Description of Spreadsheet Entries and Rationale

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This spreadsheet is used to show relative magnitudes of Vent, Fugitive and Refueling emissions throughout a range of representative California GDF. The spreadsheet includes also the environmental and economic impacts of reducing the Vent & Fugitive emissions by the use of a processor. These calculations are presented in order to guide general discussions and potential regulatory actions. ARID's firsthand experience with CA GDF has tended to be primarily related to the GDF4 and GDF5 categories.

"Emissions Calcs" tab estimates in columns 1-7 the vent and fugitive mass emissions from California GDF.

Column 1 shows a range of vent vapor flowrates generated from the evaporation of liquid phase fuel to vapor phase fuel; for ARID's Challenge Mode test, CARB imposed a minimum flowrate of 350 gph with a corresponding minimum HC concentration of 60% by vol. These flowrates are expressed in gph, or gallons per hour. Based on actual data from CA GDF, ARID tabulated a Summer vent flowrate of 195 gph and a Winter vent flowrate of 370 gph from a high throughput site using the Healy Phase II assist system.

Column 2 converts these vent vapor flowrates to ft3/hr., cubic feet per hour

Column 3 presents a typical estimate for fugitive emissions based on Table 9.1 found in TP-201.2F. Please note that CARB added the so-called m5 (Fugitive Emissions) category to the overall site vapor recovery efficiency calculation in March of 1993. Also, please note that a site will experience fugitive emissions as a function of combined ullage storage tank positive pressure; where higher pressures will yield higher levels of fugitive emissions, even without the cracking pressure of the P/V valve being attained and even with the site passing the TP-201.3 Leak Decay Test. For this site, the pressure driven fugitive emission factor was = 0.33 lb/1,000 gallon; which far exceeds the 0.19 lb/1,000-gallon limit (50% of site emission factor of 0.38 lb/1,000 gal). Exceedance of the 0.19 lb/1,000 gal limit means that the system cannot be certified by ARB.

The GDF make use of various hardware components (nozzles, swivel adaptors, spill buckets, P/V valves, etc.) which all have allowable leak rates.

In our past work, ARID has used the more rigorous methods outlined by CARB in TP-201.2F to calculate fugitive emissions in accordance with Equation 9.2.2 for Q test (Hydrocarbon pressure-related fugitive emissions leak rate), equation 9.3.1 for M (Mass emission rate of pressure-related fugitives), and equation 9.4.1 for E, the mass emission factor for pressure-related fugitive emissions. We have shared the results of these calculations with ARB Staff relative to testing conducted at specific sites; for example, the Cal Expo Certification site.

The emission factor, E (also referred to as m5) is quite important, as CARB standards do not allow certification of systems that exhibit an emission factor exceeding 50% of the maximum allowable overall site emission factor. (For example, 0.38 lb./1,000 gal emission limit or m5 value of 0.5 x 0.38 = 0.19 lb./1,000 gal). This concept appears to be a cornerstone of the EVR Regulations as seen in the following quote, "In developing the EVR Regulations, we strove to structure the regulation to minimize or eliminate pressure-related fugitive emissions, such as those from currently certified systems that sometimes have UST pressures as high as 3 iwc." (Laura McKinney, January 2002, previously attached as reference)

Column 4 shows HC concentration of the vent and fugitive emissions. With reference to graph below column 4, we show actual data of HC concentration vs time; please note that the vapors emitted in the off-hours are approaching (or have reached) saturation concentrations (or equilibrium) as the liquid phase fuel evaporates to vapor phase. As a practical matter, 60% by volume level is justified for winter grade fuel, however, we used a value of 48% which appears consistent with background information provided by ARB Staff.

Column5 tabulates a mass emission in lb./hr. by first summing the vent and fugitive volumetric flow rates and then multiplying by the hydrocarbon concentration, which is first converted into a lb./ft3 figure via the molecular weight of the gasoline vapor (MW=66) and the molar volume (Mv=384). Please reference page 2241 for CAPCOA reference on the attached, "Vent pipe emissions from storage tanks at gas stations: Implications for setback distances".

Column 6 converts the lb./hr. values into lb./day figures. We assume for purposes of this spreadsheet that the GDF under consideration is using a Healy vacuum-assisted front-end Phase II system with a Healy CAS back-end system for vapor collection. We further assume that the GDF closes for business and is not a 24-hour site.

The values in column 6 depend on a venting time per day; we use the entries in columns 28-44 (and 28b-44b) to find a value for venting time as follows:

Column32; The average low-end negative pressure when the GDF closes is -8 iwc for the Healy vac-assisted system considered. Please note that balance systems typically operate at more modest vacuum levels of -2 to -5 iwc, for example. Therefore at a given evaporation rate, the balance system will require less time to reach atmospheric pressure (and less total time to reach cracking pressure of PV valve) and will therefore have more time for venting.

Column 28 shows three typical scenarios for total volume of fuel storage tanks, column 29 assumes an average ullage volume of 50% of the total volume and column 31 calculates the volume of vapors (standard volume) contained within the ullage at the starting pressure. Column 33 lists typical evaporative growth rates which correspond to the different size tanks (we show 20k, 30k and 40k tanks; where the larger surface areas yield higher evaporative rates). For the summer and winter actual evaporative rates; the total storage tank volume was 110,000 gallons.

Column 34 shows typical atmospheric pressure at sea level, measured in iwc, absolute.

Column 35 shows gauge pressure, iwc, gauge; where the first "pressurization step" is for the storage tank ullage space to go from -8 iwc to 0 iwc

Column 36 shows the gallons of vapor phase fuel evaporated in order for the tanks to go from -8 iwc to 0 iwc

Column 37 calculates the time required for the transition from -8 iwc to 0 iwc; this time is in hrs.

Column 38 calculates the time required for the evaporation rate to fill the Healy CAS tank; where the tank has 400-gallon capacity; again, measured in hrs.

Column 39 calculates the time required for the evaporation rate to reach +2.5 iwc gauge pressure on the combined ullage, including the Healy CAS tank

Column 40 sums the three separate timing steps; -8 iwc to 0 iwc, filling the Healy CAS buffer, and then the subsequent pressurization of the combined ullage, including Healy CAS from 0 iwc to + 2.5 iwc

Column 41 then subtracts from closing hours the figure from column 40 to calculate the time for venting at each different ullage and evaporative rate; the figure at bottom of column 41 represents the average venting time, which is used in above column 6 for "hrs/day" of venting time to derive the Mass emission in lb./day in column 6; where the average is listed below the column. The average value was obtained by weighting the winter venting time by 5 months; the summer venting time by 7 months, and dividing by 12; for example; (5*Winter + 7*Summer)/12

Column 7 converts lb./day to tons/year, and averages the column below; again, using the winter and summer weighting factors

The refueling emissions are tabulated in columns 8 – 16 and 18-22

Column 8 shows average hourly fuel dispensing rates for a range of California GDF

Column 9 shows an Uncontrolled Emission factor of 8.4 lb./1,000 gallons dispensed

Column 10 lists a Phase II vapor recovery efficiency of 95%

Column 11 lists an ORVR penetration rate of 90%

Column 12 shows an ORVR vapor recovery efficiency of 95%

Column 13 calculates the recovered mass of fuel with the ORVR system, shown in lb./hr.

Column 14 calculates the recovered mass of fuel with the Phase II system, shown in lb./hr.

Column 15 assumes an average daily pumping time for the GDF, hrs/day

Column 16 calculates the recovered mass of fuel with Phase II plus ORVR systems, shown in lb./day

Column 17 calculates the Vent & Fugitive pressure driven emissions; this is average weighted value, shown in bottom of column 6

Column 18 calculates the ratio of the average (Vent + Fugitive Emissions) from column 17 to the recovered refueling mass (column 16)

Column 19 calculates the monthly gallons pumped by the GDF, using 30 days per month

Column 20 tabulates the Unrecovered refueling mass, 1-recovery efficiency for ORVR refueling

Column 21 tabulates the Unrecovered refueling mass, 1-recovery efficiency for Phase II refueling

Column 22 tabulates the total Unrecovered refueling mass for ORVR and Phase II by summing entries in column 20 and 21

Column 23 shows the ratio of average (Vent + Fugitive Emissions) from column 17 to the Unrecovered refueling mass from column 22

Column 24 calculates the GDF Vapor Recovery Efficiency using the typical CARB calculation; m4 = 0 (no processor installed) and m3 and m5 are combined in the column 17 average value

Column 25 tabulates total Phase II mass generation by multiplying column 8 x column 9/1000 x column 15

Column 26 checks the mass balance by summing column 16 with column 22 to ensure math is correct

Column 27 tabulates a site emission factor by the relationship; (column 17 + column22)/(column8*column15) *1000

GDF Categories Tab presents in Rows 33-47, throughputs and economics for five separate GDF categories; where ARID populated GDF3 – GDF5

Row 33 shows average monthly throughput in gallons

Row 34 presents % of CA GDF population falling within the throughput ranges listed; this data is historic CARB data from 2002 timeframe, and is subject to updating; we don't seek absolutely exact distribution data here; we are trying to show relative measures

Row 35 presents % of throughput for the CA GDF population shown; again, these figures are subject to updating

Row 36 calculates the approximate number of CA GDF falling within the categories listed, based on an assumption of approximately 10,000 CA GDF

Row 37; for GDF5, we chose the average weighted value from bottom of column 7, Mass Emission, tons/year from the spreadsheet found in the Emissions Calcs tab. For GDF4, we chose a smaller value (G7) from column 7 and for GDF3 we chose the smallest value from column 7. We chose progressively smaller values for illustration and comparison.

Row38; we summed the total tons /year for the GDF3, GDF4 and GDF5 category, assuming total adoption of Permeator within these categories; again, an assumption for illustration

Row39; we calculated the tons/day for the category from the previous tons/year calculation, we assumed 365 days per year.

Row40; we calculated investment expense by using Permeator List Price of $50,000 per unit and applied this to the number of GDF in the three chosen categories; for the GDF4, we used a 10% quantity discount (and for GDF3, we used a 15% discount) to reflect cost savings from component suppliers passed on to the end user. The component discount is assumed to be possible due to large order volume; where commercial roll-out in GDF3 and GDF4 categories occurs after the initial GDF5 implementation.

Row41; we calculated average installation cost of Permeator by assuming a range from $34,000 to $50,000; based on approximately equal numbers of GDF requiring excavation and GDF not requiring excavation

Row42 Useful Life, based on practical experience with installed and operating units

Row43 Cost / year is tabulated by amortizing the capital and installation expense over a “straight line” 15-year period; an assumption to facilitate a simple calculation and estimate

Row44; Annual maintenance based on $750 per site annual visit for oil change and inspection

Row45; Fuel savings calculated at $3.00 per gallon and 95% savings of the emission mass; conservative estimates on each figure

Row46; Foregone Maintenance expense by GDF owner/operator for ISD alarm response which will not be needed with processor, we use a rather conservative estimate of $5,500/year per site (5-7 field tech site visits per year)

Row47; Cost of emission reduction; we sum the annualized costs (capital + installation + maintenance) and we subtract the fuel savings and foregone maintenance expenses; and then we use 2,000 lb./ton and 365 days per year to find the normalized cost per pound for the emissions reduction. It is interesting to note that a “negative cost” yields a “revenue” per pound of emissions reduction.