REDUCING STORAGE TANK EMISSIONS USING VAPOR CONDENSATION

This report explains the process and equipment developed by Hilliard Emission Controls, Inc. d/b/a PURGIT® of Houston, Texas to improve worker safety and dramatically reduce environmental emissions from floating roof storage tanks that store volatile organic compounds (VOCs), such as gasoline. Specifically, this report is provided to explain how vapor condensation, as opposed to vapor incineration, dramatically reduces all types of environmental emissions from degassing of VOC storage tanks, improves worker safety and saves energy.

Operators of floating roof storage tanks occasionally empty and "degas" a tank to make it safe for personnel entry for inspections and/or repairs. After removing liquid product from the tank using pumps, VOC vapors remain within the vapor space underneath the floating roof structure, which is generally supported by legs when the storage tank is emptied. The remaining tank vapors may have a VOC concentration of 50% or more (by weight). "Degassing" the tank refers to the process of removing enough of the VOC vapors from the vapor space to allow unrestricted open venting.

This report analyzes the different types of emissions that are released to the environment by processes that rely on incineration of tank vapors, and it explains how condensation of tank vapors can be used to eliminate environmental contamination caused by inefficient vapor incineration methods. While this report discusses degassing in terms of gasoline, the same general principles apply to degassing tanks used to store many other liquid VOCs.

Under TCEQ rules in effect in December 2009 relating to so-called "non-attainment" areas, including the Houston/Galveston/Brazoria area, a gasoline storage tank with a nominal storage capacity of 250,000 gallons or more cannot be vented to the atmosphere, i.e. VOC emissions are not permitted, unless the vapor space partial pressure is less than 0.5 psia (3.4 kPa) under actual storage conditions. An exception applies where the vapors within the tank are processed by a vapor control system that maintains a "control efficiency" of at least 90%. That is, at least 90% of the VOC vapors must be processed in a manner that prevents atmospheric release of the raw VOC vapors. This means that if an incinerator is used as a control device to burn tank vapors, then up to 10% of the throughput can be lawfully vented without being treated.

But reliably achieving the minimum 90% control efficiency and the maximum 34,000 ppm residual VOC in the tank vapors depends heavily on an accurate determination of the composition of the vapor remaining in the tank. Where tank vapors are "controlled" by incineration, the composition of the remaining tank vapor is generally determined using gas samples from a conduit through which the tank vapors are drawn from the tank and routed to an incinerator. However it is unlikely that the tested sample will represent the actual vapor concentration because of air channeling and unmixed zones within the tank.

Some degassing contractors incinerate gasoline vapors from a storage tank to an intake manifold of one or more internal combustion (IC) engines. Engine manifold vacuum pulls the vapors into the engine. The IC engines are generally started up using propane as fuel, and then switched over to run on (and thereby incinerate) the gasoline-laden tank vapors fed to the intake manifold.

The problem with using IC engines is that, because of the limited capacity, even two or three IC engines operating in parallel may require many hours to process the vapors from a large storage tank. Also, IC engines burn the gasoline vapors to produce carbon dioxide, carbon monoxide and nitrogen oxides in the exhaust, all of which are released to the atmosphere as environmental contaminants. Unless the air / VOC vapor ratio is carefully controlled, unburned VOCs may be drawn from the tank into the IC engine and released unburned to the atmosphere. The stoichiometric amount of air required to burn gasoline is 14.7 (by weight). Excess air reduces may lower combustion temperature and impair oxidation, and insufficient air results in the release of unburned gasoline. Controlling the air / VOC vapor ratio in an incinerator is especially difficult because the concentration of gasoline in the tank vapors is constantly changing.

Other degassing contractors rely on different equipment to incinerate tank vapors. These contractors incinerate tank vapors by drawing a stream of gasoline vapors from the tank and routing the vapors to a so-called "thermal oxidation system," i.e. an incinerator. A gas mover is generally used to draw the vapors from a gasoline storage tank and move the vapors into the incinerator where they are burned.

Interestingly, some degassing contractors that operate high-rate "thermal oxidation systems" condemn the use of IC engines as being too slow. While it is true that even multiple IC engines operating in parallel take in and burn tank vapors too slowly to make that method practical for degassing a large storage tank, a high-rate incinerator is far more dangerous and environmentally harmful for use in degassing storage tanks. Degassing contractors that use high-rate incinerators generally don't tell their customers that rapid withdrawal of vapors from a storage tank causes air to enter the vapor space of the tank and to channel to the incinerator inlet. This problem can be best understood by referring to the attached Figure 1.

Figure 1 is an elevation view of a storage tank being degassed using an incinerator system. Atmospheric air channels through the vapor space of the tank because operators of high-rate incinerators, who brag about withdrawal rates of up to 4,500 cubic feet of vapor per minute, draw air into the storage tank through leg penetrations, vacuum breakers and the roof seals near the incinerator inlet. Because the density of the air entering the tank through the openings is not substantially different from the mixture within the vapor space, air entering at openings near the incinerator inlet quickly channels to the incinerator inlet to dilute the gasoline concentration in the vapors drawn to the incinerator. As a result, dead zones form in the vapor space that are far removed from the incinerator inlet. The degassing contractor generally monitors the degassing process taking gas samples taken from the incinerator inlet and measuring the gasoline concentration. As a result, air channeling causes degassing contractors that use high rate incinerator systems to detect the targeted 34,000 ppm concentration in the inlet to the incinerator long before the vapors remaining in the storage tank are safe for release to the atmosphere. As air channels through a portion of the vapor space to the incinerator inlet, only a fraction of the harmful gasoline vapors are actually removed from the storage tank, and a portion of these vapors may be replaced by regeneration from liquid gasoline residue remaining on the tank floor.

Figure 2 is a plan view of the storage tank of Figure 1 showing air channeling from leg penetrations in the floating roof assembly to the incinerator inlet that occurs due to high rate withdrawal of vapors from the storage tank. It can be seen that the leg penetrations, vacuum breaker openings, etc. on the floating roof nearest the incinerator inlet contribute a large portion of the incinerator inlet stream, while openings away from the incinerator inlet contribute little to none of the incinerator inlet stream. The entrainment of air caused by high-rate withdrawal of tank vapors to the incinerator inlet results in the degassing contractor relying on false (diluted by air) vapor concentration readings. These false readings results in premature tank venting and release of harmful gasoline vapors to the atmosphere. The result is irreparable harm to the environment, a very hazardous condition for personnel working in and around the tank and a poor job of tank degassing.

Another problem resulting from air channeling is that air channeling quickly dilutes the stream of tank vapors to the incinerator inlet to a concentration that is below the lower explosive limit (LEL), thereby requiring the use of an auxiliary source of fuel, such as propane, to maintain the air / fuel mixture to the incinerator inlet within a combustible range. The incineration of tank vapors already results in the release of combustion products and greenhouse gases to the environment, and the addition of auxiliary fuel to the incinerator feed stream causes an unnecessary increase in the release of unwanted combustion products and greenhouse gases.

The discussion above explains how degassing contractors that use high-rate incinerators, who often brag about how quickly they degas storage tanks, cause the very environmental damage and hazardous conditions that the rules are designed to prevent. Only by relying on non-representative, diluted gas samples can they even claim to meet the 90% control efficiency requirement. Air channeling leaves dead zones within the vapor space that hold undisturbed, rich gasoline vapors. These dead zones are bypassed by the air channeling from the leg penetrations and vacuum breakers to the incinerator inlet. Simply put, high-rate incineration of storage tank vapors is an environmental hoax and a safety hazard, and should be avoided.

PURGIT® offers an environmentally-sound solution to the problem of storage tank vapors by reducing or eliminating air channeling, LEL concerns and vapor regeneration. Vapor condensation of storage tank vapors provides an environmentally superior method by simultaneously preventing air channeling, mixing tank vapors to disturb dead zones, eliminating combustion emissions, obtaining representative gas samples and suppressing vapor regeneration within the tank. One result is a reliable determination of the concentration of the remaining vapors in the tank so that the degassing process is not prematurely terminated and so that high-concentration gasoline vapors are not released to the environment. Another result is the recovery of valuable quantities of the gasoline product that was stored in the tank – a valuable natural resource that would otherwise be burned in an incinerator to release unwanted combustion products to the environment.

The environmental stewardship offered by PURGIT® is achieved using vapor condensation to replace dirty and inefficient combustion. This environmentally sound process is best understood by referring to the attached Figures 3 and 4.

As shown in Figure 3, a gas mover is used to draw vapors from the storage tank and to route the tank vapors through the shell-side of a shell-and-tube heat exchanger. A pressurized tank of liquid nitrogen is brought to the tank and used to supply a cold stream of nitrogen through the tube side of the heat exchanger to super-cool the stream of tank vapors. Liquid gasoline and water are condensed from the stream cooled stream of tank vapors, and the cool, lean stream from the shell-side of the heat exchanger is routed to the vapor space of the storage tank to reduce the net withdrawal rate of tank vapors and thereby prevent unwanted air channeling. At the same time, the introduction of the cool, lean gas stream to the tank may be directed, for example, using a nozzle, to favorably mix the vapor space and disturb dead zones within the vapor space that are remotely located from the condenser inlet. Finally, the cool, lean gas stream suppresses vapor regeneration from any residual liquid gasoline on the floor of the tank by cooling these residual liquids.

The volumetric rate at which the cool gas stream returned to the vapor space is substantially lower than that of the raw stream originally drawn from the tank due to the removal of condensed gasoline and water vapors, and also due to thermal shrinkage. As a result, there remains a net volumetric rate of withdrawal of gas from the tank. The net volumetric rate of withdrawn vapor will still be made up by air entering the tank through leg penetrations, vacuum breakers and other openings. However, it will be understood that the rate at which make-up air enters the tank during the condensation process is considerably less than the damaging rate at which air enters during high-rate incineration. The substantial reduction in the rate at which air enters the tank, combined with the mixing provided by the cool, lean gas stream from the condenser that is fed into the vapor space, eliminates air channeling and ensures that the gas samples that may be taken from the condenser inlet to monitor the progress of the condensation degassing process are representive and reflect the true concentration of the vapor remaining in the tank.

The PURGIT® closed loop vapor control system has a control efficiency of 100% which is achieved by the recirculation of processed vapors afforded by the condensation degassing process. The condensation process removes and recovers gasoline instead of burning it. No vapors are burned and, therefore, no combustion products are released to the environment. No combustion means no pollution, and a net positive volumetric rate of withdrawal from the vapor space means that condensable vapors are retained within the vapor space until they can be condensed and recovered during subsequent passes through the condenser. As the vapor space becomes leaner and leaner with subsequent passes through the condenser, and as the temperature within the vapor space falls, the air component of the vapor space will increase until the 34,000 ppm VOC target (or the permit requirements – that may be lower than 10,000 ppm) is achieved.

The warmed stream of nitrogen gas emerging from the tube-side of the heat exchanger is released to the atmosphere from which it originated. This stream of nitrogen contains no combustion products and no VOCs. There is no incineration and, as a result, no air-fuel mixtures that must be controlled to ensure complete combustion. There is no need for auxiliary fuel sources that only exacerbate emissions. The continual mixing of the tank vapors ensures that a gas sample taken from the condenser inlet will reliably indicate the actual concentration of the vapors remaining in the storage tank.

This report is prepared by the undersigned, Patrick K. Steele. I am a Texas Registered Professional Engineer and patent attorney licensed by the United States Patent and Trademark Office. My firm's address is Streets & Steele, 13100 Wortham Center Drive, Suite 245, Houston, Texas 77065.

The original report bears my official stamp adjacent my signature below.

Date: February 3, 2010

Patrick K. Steele

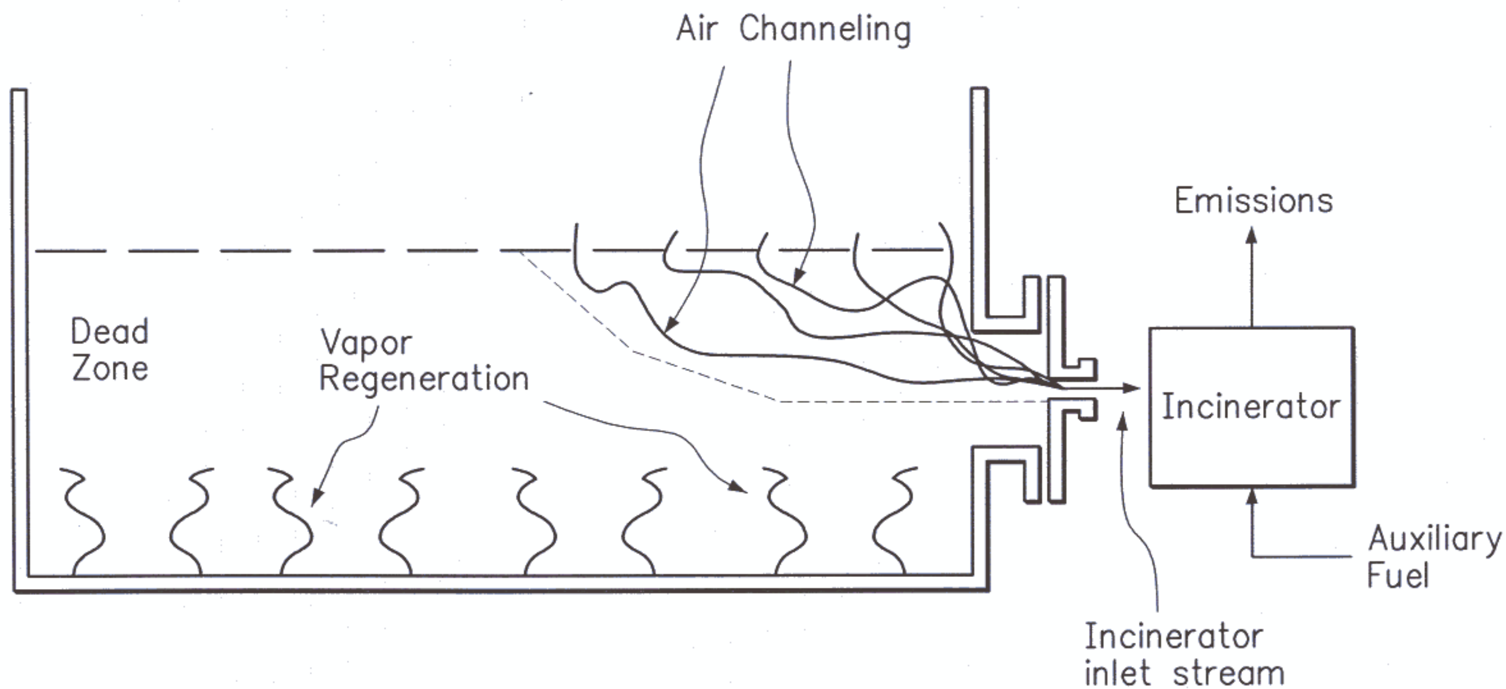

Air Channeling
Emissions
Dead
Zone
Vapor
Regeneration
Incinerator
Auxiliary
Fuel
Incinerator
inlet stream

FIG. 1

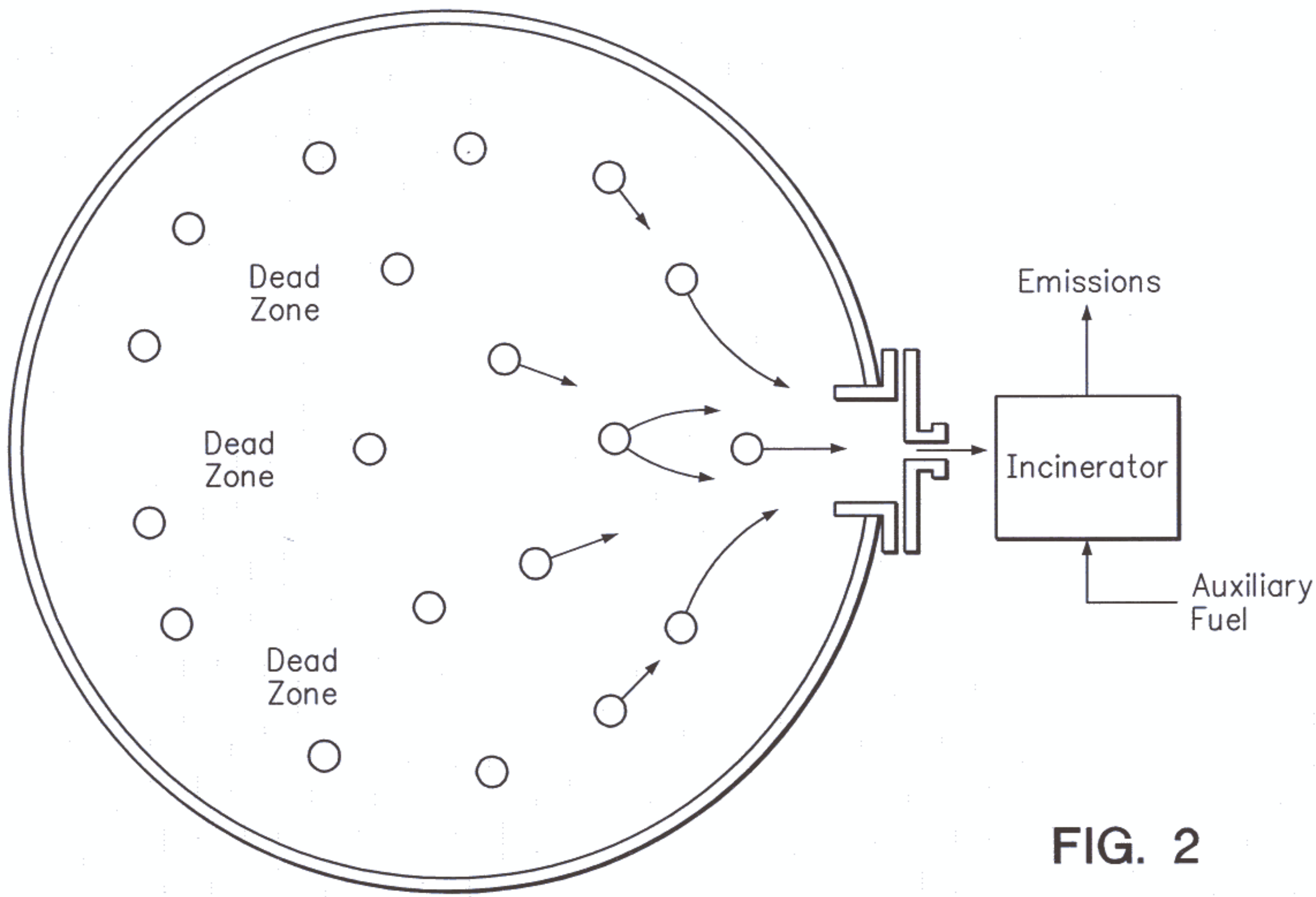
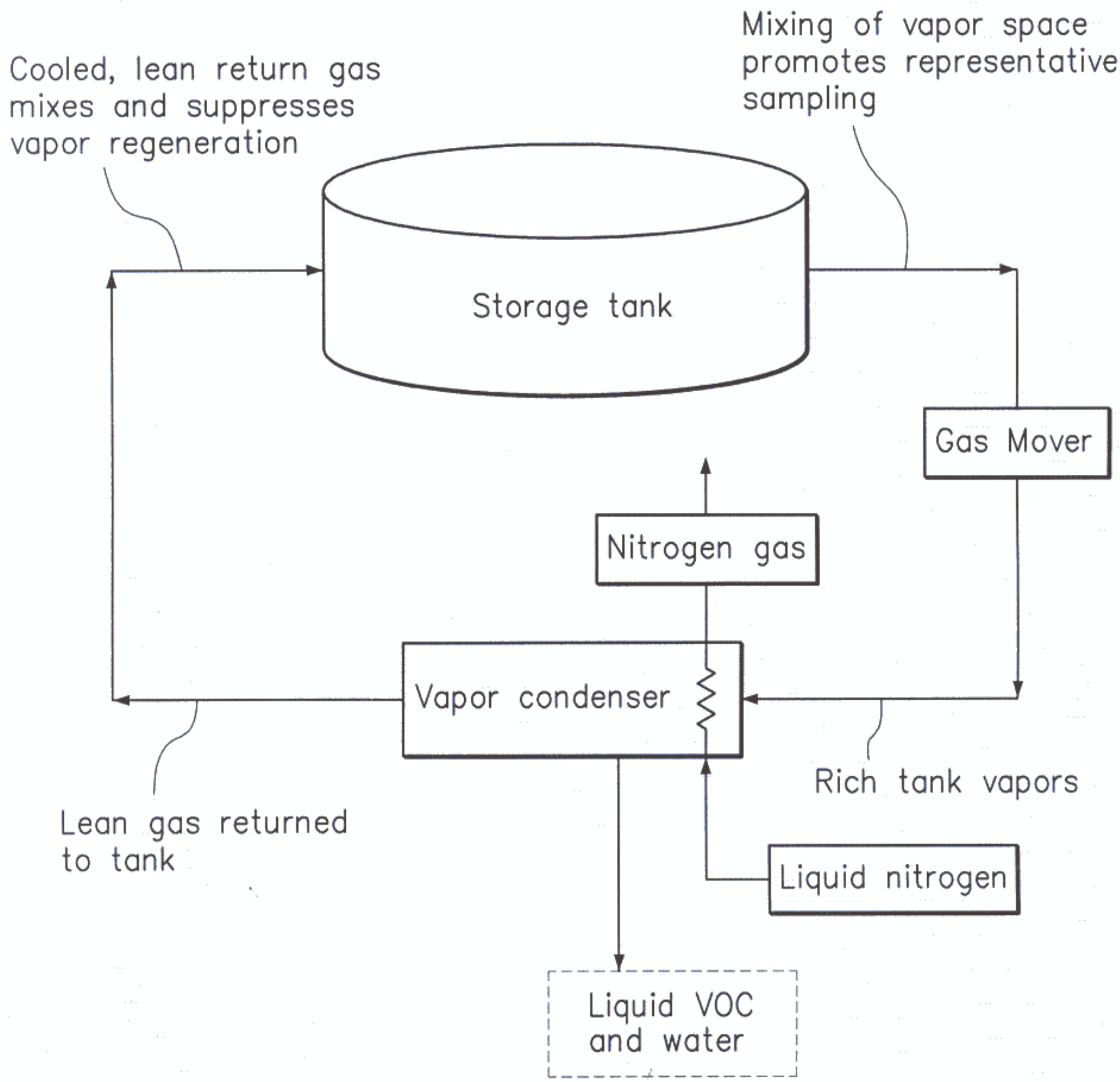

Dead
Zone
Dead
Zone
Dead
Zone
Emissions
Incinerator
Auxiliary
Fuel

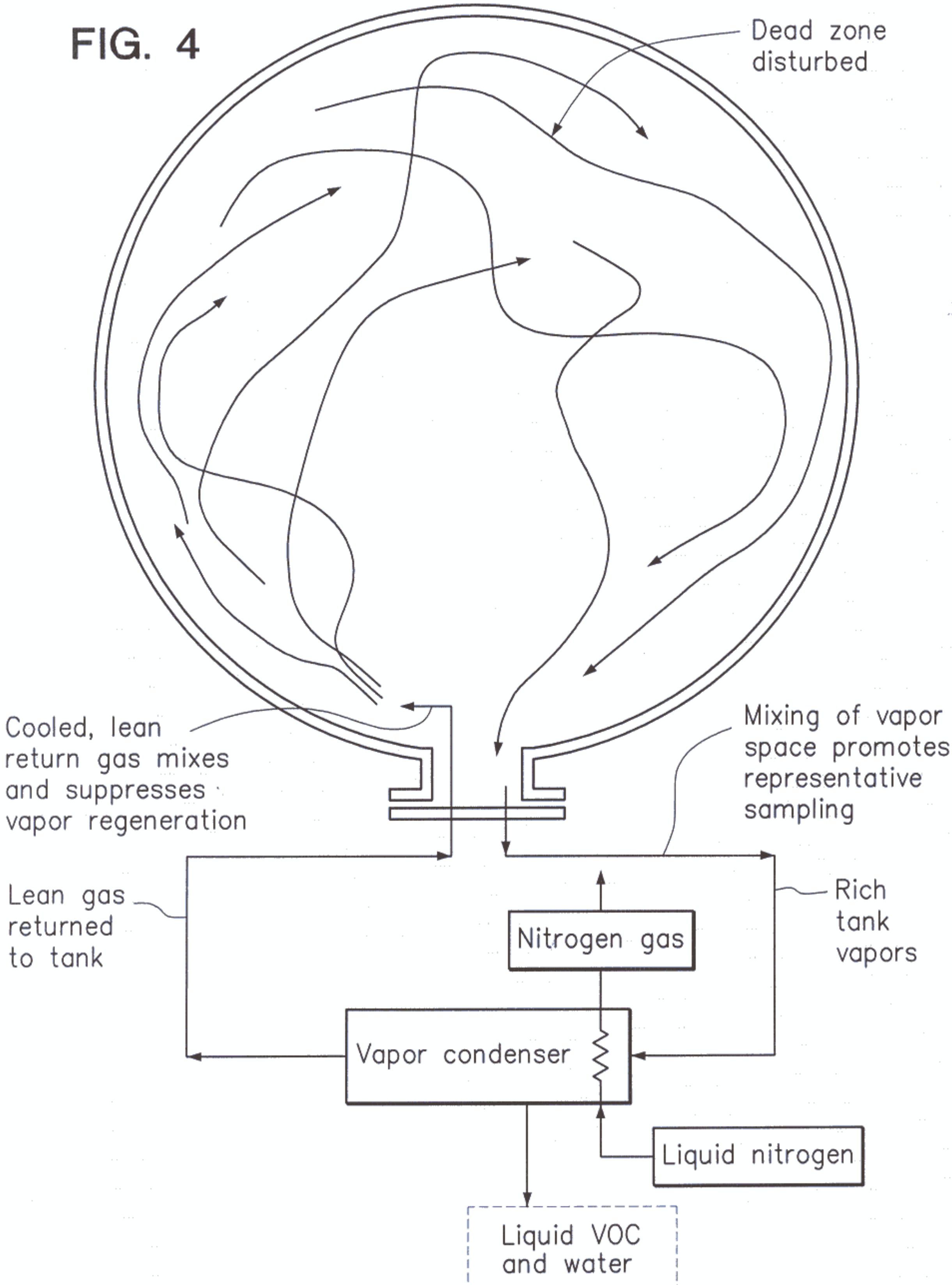
FIG. 2

FIG. 3



Cooled, lean return gas mixes and suppresses vapor regeneration
Mixing of vapor space promotes representative sampling
Storage tank
Gas Mover
Nitrogen gas
Vapor condenser
Rich tank vapors
Lean gas returned to tank
Liquid nitrogen
Liquid VOC and water

FIG. 4



Dead zone disturbed
Cooled, lean return gas mixes and suppresses vapor regeneration
Mixing of vapor space promotes representative sampling
Lean gas returned to tank
Rich tank vapors
Nitrogen gas
Vapor condenser
Liquid nitrogen
Liquid VOC and water