

WHAT IS CLAIMED:

1. A system for controlling flow of a gas to a plasma torch of an additive manufacturing device, comprising:
- 5 a source of an inert gas;
a supply manifold in fluid communication with the source of the inert gas;
a plasma torch comprising a gas inlet for receiving the inert gas from an inert gas line connected to the supply manifold, and a gas ionizer electromagnetic field for ionizing the inert gas into plasma;
- 10 sensory kit comprising a temperature measurement unit, a pressure measurement unit, and a mass flow measurement unit, wherein each unit is in communication with one or more sensory connectors connected to a position of the inert gas line between the supply manifold and the gas ionizer electromagnetic field;
- a control valve that is in fluid communication with the gas supply manifold and
15 regulates flow of the inert gas from the gas supply manifold to the plasma torch;
a process master controller in communication with the sensory kit;
a part program that provides a mass flow set value or a volumetric flow set value or both a mass flow set value and a volumetric flow set value to the process master controller;
a calculation function running on the process master controller calculating actual
20 volumetric flow; and
- a) a mass flow control function running on the process master controller; or
b) a volumetric flow control function running on the process master controller; or
c) a mass flow control function and a volumetric flow control function running on the process master controller; or
25 d) a combined mass flow and volumetric flow control function running on the process master controller.
2. The system of claim 1, wherein the mass flow control function compares the mass flow set value from the part program to the actual mass flow value from the sensory kit mass
30 flow measurement unit, and modulates either the control valve or the density control element or both the control valve and the density control element to increase or decrease mass flow of inert gas to decrease the difference between the mass flow set value and the actual mass flow value.

3. The system of claim 1, wherein the volumetric flow control function compares the volumetric flow set value from the part program to the calculated volumetric flow value from the calculation function, and modulates either the control valve or the density control element or both the control valve and the density control element to increase or decrease volumetric
5 flow of inert gas to decrease the difference between the volumetric flow set value and the calculated volumetric flow value.

4. The system of claim 1, wherein the mass flow control function and a volumetric flow control function running on the process master controller, wherein:
10 the mass flow control function compares the mass flow set value from the part program to the actual mass flow value from the sensory kit mass flow measurement unit, and the volumetric flow control function compares the volumetric flow set value from the part program to the calculated volumetric flow value from the calculation function, and modulates the control valve and the density control element to adjust both the mass flow and volumetric
15 flow of the inert gas delivered to the gas ionizer electromagnetic field of the plasma torch.

5. The system of claim 1, wherein the combined mass flow and volumetric flow control function compares the mass flow set value from the part program to the actual mass flow value from the sensory kit mass flow measurement unit, and the volumetric flow set
20 value from the part program to the calculated volumetric flow value from the calculation function, and modulates the control valve and the density control element to adjust both the mass flow and volumetric flow of the inert gas delivered to the gas ionizer electromagnetic field of the plasma torch.

25 6. The system of claim 1, wherein:
the mass flow control function compares the mass flow set value from the part program to the actual mass flow value from the sensory kit mass flow measurement unit, and modulates the control valve to increase or decrease mass flow of inert gas to decrease the difference between the mass flow set value and the actual mass flow value the mass flow of
30 the inert gas delivered to the gas ionizer electromagnetic field of the plasma torch; and
the volumetric flow control function compares the volumetric flow set value from the part program to the calculated volumetric flow value from the calculation function and adjusts the density control element to control the volumetric flow of the inert gas delivered to the gas ionizer electromagnetic field of the plasma torch.

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7. The system of any one of claims 1 to 6, wherein the process master controller is in further communication with:

- a) a mass flow controller processor on which the mass flow control function is running; or
- 5 b) a volumetric flow controller processor on which the volumetric flow control function is running; or
- c) a calculation processor on which the calculation function is running; or
- d) any combination of a), b) and c).

10 8. The system of any one of claims 1 to 7, wherein any one or a combination of the process master controller, the calculation processor, the volumetric control processor, and the mass flow control processor are in further communication with a data server, and the mass flow and volumetric flow data are sent to the data server.

15 9. The system of any one of claims 1 to 8, wherein the sensory connector of each of the temperature measurement unit, the pressure measurement unit, and the mass flow measurement unit of the sensory kit is connected in the vicinity of the plasma torch gas inlet.

20 10. The system of any one of claims 1 to 9, wherein the sensory connector of each of the temperature measurement unit and the pressure measurement unit of the sensory kit is located within the plasma torch.

25 11. The system of any one of claims 1 to 10, further comprising a density control element that controls the temperature and/or pressure of the inert gas delivered to the inlet of the plasma torch.

12. The system of claim 11, wherein the gas density modifier comprises:

- a) a temperature regulator and a temperature sensor; or
- b) a pressure regulator and a pressure sensor; or
- 30 c) a temperature regulator, a temperature sensor, a pressure regulator and a pressure sensor; or
- d) any combination of a), b) and c).

13. The system of claim 12, wherein the gas density modifier comprises the temperature regulator, and the temperature regulator comprises a heater.

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14. The system of claim 13, wherein the heater comprises an induction heater, a resistance heater, a piezoelectric ceramic heating element, or a combination thereof.

15. The system of claim 13 or 14, wherein the temperature regulator further
5 comprises a cooling apparatus.

16. The system of claim 15, wherein the cooling apparatus comprises:

- a) a pipe connected to a refrigerated fluid reservoir and a pump for forming a closed loop cooling path for supplying a cooling fluid to the temperature regulator; or
- 10 b) a conduit passing through the temperature regulator and a fan connected to the conduit for passing a cooling gas through the temperature regulator; or
- c) a combination of a) and b).

17. The system of any one of claims 12 to 16 that comprises the pressure regulator,
15 wherein the pressure regulator comprises a movable plenum chamber that can:
increase the volume of the pressure regulator and thereby decrease the pressure of the inert gas exiting the pressure regulator; or
decrease the volume of the pressure regulator and thereby increase the pressure of the inert gas exiting the pressure regulator.

20 18. The system of any one of claim 12 to 17, wherein the density control element is configured to control a speed of the inert gas to the plasma torch.

19. The system of any one of claims 1 to 18, wherein the temperature measurement
25 unit of the sensory kit comprises a temperature sensor.

20. The system of any one of claims 1 to 19, wherein the pressure measurement unit of the sensory kit comprises a pressure sensor.

30 21. The system of any one of claims 1 to 20, wherein the mass flow measurement unit of the sensory kit comprises a mass flow sensor.

22. The system of any one of claims 1 to 21, wherein the sensory connector is positioned inside a production chamber of an additive manufacturing system and at the
35 plasma torch gas inlet to measure a radiation disturbance from the plasma torch and/or the workpiece.

23. The system of any one of claims 1 to 22, further comprising a mass flow meter located upstream of the control valve and in communication with the process master controller that can detect a reduction in mass flow of the inert gas from the manifold, and the process master control sends a signal to a data monitoring system to indicate a leak.

24. A system for controlling flow of a gas to a plasma torch of an additive manufacturing device, comprising:

a source of an inert gas;

a gas supply manifold in fluid communication with the source of the inert gas;

a plasma torch comprising a gas inlet for receiving the inert gas and a gas ionizer electromagnetic field to ionize the inert gas into a plasma;

a control valve in fluid communication with the gas supply manifold and that regulates flow of the inert gas from the gas supply manifold;

a sensory kit comprising a temperature measurement unit, a pressure measurement unit, and a mass flow measurement unit, wherein each unit is in communication with a sensory connector connected to, or connected in the vicinity of, the gas inlet;

a processor group connected to the sensory kit and in communication with the control valve, wherein the processor group comprises:

a process master controller in communication with the sensory kit;

a calculation processor in communication with the sensory kit and the process master controller, the calculation processor calculating actual volumetric flow; and

a) a mass flow controller in communication with the process master controller; or

b) a volumetric flow controller in communication with the process master controller;

or

c) a mass flow controller and a volumetric flow controller in communication with the process master controller; and

a part program that provides a mass flow set value or a volumetric flow set value or both a mass flow set value and a volumetric flow set value to the process master controller.

25. The system of claim 24, wherein the processor group includes the mass flow controller, and the mass flow controller is in further in communication with the control valve and modulates the control valve to increase or decrease flow of inert gas to decrease the difference between the mass flow set value and the actual mass flow value.

26. The system of claim 24, wherein the processor group includes the volumetric flow controller, and the volumetric flow controller is in further in communication with the control valve and modulates the control valve to increase or decrease flow of inert gas to decrease the difference between the volumetric flow set value and the calculated volumetric flow value.

27. The system of claim 24, further comprising a density control element that controls the temperature and/or pressure of the inert gas delivered to the inlet of the plasma torch.

28. The system of claim 27, wherein the processor group includes the mass flow controller and the volumetric flow controller, wherein:

the mass flow controller is in further in communication with the control valve and modulates the control valve to increase or decrease flow of inert gas to decrease the difference between the mass flow set value and the actual mass flow value; and

the volumetric flow controller is in further in communication with the density control element that controls the temperature and/or pressure of the inert gas delivered to the inlet of the plasma torch and modulates the density control element to increase or decrease volumetric flow of inert gas to decrease the difference between the volumetric flow set value and the calculated volumetric flow value.

29. The system of claim 27 or 28, wherein the gas density modifier comprises:
a temperature regulator and a temperature sensor; or
a pressure regulator and a pressure sensor; or
a temperature regulator, a temperature sensor, a pressure regulator and a pressure sensor.

30. The system of claim 29, wherein the gas density modifier comprises the temperature regulator, and the temperature regulator comprises a heater.

31. The system of claim 30, wherein the heater comprises an induction heater, a resistance heater, a piezoelectric ceramic heating element, or a combination thereof.

32. The system of claim 30 or 31, wherein the temperature regulator further comprises a cooling apparatus.

33. The system of claim 32, wherein the cooling apparatus:

a) includes a pipe connected to a refrigerated fluid reservoir and a pump for forming a closed loop cooling path for supplying a cooling fluid to the temperature regulator; or

5 b) a conduit passing through the temperature regulator and a fan connected to the conduit for passing a cooling gas through the temperature regulator; or

c) a combination of a) and b).

34. The system of any one of claims 29 to 33 that comprises the pressure regulator,
10 wherein the pressure regulator comprises a movable plenum chamber that can:

increase the volume of the pressure regulator and thereby decrease the pressure of the inert gas exiting the pressure regulator; or

decrease the volume of the pressure regulator and thereby increase the pressure of the inert gas exiting the pressure regulator.

15 35. The system of any one of claims 24 to 34, wherein the temperature measurement unit of the sensory kit comprises a temperature sensor.

36. The system of any one of claims 24 to 35, wherein the pressure measurement unit
20 of the sensory kit comprises a pressure sensor.

37. The system of any one of claims 24 to 36, wherein the mass flow measurement unit of the sensory kit comprises a mass flow sensor.

25 38. The system of any one of claims 24 to 37, wherein the sensory connector is positioned between the gas manifold and the gas ionizer electromagnetic field of the plasma torch.

39. The system of any one of claims 24 to 38, further comprising a mass flow meter
30 located upstream of the control valve and in communication with the process master controller that can detect a reduction in mass flow of the inert gas from the gas supply manifold, and the process master control sends a signal to a data monitoring system to indicate a leak.

40. A method of delivering a target volumetric flow and a target mass flow of an inert gas to be ionized into plasma to a plasma torch, comprising:

providing an inert gas from a gas supply manifold to an inlet of the plasma torch through a control valve attached to an inert gas supply manifold via an inert gas line;

- 5 a) measuring a temperature, a mass flow, and a pressure of the inert gas between the inert gas supply manifold and a gas ionizer electromagnetic field of the plasma torch; or
- b) measuring a temperature, a mass flow, and a pressure of the inert gas at or in the vicinity of the plasma torch gas inlet; or
- c) measuring a temperature and a pressure of the inert gas inside the plasma torch
- 10 and a mass flow at or in the vicinity of the plasma torch gas inlet; or
- d) any combination of a), b) and c);
- calculating an actual volumetric flow rate of the inert gas to the plasma torch:
- i) at or in the vicinity of the plasma torch inlet; or
- ii) inside the plasma torch; or
- 15 iii) at a position of the inert gas supply line between the gas manifold and the plasma torch gas inlet;
- comparing the actual volumetric flow rate to a target volumetric flow rate to generate a volumetric flow differential value;
- comparing the actual mass flow rate to a target mass flow rate to generate a mass flow
- 20 differential value;
- based on the mass flow differential value and volumetric flow differential value:
- x) adjusting the control valve to increase or decrease mass flow of the inert gas through the control valve to the plasma torch gas inlet; or
- y) adjusting the density of the inert gas by increasing or decreasing the pressure
- 25 and/or temperature of the inert gas to yield a modified inert gas volumetric flow, and directing the modified inert gas to the inlet of the plasma torch; or
- z) adjusting the control valve and the density of the inert gas by increasing or decreasing the pressure and/or temperature of the inert gas to control the mass flow and volumetric flow of the inert gas to the ionizing electromagnetic field of the plasma torch.

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41. The method of claim 40, wherein adjusting the control valve comprises:
generating an adjustment signal based on the mass flow differential value and/or volumetric flow differential value; and

sending the adjustment signal to a driver attached to the control valve, the driver increasing or decreasing an opening of the control valve based on the adjustment signal.

42. The method of claim 40 or 41, wherein adjusting the density of the inert gas
5 comprises:

- a) measuring the temperature of the inert gas and increasing or decreasing the temperature of the inert gas in response to the volumetric flow differential value; or
- b) measuring the pressure of the inert gas and increasing or decreasing the pressure of the inert gas in response to the volumetric flow differential value; or
- 10 c) both a) and b).

43. The method of claim 42, wherein increasing the temperature of the inert gas comprises directing the inert gas to a temperature regulator comprising a heater and activating the heater.
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44. The method of claim 43, wherein the heater comprises an induction heater, a resistance heater, a piezoelectric ceramic heating element, or a combination thereof.

45. The method of claim 42, wherein decreasing the temperature of the inert gas
20 comprises directing the inert gas to a temperature regulator comprising a cooling apparatus and activating the cooling apparatus.

46. The method of claim 45, wherein the cooling apparatus comprises:
a) a pipe connected to a refrigerated fluid reservoir and a pump for forming a closed
25 loop cooling path for supplying a cooling fluid to the temperature regulator; or
b) a conduit passing through the temperature regulator and a fan connected to the conduit for passing a cooling gas through the temperature regulator; or
c) a combination of a) and b).

47. The method of claim 44, wherein increasing or decreasing the pressure of the inert gas comprises directing the inert gas to a pressure regulator.
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48. The method of claim 47, wherein the pressure regulator comprises a movable plenum chamber that can increase the volume of the pressure regulator and thereby decrease
35 the pressure of the inert gas exiting the pressure regulator, or decrease the volume of the

pressure regulator and thereby increase the pressure of the inert gas exiting the pressure regulator.

49. The method of any one of claims 40 to 48, wherein the inert gas is argon.

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50. The method of any one of claims 40 to 49, where the target volumetric flow rate and the target mass flow rate are provided by a part program.

51. A method of delivering a target volumetric flow of an inert gas to a plasma torch
10 to be ionized into plasma, comprising:
attaching a system of any one of claims 1 to 39 to an inert gas source; and
activating the system.

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