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(54) **Titre : CYCLONE INTERNE AMELIORE POUR REACTEUR A LIT FLUIDISE**
(54) **Title: IMPROVED INTERNAL CYCLONE FOR FLUIDIZED BED REACTOR**

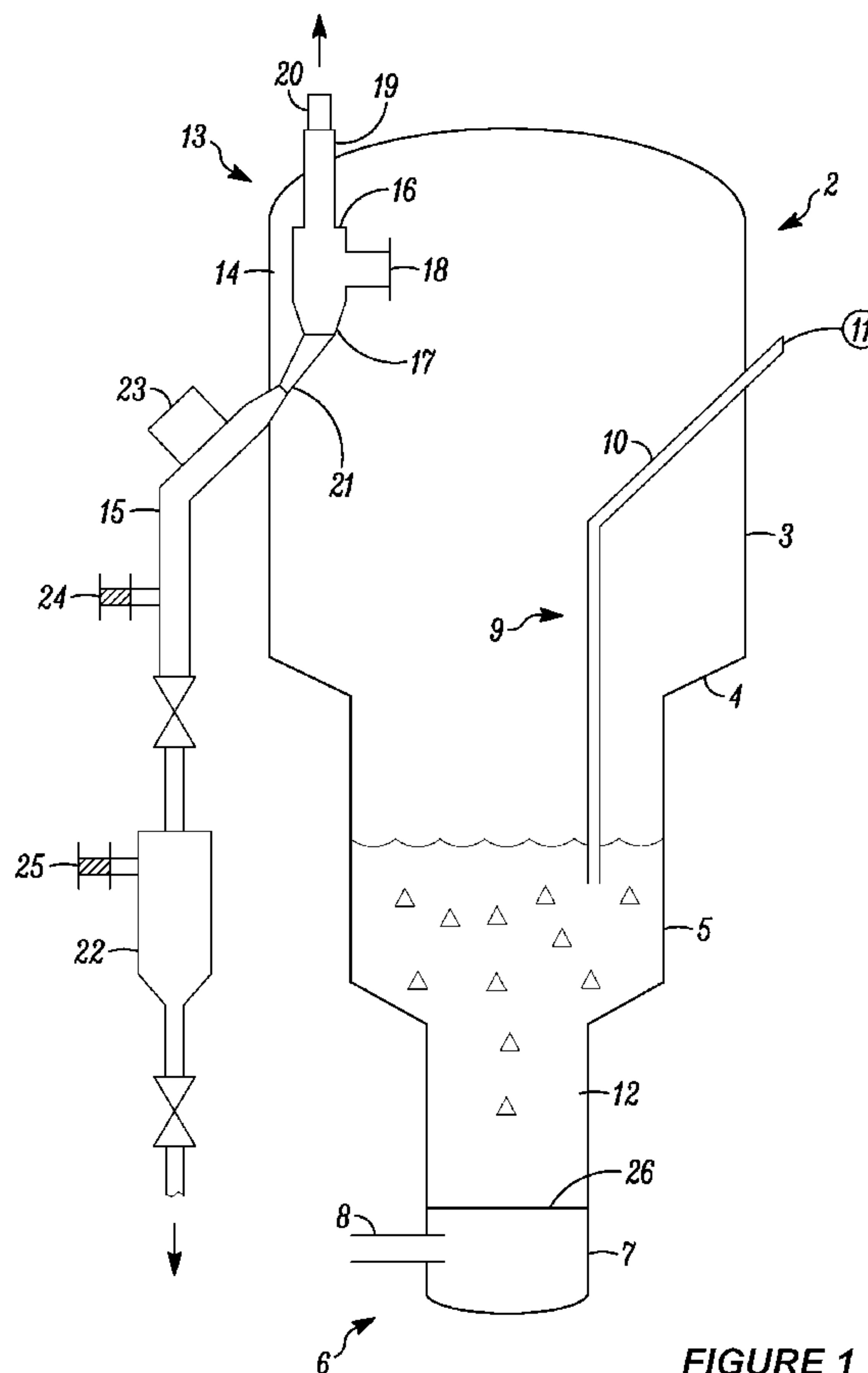


FIGURE 1

(57) **Abrégé/Abstract:**

A fluidized bed reactor comprising a reaction column having a fluid portion; a gas inflow means for flowing a gas upwardly from the fluid portion of the reaction column; a particle feed means for feeding particles to the fluid portion of the reaction column; a cyclone



(57) Abrégé(suite)/Abstract(continued):

capable of separating particles from the gas flowing upwardly from the fluid portion of the reaction column, the cyclone being located within the reaction column and being in communication with the gas flowing upwardly, wherein the cyclone comprises a cyclone body having an inlet, a gas outlet, and a particle drop port; and a particle discharge pipe having an upper part connected to the particle drop port of the cyclone body, and a lower part, wherein the particle discharge pipe is located substantially outside of the reaction column.

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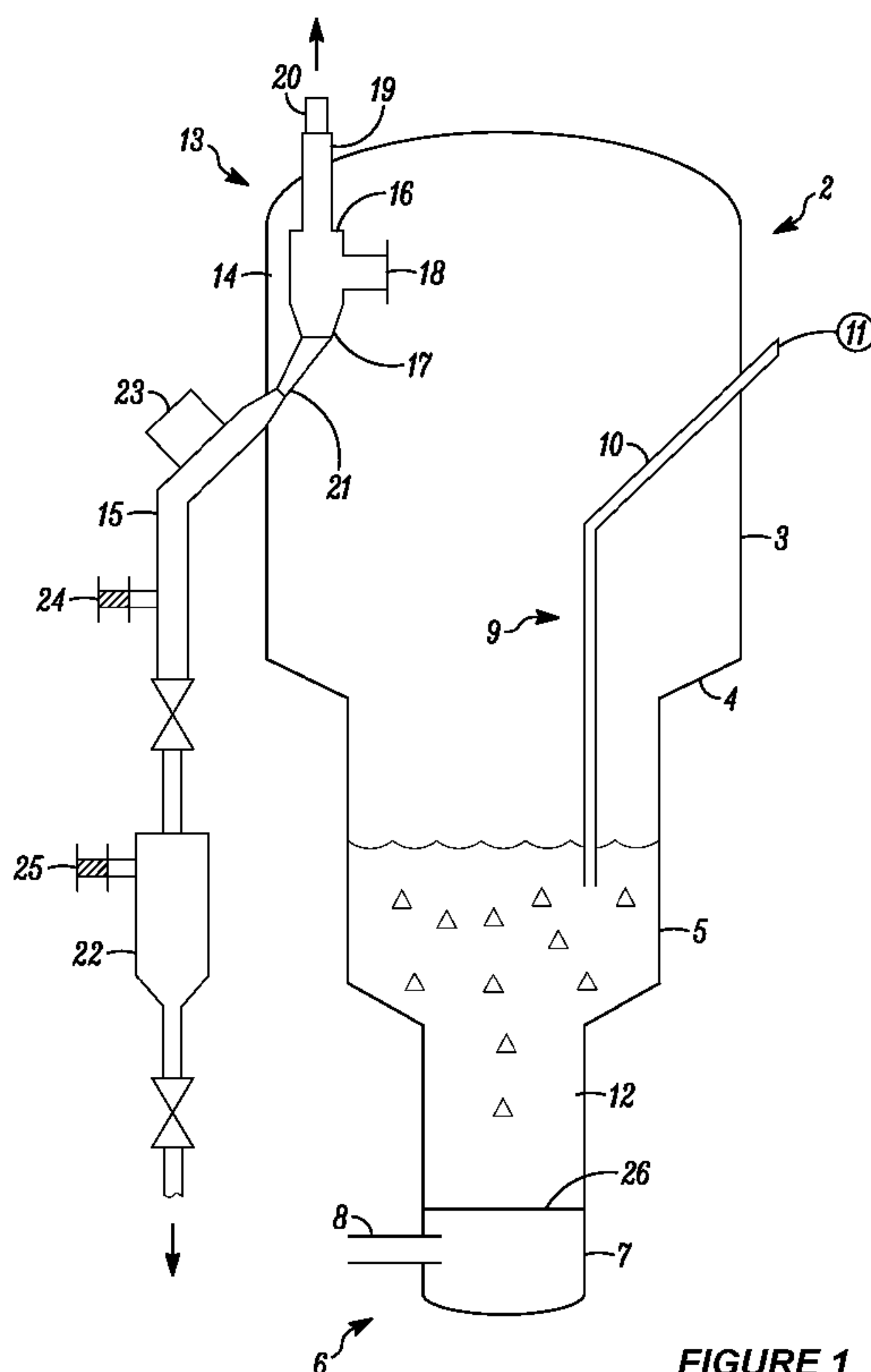


FIGURE 1

(57) Abstract: A fluidized bed reactor comprising a reaction column having a fluid portion; a gas inflow means for flowing a gas upwardly from the fluid portion of the reaction column; a particle feed means for feeding particles to the fluid portion of the reaction column; a cyclone capable of separating particles from the gas flowing upwardly from the fluid portion of the reaction column, the cyclone being located within the reaction column and being in communication with the gas flowing upwardly, wherein the cyclone comprises a cyclone body having an inlet, a gas outlet, and a particle drop port; and a particle discharge pipe having an upper part connected to the particle drop port of the cyclone body, and a lower part, wherein the particle discharge pipe is located substantially outside of the reaction column.

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IMPROVED INTERNAL CYCLONE FOR FLUIDIZED BED REACTOR

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application No. 61/695,179, filed on August 30, 2012, the disclosure of which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] This invention relates to an improved fluidized bed reactor equipped with an internal cyclone that is connected to a particle discharge pipe located substantially outside of the reaction column.

BACKGROUND OF THE INVENTION

[0003] A fluidized bed reactor (FBR) is a type of reactor device that can be used to carry out a variety of multiphase chemical reactions. In this type of reactor, a fluid (gas or liquid) is passed through a granular solid material (usually a catalyst possibly shaped as tiny spheres) at high enough velocities to suspend the solid and cause it to behave as though it were a fluid. This process, known as fluidization, imparts many important advantages to the fluidized bed reactor. The fluidized bed reactor can thus be used in many industrial applications. Fluidized bed reactors are often used to produce gasoline and other fuels, along with many other chemicals. Many industrially produced polymers are made using fluidized bed reactor technology, such as rubber, vinyl chloride, polyethylene, styrenes, and polypropylene. Fluidized bed reactors are used in various utilities, for example in nuclear power plants and water and waste treatment settings; fluidized bed reactors are also used for coal gasification. Fluidized bed reactors used in these applications allow for processes that are cleaner and more efficient than previous standard reactor technologies.

[0004] In conventional fluidized bed reactors, an internal cyclone is often used to separate fine particles from the gas that moves upwards in the fluidized bed reactor during its standard operation. The advantage of such an internal cyclone over a cyclone that is located outside the reactor is that the internal cyclone can be heated up to the process

temperature by the process gas without the need of an external heat source. Additionally, the inlet of the internal cyclone will not be easily clogged due to the high temperature of the process gas.

[0005] The cyclone is often connected to a discharge pipe that is located within the fluidized bed reactor and channels captured particles back towards the bottom of the reactor. The drawback of this type of setup is that the up-flowing fluidizing gas may bypass the cyclone's inlet and enter the internal cyclone via its discharge pipe. Another drawback is that the whole fluidized bed reactor system must be shut down in case the discharge pipe must be accessed and cleaned because it is clogged. Additionally, the removal of captured fine particles from these types of systems is often difficult.

[0006] Thus, there remains a need for a fluidized bed reactor with an improved design that allows the cleaning of a clogged discharge pipe while the fluidized bed reactor is still in operation. The present invention addresses this need.

SUMMARY OF THE INVENTION

[0007] The present invention provides a fluidized bed reactor comprising a reaction column having a fluid portion; gas inflow means for flowing a gas upwardly through the fluid portion of the reaction column; particle feed means for feeding particles to the fluid portion of the reaction column; and a cyclone capable of separating particles from the gas flowing upwardly from the fluid portion of the reaction column. The cyclone is located within the reaction column and is in communication with the gas flowing upwardly; and the cyclone comprises a cyclone body having a gas intake opening, a gas outflow opening, and a particle drop port. The cyclone also has a particle discharge pipe having an upper part connected to the particle drop port of the cyclone body, and a lower part; wherein the particle discharge pipe is located substantially outside of the reaction column.

[0008] In certain embodiments of the present invention, the fluidized bed reactor further comprises a knock-out pot attached to the lower part of the particle discharge pipe and located outside of the reaction column, wherein the knock-out pot is capable of collecting particles discharged from the particle discharge pipe.

[0009] In other embodiments of the present invention, the fluidized bed reactor further comprises a vibrator attached to the particle discharge pipe and located outside of the

reaction column, wherein the vibrator is capable of removing solids that have accumulated in the particle discharge pipe.

[0010] In even other embodiments of the present invention, the fluidized bed reactor further comprises a high pressure N₂ purge line attached to the particle discharge pipe and located outside of the reaction column, wherein the high pressure N₂ purge line is capable of removing heavy clogage in the particle discharge pipe.

[0011] In even other embodiments of the present invention, the particle discharge pipe or the knock-out pot, or both, comprise means for heat insulation.

[0012] The present invention also provides a method of producing UF₄, comprising reacting UO₂ with HF gas in any of the fluidized bed reactors discussed above.

BRIEF DESCRIPTION OF THE FIGURES

[0013] Figure 1 represents a sectional view of an improved fluidized bed reactor with an internal cyclone according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0014] The invention relates to an improved fluidized bed reactor equipped with a cyclone that is located within the fluidized bed reactor's reaction column and that is connected to a particle discharge pipe located substantially outside of said reaction column. As a result of this modification, the fluidized bed reactor of the present invention operates more efficiently because the particle discharge pipe can be cleaned while the fluidized bed reactor is still in operation.

[0015] An embodiment of a fluidized bed reactor constructed in accordance with the present invention will now be described in detail with reference to the accompanying drawing (FIGURE 1).

[0016] In FIG.1, a fluidized bed reactor designated by numeral 1 operates according to the fluidized bed principles generally known in the art. The fluidized bed reactor has a reaction column 2, which extends substantially vertically, and which has a free board portion 3 of a relatively large-diameter cylindrical shape, a taper portion 4 of an inverted truncated conical tubular shape, and a fluid portion 5 of a relatively small-diameter

cylindrical shape. A lower end part of the reaction column **2** is provided with gas inflow means **6**. The gas inflow means **6** include a gas chamber **7** disposed at the lower end part of the reaction column **2**, and a gas inflow pipe **8** in connection with the gas chamber **7**. Gases are fed to the gas chamber **7** through the gas inflow pipe **8**, and then flow upwardly through the gas distributor **26** and inside the reaction column **2**. The reaction column **2** is also provided with particle feed means **9**. The particle feed means **9** include a particle feed pipe **10** which advances into the reaction column **2** through the peripheral wall of the free board portion **4** of the reaction column **2** and extends downwardly into the fluid portion **5** of the reaction column **2**. The particle feed pipe **10** is connected to a particle feed source **11** which supplies particles at a predetermined rate to the particle feed pipe **10** which feeds the particles into a lower part of the reaction column **2**, i.e., the fluid portion **5**. Thus, a main fluidized bed **12** of particles is formed in the fluid portion **5** of the reaction column **2**. The reaction column **2**, the gas inflow means **6**, including the gas chamber **7** and the gas inflow pipe **8**, and the particle feed pipe **10** may be made of any suitable material, such as stainless steel or high nickel alloy.

[0017] The reaction column **2** is further equipped with a cyclone **13**. The cyclone **13** includes a cyclone body **14** that is connected to a particle discharge pipe **15**. In FIG 1, the cyclone body **14** is entirely disposed within the reaction column **2**, whereas the particle discharge pipe **15** is located substantially outside the reaction column **2**. The cyclone body **14** has a nearly cylindrical upper part **16** (wider end), and a conical lower part **17** (narrow end). A gas intake opening **18** is located in the peripheral wall of the upper part **16** of the cyclone body **14**, and a gas outflow opening **19** is located in the top wall of the upper part **16**. The cyclone body **14** is positioned in the upper part of the reaction column **2**, i.e., the free board portion **3**, and its gas intake opening **18** is open towards the free board portion **3** of the reaction column **2**. An outlet pipe **20** is connected to the gas outflow opening **19** of the cyclone body **14**, and this outlet pipe **20** extends through the top wall of the reaction column **2**. The bottom wall of the lower part **17** of the cyclone body **14** is opened throughout to form a particle drop port **21**. The particle discharge pipe **15** is formed of a slenderly extending cylindrical member, and its upper end is connected to the particle drop port **21**. Thus, the upper end of the particle discharge pipe **15** is in communication with the particle drop port **21** of the cyclone body **14**. The cyclone body, and particle discharge pipe may be made of any suitable material, such as stainless steel or high nickel alloy.

[0018] The fluidized bed reactor **1** is further equipped with a knock-out pot **22** connected to the lower part of the particle discharge pipe **15** outside of the reaction column **2** for collecting particles discharged from the particle discharge pipe. The fluidized bed reactor **1** may also include a vibrator **23** that is attached to the particle discharge pipe **15** outside of the reaction column **2** for removing any accumulated solids in the discharge pipe. The fluidized bed reactor **1** may preferably also include a high pressure N₂ purge line **24** that is attached to the particle discharge pipe **15** outside of the reaction column for removing any heavy clogage in the pipe. The knock-out pot **22** may further include a N₂ bump **25** for periodically freeing up space inside the knock-out pot. The particle discharge pipe **15** and the knock-out pot **22** of the fluidized bed reactor outside of the reaction column can be well insulated and/or heat traced to prevent the condensation of gases and evaporation of low boiling point compounds.

[0019] The workings of the above-described fluidized bed reactor are described using the hydrofluorination of uranium dioxide (UO₂) to uranium tetrafluoride (UF₄) as an example. When hydrogen fluoride gas (HF) flows into the reaction column **2** through the gas inflow pipe **8** and into the gas chamber **7**, it ascends inside the reaction column **2** past the main fluidized bed **12** of UO₂ particles. While the gas is ascending through the main fluidized bed **12** in the reaction column **2**, solid UO₂ reacts with gaseous HF to produce solid UF₄ and H₂O gas according to the following reaction formula: $\text{UO}_2(\text{s}) + 4\text{HF}(\text{g}) \rightarrow \text{UF}_4(\text{s}) + 2\text{H}_2\text{O}(\text{g})$. The relatively small-diameter particles of the UO₂ and UF₄ constituting the main fluidized bed **12** accompany the ascending gas stream, and flow upwardly from the main fluidized bed **12**. The linear velocity of the gas gradually decreases while the gas is moving upwards across the taper portion **4** with an upwardly gradually increasing sectional area. Thus, the particles other than considerably small particles are separated from the ascending gas stream, and fall back into the main fluidized bed **12**. In the free board portion **3** of the reaction column **2**, the gas accompanied by small-diameter UO₂ and UF₄ particles enters the cyclone body **14** through the gas intake opening **18**. In the cyclone body **14**, the small-diameter particles accompanying the gas are separated from the gas by the cyclone **13**, which works based on principles that are generally known in the art and that are therefore not further described herein. The gas accompanied only by fine particles is discharged through the outlet pipe **20** through the gas outflow opening **19**. The small-diameter particles separated from the gas in the

cyclone body **14** fall through the particle drop port **21** and through to the particle discharge pipe **15** that is located substantially outside of the reaction column **2**.

[0020] In a preferred embodiment of the present invention, a knock-out pot **22** is attached to the lower part of the particle discharge pipe **15** outside of the reaction column **2** and used to collect the particles discharged from the particle discharge pipe; knock-out pot **22** also supplies a seal that prevents process gas from escaping from the reactor system through the cyclone. In certain embodiments of the present invention, the knock-out pot **22** further includes a N₂ bump **25** for periodically freeing up space inside the knock-out pot. In certain embodiments of the present invention, the knock-out pot **22** further includes a vent line (not shown in FIG. 1) which is applied to release pressure buildup when necessary or for maintenance purposes.

[0021] In certain embodiments of the present invention, a vibrator **23** is attached to the particle discharge pipe **15** outside of the reaction column **2** and used for removing any accumulated solids from the discharge pipe.

[0022] In certain embodiments of the present invention, a high pressure N₂ purge line **24** is attached to the particle discharge pipe **15** outside of the reaction column and is used for the purpose of removing any heavy clogage in the pipe.

[0023] In certain embodiments of the present invention, the particle discharge pipe **15** and the knock-out pot **22** of the cyclone outside of the reaction column are well insulated and/or heat traced to prevent the condensation of gases and evaporation of low boiling point compounds.

[0024] In a preferred embodiment of the present invention, the cyclone body **14** is installed in close proximity to the wall of the reaction column **2** to reduce the leg length inside the reaction column. The bottom conical section of the cyclone will be modified as follows: straight on the side against the reactor wall and angled on the other side so that the fines can flow out to the discharge pipe **15** with less obstacle. A N₂ purge line **24** will be installed to prevent any pluggage in the discharge leg. The knock-out pot **22** will be bumped periodically to free up the space inside the knock-out pot. A vent line will also be applied to release pressure buildup in case of emergency or for maintenance purpose.

[0025] In the present invention, the dimensions of the cyclone can be calculated based on the actual operating conditions, such as gas flow rate, solid holdup in the gas flow and solid capture efficiency of the cyclone

CLAIMS

What is claimed is:

1. A fluidized bed reactor comprising:

a reaction column having a fluid portion;

gas inflow means for flowing a gas upwardly through the fluid portion of the reaction column;

particle feed means for feeding particles to the fluid portion of the reaction column; and

a cyclone capable of separating particles from the gas flowing upwardly from the fluid portion of the reaction column, the cyclone being located within the reaction column and being in communication with the gas flowing upwardly; wherein the cyclone comprises a cyclone body having a gas intake opening, a gas outflow opening, and a particle drop port; and

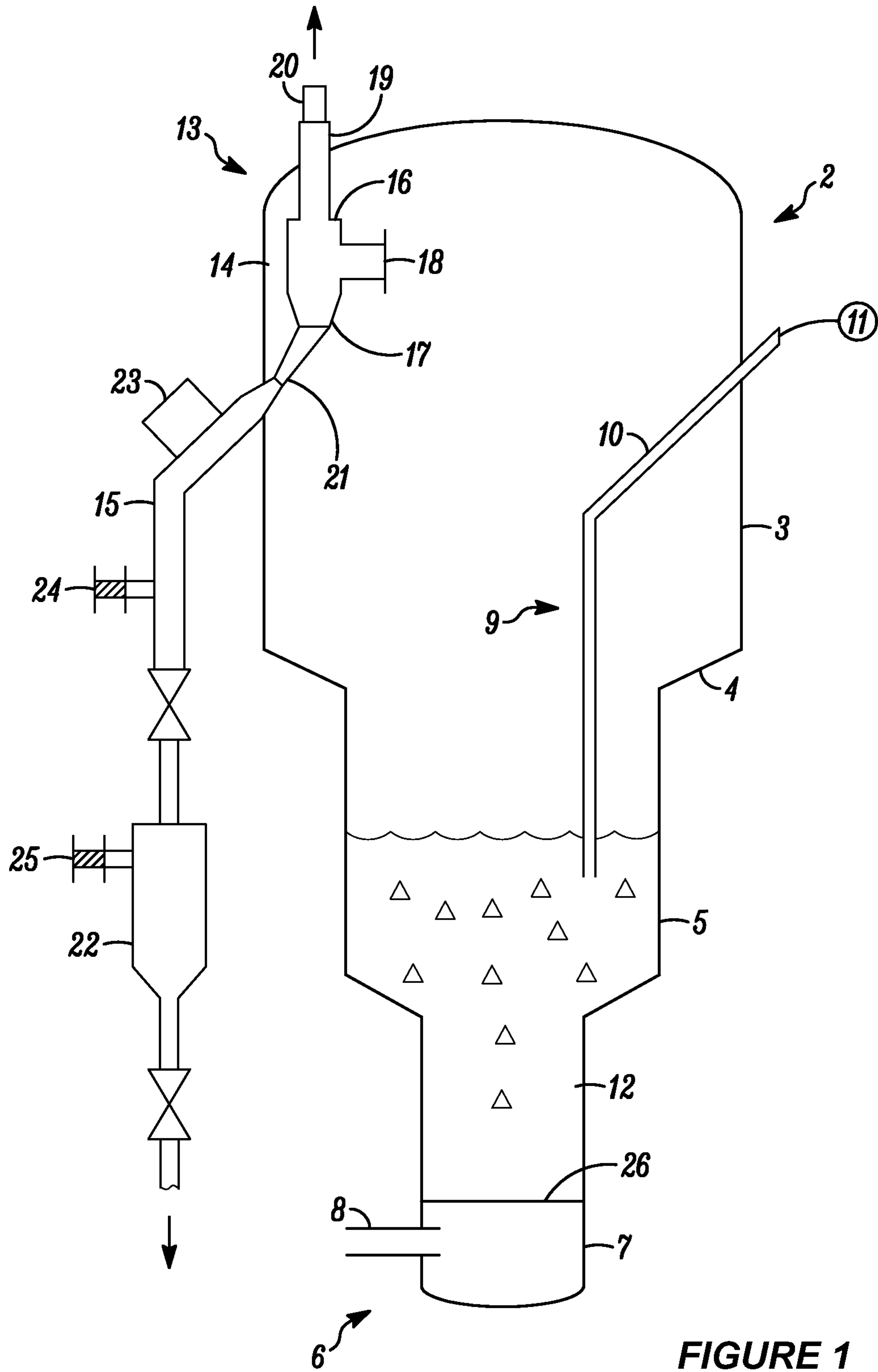
a particle discharge pipe having an upper part connected to the particle drop port of the cyclone body, and a lower part; wherein the particle discharge pipe is located substantially outside of the reaction column.

2. The fluidized bed reactor of claim 1, further comprising a knock-out pot attached to the lower part of the particle discharge pipe and located outside of the reaction column, wherein the knock-out pot is capable of collecting particles discharged from the particle discharge pipe.

3. The fluidized bed reactor of claim 1, further comprising a vibrator attached to the particle discharge pipe and located outside of the reaction column, wherein the vibrator is capable of removing solids that have accumulated in the particle discharge pipe.

4. The fluidized bed reactor of claim 1, further comprising a high pressure N₂ purge line attached to the particle discharge pipe and located outside of the reaction column, wherein the high pressure N₂ purge line is capable of removing heavy clogage in the particle discharge pipe.

5. The fluidized bed reactor of claim 2, wherein the particle discharge pipe or the knock-out pot, or both, comprise means for heat insulation.
6. A method of producing UF_4 , comprising reacting UO_2 with HF gas in the fluidized bed reactor of any one of the preceding claims.



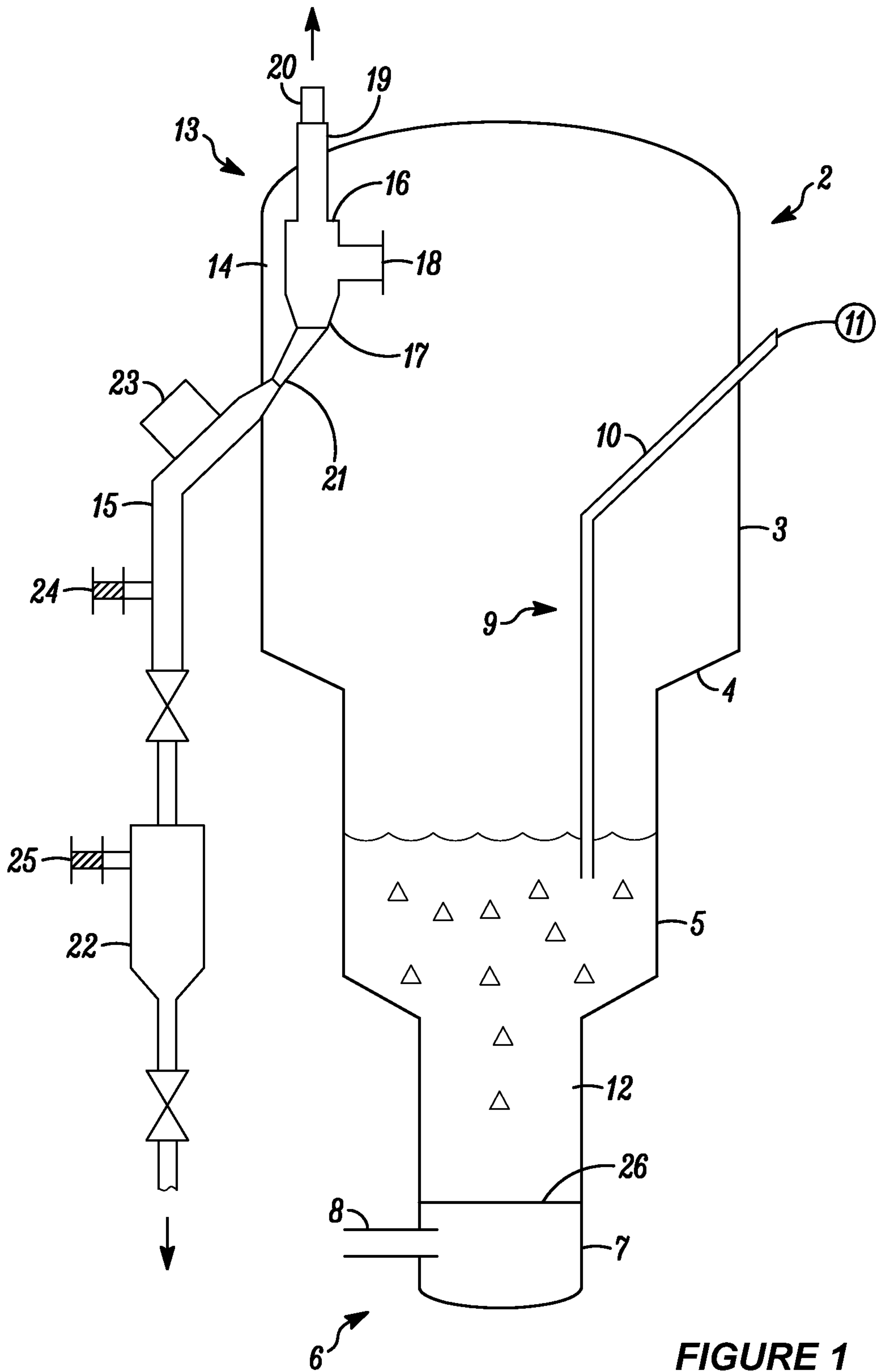


FIGURE 1