Emission Calculations and Cost/Benefit Analysis of the Regulation Revisions to Vapor Emission Control Requirements at Gas Stations in Delaware

For over 20 years, gasoline stations throughout Delaware have installed and operated vapor recovery equipment to capture gasoline vapors from a vehicle's fuel tank when refueling. This technology, known as Stage II vapor recovery, has significantly reduced volatile organic compound (VOC) emissions. VOCs contribute to summertime smog and also contain certain air toxics.

Widespread Use of Onboard Refueling Vapor Recovery (ORVR) Technology

Beginning in 1998, new vehicles were equipped with ORVR canisters. For these vehicles, the vapors displaced during refueling are controlled through the vehicle's canister, not through the Stage II system. On May 16, 2012, the U.S. Environmental Protection Agency (EPA) issued a final rule (Federal Register Vol. 77, No. 95, page 28772) determining that ORVR technology was in widespread use, and as such, was largely making Stage II obsolete. The rule provided the ability for the discontinued use of Stage II.

In the rule, EPA compared the Stage II control efficiency to the ORVR control efficiency and determined widespread use of ORVR would take place when the two control efficiencies were equal. By this method EPA determined widespread use would take place nationally in mid-2013.

EPA's analysis in this comparison was based on a Stage II control efficiency of 86% for an annual inspection program, and 90% of gasoline sold being dispensed at gas stations that are equipped with Stage II systems. Therefore, the overall control efficiency of Stage II equates to approximately 77%. Table 2 of EPA's widespread use rule indicates the efficiencies of both Stage II and ORVR occur between 2012 and 2013.

Since Stage II systems in Delaware are required for any gas station that exceeds a monthly throughput of 10,000 gallons, approximately 98.5% of gasoline sold in Delaware is dispensed at a Stage II equipped station. The greater use of Stage II controls in Delaware as compared to the national average results in an in-use emission reduction efficiency of approximately 85%. Referring back to Table 2 of EPA's widespread use rule, Delaware's widespread use date would be at the end of 2015. However, a survey conducted during the development of the proposed regulatory revision indicated a majority of gas stations needed maintenance in order to pass the annual tank tightness test. Therefore, a reduction of the Stage II in-use emission reduction efficiency to 80% is more realistic, which would change the date of widespread use in Delaware to early 2014.

The Delaware Division of Air Quality (DAQ) has evaluated the shrinking benefit of Stage II as older vehicles are replaced with newer ORVR-equipped vehicles and determined that alternative requirements at gas stations would be more cost effective than retaining the requirement to install, operate and maintain Stage 2 systems. Therefore, DAQ has embarked on an effort to revise the vapor recovery regulations.

Current Configuration at Gas Stations

When Stage II vapor recovery was introduced, emissions during refueling and emissions from gasoline storage tanks were greatly reduced. As gasoline vapors from a vehicle's gas tank were returned to the gasoline storage tank to replace the volume of liquid gasoline extracted from the storage tank during dispensing, the vapor-liquid equilibrium was maintained in the headspace of the storage tank. Once ORVR technology was introduced into new vehicles beginning with model year 1998, the return of gasoline vapors to the storage tank was altered, which results in increased emissions from the storage tanks. The change at gas stations brought about by the introduction of ORVR technology is as follows:

(1) Gasoline vapors from a vehicle's fuel tank are venting to the vehicle's ORVR canister and not being returned to the storage tank,
(2) Without vapors returning to the storage tank, fresh air replaces the volume of gasoline dispensed from the storage tank,
(3) Fresh air promotes vapor growth in the headspace of the storage tank,
(4) Vapor growth increases tank pressure, and
(5) Tank pressure above atmospheric pressure results in emissions from tanks that are not vapor tight, and may also result in venting through the pressure relief valve.

In Delaware, 95% of Stage II systems are vacuum-assisted, which means there is a small pump that creates a vacuum at the nozzle to draw vapors from the vehicle's gas tank back to the storage tank. In the case of refueling ORVR-equipped vehicle, since the gasoline vapors preferentially pass through the on-board canister, the vacuum pump places fresh air, not gasoline vapors, into the storage tank. This one-to-one volume exchange of fresh air to replace the liquid gasoline withdrawn from the tank means the pressure of the headspace remains at atmospheric pressure. As stated above, vapor growth occurs when fresh air is placed into the headspace of the storage tank and any vapor growth would cause positive pressure within the tanks.

If the storage tank is vapor tight and the Stage II system does not push fresh air into the storage tank, then a vacuum would be created up to the negative cracking pressure of the pressure/vacuum (P/V) valve, also known as a pressure relief valve. While fresh air would eventually be drawn into the storage tank through the P/V valve since unlimited vacuum can damage the tank, the amount of vacuum created would provide some cushion for pressure increases due to vapor growth and the potential for emissions would be reduced.

The incompatibility of vacuum-assisted Stage II systems when refueling ORVR-equipped vehicle gives rise to a quantified "incompatibility excess emission (IEE)" that offsets some of the benefit gained by the use of Stage II vapor recovery for older vehicles. Over time the IEE increases as a result of a greater number of ORVR-equipped vehicles entering the overall vehicle fleet, while the benefit of Stage II decreases as fewer older vehicles remain. There comes a point in time when IEE is greater than the incremental benefit of Stage 2. The Division of Air Quality has estimated the break-even point to determine when Stage II systems should be made compatible with ORVR or removed from service.

Break-even Point Calculation

DAQ estimated the IEE over time based on the following inputs:

1) Gasoline throughput in Delaware obtained from the Federal Highway Administration as published in Tables MF-21 and MF-33GA within the 2009 motor fuel use report,
2) Housing projection data from the Delaware Population Consortium for developing future year gasoline throughput,
3) EPA future year growth of ORVR-equipped vehicles as a percentage of the national gasoline vehicle fleet,
4) IEE emission factors developed from California Air Resources Board (CARB) testing and adjusted by the American Petroleum Institute to account for a 100% ORVR fleet and lower Reid Vapor Pressure gasoline,
5) Delaware-specific percentages of Gilbarco and Wayne-Dresser vacuum assisted Stage II system in use in Delaware for developing a weighted average IEE factor, and
6) Incremental benefit of Stage 2 in future years based on the use of EPA's MOVES model, based on an in-use control efficiency of 85%.

Through this analysis, the breakeven point is between 2018 and 2019, as shown in Table 1.

TABLE 1 – Delaware Break-even Point

Year	IEE tons/day	Additional Emissions w/o Stage II (tpd)	UST Control Benefit Needed to Break Even
2008		1.402	
2009	0.167		
2010	0.183		
2011	0.199		
2012	0.213		
2013	0.226	0.803	0.577
2014	0.239	0.684	0.445
2015	0.249	0.565	0.316
2016	0.260	0.446	0.186
2017	0.269	0.327	0.058
2018	0.277	0.296	0.020
2019	0.284	0.266	
2020		0.235	

Cost/Benefit Analysis of New Requirements

Based on the published AP-42 tank breathing loss emission factor of 1lb of VOC/1000 gallons of gasoline dispensed, the requirement to maintain a vapor tight system statewide demonstrated through the use of a continuous pressure monitor (CPM) would address the high rate of system deterioration (up to 70%) between annual pressure decay tests, and could reduce 225 tons of VOC emissions or more per year. Based on vendor information the cost of the CPM is approximately $5,000 and includes a pressure sensor, a console, leak detection software, and an automatic tank gauge. Note that the need for a console and an automatic tank gage is independent of the CPM requirement (i.e., they are needed with our without a CPM).

The use of a CPM system eliminates the need for the annual pressure decay test. Based on information provided by the Tanks Management Section of DNREC, the average cost of an annual pressure decay test is $1,000. Given this, the requirement to install and operate a CPM versus the requirement to conduct an annual pressure decay test results in a payback in about five years. Additional benefits to the stations will be realized because the station will no longer be required to shut down dispensing during the pressure decay test, and there will be savings in retained product.

With a vapor tight tank system, emissions may occur as a result of venting due to high pressure, and may violate the requirement to maintain system pressure below 0.5" water column (WC) below the positive cracking pressure of the P/V valve for 95% of the time, on a weekly basis. With venting taking place at the standard, which equates to 1.2 hours of venting per day, 1.08 lbs/day of emissions result based on the following conditions:

1) 10,000 gallon tanks are half full of product,
2) 3 tanks as part of a manifolded tank system,
3) Tanks are vapor tight,
4) Temperature is 68 ^{o}F,
5) Gasoline molar content is 114 lb/lb-mole
6) Pressure increase is at a rate of 1" WC/hour, and
7) Headspace is at 46% saturation at the start of venting.

Convert vapor phase volume to cubic feet:

(5,000 gal) (1ft^3/7.48 gal) = 668 ft^3

Starting conditions (T=0):

V_{air} = (668 ft^3)(0.54) = 360.72 ft^3

V_{gas} = (668 ft^3)(0.46) = 307.28 ft^3

$P_0 = P_{atm}$ + 3" water column (w.c.)

P_0 = 406.7"w.c. + 3 "w.c.

P_0 = 409.7" w.c.

At T = 1 hour, pressure will increase 1" w.c.

P_0 = 409.7" w.c.

P_1 = 410.7" w.c.

Model as balloon expanding with growth:

$P_1V_1 = P_2V_2$

(410.7)(668) = (409.7) V_2

(410.7)(668)/(409.7) = 669.63 ft^3

1.63 ft^3 increase in volume from 1" w.c. rise in pressure, thus gasoline evaporation is 1.63 ft^3/hr

Correcting to 1 atm/68oF (standard conditions)

(1.63 ft^3)(409.7)/(406.7)=1.64 ft^3 @ STP

Thus 1.64 ft_3 of emissions. Next calculate average Y_{gas} in these emissions.

Y_{gas0}=0.46; need to calculate Y_{gas1}@T=1 hr

V_{air} = 360.72(668/(668+1.64))=359.84ft^3

V_{gas} = 668-359.84 = 308.16ft^3

Y_{gas1} = 308.16/668 = 0.4613

$Y_{g\text{-}avg}$ = (0.46+0.4613)/2 = 0.4607

Therefore, emissions from a half filled 10,000 gallon tank over 1 hour with 1" vapor rise equals:

(1.64 ft^3)(0.4607)(114 lb/lb-mol)/285 ft^3/lb-mol = 0.30 lb/hr

Total emissions for 3 underground tanks at a typical gasoline dispensing facility venting for 1.2 hours in a day equals (3 tanks)(1.2 hr/day)(0.3 lb/hr) = 1.08 lb/day

At 1.08 lbs/day, a gas station venting for 1.2 hours/day equals 0.2 tons/year. At a capital cost of $12,000 for pressure management controls (carbon absorber) with a 20 year life and an assumed interest rate of 7%, the annualized cost is $1,128/year. Therefore the cost effectiveness is 1,128/0.2 = $5,460/ton. If the time of venting doubles per day, or the rate of pressure increase doubles to 2"WC/hour, then the cost will be cut in half per ton of emissions reduced. The cost of pressure management does not include retained product.

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