Retooling the Vapor Recovery System: Part 3 - Reactions by Equipment Makers: VST's membrane technology development

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Separating the good air from the bad
After 6 years of development and 18 months of field testing, Vapor Systems Technologies, Inc. has demonstrated that membrane separation technology can solve several environmental problems and address several of the new CARB requirements. These include maintaining negative operating pressure on USTs and monitoring the pressure to provide in-station diagnostics. VST has quantified the magnitude of fugitive vapor emissions and offers a mechanism that controls more than 99 percent of such emissions.

Before getting into the details of these developmental efforts, let's get a clear fix on basic refueling vapor recovery technology and some of the problems that led to CARB's decision to change the rules significantly. This may be a little repetitive to those who have followed PE&T's past coverage of vapor recovery, but my perspective on the subject hopefully will add to your understanding.

Many of the current technologies for reducing, recycling and recovering pollutants from gasoline fueling facilities still allow a large amount of toxic chemicals to escape into the environment. The technologies include Stage I and Stage II vapor recovery systems.

Stage I involves recovery of vapor from the space above the liquid level (ullage) in a storage tank. When a fuel transport delivers fuel into the UST, the fuel displaces the vapor and forces it through a hose to the transport's tank. A fuel transport arrives at a fueling facility with a full tank of fuel and returns to the bulk plant or terminal with a full tank of vapor.

Stage II vapor recovery involves recovering and recycling the vapor displaced from vehicle fuel tanks during refueling of the vehicle. An inefficient Stage II system will allow excess vapor to enter the atmosphere during refueling. Stage II systems are either balance or vacuum assist systems, each with unique advantages and disadvantages.

The original VST R&D test site was installed in 1998 in Sacramento, CA. Courtesy of Vapor Systems Technologies, Inc.

Balance systems

Balance systems are similar to Stage I systems. The system consists of a flexible bellows on the dispensing nozzle and a coaxial dispenser hose. The inner hose carries the fuel from the UST and the outer hose carries the displaced vapor to the UST. The flexible bellows extends the vapor return path around the spout and against the vehicle fill-pipe opening. A tight seal of this bellows against the vehicle fill-pipe is required so that all displaced vapor is forced through the bellows into the nozzle, through the coaxial hose and to the UST.

The advantages of the balance system include simplicity of design and automatic balancing of the recovered vapor with the volume needed to replace the fuel pumped from the UST. Due to some “vapor growth” in the UST when “new” vapor and fresh air are returned to the UST, the balance system cannot provide perfect balance. This vapor growth and increased tank pressure will cause fugitive emissions.

Other disadvantages of balance systems are the difficulty of insuring a tight seal (some force is required), heavy nozzles and easily torn bellows. In many cases, the balance system does not adequately collect vapor simply because it is difficult to insure that the proper vapor seal is present during the refueling process. This problem is worsened by the fact that a large portion of refueling facilities are “self-serve.”

Assist systems

All current vacuum assist systems are essentially positive displacement systems, providing for a fixed amount of vapor to be pumped to the UST for a given amount of fuel dispensed. Vacuum assist systems have a lighter nozzle with no bellows. The vapor is collected by a vacuum pump somewhere in the vapor return system—either in the dispenser, vapor return line or UST system.

To achieve required efficiency, the vacuum pump must be controlled by electronic logic or by direct correlation to the rate of the dispensing fuel. In some cases, this is done by electronically monitoring the fuel flow meter and electrically driving the vacuum pump at speeds which are determined to provide the best recovery response for a given fuel flow rate.

Other vacuum assist systems are simply mechanical systems that drive the vacuum pump directly in response to the fuel flow, usually with a fuel motor driving a vapor pump via a shared axis.

Efficiency and compatibility problems

During the past couple of years, extensive field testing by CARB and the California Air Pollution Control Officers Association (CAPCOA) showed that Stage II systems generally are performing at below 70 percent efficiency. Such testing played a role in CARB’s decision to adopt a new approach—the Enhanced Vapor Recovery (EVR) program—to regulating both Stage I and Stage II systems.

The new program addresses many deficiencies in existing systems. It requires a new, integrated systems approach from vehicle interface to the total service station operation. It includes a comprehensive in-station diagnostics package to ensure continued regulatory compliance. For more information on the new program requirements and the timetable for their implementation, see part 2 of this article, "Will New Rules Evade Old Concerns?" by Wolf Koch, Jun., p. 6.

VST's developmental efforts

The thrust of VST's developmental efforts has been to produce a method to separate Volatile Organic Compounds (VOC's) from the vapor or air. Separating the contaminants from the vapor will eliminate the root cause of over-pressurization. This will solve ORVR and Stage II compatibility problems and Stage I and Stage II compatibility problems. The ultimate result will be the elimination of fugitive emissions.

After completing numerous laboratory tests with various membrane designs, VST concluded that it was impossible to simulate an actual service station environment in which to test the performance of membranes. In addition, although much fragmented empirical data on UST systems was available, little actual data existed on the overall function of an underground storage tank.

To develop data on the overall function of an UST, VST set up a complete fueling station in Sacramento, CA, consisting of a dispenser-based vapor recovery system and a prototype membrane system (VST's Emission Control System).

Since the summer of 1999, VST has collected daily data that includes tank temperature, ambient temperature, continuous tank pressure, volume and hydrocarbon concentration into the membrane, volume and hydrocarbon concentration of the permeate or exhaust emissions and station throughput.

A pressure transducer connected to the underground storage tank is used to measure tank pressure. This transducer functions effectively as an on-off switch. The pressure information is sent to a control box/data logger that is used to control the entire system while logging the relevant data.

Other schemes provide the vacuum by other techniques, such as atomization of a portion of the fuel flow to generate a vacuum (and condensed liquid) in the vapor line. In all cases, vacuum assist systems are designed to provide for a certain value of vapor-to-liquid (V/L) ratio, either constantly during the fueling episode or by fixed variations during certain parts of the dispensing episode.

The major disadvantage of vacuum assist systems is the requirement to carefully determine the proper V/L ratio and maintain this setting for the extended operation of the system. Maintaining this adjustment has proven to be very difficult, especially as a function of seasonal changes affect gasoline volatility due to temperature and Reid Vapor Pressure (RVP) requirements for winter fuels. Our field-testing has indicated higher underground tank pressures and hydrocarbon concentrations that ECS processes during winter months.

When the amount of collected vapor is too small, more vapor escapes into the atmosphere from the area of the vehicle fill-pipe and the overall efficiency of the system is degraded. When the amount of the recovered vapor/air mixture is too great, the UST will become over pressurized and vapor will be discharged into the atmosphere, again degrading the efficiency of the system.

Under normal conditions, one gallon of gasoline will expand into approximately 520 gallons of vapor at 40 percent hydrocarbon concentration (“Membranes, Molecules and the Science of Permeation,” Tedmund Tiberi, April 1999 p. 30). These ratios vary with the Reid Vapor Pressure (RVP), temperature of the gasoline and other conditions. The pressurization problem is significantly increased when the Stage II system is serving a vehicle equipped with an ORVR system.

Some vacuum assist systems have attempted to overcome the variation in performance by deliberately operating at V/L’s of significantly greater than 1.0 and relieving the pressure in the UST by burning the expelled vapor before it enters the atmosphere. However, unless additional protective devices are employed, this trades one kind of environmental problem for another, in that burning the excess vapor can produce essentially the same greenhouse gases as are generated by automobile or other combustion engines.

Developmental results

VST has modified its membrane material, membrane construction design and operating parameters to develop a single-stage system that reduces fugitive emissions by more than 99 percent. Because the membrane functions at low pressures with high separation characteristics, energy consumption is extremely low. Even at peak throughput hours, the ECS operates at a maximum 25 percent run time that minimizes the total number of kilowatt-hours required to operate a single motor that drives the complete system.

VST has coordinated its developmental efforts with CARB staff to address the issues targeted by the Enhanced Vapor Recovery program. In separating the VOCs from the air, exhausting the “good” air and returning the VOCs to the underground tank, the tank system is operated at a slight vacuum. For about a year, VST operated the UST at negative pressure of -.2 inches to -.4 inches H2O, which allows total control of fugitive emissions from all sources, including vent valves, nozzle valves and pipe connections.

Hydrocarbon emissions, flow data and tank pressure data will be included in the in-station diagnostics package as part of VST’s certification process. This information can be available on site or at any remote location with communications through telephone, satellite or the Internet.

Installation

For most service stations, installing the system will involve connecting pipes into existing vapor vents for input and return circulation. A third line—for exhausting the good air—will be added to the existing vapor piping. A one-hp motor will power the entire system that drives both the circulation pump and vacuum pump. Electrical and communication lines are easily accessible for most installations.

Value of captured fugitives

As discussed earlier, VST’s development plans included not only equipment design and performance, but also allowed for significant data collection to determine the overall function of storage tanks. This included numerous “real life” experiments to answer many questions. Based on data from these experiments, VST believes the following assumptions can be made about savings attainable from the system:

• In general, the vapor generated to create excess tank pressure will be emitted to the atmosphere as fugitives, unless controlled. VST testing indicated that tank pressures increase until the system’s leak rate accommodates the effects of product throughput, temperature, atmospheric pressure and volatility.

• Operating the system in a slight vacuum reduces the effects of the variables (cited above, as well as others) associated with gasoline refueling operations.

Based on these two assumptions, VST has been able to accurately measure and quantify the magnitude of fugitive emissions. The measured losses are between 0.1 percent and 0.13 percent of station throughput. VST has made several payback analyses that are available to the industry via its website at WWW.VSTHOSE.COM.

MTBE and fugitive emissions

Methyl Tertiary Butyl Ether (MTBE) seems to be finding it’s way into the ground water via fugitive emissions. VST has recently had several third-party tests conducted on the VOC content of its membrane system.

The tests covered both the system’s “feed stream” and exhaust, using gas chromatography. The tests showed that between 15 and 20 percent of the feed stream (going into the processor) was MTBE (30,000-40,000 ppm) while MTBE in the exhaust stream was below 100 ppm. These results have been verified by three separate tests by two different laboratories.

VST believes that MTBE’s volatility is the major reason for the high percentage of MTBE in the form of vapor. This may also partially explain why MTBE has mysteriously gotten into the water supply without incidents of leaky tanks.

Status and prognosis

The new CARB Enhanced Vapor Recovery (EVR) proposal requires that all Stage II vapor recovery equipment be certified as complete systems. These new requirements are broken down into six distinct modules with staggered phase-in timetables. It is VST’s objective to incorporate as many of the six modules as possible into comprehensive system approvals.

In conjunction with various other manufactures, we anticipate having three CARB test sites, one balance and two assist type systems started by the end of 2000. We anticipate certifying five of the six CARB modules, with the only exception being the dripless nozzle requirement that is not scheduled until 2004 implementation.

Several customer test sites equipped with the VST system are scheduled for construction early this summer with CARB certified systems on the market mid-year 2001.

Working with numerous other equipment manufacturers has enabled VST to include in its system a complete diagnostics package for better managing environmental protection and compliance. VST's testing and analyses indicate that the inventory savings associated with capturing fugitive vapor may pay for cleaner air and perhaps cleaner water.

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