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[54] GAS FLOW REGULATOR FOR WELLBORE CATALYTIC HEATERS

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[52] **U.S. Cl.** **166/59**

[51] **Int. Cl.** **E21b 43/24**

[58] **Field of Search** 166/59, 57, 302, 260, 261; 431/268, 90

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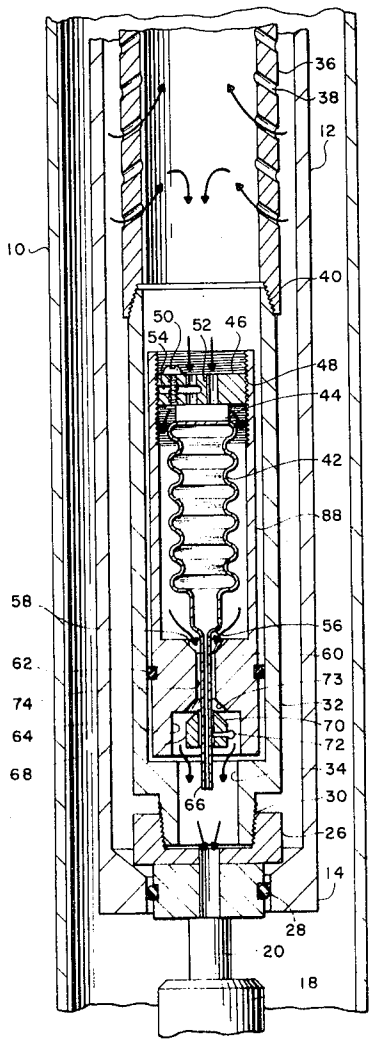
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[57] **ABSTRACT**

A downhole bellows operated regulator valve is used to control the flow rate of a fuel gas to a catalytic wellbore heater. The bellows is located in tubing and is responsive to the pressure differential between the interior and exterior of the tubing. A valve connected with the bellows is fashioned to respond to the bellows so that fuel flow to the catalyst is controlled, and backflow of formation fluids through the catalyst is prevented.

14 Claims, 3 Drawing Figures



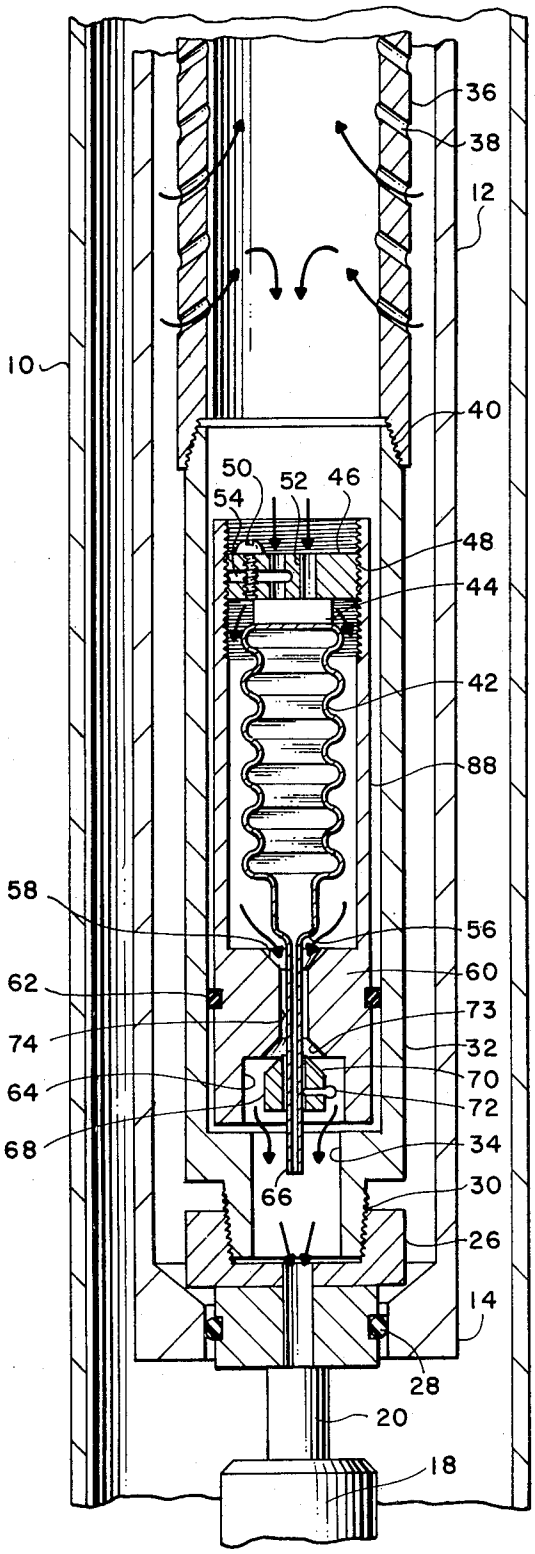


FIG. 2

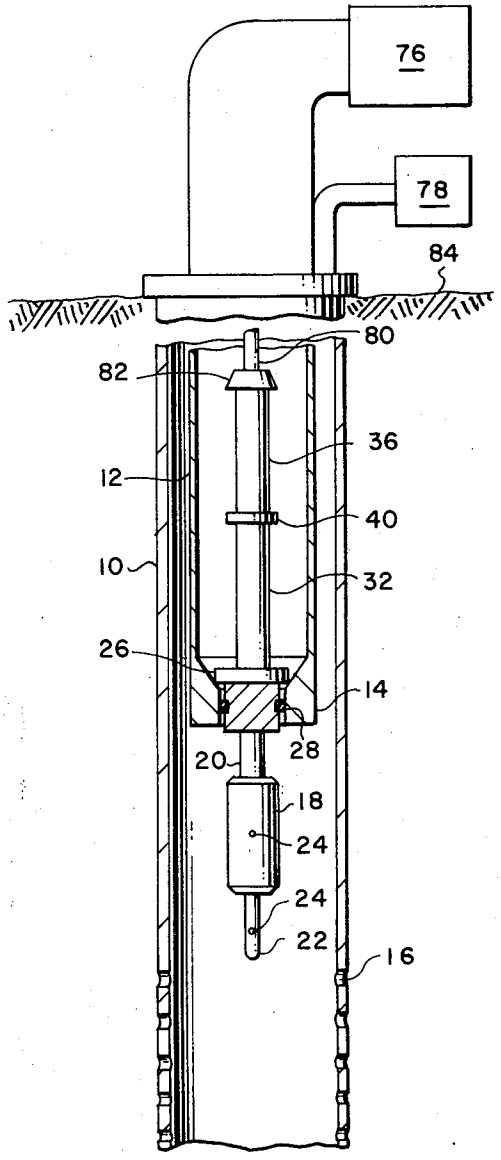


FIG. 1

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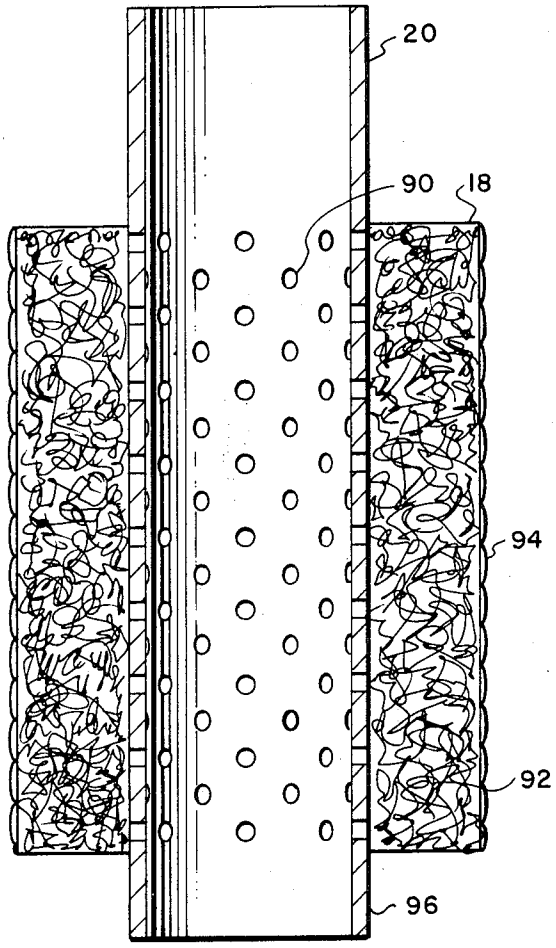


FIG. 3

GAS FLOW REGULATOR FOR WELLBORE CATALYTIC HEATERS

BACKGROUND OF THE INVENTION

This invention relates to a fuel control device for use with a catalytic wellbore heater as disclosed in Ser. No. 92,836 entitled "METHOD AND APPARATUS FOR CATALYTICALLY HEATING WELLBORES" or catalytic ignitors for conventional wellbore heaters such as described in Ser. No. 889,060 entitled "METHOD AND APPARATUS FOR IGNITING WELL HEATERS".

Wellbores are heated for various purposes including wellbore clean-out, sand consolidation and in situ combustion. Heat may be supplied by downhole electrical heaters, gas burners, catalytic reactors, etc.

Heretofore, the use of electrical heaters was limited to shallow wells due to problems related to supplying electrical power to depths in excess of 3,000 feet. High voltages are required for operation of the electrical heater and when the electrical cable exceeds a length of three thousand feet, for example, electrical resistance reduces voltage to a point below that required for operation of the heater. Electrical heaters also have a tendency to short out due to hot spots developed through poor heat exchange caused by coke formation on the surface of the heater. The temperature in the coke layer builds up until it exceeds the melting point of the heating elements, causing the electrical heater to fail. In addition, electrical energy is not always available in remote areas, necessitating use of large generators which are expensive to acquire, locate and maintain.

Gas fuel burners, unlike electrical heaters can be used at depths below 3,000 feet. In such burners the combustion temperatures of natural gas can approximate 4,000°F. Heat shields are used to prevent damage to tubing and casing. However, at higher temperatures, damage to the heat shield and well pipe may occur, especially when the flame stands off from the nozzle and extends below the heat shield. The formation adjacent the damaged casing also may suffer irreparable heat damage.

Catalytic heaters operate at temperatures sufficiently low to prevent wellbore damage. They also can be used at any depth that the electrical or gas burner systems can be used. One present type of catalytic heater relies totally or partially on radiation of heat generated by catalytic reaction. Such a system is usually totally enclosed or partially opened to allow passage of gases taking part in the catalytic reaction. This system requires separate conduits to supply the fuel mixture to the catalytic material and therefore is fairly expensive to use. Also, there is poor heat exchange because of the necessity of radiating through an enclosed system, or relying on the flow of reaction gases passing through the catalyst which are limited to fairly low rates to insure efficient reaction of such gases.

Another catalytic system utilizes a catalytic material completely open to the wellbore where a fuel gas is flowed down the tubing and passes through the catalytic material and air passes down the annulus and into contact with the exterior of the catalytic material causing a catalytic reaction. An excess of air is flowed down the annulus to carry the heat of the reaction into the formation. This system has proved highly efficient in

that the heated reaction is efficiently carried into the formation. With the above described system, heat is not lost by radiation through well pipe nor is the heat transferred limited to the flow rate of reaction gas passing through the catalytic material. In the utilization of this system, it has been discovered that changes in gas or air flow may cause extremely high temperatures which damage the catalytic heater and its operability. Changes in flow rate of the fuel gas and/or air may result from various causes. One such cause is the freeze-up of the air line, resulting in a rich mixture reaching the catalytic surface because of a lack of air. As the mixture enriches at the catalytic surface, the flame temperature of the fuel gas may be reached and act in the manner of a cutting torch on the catalytic heater. Another cause of change in flow rate may be the breakdown of the formation permeability caused by such things as the melting of paraffin or the breakdown of heavy hydrocarbons. When the formation's resistance to flow breaks down, the effect is to suck the fuel gas in the tubing out through the catalyst and thereby cause a rich mixture at the catalyst surface. This rich mixture may cause a highly intense flame or an explosion which will cause damage to the heater and possibly damage to the well pipe. Because of the cost of the catalytic heaters and the time required to retrieve and replace damaged heaters, substantial economy can be had by obviating this problem. It is therefore an object of the present invention to provide an improved catalytic heater.

SUMMARY OF THE INVENTION

With these and other objects in view, the present invention contemplates the use of a downhole fuel flow control valve in a catalytic wellbore heater which has a flow control mechanism responsive to the pressure differential between the interior and the exterior of the well pipe located in a wellbore.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an elevational view of a catalytic heater located in the wellbore;

FIG. **2** is an elevational cross sectional view of a bellows operated regulator valve positioned in well pipe above the catalytic section of the heater.

FIG. **3** is an elevational cross sectional view of the catalytic portion of the heater shown in FIG. **1**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. **1** of the drawings, there is shown a retrievable catalytic wellbore heater. The heater is partially located inside the tubing **12** with the catalytic section **18**, extending below the tubing **12** and inside the casing **10**. At the lower end of the tubing **12** is pump seating nipple **14**, which is an internal annular flange for engaging downhole well equipment. The catalytic heater is rested on pump seating nipple **14** which engages "no-go" flange **26**. Below "no-go" flange **26** is O-ring assembly **28** which provides a seal between the catalytic heater and the interior wall of pump seating nipple **14**.

The catalytic heater consists of three main sections, those being the gas inlet section **36**, flow control sec-

tion 32 and catalytic section 18. Catalytic section 18 is comprised of an oxidation catalyst on a support encircling and attached to conduit and distribution pipe 20. This conduit and distribution pipe 20 has a multiplicity of slots therein adjacent to the catalytic material for allowing communication between the interior of the conduit pipe 20 and the catalytic material.

Positioned on the exterior surface of the catalytic material is thermocouple 24. An additional thermocouple 24 is located on the surface of temperature pill holder 22. Temperature pill holder 22 contains tablets or pellets which melt at different temperatures in order that the highest temperature obtained by the heater can be verified with respect to the thermocouples. The thermocouples 24 transmit an electromotive signal which is responsive to the temperature adjacent the catalytic section 18. The electromotive force generated by thermocouples 24 are transmitted to the surface by armored thermocouple cable 80 where it is recorded on a strip chart recorder which has not been shown. The thermocouple cable 80 is attached to the catalytic heater by cable head 82 which is configured such that it can quickly be removed from the heater for repair of the thermocouple cable 80.

Gas inlet section 36 is a conduit having upwardly directed ports extending through the walls of the conduit. This gas inlet section 36 is attached to flow control section 32 by threaded connector 40. Flow control section 32 is comprised of a double acting valve operated by a bellows. A more detailed description of the flow control section 32 can be found in the description of FIG. 2.

Connected with the interior of tubing 12 is a standard gas compressor 76 which is located at the surface. The gas compressor 76 is sized such that sufficient gas is supplied to the heater for maintaining a catalytic reaction. Connected with the annular space between tubing 12 and casing 10 is standard air compressor 78 which is also located at the surface. The air compressor is sized to provide sufficient air to maintain the catalytic reaction and additionally supply sufficient air to carry the heat of the catalytic reaction to the area to be heated. In the event that the formation is being heated, sufficient air would be necessary to carry the heat of the catalytic reaction into the formation through perforations 16 located in the casing 10.

In the operation of the apparatus described in FIG. 1, the catalytic heater is lowered into the tubing 12 by the armored thermocouple cable 80. Upon the "no-go" flange 26 engaging the pump seating nipple 14 the catalytic heater comes to rest at the lower end of the tubing 12. The O-ring assembly 28 provides a seal between the interior of the tubing 12 and the casing 10. Air is pumped down the annular space between the casing 10 and the tubing 12 such that the air contacts the catalytic section 18, and enters into the formation through perforations 16 in the casing 10. A fuel gas is flowed down the interior of the tubing 12 by gas compressor 76. Upon reaching the gas inlet section 36, the gas enters the upwardly directed ports so that the gas is now in the interior bore of the catalytic heater. The gas then passes through flow control section 32 and acts on the bellows located therein for controlling the double-acting valve. If conditions of pressure are proper, the gas then enters the catalytic section 18 by way of conduit and distribution pipe. 20. The slots located in the conduit pipe 20 adjacent the catalytic material provides a path to allow the gas to pass through the catalytic material and react with the air which is being supplied by air compressor 78.

In order to elevate the temperature adjacent the catalytic section 18 sufficient to react an air and natural gas mixture a hydrogen-air reaction is used. Hydrogen is injected into the gas stream being supplied by gas compressor 76 and will spontaneously react with the air adjacent the catalyst at normal well temperatures. Once the hydrogen-air reaction reaches a temperature of 250°F, natural gas and air will react. Once the natural gas and air reaction is initiated, the hydrogen is no longer needed. Indication of a natural gas-air reaction can be observed by monitoring the strip chart recording of thermocouple information transmitted from the areas adjacent the catalytic heater. If heat is supplied to the wellbore for initiation of in situ combustion in the formation, a catalytic reaction will be maintained if sufficient BTU's for reaction of air and formation fluids have been carried into the formation by air flowing past the heater. Once in situ combustion has commenced, or sufficient heat has been supplied for other purposes, the catalytic heater may be removed from the wellbore. Such removal is effected by thermocouple cable 80. In the in situ combustion operation even though the heater has been removed from the wellbore, air is still supplied by air compressor 78 in order to provide sufficient air to support combustion of air and formation fluids.

A detailed description of appropriate fuel gas and air injection rates and ratios together with a detailed description of one form of the catalytic section 18 can be had by referring to Ser. No. 92,836 entitled "-METHOD AND APPARATUS FOR CATALYTICALLY HEATING WELLBORES".

Referring next to FIG. 2 of the drawings, there is shown a cross section of the flow control section 32 and a portion of the gas inlet section 36. As described in FIG. 1, the gas inlet section 36 has upwardly directed ports 38. The gas inlet section 36 is threadedly attached to flow control section 32 at 40. The flow control section 32 is threadedly attached to "no-go" flange 26 at 30. "No-go" flange 26 and O-ring assembly 28 engages pump seating nipple 14. This engagement was previously described in the description of FIG. 1.

Positioned below the "no-go" flange 26 is catalytic section 18 having conduit and distribution pipe 20 passing therethrough. Only a portion of the catalytic section 18 has been shown, and is the same as previously described in FIG. 1. The flow control section 32 has an outer wall which has an annular flange formed at the lower end thereof. Seated on such annular flange 34 is valve assembly 88.

The valve assembly 88 is comprised of a housing, which has a hollow cylindrically shaped upper portion and substantially solid lower portion having conduit 74 passing therethrough. At the extreme lower end of the housing, there is located support legs 64 which supports the valve assembly 88 and rest on the flange portion 34 of the outer wall of the flow control section 32.

Threadedly connected to the upper end of the housing of the valve assembly 88 is bellows positioning section 46. The bellows positioning section 46 is attached

to the upper end of bellows **42**. This bellows positioning section **46** is threadedly connected at **48** to the interior wall of the housing of valve assembly **88**. Flow channels **52** pass through the bellows positioning section **46** and communicate with the space between the exterior of bellows **42** and the interior wall of the housing of valve assembly **88**. A slot **54** is cut into the bellows positioning section **46**. A set screw **50** threadedly engages the bellows positioning section **46** and passes through the slot **54**. Tightening of the set screw **50** will draw thgether the slot **54** which will cause threads on the positioning section **46** to bind against the mating threads of the valve assembly **88**. Such binding will lock the bellows **42** into position.

The bellows **42** is a hollow corrugated metallic member which is preferably made of brass. Bellows **42** is also sufficiently flexible to be responsive to small changes in pressure. Attached to the lower end of bellows **42** is a valve stem **66** which is a hollow conduit member connecting with the interior of bellows **42**.

Located at the upper end of the valve stem **66** is an upper sealing surface **56**. This is a smooth annular metallic sealing surface which may incorporate an O-ring section for improved sealing characteristics. The valve stem **66** passes through the conduit **74** fashioned in the lower end of the housing of valve assembly **88**.

Attached to the lower portion of the valve stem **66** is lower sealing member **70** which has an annular upwardly facing sealing surface. The lower sealing member **70** is attached to the valve stem **66** by set screw **72**. Thus, the lower sealing member **70** can be positioned along the length of the lower portion of the valve stem **66**. At the upper and lower ends of the conduit **74** are upper and lower seal seats **58** and **73**, respectively. These seal seats may be made of TEFLON or other conventional valve seat material.

Providing a seal between valve assembly **88** and the interior wall of the flow control section **32** is O-ring section **62**. An O-ring encircles the valve assembly housing and prevents gas flow descending through the interior bore of the heater from by-passing the interior of valve assembly **88**.

In the operation of the apparatus described above, the bellows **42** is positioned in the valve assembly **88** prior to running the heater into the wellbore by adjusting the bellows positioning section **46**, such that approximately one pound of pressure is needed to unseat the upper sealing surface **56** from seal seat **58**. Without one pound differential pressure, the upper valve comprised of upper sealing surface **56** and upper seal seat **58** is ordinarily closed. When running the catalytic heater into the tubing **12** by the thermocouple cable **25** was described in FIG. **1**, gas is flowed down the tubing and past the catalytic heater. Upon seating of the catalytic heater in pump seating nipple **14**, an increase in fuel gas pressure is necessary to effect flow through the flow control section **32**. Thus, by monitoring pressure in the tubing it can be determined when the catalytic heater is seated. The O-ring section **28** provides the seal necessary to effect flow of the fuel gas through the valve assembly **88**.

When the catalytic heater is being run into the tubing **12**, air is pumped down the annular space between tubing **12** and casing **10**, past the heater and into the formation. A fuel gas is pumped down the tubing and upon seating of the heater the fuel gas then flows through the heater by passing through the flow control section **32**. The increase in pressure caused by the fuel gas having to compress the bellows will indicate that the heater is seated. If hydrogen is included in the fuel gas being pumped down to the tubing **12** to the catalytic heater, there will be a spontaneous reaction between hydrogen and air reaching the catalytic material. Once this reaction attains a temperature in excess of 250° F, the hydrogen is no longer needed.

In normal functioning of the catalytic heater, the valve assembly **88** does not operate to restrict or close off flow of fuel gas to the catalytic section **18**. If however, a breakdown in formation permeability were to occur, the lower sealing member **72** will engage the lower seal seat **73** in response to compression of the bellows **42**. The bellows **42** will compress because of the reduction in pressure of the formation acting through the hollow valve stem **66** to reduce the pressure in the interior of bellows **42**, and thereby facilitates its compression. Similarly, if excessive flow rates of fuel gas are passing through the valve assembly **88**, the high pressure drop across the conduit **74** will result in a compression of the bellows **42**. When such compression exceeds preset limits through positioning of the lower sealing member **70**, the compression of the bellows will pull the lower sealing member **70** into contact with lower seal seat **73**. In the event the formation pressure equals or exceeds the pressure of the fuel gas being supplied to the catalytic heater, the formation pressure will act through the hollow valve stem **66** to expand the pressure within bellows **42** which will operate to close the upper valve consisting of upper sealing surface **56** and upper seal seat **58**.

With the use of this valve assembly **88**, damage to the catalytic heater is avoided. If excess fuel, for example, were to be allowed to reach the catalytic surface, there is the liklihood of damage to the catalytic portion of the heater caused by either extremely high temperatures or an explosion in the vicinity of the heater. The valve assembly **88** also prevents contamination of the catalytic surface due to backflow of the formation occasioned by a reduction in pressure in the tubing interior or an increase in formation pressure.

If well or surface conditions result in closure of the valve to prevent gas from reaching the catalytic section of the heater it is possible that the temperature at the catalytic surface would drop below the reaction temperature of natural gas and air, to overcome the lengthy travel time of a hydrogen slug to initiate a spontaneous reaction for restarting heating operations, a fuel gas comprised of **6-12%** hydrOgen and natural gas should be used as a fuel gas so that almost instantaneous restarting of the heater occurs.

Referring next to FIG. **3** there is seen a cross sectional view of the catalytic portion of the heater **18**. In this drawing the lower portion of lower stand off member **20** is seen at the top of the drawing. The stand off member is a section of blank pipe having a hollow interior. Located below the lower stand off member **20** is a tubular member having ports **90** therein. These ports **90** extend through the wall of the tubular member and are spaced vertically and radially. Located adjacent the exterior of the ported tubular member is a fiberized silica material, such as CERAFELT. This

material is arranged around the pipe so as to form a multiplicity of tortuous pathways. Wrapped around the exterior surface of the fiberized silica material **92** is an oxidation catalyst coated on burlap **94**. Burlap **94** can be wrapped in one or several overlapping layers. The catalyst is coated on the burlap so as to provide flow channels between catalyst portions.

It can be seen from FIG. **3** that fuel gas descending the tubing **12** and entering the catalytic heater passes through the interior of the lower stand off member **20** until it reaches the ports **90** adjacent the catalytic section **18**. The fuel gas then passes out the ports **90** in the tubular member and subsequently diffuses as it passes through the fiberized silica material **92**. This diffusion allows small portion of the fuel gas to reach all or most of the outer surface of the catalytic section where the catalytic material **94** is located. When the fuel gas passes through the burlap it passes through the flow channels in the catalytic material **94**. The fuel gas then is able to combine with air being pumped down the annular space between casing **10** and tubing **12** so as to provide a fuel mixture. Because of the small diameter of the flow channels in the catalytic material the fuel gas and air can be readily catalytically reacted. A method of initiating such a catalytic reaction has been previously described in the discussion of FIG. **1**.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects. The aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

WHAT IS CLAIMED IS:

1. In a downhole catalytic wellbore heater having a catalytic material located at the lower end of the well pipe and wherein the catalytic material has flow channels therethrough such that the interior of the well pipe communicates with the environment outside the well pipe, through such flow channels, the improvement comprising: flow control means responsive to the pressure differential between the interior and exterior of the well pipe, which flow control means is located in the well pipe above the catalytic material.

2. The apparatus of claim **1** wherein the flow control means includes a bellows responsive to the pressure in the well pipe and the pressure outside the well pipe.

3. The apparatus of claim **2** wherein the exterior of the bellows is open to the well pipe and wherein the interior of the bellows is open to the environment exterior to the well pipe.

4. Apparatus for providing heat in a wellbore having well pipe therein comprising: an oxidation catalyst having flow channels therethrough positioned at the lower end of the well pipe; means for flowing a fuel gas down the well pipe, through the catalyst flow channels and into the environment surrounding the lower end of the well pipe, and means for controlling the flow of fuel gas to the oxidation catalyst, which control means is interposed in the well pipe above the oxidation catalyst.

5. The apparatus of claim **4** wherein the flow control means is a bellows connected with a double acting valve and which bellows is responsive to the pressure differential between the interior and exterior of the well pipe.

6. The apparatus of claim **5** including a housing with the bellows located therein and including means threadedly engaged with the housing for adjusting the space in the housing occupied by the bellows.

7. The apparatus of claim **5** wherein the double acting valve comprises a valve stem extending through a restricted flow channel, where the restricted flow channel has a valve seat formed at its upper end and a valve seat formed at its lower end, and wherein the valve stem has sealing surfaces positioned adjacent the valve seats.

8. The apparatus of claim **6** wherein the sealing surface adjacent the lower valve seat is adjustable along the length of the valve stem.

9. The apparatus for providing heat in a wellbore having well pipe therein comprising: a tubular member at least partially located in the lower end of the well pipe; a catalytic material positioned on the exterior of the lower end of the tubular member; ports through the wall of the tubular member adjacent the location of the catalytic material; means for flowing a gas down the well pipe, through the tubular member, out the ports and into contact with the catalytic material; and means for regulating the flow of gas contacting the catalytic material which regulating means is interposed in the tubular member above the ports.

10. The apparatus of claim **9** wherein the gas regulating means comprises: a housing having a flow passage therethrough including a constricted portion; a pressure responsive member located in the housing; and means responsive to the pressure responsive member for restricting gas flow through the constricted portion of the flow passage.

11. The apparatus of claim **10** wherein the pressure responsive member is a bellows and the gas flow restricting means includes a valve stem connected with the bellows and having at least one sealing surface thereon and wherein the constricted portion of the flow passage has a valve seat formed therein.

12. The apparatus of Claim **10** including means for adjusting the space occupied by the bellows.

13. The apparatus of Claim **10** wherein the pressure responsive member is a bellows, wherein the constricted portion of the flow passage has valve seats formed at its upper and lower ends, and wherein the gas flow restricting means includes a valve stem connected with the bellows having an upper and lower sealing surface positioned adjacent the upper and lower valve seats.

14. The apparatus of Claim **12** wherein the lower sealing surface is adjustable along the length of the valve stem.

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