



(51) International Patent Classification:

B22F 10/32 (2021.01) B29C 64/364 (2017.01)
 B22F 10/368 (2021.01) B29C 64/379 (2017.01)
 B22F 10/64 (2021.01) B33Y 10/00 (2015.01)
 B22F 12/17 (2021.01) B33Y 30/00 (2015.01)
 B22F 12/20 (2021.01) B33Y 40/00 (2020.01)
 B22F 12/82 (2021.01) B22F 10/25 (2021.01)
 B22F 12/88 (2021.01) B22F 12/00 (2021.01)
 B29C 64/25 (2017.01)

(21) International Application Number:

PCT/US2021/042582

(22) International Filing Date:

21 July 2021 (21.07.2021)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/055,266 22 July 2020 (22.07.2020) US

(71) Applicant: NIKON CORPORATION [JP/JP]; Intellectual Property Division 15-3, Konan 2-chome, Minato-ku, Tokyo, 108-6290 (JP).

(72) Inventor; and

(71) Applicant: COON, Paul, Derek [US/US]; c/o Nikon Research Corporation of America, 1399 Shoreway Road, Belmont, CA 94002-4107 (US).

(72) Inventors: MARQUEZ, Johnathan, Agustin; c/o Nikon Research Corporation of America, 1399 Shoreway Road, Belmont, CA 94002-4107 (US). BINNARD, Michael, Birk; c/o Nikon Research Corporation of America, 1399 Shoreway Road, Belmont, CA 94002-4107 (US).

(74) Agent: ROEDER, Steven, G.; Roeder & Broder LLP, 13400 Sabre Springs Pkwy., Ste. 155, San Diego, CA 92128 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,

(54) Title: ADDITIVE MANUFACTURING SYSTEM WITH MULTIPLE CHAMBERS

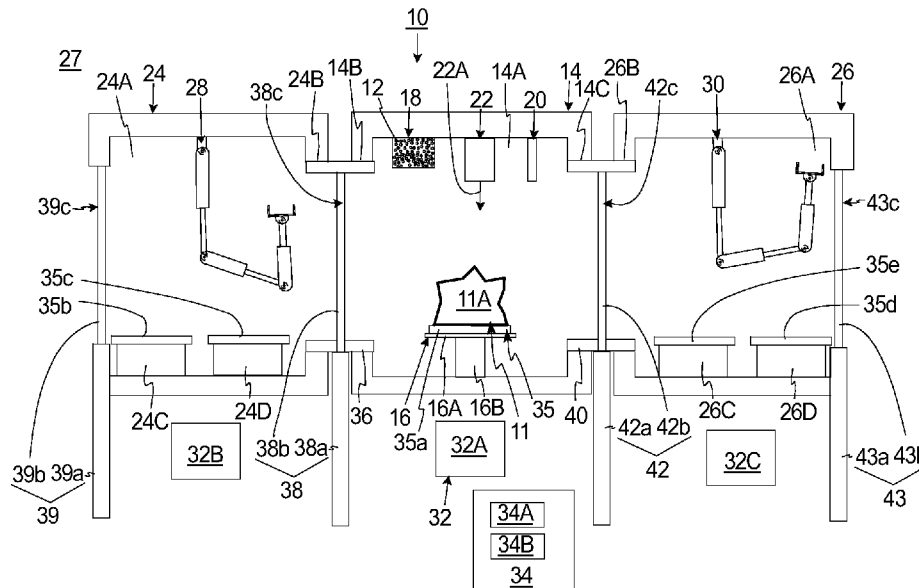


Fig. 1A

(57) Abstract: A processing machine (10) for building a first built object (11 A) includes: a build chamber (14); a chamber environmental controller (32) that controls the environment in the build chamber (14); a material supply (18) that supplies material (12) to build the first built object (11 A) in the build chamber (14); an irradiation device (22) which irradiates at least a portion of the material (12) with an energy beam 22A to form the first built object (11 A) in the build chamber (14); and a first chamber (24). After the first built object (11 A) is built in the build chamber (14), the first built object (11 A) is moved to the first chamber (24) for processing (e.g., cooling) while a subsequent object (11 B) is made in the build chamber (14). The processing machine (410) can also include movable chambers (414) (464) (466).



DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

ADDITIVE MANUFACTURING SYSTEM WITH MULTIPLE CHAMBERS

RELATED APPLICATIONS

[0001] This application claims priority on U.S. Patent Application No: 63/055,266 filed on July 22, 2020 and entitled “Additive Manufacturing System With Multiple Chambers.” As far as permitted, the contents of U.S. Patent Application No: 63/055,266 are incorporated herein by reference.

[0002] As far as permitted, the contents of (i) International Application No: PCT/US2018/067407, filed on December 22, 2018, and entitled “ADDITIVE MANUFACTURING SYSTEM WITH ROTARY POWDER BED” are incorporated herein by reference, and (ii) International Application No: PCT/US2018/067406, filed on December 22, 2018, and entitled “ROTATING ENERGY BEAM FOR THREE-DIMENSIONAL PRINTER” are incorporated herein by reference.

BACKGROUND

[0003] Certain metal, three-dimensional printing systems use an energy beam to manufacture a part in a vacuum build chamber. One of the advantages of manufacturing parts in a vacuum is that the parts have poor thermal conductivity to the surrounding environment, and require a long time to cool down. This is an advantage because the part then has very low internal stress which is highly desired when making parts.

[0004] However, the long cool down time decreases the throughput of the three-dimensional printing system and increases the cost to manufacture each part. There is a never ending search to increase the throughput and reduce the cost of operation for three-dimensional printing systems.

SUMMARY

[0005] The present embodiment is directed to a processing machine for building a first built object from a material. In one embodiment, the processing machine includes: a build chamber that forms a build space; a chamber environmental controller that controls the environment in the build space; a material supply that supplies material to build the first built object in the build space; an irradiation device which irradiates at least a portion of the material with an energy beam to form the first built object from the material in the build chamber; and a first chamber that defines a first space. The chamber environmental controller can also control the environment in the first space.

[0006] With this design, after the first built object is built in the build chamber, the first built object can be moved from the build chamber to the first chamber for cooling. As a result thereof, a new, second object can be made in the build chamber, while the previous, first built object is cooling in the controlled environment of the first chamber. Thus, the first built part can be cooled relatively slowly so that the first built part has very low internal stress, while freeing up the build chamber for subsequent manufacturing of the next object. This allows for increased throughput of the processing machine, and reduced cost for the objects.

[0007] The processing machine can include a measurement device that measures the object as it is being built in the build chamber.

[0008] Additionally, the processing machine can include a first mover assembly that moves the build object from the build chamber to the first chamber for cooling.

[0009] The chamber environmental controller can control the environment in the first space to be approximately the same as the environment in the build space. For example, the chamber environmental controller can control the environment in the first space to be approximately the same as the environment in the build space while the first built object is moved from the build chamber to the first chamber.

[0010] In certain implementations, the first space is connected in fluid communication with the build space while the first built object is moved from the build chamber to the first chamber. The processing machine can include a first gate that selectively separates the first space from the build space.

[0011] The processing machine also includes a second chamber that defines a second space. In this implementation, the material supply supplies material to build a second built object in the build space; the irradiation device irradiates at least a portion of the material with the energy beam to form the second built object from the material in the build chamber; and the second built object is moved from the build chamber to second chamber for cooling.

[0012] Additionally, the second space is connected in fluid communication with the build space while the second built object is moved from the build chamber to the second chamber. Moreover, a second gate can selectively separate the second space from the build space.

[0013] In another implementation, the processing machine includes: a machine frame; a first movable build chamber that forms a first build space, the first movable build chamber being selectively coupled to the machine frame; a chamber environmental controller that controls the environment in the first build space; a material supply that supplies material to build the first built object in the first build chamber; an irradiation device which irradiates at least a portion of the material with an energy beam to form the first built object from the material in the first build chamber; and a chamber mover assembly that moves the first movable build chamber relative to the machine frame.

[0014] In one implementation, the first movable build chamber is selectively movable relative to a least a portion of the irradiation device.

[0015] The processing machine can include a second movable build chamber that forms a second build space, the second movable build chamber being selectively coupled to the machine frame. With this design, at least one pre-processing or post-processing step can be performed in the second build space simultaneously with the building of the object in the first build space. Alternatively, at least one pre-processing step can be performed in the second build space simultaneously with at least one post-

processing step being performed in the first build space. Further, the chamber mover assembly can selectively move the movable build chambers relative to each other.

[0016] Additionally, the processing machine can include a third movable build chamber that forms a third build space, the third movable build chamber being selectively coupled to the machine frame. With this design, at least one pre-processing step can be performed in the second build space simultaneously with the building of the object in the first build space, and at least one post-processing step being performed in the third build space. Moreover, the chamber mover assembly can selectively move at least one of the movable build chambers relative to the other movable build chambers.

[0017] Additionally, the processing machine can include a column assembly that selectively couples the irradiation device to one or more of the build chambers.

[0018] In another implementation, the processing machine includes: (i) a first build chamber that forms a first build space; (ii) a second build chamber that forms a second build space; (iii) a chamber environmental controller that controls the environment in the build spaces; (iv) a material supply assembly that supplies material to build the objects in the build spaces; and (v) an irradiation device which irradiates at least a portion of the material with an energy beam, wherein the irradiation device is selectively movable to direct an energy beam into the first build chamber and the second build chamber.

[0019] In yet another implementation, a method for building a built object from a material includes: (i) providing a build chamber that forms a build space; (ii) controlling a build chamber environment in the build space with an environmental controller; (iii) supplying material to build the built object in the build space with a material supply; (iv) irradiating at least a portion of the material with an energy beam to form the built object from the material in the build chamber; (v) providing a first chamber that defines a first space; and (vi) moving the built object from the build chamber to the first chamber without adversely influencing the build chamber environment and while maintaining the build chamber environment. It should be noted that certain environments will be more greatly influenced than others by slight changes to the environment. As alternative, non-exclusive examples, as provided herein, “without adversely influencing the build

chamber environment” for a vacuum environment shall mean without degrading the vacuum pressure by an order of magnitude of one, one-half, or one-tenth. In contrast, as alternative, non-exclusive examples, as provided herein, “without adversely influencing the build chamber environment” for an inert gas (e.g., non-oxidizing) environment shall mean without degrading the atmosphere by 1/10, 1/5, 1, 2, or 5 percent. Stated in a different fashion, as alternative, non-exclusive examples, as provided herein, “without adversely influencing the build chamber environment” shall mean without changing the temperature by ten, twenty, thirty, fifty, or one hundred degrees Celsius. Stated in yet a different fashion, as alternative, non-exclusive examples, “without adversely influencing the build chamber environment” shall mean without changing the humidity by less than one, two, five, or ten percent.

[0020] In one implementation, a first chamber environment in the first space is also controlled with the environmental controller. With this design, for example, the environmental controller can control a build chamber pressure in the build chamber, and a first chamber pressure in the first chamber to be approximately the same. As alternative, non-exclusive examples, the environmental controller can control the first chamber pressure to be within at least one, two, five, ten, twenty, fifty, one hundred, or one thousand percent of the build chamber pressure. Stated in a different fashion, as alternative, non-exclusive examples, the environmental controller can control the first chamber pressure to be within at least $7.5\text{e-}10$, $3.8\text{e-}9$, $7.5\text{e-}9$, $7.5\text{e-}8$ torr of the build chamber pressure.

[0021] In still another implementation, a method for building a built object from a material includes: (i) providing a machine frame; (ii) providing a movable build chamber that forms a build space, the movable build chamber being selectively coupled to the machine frame; (iii) controlling the environment in the build space with an environmental controller; (iv) supplying material to build the built object in the build chamber; (v) irradiating at least a portion of the material with an energy beam to form the built object from the material in the build chamber; and (vi) moving the movable build chamber relative to the machine frame with a chamber mover assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The novel features of this embodiment, as well as the embodiment itself, both as to its structure and its operation, will be best understood from the accompanying drawings, taken in conjunction with the accompanying description, in which similar reference characters refer to similar parts, and in which:

[0023] Figure 1A is a simplified cut-away view of a processing machine and an object that was just made;

[0024] Figure 1B is a simplified cut-away view of the processing machine of Figure 1A after two objects have been made;

[0025] Figure 1C is a simplified cut-away view of the processing machine of Figure 1A after four objects have been made;

[0026] Figure 2A is a simplified cut-away view of another processing machine with multiple made objects;

[0027] Figure 2B is a simplified cut-away view of the processing machine of Figure 2A at a later time;

[0028] Figure 3 is a simplified cut-away view of still another processing machine;

[0029] Figure 4A is a simplified cut-away view of yet another processing machine;

[0030] Figure 4B is a simplified cut-away view of the processing machine of Figure 4A at another time;

[0031] Figure 5 is a simplified cut-away view of yet another processing machine;

[0032] Figure 6 is a simplified cut-away view of another processing machine;

[0033] Figure 7 is a simplified cut-away view of yet another processing machine;

[0034] Figures 8A is a simplified cut-away view of still another processing machine;

[0035] Figure 8B is a simplified cut-away view of the processing machine of Figure 8A at a subsequent time;

[0036] Figure 9 is a simplified top view of a build platform;

[0037] Figures 10A-10D are alternative, cross-sectional view of another implementation of the processing machine; and

[0038] Figure 11 is a flow chart that outlines one method to make an object;

DESCRIPTION

[0039] Figure 1A is a simplified side cut-away view of an implementation of a processing machine 10 that is used to manufacture one or more three-dimensional objects 11. As provided herein, the processing machine 10 may be an additive manufacturing system such as a three-dimensional printer in which a material 12 (illustrated as small circles) is joined, melted, solidified, and/or fused together to manufacture one or more three-dimensional object(s) 11.

[0040] The type of three-dimensional object(s) 11 manufactured with the processing machine 10 may be almost any shape or geometry. As a non-exclusive example, the three-dimensional object 11 may be a metal part, or another type of object, for example, a resin (plastic) part or a ceramic part, etc. The three-dimensional object 11 may also be referred to as a “part”. The object 11 can be referred to as a “partially built object” while the material is being added, or as a “built object” when the object is formed. Further, one or more built objects 11 can be referred to as a “first built object”, “second built object”, “third built object”, “fourth built object”, or “fifth built object”. Still further, sometimes the object 11 includes other portions than a designed/desired object. For example, the object 11 can include supports which supports a part of the object, or sintered metal powder which is not a part of the object but covering the designed/desired object 11.

[0041] The type of material 12 joined and/or fused together may be varied to suit the desired properties of the object(s) 11. As a non-exclusive example, the material 12 may include powder grains for metal three-dimensional printing. Alternatively, the material 12 may be metal powder, non-metal powder, a plastic, polymer, glass, ceramic powder, or any other material known to people skilled in the art. The material 12 may also be referred to as “powder” in certain implementations. Alternatively, for example, the processing can be a wire feed system in which the material is a wire that is melted to form the object 11.

[0042] In certain non-exclusive implementations, the processing machine 10 includes (i) a build chamber 14 that defines a build space 14A; (ii) a build platform 16 that supports the object 11; (iii) a material supply 18 (illustrated as a box) that supplies the powder 12; (iv) a measurement device 20 (illustrated as a box); (v) an irradiation

device 22 (illustrated as a box); (vi) a first chamber 24 that defines a first space 24A; (vii) a second chamber 26 that defines a second space 26A; (viii) a first mover assembly 28; (ix) a second mover assembly 30; (x) a chamber environmental controller 32; and (xi) a control system 34 that cooperate to make each three-dimensional object 11a. It should be noted that (i) the first chamber 24 can be referred to as the first auxiliary chamber; (ii) the first space 24A can be referred to as the first auxiliary space; (iii) the second chamber 26 can be referred to as the second auxiliary chamber; and/or (iv) the second space 26A can be referred to as the second auxiliary space. The design of each of these components the processing machine 10 may be varied pursuant to the teachings provided herein. Moreover, it should be noted that the positions of the components of the processing machine 10 may be different than that illustrated in Figure 1A.

[0043] Further, it should be noted that the processing machine 10 may include more components or fewer components than illustrated in Figure 1A. As non-exclusive examples, the processing machine 10 can be designed without the second chamber 26; without the second mover assembly 30; or with more than two, auxiliary chambers 24, 26. Further, the processing machine 10 can be designed to have two or more build chambers 14, with each additional build chamber (not shown) having one or more additional auxiliary chambers (not shown).

[0044] As an overview, in certain embodiments, the processing machine 10 is uniquely designed so that after a first built object 11A is complete, the first mover assembly 28 can move the first built object 11A into the first chamber 24 (or the second chamber 26) for cooling. As a result thereof, a new, second object 11B (illustrated in Figure 1B) can be made in the build chamber 14, while the previous, first built object 11A is cooling (or otherwise being post-processed) in the controlled environment of the first chamber 24. With this design, each built object 11 can be post-processed relatively slowly so that each built object 11 has very low internal stress, while freeing up the build chamber 14 for subsequent manufacturing of the next object 11B. This allows for increased throughput of the processing machine 10, and reduced cost for the built objects 11.

[0045] In alternative, non-exclusive examples, the post-processing time within the

respective chambers 24, 26 can be at least two, four, six, eight, ten or twelve hours. During this time, one or more additional objects 11A, 11B can be made in the build chamber 14. This process can be repeated ad infinitum so that the building process is not stopped during the cooling process. If required, more auxiliary chambers 24, 26 can be added. The number of auxiliary chambers 24, 26 can be varied depending on the expected build and cooling times. Alternatively, the first chambers 24 can be designed to be capable of storing two or more built objects 11 in its space instead of providing the second chamber 26. With this design, the build process is only stopped for a minimal amount of time during switching of the built objects 11A, 11B from the build chamber 14 to the chambers 24, 26. This also saves a great deal of energy that would otherwise be required to re-heat the entire chamber system from cool. This also allows the system to maintain an operating equilibrium where all components are at a steady state temperature. This is important because of the dramatic temperature swings and atmospheric venting (both in pressure and air content) that would otherwise be subjected on the system, and the result of things like outgassing, mechanical/thermal stress/fatigue, and thermal expansion, etc.

[0046] It should be noted that the first built object 11A is illustrated in Figure 1A to have a thick outline to represent that it is very hot because it was just built. Further, the first object 11A is illustrated in Figure 1B to have a mid-thickness outline to represent that it has cooled some and is no longer very hot.

[0047] The build chamber 14 defines the build space 14A in which the objects 11 are formed. In one, non-exclusive implementation, the build chamber 14 is generally rigid box shaped, and forms a generally rectangular shaped, sealed, build space 14A. In Figure 1A, the build chamber 14 encloses the build platform 16, the material supply 18, the measurement device 20, and the irradiation device 22, in addition to the object 11A that is being built. In this simplified example, the build platform 16 is coupled to the bottom, and the material supply 18, the measurement device 20, and the irradiation device 22 are coupled to the top of the build chamber 14. Alternatively, for example, (i) the build chamber 14 can have a different configuration (e.g., cylindrical shaped); and/or (ii) the build platform 16, the material supply 18, the measurement device 20, and the irradiation device 22 can be positioned at different locations.

[0048] The build platform 16 (directly or indirectly) supports the powder 12 while each object 11 is being formed. In the non-exclusive implementation illustrated in Figure 1A, the build platform 16 includes a platform frame 16A, and a frame mover 16B (illustrated as a box) that selectively moves the platform frame 16A while the object 11 is formed.

[0049] In certain implementations, each object 11 is built directly in/on the build platform 16. Alternatively, one or more objects 11 can be built onto a movable build frame 35 (“build plate”) which is supported by and/or selectively coupled to the build platform 16. In Figure 1A, a single object 11 is built on each build frame 35. Alternatively, two or more objects 11 can be built on each build frame 35. With this design, the build frame 35 supports the powder 12 while each object 11 is being formed. For example, each build frame 35 can be made of the same material as the powder 12 or another suitable material. In certain implementations, the build frame 35 includes one or more frame features (not shown) that allow for the build frame 35 to be selectively coupled to the build platform 16. In one implementation, the object 11 is fused (e.g. welded) to the build frame 35 during the three-dimensional printing process. For example, the first object 11A is built on and fused to a first build frame 35a. Alternatively, for example, the object 11 is not fused to the build frame 35 during the three-dimensional printing process.

[0050] In Figure 1A, the build frame 35 is generally flat shaped, e.g., flat disk shaped. Alternatively, for example, the build frame 35 can include side walls (not shown) that extend upward from a perimeter of the build frame 35 to support the powder 12, or other features.

[0051] In the embodiment of Figure 1A, the platform frame 16A supports the build frame 35, and the platform frame 16A can optionally include one or more platform features (not shown) that selectively engage and selectively retain the build frame 35.

[0052] The frame mover 16B can include one or more actuators. The frame mover 16B can move the platform frame 16A and the build frame 35 up and down, back and forth and/or in rotation as necessary relative to the other components of the processing machine 10. Alternatively, or additionally, the other components of the processing machine 10 can be moved relative to the build frame 35.

[0053] The material supply 18 supplies the material 12 that is used to build the objects 11 in the build chamber 14. The material supply 18 can deposit the material 12 onto the build frame 35 in a series of layers that are fused (melted) together with the energy from the irradiation device 22. In one embodiment, the material supply 18 can include a powder hopper (not shown) that retains the material 12, and a material director (not shown) that directs the material 12 to the correct location. Alternatively, for example, the material supply 18 can be wire feed system which feeds the material 12.

[0054] The measurement device 20 inspects and monitors the melted (fused) layers and the deposition of the powder 12 while each object 11 is being built. As non-exclusive examples, the measurement device 20 may include one or more elements such as a uniform illumination device, fringe illumination device, cameras that function at one or more wavelengths, lens, interferometer, or photodetector, or a non-optical measurement device such as an ultrasonic, eddy current, or capacitive sensor.

[0055] The irradiation device 22 irradiates at least a portion of the material 12 with an energy beam 22A (illustrated with an arrow) to form the object 11A with the material 12. Stated in another fashion, the irradiation device 22 selectively heats and melts the powder 12 to form the object 11A. In certain implementations, the irradiation device 22 sequentially exposes the powder 12 to sequentially form each of the layers of the object 11A.

[0056] In alternative non-exclusive implementations, the irradiation device 22 includes (i) an electron beam 22A system that generates a charged particle beam, (ii) a laser beam system that generates a laser beam 22A, (iii) an ion beam system that generates a charged particle beam 22A, and/or (iv) an electric discharge arc. Certain irradiation devices 22 can be required to operate in a vacuum environment.

[0057] The first chamber 24 encloses and can be used (i) to post-process one or more of the built objects 11 in the first space 24A; and/or (ii) pre-process one or more build frames 35. In one, non-exclusive implementation, the first chamber 24 is generally rigid box shaped, and forms the generally rectangular shaped, sealed, first space 24A. Alternatively, the first space 24A can have a different configuration, e.g., cylindrical shaped, or oval shaped. The chamber environmental controller 32 can

control the environment in the first chamber 24.

[0058] Additionally, the first chamber 24 can include one or more spaced apart holding stations 24C, 24D for retaining and/or supporting the built objects 11 during post-processing after they have been removed from the build chamber 14. In Figure 1A, the first chamber 24 includes two holding stations, namely, a first holding station 24C and a second holding station 24D. Alternatively, the first chamber 24 can include more than two holding stations 24C, 24D.

[0059] As illustrated in Figure 1A, because the first built object 11A was just completed, there are no built objects 11 in post-processing. As a result thereof, an unused, second build frame 35b can be retained/supported by the first holding station 24C, and an unused third build frame 35c can be retained/supported by the second holding station 24D.

[0060] In Figure 1A, the first chamber 24 is connected to the build chamber 14. More specifically, in this embodiment, the first chamber 24 includes a side opening 24B, and the build chamber 14 includes a side opening 14B. Further, in this design, a first conduit 36 connects the first chamber 24 to the build chamber 14, and a first gate assembly 38 can be used to selectively open or close the first conduit 36. The design of the first gate assembly 38 can be varied pursuant to the teachings provided herein. In one non-exclusive implementation, the first gate assembly 38 is a large gate valve that includes a first gate 38a and a first gate actuator 38b that selectively moves the first gate 38a between a closed position 38c, and an open position 38d (illustrated in Figure 1B).

[0061] More specifically, in this embodiment, when the first gate assembly 38 is in the open position 38d, the build space 14A is open to the first space 24A. At this time, the environment of the build space 14A is similar to the environment of the first space 24A. Moreover, at this time, the first built part 11A can be moved from the build space 14A to the first space 24A, and/or one of the unused build frames 35 can be moved from the first space 24A to the build space 14A. In contrast, when the first gate assembly 38 is in the closed position 38c, the build space 14A is separated (sealed) from the first space 24A. At this time, the environment of the build space 14A and the environment of the first space 24A can be controlled to be the same or different. For

example, pressure in the first space 24A can be controlled as the same vacuum state as the build space 14A, or lower vacuum state (higher pressure) than the build space 14A.

[0062] Additionally, in certain implementations, the first chamber 24 functions as a first load lock chamber that is attached to the build chamber 14. With this design, the built objects 11A can be moved between chambers 14, 24, 26 while controlling the environment (e.g. a vacuum) around the objects 11A and without venting the chambers 14, 24, 26 to the surrounding atmosphere 27 (or environment).

[0063] Moreover, the first chamber 24 can include a first outlet gate assembly 39 can be used to selectively open or close the first space 24A to the surrounding environment 27. The design of the first outlet gate assembly 39 can be varied pursuant to the teachings provided herein. In one non-exclusive implementation, the first outlet gate assembly 39 is a large gate valve that includes a first outlet gate 39a and a first outlet gate actuator 39b that selectively moves the first outlet gate 39a between a closed position 39c, and an open position 39d (illustrated in Figure 1C). Alternatively, another type of sealable doors can be used.

[0064] More specifically, in this embodiment, when the first outlet gate assembly 39 is in the open position 39d, the first space 24A is open to the surrounding environment 27. At this time, the environment of the first space 24A is similar to the surrounding environment 27. Moreover, at this time, one or more built parts 11A can be removed from the first space 24A and one or more empty build frames 35 can be added to the first space 24A. In contrast, when the first outlet gate assembly 39 is in the closed position 39c, the first space 24A is separated (sealed) from the surrounding environment 27. At this time, the environment of the first space 24A can be controlled to be the same or different from the surrounding environment 27. For example, pressure in the first space 24A can be controlled as the same vacuum state as the build space 14A, or at atmospheric pressure.

[0065] Somewhat similarly, the second chamber 26 encloses and can be used (i) to post-process one or more of the built objects 11; and/or (ii) pre-process one or more build frames 35. In one, non-exclusive implementation, the second chamber 26 is generally rigid and forms the generally rectangular shaped, sealed, second space 26A.

Alternatively, the second space 26A can have a different configuration, e.g., cylindrical shaped, or oval shaped. The chamber environmental controller 32 can control the environment in the second auxiliary chamber 26.

[0066] Additionally, the second chamber 26 can include one or more spaced apart holding stations 26C, 26D for retaining and/or supporting the built objects 11 during post-processing after they have been removed from the build chamber 14. In Figure 1A, the second chamber 26 includes two holding stations, namely, a first holding station 26C and a second holding station 26D. Alternatively, the second chamber 26 can include more than two holding stations 26C, 26D.

[0067] As illustrated in Figure 1A, because the first built object 11A was just completed, there are no built objects 11 in post-processing. As a result thereof, an unused, fourth build frame 35d can be retained/supported by the second holding station 26D, and an unused fifth build frame 35e can be retained/supported by the first holding station 26C.

[0068] In Figure 1A, the second chamber 26 is connected to the build chamber 14. More specifically, in this embodiment, the second chamber 26 includes a side opening 26B, and the build chamber 14 includes a second side opening 14C. Further, in this design, a second conduit 40 connects the second chamber 26 to the build chamber 14, and a second gate assembly 42 can be used to selectively open or close the second conduit 40. The design of the second gate assembly 42 can be similar to the design of the first gate assembly 38. In one non-exclusive implementation, the second gate assembly 42 is a large gate valve that includes a second gate 42a and a second gate actuator 42b that selectively moves the second gate 42a between a closed position 42c, and an open position 42d (illustrated in Figure 1C).

[0069] More specifically, in this embodiment, when the second gate assembly 42 is open, the build space 14A is open to the second space 26A. At this time, the environment of the build space 14A is similar to the environment of the second space 26A. Moreover, at this time, one or more built parts 11A can be moved from the build space 14A to the second space 26A, and one or more unused build frames 35 can be moved from the second space 26A to the build space 14A. In contrast, when the second gate assembly 42 is closed, the build space 14A is separated (sealed) from

the second space 26A. At this time, the environment of the build space 14A and the environment of the second space 26A can be controlled to be the same or different. For example, pressure in the second space 26A can be controlled as the same vacuum state as the build space 14A, or lower vacuum state (higher pressure) than the build space 14A.

[0070] Additionally, in certain implementations, the second chamber 26 functions as a second load lock chamber that is attached to the build chamber 14. With this design, the built objects 11A can be moved between chambers 14, 24, 26 while controlling the environment (e.g., a vacuum) around the objects 11A and without venting the chambers 14, 24, 26 to atmosphere 27.

[0071] Moreover, the second chamber 26 can include a second outlet gate assembly 43 can be used to selectively open or close the second space 26A to the surrounding environment. The design of the second outlet gate assembly 43 can be varied pursuant to the teachings provided herein. In one non-exclusive implementation, the second outlet gate assembly 43 is a large gate valve that includes a second outlet gate 43a and a second outlet gate actuator 43b that selectively moves the second outlet gate 43a between a closed position 43c, and an open position (not shown).

[0072] More specifically, in this embodiment, when the second outlet gate assembly 43 is in the open position 43d, the second space 26A is open to the surrounding environment 27. At this time, the environment of the second space 26A is similar to the surrounding environment 27. Moreover, at this time, one or more built parts 11A can be removed from the second space 26A and one or more empty build frames 35 can be added to the second space 26A. In contrast, when the second outlet gate assembly 43 is in the closed position 43c, the second space 26A is separated (sealed) from the surrounding environment 27. At this time, the environment of the second space 26A can be controlled to be the same or different from the surrounding environment 27. For example, pressure in the second space 26A can be controlled as the same vacuum state as the build space 14A, or at atmospheric pressure 27.

[0073] Alternatively, in certain implementations, the processing machine 10 can include (i) a first load lock chamber (not shown in Figure 1A) that is separate from the

first chamber 24; and/or (ii) a second load lock chamber (not shown in Figure 1A) that is separate from the second chamber 26. In such embodiment, the first load lock chamber is attached to the first chamber 24, and the object 11A that is finished cooling can be removed from the first chamber 24 and moved to the first load lock chamber without venting the first chamber 24. Similarly, the second load lock chamber is attached to the second chamber 26, and the object 11A that is finished cooling can be removed from the second chamber 26 and moved to the second load lock chamber without venting the second chamber 26. Each, load lock chamber can include an outlet from which the built object 11A taken out from the respective space 24A, 26A to the load lock chamber can be removed to the surrounding environment 27.

[0074] The mover assemblies 28, 30 are used to transfer the built object(s) 11, and build frames 35 between the chambers 14, 24, 26, and optionally the surrounding environment. In this embodiment, the first mover assembly 28 is positioned in the first chamber 24 and the second mover assembly 30 is positioned in the second auxiliary chamber 26. Alternatively, the processing machine 10 can be designed with a single mover assembly 28, 30; more than two mover assemblies 28, 30; and/or the mover assemblies 28, 30 can be alternatively positioned.

[0075] In one implementation, each mover assemblies 28, 30 can be a robotic arm that can be controlled to move the built object(s) 11 between the chambers 14, 24, 26. Alternatively, one or both mover assemblies 28, 30 can include one or more linear guides, one or more linear motors, one or more rotary motors and/or another type of conveyor assembly.

[0076] In one implementation, each mover assembly 28, 30 transfers the built object 11 with the build frame 35 on which the object 11 is built. Since the built object 11 could be a various size and shape, it can be easier in certain designs to hold the build frame 35 which is predetermined size and shape and transfer the object 11 by the build frame 35.

[0077] The chamber environmental controller 32 creates a controlled environment in the chambers 14, 24, 26. In one implementation, the chamber environmental controller 32 creates a vacuum environment in each of the chambers 14, 24, 26. Alternatively, the chamber environmental controller 32 can create a non-vacuum

environment such as inert gas (e.g. helium gas, nitrogen gas or argon gas) environment in one or more of the chambers 14, 24, 26. In another, non-exclusive example, the chamber environmental controller 32 can selectively and individually create a non-oxidizing atmosphere in one or more of the chambers 14, 24, 26.

[0078] It should be noted that in any of the implementations provided herein, the chamber environmental controller 32 can be varied to specifically treat the specific material 12 utilized and/or the part being built. As non-exclusive implementations, the chamber environmental controller 32 can be used to introduce heating, cooling, humidity or carbon content to simulate material treatments like tempering/quenching, carburizing, annealing, etc. The application rates of these environments, or simply cooling, can also be controlled by the chamber environmental controller 32 to benefit the properties of the material 12. For example, some materials 12 are best cooled quickly through low temperatures (quenching for hardening). As non-exclusive examples, the chamber environmental controller 32 can include one or more heaters, coolers, insulators, conductors, fluid pumps, vacuum pumps, gate valves, re-fill valves, and/or gas sources.

[0079] In one implementation, the chamber environmental controller 32 can individually control the environment in the chambers 14, 24, 26 to be exactly the same. Alternatively, the chamber environmental controller 32 can individually control the environment in one or more (e.g. each) of the chambers 14, 24, 26 to be the same or different. In Figure 1A, the chamber environmental controller 32 includes (i) a build environmental controller (a build chamber environmental controller) 32A that individually controls a build environment (and a build chamber pressure) in the build chamber 14; (ii) a first auxiliary environmental controller (a first chamber environmental controller) 32B that individually controls a first chamber environment (and a first chamber pressure) in the first chamber 24; and (iii) a second auxiliary environmental controller (a second chamber environmental controller) 32C that individually controls a second chamber environment (and a second chamber pressure) in the second auxiliary chamber 26. For example, each environmental controller 32A-32C can include one or more heaters, coolers, vacuum pumps or fluid pumps to control the environment to be a vacuum.

[0080] As used herein, the term “vacuum” shall mean any space in which the pressure is significantly lower than atmospheric pressure. In one embodiment, pressure in the range of approximately 1 torr to $1\text{e-}3$ torr is considered a “medium vacuum”. Further, pressure in the range of approximately $1\text{e-}3$ torr to $1\text{e-}8$ torr is considered a “high vacuum”. Additionally, pressure below $1\text{e-}8$ torr is considered an “ultra-high vacuum”.

[0081] The control system 34 controls and directs power to the components of the processing machine 10 to build the three-dimensional object 11 from the computer-aided design (CAD) model by successively adding powder 12 layer by layer. The control system 34 may include one or more processors 34A and one or more electronic storage devices 34B.

[0082] The control system 34 may include, for example, a CPU (Central Processing Unit), a GPU (Graphics Processing Unit), and a memory. The control system 34 functions as a device that controls the operation of the processing machine 10 by the CPU executing the computer program. This computer program is a computer program for causing the control system 34 (for example, a CPU) to perform an operation to be described later to be performed by the control system 34 (that is, to execute it). That is, this computer program is a computer program for making the control system 34 function so that the processing machine 10 will perform the operations provided herein. A computer program executed by the CPU may be recorded in a memory (that is, a recording medium) included in the control system 34, or an arbitrary storage medium built in the control system 34 or externally attachable to the control system 34, for example, a hard disk or a semiconductor memory. Alternatively, the CPU may download a computer program to be executed from a device external to the control system 34 via the network interface. Further, the control system 34 may not be disposed inside the processing machine 10, and may be arranged as a server or the like outside the processing machine 10, for example. In this case, the control system 34 and the processing machine 10 may be connected via a communication line such as a wired communications (cable communications), a wireless communications, or a network. In case of physically connecting with wired, it is possible to use serial connection or parallel connection of IEEE1394, RS-232x, RS-422, RS-423, RS-485,

USB, etc. or 10BASE-T, 100BASE-TX, 1000BASE-T or the like via a network. Further, when connecting using radio, radio waves such as IEEE 802.1x, OFDM, or the like, radio waves such as Bluetooth (registered trademark), infrared rays, optical communication, and the like may be used. In this case, the control system 34 and the processing machine 10 may be configured to be able to transmit and receive various types of information via a communication line or a network. Further, the control system 34 may be capable of transmitting information such as commands and control parameters to the processing machine 10 via the communication line and the network. The processing machine 10 may include a receiving device (receiver) that receives information such as commands and control parameters from the control system 34 via the communication line or the network. As a recording medium for recording the computer program executed by the CPU, a CD-ROM, a CD-R, a CD-RW, a flexible disk, an MO, a DVD-ROM, a DVD-RAM, a DVD-R, a DVD + R, a DVD-RW, a magnetic medium such as a magnetic disk and a magnetic tape such as DVD + RW and Blu-ray (registered trademark), a semiconductor memory such as an optical disk, a magneto-optical disk, a USB memory, or the like, and a medium capable of storing other programs. In addition to the program stored in the recording medium and distributed, the program includes a form distributed by downloading through a network line such as the Internet. Further, the recording medium includes a device capable of recording a program, for example, a general-purpose or dedicated device mounted in a state in which the program can be executed in the form of software, firmware or the like. Furthermore, each processing and function included in the program may be executed by program software that can be executed by a computer, or processing of each part may be executed by hardware such as a predetermined gate array (FPGA, ASIC) or program software, and a partial hardware module that realizes a part of hardware elements may be implemented in a mixed form.

[0083] Figure 1B is a simplified side view of the processing machine 10 of Figure 1A including the chambers 14, 24, 26, the mover assemblies 28, 30, the gate assemblies 38, 39, 42, 43, the chamber environmental controller 32 and the control system 34 after two objects 11A, 11B have been made. Previously, after the first object 11A was formed, the first gate assembly 38 was moved to the open position 38d, and

the first mover assembly 28 was used to move (i) the first built object 11A (and first build frame 35a) from the build chamber 14 into the first chamber 24 for post-processing; and (ii) the second build frame 35b from the first chamber 24 into the build chamber 14. Subsequently, while the first build object 11A was being processed in the controlled environment of the first chamber 24; the new, second object 11B was made in the build chamber 14. With this design, the first built part 11A can be cooled relatively slowly so that the first built part 11A has very low internal stress, while freeing up the build chamber 14 for subsequent manufacturing of the next object 11B.

[0084] At the time illustrated in Figure 1B, the second built object 11B was just built and has a thick outline to represent that it is very hot. Further, the first object 11A is illustrated to have a mid-thickness outline to represent that it has cooled some and is no longer very hot.

[0085] Moreover, in Figure 1B, the first gate assembly 38 is illustrated in the open position 38d. At this time, the first mover assembly 28 can be used to move the second built object 11B from the build chamber 14 into the first chamber 24 for post-processing, and the third build frame 35c can be moved from the first chamber 24 into the build chamber 14 for building the next built object.

[0086] Figure 1C is a simplified side view of the processing machine 10 of Figure 1A including the chambers 14, 24, 26, the mover assemblies 28, 30, the gate assemblies 38, 39, 42, 43, the chamber environmental controller 32 and the control system 34 after three objects 11A, 211, 211A have been made.

[0087] At the time illustrated in Figure 1C, a fourth built object 11D (currently in the build chamber 14) was just built and has a thick outline to represent that it is very hot. Further, a third object 11C that was previously made, is currently in the second chamber 26, and is illustrated to have a mid-thickness outline to represent that it has cooled some and is no longer very hot. Additionally, the first object 11A and the second object 11B have been in the first chamber 24 sufficiently to be fully post-processed, and is illustrated to have a thin outline to represent that they have fully or mostly cooled.

[0088] Moreover, in Figure 1C, the second gate assembly 42 is illustrated in the open position 42d. At this time, the second mover assembly 30 can be used to move the fourth built object 11D from the build chamber 14 into the second chamber 26 for

post-processing, and the fifth build frame 35e can be moved from the first chamber 24 into the build chamber 14 for building the next built object.

[0089] Furthermore, in Figure 1C, the first outlet gate assembly 39 is illustrated in the open outlet position 43d. At this time, the first mover assembly 28 can be used to (i) move the first object 11A and the second object 11B from the first chamber 24 to the surrounding environment, and (ii) move new, unused build frames (not shown) into the first chamber 24.

[0090] As provided herein, this process can be repeated so that the processing machine 10 can continuously build the objects 11.

[0091] Figure 2A is a simplified cut-away view of another implementation of a processing machine 210, with a first built object 211A, a second built object 211B, a third built object 211C, and a partly built fourth object 211D. In this implementation, the processing machine 210 includes (i) a build chamber 214; (ii) a build platform 216; (iii) a material supply 218 (illustrated as a box); (iv) a measurement device 220; (v) an irradiation device 222; (vi) a first chamber 224 including gate assemblies 238, 239; (vii) a second chamber 226 including gate assemblies 242, 243; (viii) a first mover assembly 228; (ix) a second mover assembly 230; (x) a chamber environmental controller 232; and (xi) a control system 234 that are somewhat similar to the corresponding components described above and illustrated in Figure 1A.

[0092] However, in implementation of Figure 2A, the processing machine 210 additionally includes (i) a first load lock chamber 244; (ii) a first load lock mover assembly 246; (iii) a second load lock chamber 248; and (iv) a second load lock mover assembly 250. The design of each of these components can be varied.

[0093] In this implementation, the first load lock chamber 244 and the first load lock mover assembly 246 are used to move build objects 211 out of the first chamber 224 to the surrounding environment, and unused build frames 235 from the surrounding environment into the first chamber 224 while minimizing the influence on the environment in the first chamber 224. In a specific, non-exclusive example, the first load lock chamber 244 and the first load lock mover assembly 246 are used to mechanically move build objects 211A out of the first chamber 224, and unused build frames 235 into the first chamber 224 without compromising the vacuum in the first

chamber 224. In Figure 2A, the first load lock chamber 244 defines a first load lock space 244A that is positioned adjacent to the first chamber 224 and separated from the first chamber 244 with the first outlet gate assembly 239.

[0094] Further, the first load lock chamber 244 can include a first load gate assembly 252 (“first load lock outlet”) that can be used to selectively open or close the first load lock chamber 244 to the surrounding environment. The design of the first load gate assembly 252 can be varied pursuant to the teachings provided herein. In one non-exclusive implementation, the first load gate assembly 252 is a large gate valve that includes a first load gate 252a and a first load gate actuator 252b that selectively moves the first load outlet gate 252a between a closed position 252c, and an open position 252d (illustrated in Figure 2B).

[0095] Further, in this implementation, the second load lock chamber 248 and the second load lock mover assembly 250 are used to move build objects 211 out of the second chamber 226 to the surrounding environment, and unused build frames 235 from the surrounding environment into the second chamber 226 while minimizing the influence on the environment in the second chamber 226. In a specific, non-exclusive example, the second load lock chamber 248 and the second load lock mover assembly 240 can be used to mechanically move build objects 211 out of the second chamber 226, and unused build frames 235 into the second chamber 226 without compromising the vacuum in the second chamber 226. In Figure 2A, the second load lock chamber 248 defines a second load lock space 248A that is positioned adjacent to the second chamber 226 and separated from the second chamber 226 with the second gate assembly 243.

[0096] Further, the second load lock chamber 248 can include a second load gate assembly 254 (“second load lock outlet”) that can be used to selectively open or close the second load lock chamber 248 to the surrounding environment. The design of the second load gate assembly 254 can be varied pursuant to the teachings provided herein. In one non-exclusive implementation, the second load gate assembly 254 is a large gate valve that includes a second load gate 254a and a second load gate actuator 254b that selectively moves the second load outlet gate 254a between a closed position 254c, and an open position (not shown).

[0097] Each load lock mover assembly 246, 250 can be similar to the gate movers 38b, 42b described and illustrated in Figure 1A. Alternatively, the processing machine 210 can be designed to have fewer mover assemblies or more mover assemblies than illustrated in Figure 2A.

[0098] Additionally, in this implementation, the chamber environmental controller 232 can include a first load lock environmental 232D, and a second load lock environmental controller 232E, in addition to the build environmental controller 232A, the first environmental controller 232B, and the second environmental controller 232C. In this design, the first load lock environmental controller 232D independently controls a first load lock environment (and first load lock pressure) in the first load lock chamber 244, and the second load lock environmental controller 232E independently controls a second load lock environment (and second load lock pressure) in the second load lock chamber 248. For example, each environmental controller 232A-232E can include one or more heaters, coolers, vacuum pumps or fluid pumps to control the environment to be a vacuum.

[0099] At the time illustrated in Figure 2A, a fourth built object 211B (currently in the build chamber 214) is being built and has a thick outline to represent that it is very hot. Further, a third object 211C that was previously made, is currently in the second chamber 226, and is illustrated to have a slightly less thick outline to represent that it has cooled slightly. Additionally, the first object 211A has been in the first chamber 224 sufficiently to be fully post-processed, and is illustrated to have a thin outline to represent that they have fully or mostly cooled. Alternatively, the second object 211B has not been in the first chamber 224 long enough to be fully post-processed, and is illustrated to have a slightly thicker outline to represent that it still has some cooling to do.

[00100] Moreover, in Figure 2A, the first outlet gate assembly 239 is illustrated in the open position 239d. At this time, the first load lock mover assembly 246 can be used to move the fully processed, first built object 211A from the first chamber 224 to the first load lock chamber 244 and a new, unused build frame (not shown) to the first chamber 224. Further, the first load lock environmental controller 232D is controlling the environment in the first load lock chamber 244 to be the same as the first chamber

224. As a result thereof, the first built object 211A can be removed from the first chamber 224 without compromising the controlled environment (e.g., venting the vacuum) in the first chamber 224.

[00101] Figure 2B is a simplified cut-away view of the processing machine 210 of Figure 2A at a subsequent time than is illustrated in Figure 2A. At the time illustrated in Figure 2B, the fourth built object 211D (currently in the build chamber 214) is still being built and has a thick outline to represent that it is very hot. Further, the third built object 211C is currently in the second chamber 226, and the second built object 211B is in the first chamber 224.

[00102] Moreover, the first built object 211A is now in the first load lock chamber 244, and the first outlet gate assembly 239 has been moved to the closed outlet position 239c to separate the first chamber 224 from the first load lock chamber 244. Further, at this time, the first load lock chamber 244 has been vented to the atmosphere, and the first load gate assembly 252 is in the open position 252d. At this time, the first built object 211A can be moved to the surrounding environment with the first load lock mover assembly 246.

[00103] Moreover, in the implementation of Figures 2A and 2B, (i) the built objects 211 and the build frames 235 can be moved between the build chamber 214 and the auxiliary chambers 224, 226 without adversely influencing the build chamber environment in the build chamber 214; and (ii) the built objects 211 and the build frames 235 can be moved between the auxiliary chambers 224, 226, and the load lock chambers 244 without adversely influencing the auxiliary chamber environment in the auxiliary chambers 224, 226.

[00104] For example, the chamber environment controller 232 can control (i) a build chamber pressure in the build chamber 214, and an auxiliary chamber pressure in one or both of the auxiliary chambers 224, 226 to be approximately the same; and/or (ii) the auxiliary chamber pressures and a load lock chamber pressure in the load lock chambers 244, 248 and to be approximately the same. As alternative, non-exclusive examples, “approximately the same pressure” shall mean within at least one, two, five, ten, twenty, fifty, one hundred, or one thousand percent of each other. Stated in a different fashion, as alternative, non-exclusive examples, “approximately the same

pressure” shall mean within at least $7.5\text{e-}10$, $3.8\text{e-}9$, $7.5\text{e-}9$, or $7.5\text{e-}8$ torr of each other.

[00105] Figure 3 is simplified view of another implementation of the processing machine 310. In this implementation, the processing machine 310 includes (i) a build chamber 314; (ii) a build platform 316 that supports the object 311 and the build frame 335; (iii) a material supply 318 (illustrated as a box); (iv) a measurement device 320; (v) an irradiation device 322; (vi) a first chamber 324 including the first gate assembly 338; (vii) a second chamber 326 including the second gate assembly 340; (viii) a chamber environmental controller 332; and (ix) a control system 334 that are similar to the corresponding components described above and illustrated in Figure 1A. However, in Figure 3, the first mover assembly 28 and the second mover assembly 30 from Figure 1A, have been replaced with a single mover assembly 328 that moves the object(s) 311 between the chambers 314, 324, 326.

[00106] For example, the mover assembly 328 can include a linear guide 328A, and a linear actuator 328B (illustrated in phantom) that cooperate to move the build object 311 (and the build platform 316) between the chambers 314, 324, 326 when the gate assemblies 338, 340 are open. Alternatively, or additionally, the mover assembly 328 can include one or more rotary motors and/or another type of conveyor assembly.

[00107] Additionally, (i) the first chamber assembly 324 can include a first outlet gate assembly 39 (illustrated in Figure 1A); and/or (ii) the second chamber assembly 326 can include a second outlet gate assembly 39 (illustrated in Figure 1A). Further, in certain implementations, the processing machine 310 include a first load lock chamber 244 (illustrated in Figure 2A); and/or a second load lock chamber 248 (illustrated in Figure 2A).

[00108] Figure 4A is a simplified side, cut-away view of another implementation of a processing machine 410 that can be used to build one or more built objects 411A, 411B. In this implementation, the processing machine 410 includes multiple (two or more) interchangeable, movable build chambers 414, 444, 446 that can be individually moved relative to the rest of the processing machine 410.

[00109] In the non-exclusive implementation illustrated in Figure 4A, the processing machine 410 includes three separate, movable build chambers 414, 464, 466. These

build chambers can be referred to as a first build chamber 414, a second build chamber 464, and a third build chamber 466 for convenience. Alternatively, the processing machine 410 can be designed to include more than three or fewer than three, movable build chambers 414, 464, 466.

[00110] With the multiple chamber designs disclosed herein, throughput can be increased because simultaneously (i) any pre-processing steps needed to build an object can be performed in one of the build chambers 414, 464, 466; (ii) building steps of an object can be performed in a different one of the build chambers 414, 464, 466; and (iii) post-processing steps (e.g. cooling) of a previously made object can occur in the remaining build chamber 414, 464, 466.

[00111] With the design of Figure 4A, the problem of increasing throughput and decreasing downtime in a three-dimensional manufacturing system 410 is solved by providing multiple reusable, controlled environment, build chambers 414, 464, 466 so that the pre-processing steps, building steps, and post-processing steps can be performed simultaneously (in parallel) in different chambers 414, 464, 466. For example, at the time illustrated in Figure 4A, simultaneously, (i) building of the second object 411B can be occurring in the first build chamber 414; (ii) post-processing of the first object 411A can be occurring in the second build chamber 464; and (iii) pre-processing (e.g., heating the build frame 435) can be occurring in the third build chamber 466.

[00112] Stated in another fashion, with the present design, as an object 411A, 411B is being built in one build chamber 414, 464, 466, simultaneously, pre-processing steps (e.g., material change or other preparation) can be taken with respect to another build chamber 414, 464, 466. When the build object 411A, 411B is completed in the build chamber 414, 464, 466, this build chamber 414, 464, 466 (along with the build object) can be moved and replaced with another build chamber 414, 464, 466, which is ready for a new build cycle. For example, post-processing steps can then be performed on the first built object 411A in the second build chamber 464 while the second object 411B is being built within the first build chamber 414. Simultaneously, the third build chamber 466 can undergo pre-processing steps as the object is being built and while the built object is undergoing post-processing steps. In this manner, downtime is

significantly reduced and the system can be configured to continuously print objects within multiple reusable build chambers 414, 464, 466 without the need to wait for the performance of pre-processing or post-processing steps.

[00113] It should be noted that the chambers 414, 464, 466 may also have different designs that specifically accommodate a particular type of part 411A, 411B or material 12. For example, a chamber 414, 464, 466 used to make a titanium part may be different from a chamber 414, 464, 466 used to make a steel part, however, but both chambers 414, 464, 466 can attach to the same system. This system provides the convenience of being able to do a compatible material change as a parallel pre-processing step.

[00114] A further advantage of this system is that each object 411A, 411B is isolated within its own reusable build chamber 414, 464, 466, and each build chamber 414, 464, 466 is isolated from the rest of the components of the overall system. This isolation protects expensive components of the overall system from being damaged or being subject to additional downtime due to a problem with an object 411A, 411B in the build chamber 414, 464, 466 by providing an ability to move the build chamber 414, 464, 466 with the problematic object out of the system and replacing it with another build chamber 414, 464, 466.

[00115] As non-exclusive examples, (i) pre-processing steps can include preparing the build platform, chamber, powder supply, and other components for the subsequent building process; (ii) building steps can include depositing powder 12 on the build platform 416 and fusing the powder 12 together; and (iii) post-processing steps can include gradually cooling the built object 411A and performing some method of extracting the part from the chamber.

[00116] In the simplified design illustrated in Figure 4A, the processing machine 410 includes: (i) a machine frame 468; (ii) the movable first build chamber 414; (iii) the movable second build chamber 464; (iv) the movable third build chamber 466; (v) the measurement device 420; (vi) the chamber environmental controller 432; (vii) the irradiation device 422; (viii) the material supply 418 that supplies material 12; (ix) a platform mover assembly 428; (x) a chamber mover assembly 470 that selectively moves the movable build chambers 414, 466, 468 relative to each other and the

machine frame 468; (xi) the control system 434; and (xii) a column assembly 472. Alternatively, the processing machine 410 can be designed to include more components or fewer components than illustrated in Figure 4A. Further, the design of the components illustrated in Figure 4A can be varied pursuant to the teachings provided herein.

[00117] The machine frame 468 provides a rigid frame for retaining one or more of the components of the processing machine 410. In Figure 4A, the machine frame 468 selectively retains each build chamber 414, 464, 466. For example, the machine frame 468 can include one or more selective fastener assemblies (not shown) for individually and selectively securing each build chamber 414, 464, 466 to the rigid frame.

[00118] The design of each build chamber 414, 464, 466 can be varied. In Figure 4A, each build chamber 414, 464, 466 is similar in design. Alternatively, one or more of the build chambers 414, 464, 466 can be different from the other build chambers 414, 464, 466. For example, one or all of the build chambers 414, 464, 466 can be somewhat similar to the build chamber 14 described above and illustrated in Figure 1A. Further, one or more of the build chambers 414, 464, 466 can include a gate assembly (not shown in Figure 4A) that is similar to the gate assemblies 38, 39, 42, 43 described above and illustrated in Figure 1A.

[00119] The first movable build chamber 414 defines a first build space 414A that can sequentially be used for pre-processing, forming, and post-processing of one or the objects 411B. In one, non-exclusive implementation, the first build chamber 414 is generally rigid box shaped, and forms the generally rectangular shaped, sealed, first build space 414A. As other, alternative, non-exclusive examples, one or more of the build chambers 414, 464, 466 can be cylindrical shaped, trapezoidal shaped, a sector of an annulus shaped, or have a different configuration. In Figure 4A, the first build chamber 414 encloses the first build platform 416.

[00120] Similarly, the second movable build chamber 464 defines a second build space 464A that can sequentially be used for pre-processing, forming, and post-processing of one of the built objects 411A. In one, non-exclusive implementation, the second build chamber 464 is generally rigid box shaped, and forms the generally rectangular shaped, sealed, second build space 464A. In Figure 4A, the second build

chamber 464 encloses a second build platform 465.

[00121] Further, the third movable build chamber 466 defines a third build space 466A that can sequentially be used for pre-processing, forming, and post-processing of a third object (not shown in Figure 4A). In one, non-exclusive implementation, the third build chamber 466 is generally rigid box shaped, and forms the generally rectangular shaped, sealed, third build space 466A. In Figure 4A, the third build chamber 466 encloses a third build platform 467. As noted above, the chambers 414, 464, 466 do not need to be identical.

[00122] The material supply 418, the measurement device 420, the irradiation device 422, the chamber environmental controller 432, and the control system 434 can be similar to the corresponding components described above and illustrated in Figure 1A. However, in one embodiment, the column assembly 472 can selectively couple one or more of these components to each build chamber 414, 464, 466.

[00123] In one non-exclusive embodiment, the column assembly 472 includes (i) a first column 472A that selectively (and individually) couples the material supply 418, the measurement device 420, the irradiation device 422, and the control system 434 to each build chamber 414, 464, 466; and (ii) a second column 472B that selectively (and individually) couples the platform mover assembly 428 to each build chamber 414, 464, 466.

[00124] It should be noted that one or more of the material supply 418, the measurement device 420, the irradiation device 422, the control system 434, the chamber environmental controller 432 and the platform mover assembly 428 can be referred to as a “machine subassembly”. Alternatively, one or more of the machine subassemblies can be selectively coupled to the build chambers 414, 464, 466 in a different fashion.

[00125] With the design in Figure 4A, each of the build chambers 414, 464, 466 can be moved to be coupled to or uncoupled from the material supply 418, the measurement device 420, the irradiation device 422, and the control system 434. For example, in Figure 4A, the first build chamber 414 is connected to the material supply 418, the measurement device 420, the irradiation device 422, and the control system 434 so that the object 411B can be built in the first build chamber 414; and the other

build chambers 464, 466 are not connected to these machine subassemblies. Subsequently, after the first built object 414A is built, the first build chamber 414 can be moved (decoupled from the machine subassemblies), and one of the other build chambers 464, 466 can be moved to be coupled to the machine subassemblies.

[00126] As non-exclusive examples, the column assembly 472 can include one or more mechanical and/or electrical connectors or couplers that selective connect one or more of the machine subassemblies to the respective build chamber 414, 464, 466.

[00127] The platform mover assembly 428 can include one or more actuators. The platform mover assembly 428 can move the respective build platform 416, 465, 467 up and down, back and forth and/or in rotation as necessary.

[00128] The material supply 418 supplies the material 12 that is used to build the objects 411A, 441B in the respective build chamber 414, 464, 466. The measurement device 420 inspects and monitors the melted (fused) layers and the deposition of the powder 12 while the object 411A, 441B is being built. The irradiation device 422 irradiates at least a portion of the material 12 to form the respective object 411A, 411B.

[00129] The chamber environmental controller 432 can control the environment in each of the build chambers 414, 464, 466. For example, the chamber environmental controller 432 can includes a separate environmental controller 432A, 432B, 432C that individually controls the environment in each of the build chambers 414, 464, 466 to be a vacuum or another environment. With this design, the separate environmental controller 432A, 432B, 432C can control the environment in the respective build chambers 414, 464, 466, even as the build chambers 414, 464, 466 are moved. Moreover, the separate environmental controller 432A, 432B, 432C can be moved concurrently with the respective build chambers 414, 464, 466. Alternatively, the environment in each build chambers 414, 464, 466 can be independently controlled in another fashion.

[00130] The chamber mover assembly 470 is controlled to selectively move the movable build chambers 414, 466, 468 relative to each other, and one or more of the machine subassemblies. As a non-exclusive example, the chamber mover assembly 470 can include one or more robotic arms that selective grab and move the build chambers 414, 464, 466. Alternatively, the chamber mover assembly 470 can include

one or more linear guides, one or more linear motors, one or more rotary motors and/or another type of conveyor assembly.

[00131] In Figure 4A, the built object 411B in the first build chamber 414 is illustrated to have a thick outline to represent that it is very hot because it was just built. Further, the built object 411A in the second build chamber 464 is illustrated to have a mid-thickness outline to represent that it has cooled some and is no longer very hot.

[00132] Figure 4B is a simplified side cut-away view of the processing machine 410 of Figure 4A including the (i) build chambers 414, 464, 466; (ii) the machine frame 468; (iii) the measurement device 420; (iv) the chamber environmental controller 432; (v) the irradiation device 422; (vi) the material supply 418 that supplies material 12; (vii) the platform mover assembly 428; (viii) the chamber mover assembly 470; (ix) the control system 434; and (x) the column assembly 472.

[00133] When comparing Figure 4B to Figure 4A, (i) the first build chamber 414 was moved for cooling of the second built part 411A; (ii) the third build chamber 446 was moved to be coupled to the column assembly 472, the platform mover assembly 428, and the machine sub-assemblies, and a third built object 411C is being built in the third build chamber 466; and (iii) the second build chamber 464 was moved, the first build object 411A (illustrated in Figure 4A) was removed, and pre-processing steps on the build frame 435 has started. In this design, the chamber mover assembly 470 can be used to move the build chambers 414, 464, 466.

[00134] It should be noted that subsequently, the build chambers 414, 464, 466 can be moved to sequentially perform pre-processing, building, and post-processing steps in each build chambers 414, 464, 466.

[00135] In Figure 4B, the third built object 411C in the third build chamber 466 is illustrated to have a thick outline to represent that it is very hot because it was just built. Further, the second built object 411B in the first build chamber 414 is illustrated to have a mid-thickness outline to represent that it has cooled some and is no longer very hot.

[00136] Figure 5 is simplified view of another implementation of the processing machine 510. In this implementation, the processing machine 510 for building one or more objects 511A includes (i) a first build chamber 514; (ii) a material supply 518 (illustrated as a box); (iii) a measurement device 520; (iv) an irradiation device 522; (v)

a second build chamber 564; (vi) a third build chamber 566; (vii) a chamber environmental controller 532; (viii) a machine frame 568; (ix) a column assembly 572; (x) a platform mover assembly 528; and (xi) a control system 534 that are similar to the corresponding components described above and illustrated in Figure 4A. However, in Figure 5, the chamber mover assembly 570 is a guide mover assembly instead of a robotic arm design. For example, the chamber mover assembly 570 can include a guide 570A (illustrated in phantom) that guides the movement build chambers 514, 564, 566, and one or more actuators 570B (illustrated in phantom) that cooperate to move selectively move the chambers 514, 564, 566 relative to each other and the column assembly 572 and the platform mover assembly 528. Alternatively, or additionally, the chamber mover assembly 570 can include one or more rotary motors, linear actuators, and/or another type of conveyor assembly.

[00137] Figure 6 is a simplified side, cut-away view of yet another implementation of a processing machine 610 that can be used to build one or more built objects 611A, 611B. In this implementation, the processing machine 610 again includes multiple interchangeable, movable build chambers 614, 664, 666 that can be individually moved relative to the rest of the processing machine 610.

[00138] The processing machine 610 of Figure 6 is somewhat similar to the processing machine 410 of Figure 4A. However, one or more of the machine subassemblies can be a distributed system that is connected to and moves concurrently with the respective build chamber 614, 664, 666.

[00139] More specifically, in the non-exclusive implementation illustrated in Figure 6, the processing machine 610 includes (i) the build chambers 614, 664, 666; (ii) the machine frame 668; (iii) the irradiation device 622; (iv) the platform mover assembly 628; (v) the chamber mover assembly 670; (vi) the platform mover assembly 628; and (vii) the column assembly 672 that are somewhat similar to the corresponding components described above and illustrated in Figure 4A. However, in Figure 6, (i) the measurement device 620 is a distributed system that includes a first measurement device 620A, a second measurement device 620B, and a third measurement device 620C; (ii) the chamber environmental controller 632 is a distributed system that includes a first chamber environmental controller 632A, a second chamber

environmental controller 632B, and a third chamber environmental controller 632C; and (iii) the material supply 618 is a distributed system that includes a first material supply 618A, a second material supply 618B, and a third material supply 618C.

[00140] In this embodiment, (i) the first measurement device 620A, the first chamber environmental controller 632A, and the first material supply 618A are secured to and move with the first build chamber 614; (ii) the second measurement device 620B, the second chamber environmental controller 632B, and the second material supply 618B are secured to and move with the second build chamber 664; and (iii) the third measurement device 620C, the third chamber environmental controller 632C, and the third material supply 618C are secured to and move with the third build chamber 666.

[00141] In Figure 6, the second built object 611B in the first build chamber 614 is illustrated to have a thick outline to represent that it is very hot because it was just built. Further, the first built object 611A in the second build chamber 664 is illustrated to have a mid-thickness outline to represent that it has cooled some and is no longer very hot.

[00142] In this design, the build chambers 614, 664, 666 are moved relative to the column assembly 672, the irradiation device 622, and the platform mover assembly 628. At the time illustrated in Figure 6, the first build chamber 614 is positioned adjacent to the column assembly 672, the irradiation device 622, and the platform mover assembly 628, and these components are used to make the second built object 611B. Prior to this time, the second build chamber 664 was positioned adjacent to the column assembly 672, the irradiation device 622, and the platform mover assembly 628, and these components were used to make the first built object 611A.

[00143] Subsequently, the first build chamber 614 can be moved away, and the third build chamber 666 can be positioned adjacent to the column assembly 672, the irradiation device 622, and the platform mover assembly 628. At this time, these components were used to make a third built object (not shown in Figure 6) in the third build chamber 666, while the second built object 611B is being post-processed in the first build chamber 614.

[00144] Figure 7 is a simplified side, cut-away view of yet another implementation of a processing machine 710 that can be used to build one or more built objects 711A, 711B. In this implementation, the processing machine 710 again includes multiple

interchangeable, movable build chambers 714, 764, 766 that can be individually moved relative to some of the rest of the processing machine 710.

[00145] The processing machine 710 of Figure 7 is somewhat similar to the processing machine 610 of Figure 6. More specifically, in the non-exclusive implementation illustrated in Figure 7, the processing machine 710 includes (i) the build chambers 714, 764, 766; (ii) the machine frame 768; (iii) the irradiation device 722; (iv) the measurement device 720 includes the first measurement device 720A, the second measurement device 720B, and the third measurement device 720C; (v) the chamber environmental controller 732 includes the first chamber environmental controller 732A, the second chamber environmental controller 732B, and the third chamber environmental controller 732C; (vi) the material supply 718 includes the first material supply 718A, the second material supply 718B, and the third material supply 718C; (vii) the platform mover assembly 728; and (viii) the column assembly 772 that are somewhat similar to the corresponding components described above and illustrated in Figure 6.

[00146] However, in Figure 7, the chamber mover assembly 770 includes a guided mover instead of a robotic arm design. For example, the chamber mover assembly 770 can include a guide 770A (illustrated in phantom) (e.g., a linear guide), and one or more actuators 770B (illustrated in phantom) that cooperate to move selectively move the chambers 714, 764, 766 relative to the column assembly 772, the irradiation device; and/or the platform mover assembly 728. For example, actuators 770B can include one or more linear actuators, rotary motors and/or another type of conveyor assembly.

[00147] Figure 8A is a simplified side, cut-away view of still another implementation of a processing machine 810 that can be used to build one or more built objects 811A, 811B. In this implementation, the processing machine 810 again includes multiple, independent build chambers 814, 864, 866 and is somewhat similar to the processing machine 410 described above and illustrated in Figure 7.

[00148] However, in the implementation of Figure 8A, the build chambers 814, 864, 866 can be fixed, and one or more of the machine sub-assemblies can be moved relative to the build chambers 814, 864, 866 to allow for simultaneous pre-processing,

building, and post-processing with the build chambers 814, 864, 866. In this non-exclusive embodiment, the column assembly 872 includes (i) the first column 872A that selectively (and individually) couples the material supply 818, the measurement device 820, the irradiation device 822, and the control system 834 to each build chamber 814, 864, 866; and (ii) the second column 872B that selectively (and individually) couples the chamber environmental controller 832 and the platform mover assembly 828 to each build chamber 814, 864, 866. Further, the first column 872A and the second column 872B can be movable relative to the build chambers 814, 864, 866.

[00149] In one embodiment, the processing machine 810 includes a column mover assembly 874 (illustrated as a box) that can be used to selectively and independently move the column 872A, 872B relative to the build chambers 814, 864, 866. The column mover assembly 874 can include one or more actuators, guides, and/or robotic arms.

[00150] In Figure 8A, the columns 872A, 872B are illustrated coupled to and position by the first build chamber 814. At this time, (i) the material supply 818 directs powder into the first build chamber 814; (ii) the measurement device 820 measures what is in the first build chamber 814; (iii) the irradiation device 822 directs the energy beam 822A into the first build chamber 814; (iv) the control system 834 is coupled to the first build chamber 814; (v) the chamber environmental controller 832 is coupled to the first build chamber 814; and (vi) the platform mover assembly 828 is coupled to the first build chamber 814. As a result thereof, the second built object 811B can be built in the first build chamber 814. In Figure 8A, the second built object 811B in the first build chamber 814 is illustrated to have a thick outline to represent that it is very hot because it was just built.

[00151] Prior to this time, when the first build object 811A was being built, (i) the columns 872A, 872B were coupled to and positioned adjacent to the second build chamber 864; (ii) the material supply 818 directs powder into the second build chamber 864; (iii) the measurement device 820 measures what is in the second build chamber 864; (iv) the irradiation device 822 directs the energy beam 822A into the second build chamber 864; (v) the control system 834 is coupled to the second build chamber 864;

(vi) the chamber environmental controller 832 is coupled to the second build chamber 864; and (vii) the platform mover assembly 828 is coupled to the second build chamber 864. The first built object 811A in the second build chamber 864 is illustrated to have a mid-thickness outline to represent that it has cooled some and is no longer very hot.

[00152] Subsequently in time, the columns 872A, 872B can be moved, coupled to, and positioned adjacent to the third build chamber 866. At this time, (i) the material supply 818 can direct powder into the third build chamber 866; (ii) the measurement device 820 can measure what is in the third build chamber 866; (iii) the irradiation device 822 can direct the energy beam 822A into the third build chamber 866; (iv) the control system 834 is coupled to the third build chamber 866; (v) the chamber environmental controller 832 is coupled to the third build chamber 866; (vi) the platform mover assembly 828 is coupled to the third build chamber 866; and (vii) a third built object (not shown in Figure 8A) can be built in the third build chamber 866, while the first built object 811A and the second built object 811B (if necessary) are being post-processed in the respective build chamber 814, 864.

[00153] Alternatively, it should be noted that one or more of the machine subassemblies can be a distributed system that is fixedly connected to the respective build chamber 814, 864, 866 similar to that illustrated in Figure 6. Still alternatively, one or more of the build chambers 814, 864, 866 can be moved in addition to the moving columns 872A, 872B.

[00154] Figure 8B is a simplified side, cut-away of the processing machine 810 of Figure 8A at a subsequent time. When comparing Figure 8B to Figure 8A, (i) the first column 872A with the material supply 818, the measurement device 820, the irradiation device 822, and the control system 834 were moved to the third build chamber 866 from the first build chamber 814 with the column mover assembly 874; and (ii) the second column 872B with the chamber environmental controller 832 and the platform mover assembly 828 were also moved to the third build chamber 866 from the first build chamber 814 with the column mover assembly 874.

[00155] Further, at the time illustrated in Figure 8B, the third built object 811C has been completed (or almost completed) and is illustrated with a thick line to represent that it is still hot. Moreover, (i) the material supply 818 has directed powder into the third

build chamber 866; (ii) the measurement device 820 has taken measurements of the third built object 811C in the third build chamber 866; (iii) the irradiation device 822 has directed the energy beam 822A into the third build chamber 866; (iv) the control system 834 is coupled to the third build chamber 866; (v) the chamber environmental controller 832 is coupled to the third build chamber 866; and (vi) the platform mover assembly 828 is coupled to the third build chamber 866.

[00156] The second built object 811B in the first build chamber 814 is illustrated to have a mid-thickness outline to represent that it has cooled some and is no longer very hot.

[00157] Further, in Figure 8B, the first built object 811A has been fully post-processed and has been removed from the second build chamber 864. Next, the columns 872A, 872B can be moved to be coupled and adjacent to the second build chamber 864 for building a fourth built object (not shown in Figure 8B).

[00158] It should be noted that (i) the first column 872A with the material supply 818, the measurement device 820, the irradiation device 822, and the control system 834 was moved to the third build chamber 866; and (ii) the second column 872B with the platform mover assembly 828 and the chamber environmental controller 832 can be secured with one or more guides and moved with one or more actuators. For example, each can be coupled to a linear guide, and a linear actuator that cooperate to move these components. Alternatively, or additionally, the chamber mover assembly 850 can include one or more rotary motors and/or another type of conveyor assembly.

[00159] Figure 9 is a simplified top view of a build frame 935 positioned on a build platform 916 that can be used in any of the build chambers disclosed herein. In this embodiment, the build frame 935 and the build platform 916 are each disk shaped. Further, in this embodiment, the build platform 916 with the build frame 935 can be rotated (e.g. with the platform mover assembly) while each object is being made on the build frame 935.

[00160] Figure 10A is a simplified cut-away view of yet another implementation of a processing machine 1010, with a first built object 1011A, a second built object 1011B, and a third built object 1011C. In this implementation, the processing machine 1010 includes (i) a build chamber 1014; (ii) a build platform 1016; (iii) a material supply 1018

(illustrated as a box); (iv) a measurement device 1020; (v) an irradiation device 1022; (vi) a first chamber (an auxiliary chamber) 1024 including gate assemblies 1038, 1039; (vii) a first mover assembly (an auxiliary mover assembly) 1028; (viii) a load lock chamber 1044; (ix) a load lock mover assembly 1046; and (x) a control system 1034 that are somewhat similar to the corresponding components described above and illustrated in Figures 2A and 2B.

[00161] However, in implementation of Figure 10A, the processing machine 1010 includes (i) only one auxiliary chamber 1024 (“first chamber”) for post-processing the built objects 1011, and pre-processing the unused build frames 1035; and (ii) only one load lock chamber 1044. Alternatively, the processing machine 1010 can be designed to have more chambers 1024, 1044 than illustrated in Figure 10A. Still alternatively, the processing machine 1010 can be designed to have only one of the first chamber 1024 and the load lock chamber 1044. In this design, the single, additional chamber 1024 would be used for (i) preprocessing the unused build frames 1035; (ii) post-processing the built objects 1011; and/or (iii) moving unused (pre-processed) build frames 1035 into, and built objects 1011 out of the build chamber 1014.

[00162] In one implementation, (i) the first chamber 1024 and the first mover assembly 1028 are used to selectively move build objects 1011 out of the build chamber 1014 to the first chamber 1024, and unused build frames 1035 from the first chamber 1024 into the build chamber 1014 while minimizing the influence on the environment (e.g., without compromising the vacuum) in the build chamber 1014; and (ii) the load lock chamber 1044 and the load lock mover assembly 1046 are used to selectively move build objects 1011 out of the first chamber 1024 to the surrounding environment, and unused build frames 1035 from the surrounding environment into the first chamber 1024 while minimizing the influence on the environment (e.g., without compromising the vacuum) in the first chamber 1024. In Figure 10A, the load lock chamber 1044 is positioned adjacent to the first chamber 1024 and separated from the first chamber 1024 with the outlet gate assembly 1039.

[00163] Further, the load lock chamber 1044 can include a load gate assembly 1052 (“load lock outlet”) that can be used to selectively open or close the load lock chamber 1044 to the surrounding environment. The first load gate assembly 1052 can be similar

to the corresponding component described above and illustrated in Figure 2A.

[00164] The first chamber 1024 includes one or more holding stations 1024C-1024F. In Figure 10A, the first chamber 1024 includes four holding stations, namely a first holding station 1024C, a second holding station 1024D, a third holding station 1024E, and a fourth holding station 1024F. However, it should be noted that the number of holding stations 1024C-1024F in the first chamber 1024 is selected to avoid delays in the manufacturing of the built objects 1011. As provided herein, the required number of holding stations 1024C-1024F will depend upon a number of factors, including the required build time of each object 1011 in the build chamber 1014, the desired post-processing time of each built object 1011, and the desired pre-processing time of each build frame 1035. For example, the desired post-processing time can include a required time of cooling the built object 1011 and/or a required time of annealing the built object 1011.

[00165] Moreover, the load lock chamber 1044 can optionally include one or more holding stations 1044B, 1044C to assist in the transfer of built objects 1011 out of the first chamber 1024 and unused build frame(s) 1035 into the first chamber 1024. In the non-exclusive example of Figure 10A, the load lock chamber 1044 includes a first load lock holding station 1044B and a second load lock holding station 1044C. However, it should be noted that the number of holding stations 1044B-1024F in the first chamber 1024 can be selected to avoid delays in transfer of built objects 1011 out and unused build frames 1035 into the first chamber 1024. Generally, as the number of holding stations 1044B, 1044C is increased, the number of times that the load lock chamber 1044 needs to be vented to the surrounding environment is reduced.

[00166] With this design, the build process is only stopped for a minimal amount of time during switching of the built objects 1011 from the build chamber 1014 to the first chamber 1024. This also saves a great deal of energy that would otherwise be required to re-heat the entire build chamber 1014. This also allows the system to maintain an operating equilibrium where all components are at a steady state temperature. This is important because of the dramatic temperature swings and atmospheric venting (both in pressure and air content) that would otherwise be subjected on the system, and the result of things like outgassing, mechanical/thermal stress/fatigue, and thermal

expansion, etc.

[00167] Additionally, in the implementation of Figure 10A, the chamber environmental controller 1032 can include (i) a build environmental controller 1032A that individually controls the environment in the build chamber 1014, (ii) an auxiliary environmental controller 1032B that individually controls the environment in the first chamber 1024, and (iii) a load lock environmental controller 1032C that individually controls the environment in the load lock chamber 1044. For example, each environmental controller 1032A, 1032B, 1032C can include one or more heaters, coolers, vacuum pumps or fluid pumps to control the environment to be a vacuum.

[00168] In one, non-exclusive implementation, the auxiliary environmental controller 1032B can include one or more individual regional environmental controllers 1032Ba-1032Bd. In the specific example of Figure 10A, the auxiliary environmental controller 1032B includes (i) a first regional environmental controller 1032Ba that controls the environment around the first holding station 1024C; (ii) a second regional environmental controller 1032Bb that controls the environment around the second holding station 1024D; (iii) a third regional environmental controller 1032Bc that controls the environment around the third holding station 1024E; and (iv) a fourth regional environmental controller 1032Bd that controls the environment around the fourth holding station 1024D. This design allows for the individual post-processing of each built object 1011 from the build chamber 1014, and individual pre-processing of the build frames 1035 (e.g., heating) prior to entry into the build chamber 1014. For example, each regional environmental controller 1032Ba-1032Bd can include one or more heaters, chillers, or other environmental controllers.

[00169] In the non-exclusive implementation of Figure 10A, the regional environmental controllers 1032Ba-1032Bd are illustrated above the holding stations 1024C-1024F. However, the regional environmental controllers 1032Ba-1032Bd can be alternatively located. For example, one or more of the regional environmental controllers 1032Ba-1032Bd can include a heater and/or chiller integrated into the respective holding station 1024C-1024F, and/or an adjacent sidewall.

[00170] At the time illustrated in Figure 10A, the third built object 1011C is being built in the build chamber 1014, and has a thick outline to represent that it is very hot.

Further, the second object 1011B that was previously made, is currently in the first chamber 1024 on the second holding station 1024D, and is illustrated to have a slightly less thick outline to represent that it has cooled slightly. At this time, the second regional environmental controller 1032Bb can control the environment around the second built object 1011B to individually control the post-processing of the second built object 1011B. For example, the second regional environmental controller 1032Bb may comprise a high power lamp that supplies heat to the second built object 1011B via radiation and/or a liquid-cooled cold plate that absorbs radiated energy from the second built object 1011B.

[00171] Somewhat similarly, the first object 1011A is in the first chamber 1024 on the first holding station 1024C, and is illustrated to have an almost thin outline to represent that it has almost fully cooled. At this time, the first regional environmental controller 1032Ba can control the environment around the first built object 1011A to individually control the post-processing of the first built object 1011A.

[00172] Additionally, at this time, the fourth regional environmental controller 1032Bd can control the environment around the build frame 1035 on the fourth holding station 1024F to individually control the pre-processing of this build frame 1035. In Figure 10A, the build frame 1035 is illustrated with a thick outline to represent that it is being heated (pre-heated) by the fourth regional environmental controller 1032Bd before the build frame 1035 is loaded into the build chamber 1014.

[00173] It should be noted in Figure 10A, the gate assemblies 1038, 1039, 1052 are illustrated in the closed position. At this time, the environment in each chamber 1014, 1024, 1044 can be individually controlled.

[00174] Figure 10B is a simplified cut-away view of the processing machine 1010 of Figure 10A including (i) the build chamber 1014; (ii) the build platform 1016; (iii) the material supply 1018; (iv) the measurement device 1020; (v) the irradiation device 1022; (vi) the first chamber 1024 including gate assemblies 1038, 1039; (vii) the auxiliary mover assembly 1028; (viii) the load lock chamber 1044 including the gate assembly 1052; (ix) a load lock mover assembly 1046; and (x) the control system 1034; with the built objects 1011A-1011C at a subsequent time than is illustrated in Figure 10A.

[00175] At the time illustrated in Figure 10B, (i) the first gate assembly 1038 is open; (ii) the third built object 1011C has been moved to the third holding station 1024E for post-processing in the first chamber 1024 with the third regional environmental controller 1032Bc; (iii) the unused, pre-processed build frame 1035 is being moved from the fourth holding station 1024F to the build platform assembly 1016 in the build chamber 1014; (iv) the second built object 1011B is still on the second holding station 1024D with post-processing being controlled by the second regional environmental controller 1032Bb; and (v) the first built object 1011A is still on the first holding station 1024C with post-processing being controlled by the first regional environmental controller 1032Ba. In Figure 10B, (i) the third built object 1011C has a thick outline to represent it is still very hot; (ii) the second built object 1011B has a slightly less thick outline to represent that it has been partly post-processed; and (iii) the first built object 1011A has a thin outline to represent that it has almost completely been post-processed.

[00176] Figure 10C is a simplified cut-away view of the processing machine 1010 of Figures 10A and 10B including (i) the build chamber 1014; (ii) the build platform 1016; (iii) the material supply 1018; (iv) the measurement device 1020; (v) the irradiation device 1022; (vi) the first chamber 1024 including gate assemblies 1038, 1039; (vii) the auxiliary mover assembly 1028; (viii) the load lock chamber 1044 including the gate assembly 1052; (ix) a load lock mover assembly 1046; and (x) the control system 1034; with the built objects 1011A-1011C at a subsequent time than is illustrated in Figures 10A and 10B.

[00177] At the time illustrated in Figure 10C, (i) the first gate assembly 1038 is closed; (ii) a fourth built object 1011D is being built in the build chamber 1014; (iii) the third built object 1011C is still on the third holding station 1024E for post-processing in the first chamber 1024 with the third regional environmental controller 1032Bc; (iv) the outlet gate assembly 1039 is open, and the environments in the load lock chamber 1044 and the first chamber 1024 are controlled to be the same; (v) an unused build frame 1035 has been moved from the load lock chamber 1044 to the fourth holding station 1024F with one or both of the mover assemblies 1028, 1046 for pre-processing with the fourth regional environmental controller 1032Bd; (iv) the second built object

1011B is still on the second holding station 1024D with post-processing being controlled by the second regional environmental controller 1032Bb; and (v) the finished, first built object 1011A is being moved by the load lock mover assembly 1046 to the load lock chamber 1044.

[00178] In Figure 10C, (i) the third built object 1011C has a relatively thick outline to represent it is still hot and partly post-processed; (ii) the second built object 1011B has a slightly less thick outline to represent that it has been further post-processed; and (iii) the first built object 1011A has a thin outline to represent that it has been completely been post-processed.

[00179] Figure 10D is a simplified cut-away view of the processing machine 1010 of Figures 10A-10C including (i) the build chamber 1014; (ii) the build platform 1016; (iii) the material supply 1018; (iv) the measurement device 1020; (v) the irradiation device 1022; (vi) the first chamber 1024 including gate assemblies 1038, 1039; (vii) the auxiliary mover assembly 1028; (viii) the load lock chamber 1044 including the gate assembly 1052; (ix) a load lock mover assembly 1046; and (x) the control system 1034; with the built objects 1011A-1011D at a subsequent time than is illustrated in Figures 10A-110C.

[00180] At the time illustrated in Figure 10D, (i) the first gate assembly 1038 and the outlet gate assembly 1039 are closed; (ii) the fourth built object 1011D is still being built in the build chamber 1014; (iii) the third built object 1011C is still on the third holding station 1024E for post-processing with the third regional environmental controller 1032Bc; (iv) the second built object 1011B is still on the second holding station 1024D with post-processing being controlled by the second regional environmental controller 1032Bb; (v) the unused build frame 1035 is on the first holding station 1024C and is being pre-processing with the first regional environmental controller 1032Ba; (vi) the load lock gate assembly 1052 is open, and the load lock chamber 1044 is at the surrounding environment; and (vii) the finished, first built object 1011A is being moved by the load lock mover assembly 1046 to the surrounding environment.

[00181] With reference to Figures 10A-10D, the problem of loading build frames 1035, and removing finished built objects 1011 from a fully-automated, continuously

running three-dimensional processing machine 1010 is solved by using the first chamber 1024, the auxiliary mover assembly 1028, the load lock chamber 1044 and the load lock mover assembly 1046. Stated in another fashion, with the present designs, the processing machine 1010 can be continuous operated in an automated fashion.

[00182] It should be noted that the design and location of the components can be different from that illustrated in Figures 10A-10D. As a non-exclusive example, a plurality of build platforms 1016 can be provided in the build chamber 1014 and the plurality of built objects 1011 could be manufactured in parallel. Still alternatively, the load lock mover assembly 1046 could be positioned outside the load lock chamber 1044 and can reach into the load lock chamber 1044 to retrieve the built objects 1011 and move build frames 1035 into the load lock chamber 1044. Still alternatively, processing machine 1010 can be built without the auxiliary mover assembly 1028. In this design, the load lock mover assembly 1046 can be used to perform the task of retrieving built objects 1011 from the build chamber 1014, and moving unused build frames 1035 into the build chamber 1014.

[00183] With the implementation of Figures 10A-10D, part fabrication happens in the build chamber 1014 on the right. The first chamber 1024 in the middle of the diagram has four loading stations 1024C-1024F that can hold a new build frame 1035, or a built object 1011. The auxiliary mover assembly 1028 is capable of reaching into the build chamber 1014 to load build frames 1035, and unload finished objects 1011. The first chamber 1024 can be maintained at a similar atmosphere (or vacuum) to the build chamber 1014. The load lock chamber 1044 on the right is used to transfer objects (built objects 1011, and unused build frames 1035) between the normal ambient atmosphere and the controlled atmosphere or vacuum of the first chamber 1024. In the embodiment shown, the load lock mover assembly 1046 can reach in to the auxiliary 1024 and/or hand-off objects to/from the auxiliary mover assembly 1028.

[00184] Moreover, in the implementation of Figures 10A-10D, (i) the built objects 1011 and the build frames 1035 can be moved between the build chamber 1014 and the first chamber 1024 without adversely influencing the build chamber environment in the build chamber 1014; and (ii) the built objects 1011 and the build frames 1035 can

be moved between the first chamber 1024 and the load lock chamber 1044 without adversely influencing the first chamber environment in the first chamber 1024.

[00185] For example, the chamber environment controller 1032 can control (i) a build chamber pressure in the build chamber 1014, and a first chamber pressure in the first chamber 1024 to be approximately the same; and/or (ii) the first chamber pressure and a load lock chamber pressure in the load lock chamber 1044 and to be approximately the same.

[00186] Figure 11 is a simplified flow chart that illustrates one, non-exclusive method for making one or more built objects. At step 1110, preprocessing steps are performed in one of the chambers. Next, at step 1112, a powder layer is deposited onto the build frame using the material supply. Subsequently, at step 1114, the measurement device can be used to inspect/measure the characteristics of the powder layer. Next, at step 1116, a portion of the powder layer is melted with the irradiation device. The control system controls the irradiation device to precisely irradiate the powder layer. Next, at step 1118 the measurement device can be used to inspect/measure the characteristics of the melted powder. Subsequently, at step 1120, the control system can determine if the build object is complete. If the object is not complete, steps 1112-1120 can be repeated until the object is complete.

[00187] After the object is complete, at step 1122, the object can be moved to a different chamber (as illustrated in Figures 1-2B, 10A-10D) or the chamber with the object (as illustrated in Figures 4A-4B) can be moved for controlled post-processing. At this time the environmental controller can be used to maintain and provide the desired environment for post-processing of the built object. In alternative, non-exclusive examples, the cool down time can be at least two, four, six, eight, ten or twelve hours.

[00188] While the build object is being post-processed, at step 1124, another object can be built by repeating steps 1110-1124 as necessary. Stated in another fashion, during the post-processing of the built object, one or more additional objects can be made in the build chamber. This process can be repeated ad infinitum so that the building process is not stopped during the cooling process.

[00189] If no more objects are desired to be built, the process is finished at step

1126.

[00190] It should be noted that the processing machine provided herein can be designed to have one or more of the following features during the printing process: (i) one or more of the material supply, the measurement device, and the irradiation device can be selectively moved relative to the build platform in one or more of the six degrees of freedom (along an X, Y, and Z axis, or about an X, Y, and Z axis); or (ii) build platform can be selectively moved relative to the build platform in one or more of the six degrees of freedom relative to one or more of the material supply, the measurement device, and the irradiation device.

[00191] Additionally and non-exclusively, it should be noted that one or more of the chamber(s) provided herein can include one or more of the following: (i) a separate powder supply; (ii) a heater element; (iii) build piston/gears for the build platform, and (iv) a coupling to connect to a motor for driving the build piston/gears. Here, the chamber is configured to be as simple as possible, with the motor or driving mechanism for the build piston/gears located outside the chamber unit in the overall system. Further, the build chambers are reusable.

[00192] Additionally, or alternatively, for all of the various implementations provided herein, some or all of the mechanical equipment (e.g., pistons, motors, gears, etc.) can be external to the chambers, and able to couple and decouple from any chamber. It might also be mentioned that one or more of these components could alternatively exist and remain inside of each chamber.

[00193] The disclosed techniques provided herein can be used to continuously print one or more object(s) within multiple reusable chambers and streamlines pre-processing and post-processing steps to occur simultaneously as the parts are built reducing downtime increasing throughput. Each object can be isolated within its own reusable chamber, and each chamber can be isolated from the rest of the components of the overall system. This isolation protects expensive components of the overall system (e.g., the column) from being damaged or being subject to additional downtime due to a problem with an object in a chamber by providing an ability to move the chamber with the problematic part out of the system and replacing it with another chamber. This isolation also provides flexibility for parts requiring different pre-

processing or post-processing steps (e.g., material change or different cooling requirements). The reusable chambers can also be used in other systems (e.g., rotary powder bed).

[00194] Further, it should be noted that the embodiments mentioned above include one or more of the technical aspects listed below.

[00195] In one implementation, a processing machine for building a first built object from a material includes: (i) a machine frame; (ii) a first movable build chamber that forms a first build space, the first movable build chamber being selectively coupled to the machine frame; (iii) a chamber environmental controller that controls the environment in the first build space; (iv) a material supply assembly that supplies material to build the first built object in the first build chamber; (v) an irradiation device which irradiates at least a portion of the material with an energy beam to form the first built object from the material in the first build chamber; and (vi) a chamber mover assembly that moves the first movable build chamber relative to the machine frame. In this implementation (and other implementations discussed above), the processing machine can include one or more of the following features: (i) wherein the first movable build chamber is selectively movable relative to at least a portion of the irradiation device; (ii) a second movable build chamber that forms a second build space, the second movable build chamber being selectively coupled to the machine frame; (iii) wherein at least one pre-processing or post-processing step is performed in the second build space simultaneously with the building of the object in the first build space; (iv) wherein at least one pre-processing step is performed in the second build space simultaneously with at least one post-processing step being performed in the first build space; (v) wherein the chamber mover assembly selectively moves the movable build chambers relative to each other; (vi) wherein the chamber mover assembly selectively moves the first movable build chamber relative to the second movable build chamber; (vii) a third movable build chamber that forms a third build space, the third movable build chamber being selectively coupled to the machine frame; (viii) at least one pre-processing step is performed in the second build space simultaneously with the building of the object in the first build space, and at least one post-processing step being performed in the third build space; (ix) wherein the chamber mover assembly

selectively moves at least one of the movable build chambers relative to the other movable build chambers; and/or (x) a column assembly that selectively couples the irradiation device to the first build chamber.

[00196] In another implementation, a processing machine for building a first built object from a material includes: (i) a first build chamber that forms a first build space; (ii) a second build chamber that forms a second build space; (iii) a chamber environmental controller that controls the environment in the build spaces; (iv) a material supply assembly that supplies material to build the objects in the build spaces; and (v) an irradiation device which irradiates at least a portion of the material with an energy beam, wherein the irradiation device is selectively movable to direct an energy beam into the first build chamber and the second build chamber.

[00197] In yet another implementation, a method for building a built object from a material comprises: (i) providing a machine frame; (ii) providing a movable build chamber that forms a build space, the movable build chamber being selectively coupled to the machine frame; (iii) controlling the environment in the build space with an environmental controller; (iv) supplying material to build the built object in the build chamber; (v) irradiating at least a portion of the material with an energy beam to form the built object from the material in the build chamber; and (vi) moving the movable build chamber relative to the machine frame with a chamber mover assembly.

[00198] Those of ordinary skill in the art will realize that the following detailed description of the present embodiment is illustrative only and is not intended to be in any way limiting. Other embodiments of the present embodiment will readily suggest themselves to such skilled persons having the benefit of this disclosure. Reference will now be made in detail to implementations of the present embodiment as illustrated in the accompanying drawings.

[00199] In the interest of clarity, not all of the routine features of the implementations described herein are shown and described. It will, of course, be appreciated that in the development of any such actual implementation, numerous implementation-specific decisions must be made in order to achieve the developer's specific goals, such as compliance with application-related and business-related constraints, and that these specific goals will vary from one implementation to another and from one

developer to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking of engineering for those of ordinary skill in the art having the benefit of this disclosure.

What is claimed is:

1. A processing machine for building a built object from a material, the processing machine comprising:

a build chamber that forms a build space;

a material supply that supplies material to build the built object in the build space;

an irradiation device which irradiates at least a portion of the material with an energy beam to form the built object from the material in the build chamber; and

a first chamber that defines a first space, the first chamber is connected to the build chamber via a first gate through which the built object is transferred from the build chamber to the first space for post-processing of the built object.

2. The processing machine of claim 1 wherein the first chamber is adapted to store a plural of built objects in the first space.

3. The processing machine of claim 1 or 2, further comprising a load lock chamber that defines a load lock space and is connected to the first chamber via a first outlet gate through which the built object is transferred from the first space to the load lock space.

4. A processing machine for building a built object from a material, the processing machine comprising:

a build chamber that forms a build space;

a material supply that supplies material to build the built object in the build space;

an irradiation device which irradiates at least a portion of the material with an energy beam to form the built object from the material in the build chamber; and

a load lock chamber that defines a load lock space and is connected to the build chamber via a first outlet gate through which the built object is transferred from the build space to the load lock space.

5. The processing machine of claim 3 wherein the first gate selectively separates the first space from the build space, the first outlet gate selectively separates the load lock space from the first space.

6. The processing machine of claim 4 or 5 wherein the load lock chamber includes a load gate through which the built object is taken out from the load lock space, the load gate selectively separates the load lock space from the atmosphere.

7. The processing machine of any of claims 3-6 further comprising a load lock chamber environmental controller that controls the environment in the load lock space.

8. The processing machine of any of claim 1-3 further comprising: a first chamber environmental controller that controls the environment in the first space.

9. The processing machine of claim 8 wherein the first chamber environmental controller controls temperature in the first space for controlling temperature of the first built object stored in the first space.

10. The processing machine of claim 9 wherein the first chamber environmental controller controls temperature in the first space for cooling the first built object stored in the first space.

11. The processing machine of any of claims 1-7 further comprising: a build chamber environmental controller that controls the environment in the build space.

12. The processing machine of any of claims 8-10 further comprising: a build chamber environmental controller that controls the environment in the build space.

13. The processing machine of claim 12 wherein the build chamber environmental controller controls the built space to be in vacuum state, and the first chamber environmental controller controls the first space to be in vacuum state independently of the build chamber environmental controller.

14. The processing machine of any of claims 7-13 wherein the build chamber environmental controller controls at least one of temperature and internal pressure in the build space; and wherein the first chamber environmental controller controls at least one of temperature and internal pressure in the first space.

15. A processing machine for building a first built object from a material, the processing machine comprising:

a build chamber that forms a build space;

a build chamber environmental controller that controls the environment in the build space;

a material supply that supplies material to build the first built object in the build space;

an irradiation device which irradiates at least a portion of the material with an energy beam to form the first built object from the material in the build chamber;

a first chamber that defines a first space, wherein the first built object is moved from the build chamber to the first chamber; and

a first chamber environmental controller that controls the environment in the first space.

16. The processing machine of claim 15 wherein the first chamber environmental controller controls temperature in the first space.

17. The processing machine of claim 15 wherein the first chamber environmental controller controls temperature in the first space for cooling the first built object.

18. The processing machine of claim 15 further comprising a measurement device that measures the object as it is being built in the build chamber.

19. The processing machine of any of claims 15-18 further comprising a first mover assembly that moves the first built object from the build chamber to the first chamber.

20. The processing machine of claim 19 wherein the first built object is hot while being moved by the first mover assembly from the build chamber.

21. The processing machine of any of claims 15-20 wherein the first chamber environmental controller controls the environment in the first space to be approximately the same as the environment in the build space.

22. The processing machine of claim 21 wherein the build chamber environmental controller controls the built space to be in vacuum state, and the first

chamber environmental controller controls the first space to be in vacuum state independently of the build chamber environmental controller.

23. The processing machine of claim 21 wherein the build chamber environmental controller controls the built space to be a non-oxidizing atmosphere, and the first chamber environmental controller controls the first space to be a non-oxidizing atmosphere independently of the build chamber environmental controller.

24. The processing machine of any of claims 15-23 wherein the first chamber environmental controller controls the environment in the first space to be approximately the same as the environment in the build space while the first built object is moved from the build chamber to the first chamber.

25. The processing machine of claim 24 wherein the first space is spatially connected with the build space while the first built object is moved from the build chamber to the first chamber.

26. The processing machine of claim 25 further comprising a first gate that selectively separates the first space from the build space.

27. The processing machine of claim 15 further comprising a first outlet gate that selectively opens the first space.

28. The processing machine of claim 27 further comprising a load lock chamber that is connected to the first chamber via the first outlet gate.

29. The processing machine of claim 15 wherein the first chamber is adapted to store a plurality of built objects in the first space.

30. The processing machine of claim 15 wherein the build chamber environmental controller and the first chamber environmental controller are a part of a chamber environmental controller.

31. The processing machine of claim 15 further comprising a second chamber that defines a second space and a second chamber environmental controller that controls the environment in the second space; wherein the material supply supplies material to build a second built object in the build space; wherein the irradiation device irradiates at least a portion of the material with the energy beam to form the second built object from the material in the build chamber; and wherein the second built object is moved from the build chamber to second chamber.

32. The processing machine of claim 31 wherein the second space is connected in fluid communication with the build space while the second built object is moved from the build chamber to the second chamber.

33. The processing machine of any of claims 31 and 32 further comprising a second gate that selectively separates the second space from the build space.

34. The processing machine of claim 15 wherein the first built object is built on a build frame.

35. The processing machine of claim 34 wherein the build frame is heated in the first space and moved to the build space while hot.

36. The processing machine of claim 34 wherein the build chamber environmental controller maintains at least a portion of the build space at an elevated temperature while (i) the build frame is moved from the first space to the build space; (ii) the first built object is built in the build chamber; and (iii) the first built object is moved from the build space to the first space.

37. The processing machine of claim 36 wherein the first chamber environmental controller maintains at least a portion of the first space at an elevated temperature while (i) the build frame is moved from the first space to the build space; (ii) the first built object is built in the build chamber; and (iii) the first built object is moved from the build space to the first space.

38. The processing machine of claim 15 wherein the first built object, while in the first space, is maintained at an elevated temperature and then subsequently cooled at a controlled rate.

39. A method for building a built object from a material comprising:

- providing a build chamber that forms a build space;
- controlling a build chamber environment in the build space with an environmental controller;
- supplying material to build the built object in the build space with a material supply;
- irradiating at least a portion of the material with an energy beam to form the built object from the material in the build chamber;
- providing a first chamber that defines a first space; and
- moving the built object from the build chamber to the first chamber without adversely influencing the build chamber environment.

40. The method of claim 39 further comprising controlling a first chamber environment in the first space with the environmental controller; wherein the environmental controller controls a build chamber pressure in the build chamber, and a first chamber pressure in the first chamber to be approximately the same.

41. A method for building a built object from a material comprising:

providing a build chamber that forms a build space;

providing a first chamber that defines a first space, the first chamber is connected to the build chamber via a first gate through which the built object is transferred from the build space;

supplying material to build the built object in the build space with a material supply;

irradiating at least a portion of the material with an energy beam to form the built object from the material in the build chamber;

transferring the built object from the build space to the first space through the first gate; and

post-processing the built object in the first space.

42. The method of claim 41 further comprising:

providing a load lock chamber that defines a load lock space that is connected to the first chamber via a first outlet gate through which the built object is transferred from the first space to the load lock space;

transferring the built object which finish post-processing from the first space to the load lock space through the first outlet gate; and

removing the built object from the load lock chamber.

43. A method for building a built object from a material comprising:

providing a build chamber that forms a build space;

providing a load lock chamber that defines a load lock space that is connected to the built chamber via a first outlet gate through which the built object is transferred from the build space to the load lock space;

supplying material to build the built object in the build space with a material supply;

irradiating at least a portion of the material with an energy beam to form the built object from the material in the build chamber;

transferring the built object from the build space to the load lock space through the ; and

removing the built object from the load lock chamber.

1/10

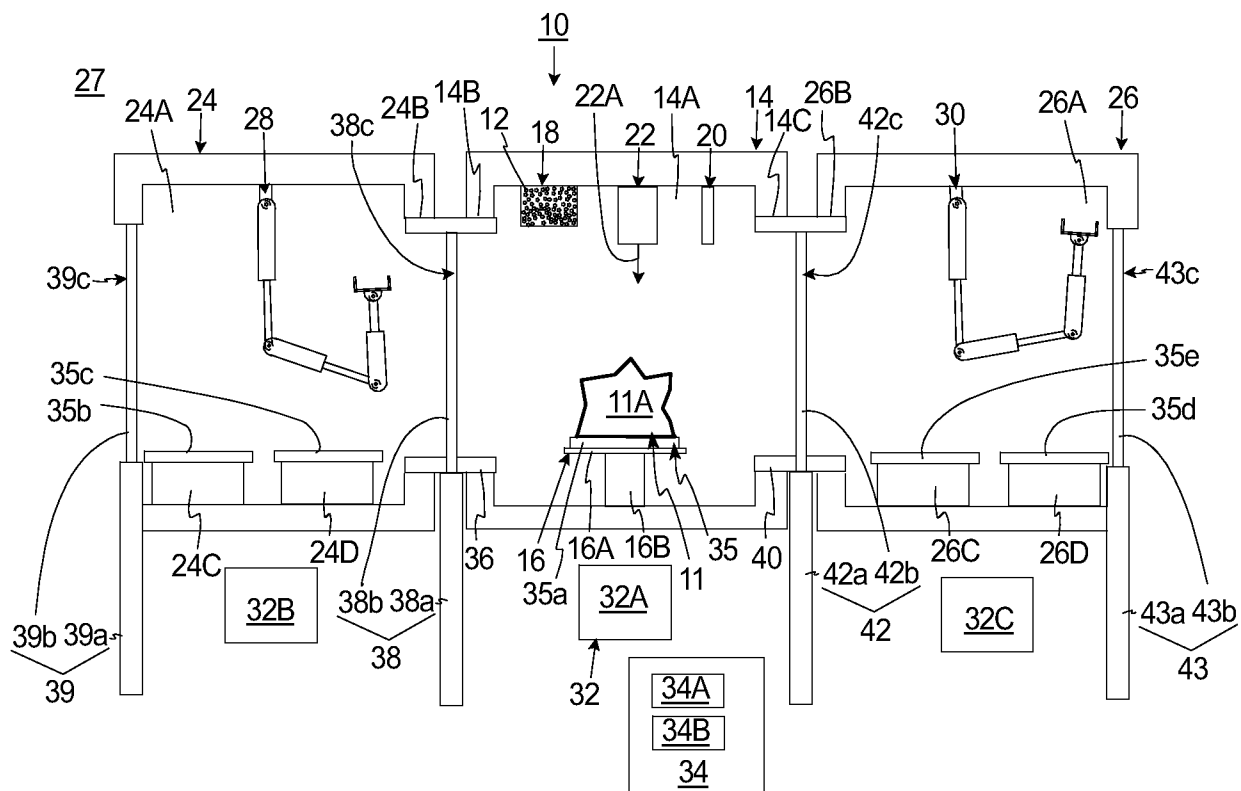


Fig. 1A

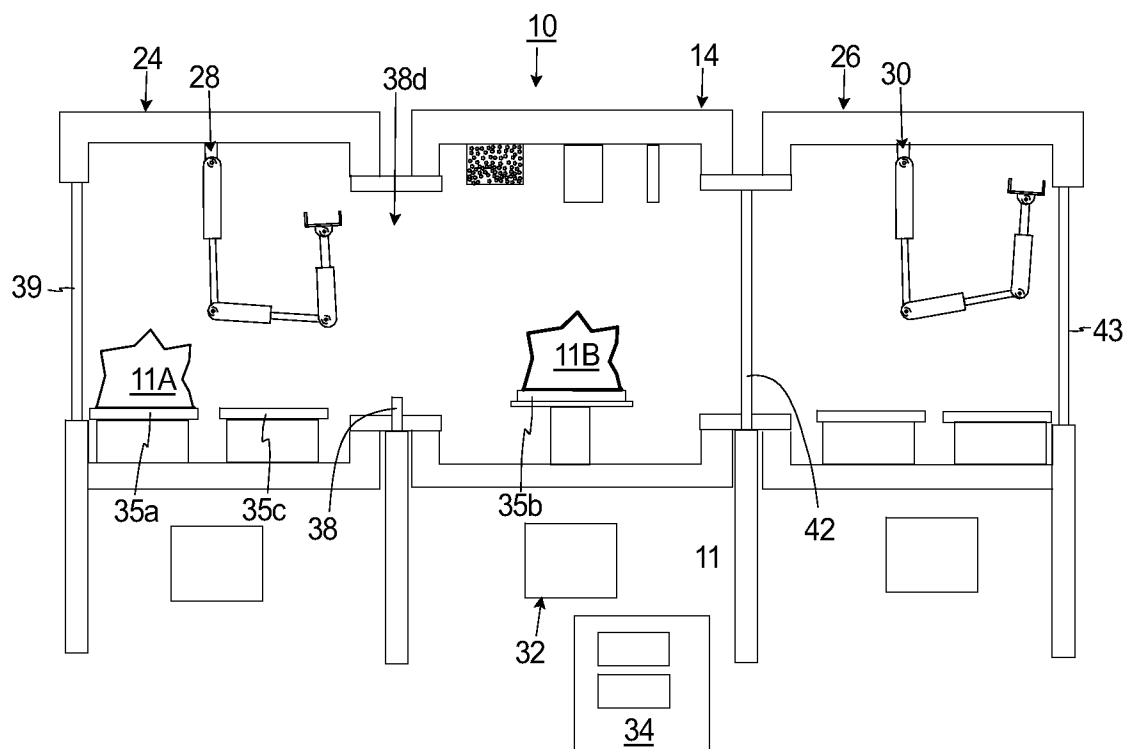
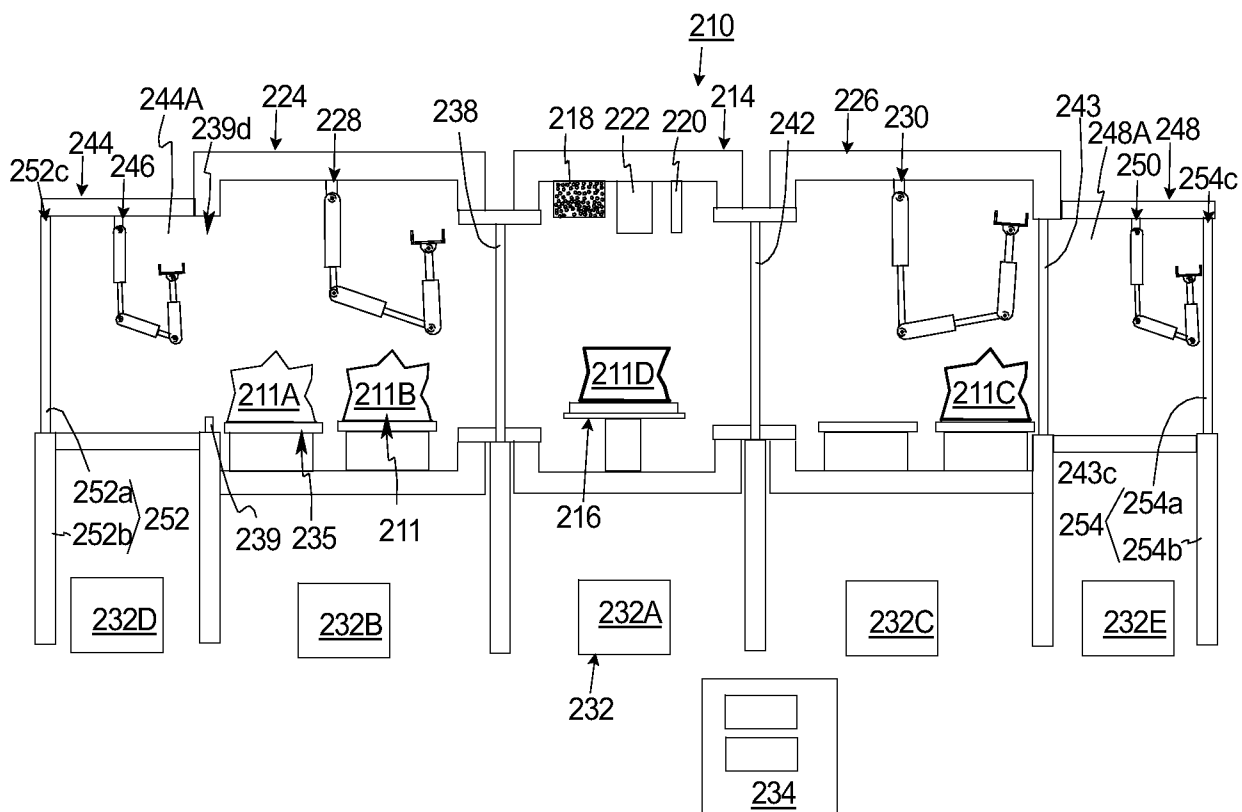
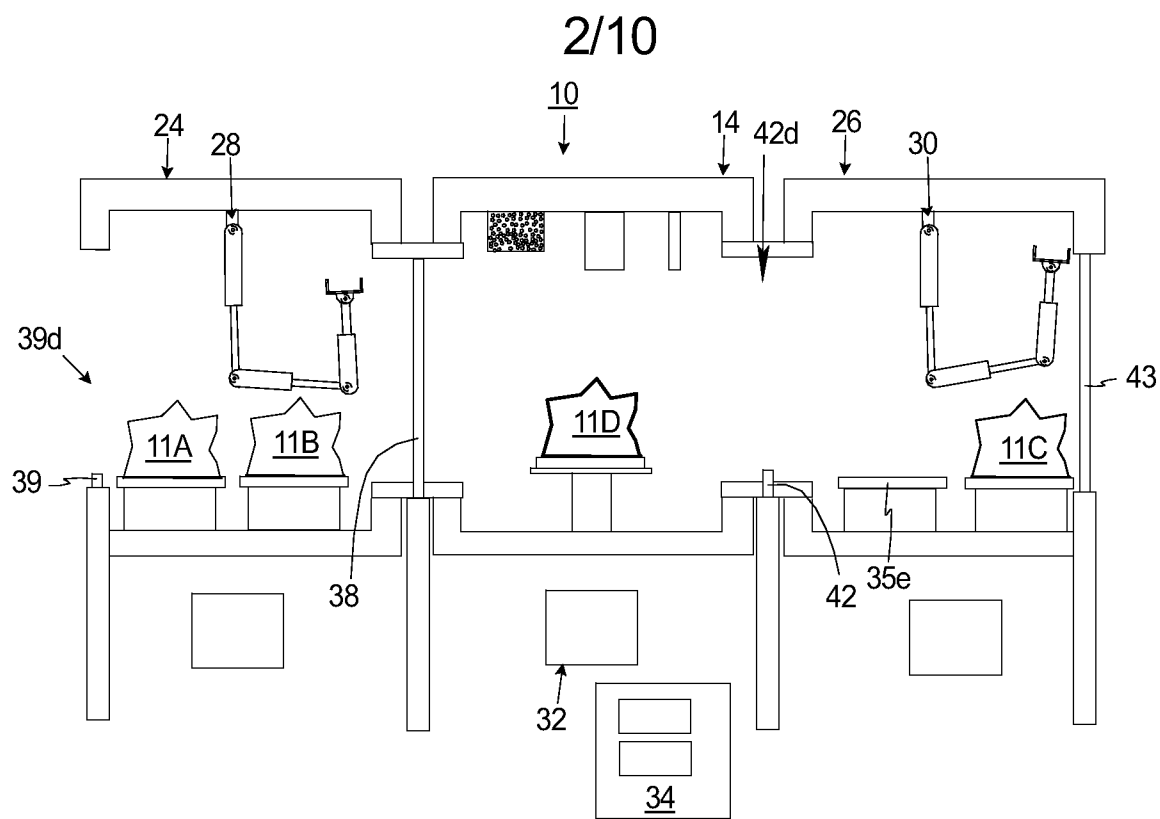


Fig. 1B



3/10

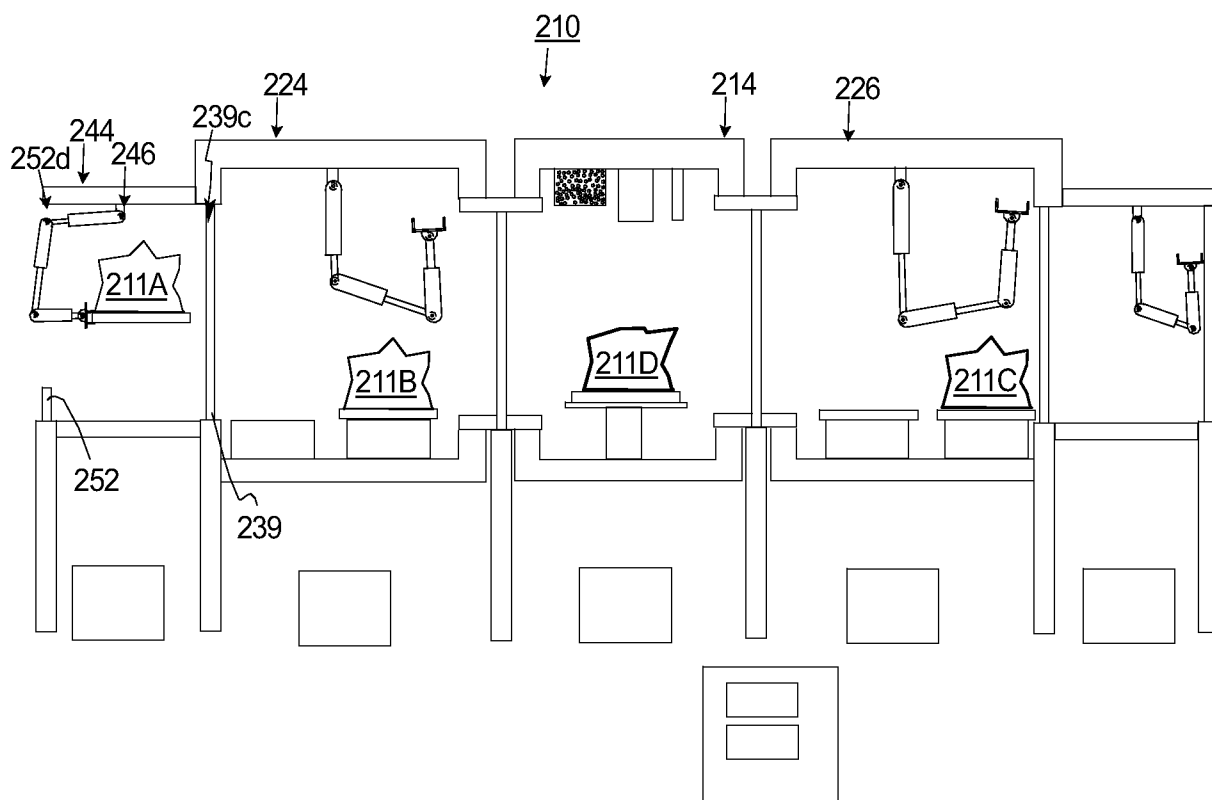


Fig. 2B

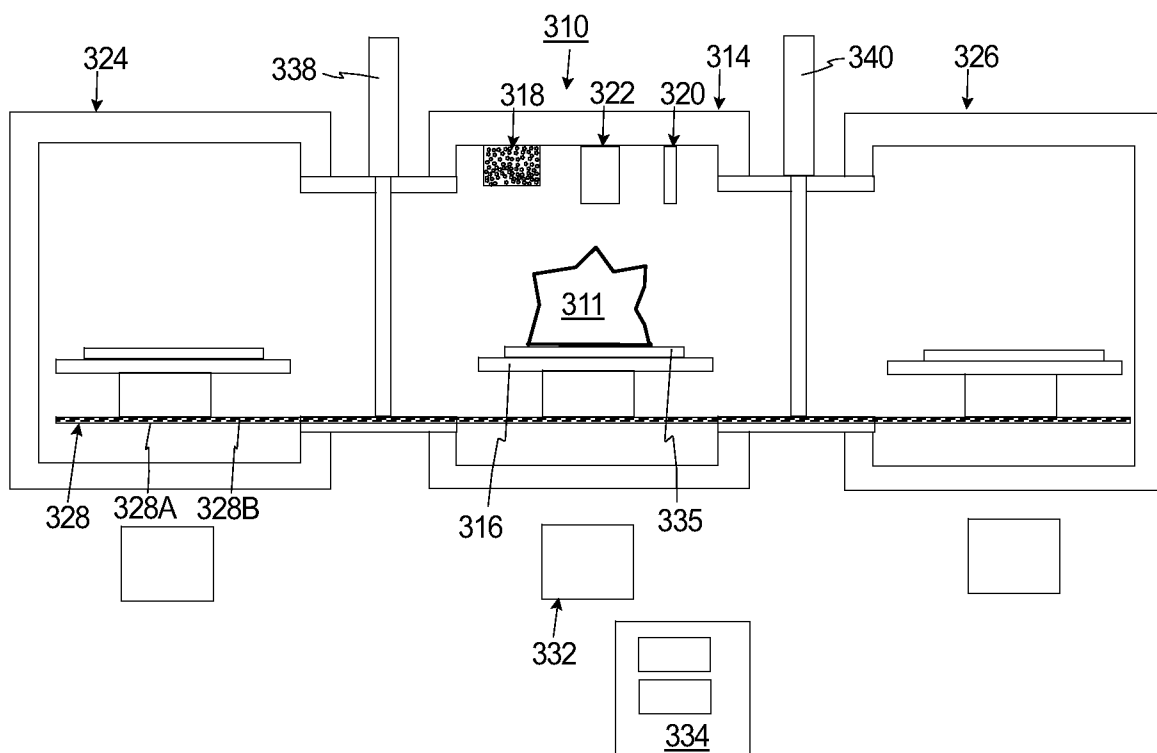


Fig. 3

4/10

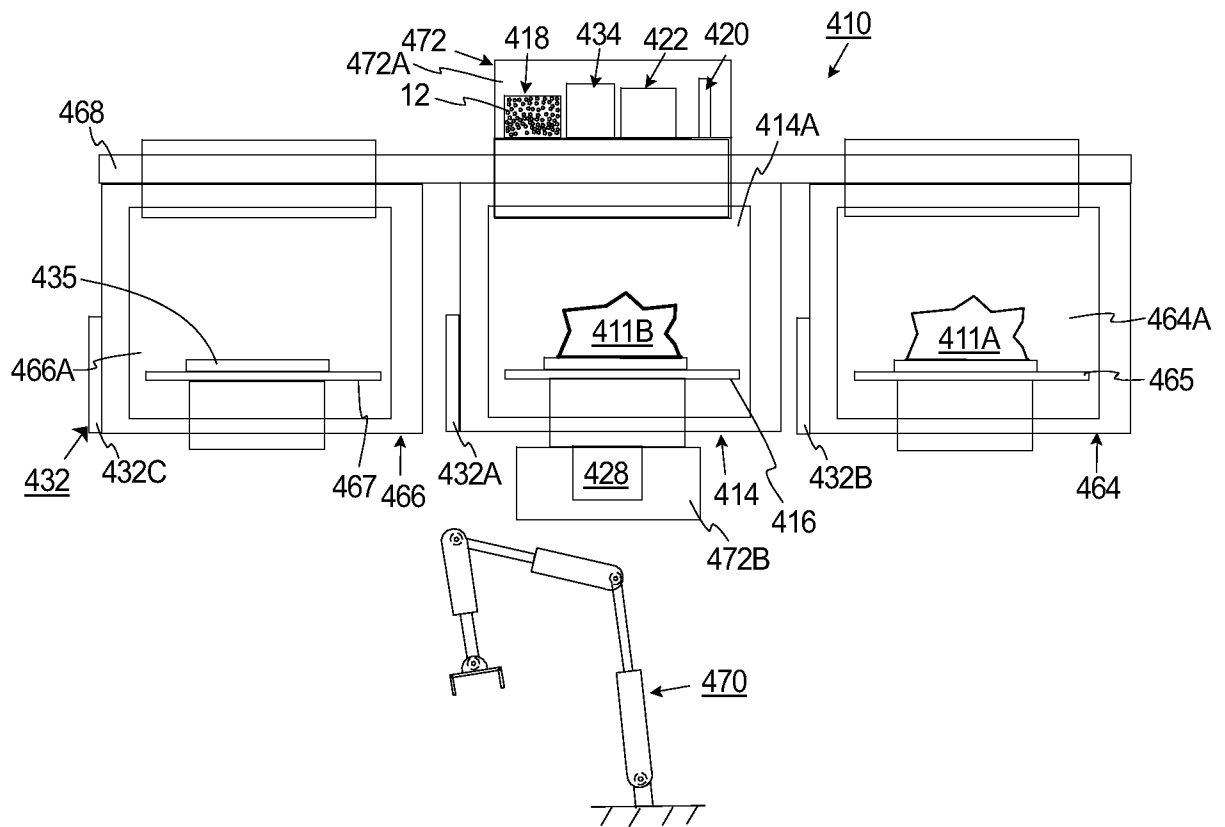


Fig. 4A

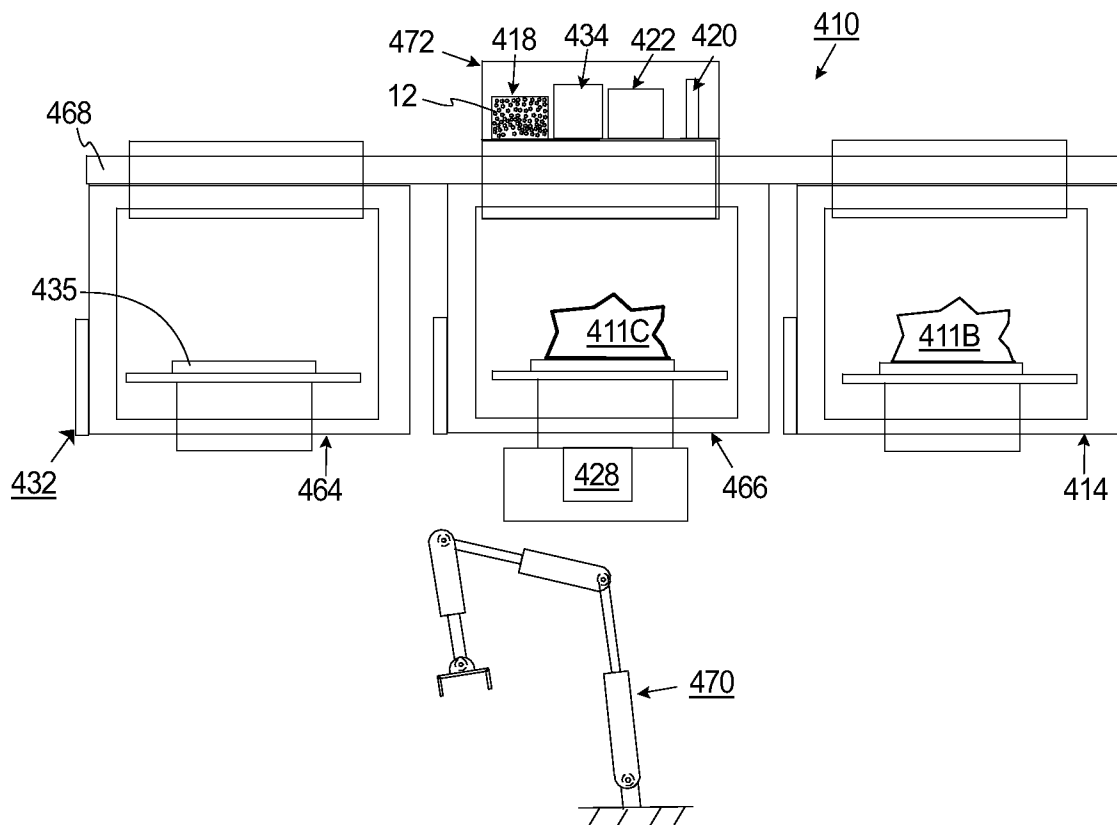


Fig. 4B

5/10

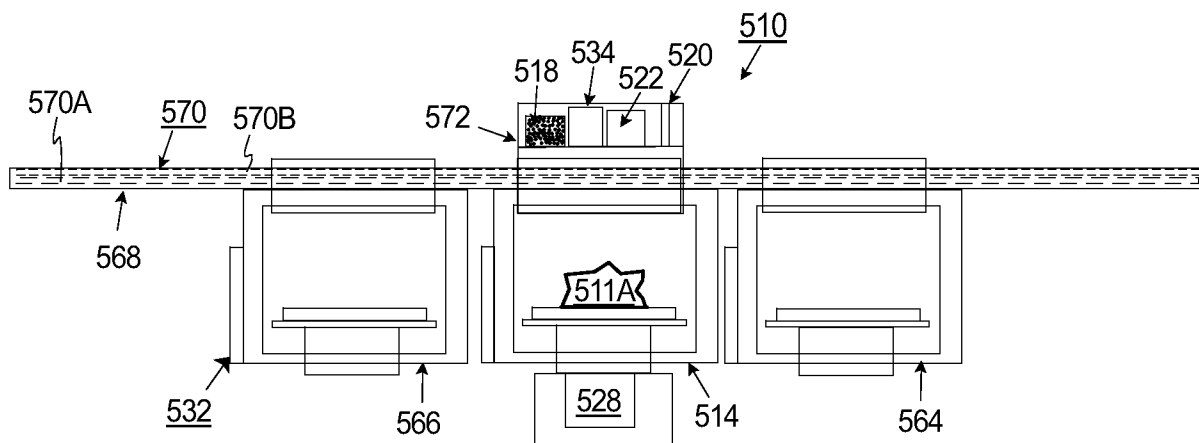


Fig. 5

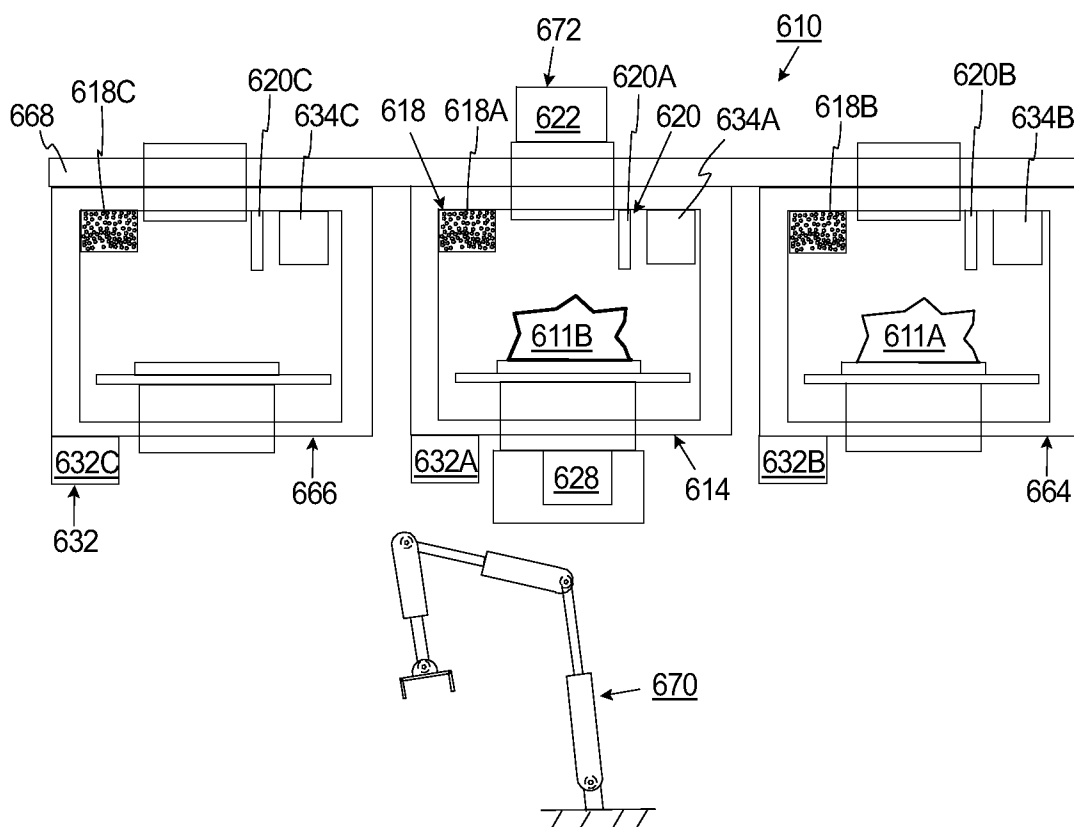


Fig. 6

6/10

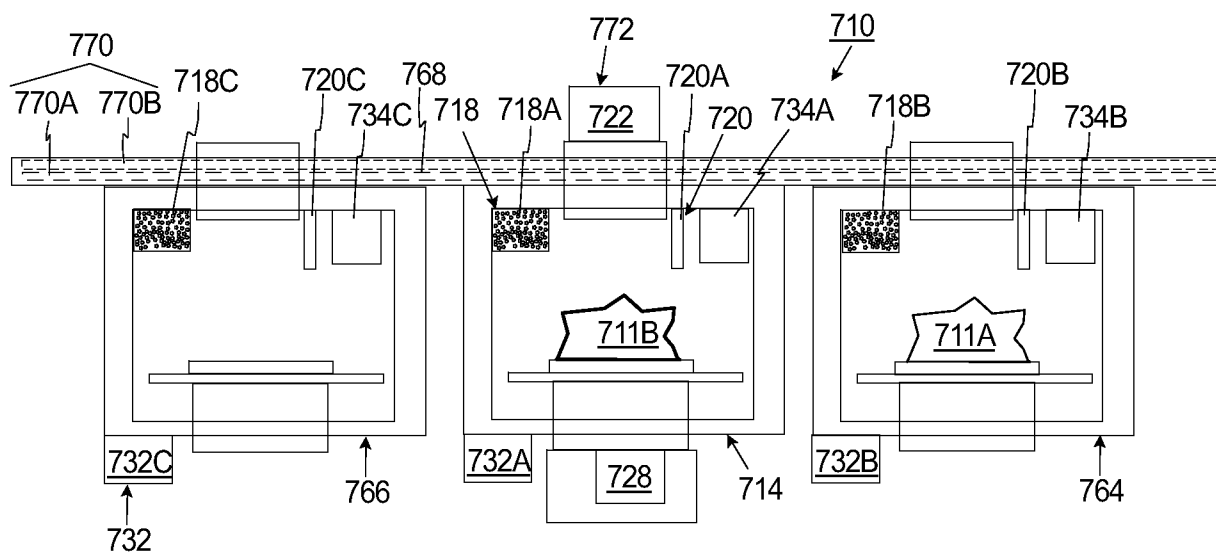


Fig. 7

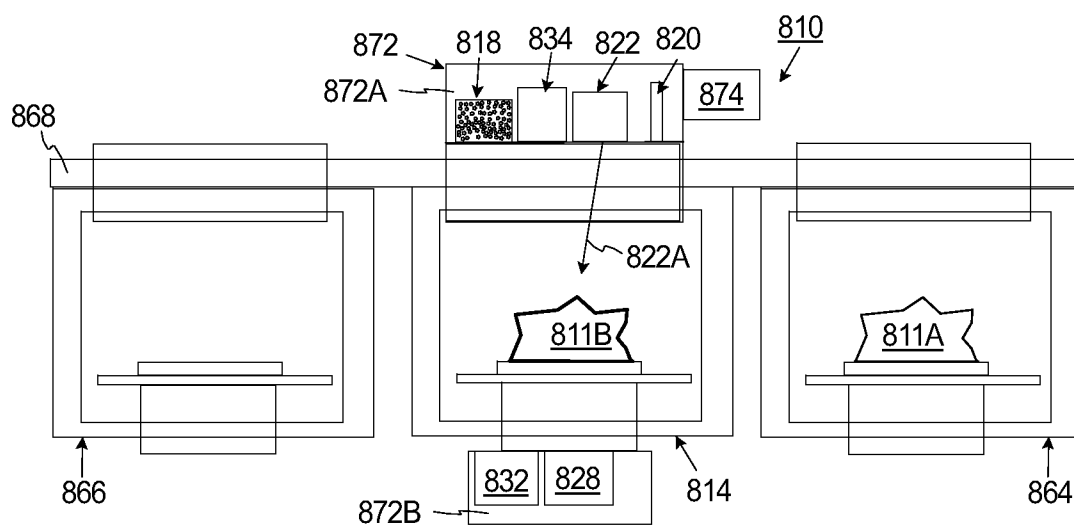


Fig. 8A

7/10

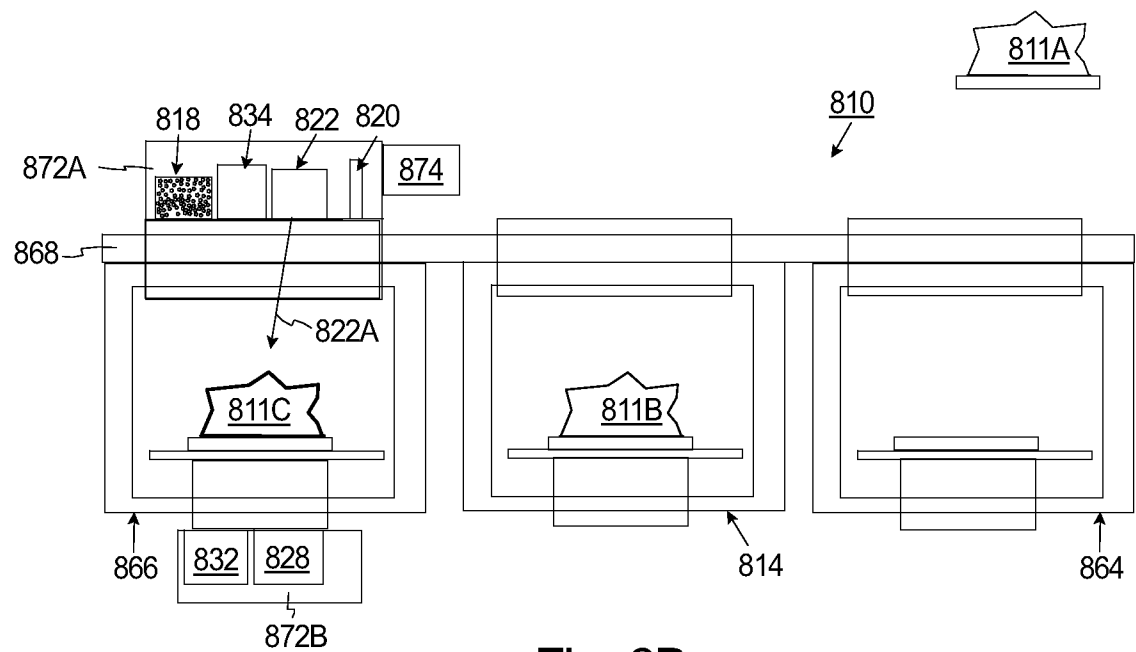


Fig. 8B

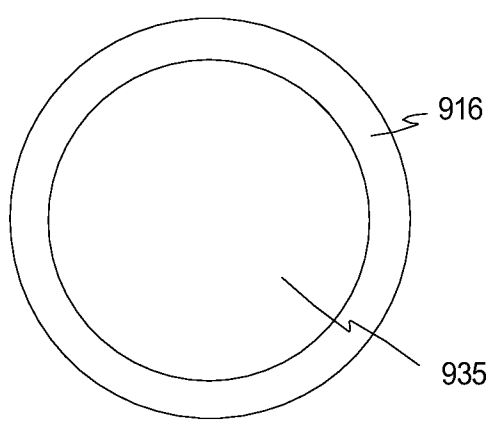


Fig. 9

8/10

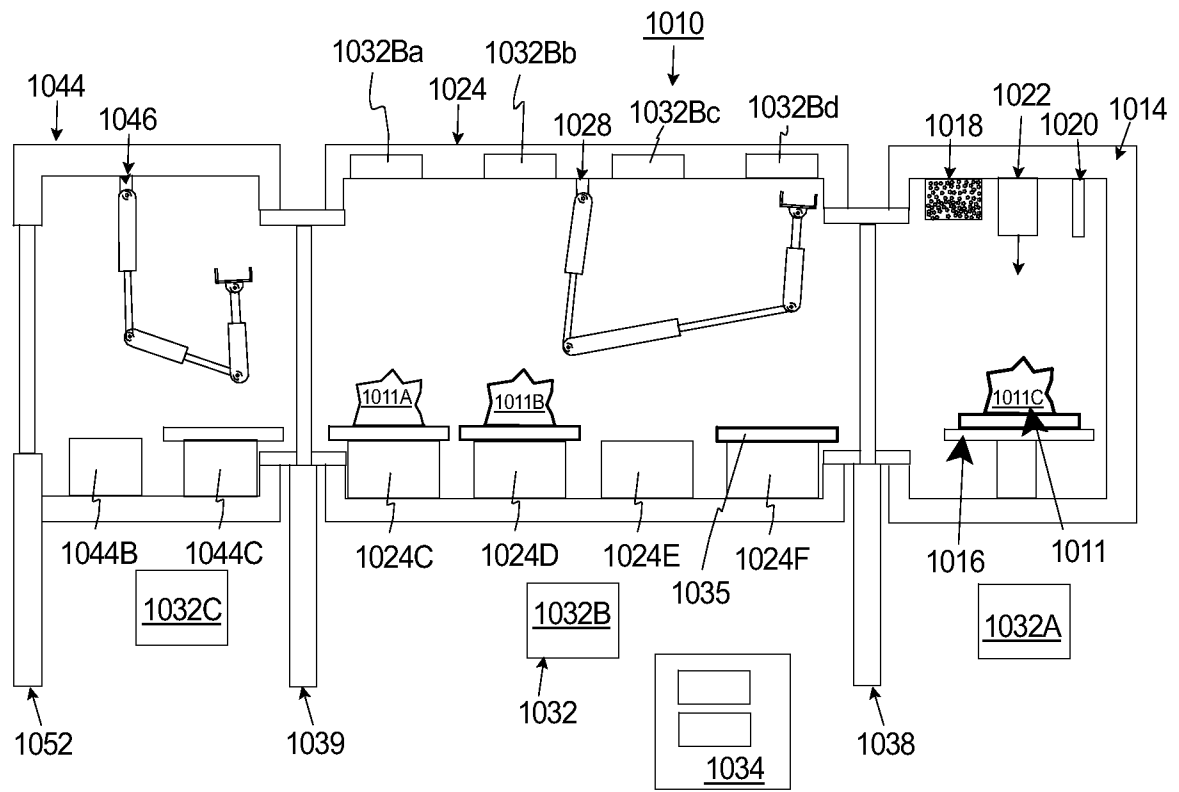


Fig. 10A

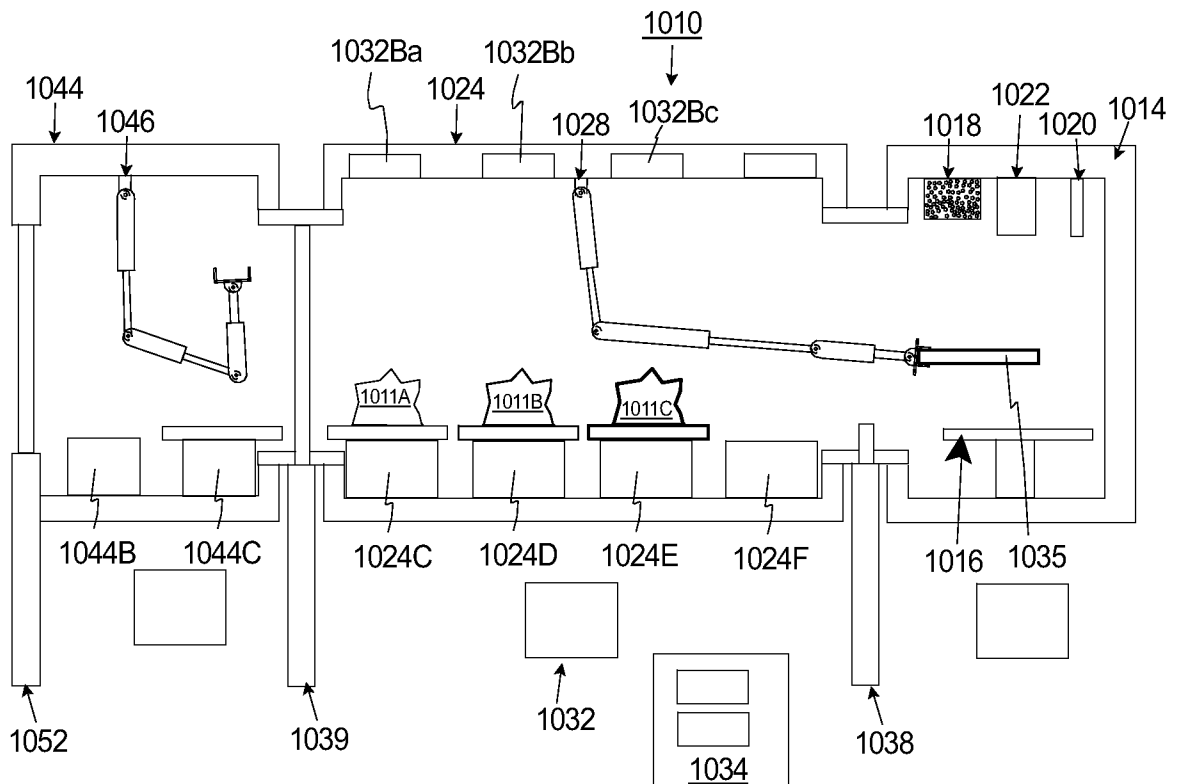


Fig. 10B

9/10

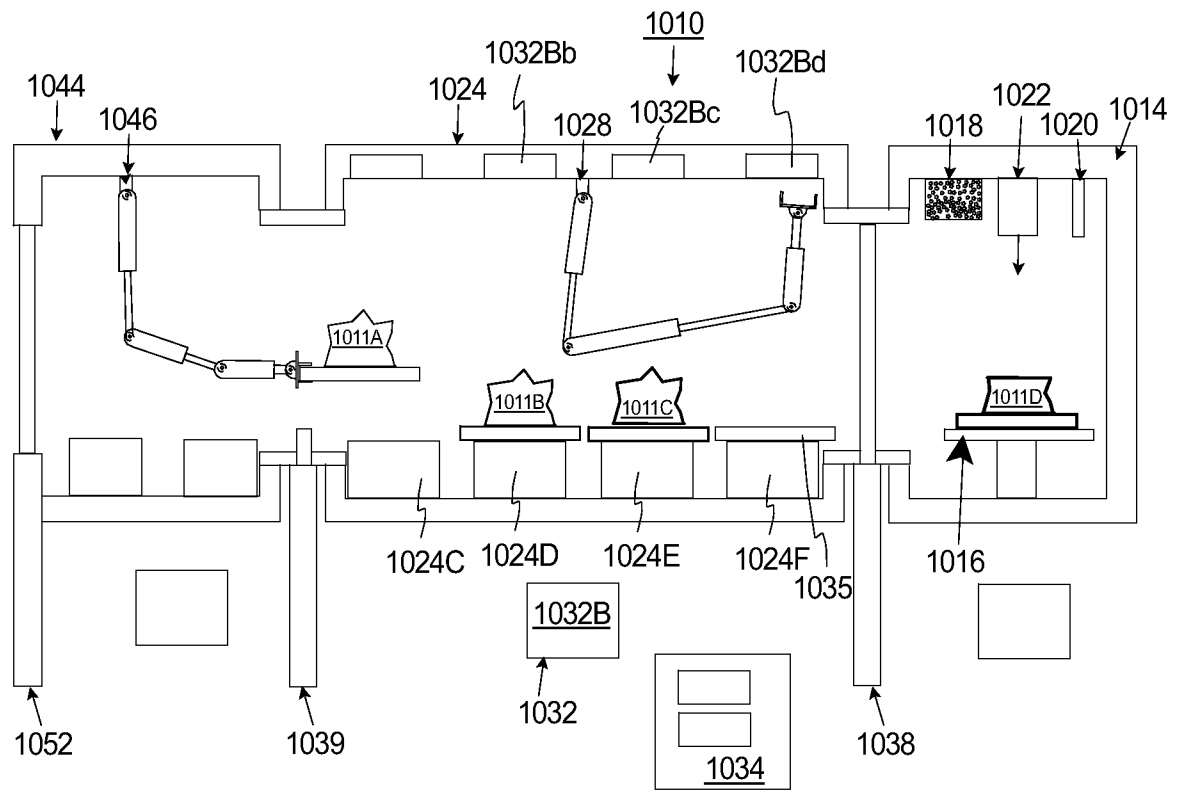


Fig. 10C

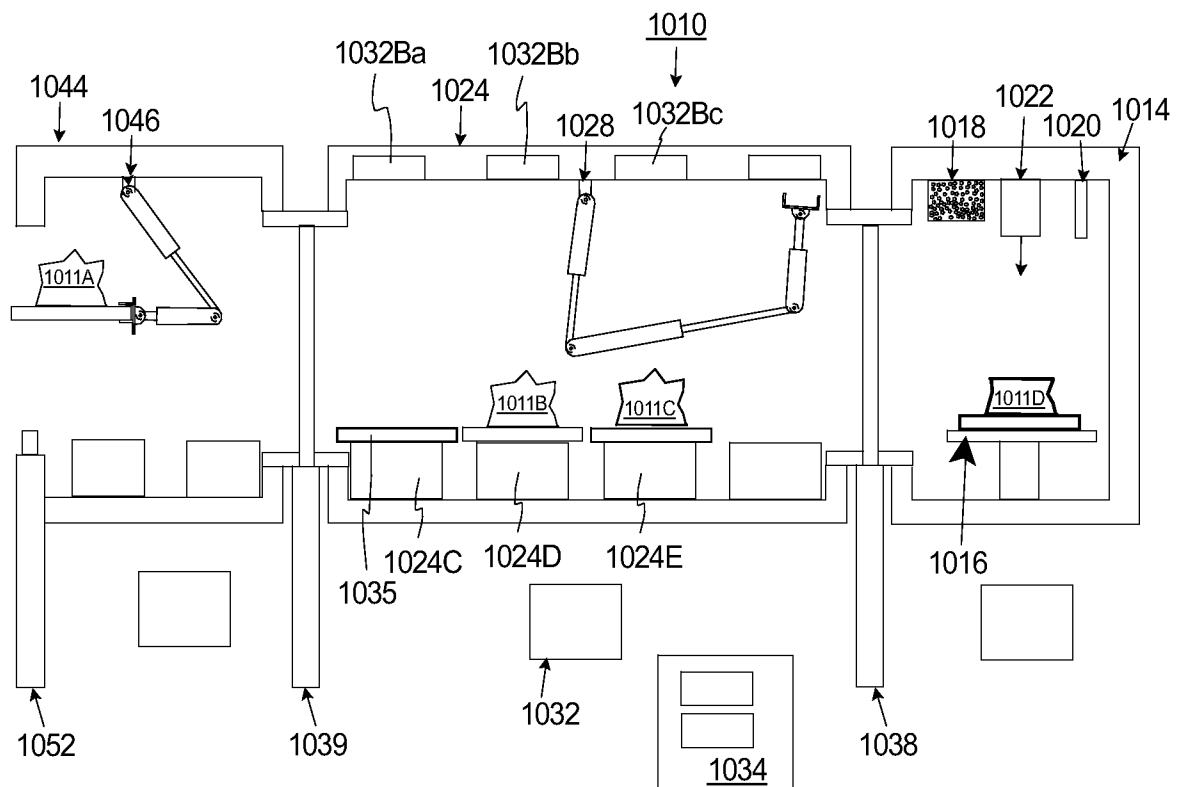


Fig. 10D

10/10

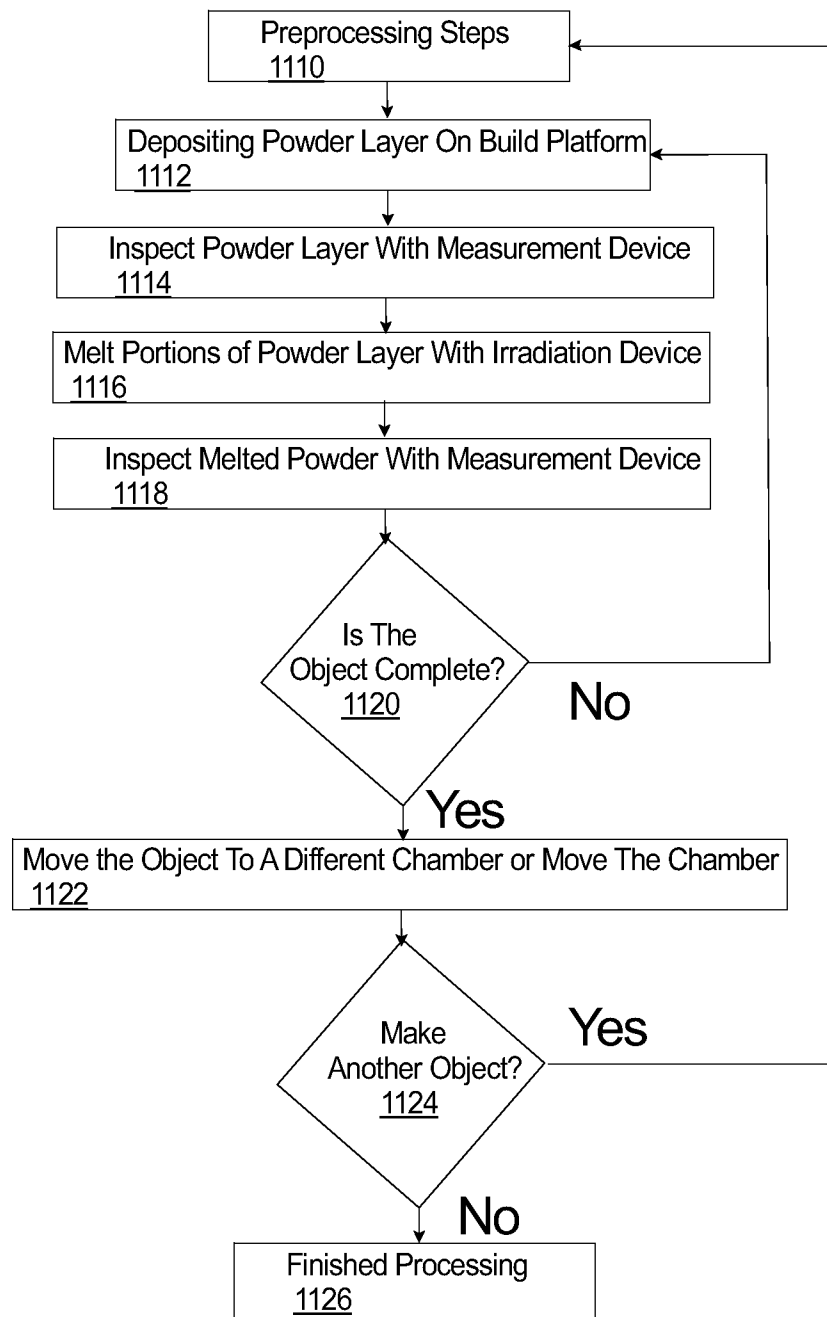


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2021/042582

A. CLASSIFICATION OF SUBJECT MATTER

INV. B22F10/32 B22F10/368 B22F10/64 B22F12/17 B22F12/20
B22F12/82 B22F12/88 B29C64/25 B29C64/364 B29C64/379
B33Y10/00 B33Y30/00 B33Y40/00 B22F10/25 B22F12/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B22F B29C B33Y C22C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2019/213154 A1 (APPLIED MATERIALS INC [US]) 7 November 2019 (2019-11-07) page 3, lines 16-21 page 4, line 26 - page 6, line 3 page 7, line 8 - page 8, line 8 page 10, lines 21-29 figures 1,2,4A	1-43
X	DE 10 2016 222959 A1 (BOSCH GMBH ROBERT [DE]) 24 May 2018 (2018-05-24) paragraphs [0006], [0023], [0040] - [0041] figures 1,2	1,2,4,6, 41,43



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 October 2021

Date of mailing of the international search report

25/10/2021

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Knoflachner, Andreas

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2021/042582

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2018/222115 A1 (WATANABE ITARU [JP] ET AL) 9 August 2018 (2018-08-09) figures 1-3 paragraphs [0030] - [0040], [0071] - [0086] claims 1-7 -----	1-43

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2021/042582

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2019213154 A1	07-11-2019	CN 112074398 A US 2021154744 A1 WO 2019213154 A1	11-12-2020 27-05-2021 07-11-2019
DE 102016222959 A1	24-05-2018	NONE	
US 2018222115 A1	09-08-2018	JP 6776056 B2 JP 2017047681 A US 2018222115 A1	28-10-2020 09-03-2017 09-08-2018