Device And Method For Blowing Down and Measuring The Back Pressure of Chemical Reactor Tubes

Background

This application claims priority from and incorporates by reference U.S. Provisional application S.N. 60/276,780, filed March 16, 2001 and U. S. Provisional application S.N. 60/314,859, filed August 24, 2001.

The present invention relates to tubes in chemical reactors, and, in particular, to a device and method for measuring the back pressure in the tubes and for blowing dust out of the tubes.

Many chemical reactors use a catalyst as part of the reaction process. The catalyst material frequently is coated onto or contained in a substrate which is packed in tubes within the reactor. The reactants flow through the tubes and out the open ends of the tubes, reacting in the presence of the catalyst to form the products of the reaction. It is desirable to be able to measure the packing of catalyst within the tube in order to determine whether the tube will function properly. Ideally, the catalyst packing in all the tubes will be very close to the same. However, in reality, there is a variation in packings which adversely affects the efficiency of the reaction by providing for different residence times in different tubes.

In order to assess the catalyst packing, a constant flow rate test gas is injected into the tubes, and the back pressure is measured, with the back pressure being proportional to the packing density. Higher densities produce higher back pressures, and lower densities produce lower back pressures. High back pressures can also indicate problems other than high packing density, such as dust, fines, obstructions in tubes, and the presence of foreign material. Low back pressures can also indicate problems other than low packing density, such as bridging. The goal is to measure the back pressure on each tube and determine which tubes require corrective action. Then, once the appropriate corrective action has been taken, the corrected tubes can be retested.

Measurements may be taken when the tubes are first loaded with catalyst, in order to ensure that they are properly loaded, as well as periodically during the operation of the reactor, such as during normal maintenance shut-downs, and after cleaning. However, the devices and

methods that have been used in the past have been labor intensive and time consuming, their accuracy has depended largely upon the skill of the operator, and they have yielded data that is not readily usable.

In order to obtain a seal between the test device and the chemical reactor tube, the operator has typically inserted a stopper into the tube. Weldments at the top of the tube can interfere with the ability to obtain a good seal, and failure of the operator to maintain the device in a vertical orientation may also interfere with the ability to obtain a good seal. The operator typically must keep track of his position manually, and the data that is obtained is typically written down on a notepad by a second person, sometimes with the person who takes the measurements shouting over the noise of the plant to the person writing down the results. Also, the tubes are typically measured one at a time, requiring many workers and a long shut-down time. With typical prior art methods, it is difficult to keep track of all the measurements, since there may be as many as 35,000 tubes to be measured in a reactor, and transferring data from the many notepads is slow and provides an opportunity for errors. In order to display the progress of the measurement process, the operators usually put colored caps on the tubes as they are measured, which is time-consuming.

Summary of the invention

The present invention provides a device and method that improves the ability to measure the back pressure in tubes, making the process much more accurate, faster, less labor intensive, more efficient, safer, less dependent on the skill of the worker, and yielding more accurate and more useful results. In a preferred embodiment, the measuring device uses an inflatable, conforming seal, which provides a good seal between the measuring device and the chemical reactor tubes. Also, in a preferred embodiment, the measuring device measures multiple tubes at once rather than measuring only one tube at a time. Also, in a preferred embodiment, measurements are stored at the measuring device, are transmitted electronically to a remote computer, and are displayed graphically in real time at a remote display, such as in the control room, including indications of which tubes are within predetermined specifications and which are not.

The visual display helps the plant engineer determine which tubes require corrective action and may permit the elimination of the time-consuming prior art process of putting caps on all the tubes as the measurements are being taken.

Preferred embodiments of the present invention also permit automated handling of the data and prompt statistical analysis and cost-effectiveness analysis of the measurement data in order to help the plant engineer make quick decisions about corrective actions to be taken. The measurements that have been taken with a prototype device made in accordance with the present invention are so accurate that the engineers can begin to recognize what particular variations in pressure drops mean-for example, one pressure drop indicates that a foam pig accidentally has been left in the tube after cleaning, while another indicates that an extra clip has been inserted to retain the catalyst. In addition, in a preferred embodiment of the invention, a device and method are provided to remove dust from the tubes by blowing gas through them.

The gas used in the preferred embodiments as described herein may be air, nitrogen, or some other gas.

Brief Description of the Drawings

Figure 1 is a schematic front view, partially in section, of a chemical reactor including tubes packed with catalyst, and including a worker measuring the back pressure in the tubes in accordance with the present invention;

Figure 2 is a schematic view of a worker measuring the back pressure of the tubes in accordance with the present invention;

Figure 3 is a plan view of a tube layout for the reactor being measured, which is displayed on a graphic display as the measurements are being made;

Figure 4 is a schematic front perspective view of a device for measuring the back pressure of tubes, made in accordance with the present invention;

Figure 5 is a rear view of the device of Figure 4;

Figure 6 is a schematic front view of the device of Figure 4, with some parts removed for clarity;

Figure 7 is a schematic side view of the device of Figure 4;

Figure 8 is a schematic gas flow diagram for the device of Figure 4;

Figure 8A is a schematic gas flow diagram for the device of Figure 4 after it has been reconfigured for blowing down the chemical reactor tubes;

Figure 9 is a side view partially in section showing one of the injector tubes of the device of Figure 4;

Figure 10 is a side view partially in section of the umbilical wand portion of the device of Figure 4;

Figure 11 is a plan view of the control panel of the device of Figure 4;

Figure 12 is a schematic view of the graphic display shown at the remote computer in the arrangement of Figure 2;

Figure 12A shows a portion of the graphic display of Figure 12;

Figure 12B shows another portion of the graphic display of Figure 12;

Figure 13 is a broken-away schematic view of the upper portion of the reactor as the chemical reactor tubes are being blown down or measured by the device of Figure 4;

Figure 14 is a front view of a target for use with the device of Figure 4;

Figure 15 is a side view of the target of Figure 14;

Figure 16 is a view taken along the section 16-16 of Figure 15;

Figure 17 is a schematic front view of the device of Figure 4 after it has been reconfigured for blowdown;

Figure 18 is a perspective view of a calibration fixture for use with the device of Figure 4;

Figure 18A is an exploded perspective view showing how the tubes of the calibration fixture of Figure 18 are mounted on the frame, and this is the same mounting arrangement used for the tubes on the wand of Figure 4;

Figure 19 is a broken-away top view of the calibration fixture of Figure 18;

Figure 20 is a broken-away bottom perspective view of a portion of the calibration fixture of Figure 18;

Figure 21 is an electrical schematic of the device of Figure 4;

Figure 22 is an electrical schematic of the power and data module portion of Figure 21; and

Figure 23 is an electrical schematic of the blowdown control module of Figure 17.

Description of the preferred embodiments:

Figure 1 is a schematic view of a chemical reactor 10, including a plurality of tubes 12, which hold catalyst. The tubes 12 extend downwardly from an upper plate (or tube sheet) 11 and are open on the bottom, except for clips (not shown), which may be used to prevent the catalyst from falling out the bottom of the tubes. A manway 14 provides access for workers to get into the reactor 10. A worker 16 is shown inside the reactor 10, measuring the back pressure in the catalyst tubes 12. In other reactors, the top may be fully removable, providing improved access.

Figure 2 shows the worker 16 standing on the plate 11 and operating a hand-held wand 18, which measures the back pressure in the tubes 12. The details of the wand 18 are shown better in FIG. 4. The wand includes a handle 28, a wand body 26, and a plurality of injector tubes 30 rigidly mounted together to form a single portable unit which is sufficiently rigid that the injector tubes can be inserted simultaneously into their respective reactor tubes simply by picking up the wand 18 by the handle 28, aligning the wand 18 with the group of reactor tubes to be measured, and then lowering the wand's handle 28 so that all the injector tubes 30 enter into respective reactor tubes 12. When the wand 18 is inserted into a bank of ten tubes in the plate 11, it is self-supporting and rests on the plate 11. The wand 18 is connected to a gas line 20 and communicates with a remote computer 22 through a power and data module 24. In this particular embodiment, the gas line 20 is the plant air supply. The power and data module 24 may supply the power to the computer 22 and to the hand-held wand 18. However, the wand 18 preferably operates on battery power, and the computer 22 preferably operates on a battery or is plugged into a regular alternating current outlet. The wand 18 communicates with the power and data module 24 in real time by means of radio signals, but other means for transmitting data to the computer 22 could be used, such as hard wiring the wand 18 to the power and data module 24 or downloading data from the wand 18 onto a portable medium such as a disk, which can then be carried to the remote computer 22.

The remote computer 22 may be located in the control room or in some other convenient location.

Also shown in Figure 2 is a target 25, which is used by a laser measuring device 27 on the wand 18 to determine the position of the wand 18 in order to confirm which tubes 12 are being measured. The target 25 preferably is placed in the first tube 12 of a row, and serves as a reference point, as will be described later. While the target 25 has proven to be a convenient reference point for making measurements, other reference points could be used, such as the side wall of the reactor, for example.

Figure 4 shows that the laser measuring device 27 is fixed relative to the injector tubes 30 by being affixed to the wand. As a result, the distance measured by the laser to the reference point also establishes the position of each of the injector tubes 30 relative to the reference point. Thus, when the injector tubes 30 are placed in their respective receptacles, the reactor tubes 12 that are receiving those injector tubes can be identified automatically, based on the distance measured by the laser. So the injector tubes 30 are not only used to inject fluid but also function as probes which locate the tube positions.

Figure 3 is a plan view of the plate 11. This plan view is also a portion of the screen display that is shown on the display screen of the computer 22 to visually indicate the tubes that are being measured, as shown in Figure 12.

Prior to using the wand 18 in the reactor 10, a layout of the tubes is obtained and is made available to the computer 22 and to the controller 32 for the wand 18. This layout is shown graphically as in Figure 3. As the wand 18 is being used, the data from the wand 18 is stored at the wand 18 and is transmitted to the computer 22. This data is displayed on the screen of the computer 22 or other graphic interface, as will be explained later.

Figure 4 is a front schematic view of the wand 18. The wand 18 includes a hollow wand body 26 (see Fig. 5), with a hollow handle 28 at its upper end and a plurality of injector tubes 30 at its lower end. The wand 18 receives regulated pressurized gas (such as air, nitrogen, or another gas) through a gas line 20. The wand 18 defines two different gas paths for each injector tube 30-a test gas path and an inflation gas path. The test gas path provides the gas that passes through the injector tube 30 into the respective

chemical reactor tube 12 for testing the chemical reactor tube. The inflation gas path provides the gas that is used to inflate the seal on the injector tube 30 so that the injector tubes 30 of the wand 18 seal against the interior of the respective chemical reactor tubes 12.

As shown in Figure 9, each of the injector tubes 30 includes a hollow tubular member 52 defining an internal gas flow path 54 with an open bottom outlet through which the test gas passes into the respective chemical reactor tube 12. A gas-impermeable, elastic sleeve 56 is mounted over the tubular member 52 and is sealed against the tubular member 52 by means of upper and lower ferrules or clamps 58. A recess 60 is formed in the outer surface of the tubular member, and that recess 60 receives an inflation tube 62. The depth of the recess 60 preferably is the same as the thickness of the inflation tube 62 at the upper ferrule or clamp 58, so that a good seal is formed there. The inflation tube 62 forms an inflation gas path that allows gas to be injected between the outer surface of the tubular member 52 and the inner surface of the sleeve 56 in order to inflate the sleeve 56. The inflation tube 62 preferably is welded, adhered, or otherwise secured to the tubular member 52. The bottom of the tubular member 52 is threaded, and this particular tubular member 52 receives a frustro-conical guide member 80 on its threaded end, which helps guide the injector tube 30 into the chemical reactor tube 12.

Figures 4-10 show the main components of the wand 18. Mounted on the wand 18 is a main wand control box 34, which houses the main controls for the wand 18. An antenna 37 projects out of the control box 34. Below the main wand control box 34 is a secondary control box 35. A conduit 39 houses wires and a measuring tube 74A that extend between the control boxes 34, 35. A manual shut-off valve 36 can be used to shut off the flow of gas through the wand body 26. An inflation gas pressure regulator 38 regulates the pressure of gas going to the inflation tubes 62. An inflation path solenoid valve 42 (see Fig. 8) opens and closes the gas flow to the inflation tubes 62. An inflation path manifold 44 (see Fig. 7) distributes the incoming inflation gas to a plurality of hose fittings 46, which connect to hoses 48, which lead to the inflation gas paths 62 of the injector tubes 30.

In this particular embodiment, there are eleven injector tubes-ten injector tubes 30 mounted on a frame member 50, and the eleventh injector

tube 30A is on a freely-movable umbilical wand 18A, generally for use in locations that are not accessible by the larger wand 18. There is a cushion 83 on the bottom of the frame member 50 to help absorb the impact as the injector tubes 30 of the wand 18 are inserted into the chemical reactor tubes 12. It is preferred that a separate inflation path solenoid valve 42A be provided for the umbilical seal 30A, as shown in the schematic of Figure 21.

Referring to Figure 8, the test gas passes through the shut-off valve 36, through the main pressure regulator 40, and to the main manifold 64, which distributes the test gas to a plurality of needle valves or other constant flow devices 66, such as sonic nozzles, orifice plates, or precision orifices. From each constant flow device 66, the test gas passes through a respective T 68, and through the internal path 54 of the respective tubular member 52 into the respective chemical reactor tube 12. Another T fitting 70 is located just above each tubular member 52, and a measurement tube 72 extends from each fitting 70 to its respective inlet at the multiplex manifold at the multiplex valve 74. The outlet of the multiplex valve 74 is connected to a pressure sensor 76. A pressure switch 78 is in communication with each measurement tube 72, and, if the pressure in the line exceeds a predetermined limit, the pressure switch 78 closes and prevents the channel of the multiplex valve 74 corresponding to that measurement tube 72 from opening, thereby preventing gas communication with the digital pressure sensor 76. This protects the pressure sensor 76 from being damaged by exposure to high pressure gas.

When the wand 18 is being used to test a plurality of chemical reactor tubes 12, the test gas flows continuously through the tubular members 52 into the chemical reactor tubes 12, and the multiplex valve 74 goes through a cycle by which it puts each of the measurement tubes 72 in gas communication with the pressure sensor 76, one at a time. In this manner, a single pressure sensor 76 is used to measure the back pressure in all the injector tubes 30 of the wand 18. Since the gas flow entering the chemical reactor tubes 12 through the injector tubes 30 has been carefully regulated by the flow control devices 66 to establish a pressure drop across the flow control devices 66 and a constant gas flow to the tubes 12, the back pressure that is generated in each chemical reactor tube 12 is in proportion to the flow resistance produced by the catalyst in that chemical reactor tube 12. That

resistance, in turn, is proportional to the density with which the catalyst is packed (which is to be assessed by the testing operation). As the chemical reactor tube 12 becomes more and more packed, the back pressure approaches the pressure on the supply side of the flow control device 66.

It will be noted that at least the injector tubes 30 at the ends of the wand 18 and on the umbilical injector tube 30A have tapered end pieces 80, which help in guiding the wand 18 into the chemical reactor tubes 12 to be tested. Of course, tapered ends 80 could be provided for all the injector tubes 30 if desired. In this embodiment, the injector tubes 30 are arranged linearly, with an equal spacing between the injector tubes 30. However, other arrangements, such as a triangular array of injector tubes 30 could be provided if desired. The spacing between the injector tubes 30 can be adjusted, and different diameter injector tubes 30 may be used, depending upon the configuration of the reactor, as will be described later.

There is an interlock switch 82 on an adjustable position clip (see Fig. 5) which projects downwardly from behind the frame member 50. The purpose of the switch 82 is to ensure that the injector tubes 30 are inserted all the way into the chemical reactor tubes 12, and the switch 82 is contacting the plate 11, before the sleeves 56 can be inflated. When the interlock switch 82 closes, and the start switch 109 is depressed, the central processor 32 causes the inflation path solenoid valve 42 to open and initiates inflation of the sleeves 56. In this embodiment, the switch 82 signals the central processor 32 in the control box 34, which, in turn, closes a relay which opens the inflation path solenoid valve 42, allowing gas to pass through the inflation path manifold 44 to inflate the injector tubes 30. The switch 82 protects the sleeves or bladders 56 against overinflation by preventing them from inflating unless they are inside the chemical reactor tubes 12 to be tested.

The umbilical injector wand 18A (shown best in Figure 10) includes an injector tube 30A that is essentially the same as the other ten injector tubes 30, except that it is not fixed onto the main frame 50. Instead, as shown in Figure 5, it is connected to a longer gas inlet hose 84 and has a longer measuring tube 72A and longer inflation tube 62, so that it can be held in the operator's hand and inserted individually into one of the chemical reactor tubes 12. This is helpful in the event that some of the chemical reactor tubes

12 are not accessible by the regular bank of injector tubes 30. The umbilical injector tube 30A also includes a tubular member 52 defining an internal path 54, and a sleeve 56 and an inflation tube 62, which is used to inflate the sleeve 56.

At the top of the body of the umbilical wand 18A is a frame member 85, and a handle 86 is mounted onto the frame member 85. Projecting downwardly from the bottom of the frame member 85 is an interlock switch 82A, which serves the same function as the interlock switch 82 on the main frame 50, ensuring that the umbilical injector tube 30A is inserted into the chemical reactor tube 12 and the switch 82A is depressed against the plate 11 before the solenoid valve 42A is activated so that the sleeve 56 can be inflated. There is also a start switch 88 on the rear surface of the frame member 85, which the operator uses to initiate a test using the umbilical wand 18A. The tubular member 52 of the umbilical injector tube 30A mounts onto its frame member 85 in the same manner that the other injector tubes 30 mount onto their frame member 50, as will be described later.

A holster 90 (see Fig. 10) mounts on the main wand 18 to hold the umbilical injector tube 30A when the umbilical wand 18A is not in use. When the umbilical injector tube 30A is inside the holster 90, its sleeve 56 is enclosed and contained by the holster 90.

Figure 11 is a view looking down on the control box 34 of the wand 18. The control box 34 includes a display 92 as well as a number of controls. The display 92 in this example is indicating R: 7; T: 1, which tells the operator that the wand 18 is measuring the chemical reactor tubes 12 in row 7, beginning with tube 1. The display 92 in this view also includes ten pressure readings, which indicate the back pressure in tubes 1-10 of row 7. In the upper left corner is a stop button 94, which can be used to shut off the gas supply to the inflation tubes 62 and stop the measurement. Below that is a keyed switch 96, which is used for initializing and calibrating the unit. Next is a switch 98 that switches the unit between automatic and manual modes. Next is a switch 100 which permits the worker to alternate between viewing the measurements for the current set of chemical reactor tubes 12 and for the previous set of chemical reactor tubes 12. Next is a "find" button 102, which, when pushed, uses the laser measuring device 27 to take a distance measurement relative

to the target 25 to determine which group of chemical reactor tubes 12 is being measured. When the "find" button 102 is depressed, it also includes a light 102A, which lights up (see electrical schematic of Fig. 21). Next is a "first tube" button 104, which is depressed to indicate that the wand 18 is at the first tube in the particular row. This button also includes a light 104A (see Fig. 21), which lights up when the button is depressed. Next is a toggle switch 106 for increasing or decreasing the tube number on the display 92, and above that is a toggle switch 108 for increasing or decreasing the row number on the display 92. A "start" button 109 is located on the handle 28A of the wand 18 (see Figs. 5 and 6), and is depressed by the worker to begin the sequence for measuring a group of chemical reactor tubes 12.

Figures 3, 12, 12A, and 12B show an example of the graphic display that is available at the remote laptop computer 22. The data that is input into the laptop 22 and the central processor 32 prior to the test preferably also includes information as to which tube locations actually are taken up by thermocouples or actually house supporting structure or mechanical plugs rather than tubes. If so, this is shown on the screen even before any measurements are taken (as well as afterwards). For example, thermocouples may be shown in orange, while support structure may be shown in black. It should be noted that the modem 24 and computer 22 may be receiving data from several wands 18 at once. The initial layout specifies a row and tube number for every tube position, so that the data that comes in can be associated with a particular position on the stored layout.

As measurements are taken by the wand (or wands) 18, the data, including row and tube number location as well as the back pressure readings and the wand identifier are transmitted back to the modem 24 and are displayed at the computer screen 22. In this embodiment, the data is transmitted from the antenna 37 on the control box 34 to the antenna on the remote modem 24, but the data could be transmitted through wires, through an internet connection, or through other known transmission means. The data which is stored at the wand 18 could also be downloaded later to the remote computer 22.

This linked data transmitted from the wand is graphically displayed in pictorial format at the remote computer 22, as shown in Figures 3, 12, 12A, and 12B.

The view of Figure 3 showing the chemical reactor tubes 12 will indicate the tubes in various colors as they are measured, depending upon whether they have passed the preset criteria for the test. For example, if the tube back pressure measurement is within the specifications for that reactor, then that tube will show up in green on the screen. If the tube fails high, it will show up in red. If it fails low, it will show up in yellow. If the tube back pressure is so high that it is considered plugged, it will show up in dark gray. If the tube back pressure is so low that it is considered open, it will show up in white. Untested tubes show up as a gray ring with a black dot in the center. Of course, this proposed color scheme could be altered by the user if desired, as long as the color usage is consistent. It should also be noted that separate data sets may be kept for various conditions of the reactor, such as for measurements taken after cleaning out the tubes, after filling the tubes, after blowing down the tubes, after operation of the reactor for a period of time, for sample measurements that may be taken to establish the test specifications, and for measurements taken after various corrective actions are taken. Also, these data sets may be stored during the life of the reactor, providing the plant engineer with valuable historic information about the reactor.

The person viewing the computer screen may choose to zoom in on a particular section of the reactor, if desired. If the person viewing the screen wants information about a particular chemical reactor tube 12, he moves his cursor over that tube in the portion of the screen shown in the graphic of Figure 3, and the information for that tube will appear in the portion of the screen shown in Figure 12A. For example, the sample shown in Figure 12A indicates that we are viewing the information for row #12, tube #12. The display indicates the pressure in the most recent test, the status of the tube, the wand 18 which took the measurement, and the date, time, and operator for that measurement. There is also a graphic indicator in the upper right of the screen of Figure 12A, with rings of color indicating the status of this tube in previous measurements and in the current measurement.

The circle 112 includes an outer band 114, which has a color indicating which wand 18 took the most recent measurement prior to correction. Just inside the outer band 114 is a large color field 116, which indicates by color the results of the most recent test prior to correction. Then there is an inner band 118, which indicates by color which wand took the most recent test after correction. Inside the inner band 118 is another color field 120, which indicates by color the results of the most recent test after correction, and the number 122 inside that field 120 represents the number of times the tube has been retested during the correction process. So, in this case, if the outermost band 114 is blue, that indicates that the blue wand conducted the most recent test prior to making corrections. If the color field 116 just inside the outer band is red, that indicates that the tube failed high on the most recent test prior to correction. If the inner band 118 is also blue, that indicates that the same wand conducted the most recent test during the correction process, and if the small inner color field 120 is green, that indicates that the tube has now passed. The number "2" inside the color field 120 indicates that this tube has been retested twice during the correction process. The original test data are not shown in this icon, but they are stored and can be retrieved as desired. Since the display for any particular tube in Figure 3 is too small to include all this detail, it will, by default, simply show the color indicating the results of the most recent test. However, if the plant engineer wanted to view the display of Figure 3 for any historic data set, he could obtain that as well.

The portion of the display shown in Figure 12A also indicates the row and tube, the pressure measured for that tube, the last status as of the previous measurement (if any), the wand number, date, time, and operator for the measurement. Below the data for that particular tube is data about the test in general-the total number of tubes, the number of tubes tested, the percent completed, and statistical information. The plant engineer may access the complete information for any tube simply by pointing to the particular tube on the display of Fig. 3 with the cursor, or he may input the particular tube and row number, or he may run a "list to fix" report or other report, pick up the tubes with problems from that report, and may access the data about those tubes by clicking on them in the report.

Figure 12B shows additional data that is presented on the computer screen. This portion provides the specifications for what pressure would be considered a failure on the high side, what pressure would be considered a failure on the low side, what pressure would indicate that the tube is plugged, and what pressure would indicate that the tube is open. It also indicates how many tubes met those criteria, and what those tubes' failure costs in terms of lost production, wasted reactants, and so forth. There is also an analysis of the number and percentage of tubes that met the criteria for being within the specifications for each test.

In addition to the data shown in these figures, the computer 22 generates a "list to fix", which is a prioritized list of which tubes should be corrected and what should be done to correct them, based on the criteria that have been set, such as cost or pressure criteria.

Of course, once the data has been acquired, the information displayed in these screens can be varied, depending upon what the user wants. For example, the plant engineer may wish to display the "list to fix", indicating in order of priority which chemical reactor tubes 12 should be plugged, which tubes should be blown down, which tubes should be re-loaded with catalyst, and so forth. The plant engineer may set his own criteria, which the computer 22 will use to establish the "list to fix", prioritizing the list based on the criteria that have been established by the plant engineer. The criteria that are established to set the specifications for what is a failure on the high side or the low side and what is "plugged" or "open" may be specific pressure readings, or they may be based on a statistical analysis of the data. As more data is collected, and as the plant engineer has more experience with the actual pressure data, actual production data, and actual costs, the specifications for determining which tubes pass and which tubes have the highest priority for corrections, and the way the data is used may become much more sophisticated.

The information provided by this arrangement, the speed with which it is delivered, its accuracy, as well as the way it is presented, make it very useful for the plant engineer. The plant engineer now has a way of determining the cost of out-of-specification tubes and the ability to pinpoint them and correct them promptly during the plant shut-down, when time is of

the essence. He then can adjust his specification criteria and cost information based on experience. Since the wand reports each tube's measurements back to the computer 22, the plant engineer knows for certain, as the test is being conducted, that the equipment tubes 12 have been tested. This system provides a quality control check on the installers of catalyst. This device and method provide a tremendous amount of useful information in very user friendly format that the plant engineer has never had before. In a variety of ways, it helps the plant engineer make better decisions to improve the efficiency of the plant.

In the prior art, each chemical reactor tube 12 was capped in a certain color as the testing process was proceeding in order to provide a visual indication of the test results and the progress of the test. If desired, a detachable tube capping guide 33 (shown in Figure 2) may be plugged into the control box 35, including ten rows of lights, with three different colors of lights 33A for each injector tube 30, to indicate by the color of light that is lit up by the central processor 32 whether that tube failed high, failed low, or passed the test criteria. The operator could then use that guide to place the appropriate color of cap onto each tube as the measurements progress. However, it is expected that the visual data provided at the computer 22 will be so much more helpful than were the prior art caps that plant engineers will find the capping step to be unnecessary and will decide to save money by eliminating the use of caps in tests that use the wand 18.

In addition, a simulation package may be provided to the plant engineer prior to taking measurements, to give the plant engineer experience in making decisions about corrective actions to be taken before the measurements are even taken. This may help the plant engineer make quick decisions during the plant shut-down, when time is especially valuable.

Figure 13 shows schematically the laser measurement device 27 on the wand 18 measuring a distance back to a target 25, which is mounted in the first tube 12 of the row of chemical reactor tubes 12 being measured. The laser measurement device 27 shines a light onto the reflector portion 110 of the target 25, and the light is reflected back to the device 27, establishing a distance measurement from the wand to the target, which is converted by the microcomputer 32 to a tube number. The software also permits the operator

to put the flag into a different chemical reactor tube 12 other than the first tube and to instruct the central processor 32 to compensate accordingly, so that the central processor 32 always indicates the correct position of the wand 18. As shown in Figures 15 and 16, the target 25 has two legs 111, which fit into two adjacent chemical reactor tubes 12 in a row. One of the legs 111 preferably is mounted in a slot in order to permit adjustment of the spacing between the legs 111 to fit the spacing between chemical reactor tubes 12 in a particular reactor.

When the first tubes in a row are being measured, there is no reflector present, and the operator simply presses the "first tube" button104 on the control panel to indicate that the first injector tube 30 on the wand 18 is being inserted into the first chemical reactor tube 12 in that row. When the operator removes the wand 18 from the first group of tubes, he inserts the reflector 110, and thereafter the display 92 on the control box 34 automatically indicates the tube position being measured based on the distance measurement from the laser measurement device 27. After the wand 18 has measured the end of a row, the display 92 automatically increases the row number in preparation for measuring the next row.

Figure 17 shows a wand 18 that has been reconfigured for use in blowing down the chemical reactor tubes 12. (While it is possible to use the wand 18 in its initial configuration to blow down tubes, the flow control devices 66 may prevent a high enough volume of gas from flowing through to be effective for blowing down the chemical reactor tubes 12 to remove dust. In that case, this reconfiguration may be used.) While there is still a gas inlet at the handle 28 in order to inflate the sleeves 56, a new gas inlet 124 has been provided to supply high volume gas for blowdown. This new gas inlet 124 feeds the main manifold 64, but the flow control devices 66 have been removed from the line, so that the gas simply flows straight through the main manifold 64 and through the lines 84, through the internal paths 54 of the tubes 52, and into the chemical reactor tubes 12. This permits a high volume of gas to be supplied into the chemical reactor tubes 12 to blow them down, removing dust. The operator may choose not to take pressure measurements during the blow-down operation, or the wand may be configured not to take pressure measurements during blow-down, if desired. However, the display

92 on the control panel of Figure 11 will show which chemical reactor tubes 12 are being blown down, and the data may be transmitted to the laptop computer 22, indicating which tubes are being blown down, which wand 18 is being used, and the time and date of the procedure. The visual display 92 then will show the chemical reactor tubes 12 that have been blown down by indicating those tubes in a special color. This provides quality control, so the plant engineer can confirm that the tubes actually have been blown down.

While the wand 18 can be converted back and forth from the measurement mode to the blowdown mode, with the configurations shown here, it takes time to make the conversion. Therefore, it may be preferable simply to provide two different types of wands-one for taking measurements and one for blowdown. Alternatively, a valving arrangement may be provided to permit conversion from one mode to the other simply by opening and closing valves to open and close the different pathways that are used for the different operations, preferably bypassing the flow control devices 66 and closing the flow through the measurement tubes 72 during the blow down operation. Or, if sufficient gas flow can be achieved in the normal measurement arrangement to accomplish effective blowdown, then the original configuration of the wand may be used, and the wand's central processor 32 may simply provide for a delay in taking measurements, so that the test gas is first used for blowdown and then for taking measurements.

In the blowdown mode of Figure 17, the control box 34 continues to function, using the laser measurement device 27 and target 25 to determine the chemical reactor tubes 12 that are being blown down and sending that information to the remote computer 22.

Figure 8A shows the gas flow arrangement for the blowdown mode of Figure 17. In that arrangement, the inflation gas route is the same as in the measurement mode. However, instead of the regular test gas route, the test gas used for blowdown simply goes through a valve, and then through the main manifold 64 to all the tubular members 52.

Figures 18-20 show a test stand 126 used to calibrate the wand 18 for taking back pressure measurements. The stand 126 includes a frame member 128, which is supported on base frame members 130 by means of

uprights 132. Several calibration tubes 134 are mounted on the frame member 128.

As shown in Figure 18A, the frame member 128 has a substantially U-shaped cross-section and includes lips 129 that project inwardly toward the base 131 of the U Straps 133 have T-shaped ends, including hooked portions 135, which fit into the recesses 137 formed in the frame member 128. The straps 133 preferably are assembled onto the frame member 128 by sliding them in from the end, and their shape, in cooperation with the shape of the frame member 128, restricts their movement relative to the frame member to linear movement along the frame member 128. A plastic end piece 138 is placed over the end of the calibration tube 134, and the straps 133 are clamped together around the end piece 138 and calibration tube 134 by means of bolts 140 and nuts 142, with the bolts 140 extending through holes 144 in the straps 133. This mounting arrangement allows the position of the calibration tube 134 to be adjusted along the length of the frame member128 by sliding the straps 133 linearly along the frame and then to be fixed in place once the bolts 140 are tightened.

The uprights 132 are secured to the frame members 128,130 in the same manner that the calibration tubes 134 are mounted onto the frame member 128, and the injector tubes 30 are secured onto the frame 50 of the wand18 in the same manner as well. This permits adjustment of the positions of the injector tubes 30 along the frame members, and it permits different sizes of injector tubes 30 to be used on the same frame member 50. In this manner, the wand 18 can be reconfigured for measuring different reactors, having different tube diameters and different tube spacings.

Each of the calibration tubes 134 is closed at the bottom, except for a precision orifice 136 (see Fig. 20), which imitates the effect of the packing in the open-ended chemical reactor tubes 12. In order to calibrate the wand 18, the injector tubes 30 are inserted into the calibration tubes 134, gas is sent through the inflation path to seal the injector tubes 30 against the inside of the calibration tubes 134, and then gas is sent through the test path, and a back pressure reading is taken for each chemical reactor tube 12. The central processor 32 then generates correction factors as needed for each injector tube 30 in order to correct for any variations in the measurements, and these

correction factors are used by the central processor 32 as the chemical reactor tubes 12 in a reactor are measured, in order to standardize the measurements from one injector tube 30 to another.

Figures 21 and 22 are an electrical schematic of the wand 18, showing the inputs and outputs to and from the central processor 32, which have already been described. There is a direct current power connection to the control box 34 of the wand 18, which may come from the remote power and data module 24 or from another power source. Measurements taken by the wand 18 may be transmitted through a modem and antenna 37 on the wand 18 to the antenna on the remote power and data module 24, or they may be transmitted through another means, as discussed earlier. The power and data module 24 communicates with the laptop computer 22. Alternatively, the data may simply be stored in the wand 18 and later downloaded to the remote computer 22.

Figure 23 shows the additional controls that are added for the blowdown mode as shown in Figure 17. These controls take their power from the main control box 34 for the wand 18 through a power cord 146, and the valve 148 which opens a gas path from the inlet 124 to the main manifold 64 is only opened after the seals 56 are inflated.

In a typical setting, the wand 18 (or several wands 18) would be prepared with injector tubes 30,30A having the correct diameters and spacings for the reactor to be measured. The configuration of the reactor, including the locations of the chemical reactor tubes 12 would be loaded into the wand central processor 32 and into the laptop computer 22. Then, the wands 18, power and data module 24, laptop computer 22, and calibration or test stand 126 would be transported to the site.

If blowdown is to be done first, then the wands 18 may be configured for blowdown, or special blowdown wands may be used if needed. The workers would then go along the plate 11, blowing down all the chemical reactor tubes 12. The workers would take their wands 18 to the end of a row, would use the toggle switch 108 if needed to make sure the display 92 is indicating the correct row, would insert the injector tubes 30 into the first group of chemical reactor tubes 12 in the row, and would push the "first tube" button 104, to indicate that the first tube is being measured. Then, the worker would

push the "start" button 109 on the handle 28A. If the switch 82 is depressed, indicating that the wand 18 has been properly inserted into the chemical reactor tubes 12, then, when the "start" button 109 is pushed, the central processor 32 would open the solenoid valve 42 for the tube seals, inflating the sleeves 56 to seal against the inside of the chemical reactor tubes 12. The test gas would be flowing through the injector tubes 30 continuously. Once the first group of chemical reactor tubes 12 has been blown down, the worker would move to the next group of ten (or whatever number is provided on the wand) and would insert the target 25 into the first two tubes of the row so that the laser measuring device 27 could automatically measure the distance from the wand 18 to the target 25, thereby automatically determining which chemical reactor tubes 12 are being blown down. The central processor 32 would transmit this information electronically to the power and data module 24, telling it which wand 18 is being used, the time and date, and which chemical reactor tubes 12 are being blown down. (The identification of the worker who is using the wand 18 is expected to be in the set-up information that is input into the computer 22 before the test and therefore would not have to be transmitted.) The power and data module 24 would, in turn, transmit this information to the laptop computer 22, so the plant engineer could see in real time on the computer screen the chemical reactor tubes 12 being blown down. If the wand 18 does not have to be reconfigured for blow-down, then the workers may perform the blow-down and the back-pressure measurement in one step, inserting the wand 18 into a bank of reactor tubes 12, blowing down the tubes, and then measuring the back pressure in the tubes before moving on to the next group of reactor tubes 12.

Before measurements are taken, the wands 18 would be configured for taking measurements and would be calibrated at the test stand 126. Again, each worker would take his wand 18 to the beginning of a row of chemical reactor tubes 12 to be measured and would insert the injector tubes 30 into the chemical reactor tubes 12. He would then use the row toggle switch 108 to make sure the correct row is showing on the display 92 and would then press the "first tube" button 104. Then, he would push the "start" button 109. If the switch 82 indicates that the injector tubes 30 are properly inserted into the chemical reactor tubes 12, the central processor 32 would open the

solenoid valve 42 to inflate the seals on the injector tubes 30. Then, the central processor 32 would open the multiplex valve 74, one channel at a time, permitting the pressure sensor 76 to measure the back pressures in the measurement tubes 72 one at a time, until the back pressure for all the injector tubes 30 has been measured, stored at the wand 18, and transmitted to the power and data module 24.

Once the first group of chemical reactor tubes 12 has been measured, the worker would move to the next group (of ten tubes in this arrangement) and would insert the target 25 in the first tube. Thereafter, the central processor 32 will automatically keep track of which chemical reactor tubes 12 are being measured, with the operator simply pressing the "start" button 109 each time a group of chemical reactor tubes 12 is to be measured, thereby causing the wand 18 to take the distance and pressure measurements and transmit the data for each chemical reactor tube 12 to the power and data module 24. If the worker comes to an obstacle or to the end of a row, he will put his tenth (or last) injector tube 30 into the last tube before the obstacle or the last tube at the end of the row, and may re-measure some of the chemical reactor tubes 12 that have already been measured.

If the worker comes to a chemical reactor tube 12 that cannot readily be reached by the whole wand 18, he may choose to use the umbilical wand 18A. This works in the same manner as the regular measurements, except that the worker would use the switch 98 to put the wand 18 into the manual mode and would use the toggle switches 106, 108 to be sure the correct tube row and tube number are being indicated. Then he would press the "start" switch 88 on the umbilical wand 18A, and, if the interlock switch 82A is closed, indicating that the injector tube 30 is fully inserted into the chemical reactor tube 12 to be tested, a measurement will be taken.

Adjustments for changed conditions

Since testing a reactor with as many as 30,000 chemical reactor tubes 12 can take a number of hours, even when using multiple wands 18 at the same time, changes in ambient conditions and in gas supply conditions during the test period can affect the pressure measurements. These changes may be corrected for based on the gas law pv=nrT. Changes in the ambient environment and in the gas supply that may be measured and adjusted for

include: supply gas temperature, supply gas pressure, discharge gas temperature, barometric pressure, and ambient temperature. Also, chemical reactor tube 12 temperature changes may be considered and corrected for based on Darcy's equation. These pressure and temperature changes may be measured during the vessel testing period, and corrections to the pressure measurements may be made to assure that the results reflect a standard condition of pressure, temperature and flow as initially calibrated, such that all pressure results correlate to the standard condition established when testing began. This is an especially important consideration if testing must be interrupted for an unrelated plant emergency or for inclement weather. Since these parameters generally change slowly over time, they can be measured with each and every use of the wand or at specified periods during the testing process. These measurements can be made on or off the wand 18 and applied to the raw pressure measurements or stored in the memory of the wand 18 or of the host computer 22 for later analysis.

The embodiments described above are intended simply as examples of devices and methods in accordance with the present invention. It will be obvious to those skilled in the art that a wide variety of modifications may be made to the embodiments described above without departing from the scope of the present invention.

What is claimed is:

1. A device for measuring back pressure in open-ended chemical reactor tubes, comprising:

a wand body having upper and lower ends;

a handle mounted on said wand body;

a plurality of injector tubes mounted adjacent said lower end;

a gas inlet on said wand body;

a test gas path from said gas inlet through said injector tubes, including a flow control device in said test gas path;

at least one pressure sensor mounted on said wand body; and

at least one measurement path from one of said injector tubes to said pressure sensor for measuring the back pressure in said one injector tube; wherein said wand body, said handle, and said injector tubes are rigidly mounted together to form a single unit which is sufficiently rigid that said plurality of injector tubes can be inserted simultaneously into their respective reactor tubes by moving said handle.

2. A device as recited in claim 1, and further comprising inflatable seals on said injector tubes and inflation gas paths from said gas inlet to said inflatable seals.

3. A device as recited in claim 1, wherein said flow control device is a precision orifice.

4. A device as recited in claim 1, and further comprising means for associating measurements taken by said pressure sensor with the specific tubes for which the measurements are taken, and means for electronically storing that associated data on the wand.

5. A device as recited in claim 1, and further comprising a frame portion on said wand body, said frame portion having a bottom surface, wherein said plurality of injector tubes is mounted on said frame portion, with

said injector tubes projecting downwardly from said bottom surface; and further comprising a cushion mounted on said bottom surface.

6. A device as recited in claim 5, and further comprising seals on said injector tubes below the bottom surface of said frame portion.

7. A device as recited in claim 1, and further comprising an umbilical wand body including an umbilical handle and an umbilical injector tube, and a flexible tube connecting said umbilical wand body to said wand body so the umbilical wand body can move independently of the wand body.

8. A device for measuring back pressure in open-ended chemical reactor tubes, comprising:

a wand body having upper and lower ends;

a handle mounted on said wand body;

a plurality of injector tubes mounted adjacent said lower end;

a gas inlet on said wand body;

a test gas path from said gas inlet through said injector tubes, including a flow control device in said test gas path;

at least one pressure sensor mounted on said wand body; and

at least one measurement path from one of said injector tubes to said pressure sensor for measuring the back pressure in said one injector tube,

wherein said pressure sensor is a digital pressure sensor; and further comprising:

a multiplexing valve in gas communication with said digital pressure sensor; and

a plurality of measurement gas paths from said injector tubes to said multiplexing valve.

9. A device as recited in claim 8, and further comprising:

means for transmitting the pressure measurement for a specific chemical reactor tube electronically from said pressure sensor to a remote location.

10. A device as recited in claim 9, and further comprising:

means for receiving the pressure measurements at a remote location; and

display means, in communication with said receiving means, for graphically displaying the layout of the tubes and the pressure data in real time as it is being measured.

11. A device for measuring back pressure in open-ended chemical reactor tubes, comprising:

a wand body having upper and lower ends;

a handle mounted on said wand body;

a plurality of injector tubes mounted adjacent said lower end;

a gas inlet on said wand body;

a test gas path from said gas inlet through said injector tubes, including a flow control device in said test gas path;

at least one pressure sensor mounted on said wand body;

at least one measurement path from one of said injector tubes to said pressure sensor for measuring the back pressure in said one injector tube;

inflatable seals on said injector tubes;

inflation gas paths from said gas inlet to said inflatable seals; and

an interlock switch which prevents the inflatable seals from being inflated unless said injector tubes are properly inserted into their respective chemical reactor tubes.

12. A device as recited in claim 11, and further comprising a multiplexing valve in gas communication with said pressure sensor.

13. A device for measuring back pressure in open-ended chemical reactor tubes, comprising:

a wand body having upper and lower ends;

a handle mounted on said wand body;

a plurality of injector tubes mounted adjacent said lower end;

a gas inlet on said wand body;

a test gas path from said gas inlet through said injector tubes, including a flow control device in said test gas path;

at least one pressure sensor mounted on said wand body;

at least one measurement path from one of said injector tubes to said pressure sensor for measuring the back pressure in said one injector tube;

seals on said injector tubes; and

a laser measuring means on said wand body for automatically measuring the position of said wand relative to a reflecting surface.

14. A device as recited in claim 13, and further comprising a multiplexing valve in gas communication with said pressure sensor.

15. A device as recited in claim 13, and further comprising inflatable seals on said injector tubes.

16. A device as recited in claim 15, and further comprising means for transmitting the pressure measurement for a specific chemical reactor tube electronically from said pressure sensor to a remote location.

17. A device as recited in claim 16, and further comprising means for receiving the pressure measurements at a remote location; and

display means, in communication with said receiving means, for graphically displaying the layout of the tubes and the pressure data in real time as it is being measured.

18. A device for measuring back pressure in open-ended chemical reactor tubes, comprising:

a wand body having upper and lower ends;

a handle mounted on said wand body;

a plurality of injector tubes mounted adjacent said lower end;

a gas inlet on said wand body;

a test gas path from said gas inlet through said injector tubes, including a flow control device in said test gas path;

at least one digital pressure sensor mounted on said wand body;

a multiplexing valve in gas communication with said digital pressure sensor;

a plurality of measurement gas paths from said injector tubes to said multiplexing valve and at least one measurement gas path from said multiplexing valve to said digital pressure sensor for measuring the back pressure in said injector tubes;

means for transmitting the pressure measurement for a specific chemical reactor tube electronically from said pressure sensor to a remote location; and

a laser measuring means on said wand body for automatically measuring the position of said wand relative to a reflecting surface.

19. A device for measuring back pressure in open-ended chemical reactor tubes, comprising:

a wand body having upper and lower ends;

a handle mounted on said wand body;

a plurality of injector tubes mounted adjacent said lower end;

a gas inlet on said wand body;

a test gas path from said gas inlet through said injector tubes, including a flow control device in said test gas path;

at least one pressure sensor mounted on said wand body;

at least one measurement path from one of said injector tubes to said pressure sensor for measuring the back pressure in said one injector tube; and

slidable mounting means, by which said injector tubes are mounted on said wand body.

20. A device for measuring back pressure in open-ended chemical reactor tubes, comprising:

a wand body having upper and lower ends;

a handle mounted on said wand body;

a plurality of injector tubes mounted adjacent said lower end;

a gas inlet on said wand body;

a test gas path from said gas inlet through said injector tubes, including a flow control device in said test gas path;

at least one pressure sensor mounted on said wand body;

at least one measurement path from one of said injector tubes to said pressure sensor for measuring the back pressure in said one injector tube; and

interlock means to prevent high pressure gas from reaching said pressure sensor.

21. A device for use with reactor tubes in a chemical reactor, comprising:

at least one probe sized to fit into a chemical reactor tube;

an automatic measuring device fixed relative to said probe for automatically measuring the distance to a fixed reference point within the chemical reactor; and

means for automatically identifying the reactor tube in which said probe is inserted based on the distance measured by said automatic measuring device.

22. A device for use with reactor tubes in a chemical reactor as recited in claim 21, wherein said automatic measuring device includes a laser.

23. A device for use with reactor tubes in a chemical reactor as recited in claim 22, and further comprising a target including at least one leg sized to fit into one of said chemical reactor tubes.

24. A device for use with reactor tubes in a chemical reactor as recited in claim 22, and further comprising:

means for automatically electronically storing data identifying the reactor tube in which said probe is inserted.

25. A device for use with reactor tubes in a chemical reactor as recited in claim 24, and further comprising:

means for transmitting the data identifying the reactor tube to a remote location.

26. A device for use with reactor tubes in a chemical reactor as recited in claim 25, and further comprising:

means for graphically displaying the identity of said identified reactor tube at said remote location.

27. A device for use with reactor tubes in a chemical reactor as recited in claim 26, wherein said means for graphically displaying includes means for displaying the identity of said identified reactor tube at said remote location shortly after the distance measurement is taken so an operator at the remote location can watch the progress of the device as its probe is moved from one reactor tube to another within the reactor.

28. A device for use with reactor tubes in a chemical reactor as recited in claim 21, wherein said probe is a tubular member having an outer surface and an inner surface, said inner surface defining an internal fluid path; said device further comprising:

a fluid inlet in fluid communication with said internal fluid path.

29. A device for use with reactor tubes in a chemical reactor as recited in claim 28, and further comprising:

a plurality of injector tubes fixed relative to each other and to said tubular member, said injector tubes being spaced apart and sized to fit into respective reactor tubes, each of said injector tubes also defining an internal fluid path in fluid communication with said fluid inlet; and

means for automatically identifying the reactor tubes which receive said injector tubes based on the distance measured by said automatic measuring device.

30. A device for use with reactor tubes in a chemical reactor as recited in claim 28, and further comprising:

a tubular elastic sleeve mounted over said outer surface of said tubular member, said elastic sleeve having both an upper end and a lower end sealed against said outer surface to define a sealed space between said elastic sleeve and said outer surface; and

an inflation tube in fluid communication with said fluid inlet and extending into said sealed space for inflating said elastic sleeve in order to allow it to seal against its respective chemical reactor tube.

31. A device for use with reactor tubes in a chemical reactor as recited in claim 30, and further comprising:

a plurality of injector tubes fixed relative to each other and to said tubular member, said injector tubes being spaced apart and sized to fit into respective reactor tubes, each of said injector tubes including a tubular elastic sleeve having upper and lower ends sealed against their respective injector tube to define a sealed space between the injector tube and the sleeve and an inflation tube extending into the respective sealed space for inflating said elastic sleeve.

32. A device for use with reactor tubes in a chemical reactor as recited in claim 30, wherein said outer surface of said tubular member defines a recess, and a portion of said inflation tube is received in said recess and extends along said outer surface.

33. A device for use with reactor tubes in a chemical reactor as recited in claim 30, and further comprising:

at least one constant flow device in fluid communication with said internal fluid path; and

a pressure sensor in fluid communication with said internal fluid path.

34. A device for use with reactor tubes in a chemical reactor as recited in claim 33, wherein said constant flow device is a precision orifice.

35. A device for injecting fluid, comprising:

a fluid inlet;

at least one tubular member having an outer surface and an inner surface, said outer surface defining a recess and said inner surface defining an internal fluid path;

a tubular elastic sleeve mounted over said outer surface of said tubular member, said elastic sleeve having upper and lower ends sealed against the outer surface of said tubular member to define a sealed space between said elastic sleeve and said outer surface of said tubular member; and

an inflation tube received in said recess and extending along said outer surface of said tubular member from outside said sealed space to inside said sealed space, said inflation tube being in fluid communication with said fluid inlet for inflating said elastic sleeve.

36. A device for injecting fluid as recited in claim 35, wherein the depth of said recess is substantially the same as the thickness of the inflation tube that is lying in said recess in order to provide a substantially smooth surface against which one of the upper and lower ends of said elastic sleeve seals.

37. A device for injecting fluid as recited in claim 35, wherein said internal fluid path is also in fluid communication with said fluid inlet.

38. A device for injecting fluid as recited in claim 35, and further comprising:

a plurality of injector tubes fixed relative to each other and to said tubular member, each of said injector tubes including a tubular elastic sleeve and an inflation tube for inflating its respective elastic sleeve.

39. A device for injecting fluid as recited in claim 38, and further comprising:

a wand body having upper and lower ends, wherein said injector tubes are mounted adjacent said lower end.

40. A device for injecting fluid as recited in claim 35, and further comprising:

at least one constant flow device in fluid communication with said internal fluid path; and

a pressure sensor in fluid communication with said internal fluid path.

41. A device for injecting fluid as recited in claim 40, wherein said at least one constant flow device is a precision orifice.

42. A device for injecting fluid as recited in claim 35, and further comprising:

an interlock switch which prevents said elastic sleeve from being inflated until said tubular member is properly inserted into a receptacle.

43. A device for injecting fluid as recited in claim 38, and further comprising:

an interlock switch which prevents said elastic sleeves from being inflated until said injector tubes and said tubular member are properly inserted into receptacles.

44. A device for injecting fluid as recited in claim 40, and further comprising:

means for automatically electronically storing pressure measurements from said pressure sensor.

45. A device for injecting fluid as recited in claim 44, and further comprising:

means for transmitting said electronically stored pressure measurements from said pressure sensor to a remote location; and

means for receiving said pressure measurements at said remote location.

46. A device for injecting fluid as recited in claim 45, and further comprising:

display means for displaying said electronically stored pressure measurements at said remote location.

47. A device for injecting fluid as recited in claim 46, wherein said display means is graphical and displays a plurality of pressure measurements associated with a plurality of locations.

48. A method for working on reactor tubes in a chemical reactor, comprising the steps of:

establishing a reference point inside the reactor;

inserting a probe into one of the reactor tubes;

automatically measuring the distance between a point fixed relative to the probe and the reference point; and

automatically identifying the reactor tube in which said probe is inserted based on the measured distance.

49. A method for working on reactor tubes in a chemical reactor as recited in claim 48, wherein the step of automatically measuring the distance is performed by a laser measurement device.

50. A method for working on reactor tubes in a chemical reactor as recited in claim 48, wherein said probe is an injector tube, and further comprising the steps of:

sealing between said injector tube and said reactor tube; and

injecting fluid through said injector tube into said reactor tube.

51. A method for working on reactor tubes in a chemical reactor as recited in claim 50, wherein said step of sealing between said injector tube

and said reactor tube includes inflating an elastic sleeve that is mounted on said injector tube.

52. A method for working on reactor tubes in a chemical reactor as recited in claim 50, and further comprising the steps of:

measuring the pressure in said chemical reactor tube;

automatically associating the pressure measurement with the particular chemical reactor tube being measured;

storing the associated pressure measurement and data identifying the particular chemical reactor tube;

electronically transmitting the associated pressure measurement and data identifying the particular chemical reactor tube to a remote location;

receiving the pressure measurement and associated data at the remote location; and

graphically displaying the associated measurement and tube identification at the remote location.

53. A method for working on reactor tubes in a chemical reactor as recited in claim 52, wherein said graphical display also displays the layout of the chemical reactor tubes.

54. A method for working on reactor tubes in a chemical reactor as recited in claim 53, wherein said display uses color on the graphical layout of the chemical reactor tubes to show how the pressure measurements compare to a set of pressure specifications for the respective reactor tubes.

55. A method for working on reactor tubes in a chemical reactor as recited in claim 54, and further comprising the step of:

generating a list of the reactor tubes that need corrective action based on comparing said pressure measurements to said pressure specifications.

56. A method for assessing reactor tubes in a chemical reactor, comprising the steps of:

providing a device for injecting gas and measuring pressure, said device including a plurality of injector tubes, a plurality of inflatable elastic sleeves mounted on their respective injector tubes, and a start button;

inserting said plurality of injector tubes into respective reactor tubes; and

pressing said start button which initiates an automatic sequence of steps including:

inflating said elastic sleeves so that said sleeves seal against the their respective reactor tubes;

injecting constant gas flow through said injector tubes into their respective reactor tubes; and

measuring the pressure in each of the respective reactor tubes.

57. A method for assessing reactor tubes in a chemical reactor as recited in claim 56, wherein said automatic sequence includes cycling a multiplex valve to sequentially put each of the injector tubes in fluid communication with a single pressure sensor.

58. A method for assessing reactor tubes in a chemical reactor as recited in claim 57, wherein said automatic sequence of steps further includes:

associating each pressure measurement with its respective reactor tube; and

electronically transmitting data representing the associated pressure measurements and reactor tube identifications to a remote location.

59. A method for assessing reactor tubes in a chemical reactor as recited in claim 58, and further comprising the steps of:

receiving said electronically transmitted data at said remote location; and

graphically displaying said associated reactor tube identifications and said pressure measurements at said remote location as the measurements are being taken.

60. A method for assessing reactor tubes in a chemical reactor as recited in claim 59, and further comprising the steps of:

establishing specifications for said reactor tubes;

comparing said pressure measurements to said specifications;

graphically displaying the layout of the tubes in the reactor; and

color-coding said graphical layout of the reactor tubes to show how the pressure measurements for the respective tubes compare to the specifications.

61. A method for displaying pressure measurement data for chemical reactor tubes, comprising the steps of:

graphically displaying the layout of the reactor tubes in an electronic medium;

establishing specifications for the pressure measurements; and

color coding the tubes in said graphical display to indicate the relationship between the pressure measurements and the specifications for the respective tubes.

62. A method for displaying pressure measurement data for chemical reactor tubes as recited in claim 61, wherein said color coding includes separate colors for tubes that are within the specifications, tubes that fail high, and tubes that fail low.

63. A method for displaying pressure measurement data for chemical reactor tubes as recited in claim 62, wherein said color coding is displayed as the pressure measurements are being taken.

64. A method for displaying pressure measurement data for chemical reactor tubes as recited in claim 63, and further comprising the steps of:

selecting a particular reactor tube in said layout display; and

electronically displaying a detailed view of that particular reactor tube simultaneously with the tube layout.

65. A method for displaying pressure measurement data for chemical reactor tubes as recited in claim 64, wherein said detailed view includes rings of color to show how pressure measurements for the particular reactor tube have compared to the specifications over time.

66. A method for displaying pressure measurement data for chemical reactor tubes as recited in claim 61, wherein said color coding includes rings of color to show how the pressure measurements for the reactor tubes have compared to the specifications over time.

67. A method for displaying pressure measurement data for chemical reactor tubes as recited in claim 65, wherein the innermost ring of color shows the most recent comparison to the specifications.

68. A method for collecting and transmitting data related to multiple positions within a defined area, comprising the steps of:

establishing a reference position within the defined area;

locating a probe at a desired location spaced away from said reference position;

providing an automatic measuring device fixed relative to said probe;

taking a first measurement of the distance from said measuring device to said reference position to establish the location of the probe within the defined area;

taking a second measurement of a physical characteristic at the position of the probe;

linking together data representing the second measurement and data representing the position of the probe;

transmitting that linked data electronically to a remote location;

repeating the foregoing steps at multiple positions within the defined area;

receiving the linked data at a remote location; and

displaying the linked data in a graphic electronic medium at a remote location as the measurements are being taken at various locations within the defined area, said graphic display showing the positions at which the second measurements are taken in a graphic map representing the defined area.

69. A method for collecting and transmitting data related to multiple positions within a defined area as recited in claim 68, and further comprising the steps of:

establishing specifications for the physical characteristic measured by the second measurement;

automatically comparing the second measurements to the specifications; and

using color to display the second measurements on said graphic map as the measurements are being taken, with at least one color indicating second measurements that fall within the specifications and at least another color indicating second measurements that fall outside of the specifications.

70. A method for collecting and transmitting data related to multiple positions within a defined area as recited in claim 68, wherein the step of transmitting the data includes a wireless electronic transmission.

71. A method for measuring and displaying data, comprising the steps of:

using a laser measuring device at a first position to measure the distance between the first position and a fixed target;

electronically transmitting data corresponding to the distance measurement to a remote location; and

graphically displaying the data in pictorial format at the remote location as the measurements are being taken.

72. A method for measuring and displaying data as recited in claim 71, wherein the laser measuring device is fixed to a wand including at least one probe, and further comprising the steps of:

inserting the probe into a chemical reactor tube; and

using the distance measurement to determine which tube is receiving the probe;

wherein the graphical display includes a map showing the tubes in the reactor and indicates the tube position of the probe.

73. A method for measuring and displaying data as recited in claim 71, and further comprising the steps of:

measuring a second physical characteristic while the device is at the first position;

linking data corresponding to the measurement of the second physical characteristic to data corresponding to the first position;

transmitting the linked data to the remote location; and

graphically displaying the linked data in pictorial format at the remote location as the measurements are being taken.

74. A method for measuring and displaying data as recited in claim 73, wherein the second physical characteristic is pressure; and wherein the pressure is displayed pictorially using one color for pressure that is within a set specification range, using a second color for pressure that is above the specification range, and using a third color for pressure that is below the specification range.

75. A method for measuring the back pressure in open-end chemical reactor tubes, comprising the steps of:

inserting a hollow tube body into one of said chemical reactor tubes;

sealing between the hollow tube body and the chemical reactor tube;

introducing a controlled gas flow through said hollow tube body into said chemical reactor tube;

measuring the pressure in said hollow tube body;

automatically associating the pressure measurement with the particular chemical reactor tube being measured;

electronically transmitting the pressure measurement and data identifying the particular chemical reactor tube to a remote location;

receiving the pressure measurement and data at the remote location; and

graphically displaying the measurement at the remote location as the measurement is taken.

76. A method as recited in claim 75, and further comprising the step of electronically comparing the measurement to predetermined criteria; making a pass-fail decision for the particular tube being measured; and electronically recording the measurement and the pass-fail decision for the particular tube.

77. A method for measuring the back pressure in open-end chemical reactor tubes, comprising the steps of:

rigidly mounting a plurality of hollow tube bodies on a single hand-held wand with spacings corresponding to the spacings of the chemical reactor tubes;

inserting said plurality of hollow tube bodies as a single unit into a corresponding plurality of said chemical reactor tubes;

inflating a plurality of seals to seal between the hollow tube bodies and their respective chemical reactor tubes;

introducing a controlled gas flow through said hollow tube bodies into their respective chemical reactor tubes;

measuring the pressure in said hollow tube bodies;

automatically associating the pressure measurements with the particular chemical reactor tubes being measured; and

electronically recording said associated pressure measurements for the respective chemical reactor tubes.

78. A method for measuring the back pressure in open-end chemical reactor tubes as recited in claim 77, and further comprising the step of

measuring the position of said wand relative to a fixed point and automatically keeping track of the particular chemical reactor tubes being measured based on the position of said wand relative to said fixed point.

79. A method for measuring the back pressure in open-end chemical

reactor tubes as recited in claim 78, wherein said position is measured using a laser device mounted on said wand.

80. A method for making decisions about the operation of a chemical reactor including a large number of open-ended chemical reactor tubes, comprising the steps of:

injecting gas into the chemical reactor tubes;

measuring the back pressure in said chemical reactor tubes;

electronically transmitting the measurements, together with identifying information about the chemical reactor tubes for which the measurements are being taken, to a remote computer as the measurements are being taken;

automatically comparing the measurements to predetermined criteria as the measurements are being taken to determine which chemical reactor tubes need further attention; and

providing a visual display at the remote location indicating the relationship of the measurements to the predetermined criteria as the measurements are being taken.

81. A method for making decisions about the operation of a chemical reactor including a large number of open-ended chemical reactor tubes as recited in claim 80, wherein said measuring, transmitting, comparing, and providing a visual display are done electronically and substantially simultaneously.

82. A method for making decisions about the operation of a chemical reactor as recited in claim 81, and further comprising the step of performing statistical analysis on the measurements at the remote computer.

83. A method for making decisions about the operation of a chemical reactor as recited in claim 81, and further providing cost information output to indicate the cost of leaving the chemical reactor tubes as they stand and the benefit of making corrections.

84. A method for making decisions about the operation of a chemical

reactor as recited in claim, and further showing on a display screen the chemical reactor tubes as they are being measured, with color indications showing how the chemical reactor tube measurements compare to the predetermined criteria.

85. A method for identifying, recording, and tracking information about chemical reactor tubes over the useful life of the chemical reactor, comprising the steps of:

creating an initial electronic file for the chemical reactor, defining the positions of the chemical reactor tubes and the conditions of each position, including defining which positions contain thermocouples, which contain support structure, and which chemical reactor tubes are plugged, and storing that data at a first location;

then, using a handheld wand at a remote second location to measure the back pressure in the chemical reactor tubes, creating an electronic data file representing the back pressure measurements for the tube positions;

transmitting the electronic back pressure data to said first location;

storing the electronic back pressure data at said first location; and

indicating said chemical reactor tube data graphically at the first location as the measurements are being taken.

86. A method for identifying, recording, and tracking information about chemical reactor tubes over the useful life of the chemical reactor as recited in claim 25, and further comprising the step of repeating the back pressure measurement, and storing each set of measurements at said first location, so as to permit the plant engineer to study the history of the chemical reactor.

Abstract

A device for measuring the back pressure in chemical reactor tubes includes many automated features. Inflatable tube seals may be automatically inflated. The device may measure several tubes at once. It may transmit data electronically to a remote computer for analysis and graphic display.