# Estimating Emissions Associated with Portable Fuel Containers (PFCs)

United States
Environmental Protection
Agency

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Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

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## 1.0 INTRODUCTION

Portable fuel containers (PFCs, or gas cans) are consumer products used to refuel a wide variety of gasoline-powered equipment. California has established an emissions control program for gas cans which began in 2001. Since then, some other states have adopted the California requirements. Last year, California adopted a revised program.

EPA is planning to propose standards to control VOCs as an ozone precursor and also to minimize exposure to VOC-based toxics such as benzene and toluene. Gasoline is highly volatile and evaporates easily from containers that are not sealed or closed properly. Although an individual gas can is a relatively modest emission source, the cumulative VOC emissions from estimated population of 80 million gas cans are quite significant. Left uncontrolled, the evaporative emissions from a gas can are up to 60 times the VOC of a new Tier 2 vehicle evaporative control system. Gas can emissions are primarily of three types: evaporative emissions from unsealed or open containers; permeation emissions from gasoline passing through the walls of the plastic containers; and evaporative emissions from gasoline spillage during use.

This report proposes an approach to estimating the VOC inventory associated with PFCs used for gasoline. (This analyses does not consider PFCs used for either kerosene or diesel fuel.)

In 1999, California's Air Resources Board (ARB) proposed a methodology to estimate annual emissions from portable fuel containers (PFCs) within California.**[1,2]** Their approach involved first distinguishing and characterizing the various mechanisms (i.e., sources) of emissions of hydrocarbons (HCs) and then estimating the frequency of occurrence and emission rates associated with each of those sources.

For most of those sources, the daily emission rates also depend upon these four factors:

- Composition of the PFC (plastic versus metal),
- Whether the PFC was stored open or closed (i.e., a PFC is considered “open” if its vent and or spout is uncapped),
- Average size/capacity of the PFC, and
- Frequency the PFC was refilled.

ARB found (based upon analysis of their survey data) that those four factors were themselves dependent upon whether the PFC was used for residential or commercial use. The ARB survey results are given in the following table.

**Table 1**

**Distribution of PFCs by Usage Type**

| | Plastic Closed | Plastic Open | Metal Closed | Metal Open |
|---|---|---|---|---|
| **Residential Usage** | **53%** | **23%** | **13%** | **11%** |
| **Commercial Usage** | **33%** | **39%** | **18%** | **10%** |

ARB also determined that the average PFC in residential usage had a capacity of 2.34 gallons and was refilled 6.4 times annually; the average PFC in commercial usage had a capacity of 3.4 gallons and was refilled 352 times annually. Combining those survey results leads to the estimates that each PFC in a residential unit represents, on average, 14.9 gallons of gasoline annually, and each PFC in commercial unit represents 1,206.9 gallons of gasoline annually.

The analysis also provided ARB with an estimate of the number of PFCs per each residential unit (1.8 per household) and per each commercial unit (6.9 per business). Census data (of the number of households and the number of businesses within California) were then used by ARB to estimate the total number of PFCs within California.

The Ozone Transport Commission (through its contractor Pechan) modified ARB's methodology to apply to Northeastern states.**[3]** The New Jersey Department of Environmental Protection then continued that approach to estimating emissions from PFCs in the state of New Jersey.**[4]**

## 2.0 EPA APPROACH

In this report, EPA proposes to modify ARB's proposed methodology in two ways. The first of those modifications was how the number of PFCs (and the number of gallons of associated gasoline) was estimated, and the second were revisions to those sources of emissions of HC emissions.

### 2.1 Estimating Number of PFCs

Rather than assuming that the numbers of PFCs per household and per business were consistent across the entire country, EPA used its non-road emissions model (NONROAD2005*) to estimate the seasonal (nonroad) consumption of gasoline by source category classification (SCC) code for each state plus the District of Columbia. Each SCC code has a unique usage (commercial versus residential), a unique ratio of the percent of fuel dispensed from PFCs (versus from fuel pumps), and a unique spillage rate (grams per gallon). The spillage (from PFCs) in the NONROAD2005 model is assumed to be a constant 17 grams for each refueling event. Since the fuel tank capacity varies for different pieces of equipment, the spillage rate (in terms of grams per gallon of dispensed gasoline) also varies greatly. (See Appendix A.) Thus,

* The previous draft version of this report (EPA420-D-06-003) was based on estimates from the draft NONROAD2004 model.

by combining those two outputs of NONROAD2005, EPA was able to estimate (by state) the total quantity of gasoline supplied from PFCs as well as the total spillage (from using the PFCs to refuel the individual pieces of equipment) for residential usage and for commercial usage. For example, running the NONROAD2005 model for calendar year 2005 produced the following estimates (obtained by summing the individual state-by-state estimates):

**Table 2**

**Estimate of Gallons of Gasoline Dispensed Nationwide by PFCs in 2005**

| Season | Residential Usage (gallons) | Commercial Usage (gallons) | Spillage at Equipment (tons) |
|---|---|---|---|
| Winter 2005 | 107,369,000 | 303,321,000 | 10,170 |
| Spring 2005 | 281,789,000 | 553,932,000 | 17,891 |
| Summer 2005 | 456,122,000 | 742,357,000 | 24,377 |
| Autumn 2005 | 281,374,000 | 551,282,000 | 17,824 |
| **Annual 2005** | 1,126,653,000 | 2,150,892,000 | 70,262 |

Using ARB's survey-based estimates of the total annual gallons of gasoline represented by each PFC (14.9 gallons for PFCs in residential usage and 1,206.9 gallons for PFCs in commercial usage), EPA estimated the number of PFCs in use. This method produced an estimate of 76,284,000 PFCs in use nationally which is close to industry estimates of 80.5 million PFCs.* The fact that some PFCs are only used seasonally would increase that calculated number of PFCs, bringing it even closer to that industry estimate. This suggests that this approach produces estimates that are reasonable on an annual basis. To apply this approach to seasonal estimates, we first had to distribute the estimated 6.4 annual refills (for the residential PFCs) on a seasonal basis. Distributing those refills proportional to the gasoline used (Table 2) led to an estimated average 0.6 refills each winter. Rounding that up to an even 1.0 and distributing the remaining refills proportional to the remaining gasoline produced the values in Table 3. The seasonal distribution of the refills of PFCs in commercial usage (also given below in Table 3) was estimated to be proportional to the distribution of the refills of PFCs in residential usage.

* The US Consumer Products Safety Commission estimated 80.5 million PFCs in use nationwide, and about 20 million additional PFCs are sold annually.**[5]** Assuming a slow growth rate in the national population of PFCs (e.g., the one percent rate estimated from the NONROAD model and illustrated in Figure 1), the average useful life of a PFC would have to be between four and five years. That estimate of useful life is consistent with the estimates given in that memorandum (i.e., 3-5 years for plastic PFCs and 25 years for metal PFCs).

**Table 3**

**Number of Refills for Each PFC by Season**

| Season | Residential Usage | Commercial Usage |
|---|---|---|
| Winter | 1.0000 | 55.4023 |
| Spring | 1.4755 | 81.7468 |
| Summer | 2.4000 | 132.9655 |
| Autumn | 1.4755 | 81.7468 |
| **Annual** | 6.3510 | 351.8614 |

This distribution of refills predicts (for calendar year 2005) that approximately 47 million PFCs would be in use during the three winter months and approximately 82 million would be in use during each of the remaining nine months. EPA proposes to use this seasonal rate of refilling the PFCs to estimate the season emissions associated with PFC usage.

## 2.2 Revising Sources of HC Emissions

The second modification to ARB's proposed methodology was a revision to those sources of emissions of HC emissions, by:

- including the emissions produced by displacing the vapor within the PFC and within the equipment when each is filled,
- including the spillage occurring when the PFC is filled at the pump, and
- adjusting the estimates of evaporation/diurnal and permeation emissions to account for the fuel RVP and the ambient temperature (using the same approach used by EPA in its NONROAD2005 model **[6]**).

This modification produced the following list of seven sources:

- Emissions associated with filling the gas can (PFC) at the gas pump
  - (1) Displacement of the vapor within the can
  - (2) Spillage of gasoline while filling the can
- Emissions associated with transporting the gas can to the piece of nonroad equipment
  - (3) Spillage of gasoline during transport
- Emissions associated with using the gas can to refuel the piece of nonroad equipment (These emissions are already accounted for in EPA's NONROAD model.)
  - (4) Displacement of the vapor within the nonroad equipment
  - (5) Spillage of gasoline while filling the nonroad equipment
- Emissions (adjusted for changes in ambient temperature) associated with storage of the gasoline in the PFCs
  - (6) Emissions due to evaporation (i.e., diurnal emissions)
  - (7) Emissions due to permeation

Since (as noted above) the spillage and vapor displacement associated with using the PFCs to refuel the pieces of nonroad equipment (i.e., items 4 and 5 in the above list) are already included in the estimates of EPA's NONROAD model; care should, therefore, be taken to avoid double counting them in inventory estimates.

### 2.2.1 HC Emissions from Vapor Displacement

Each gallon of gasoline pumped into each PFC or poured into each piece of nonroad equipment displaces the same volume of vapor. In EPA's NONROAD model (for equipment fueled using PFCs), the mass of that displaced vapor is a function of the ambient temperature (in degrees Fahrenheit) and the Reid Vapor Pressure (RVP) of the fuel, specifically the mass of HC in the vapor (in grams) displaced by each gallon of gasoline is given by the following formula:

$$\exp(-1.2798 + 0.0203*\text{Temperature} + 0.1315*\text{RVP})$$

Where (ambient) temperature is in degrees Fahrenheit (between 40 and 95° F), and fuel RVP is in pounds per square inch (psi). For ambient temperatures under 40° F, the temperature is rounded up to 40° F in the formula. Similarly, for ambient temperatures over 95° F, the temperature is rounded down to 95° F.

Since (as noted in Section 2.2) the vapor displaced from the individual non-road equipment is already being estimated by EPA's NONROAD model, care must be taken not to double count this quantity in inventory estimates.

### 2.2.2 HC Emissions from Spillage at Pump

In EPA's MOBILE6 model, spillage at the pump is estimated at 0.3128 grams per gallon pumped into each on-road vehicle. EPA proposes to use this same estimate of spillage for each gallon pumped into each PFC.

### 2.2.3 HC Emissions from Spillage During Transport

ARB determined that the spillage of gasoline during transport was dependent upon whether the PFC was opened or closed. Specifically, ARB set the transport spillage at 23.0 grams/refill for closed PFCs and at 32.5 grams/refill for opened PFCs. EPA proposes to use those same ARB estimates in combination with ARB's survey estimates that, for residential usage, the average PFC has a capacity of 2.34 gallons and, for commercial usage, the average PFC has a capacity of 3.43 gallons. Combining these ARB estimates leads to the following results:

**Table 3**

**Transport Spillage (grams / gallon)**

| | **Closed PFCs** | **Open PFCs** |
|---|---|---|
| **Residential Usage** | **9.829** | **13.889** |
| **Commercial Usage** | **6.706** | **9.475** |

### 2.2.4 HC Emissions from Spillage During Refueling Non-Road Equipment

As described (in Section 2.1), EPA used its non-road emissions model (NONROAD2005) to estimate the spillage (per gallon) for each piece of non-road equipment that is fueled using a PFC. Since this spillage for the individual non-road equipment is already being estimated by EPA's NONROAD model, care must be taken not to double count this quantity in inventory estimates. If control measures such as automatic fuel shut-offs are used, this could reduce the spillage rate to below what is currently assumed in the NONROAD model.

### 2.2.5 HC Emissions Due to Permeation

For closed PFCs, ARB estimated the daily permeation rates at 1.6 grams/gallon for plastic containers and at 0.06 grams/gallon for metal containers.**[2]** These estimates were based on testing PFCs with an average fill level to be 49 percent. EPA modified ARB's permeation rate for closed metal containers by assuming a rate of zero because fuel does not permeate through metal. (For open PFCs, the quantity of evaporative emissions far exceeds the permeation; thus, ARB simply used a combined value. See Section 2.2.6.) Based on ARB's survey results that the capacity of the typical PFC in residential use is 2.3 gallons and that the capacity of the typical PFC in commercial use is 3.4 gallons, assuming (as ARB did) the average fill level to be 49 percent, we estimated the average daily permeation for each type of container. Those estimates are given in Table 4.

**Table 4**

**Daily Permeation (grams / container)**

| | Closed Plastic PFCs | Closed Metal* PFCs |
|---|---|---|
| **Residential Usage** | **1.80016** | **0** |
| **Commercial Usage** | **2.63870** | **0** |

***** Although ARB estimated permeation from metal cans to be 0.06 grams per gallon, EPA believes that a permeation rate (through a metal container) is more likely to be zero.

Testing has shown that the permeation rate is the same whether the PFC is completely filled with liquid gasoline or with saturated vapor. Thus, the total permeation emission is a function of the total number of PFCs (in use) rather than of the total amount of gasoline.

EPA has assumed (in its recent rule makings) that emissions due to permeation are a function of ambient temperature, doubling approximately every 10 to 12 degrees Celsius (18 to 22 degrees Fahrenheit). We developed an exponential temperature adjustment factor which when applied (multiplicatively) to those permeation values allow modeling at various ambient temperatures. The formula for that adjustment factor is:

$$\exp(0.0327 * (\text{Temperature} - 85.53))$$

The temperature adjustment factors were calculated separately for each state and for each day of the year and were then averaged to produce estimates for each state for each season of the year (see Section 2.3).

### 2.2.6 HC Emissions Due to Evaporation/Diurnal

Diurnal (or evaporative) emissions result from fuel expansion and vapor production due to rising temperatures during the day. ARB performed 24-hour diurnal testing (with temperatures cycling between 65° and 105° F) on PFCs using a fuel with an RVP of 7.0 psi. For closed PFCs, ARB estimated the average daily emissions (permeation plus diurnal) for plastic containers at 2.95 grams/gallon and for metal containers at 0.50 grams/gallon.**[2]** (As before, the average fill level of the containers was 49 percent.)

Subtracting the estimated daily permeation rates (Section 2.2.5) produced these estimates of daily diurnal emissions:

- Closed, plastic PFCs: 1.38 grams per gallon per day
- Closed, metal PFCs: 0.50 grams per gallon per day

For "open" containers (regardless of material or capacity), a single rate was calculated **[2]**:

- Open PFCs: 21.8 grams per day (per container)

Assuming an average daily fill level of 49 percent, we estimated daily diurnal emissions for each in-use (closed) PFC to be:

**Table 5**

**Daily Diurnal Emissions (grams / container)**

| | Closed Plastic PFCs | Closed Metal* PFCs |
|---|---|---|
| **Residential Usage** | **1.6** | **0.6** |
| **Commercial Usage** | **2.3** | **0.8** |

EPA applied an adjustment factor to those values to estimate the diurnal emissions resulting from daily temperature cycles different than the 65° to 105° F cycle test used to develop these rates as well as from gasoline with different RVPs. These temperature/RVP adjustment factors were calculated separately for each state and for each day of the year and were then averaged to produce estimates for each state for each season of the year (see Section 2.3). (Estimates of future RVPs include the effects of the renewable fuel standards; see Section 3.3.)

## 2.3 Determining Ambient Temperatures

As noted in the previous section, the estimates of emissions (except for spillage) are dependent upon the temperature of the fuel which is assumed to track the "ambient" temperature. A common approach to determining ambient temperatures is simply to use the outdoor temperatures which are readily available. However, some recent testing .**[7]** suggests that the mean temperatures in garages (in which PFCs may be stored) can exceed the (mean) outdoor daily temperatures by an average of 10 degrees Fahrenheit.* The differences between outdoor and "ambient" temperatures are influenced by factors such as:

- Is a vehicle or a piece of (non-road) equipment with a hot engine stored in that enclosure?
- Where in that enclosure are the PFCs stored (i.e., on a cool floor, on a shelf, near a hot engine)?
- How frequently is the door of the enclosure opened (allowing an exchange of air with the outdoors)? Similarly, is there a vent (or open window) in the enclosure?
- Is the enclosure shielded either from direct sunlight or from the cooling effects of wind? Similarly, is the enclosure insulated?

Further study would be necessary to precisely quantify the differences between outdoor temperatures and the corresponding "typical" PFC storage temperatures. The more the storage (or ambient) temperature exceeds the outdoor temperature, the higher will be the estimated inventory of VOC emissions from PFCs. EPA believes that half the difference observed in that recent study (i.e., 5 degrees Fahrenheit) would be a reasonable estimate of that temperature difference.

Therefore, EPA proposes (for the purpose of estimating PFC inventories) to estimate the daily PFC storage temperatures by simply adding 5 degrees Fahrenheit to the average (local) daily temperatures. These adjusted temperatures will be used in these analyses.

## 3.0 RESULTS

### 3.1 Estimates of HC Emissions (Calendar Year 2005)

Using the NONROAD2005 model for calendar year 2005, we estimated (for each state for each season, and for each SCC code) both the total gasoline dispensed by PFC and the total spillage occurring when the PFCs were used to fuel the individual pieces of equipment. Summarizing those results nationwide (50 states plus the District of Columbia), we obtain the seasonal estimates in Table 2 of Section 2.1.

By the 2005 calendar year, California had already implemented rules which would require the PFCs to be designed in such a way as to reduce (probably eliminate) the likelihood of a PFC being left in the “open” condition. Additionally, California’s ARB predicts that those changes will also reduce both the spillage (occurring when refueling the equipment) by 60 percent as well as the permeation rate (for the closed plastic PFCs) by 50 percent. Our estimates for the 2005 calendar year assume that those rules have been in place long enough for all of the older PFCs to be replaced by PFCs that meet the California requirements (see footnote on Page 3). (Note that by eliminating the possibility that PFCs can be accidentally left in the “open” condition, not only

* In a soon to be published report, two researchers from the Department of Environmental Health Sciences at the University of Michigan report that a study of at 15 residential garages in Michigan found that the temperatures in those garages averaged about five degrees Celsius warmer than outside air.

are evaporative plus permeation emissions reduced but also spillage during transport is also reduced.)

Using ARB's estimates of PFC distribution, we can use the estimates from Section 2.1 to estimate PFC usages and then the associated PFC emissions. These estimates of the annual inventory of HC emissions resulting from PFCs are summarized in Appendix B-2 on a state by state basis. A breakdown of nationwide annual emissions (in tons) for calendar year 2005 is given in the Table 6. Fourteen (14) additional states plus the District of Columbia are planning to adopt the California PFC requirements. By 2010, we anticipate that all of the PFCs in those states will also be compliant with the California rules. We are incorporating that assumption into our estimates for calendar years beyond 2005.

**Table 6**

**Breakdown of Annual (2005) Nationwide PFC Emissions (tons)**

| | ---------------------- PFC Type ---------------------- | | | | |
|---|---|---|---|---|---|
| | **Plastic Closed** | **Plastic Open** | **Metal Closed** | **Metal Open** | **Total** |
| **Residential Usage:** | | | | | |
| Permeation + Diurnal | 34,311 | 102,033 | 7,353 | 48,798 | 192,495 |
| Filling PFCs | | | | | |
| -- Spillage | 223 | 81 | 46 | 39 | 388 |
| -- Vapor Displacement | 2,532 | 927 | 532 | 443 | 4,434 |
| Transport Spillage | 7,011 | 3,576 | 1,455 | 1,710 | 13,752 |
| Fueling Non-Road Equipment* | | | | | |
| -- Spillage | 13,560 | 5,008 | 2,813 | 2,395 | 23,776 |
| -- Vapor Displacement | 2,532 | 927 | 532 | 443 | 4,434 |
| **Commercial Usage:** | | | | | |
| Permeation + Diurnal | 882 | 3,982 | 196 | 1,021 | 6,080 |
| Filling PFCs: | | | | | |
| -- Spillage | 321 | 244 | 115 | 62 | 742 |
| -- Vapor Displacement | 3,577 | 2,799 | 1,316 | 718 | 8,410 |
| Transport Spillage | 6,872 | 7,384 | 2,462 | 1,893 | 18,610 |
| Fueling Non-Road Equipment* | | | | | |
| -- Spillage | 19,481 | 15,155 | 6,979 | 3,886 | 45,500 |
| -- Vapor Displacement | 3,577 | 2,799 | 1,316 | 718 | 8,410 |
| **TOTALS** | 94,877 | 144,913 | 25,115 | 62,127 | 327,031 |
| **TOTALS Excluding Overlap*** | 54,968 | 121,025 | 13,249 | 54,685 | 243,926 |

* The NONROAD model (and hence local inventories) includes estimates of vapor displacement and spillage associated with refueling non-road equipment. However, those NONROAD estimates do not exactly match the values in the above table since they do not take into account the California control measures.

From the preceding table, EPA estimates that the nationwide HC inventory resulting from PFCs in 2005 to be 327,000 tons per year which is 244,000 tons above what is already being estimated by EPA's NONROAD2005 model.

### 3.1.1 Sensitivity of Estimated VOC Emissions to Ratio of Open PFCs

These analyses are based on the distribution of PFCs found by ARB in their surveys. As shown in Table 1, ARB estimated that 49 percent of the PFCs in commercial use and 34 percent of the PFCs in residential use were stored in the open position. As the ratio of open PFCs changes, so do the estimated total emissions. In fact, redesigning the PFCs to make it difficult for them to be stored in the open position is one strategy used to reduce VOC emissions. For example, as the ratio of all PFCs being open varies between 30 and 40 percent, the estimated total VOC emissions vary by plus or minus seven percent.

## 3.2 Estimates of HC Emissions (Calendar Year 1990)

Using EPA's NONROAD model, we repeated the preceding approach and obtained estimates of gasoline consumed by non-road equipment (by state for each SCC code) for calendar year 1990 (instead of for 2005). Assuming the same distribution of PFCs (i.e., open versus closed, plastic versus metal), we obtained a national inventory of HC emissions from PFCs as 299,000 tons (which is 222,000 tons above what is already being estimated by EPA's NONROAD2005 model for 1990).

This suggests that the national inventory of HC emissions from PFCs increased by about nine percent during the 15 years from 1990 to 2005. That growth rate in HC emissions appears small because it is being offset by the effect of California adopting its PFC requirements. As illustrated in Figure 1 (in the following section), without the effect of California (and later, 14 other states plus DC), the annual growth rate would be slightly over one percent.

## 3.3 Estimating Annual PFC Emissions into the Future

As noted in Section 3.1, EPA estimated the HC inventory resulting from PFCs for calendar year 2005 to be 327,000 tons per year. A substantial portion of those emissions are due to the fact that many of the PFCs are left open by the users. If the PFCs were redesigned so that neither the vent nor the spout could be left "open" while being transported or stored, the resulting 2005 national inventory would decrease. Additionally, if the PFCs were redesigned to decrease spillage by 50 percent, the reduction in HC emissions would be much greater.

Twelve states plus the District of Columbia (California, Connecticut, Delaware, Maine, Maryland, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Texas, Virginia, and Washington DC) already have or will implement controls on the design of PFCs that will reduce HC emissions. Additionally, three other states (Massachusetts, Rhode Island, and Vermont) are also planning to adopt the California PFC programs which are expected to reduce (for the modified containers) spillage (while fueling the equipment) and permeation (each reduced by 50 percent) and reduce evaporation by designing the PFCs so that they are not easily left open.

Additionally, California (alone among those 15 states) has adopted more stringent emission standards that will require each PFC to emit (permeation plus evaporation) no more than 0.3 grams of VOC per day for each gallon of capacity. This requirement will be effective July 1,

2007.  Assuming that gas cans have a typical life of about five years on average, the "new" versions of the PFCs should replace virtually all of the earlier versions by 2013.

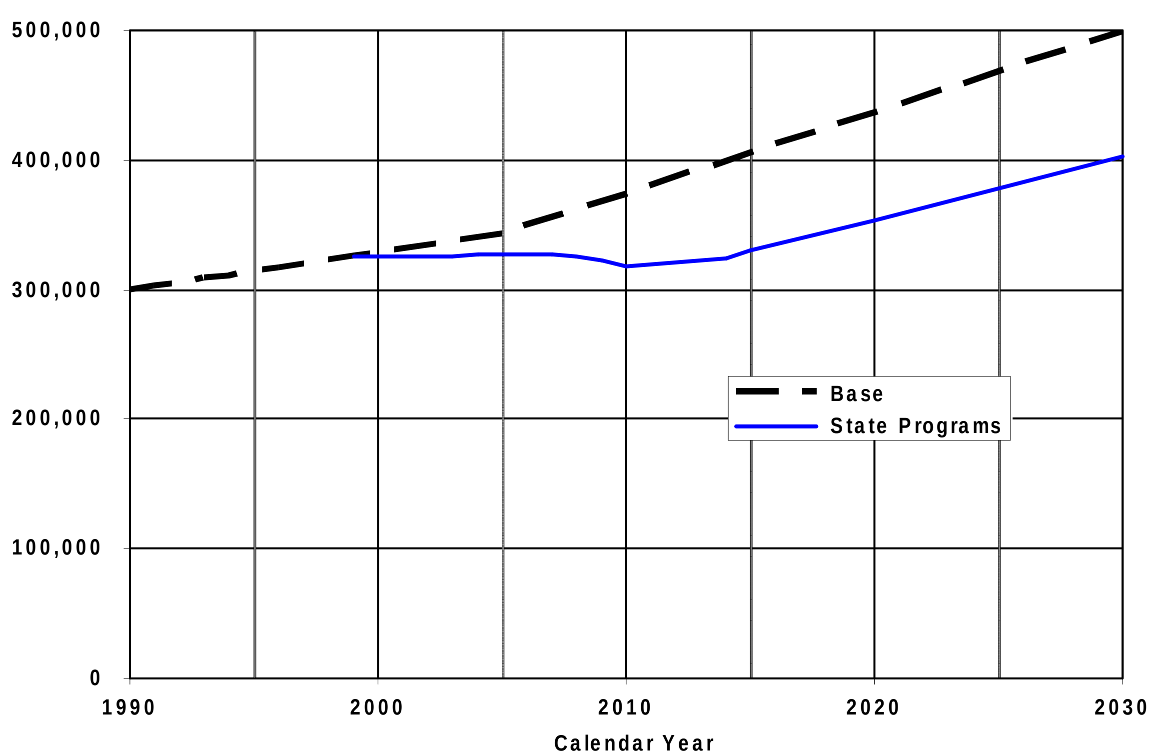
Assuming that those 15 states plus DC will have fully implemented their own controls and using this methodology, we estimate that that the total annual nationwide HC emissions associated with PFCs for 2015 would be 330,000 tons (which includes the "double counted" emissions from the NONROAD2005).

Additionally, the renewable fuel standards (RFS) are expected to affect the RVP of the local fuels which in turn would affect the estimates of evaporative emissions and vapor displacement. These estimates of future RVP levels are incorporated in the estimates of VOC emissions for future years.

Using this methodology repeatedly, we can obtain estimates of annual PFC emissions for two basic scenarios, namely a base case (in which no PFC controls are implemented) and a case in which 15 states plus DC implement California type requirements.  Those two scenarios are plotted in the following graph in which the base scenario is represented by a dotted (black) line and the 15-state control scenario (California beginning in 1999) is represented by a solid (blue) line.  The annual growth in the base scenario (about 1.2 percent annually) is being driven by the increasing estimates of PFC related fuel consumption from the NONROAD model.**[8]**

**Figure 1**

**Comparison of PFC Control Scenarios**
**Annual Nationwide VOC Emissions (Tons) from PFCs by Calendar Year**



## 4.0 REFERENCES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2. "Notice of Public Meeting to Consider the Approval of California's Portable Gasoline-Container Emissions Inventory" (Mail-Out MSC 99-25).

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4. "Estimated VOC Emission Reductions and Economic Impact Analysis for Proposed Portable Fuel Containers Rule," by the State of New Jersey Department of Environmental Protection, July 2003.

5 . "Market Information --- Gasoline Cans," Memorandum from Terrance R. Karels (US Consumer Products Safety Commission) to Suzanne Barone, January 3, 2003.

6. "Nonroad Evaporative Emission Rates," US EPA Number EPA420-R-05-020 (NR-007c), December 2005. (Posted at: http://www.epa.gov/otaq/nonrdmdl.htm#techrept)

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8. "Calculation of Age Distributions in the Nonroad Model -- Growth and Scrappage," US EPA Number EPA420-R-05-018 (NR-007c), December 2005. (Posted at: http://www.epa.gov/otaq/nonrdmdl.htm#techrept)

# Appendix A–1

## Commercial (Non–Road) Equipment Fueled Using PFCs
## By Source Category Classification (SCC) Codes

| Classification | SCC | Equipment | 2 vs 4 Stroke | % of Fuel From PFCs | Spillage (gr/gal) |
|---|---|---|---|---|---|
| Commercial Equipment | 2260006005 | Generator Sets | 2 | 100% | 21.250 |
| | 2260006010 | Pumps | 2 | 98.459% | 21.250 |
| | 2260006015 | Air Compressors | 2 | 100% | 15.455 |
| | 2265006005 | Generator Sets | 4 | 52.297% | 7.275 |
| | 2265006010 | Pumps | 4 | 76.737% | 12.798 |
| | 2265006015 | Air Compressors | 4 | 57.208% | 8.437 |
| | 2265006025 | Welders | 4 | 10.290% | 11.333 |
| | 2265006030 | Pressure Washers | 4 | 77.253% | 12.448 |
| Industrial Equipment | 2260003030 | Sweepers/Scrubbers | 2 | 100% | 26.123 |
| | 2260003040 | Other General Industrial Eqp | 2 | 100% | 16.308 |
| | 2265003010 | Aerial Lifts | 4 | 1.587% | 5.862 |
| | 2265003030 | Sweepers/Scrubbers | 4 | 18.803% | 4.375 |
| | 2265003040 | Other General Industrial Eqp | 4 | 63.058% | 6.741 |
| | 2265003050 | Other Material Handling Eqp | 4 | 0.156% | 11.111 |
| Lawn and Garden Equipment | 2260004016 | Rotary Tillers < 6 HP | 2 | 100% | 56.667 |
| | 2260004021 | Chain Saws < 6 HP | 2 | 100% | 122.324 |
| | 2260004026 | Trimmers/Edgers/Brush Cutter | 2 | 100% | 85.000 |
| | 2260004031 | Leafblowers/Vacuums | 2 | 100% | 24.286 |
| | 2260004071 | Commercial Turf Equipment | 2 | 100% | 6.800 |
| | 2265004011 | Lawn mowers | 4 | 100% | 42.500 |
| | 2265004016 | Rotary Tillers < 6 HP | 4 | 100% | 56.667 |
| | 2265004026 | Trimmers/Edgers/Brush Cutter | 4 | 100% | 85.000 |
| | 2265004031 | Leafblowers/Vacuums | 4 | 100% | 24.286 |
| | 2265004036 | Snowblowers | 4 | 100% | 24.286 |
| | 2265004041 | Rear Engine Riding Mowers | 4 | 100% | 6.954 |
| | 2265004046 | Front Mowers | 4 | 100% | 6.987 |
| | 2265004051 | Shredders < 6 HP | 4 | 100% | 54.839 |
| | 2265004056 | Lawn & Garden Tractors | 4 | 100% | 6.526 |
| | 2265004066 | Chippers/Stump Grinders | 4 | 100% | 1.478 |
| | 2265004071 | Commercial Turf Equipment | 4 | 100% | 3.290 |
| | 2265004076 | Other Lawn & Garden Eqp. | 4 | 100% | 5.141 |
| Logging Equipment | 2260007005 | Chain Saws > 6 HP | 2 | 100% | 62.408 |
| Recreational Equipment | 2265001060 | Specialty Vehicles/Carts | 4 | 0.021% | 4.722 |

# Appendix A–2

## Residential (Non–Road) Equipment
## By Source Category Classification (SCC) Codes Fueled Using PFCs

| Classification | SCC | Equipment | 2 vs 4 Stroke | % of Fuel From PFCs | Spillage (gr/gal) |
|---|---|---|---|---|---|
| Lawn and Garden Equipment | 2260004015 | Rotary Tillers < 6 HP | 2 | 100% | 56.667 |
| | 2260004020 | Chain Saws < 6 HP | 2 | 100% | 201.422 |
| | 2260004025 | Trimmers/Edgers/Brush Cutter | 2 | 100% | 85.000 |
| | 2260004030 | Leafblowers/Vacuums | 2 | 100% | 24.286 |
| | 2265004010 | Lawn mowers | 4 | 100% | 42.500 |
| | 2265004015 | Rotary Tillers < 6 HP | 4 | 100% | 56.667 |
| | 2265004025 | Trimmers/Edgers/Brush Cutter | 4 | 100% | 85.000 |
| | 2265004030 | Leafblowers/Vacuums | 4 | 100% | 24.286 |
| | 2265004035 | Snowblowers | 4 | 100% | 24.286 |
| | 2265004040 | Rear Engine Riding Mowers | 4 | 100% | 6.953 |
| | 2265004055 | Lawn & Garden Tractors | 4 | 100% | 6.526 |
| | 2265004075 | Other Lawn & Garden Eqp. | 4 | 100% | 5.155 |
| Pleasure Craft | 2282005010 | Outboard | 2 | 5.001% | 5.963 |
| | 2282010005 | Inboard/Sterndrive | 4 | 0.003% | 7.194 |
| Recreational Equipment | 2260001010 | Motorcycles: Off-Road | 2 | 100% | 6.538 |
| | 2260001030 | ATVs | 2 | 100% | 6.538 |
| | 2265001010 | Motorcycles: Off-Road | 4 | 100% | 6.538 |

# Appendix B-1

## PFC Emissions (Tons / Year) by Source
## (for 1990)

| State | Refilling PFC at Pump: Vapor Displacement | Refilling PFC at Pump: Spillage | Spillage During Transport | Refueling Equipment: Vapor Displacement | Refueling Equipment: Spillage | Permeation Plus Evaporation |
|---|---|---|---|---|---|---|
| AL | 224.8 | 15.0 | 447.1 | 224.8 | 1,010.8 | 4,286.7 |
| AK | 24.8 | 1.9 | 60.1 | 24.8 | 103.2 | 776.6 |
| AZ | 279.1 | 22.9 | 647.9 | 279.1 | 1,630.1 | 3,936.1 |
| AR | 105.7 | 8.5 | 262.7 | 105.7 | 533.4 | 2,813.4 |
| CA | 1,532.1 | 133.9 | 3,760.8 | 1,532.1 | 9,284.9 | 19,682.1 |
| CO | 202.7 | 18.9 | 536.5 | 202.7 | 1,319.4 | 2,137.2 |
| CT | 123.2 | 12.0 | 342.7 | 123.2 | 837.2 | 1,422.5 |
| DE | 36.6 | 3.1 | 89.1 | 36.6 | 217.9 | 514.9 |
| DC | 7.6 | 0.7 | 25.0 | 7.6 | 56.6 | 235.1 |
| FL | 933.1 | 72.5 | 2,055.5 | 933.1 | 5,050.7 | 14,664.5 |
| GA | 390.9 | 32.4 | 930.8 | 390.9 | 2,234.7 | 5,918.5 |
| HI | 58.1 | 4.0 | 112.9 | 58.1 | 285.3 | 1,208.2 |
| ID | 50.6 | 4.9 | 146.3 | 50.6 | 316.0 | 780.1 |
| IL | 405.1 | 36.3 | 1,058.5 | 405.1 | 2,458.1 | 5,764.9 |
| IN | 241.4 | 19.8 | 578.2 | 241.4 | 1,353.8 | 3,914.8 |
| IA | 99.6 | 8.3 | 248.5 | 99.6 | 541.9 | 1,886.4 |
| KS | 93.5 | 8.5 | 247.9 | 93.5 | 567.2 | 1,457.6 |
| KY | 129.1 | 11.1 | 340.2 | 129.1 | 727.8 | 2,914.7 |
| LA | 168.9 | 12.1 | 370.7 | 168.9 | 771.4 | 5,178.9 |
| ME | 40.7 | 4.3 | 130.7 | 40.7 | 297.7 | 620.4 |
| MD | 226.0 | 21.1 | 597.8 | 226.0 | 1,520.6 | 2,528.1 |
| MA | 199.0 | 19.1 | 556.1 | 199.0 | 1,322.3 | 2,561.3 |
| MI | 316.9 | 29.6 | 886.3 | 316.9 | 1,966.1 | 5,253.7 |
| MN | 181.4 | 15.5 | 463.1 | 181.4 | 992.3 | 3,281.1 |
| MS | 97.0 | 7.4 | 230.6 | 97.0 | 476.0 | 2,997.4 |
| MO | 212.6 | 19.0 | 560.9 | 212.6 | 1,271.6 | 3,427.2 |
| MT | 26.4 | 2.6 | 81.9 | 26.4 | 160.5 | 506.1 |
| NE | 55.0 | 5.2 | 154.0 | 55.0 | 336.4 | 911.4 |
| NV | 123.4 | 10.6 | 295.8 | 123.4 | 759.6 | 1,362.6 |
| NH | 44.1 | 4.5 | 131.0 | 44.1 | 299.6 | 572.4 |
| NJ | 332.9 | 30.0 | 857.4 | 332.9 | 2,041.2 | 4,049.9 |
| NM | 58.0 | 5.2 | 155.6 | 58.0 | 358.7 | 1,050.8 |
| NY | 517.1 | 47.5 | 1,414.3 | 517.1 | 3,095.2 | 8,473.6 |

# **Appendix B-1** (Continued)

## PFC Emissions (Tons / Year) by Source
## (for 1990)

| State | Refilling PFC at Pump: Vapor Displacement | Refilling PFC at Pump: Spillage | Spillage During Transport | Refueling Equipment: Vapor Displacement | Refueling Equipment: Spillage | Permeation Plus Evaporation |
|---|---|---|---|---|---|---|
| NC | 407.9 | 31.5 | 911.8 | 407.9 | 2,179.0 | 6,950.0 |
| ND | 17.2 | 1.8 | 54.1 | 17.2 | 103.9 | 302.1 |
| OH | 507.3 | 41.1 | 1,188.5 | 507.3 | 2,843.0 | 7,500.9 |
| OK | 139.6 | 12.1 | 352.5 | 139.6 | 824.4 | 2,322.6 |
| OR | 133.8 | 12.8 | 373.6 | 133.8 | 864.5 | 1,889.7 |
| PA | 419.5 | 38.5 | 1,132.0 | 419.5 | 2,644.5 | 6,498.5 |
| RI | 28.3 | 2.7 | 80.8 | 28.3 | 188.9 | 422.5 |
| SC | 207.8 | 15.1 | 438.3 | 207.8 | 1,066.9 | 3,981.0 |
| SD | 20.9 | 2.0 | 62.1 | 20.9 | 124.8 | 398.1 |
| TN | 237.0 | 18.6 | 553.4 | 237.0 | 1,245.3 | 4,944.1 |
| TX | 875.0 | 67.6 | 1,954.5 | 875.0 | 4,645.6 | 15,730.9 |
| UT | 70.8 | 6.7 | 201.4 | 70.8 | 418.4 | 1,208.1 |
| VT | 18.7 | 1.9 | 57.6 | 18.7 | 127.6 | 296.3 |
| VA | 309.8 | 27.6 | 786.6 | 309.8 | 1,986.7 | 3,853.6 |
| WA | 225.6 | 20.5 | 595.1 | 225.6 | 1,399.7 | 3,174.0 |
| WV | 65.4 | 5.4 | 170.6 | 65.4 | 345.8 | 1,700.5 |
| WI | 166.3 | 16.4 | 488.5 | 166.3 | 1,089.3 | 2,512.5 |
| WY | 14.8 | 1.5 | 48.1 | 14.8 | 92.7 | 265.7 |
| **50-State** | 11,403.3 | 972.1 | 28,226.3 | 11,403.3 | 66,389.1 | 181,040.0 |

# Appendix B-2

## PFC Emissions (Tons / Year) by Source
## (for 2005)

| State | Refilling PFC at Pump: Vapor Displacement | Refilling PFC at Pump: Spillage | Spillage During Transport | Refueling Equipment: Vapor Displacement | Refueling Equipment: Spillage | Permeation Plus Evaporation |
|---|---|---|---|---|---|---|
| AL | 224.8 | 17.5 | 527.1 | 224.8 | 1,069.0 | 5,292.6 |
| AK | 29.7 | 2.2 | 72.4 | 29.7 | 109.1 | 955.2 |
| AZ | 333.8 | 26.4 | 751.8 | 333.8 | 1,723.4 | 5,161.0 |
| AR | 124.9 | 10.1 | 312.6 | 124.9 | 564.2 | 3,471.7 |
| CA | 1,637.4 | 154.9 | 3,703.0 | 1,637.4 | 8,870.9 | 6,767.7 |
| CO | 234.0 | 21.8 | 623.4 | 234.0 | 1,395.9 | 2,630.5 |
| CT | 129.2 | 13.8 | 399.5 | 129.2 | 885.9 | 1,424.3 |
| DE | 38.0 | 3.6 | 103.7 | 38.0 | 230.3 | 510.7 |
| DC | 9.0 | 0.9 | 30.4 | 9.0 | 59.9 | 273.6 |
| FL | 1,078.4 | 83.6 | 2,386.6 | 1,078.4 | 5,340.5 | 18,167.2 |
| GA | 452.6 | 37.6 | 1,084.7 | 452.6 | 2,363.2 | 7,296.1 |
| HI | 67.5 | 4.6 | 131.6 | 67.5 | 302.9 | 1,511.5 |
| ID | 59.2 | 5.7 | 172.6 | 59.2 | 334.4 | 962.5 |
| IL | 432.0 | 42.3 | 1,239.6 | 432.0 | 2,600.8 | 5,933.4 |
| IN | 277.8 | 23.0 | 677.6 | 277.8 | 1,432.1 | 4,713.6 |
| IA | 116.5 | 9.7 | 293.1 | 116.5 | 573.4 | 2,318.4 |
| KS | 108.8 | 9.9 | 290.8 | 108.8 | 600.3 | 1,792.6 |
| KY | 146.2 | 13.1 | 404.0 | 146.2 | 770.0 | 3,313.9 |
| LA | 199.4 | 14.2 | 440.6 | 199.4 | 815.9 | 6,404.7 |
| ME | 45.5 | 5.1 | 154.8 | 45.5 | 315.0 | 691.7 |
| MD | 254.0 | 24.3 | 694.1 | 254.0 | 1,608.9 | 2,960.0 |
| MA | 209.1 | 22.2 | 651.0 | 209.1 | 1,399.0 | 2,576.5 |
| MI | 371.2 | 34.6 | 1,046.1 | 371.2 | 2,079.8 | 6,476.4 |
| MN | 212.2 | 18.2 | 546.2 | 212.2 | 1,049.9 | 4,031.7 |
| MS | 115.1 | 8.8 | 275.4 | 115.1 | 503.5 | 3,706.5 |
| MO | 245.4 | 22.2 | 659.1 | 245.4 | 1,345.2 | 4,125.5 |
| MT | 31.3 | 3.1 | 97.7 | 31.3 | 169.8 | 625.4 |
| NE | 64.3 | 6.1 | 181.5 | 64.3 | 355.9 | 1,120.9 |
| NV | 141.5 | 12.1 | 341.9 | 141.5 | 803.0 | 1,668.5 |
| NH | 47.3 | 5.2 | 153.8 | 47.3 | 317.0 | 598.1 |
| NJ | 346.5 | 34.8 | 998.2 | 346.5 | 2,160.2 | 4,020.0 |
| NM | 67.9 | 6.1 | 183.5 | 67.9 | 379.5 | 1,295.2 |
| NY | 562.4 | 55.6 | 1,667.5 | 562.4 | 3,275.4 | 8,968.4 |

# Appendix B-2 (Continued)

## PFC Emissions (Tons / Year) by Source (for 2005)

| State | Refilling PFC at Pump: Vapor Displacement | Refilling PFC at Pump: Spillage | Spillage During Transport | Refueling Equipment: Vapor Displacement | Refueling Equipment: Spillage | Permeation Plus Evaporation |
|---|---|---|---|---|---|---|
| NC | 472.9 | 36.6 | 1,064.7 | 472.9 | 2,303.8 | 8,546.9 |
| ND | 20.2 | 2.1 | 64.4 | 20.2 | 109.9 | 371.4 |
| OH | 588.1 | 47.7 | 1,388.0 | 588.1 | 3,007.6 | 9,236.1 |
| OK | 162.3 | 14.0 | 413.0 | 162.3 | 871.7 | 2,860.6 |
| OR | 154.8 | 14.9 | 437.9 | 154.8 | 914.8 | 2,319.1 |
| PA | 472.9 | 44.9 | 1,329.5 | 472.9 | 2,798.4 | 7,495.4 |
| RI | 30.2 | 3.2 | 95.0 | 30.2 | 199.9 | 433.6 |
| SC | 241.0 | 17.6 | 512.0 | 241.0 | 1,128.1 | 4,898.7 |
| SD | 24.7 | 2.4 | 73.8 | 24.7 | 132.1 | 489.8 |
| TN | 276.8 | 21.8 | 651.5 | 276.8 | 1,316.9 | 6,086.9 |
| TX | 1,002.5 | 78.4 | 2,282.0 | 1,002.5 | 4,912.3 | 18,891.1 |
| UT | 82.9 | 7.9 | 237.8 | 82.9 | 442.7 | 1,486.5 |
| VT | 22.0 | 2.2 | 68.3 | 22.0 | 135.1 | 365.5 |
| VA | 351.2 | 31.9 | 914.9 | 351.2 | 2,101.4 | 4,566.5 |
| WA | 246.4 | 23.8 | 696.7 | 246.4 | 1,481.0 | 3,493.7 |
| WV | 77.6 | 6.5 | 203.9 | 77.6 | 365.9 | 2,103.5 |
| WI | 186.7 | 19.1 | 576.0 | 186.7 | 1,152.4 | 2,836.2 |
| WY | 17.6 | 1.8 | 57.3 | 17.6 | 98.1 | 327.7 |
| **50-State** | 12,843.7 | 1,130.1 | 32,362.5 | 12,843.7 | 69,276.1 | 198,575.1 |

# Appendix C-1

## Response to Peer Review Comments from Sam Wells

This report was formally peer reviewed by two peer reviewers (Sam Wells and Sandeep Kishan). In this appendix, comments from Sam Wells are reproduced in plain text, and EPA's responses to those comments are interspersed in indented italics. Comments from the other peer reviewer appear in the following appendix (Appendix C-2).

***********************************

**Peer Review of 'Estimating emissions associated with portable fuel containers (PFCs)'**

Sam Wells
January 16, 2006

**Introduction**

Comments are offered on draft documentation of calculation used in 'Estimating emissions associated with portable fuel containers (PFCs). In general, the document is clear and concise, making improvements upon previous work done by California Air Resources Board (ARB) and others. Further, the proposed methodology is more complete, as it includes all possible modes of hydrocarbon emissions from the gas pump to the non-road fuel tank, as opposed to ARB's single focus upon the PFC.

Similar to other peer review comments I have submitted recently, the introduction appears perhaps a little too concise and brief, with the first sentence mentioning an ARB study- without an overview of the problem and why estimating PFC emissions are important to understand. Also, the types of hydrocarbon emissions are grouped into seven (7) categories, but only six (6) are discussed. These are not fatal flaws but a little editing would make the document much more readable.

> *Two paragraphs have been added to the introduction to explain the importance of estimating emissions from PFCs.*

**Surveys**

Realizing that the EPA is constrained as to obtaining consumer survey information, one could make a case that the ARB survey was (a) a small, (b) old, and (c) perhaps geographically biased towards northern and southern California and perhaps not representative the US. These are important considerations because the ARB survey findings indicated a very high incidence of PFC stored in the "open" condition:

- Residential open – 34% (random survey = 1,500, response = 26%)
- Commercial open – 49% (nonrandom survey = 161, response = 94%)

These high frequencies have a disproportional impact on hydrocarbon emissions because these PFC are freely vented to the atmosphere; thus small changes in the proportions could cause large changes to the emissions inventory.

Therefore, I would recommend a future survey on a national basis to update these statistics and the 1991 Outdoor Power Equipment Institute study used to provide NEVES and NONROAD spillage and vapor displacement at the gasoline pump. The EPA should consider funding such a study if it considers regulation of PFC in the future or analysis of SIP credits; it is understood that the current methodology used the "best current science."

> *The reviewer is correct that while this survey is the "best current science," it is very limited. A survey of a larger number of businesses and households over a larger geographic area (i.e., more than just one state) might produce somewhat different inventory estimates. However, we performed several supplemental analyses in which we made relatively large changes to the survey ratios in Table 1, and we found that the total estimated VOC inventory changed by less than 13 percent. Therefore, EPA does not believe that such an undertaking would result in a significantly different estimate of the overall VOC inventory.*

**EPA Approach**

Although the ARB survey had its limitations, the EPA application to seasonally and geographically allocate PFC is considered to be good. It was also beneficial to have estimates of approximately 80 million PFC in the US so as to validate the estimates. A brief analysis of residential and commercial landscaping equipment found in NONROAD appears to bolster this contention, since those are the leading contributors in terms of PFC (indeed one could almost call PFC the "lawnmower and weed whacker gas can inventory").

**Revising Sources of HC Emissions**

As mentioned previously, this section includes seven hydrocarbon sources but only six are mentioned. For document clarity perhaps vapor displacement at the pump should follow the exact list as enumerated. Section 2.2.1 seems confusing because it related to both "each gallon of gasoline pumped into each PFC or poured into each piece of nonroad equipment…" This seems to assume that the displacement of a PFC and the gas tank on an engine are exactly the same, which seems awkward at best, and the caveat to not double-count emissions raises even more questions. Please clarify this double-counting issue as it is mentioned again in latter text.

> *The goal of the analyses in this report was to estimate all of the VOC emissions associated with the use of PFCs. When a PFC is filled at the gas pump, vapor (containing VOC) is displaced into the atmosphere. Then, when that same PFC is used to refuel a piece of equipment, the vapor in the fuel tank of the piece of equipment is displaced. Thus, when one gallon of gasoline is pumped into a PFC, it displaces 231 cubic inches of vapor from the PFC, and a second 231 cubic inches (again) of vapor when it is pour from the PFC into the equipment. Thus, there are two vapor displacements occurring. However, EPA's NONROAD2004 model already includes that second vapor displacement in its estimates.*

*Therefore, if an estimate of all VOC emissions associated with PFCs is needed, then both displacements need to be counted. However, if an inventory of VOC emissions is being calculated and if that inventory already includes the estimates from the NONROAD2004 model, then that second vapor displacement should not be double counted.*

**Results**

The ARB rule also adopted in similar form by other states is purported to reduce spillage (from gas can to fuel tank) by up to 60 percent. This claim may be exaggerated or have unknown effects because by the ARB's own admission there were some difficulties:[1]

> Shortly after implementing the PFC regulations, consumers began to express complaints regarding spillage from the new PFCs. Specifically, ARB staff received complaints expressing dissatisfaction with the design and functionality of the PFC's "spill-proof" spouts. ARB staff researched these complaints and learned that while the regulations have been successful in reducing emissions from evaporation and permeation, emissions from spillage continued to occur. This is a direct result of the spout design.

Please verify the reductions if possible or state that "good engineering judgment" was used to develop these reduction estimates, as the previous SIP reductions appear to be somewhat tenuous.

*The reviewer is correct that California's original approach was not only unpopular with the consumers, but it was also not effective in controlling spillage. California reduced its estimates of spillage reduction down to zero (i.e., their design change had no effect on spillage). However, California has since revised its approach to spillage control, and they now believe that the current approach will reduce spillage by 60 percent. Since California's current approach is similar to the one that EPA plans to propose in its new (proposed) rule, EPA's belief (based on its own "good engineering judgment") is that the design will reduce spillage by 50 to 60 percent.*

**Growth, Useful Life, and Scrappage**

Sections 2.2, 3.1, and 3.3 rely on some rather "shaky" assumptions regarding growth, useful life, and scrappage of PFC over time. One of the assumptions is that after four to five years, all the plastic PFC will be replaced by new containers, some in areas having the ARB regulations. These assumptions are based on NONROAD and an estimate that 20 million PFC (of 80 million) are purchased each year. The question as to whether these old, "scrapped" PFC are indeed sent to a hazardous or municipal solid waste landfill[2] is an interesting one that can lead to some conjecture – that perhaps not as many PFC are truly scrapped but are still emitting hydrocarbons (diurnal and evaporative). It could be that as families and businesses purchase new equipment,

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[1] ARB, 2005, 'Staff report: Initial statement of reasons for proposed amendments to the portable fuel container regulations,' July 29, 2005

[2] Most Subtitle D landfills will not accept hazardous materials including gasoline and oil, including any red/orange container (including medical wastes)

many PFC could simply be added to the inventory.  This again would be subject to another survey, which was recommended in previous sections, yet may be based in some logic.

- A cursory review of gas can exchange programs in various states and local regions indicated numbers in the thousands, not millions
- As families acquire more equipment, such as 2-stroke chain saws and personal watercraft,[1] more gas cans may be needed
- As landscaping companies[2] expand, more PFC are required for additional crew trucks

In light of such perceived issues, one might recommend a statement saying that there is considerable uncertainty as to the PFC scrappage rates, since one would think they would be similar to the NONROAD scrappage curves but we simply do not have any hard data.

*The reviewer makes two distinct comments concerning scrappage of PFCs.  The question as to whether the disposal of PFCs is itself an environmental problem is beyond the scope of this study.  Those PFCs would be disposed of regardless of governmental actions to modify future PFCs.  Also, programs dealing with the disposal of those PFCs would not be under the control of EPA's Office of Air.*

*As to the estimates of the scrappage rate, EPA agrees with the reviewer that this estimated rate is subject to considerable uncertainty.  However, if we accept the estimate of the PFC manufacturers that there are approximately 80 million PFCs in use (in the USA), that this number is slowly rising, and that approximately 20 million new PFCs are sold each year; then (as stated in the footnote on page 3) mathematically we must conclude that the typical PFC has to be replaced every three to five years.  Therefore, EPA will continue to use this estimate of scrappage rate.*

**Conclusion**

The PFC document is very well presented; I have made a few minor suggestions.  However, it may be prudent to consider the level of uncertainty amongst the variables when documenting emission inventory tools and resulting inventories.  The math itself may be perfect and executed with a high degree of precision, but accuracy may suffer as a result of extrapolating large-scale inferences from very small surveys.  This appears to be the case with PFC.  Since documents such as this are often used as guidance or models for states, locals, and consultants as boilerplate to conduct emission inventories, perhaps a few sentences regarding use of special local surveys would be a good idea.

[1] Note that personal watercraft are not included in the list of covered equipment in Appendix A, but are extensively used in the expanding rental market

[2] This may be counter-balanced by an increase in diesel mowers and diesel PFC are assumed to have zero hydrocarbon emissions

# Appendix C-2

## Response to Peer Review Comments from Michael Hutcheson

This report was formally peer reviewed by two peer reviewers (Sam Wells and Michael Hutcheson). In this appendix, comments from Michael Hutcheson are reproduced in plain text, and EPA's responses to those comments are interspersed in indented italics. Comments from the other peer reviewer appear in the preceding appendix (Appendix C-1).

***********************************

**Peer Review Comments on the Draft Report**
**"Estimating Emissions Associated with Portable Fuel Containers (PFCs)"**

This document details comments from the peer review of the draft US EPA report on evaporative emissions related to portable fuel container use in the following document:

"Estimating Emissions Associated with Portable Fuel Containers (PFCs)"
dated November 18, 2005.

Comments are provided in general for the overall report and for each subject area including population estimates, sources of emissions, ambient temperatures and results.

**General Comments**
In general the reviewer found the report confusing in some very important areas. The most obvious of which is there is no stated purpose for the report. It appears that the estimates are being made because ARB did some similar estimates and now is controlling PFC emissions. If this is a guide for states to estimate PFC emissions or alternatively use these emission estimates then that purpose should be stated. If these estimates are the basis of federal rule making, then that purpose should be included. The description of the CARB methodology should not be the introduction but should be included in an analysis of existing data and methodologies. The introduction should start with a determination of purpose, history, etc.

> *Two paragraphs have been added to the introduction to explain the importance of estimating emissions from PFCs.*

The most confusing aspect is the allegiance of the report to its CARB counterpart to the point that it the CARB estimates get confused with the EPA estimates. It is abundantly clear in Section 2.2 as well as other sections that changes have been made to the CARB methodology. Because of these changes, it would be more clear to the reader if sections described EPA's methodology with reference to CARB data when used instead of reference to CARB's data and methodology then EPA's changes to the methodology and data used. It is recommended that all sections which begin with "ARB determined..." be reworded so that the reader is aware that "EPA estimates ... based on the information from...". It appears to the reviewer that the EPA attributes more weight to the CARB method than is due because of the numerous basic adjustments EPA has made to the methodology to fit other states.

*The reviewer is correct that EPA's analysis relies greatly upon ARB's original, groundbreaking analysis. EPA's goals were slightly different from ARB's, thus, requiring some modifications to ARB's approach. (ARB seems primarily concerned with controlling the VOC emissions from PFCs as a means to control ozone during the summer months. EPA similarly plans to use these estimates for control of summertime ozone on a nationwide basis. However, EPA is also interested in the control of those VOCs on an annual basis as a means of controlling certain toxic chemicals contained in the VOCs) In this report, we found only one use of the phrase "ARB determined . . ." (Section 2.2.3), and in that instance EPA used exactly what ARB had determined (unmodified).*

**Population Estimates**
The use of the NONROAD model for PFC estimates is an excellent integration of the NONROAD model into these estimates. It appears based on the comparison of the EPA estimate of 76.284 million units to the industry estimate of 80.5 million units that the methodology is a fair estimate. However, the reviewer fails to see how seasonal non-use of containers increases the estimate of the number of containers when it is based on the total fuel consumed divided by the average fuel consumed per container. Furthermore, it is unclear why EPA revises the seasonal estimates of fuel consumed when they are based on seasonal fuel consumption. Revising the estimated number of winter refills upward from 0.6 to 1.0 creates a winter bias and possibly underestimating emissions.

*The reviewer makes two distinct comments concerning the estimate of the number of PFCs First, the estimate of 76.284 million PFCs in use was based on EPA's estimate (from the NONROAD2004 model) of the number of gallons of gasoline being dispensed by PFCs However, if some PFCs are out of use for one or more seasons, then the total number of PFCs would be the sum of those in use plus the number of those not in use. Hence, assuming that some PFCs are used only part of the year would increase the total (estimated) number of PFCs.*

*As to EPA's decision to round up the number of refills during winter from 0.6 up to 1.0, EPA reasoned that PFCs used for only one season (i.e., winter) would be refilled at the beginning of that season, thus insuring at least one refill. PFCs used for two or more season would likely require more than a single refill during the year; thus, suggesting (but not requiring) a refill during the winter. PFCs not used during the winter would not be averaged in to determine the number of refills. Thus, EPA believes that assuming (for only those residential PFCs used during the winter) that a refill rate of 1.0 was more reasonable than 0.6. Also, note that using the 0.6 rate and distributing the remaining 0.4 refills over the remaining nine months results in an increase of VOCs during the summer months of only four percent.*

It is also unclear to the reader if the seasonal estimates are nationwide or state by state. Because the state by state description is lacking, it is assumed the state by state analysis was not performed. It seems to the reviewer that a state by state analysis of fuel consumption is appropriate because warmer states would have substantially higher summer consumption and lower winter consumption than colder climates. This is because colder climates would have additional snow and cold weather nonroad units to maintain. Therefore the reviewer recommends that the seasonal fuel consumption estimates be made on a state by state basis.

> *EPA used its NONROAD2004 model to estimate fuel consumption related to PFCs. These fuel consumption estimates were made for each season and for each state. Thus, this component of EPA's approach already met the reviewers suggestion. A statement has been added to the text to the effect that the fuel consumption estimates (from Table 2) were calculated by adding the individual state-by-state estimates.*

**Sources of Emissions**

The reviewer recommends that EPA eliminate the discussion of the changes to the CARB methodology and limit the discussion to EPA's methodology and data sources. The description of changes to methods only confuses the findings in the report as discussed above. Additional discussion of individual sources of emissions are discussed below.

**Vapor Displacement**

The reviewer can not tell from the discussion of vapor displacement if EPA conducted separate daily analyses for each state based on daily average temperatures or if the estimates made by NONROAD for filling equipment are simply assumed equal to the vapor displacement during filling of the PFC. Based on the amount of transport spillage, permeation and diurnal emissions and equipment refueling spillage, vapor displacement during filling of PFC's must be greater than vapor displacement during fueling of non-road equipment.

> *The reviewer is correct that because of gasoline lost to permeation, evaporation, and transport spillage the vapor displacement at the time the PFC is filled is greater than the vapor displacement when the PFC is then used to fill the equipment. However, that spillage estimates matches the estimates from the NONROAD2004 model which are already included in the inventory. Also, that difference is not only tiny compared to the total VOC emitted, it is not affected by EPA's proposed rules. Therefore, EPA will retain its current spillage estimate.*

**Spillage at the Pump**

EPA errs by using the Mobile6 model spillage estimates as the basis for estimating spillage on a per gallon basis for one basic reason. Simply put, on-road vehicles have much larger tank capacities than PFCs. Testing by URS Corporation for Missouri refueling regulations shows that spillage during refueling is independent of the amount of gasoline dispensed and is only dependent on the number of fills. In other words, spillage is caused at the fuel pump by the act of removing the nozzle from the tank regardless of the amount of gasoline dispensed. On average, each nozzle will spill approximately 1.5 grams of fuel per refill, even if 1,000 gallons were dispensed each time. Based on the average capacity of a container for residential use, EPA estimates less than 1 gram of spillage per refill and for commercial containers EPA estimates approximately 1 gram of spillage per refill. Therefore on a per gallon of fuel dispensed basis, the reviewer believes the Mobile6 model underestimates spillage during refilling of PFC.

*The reviewer is likely correct that EPA is underestimating the spillage occurring when the PFC is filled at the pump. However, since that underestimation is small relative to the total VOC emitted and is not affected by EPA's proposed rule, EPA will continue to use the estimates based on its MOBILE model.*

**Spillage during Transport**

The reviewer believes the EPA methodology for estimating emissions from spillage during PFC transport are incorrect and the CARB data underlying these estimates are incorrectly based. Transport spillage should be directly proportional to number of gallons as well as distance transported. Commercial usage of portable fuel containers is necessary only to transport gasoline to a piece of equipment where transport of the equipment to a central refueling location is infeasible. Typically, these uses are predominantly related to transport of the container between operational locations as in a commercial landscaping business. Because of the large number of miles these containers must be transported in comparison to residential PFC usage, it is beyond belief that spillage during transport for an open commercial PFC transported 50 miles per refill would be less on a per gallon basis than for a residential closed PFC transported less than 5 miles from the pump to the residence. For this reason, the reviewer recommends that additional consideration of the transport spillage estimates be made.

*The reviewer does not disagree that the estimates EPA proposes to use to estimate spillage during transport are "the best available" estimates; rather, he only suggests that those estimates might not be "good enough." EPA agrees with the reviewer that those estimates (from Table 3) could be improved. However, we do not agree that those estimates are too far from reality to be useful. As we can see in Table 6, the current estimate of spillage during transport is actually less than six percent of the estimated total VOCs. Therefore, even if we were to double the estimated spillage during transport, we would be increasing the total inventory of VOCs from PFCs by lest than six percent. Since EPA believes that the assumptions underlying Table 3 are directionally correct (i.e., spillage from open PFCs is greater than from closed PFCs) and since the sensitivity of the total inventory to the assumed spillage rate is small, EPA will retain this approach.*

**Spillage during Refueling Non-road Equipment**

The reviewer believes the NONROAD estimates of spillage are appropriate for this analysis.

**Permeation**

The reviewer agrees the CARB estimates of permeation rates are appropriate to use, however, it is not clear in this document if the CARB estimates are on a per gallon of fuel or per gallon of capacity basis. It appears that EPA has based their estimates assuming the CARB testing is based on a per gallon of gasoline basis, however this is not immediately clear. If additional testing has shown the permeation rate is independent of fill level, as stated, then any additional testing relied upon should be referenced in this document and any analysis of permeation rate included for comparison.

*EPA has used these factors to adjust both permeation and diurnal/evaporative emissions to reflect changes both in ambient temperatures and (for evaporation/ diurnal emissions) in fuel RVP. Most recently these adjustment factors were used* *in EPA's NONROAD2005 model. We added a reference to EPA technical report NR-007c which documents these factors.*

EPA does not clearly identify whether the permeation temperature adjustment factor is used for these estimates or just previous rule makings. It is presumed that the estimates tabulated in the results section include temperature adjustment for permeation. The reviewer agrees with the temperature adjustment of permeation, however, it is not clear at what temperature the CARB testing data was completed. Since this would influence the adjustment factor, this data should be provided in this report.

*As noted in Section 2.2.6, the ARB testing was performed (in a variable temperature, diurnal SHED) with ambient temperatures cycling over a 40 degree Fahrenheit range (6*5° to 105° F).

**Evaporation/Diurnal**
EPA does not explain or identify the method used to determine the adjustment factor for diurnal emissions. These emissions are closely related to permeation emissions in closed containers as illustrated by the CARB data but it is not clear if the same temperature adjustment factor is appropriate. EPA needs to identify this adjustment factor for diurnal emissions and explain its development.

*As previously noted, EPA used the same temperature adjustment factor that it used in its NONROAD2005 model.*

**Ambient Temperatures**
The EPA makes a statement regarding temperature testing in PFC storage areas (garages) but does not reference this testing. Any testing identified by EPA in this report should be adequately referenced.

*Information and reference material regarding that testing program have been added.*

The reviewer agrees with the EPA's method of adjusting ambient temperature for residential units but believes that the 10 degree average increase based on testing is more appropriate than the 5 degree increase used because it is based on testing. However, for commercial units which are assumed to get almost daily refills, it is more appropriate to rely on true daily temperatures than to make this correction as storage in a garage can not be presumed. Therefore separate adjustments to temperature should be made for residential and commercial PFC emission estimate calculations.