

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. 16/665,377, 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 reactor 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.

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

Summary

A device for centering a temperature measurement device inside a reactor tube
30 that will be filled with catalyst, including multiple inflatable bladders 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
5 analogous reference numbers and wherein:

Figure 1 is a schematic representation of a cross-sectional view of a reactor tube and catalyst springs, as known to the art.

Figure 2 is a schematic representation of a cross-sectional view of a reactor tube and catalyst springs, with the multiple bladder positioning system, in accordance
10 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
15 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 a cross-sectional view of a reactor tube and the centering ring, accordance with one embodiment of the present invention.

Figure 5 is a schematic representation of a cross-sectional view of a reactor
20 tube and inflated multiple bladder positioning system, accordance with one embodiment of the present invention.

Figure 6a is a schematic representation of a cross-sectional view of the uninflated multiple bladder positioning system, accordance with one embodiment of
25 the present invention.

Figure 6b is a schematic representation of an isometric view of the uninflated multiple bladder positioning system, accordance with one embodiment of the present
invention.

Figure 7 is a schematic representation of a cross-sectional view of the inflated multiple bladder positioning system, accordance with one embodiment of the present
30 invention.

Figure 8 is a schematic representation of an isometric view of the uninflated multiple bladder positioning system located at the bottom of a reactor tube, in accordance with one embodiment of the present invention.

Figure 9 is a schematic representation of an isometric view of the inflated multiple bladder positioning system located at the bottom of a reactor tube, in accordance with one embodiment of the present invention.

Figure 10 is a schematic representation of an isometric view of the inflated multiple bladder positioning system located at the bottom of a reactor tube indicating the introduction of catalyst into the tube, accordance with one embodiment of the present invention.

Figure 11 is a schematic representation of an isometric view of the inflated multiple bladder positioning system located at the bottom of a reactor tube with the catalyst packing complete, accordance with one embodiment of the present invention.

Figure 12 is a schematic representation of an isometric view of the uninflated multiple bladder positioning system being relocated to the next position within the reactor tube, in accordance with one embodiment of the present invention.

15 **Element Numbers**

- 101 = reactor tube (SMR tube)
- 102 = tube inner surface
- 103 = centering ring
- 104 = multiple inflatable bladders
- 20 106 = temperature measurement device
- 107 = pressurized gas conduit
- 109 = area between multiple inflatable bladders (for catalyst filling)
- 110 = multiple bladder positioning system (including centering ring 103 and multiple inflatable bladders 104)
- 25 112 = catalyst
- 113 = bottom (distal end) of the reactor tube
- 114 = top (proximal end) of the reactor tube
- 115 = catalyst springs
- 116 = centering ring and catalyst springs tether
- 30 117 = vibration device
- 118 = compressed gas source
- 119 = compressed gas source valve
- 122 = compressed air bleed valve
- 123 = distal end mesh disk

Description of Preferred Embodiments

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.

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 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%.

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.

As an overview, a method is provided that uses a dense catalyst loading technique. A centering ring is centered within the reformer tube using multiple inflatable bladders (typically 3) that will allow the catalyst to pass between them through the openings and into the lower empty space of the reactor tube. To start, the bladders are positioned above the tube's catalyst layer. Or, if the tube is completely empty, the bladders are 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 bladders are inflated, typically using nitrogen or dry service air. Then a "dense loading" technique is used to introduce the catalyst to just below the height of

the bladders. The bladders are then repositioned, typically 1 foot above catalyst layer, and the process is repeated until the tube is fully loaded with catalyst.

Figure 1 and Figure 2 represent a cross-sectional view of steam methane reformer (SMR) tube **101** utilizing the instant device and method. Each of at least three inflatable bladders **104** are attached at one end to, and preferably spaced evenly around, the perimeter of centering ring **103**. As indicated in Figure 6a (cross-sectional view, uninflated), Figure 6b (isometric view, uninflated), and Figure 7 (cross-sectional view, inflated), for ease of explanation, this assembly will be referred to as multiple bladder positioning system **110**.

As indicated in Figures 6a, 6b, and 7, 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 multiple inflatable bladders **104**. Pressurized gas conduit **107** connects directly to with multiple inflatable bladders **104**, thus allowing them to be inflated and deflated.

When inflated (as indicated in Figure 2), multiple inflatable bladders **104** make at least partial contact with reactor tube wall inner surface **102**, and act to locate centering ring **103** centrally within reactor tube wall inner surface **102**. Temperature measurement device **106** is located inside of centering ring **103**, and after inflation of multiple inflatable bladders **104** 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 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 2 – 12.

In a typical catalyst dense loading procedure, radial springs (or brushes) **115** are positioned at a predetermined spacing down the length of reactor tube **101**. Reactor tube **101** may be an SMR tube. Springs **115** radiate from a generally central circular ring and act to impede the catalyst as it falls down the length of reactor tube **101**. Springs **115** act to slow down the catalyst as it falls and helps prevent the catalyst from being damaged. It is understood that springs **115** may be used along with the instant invention. Springs **115** may be distributed along reactor tube **101**, in circular rings above the instant invention. These circular rings encompass temperature measurement device **106** and pressurized gas conduit **107**. These rings are sequentially withdrawn as the instant invention moves up reactor tube **101**. These

circular rings, from which springs **115** emanate, are connected to each other, and to positioning system **110** by tethers **116**.

Before the filling of reactor tube **101** with catalyst may commence, the tube is positioned in an essentially vertical orientation, and a sieve has been located at the distal end of the reactor tube, in order to keep the catalyst within the reactor tube. It is preferred that the inside of the tube 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 the reactor tube is clean.

First, temperature measurement device **106** 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 **106** from migrating up reactor tube **101** during the subsequent steps.

Starting at proximal end **114**, temperature measurement device **106** is then inserted down the length of the empty reactor tube. 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 **103** if desired (not shown). Then, while holding and extending centering ring tether **116**, lower multiple bladder positioning system **110** into reactor tube **101**. Then, lower multiple bladder positioning system **110** 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. Temperature measurement device **106** may be any device known to the art, suitable for this purpose. Temperature measurement device **106** may be a single thermocouple as indicated in Figure 3a. Temperature measurement device **106** may be a strand of multiple thermocouple sensors as indicated in Figure 3b.

Multiple bladder positioning system **110** 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 multiple bladder positioning system **110**.

When uninflated, Multiple inflatable bladders **104** are simultaneously inflated, 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**. A predetermined, or calculated amount of catalyst **112** is added to reactor tube **101**. Catalyst **112** passes through open area **107** between multiple inflatable bladders **104**, centering ring **103**, and tube wall inner surface **102**.

Utilizing a dense loading technique, catalyst **112** may be added at a prescribed filling rate to reactor tube **101** by any such system known in the art. As catalyst **112** is added to reactor tube **101**, it falls through the spaces between the multiple inflatable bladders **104** and settles into the void below. In order to promote better catalyst packing, and to help avoid unwanted voids in the catalyst, reactor tube **101** may be vibrated **117** while filling. When an amount sufficient to approximately fill this void has been added, filling stops and multiple inflatable bladders **104** are deflated.

Multiple bladder positioning system **110** 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 three feet. 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**. Care must be taken not to overfill with catalyst and covering device **110**.

In the second, and subsequent, iterations, catalyst **112** is allowed to fill the space below multiple inflatable bladders **104** as well. This ensures that catalyst **112** fully fills reactor tube **101**, and the temperature measurement device **106** remains centered. 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**.

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
5 invention is not intended to be limited to the specific embodiments in the examples given above.