Developing Technology for Enhanced Vapor Recovery: Part 1—Vent Processors

In 1996 CARB first met with industry to address the ORVR/Stage II interaction problem. In 1999 they established the current enhanced vapor recovery (EVR) program. While there currently are no vapor recovery systems on the market that are certified as meeting the EVR rules (which will be operational in 2003), many patents have been issued which may cover potential solutions. One alternative that may help compliance with the new regulations is to treat vent emissions at the station. Today, several thermal oxidizers and membrane systems are available or are being developed. Wolf Koch reviews the available patent literature and discuss the technical merits of vent processing.

Early in the 1990s, the California Air Resources Board (CARB) began looking at how to deal with potential increases in fugitive emissions resulting from the negative interaction of Stage II vapor recovery systems and mandated vehicle onboard refueling vapor recovery (ORVR) systems. Also, equipment suppliers started developing new or adapting existing vapor recovery technology to solve the problem.

In 1999, CARB developed additional requirements, as part of its Enhanced Vapor Recovery (EVR) program to meet the terms of a litigation settlement, requiring significant future reductions in fugitive emissions. The Air Resources Board passed the EVR requirements in March 2000. I described them in two previous articles in PE&T: "Retooling the Vapor Recovery System, Part 2: Will New Rules Evade Old Concerns?" (Jul 2000), and "Enhanced Vapor Recovery Program: Unanswered Questions Plague CARB's Efforts" (Oct 2000).

To help stay abreast of developing service station equipment technology, I monitor patents issued to the petroleum equipment industry. Since 1995, many patents have been issued describing various solutions to the Stage II-ORVR interaction problem. Some of these patents are for technology that can be used to address CARB's EVR requirements. Together with equipment prototypes shown or discussed at recent trade shows, the patent literature provides a glimpse of possible options for service station operators to meet the EVR requirements.

The ORVR compatibility problem

When an ORVR vehicle is refueled, vapor displaced from the vehicle's fuel tank is diverted to an active carbon canister in the vehicle and later used as fuel through the evaporative control system.

CARB has maintained that Stage II balance systems, so long as they are tight, do not have interactive problems with ORVR cars. Unfortunately, CARB’s own testing has shown that most existing stations are not vapor tight, which means that fuel dispensed from the underground storage tank (UST) will be replaced by air entering the UST.

Stage II assist systems, those with active vapor pumps, will return air to the UST when fueling ORVR cars, unless the Stage II vapor pump is shut off during the fueling process. CARB has estimated that 50 percent of the fuel dispensed in California is dispensed through assist systems. Outside California, more than 90 percent of the Stage II systems in use are assist systems.

For both systems, when air enters the UST, it causes evaporation of gasoline until the hydrocarbon concentration of the mixture reaches equilibrium. CARB estimates that the resulting growth in the volume of hydrocarbon vapor varies between 4 and 30 percent and assumes that the increased volume is lost as fugitive emissions.

To prevent these emissions, the new EVR rules require both balance and assist Stage II vapor recovery systems to operate so that the UST systems remain at small negative pressures most of the time. Systems that remain at atmospheric pressure are assumed to be leaking air in and vapor out (fugitive emissions). EVR rules require also that in April 2003, assist vapor recovery systems must operate at a vapor-to-liquid (V/L) ratio of 1.0 or less, unless they incorporate vent processors which will allow V/L ratios of 1.3 or less. The V/L ratio refers to the ratio of vapor collected to the fuel dispensed. In April 2003, all systems must also be compatible with ORVR (i.e., have no additional fugitive emissions by returning air to the UST).

Inside look at the dispenser-based cooling coil added to the system by OPW.

The solutions

Solutions to the UST pressure and fugitive emissions problem include (1) changes in vapor recovery systems and “hanging hardware” such as nozzles, hoses and fittings and (2) using devices, referred to as “vent processors,” that can be retrofitted to UST vents to ensure negative pressure in the USTs. These measures must be coupled with other future EVR requirements for continuous monitoring of UST pressure and the ratio of vapor collected to fuel dispensed.

In a future PE&T article, I will describe new developments in vapor recovery systems and hanging hardware. The remainder of this article will deal with the technology of vent processors, which include thermal oxidizers, membrane systems or other suitable devices.

Vent processor history

Some readers will recall that vent vapor processing is not a new development. In 1973, the American Petroleum Institute (API), the Environmental Protection Agency (EPA), the Petroleum Equipment Institute (PEI) and CARB hosted a seminar on refueling vapor recovery. Most of the equipment discussions centered around using vent processors with Stage II assist systems. Three companies—Clean Air Research, Environics and Calgon— described carbon bed adsorption processes similar to those used in petroleum terminals today. Three other companies—Vaporex, Intermark and Process Products —discussed refrigeration technology.

The Environics process went a step further in that it disclosed the use of a carbon bed for temporary vapor storage, with vapor disposal being accomplished in a catalytic oxidizer as shown in Lee's patent 3,918,932 (see Table). Of the companies mentioned here, only Calgon is still in business. In 1980, several years after the developments by Environics, Amoco simplified the process by eliminating the carbon bed and using catalytic oxidizers—but only at several test terminals in Washington and Illinois. In 1998, Marconi received patent 5,803,136 describing the use of a catalytic oxidizer on the station vent.

During the 1970s, John Hirt (Hirt Combustion Engineering) and Ed Hasselmann (Hasstech) both developed combustion-based vapor recovery systems. Vapor pumps in both systems provide an excess air sweep by sucking in more air at the nozzle than the volume of gasoline dispensed—Hirt at a V/L ratio of about 1.4 and Hasstech at about 2.0. For the Hirt system, a vapor valve set to a slightly negative pressure will open the vent at that pressure and thermally oxidize the hydrocarbons in the vent gas stream. The Hasstech system operation, while similar, may experience positive UST pressures under some conditions. Both systems are certified by CARB and meet current, but not future CARB requirements.

OPW's membrane unit.

Fugitive emissions

CARB and EPA distinguish between two types of emissions at service stations: transfer emissions and fugitive emissions. Both agencies have accepted the following estimates of the average quantities of hydrocarbon emissions at uncontrolled service stations (i.e., stations without Stage II systems): 8.4 lb. per 1,000 gallons dispensed for transfer emissions and 0.84 lb. per 1,000 gallons dispensed for fugitive emissions. See Figure 1.

As part of the approved EVR rules, CARB lowered its estimate of transfer emissions to 7.6 lb. per 1,000 gallons. The basis for the reduction is questionable, in my view, as pointed out in my July article (cited above). These CARB estimates assume that Stage I vapor recovery is in place and returns most vapor from the UST ullage back to the tank truck during fuel deliveries. Without Stage I, transfer emissions would be almost double, because both the vehicle tank and the UST would emit equal volumes of air and hydrocarbon. These emissions would consist of differing concentrations because the temperature in the vehicle tank is generally higher than in the UST.

As gasoline is dispensed at an uncontrolled station, air is sucked into the vent, thereby maintaining atmospheric pressure. This air will grow in volume, as gasoline evaporates, and reach equilibrium, which is a function of temperature and gasoline vapor pressure. Because the UST will maintain atmospheric pressure through the vent, the excess vapor will be expelled as fugitive emissions.

In the presence of Stage II vapor recovery, vapor from the vehicle tank is returned to the UST. During much of the year, especially during the summer months, vehicle tank temperatures are generally higher than UST temperatures. The temperature difference results in vapor shrinkage, as returned vapor cools and condenses. During the winter, especially in northern locations, it is possible to experience vapor growth as cooler vehicle vapor is warmed in the UST.

Ideally, tight vapor recovery systems operating at a V/L ratio close to 1.0 will produce slight negative pressure in the UST ullage during warm weather. Currently, only one assist vapor recovery system operates at a V/L ratio of 1.2. Actual data from CARB certification tests for all other systems show real V/L ratios of about 1.0; for the other systems there should be no losses during periods of vapor shrinkage.

To dampen the effects of small pressure increases or decreases and prevent ingress of air through the UST vent, most Stage II stations protect the vents with pressure/vacuum (P/V) valves that usually are set to open at 3 inches H2O pressure or 8 inches H2O vacuum. (For comparison, one atmosphere equals about 400 inches H2O.) Leaks in the vapor piping will negate the dampening effects of P/V valves and return USTs to atmospheric pressure by leaking air in and vapor out, similar to an uncontrolled station. In the case of assist systems fueling ORVR cars, the P/V valve may allow air to enter the vent if the ullage pressure falls below –8 inches H2O. The resulting volume increase due to hydrocarbon saturation will become a fugitive emissions problem only during prolonged quiet periods; during normal operations it will be accomodated by allowing less air to enter during the next fueling episode.

The primary objective of vent processors is to reduce UST pressure to somewhat below atmospheric pressure and thus avoid the possibility of fugitive emissions. Small leaks in the vapor piping systems can be overcome by these systems. Today’s vent processor technologies include two basic types: thermal oxidizers and membrane systems, which are described below.

Figure 1:
Fugitive and transfer emissions

Thermal oxidizers

While the Hirt and Hasstech vapor recovery systems are currently certified by CARB, they will not meet EVR requirements without some modifications. The maximum V/L ratio that will be permitted for these systems will be 1.3 under the new rules. In my opinion, the 1.3 maximum is arbitrary and not based on engineering data, but appears to have been chosen by CARB to ensure that all current systems will be decertified under the new rules. With minor modifications, the thermal oxidizers of both systems may be used as vent processors for existing vapor recovery systems. OPW has chosen not to pursue this route with its Hasstech system.

Hirt has assured me that a modified package for vent processing is now available and could be certified under the new EVR rules if sufficient interest exists. Hirt’s system was discussed by Dr. Robert Bradt in two previous PE&T articles (“Hirt System Design Changes,” Aug) and (“The Latest Word On Thermal Oxidizers,” Sept). These articles point out that changes necessary for EVR compliance are minimal and that past concerns about the system's "burner" characteristics have been alleviated.

In the past, I have observed that major oil companies have been reluctant to install thermal oxidizers at stations. A possible alternative that might lessen any continuing reluctance would be to use catalytic oxidizers. Although not currently available, catalytic oxidizers could be developed by integrating the control system of current thermal oxidizers with catalyst beds. Such systems may find fewer objections, but will have a higher capital cost than Hirt's currently proposed package.

Membrane systems

Three companies are currently offering membrane systems for station vent processing: Arid Technologies, OPW and Vapor Systems Technologies (VST). Arid and VST described their systems in the August issue of PE&T (Glenn K. Walker, "VST's Membrane Technology Development,"; and Ted Tiberi, "Some Fugitive Emissions Remain At Large,"). In addition, Arid's technology and rationale were discussed by Tiberi in PE&T in April 1999 ("Membranes, Molecules and the Science of Permeation,") and September 2000 ("Vapor Recovery Around the World,").

The accompanying Table lists patents covering various aspects of membrane technology. The basic technology of separating air and hydrocarbon mixtures is covered in patents issued to GKSS, Membrane Technology & Research (MTR), Compact Membrane Systems (CMS) and Praxair. One MTR patent (5,611,841) and GKSS' two Ohlrogge patents cover applications to gasoline vapor recovery. The VST patent and three Marconi patents (5,464,466; 5,571,310 and 5,843,212) also teach applications of membrane technology to vapor recovery. Figure 2 illustrates the technology covered by the earliest of the Marconi patents.

All membrane separators work on similar principles. An air/hydrocarbon mixture is passed over a membrane designed to exhibit selective permeability to either the air or hydrocarbon. A large pressure drop across the membrane forces the permeating compounds to migrate through the membrane pores, leaving a stream that has a low concentration of the permeating material and creating another stream, downstream of the membrane, that has a high concentration of the permeating material.

Mobility of the permeating substance is determined by operating variables, such as temperature and pressure differential. Pressure upstream or a vacuum downstream of the membrane may produce the pressure difference. A combination of pressure and vacuum may be employed to optimize process conditions.

Designing an effective separator using a membrane is very much an art. Entire journals are devoted to describing the technology, which would take far more space than can be given the subject in this article. An essential fact to understanding the technology is that transport rates of hydrocarbon (or air) molecules across membranes are generally low and depend on large pressure drops across the membrane and permeate concentration at the membrane surface. Once transport occurs, there will be a concentration gradient of the permeating substance on both sides of the membrane. As the permeating molecules diffuse across the membrane, the vapor layer closest to the membrane will experience a lower concentration, while the vapor layer on the other side of the membrane will be rich in the permeating species. While almost complete separation must occur in order to meet required efficiencies, proper mixing is necessary on both sides of the membrane, or the diffusion process will slow to a trickle.

Arid Technologies

Arid sells membrane separators under a GKSS license. GKSS (a German manufacturer) has installed a number of its systems through other licensees in several European countries. Here, Arid installed a membrane system at an Illinois site about two years ago; it does not currently maintain a testing installation.

GKSS' Behling patent describes the separation properties of two membrane types as a function of hydrocarbon composition, temperature and pressure drop across the membranes, showing that permeation for nitrogen and oxygen are very low compared to those for hydrocarbon.

The two Ohlrogge patents describe two different process configurations for vapor recovery. The older patent shows the membrane connected between the dispenser and the station vent. Hydrocarbon diffusing through the membrane is returned to the tank ullage. Patent 6,059,856 shows the vapor as returning from the dispenser back to the tank ullage. The membrane processor is attached to the vent line, venting air and returning hydrocarbon to the UST.

Figure 2:
Diagram from Marconi patent 5,464,466

OPW

During CONVEX 2000, OPW announced a partnership with Membrane Technology Research. Previously, OPW had licensed patents covering vapor recovery membrane applications from Marconi. Incorporating the two licenses, OPW has developed a process that combines the membrane module with the pressure management of the Hasstech vapor recovery systems. The system will be offered as a complete vapor recovery system and as a vent processor for eliminating fugitive emissions. This will allow for use of the technology as a vent processor with existing vapor recovery systems or as a complete vapor recovery system for new installations.

Marconi's patent 5,464,466 describes the use of "fractionating" (separating) membranes for controlling vent emissions. Marconi's patent 5,843,212 adds several control schemes for UST pressure and vapor withdrawal rates. Finally, patent 5,571,310 provides further pressure control and extends the application of the technology to recovering vapor from dry cleaning operations and other processes that use solvents. All three Marconi patents incorporate the use of GKSS membranes as part of the patent specifications.

Five of the seven patents listed for MTR cover variations of separating condensable vapor from air.

The Hofmann patent describes the construction of the actual membrane module, while Baker's patent 5,611,8411 teaches its use in a service station vapor recovery process. Similar to the GKSS patent, the MTR patent shows a membrane module connected to the vent line. Vent gas passes through the module and hydrocarbon molecules diffuse through the membrane and are returned to the UST while clean air is passed to the atmosphere. What distinguishes the MTR process is that it uses spiral-wound membranes arranged in a baffled enclosure. The patents claim an increase in efficiency by operating in a countercurrent mode between the feed and the diffusing vapor and at a significantly higher feed velocity due to the baffled enclosure, providing for a reduction in transport resistance.

Hasstech, now an OPW division, tested membrane technologies in California service stations several years ago. OPW improved the process by adding a cooling coil before the membrane module and condensing heavier hydrocarbons before they reach the membrane. OPW has just received Patent 6,174,351 covering its commercial process. It has been operating a test site in Cincinnati for some time now and expects to start certification testing in California soon. The photograph on p. 16 depicts the dispenser-based cooling coil in the OPW unit. The photograph on p. 17 shows OPW's membrane unit.

Vapor Systems Technologies

During the last several years, VST had been showing a vent processing system with three staged membrane modules. The VST patent listed in the Table covers such a system and claims that it provides improvements in pressure management and energy efficiency. A similar three-module separation scheme is also shown in the recent Praxair patent listed in the Table.

At Convex 2000, VST showed a membrane vent processor system utilizing a single membrane module manufactured by Compact Membrane Systems (CMS) and covered by a CMS patent. The membrane operates differently from the ones discussed above: it passes air rather than hydrocarbon molecules. The downstream side of the membrane is connected to the atmospheric vent. If all of the air must pass across it, flow rates across the membrane are higher than for the other systems, especially when the hydrocarbon levels in the ullage are low. However, since the membrane passes air, it is not necessary that all air is separated from hydrocarbon. In fact, the membrane has a high selectivity for oxygen and passes about half the total feed volume during normal operations, enriching the vent gas to about double the 19 percent normal oxygen concentration in air and returning the other half as a hydrocarbon/nitrogen mixture to the UST. To me, the real advantage of the VST system is that it does not need to pass a large volume of air in order to be an effective vent processor; the passage of any air will result in negative UST pressures and meet CARB's future requirements.

VST recently announced a partnership with Veeder-Root, providing a complete solution to future CARB EVR requirements. The company has been operating a test site in California for about two years and expects to install 8-10 membrane systems during the second quarter of 2001.

Other vent processors

While Hirt, Arid, OPW and VST are offering vent processors, the patent literature describes other process schemes that, to my knowledge, are not being marketed. I discussed the Webb patent in an earlier PE&T article ("1996 Service Station Patents," Mar/Apr 1997, p. 17), indicating that significant omissions in the specifications and claims would make it nearly impossible to reduce the concept to practice. The patent claims a process for separating air from hydrocarbon, returning the latter to the UST and discharging air to the vent. It is interesting to note that one of the Bay Area's district regulators is listed as a co-inventor, a potential conflict if the patent is exploited for commercial gains.

A process similar to the Webb patent has been proposed in Marconi's patent 5,755,854. The patent teaches the use of one or two canisters containing a hydrocarbon absorbing material, venting hydrocarbon-free air to the atmosphere. The process contemplated the use of a portion of hydrocarbon-free air to regenerate a saturated canister. Based on early experiences with active carbon as absorbent, it is doubtful that this idea will ever be commercialized.

Recently developed technology for photothermal destruction of hydrocarbons has not been applied to vent processing, although it appears to be a viable, cost-effective solution. Patents 5,045,288; 5,417,825 and 5,650,549 describe processes that destroy hydrocarbons by passing them through a heated chamber while subjecting them to a source that emits light tuned to specific frequencies. The patents show experimental data that indicate that complete destruction of pollutants is possible with proper control of temperature, light intensity and light frequency.

Future CARB certifications

OPW and VST indicated that they soon will be starting CARB certification testing under the new EVR requirements. Hirt officials advised me that a modified thermal oxidizer package is now available and that CARB certification testing could start now, if sufficient interest exists. Arid president, Ted Tiberi, in his September 2000 PE&T article (cite above), pointed out that vent processor technology is not required to be certified in areas that do not require vapor recovery. He said that Arid was waiting for clear specifications to be adopted by CARB and has asked CARB for a standard specification protocol.

Table:
US patents covering vent processing technology

Company and Inventor	Patent Number	Patent Title
Compact Membrane Systems, Inc:		
Nemser	5,914,154	Non-porous gas permeable membrane
GKSS Forschungszentrum Geesthacht:		
Behling, et. al.	4,994,094	Method of removing organic compounds from air/permanent gas mixture
Ohlrogge, et. at.	5,537,911	Method and device for separating gas mixtures formed above liquids
Ohlrogge, et. al.	6,059,856	Method and apparatus for reducing emissions from breather lines of storage tanks
Hasstech:		
Hasselmann	4,295,504	Gasoline vapor recovery system
Hasselmann	4,295,505	Gasoline vapor recovery system
Buck, et. al.	4,983,364	Multi-mode combustor
Fiechtner	5,050,634	Very low differential pressure switch
Hasselmann	5,484,000	Vapor recovery processing system and method
Hirt Combustion Engineers:		
Hirt	4,009,985	Method and apparatus for abatement of gasoline vapor emissions
Hirt	4,118,170	Method and apparatus for controlling gasoline vapor emissions
Hirt	4,292,020	Method and apparatus for abatement and recovery of gasoline emissions
Hirt	4,480,004	Method and apparatus for control of gasoline emissions
Membrane Technology & Research, Inc:		
Baker	4,553,983	Process for recovering organic vapors from air
Wijmans	5,071,451	Membrane process and apparatus for removing vapors from gas streams
Wijmans	5,199,962	Process for removing condensable components from gas streams
Kaschemekat, et. al.	5,205,843	Process for removing condensable components from gas streams
Hofmann, et. al.	5,711,882	Gas separation membrane module and process
Baker, et.al.	5,611,841	Vapor recovery process using baffled membrane module
Baker, et.al.	5,762,685	Membrane expansion process for organic component recovery from gases
Marconi Commerce Systems Inc. (Gilbarco)		
Nanaji, et. al.	5,464,466	Fuel storage tank vent filter system
Nanaji	5,571,310	Volatile organic chemical tank ullage pressure reduction
Nanaji	5,755,854	Fuel tank ullage pressure control
Nanaji	5,843,212	Fuel tank ullage pressure reduction
OPW (Dover):		
McDowell, et.al.	6,174,351	Pressure management and vapor recovery system for filling stations
Praxair Technology, Inc:		
Prasad	5,709,732	Advanced membrane system for separating gaseous mixtures
Vapor Systems Technologies, Inc.		
Grantham	5,985,002	Fuel storage system with vent filter assembly
Miscellaneous:		
Lee, et. al.	3,918,932	Method and apparatus for collecting and disposing of fuel vapors
Webb, et. al.	5,494,409	Gas pump vapor recovery system
Photothermal Processing		
Raupp, et. al	5,045,288	Gas-solid photocatalytic oxydation of environmental pollutants
Graham, et. al.	5,417,825	Method for photothermal destruction of toxic organic compounds
Dellinger, et. al.	5,650,549	Method and apparatus for photothermal destruction of toxic organic compounds contained in a gas stream

Vent processing economics

The cost of vent processing to the end user depends on many factors, only one of which is the acquisition cost of the equipment. Operating costs, maintenance costs and “credits” for recovered product may all be important.

For the three membrane systems, operating costs should be similar, except for VST's system, which may have somewhat lower operating costs because it does not experience the low concentrations and resulting mixing problems that I described earlier. In addition, it can achieve compliance by transferring smaller volumes through the membrane.

Membrane processors recover and return hydrocarbons to the UST. Assigning an appropriate value to the recovered product is complicated because the product's vapor pressure ranges from 50 to 60 psi, which makes them the least desirable of the gasoline components. Membranes concentrate the vent hydrocarbon stream to a point where they may exceed saturation and condense as they are returned (usually to the regular unleaded tank); condensate from all tanks finds its way back into a single tank. Returning such product back to a tank that has a low liquid level may result in the UST exceeding legal vapor pressure limits and may result in fines from local regulators (which generally far exceed any product credits). Legal limits for gasoline vapor pressure are seasonal and may also vary regionally.

Based on my experience in the oil industry and many recent conversations with oil company personnel at the terminal, the industry often prefers incinerating these streams rather than risking the delicate balance of product vapor pressure specifications. I should note that, while condensed vapors at the terminal are generally returned to one tank, most terminals have many more tanks than do service stations, amplifying the potential problem when compared to a station.

In addition to the question of what value to assign to recovered products, there is also the question of who benefits from them. Oil companies generally allocate capital expenditures such as vent processors to a station's capital basis and recover their investment through higher rents to the station operator. Operating costs and credits for recovered products belong to the station operator and have no effect on the oil companies' bottom line. Minimizing capital expenses is often the most important criteria for evaluating projects. The economics are obviously different for jobbers and operator-owned facilities.

Thermal vent processors, such as the Hirt system, enjoy no credits for product recovered, but do not suffer from the dilemma of how such product is valued or if it will cause other associated regulatory difficulties (such as increasing the product vapor pressure in a UST). The Hirt system has been marketed as a vapor recovery system for 25 years. Operating it as a vent processor will incur similar operating costs, which should be substantially lower than membrane units.

This article has concerned itself primarily with applications to vapor recovery stations, where product recovery from membranes is relatively low because evaporative losses are reduced by the vapor returned from the vehicle tank to the UST. The use of membrane systems in uncontrolled stations results in different economics. However, my points above on the value of any recovered product are even more applicable because the amount of product recovered is greater and the likelihood of affecting tank vapor pressure is increased.

Outlook

In my conversations with oil company officials, I have yet to meet a champion of vent processing. While my discussions do not represent a statistically significant sampling of opinions, the great majority of those questioned were negative. However, some thought that the application of some form of vent processing may be inevitable.

Under the new EVR rules, V/L ratios of 1.0 for assist systems and 1.3 for systems with vent processors and ORVR compatibility are mandatory beginning in 2003. CARB expects the market share of ORVR cars to be about 20 percent in 2003 and over 30 percent in 2005. Due to faster vehicle turnover, other parts of the country may see an even higher share of ORVR vehicles. The significance of this data is that, in the past, CARB defined ORVR compatibility as requiring a V/L ratio of no greater than 0.5 for systems that ensure compatibility through modifications of assist vapor recovery systems. If vapor system tightness is maintained, by 2003, stations with assist vapor recovery systems will be operating with negative pressures in the USTs, because about 20 percent of fueling episodes will return about half of the volume of air compared to liquid dispensed, allowing a properly functioning P/V valve to maintain the USTs at negative pressures.

However, future operations without vent processing are possible only if vapor systems are maintained and remain tight. The most important cost comparison will be the cost of maintaining a tight station versus maintaining a slight negative pressure on the UST through vent processing.

While any of the systems discussed may be used in uncontrolled stations now, none are certified by CARB under the new EVR requirements. Unfortunately, these certifications are not going to happen any time soon. Before Stage II certifications can begin, CARB must first certify Stage I systems under the new requirements, sometime in 2001. I will be discussing technology to achieve ORVR compatibility in a follow-up article. For now, the question to contemplate is the cost of maintaining vapor piping tightness at stations compared to the cost of vent processing.

Al Kovach of K-Tek Services assisted in reviewing this article. His help and the suggestion to mention photothermal processing are greatly appreciated.

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