# Tank Pressure Management for Enhanced Vapor Recovery

**Gasoline vapor displaced during vehicle fueling must be captured, handled, controlled and processed to prevent it from being released into the atmosphere. Marketers are increasingly concerned about fuel lost through on-site thermal oxidizing, inadvertent venting, or having it returned to the terminal in the delivery transport tank. Steve Dean explains how the use of membrane technology addresses these issues with excellent benefits to all parties involved.**

Developing technology to meet new CARB requirements
Several previous PE&T articles have dealt with the new, more stringent requirements for control the emission of fuel vapors during transfer, Enhanced Vapor Recovery (EVR) requirements were approved last March by the California Air Resources Board (CARB). Our most recent of these articles dealt with the evolving technology for meeting the EVR requirement that both balance and assist Stage II vapor recovery systems remain at atmospheric pressure most of the time. (See "Developing Technology for Enhanced Vapor Recovery: Part I-Vent Processors," February-March 2001) In that article, Dr. Wolf Koch discussed technology in existing patents and recent efforts by equipment manufacturers to meet the new EVR requirements. In the following article, OPW's Steven Dean provides additional insight into his company's efforts toward, particularly as they relate to using "membrane" technology for managing UST pressure.
Stage II vapor recovery has a long history in the United States, going back to 1975 in California. This history includes a variety of balance systems, dispenser-based vacuum assist systems, and centralized vacuum assist systems. One fact that can be agreed upon today is that current Stage II technologies do not meet the long-term goals of the new EVR program. Of significant concern is how to best meet the requirements for managing underground storage tank (UST) pressure to avoid pressure build-up and related fugitive emissions. This article describes why this is a problem, OPW's approach to solving it and progress towards a solution.

**Typical installation of a complete membrane-based Stage II vapor recovery system.**

**The pressure problem**
A key problem with many of today's Stage II systems is their inability to directly manage the pressure in the UST. When USTs are held at a slight vacuum (negative pressure), any potential for fugitive emissions is eliminated. This is the rationale behind CARB's EVR requirement that balance and assist

Stage II systems must operate so that the UST systems remain at small negative pressure most of the time to prevent fugitive emissions.

When the pressure in an UST is not equal to atmospheric pressure, it will seek to return to equilibrium. USTs in vacuum will breath in fresh air through the vents or any leaks in the system. USTs in positive pressure breathe out gasoline vapor through these same orifices. Once fresh air is taken into the UST, several things happen. First, the fresh air causes some of the liquid gasoline to evaporate, creating more vapors. This will continue until the gasoline saturates the air, which is usually around 35 to 40 percent gasoline vapor by volume. This saturated vapor occupies one-and-a-half times the volume occupied by fresh air that was drawn into the tank. Because the size of the tank is constant, this vapor growth increases the pressure inside the tank.

**Today's technology**

UST pressure management in most Stage II systems today relies on Stage I-controlled product deliveries to reduce build-up of tank pressure. However, experience and site monitoring shows that such deliveries often increase, rather than reduce, tank pressure. Many variables can cause such pressure build-up, including incorrect hose-hook-up sequence, driver error, and system hardware problems. Contributing factors include ambient temperature, product temperature, air pressure, tank pressure, product level and many others.

Everyday dispensing with Stage II vapor recovery systems can also cause storage tanks to become pressurized. Any condition that does not allow the Stage II system to draw back one part saturated vapor from the vehicle tank for each part liquid product dispensed will upset the pressure balance in the UST. An UST operating at this ideal condition is referred to as having a vapor-to-liquid (V/L) ratio of 1:1. Vacuum assist systems with V/L ratios over 1.0 will tend to pressurize the UST's over time. Also, any vapor that is less than saturated (35 to 40 percent gasoline vapor) will tend to cause gasoline evaporation in the storage tanks and cause pressure build-up.

**ORVR Vehicles**

Dispensing gasoline with Stage II systems to vehicles equipped with onboard refueling vapor recovery (ORVR) systems poses an additional pressure problem. Beginning with the model year 2000, all new passenger cars must be equipped with ORVR systems to prevent gasoline vapor from escaping out the fill pipe when the vehicle is being refueled. When dispenser-based vacuum assist systems refuel ORVR vehicles, fresh air is returned to the UST rather than vapor. As previously mentioned, any air introduced into the UST quickly becomes saturated vapor, expands, and becomes a pressure problem and a possible source of fugitive emissions.

**CARB's Enhanced Vapor Recovery Regulations**

CARB has recognized that the conditions as described above are a major cause of fugitive emissions and vapor leaks to the atmosphere. An entire section of CARB's EVR program is concerned with the length of time that storage tank pressure will be allowed above specified limits, how carefully these times will be monitored and the data stored, and how often the dispensing equipment is shut down if it does not comply. These are detailed in the In-Station-Diagnostics (ISD) Appendix to the EVR program.

**Maximum tank pressures**

The V/L ratio refers to the ratio of vapor collected (by the vapor recovery system) to the fuel dispensed. The CARB EVR rules assume that systems that remain at atmospheric pressure are considered to be leaking air in and vapor out to maintain equilibrium. The rules require that balance and assist Stage II systems maintain a slight negative pressure in the UST systems most of the time and that, by April 2003, assist systems must operate at a V/L ratio of 1.0 or less. If they incorporate vent processors a V/L ratio of 1.3 or less is required. In April 2003, all systems must also be compatible with ORVR vehicles. In other words, the systems must operate with ORVR vehicles without creating additional fugitive emissions by returning air to the UST.

In summary, UST pressure issues can be caused by Stage I deliveries, dispensing with vacuum assist Stage II systems, and/or fueling of ORVR vehicles. The results can vary from slight fugitive emissions to massive storage tank breathing through the vents. CARB recognized this as an issue and established limits on tank operating pressures. Exceeding the limits can result in fines and the shutting-down of fuel dispensing. Practical compliance with the tank pressure management rules necessitates the development of new, improved technology.

**Centralized assist systems**

Presently only the Hasstech and Hirt centralized vapor recovery systems have the ability to directly manage tank pressure. When a preset pressure threshold is reached, the centralized system turns on and reduces the pressure by oxidizing (burning) surplus gasoline vapor that created the excess pressure. Because the preset points are close to or below atmospheric pressure, the system usually operates with a slight vacuum. Pressure spikes occurring during fuel deliveries or other events are quickly brought under control and UST "breathing" is virtually eliminated and the possibility of fugitive emissions greatly reduced.

A centralized vapor recover system requires that all components be leak-free and work together. This includes the USTs, Stage I fittings, underground piping, dispensers and the Stage II equipment. Leaks anywhere in the vapor recovery system can cause them to operate abnormally and eventually go into alarm. Leaks of air into vapor lines can cause centralized systems to operate more often and for longer periods to maintain the desired level of UST vacuum.

When properly maintained, centralized systems have had some of the highest efficiencies recorded by CARB during certification testing. In effect, centralized systems monitor the entire station. While alarms do not directly identify the cause for alarm or the location of a problem, they do inform the operator that the system is not operating within normal limits.

Frequently station operators and maintenance contractors assume that if a centralized vapor recovery system is in alarm, the problem is limited to the vapor recovery system. Frustration grows when the problem cannot be readily identified and cheaply corrected. For these reasons, using centralized systems to comply with the EVR provisions will require improving the centralized systems' ISD technology.

**Membrane technology**

The use of membrane technology to separate fuel from air as part of a vapor recovery system came from divergent directions. One was from the refinery community where there was a need for a material that would allow hydrocarbon to be separated from other gases. A pioneer in the development of membrane technology for refineries was MTR Corporation who introduced an acceptable membrane about ten years ago. Since then, its performance and durability have been excellent.

**Schematic of the OPW membrane Stage II vapor recovery system.**

MTR independently was awarded a patent for service station use based on their previous hydrocarbon permeable membrane patent. Other companies were also doing research on membranes and different system applications. At that time, there was no regulation that would encourage adding any type of processor (or cost) to existing dispenser-based systems. As a result, none of these concepts were commercially developed. Other technologies were explored, but nothing that was as cost effective as either the existing system or membrane technology was found.

Several vacuum assisted Stage II vapor recovery equipment manufacturers were thinking about the next generation of equipment. Based on their experience they realized some type of system that actively managed UST pressure would be necessary. Initially, the most efficient systems with the best chance of doing the total job were the centralized combustion systems. Their primary advantages were their efficiency in recovering vapor and their capability for keeping the USTs in a slight vacuum by burning the excess vapor. Although the safety record of these units had been perfect, there was still much reluctance by code officials and owners to installing them in the field. A better method of reducing UST pressure was needed.

Gilbarco (now Marconi) was the first to patent the use of a hydrocarbon permeable membrane as a tank pressure management too; five patents were awarded to Gilbarco for a processor that managed tank pressure. The concept was to work with existing vacuum assisted vapor recovery systems, such as their VaporVac system.

**Taking the next step**

Enter OPW/Hasstech. OPW was interested in developing the second generation of Stage II vacuum assist systems. At this time, the basic Hasstech VacuRite burner technology was over 20 years old. OPW's interest focused on systems that would be as efficient as the VacuRite combustion processors but without the burner. Hasstech's experience with centralized processors pointed to the use membrane technology. OPW licensed the Gilbarco patents and made a strategic alliance with MTR.

When CARB announced its EVR program, OPW had already been developing the membrane technology for several years. The product evolved into two types of offerings to the market, a stand-alone system that provided both vapor collection and tank pressure management and a system that only managed tank pressure, and that required a separate, independent vapor collection system that would return refueling vapor from the dispenser nozzle to the UST.

**Membrane system components.**

The availability of the stand-alone and tank pressure management system permits membrane technology to be used in new and existing Stage II facilities. OPW took advantage of MTR's ten-years of experience with its membrane material and its proven experience in hydrocarbon environments at refineries. The question of whether membrane technology would work had already been answered. OPW's task was to develop a workable membrane system for Stage II vapor recovery.

### The approach to improvement

OPW engineers believed that a membrane-based system could actively manage the UST pressure by releasing mainly air to atmosphere (vapors with less than 30-40% hydrocarbon saturated vapors) while containing vapors with 60-70% of saturated hydrocarbon vapor. The captured hydrocarbon molecules pass through the membrane and form super saturated vapor because most of the air has been removed. This super saturated vapor (permeate) could be returned to the UST.

Permeate has some interesting characteristics. It is unstable and wants to either precipitate out as liquid or form a blanket in the UST over the liquid product. Once the blanket of super saturated vapor is formed, it theoretically should reduce evaporation of liquid gasoline in the tanks when fresh air is introduced.

The OPW membrane concept uses a selectively permeable hydrocarbon membrane that attracts and chemically bonds to the large hydrocarbon molecules and, at the same time, repels smaller molecules such as oxygen and nitrogen (air). A pressure differential between the two sides of the membrane breaks the chemical bond between the hydrocarbon and the membrane and forces the hydrocarbon molecules through the membrane and back into the UST. The membrane surface is then ready to receive the next hydrocarbon molecule.

Early testing indicated that the pressure differential needed to be a constant value. It was quickly learned that there were several different but equally effective methods to achieve this pressure differential. The pressure differential could result from high pressure, high vacuum or a combination of both. It was quickly noted that pumps capable of providing sufficient pressure or vacuum had several things in common. They were large, very expensive, and required periodic maintenance. Either would increase total system costs because the rest of the system would have to be designed to deal with the operating pressure or vacuum developed.

OPW's goal was to find a way to develop the required pressure while avoiding the large, expensive pumps that required periodic maintenance. By using a combination of a pressure pump on the "feed" side of the membrane surface and a vacuum pump on the "permeate" side, OPW engineers found that this goal could be achieved. An added benefit was that the overall system working pressures and vacuums were relatively low, so the total system costs could be minimized as well. After several months of development work, a combination of pressure and vacuum pumps was found that worked well with the MTR membrane material and the design goals were met.

**Cool innovation**

The OPW design team knew that vapor heated up when compressed in a fixed space. This led to an important innovation in the membrane system design: the addition of an air-cooler after the pressure pump to cool the pressurized vapor. A benefit of cooling was that liquid condenses from the vapor as it cooled. A cyclone separator was added to collect this liquid gasoline while allowing the rest of the vapor stream to continue to the membrane. This reduced the amount of hydrocarbon actually processed through the membrane and made the system more efficient. Current testing shows that the product returned is 1 ml to 2 ml per gallon dispensed.

With these innovations in place, it was time to solve one of the larger problems in Stage II vapor recovery One of the goals of further development and testing, which are ongoing, is to determine how much liquid product this part of the membrane process will return to the tank from the super saturated vapor. A related goal is to assess what the prevention of wet stock loss through evaporation might mean in terms of additional salable product and saving to the station operator, as discussed further below.

**Installation in progress**

**Benefits**

The principal benefit being sought in the development of State II membrane technology is the ability to efficiently and effectively comply with EVR requirements for tank pressure management and vapor recovery. But there are several related benefits. The addition of a membrane system allows for the tank pressure to be actively managed, preventing the UST pressure from building up and releasing vapor by venting. Development work to document these benefits at uncontrolled stations is also currently in process at OPW.

One is the reduction of wet stock losses during product deliveries (drops). It has long been known that the turbulence created inside a UST during a drop can create pressure greater than the Stage I system can handle. The result is pressure relief by the pressure/vacuum vent. Any hydrocarbon that escapes in this manner is lost to atmosphere. Although membrane systems in general cannot keep up with this increasing UST pressure to prevent any release to atmosphere, a membrane system will minimize the problem by quickly restoring the tanks to their nominal pressure.

One major international oil company has estimated that 0.25 percent of throughput is lost to the atmosphere during every drop, 25 gallons for every 10,000 delivered. This loss equates to 375 gallons per month at a facility that pumps 150,000 gallons per month. Reducing this by 50 percent would yield a saving of 2,250 gallons per year. Development of actual data from test sites is ongoing.

Successful management of tank pressure can also be of significant benefit at non-controlled stations (i.e., those without Stage II systems). At these sites, each dispensing episode causes fresh air to enter the UST. As previously discussed, this fresh air will cause evaporation of product and the formation of saturated vapor. The vapor expands to 1.5 times the original volume of the air, creating surplus vapors and pressure in the UST that will seek to relieve by venting to atmosphere.

This can be controlled to a certain extent by closing the system with a pressure/vacuum (P/V) vent valve that allows the tank to breathe in air when a vacuum is drawn on the system, but prevents venting when vapor growth causes high pressure. The tank will vent to atmosphere is the relief pressure of the P/V vent is exceeded.

**ORVR compatibility**

All Stage II systems must deal with ORVR compatibility. The overall on-the-road population of ORVR-equipped vehicles will continue to rise in the coming years. How the Stage II system will work with ORVR without raising UST pressure or causing uncontrolled releases of vapor is a crucial test. A hydrocarbon semi-permeable membrane is perfect for use in this application.

The hydrocarbon-permeable membrane system's limiting factor is how quickly the hydrocarbon bonds with the membrane material and is forced on through. Air passes down the membrane face rather than through it and is released to atmosphere. ORVR-equipped cars produce less hydrocarbon-saturated vapor while being fueled, reducing the chance that hydrocarbon-permeable membrane system-limiting factor is likely to be a concern.

An air-permeable membrane might have difficulty with the added volume of air from an ORVR vehicles being fueled. Higher air volumes may limit the effectiveness of the air-permeable membrane to relieve the pressure in the UST.

CARB's EVR rules stipulate that all membrane systems at Stage II sites monitor the air being released to the atmosphere and that no more than 0.38 pounds of hydrocarbon can be released for each 1,000 gallons of fuel dispensed. Typically, the OPW membrane system releases only 20 to 30 percent of the allowable amount. This ensures that only clean air is being released under all conditions. Part of the system's ISD should be an automatic shutdown of the system and the site if the CARB limit is exceeded.

**Membrane system problem solver.**

## Outlook

This then, is the promise of membrane systems. The systems will be affordable, costing roughly the same as today's dispenser-based assist Stage II system for a 12-fueling-point site. The systems will address the key issue of tank pressure management that most of the previous generation of Stage II systems did not. The system's daily performance will be monitored constantly and will help improve system maintainability through ISD.

Most importantly to the industry, the membrane technology represents the first Stage II vapor recovery system that has a direct pay back. Thousands of gallons per year of salable product will be returned to the USTs and thousands of gallons of wet stock losses from product deliveries and other system conditions will be prevented. These systems represent a long-term promise of benefits that will continue after ORVR has made Stage II vapor recovery obsolete. The challenge now is to develop this promise into reality. Systems are under test and data is being collected for the development for the EVR/ISD software requirements and interaction with other systems on site. OPW is one of several companies actively working on these issues, and is planning to bring this product to market in time to meet the CARB EVR April 2003 deadline.

Steven Dean is the product manager for vapor recovery system manufactured by the OPW Fluid Containment Division. OPW is a Dover Resources Company.



 