(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
3 April 2014 (03.04.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/049429 A2

(51) International Patent Classification:
B23K 9/16 (2006.01)

(21) International Application Number:
PCT/IB2013/002171

(22) International Filing Date:
30 September 2013 (30.09.2013)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/630,591 28 September 2012 (28.09.2012) US

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(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, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, 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, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, 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, 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:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) Title: WELDER HAVING FEEDBACK CONTROL

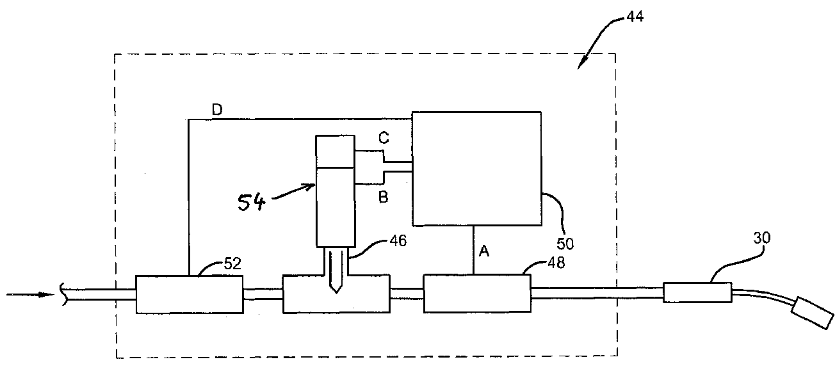

FIG. 5

(57) Abstract: A method and apparatus for improving the flow control of a shielding gas in a welding unit is described which uses feedback from at least one of a mass or volume flow controller, a pressure sensor and a valve position sensor to regulate shielding gas flow through a controller.

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WELDER HAVING FEEDBACK CONTROL

Technical Field

[0001] The present invention relates to an improved gas flow controller for welding and, in particular, for arc welding or for cutting; and more specifically relates to an arc welder having improved gas control.

Background of the Invention

[0002] Welding operations often employ the use of inert or semi-inert gases, e.g., helium, argon, carbon dioxide, etc., as a shielding gas to protect the weld area. Air in the weld zone is displaced by a shielding gas in order to prevent contamination of the molten weld puddle. This contamination is caused mainly by nitrogen, oxygen and water vapor present in the atmosphere. As an example, nitrogen in solidified steel reduces the ductility and impact strength of the weld and can cause cracking. In large amounts, nitrogen can also cause weld porosity. Excess oxygen in steel combines with carbon to form carbon monoxide (CO). This gas can be trapped in the metal, causing porosity. In addition, excess oxygen can combine with other elements in steel and form compounds that produce inclusions in the weld metal. When hydrogen, present in water vapor and oil, combines with either iron or aluminum, porosity will result and "underbead" weld metal cracking may occur. Argon, helium and carbon dioxide can be used alone, in combinations or mixed with other gases to provide defect free welds in a variety of weld applications and weld processes.

[0003] Metal Inert Gas ("MIG") welding is negatively impacted by excess shielding gas flow rate, and requires minimizing turbulent gas flow to exclude air from the arc. Several devices are used to set shielding gas flow rates. One is used on the cylinder or pipeline gas supply, e.g., a flowmeter with a flow control knob. The knob adjusts a needle valve that lowers the pressure in the gas delivery hose to that needed to achieve the desired flow of shielding gas, typically employing a float ball.

Another is only for cylinder gas supply, and employs a very small orifice and varies the pressure upstream of the orifice using a regulator to control flow.

[0004] It is important that the flow rate set on the flowmeter or regulator remain at the set value while welding. However, restrictions occur in production which alter flow such as spatter build-up in the MIG gun nozzle, twists occurring in the gas passages in the MIG gun cable, or debris build-up in the conduit passage sections. In an effort to minimize the above variations, choked flow systems were developed. These systems required higher pressure upstream of the restriction of the orifice or valve. However, high pressure causes an initial gas surge, which is undesirable toward achieving high quality welds. In fact, excessively high gas surges at the start of the welding process allows air to be mixed with the gas stream and can cause internal weld porosity until steady state is achieved.

[0005] Low-pressure devices equally suffer from problems. These systems typically lack the automatic flow compensation of high pressure devices, and insufficient extra gas at the start of the welding operation causes inferior weld starts.

[0006] Overflow as well as underflow from the gas line to the welding torch causes initial weld irregularities, including spatter, porosity, and contamination of the weld. Therefore, it is desired to reduce and/or minimize the variation of shielding gas flow.

[0007] Finally, different brands of welding guns and different locations may have different flow characteristics that may further affect the flow of gas. Pressure or volume-based flow controllers do not have means for determining the flow rate that actually passes to the weld site, and therefore variations in flow from a gas source or through the weld gun will not be captured by the flow controller. Therefore, there is recognized a need for an improved gas flow controller that is capable of regulating the flow of a shielding gas to a welding operation, particularly during start-up.

Summary of the Invention

[0008] The problem of reducing and/or minimizing the variation of shielding gas flow in a welding operation, particularly during start up, is solved by a welding system according to claim 1, a method according to claim 10 and a control feedback system according to claim 15. Preferred embodiments are disclosed – amongst others – in the subclaims. With respect to the method, it is particularly preferred, if the method further comprises the step of: rectifying a position signal with said valve signal by said controller and/or said controller closes said valve when a trigger on said welding gun is not engaged and/or said mass flow sensor is positioned adjacent or within said welding gun. With respect to the control feedback system, it is particularly preferred, if it further comprises: a pressure sensor upstream of said metering valve and in communication with said controller and/or said mass flow sensor is positioned adjacent or within said welding gun. The welding system which includes at least a shielding gas input; a shielding gas output coupled to a welding gun having a trigger; and a feedback control system for at least the shielding gas in which the shielding gas feedback control system includes a mass flow sensor for measuring flow between the shielding gas input and shielding gas output; a valve for regulating flow between the shielding gas input and shielding gas output; and a controller for communicating a valve position output to the valve based on input received from the flow sensor.

[0009] In one aspect of the invention, the control system may include a valve position sensor, which communicates a valve position to said controller which adjusts the valve based on valve position feedback. The feedback control system may optionally further include a pressure sensor for determining the pressure of the flow and communicating this information to the controller.

[0010] The feedback control system may analyze signals from at least two of sensors selected from the group consisting of the flow sensor, the pressure sensor, and the valve position sensor and adjusts said shielding gas output based on at least two signals. In another aspect of the invention, the control system may analyze signals from all three sensors.

[0011] In another aspect of the invention, a method is described of providing a targeted shielding gas flow rate to a weld site. The weld site may comprise a gas input, an electrical input, a wire feeder, a welding gun and a feedback control system for regulating the flow of gas from the gas input to the welding gun, the feedback control system including at least a valve for controlling a shielding gas flow rate to the welding gun, a mass flow sensor for determining the rate of gas flow to the gun, and a controller for receiving a flow rate signal from the flow sensor and communicating a valve signal to the valve, comprising the steps of: communicating the flow rate of the shielding gas after the valve to the controller; determining a flow rate signal based on the flow rate of the shielding gas; comparing the flow rate to the targeted flow rate; calculating the valve signal; providing the valve signal to the valve; and adjusting the shielding gas flow rate through the valve based on the valve signal.

[0012] The method may optionally include the step of monitoring a feed gas input pressure, the monitoring generating a pressure signal for communication to the controller and wherein the process may further include a subsequent step of calculating the valve signal from analysis of the flow rate and pressure signals.

[0013] The method may further optionally include the step of monitoring a valve position and communicating that position signal to the controller.

[0014] In one aspect of the invention, the mass flow sensor is positioned adjacent or within the welding gun.

[0015] The invention extends to the components of the shielding gas flow control feedback system in which the system may include at least a shielding gas metering valve, a mass flow sensor downstream of the metering valve, and a controller in communication with the mass flow sensor and metering valve which adjusts the metering valve based at least upon signals received from the mass flow sensor.

[0016] As described previously, the gas flow control feedback system may optionally include a pressure sensor upstream of the metering valve and in communication with the controller as well as a valve position sensor in communication with the controller.

[0017] ***Brief Description of the Drawings***

[0018] The invention may take physical form in certain parts and arrangements of parts, a preferred embodiment of which will be described in detail in the specification and illustrated in the accompanying drawings which form a part hereof, and wherein:

[0019] *Fig. 1* is a schematic view of a welder having a shield gas supply;

[0020] *Fig. 2* is a schematic view of a gas feedback control system for the welder shown in *Fig. 1*;

[0021] *Fig. 3* is a schematic view of a gas feedback control system for the welder shown in *Fig. 1*;

[0022] *Fig. 4* is a schematic view of a gas feedback control system according to another variation;

[0023] *Fig. 5* is a schematic view of a gas feedback control system according to another variation;

[0024] *Fig. 6* is a graph illustrating ideal conditions for gas flow rate against time;

[0025] *Fig. 7* is a graph illustrating gas flow rate for a blocked passage against time;

[0026] *Fig. 8* is a graph illustrating gas flow rate for a high pressure situation against time;

[0027] *Fig. 9* is a graph illustrating an ideal gas flow rate against time;

[0028] *Fig. 10* is a graph illustrating gas flow rate for a high pressure situation against time; and

[0029] *Fig. 11* is a graph illustrating gas flow rate for a low pressure situation against time.

Detailed Description of the Invention

[0030] The best mode for carrying out the invention will now be described for the purposes of illustrating the best mode known to the applicant at the time of the filing of this patent application. The examples and figures are illustrative only and not meant to limit the invention, which is measured by the scope and spirit of the claims. Referring now to the drawings, wherein the showings are for the purpose of illustrating an exemplary embodiment of the invention only and not for the purpose of limiting same, *Fig. 1* illustrates a welding system **20** which includes welding user interface **22**, wire feeder & spindle **24**, gas flow rate controller **26**, welding power supply **28** and gun **30**. Shield gas is fed to gas flow rate controller **26** from gas supply **32**, such as a gas line, gas-filled cylinder, or other pressurized supply. The shield gas is preferably selected from the group consisting of helium, nitrogen, argon, carbon dioxide, or other well known shielding gas, often having non-reactive properties for improving the quality of a weld. As illustrated in *Fig. 1*, gas flow rate controller **26** includes a variable flow control, such as an electrically actuated solenoid, that allows a user to select a preferred pressure or flow rate.

[0031] The shield gas is fed from gas supply **32** to flow rate controller **26** by means of feed hose or tube **34**, which may be made of a flexible material, such as rubber, nylon or fiberglass-reinforced plastics, or rigid material, such as stainless steel or copper. Pressure regulator **36** is positioned between gas supply **32** and feed hose **34** for regulating the output pressure. In a preferred arrangement, pressure regulator **36** is directly coupled to gas supply **32** and is controllable between an "on" state where shield gas flows at a preferred pressure and an "off" state where no gas passes through pressure regulator **36**.

[0032] As further referenced in the figure, gas torch line **38** extends from gas flow rate controller **26** to gun **30**. Gas torch line **38** may be flexible or rigid. Gun **30** includes trigger **40** that optionally includes gas valve **42** and allows shield gas to flow through gun **30**, thereby providing shielding gas to the weld site. In some arrangements, gas valve **42** of trigger **40** is an on/off switch, either allowing or disallowing flow through gun **30**; while in other arrangements gas valve **42** is a variable valve, allowing variable amounts of shield gas to flow through gun **30** according to the degree of engagement of trigger **40**.

[0033] *Fig. 2* illustrates feedback control system **44** for accurately controlling the flow of gas from feed hose **34** to gun **30**. In this arrangement, a valve **46**, preferably being a proportional valve **46**, flow sensor **48**, and controller **50** are provided in which flow sensor **48** detects the amount of shielding gas flowing from feed hose **34** to gun **30** and conveys this information to controller **50** which adjusts proportional valve **46** in order to increase or decrease the amount of flow depending upon a preset flow of shielding gas.

[0034] Flow sensor **48** measures either the volumetric flow rate or the mass flow rate of the shielding gas to gun **30**. This information is digitized and transmitted to controller **50** through signal **A**. Controller **50** receives the flow rate of the shielding gas and determines whether this is above or below the preselected flow rate. If the flow rate is below the preselected flow rate, a high output signal is sent by flow signal **B** to proportional valve **46** and the flow rate is increased. If the flow rate is above the preselected flow rate, then a low output is sent by flow signal **B** to proportional valve **46** and the flow rate is decreased.

[0035] Flow sensor **48**, according to a preferred arrangement, is a Coriolis mass flow sensor capable of outputting flow signal **A**, for example a digital electrical signal. Flow signal **A** may vary based on a wave frequency, voltage, current, or other variable signal. Alternatively, flow sensor **48** may sense pressure, flow rate, or other characteristic indicative of the amount of shielding gas flowing to gun **30**.

[0036] Controller **50** is often a microprocessor capable of receiving flow signal **A**, which may be a digital or analog electrical input, comparing that input to a set state, and providing valve control signal **B** to the motorized valve. In this arrangement, the set state may be determined based on a user-selected value, such as from a user nterface screen, or may be a preset constant value.

0037] As better illustrated in *Fig. 3*, feedback control system **44** includes proportional valve **46** which may further include valve position signal **C** that communicates the position of motorized valve **46** to controller **50**. The arrangement shown in *Fig. 2* requires controller **50** to calculate the position of valve **46** based on valve control signal **B**, which may not be accurate due to wear or inaccuracies in calculation or transmission. However, by providing valve position signal **C** from proportional valve **46** to controller **50**, the position of proportional valve **46** is more accurately conveyed to controller **50.** The expected position of the valve **46** now matches the actual position of valve **46**. This arrangement allows for more accurate control over the flow through flow sensor **48** to gun **30**.

0038] As better illustrated in *Fig. 4*, feedback control system **44** valve position signal **C** may be omitted and pressure sensor **52** may be included upstream from motorized valve **46**. Pressure sensor **52** includes pressure signal **D** that is transmitted from pressure sensor **52** to controller **50**. Pressure sensor **52** is configured to detect ine pressure of the shield gas and transmit that information through pressure signal **D** to controller **50** which uses this information to determine if a low flow condition, as ndicated by flow signal **A**, is caused by low inlet pressure or by a restriction within he gun. For example, if flow signal **A** is low and pressure signal **D** is low, then the ow flow condition is caused by a low inlet pressure. However, if flow signal **A** is low and pressure signal **D** is high, this indicates a blockage and controller 50 may output an error.

0039] At least one advantage of communicating pressure signal **D** from pressure sensor **52** to controller **50** is that controller **50** may more accurately control the gain or adjusting valve **46**. In one scenario, pressure signal **D** may report a high pressure and flow signal **A** may report a low flow. In order to prevent a sudden change n flow of shielding gas, controller **50** may command valve **46** to open slowly, allowing for a gradual change in line pressure and flow. However, if the pressure signal) is low and flow signal **A** is low, then controller **50** may command valve **46** to open quickly, allowing for a higher rate of increase in flow of the shielding gas.

0040] As shown in *Fig. 5*, a more sophisticated feedback control system 44 may nclude proportional valve **46** for controlling shield gas flow to gun **30**, flow sensor **8** for determining the amount of shield gas flow, controller **50** for adjusting valve **6**, and pressure sensor **52** for determining the line pressure of the shield gas. Flow signal **A** communicates the amount of flow from flow sensor **48** to controller **50**, valve control signal **B** allows controller **50** to adjust the position of valve **46**, valve position signal **C** relays the position of valve **46** to controller **50** and pressure signal) communicates the line pressure from pressure sensor **52** to controller **50**. This arrangement combines the advantages of the previous two arrangements described above.

0041] Specifically, according to this arrangement controller **50** receives input concerning the pressure of the shielding gas (pressure signal **D**), the position of valve **6** (valve position signal **C**), and the amount of shield gas flowing to gun **30** (flow signal **A**). Controller **50** then uses this information to control valve **46** by transmitting an output through valve control signal **C** to valve **46**. The various input signals to controller **50** require the controller to analyze a variety of situations and provide an output in valve control signal **B**.

0042] Each of these input signals (flow signal **A**, valve position signal **C**, and pressure signal **D**) to controller **50** communicates a digital signal, such as a high voltage, a low voltage, or zero voltage, indicating that the value being measured is above, below, or at the preferred level. Similarly, any output communicated to valve **46** by valve control signal **B** is selectively an open, close, neutral signal. Controller **50** is capable of outputting valve control signal **B** as a high, low, or zero voltage, and may also include an option for outputting an error signal. If valve control signal B is high or low, then valve 46 will open or close, respectively. If the output is zero, then the valve will not change position. If the output is error, the valve may shut off completely or interpret the error output as an zero output, depending on the type of error. For example, if the pressure is too low to support the desired flow rate, the valve **46** may open to maximize flow; but if pressure signal **D** is high and flow rate signal **A** is low, there may be a blockage in the gun **30**, requiring the valve **46** to close and avoid damage or non-quality welds. Alternatively, the signals may communicate an analog value.

[0043] Various graphs of gas flow rate and valve position are shown in *Figs. 6-8*. In these graphs, the position of valve **46** are shown as a percentage from 0 to 100%, with a preferred operating range of about 50%. The left side of these graphs indicate the target gas flow rate while the right side indicates the amount valve **46** has been opened. In the ideal condition, shown in *Fig. 6*, valve **46** is opened at a steady rate and gas flow increases steadily. Once valve **46** reaches 50% and the target gas flow rate is achieved, valve **46** remains open until the weld is finished. The valve may close cleanly, reducing gas flow rate from the target flow rate to zero.

[0044] In *Fig. 7*, a blocked passage or gas shortage scenario is shown. In this scenario, valve **46** must be opened to 100% in order to achieve the desired gas flow rate. This required valve **46** to be opened at a faster rate to achieve the same time to maximize flow as in the ideal condition.

[0045] In *Fig. 8*, a high gas pressure scenario is shown. In this scenario, valve **46** is opened to a lower percent total flow, for example, about 25%. This requires a higher degree of control to avoid spikes in the flow rate.

[0046] *Figs. 9-11* show various scenarios demonstrating the gas flow and actual weld output as a function of time. The target gas flow rate is shown along the left side of the graph and the welding output is shown along the right side of the graph. Once trigger **40** on gun **30** is pulled, gas will flow through gun **30** to the output. In these figures various scenarios, namely ideal, high pressure and low pressure, demonstrate gas flow as a function of time after trigger **40** is engaged.

[0047] In *Fig. 9*, an ideal scenario is shown. According to this condition, once trigger **40** is pulled the gas flow rate will increase to a maximum slightly (approximately 5%) above the target gas flow rate. The gas flow rate will then decrease to the target gas flow rate, allowing for ideal weld output.

[0048] In *Fig. 10*, a high gas pressure scenario is shown. When trigger **40** is pulled, because of the high pressure, the gas flow rate will spike in an adaptive pre-flow condition before settling to the target gas flow rate. In this condition, controller **50** allows a brief spike in gas pressure in order to prevent fluctuation or slow build-up.
[0049] In *Fig. 11*, a low pressure scenario is shown. When trigger **40** is pulled, controller **50** will open the valve for a longer adaptive pre-flow time, increasing the flow rate until it reaches the target gas flow rate.

[0050] The best mode for carrying out the invention has been described for purposes of illustrating the best mode known to the applicant at the time. The examples are illustrative only and not meant to limit the invention, as measured by the scope and merit of the claims. The invention has been described with reference to preferred and alternate embodiments. Obviously, modifications and alterations will occur to others upon the reading and understanding of the specification. It is intended to include all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

Reference numbers:

20	welding system
22	user interface
24	wire feeder with spindle
26	gas flow rate controller
28	welding power supply
30	gun
32	gas supply
34	feed hose or tube
36	pressure regulator
38	gas torch line
40	trigger
42	gas valve
44	feedback control system
46	valve
48	flow sensor
50	controller
52	pressure sensor
54	valve positioning sensor

A	signal
B	flow signal
C	valve position signal
D	pressure signal

What is claimed is:

1. A welding system comprising:
a shielding gas input;
a shielding gas output coupled to a welding gun (30) having a trigger (40); and
a feedback control system (44) for at least said shielding gas comprising:
a flow sensor (48) for measuring flow between said shielding gas input and said shielding gas output; and
a valve (46) for regulating flow between said shielding gas input and said shielding gas output.

2. The welding system of claim 1, wherein said valve (46) further comprises a valve position sensor (54) for communicating a valve position to a controller (50) based upon valve position output from a valve position sensor.

3. The welding system of claim 2, wherein
said controller (50) interactively controls said valve position.

4. The welding system of claim 2 or 3, wherein
said controller (50) includes an alarm for indicating when feedback from said valve position is different than said valve position output.

5. The welding system of anyone of the claims 2 to 4 wherein
said feedback control system (44) further comprises a pressure sensor (52) for determining the pressure of the flow and communicating said pressure to said controller (50) for adaptive preflow control.

6. The welding system of anyone of the claims 1 to 5 wherein
said feedback control system analyzes signals (44) from at least two of said flow sensor (48), said pressure sensor (52), and said valve position sensor (54) and adjusts said shielding gas output based on said at least two signals.

7. The welding system of anyone of the claims 1 to 5, wherein said feedback control system (44) analyzes signals from all of said flow sensor (48), said pressure sensor (52), and said valve position sensor (54) and adjusts said shielding gas output based on said three signals.

8. The welding system of anyone of the claims 1 to 7, wherein said flow sensor (48) is positioned within a welding gun (30).

9. The welding system of anyone of the claims 1 to 8, wherein the flow sensor (48) is a mass flow sensor and preferably a coriolis mass flow sensor, or a volumetric flow rate sensor or the flow sensor (48) senses pressure or other characteristic indicative of the amount of shielding gas flowing to a welding gun (30).

10. A method of providing a targeted shielding gas flow rate to a weld site, said weld site comprising a gas input, an electrical input, a wire feeder, a welding gun and a feedback control system for regulating the flow of gas from said gas input to said welding gun, said feedback control system comprising a valve for controlling a shielding gas flow rate to said welding gun, a mass flow sensor for determining the rate of gas flow to said gun, and a controller for receiving a flow rate signal from said flow sensor and communicating a valve signal to said valve, comprising the steps of:
communicating said flow rate of said shielding gas after said valve to said controller;
determining a flow rate signal based on said flow rate of said shielding gas;
comparing said flow rate to said targeted flow rate;
calculating said valve signal;
providing said valve signal to said valve; and
adjusting said shielding gas flow rate through said valve based on said valve signal.

11. The method of claim 10which further comprises the step of:
monitoring a feed gas input pressure.

12. The method of claim 11 wherein
said step of monitoring generates a pressure signal for communication to said controller.

13. The method of claim 11 or 12 which further comprises the step of:
calculating said valve signal from analysis of said flow rate signal and said pressure signal for adaptive preflow control.

14. The method of anyone of the claims 10 to 13 which further comprises the step of:
monitoring a valve position and, preferably, further communicating said position signal to said controller.

15. A shielding gas flow control feedback system (44) for use in a welding unit comprising:
a shielding gas valve (46) in form of a metering valve;
a flow sensor (48) downstream of said metering valve; and
a controller (50) in communication with said flow sensor (48) and said metering valve which adjusts said metering valve based at least upon signals (A) received from said flow sensor.

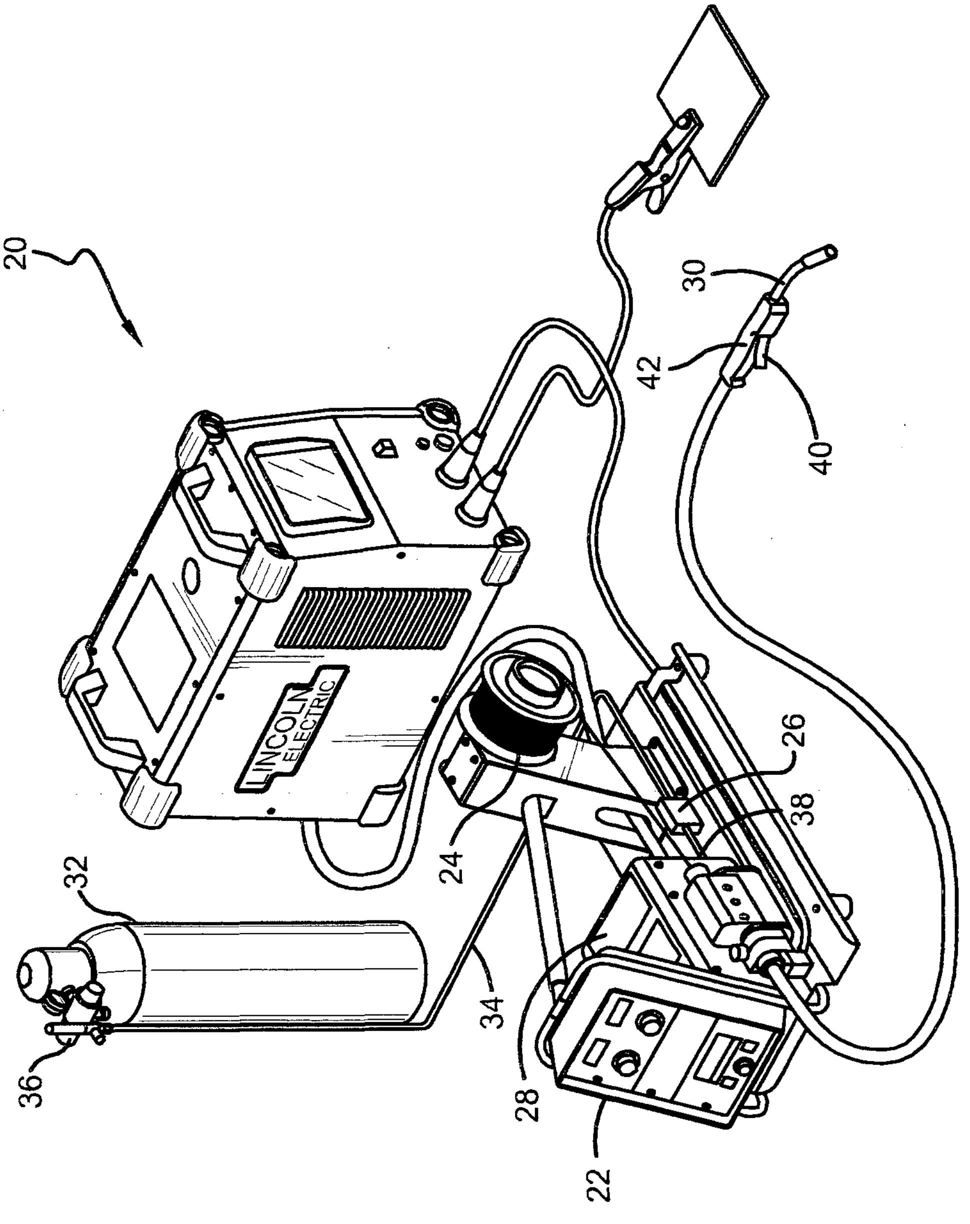

FIG. 1

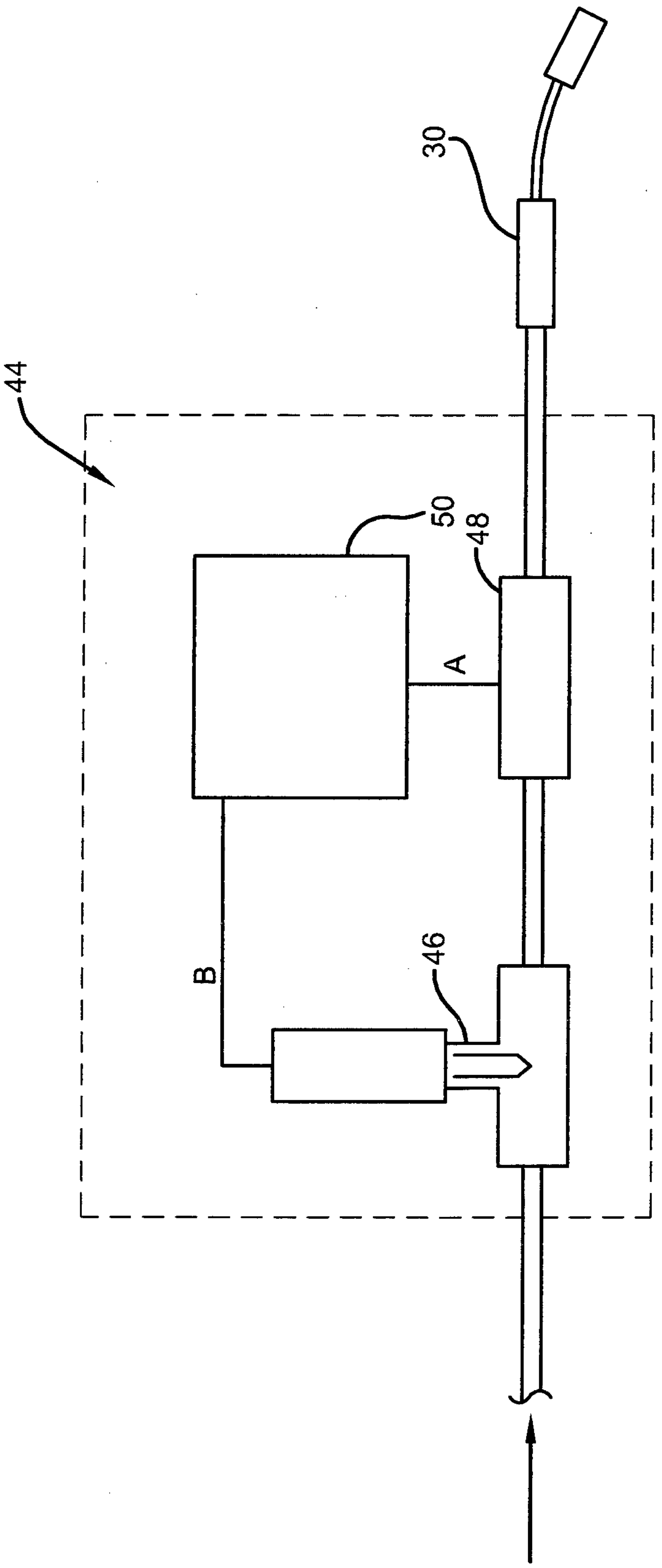

FIG. 2

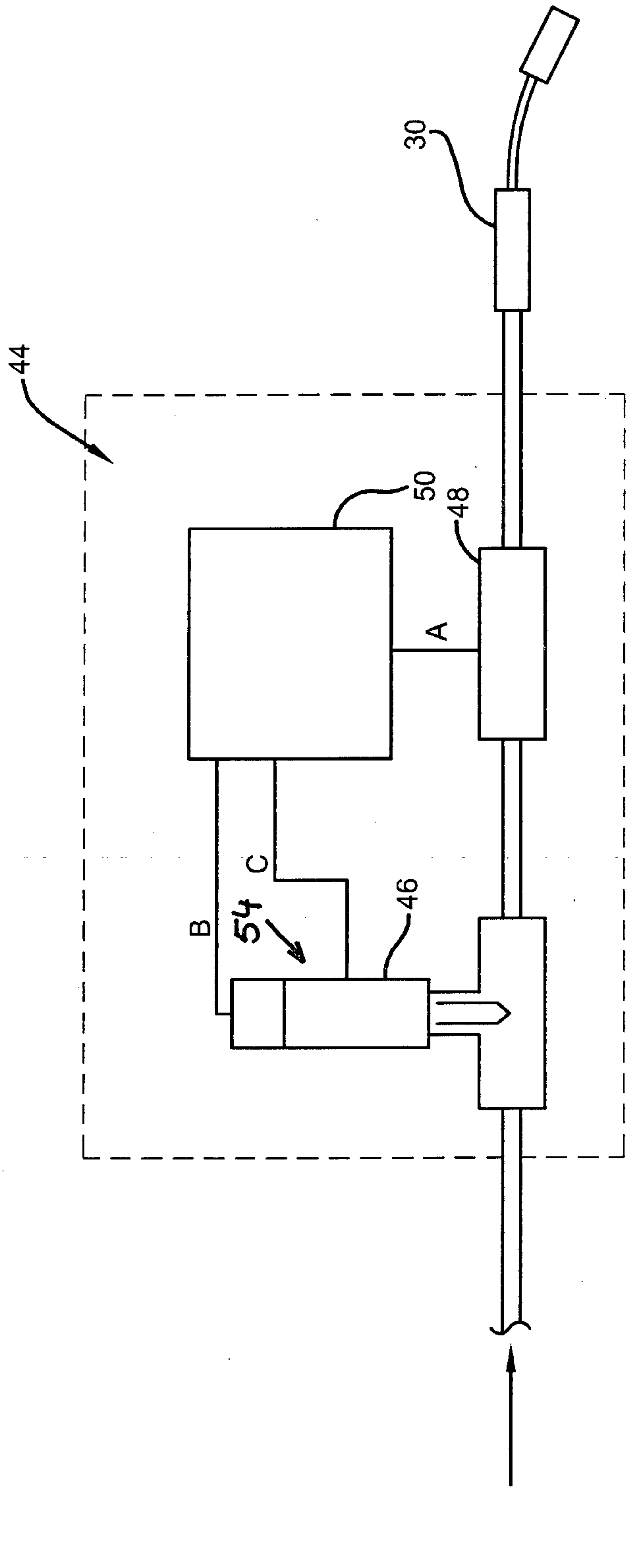

FIG. 3

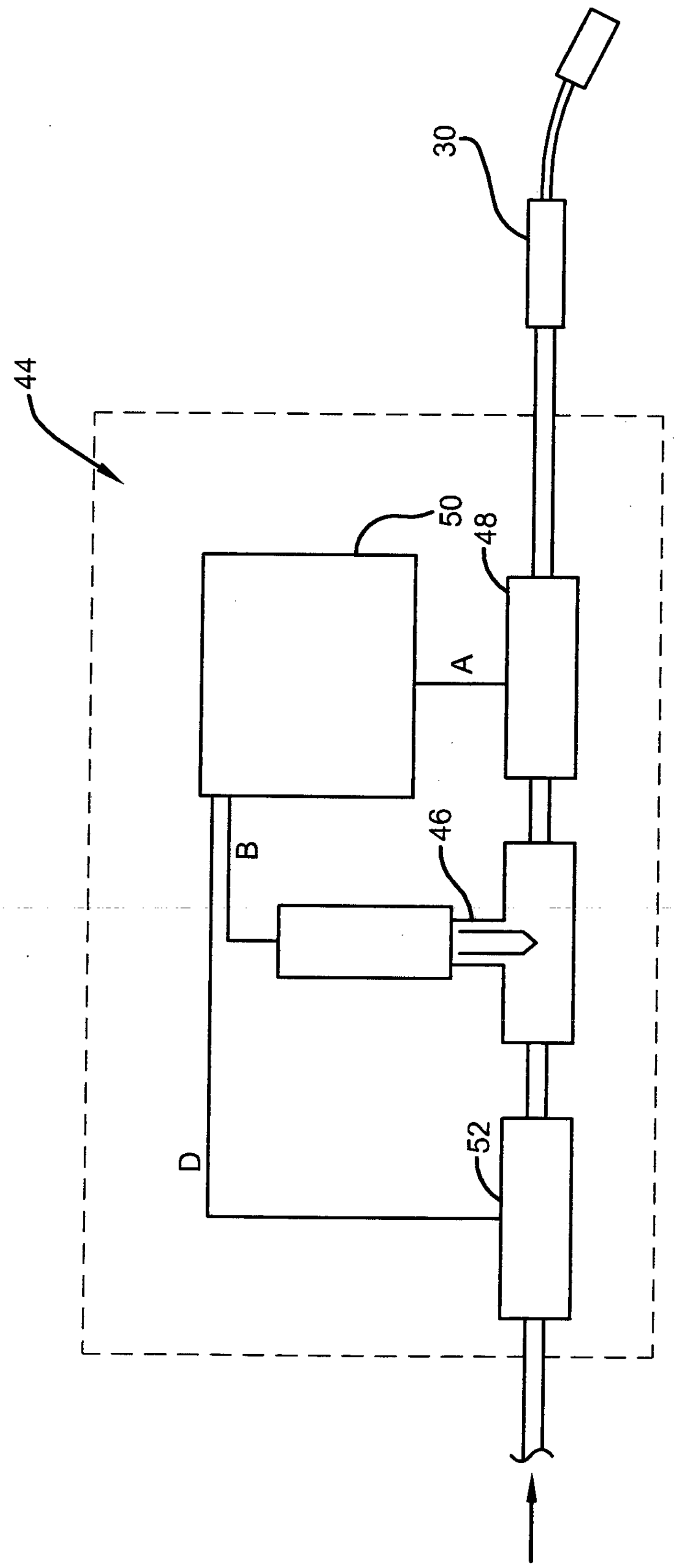

FIG. 4

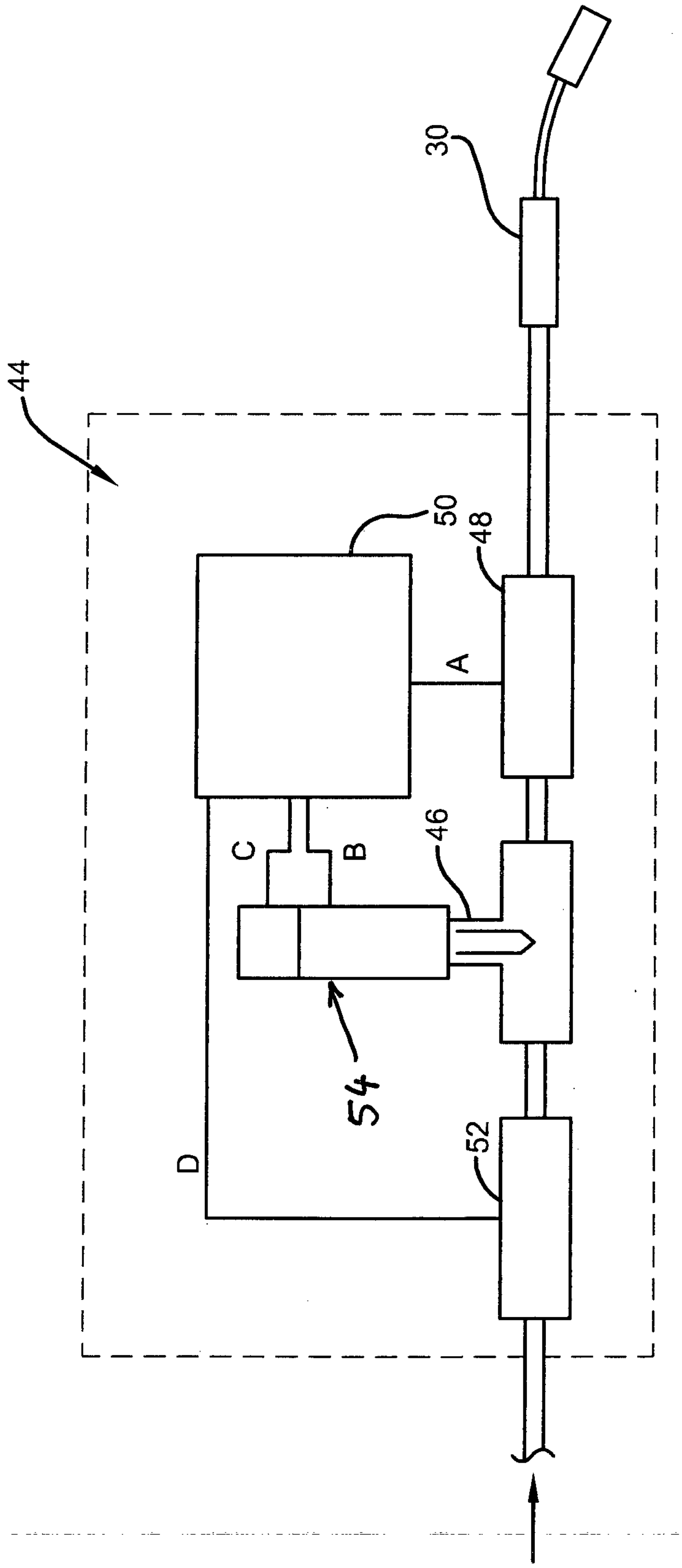

FIG. 5

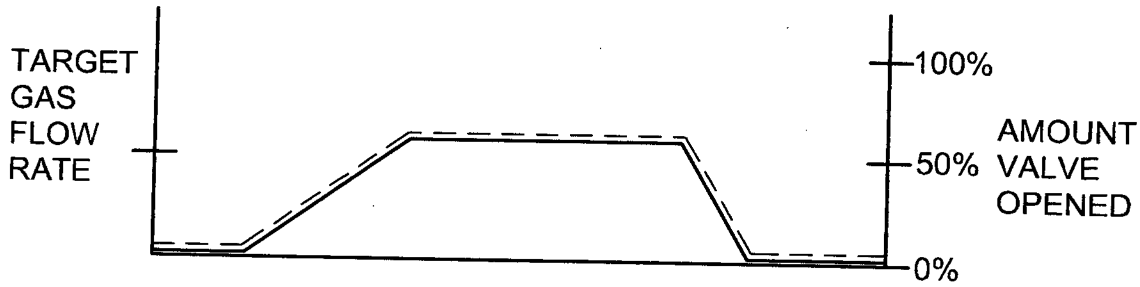

FIG. 6

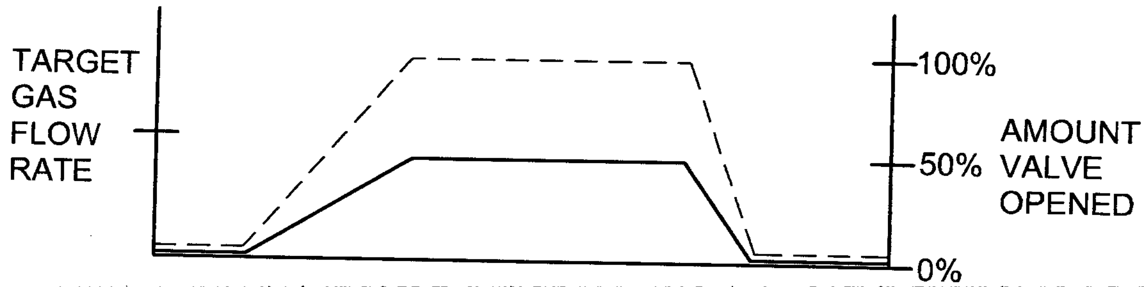

FIG. 7

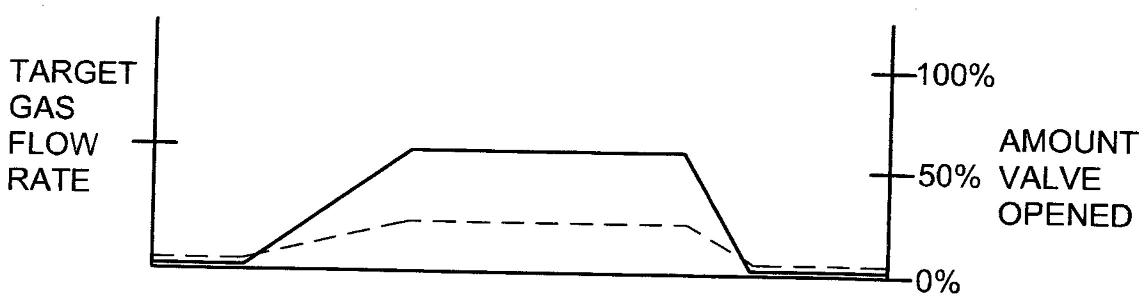

FIG. 8

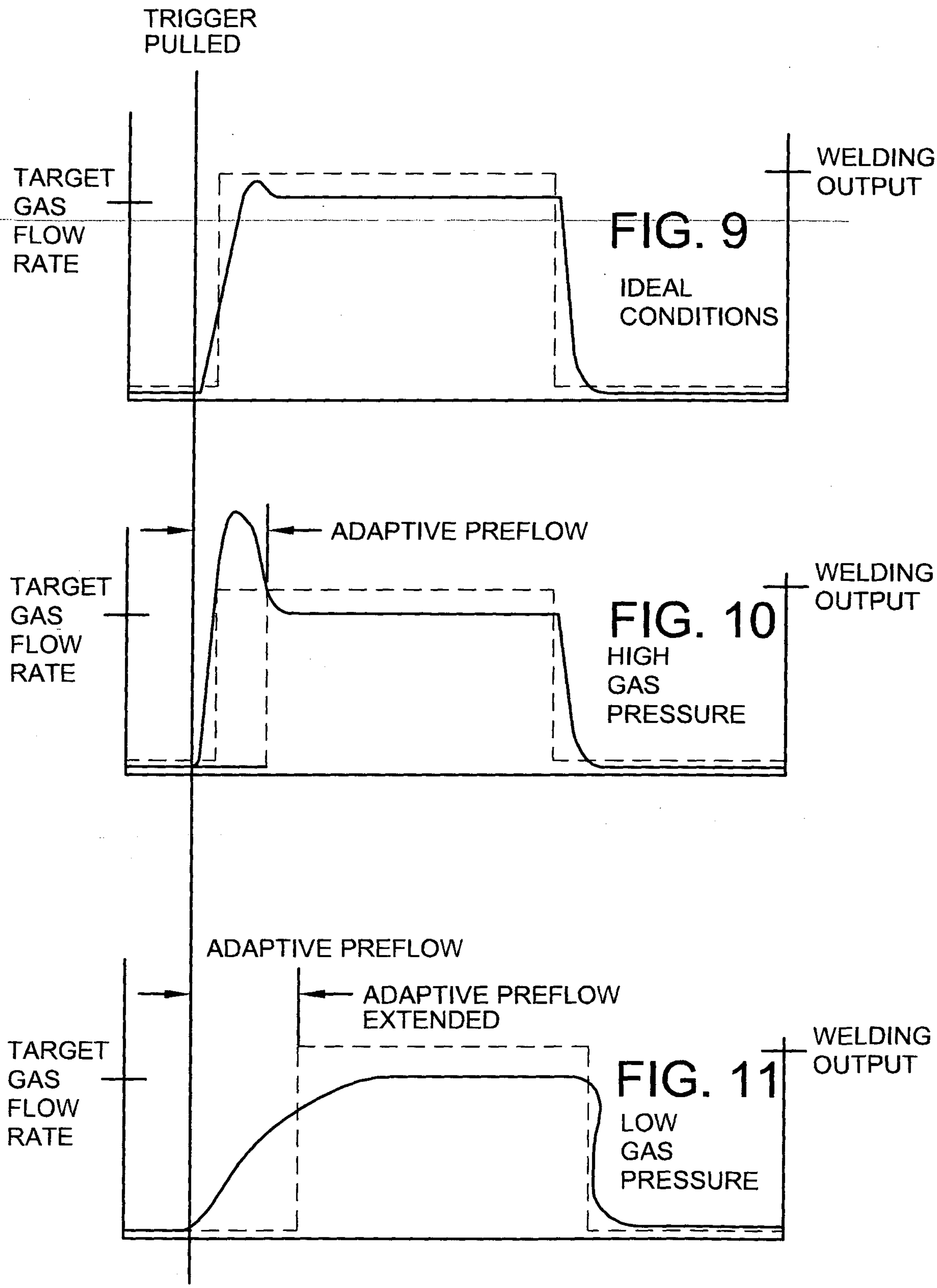

FIG. 9

FIG. 10

FIG. 11