

APPARATUS FOR INSTALLING A THERMOCOUPLE INSIDE A REACTOR TUBE FILLED WITH CATALYST

5 **Cross Reference to Related Applications**

This application claims priority to U.S. Patent Application No. 16/665,394, filed October 28, 2019, which claims the benefit of priority under 35 U.S.C. § 119 (a), the entire contents of which are incorporated herein by reference.

10 Background

A steam methane reformer (SMR) is an industrial apparatus that utilizes heat, pressure, and a catalyst to convert methane (CH_4) and steam (H_2O) into hydrogen (3H_2) and carbon monoxide (CO). The CH_4 and H_2O react with each other in catalyst-filled tubes that are enclosed within a furnace which provides heat to the endothermic reaction that forms H_2 and CO . In order for this endothermic reaction to proceed, a very high furnace temperature is required. Typically, the temperature will be within $700\text{--}1,000^\circ\text{C}$ ($1,292\text{--}1,832^\circ\text{F}$), while the pressure may typically range from 3 to 25 bar.

Some companies manufacture thermocouples that can be inserted into SMR tubes, by which the temperature can be measured along the length of the tube. Knowing this inside-of-SMR-tube temperature is valuable, so that the SMR reaction can be monitored, the process can be optimized, and the tube failure can be predicted.

Installing these inside-of-SMR-tube thermocouples can be challenging because they need to be installed before catalyst is installed around them.

25 This invention outlines an apparatus by which the inside-of-reactor tube thermocouple is installed and centered, and then catalyst is loaded into the tube afterwards.

Summary

30 A device for centering a temperature measurement device inside a tube reactor that will be filled with catalyst, including a single inflatable bladder mechanically and fluidically attached to a centering ring.

Brief Description of the Figures

For a further understanding of the nature and objects for the present invention, reference should be made to the following detailed description, taken in conjunction with the accompanying drawings, in which like elements are given the same or analogous reference numbers and wherein:

Figure 1 is a schematic representation of a cross-sectional view of a reactor tube and the centering ring, in accordance with one embodiment of the present invention.

Figure 2 is a schematic representation of a cross-sectional view of a reactor tube and inflated single bladder positioning system, in accordance with one embodiment of the present invention.

Figure 3a is a schematic representation of a cross-sectional view of a reactor tube with a single temperature measurement device, in accordance with one embodiment of the present invention.

Figure 3b is a schematic representation of a cross-sectional view of a reactor tube with a strand of multiple temperature measurement devices, in accordance with one embodiment of the present invention.

Figure 4 is a schematic representation of an isometric view of the uninflated single bladder positioning system located in a reactor tube, in accordance with one embodiment of the present invention.

Figure 5 is a schematic representation of an isometric view of the inflated single bladder positioning system located in a reactor tube, in accordance with one embodiment of the present invention.

Figure 6 is a schematic representation of an isometric view of the inflated single bladder positioning system located in a reactor tube indicating the lowering of the sock containing catalyst into the tube, in accordance with one embodiment of the present invention.

Figure 7 is a schematic representation of an isometric view of the inflated single bladder positioning system located in a reactor tube indicating the introduction of catalyst into the tube from the sock, in accordance with one embodiment of the present invention.

Figure 8 is a schematic representation of an isometric view of the inflated single bladder positioning system located in a reactor tube after catalyst introduction is complete, in accordance with one embodiment of the present invention.

Figure 9 is a schematic representation of an isometric view of the deflated single bladder positioning system located in a reactor tube with the catalyst falling to the volume below, accordance with one embodiment of the present invention.

5 Figure 10 is a schematic representation of an isometric view of the uninflated single bladder positioning system being relocated to the next position within the reactor tube, in accordance with one embodiment of the present invention.

Element Numbers

- 101 = steam methane reformer tube
- 10 102 = tube inner surface
- 103 = centering ring
- 105 = single inflatable bladder
- 106 = temperature measurement device
- 107 = pressurized gas conduit
- 15 111 = single bladder positioning system (including centering ring 103 and single inflatable bladders 105)
- 112 = catalyst
- 113 = bottom (distal end) of the reactor tube
- 114 = top (proximal end) of the reactor tube
- 20 116 = centering ring tether
- 117 = vibration device
- 118 = compressed gas source
- 119 = compressed gas source valve
- 120 = catalyst sock
- 25 121 = catalyst sock tether
- 122 = compressed air bleed valve
- 123 = distal end mesh disk

Description of Preferred Embodiments

30 Illustrative embodiments of the invention are described below. While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular

forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

5 It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developer's specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill
10 in the art having the benefit of this disclosure.

The term "about 1 foot" means as close to one foot as is reasonable given the conditions. As used herein, "about 1 foot" is defined as meaning 12 inches plus or minus 20%. Likewise, "about 5 feet" is defined as 60 inches plus or minus 20%.

15 The term "essentially vertical orientation" means as close to vertical is reasonable given the conditions. The term "essentially vertical orientation" means sufficiently vertical such that the performance of the instant invention, from the perspective of one with ordinary skill in the art, is the same as if the tubes were precisely vertical. As used herein, "essentially vertical orientation" is defined as within 10 degrees from true vertical, preferably within 5 degrees of true vertical.

20 As an overview, a method is provided that uses a sock catalyst loading technique. A centering ring is centered within the reformer tube using a single multiple inflatable bladder that will allow the catalyst to collect on the upper surface, then fall into the lower empty space of the reactor tube once deflated. To start, the bladder is positioned above the tube's catalyst layer. Or, if the tube is completely empty, the
25 bladder is positioned above the end of the tube. The distance above the tube end (or catalyst layer) may vary, but about 12 inches is typical. The bladder is inflated, typically using nitrogen or dry service air. Then a "sock loading" technique is used to introduce the catalyst to the surface of the bladder. After the bladder is deflated and the catalyst fills the void beneath, the bladder is then repositioned, typically 1 foot
30 above catalyst layer, and the process is repeated until the tube is fully loaded with catalyst.

Figure 1 represents a cross-sectional view of reactor tube **101** utilizing the instant device and method. The reactor tube may be a steam methane reformer (SMR) tube. Inflatable bladder **105** is attached to, and preferably spaced evenly

around, the perimeter of centering ring **103**. As indicated in Figure 2 (cross-sectional view, inflated), for ease of explanation, this assembly will be referred to as single bladder positioning system **111**.

5 Within centering ring **103** are at least temperature measurement device **106** and pressurized gas conduit **107**. Pressurized gas conduit **107** introduces and evacuates the gas used to inflate and deflate single inflatable bladder **105**. Pressurized gas conduit **107** connects directly to single inflatable bladder **105**, thus allowing it to be inflated and deflated.

10 When inflated (as indicated in Figure 5), single inflatable bladder **105** makes at least partial contact with tube wall inner surface **102** and acts to locate centering ring **103** centrally within tube wall inner surface **102**. Temperature measurement device **106** is located inside of centering ring **103**, and after the inflation of single inflatable bladder **105** is also positioned near the axial center of reactor tube **101**. Although only one temperature measurement device **106** is indicated in the figures, it is understood
15 that two or more temperature measurement devices **106** may be located inside centering ring **103** (not shown).

 This embodiment may be better understood with reference to Figures 1 – 10.

 Before the filling of reactor tube **101** with catalyst may commence, the tube is positioned in an essentially vertical orientation, and a sieve (not shown) has been
20 located at distal end **113** of reactor tube **101**, in order to keep catalyst **112** within reactor tube **101**. It is preferred that the inside of reactor tube **101** be inspected to ensure that undesired objects or foreign material not be present. In some cases, a Boroscope (not shown) is used to determine that the inside of reactor tube **101** is clean.

25 First, temperature measurement device **105** is attached to distal end mesh disk **123**. This helps secure temperature measurement device in place when catalyst **112** is loaded above it. This keeps temperature measurement device **105** from migrating up reactor tube **101** during the subsequent steps.

 Starting at proximal end **114**, temperature measurement device **106** is then
30 inserted down the length of empty reactor tube **101**. Temperature measurement device **106** and pressurized gas conduit **107** are inserted into the center of centering ring **103**, and centering ring tether **116** is attached to centering ring **103**. While two centering ring tethers **116** are shown in the figures, temperature measurement device **106** may be fitted with one or multiple centering ring tethers **116**. Pressurized gas

conduit **107** may be inserted through centering ring **103**, or pressurized gas conduit **107** may not be inserted through centering ring **103**. Pressurized gas conduit **107** may be left outside centering ring **102** if desired (not shown). Then, while holding and extending centering ring tether **116**, lower single bladder positioning system **111** into reactor tube **101**. Then lower single bladder positioning system **111** until it touches the bottom of reactor tube **101**. At this time, it is recommended that centering ring tether **116** is marked to indicate the level at proximal end **114** of the tube, as a point of reference.

Single bladder positioning system **111** is then raised a first distance H1 from the end of reactor tube **101**. H1 is entirely discretionary, but a typical value would be about one foot. This distance may be determined from the mark previously made on centering ring tether **116**. An additional reference mark may be made at this time on centering ring tether **116** with reference to proximal end **114**, to indicate the new location of single bladder positioning system **111**.

Single inflatable bladder **105** is inflated, by closing valve **122** and opening valve **107**, thereby at least partially contacting tube wall inner surface **102** and locating centering ring **103** centrally within reactor tube **101**. Any available and suitable compressed gas source **118** may be used for inflating the bladders, such as compressed nitrogen or dry service or plant air.

Temperature measurement device **106**, which may be approximately the same length as reactor tube **101**, is essentially centered within reactor tube **101**. Catalyst sock **120** is loaded with a predetermined, or calculated amount of catalyst **112**. Catalyst sock **120** is introduced into reactor tube **101** by conforming it around temperature measurement device **106** and pressurized gas conduit **107**. It is recommended that catalyst sock **120** has approximately 2 inches of overlapping fold.

As catalyst sock **120** is then lowered, tension must be kept on both centering ring tether **116** and pressurized gas conduit **107**, in order to allow catalyst sock **120** to pass down reactor tube **101**. Catalyst sock **120** is lowered until it reaches, or is in near proximity to, single bladder positioning system **111**. It is important that the release point is close to single bladder positioning system **111**, in order to reduce any damage to the falling catalyst. Catalyst sock **120** is then unloaded of catalyst **112**. This is done by quickly tugging on the sock and releasing the overlapping fold. The empty sock is then removed from reactor tube **101**. It is understood that this is an illustrative, but

non-limiting, example of a method of sock loading a reactor tube. Other methods of sock loading known to the art may also be used with the instant method and device.

As catalyst **112** is emptied, it collects on top of single inflatable bladder **105**. Single inflatable bladder **105** is then deflated by closing valve **107** and opening valve **122**. Catalyst **112** falls into the void below and is allowed to settle in and around centering ring **103** and temperature measurement device **106**, thus maintaining their central position. In order to promote better catalyst packing, and to help avoid unwanted voids in the catalyst, reactor tube **101** may be vibrated **117**.

Catalyst sock **120** is then refilled with a predetermined amount of catalyst. Single bladder positioning system **111** is then raised a predetermined distance H2 and the process is repeated. Predetermined distance H2 may be any distance useful or meaningful to the installer, for example one foot. Again, this distance may be determined from the mark previously made on centering ring tether **116**, and an additional reference mark may be made at this time on centering ring tether **116**.

This process is repeated to the desired location within reactor tube **101**, which may be a desired distance from the top of the tube. Reactor tube **101** is now fully reloaded and full of fresh catalyst, and temperature measurement device **106** is centrally located and able to provide accurate and meaningful readings of temperature along the length of reactor tube **101**.

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It will be understood that many additional changes in the details, materials, steps and arrangement of parts, which have been herein described in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims. Thus, the present invention is not intended to be limited to the specific embodiments in the examples given above.

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