United States Patent	12390986
Kind Code	B2
Date of Patent	August 19, 2025
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Resin management system for additive manufacturing

Abstract

An additive manufacturing apparatus includes a stage configured to hold a component. A radiant energy device is operable to generate and project radiant energy in a patterned image. An actuator is configured to change a relative position of the stage relative to the radiant energy device. A resin management system includes a material deposition assembly upstream configured to deposit a resin on a resin support. The material deposition assembly includes a reservoir configured to retain a first volume of the resin and define a thickness of the resin on the resin support as the resin support is translated in an X-axis direction. The material deposition assembly further includes a vessel positioned above the reservoir in a Z-axis direction and configured to store a second volume of the resin. In addition, the material deposition assembly includes a conduit configured to direct the resin from the vessel to the reservoir.

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Appl. No.: **18/497369**

Filed: **October 30, 2023**

Prior Publication Data

Document Identifier	Publication Date
US 20240059008 A1	Feb. 22, 2024

Related U.S. Application Data

continuation parent-doc US 17371484 20210709 US 11826950 child-doc US 18497369

Publication Classification

Int. Cl.: **B29C64/124** (20170101); **B29C64/214** (20170101); **B29C64/232** (20170101); **B29C64/241** (20170101); **B29C64/245** (20170101); **B29C64/255** (20170101); **B29C64/264** (20170101); **B29C64/393** (20170101); **B33Y10/00** (20150101); **B33Y30/00** (20150101); **B33Y50/02** (20150101)

U.S. Cl.:

CPC **B29C64/124** (20170801); **B29C64/214** (20170801); **B29C64/232** (20170801); **B29C64/241** (20170801); **B29C64/245** (20170801); **B29C64/255** (20170801); **B29C64/264** (20170801); **B29C64/393** (20170801); **B33Y10/00** (20141201); **B33Y30/00** (20141201); **B33Y50/02** (20141201);

Field of Classification Search

CPC: B29C (64/124); B29C (64/129); B29C (64/135); B29C (64/321); B29C (64/329); B29C (64/393); B29C (64/255); B33Y (10/00); B33Y (30/00); B33Y (50/02)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION (1) This application is a continuation application of U.S. patent application Ser. No. 17/371,484, filed on Jul. 9, 2021, the disclosure of which is incorporated by reference herein in its entirety.

FIELD
(1) The present subject matter relates generally to an additive manufacturing apparatus, and more particularly to a resin management system for the additive manufacturing apparatus.
BACKGROUND
(2) Additive manufacturing is a process in which material is built up layer-by-layer to form a component. Stereolithography (SLA) is a type of additive manufacturing process, which employs a vessel of radiant-energy curable photopolymer “resin” and a curing energy source, such as a laser. Similarly, Digital Light Processing (DLP) three-dimensional (3D) printing employs a two-dimensional image projector to build components one layer at a time. For each layer, the energy source draws or flashes a radiation image of the cross section of the component onto the surface of the resin. Exposure to the radiation cures and solidifies the pattern in the resin and joins it to a previously cured layer.
(3) In some instances, additive manufacturing may be accomplished through a “tape casting” process. In this process, a resin is deposited onto a resin support, which may be a flexible radiotransparent tape, a foil, and/or another type of resin support, that is fed out from a supply reel to a build zone. Radiant energy is used to cure the resin to a component that is supported by a stage in the build zone. Once the curing of the first layer is complete, the stage and the resin support are separated from one another. The resin support is then advanced and fresh resin is provided to the build zone. In turn, the first layer of the cured resin is placed onto the fresh resin and cured through the energy device to form an additional layer of the component. Subsequent layers are added to each previous layer until the component is completed.
(4) In operation, as each layer of the component is formed, resin may be deposited on the resin support for forming the next sequential layer of the component. A first portion of the resin may be cured, and a

second portion may be translated out of the build zone. Accordingly, it may be beneficial for the additive manufacturing apparatus to include a resin management system that manages the deposition of the resin onto the resin support and/or the reclamation of the second portion of the resin.

BRIEF DESCRIPTION

(5) Aspects and advantages of the present disclosure will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the present disclosure.

(6) In some embodiments of the present disclosure, an additive manufacturing apparatus includes a stage configured to hold a component. A radiant energy device is operable to generate and project radiant energy in a patterned image. An actuator is configured to change a relative position of the stage relative to the radiant energy device. A resin management system includes a material deposition assembly upstream of the stage and is configured to deposit a resin on a resin support. The material deposition assembly includes a reservoir configured to retain a first volume of the resin, a vessel separated from the reservoir and configured to store a second volume of the resin, and an impeller positioned within the vessel and configured to agitate the resin within the vessel.

(7) In some embodiments of the present disclosure, a method of operating an additive manufacturing apparatus includes operably coupling a bracket of a first vessel with a brace of said additive manufacturing apparatus. The method also includes coupling a conduit to direct a resin within the first vessel to a reservoir. The method further includes actuating a regulator to allow the resin to be gravity fed from the first vessel to the reservoir.

(8) In some embodiments of the present disclosure, an additive manufacturing apparatus includes a stage configured to hold one or more cured layers of a resin that form a component. A radiant energy device is positioned opposite to the stage such that it is operable to generate and project radiant energy in a patterned image. A resin management system includes a reclamation system downstream of the stage. The reclamation system includes a collection structure configured to remove at least a portion of the resin from a resin support. The reclamation system further includes a vessel configured to retain the resin removed from the resin support. An impeller positioned within the vessel and configured to agitate the resin within the vessel.

(9) These and other features, aspects, and advantages of the present disclosure will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the present disclosure and, together with the description, serve to explain the principles of the present disclosure.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) A full and enabling disclosure of the present disclosure, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures.

(2) FIG. **1** is a schematic side view of an additive manufacturing apparatus in accordance with various aspects of the present disclosure;

(3) FIG. **2** is a front perspective view of a feed panel configured to support one or more components of a feed module in accordance with various aspects of the present disclosure;

(4) FIG. **3** is a rear perspective view of the feed panel of the feed module in accordance with various aspects of the present disclosure;

(5) FIG. **4** is a front perspective view of a take-up panel configured to support one or more components of a take-up module in accordance with various aspects of the present disclosure;

(6) FIG. **5** is a rear perspective view of the take-up panel of the take-up module in accordance with various aspects of the present disclosure;

(7) FIG. **6** is a schematic view of a material deposition assembly in accordance with various aspects of the present disclosure;

(8) FIG. **7** is a side perspective view of a vessel of the material deposition assembly in accordance with various aspects of the present disclosure;
(9) FIG. **8** is a rear perspective view of the material deposition assembly in accordance with various aspects of the present disclosure;
(10) FIG. **9** is a schematic view of a material deposition assembly in accordance with various aspects of the present disclosure;
(11) FIG. **10** is a front perspective view of the material deposition assembly in accordance with various aspects of the present disclosure;
(12) FIG. **11** is a cross-sectional view of the material deposition assembly of FIG. **10** taken along the line XI-XI;
(13) FIG. **12** is a perspective view of a conduit fluidly coupled with a reservoir of the material deposition assembly in accordance with various aspects of the present disclosure;
(14) FIG. **13** is a rear perspective view of a reclamation system including the vessel in accordance with various aspects of the present disclosure;
(15) FIG. **14** is a front perspective view of the material deposition assembly in accordance with various aspects of the present disclosure;
(16) FIG. **15** is a side perspective view of a dolly for moving the vessel in accordance with various aspects of the present disclosure;
(17) FIG. **16** is a side perspective view of a carrier of the dolly in accordance with various aspects of the present disclosure;
(18) FIG. **17** depicts an exemplary computing system for an additive manufacturing apparatus in accordance with various aspects of the present disclosure; and
(19) FIG. **18** is a method of operating the manufacturing apparatus in accordance with various aspects of the present disclosure.
(20) Repeat use of reference characters in the present specification and drawings is intended to represent the same or analogous features or elements of the present disclosure.

DETAILED DESCRIPTION

(21) Reference will now be made in detail to present embodiments of the present disclosure, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the present disclosure.
(22) As used herein, the terms “first,” “second,” and “third” may be used interchangeably to distinguish one component from another and are not intended to signify a location or importance of the individual components. The terms “coupled,” “fixed,” “attached to,” and the like refer to both direct coupling, fixing, or attaching, as well as indirect coupling, fixing, or attaching through one or more intermediate components or features, unless otherwise specified herein. The terms “upstream” and “downstream” refer to the relative direction with respect to a resin support movement along the manufacturing apparatus. For example, “upstream” refers to the direction from which the resin support moves, and “downstream” refers to the direction to which the resin support moves. The term “selectively” refers to a component's ability to operate in various states (e.g., an ON state and an OFF state) based on manual and/or automatic control of the component.
(23) The singular forms “a,” “an,” and “the” include plural references unless the context clearly dictates otherwise.
(24) Approximating language, as used herein throughout the specification and claims, is applied to modify any quantitative representation that could permissibly vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as “about,” “approximately,” “generally,” and “substantially,” is not to be limited to the precise value specified. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value, or the precision of the methods or apparatus for constructing or manufacturing the components and/or systems. For example, the approximating language may refer to being within a ten percent margin.
(25) Moreover, the technology of the present application will be described in relation to exemplary

embodiments. The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any embodiment described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments. Additionally, unless specifically identified otherwise, all embodiments described herein should be considered exemplary.

(26) Here and throughout the specification and claims, range limitations are combined, and interchanged, such ranges are identified and include all the sub-ranges contained therein unless context or language indicates otherwise. For example, all ranges disclosed herein are inclusive of the endpoints, and the endpoints are independently combinable with each other.

(27) As used herein, the term “and/or,” when used in a list of two or more items, means that any one of the listed items can be employed by itself, or any combination of two or more of the listed items can be employed. For example, if a composition or assembly is described as containing components A, B, and/or C, the composition or assembly can contain A alone; B alone; C alone; A and B in combination; A and C in combination; B and C in combination; or A, B, and C in combination.

(28) The present disclosure is generally directed to an additive manufacturing apparatus that implements various manufacturing processes such that successive layers of material(s) (e.g., resins) are provided on each other to “build up,” layer-by-layer, a three-dimensional component. The successive layers generally cure together to form a monolithic component which may have a variety of integral sub-components. Although additive manufacturing technology is described herein as enabling the fabrication of complex objects by building objects point-by-point, layer-by-layer, variations of the described additive manufacturing apparatus and technology are possible and within the scope of the present subject matter.

(29) The additive manufacturing apparatus can include a support plate, a window supported by the support plate, and a stage moveable relative to the window. The additive manufacturing apparatus further includes a resin support (such as a flexible tape or foil) that supports a resin. The resin support, with the resin thereon, is positioned between the stage and the window. A radiant energy device is configured to cure a portion of the resin forming the component, which is translated towards and away from the resin support by the stage between successive curing operations.

(30) In various embodiments, the apparatus further includes a resin management system, which may include a material deposition assembly and/or a reclamation system. The material deposition assembly may be any device or combination of devices that is operable to apply a layer of the resin on the resin support. Conversely, the reclamation system may be configured to remove at least a portion of the resin that remains on the resin support after the resin support is removed from a build zone.

(31) In some instances, the material deposition assembly includes a reservoir configured to retain a first volume of the resin and define a thickness of the resin on the resin support as the resin support is translated in an X-axis direction. A vessel is positioned above the reservoir in a Z-axis direction and is configured to store a second volume of the resin. A conduit is configured to direct the resin from the vessel to the reservoir. The conduit may be positioned along a bottom portion of the vessel such that the resin may be gravity fed from the vessel to the conduit, which may generally prevent the introduction of air to the resin as the air is transferred into and/or through the conduit. As used herein, “gravity fed” is any system that utilizes gravity to move the resin into and/or out of a vessel or reservoir without the use of a pump or other fluid moving device.

(32) The reclamation system may include a collection structure, such as a wiper assembly, a blade assembly, and/or any other removal assembly. The resin may be directed from the collection structure through a conduit and to a vessel. In some instances, the vessel may be positioned below the collection structure in the Z-axis direction such that the resin is gravity fed from the collection structure to the vessel through the conduit. The vessel within the material deposition assembly may have a common geometry to that within the reclamation system such that the vessels may be interchangeably used within each system. Alternatively, the vessel within the material deposition assembly may have a first geometry and the vessel within the reclamation system may have a second, different geometry.

(33) The resin management system provided herein may allow for the resin to be moved through the apparatus while minimizing any alterations to the resin composition. Such alterations may include aerating the composition, which may negatively impact the quality of a component built by the

apparatus.
(34) Referring to the drawings wherein identical reference numerals denote the similar elements throughout the various views, FIG. **1** schematically illustrates an example of one type of suitable apparatus **10** for forming a component **12** created through one or more cured layers **14** of the resin R. The apparatus **10** can include one or more of a support plate **16**, a window **18**, a stage **20** that is movable relative to the window **18**, and a radiant energy device **22**, which, in combination, may be used to form any number (e.g., one or more) of additively manufactured components **12**.
(35) In the illustrated example, the apparatus **10** includes a feed module **24**, which may include a feed mandrel **24**A, and a take-up module **26**, which may include a take-up mandrel **26**A, that are spaced-apart and configured to couple with respective end portions of a resin support **28**, such as a flexible tape or foil or another type of the resin support extending therebetween. A portion of the resin support **28** can be supported from underneath by the support plate **16**. Suitable mechanical supports (frames, brackets, etc.) may be provided for the mandrels **24**A, **26**A and the support plate **16**. The feed mandrel **24**A and/or the take-up mandrel **26**A can be configured to control the speed and direction of the resin support **28** such that the desired tension and speed is maintained in the resin support **28** through a drive system **30**. In various examples, the drive system **30** can be configured as one or more control devices **32**, **34** associated with the feed mandrel **24**A and/or the take-up mandrel **26**A. Moreover, the drive system **30** may include various components, such as motors, actuators, feedback sensors, and/or controls can be provided for driving the mandrels **24**A, **26**A in such a manner to move at least a portion of the resin support **28** between the mandrels **24**A, **26**A.
(36) In various embodiments, the window **18** is transparent and can be operably supported by the support plate **16**. Further, the window **18** and the support plate **16** can be integrally formed such that one or more windows **18** are integrated within the support plate **16**. Likewise, the resin support **28** is also transparent or includes portions that are transparent. As used herein, the terms “transparent” and “radiotransparent” refer to a material that allows at least a portion of radiant energy of a selected wavelength to pass through. For example, the radiant energy that passes through the window **18** and the resin support **28** can be in the ultraviolet spectrum, the infrared spectrum, the visible spectrum, or any other practicable radiant energy. Non-limiting examples of transparent materials include polymers, glass, and crystalline minerals, such as sapphire or quartz.
(37) The resin support **28** extends between the feed module **24** and the take-up module **26** and defines a “resin surface” **36**, which is shown as being planar, but could alternatively be arcuate. In some instances, the resin surface **36** may be defined by a first side **38** of the resin support **28** and may be positioned to face the stage **20** with the window **18** on an opposing, second side **40** of the resin support **28** from the stage **20**. For purposes of convenient description, the resin surface **36** may be considered to be oriented parallel to an X-Y plane of the apparatus **10**, and a direction perpendicular to the X-Y plane is denoted as a Z-axis direction (X, Y, and Z being three mutually perpendicular directions). As used herein, the X-axis refers to the machine direction along the length of the resin support **28**. As used herein, the Y-axis refers to the transverse direction across the width of the resin support **28** and generally perpendicular to the machine direction. As used herein, the Z-axis refers to the stage direction that can be defined as the direction of movement of the stage **20** relative to the window **18**.
(38) The resin surface **36** may be configured to be “non-stick,” that is, resistant to adhesion of a cured resin R. The non-stick properties may be embodied by a combination of variables such as the chemistry of the resin support **28**, its surface finish, and/or applied coatings. For instance, a permanent or semi-permanent non-stick coating may be applied. One non-limiting example of a suitable coating is polytetrafluoroethylene (“PTFE”). In some examples, all or a portion of the resin surface **36** may incorporate a controlled roughness or surface texture (e.g. protrusions, dimples, grooves, ridges, etc.) with nonstick properties. Additionally or alternatively, the resin support **28** may be made in whole or in part from an oxygen-permeable material.
(39) For reference purposes, an area or volume immediately surrounding the location of the resin support **28** and the window **18** or transparent portion defined by the support plate **16** may be defined as a “build zone,” labeled **42**.
(40) In some instances, the apparatus **10** may further include a resin management system **44**, which may

include a material deposition assembly **46** and/or a reclamation system **48**. The material deposition assembly **46** may be any device or combination of devices that is operable to apply a layer of the resin R on the resin support **28**. The material deposition assembly **46** may optionally include a device or combination of devices to define a height of the resin R on the resin support **28** and/or to level the resin R on the resin support **28**. Nonlimiting examples of suitable material deposition assemblies include chutes, hoppers, pumps, spray nozzles, spray bars, or printheads (e.g. inkjets).

(41) In the illustrated embodiment, the material deposition assembly **46** includes a vessel **50** and a reservoir **52**. A conduit **54** extends from the vessel **50** to direct resin from the vessel **50** to the reservoir **52**. The conduit **54** may be positioned along a bottom portion of the vessel **50** such that the resin R may be gravity fed from the vessel **50** to the conduit **54**, which may generally prevent the introduction of air to the resin R as the air is transferred into and/or through the conduit **54**. In some instances, a filter may be positioned upstream, downstream, and/or within the conduit with respect to the flow of resin from the vessel to the reservoir. In such instances, the resin may be gravity fed through the filter prior to entering the reservoir to catch various agglomerates, partially cured resin pieces, and/or other foreign objects that may affect the resin once it is thinned out on the resin support **28** or may affect the quality of the component **12**.

(42) The reservoir **52** may include any assembly to control the thickness of the resin R applied to the resin support **28**, as the resin support **28** passes under and/or through the reservoir **52**. The reservoir **52** may be configured to retain a first volume of the resin R and define a thickness of the resin R on the resin support **28** as the resin support **28** is translated in an X-axis direction. The vessel **50** may be positioned above the reservoir **52** in a Z-axis direction, or in any other position, and configured to store a second volume of the resin R. In various embodiments, when the first volume of the resin R deviates from a predefined range, additional resin R is supplied from the vessel **50** to the reservoir **52**. In various non-limiting examples, the vessel **50** may be configured to retain 1 liter (L), 2 L, 5 L, 10 L, 15 L, 19 L, 20 L, 30 L, or more of resin therein and the reservoir **52** may be configured to retain 100 milliliters (mL), 150 mL, 200 mL, 250 mL, 280 mL, 300 mL or more of resin therein. Due to the variations in volume between the vessel **50** and the reservoir **52**, the material deposition assembly **46** may have a vessel volume to reservoir volume ratio of greater than 5:1, 15:1, 25:1, 35:1, 45:1, 55:1, 65:1, 67:1, or more. It will be appreciated that these ratios are generally greater than commercially available apparatuses.

(43) In various embodiments, the vessel **50** may be operably coupled with a material deposition assembly panel **78**, which is then operably coupled with a frame on the apparatus **10**. Similarly, various components of the feed module **24** may be operably coupled with a feed panel **80** and various components of the take-up module **26** may be operably coupled with a take-up panel **82**.

(44) In some embodiments, the reclamation system **48** may be configured to remove at least a portion of the resin R that remains on the resin support **28** after the resin support **28** is removed from a build zone **42**. For example, the reclamation system **48** may include a collection structure **238** (FIG. **13**), such as a wiper assembly, a blade assembly, and/or any other removal assembly. The resin R may be directed from the collection structure **238** through a conduit **54** and to a vessel **50**. In some instances, the vessel **50** may be positioned below the collection structure **238** in the Z-axis direction such that the resin R is gravity fed from the collection structure **238** to the vessel **50** through the conduit **54**. The vessel **50** within the material deposition assembly **46** may have a common geometry to that within the reclamation system **48** such that the vessels **50** may be interchangeably used within each system. Alternatively, the vessel **50** within the material deposition assembly **46** may have a first geometry and the vessel **50** within the reclamation system **48** may have a second, different geometry.

(45) The resin R includes any radiant-energy curable material, which is capable of adhering or binding together the filler (if used) in the cured state. As used herein, the term “radiant-energy curable” refers to any material which solidifies or partially solidifies in response to the application of radiant energy of a particular frequency and energy level. For example, the resin R may include a photopolymer resin containing photo-initiator compounds functioning to trigger a polymerization reaction, causing the resin R to change from a liquid (or powdered) state to a solid state. Alternatively, the resin R may include a material that contains a solvent that may be evaporated out by the application of radiant energy. The

resin R may be provided in solid (e.g. granular) or liquid form, including a paste or slurry.

(46) Furthermore, the resin R can have a relatively high viscosity fluid that will not “slump” or run off during the build process. The composition of the resin R may be selected as desired to suit a particular application. Mixtures of different compositions may be used. The resin R may be selected to have the ability to out-gas or burn off during further processing, such as a sintering process.

(47) The resin R may incorporate a filler. The filler may be pre-mixed with the resin R, then loaded into the material deposition assembly **46**. The filler includes particles, which are conventionally defined as “a very small bit of matter.” The filler may include any material that is chemically and physically compatible with the selected resin R. The particles may be regular or irregular in shape, may be uniform or non-uniform in size, and may have variable aspect ratios. For example, the particles may take the form of powder, of small spheres or granules, or may be shaped like small rods or fibers.

(48) The composition of the filler, including its chemistry and microstructure, may be selected as desired to suit a particular application. For example, the filler may be metallic, ceramic, polymeric, and/or organic. Other examples of potential fillers include diamond, silicon, and graphite. Mixtures of different compositions may be used. In some examples, the filler composition may be selected for its electrical or electromagnetic properties, e.g. it may specifically be an electrical insulator, a dielectric material, an electrical conductor, and/or magnetic.

(49) The filler may be “fusible,” meaning it is capable of consolidation into a mass upon via application of sufficient energy. For example, fusibility is a characteristic of many available powders including, but not limited to, polymeric, ceramic, glass, and/or metallic materials. The proportion of filler to resin R may be selected to suit a particular application. Generally, any amount of filler may be used so long as the combined material is capable of flowing and being leveled, and there is sufficient resin R to hold together the particles of the filler in the cured state.

(50) With further reference to FIG. **1**, the stage **20** is capable of being oriented parallel to the resin surface **36** or the X-Y plane. Various devices may be provided for moving the stage **20** relative to the window **18** parallel to the Z-axis direction. For example, as illustrated in FIG. **1**, the movement may be provided through an actuator **56** connected between the stage **20** and a static support **58** and configured to change a relative position of the stage **20** relative to the radiant energy device **22**, the support plate **16**, the window **18**, and/or any other static component of the apparatus **10**. The actuator **56** may be configured as a ballscrew electric actuator, linear electric actuator, pneumatic cylinder, hydraulic cylinder, delta drive, or any other practicable device may additionally or alternatively be used for this purpose. In addition to, or as an alternative to, making the stage **20** movable, the resin support **28** could be movable parallel to the Z-axis direction.

(51) The radiant energy device **22** may be configured as any device or combination of devices operable to generate and project radiant energy on the resin R in a suitable pattern and with a suitable energy level and other operating characteristics to cure the resin R during the build process. For example, as shown in FIG. **1**, the radiant energy device **22** may include a projector **60**, which may generally refer to any device operable to generate a radiant energy patterned image of suitable energy level and other operating characteristics to cure the resin R. As used herein, the term “patterned image” refers to a projection of radiant energy comprising an array of one or more individual pixels. Non-limiting examples of patterned imaged devices include a DLP projector or another digital micromirror device, a two-dimensional array of LEDs, a two-dimensional array of lasers, and/or optically addressed light valves. In the illustrated example, the projector **60** includes a radiant energy source **62** such as a UV lamp, an image forming apparatus **64** operable to receive a source beam **66** from the radiant energy source **62** and generate a patterned image **68** to be projected onto the surface of the resin R, and optionally focusing optics **70**, such as one or more lenses.

(52) The image forming apparatus **64** may include one or more mirrors, prisms, and/or lenses and is provided with suitable actuators, and arranged so that the source beam **66** from the radiant energy source **62** can be transformed into a pixelated image in an X-Y plane coincident with the surface of the resin R. In the illustrated example, the image forming apparatus **64** may be a digital micro-mirror device.

(53) The projector **60** may incorporate additional components, such as actuators, mirrors, etc.

configured to selectively move the image forming apparatus **64** or another part of the projector **60** with the effect of rastering or shifting the location of the patterned image on the resin surface **36**. Stated another way, the patterned image may be moved away from a nominal or starting location.

(54) In addition to other types of radiant energy devices **22**, the radiant energy device **22** may include a "scanned beam apparatus" used herein to refer generally to any device operable to generate a radiant energy beam of suitable energy level and other operating characteristics to cure the resin R and to scan the beam over the surface of the resin R in a desired pattern. For example, the scanned beam apparatus can include a radiant energy source **62** and a beam steering apparatus. The radiant energy source **62** may include any device operable to generate a beam of suitable power and other operating characteristics to cure the resin R. Non-limiting examples of suitable radiant energy sources **62** include lasers or electron beam guns.

(55) The apparatus **10** may be operably coupled with a computing system **72**. The computing system **72** in FIG. **1** is a generalized representation of the hardware and software that may be implemented to control the operation of the apparatus **10**, including some or all of the stage **20**, the radiant energy device **22**, the actuator **56**, and the various parts of the apparatus **10** described herein. The computing system **72** may be embodied, for example, by software running on one or more processors embodied in one or more devices such as a programmable logic controller ("PLC") or a microcomputer. Such processors may be coupled to process sensors and operating components, for example, through wired or wireless connections. The same processor or processors may be used to retrieve and analyze sensor data, for statistical analysis, and for feedback control. Numerous aspects of the apparatus **10** may be subject to closed-loop control.

(56) Optionally, the components of the apparatus **10** may be surrounded by a housing **74**, which may be used to provide a shielding or inert gas (e.g., a "process gas") atmosphere using gas ports **76**. Optionally, pressure within the housing **74** could be maintained at a desired level greater than or less than atmospheric. Optionally, the housing **74** could be temperature and/or humidity controlled. Optionally, ventilation of the housing **74** could be controlled based on factors such as a time interval, temperature, humidity, and/or chemical species concentration. In some embodiments, the housing **74** can be maintained at a pressure that is different than an atmospheric pressure.

(57) Referring to FIGS. **2** and **3**, exemplary perspective views of the feed module **24** including a feed panel **80** are illustrated in accordance with exemplary embodiments of the present disclosure. As illustrated, the feed mandrel **24**A can be anchored to the feed panel **80** and may support and rotate a feed portion **84** (FIG. **1**) of the resin support **28** (FIG. **1**). In various embodiments, the feed mandrel **24**A includes a front portion **86** on a first side **88** of the feed panel **80** and a rear portion **90** on a second, opposing side **92** of the feed panel **80**. In some instances, a bearing **94** may be positioned along the front portion **86**, the rear portion **90**, and/or between the front and rear portions **86**, **90**.

(58) The front portion **86** of the feed mandrel **24**A may include a cylindrical portion **96** that is configured to accept the first portion **84** of the resin support **28** thereabout. In various instances, the resin support **28** may be operably coupled to a feed spool (e.g., cardboard spool, polymeric spool, paper-based spool, metallic spool, composite spool, elastomeric spool, etc.). The feed spool may be positioned about the feed mandrel **24**A.

(59) A stop **98** may be positioned between the cylindrical portion **96** and the feed panel **80**. As such, when the resin support **28** is wrapped about the feed mandrel **24**A, the stop **98** defines a first distance d **1** between an inner edge of the resin support **28** and the feed panel **80**. In some examples, the feed mandrel **24**A may be configured to move between a disengaged position and an engaged position. In operation, the feed mandrel **24**A may be placed in the disengaged position to allow the feed spool, and the resin support **28** wound thereabout, to be slid along the feed mandrel **24**A to a position in which an end portion of the feed spool is in contact or close proximity to the stop **98**. Once the feed spool is positioned about the feed mandrel **24**A, the feed mandrel **24**A may be placed in the engaged position causing the feed spool, and, consequently, the feed portion **84** of the resin support **28** to rotate with the feed mandrel **24**A.

(60) In some embodiments, the drive system **30** (FIG. **1**) may include a first control device **32** operably coupled with the rear portion **90** of the feed mandrel **24**A. The first control device **32** may be

configured as one or more motors, actuators, or any other device that may rotate the feed mandrel **24**A. Further, as illustrated in FIG. **3**, the first control device **32** may include a transmission **100** in the form of a belt system, a gear system, and/or any other practicable system.

(61) With further reference to FIGS. **2** and **3**, one or more rollers **102**A, **102**B and/or a load cell **104** may be anchored to the first side **88** of the feed panel **80**. For example, a pair of rollers **102**A, **102**B may be positioned above the feed mandrel **24**A in the Z-axis direction. In some instances, the pair of rollers **102**A, **102**B may have an axis of rotation **106** that is generally parallel to an axis of rotation **108** of the feed mandrel **24**A.

(62) The load cell **104** may be positioned between the pair of rollers **102**A, **102**B and the feed mandrel **24**A in the Z-axis direction. The load cell **104** may be configured as a force transducer that converts a tension or torque provided by the resin support **28** onto the load cell **104** into an electrical signal that can be measured by the computing system **72** to determine a tension of the resin support **28**. In some embodiments, the resin support **28** may be provided from the feed mandrel **24**A around the first roller **102**A, the load cell **104**, and, subsequently, the second roller **102**B.

(63) Referring to FIGS. **4** and **5**, respective front and rear perspective views of the take-up module **26** including a take-up panel **82** are illustrated in accordance with exemplary embodiments of the present disclosure. As illustrated, the take-up mandrel **26**A may be anchored to the take-up panel **82** and configured to support a second portion **110** (FIG. **1**) of the resin support **28** (FIG. **1**). In various embodiments, the take-up mandrel **26**A includes a front portion **112** on a first side **114** of the take-up panel **82** and a rear portion **116** on a second, opposing side **118** of the take-up panel **82**. In some instances, a bearing **120** may be positioned along the front portion **112**, the rear portion **116**, and/or between the first and second portions **112**, **116** of the take-up mandrel **26**A.

(64) The front portion **112** of the take-up mandrel **26**A may include a cylindrical portion **122** that is configured to accept the second portion **110** of the resin support **28** thereabout. In various instances, the resin support **28** may be operably coupled to a take-up spool (e.g., cardboard spool, polymeric spool, paper-based spool, metallic spool, composite spool, elastomeric spool, etc.). The take-up spool may be positioned about the take-up mandrel **26**A.

(65) A stop **124** may be positioned between the cylindrical portion **122** and the take-up panel **82**. As such, the resin support **28** is wrapped about the take-up mandrel **26**A, the stop **124** defines a second distance d **2** between the inner edge of the resin support **28** and the take-up panel **82**. In some examples, the take-up mandrel **26**A may be configured to move between a disengaged position and an engaged position. In operation, the take-up mandrel **26**A may be placed in the disengaged position to allow the take-up spool to be slid along the take-up mandrel **26**A to a position in which an end portion of the take-up spool is in contact or close proximity to the stop **124**. Once the take-up spool is positioned about the take-up mandrel **26**A, the take-up mandrel **26**A may be placed in the engaged position causing the take-up spool, and, consequently, the second portion **110** of the resin support **28** to rotate with the take-up mandrel **26**A.

(66) Similar to the feed module **24**, a second control device **34** may be operably coupled with the rear portion **116** of the take-up mandrel **26**A. The second control device **34** may be configured as one or more motors, actuators, or any other device that may rotate the take-up mandrel **26**A. Further, as illustrated in FIG. **5**, the second control device **34** may include a transmission **126** in the form of a belt system, a gear system, and/or any other practicable system. Moreover, the first control device **32** and the second control device **34** may be operably coupled with feedback sensors and/or controls that can be provided for driving the mandrels **24**A, **26**A in such a manner to maintain the resin support **28** tensioned between the mandrels **24**A, **26**A and to wind the resin support **28** from the feed mandrel **24**A to the take-up mandrel **26**A.

(67) With further reference to FIGS. **4** and **5**, one or more rollers **128** may be anchored to the first side **114** of the take-up panel **82**. For example, a set of three rollers **128**A, **128**B, **128**C may be positioned on various portions of the take-up panel **82**. In some instances, each roller **128**A, **128**B, **128**C may have an axis of rotation **130** that is generally parallel to an axis of rotation **132** of the take-up mandrel **26**A.

(68) The take-up panel **82** may further support the resin reclamation system **48**, which may be configured to remove at least a portion of the resin R that remains on the resin support **28** after the resin

support **28** is removed from a build zone **42** (FIG. **1**).

(69) Referring now to FIG. **6**, the material deposition assembly **46** is schematically illustrated according to various embodiments of the present disclosure. As illustrated, the material deposition assembly **46** includes a vessel **50** and a reservoir **52**. A conduit **54** extends from the vessel **50** to direct resin R from the vessel **50** to the reservoir **52**. The conduit **54** may be positioned along a bottom portion of the vessel **50** such that the resin R may be gravity fed from the vessel **50** to the conduit **54**, which may generally prevent the introduction of air to the resin R as the air is transferred into and/or through the conduit **54**.

(70) The reservoir **52** may be configured to retain a first volume **136** of the resin R and produce a layer of the resin R on the resin support **28** as the resin support **28** is translated in an X-axis direction. The vessel **50** may be positioned above the reservoir **52** in a Z-axis direction, or in any other position, and configured to store a second volume **138** of the resin R. In various embodiments, when the first volume **136** of the resin R deviates from a predefined range, additional resin R is supplied from the vessel **50** to the reservoir **52**.

(71) In some embodiments, the reservoir **52** includes a base **134**, an upstream wall **142**, a downstream wall **144**, and sidewalls **146**. The upstream wall **142** may define a slot **148** therein to receive the resin support **28**. The downstream wall **144** may define an aperture **150** that serves as an outlet for the resin support **28** and the layer **140** of the resin R. In various embodiments, the upstream wall **142**, the downstream wall **144**, and the sidewalls **146** define a cavity **152** that is configured to retain the first volume **136** of the resin R, which may be supplied by the conduit **54**.

(72) Continuing to refer to FIG. **6**, in various examples, the material deposition assembly **46** can include a first doctor blade **154** and/or a second doctor blade **156** that are used to control the thickness of the resin R applied to the resin support **28**, as the resin support **28** passes under the material deposition assembly **46**. In the illustrated embodiment, the thickness of layer **140** is determined by the doctor blades **154**, **156**. In various embodiments, other material depositing apparatuses can be used separately or in combination with the first and second doctor blades **154**, **156** such as, but not limited to, gravure rolls, metering rolls, weir-based cascades, direct die casting, and a combination thereof.

(73) The first doctor blade **154** may be configured to act as a gross control for the thickness **158** of an initial deposited layer **160** of the resin R. An adjustment device **162** may be configured to adjust an angle **164** defined by a surface of the first doctor blade **154** and the top edge of the sidewall **146**. The greater the angle **164**, the lower thickness **158**, i.e., the thinner initial deposited layer **160** will be. The adjustment device **162** can be a threaded screw assembly configured to extend and retract the order to affect change in the angle **164**. The adjustment device **162** is mechanically linked to the first doctor blade **154**.

(74) The second doctor blade **156** can be movingly linked to the downstream wall **144** and can be moved by an actuator **166** to adjust and define the outlet gap. A control signal can be utilized to controllably connect the actuator **166** with the computing system **72**. The layer **140** has a thickness **168** that is the distance between the surface of the resin R and the base of layer **140** which is in contact with the first surface of the resin support **28**. Accordingly, the thickness **168** of the material layer **140** can be adjusted by a control action such as movement of the doctor blade **154** in response to signals from the computing system **72**. In various embodiments, suitable control signals can be electrical, pneumatic, sonic, electromagnetic, a combination thereof, and/or any other type of signal. In addition, other suitable control actions include varying the speed of the resin support **28**, adjusting the viscosity or other rheological property of the resin R, changing the width of the deposited material layer **140** such as by the repositioning of side dams.

(75) Continuing to refer to a FIG. **6**, a thickness sensor **170** is positioned downstream of the second doctor blade **156** and/or the downstream wall **144**. The thickness sensor **170** is configured to determine a thickness **168** of the deposited material layer **140**. As a result, the deposited material layer **140** has the thickness **168** as it passes from the material deposition assembly **46** into and through a build zone **42** as shown in FIG. **1**. As represented in FIG. **6**, the thickness sensor **170** is configured to generate monitoring signals indicative of the thickness **168** of the deposited material layer **140** and to transmit such signals to the computing system **72**. The thickness sensor **170** may be embodied as one or more confocals, imaging sensor, or any other vision-based device. The thickness sensor **170** may additionally

and/or alternatively be configured as any other practicable proximity sensor, such as, but not limited to, an ultrasonic sensor, a radar sensor, a LIDAR sensor, or the like.
(76) The computing system **72** is configured to receive the monitoring signals and process such signals using predetermined algorithms to generate control signals for controlling the thickness of the deposited material layer **140**. In this manner, closed loop control of the thickness **168** of the deposited material layer **140** can be achieved. Optionally, when the sensor indicates that the layer **140** is too thin additional resin R can be added to increase the thickness of the layer **140**.
(77) Still referring to FIG. **6**, in several embodiments, the material deposition assembly **46** further includes a regulator **174** operably coupled with the conduit **54**. The regulator **174** is configured to restrict flow of the resin R from the vessel **50** to the reservoir **52** in a first position and allow flow from the vessel **50** to the reservoir **52** in a second position. In some embodiments, the regulator **174** may be configured as a pneumatically actuated pinch valve. In various embodiments, suitable control of the regulator **174** can be accomplished through activation of an electrical device, a pneumatic device, a sonic device, an electromagnetic device, a combination thereof, and/or any other practicable device.
(78) In various embodiments, the material deposition assembly **46** can further include a volume sensor **176**. The volume sensor **176** can be configured to provide signals to the computing system **72** related to the first volume **136** of the resin R within the cavity **152** of the reservoir **52**. The computing system **72** is configured to receive the monitoring signals and process such signals using predetermined algorithms to generate control signals for controlling the regulator **174**. For instance, the computing system **72** can actuate the regulator **174** from the second position to the first position when the first volume **136** of the resin R is within a predefined range. In this manner, closed-loop control of the first volume **136** of the resin R can be achieved. Once the first volume **136** of the resin R returns to the predefined range, the computing system **72** can actuate the regulator **174** from the first position to the second position thereby blocking further flow of the resin R from the vessel **50** to the reservoir **52**. The volume sensor **176** may be embodied as one or more imaging sensors or any other vision-based device. The volume sensor **176** may additionally and/or alternatively be configured as any other practicable proximity sensor, such as, but not limited to, an ultrasonic sensor, a radar sensor, a LIDAR sensor, or the like.
(79) In some embodiments, the actuation of the regulator **174** may additionally or alternatively be based on any other input. For example, the volume of the resin R transferred from the vessel **50** to the reservoir **52** may be at least partially based on data provided by the thickness sensor **170**, the volume of resin support **28** translated through the reservoir **52**, and/or any other information.
(80) In some examples, a restrictor **178** may also be operably coupled with the conduit **54** and configured to block flow of the resin R past the restrictor **178** when placed in a restricted position. Conversely, when placed in a flow position, the restrictor **178** may allow the resin R to flow past the restrictor **178**. In some examples, the restrictor **178** may be manually moved between the blocked position and the flow position through a handle **180**. However, the restrictor **178** may be moved between positions in any other manner without departing from the scope of the present disclosure.
(81) In some instances, the restrictor **178** may be moved to the blocked position prior to the vessel **50** being removed from the apparatus **10**. When the vessel **50** and/or a new vessel **50** is to be installed in the apparatus **10**, the restrictor **178** may be maintained in the blocked position. Next, the conduit **54** may be operably coupled with the regulator **174**. Once the conduit **54** is coupled with the regulator **174**, the restrictor **178** may be placed in the flow position. As such, the restrictor **178** may be used to control the resin R during installation and removal of the vessels **50** from the apparatus **10**.
(82) With further reference to FIG. **6**, in various embodiments, a brace **182** may be operably coupled with a frame of the manufacturing apparatus **10**. For example, the brace **182** may be operably coupled with the material deposition assembly panel **78**. In some instances, the brace **182** may extend from the material deposition assembly panel **78** in the Y-axis direction. Further, the brace **182** may define one or more support surfaces **184** that is configured to support and/or otherwise retain the vessel **50** in a predefined location.
(83) As illustrated, in some examples, the vessel **50** may include one or more brackets **186** coupled thereto. For example, first and second brackets **186** may be operably coupled with opposite sides of the vessel **50**. The one or more brackets **186** may be configured to retain the vessel **50** in a predefined

location. In various embodiments, the one or more brackets **186** may include an upper portion **188**, a lower portion **190**, and a body portion **192** extending between the upper portion **188** and the lower portion **190**. In some examples, the one or more brackets **186** may be retained or operably coupled with the braces **182**. For instance, the lower portion **190** of the bracket **186**, and/or any other portion of the bracket **186**, may be positioned at least partially on the support surface **184**.

(84) In several embodiments, the brace **182** may include a brace locating pin **194** that extends from the support surface **184**. The support pin may be integrally formed with the brace **182** and/or later attached thereto. The lower portion **190** of the bracket **186** may define a first locating void **196** that is sized to surround the brace locating pin **194** when the lower portion **190** of the bracket **186** is supported by the brace **182**.

(85) With further reference to FIG. **6**, in some instances, a mixing assembly **198** may be configured to continuously and/or intermittently agitate the resin R within the vessel **50** to increase the consistency and quality of the resin R. As illustrated, in some embodiments, the mixing assembly **198** may include a housing **200** positioned above the vessel **50**. The housing **200** supports a rotation assembly **202** capable of rotating an impeller **204** within the vessel **50**. The rotation assembly **202** may be configured as a direct drive system that includes one or more motors, actuators, or any other device that may rotate the impeller **204**. Alternatively, the rotation assembly **202** may be configured as an offset drive system in which the rotation assembly **202** is operably coupled with the impeller **204** through a transmission.

(86) In various embodiments, the mixing assembly may be configured to rotate the impeller **204** at one or more speeds. In some instances, the impeller **204** may be rotated as a first speed (e.g., 0.01 to 40 rpm), which may be sufficient to generally prevent segregation and decrease the possibility of trapping air (aerating the slurry). In addition, the impeller **204** may be rotated at a second, faster speed (e.g., greater than 40 rpm), which may allow for the breaking up of agglomerates by providing more shear force to the resin R.

(87) In various embodiments, the impeller **204** may be made from a wide array of materials, including, but not limited to, polymers, which may allow for the resin R to burn off in a sintering cycle, metals, which may provide wear resistance, ceramics (e.g. alumina coated), which may further increase wear resistance, and/or any other practicable material. In some embodiments, the impeller material may be matched to and/or compatible with the resin R being used in the manufacturing process as some resins R will be more abrasive and others will be less. Moreover, the impeller **204** may be cleanable (with solvents e.g. isopropyl alcohol, acetone, etc.) and the material of the impeller **204** may be based on the ability to clean the resin R from the impeller **204**.

(88) In the exemplary embodiment illustrated in FIG. **6**, the impeller **204** is configured as a double-helix impeller. However, it will be appreciated that the impeller **204** may be of any design without departing from the scope of the present disclosure. For example, as illustrated in FIG. **9**, the impeller **204** may be a pitched blade impeller. In embodiments utilizing a double-helix impeller, such as the one illustrated in FIG. **6**, the impeller **204** may be used to blend high viscosity resins R operating in a laminar flow regime. The helical ribbons of the impeller **204** may also be designed for close wall clearance. Furthermore, the helical ribbons operate at relatively slow speeds rotating in a direction to create resin movement up along the wall. The resin R returns down the center of the vessel **50** providing overall blending in the vessel **50**.

(89) Referring to FIGS. **6-8**, various views of the material deposition assembly **46** are exemplary illustrated in accordance with aspects of the present disclosure. As provided herein, the rotation assembly **202** is operably coupled with the impeller **204**. In various embodiments, the material deposition assembly panel **78** may define a channel **208** and at least a portion of the rotation assembly **202** may extend through the channel **208** and to a position over the vessel **50**. The rotation assembly **202** may include a coupler **210** that allows for the impeller **204** to be selectively coupled thereto.

(90) In some embodiments, the rotation assembly **202** may be movable within the channel **208** generally in the Z-axis direction. In some examples, the rotation assembly **202** may be operably coupled with a track assembly **212** to guide movement in the Z-axis. As illustrated, the track assembly **212** may be operably coupled with a rear side of the material deposition assembly panel **78**, and/or any other component of the apparatus **10**.

(91) In the illustrated embodiment, the track assembly **212** includes first and second rails **214**, **216** positioned on opposing sides of the channel **208** of the material deposition assembly panel **78**. The rotation assembly **202** includes guides **218** coupled with each of the first and second rails **214**, **216**. The guides **218** are configured to slide along each of the first and second rails **214**, **216**. In some examples, the track assembly **212** may include one or more retainers that are configured to retain the rotation assembly **202** in predefined positions along the first and second rails **214**, **216**.
(92) Additionally or alternatively, in some instances, a movement device **220** may be operably coupled with rotation assembly **202** and configured to move the rotation assembly **202** along the track assembly **212** and/or retain the rotation assembly **202** in a position along the track assembly **212**. For example, the movement device **220** provides upward vertical force through hydraulics, pneumatics, spring mechanics, actuator, and/or otherwise.
(93) In some examples, the movement device **220** may include a pneumatic linear actuator that includes a body, a piston, and a slide or carriage that is operably coupled with the piston and the rotation assembly **202**. The piston is moved by a fluid sent into a chamber that is present on both ends of the piston.
(94) First and second valves may be fluidly coupled with the chamber that allows for fluid to be selectively provided to either side of the piston causing the piston to move in response. The movement of the piston also causes the slide to move, which, in turn, moves the rotation assembly **202**. The first and second valves can also have flow control features to be able to adjust the speed at which the rotation assembly **202** is moved along the first and second rails **214**, **216**.
(95) With further reference to FIG. **8**, in some embodiments, an access may be positioned above the material deposition assembly **46** in the Z-axis direction. For example, the access may be a pane **222** that allows visibility of the vessel **50**. The pane **222** may be configured to block UV light, and/or any other spectrum of light, from being able to pass therethrough. Furthermore, in various embodiments, the pane **222** may be moveable such that the material deposition assembly **46** may be accessible through the pane **222**.
(96) Referring now to FIGS. **9-12**, views of a material deposition system in accordance with various aspects of the present disclosure are provided. In certain exemplary embodiments, the material deposition device may have various components that are configured in a generally common manner with the exemplary material deposition assembly **46** described above with reference to FIGS. **1-8**. Accordingly, the same or similar numbers may refer to the same or similar parts.
(97) In some embodiments, such as those illustrated in FIGS. **9-12**, the vessel **50** may be offset from the reservoir **52** in the X-axis direction. As such, the conduit **54** extending between the vessel **50** and the reservoir **52** may be non-linear in the Z-axis direction. In various embodiments, a connector **224** may be operably coupled with the reservoir **52** to maintain the conduit **54** in a predefined orientation. The connector **224** may be integrally formed with the reservoir **52** and/or operably coupled therewith. The connector **224** may be configured to direct an end portion of the conduit **54** towards the cavity **152** of the reservoir **52**.
(98) With further reference to FIGS. **9-12**, the regulator **174** may be coupled with the conduit **54**. As provided herein, the regulator **174** is configured to restrict flow of the resin R from the vessel **50** to the reservoir **52** in a first position and allow flow from the vessel **50** to the reservoir **52** in a second position. In some embodiments, the regulator **174** may be configured as a pneumatically actuated pinch valve. In various embodiments, suitable control of the regulator **174** can be accomplished through activation of an electrical device, a pneumatic device, a sonic device, an electromagnetic device, a combination thereof, and/or any other practicable device.
(99) As discussed above, the material deposition assembly **46** can further include a volume sensor **176**. The volume sensor **176** can be configured to provide signals to the computing system **72** related to the first volume **136** of the resin R within the cavity **152** of the reservoir **52**. The computing system **72** is configured to receive the monitoring signals and process such signals using predetermined algorithms to generate control signals for controlling the regulator **174**. For instance, the computing system **72** can actuate the regulator **174** from the second position to the first position when the first volume **136** of the resin R is within a predefined range. In this manner, closed-loop control of the first volume **136** of the

resin R can be achieved. Once the first volume **136** of the resin R returns to the predefined range, the computing system **72** can actuate the regulator **174** from the first position to the second position thereby blocking further flow of the resin R from the vessel **50** to the reservoir **52**. The volume sensor **176** may be embodied as one or more imaging sensors or any other vision-based device. The volume sensor **176** may additionally and/or alternatively be configured as any other practicable proximity sensor, such as, but not limited to, an ultrasonic sensor, a radar sensor, a LIDAR sensor, or the like.

(100) In some embodiments, the actuation of the regulator **174** may additionally or alternatively be based on any other input. For example, the volume of the resin R transferred from the vessel **50** to the reservoir **52** may be at least partially based on the thickness sensor **170**, the volume of resin support **28** translated through the reservoir **52**, and/or any other information.

(101) In some examples, the restrictor **178** may also be operably coupled with the conduit **54** and configured to block flow of the resin R past the restrictor **178** when placed in a restricted position. Conversely, when placed in a flow position, the restrictor **178** may allow the resin R to flow past the restrictor **178**. In some examples, the restrictor **178** may be manually moved between the blocked position and the flow position through a handle **180**. However, the restrictor **178** may be moved between positions in any other manner without departing from the scope of the present disclosure.

(102) With further reference to FIGS. **9-12**, the rotation assembly **202** may include a transmission **226** in the form of a belt system but may also be configured as any other practicable system. In some cases, the transmission **226** may be operably coupled with a transmission plate **228**. In some instances, a first pulley **230** may be operably coupled the transmission plate **228** and an actuator **232**. A second pully **234** may be coupled with the impeller **204**. A belt **236** or other energy transferring device may be positioned about the first and second pulleys **230**, **234** to transfer energy from the actuator **232** to the impeller **204**.

(103) In some instances, a housing **200** may at least partially surround the transmission **226** plate and/or the movement device **220**. In addition, the housing **200** (or the transmission plate **228**) may be operably coupled with the track assembly **212** to allow for movement of the transmission plate **228** along the Z-axis direction. Additionally, in some instances, a movement device **220** may be operably coupled with rotation assembly **202** and configured to move the rotation assembly **202** along the track assembly **212** and/or maintain the rotation assembly **202** in a position along the track assembly **212**. For example, the movement device **220** provides upward vertical force through hydraulics, pneumatics, spring mechanics, actuator, and/or otherwise.

(104) With further reference to FIGS. **9-12**, in some embodiments, the impeller **204** may be configured as a pitched, or double-pitched, blade impeller. Moreover, the impeller **204** may include any number of blades. For example, as illustrated, the impeller **204** may include three blades. The pitched impellers may induce a top-to-bottom turnover of the resin R and circulate the resin R without excessive swirling.

(105) Referring now to FIG. **13**, a view of a reclamation system **48** within the resin management system **44** in accordance with various aspects of the present disclosure is provided. In certain exemplary embodiments, the reclamation system **48** may be configured to include various components that are generally common with the exemplary material deposition assemblies described above with reference to FIGS. **1** through **12**. Accordingly, the same or similar numbers may refer to the same or similar parts.

(106) In some embodiments, the reclamation system **48** may include a collection structure **238** that is configured to remove at least a portion of the resin R from the resin support **28**. As the resin R is removed by the collection structure **238**, the resin R is directed through a conduit **54** and into a vessel **50**. In some examples, the collection structure **238** is supported by and positioned on a first side **114** of the take-up panel **102** and the vessel **50** is positioned on an opposing second side **118** of the take-up panel **102**.

(107) With further reference to FIGS. **13** and **14**, the vessel **50** may be suspended by a reinforcement and/or a brace **182**. In some instances, a mixing assembly **198** may be configured to continuously and/or intermittently agitate the resin R within the vessel **50** to generally maintain the consistency and quality of the resin R. As illustrated, in some embodiments, the mixing assembly **198** may include a housing **200** operably coupled with the reinforcement. The housing **200** supports a rotation assembly **202** capable of rotating an impeller **204** that extends into the vessel **50**. The mixing assembly **198** may allow for the resin R to be continually agitated to prevent excessive settling or separation of the resin R.

(108) As discussed above, the vessel **50** may include a bracket **186** that is operably coupled with the brace **182** to maintain the vessel **50** in a predefined location. The bracket **186** may be of any practicable geometry. In some embodiments, such as the one illustrated in FIG. **13**, the bracket **186** may include an upper portion **188**, a lower portion **190**, and a body portion **192** extending between the upper portion **188** and the lower portion **190**.
(109) In some instances, the brace **182** may include a brace locating pin **194**. The lower portion **190** of the bracket **186** may include a first locating void **196** that is configured to at least partially surround the brace locating pin **194**. As such, the bucket may be placed in a generally consistent location within the reclamation system **48**.
(110) In the illustrated embodiment, the reclamation system **48** may also include a track assembly **212**. The housing **200** can include guides **218** coupled with each of the rails **214**. The guides **218** are configured to slide along each of the rails **214**. In some examples, the track assembly **212** may include one or more retainers that are configured to retain the rotation assembly **202** in predefined positions along the rails **214**. Additionally or alternatively, in some instances, a movement device **220** may be operably coupled with rotation assembly **202** and configured to move the rotation assembly **202** along the track assembly **212** and/or maintain the rotation assembly **202** in a position along the track assembly **212**. For example, the movement device **220** provides upward vertical force through hydraulics, pneumatics, spring mechanics, actuator, and/or otherwise.
(111) Referring now to FIGS. **14-16**, in some instances, the bracket **186** of vessel **50** of the material deposition assembly **46** and the bracket **186** of the vessel **50** of the reclamation system **48** may be generally of the same configuration. For example, as provided herein, the lower portion **190** of each bracket **186** may include a first locating void **196** that is configured to at least partially surround a brace locating pin **194** of the brace **182** within the material deposition assembly **46** and/or the reclamation system **48**. In addition, each of the upper portions **188** of the brackets **186** may also define a second locating void **240**. The second locating voids **240** of the upper portions **188** may be of a similar size or geometry to that of the first locating voids **196** of the lower portions **190**. Alternatively, the second locating voids **240** of the upper portions **188** may be of a different size or geometry to that of the location voids of the lower portions **190**.
(112) Referring still to FIGS. **14-16**, in various embodiments, due to a common geometry of the bracket **186** of the vessel **50** of the material deposition assembly **46** and the bracket **186** of the vessel **50** of the reclamation system **48**, a common dolly **244** may be used to place the vessels **50** within and/or remove the vessels **50** from the apparatus **10** (FIG. **1**). For example, the dolly **244** may include a base portion **246** that includes one or more movement assemblies **248**, such as wheels, rollers, and the like. A beam **250** may extend from the base portion **246**. The beam **250** may include a slide assembly **252** that allows for a carrier **254** to slide along the beam **250**. In some examples, the slide assembly **252** may include one or more retainers that are configured to retain the carrier **254** in predefined positions along the slide assembly **252**.
(113) Additionally or alternatively, in some instances, a movement device **256** may be operably coupled with the carrier **254** and configured to move the carrier **254** along the slide assembly **252** and/or maintain the carrier **254** in a position along the slide assembly **252**. For example, the movement device **256** provides upward vertical force through an actuator (e.g., electric) hydraulics, pneumatics, spring mechanics, and/or otherwise.
(114) In various embodiments, the dolly **244** may further include an input device **258** for altering the position of the carrier **254** along the slide assembly **252**. For example, as illustrated in FIGS. **15** and **16**, the input device **258** may be in the form of a lever that allows for selective movement of the carrier **254**.
(115) Referring back to FIGS. **14-16**, in several embodiments, the carrier **254** includes a pair of arms **260**. Each of the arms **260** may be of a height h, that is less than a height hi, defined between the upper portion **188** and the lower portion **190** of each bracket **186**. As such, the arms **260** may be slid between the upper portion **188** and the lower portion **190** of each bracket **186**. Furthermore, the first arm **260** of the carrier **254** may be separated from the second arm **260** of the carrier **254** by a width that is greater than the width defined by the vessel **50** and the opposing body portions **192** of the brackets **186** installed on a common vessel **50**. Thus, in some embodiments, the carrier **254** may be positioned within

the channels defined by the brackets **186** on the opposing sides of the vessel **50**. To make insertion of the first and second arms **260** into the respective channels of the brackets **186**, the an outer end portion of each arm **260** may be chamfered.
(116) In several embodiments, each arm **260** may also define a carrier locating pin **262** on an upper surface thereof. The carrier locating pin **262** on each arm **260** may be surrounded by the second locating void **240** on the upper portion **188** of each bracket **186**. As such, the first locating void **196** within the lower portion **190** of each bracket **186** may surround a brace carrier locating pin **262** when installed within the apparatus **10** and the second locating void **240** of the upper portion **188** of each bracket **186** may surround a carrier locating pin **262** on the carrier **254** when transported by the dolly **244**.
(117) FIG. **17** depicts certain components of the computing system **72** according to example embodiments of the present disclosure. The computing system **72** can include one or more computing device(s) **72**A which may be used to implement the method **300** such as described herein. The computing device(s) **72**A can include one or more processor(s) **72**B and one or more memory device(s) **72**C. The one or more processor(s) **72**B can include any suitable processing device, such as a microprocessor, microcontroller, integrated circuit, an application specific integrated circuit (ASIC), a digital signal processor (DSP), a field-programmable gate array (FPGA), logic device, one or more central processing units (CPUs), graphics processing units (GPUs) (e.g., dedicated to efficiently rendering images), processing units performing other specialized calculations, etc. The memory device(s) **72**C can include one or more non-transitory computer-readable storage medium(s), such as RAM, ROM, EEPROM, EPROM, flash memory devices, magnetic disks, etc., and/or combinations thereof.
(118) The memory device(s) **72**C can include one or more computer-readable media and can store information accessible by the one or more processor(s) **72**B, including instructions **72**D that can be executed by the one or more processor(s) **72**B. The instructions **72**D may include one or more steps of the method **300** described herein, such as to execute operations of the additive manufacturing apparatus **10** described above. For instance, the memory device(s) **72**C can store instructions **72**D for running one or more software applications, displaying a user interface, receiving user input, processing user input, etc. In some implementations, the instructions **72**D can be executed by the one or more processor(s) **72**B to cause the one or more processor(s) **72**B to perform operations, e.g., such as one or more portions of methods described herein. The instructions **72**D can be software written in any suitable programming language or can be implemented in hardware. Additionally, and/or alternatively, the instructions **72**D can be executed in logically and/or virtually separate threads on processor(s) **72**B.
(119) The one or more memory device(s) **72**C can also store data **72**E that can be retrieved, manipulated, created, or stored by the one or more processor(s) **72**B. The data **72**E can include, for instance, data to facilitate performance of the method **300** described herein. The data **72**E can be stored in one or more database(s). The one or more database(s) can be connected to computing system **72** by a high bandwidth LAN or WAN, or can also be connected to the computing system **72** through network(s) (not shown). The one or more database(s) can be split up so that they are located in multiple locales. In some implementations, the data **72**E can be received from another device.
(120) The computing device(s) **72**A can also include a communication module or interface **72**F used to communicate with one or more other component(s) of computing system **72** or the additive manufacturing apparatus **10** over the network(s). The communication interface **72**F can include any suitable components for interfacing with one or more network(s), including, for example, transmitters, receivers, ports, controllers, antennas, or other suitable components.
(121) As provided herein, the computing system **72** may be operably coupled with one or more of the drive system **30**, the material deposition assembly **46**, and/or the reclamation system **48**. The computing system **72** may be configured to control the actuation of the drive system **30** based on the information from one or more sensors **264**. Likewise, the computing system **72** may be operably coupled with the material deposition assembly **46** and/or the reclamation system **48** to actuate one or more respective components thereof.
(122) Now that the construction and configuration of the additive manufacturing apparatus having one or more accumulators have been described according to various examples of the present subject matter,

a method **300** for operating an additive manufacturing apparatus is provided. In general, the method **300** will be described herein with reference to the additive manufacturing apparatus shown in FIGS. **1-16** and the various system components shown in FIG. **17**. However, it will be appreciated that the disclosed method **300** may be implemented with additive manufacturing apparatuses having any other suitable configurations and/or within systems having any other suitable system configuration. In addition, although FIG. **18** depicts steps performed in a particular order for purposes of illustration and discussion, the methods discussed herein are not limited to any particular order or arrangement. One skilled in the art, using the disclosures provided herein, will appreciate that various steps of the methods disclosed herein can be omitted, rearranged, combined, and/or adapted in various ways without deviating from the scope of the present disclosure.

(123) Referring now to FIG. **18**, at step **302**, the method **300** includes operably coupling a bracket of a first vessel with a brace of said additive manufacturing apparatus. As provided herein, the brace may be operably coupled with a frame of the manufacturing apparatus and the bracket may be coupled with the first vessel. Further, the bracket can define an upper support and a lower support with the lower support positioned above the brace in the Z-axis direction. In some instances, the brace can define a locator pin and the lower support can define a locating void. In such instances, operably coupling a bracket of a first vessel with a brace may include positioning the locating void of the bracket about the locator pin of the brace.

(124) Next, at step **304**, the method **300** includes coupling a conduit to direct resin within the first vessel to a reservoir. The reservoir can be configured to retain a first volume of the resin therein and define a thickness of the resin on the resin support as the resin support is translated in an X-axis direction. The vessel can be positioned above the reservoir in a Z-axis direction and configured to store a second volume of the resin.

(125) At step **306**, the method **300** includes actuating a regulator to allow the resin to be gravity fed from the first vessel to the reservoir. At step **308**, the method **300** can include detecting, with a sensor, a first volume of the resin within the reservoir. The regulator may be actuated when the first volume of the resin is below a predefined range. In various embodiments, the resin may be gravity fed from the first vessel to the reservoir to generally prevent the introduction of air to the resin R as the air is transferred into and/or through the conduit to the reservoir.

(126) At step **310**, the method **300** includes depositing, with a material deposition assembly, the resin to form a deposited resin layer on a resin surface. In various instances, the resin surface can include at least a portion that is transparent. The material deposition assembly may be any device or combination of devices that is operable to apply a layer of the resin on the resin support. The material deposition assembly may optionally include a device or combination of devices to define a height of the resin on the resin support and/or to level the resin on the resin support. Nonlimiting examples of suitable material deposition assemblies include chutes, hoppers, pumps, spray nozzles, spray bars, or printheads (e.g. inkjets).

(127) At step **312**, the method **300** includes executing a build cycle. In various embodiments, the build cycle can include positioning a stage relative to the resin surface so as to define a layer increment in the deposited resin layer, selectively curing the resin using an application of radiant energy in a specific pattern so as to define the geometry of a cross-sectional layer of the component, and/or moving the resin surface and the stage relatively apart so as to separate the component from the resin surface.

(128) At step **314**, the method **300** can include removing a portion of the resin from the resin support through a collection structure. Moreover, at step **316**, the method can include directing the portion of the resin from the collection structure to a second vessel through a conduit.

(129) It should be appreciated that the additive manufacturing apparatus is described herein only for the purpose of explaining aspects of the present subject matter. In other example embodiments, the additive manufacturing apparatus may have any other suitable configuration and may use any other suitable additive manufacturing technology. Further, the additive manufacturing apparatus and processes or methods described herein may be used for forming components using any suitable material. For example, the material may be plastic, metal, concrete, ceramic, polymer, epoxy, photopolymer resin, or any other suitable material that may be embodied in a layer of slurry, resin, or any other suitable form

of sheet material having any suitable consistency, viscosity, or material properties. For example, according to various embodiments of the present subject matter, the additively manufactured components described herein may be formed in part, in whole, or in some combination of materials including but not limited to pure metals, nickel alloys, chrome alloys, titanium, titanium alloys, magnesium, magnesium alloys, aluminum, aluminum alloys, iron, iron alloys, stainless steel, and nickel or cobalt-based superalloys (e.g., those available under the name Inconel® available from Special Metals Corporation). These materials are examples of materials suitable for use in the additive manufacturing processes described herein, and may be generally referred to as "additive materials."

(130) Further aspects are provided by the subject matter of the following clauses:

(131) An additive manufacturing apparatus comprising: a stage configured to hold a component; a radiant energy device operable to generate and project radiant energy in a patterned image; an actuator configured to change a relative position of the stage relative to the radiant energy device; and a resin management system including a material deposition assembly upstream of the stage and configured to deposit a resin on a resin support, the material deposition assembly comprising: a reservoir configured to retain a first volume of the resin; a vessel separated from the reservoir and configured to store a second volume of the resin; and an impeller positioned within the vessel and configured to agitate the resin within the vessel.

(132) The additive manufacturing apparatus of one or more of these clauses, wherein the reservoir is configured to define a thickness of the resin on the resin support as the resin support is translated in an X-axis direction and a conduit configured to direct the resin from the vessel to the reservoir.

(133) The additive manufacturing apparatus of one or more of these clauses, wherein the reservoir includes an upstream wall, a downstream wall, and sidewalls that define a cavity, and wherein the conduit is configured to direct resin into the cavity.

(134) The additive manufacturing apparatus of one or more of these clauses, wherein the upstream wall defines a slot to receive the resin support and the downstream wall defines an aperture that serves as an outlet for the resin support and a layer of the resin deposited on the resin support.

(135) The additive manufacturing apparatus of one or more of these clauses, wherein the material deposition assembly further comprises a regulator operably coupled with the conduit, the regulator configured to restrict flow of the resin from the vessel to the reservoir in a first position and allow flow from the vessel to the reservoir in a second position.

(136) The additive manufacturing apparatus of one or more of these clauses, further comprising: a computing system operably coupled with the regulator and a volume sensor, the volume sensor configured to provide data to the computing system related to the first volume of the resin, and wherein the computing system actuates the regulator from the second position to the first position when the first volume of the resin deviates from a predefined range.

(137) The additive manufacturing apparatus of one or more of these clauses, wherein the material deposition assembly further comprises a connector coupled with the upstream wall, the connector configured to maintain a portion of the conduit in a predefined position.

(138) The additive manufacturing apparatus of one or more of these clauses, wherein the impeller is operably coupled with a rotation assembly, and wherein the rotation assembly is translatable in a Z-axis direction along a track assembly.

(139) The additive manufacturing apparatus of one or more of these clauses, further comprising: a brace operably coupled with a frame of said manufacturing apparatus, wherein the material deposition assembly further comprises a bracket coupled with the vessel, the bracket selectively coupled with the brace.

(140) The additive manufacturing apparatus of one or more of these clauses, wherein the bracket defines an upper support and a lower support, and wherein the lower support is positioned above the brace in a Z-axis direction.

(141) The additive manufacturing apparatus of one or more of these clauses, wherein the brace defines a locator pin and the lower support defines a locating void, and wherein the locating void configured to surround the locator pin.

(142) A method of operating an additive manufacturing apparatus, the method comprising: operably

coupling a bracket of a first vessel with a brace of said additive manufacturing apparatus; coupling a conduit to direct a resin within the first vessel to a reservoir; and actuating a regulator to allow the resin to be gravity fed from the first vessel to the reservoir.
(143) The method of one or more of these clauses, further comprising: depositing, with a material deposition assembly, the resin to form a deposited resin layer on a resin surface, at least a portion of which is transparent.
(144) The method of one or more of these clauses, further comprising: detecting, with a sensor, a volume of the resin within the reservoir, wherein actuating the regulator to allow the resin to be gravity fed from the first vessel to the reservoir occurs when the volume of the resin within the reservoir deviates from a predefined range.
(145) The method of one or more of these clauses, further comprising: executing a build cycle, including the steps of: positioning a stage relative to a resin surface so as to define a layer increment in the resin; selectively curing the resin using an application of radiant energy in a specific pattern so as to define a cross-sectional layer of a component; and moving the resin surface and the stage relatively apart so as to separate the component from the resin surface.
(146) The method of one or more of these clauses, further comprising: removing a portion of the resin from a resin support through a collection structure; and directing the portion of the resin from the collection structure to a second vessel through the conduit.
(147) An additive manufacturing apparatus comprising: a stage configured to hold one or more cured layers of a resin that form a component; a radiant energy device positioned opposite to the stage such that it is operable to generate and project radiant energy in a patterned image; and a resin management system including a reclamation system downstream of the stage, the reclamation system comprising: a collection structure configured to remove at least a portion of the resin from a resin support; a vessel configured to retain the resin removed from the resin support; and an impeller positioned within the vessel and configured to agitate the resin within the vessel.
(148) The additive manufacturing apparatus of one or more of these clauses, further comprising: first and second brackets operably coupled with opposite sides of the vessel.
(149) The additive manufacturing apparatus of one or more of these clauses, further comprising: a first brace and a second brace each defining a locating pin, wherein the first and second brackets define locating voids that are configured to respectively surround the locating pin of the first brace and the locating pin of the second brace.
(150) The additive manufacturing apparatus of one or more of these clauses, wherein the first and second brackets define locating voids that are configured to respectively surround locating pins of a carrier of a dolly.
(151) This written description uses examples to disclose the concepts presented herein, including the best mode, and also to enable any person skilled in the art to practice the present disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the present disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

Claims

1. An additive manufacturing apparatus comprising: a stage configured to hold a component; a radiant energy device operable to generate and project radiant energy in a patterned image; a resin management system including a material deposition assembly upstream of the stage and configured to deposit a resin on a resin support, the material deposition assembly comprising: a reservoir configured to retain a first volume of the resin, wherein the reservoir defining an aperture that serves as an outlet for the resin support and a layer of the resin deposited on the resin support; a vessel separated from the reservoir and configured to store a second volume of the resin; an impeller positioned within the vessel and configured to agitate the resin within the vessel; a conduit configured to direct the resin from the vessel

to the reservoir; and a regulator operably coupled with the conduit, the regulator configured to restrict flow of the resin from the vessel to the reservoir in a first position and allow flow from the vessel to the reservoir in a second position; a restrictor operably coupled with the conduit upstream of the regulator, the restrictor configured to block a flow of the resin within the conduit between the vessel and the regulator when placed in a restricted position, the restrictor configured to maintain a blocked position while the conduit is disconnected from the regulator; and a computing system operably coupled with the regulator, the computing system configured to actuate the regulator from the second position to the first position when the first volume of the resin deviates from a predefined range.
2. The additive manufacturing apparatus of claim 1, further comprising: a volume sensor positioned upstream of the aperture and configured to provide data related to the first volume of the resin.
3. The additive manufacturing apparatus of claim 1, wherein the reservoir is configured to define a thickness of the resin on the resin support as the resin support is translated in an X-axis direction.
4. The additive manufacturing apparatus of claim 3, wherein the reservoir includes an upstream wall, a downstream wall, and sidewalls that define a cavity, and wherein the conduit is configured to direct resin into the cavity.
5. The additive manufacturing apparatus of claim 4, wherein the upstream wall defines a slot to receive the resin support and the downstream wall defines an aperture that serves as an outlet for the resin support and a layer of the resin deposited on the resin support.
6. An additive manufacturing apparatus comprising: a frame; a stage operably coupled with the frame and configured to hold a component; a radiant energy device operable to generate and project radiant energy in a patterned image; an actuator configured to change a relative position of the stage relative to the radiant energy device; and a resin management system including a material deposition assembly upstream of the stage and configured to deposit a resin on a resin support, the material deposition assembly comprising: a reservoir operably coupled with the frame, the reservoir configured to retain a first volume of the resin; a vessel separated from the reservoir and operably coupled with the frame, the vessel configured to store a second volume of the resin vertically above the reservoir relative to the frame; an impeller positioned within the vessel and configured to agitate the resin within the vessel; and a conduit configured to direct the resin from the vessel to the reservoir, the conduit positioned below the vessel and above the reservoir in a vertical direction.
7. The additive manufacturing apparatus of claim 6, wherein the reservoir is configured to define a thickness of the resin on the resin support as the resin support is translated in an X-axis direction.
8. The additive manufacturing apparatus of claim 7, wherein the reservoir includes an upstream wall, a downstream wall, and sidewalls that define a cavity, and wherein the conduit is configured to direct resin into the cavity.
9. The additive manufacturing apparatus of claim 8, wherein the upstream wall defines a slot to receive the resin support and the downstream wall defines an aperture that serves as an outlet for the resin support and a layer of the resin deposited on the resin support.
10. The additive manufacturing apparatus of claim 7, wherein the material deposition assembly further comprises a regulator operably coupled with the conduit, the regulator configured to restrict flow of the resin from the vessel to the reservoir in a first position and allow flow from the vessel to the reservoir in a second position.
11. The additive manufacturing apparatus of claim 10, further comprising: a computing system operably coupled with the regulator and a volume sensor, the volume sensor configured to provide data to the computing system related to the first volume of the resin, and wherein the computing system actuates the regulator from the second position to the first position when the first volume of the resin deviates from a predefined range.
12. The additive manufacturing apparatus of claim 8, wherein the material deposition assembly further comprises a connector coupled with the upstream wall, the connector configured to maintain a portion of the conduit in a predefined position.
13. The additive manufacturing apparatus of claim 6, wherein the impeller is operably coupled with a rotation assembly, and wherein the rotation assembly is translatable in a Z-axis direction along a track assembly.

14. The additive manufacturing apparatus of claim 10, further comprising: a restrictor operably coupled with the conduit and configured to block a flow of the resin within the conduit past the restrictor when placed in a restricted position.
15. The additive manufacturing apparatus of claim 14, wherein the restrictor is upstream of the regulator.
16. An additive manufacturing apparatus comprising: a stage configured to hold a component; a radiant energy device operable to generate and project radiant energy in a patterned image; a resin management system including a material deposition assembly upstream of the stage and configured to deposit a resin on a resin support, the material deposition assembly comprising: a reservoir configured to retain a first volume of the resin, the reservoir defining an aperture that serves as an outlet for the resin support and a layer of the resin deposited on the resin support; a vessel separated from the reservoir and configured to store a second volume of the resin; an impeller positioned within the vessel and configured to agitate the resin within the vessel; a conduit configured to direct the resin from the vessel to the reservoir; and a regulator operably coupled with the conduit, the regulator configured to restrict flow of the resin from the vessel to the reservoir in a first position and allow flow from the vessel to the reservoir in a second position; a volume sensor positioned upstream of the aperture and configured to provide data related to the first volume of the resin; a thickness sensor configured to determine a thickness of the resin on the resin support, the thickness sensor downstream of the reservoir; and a computing system operably coupled with the regulator, the computing system configured to actuate the regulator from the second position to the first position when the first volume of the resin deviates from a predefined range based on data from the volume sensor and the thickness sensor.
17. The additive manufacturing apparatus of claim 16, wherein the material deposition assembly further comprises a connector coupled with the upstream wall, the connector configured to maintain a portion of the conduit in a predefined position.
18. The additive manufacturing apparatus of claim 16, wherein the reservoir is configured to define a thickness of the resin on the resin support as the resin support is translated in an X-axis direction.
19. The additive manufacturing apparatus of claim 18, wherein the reservoir includes an upstream wall, a downstream wall, and sidewalls that define a cavity, and wherein the conduit is configured to direct resin into the cavity.
20. The additive manufacturing apparatus of claim 19, wherein the upstream wall defines a slot to receive the resin support and the downstream wall defines an aperture that serves as an outlet for the resin support and a layer of the resin deposited on the resin support.