Stage II & ORVR: Will state proposal expose motorists to an increase in toxic benzene vapors at the petrol station? - PART 1

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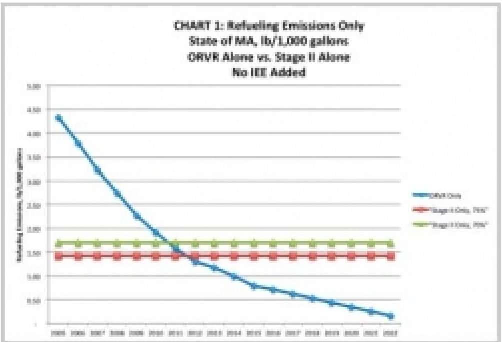

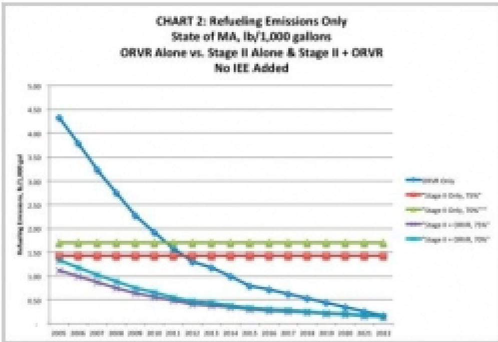

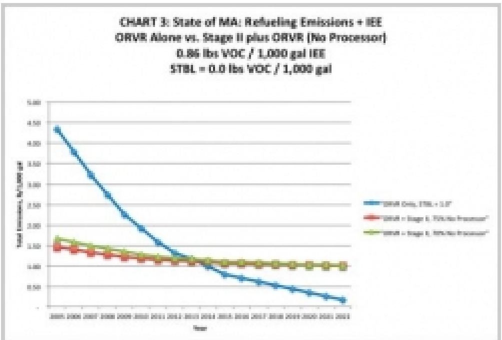

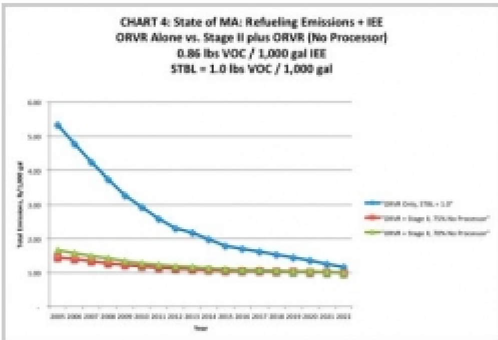

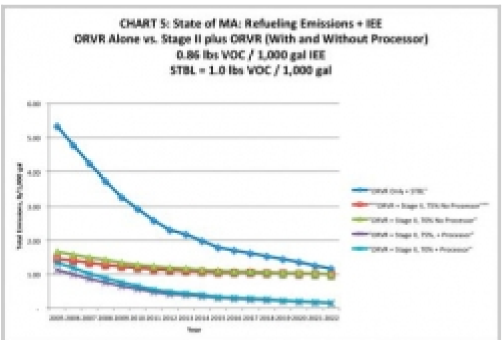

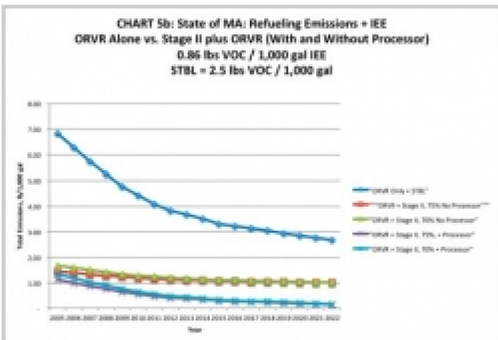

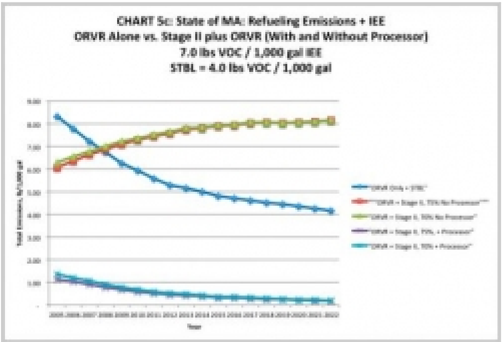

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Executive Summary

Gas stations; also called gasoline dispensing facilities (GDF) typically store fuel in underground tanks (called UST's). The gasoline is dispensed through nozzles to the motorist's vehicle tank. When the vehicle tank is refilled, the liquid gasoline entering the tank will displace a volume of vapor phase gasoline; for example, if 10 gallons of fuel are pumped into the vehicle tank, approximately 10 gallons of vapor will be displaced. This displaced vapor is comprised of air and hydrocarbons. Some of the hydrocarbons (also called VOC's – Volatile Organic Compounds) contain HAP's (Hazardous Air Pollutants), and direct exposure to some HAP's are known to increase risks for cancer; for example benzene. In addition, the emissions of VOC's to the atmosphere are ozone precursors; where ozone formation in the lower atmosphere is detrimental to human health.

To reduce emissions of VOC's and HAP's to humans and the environment, Stage II vapor recovery systems were put in place. The Stage II systems use a small vacuum pump located in the fuel dispenser along with a coaxial hose (hose within a hose) arrangement to allow liquid gasoline to flow from the UST's to the vehicle and at the same time to collect displaced vapors from the vehicle tank and then direct these collected vapors back to the UST's.

The operation of Stage II vapor recovery provides three key benefits:

- Reduced health risks to motorists as direct exposure to benzene and other HAP's is avoided
- Reduced impact of hydrocarbon emissions to the environment as the displaced vapors are captured and directed back to the UST's
- Operational savings to the GDF owner/operator since the recovered vapors from the motorist's vehicle tank are used to blanket the liquid gasoline stored in the UST's. By keeping the hydrocarbon vapor concentration at elevated levels in the vapor space of the UST's, the natural phenomena of evaporation of liquid gasoline to vapor phase gasoline is avoided. In this manner, there is a kind of linked or interdependency between the Stage II system and the UST's
    - The vapor space above the liquid gasoline has a hydrocarbon vapor concentration that attains some "equilibrium level", where the rate of liquid evaporating to vapor equals the rate of vapor condensing to liquid. When the equilibrium hydrocarbon concentration is

altered by ingestion of atmospheric air, liquid fuel will evaporate to increase the hydrocarbon concentration back up to the original equilibrium level. During this process of "re-saturation" of the UST vapor space, the storage tank pressure will increase and excess volume of hydrocarbon vapors will be exhausted from the UST vapor space (One gallon of liquid gasoline evaporates into 520 gallons of vapor phase gasoline, at 40% hydrocarbon concentration). This storage tank breathing loss is the primary reason that very large above ground storage tanks at bulk gasoline terminals, refineries and distribution facilities use so-called "floating roof tanks"; these tanks use a roof that literally floats on the surface of the gasoline, therefore eliminating any vapor space above the liquid, to subsequently eliminate the breathing loss dynamics.

A debate emerged between the Auto and Oil Industries as to what party should be responsible for controlling the refueling losses. The Oil Industry prevailed and the Auto industry was forced to equip new vehicles with the so-called ORVR (On Board Refueling Vapor Recovery) system. The ORVR system is primarily comprised of an activated carbon canister, which captures the displaced vapor during refueling. As the motorist drives down the highway, the carbon canister is regenerated by a portion of engine intake air "back flushing" through the carbon canister, where the hydrocarbons are desorbed and burned as fuel in the engine. Since the ORVR systems are not retrofit to vehicles, but rather incorporated into new vehicle production, the population of ORVR equipped vehicles has been slowly increasing throughout the United States. Passenger vehicles were first equipped in 1998, with 40%, 80%, and 100% of new vehicle production having ORVR systems in 1998, 1999 and 2000, respectively.

At the time of the Oil Industry "victory", the oil industry wanted to remove the Stage II hardware from GDF. Since only a low proportion of vehicles had ORVR systems in 1998, immediate removal of the Stage II systems was not possible. However, the oil industry negotiated for a timed "phase-out" of the Stage II hardware in conjunction with a greater proportion of ORVR equipped vehicles in the fleet. The notion of widespread use (WSU) was discussed between USEPA and the Oil Industry; whereby a certain population of ORVR equipped vehicles would trigger the removal of Stage II vapor recovery controls. The rough idea formulated at that time (without in-depth study or understanding) was that after a threshold population of ORVR vehicles was attained in the fleet, the use of overlapping controls (Stage II at the GDF and ORVR within the vehicles) would be counterproductive since the emissions controlled by ORVR Alone would exceed the emissions controlled by either Stage II Alone or Stage II in conjunction with ORVR. However, in practice, these fundamental assumptions are not accurate or true. For the first assumption regarding the refueling emissions controlled by ORVR Alone in comparison to Stage II Alone; we show in our CHART1 of this report, that there is a cross-over for the ORVR Alone curve with the Stage II Alone curves; however, in practice Stage II is never able to be used "Alone" as there will always now be some proportion of ORVR equipped vehicles in the fleet. Thus, our CHART2 shows that the combination of Stage II + ORVR provides the lowest emissions in comparison to ORVR Alone over the entire interval presented; which incorporates increased proportion of ORVR vehicles in the fleet. Basically, the presence of the Stage II system acts as a “backstop” to provide a chance to capture the refueling emissions from non-ORVR vehicles. Therefore the combined Stage II + ORVR efficiency will always be higher than ORVR Alone.

Note: Please click on the images in the gallery to enlarge them

For the second assumption from above, regarding the total emissions controlled by ORVR Alone in comparison to Stage II in conjunction with ORVR; we show in CHART3 that there is a cross-over for the ORVR Alone curve with the Stage II + ORVR curves; however, this ORVR Alone curve is generated without including any storage tank breathing losses. These storage tank-breathing losses are the category of emissions described above under the “Operational Savings” section of this Executive Summary. Since Stage II is removed under the ORVR Alone option, the UST’s are not able to use any of the hydrocarbon vapors displaced from the motorist’s vehicle tank; as these vapors are now adsorbed on the activated carbon used in the ORVR system. As such, the UST’s will ingest atmospheric air to offset the vacuum developed as product is withdrawn and directed to vehicles.

The interdependency of Stage II and the UST’s is now interrupted, and the ingested air will cause storage tank breathing losses to occur. The dynamics of this situation have been overlooked or ignored by the Regulatory Community, Lawmakers, and other Stakeholders. When the storage tank breathing losses are properly accounted for and added back to the emissions inventory, the ORVR Alone curve never crosses over the ORVR +Stage II curves, and therefore the ORVR Alone case never provides for the maximum amount of emissions reductions. The fact that Stage II systems “solve two problems simultaneously” by recovering displaced vapors from the vehicle tank AND using these recovered vapors to blanket the UST vapor space and thereby avoid subsequent evaporation of fuel and storage tank breathing losses has not been understood.

A quick word about IEE, Incompatibility Excess Emissions. IEE have been recognized by various Stakeholders’; whereby the higher proportion of ORVR equipped vehicles will cause higher amounts of ambient air to be ingested by the Stage II systems. This greater quantity of air will dilute the hydrocarbon vapor space, and cause liquid fuel to evaporate and eventually be exhausted from the UST combined vapor spaces. When the IEE are properly quantified, there is a crossover with the ORVR Alone case with the Stage II + ORVR Case (Please see CHART5c); when a vapor processor is not used to actively manage the UST pressure. When a vapor processor such as the ARID Permeator is employed, the IEE emissions are reduced by 99.3%, and this is clearly the optimium configuration. For clarity, ORVR Alone storage tank breathing losses and Stage II + ORVR IEE are generated by a similar mechanism. Storage tank breathing losses are caused by pure air ingested through the vent line, and IEE emissions are generated by a combination of air and hydrocarbons pumped back into the UST by the Stage II system, while refueling an ORVR equipped vehicle.

Widespread Use and General Overview

In general, vapor emissions at gasoline dispensing facilities (GDF) are comprised of **refueling emissions** and **storage tank emissions**. In turn, refueling emissions are generated at the nozzle/vehicle interface and at the outlet from the carbon canister used on the ORVR systems. The storage tank emissions are comprised of vent line emissions through the pressure/vacuum valve (p/v valve) and fugitive emissions through various point sources within the vapor containing hardware; where the vent & fugitive emissions are a function of storage tank pressure.

At a GDF using a combination of Stage II and ORVR, the storage tank vent and fugitive emissions comprise the so-called "IEE" or incompatibility excess emissions. The IEE emissions are generated from the combined storage tanks due to air ingestion, dilution of the hydrocarbon concentration within the vapor spaces of the tanks, and subsequent evaporation of liquid gasoline to increase the vapor space concentration back to the original "equilibrium" value. As ORVR penetration increases with time, the IEE will increase due to leaner vapors (more air) being returned to the storage tank vapor space, which in-turn triggers the evaporative process described above.

With non-Stage II and ORVR alone, air ingestion via Stage II vacuum pumps located in the fuel dispensers is eliminated, however ***air will still be ingested into the storage tanks through the vent line.*** During busy refueling periods, the negative cracking pressure of the p/v valve is quickly reached since the volume of fuel removed from the tank will draw down the level of fuel and this "piston effect" will create a vacuum in the tank vapor space. Typically, the air ingestion will occur when a negative pressure of -6 to -8 inches of water column is reached. The ambient air entering the system will cause the liquid fuel in the tank to evaporate (similar to IEE mechanism), and when the GDF experiences slower pumping periods or when the GDF is closed for business, the combined storage tank pressure will quickly increase. Let's refer to these emissions as "*Storage Tank Breathing Losses*".

To summarize, when Stage II and ORVR are used together at a GDF, the storage tank emissions are called IEE (Incompatibility Excess Emissions). When Stage II is not present at the GDF, and only ORVR is employed, the storage tank emissions are called Storage Tank Breathing Losses (STBL).

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ORVR and Stage II Emissions

In our view, the concept of ORVR WSU "widespread use" has been misunderstood and misinterpreted. The primary flaw centers on the "breakeven" or "cross over point"; where (1) the refueling emissions from ORVR alone are said to equal the refueling emissions from Stage II alone; or (2) when refueling emissions from ORVR alone are said to equal the refueling emissions from Stage II plus ORVR.

It is best to illustrate these points by charts. Chart 1, represents similar data from the dKC Report shown as Figure 3-1 on page 3-6. As opposed to the dkC chart, our Chart1 does not add IEE, as we want to illustrate this effect later in the report.

Here ARID recreates the dkC data by using a simple spreadsheet instead of MOVES. Our spreadsheet uses all the same assumptions as dKC. First, we plot the ORVR Alone vs. Stage II Alone refueling emissions from 2005 through 2022; we show ORVR only and two control efficiencies for Stage II only, 75% and 70%.

Next, we show Chart 2, which incorporates Stage II + ORVR refueling emissions, using the same Stage II efficiencies of 75% and 70%. The refueling emissions with the combined use of Stage II and ORVR are always lower than the emissions with ORVR only; and there is no “crossover” point with ORVR only and the Stage II + ORVR curves. Thus definition (1) from above on WSU is negated, and there is no benefit to using ORVR Alone in comparison to Stage II + ORVR over the entire interval shown. This data is not shown in the dKC report.

Next, we move to Chart 3, which very closely represents the data from the dKC Report shown as Figure 3-1 on page 3-6. Here ARID recreates the dKC data by again using our simple spreadsheet instead of MOVES; incorporating the relevant dKC assumptions. First we plot ORVR Alone vs. Stage II plus ORVR, at the two Stage II efficiency levels. Even though ARID has directly measured values for IEE which far exceed the value of 0.86 lbs. VOC / 1,000 gal figure used by dKC for their Figure 43-1 plot; ARID uses the low figure in our Chart 3. Chart 3, if realistic, would show a benefit to using ORVR Alone beyond 2013.

However, the major problem with Chart 3 (and Figure 3-1 in dKC report) is that the Storage Tank Breathing Losses (STBL) for the ORVR Alone plot are ignored and mathematically are **set to zero**. The assumption of zero STBL is totally unrealistic and not supportable by actual measured data. The STBL are a very important contribution to the total vapor losses, and the dKC Report (and US EPA rationale) have totally neglected this category of emissions. For decades, the USEPA has ignored this category of important emissions in their analysis of Stage II and ORVR interactions.

It is this very same category of emissions which dKC recommends the use of a vapor processor for mitigating; however, the magnitude of these emissions is strangely assigned a zero in this part of the dKC analysis. This is highly unusual and represents a fundamental flaw in the dKC, USEPA and MA DEP rationale.

We incorporate a very conservative figure of 1.0 lbs./1,000 gal STBL in our Chart 4. Please note a gap between the ORVR Only emissions and the ORVR + Stage II emissions; there is no intersection of the curves and therefore no emissions reduction advantage to using ORVR Alone in comparison to ORVR + Stage II. Please also note that the emissions gap is relatively modest in future years without the use of a technology to mitigate the storage tank losses. To view the impact of using a means to reduce the storage tank evaporative losses, our Chart 5 now incorporates emissions curves for ORVR + Stage II + Vapor Processor; where an active vapor processor is used to control storage tank pressure and to reduce IEE by 99.3%, as confirmed by objective, third-party field testing.

In Chart 5b, below; we incorporate a still conservative figure of 2.5 lbs./1,000 gal STBL. Please note that further “upward shift” in the ORVR only emissions curve.

As seen in Chart 5, the ORVR + Stage II + Processor curves show a large reduction in total emissions from the ORVR Alone case, when STBL emissions are properly accounted for in the emissions inventory. We use a very conservative figure of 1.0 lbs. VOC / 1,000 gal for STBL; in practice ARID has measured values nearly five times higher than this figure, or about 5 lbs. of VOC per 1,000 gallons of fuel dispensed.

Chart 5b, above, shows the same curves but with STBL incremented to 2.5 lbs./1,000 gallons; still in our view a conservative figure.

Ironically, as mentioned previously, the dKC Report (and USEPA and MA DEP rationale) seems to recommend the elimination of Stage II (without considering enhancement via vapor processors); but then the report recommends further investigation for the use of vapor processors to mitigate ***the new problem*** caused by STBL, in an ORVR only environment.

Especially bothersome is that STBL are not included in the dKC report to MA DEP. The omission of these important storage tank emissions results in dramatically different (and incorrect) conclusions drawn from this study.

Thus far, we have explained a fundamental flaw in the dKC Report and USEPA and MA DEP treatment of storage tank emissions in an ORVR Alone environment. In addition, we have shown a large emissions gap between the MA DEP proposal and the simple enhancement of Stage II vapor recovery. In the section to follow, we wil lquantify the costs per ton of VOC reduced under the MA DEP proposal and compare these to the costs per ton of VOC reduced for a state-of-the-art approach using the ARID processor. For our economic analysis, we will incorporate the most conservative assumptions from our perspective (in other words; even though ARID has directly measured higher parameters for IEE and STBL; we will use lower figures referenced in the dKC Report and by USEPA).

We insert Chart 5c, above to view the slope and direction of the curves when more representative values of IEE and STBL are used in the calculations. Note the upward sloping curves for the ORVR + Stage II case, without the use of a processor to mitigate the increasing storage tank emissions. Note also the early cross over point, where ORVR Alone would yield better emissions reductions in 2008 (compared to ORVR + Stage II), if not for the use of a processor on the storage tank. Please note the large gap between ORVR Alone and the ORVR +Stage II + Processor Case. The economics for this case will be tabulated later in this report.

[FOLLOW THIS LINK] to read Part 2 of this article.

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