



(12) **United States Patent  
Goldberg**

(10) **Patent No.: US 9,222,702 B2**  
(45) **Date of Patent: Dec. 29, 2015**

(54) **SYSTEMS AND METHODS FOR CONTROL AND CALIBRATION OF A SOLAR POWER TOWER SYSTEM**

(71) Applicant: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(72) Inventor: **Nitzan Goldberg**, Jerusalem (IL)

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 431 days.

(21) Appl. No.: **13/686,630**

(22) Filed: **Nov. 27, 2012**

(65) **Prior Publication Data**  
US 2013/0139804 A1 Jun. 6, 2013

**Related U.S. Application Data**

(60) Provisional application No. 61/565,883, filed on Dec. 1, 2011.

(51) **Int. Cl.**  
**F24J 2/38** (2014.01)

(52) **U.S. Cl.**  
CPC ..... **F24J 2/38** (2013.01); **F24J 2002/385** (2013.01); **F24J 2200/04** (2013.01); **Y02E 10/47** (2013.01)

(58) **Field of Classification Search**  
CPC ..... F24J 2/38; F24J 2/40; F24J 2/542; F24J 2/5424; F24J 2200/04; F24J 2002/385; Y02E 10/41; Y02E 10/47; G01S 3/7861  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 5/2004  
EP 0106688 3/1985  
(Continued)

**OTHER PUBLICATIONS**

“Mean and Peak Wind Load Reduction on Heliostats,” Colorado State University, Solar Energy Research Institute, U.S. Department of Energy [online], Sep. 1987 [retrieved on May 16, 2012]. Retrieved from the Internet: <URL: <http://www.nrel.gov/docs/legosti/old/3212.pdf>>.

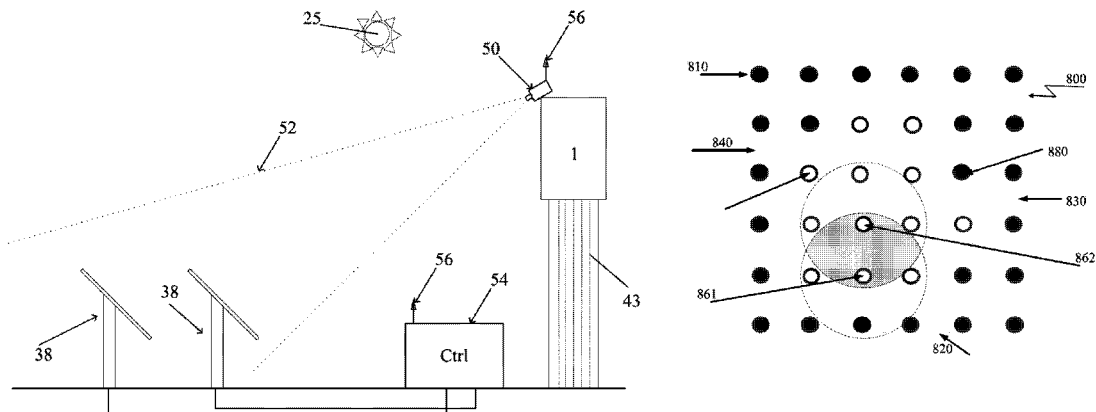
(Continued)

*Primary Examiner* — Alfred Basicchas  
(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy collection system can include a plurality of heliostats configured to reflect sunlight to a target mounted on a tower. Each of the heliostats can have a heliostat controller configured to control a respective heliostat so that the sunlight reflected therefrom is directed to at least one of a plurality of cameras. The cameras can be oriented to image the heliostat. A second controller can be configured to compute geometry data that defines a geometry of the surface of the heliostat from captured images thereof. The geometry data can designate a plurality of subsections of the surface. The computing by the second controller can include storing data indicating sections of the captured images corresponding to the plurality of subsections of the heliostat. The second controller can also calculate data indicating respective surface normals of each of said subsections of each of said heliostat.

**20 Claims, 8 Drawing Sheets**



(12) **United States Patent**  
**Kroyzer**

(10) **Patent No.:** **US 9,170,033 B2**  
(45) **Date of Patent:** **Oct. 27, 2015**

(54) **METHOD AND APPARATUS FOR OPERATING A SOLAR ENERGY SYSTEM TO ACCOUNT FOR CLOUD SHADING**

(75) Inventor: **Gil Kroyzer**, Jerusalem (IL)

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1259 days.

(21) Appl. No.: **13/010,608**

(22) Filed: **Jan. 20, 2011**

(65) **Prior Publication Data**  
US 2011/0220091 A1 Sep. 15, 2011

**Related U.S. Application Data**  
(60) Provisional application No. 61/296,821, filed on Jan. 20, 2010.

(51) **Int. Cl.**  
**F03G 6/00** (2006.01)  
**F24J 2/40** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC .... **F24J 2/40** (2013.01); **F24J 2/38** (2013.01); **H01L 31/0547** (2013.01); **F24J 2002/0084** (2013.01); **F24J 2002/385** (2013.01); **Y02E 10/47** (2013.01); **Y02E 10/52** (2013.01)

(58) **Field of Classification Search**  
CPC ..... F24J 2/38; F24J 2/40; F24J 2/00; F22B 1/006; F22B 35/00; Y02E 10/46; Y02E 10/47  
USPC ..... 60/641.8–641.15; 126/569–713; 136/243–251  
IPC ..... F24J 2/38  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,999,943 A 9/1961 Willard  
3,892,433 A 7/1975 Blake

(Continued)

FOREIGN PATENT DOCUMENTS

DE 10248068 5/2004  
EP 0106688 3/1985

(Continued)

OTHER PUBLICATIONS

Lopez-Martinez et al., "Vision-based System for the Safe Operation of a Solar Power Tower Plant," Iberamia, 2002, LNAI 2527:pp. 943-952.\*

(Continued)

*Primary Examiner* — Thomas Denion

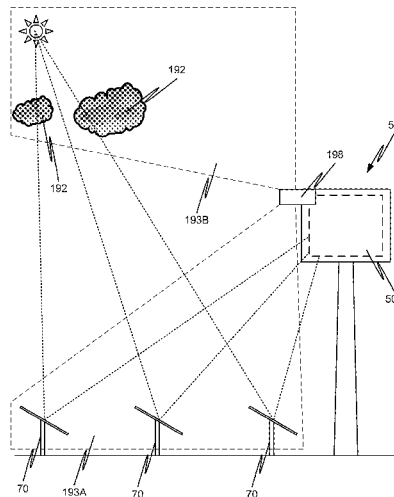
*Assistant Examiner* — Kelsey Stanek

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

Images representative of cloud shadows with respect to a field of heliostats can be used to adjust operation of a solar energy system. For example, images of a field of heliostats and shadows produced by the clouds can be obtained. Additionally or alternatively, images of the sky and clouds can be obtained. The images can be analyzed to determine a shading parameter. Based on the shading parameter, an operating parameter of the solar energy system can be changed or maintained. For example, the operating parameter may include aiming directions for one or more of the heliostats. Cloud characteristics in addition to the location of the cloud shadow can be used in determining the shading parameter. Such characteristics can be used in determining if and/or how to change the operating parameter of the solar energy system.

**8 Claims, 17 Drawing Sheets**





US009161385B2

(12) **United States Patent**  
**Azancot et al.**

(10) **Patent No.:** **US 9,161,385 B2**  
(45) **Date of Patent:** **Oct. 13, 2015**

(54) **SYSTEMS AND METHODS FOR WIRELESS COMMUNICATIONS IN A SOLAR FIELD**

Y02B 90/2638; Y02B 90/2653; F24J 2/40; F24J 2002/0084; F24J 2200/04; C10J 2300/123; C10J 2300/1292; G02B 19/0042; G01R 22/063; H04W 16/18; H04W 84/12; H02G 1/00; H02J 3/383; H02J 3/385; H02J 7/0052; H02J 7/35; H02J 13/0024; H02J 13/0062; H02J 13/0075

(71) Applicant: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

USPC ..... 370/310-350  
See application file for complete search history.

(72) Inventors: **Yossi Azancot**, Jerusalem (IL); **Lev Razamat**, Rishon Letziyon (IL)

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(56) **References Cited**

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 135 days.

U.S. PATENT DOCUMENTS

2004/0054774 A1 3/2004 Barber et al.  
2008/0084858 A1 4/2008 Hart et al.  
2009/0137221 A1 5/2009 Nanda et al.

(21) Appl. No.: **14/088,529**

(Continued)

(22) Filed: **Nov. 25, 2013**

OTHER PUBLICATIONS

(65) **Prior Publication Data**

International Search Report and Written Opinion for International Application No. PCT/IB13/60389, mailed May 12, 2014.

US 2014/0146741 A1 May 29, 2014

**Related U.S. Application Data**

*Primary Examiner* — Tri H Phan

(60) Provisional application No. 61/729,701, filed on Nov. 26, 2012.

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(51) **Int. Cl.**

(57) **ABSTRACT**

**H04B 7/00** (2006.01)  
**H04B 7/185** (2006.01)  
**H04W 4/00** (2009.01)  
**H04W 84/12** (2009.01)  
**H04W 16/18** (2009.01)

Embodiments relate to methods and systems of controlling and operating a wirelessly controlled solar field. By placing a higher density of access points in regions close to the solar field border, communication interference may be mitigated. A method of mitigating interference between an access point and a heliostat in a wireless communication system located in a solar field, may include in a first section of the solar field, deploying a first plurality of access points such that each of the access points is a first distance from its neighbor; and in a second section of the solar field, deploying a second plurality of access points such that each of the access points is a second distance from its neighbor. The first distance is greater than the second distance and the second section of the solar field may be closer to a perimeter of the solar field.

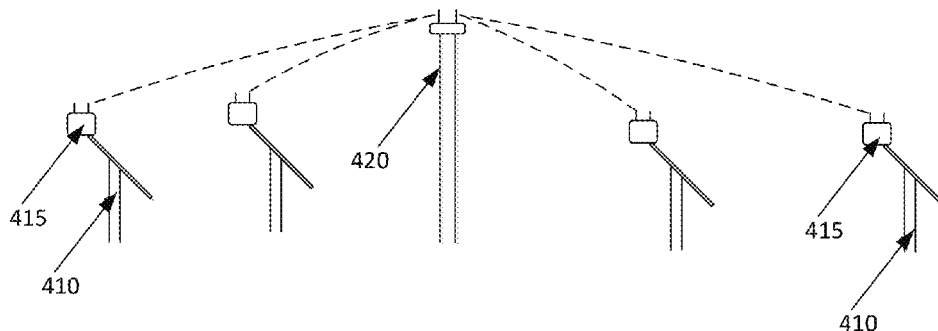
(52) **U.S. Cl.**

CPC ..... **H04W 84/12** (2013.01); **H04W 16/18** (2013.01)

(58) **Field of Classification Search**

CPC ..... Y02E 10/40; Y02E 40/00; Y02E 40/72; Y04S 10/30; Y04S 10/40123; Y04S 20/34; Y04S 20/40; Y04S 20/52; Y04S 20/322; Y04S 20/525; Y04S 40/122; Y04S 1/24; Y04S 1/126; Y02B 70/343; Y02B 70/3208; Y02B 90/242; Y02B 90/248; Y02B 90/2623;

**27 Claims, 10 Drawing Sheets**





(12) **United States Patent**  
**Luz et al.**

(10) **Patent No.:** **US 9,046,307 B2**  
(45) **Date of Patent:** **Jun. 2, 2015**

(54) **INTEGRATED SOLAR ENERGY THERMAL STORAGE SYSTEM AND METHODS**

(71) Applicant: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(72) Inventors: **Moshe Luz**, Petach Tikva (IL); **Alon Ganany**, Tel Aviv (IL)

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 226 days.

(21) Appl. No.: **13/873,319**

(22) Filed: **Apr. 30, 2013**

(65) **Prior Publication Data**

US 2013/0292084 A1 Nov. 7, 2013

**Related U.S. Application Data**

(60) Provisional application No. 61/641,739, filed on May 2, 2012.

(51) **Int. Cl.**

**F03G 6/00** (2006.01)  
**F01K 1/00** (2006.01)  
**F28D 20/00** (2006.01)  
**F03G 6/06** (2006.01)  
**F24J 2/07** (2006.01)  
**F24J 2/40** (2006.01)  
**F24J 2/16** (2006.01)  
**F24J 2/10** (2006.01)

(52) **U.S. Cl.**

CPC **F28D 20/00** (2013.01); **F03G 6/06** (2013.01); **F28D 2020/0047** (2013.01); **F24J 2/07** (2013.01); **F24J 2/16** (2013.01); **F24J 2/40** (2013.01); **F24J 2002/1076** (2013.01); **Y02E 10/41** (2013.01)

(58) **Field of Classification Search**

CPC ... **F28D 20/00**; **F28D 2020/0047**; **F03G 6/06**; **F24J 2/40**; **F24J 2/07**; **F24J 2/16**; **F24J 2002/1076**; **Y02E 10/41**  
USPC ..... **60/641.8–641.15, 659**  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,455,826 A \* 6/1984 Knoos ..... 60/526  
7,191,597 B2 \* 3/2007 Goldman ..... 60/641.8  
7,654,073 B2 \* 2/2010 Primlani ..... 60/39.183  
2011/0153095 A1 \* 6/2011 Rock et al. .... 700/286  
2012/0319410 A1 \* 12/2012 Ambrosek et al. .... 290/1 R

\* cited by examiner

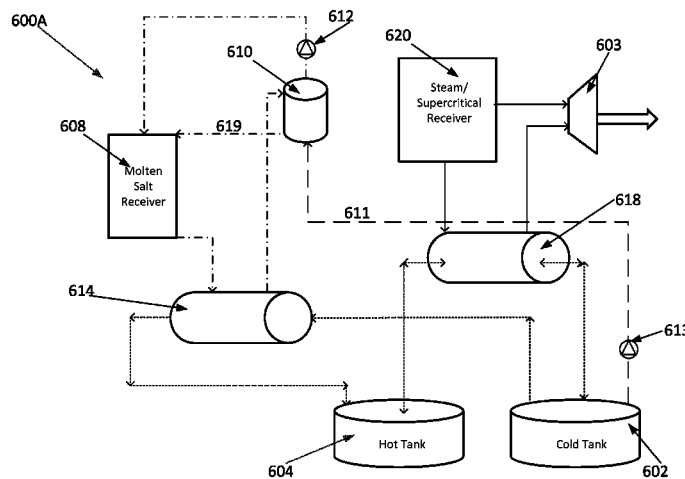
*Primary Examiner* — Hoang Nguyen

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy thermal storage system can include a receiver in which a first storage medium is heated by insolation. First and second thermal storage reservoirs for a second storage medium can be provided. A first heat exchanger can be configured to transfer heat in the first storage medium to the second storage medium. A buffer tank can be located at a height above the receiver and can be fluidically connected to the first heat exchanger at its inlet and the receiver at its outlet. A second heat exchanger can be configured to transfer heat between the second storage medium and pressurized water and/or steam. The use of a buffer tank in conjunction with the first storage medium increases the overall efficiency of the system and results in a higher temperature for the thermal storage system, which can be used to generate superheated steam.

**22 Claims, 7 Drawing Sheets**





(12) **United States Patent**  
**Kaufmann et al.**

(10) **Patent No.:** **US 9,038,387 B2**  
(45) **Date of Patent:** **May 26, 2015**

(54) **SOLAR THERMAL ELECTRICITY GENERATING SYSTEMS WITH THERMAL STORAGE**

(75) Inventors: **Gabriel Kaufmann**, Beit Hanany (IL); **Leon Afremov**, Tel Aviv (IL); **Yona Magen**, Moshav Nehosha (IL); **Binyamin Koretz**, Eilat (IL)

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 151 days.

(21) Appl. No.: **13/600,176**

(22) Filed: **Aug. 30, 2012**

(65) **Prior Publication Data**  
US 2013/0049368 A1 Feb. 28, 2013

**Related U.S. Application Data**

(60) Provisional application No. 61/529,875, filed on Aug. 31, 2011.

(51) **Int. Cl.**  
**H01L 31/052** (2014.01)  
**F01D 15/10** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC . **F01D 15/10** (2013.01); **F02C 1/05** (2013.01); **F03G 6/00** (2013.01); **F24J 2/07** (2013.01); **F24J 2/18** (2013.01); **F24J 2/38** (2013.01); **F28D 20/00** (2013.01);  
(Continued)

(58) **Field of Classification Search**  
USPC ..... 290/52; 60/641.8, 653  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

4,094,148 A 6/1978 Nelson  
4,119,143 A 10/1978 Robinson, Jr.  
(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 2510168 A1 9/1976  
DE 10329623 B3 1/2005  
(Continued)

**OTHER PUBLICATIONS**

Abengoa Solar, Inc., "Advanced Thermal Storage for Central Receivers with Supercritical Coolants," Grant DE-FG36-08G018149, Jun. 2010.

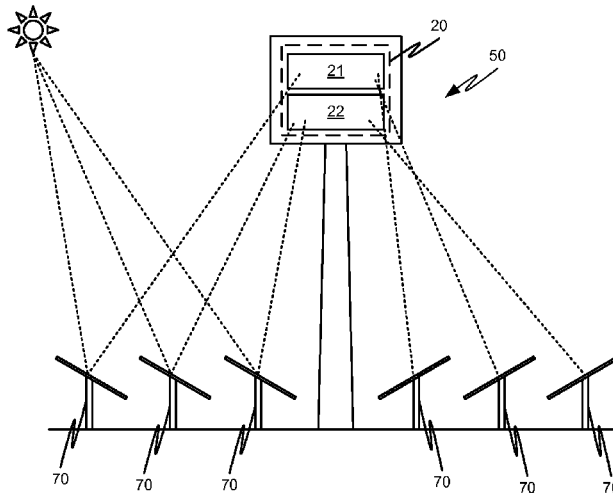
(Continued)

*Primary Examiner* — Kenneth Bomberg  
*Assistant Examiner* — Shafiq Mian  
(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

Thermal energy can be stored in a fluid-based thermal storage system for later use. The stored thermal energy may be derived from steam generated using insolation in a steam-based solar power system. The thermal storage system can store energy when insolation is generally available. Alternatively or additionally, the thermal energy may be derived from electricity from the electrical grid. For example, the thermal energy can store energy when the electrical grid has excess electricity available for storage. At a later time, the energy stored in the thermal storage system can be released to heat pressurized water or steam in addition to or in place of steam generated by the insolation. For example, the stored thermal energy may be used in preheating the solar power system during startup, in supplementing steam output of the solar power system, or to replace steam generation during low insolation periods.

**16 Claims, 6 Drawing Sheets**





US009003795B2

(12) **United States Patent**  
**Katz et al.**

(10) **Patent No.:** **US 9,003,795 B2**  
(45) **Date of Patent:** **Apr. 14, 2015**

(54) **METHOD AND APPARATUS FOR OPERATING A SOLAR STEAM SYSTEM**

USPC ..... 60/641.1-641.15, 641.8, 664, 645;  
126/600, 617, 601, 605, 610  
See application file for complete search history.

(75) Inventors: **Sami Katz**, Kiryat Bialik (IL); **Israel Kroizer**, Jerusalem (IL)

(56) **References Cited**

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

U.S. PATENT DOCUMENTS

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 31 days.

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
(Continued)

FOREIGN PATENT DOCUMENTS

(21) Appl. No.: **13/511,158**

DE 10248068 5/2004  
EP 0106688 3/1985

(22) PCT Filed: **Nov. 23, 2010**

(Continued)

(86) PCT No.: **PCT/IB2010/055368**

OTHER PUBLICATIONS

§ 371 (c)(1),  
(2), (4) Date: **May 22, 2012**

BCB Informatica y Control. Heliostat Calibration for Concentrating Solar Power Plants Using Machine Vision [online]. [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: http://beb.es/documentos/descargar.php?id=29>.

(87) PCT Pub. No.: **WO2011/064718**

PCT Pub. Date: **Jun. 3, 2011**

(Continued)

(65) **Prior Publication Data**

US 2012/0227401 A1 Sep. 13, 2012

*Primary Examiner* — Thomas Denion

*Assistant Examiner* — Kelsey Stanek

**Related U.S. Application Data**

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(60) Provisional application No. 61/264,055, filed on Nov. 24, 2009.

(57) **ABSTRACT**

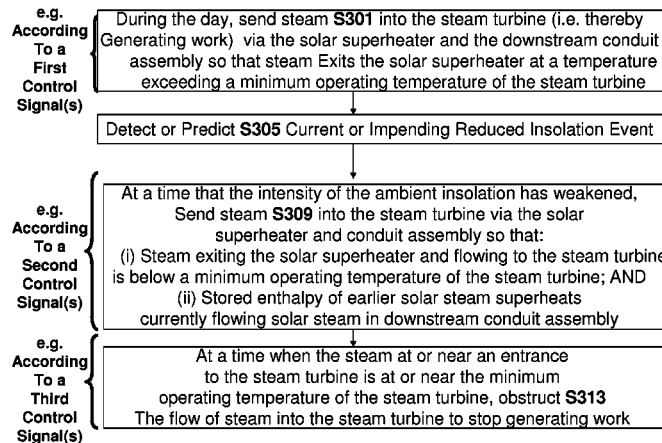
(51) **Int. Cl.**  
**B60K 16/00** (2006.01)  
**F24J 2/07** (2006.01)  
**F24J 2/16** (2006.01)

The disclosed subject matter relates to methods and systems for operating a solar steam system in response to a detected or predicted reduced insolation condition (for example, sunset or a cloud condition). In some embodiments, for a period of time, enthalpy stored within a solid material of a conduit via which steam travels en route to a steam turbine is used to heat the steam to drive the turbine. In some embodiments, a net migration of heliostats away from the steam superheater is carried out in response to the detected or predicted reduced insolation condition.

(52) **U.S. Cl.**  
CPC .. **F24J 2/07** (2013.01); **Y02E 10/41** (2013.01);  
**F24J 2/16** (2013.01); **Y02E 10/46** (2013.01)

(58) **Field of Classification Search**  
CPC ..... F03G 6/003; F03G 6/065; F22B 1/006;  
F24J 2/07; F24J 2/16; Y02E 10/41; Y02E  
10/46

**20 Claims, 27 Drawing Sheets**





(12) **United States Patent**  
**Magdassi et al.**

(10) **Patent No.:** **US 9,574,092 B2**  
(45) **Date of Patent:** **Feb. 21, 2017**

- (54) **SOLAR-RADIATION-ABSORBING FORMULATIONS AND RELATED APPARATUS AND METHODS**
- (75) Inventors: **Shlomo Magdassi**, Jerusalem (IL);  
**Daniel Mandler**, Jerusalem (IL);  
**Mubeen Baidossi**, Kefar Qara (IL);  
**Rachel Assa**, Moshav Ginaton (IL);  
**Ophir Chernin**, Beit Shemesh (IL);  
**Yaniv Binyamin**, Tzur Hadassah (IL)
- (73) Assignee: **BrightSource Industries (Israel), Ltd.**,  
Jerusalem (IL)

4,278,829	A	7/1981	Powell	
4,300,532	A	11/1981	Olsen	
4,530,722	A	7/1985	Moore et al.	
4,849,298	A	7/1989	Raevsky	
5,154,769	A	10/1992	Kuske et al.	
5,196,228	A *	3/1993	Kirby .....	C09D 183/04 427/226
5,250,112	A	10/1993	Wussow et al.	
5,409,777	A	4/1995	Kennedy et al.	
5,814,434	A	9/1998	Nakamura et al.	
6,632,529	B1	10/2003	Clough	
2002/0047058	A1	4/2002	Verhoff et al.	
2003/0035917	A1	2/2003	Hyman	
2004/0011252	A1	1/2004	Sturgill et al.	
2005/0107870	A1	5/2005	Wang et al.	
2006/0011490	A1 *	1/2006	Nguyen .....	C25C 3/08 205/372
2006/0052233	A1	3/2006	Beeckman et al.	
2006/0249705	A1	11/2006	Wang et al.	
2007/0027241	A1	2/2007	Akamatsu	
2007/0149673	A1	6/2007	Sturgill et al.	
2008/0038561	A1	2/2008	Yoshizawa et al.	
2009/0162651	A1	6/2009	Rios et al.	
2010/0139749	A1	6/2010	Mapel	
2010/0139818	A1	6/2010	Ishii et al.	
2010/0167033	A1	7/2010	Poppe et al.	
2010/0218822	A1	9/2010	Yamasaki et al.	
2010/0239871	A1	9/2010	Scheffer et al.	
2011/0017097	A1	1/2011	Ruckebusch et al.	

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 786 days.

- (21) Appl. No.: **14/112,052**
- (22) PCT Filed: **Apr. 17, 2012**
- (86) PCT No.: **PCT/US2012/033878**  
§ 371 (c)(1),  
(2), (4) Date: **Jan. 24, 2014**

- (87) PCT Pub. No.: **WO2012/145283**  
PCT Pub. Date: **Oct. 26, 2012**

- (65) **Prior Publication Data**  
US 2014/0141236 A1 May 22, 2014

- Related U.S. Application Data**
- (60) Provisional application No. 61/476,301, filed on Apr. 17, 2011.

- (51) **Int. Cl.**  
**C09D 5/32** (2006.01)  
**C09D 183/16** (2006.01)  
**F24J 2/48** (2006.01)  
**C09D 7/12** (2006.01)  
**B05D 3/00** (2006.01)  
**F24J 2/07** (2006.01)

- (52) **U.S. Cl.**  
CPC ..... **C09D 5/32** (2013.01); **B05D 3/002** (2013.01); **C09D 7/1216** (2013.01); **F24J 2/485** (2013.01); **F24J 2/07** (2013.01); **Y02E 10/40** (2013.01); **Y10T 428/26** (2015.01); **Y10T 428/31612** (2015.04)

- (58) **Field of Classification Search**  
CPC ..... C09D 5/32; F24J 2/485; B05D 3/002  
See application file for complete search history.

- (56) **References Cited**  
**U.S. PATENT DOCUMENTS**  
3,755,223 A \* 8/1973 Engel ..... C08L 63/00  
244/1 R  
4,224,355 A 9/1980 Lampkin et al.

**OTHER PUBLICATIONS**

International Search Report and Written Opinion for International Application No. PCT/US12/33878.  
Office Action issued Apr. 28, 2015, in Chinese Application No. 201280001921.9.

\* cited by examiner

*Primary Examiner* — Charles Boyer  
(74) *Attorney, Agent, or Firm* — Potomac Law Group, PLLC; Mark Catan

(57) **ABSTRACT**

Paint formulations having a high absorptivity with respect to solar radiation are disclosed herein. The disclosed paint formulations are also thermally and mechanically durable, thereby enabling the paint formulations to be used on components in solar thermal applications where exposure to high temperatures and environmental conditions may be an issue. The paint formulation can include an oxide-based pigment, an organic binder, one or more additives, an inorganic filler, and/or an organic solvent. The pigment can have a relatively high absorptivity with respect to light having a wavelength in the range from 250 nm to 3000 nm. Curing of the paint formulation can irreversibly convert the organic binder into an inorganic binder.

(12) **United States Patent**  
**Gilon et al.**

(10) **Patent No.:** **US 8,931,475 B2**  
(45) **Date of Patent:** **Jan. 13, 2015**

(54) **SYSTEMS AND METHODS FOR CONTROL OF A SOLAR POWER TOWER USING INFRARED THERMOGRAPHY**

USPC ..... 431/600, 603, 680, 681, 696, 701, 714;  
126/572, 601, 584, 604, 605, 600, 603,  
126/680, 681, 696, 701, 714

See application file for complete search history.

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Ophir Chernin**, Ramat Beit Shemesh (IL); **Gideon Goldwine**, Jerusalem (IL); **Gil Kroyzer**, Jerusalem (IL); **Rotem Hayut**, Jerusalem (IL); **Dan Franck**, Modi'in (IL); **Israel Kroizer**, Jerusalem (IL); **Ziv Aumann**, Jerusalem (IL)

(56) **References Cited**

U.S. PATENT DOCUMENTS

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
(Continued)

FOREIGN PATENT DOCUMENTS

DE 10248068 5/2004  
EP 0106688 3/1985

(Continued)

OTHER PUBLICATIONS

Cohen et al., "Final Report on the Operation and Maintenance Improvement Project for Concentrating Solar Power Plants," SAND99-1290 [online], Jun. 1999 [retrieved on May 16, 2012]. Retrieved from the Internet: <URL: <http://infohouse.p2ric.org/ref/17/16933/1693301.pdf>>.

(Continued)

*Primary Examiner* — Avinash Savani

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

Systems and methods for directly monitoring energy flux of a solar receiver in a solar energy-based power generation system include measuring infrared radiation emanating from the solar receiver. Such measurement can be achieved using one or more infrared thermography detectors, such as an IR camera. Resulting thermal data obtained by the imaging can be used to determine energy flux distribution on the receiver. A user or a system controller can use the determined flux distribution to adjust heliostat aiming to achieve a desired operation condition. For example, heliostats can be adjusted to achieve a uniform energy flux distribution across the external surface of the receiver and/or to maximize heat transfer to a fluid flowing through the receiver within system operating limits.

**27 Claims, 6 Drawing Sheets**

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1228 days.

(21) Appl. No.: **12/500,101**

(22) Filed: **Jul. 9, 2009**

(65) **Prior Publication Data**

US 2010/0006087 A1 Jan. 14, 2010

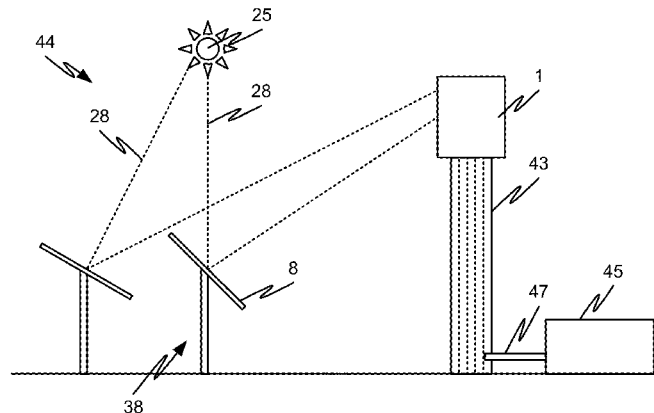
**Related U.S. Application Data**

(60) Provisional application No. 61/079,441, filed on Jul. 10, 2008.

(51) **Int. Cl.**  
**F24J 2/07** (2006.01)  
**F24J 2/10** (2006.01)  
(Continued)

(52) **U.S. Cl.**  
CPC .... **F24J 2/07** (2013.01); **F24J 2/10** (2013.01);  
**F24J 2/402** (2013.01); **F24J 2/38** (2013.01);  
**Y02E 10/41** (2013.01); **Y02E 10/47** (2013.01)  
USPC ..... **126/572**; 126/600; 126/603; 126/680;  
126/601; 126/701

(58) **Field of Classification Search**  
CPC ..... F24J 2/402; F24J 2/07; F24J 2/10;  
F24J 2/38; Y02E 10/41







US009541071B2

(12) **United States Patent**  
**Kroizer**

(10) **Patent No.:** **US 9,541,071 B2**  
(45) **Date of Patent:** **\*Jan. 10, 2017**

(54) **CONCENTRATED SOLAR POWER PLANT WITH INDEPENDENT SUPERHEATER**

(71) Applicant: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(72) Inventor: **Israel Kroizer**, Jerusalem (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 233 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/092,130**

(22) Filed: **Nov. 27, 2013**

(65) **Prior Publication Data**

US 2014/0152024 A1 Jun. 5, 2014

**Related U.S. Application Data**

(60) Provisional application No. 61/733,019, filed on Dec. 4, 2012.

(51) **Int. Cl.**  
**F03G 6/06** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **F03G 6/065** (2013.01); **F03G 6/06** (2013.01); **Y02E 10/46** (2013.01); **Y02E 20/14** (2013.01)

(58) **Field of Classification Search**  
CPC ..... **F03G 6/065**; **F03G 6/06**; **Y02E 20/14**; **Y02E 10/46**

(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,933,885 A 4/1960 Vago et al.  
3,977,197 A 8/1976 Brantley et al.  
(Continued)

FOREIGN PATENT DOCUMENTS

DE 2510168 A1 9/1976  
DE 10329623 B3 1/2005  
(Continued)

OTHER PUBLICATIONS

Abengoa Solar, Inc., "Advanced Thermal Storage for Central Receivers with Supercritical Coolants," Grant DE-FG36-08G018149, Jun. 2010.

(Continued)

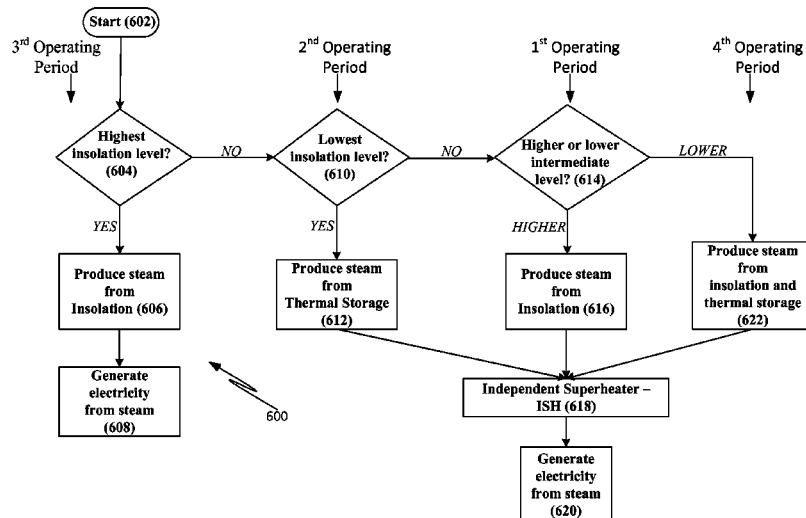
*Primary Examiner* — Hoang Nguyen

(74) *Attorney, Agent, or Firm* — Potomac Law Group, PLLC; Mark Catan

(57) **ABSTRACT**

Steam can be generated using insolation by a solar collection system. A thermal storage system can store enthalpy in insolation-generated steam at times and can generate steam from stored enthalpy at other times. During some operating periods, a gas-fired superheater can further heat the generated steam to provide superheated steam to generate electricity. Steam at a substantially uniform electricity generating temperature may be produced selectively and at different operating periods from insolation only, from insolation and gas firing, from transfer of enthalpy from a thermal storage system and gas firing, or from a combination of insolation, stored enthalpy transfer, and gas firing. Operating periods can be characterized by at least one of an insolation level, a time of day, or a stage in the operation process. The generated steam can be used in the production of electricity.

**20 Claims, 8 Drawing Sheets**





(12) **United States Patent**  
**Kroyzer et al.**

(10) **Patent No.:** **US 8,739,775 B2**  
(45) **Date of Patent:** **Jun. 3, 2014**

(54) **DEVICES, METHODS, AND SYSTEMS FOR CONTROL OF HELIOSTATS**

(75) Inventors: **Gil Kroyzer**, Jerusalem (IL); **Rotem Hayut**, Yavne (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 856 days.

(21) Appl. No.: **12/867,552**

(22) PCT Filed: **Feb. 17, 2009**

(86) PCT No.: **PCT/US2009/034323**

§ 371 (c)(1),  
(2), (4) Date: **Oct. 12, 2010**

(87) PCT Pub. No.: **WO2009/103077**

PCT Pub. Date: **Aug. 20, 2009**

(65) **Prior Publication Data**

US 2011/0036343 A1 Feb. 17, 2011

**Related U.S. Application Data**

(60) Provisional application No. 61/028,525, filed on Feb. 14, 2008.

(51) **Int. Cl.**  
**F24J 2/38** (2006.01)

(52) **U.S. Cl.**  
USPC ..... **126/601**; 126/574; 126/593; 126/599

(58) **Field of Classification Search**  
USPC ..... 126/571–577, 593, 599, 600–603, 126/605–607

See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 5/2004  
EP 0106688 3/1985

(Continued)

**OTHER PUBLICATIONS**

BCB Informatica y Control. Heliostat Calibration for Concentrating Solar Power Plants Using Machine Vision [online]. [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: http://ccb.es/documentos/descargar.php?id=29>.

(Continued)

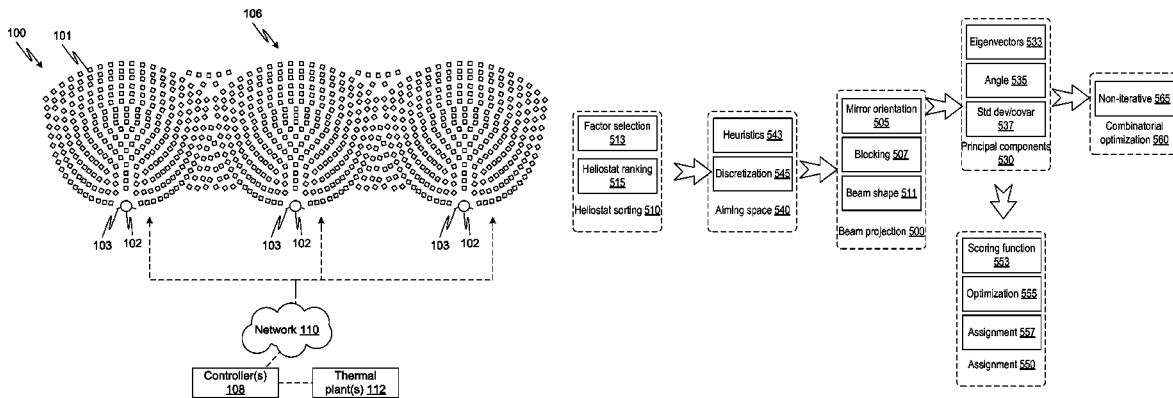
*Primary Examiner* — Scott J Sugarman  
*Assistant Examiner* — Robert E Tallman

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge, P.C.; Mark A. Catan

(57) **ABSTRACT**

Adherence to flux or resultant measurable parameter limits, ranges, or patterns can be achieved by directing heliostat mounted mirrors to focus on aiming points designated on the surface of a solar receiver. Different heliostats can be directed to different aiming points, and a heliostat can be directed to different aiming points at different times. The cumulative flux distribution resulting from directing a plurality of heliostats to any aiming point on a receiver surface can be predicted by using statistical methods to calculate the expected beam projection for each individual heliostat or alternatively for a group of heliostats. Control of the heliostats in a solar power system can include designating aiming points on a receiver from time to time and assigning heliostats to aiming points from time to time in accordance with an optimization goal.

**26 Claims, 5 Drawing Sheets**





(12) **United States Patent**  
**Silberstein et al.**

(10) **Patent No.:** **US 9,249,785 B2**  
(45) **Date of Patent:** **Feb. 2, 2016**

(54) **METHOD AND SYSTEM FOR OPERATING A SOLAR STEAM SYSTEM DURING REDUCED-INSOLATION EVENTS**

(71) Applicant: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

(72) Inventors: **Elon Silberstein**, Arad (IL); **Rotem Hayut**, Jerusalem (IL)

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISREAL) LTD.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 229 days.

(21) Appl. No.: **13/728,328**

(22) Filed: **Dec. 27, 2012**

(65) **Prior Publication Data**

US 2013/0192589 A1 Aug. 1, 2013

**Related U.S. Application Data**

(60) Provisional application No. 61/593,123, filed on Jan. 31, 2012.

(51) **Int. Cl.**

**F03G 6/06** (2006.01)

**F01K 13/02** (2006.01)

**F22G 5/12** (2006.01)

(52) **U.S. Cl.**

CPC . **F03G 6/06** (2013.01); **F01K 13/02** (2013.01); **F03G 6/065** (2013.01); **F22G 5/12** (2013.01); **Y02E 10/46** (2013.01)

(58) **Field of Classification Search**

CPC ..... **Y02E 10/40–10/46**; **F24J 2/40–2/407**; **F22B 35/104**; **F22B 1/006**; **F03G 6/003**; **F03G 6/065**

USPC ..... **60/600**, **641.8–641.15**; **126/569–620**  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 5/2004  
EP 0106688 3/1985

(Continued)

**OTHER PUBLICATIONS**

“Mean and Peak Wind Load Reduction on Heliostats,” Colorado State University, Solar Energy Research Institute, U.S. Department of Energy [online], Sep. 1987 [retrieved on May 16, 2012]. Retrieved from the Internet: <URL: <http://www.nrel.gov/docs/legosti/old/3212.pdf>>.

(Continued)

*Primary Examiner* — Thomas Denion

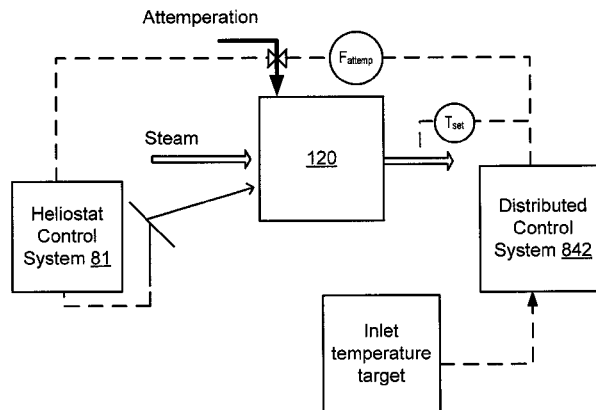
*Assistant Examiner* — Laert Dounis

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy system can be controlled during periods of reduced insolation. For example, one or more environmental condition sensors can detect environmental properties indicating current or expected insolation levels and can generate at least one signal indicating a current or impending transient reduced-insolation event. The at least one signal can be received (for example, by a controller) from the sensors that indicates changes in insolation. Responsively to the at least one signal, characteristics of a current reduced insolation event or of an impending transient reduced-insolation event can be calculated. In response to the calculated characteristics, a quantity of available insolation can be calculated. An attemperation flow rate in the solar steam system can be controlled responsively to the calculated quantity of available insolation such that the temperature of steam entering the steam turbines is maintained within a predefined range.

**18 Claims, 12 Drawing Sheets**





US008627664B2

(12) **United States Patent**  
**Katz et al.**

(10) **Patent No.:** **US 8,627,664 B2**  
(45) **Date of Patent:** **Jan. 14, 2014**

(54) **METHOD AND SYSTEM FOR OPERATING A SOLAR STEAM SYSTEM**

(75) Inventors: **Sami Katz**, Kiriati-Bialik (IL); **Israel Kroizer**, Jerusalem (IL)

(73) Assignee: **BrightSource Industries (Israel), Ltd.**, Jerusalem (IL)

4,034,735	A	7/1977	Waldrup
4,044,753	A	8/1977	Fletcher et al.
4,102,326	A	7/1978	Sommer
4,117,682	A	10/1978	Smith
4,146,785	A	3/1979	Neale
4,172,443	A	10/1979	Sommer
4,219,729	A	8/1980	Smith
4,227,513	A	10/1980	Blake et al.

(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 448 days.

**FOREIGN PATENT DOCUMENTS**

DE	10248068	5/2004
EP	0106688	3/1985

(Continued)

(21) Appl. No.: **12/905,789**

(22) Filed: **Oct. 15, 2010**

**OTHER PUBLICATIONS**

(65) **Prior Publication Data**

US 2011/0088396 A1 Apr. 21, 2011

Lopez-Martinez et al., "Vision-based system for the safe operation of a solar power tower plant," Iberamia, 2002, LNAI 2527: pp. 943-952.\*

(Continued)

**Related U.S. Application Data**

(60) Provisional application No. 61/252,121, filed on Oct. 15, 2009.

*Primary Examiner* — Thomas Denion

*Assistant Examiner* — Philip Eklem

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(51) **Int. Cl.**  
**F03G 6/00** (2006.01)

(52) **U.S. Cl.**  
USPC ..... **60/641.8**; 60/641.11; 60/641.13;  
60/641.14; 60/641.15

(57) **ABSTRACT**

Methods, apparatus and systems for operating a solar steam system in response to a detected or predicted reduced or impending reduced insolation event are disclosed herein. Examples of transient reduced insolation events include but are not limited to cloud-induced reduction in insolation, dust-induced reduction in insolation, and insolation events caused by solar eclipses. In some embodiments, in response to the detecting or predicting, steam flow is regulated within the solar steam system to reduce a flow rate into a steam turbine. Alternatively or additionally, one or more heliostats may be responsively redirected onto a steam superheater or steam re-heater.

(58) **Field of Classification Search**  
USPC ..... 60/641.8, 641.11–641.15, 653,  
60/677–679, 663, 666; 126/585, 593, 595,  
126/601

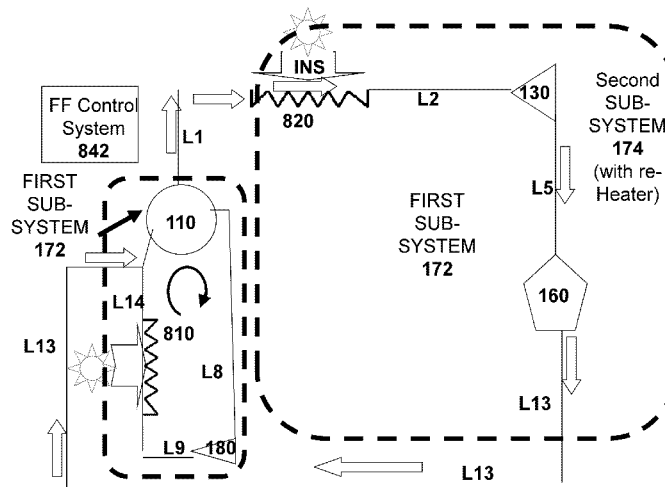
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274	A	1/1906	Carter
2,999,943	A	9/1961	Willard
3,892,433	A	7/1975	Blake
3,924,604	A	12/1975	Anderson

**3 Claims, 33 Drawing Sheets**





US008544272B2

(12) **United States Patent**  
**Kroizer et al.**

(10) **Patent No.:** **US 8,544,272 B2**  
(45) **Date of Patent:** **Oct. 1, 2013**

(54) **SOLAR RECEIVER**

(56) **References Cited**

(75) Inventors: **Israel Kroizer**, Jerusalem (IL); **Gabriel Kaufmann**, Beit Hananya (IL); **Leon Afremov**, Yehud (IL); **Yoel Gilon**, Jerusalem (IL)

U.S. PATENT DOCUMENTS  
811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
(Continued)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

FOREIGN PATENT DOCUMENTS  
EP 0106688 3/1985  
JP 56-102646 8/1981  
(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 732 days.

OTHER PUBLICATIONS

(21) Appl. No.: **12/664,038**

"Mean and Peak Wind Load Reduction on Heliostats," Colorado State University, Solar Energy Research Institute, U.S. Department of Energy [online], Sep. 1987 [retrieved on May 16, 2012]. Retrieved from the Internet: <URL: <http://www.nrel.gov/docs/legosti/old/3212.pdf>>.

(22) PCT Filed: **Jun. 11, 2008**

(86) PCT No.: **PCT/US2008/066597**

§ 371 (c)(1),  
(2), (4) Date: **Jun. 1, 2010**

(Continued)

(87) PCT Pub. No.: **WO2008/154599**

PCT Pub. Date: **Dec. 18, 2008**

*Primary Examiner* — Kenneth Bomberg  
*Assistant Examiner* — Shafiq Mian  
(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(65) **Prior Publication Data**

US 2010/0236239 A1 Sep. 23, 2010

(57) **ABSTRACT**

**Related U.S. Application Data**

(60) Provisional application No. 60/943,096, filed on Jun. 11, 2007.

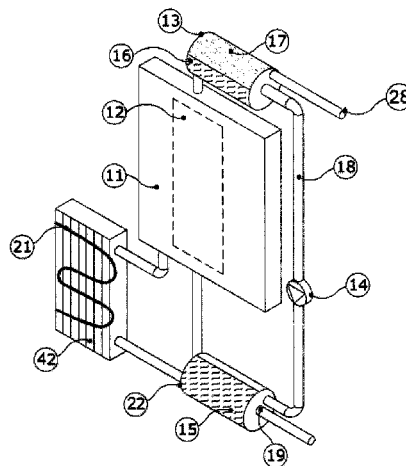
(51) **Int. Cl.**  
**F03G 6/06** (2006.01)  
**F01K 7/34** (2006.01)

A method for generating steam for a turbine electric power plant uses solar radiation. Solar radiation is directed onto a solar receiver. The solar receiver includes a first section, which receives feedwater input and is arranged to heat the feedwater input to generate steam using the directed solar radiation. Feedwater flows through a feedwater vessel to serve as feedwater input to an inlet of the first section of the receiver. Water is separated from the steam in steam separation vessel, which is in fluid communication with an outlet of the first section of the receiver. The feedwater input may be selectively preheated by a source of preheat other than solar energy in response to system operating conditions, predicted insolation schedule, or an electrical energy tariff schedule.

(52) **U.S. Cl.**  
USPC ..... **60/641.8**; 60/653

(58) **Field of Classification Search**  
USPC ..... 60/641.8, 653  
See application file for complete search history.

**9 Claims, 9 Drawing Sheets**



(12) **United States Patent**  
**Kaufmann et al.**

(10) **Patent No.:** **US 9,255,569 B2**  
(45) **Date of Patent:** **Feb. 9, 2016**

(54) **SYSTEMS, METHODS, AND DEVICES FOR OPERATING A SOLAR THERMAL ELECTRICITY GENERATING SYSTEM**

126/584–588, 594–598, 609–616;  
60/641.8–641.15, 646, 676;  
700/286–288, 291

(75) Inventors: **Gabriel Kaufmann**, Beit Hananya (IL);  
**Leon Afremov**, Tel Aviv (IL); **Yona Magen**, Moshav Nehosha (IL)

See application file for complete search history.

(56) **References Cited**

(73) Assignee: **BRIGHTSOURCE INDUSTRIES (ISRAEL) LTD.**, Jerusalem (IL)

U.S. PATENT DOCUMENTS

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 220 days.

3,243,961 A \* 4/1966 Caracristi ..... 60/646  
4,102,326 A 7/1978 Sommer

(Continued)

(21) Appl. No.: **13/695,145**

FOREIGN PATENT DOCUMENTS

(22) PCT Filed: **May 3, 2011**

WO 2008/154599 12/2008

(86) PCT No.: **PCT/US2011/034900**

OTHER PUBLICATIONS

§ 371 (c)(1),

(2), (4) Date: **Dec. 5, 2012**

International Search Report and Written Opinion for International Application No. PCT/US11/34900.

(87) PCT Pub. No.: **WO2011/140021**

(Continued)

PCT Pub. Date: **Nov. 10, 2011**

*Primary Examiner* — Thomas Denion

(65) **Prior Publication Data**

*Assistant Examiner* — Laert Dounis

US 2013/0091842 A1 Apr. 18, 2013

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

**Related U.S. Application Data**

(57) **ABSTRACT**

(60) Provisional application No. 61/330,500, filed on May 3, 2010.

In a startup period for a solar thermal electricity generating system, a non-solar source of steam heats a downstream receiver (for example, a superheating receiver) prior to insolation being available. Insolation, once available, heats an upstream receiver (for example, an evaporator). The upstream receiver can be arranged in a recirculation loop with a steam separation drum, which may be bypassed during the initial heating of the upstream receiver by insolation. Once sufficient temperature and pressure have been reached, steam from the upstream receiver is directed to the downstream receiver by way of the steam separation drum to replace the non-solar source of steam. Heating of the downstream receiver using steam from the upstream receiver continues until a threshold temperature and pressure are reached. Insolation is then directed at both the upstream and downstream receivers to generate steam for electricity production by a turbine.

(51) **Int. Cl.**

**F03G 6/06** (2006.01)

**F03G 6/00** (2006.01)

(Continued)

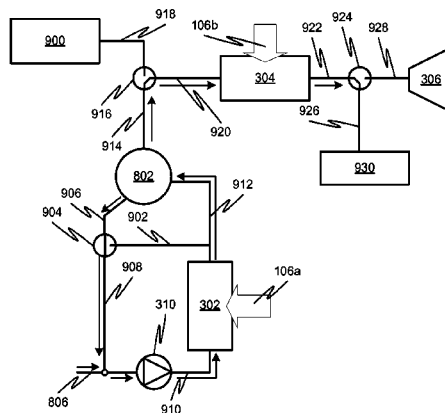
(52) **U.S. Cl.**

CPC ..... **F03G 6/003** (2013.01); **F01K 13/02** (2013.01); **F02C 1/05** (2013.01); **F03G 6/065** (2013.01); **F22B 1/006** (2013.01); **F22B 35/08** (2013.01); **F22B 35/14** (2013.01); **Y02E 10/46** (2013.01)

(58) **Field of Classification Search**

CPC ..... F03G 6/00; F03G 6/003; F03G 6/005; F03G 6/06; F03G 6/065; F03G 6/067; F22G 1/005; F22G 1/06; F22G 1/16; Y02E 10/46  
USPC ..... 126/640, 646, 572–575, 601–602,

**20 Claims, 9 Drawing Sheets**





(12) **United States Patent**  
**Kroizer et al.**

(10) **Patent No.:** **US 8,490,618 B2**  
(45) **Date of Patent:** **Jul. 23, 2013**

(54) **SOLAR RECEIVER**

(75) Inventors: **Israel Kroizer**, Jerusalem (IL); **Gabriel Kaufmann**, Beit Hananya (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 653 days.

(21) Appl. No.: **12/670,622**

(22) PCT Filed: **Jul. 28, 2008**

(86) PCT No.: **PCT/US2008/071366**

§ 371 (c)(1),

(2), (4) Date: **Jun. 2, 2010**

(87) PCT Pub. No.: **WO2009/015388**

PCT Pub. Date: **Jan. 29, 2009**

(65) **Prior Publication Data**

US 2010/0252025 A1 Oct. 7, 2010

**Related U.S. Application Data**

(60) Provisional application No. 60/951,970, filed on Jul. 26, 2007.

(51) **Int. Cl.**  
**F24J 2/24** (2006.01)

(52) **U.S. Cl.**  
USPC ..... **126/600; 126/651; 126/571; 126/634; 126/684; 126/696**

(58) **Field of Classification Search**  
USPC ..... **126/600, 569, 571, 572, 573, 634, 126/684, 696; 60/641.8**  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

3,921,711 A	11/1975	Westbrock
4,015,584 A	4/1977	Haberman
4,055,948 A	11/1977	Kraus et al.
4,117,682 A	10/1978	Smith
4,119,083 A	10/1978	Heyen et al.
4,129,117 A	12/1978	Harvey

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE	2828118	1/1980
DE	10248068	5/2004

(Continued)

**OTHER PUBLICATIONS**

Paul et al., "Optimization of bed parameters for packed bed solar energy collection system," *Renewable Energy*, 2004, 29:pp. 1863-1876.

(Continued)

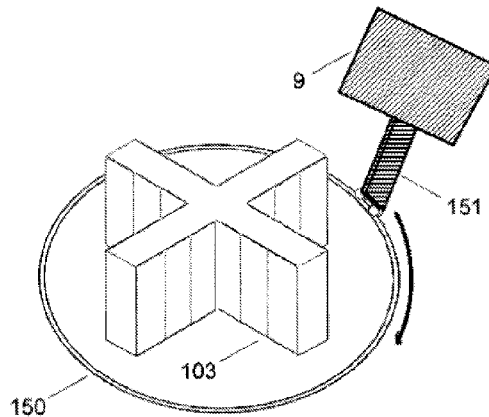
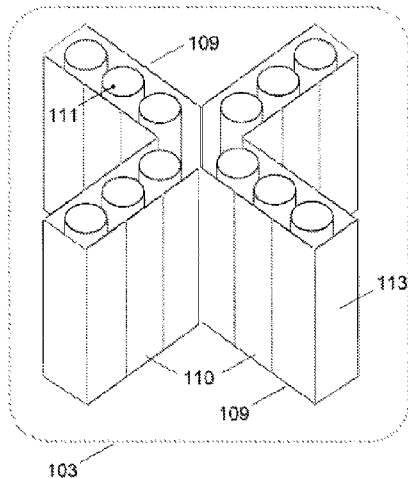
*Primary Examiner* — Alfred Bashichas

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy conversion system may include a receiver with a first heat transfer fluid channel having at least two opposite sides. Each side may present an external surface facing in a direction opposite to that of the external surface of the other opposite side. Each side may be configured to contact a heat transfer fluid carried in the first heat transfer fluid channel. A heliostat field may be configured to direct solar energy to each of the at least two opposite sides during the course of a day such that a thermal stress tending to bend the channel remains below a specified level.

**19 Claims, 8 Drawing Sheets**





US008365718B2

(12) **United States Patent**  
**Gilon et al.**

(10) **Patent No.:** **US 8,365,718 B2**  
(45) **Date of Patent:** **Feb. 5, 2013**

(54) **METHOD AND CONTROL SYSTEM FOR OPERATING A SOLAR POWER TOWER SYSTEM**

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Israel Kroizer**, Jerusalem (IL); **Gil Kroyzer**, Jerusalem (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/192,858**

(22) Filed: **Jul. 28, 2011**

(65) **Prior Publication Data**

US 2012/0024282 A1 Feb. 2, 2012

**Related U.S. Application Data**

(63) Continuation of application No. 12/269,785, filed on Nov. 12, 2008, now Pat. No. 8,001,960.

(60) Provisional application No. 60/987,132, filed on Nov. 12, 2007.

(51) **Int. Cl.**  
**F24J 2/40** (2006.01)

(52) **U.S. Cl.** ..... **126/595**; 126/600; 126/572; 126/601; 126/602; 126/643; 353/3; 136/246; 136/248; 60/641.5

(58) **Field of Classification Search** ..... 126/600, 126/595, 572, 601, 643, 602; 353/3; 136/248, 136/246; 60/641.5

See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard

3,892,433 A 7/1975 Blake  
3,924,604 A 12/1975 Anderson  
4,034,735 A 7/1977 Waldrup  
4,044,753 A 8/1977 Fletcher et al.  
4,102,326 A 7/1978 Sommer  
4,117,682 A 10/1978 Smith  
4,146,785 A 3/1979 Neale  
4,172,443 A 10/1979 Sommer  
4,219,729 A 8/1980 Smith

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 5/2004  
EP 0106688 3/1985

(Continued)

**OTHER PUBLICATIONS**

“Central Receiver Systems” in: Stine, W.B., and Geyer, M., Power from the Sun [online], 2001 [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: <http://www.powerfromthesun.net/Chapter10/Chapter10new.htm>>, Chapter 10.

(Continued)

*Primary Examiner* — Steven B McAllister

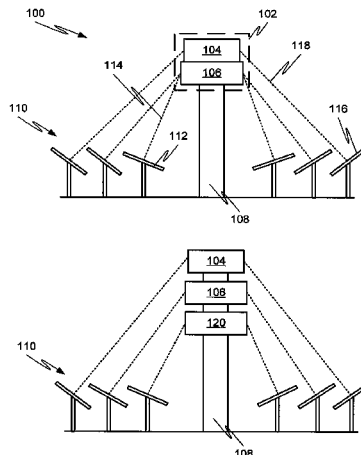
*Assistant Examiner* — Avinash Savani

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy collection system includes a primary solar receiver and a secondary solar receiver. The secondary solar receiver generates steam using energy from solar radiation incident thereon. The primary solar receiver receives the generated steam from the secondary solar receiver and superheats the steam using energy from solar radiation incident thereon. A plurality of heliostat-mounted mirrors reflects incident solar radiation onto one of the primary and secondary solar receivers. A controller aims a portion of the heliostat-mounted mirrors at the primary solar receiver such that a predetermined thermal profile is provided on a surface of the primary solar receiver.

**14 Claims, 3 Drawing Sheets**







(12) **United States Patent**  
**Gilon et al.**

(10) **Patent No.:** **US 8,360,051 B2**  
(45) **Date of Patent:** **Jan. 29, 2013**

(54) **SOLAR RECEIVER WITH ENERGY FLUX MEASUREMENT AND CONTROL**

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Gil Kroyzer**, Jerusalem (IL); **Rotem Hayut**, Jerusalem (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1077 days.

(21) Appl. No.: **12/269,793**

(22) Filed: **Nov. 12, 2008**

(65) **Prior Publication Data**

US 2009/0250052 A1 Oct. 8, 2009

**Related U.S. Application Data**

(60) Provisional application No. 60/987,133, filed on Nov. 12, 2007.

(51) **Int. Cl.**  
**F24J 2/38** (2006.01)

(52) **U.S. Cl.** ..... **126/578**; 126/573; 126/572; 126/600; 126/680; 126/684; 126/688; 374/137; 250/203.4; 60/641.8; 60/641.11; 60/641.15; 359/853

(58) **Field of Classification Search** ..... 126/578, 126/573, 600, 680, 684, 688; 374/137; 250/203.4; 359/853; 60/641.8, 641.11, 641.15  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A	1/1906	Carter	
2,999,943 A	9/1961	Willard	
3,504,524 A *	4/1970	Maley	374/5
3,563,771 A *	2/1971	Tung	501/33
3,670,717 A *	6/1972	Abbot	126/687

3,892,433 A	7/1975	Blake	
3,924,604 A	12/1975	Anderson	
4,034,735 A	7/1977	Waldrup	
4,044,753 A	8/1977	Fletcher et al.	
4,102,326 A	7/1978	Sommer	
4,117,682 A	10/1978	Smith	
4,146,785 A	3/1979	Neale	
4,172,443 A	10/1979	Sommer	
4,219,729 A *	8/1980	Smith	250/203.4

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE	3325919 A1 *	1/1985
DE	10248068	5/2004

(Continued)

**OTHER PUBLICATIONS**

BCB Informatica y Control. Heliostat Calibration for Concentrating Solar Power Plants Using Machine Vision [online]. [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: http://beb.es/documentos/descargar.php?id=29>.

(Continued)

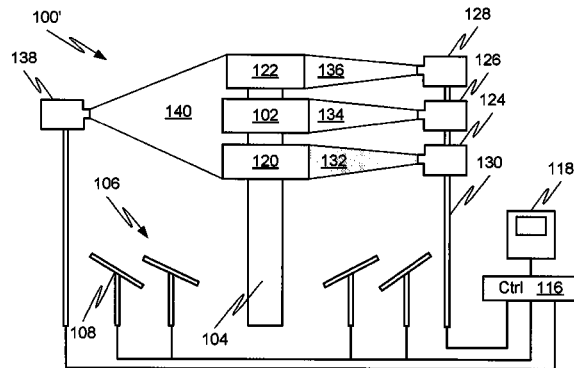
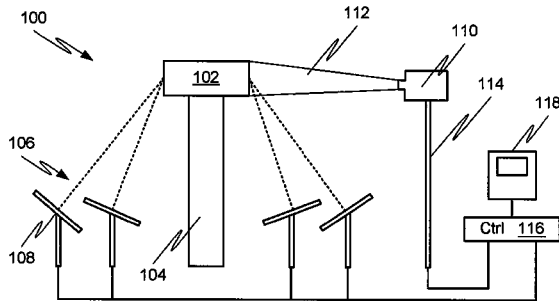
*Primary Examiner* — Carl Price

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge PC; Mark A. Catan

(57) **ABSTRACT**

A solar energy collection system has a solar receiver with an external surface configured for high absorption of light incident thereon. The solar receiver also has a plurality of light-reflecting elements arranged on the external surface. The light-reflecting elements produce at least partially diffuse reflection of light energy incident thereon. Heliostats concentrate solar radiation onto the external surface of the solar receiver. An imaging device provides a digital image of at least a portion of the external surface of the solar receiver. A controller can control the heliostats in response to apparent brightness of the light-reflecting elements as represented in the digital image.

**20 Claims, 3 Drawing Sheets**





US008327840B2

(12) **United States Patent**  
**Gilon et al.**

(10) **Patent No.:** **US 8,327,840 B2**  
(45) **Date of Patent:** **Dec. 11, 2012**

(54) **SOLAR POWER TOWER SYSTEM  
OPERATION AND CONTROL**

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Israel  
Kroizer**, Jerusalem (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**,  
Jerusalem (IL)

(\*) Notice: Subject to any disclaimer, the term of this  
patent is extended or adjusted under 35  
U.S.C. 154(b) by 140 days.

(21) Appl. No.: **12/841,335**

(22) Filed: **Jul. 22, 2010**

(65) **Prior Publication Data**

US 2010/0282242 A1 Nov. 11, 2010

**Related U.S. Application Data**

(62) Division of application No. 12/269,785, filed on Nov.  
12, 2008, now Pat. No. 8,001,960.

(60) Provisional application No. 60/987,132, filed on Nov.  
12, 2007.

(51) **Int. Cl.**  
**F24J 2/38** (2006.01)

(52) **U.S. Cl.** ..... **126/600**; 126/643; 126/602; 126/572;  
126/601; 136/248; 136/246; 60/641.5; 353/3

(58) **Field of Classification Search** ..... 126/600,  
126/602, 572, 601, 643; 353/3; 136/248,  
136/246; 60/641.5

See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A 1/1906 Carter  
2,999,943 A 9/1961 Willard  
3,892,433 A 7/1975 Blake

3,924,604 A 12/1975 Anderson  
4,034,735 A 7/1977 Waldrip  
4,044,753 A 8/1977 Fletcher et al.  
4,102,326 A 7/1978 Sommer  
4,117,682 A 10/1978 Smith  
4,146,785 A 3/1979 Neale  
4,172,443 A 10/1979 Sommer  
4,219,729 A 8/1980 Smith  
4,227,513 A 10/1980 Blake et al.

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 A1 5/2004  
(Continued)

**OTHER PUBLICATIONS**

BCB Informatica y Control. Heliostat Calibration for Concentrating  
Solar Power Plants Using Machine Vision [online]. [retrieved on  
Nov. 17, 2009]. Retrieved from the Internet: <URL: [http://beb.es/  
documentos/descargar.php?id=29](http://beb.es/documentos/descargar.php?id=29)>.

(Continued)

*Primary Examiner* — Steven B McAllister

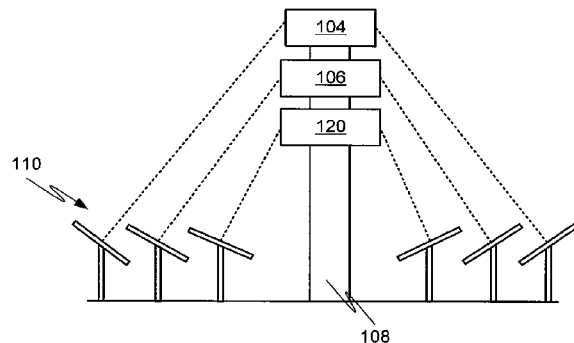
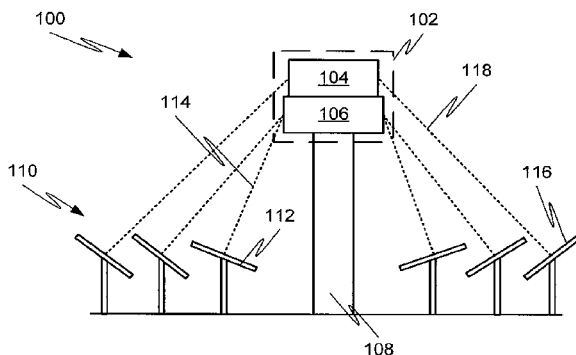
*Assistant Examiner* — Avinash Savani

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.;  
Mark A. Catan

(57) **ABSTRACT**

A solar energy collection system includes a primary solar  
receiver and a secondary solar receiver. The secondary solar  
receiver generates steam using energy from solar radiation  
incident thereon. The primary solar receiver receives the gen-  
erated steam from the secondary solar receiver and superheats  
the steam using energy from solar radiation incident thereon.  
A plurality of heliostat-mounted mirrors reflects incident  
solar radiation onto one of the primary and secondary solar  
receivers. A controller aims a portion of the heliostat-  
mounted mirrors at the primary solar receiver such that a  
predetermined thermal profile is provided on a surface of the  
primary solar receiver.

**20 Claims, 3 Drawing Sheets**



(12) **United States Patent**  
**Huss et al.**

(10) **Patent No.:** **US 8,063,349 B2**  
(45) **Date of Patent:** **Nov. 22, 2011**

(54) **HELIOSTATS AND SOLAR CONCENTRATION SYSTEMS EMPLOYING HELIOSTATS**

(75) Inventors: **Shmuel Huss**, Jerusalem (IL); **Hagai Huss**, Jerusalem (IL); **Israel Kroizer**, Jerusalem (IL); **Yoel Gilon**, Jerusalem (IL); **Danny Franck**, Modi'in (IL); **Susan Walzer**, Givat Ze'ev (IL)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/595,241**

(22) PCT Filed: **Apr. 15, 2008**

(86) PCT No.: **PCT/US2008/060388**  
§ 371 (c)(1),  
(2), (4) Date: **Mar. 29, 2010**

(87) PCT Pub. No.: **WO2008/128237**  
PCT Pub. Date: **Oct. 23, 2008**

(65) **Prior Publication Data**  
US 2010/0175738 A1 Jul. 15, 2010

**Related U.S. Application Data**

(60) Provisional application No. 60/911,893, filed on Apr. 15, 2007.

(51) **Int. Cl.**  
**G02B 7/04** (2006.01)  
**G02B 27/40** (2006.01)  
**G02B 27/64** (2006.01)

(52) **U.S. Cl.** ..... **250/203.4**; 353/3; 359/853; 126/680; 126/684

(58) **Field of Classification Search** ..... 353/3; 126/680, 126/683, 684, 685, 686, 689, 690, 691; 250/203.4, 250/203.7; 359/853  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

811,274 A	1/1906	Carter	
3,892,433 A	7/1975	Blake	
3,924,604 A	12/1975	Anderson	
4,034,735 A	7/1977	Waldrup	
4,122,827 A	10/1978	Rhodes	
4,162,825 A *	7/1979	Dowty	359/847
4,209,236 A	6/1980	Horton et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

WO WO 2008/118980 10/2008

(Continued)

OTHER PUBLICATIONS

Pottler et al., "Photogrammetry: A Powerful Tool for Geometric Analysis of Solar Concentrators and Their Components," Journal of Solar Energy Engineering, Feb. 2005, 127(1):pp. 94-101.

(Continued)

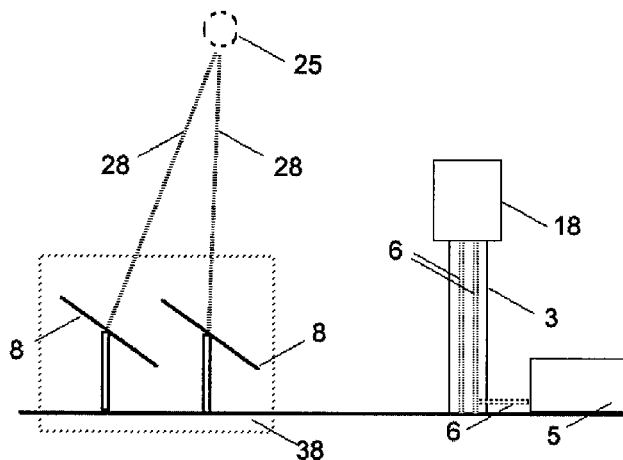
*Primary Examiner* — Francis M Legasse, Jr.

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar heliostat and system are described with various characteristics particularly suitable for concentrating systems with a relatively large number of small heliostats. Other features contribute to high performance, low cost, high durability, and high temperature operation, such as desired for high efficiency thermal power generation.

**20 Claims, 9 Drawing Sheets**





US008033110B2

(12) **United States Patent**  
**Gilon et al.**

(10) **Patent No.:** **US 8,033,110 B2**  
(45) **Date of Patent:** **Oct. 11, 2011**

(54) **SOLAR POWER GENERATION WITH MULTIPLE ENERGY CONVERSION MODES**

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Arnold J. Goldman**, Jerusalem (IL); **Israel Kroizer**, Jerusalem (IL); **Gideon Goldwine**, Jerusalem (IL); **Gil Kroyzer**, Jerusalem (IL)

4,117,682 A 10/1978 Smith  
4,172,443 A 10/1979 Sommer  
4,219,729 A 8/1980 Smith  
4,227,513 A 10/1980 Blake et al.  
4,245,618 A 1/1981 Wiener  
4,265,223 A 5/1981 Miserlis et al.  
4,289,114 A 9/1981 Zadiraka

(Continued)

(73) Assignee: **Brightsource Industries (Israel) Ltd.**, Jerusalem (IL)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 5/2004

(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 252 days.

**OTHER PUBLICATIONS**

BCB Informatica y Control. Heliostat Calibration for Concentrating Solar Power Plants Using Machine Vision [online]. [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: <http://bcb.es/documentos/descargar.php?id=29>>.

(Continued)

(21) Appl. No.: **12/404,663**

(22) Filed: **Mar. 16, 2009**

**Prior Publication Data**

US 2009/0229264 A1 Sep. 17, 2009

**Related U.S. Application Data**

(60) Provisional application No. 61/036,959, filed on Mar. 16, 2008, provisional application No. 61/053,341, filed on May 15, 2008, provisional application No. 61/140,966, filed on Dec. 28, 2008.

*Primary Examiner* — Hoang Nguyen

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(51) **Int. Cl.**  
**B60K 16/00** (2006.01)

(52) **U.S. Cl.** ..... **60/641.11**; 60/641.15

(58) **Field of Classification Search** ..... 60/641.8–641.15  
See application file for complete search history.

(57) **ABSTRACT**

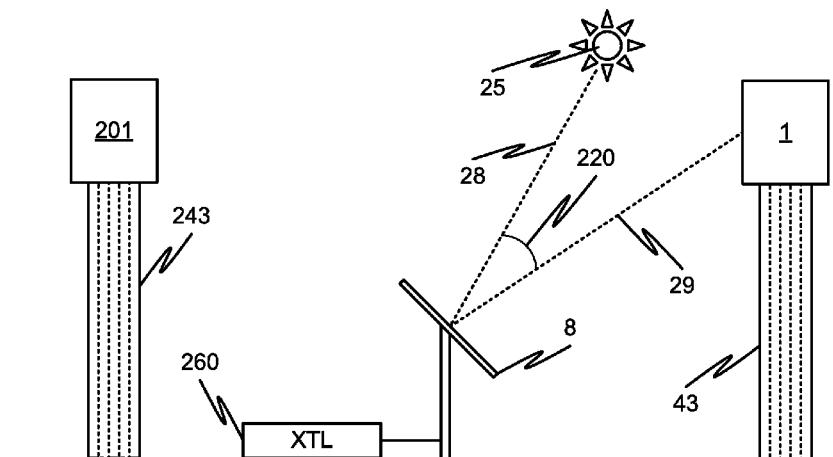
A multi-mode solar power generation system can include a first energy conversion system that generates electricity from a working fluid heated by a portion of solar radiation focused by a plurality of heliostats. The multi-mode solar power generation system can also include a second energy conversion system that generates electricity from an unused portion of the focused solar radiation using a different energy conversion mode than that of the first energy conversion system. The second energy conversion system can include one or more photovoltaic converters, which directly convert solar radiation to electricity. The unused radiation from the first energy conversion system can include radiation spillage or dumped radiation from a thermal receiver of the first energy conversion system.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

3,892,433 A 7/1975 Blake  
3,924,604 A 12/1975 Anderson  
4,034,735 A 7/1977 Waldrip  
4,044,753 A 8/1977 Fletcher et al.

**38 Claims, 13 Drawing Sheets**





(12) **United States Patent**  
**Goldman et al.**

(10) **Patent No.:** **US 8,003,379 B2**  
(45) **Date of Patent:** **Aug. 23, 2011**

(54) **HIGH DENSITY BIOREACTOR SYSTEM, DEVICES, AND METHODS**

(75) Inventors: **Arnold J. Goldman**, Jerusalem (IL); **Michael Kagan**, Jerusalem (IL); **Yuri Kokotov**, Ma'aleh Adumim (IL)

(73) Assignee: **Brightsource Energy, Inc.**, Oakland, CA (US)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 757 days.

(21) Appl. No.: **11/832,201**

(22) Filed: **Aug. 1, 2007**

(65) **Prior Publication Data**

US 2008/0293132 A1 Nov. 27, 2008

**Related U.S. Application Data**

(60) Provisional application No. 60/821,074, filed on Aug. 1, 2006.

(51) **Int. Cl.**

**C12M 1/00** (2006.01)  
**C12M 3/00** (2006.01)  
**A01G 7/00** (2006.01)  
**A01H 13/00** (2006.01)

(52) **U.S. Cl.** ..... **435/292.1**; 435/298.1; 435/307.1; 435/303.1; 435/290.4; 435/286.6; 435/293.1; 435/289.1; 435/294.1; 435/299.1; 47/1.4; 385/900; 385/901; 385/147

(58) **Field of Classification Search** ..... 435/292.1, 435/298.1, 307.1, 303.1, 290.4, 286.6, 293.1, 435/289.1, 294.1, 299.1; 47/1.4; 385/900, 385/901, 147

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,800,761 A	4/1974	Sata	
3,959,923 A *	6/1976	Selke	47/1.4
3,982,878 A	9/1976	Yamane et al.	
4,099,381 A	7/1978	Rappoport	
4,117,682 A	10/1978	Smith	
4,167,856 A	9/1979	Seidel et al.	
4,266,179 A	5/1981	Hamm, Jr.	
4,313,304 A	2/1982	Hunt	
4,317,659 A	3/1982	Down	
4,365,618 A	12/1982	Jones	
4,403,601 A	9/1983	Hunt	
4,433,673 A	2/1984	Vierling	
4,435,198 A	3/1984	Gray	

(Continued)

FOREIGN PATENT DOCUMENTS

DE 3710611 10/1988

(Continued)

OTHER PUBLICATIONS

Cheng-Wu et al., "Characterization of Growth and Arachidonic Acid Production of *Parietochloris incisa* Comb. Nov (Trebouxiophyceae, Chlorophyta)" *Journal of Applied Phycology*, 2002, 14(6):pp. 453-460.

(Continued)

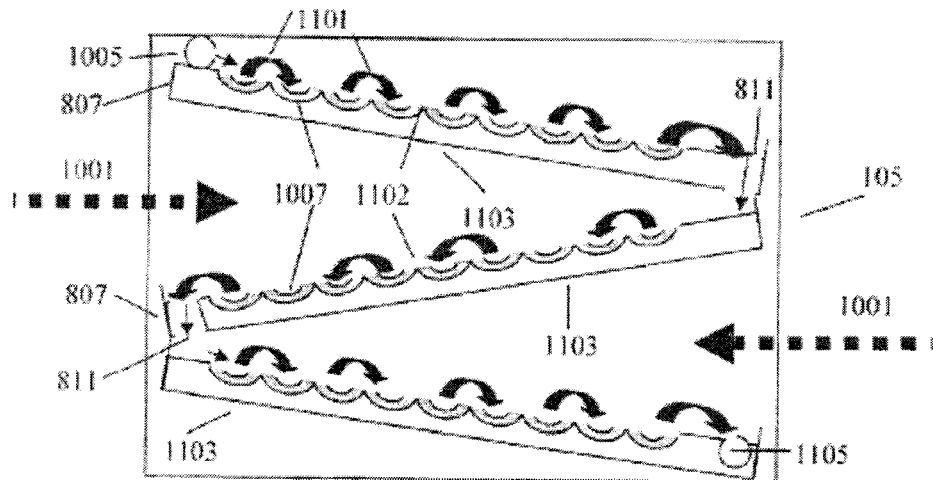
*Primary Examiner* — Nathan A Bowers

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A bioreactor and bioreactor system are suitable for the growth of materials from algae. More specifically, the system preferred embodiments use concentrated sunlight in a solo- or co-generation system to produce algae and products therefrom as well as solar thermal energy.

**19 Claims, 5 Drawing Sheets**



(12) **United States Patent**  
**Gilon et al.**

(10) **Patent No.:** **US 8,001,960 B2**  
(45) **Date of Patent:** **Aug. 23, 2011**

(54) **METHOD AND CONTROL SYSTEM FOR OPERATING A SOLAR POWER TOWER SYSTEM**

(75) Inventors: **Yoel Gilon**, Jerusalem (IL); **Israel Kroizer**, Jerusalem (IL); **Gil Kroyzer**, Jerusalem (IL)

(73) Assignee: **BrightSource Industries (Israel) Ltd.** (IL)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 19 days.

(21) Appl. No.: **12/269,785**

(22) Filed: **Nov. 12, 2008**

(65) **Prior Publication Data**

US 2009/0217921 A1 Sep. 3, 2009

**Related U.S. Application Data**

(60) Provisional application No. 60/987,132, filed on Nov. 12, 2007.

(51) **Int. Cl.**  
**F24J 2/38** (2006.01)

(52) **U.S. Cl.** ..... **126/600**; 126/572; 126/601; 126/605; 126/610; 126/643; 60/641.8; 60/641.15; 136/246; 136/248; 700/275

(58) **Field of Classification Search** ..... 126/600, 126/572, 684, 601, 643, 610, 605, 578; 60/641.8, 60/641.15; 136/246, 248; 250/203.4; 700/275  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

811,274 A	1/1906	Carter
3,892,433 A	7/1975	Blake
3,924,604 A	12/1975	Anderson

4,034,735 A	7/1977	Waldrup	
4,044,753 A	8/1977	Fletcher et al.	
4,102,326 A *	7/1978	Sommer	126/575
4,117,682 A	10/1978	Smith	
4,172,443 A *	10/1979	Sommer	126/680
4,219,729 A	8/1980	Smith	
4,227,513 A	10/1980	Blake et al.	
4,245,618 A	1/1981	Wiener	

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 10248068 A1 \* 5/2004

(Continued)

**OTHER PUBLICATIONS**

BCB Informatica y Control. Heliostat Calibration for Concentrating Solar Power Plants Using Machine Vision [online]. [retrieved on Nov. 17, 2009]. Retrieved from the Internet: <URL: <http://bcb.es/documentos/descargar.php?id=29>>.

(Continued)

*Primary Examiner* — Steven B McAllister

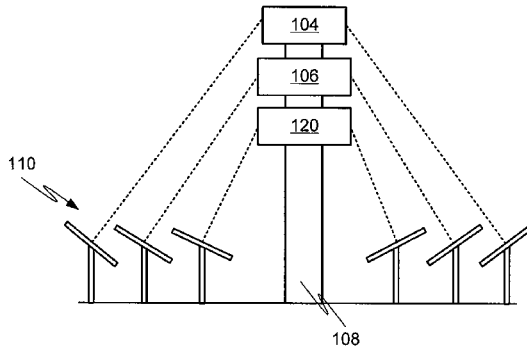
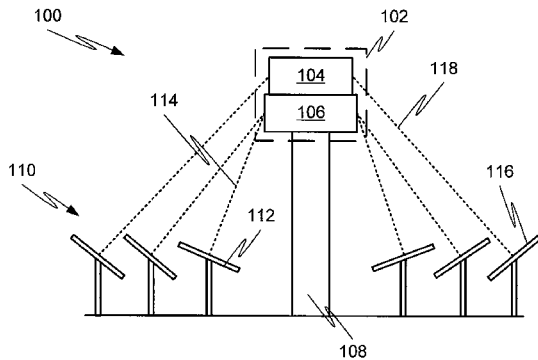
*Assistant Examiner* — Avinash Savani

(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.; Mark A. Catan

(57) **ABSTRACT**

A solar energy collection system includes a primary solar receiver and a secondary solar receiver. The secondary solar receiver generates steam using energy from solar radiation incident thereon. The primary solar receiver receives the generated steam from the secondary solar receiver and superheats the steam using energy from solar radiation incident thereon. A plurality of heliostat-mounted mirrors reflects incident solar radiation onto one of the primary and secondary solar receivers. A controller aims a portion of the heliostat-mounted mirrors at the primary solar receiver such that a predetermined thermal profile is provided on a surface of the primary solar receiver.

**20 Claims, 3 Drawing Sheets**



(12) **United States Patent**  
**Goldman**

(10) **Patent No.:** US 7,845,172 B2  
(45) **Date of Patent:** Dec. 7, 2010

(54) **HYBRID GENERATION WITH ALTERNATIVE FUEL SOURCES**

(56) **References Cited**

U.S. PATENT DOCUMENTS

(75) Inventor: **Arnold J. Goldman**, Jerusalem (IL)

3,800,761 A 4/1974 Sata

(73) Assignee: **BrightSource Energy, Inc.**, Oakland, CA (US)

(Continued)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1050 days.

FOREIGN PATENT DOCUMENTS

DE 3710611 A1 10/1988

(21) Appl. No.: **11/562,715**

(Continued)

(22) Filed: **Nov. 22, 2006**

OTHER PUBLICATIONS

(65) **Prior Publication Data**

US 2007/0084208 A1 Apr. 19, 2007

Ashkenazi, R., "The Response of Dunalialla Bardawil to the Natural Changes in the Sunlight Spectrum and Intensity," Weizmann Institute of Science, PhD Dissertation, Sep. 1999.

(Continued)

**Related U.S. Application Data**

*Primary Examiner*—Hoang M Nguyen

(63) Continuation of application No. 11/142,848, filed on May 31, 2005, now Pat. No. 7,331,178, which is a continuation-in-part of application No. 10/760,915, filed on Jan. 20, 2004, now Pat. No. 7,191,736.

(74) *Attorney, Agent, or Firm*—Miles & Stockbridge P.C.; Mark A. Catan

(60) Provisional application No. 60/441,088, filed on Jan. 21, 2003, provisional application No. 60/575,301, filed on May 28, 2004, provisional application No. 60/575,300, filed on May 28, 2004, provisional application No. 60/575,759, filed on May 28, 2004, provisional application No. 60/575,225, filed on May 28, 2004, provisional application No. 60/575,641, filed on May 28, 2004, provisional application No. 60/584,653, filed on Jul. 1, 2004, provisional application No. 60/611,825, filed on Sep. 21, 2004.

(57) **ABSTRACT**

A generating facility is provided for generating electricity from both solar and non-solar energy sources. The solar generating portion of the facility includes capability to directly generate electricity from solar insolation, or to store the solar energy in a tangible medium, including stored heat, or solar generating fuel. The generating facility is configured to generate electricity simultaneously from both solar and non-solar sources, as well a solely from immediate solar insolation and from solar energy stored in a tangible medium. Additionally, the solar generating capacity may be segregated; such that separate spectra of solar insolation are used to capture heat for steam turbine based electrical generation, capture light energy for photovoltaic based electrical generation, and to grow biomass to generate a solar fuel.

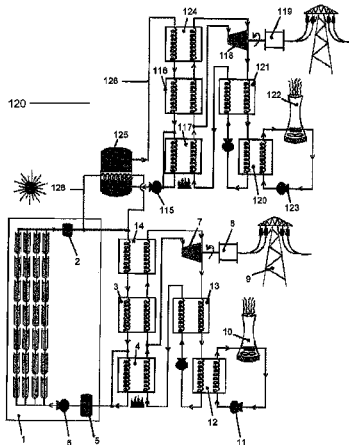
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**B60K 16/00** (2006.01)

(52) **U.S. Cl.** ..... **60/641.8**; 60/641.15

(58) **Field of Classification Search** .... 60/641.8–641.15

See application file for complete search history.

**12 Claims, 8 Drawing Sheets**





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(12) **United States Patent**  
**Goldman et al.**

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(45) **Date of Patent:** **Apr. 6, 2010**

(54) **HIGH TEMPERATURE SOLAR RECEIVER**

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/747,595**

(22) Filed: **May 11, 2007**

(65) **Prior Publication Data**

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(51) **Int. Cl.**  
**F24J 2/24** (2006.01)

(52) **U.S. Cl.** ..... **126/655**; 126/651; 126/652

(58) **Field of Classification Search** ..... 126/655, 126/634, 651, 652, 595, 628, 631, 643, 629  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

1,015,131 A *	1/1912	Bone et al. ....	122/421
3,921,711 A *	11/1975	Westbrock .....	165/109.1
4,015,584 A *	4/1977	Haberman .....	126/600
4,055,948 A *	11/1977	Kraus et al. ....	60/641.8
4,117,682 A *	10/1978	Smith .....	60/641.8
4,119,083 A *	10/1978	Heyen et al. ....	126/674
4,129,117 A *	12/1978	Harvey .....	126/655

4,132,217 A *	1/1979	Rom et al. ....	126/675
4,136,674 A *	1/1979	Korr .....	126/607
4,137,899 A *	2/1979	Weslow .....	126/649
4,164,123 A *	8/1979	Smith .....	60/641.11
4,190,037 A *	2/1980	Niedermeier .....	126/655
4,197,830 A *	4/1980	Wilson .....	126/620
4,205,656 A *	6/1980	Scarлата .....	126/400
4,210,126 A *	7/1980	Kellberg et al. ....	126/655

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 2828118 A \* 1/1980

(Continued)

**OTHER PUBLICATIONS**

Optimization of bed parameters for packed bed solar energy collection system B. Paul a, , J.S. Saini b Renewable Energy 29 (2004) 1863-1876 Received Oct. 10, 2002; accepted Jan. 28, 2004.\*

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(74) *Attorney, Agent, or Firm*—Mark A. Catan, Esq.; Miles & Stockbridge, PC

(57) **ABSTRACT**

The invention provides receivers which can be used to heat a working fluid to high temperature. In preferred embodiments, concentrated solar radiation is received and converted to heat at varying depths in the receiver such that multiple layers of surface are used to heat the working fluid. In addition, the depth-loading configuration helps to trap received heat to reduce radiant thermal loss.

**14 Claims, 21 Drawing Sheets**

