What is claimed is:

1. A mass flow control system whose accuracy can be self verified in real time when controlling a flow of a fluid to a process, the system comprising:

a control valve for controlling the flow of fluid through the system as a function of a control signal;

a controller for generating the control signal as a function of measured flow of fluid through the system and a set point; and

a source of fluid for providing a known volume of fluid for use in verifying the accuracy of the system anytime between steps of the flow control process.

2. A mass flow control system according to claim 1, further including a flow restrictor for creating choked flow conditions for the flow of fluid through the system.

3. A mass flow control system according to claim 2, wherein the flow restrictor has an orifice whose cross sectional area is adjustable.

4. A mass flow control system according to claim 2, further including a second control valve for providing an adjustable opening that defines the flow restrictor.

5. A mass flow control system according to claim 1, further including a pressure sensor configured to provide a pressure measurement signal representative of the measured pressure of fluid in the system; and a temperature sensor configured to provide a temperature measurement signal representative of the measured temperature of fluid in the system.

6. A mass flow control system according to claim 5, wherein the controller is configured to determine the measured flow of fluid Q_p through the system as a function of the measured pressure and temperature of the fluid in the system as

$$Q_p = C' \cdot A \cdot f(m, \gamma, T) \cdot P_u,$$

Where C' is the orifice discharge coefficient of the flow restrictor, A the effective orifice area of the flow restrictor, m the molecular weight of the gas, γ the specific heat capacity ratio of the gas, T the gas temperature, P_u the upstream pressure, and $f(m, \gamma, T)$ a mathematic function which is related to the gas molecular weight, the specific heat capacity of the gas, and the gas temperature.

7. A mass flow control system according to claim 1, wherein the source of fluid is a reservoir of known volume positioned downstream from the control valve such that the control valve is closed when a zero flow set point is commanded, and fluid is still allowed to flow from the reservoir and measured by the system based on chocked flow condition Q_p, wherein another flow measurement Q_v can be made by the rate of decay of the fluid from the reservoir as

$$Q_v = -k \cdot V \cdot \frac{d(P_u/T)}{dt},$$

where t denotes time, k denotes a conversion constant and V, P_u, and T respectively denote the volume of the reservoir, the pressure and temperature of the gas in the reservoir.

8. A mass flow control system according to claim 7, wherein the system can self verify its flow accuracy as a function of any differences between flow measurement made by the rate of decay of the fluid from the reservoir Q_v, and the flow rate measured by the system based on chocked flow condition Q_p.

9. A mass flow control system according to claim 7, further including a second valve wherein the second control valve is closed to fulfill the zero flow set point command after the flow verification is completed.

10. A mass flow control system according to claim 7, wherein verification occurs during a verification period anytime between steps of the flow control process, the verification period being between 100 and 300 milliseconds.

11. A mass flow control system according to claim 7, wherein the reservoir is positioned between the control valve and the flow restrictor.

12 A mass flow control system according to claim 7, wherein the system provides an alarm to a host controller to warn of an out of calibration condition if the deviation of Q_p from Q_v is above a predetermined accuracy tolerance limit.

13 A mass flow control system according to claim 7, wherein the system can adjust the coefficients of flow calculation equation for the measured flow rate Q_p based on the verification results such that the flow error between Q_p and Q_v is minimized, at or below the predetermined accuracy tolerance limit so that the system is recalibrated within the tolerance limits during the flow verification period.

14. A mass flow control system according to claim 1, further including a flow restrictor, a first pressure sensor for generating a signal as a function of the pressure of the fluid upstream from the flow restrictor and a second pressure sensor for generating a signal as a function of the pressure of fluid downstream from the flow restrictor for measure the flow of fluid during non-choke flow conditions, where the measured flow rate Q_p is based on the following equation:

$$Q_p = f(P_u, P_d, T, m, \gamma, A),$$

Wherein f is a mathematic function of the upstream pressure P_u, the downstream pressure P_d, the gas temperature T, the gas molecular weight m, the gas specific heat ratio γ and the effective office area A.

15. A method of verifying the accuracy of a mass flow control system when controlling a flow to a process, the method comprising:

controlling the flow of fluid through the system as a function of a control signal;

generating the control signal as a function of measured flow of fluid through the system and a set point; and

providing a known volume of fluid for use in calibrating the system anytime between steps of the flow control process.

16. A method according to claim 15, wherein controlling the flow of fluid includes controlling the flow of fluid through a flow restrictor so as to create choked flow conditions.

17. A method according to claim 16, wherein controlling the flow through a flow restrictor includes controlling the flow through an orifice whose cross sectional area is adjustable.

18. A method according to claim 16, wherein controlling the flow through a flow restrictor includes controlling the flow through a second control valve for providing an adjustable opening that defines the flow restrictor.

19. A method according to claim 15, further including providing a pressure measurement signal representative of the measured pressure of fluid in the system; and providing a temperature measurement signal representative of the measured temperature of fluid in the system.

20. A method according to claim 19, further including determining the measured flow of fluid Q_p through the system as a function of the measured pressure and temperature of the fluid in the system as

$$Q_p = C' \cdot A \cdot f(m, \gamma, T) \cdot P_u,$$

Where C' is the orifice discharge coefficient of the flow restrictor, A the effective orifice area of the flow restrictor, m the molecular weight of the gas, γ the specific heat capacity ratio of the gas, T the gas temperature, Pu the upstream pressure, and $f(m, \gamma, T)$ a mathematic function which is related to the gas molecular weight, the specific heat capacity of the gas, and the gas temperature.

21. A method according to claim 15, further including providing a source of fluid from a reservoir of known volume positioned downstream from a control valve such that the control valve is closed when a zero flow set point is commanded, and allowing fluid to still be allowed to flow from the reservoir and measured by the system based on chocked flow condition Q_p, wherein another flow measurement Q_v can be made by the rate of decay of the fluid from the reservoir as

$$Q_v = -k \cdot V \cdot \frac{d(P_u/T)}{dt},$$

where t denotes time, k denotes a conversion constant and V, P_u, and T respectively denote the volume of the reservoir, the pressure and temperature of the gas in the reservoir.

22. A method according to claim 21, further including self-verifying system flow accuracy as a function of the any differences between flow measurement made by the rate of decay of the fluid from the reservoir Q_v, and the flow rate measured by the system based on chocked flow condition Q_p.

23 A method according to claim 21, further including closing a second control valve to fulfill the zero flow set point command after the flow verification is completed.

24. A method according to claim 21, wherein verification occurs during a verification period anytime between steps of the flow control process, the verification period being between 100 and 300 milliseconds.

25. A method according to claim 21, wherein the reservoir is positioned between a control valve and a flow restrictor.

26 A method according to claim 21, further including sending an alarm to a host controller to warn of an out of accuracy condition if the deviation of Q_p from Q_v is above a predetermined accuracy tolerance limit.

27 A method according to claim 21, further including adjusting the coefficients of a flow calculation equation for the measured flow rate Q_p based on the verification results such that the flow error between Q_p and Q_v is minimized, at or below the predetermined accuracy tolerance limit so as to recalibrate the system within the tolerance limits during the flow verification period.

28. A method according to claim 15, further including generating a signal as a function of the pressure of the fluid upstream from a flow restrictor, and generating a signal as a function of the pressure of fluid downstream from the flow restrictor for measuring the flow of fluid during non-choke flow conditions, where the measured flow rate Q_p is based on the following equation:

$$Q_p = f(P_u, P_d, T, m, \gamma, A),$$

Wherein f is a mathematic function of the upstream pressure P_u, the downstream pressure P_d, the gas temperature T, the gas molecular weight m, the gas specific heat ratio γ and the effective office area A.

What is claimed is:

1. A mass flow control system whose accuracy can be self-verified in real time when controlling a flow of a fluid to a process, the system comprising:

an inlet port for receiving the fluid under pressure;

an outlet port for delivering the fluid under pressure;

a conduit through which the fluid under pressure flows;

a control valve for controlling a flow of the fluid in the conduit from the inlet port to the outlet port;

a reservoir connected to the conduit to store a known volume of fluid;

a flow restrictor disposed between the reservoir and the outlet port to restrict the flow of the fluid between the reservoir and the outlet port such that the flow of the fluid can be controlled;

a pressure sensor for sensing pressure of the fluid in the conduit; and

a controller,

wherein the controller controls the control valve based on a signal from the pressure sensor such that the flow of the fluid passing through the conduit can be equal to a flow set point and determines a decay rate of pressure in the reservoir based on a signal from the same pressure sensor to verify the accuracy of a fluid flow control.

2. The mass flow control system of claim 1, wherein the flow restrictor is controlled to create choked flow conditions for the flow of the fluid passing through the conduit.

3. The mass flow control system of claim 2, wherein the flow restrictor has an

orifice and a cross sectional area of the orifice is adjustable.

4. The mass flow control system of claim 2, further comprising a second control valve configured to provide an adjustable opening that defines the flow restrictor.

5. The mass flow control system of claim 1, further comprising a temperature sensor configured to provide a temperature measurement signal representing a measured temperature of the fluid in the conduit.

6. The mass flow control system of claim 5, wherein the controller is configured to determine a measured flow of fluid Q_p passing through the conduit based on the measured pressure and temperature of the fluid in the system as:

$$Q_p = C' \cdot A \cdot f(m, \gamma, T) \cdot P_u$$

wherein C' is an orifice discharge coefficient of the flow restrictor, A is an effective orifice area of the flow restrictor, m is a molecular weight of the fluid, γ is a specific heat capacity ratio of the fluid, T is a fluid temperature, P_u is pressure, and f(m, γ, T) is a mathematic function which is related to the molecular weight of the fluid, the specific heat capacity of the fluid, and the temperature of the fluid.

7. The mass flow control system of claim 1, wherein the reservoir is positioned downstream from the control valve such that the control valve is closed when a zero flow set point is commanded, the fluid is still allowed to flow from the reservoir and to be measured by the mass flow control system under chocked flow condition Q_p, and another flow measurement Q_v is made by the decay rate of the fluid from the reservoir as:

$$Q_v = -k \cdot V \cdot \frac{d(P_u/T)}{dt}$$

wherein t denotes time, k denotes a conversion constant and V, P_u, and T denote a volume of the reservoir, and pressure and temperature of the fluid in the reservoir, respectively.

8. The mass flow control system of claim 7, wherein the system can self-verify the flow accuracy thereof as a function of a certain difference between a flow measurement made by the decay rate of the fluid from the reservoir Q_v and a flow rate measured by the system based on the chocked flow condition Q_p.

9. The mass flow control system of claim 7, further comprising a second valve, wherein the second control valve is closed after flow verification is completed to fulfill the zero flow set point command.

10. The mass flow control system of claim 7, wherein verification occurs during a verification period anytime between steps of the flow control process, and the verification period is between 100 milliseconds and 300 milliseconds.

11. The mass flow control system of claim 7, wherein the reservoir is positioned between the control valve and the flow restrictor.

12. The mass flow control system of claim 7, wherein the system provides an alarm to a host controller to warn of an out of calibration condition if deviation of Q_P from Q_v is higher than a predetermined accuracy tolerance limit.

13. The mass flow control system of claim 7, wherein the system adjusts coefficients of a flow calculation equation for the measured flow rate Q_P based on verification results such that a flow error between Q_p and Q_v is minimized at or below the predetermined accuracy tolerance limit, so that the system is recalibrated within the tolerance limit during the flow verification period.

14. The mass flow control system of claim 1, wherein the pressure sensor includes a first pressure sensor for generating a signal according to the pressure of the fluid present upstream of the flow restrictor, the system further comprises a second pressure sensor for generating a signal according to the pressure of fluid present downstream of the flow restrictor to measure the flow of fluid during non-choke flow conditions, and the measured flow rate Q_p is based on the following equation:

$$Q_p = f(P_u, P_d, T, m, \gamma, A)$$

wherein f is a mathematic function of an upstream pressure P_u, a downstream pressure P_d, the fluid temperature T, the fluid molecular weight m, the fluid specific heat ratio γ and the effective office area A.