FUEL TANK LEAK PREVENTION AND DETECTION SYSTEM AND METHOD

Abstract: A pump housing contains a pump that draws fuel from an underground storage tank to deliver fuel to fuel dispensers in a service station environment. The pump is coupled to a double-walled riser pipe that carries the fuel from the underground storage tank to the pump. The double-walled fuel piping contains an inner space that carries the fuel and an outer annular space that captures any leaked fuel from the inner space. The outer annular space is coupled to a vacuum created by the pump to determine if a leak exists in the outer annular space. An alternate submersible turbine pump has a double-walled housing with a pressure sensor disposed in the interstitial space of the double-walled housing. A vacuum may be created therein to determine if leaks are present in the housing of the submersible turbine pump.
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Related Applications

[0001] This patent application is a continuation-in-part application of patent application Serial No. 10/430,890, filed on May 6, 2003, which is a continuation-in-part of patent application Serial No. 10/238,822, filed on September 10, 2002, both of which are hereby incorporated by reference in their entireties.

[0002] Patent application Serial No. 10/390,346 entitled "Fuel Storage Tank Leak Prevention and Detection System and Method," filed on March 17, 2003 and including the same inventors as included in the present application is related to the present application and is also incorporated herein by reference in its entirety.

Field of the Invention

[0003] The present invention relates to detection of a leak or breach in the secondary containment of a riser pipe associated with a submersible turbine pump and/or the submersible turbine pump housing in a retail service station environment.

Background of the Invention

[0004] In service station environments, fuel is delivered to fuel dispensers from underground storage tanks (UST), sometimes referred to as fuel storage tanks. USTs are large containers located beneath the ground that contain fuel. A separate UST is provided for each fuel type, such as low octane gasoline, high octane gasoline, and diesel fuel. In order to deliver the fuel from the USTs to the fuel dispensers, a submersible turbine pump (STP) is provided that pumps the fuel out of the UST and delivers the fuel through a main fuel piping conduit that runs beneath the ground in the service station.

[0005] Due to regulatory requirements governing service stations, the main fuel piping conduit is usually required to be double-walled piping. Double-walled piping contains an inner space that carries the fuel. An outer annular space, also called an "interstitial space," surrounds the inner space so as to
capture and contain any leaks that occur in the inner space, so that such leaks do not reach the ground. An example of double-walled fuel pipe is disclosed in U.S. Patent No. 5,527,130, incorporated herein by reference in its entirety.

[0006] It is possible that the outer annular space of the double-walled fuel piping could fail, thereby leaking fuel outside of the fuel piping if the inner space were to fail as well. Fuel sump sensors that detect leaks are located underneath the ground in the STP sump and the fuel dispenser sumps. These sensors detect any leaks that occur in the fuel piping at the location of the sensors. However, if a leak occurs in the double-walled fuel piping between these sensors, it is possible that a leak in the double-walled fuel piping will go undetected since the leaked fuel will leak into the ground, never reaching one of the fuel leak sensors. The STP will continue to operate as normal, drawing fuel from the UST; however, the fuel may leak to the ground instead of being delivered to the fuel dispensers.

[0007] Therefore, there exists a need to be able to monitor the double-walled fuel piping to determine if there is a leak or breach in the outer wall. Detection of a leak or breach in the outer wall of the double-walled fuel piping can be used to generate an alarm or other measure so that preventive measures can be taken to correct the leak or breach in the outer wall of the double-walled piping before a leak in the inner piping can escape to the ground.

[0008] Recent proposed changes in state and federal regulations will tighten the requirements to contain leaks and will further require better leak detection so that environmental damage may be minimized. As a result, it is becoming imperative that all potential leak sources be evaluated and steps taken to detect and contain leaks in the piping systems. One area that has not been specifically addressed by the parent disclosures is within the submersible turbine pump and in the riser pipe that connects the submersible turbine pump to the UST.

Summary of the Invention

[0009] The parent disclosures relate to a sensing unit and a tank monitor that monitors the vacuum level in the outer annular space of the double-
walled fuel piping to determine if a breach or leak exists in the outer wall of the fuel piping. If the outer annular space cannot maintain a pressure or vacuum level over a given amount of time after being pressurized, this is indicative that the outer wall of the fuel piping contains a breach or leak. If the inner conduit of the fuel piping were to incur a breach or leak such that fuel reaches the outer annular space of the fuel piping, this same fuel would also have the potential to reach the ground through the breach in the outer wall in the fuel piping.

[0010] A sensing unit is provided that is communicatively coupled to a tank monitor or other control system. The sensing unit contains a pressure sensor that is coupled to vacuum tubing. The vacuum tubing is coupled to the outer annular space of the fuel piping, and is also coupled to a submersible turbine pump (STP) so that the STP can be used as a vacuum source to generate a vacuum level in the vacuum tubing and the outer annular space. The sensing unit and/or tank monitor determines if there is a leak or breach in the outer annular space by generating a vacuum in the outer annular space using the STP. Subsequently, the outer annular space is monitored using a pressure sensor to determine if the vacuum level changes significantly to indicate a leak. The system checks for both catastrophic and precision leaks.

[0011] In one leak detection embodiment of the present invention, the STP provides a vacuum source to the vacuum tubing and the outer annular space of the fuel piping. The tank monitor receives the vacuum level of the outer annular space via the measurements from the pressure sensor and the sensing unit. After the vacuum level in the outer annular space reaches a defined initial threshold vacuum level, the STP is deactivated and isolated from the outer annular space. The vacuum level of the outer annular space is monitored. If the vacuum level decays to a catastrophic threshold vacuum level, the STP is activated to restore the vacuum level. If the STP cannot restore the vacuum level to the defined initial threshold vacuum level in a defined amount of time, a catastrophic leak detection alarm is generated and the STP is shut down.

[0012] If the vacuum level in the outer annular space is restored to the defined initial threshold vacuum level within a defined period of time, a
precision leak detection test is performed. The sensing unit monitors the vacuum level in the outer annular space to determine if the vacuum level decays to a precision threshold vacuum level within a defined period of time, in which case a precision leak detection alarm is generated, and the STP may be shut down.

[0013] Once a catastrophic leak or precision leak detection alarm is generated, service personnel are typically dispatched to determine if a leak really exists, and if so, to take corrective measures. Tests are conducted to determine if the leak exists in the vacuum tubing, in the sensing unit, or in the outer annular space.

[0014] The sensing unit also contains a liquid detection conduit. A liquid detection sensor is placed inside the liquid detection conduit, which may be located at the bottom of the liquid detection conduit, so that any liquid leaks captured in the outer annular space of the fuel piping are stored and detected. The sensing unit and tank monitor can detect liquid in the sensing unit at certain times or at all times. If a liquid leak is detected by the tank monitor, the tank monitor will shut down the STP if so programmed.

[0015] The tank monitor may be communicatively coupled to a site controller and/or remote system to communicate leak detection alarms and other information obtained by the sensing unit. The site controller may pass information from the tank monitor onward to a remote system, and the tank monitor may communicate such information directly to a remote system.

[0016] The present invention builds on these teachings by extending the functionality introduced in the parent disclosures to the submersible turbine pump. Specifically, the submersible turbine pump typically includes some hardware positioned in a head unit. The head unit sits within a sump on top of a riser pipe. The riser pipe connects the head unit to the underground storage tank. The present invention makes the riser pipe a double-walled pipe and associates the vacuum and sensing system described above with the interstitial space of the riser pipe.

[0017] A first embodiment of the present invention fluidly connects the interstitial space of the double-walled riser pipe with the interstitial space of the underground storage tank. In this manner, leaks in either location can be
detected by a single pressure sensor. A second embodiment fluidly connects the interstitial space of the double-walled riser pipe with the interior of the head unit. In this manner, leaks in either location can be detected by a single pressure sensor. A third embodiment has special fittings at either end of the double-walled riser pipe which would allow the vacuum to be applied therethrough. Still another embodiment of the present invention is to create a double-wall around the head unit and apply the vacuum and sensing techniques of the present invention thereto.

[0018] Another aspect of the present invention lies in the fittings that may be used to connect pipes to sumps or the like. Specifically, a double-walled pipe may terminate in a fitting of the present invention. This fitting is adapted to provide, in a first embodiment, a tight seal against the housing of the element to which the piping is being connected. A protuberance is created that allows a fluid connection with the outer annular space of the double-walled piping. A hose or other fluid communication means may be connected to the protuberance such that a fluid communication path can be created from the outer annular space. In a second embodiment, the housing may have an aperture that allows for a fluid communication path to be created from the outer annular space into the housing of the device to which the double-walled piping is being connected.

[0019] Those skilled in the art will appreciate the scope of the present invention and realize additional aspects thereof after reading the following detailed description of the invention in association with the accompanying drawing figures.

**Brief Description of the Drawings**

[0020] The accompanying drawing figures incorporated in and forming a part of this specification illustrate several aspects of the invention, and together with the description serve to explain the principles of the invention.

[0021] Figure 1 is an underground storage tank, submersible turbine pump and fuel dispenser system in a service station environment in the prior art;

[0022] Figure 2 is a schematic diagram of the outer annular space of the double-walled fuel piping extending into the submersible turbine pump sump and housing;
[0023] Figure 3 is a schematic diagram of another embodiment of the present invention;

[0024] Figures 4A and 4B are flowchart diagrams illustrating one embodiment of the leak detection test of the present invention;

[0025] Figure 5 is a flowchart diagram of a liquid leak detection test for one embodiment of the present invention;

[0026] Figure 6 is a flowchart diagram of a functional vacuum leak detection test for one embodiment of the present invention that is carried out in a tank monitor test mode;

[0027] Figure 7 is a flowchart diagram of a functional liquid leak detection test for one embodiment of the present invention that is carried out in a tank monitor test mode;

[0028] Figure 8 is a schematic diagram of a tank monitor communication architecture;

[0029] Figure 9 illustrates an exemplary embodiment of the double-walled riser pipe using the vacuum and sensing of the present invention;

[0030] Figure 10 illustrates a second embodiment of the double-walled riser pipe wherein the vacuum and sensing are introduced to the interstitial space at the fittings;

[0031] Figure 11 illustrates a third embodiment of the double-walled riser pipe wherein the interstitial space of the double-walled riser pipe is fluidly connected to the interstitial space of the underground storage tank;

[0032] Figure 12 illustrates a fourth embodiment of the double-walled riser pipe wherein the interstitial space of the double-walled riser pipe is fluidly connected to an interior portion of the head unit of the submersible turbine pump;

[0033] Figure 13 illustrates an alternate embodiment of the present invention wherein the head unit of the submersible turbine pump includes a double-wall, and the interstitial space thereof is subjected to the vacuum and sensing of the present invention;

[0034] Figure 14 illustrates a first embodiment of a pipe fitting for use with the present invention; and
Figure 15 illustrates a second embodiment of a pipe fitting for use with the present invention.

**Detailed Description of the Preferred Embodiments**

The embodiments set forth below represent the necessary information to enable those skilled in the art to practice the invention and illustrate the best mode of practicing the invention. Upon reading the following description in light of the accompanying drawing figures, those skilled in the art will understand the concepts of the invention and will recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure and the accompanying claims.

Figures 1-8 represent the disclosures made in the parent applications. This background material may be helpful to understand some of the details of the creation of a vacuum in an interstitial space and the sensing that accompanies this vacuum that is used to determine if there is a leak. The discussion of the present invention begins with the discussion of Figure 9; however, it should be appreciated that the teachings of the sensing element and the algorithms used to detect leaks with the sensing element are applicable to the embodiments introduced in Figures 9-13.

Figure 1 illustrates a fuel delivery system known in the prior art for a service station environment. A fuel dispenser 10 is provided that delivers fuel 22 from an underground storage tank (UST) 20 to a vehicle (not shown). The fuel dispenser 10 is comprised of a fuel dispenser housing 12 that typically contains a control system 13 and a display 14. The fuel dispenser 10 contains valves and meters (not shown) to allow fuel 22 to be received from underground piping and delivered through a hose and nozzle (not shown). More information on a typical fuel dispenser 10 can be found in U.S. Patent No. 5,782,275, assigned to same assignee as the present invention, incorporated herein by reference in its entirety.

The fuel 22 that is dispensed by the fuel dispenser 10 is stored beneath the ground in the UST 20. There may be a plurality of USTs 20 in a service station environment if more than one type of fuel 22 is to be delivered by fuel dispensers 10 in the service station. For example, one UST 20 may
contain high octane gasoline, another UST 20 may contain low octane gasoline, and yet another UST 20 may contain diesel fuel. The UST 20 is typically a double-walled tank comprised of an inner vessel 23 that holds the fuel 22 surrounded by an outer casing 25. The outer casing 25 provides an added measure of security to prevent leaked fuel 22 from reaching the ground. Any leaked fuel 22 from a leak in the inner vessel 23 will be captured in an annular space 27 that is formed between the inner vessel 23 and the outer casing 25. This annular space is also called an "interstitial space" 27. More information on USTs 20 in service station environments can be found in U.S. Patent No. 6,116,815, which is incorporated herein by reference in its entirety.

[0040] A submersible turbine pump (STP) 30 is provided to draw the fuel 22 from the UST 20 and deliver the fuel 22 to the fuel dispensers 10. An example of a STP 30 is the Quantum™ manufactured and sold by the Marley Pump Company and disclosed at http://www.redjacket.com/quantum.htm. Another example of a STP 30 is disclosed in U.S. Patent No. 6,126,409, incorporated hereby by reference in its entirety. The STP 30 is comprised of a STP housing 36 that incorporates a vacuum pump and electronics (not shown). Typically, the vacuum pump is a venturi that is created using a portion of the pressurized fuel product, but the STP 30 is not limited to such an embodiment. The STP 30 is connected to a riser pipe 38 that is mounted using a mount 40 connected to the top of the UST 20. The riser pipe 38 extends down from the STP 30 and out of the STP housing 36 (sometimes referred to herein as a head unit). A fuel supply pipe (not shown) is coupled to the STP 30 and is located inside the riser pipe 38. The fuel supply pipe extends down into the UST 20 in the form of a boom 42 that is fluidly coupled to the fuel 22.

[0041] The boom 42 is coupled to a turbine housing 44 that contains a turbine, also called a "turbine pump" (not shown), both of which terms can be used interchangeably. The turbine pump is electrically coupled to the STP electronics in the STP 30. When one or more fuel dispensers 10 in the service station are activated to dispense fuel 22, the STP 30 electronics are activated to cause the turbine inside the turbine housing 44 to rotate to pump
fuel 22 into the turbine housing inlet 46 and into the boom 42. The fuel 22 is
drawn through the fuel supply pipe in the riser pipe 38 and delivered to the
main fuel piping conduit 48. The main fuel piping conduit 48 is coupled to the
fuel dispensers 10 in the service station whereby the fuel 22 is delivered to a
vehicle (not shown). If the main fuel piping conduit 48 is a double-walled
piping, the main fuel piping conduit 48 will have an interstitial space 56 as well
to capture any leaked fuel.

[0042] Regulatory requirements require that any main fuel piping conduit
48 exposed to the ground be contained within a housing or other structure so
that any leaked fuel 22 from the main fuel piping conduit 48 is captured. This
secondary containment is provided in the form of a double-walled main fuel
piping conduit 48, as illustrated in Figure 1. The double-walled main fuel
piping conduit 48 contains an inner space 55 surrounded by an outer annular
space 56 formed by outer wall 54, referred to in the figures as "secondary
containment" (the outer annular space 56 is sometimes also called herein the
"interstitial space" 56). The terms "outer annular space" and "interstitial
space" are well known interchangeable terms to one of ordinary skill in the art.
The fuel 22 is carried in the inner space 55. In Figure 1 and in prior art
systems, the outer annular space 56 runs through the STP sump wall 32 and
terminates to the inner space 55 once inside the STP sump wall 32 via
clamping. This is because the STP sump wall 32 provides the secondary
containment of the inner space 55 for the portion the main fuel piping conduit
48 inside the STP sump wall 32.

[0043] The STP 30 is typically placed inside a STP sump 31 so that any
leaks that occur in the STP 30 are contained within the STP sump 31 and are
not leaked to the ground. A sump liquid sensor 33 may also be provided
inside the STP sump 31 to detect any such leaks so that the STP sump 31
can be periodically serviced to remove any leaked fuel. The sump liquid
sensor 33 may be communicatively coupled to a tank monitor 62, site
controller 64, or other control system via a communication line 81 so that
liquid detected in the STP sump 31 can be communicated to an operator
and/or an alarm be generated. An example of a tank monitor 62 is the TLS-
350 manufactured by the Veeder-Root Company. An example of a site
controller 64 is the G-Site® manufactured by Gilbarco Inc. Note that any type of monitoring device or other type of controller or control system can be used in place of a tank monitor 62 or site controller 64.

[0044] The main fuel piping conduit 48, in the form of a double-walled pipe, is run underneath the ground in a horizontal manner to each of the fuel dispensers 10. Each fuel dispenser 10 is placed on top of a fuel dispenser sump 16 that is located beneath the ground underneath the fuel dispenser 10. The fuel dispenser sump 16 captures any leaked fuel 22 that drains from the fuel dispenser 10 and its internal components so that such fuel 22 is not leaked to the ground. The main fuel piping conduit 48 is run into the fuel dispenser sump 16, and a branch conduit 50 is coupled to the main fuel piping conduit 48 to deliver the fuel 22 into each individual fuel dispenser 10. The branch conduit 50 is typically run into a shear valve 52 located proximate to ground level so that any impact to the fuel dispenser 10 causes the shear valve 52 to engage, thereby shutting off the fuel dispenser 10 access to fuel 22 from the branch conduit 50. The main fuel piping conduit 48 exits the fuel dispenser sump 16 so that fuel 22 can be delivered to the next fuel dispenser 10, and so on until a final termination is made. A fuel dispenser sump sensor 18 is typically placed in the fuel dispenser sump 16 so that any leaked fuel from the fuel dispenser 10 or the main fuel piping conduit 48 and/or branch conduit 50 that is inside the fuel dispenser sump 16 can be detected and reported accordingly.

[0045] Figure 2 illustrates a fuel delivery system in a service station environment according to one embodiment of the present invention. The secondary containment 54 provided by the outer annular space 56 of the main fuel piping conduit 48 is run through the STP sump 31 and into the STP housing 36, as illustrated. In this manner, the pressure or vacuum level created by the STP 30 can also be applied to the outer annular space 56 of the main fuel piping conduit 48 to detect leaks via monitoring of the vacuum level in the outer annular space 56, as will be discussed later in this patent application. The terms “pressure” and “vacuum level” are used interchangeably herein. One or more pressure sensors 60 may be placed in the outer annular space 56 in a variety of
locations, including but not limited to inside the STP sump 31, the STP housing 36, and the outer annular space 56 inside the fuel dispenser sump 16.

[0046] In the embodiment illustrated in Figure 2, the outer annular space 56 of the main fuel piping conduit 48 is run inside the STP housing 36 so that any fuel 22 that has leaked into the outer annular space 56 can be detected by the sump liquid sensor 33 and/or be collected in the STP sump 31 for later evacuation. By running the outer annular space 56 of the main fuel piping conduit 48 inside the STP housing 36, it is possible to generate a vacuum level in the outer annular space 56 from the same STP 30 that draws fuel 22 from the UST 20 via the boom 42. Any method of accomplishing this function is contemplated by the present invention. One method may be to use a siphon system in the STP 30 to create a vacuum level in the outer annular space 56, such as the siphon system described in U.S. Patent No. 6,223,765, assigned to Marley Pump Company and incorporated herein by reference its entirety. Another method is to direct some of the vacuum generated by the STP 30 from inside the boom 42 to the outer annular space 56. The present invention is not limited to any particular method of the STP 30 generating a vacuum level in the outer annular space 56.

[0047] Figure 3 illustrates another embodiment of running the outer annular space 56 of the main fuel piping conduit 48 only into the STP sump 31 rather than the outer annular space 56 being run with the inner space 55 into the STP housing 36. A vacuum tubing 70 connects the outer annular space 56 to the STP 30. Again, as discussed for Figure 2 above, the STP 30 is coupled to the outer annular space 56, such as using direct coupling to the STP 30 (as illustrated in Figure 2), or using a vacuum tubing 70 (as illustrated in Figure 3) as a vacuum generating source to create a vacuum level in the outer annular space 56. Whether the configuration of coupling the STP 30 to the outer annular space 56 is accomplished by the embodiment illustrated in Figure 2, Figure 3, or other manner, the vacuum level monitoring and liquid leak detection aspects of the present invention described below and with respect to a sensing unit 82 illustrated in Figure 3 is equally applicable to all embodiments.
[0048] Figure 3 also illustrates a sensing unit 82, which may be provided either inside or outside the STP sump 31 and/or STP housing 36, that monitors the vacuum level in the outer annular space 56 of the main fuel piping conduit 48. If the outer annular space 56 cannot maintain a vacuum level over a given period of time after being pressurized, this is indicative that the outer wall 54 contains a breach or leak. In this instance, if the inner vessel 12 were to incur a breach or leak such that fuel 22 reaches the outer annular space 56, this same fuel 22 would also have the potential to reach the ground through the breach in the outer wall 54. Therefore, it is desirable to know if the outer wall 54 contains a breach or leak when it occurs and before a leak or breach occurs in the inner space 55, if possible, so that appropriate notifications, alarms, and measures can be taken in a preventive manner rather than after a leak of fuel 22 to the ground occurs. It is this aspect of the present invention that is described below.

[0049] The sensing unit 82 is comprised of a sensing unit controller 84 that is communicatively coupled to the tank monitor 62 via a communication line 81. The communication line 81 is provided in an intrinsically safe enclosure inside the STP sump 31 since fuel 22 and or fuel vapor may be present inside the STP sump 31. The sensing unit controller 84 may be any type of microprocessor, micro-controller, or electronics that is capable of communicating with the tank monitor 62. The sensing unit controller 84 is also electrically coupled to a pressure sensor 60. The pressure sensor 60 is coupled to a vacuum tubing 70. The vacuum tubing 70 is coupled to the STP 30 so that the STP 30 can be used as a vacuum source to generate a vacuum level, which may be a positive or negative vacuum level, inside the vacuum tubing 70. The vacuum tubing 70 is also coupled to the outer annular space 56 of the main fuel piping conduit 48. A check valve 71 may be placed inline to the vacuum tubing 70 if it is desired to prevent the STP 30 from ingressing air to the outer annular space 56 of the main fuel piping conduit 48.

[0050] An isolation valve 88 may be placed inline with the vacuum tubing 70 between the sensing unit 82 and the outer annular space 56 of the main fuel piping conduit 48 to isolate the sensing unit 82 from the outer annular
space 56 for reasons discussed later in this application. A vacuum control valve 90 is also placed inline to the vacuum tubing 70 between the pressure sensor 60 and the STP 30. The vacuum control valve 90 is electrically coupled to the sensing unit controller 84 and is closed by the sensing unit controller 84 when it is desired to isolate the STP 30 from the outer annular space 56 during leak detection tests, as will be described in more detail below. The vacuum control valve 90 may be a solenoid-controlled valve or any other type of valve that can be controlled by sensing unit controller 84.

[0051] An optional differential pressure indicator 98 may also be placed in the vacuum tubing 70 between the STP 30 and sensing unit 82 on the STP 30 side of the vacuum control valve 90. The differential pressure indicator 98 may be communicatively coupled to the tank monitor 62. The differential pressure indicator 98 detects whether a sufficient vacuum level is generated in the vacuum tubing 70 by the STP 30. If the differential pressure indicator 98 detects that a sufficient vacuum level is not generated in the vacuum tubing 70 by the STP 30, and a leak detection test fails, this may be an indication that a leak has not really occurred in the outer annular space 56. The leak detection may have been a result of the STP 30 failing to generate a vacuum in the vacuum tubing 70 in some manner. The tank monitor 62 may use information from the differential pressure indicator 98 to discriminate between a true leak and a vacuum level problem with the STP 30 in an automated fashion. The tank monitor 62 may also generate an alarm if the differential pressure indicator 98 indicates that the STP 30 is not generating a sufficient vacuum level in the vacuum tubing 70. Further, the tank monitor 62 may first check information from the differential pressure indicator 98 after detecting a leak, but before generating an alarm, to determine if the leak detection is a result of a true leak or a problem with the vacuum level generation by the STP 30.

[0052] In the embodiments further described and illustrated herein, the differential pressure indicator 98 does not affect the tank monitor 62 generating a leak detection alarm. The differential pressure indicator 98 is used as a further information source when diagnosing a leak detection alarm generated by the tank monitor 62. However, the scope of the present
invention encompasses use of the differential pressure indicator 98 as both an information source to be used after a leak detection alarm is generated and as part of a process to determine if a leak detection alarm should be generated.

[0053] The sensing unit 82 also contains a liquid detection conduit 92. The liquid detection conduit 92 is fluidly coupled to the outer annular space 56. The liquid detection conduit 92 is nothing more than a conduit that can hold liquid and contains a liquid detection sensor 94 so that any liquid that leaks in the outer annular space 56 will be contained and cause the liquid detection sensor 94 to detect a liquid leak, which is then reported to the tank monitor 62. The liquid detection sensor 94 may contain a float (not shown) as is commonly known in one type of liquid detection sensor 94. An example of such a liquid detection sensor 94 that may be used in the present invention is the "Interstitial Sensor for Steel Tanks," sold by Veeder-Root Company and described on the website [http://www.veeder-root.com/dynamic/index.cfm?pageID=175](http://www.veeder-root.com/dynamic/index.cfm?pageID=175), filed with the Information Disclosure Statement, incorporated herein by reference in its entirety.

[0054] The liquid detection sensor 94 is communicatively coupled to the sensing unit controller 84 via a communication line 65. The sensing unit controller 84 can in turn generate an alarm and/or communicate the detection of liquid to the tank monitor 62 to generate an alarm and/or shut down the STP 30. The liquid detection sensor 94 can be located anywhere in the liquid detection conduit 92, but is preferably located at the bottom of the liquid detection conduit 92 at its lowest point so that any liquid in the liquid detection conduit 92 will be pulled towards the liquid detection sensor 94 by gravity. If liquid, such as leaked fuel 22, is present in the outer annular space 56, the liquid will be detected by the liquid detection sensor 94. The tank monitor 62 can detect liquid in the outer annular space 56 at certain times or at all times, as programmed.

[0055] If liquid leaks into the liquid detection conduit 92, it will be removed at a later time, typically after a liquid leak detection alarm has been generated, by service personnel using a suction device that is placed inside the liquid detection conduit 92. In an alternative embodiment, a drain valve
is placed inline between the liquid detection conduit 92 and the STP sump 31 that is opened and closed manually. During normal operation, the drain valve 96 is closed, and any liquid collected in the liquid detection conduit 92 rests at the bottom of the liquid detection conduit 92. If liquid is detected by the liquid detection sensor 94 and service personnel are dispatched to the fueling environment, the service personnel can drain the trapped liquid by opening the drain valve 96, and the liquid will drain into the STP sump 31 for safe keeping and so that the system can again detect new leaks in the sensing unit 82. When it is desired to empty the STP sump 31, the service personnel can draw the liquid out of the STP sump 31 using a vacuum or pump device.

[0056] Against this backdrop, the functional operation of these components is better explicated. The parent disclosures teach that the present invention is capable of performing two types of leak detection tests: precision and catastrophic. A catastrophic leak is defined as a major leak where a vacuum level in the outer annular space 56 changes very quickly due to a large leak in the outer annular space 56. A precision leak is defined as a leak where the vacuum level in the outer annular space 56 changes less drastically than a vacuum level change for a catastrophic leak.

[0057] Figures 4A and 4B provide a flowchart illustration of the leak detection operation of the sensing unit that, according to one embodiment of the present invention, performs both the catastrophic and precision leak detection tests for the outer wall 54 of the main fuel piping conduit 48. The tank monitor 62 directs the sensing unit 82 to begin a leak detection test to start the process (step 100). Alternatively, a test may be started automatically if the vacuum level reaches a predefined threshold. In response, the sensing unit controller 84 opens the vacuum control valve 90 (step 102) so that the STP 30 is coupled to the outer annular space 56 via the vacuum tubing 70. The STP 30 provides a vacuum source and pumps the air, gas, and/or liquid out of the vacuum tubing 70 and the outer annular space 56, via its coupling to the vacuum tubing 70, after receiving a test initiation signal from the tank monitor 62. The STP 30 pumps the air, gas or liquid out of the outer annular space 56 until a defined initial threshold vacuum level is reached or
substantially reached (step 104). The tank monitor 62 receives the vacuum level of the outer annular space 56 via the measurements from the pressure sensor 60 communication to the sensing unit controller 84. This defined initial threshold vacuum level is -15 inches of Hg in one embodiment of the present invention, and may be a programmable vacuum level in the tank monitor 62. Also, note that if the vacuum level in the outer annular space 56 is already at the defined initial threshold vacuum level or substantially close to the defined initial vacuum threshold level sufficient to perform the leak detection test, steps 102 and 104 may be skipped.

[0058] After the vacuum level in the vacuum tubing 70 reaches the defined initial threshold vacuum level, as ascertained by monitoring of the pressure sensor 60, the tank monitor 62 directs the sensing unit controller 84 to deactivate the STP 30 (unless the STP 30 has been turned on for fuel dispensing) and to close the vacuum control valve 90 to isolate the outer annular space 56 from the STP 30 (step 106). Next, the tank monitor 62 monitors the vacuum level using vacuum level readings from the pressure sensor 60 via the sensing unit controller 84 (step 108). If the vacuum level decays to a catastrophic threshold vacuum level, which may be -10 inches of Hg in one embodiment of the present invention and also may be programmable in the tank monitor 62, this is an indication that a catastrophic leak may exist (decision 110). The sensing unit 82 opens the vacuum control valve 90 (step 112) and activates the STP 30 (unless the STP 30 is already turned on for fuel dispensing) to attempt to restore the vacuum level back to the defined initial threshold vacuum level (-15 inches of Hg in the specific example) (step 114).

[0059] Continuing to Figure 4B, the tank monitor 62 determines if the vacuum level in the outer annular space 56 has lowered back down to the defined initial threshold vacuum level (-15 inches of Hg in the specific example) within a defined period of time, which is programmable in the tank monitor 62 (decision 116). If not, this is an indication that a major leak exists in the outer wall 54 of the main fuel piping conduit 48 or the vacuum tubing 70, and the tank monitor 62 generates a catastrophic leak detection alarm (step 118). The tank monitor 62, if so programmed, will shut down the STP
30 so that the STP 30 does not pump fuel 22 to fuel dispensers 10 that may leak due to the breach in the outer wall 54 (step 120), and the process ends (step 122). An operator or service personnel can then manually check the integrity of the outer annular space 56, vacuum tubing 70 and/or conduct additional leak detection tests on-site, as desired, before allowing the STP 30 to be operational again. If the vacuum level in the outer annular space 56 does lower back down to the defined initial threshold vacuum level within the defined period of time (decision 116), no leak detection alarm is generated at this point in the process.

[0060] Back in decision 110 (shown in Figure 4A), if the vacuum level did not decay to the defined initial threshold vacuum level (~10 inches of Hg in specific example), this is also an indication that a catastrophic leak does not exist. Either way, if the answer to decision 110 is no, or the answer to decision 116 is yes, the tank monitor 62 goes on to perform a precision leak detection test since no catastrophic leak exists.

[0061] For the precision leak detection test, the tank monitor 62 directs the sensing unit controller 84 to close the vacuum control valve 90 if it is not already closed (step 124). Next, the tank monitor 62 determines if the vacuum level in the outer annular space 56 has decayed to a precision threshold vacuum level within a defined period of time, both of which may be programmable (decision 126). If not, the tank monitor 62 logs the precision leak detection test as completed with no alarm (step 136), and the leak detection process restarts again as programmed by the tank monitor 62 (step 100).

[0062] If the vacuum level in the outer annular space 56 has decayed to a precision threshold vacuum level within the defined period of time, the tank monitor 62 generates a precision leak detection alarm (step 128). The tank monitor 62 determines if the tank monitor 62 has been programmed to shut down the STP 30 in the event of a precision leak detection alarm (decision 130). If yes, the tank monitor 62 shuts down the STP 30, and the process ends (step 134). If not, the STP 30 can continue to operate when fuel dispensers are activated, and the leak detection process restarts again as programmed by the tank monitor 62 (step 100). This is because it may be
acceptable to allow the STP 30 to continue to operate if a precision leak
detection alarm occurs depending on regulations and procedures. Also, note
that both the precision threshold vacuum level and the defined period of time
may be programmable at the tank monitor 62 according to levels that are
desired to be indicative of a precision leak.

[0063] Once a catastrophic leak or precision leak detection alarm is
generated, service personnel are typically dispatched to determine if a leak
really exists, and if so, to take corrective measures. The service personnel
can close the isolation valve 88 between the sensing unit 82 and the outer
annular space 56 to isolate the two from each other. The service personnel
can then initiate leak tests manually from the tank monitor 62 that operate as
illustrated in Figures 4A and 4B. If the leak detection tests pass after
previously failing and after the isolation valve 88 is closed, this is indicative
that some area of the outer annular space 56 contains the leak. If the leak
detection tests continue to fail, this is indicative that the leak may be present
in the vacuum tubing 70 connecting the sensing unit 82 to the outer annular
space 56, or within the vacuum tubing 70 in the sensing unit 82 or the
vacuum tubing 70 between sensing unit 82 and the STP 30. Closing of the
isolation valve 88 also allows components of the sensing unit 82 and vacuum
tubing 70 to be replaced without relieving the vacuum in the outer annular
space 56 since it is not desired to recharge the system vacuum and possibly
introduce vapors or liquid into the outer annular space 56 since the outer
annular space 56 is under a vacuum and will draw in air or liquid if vented.

[0064] Figure 5 is a flowchart diagram of a liquid leak detection test
performed by the tank monitor 62 to determine if a leak is present in the outer
annular space 56. The liquid leak detection test may be performed by the
tank monitor 62 on a continuous basis or at periodic times, depending on the
programming of the tank monitor 62. Service personnel may also cause the
tank monitor 62 to conduct the liquid leak detection test manually.

[0065] The process starts (step 150), and the tank monitor 62 determines
if a leak has been detected by the liquid detection sensor 94 (decision 152).
If not, the tank monitor 62 continues to determine if a leak has been detected
by the liquid detection sensor 94 in a continuous fashion. If the tank monitor
62 does determine from the liquid detection sensor 94 that a leak has been detected, the tank monitor 62 generates a liquid leak detection alarm (step 154). If the tank monitor 62 has been programmed to shut down the STP 30 in the event of a liquid leak detection alarm being generated (decision 156), the tank monitor 62 shuts down the STP 30 (if the STP 30 is on for fuel dispensing) (step 158), and the process ends (step 160). If the tank monitor 62 has not been programmed to shut down the STP 30 in the event of a liquid leak detection alarm being generated, the process just ends without taking any action with respect to the STP 30 (step 160).

[0066] Figure 6 is a flowchart diagram that discloses a functional vacuum leak detection test performed to determine if the sensing unit 82 can properly detect a purposeful leak. If a leak is introduced into the outer annular space 56, and a leak is not detected by the sensing unit 82 and/or tank monitor 62, this is an indication that some component of the leak detection system is not working properly.

[0067] The process starts (step 200), and a service person programs the tank monitor 62 to be placed in a functional vacuum leak detection test mode (step 202). Next, a service person manually opens the drain valve 96 or other valve to provide an opening in the outer annular space 56 or vacuum tubing 70 so that a leak is present in the outer annular space 56 (step 204). The tank monitor 62 starts a timer (step 206) and determines when the timer has timed out (decision 208). If the timer has not timed out, the tank monitor 62 determines if a leak detection alarm has been generated (decision 214). If not, the process continues until the timer times out (decision 208). If a leak detection alarm has been generated, as is expected, the tank monitor 62 indicates that the functional vacuum leak detection test passed and that the leak detection system is working properly (step 216) and the process ends (step 212).

[0068] If the timer has timed out without a leak being detected, this is indicative that the functional vacuum leak detection test failed (step 210) and that there is a problem with the system, which could be a component of the sensing unit 82 and/or tank monitor 62. Note that although this functional vacuum leak detection test requires manual intervention to open the drain
valve 96 or other valve to place a leak in the outer annular space 56 or vacuum tubing 70, this test could be automated if the drain valve 96 or other valve in the outer annular space 56 or vacuum tubing 70 was able to be opened and closed under control of the sensing unit 82 and/or tank monitor 62.

[0069] Figure 7 illustrates a functional liquid leak detection test that can be used to determine if the liquid detection system of the present invention is operating properly. The liquid detection sensor 94 is removed from the liquid detection conduit 92 and submerged into a container of liquid (not shown). Or in an alternative embodiment, a purposeful liquid leak is injected into the liquid detection conduit 92 to determine if a liquid leak detection alarm is generated. If a liquid leak detection alarm is not generated when liquid is placed on the liquid detection sensor 94, this indicates that there has been a failure or malfunction with the liquid detection system, including possibly the liquid detection sensor 94, the sensing unit 82, and/or the tank monitor 62.

[0070] The process starts (300), and the tank monitor 62 is set to a mode for performing the functional liquid leak detection test (step 302). The vacuum control valve 90 may be closed to isolate the liquid detection conduit 92 from the STP 30 so that the vacuum level in the outer annular space 56 and sensing unit 82 is not released when the drain valve 96 is opened (step 304). Note that this is an optional step. Next, the drain valve 96, if present, or outer annular space 56 is opened in the system (step 306). The liquid detection sensor 94 is either removed and placed into a container of liquid, or liquid is inserted into the liquid detection conduit 92, and the drain valve 96 is closed (step 308). If the tank monitor 62 detects a liquid leak from the sensing unit 82 (decision 310), the tank monitor 62 registers that the functional liquid leak detection test has passed (step 312). If no liquid leak is detected (decision 310), the tank monitor 62 registers that the functional liquid leak detection test failed (step 316). After the test is conducted, if liquid was injected into the liquid detection conduit 92 as the method of subjecting the liquid detection sensor 94 to a leak, either the drain valve 96 is opened to allow the inserted liquid to drain and then closed afterwards for normal operation, or a suction device is placed into the liquid detection conduit 92 by
service personnel to remove the liquid (step 313), and the process ends (step 314).

[0071] Note that although this functional liquid leak detection test requires manual intervention to open and close the drain valve 96 and to inject a liquid into the liquid detection conduit 92, this test may be automated if a drain valve 96 is provided that is capable of being opened and closed under control of the sensing unit 82 and/or tank monitor 62 and a liquid could be injected into the liquid detection conduit 92 in an automated fashion.

[0072] Figure 8 illustrates a communication system whereby leak detection alarms and other information obtained by the tank monitor 62 and/or site controller 64 from the communication line 81 may be communicated to other systems if desired. This information, such as leak detection alarms for example, may be desired to be communicated to other systems as part of a reporting and dispatching process to alert service personnel or other systems as to a possible breach or leak in the outer wall 54 of the main fuel piping conduit 48.

[0073] The tank monitor 62 that is communicatively coupled to the sensing unit 82 and other components of the present invention via the communication line 81 may be communicatively coupled to the site controller 64 via a communication line 67. The communication line 67 may be any type of electronic communication connection, including a direct wire connection, or a network connection, such as a local area network (LAN) or other bus communication. The tank monitor 62 may communicate leak detection alarms, vacuum level/pressure level information and other information from the sensing unit 82 to the site controller 64. Alternatively, the sensing unit 82 may communicate this with the site controller 64 directly via the communication line 78. The site controller 64 may be further communicatively coupled to a remote system 72 to communicate this same information to the remote system 72 from the tank monitor 62 and the site controller 64 via a remote communication line 74. The remote communication line 74 may be any type of electronic communication connection, such as a PSTN, or network connection such as the Internet, for example. The tank monitor 62 may also be directly connected to the remote
system 72 using a remote communication line 76 rather than communication through the site controller 64. The site controller 64 may also be connected to the communication line 81 so that the aforementioned information is obtained directly by the site controller 64 rather than through the tank monitor 62.

[0074] Note that any type of controller, control system, sensing unit controller 84, site controller 64 and remote system 72 may be used interchangeably with the tank monitor 62 as described in this application and the claims of this application.

[0075] The present invention takes the vacuum creation technology and sensing technology of the parent disclosures and applies these technologies to the riser pipe 38 and the STP housing 36 as will be explained with reference to Figures 9-13. The use of the vacuum creation technology and the sensing technology extends the leak detection of the parent disclosures to new locations in the fueling system. Specifically, the extension detects leaks in the riser pipe 38 or in the STP housing 36 of the submersible turbine pump 30. This leak detection can be done in conjunction with the leak detection of the parent disclosures. For example, a holistic system might detect leaks in the underground storage tank 20, the riser pipe 38, the STP housing 36, and the main fuel piping conduit 48. Specifically, a vacuum may be created by the vacuum siphon of the submersible turbine pump 30 and applied to all of these regions. Then, the leak detection algorithms of Figures 4A-7 may be applied to these regions so that leaks may be detected. This extension may help comply with new regulations being imposed on fueling environments. Even if this extension is not required by regulation or statute, fueling environment operators may wish to install such systems to increase the likelihood of detecting a leak to minimize environmental damage and/or prevent loss of inventory.

[0076] Turning to Figure 9, the STP sump 31 is illustrated. As explained above, the STP housing 36 sits atop the riser pipe 38. While Figure 9 shows the riser pipe 38 completely contained within the STP sump 31, it is possible that a portion of the riser pipe 38 may be external to the STP sump 31 as is illustrated in Figure 3. In the embodiment of Figure 9, the riser pipe 38 has an
interior fuel flow pipe 400, an interstitial space 402, and an exterior wall 404. A pressure sensor 60 may be positioned within the interstitial space 402. Further, the vacuum tubing 70 may be connected to the interstitial space 402 through the sensing unit 82 or directly as needed or desired. If the sensing unit 82 is used, then it is possible to omit the pressure sensor 60 within the interstitial space 402. As illustrated, the exterior wall 404 is crimped at each end of the riser pipe 38 so that the interstitial space 402 is isolated from other interstitial spaces such as areas 27 and 56. While crimping is one specifically contemplated treatment for the end of the riser pipe 38, other sealing treatments may also be used and still be within the scope of the present invention. Such seals can be made by welding, potting, and the like as is well understood in the industry. By isolating interstitial space 402 in this manner, the pressure sensor 60 may detect a leak within the confines of interstitial space 402 independently of leaks in other interstitial spaces 27 and 56. It should be appreciated that the processes of detecting the leak described with reference to Figures 2-8 would be used to detect the leak in interstitial space 402.

[0077] In contrast to the embodiment of Figure 9, wherein the vacuum tubing 70 fluidly connects to the interstitial space 402 through the exterior wall 404, Figure 10 illustrates that the vacuum tubing 70 may alternatively connect to the interstitial space 402 through a fitting 406 or 406A (or both) positioned at either end of the riser pipe 38. The use of a fitting 406 or 406A allows the vacuum tubing to 70 to connect to the interstitial space 402 without creating a breach in exterior wall 404. This further precludes the necessity for custom made riser pipes 38 with specialized elements that allow the vacuum tubing 70 to be connected thereto. Two embodiments of exemplary fittings are explained below in Figures 14 and 15. A brief summary is provided here for convenience. The fittings described in this application contemplate a number of different options. In one embodiment, the fitting allows the connection of the interstitial space 402 to the vacuum tubing 70. Additionally, the fitting has threads that are adapted to be threaded into a complementary element such as the STP housing 36. The fitting lies flush against the element, and may capture any leaks through the threads and convey these leaks to the
interstitial space 402. The interested reader is referred to the fitting application for more details about the structure and function of the fitting.

[0078] A third embodiment of the leak detection system of the present invention is illustrated in Figure 11 wherein the interstitial space 402 is fluidly connected to the interstitial space 27 of the underground storage tank 20. Specifically, the interstitial spaces 27 and 402 are connected through the fitting 408, which is designed to allow fluid communication therethrough. The vacuum tubing 70 is connected to the interstitial space 402 through the exterior wall 404, through the fitting 408 (not shown, but suggested by fitting 406 in Figure 10), or could alternatively be connected to the interstitial space 27 as explained in the previously incorporated related application serial number 10/390,346. Pressure sensors 60 may be positioned in the interstitial space 402 or in the sensing unit 82 as needed or desired. It should be appreciated that the processes of detecting the leak described with reference to Figures 2-8 would be used to detect the leak in interstitial space 402. This embodiment allows a single pressure sensor 60 or sensing unit 82 to detect a leak in interstitial spaces 27 and 402. This may allow equipment costs to be reduced, albeit at the expense of resolution. Specifically, if these interstitial spaces 27 and 402 are fluidly connected, it may be difficult to determine if a detected leak is in the interstitial space 27 or the interstitial space 402 without a visual inspection.

[0079] As yet another alternative, the interstitial space 402 of Figure 12 may extend into the STP housing 36. In this embodiment, the vacuum tubing 70 may be located entirely within the STP housing 36. The sensing unit 82 may likewise be positioned within the STP housing 36 and connected to the vacuum siphon of the STP 30 via the vacuum tubing 70. In this embodiment, it is possible that the exterior wall 404 may be threaded into a complementary threaded portion of the STP housing 36, while the interior fuel flow pipe 400 extends into the fuel flow area 410 of the STP 30. It should be appreciated that the processes of detecting the leak described with reference to Figures 2-8 would be used to detect the leak in interstitial space 402. This embodiment allows a single sensor 60 or sensing unit 82 to detect leaks in the interstitial space 402 and the interior of the STP housing 36. This may allow equipment
costs to be reduced, albeit at the expense of resolution. Specifically, if these interstitial spaces are fluidly connected, it may be difficult to determine if a detected leak is in the interstitial space 402 or within the STP housing 36.

Another variation of the present invention is illustrated in Figure 13, wherein the STP 30 has an interstitial space 412 delimited by interior wall 414 and exterior wall 416. A pressure sensor 60 may be positioned in the interstitial space 412, and the interstitial space 412 may be connected to the vacuum-creating siphon of the STP 30 through vacuum tubing 70 as previously explained. It should be appreciated that the processes of detecting the leak described with reference to Figures 2-8 would be used to detect the leak in interstitial space 412. This embodiment allows a sensor 60 or sensing unit 82 to detect leaks in the STP housing 36. This may help comply with environmental regulations or minimize environmental damage. Further, this embodiment helps provide complete double-walled protection for every element within the fueling environment.

Turning now to Figures 14 and 15, two embodiments of the fitting 406 are shown. Double-walled piping, which may be the riser pipe 38, the main fuel piping conduit 48, or the like, is fluidly connected to a receptacle 490, such as the STP housing 36, the STP sump 31, or the like. To help effectuate this connection, a fitting 500 is secured to the end of the double-walled piping. The fitting 500 may be secured to the double-walled piping with glue, crimping, welding, threaded elements, or the like, as is well understood in the industry. Fitting 500 includes an interior space 502 through which fuel flows. Interior space 502 is delimited by interior wall 504. Interior wall 504 is surrounded by outer wall 506. Interstitial space 508 is fluidly connected to the interstitial space of the double-walled piping.

Interior wall 504 has threads 510 on a terminal end thereof. In the exemplary embodiment, the threads 510 are male threads adapted to be received by complementary female threads 494 in the wall 492 of the receptacle 490.

Outer wall 506 has a flange 512 on a terminal end thereof. Flange 512 has a groove 514 that is adapted to receive an o-ring 516 therein. An upper surface 518 of flange 512 lies flush with an exterior surface 496 of the
wall 492, and o-ring 516 causes a seal to be formed between the receptacle 490 and the fitting 500. By forming this seal, any fluid that leaks through the threads 510 and 494 is captured in interstitial space 508.

**[0084]** A fluid channel 520 is delimited by outer wall 506 and protuberance 522. Vacuum tubing (not shown, but, for example, vacuum tubing 70) may be snap-fit over or otherwise connected to protuberance 522. Vacuum tubing may then be connected to a vacuum source, such as the siphon area of the STP, or the vacuum tubing may be connected to another interstitial space that is already under vacuum. This connection to an interstitial space already under vacuum will create a vacuum in interstitial space 508 for monitoring or other purposes as needed or desired. In this manner, the interstitial space 508 can be monitored up to the point of the threads 510 of the fitting 500 rather than only up to the point of the connection between the fitting 500 and the double-walled piping. Further, the fluid channel 520 can be provided at the fitting 500 instead of in the double-walled piping.

**[0085]** An alternate embodiment for the fitting 500 is illustrated in Figure 15. Instead of the protuberance 522 and channel 520, the embodiment of Figure 15 has a channel 524 that extends through the wall 492 of the receptacle 490. In this manner, the interstitial space 508 is extended through the fitting 500 to the receptacle 490 so that a vacuum source within the receptacle 490 can be used to generate a vacuum in the interstitial space 508. An example would be an STP generating a vacuum in a riser pipe. Alternatively, if the interstitial space 508 is already under a vacuum, the channel 524 can be used to create a vacuum within the receptacle 490. Other variations of fittings are also possible.

**[0086]** The various embodiments presented herein allow for double-walled containment to be positioned in virtually every location within the fueling environment. Further, the present invention teaches a method of leak detection for each of these situations so as to avoid contaminating the environment with leaking fuel.

**[0087]** Those skilled in the art will recognize improvements and modifications to the preferred embodiments of the present invention. All such improvements and modifications are considered within the scope of the
concepts disclosed herein and the claims that follow. Note that the sensing unit 82 may be contained inside the STP housing 36 or outside the STP housing 36, and may be contained inside or outside the STP sump 31.
Claims

What is claimed is:

1. A system for detecting a leak, comprising:
   a riser pipe formed from a length of double-walled piping, said riser pipe comprising:
   - an inner space adapted to draw fuel from a storage tank; and
   - an interstitial space between walls of the double-walled piping;
   a sensing unit, comprising:
   - vacuum tubing coupled to the interstitial space;
   - a pressure sensor coupled to said vacuum tubing to detect a vacuum level in the interstitial space; and
   - a sensing unit controller that is coupled to said pressure sensor to determine the vacuum level in the interstitial space; and
   a submersible turbine pump associated with said riser pipe, said submersible turbine pump fluidly coupled to the fuel in the storage tank to draw the fuel out of the storage tank through the inner space of the riser pipe, wherein said submersible turbine pump is also coupled to said vacuum tubing;
   - said submersible turbine pump creates a vacuum level in said vacuum tubing to create a vacuum level in the interstitial space; and
   - said sensing unit controller determines the vacuum level in the interstitial space using said pressure sensor.

2. The system of claim 1, further comprising a tank monitor that is electrically coupled to said submersible turbine pump wherein said submersible turbine pump creates a defined initial threshold vacuum level in the interstitial space after receiving a test initiation signal from said tank monitor.

3. The system of claim 2, wherein said tank monitor generates a catastrophic leak detection alarm if said submersible turbine pump cannot create said defined initial threshold vacuum level in the interstitial space.
4. The system of claim 2, wherein said tank monitor is electrically coupled to said sensing unit controller to receive the vacuum level in the interstitial space.

5. The system of claim 4, wherein said tank monitor determines if the vacuum level in the interstitial space has decayed to a catastrophic threshold vacuum level from said defined initial threshold vacuum level.

6. The system of claim 5, wherein said tank monitor activates said submersible turbine pump to attempt to lower the vacuum level in the interstitial space back down to said defined initial threshold vacuum level if the vacuum level in the interstitial space decays to said catastrophic threshold vacuum level.

7. The system of claim 6, wherein said tank monitor determines if the vacuum level in the interstitial space lowers to said defined initial threshold vacuum level within a defined amount of time.

8. The system of claim 7, wherein said tank monitor generates a catastrophic leak detection alarm if said tank monitor determines that the vacuum level in the interstitial space does not lower to said defined initial threshold vacuum level within said defined amount of time.

9. The system of claim 4, wherein said tank monitor determines if a leak exists in the riser pipe by determining if the vacuum level in the interstitial space decays to a threshold vacuum level in a predetermined amount of time.

10. The system of claim 9, wherein said threshold vacuum level is a precision threshold vacuum level.

11. The system of claim 4, further comprising a liquid detection sensor that is coupled to the interstitial space, wherein said liquid detection sensor is
coupled to said sensing unit controller and wherein said liquid detection sensor detects if liquid is present in the interstitial space.

12. The system of claim 11, wherein said sensing unit controller communicates a liquid detection by said liquid detection sensor to said tank monitor.

13. The system of claim 12, wherein said tank monitor generates a leak detection alarm when said liquid detection is communicated from said sensing unit controller.

14. The system of claim 12, wherein said tank monitor disables said submersible turbine pump when said liquid detection is communicated from said sensing unit controller.

15. The system of claim 11, wherein said liquid detection sensor comprises a float.

16. The system of claim 1, further comprising a vacuum control valve that is coupled inline to said vacuum tubing between said submersible turbine pump and said pressure sensor wherein said vacuum control valve is electrically coupled to and under control of said sensing unit controller.

17. The system of claim 16, wherein said sensing unit controller closes said vacuum control valve before monitoring the vacuum level in the interstitial space to determine if a leak exists in the fuel piping so that said submersible turbine pump is isolated from the interstitial space.

18. The system of claim 1, wherein said riser pipe is sealed.

19. The system of claim 1, wherein said vacuum tubing is connected to the interstitial space through a fitting.
20. The system of claim 1, wherein said vacuum tubing is connected to the interstitial space through an outer wall of the double-walled piping.

21. The system of claim 1, wherein said interstitial space is fluidly coupled to a second interstitial space, said second interstitial space surrounding the storage tank.

22. The system of claim 1, further comprising a check valve located in said vacuum tubing between said submersible turbine pump and said sensing unit to prevent ingress from the interstitial space to said submersible turbine pump.

23. The system of claim 1 wherein said interstitial space is fluidly connected to an interior portion of the submersible turbine pump.

24. The system of claim 23, wherein said riser pipe threads into said submersible turbine pump.

25. The system of claim 24, wherein said vacuum tubing is positioned within the submersible turbine pump.

26. The system of claim 1 further comprising a sump, said submersible turbine pump and said riser pipe positioned within said sump.

27. The system of claim 26, wherein said vacuum tubing is positioned within said sump.

28. A system for detecting a leak, comprising:
   a riser pipe formed from a length of double-walled piping, said riser pipe comprising:
       an inner space adapted to draw fuel from a storage tank; and
an interstitial space between walls of the double-walled piping;
a pressure sensor positioned in said interstitial space and adapted to
sense a pressure level within said interstitial space; and
a submersible turbine pump associated with said riser pipe, said
submersible turbine pump fluidly coupled to the fuel in the storage tank to
draw the fuel out of the storage tank through the inner space of the riser pipe,
wherein said submersible turbine pump is also coupled to said vacuum
tubing;
wherein said submersible turbine pump creates a vacuum level in said
vacuum tubing to create a vacuum level in the interstitial space, and
wherein said pressure sensor reports the vacuum level in the interstitial
space to a controller.

29. The system of claim 28 further comprising a sump, said riser pipe
positioned within said sump.

30. A system for detecting a leak, comprising:
a submersible turbine pump, comprising:
a head unit, said head unit comprising:
an inner wall;
an outer wall; and
an interstitial space therebetween;
a boom adapted to draw fuel from a storage tank, said boom
operatively coupled to said head unit; and
a vacuum generator adapted to draw a vacuum, said vacuum
generator positioned within said head unit;
a sensing unit, comprising:
vacuum tubing connecting the vacuum generator to the
interstitial space; and
a pressure sensor coupled to said vacuum tubing to detect a vacuum
level in the interstitial space.
31. The system of claim 30, wherein said pressure sensor is positioned within said interstitial space.

32. The system of claim 30, further comprising a sensing unit controller adapted to communicate with the pressure sensor and control the vacuum generator as needed to maintain a vacuum in the interstitial space.

33. A method for detecting a leak in a double-walled riser pipe having an interstitial space, comprising:

   creating a vacuum level in the interstitial space of the riser pipe using a submersible turbine pump that is also fluidly coupled to the fuel in the storage tank to draw the fuel out of the storage tank;

   sensing the vacuum level in the interstitial space using a pressure sensor; and

   monitoring the vacuum level in the interstitial space to determine if a leak exists in the fuel piping.

34. The method of claim 33, further comprising coupling the submersible turbine pump to the interstitial space using vacuum tubing.

35. The method of claim 34, wherein said step of coupling the submersible turbine pump to the interstitial space using vacuum tubing comprises coupling the vacuum tubing to the interstitial space through an outer wall of the riser pipe.

36. The method of claim 34, wherein said step of coupling the submersible turbine pump to the interstitial space using vacuum tubing comprises coupling the vacuum tubing to the interstitial space through a fitting associated with the riser pipe.

37. The method of claim 33 further comprising fluidly connecting the interstitial space of the riser pipe to an interstitial space of the storage tank.
38. The method of claim 33 further comprising fluidly connecting the interstitial space of the riser pipe to an interior portion of the submersible turbine pump.

39. The method of claim 33 further comprising crimping both ends of the riser pipe.

40. The method of claim 33 wherein the step of sensing the vacuum level in the interstitial space using a pressure sensor comprises sensing the vacuum level with a pressure sensor positioned in the interstitial space.

41. The method of claim 33, further comprising the step of sensing whether fluid is present in the interstitial space using a liquid detection sensor.

42. The method of claim 41, further comprising generating a liquid leak detection alarm if said liquid detection sensor senses liquid in the interstitial space.

43. The method of claim 41, further comprising disabling said submersible turbine pump if said liquid detection sensor senses liquid in the interstitial space.

44. The method of claim 33, further comprising closing a vacuum control valve to isolate said submersible turbine pump from the interstitial space before performing said step of monitoring the vacuum level in the interstitial space.

45. The method of claim 34, further comprising verifying a leak in the interstitial space by closing an isolation valve in said vacuum tubing that isolates the interstitial space from said submersible turbine pump.

46. The method of claim 33, further comprising preventing ingress from the interstitial space to said submersible turbine pump.
47. The method of claim 33, further comprising determining if said submersible turbine pump is drawing a sufficient vacuum level in the interstitial space.

48. The system of claim 47, further comprising generating an alarm if said submersible turbine pump is not drawing a sufficient vacuum level in the interstitial space.

49. A method for detecting a leak in a head unit of a submersible turbine pump, comprising:
   forming an interstitial space in the head unit between an inner wall and an outer wall;
   creating a vacuum level in the interstitial space of the head unit using a vacuum generator within the submersible turbine pump;
   sensing the vacuum level in the interstitial space using a pressure sensor; and
   monitoring the vacuum level in the interstitial space to determine if a leak exists in the head unit.

50. A fitting adapted for use with a double-walled piping system, said fitting comprising:
   an interior space delimited by an interior wall;
   an outer wall surrounding said interior wall and defining an interstitial space therebetween;
   said interstitial space adapted to be connected fluidly to a vacuum.

51. The fitting of claim 50 wherein said interstitial space is adapted to be connected fluidly to a vacuum via a fluid channel delimited by a protuberance.

52. The fitting of claim 50 wherein said interstitial space is adapted to be connected fluidly to a vacuum via a fluid channel piercing a wall of a receptacle to which said fitting is secured.
53. A method of using a fitting comprising
    placing a flange on said fitting against an exterior wall of a receptacle;
    fluidly connecting an interstitial space of the fitting to a vacuum.

54. The method of claim 53 wherein fluidly connecting an interstitial space
    of the fitting to a vacuum comprises connecting vacuum tubing to a
    protuberance.

55. The method of claim 53 wherein fluidly connecting an interstitial space
    of the fitting to a vacuum comprises fluidly connecting the interstitial space to
    a vacuum within the receptacle.
FIG. 2
FIG. 3
START

OPEN THE VACUUM CONTROL VALVE (90)

PUMP OUTER ANNULAR SPACE (56) TO DEFINED INITIAL VACUUM LEVEL USING STP (30) AS VACUUM GENERATOR

CLOSE THE VACUUM CONTROL VALVE (90) TO ISOLATE OUTER ANNULAR SPACE (56) FROM STP (30) VACUUM SOURCE

MONITOR THE VACUUM LEVEL IN THE OUTER ANNULAR SPACE (56) USING THE PRESSURE SENSOR (60)

HAS VACUUM LEVEL DECAYED TO CATASTROPHIC THRESHOLD PRESSURE LEVEL?

OPEN THE VACUUM CONTROL VALVE (90)

ACTIVATE THE STP (30)

FIG. 4A
5/16

118
GENERATE CATASTROPHIC LEAK ALARM

120
DISABLE THE STP (30) IF PROGRAMMED FOR SHUTDOWN

122
END

116
HAS VACUUM LEVEL IN OUTER ANNULAR SPACE (56) LOWERED TO DEFINED LEVEL IN DEFINED TIME?

118

3

124
CLOSE THE VACUUM CONTROL VALVE (90)

126
HAS VACUUM LEVEL DECAYED TO PRECISION THRESHOLD PRESSURE LEVEL IN DEFINED TIME?

128
GENERATE PRECISION LEAK DETECTION ALARM

130
IS STP (30) PROGRAMMED FOR SHUTDOWN?

132
SHUT DOWN STP (30)

134
END

130
NO

132
YES

134

4

FIG. 4B
START 150

LEAK DETECTED BY LIQUID DETECTION SENSOR (94)?

NO

YES

GENERATE LIQUID LEAK DETECTION ALARM 154

SHUT DOWN STP (30) 158

YES

STP (30) PROGRAMMED FOR SHUTDOWN IF LIQUID LEAK DETECTED?

NO

END 160

FIG. 5
START

PROGRAM TANK MONITOR (62) FOR VACUUM LEAK DETECTION TEST MODE

OPEN DRAIN VALVE (96) OR OUTER ANNULAR SPACE (56)

START TIMER

HAS TIMER TIMED OUT?

LEAK DETECTION ALARM DETECTED?

INDICATE VACUUM LEAK DETECTION TEST FAILED

INDICATE VACUUM LEAK DETECTION TEST PASSED

END

FIG. 6
START 300

SET TANK MONITOR (62) FOR LIQUID LEAK DETECTION TEST MODE 302

CLOSE VACUUM CONTROL VALVE (90) 304

OPEN DRAIN VALVE (96) OR OUTER ANNULAR SPACE (56) IF PRESENT IN THE SYSTEM 306

REMOVE LIQUID DETECTION SENSOR (94) AND PLACE INTO CONTAINER OF LIQUID OR INJECT LIQUID INTO LIQUID DETECTION CONDUIT (92) AND CLOSE DRAIN VALVE (96) 308

INDICATE LIQUID LEAK DETECTION TEST FAILED 316

LIQUID LEAK DETECTION ALARM GENERATED? 310

NO

YES

INDICATE LIQUID LEAK DETECTION TEST PASSED 312

OPEN DRAIN VALVE (96) TO DRAIN LIQUID AND CLOSE DRAIN VALVE (96) OR USE SUCTION TO REMOVE INJECTED LIQUID 313

END 314

FIG. 7
FIG. 15
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

| IPC 7 | B67D5/32 |

According to International Patent Classification (IPC) or to both national classification and IPC.

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

| IPC 7 | B67D | G01M | B65D |

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched.

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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Further documents are listed in the continuation of box C. Patent family members are listed in annex.

* Special categories of cited documents *

- **A** document defining the general state of the art which is not considered to be of particular relevance
- **D** earlier document but published on or after the international filing date
- **L** document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- **O** document referring to an oral disclosure, use, exhibition or other means
- **P** document published prior to the international filing date but later than the priority date claimed

**Date of the actual completion of the international search**

29 March 2005

**Date of mailing of the international search report**

14.04.2005

Name and mailing address of the ISA

European Patent Office, P B 5918 Patentan 2 NL - 2280 HV Rijswijk
Tel (+31-70) 346-2040, Tx 31 651, opra nl
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Authorized officer

Mueller, C
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## INTERNATIONAL SEARCH REPORT

### Box II  Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.: because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. □ Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 9.4(a).

### Box III  Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. □ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. □ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

□ The additional search fees were accompanied by the applicant's protest.

X No protest accompanied the payment of additional search fees

Form PCT/ISA/210 (continuation of first sheet (2)) (January 2004)
This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-29, 33-48
   Leak detecting system with submersible turbine pump

2. claims: 30-32, 49-52
   Leak detecting system with a vacuum generator

3. claims: 53-55
   Method of using a fitting
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<tr>
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