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Refueling Vapor Recovery in the United States

In 1870, two Americans got a U.S. patent for a coaxial tube fitting for removing vapors when filling bottles with lamp oil–and a form of vapor recovery was born. Technology expert Wolf H. Koch, Ph.D., takes it from there all the way to the future.

Everything you never wanted to know and were afraid to ask
In January 1998, the California Air Resources Board (CARB) and the Society of Automotive Engineers (SAE) held three meetings on the compatibility of Onboard Refueling Vapor Recovery (ORVR) and Stage II vapor recovery. In his March column, Dr. Koch reported on these three meetings ("ORVR Cars Are Safe and Efficient"). This article, the third of three articles on vapor recovery practices on three continents, includes an update on CARB meetings and decisions made on vapor recovery over the last six months.
The recovery of refueling vapors at the service station is a two-stage process: Stage I vapor recovery returns gasoline vapors from the service station's underground tank system back to the tanker truck during product delivery **(see Figure 1).** Stage II vapor recovery collects vapors **(see Figure 2)** from the vehicle fuel tank during refueling and returns them to the underground tank. **Figure 3** provides an overview of the two processes and shows the magnitude of refueling emissions.

In absolute terms, data for 1996 shows a nationwide gasoline consumption of more than 120 billion gallons. Uncontrolled refueling emissions would have been more than 0.5 million tons, which is equivalent to about 140 million gallons of gasoline.

Figure 1: Uncontrolled (a) and Controlled (b) Stage I Delivery

Figure 2: Uncontrolled (a) and Controlled (b) Stage II Fueling

Figure 3 Refueling Transfer Emissions

Early years of Stage II

As we know it today, Stage II vapor recovery originated in California. However, a process to recover vapors during the filling of containers with volatile liquid has been known for almost 130 years.

In 1870 Thomas Simmons and David Lowe received US Patent 110 504, Improvements in Bottle-Filling Apparatus, a patent describing a coaxial tube fitting for removing vapors during the filling of bottles with lamp oil. Since the 1970s, more than a century later, concentric or coaxial adapters have been in use for Stage I. The idea was scaled down and adapted for bootless assist nozzle spouts.

San Diego County became the first political entity to require vapor recovery with the passage of its Rules 61 and 63 in 1972. These rules were unique in that they specifically encouraged the development of new technology. Orange County and the Bay Area adopted requirements a year later and the California Air Resources Board (CARB) passed statewide requirements for California's non-attainment areas in 1976 and for the entire state in 1991.

At the federal level, the 1970 Clean Air Act (CAA) established the Environmental Protection Agency (EPA). In 1977 EPA published proposed national requirements for Stage II , but did not finalize them. The 1990 CAA Amendments (CAAA), however, provided for a November 1993 implementation of Stage II for most non-attainment areas. In 1994, EPA issued implementation guidelines for a phase-in of vehicle on-board vapor recovery (ORVR), beginning with the 1998 model year.

With the initial push for San Diego County, a number of Stage II systems were developed and tested during the early 1970s. Some systems were scaled down versions of terminal Stage I units, using carbon bed absorbers and refrigeration. Most of the early systems existed only for a few years under names such as Vaporex, Clean Air Research, Environics, Intermark, Atlantic Engineering, Process Products and Calgon.

Nozzles from the following manufacturers appeared with vapor recovery modifications supplied by the manufacturer or by third parties: OPW, Emco Wheaton, Husky, Ace, Cardinal, A. Y. McDonald, Gilbarco, Sun Oil Company, Wayne, Texaco and Arco. Most systems relied on a sealed nozzle/fill pipe interface and utilized a vacuum source and vent processor.

One of the early non-sealing nozzle adaptations was developed by Barney McEntire of the San Diego Air Pollution Control District. Figure 4 shows a typical early nozzle of the era, illustrating the bulk resulting from adding plumbing hardware to a standard nozzle. A second hose was added to dispensing systems for the return of vapors.

Stage II development

Starting in the late 1960s, oil companies and the American Petroleum Institute (API) conducted a number of paper studies on service station hydrocarbon losses, later under API Task Force EF-14. Studies were generally directed at assessing the cost and reliability of Stage II equipment and determining whether vapor recovery should be done as part of the evaporative control systems in automobiles.

By late 1974 API had lost its arguments with the automakers on ORVR, and recommended that, based on cost and performance, the industry standardize the balance system for vapor recovery. This recommendation resulted in the development of a number of new balance nozzles and a number of patents, issued to the oil companies and equipment suppliers. A review of files at the San Diego Air Pollution Control District shows that district engineers opposed the oil industry recommendation on the basis that it would impede further development of significant process improvements.

In December 1973, API, CARB, EPA and PEI hosted a two-day Vehicle Refueling Emissions Seminar in Anaheim, California. Everything known up to that time about refueling emissions was discussed by the various interested parties. Regulators reviewed the need for controls; the auto industry advocated Stage II controls; the oil industry pushed for vehicle on-board systems; while equipment suppliers promoted their respective systems or nozzles. The symposium proceedings were published as API Publication 4222 and present the best review of the early state-of-the-art in vapor recovery.

In the late 1970s equipment manufacturers who survived the early years focused on integrating vapor passages into the nozzle design, and developed better, more user-friendly systems. In addition, three new players, Hirt Combustion Systems, Healy and Hasstech, commercialized assist systems utilizing proprietary nozzles with boots.

Outside California, requirements for Stage II implementation proceeded slowly. The District of Columbia was first to convert retail stations in 1977; followed by Missouri in 1987 with implementation requirements for the St. Louis area; by New York in 1989; and by Oregon with a small program in 1992.

Other non-attainment areas followed EPA 1990 CAAA provisions, and converted between 1992 and 1996 depending on station throughput and affiliation. The majority of stations faced mandatory compliance with the EPA provisions in November of 1993.

Early certification testing

In late 1975, CARB published the initial version of what was to become Method 2-1, Test Procedures for Determining the Efficiency of Gasoline Vapor Recovery Systems at Service Stations. The test procedure was a joint developmental effort among CARB and the various California Air Pollution Control Districts, which had earlier developed independent tests.

During the next 15 years, Method 2-1 was amended frequently. The method required testing during 100 fueling episodes with vehicles representative of the registered vehicle fleet. Leaks at the fill pipe were monitored with an explosimeter. At least 40 vehicles with no significant leakage were then used to establish a statistical correlation of efficiency as a function of gasoline vapor pressure, vehicle tank temperature and the average temperature of the dispensed gasoline.

After correcting for vent losses, overall system efficiency was determined by comparing all 100 test sets against the correlation. This certification test was at best an indirect approximation of actual equipment performance. It allowed those familiar with regression analysis to manipulate the base line sample of 40 cars and substitute different dependent variables. In actual practice, these manipulations generally resulted in very high collection efficiencies, at times above 100 percent.

Typical early vapor recovery nozzle.

Assist system developments

Throughout the 1970s and ‘80s, Amoco had been working on a proprietary assisted vapor recovery system with bootless nozzles, making the process of refueling with vapor recovery transparent to the motorist. Two test stations, located in Washington and Chicago suburbs, operated between 1982 and 1986 with an early version of the Amoco V-1 system. When Missouri promulgated Stage II requirements and mandated conversion by late 1987 with CARB certified equipment, Amoco, which does not market in California, applied for certification of an enhanced version of its earlier system.

In 1987 the V-1 system became the first bootless assisted Stage II system to receive a CARB certification, and was installed in most of Amoco’s St. Louis stations in 1988. While it had been difficult for Amoco to obtain significant support from most equipment suppliers during the pre-commercialization phase, that picture changed dramatically with requirements imposed by the 1990 CAAA.

The rest of the oil industry, even though it had long ago decided on the balance system and had been pushing for vehicle on-board controls, demanded variations of Amoco’s system from its suppliers. The rest is history.

By 1994, more than 300,000 nozzles had been converted to vapor recovery outside of California, with more than 90 percent of the total installations going to bootless assist systems This came to an increased cost of about $10,000 per 24-nozzle station over the cost of balance systems. New Jersey and Oregon, the only states not allowing self-serve, became the primary holdouts for balance systems. Customer preferences in the relatively small St. Louis market had changed an entire industry.

Current certification testing

With 1990 CAAA implementation requirements, all affected areas opted for CARB certified equipment requirements except Missouri, which is now requiring an additional series of local certification tests. In the late 1980s, CARB personnel acknowledged deficiencies in Method 2-1, and began adapting a material balance procedure first proposed by EPA almost 15 years earlier.

In 1991, Amoco became the first company to test a new variant of its vapor recovery system under a new certification procedure, which became CP-201, Certification Procedure for Vapor Recovery Systems of Dispensing Facilities. At that time, however, it was only a series of handwritten notes. Various drafts of the test methods were developed and discussed at industry-wide workshops, with the current version being officially adopted on April 12, 1996.

The current test method consists of 12 procedures for service stations and represents a logical approach to conducting engineering material balances. Efficiency is determined by measuring collected and lost vapors at all transfer points and comparing them to the volume of gasoline dispensed.

Current testing requirements call for a 90-day durability test of all equipment. Between demonstrating tightness of the station's vapor system before and again after the actual efficiency testing, 100 cars are refueled and must achieve a combined efficiency of 95 percent. In order to be certified, additional testing by the California Weights and Measures Department and approvals by the State Fire Marshal and OSHA are necessary.

Additional testing is required periodically for operating stations. For assist systems, an annual station tightness test is mandated along with an operational test, known as air-to-liquid ratio or A/L test. For the latter, gasoline is dispensed and the resulting volume of air returned by the vapor pump is measured and compared to the liquid volume. The results must correspond to specifications identified in the certification document for the particular system.

Both balance and assist systems are subject to periodic visual inspections of nozzles and hoses. Balance systems in stations with underground tanks have no station tightness test requirements. Because of the high efficiency requirements for testing, most of it is accomplished during the summer months when temperature differences between vehicle and underground tanks result in vapor shrinkage. The opposite can occur during the winter, when the underground tanks may be warmer than the vehicle tank, leading to vapor growth and potential fugitive emissions.

It is important to recognize that test conditions replicate at only one point in time. For that reason, EPA provides a reduced VOC reduction credit on State Implementation Plans (SIP), based on the station throughput exemption and equipment inspection intervals. For example, Figure 5 shows an actual EPA in-use efficiency of 84 percent for non-attainment areas that exempt stations under 10K gallon/month throughput and require annual equipment inspections.

EPA In-Use Efficiency Frequency of Inspection				
Exemption Level	**Minimal**	**Annual**	**Semi-Annual**	**Certification**
No Exemption	62	86	92	95
2,000	61	84	90	93
10,000	61	84	90	93
10,000* and 50,000**	56	77	83	86
* Major Oil Companies ** Independents				

Future Certification Needs

The advent of ORVR cars, with the 1998 model year, has resulted in a new set of difficulties. CARB will require one of two control strategies for avoiding fugitive emissions that come from the saturation of returned air in underground tanks when assist vapor recovery systems fuel ORVR equipped cars. Station operators will either need to install a vent processor, or control the vapor pump operation during the refueling of cars with ORVR systems.

The agency is proposing a new certification test procedure, TP-201.2D, which will measure the amount of air returned by assisted systems. Systems returning more than 50 percent air relative to the dispensed liquid will fail unless they incorporate a vent processor.

In its new test procedures CARB appears to favor balance over assist vapor recovery systems. While the impact of this fact is minimal in California, the rest of the country has installed mostly assist systems. CARB has stated that the balance system will not cause additional fugitive emissions when used with ORVR cars. That statement, however, is true only if two additional conditions are met: (1) balance systems are required to comply with periodic tightness tests; and (2) balance systems are required to utilize a pressure/vacuum (P/V) vent valve, currently a local option in California.

CARB’s own testing has shown that more than 90 percent of vapor piping in balance stations are leaking. The absence of either of the above requirement will make potential fugitive emissions from balance systems equal to those of assist systems.

At its recent May Board meeting, CARB postponed a vote on new test procedures until its July meeting. The new guidelines also outline requirements for equipment decertification and recertification. Currently, it does appear that CARB will decertify existing equipment after the new rules are approved and reviewed by its administrative law office.

Most early vapor recovery nozzles were converted from standard dispenser nozzles.

Is more always better?

Some time ago, I discussed CARB procedures with Dieter Hassel, manager of the vapor recovery section at TÜV, the German regultory agency. He expressed amazement at our certification requirement of 95 percent efficiency, especially since our EPA in-use efficiencies are so much lower. He attributedd the certification requirement to the prevailing American attitude that "more must be better". Mr. Hassel mused that the U.S. has designed the experiment to show the required efficiency rather than having the experimental results guide the legal requirements.

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