or between any of the described operations. Further, the operations may be rearranged or reordered in other implementations. Those skilled in the art will appreciate that in some examples, the actual steps taken in the processes illustrated and/or disclosed may differ from those shown in the figures. Depending on the example, certain of the steps described above may be removed, others may be added. Furthermore, the features and attributes of the specific examples disclosed above may be combined in different ways to form additional examples, all of which fall within the scope of the present disclosure. Also, the separation of various system components in the implementations described above should not be understood as requiring such separation in all implementations, and it should be understood that the described components and systems can generally be integrated together in a single product or packaged into multiple products.
(61) For purposes of this disclosure, certain aspects, advantages, and novel features are described herein. Not necessarily all such advantages may be achieved in accordance with any particular example. Thus, for example, those skilled in the art will recognize that the disclosure may be embodied or carried out in a manner that achieves one advantage or a group of advantages as taught herein without necessarily achieving other advantages as may be taught or suggested herein.
(62) Conditional language, such as “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain examples include, while other examples do not include, certain features, elements, and/or steps. Thus, such conditional language is not generally intended to imply that features, elements, and/or steps are in any way required for one or more examples or that one or more examples necessarily include logic for deciding, with or without user input or prompting, whether these features, elements, and/or steps are included or are to be performed in any particular example.
(63) Conjunctive language such as the phrase “at least one of X, Y, and Z,” unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, term, etc. may be either X, Y, or Z. Thus, such conjunctive language is not generally intended to imply that certain examples require the presence of at least one of X, at least one of Y, and at least one of Z.
(64) Language of degree used herein, such as the terms “approximately,” “about,” “generally,” and “substantially” as used herein represent a value, amount, or characteristic close to the stated value, amount, or characteristic that still performs a desired function or achieves a desired result. For example, the terms “approximately”, “about”, “generally,” and “substantially” may refer to an amount that is within less than 10% of, within less than 5% of, within less than 1% of, within less than 0.1% of, and within less than 0.01% of the stated amount. As another example, in certain examples, the terms “generally parallel” and “substantially parallel” refer to a value, amount, or characteristic that departs from exactly parallel by less than or equal to 15 degrees, 10 degrees, 5 degrees, 3 degrees, 1 degree, or 0.1 degree.
(65) The scope of the present disclosure is not intended to be limited by the specific disclosures of

preferred examples in this section or elsewhere in this specification, and may be defined by claims as presented in this section or elsewhere in this specification or as presented in the future. The language of the claims is to be interpreted broadly based on the language employed in the claims and not limited to the examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive.
(66) Of course, the foregoing description is that of certain features, aspects and advantages of the present invention, to which various changes and modifications can be made without departing from the spirit and scope of the present invention. Moreover, the devices described herein need not feature all of the objects, advantages, features and aspects discussed above. Thus, for example, those of skill in the art will recognize that the invention can be embodied or carried out in a manner that achieves or optimizes one advantage or a group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein. In addition, while a number of variations of the invention have been shown and described in detail, other modifications and methods of use, which are within the scope of this invention, will be readily apparent to those of skill in the art based upon this disclosure. It is contemplated that various combinations or subcombinations of these specific features and aspects of examples may be made and still fall within the scope of the invention. Accordingly, it should be understood that various features and aspects of the disclosed examples can be combined with or substituted for one another in order to form varying modes of the discussed devices.

Claims

1. A collector ring for a centrifugal solar receiver, the collector ring comprising a plurality of collection members arranged circumferentially about a central longitudinal axis of the collector ring, wherein the plurality of collection members are configured to capture particles and reduce a speed of the particles; wherein the plurality of collection members comprises a plurality of shovels, each of the plurality of shovels comprising: a front wall; a bottom wall extending from the front wall; and a rear wall extending from the bottom wall, wherein the front wall, the bottom wall, and the rear wall define a trough configured to collect particles; wherein the plurality of shovels are configured to receive and collect particles from the centrifugal solar receiver when the plurality of shovels are positioned between about 9 o'clock about 4 o'clock along a clockwise rotation cycle of the collector ring, and wherein the plurality of shovels are configured to release particles when the plurality of shovels are positioned between about 6 o'clock and about 9 o'clock along the clockwise rotation cycle of the collector ring.
2. The collector ring of claim 1, wherein each of the plurality of shovels further comprise: an angled shield extending from the front wall, the angled shield comprising an angled surface, wherein the angled shield is configured to direct particles into the trough; a lateral lip extending from the front wall, wherein the lateral lip is configured to capture particles that travel past the angled shield and direct those particles into the trough; and a top wall extending from the front wall.
3. The collector ring of claim 2, wherein the rear wall comprises a wide portion and a narrow portion.
4. The collector ring of claim 2, wherein each of the plurality of shovels is configured to receive particles travelling in a direction from a first end of the shovel to a second end of the shovel, wherein the lateral lip is disposed at the second end of the shovel.
5. The collector ring of claim 2, wherein the bottom wall, the top wall, and the lateral lip each extend substantially perpendicular to the front wall.
6. The collector ring of claim 2, wherein the top wall is angled from the bottom wall by a mouth angle of about 12.5 degrees.
7. The collector ring of claim 1, wherein each of the plurality of shovels is at least partially nested

within an adjacent shovel.
8. The collector ring of claim 1, wherein the rear wall is angled from the front wall by a tray angle of about 9 degrees.
9. The collector ring of claim 1, further comprising a stationary shroud disposed around the collector ring, the stationary shroud configured to collect and funnel particles exiting from the collector ring.
10. The collector ring of claim 9, wherein the stationary shroud comprises a pointed top shelf and a stepped bottom shelf.
11. The collector ring of claim 1, wherein the collector ring is configured to rotate with a rotating inliner drum of the centrifugal solar receiver.
12. The collector ring of claim 1, wherein the plurality of collection members comprises a plurality of curved vanes.
13. The collector ring of claim 12, further comprising: an end wall; and a front wall defining an opening aligned with an aperture of the centrifugal solar receiver, wherein the front wall is angled towards the central longitudinal axis of the collector ring, wherein the front wall is spaced from an inliner of the centrifugal solar receiver to form a circumferential gap between the front wall and the inliner via which particles flow from the inliner into the collector ring.
14. A collector ring assembly for a centrifugal solar receiver, the collector ring assembly comprising: a collector ring configured to capture particles from the centrifugal solar receiver and reduce a speed of the particles, the collector ring comprising a plurality of shovels arranged circumferentially about a central longitudinal axis of the collector ring, each of the plurality of shovels comprising: a front wall; a bottom wall extending from the front wall; and a rear wall extending from the bottom wall, wherein the front wall, the bottom wall, and the rear wall define a trough configured to collect particles; and a stationary shroud disposed around the collector ring, the stationary shroud configured to collect and funnel particles exiting from the collector ring, the stationary shroud comprising a pointed top shelf and a stepped bottom shelf.
15. The collector ring assembly of claim 14, wherein each of the plurality of shovels further comprise: an angled shield extending from the front wall, the angled shield comprising an angled surface, wherein the angled shield is configured to direct particles into the trough; a lateral lip extending from the front wall, wherein the lateral lip is configured to capture particles that travel past the angled shield and direct those particles into the trough; and a top wall extending from the front wall.
16. A collection member of a collector ring for a centrifugal solar receiver, the collection member comprising: a front wall; a bottom wall extending from the front wall; a rear wall extending from the bottom wall, the rear wall comprising a wide portion and a narrow portion, wherein the front wall, the bottom wall, and the rear wall define a trough configured to collect particles; an angled shield extending from the front wall, the angled shield comprising an angled surface, wherein the angled shield is configured to direct particles into the trough; a lateral lip extending from the front wall, wherein the lateral lip is configured to capture particles that travel past the angled shield and direct those particles into the trough; and a top wall extending from the front wall.
17. The collection member of claim 16, wherein the collection member is configured to receive particles travelling from a first end of the collection member to a second end of the collection member, wherein the lateral lip is disposed at the second end of the collection member.
18. The collection member of claim 16, wherein the bottom wall, the top wall, and the lateral lip each extend substantially perpendicular to the front wall.