The title of the document is "VAPOUR RECOVERY SYSTEM WITH FLOW RATE SENSOR".

The abstract describes a vapour recovery system that includes a vapour monitor (66) comprising a solid state anemometer (80) positioned in the vapour return line to calculate the volume of vapour returning in a vapour return line (34). The anemometer (80) is connected to a control system (50) which compares the volume of returning vapour to the volume of fuel being dispensed and adjusts the speed at which vapour is recovered to a desired value. The anemometer (80) may be a Wheatstone bridge arrangement (82) or a pair of thermometers.
VAPOUR RECOVERY SYSTEM WITH FLOW RATE SENSOR

The present invention pertains to a fuel dispensing system having a vapour recovery system with a feedback mechanism to control more accurately vapour flow. The invention is particularly applicable to dispensers for refueling motor vehicles.

The primary purpose of using a vapour recovery fuel dispenser is to retrieve or recover vapours, which would otherwise be emitted from a vehicle to the atmosphere during a refuelling operation which vapour is displaced and forced out through the filler pipe when fuel is pumped into the tank.

A vapour recovery system for fuel dispensers is disclosed in U.S. Patent 5,040,577 to Pope, which is herein incorporated by reference. This patent discloses vapour recovery apparatus in which a vapour pump in the vapour return line is driven by a variable speed motor. The liquid fuel flow line includes a pulser, conventionally used for generating pulses indicative of the volume of liquid fuel being pumped to permit computation of the total sale and the display of the volume in a conventional display. Additionally a microprocessor translates the pulses indicative of the fuel flow rate into a desired vapour pump operating rate. This permits the vapour to be pumped at a rate correlated with the liquid flow rate.

There are three basic arrangements which can be used to control vapour flow during a fuelling operations. The first uses of a constant speed vapour pump during fuelling without any sort of control mechanism. The second is the use of a pump driven by a
constant speed motor coupled with a controllable valve to extract vapour from the vehicle gas tank. While the speed of the pump is constant, the valve may be adjusted to increase or decrease the flow of vapour. The third is the use of a variable speed motor as described above with reference to US 5,040,577. All three techniques have advantages either in terms of cost or effectiveness, and depending on the reasons driving the installation, any of the three may be appropriate. The present state of the art is also indicated in US patent 5,345,979.

A feedback mechanism in the vapour return line may help to ensure that the amount of vapour being returned to the underground storage tank is correct. Accurate control of the vapour to liquid (V/L) ratio, (which is the ratio of vapour-air being returned to the underground storage tank to the amount of liquid being dispensed) is important. Often, systems have a V/L ratio greater than 1 to ensure that excess air is recovered rather than allowing some vapour to escape. This higher V/L ratio causes excess air to be pumped into the underground storage tank, which can result in a pressure build up therein and may also result in a weak, and thus potentially explosive mixture in the storage tank. The pressure build up can also be hazardous, and as a result most underground storage tanks have a vent that releases vapour-air mixtures resident in the underground storage tank to the atmosphere should the pressure within the underground storage tank exceed a predetermined threshold. While effective to relieve the pressure, it does allow hydrocarbons or other volatile vapours to escape into the atmosphere.

While PCT application Serial No. PCT/GB98/00172 published 23 July 1998 as WO 98/31628, discloses one method to create a feedback loop using a Fleisch tube, there remains a need to create alternate feedback mechanisms to more accurately measure the
vapour flow in a vapour recovery system in order to minimize the need to vent the underground storage tank to the atmosphere and ensure proper vapour recovery.

According to the present invention there is provided a fuel dispensing system comprising: a fuel delivery system adapted to deliver fuel along a fuel delivery path from a storage tank to a vehicle during a fueling operation: a variable flow rate vapour recovery system having a vapour recovery path to deliver vapours expelled from the vehicle to the storage tank when fuel is delivered during a fueling operation: and a control system for controlling the vapour recovery system, wherein the system further comprises a solid state anemometer, the control system being coupled to said anemometer to determine vapour flow rate and control the vapour flow rate accordingly.

Employing the present invention an anemometer is placed in the vapour return line, and may be formed in an integrated circuit preferably proximate the vapour pump. The anemometer, which may use microanemometer technology provides an accurate measurement of the velocity of the vapour flow there across. Coupled with the knowledge of the diameter of the vapour return line, an accurate measurement of the volume of the returning vapour can be calculated. From this volume measurement, a microprocessor can control the variable speed motor, or valve associated with a constant speed motor to accurately control the vapour extraction rate.

The anemometer preferably comprises a Wheatstone bridge circuit, but in an alternative embodiment may include at least one, and preferably a pair, of thermometers or
temperature probes positioned in the vapour recovery line that can be used to determine the vapour flow therethrough.

The present invention provides a practical feedback mechanism that enables problems previously encountered to be overcome. Previously, a single motor and pump has been impractical for use with a two sided fuel dispenser. The reason for this is that it would be difficult to use one motor to recover vapours for two different fuelling positions when two different cars are being fuelled at potentially different rates. This is due in large part to the inability to ensure that a proper vacuum is created at both sides of the dispenser to recover the vapours. In essence, what would happen in the prior art devices would be a good vacuum would be created on one side to recover vapour during a fuelling transaction, and then the other side would begin dispensing fuel, resulting in the partial loss or reduction of vacuum at the first side. Without a feedback mechanism, there was no way to know how much to compensate in the first vapour recovery line.

The above mentioned problem is solved in a preferred embodiment of the present invention by providing valves upstream of the vapour pump together with the feedback mechanism associated with each side of the dispenser. This combination allows the vapour recovery to be monitored in each vapour recovery line while the valves are independently adjusted to ensure the proper vapour flow. Rather than rely on some sort of estimation of the impact of the second side vapour recovery, a real time measurement can be made and the valves adjusted until the desired vapour recovery is achieved. In this manner, the flow rates of the respective lines may be varied relative to one another, while operating a common vapour recovery pump at a constant speed.
Various embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings in which:

Fig. 1 is a vapor recovery system according to the present invention;

Fig. 2A is the vapor flow meter coupled with a variable speed motor;

Fig. 2B is the vapour flow meter coupled with a constant speed motor and adjustable valve;

Fig. 2C is the vapor flow meter coupled with a constant speed motor and two adjustable valves for use in both sides of a fuel dispenser;

Fig. 3 is a first embodiment of the vapour return flow monitor and

Fig 4 is a second embodiment of the vapor return flow monitor.

Referring now to Figure 1, a fuel dispenser 10 is adapted to deliver a fuel, such as gasoline or diesel fuel, to a vehicle 12 through a delivery hose 14, and more particularly through a nozzle 16 and spout 18. The vehicle 12 includes a fill neck 20 and a tank 22.

The dispenser has a flexible delivery hose 14 with an outer conduit 30 and an inner conduit 32. The annular chamber formed between the inner and outer conduits 30, 32 form the fuel delivery line 36. The interior of the inner conduit 32 forms the vapour return line 34. Line 36 and 34 split at connection 51 before being connected, via dispenser 10, to an underground storage tank 40. The underground storage tank 40 is
equipped with a vent shaft 42 and a vent valve 44. During delivery of fuel into the tank
22, the incoming fuel displaces air containing fuel vapours. The vapours are captured by
the vapour recovery system and travel through the vapour return line 34 to the
underground storage tank 40.

The fuel dispenser 10 is controlled by a control system 50, which includes appropriate
electronic circuitry including microprocessor. The control system 50 controls a vapour
recovery system 52 as described below with reference to Figs. 2A-2C.

Fig. 2A shows the product delivery line 36, which includes a flow meter 54 and a pulser
56. The pulser 56 generates electrical pulse signals indicative of the amount of
displacement occurring in the meter 54. Typical pulse 56 generate approximately 1000
pulses for every 4.55 litres of fuel dispensed. The pulser 56 is connected to the control
system 50 as generally indicated by pulse data stream 70. The vapour recovery system
52 includes a vapour pump 60 proximate the vapour return line 34, driven by a vapour
motor 62. A vapour flow monitor 66 is positioned within the vapour return line as
explained in greater detail below. The motor 62 is connected to the control system 50 by
vapour pump control data stream 72. The vapour flow monitor 66 is connected to the
control system by flow feedback data stream 74. It should be appreciated that data
streams 70, 72, 74 and valve control data stream 76 (explained below) could be
implemented by conventional wiring or wireless transceivers or similar.

In operation, the motor 62 in Figure 2A, is a variable speed motor, thus pump 60 is a
variable speed pump. The pump 60 is a conventional pump constructed to handle
vapour laden air and liquid fuel without risk of explosion or overheating.
An alternate arrangement using a constant speed pump is shown in Figure 2B, wherein motor 62’ is a constant speed motor. To control the flow of vapour through the vapour recovery line 34, a vapour return valve 64 is positioned in the vapour return line 34. The vapour return valve 64 is connected to the control system by valve control data stream 76. To control the vapour flow, the position of valve 64 is set accordingly.

A third arrangement is shown in Figure 2C, where a constant speed motor 62’ coupled with a pump 60, is positioned downstream of a Y-branch 68 of the vapour return line 34. In this configuration, the motor 62’ drives the pump 60 continuously, creating a vacuum at the branch 68. However, vapour/air is not drawn into the line 34 unless one of the valves 64 is opened. Thus, it is possible to recover simultaneously vapour from both sides of a fuel dispenser 10 using the same vapour pump 60.

The vapour flow monitor 66 allows the V/L ratio to be monitored in real time and the vapour flow rate controlled as desired. Once fuel flow begins and the vapour recovery process starts. The vapour flow monitor 66 detects the vapour flow. The vapour pump 60 may begin operation when the nozzle 16 is lifted from the fuel dispenser 10 to create an initial vacuum pressure by the time fuel begins to be dispensed. This helps ensure immediate capture of the “puff” of vapour known to be released during the initial stage of the fuelling process. The flow rate detected by the monitor 66 is converted to an electrical signal and sent to the control system 50. The system 50 compares the actual vapour recovery rate with the expected rate for the volumetric flow rate of fuel being delivered. The system 50 then adjusts, depending on the embodiment, either the variable speed motor 62 or the valves 64 to ensure the desired vapour recovery rate is
maintained. Whilst it may be preferred that a V/L ratio of 1 is achieved other ratios may be desired.

To cope with Onboard Recovery Vapour Recovery (ORVR) technology, in which the vehicle 12 recovers a large percentage of the vapour from within the gas tank 22, some modification to the embodiments described above will be necessary because when a vehicle 12 being fuelled includes an ORVR system it is not desirable for the vapour recovery system 52 of the fuel dispenser 10 to compete with the ORVR system.

There are several commercially available ORVR detection systems, one such system being disclosed in U.S. patent 5,782,275, which is herein incorporated by reference. The present system can address the problem presented by ORVR by providing an ORVR sensor, which may be a pressure or hydrocarbon sensor within the vapour recovery line 34. However alternatively a transponder arrangement may be used, which receives an RF signal from a vehicle 12 with instructions that the vehicle 12 includes an ORVR system.

Once detection of a vehicle 12 with an ORVR system occurs, various vapour recovery control options are available. Disabling the fuel dispenser’s vapour recovery system 52 reduces underground storage tank 40 pressure, and thereby reduces losses due to fugitive emissions and reduces wear and unnecessary use of vapour recovery system 52. Alternatively, the dispenser’s vapour recovery system 52 can be adjusted to reduce the vacuum created by the fuel dispenser 10 during the fuelling of an onboard vapour recovery equipped vehicle 12. Preferably, the vapour recovery system 52 provides enough vapour/air to the underground storage tank 40, that when the air saturates with
hydrocarbons the volume is approximately equal to the amount of fuel dispensed; thereby minimizing pressure fluctuation in the underground storage tank 40.

The vapour monitor 66 comprises an anemometer, and two preferred embodiments utilising a microanemometer are illustrated in Figures 3 and 4. The first embodiment, (Figure 3), comprises a solid state microanemometer 80 including a Wheatstone bridge. A Wheatstone bridge comprises four resistances connected together in a square configuration, with two pairs of parallel connecting legs forming the sides of the square, and four electrically conductive contacts located at the corners. Application of a known voltage between two diagonally opposed corner contacts results in a voltage reading on a meter connected across the other diagonally opposed corner contacts.

A Wheatstone bridge with four resistances of known value can be used as a sensor to measure parameters such as pressure, force, flow rate and direction. Such a Wheatstone bridge is symmetrical, and, in principal, remains in balance for any ambient temperature. However, gas or other mass flow across the bridge cools the legs. Because resistivity of most materials is temperature dependent, the flow affects the resistance of these legs generally, the resistors most affected by the air flow will be the resistors that are oriented transverse to the direction of the air flow, i.e., the resistors whose entire length is exposed to the flow and thus sets the bridge into imbalance, and results in a voltage change corresponding to the velocity of the flow. However, the resistors oriented in parallel to the flow will also be somewhat affected, depending upon the aspect ratio of the resistor legs. The aspect ratio is the ratio of the length to the width of each resistor leg. The sensitivity of such a device increases as the aspect ratio increases.
Thus, for a Wheatstone bridge with legs of a predetermined length, sensitivity can be increased by decreasing the width of the legs.

Exemplary anemometers 80 are fully disclosed in U.S. Patents 4,930,347; 5,231,877 and 5,310,449 to Henderson, which are herein incorporated by reference. The change in the resistance and the corresponding change in the voltage of the Wheatstone bridge 82 is used to calculate the velocity of the vapour flowing thereacross, thus providing the basis for a volume calculation by the control system 50. This velocity calculation can be done by using formulas or look-up tables derived during calibration of the system. Thus, prior to the introduction of the anemometer 80 into the vapour recovery line, it is tested in a factory setting and anemometer readings are taken corresponding to known velocities of vapours. The readings are then placed in a look-up table in a memory (not shown) in the control system 50. Alternatively, a formula may be used, which translates a given anemometer reading to a given velocity, again based on the calibration testing performed in the factory.

The anemometer 80 may be positioned at any spot on the vapour return line 34, so long as it is not integrated with the product delivery line 36. This is due to the fact that the heat from the fuel flow in the adjacent line 36 may affect the measurements of the anemometer 80. Thus, while it is possible to place the anemometer 80 anywhere between the split 51 and the pump 60, it is more advantageous to place the anemometer 80 in a location where the vapour flow will be more accurate, such as proximate the pump 60. The closer the anemometer 80 is to the pump 60, the more accurate the measurement because that will be the point at which pressure in the vapour return line is most constant. Additionally, the closer to the pump 60, the less likely that the
anemometer 80 will be exposed to liquid fuel. While not inherently problematic or
dangerous, the liquid fuel may affect the readings of the anemometer 80, and thus, it is
desirable to avoid such fuel to anemometer contact.

The anemometer 80 may be enclosed in a metal sleeve or covered in a coating suitable
to the environment in which the anemometer will be placed. Additionally, a temperature
sensor 81 may incorporated into the anemometer 80, or positioned proximate thereto, to
provide an ambient temperature level within the vapour recovery line 34. This would
allow a more accurate determination of the velocity of the vapour flow across the
Wheatstone bridge 82.

Alternatively, the monitor 66 could take the form seen in Figure 4, where two
temperature probes 84 and 88 are used, and wherein the second probe 88 forms a
simple, but effective anemometer. Thus, while the following discussion is in terms of a
temperature probe, the use of a temperature probe is equivalent to an anemometer. The
first temperature probe 84 includes a temperature sensing device 86. The second
temperature probe 88 includes a heat sensing and/or heat creating element 90, which is
controlled by a heating control circuit 92. The element 90 may comprise sensing and
heating elements combined into a single resistive element such as a resistive
temperature device (RTD) or a series of distinct elements such as two thermistors. The
temperature probes 84 and 88 in general may be thermistors, thermocouplings, solid
state devices, platinum RTDS, or the like. Probe 88 can be positioned within the vapour
recovery line 34 similarly to anemometer 80. Additionally, it should be noted that the
temperature probes 84 and 88 could, in some embodiments, be part of an integrated
chip.
The first temperature probe 84 is adapted to measure the temperature of the vapour or air present in the vapour recovery line 34 to provide a frame of reference for the activities of the second temperature probe 88. This is particularly useful where temperatures fluctuate dramatically during the day or even over the course of the year. Because this probe 84 only measures the ambient temperature within the recovery line 34, it is an optional feature, and one probe 88 would suffice to function as an anemometer.

The second temperature probe 88 may function in several ways, both of which are concerned with the emissivity, or the amount of heat radiation from the probe as caused by vapour flow thereacross. Two ways of functioning are of particular interest. First, the heating control circuit 92 can supply a fixed amount of energy to the heat creating portion of element 90, and the sensing portion of element 90 will measure how much the element 90 is cooled by the flow of vapour thereacross. While designed to be precalibrated, ambient temperatures may affect the results elicited from the second temperature probe 88. That is, colder days will usually result in colder vapour, which would cool the probe 88 faster than the actual vapour flow would reflect. The end result could be an erroneous reading that the vapour flow was higher than the actual flow. By detecting the ambient temperature in the vapour recovery line 34 with probe 84, a more accurate measurement of the vapour flow may be accomplished.

The second way that the second temperature probe 88 may function is to calculate how much energy it takes to elevate the second temperature probe 88 to a preselected temperature, or how much energy it takes to elevate the second temperature probe 88 by
a desired amount (e.g. 5 degrees). Again, the first temperature probe 84 may be used to provide a reference point so that the ambient temperature does not alter the results.

In either case, the emissivity of the monitor 66 is measured as the vapour passing across the anemometer cools the monitor 66, providing an accurate reflection of the vapour velocity. This knowledge coupled with the knowledge of the cross-sectional area of the vapour recovery line 34 allows an accurate calculation of the vapour flow rate.

The present invention provides another advantage over the prior art systems in that it provides information about the vapour being returned, specifically the amount being returned to the underground storage tank 40. The actual vapour flow data could be used to show a user (not shown) on the outside, the amount of vapour being captured, or the information could be sent to a further control device in case a problem occurs.

The present invention may be carried out in other specific ways within the scope of the claims other than those herein set forth by way of example.
CLAIMS

1. A fuel dispensing system (10) comprising: a fuel delivery system (36,54) adapted to deliver fuel along a fuel delivery path (36) from a storage tank (40) to a vehicle (12) during a fueling operation: a variable flow rate vapour recovery system (60,62,64) having a vapour recovery path (34) to deliver vapours expelled from the vehicle (12) to the storage tank (40) when fuel is delivered during a fueling operation: and a control system (50) for controlling the vapour recovery system, characterised in that the system further comprises a solid state anemometer (66,80), the control system being coupled to said anemometer to determine vapour flow rate and control the vapour flow rate accordingly.

2. The system of claim 1 wherein said fuel delivery path (36) and said vapour recovery path (34) are spaced apart from one another in a portion of the dispensing system (10) and said anemometer (80) is placed in said vapour recovery path in said portion.

3. The system claim 1 or 2 comprising a vapour recovery pump (60) and wherein said anemometer is placed proximate said vapour recovery pump.

4. The system of any preceding claim wherein the anemometer (80) comprises a Wheatstone bridge circuit (82)

5. The system of any preceding claim wherein the anemometer (80) measures a parameter corresponding to emissivity associated with vapour flowing past the anemometer.
6. The system of claim 5 further comprising an ambient temperature sensor (81) associated with said anemometer (80) in said vapour recovery path and coupled to said control system (50), said control system adapted to modify emissivity measurement based on an ambient temperature of the vapour in said vapour recovery path when determining the actual flow rate of vapour in said vapour recovery path.

7. The system of claim any preceding claim wherein said control system (50) is adapted to control the temperature of said anemometer.

8. The system of claim 7 wherein said control system is adapted to monitor the amount of energy necessary to maintain said anemometer at a constant temperature and determine a vapour flow rate based on the amount of energy necessary to maintain the constant temperature.

9. The system of claim 7 wherein said control system is adapted to provide a fixed amount of energy to heat said anemometer; monitor a temperature drop caused by vapour flow during a fueling operation; and determine vapour flow rate based on the temperature drop caused by the vapour flow.

10. The system of any preceding claim wherein the anemometer is an integrated circuit.
11. The system of any preceding claim wherein the anemometer is contained within the vapour recovery flow path.

12. The system of any preceding claim wherein said vapour recovery system includes a variable speed pump.

13. A fuel dispenser (10) comprising the system of any one of claims 1 to 11.

14. The dispenser of claim 13 wherein said vapour recovery system comprises two vapour recovery paths (36) associated with different sides of the dispenser, each path having an anemometer (66) associated therewith, and means (64) for varying independently the flow rate through each respective vapour path in-dependence on the output of a respective anemometer (66).

15. The dispenser of claim 13 comprising two constant speed pumps operatively connected to said control system and wherein each pump is associated with a valve controlled by said control system, wherein each of said valves is adapted to control the rate of vapour recovery within a respective vapour recovery path.

16. The dispenser of claim 14 wherein said vapour recovery system includes one constant speed pump (60) operatively connected to said control system (50) said pump associated with two valves (64) controlled by said control system and wherein each of said valves is adapted to control the rate of vapour recovery within a respective vapour recovery paths (34).
**INTERNATIONAL SEARCH REPORT**

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