Peer Review of Draft Report "Estimated Summer Hot Soak Distributions for Denver's Ken Caryl IM Station Fleet"

September 25, 2013

Prepared for
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Contents

Tables

Acronyms and Abbreviations

Acronym / Abbreviation	Stands For
CDPHE	Colorado Department of Public Health and Environment
CO_2	Carbon dioxide
EI23	The 23rd running-loss index created under ERG's RSD evaporative emissions study, calculated based on a regression of the HC vs. CO2 concentration pathlengths captured during an RSM
EPA	U.S. Environmental Protection Agency
ERG	Eastern Research Group, Inc.
ESP	Environmental Systems Products, Inc.
ESP RSD4000/4600 instrument	A remote sensing device built by ESP and designed to measure exhaust emissions concentrations from gasoline vehicles. Designed to measure exhaust emissions concentrations using Method A, but with software modifications can simulate exhaust emissions measurements by Method B
g/Qhr	grams per quarter hour, grams per 15 minutes
HC	Hydrocarbon
I/M or IM	Inspection and Maintenance
LDT	Light-Duty Truck
LDV	Light-Duty Vehicle
MCM	Modified California Method; a method of inspecting the fuel handling system and evaporative emissions control system of a vehicle using visual, olfactory (smelling), and electronic HC detector
Method A	An ESP method used by newer RSD units (ESP RSD4000 and RSD4600) to calculate exhaust emissions.
Method B	An ESP method used by older RSD units (ESP RSD3000) to calculate exhaust emissions. Newer ESP RSD units can be installed with software that can simulate the Method B calculations.
ppEI	Probability proportional to Evaporative Index
PSHED	Portable vehicle emissions test SHED
PZEV	Partial Zero Emission Vehicle. PZEVs have zero evaporative emissions.
RSD	Remote Sensing Device. Instrumentation that uses a light beam shining across the road to measure the near-instantaneous emissions of the vehicle as it drives past the instrument
RSM	Remote-sensing measurement
RVP	Reid Vapor Pressure
SHED	Sealed Housing for Evaporative Determination
WAM	Work Assignment Manager

1. Introduction

Gasoline vehicles are equipped with an evaporative emission control system that limits vapor from the fuel storage system when a vehicle is parked or moving. When this system or the vehicle's gasoline delivery system malfunctions, excessive evaporative emissions can be released. Few estimates of the frequency of vehicles with evaporative emission malfunctions or 'leaks', in the fleet exist. These vehicles could have a significant impact on air quality and the hydrocarbon (HC) emission inventory.

In 2008, EPA partnered with the Colorado Department of Public Health and Environment (CDPHE) to collect light-duty vehicle (LDV) evaporative emission data at CDPHE's Lipan inspection /maintenance (I/M) station in Denver. CDPHE temporarily operated a portable vehicle emissions test SHED (PSHED) at that I/M station as a pilot test program for recruiting higher evaporative emission vehicles and testing them in large numbers. The following summer, using the Lipan pilot study as its model, CDPHE collected new light duty vehicle (LDV) and truck (LDT) evaporative emission data from the in-use vehicle fleet passing through the Ken Caryl I/M station in Denver. EPA acquired the test results from CDPHE for analysis by EPA's contractor, Eastern Research Group (ERG).

EPA's primary goal in documenting and analyzing the findings from the Ken Caryl project data is to estimate the distribution of the level of hot-soak emissions from gasoline-fueled LDVs and LDTs. The report of the analysis has been revised and updated from its original content and title, Estimates of the Fraction of the Fleet with High Evaporative Emissions based on the Ken Caryl Station (Denver, Colorado) Field Study, which was sent out for peer review in late 2011. Comments on the original report were extensive and led to a complete reworking of the report's premise and analysis. This new Ken Caryl data analysis, a draft report entitled, Estimated Summer Hot Soak Distributions for Denver's Ken Caryl IM Station Fleet (last revised May 15, 2013), is being submitted for a new round of peer review.

This report details the peer review of the subject draft report, *Estimated Summer Hot Soak Distributions for Denver's Ken Caryl IM Station Fleet (May 15, 2013)*, which documents the 2009 Ken Caryl summer test program and presents an analysis of the resulting data. A number of independent subject matter experts were identified and the process managed to provide reviews and comments on the new evaporative data analysis. This peer review process was carried out under EPA's peer review guidelines[1].

This report is organized as follows:

- Chapter 2 details the selection of the peer reviewers
- Chapter 3 details the peer review process

[1] U.S. Environmental Protection Agency, Peer Review Handbook, 3rd Edition with appendices. Prepared for the U.S. EPA by Members of the Peer Review Advisory Group, for EPA's Science Policy Council, EPA/100/B-06/002. Available at http://www.epa.gov/peerreview

- Chapter 4 summarizes the reviews
- Appendix A provides resumes and conflict of interest statements for the three selected reviewers
- Appendix B provides the charge letter sent to the selected reviewers
- Appendix C, D and E provide the actual reviews submitted by the three selected reviewers

2. Selection of Peer Reviewers

The EPA WAM supplied a list of five reviewers that EPA determined would be capable of reviewing the subject report. They are listed in Table 2-1.

Table 2-1. EPA Suggested Reviewers

Reviewer	Affiliation	Results
Dr. Michael Tschantz	MeadWestvaco Corporation Specialty Chemicals Division	Had the necessary expertise and agreed to review the report
Eric Fujita	Desert Research Institute Division of Atmospheric Sciences	Retired. Suggested David Campbell, however in reviewing Campbell's resume, it was determined that he did not have the necessary expertise to review the report
David Chen	California Air Resources Board Emission Research Section	Chen recommended Leela Rao from his office. Rao had the necessary expertise and agreed to do the review
Giorgio Martini	European Commission Joint Research Center	Martini was not contacted as we found three reviewers within North America
Stephen Stewart	British Columbia AirCare Program	Had the necessary expertise and agreed to review the report

The three selected reviewers are listed in Table 2-2. Each had the necessary expertise, were available to review the report in a timely manner and had no conflict of interest. All were agreed upon by the EPA WAM.

Table 2-2. Final Reviewers

Reviewer	Contact Information	Necessary Expertise	Conflict of Interest
Dr. Michael Tschantz	MeadWestvaco Corporation Specialty Chemicals Division P: 843-740-2334 michael.tschantz@mwv.com	Yes	No
Leela Rao	California Air Resources Board Emission Research Section P: 626-350-6469 lrao@arb.ca.gov	Yes	No
Stephen Stewart	British Columbia AirCare Program P: 604 453 5155 stephen_stewart@translink.bc.ca	Yes	No

Resumes and conflict of interest statements for the three reviewers can be found in Appendix A.

3. Peer Review Process

Once the three reviewers had been decided upon and approved by the EPA WAM, a charge letter and the subject report were sent to each reviewer via secure email. Shortly after distributing the charge letter (see Appendix B) and supporting materials for the peer review, a teleconference was held between the selected peer reviewers, the EPA WAM, EPA-identified relevant project-related staff and ICF staff to clarify any questions the peer reviewers may have regarding the report/written materials. At the conference call, EPA provided technical and/or background information on the particular report under review.

During the review process, no reviewers had questions. Each reviewer provided a written peer review in a timely manner. These were sent to ICF who forwarded them directly to the EPA WAM.

ICF managed the peer review process to ensure that each peer reviewer had sufficient time to complete their review of the data analysis by the deliverable data told to them (1st week of September 2013). ICF adhered to the provisions of EPA's Peer Review Handbook guidelines to ensure that all segments of the peer review conformed to EPA peer review policy.

4. Summary of Review Comments

In this section, review comments from the three reviewers are summarized. Full comments can be found in Appendix C for Michael Tschantz, Appendix D for Leela Rao and Appendix E for Stephen Stewart. Responses are summarized below relative to the charge questions.

4.1. Responses to Charge Questions

Does the report meet its primary goal?

The primary goal was to estimate the cumulative distributions of evaporative emissions in the light-duty vehicle and light-duty truck fleets. There were also two secondary goals. One was to apply a cost effective and efficient method of measuring evaporative emissions, and this was by measuring hot-soak emissions using a PSHED. The other was to use RSD screening and a probability index to improve efficiency of sampling vehicles with elevated evaporative emissions.

All three reviewers felt that the report met its primary goal and secondary goals. Tschantz felt that the report could be improved by adding a paragraph or section that summarizes the specific work that would be necessary or recommended to construct an inventory. Rao felt that the ability to generalize the results from the study to a larger fleet is limited due to the fact that controlling variables such as ambient temperature, fuel volatility, and barometric pressure were not standardized. Stewart mentioned that the project did not include full sized trucks, vehicles that had been exempted from the IM program, vehicles newer than 2006 and vehicles older than 1981. For the most part, he felt that the study could be extrapolated to cover these missing vehicles, however, he did mention that it was important to understand the percentage of vehicles older than 1981 that were leaking.

Was the sampling methodology using the probability proportional to Index (ppEI) appropriately applied for the situation, allowing for appropriate distribution of the fleet in the end product?

All three reviewers felt that the sampling methodology using the ppEI was appropriately applied for the situation. However, Rao felt that because sampling was limited to one location with a possibly unrepresentative population of vehicles, it is difficult to extrapolate these results to the fleet at large.

Is the description of analytic methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made to develop the Fractions in Table 4-11? Are examples selected for tables and figures well-chosen and designed to assist the reader in understanding the approach and methods?

All three reviewers felt that the report was clearly written and the analyses clearly described. No one felt there were any major flaws in the methodology given the relatively narrowly defined project goals. They also felt that potential biases and sources of uncertainty were identified. However Tschantz felt while he could eventually reconstruct the methodology, Appendix A of the report seemed disjointed and difficult to follow. He lists seven bullet points on issues he identified (see Appendix C).

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics? Are you able to suggest or recommend alternate approaches? In making recommendations please distinguish between cases involving reasonable disagreement in adoption of methods as opposed to cases where you conclude that current methods involve specific technical errors.

All three reviewers found the methods and procedures employed technically sound. They found them well explained and clear to the reader. Stewart commented that while low EI23 values would correspond to low PSHED values, high EI23 values equally corresponded to low and high PSHED values, but still felt that EI23 was a good screening tool. He also felt that the Modified California Method (MCM) provided the only data to link high hot-soak emissions to the overall condition of the vehicle's evaporative control system.

Is the use of hot-soak as a surrogate for elevated evaporative emissions a reasonable premise? Is it reasonable to conclude that there is potentially a link between fuel/evaporative control system leaks and high hot soak emissions?

While all three reviewers felt that hot soak made a good surrogate for elevated evaporative emissions, each had concerns. Tschantz mentioned that running losses were affected by fuel system pressure which fluctuated when the engine was shut off. In addition, tank pressure due to heating when the system is shut off may cause different areas to leak than during running. Rao mentioned that vehicles with moderate fuel system defects, such as bleed emissions are only observable on the second day of a multi-day diurnal test and thus would not show up in a single hot soak test. Stewart mentions that there are no data presented to evaluate the validity of using hot-soak as a surrogate for elevated evaporative emissions. He also mentions that the MCM results show some problems that are likely to cause both running losses and hot-soak emissions, and some that are likely to cause both diurnal and hot-soak emissions.

Is stratification of the results by model year group a reasonable approach to distinguish fuel system and emission control technology changes?

Generally, the three reviewers agreed with the approach but there were some concerns regarding it. The main objection was that there is a phase in period for new emission standards and this can confuse the results. Tschantz mentioned that two factors affect hot soak and running loss evaporative emissions, namely emission control technology and vehicle age. Since the data is a snapshot in time, vehicle age effects separated from control technology could not be evaluated. Tschantz replotted the data several ways to show there was some correlation between vehicle emissions and PSHED values (see Appendix C). He recommends the authors spend some time trying to address and differentiate effects of aging and technology advancements based on the data available. Rao brings up that some of the vehicles could be PZEVs with additional emission control technology above and beyond that found on vehicles with enhanced evaporative emission controls. She believes a better approach would have been to determine the certification classification of each tested vehicle.

Does the methodology, data, and analyses support the report's conclusion?

Generally, all three reviewers felt the methodology, data and analyses support the report's conclusions. Tschantz commented that the authors suggest that temperature, pressure, fuel RVP, etc. can also impact the results and that these factors were not controlled but recorded. He suggests that the authors show either correlations or lack of correlations based upon the data. He replotted the data to show such correlations where they may exist (see Appendix C). Rao commented that using remote sensing to pre-screen vehicles was a cost-effective way of characterizing the evaporative emissions from this fleet.

Other Comments

Stewart provided two other comments on the report formatting. He mentioned that page numbering in Appendix D went awry and that Figure 3.1 makes the RSD vehicle look like it has a chemical refinery loaded onto it.

Appendix A. Resumes and Conflict of Interest Statements

RESUME Michael Ford Tschantz

PERSONAL DATA

Business Development
Carbon Technologies Department
Specialty Chemicals Division
MeadWestvaco Corporation
(843) 740-2334 (office)

525 London Bridge Road
Mount Pleasant, SC 29464
(540) 969-7283
michael.tschantz@mwv.com

DOB: February 7, 1969, Knoxville, TN
Citizenship: United States

EDUCATION

1996	Ph.D. Chemical Engineering, The University of Tennessee. Dissertation: "Experimental Evaluation and Mathematical Modeling of the Fundamental Processes Affecting TCE Co-oxidation by the sMMO Enzyme System of *Methylosinus trichosporium* OB3b."
1994	M.S. Chemical Engineering, The University of Tennessee. Thesis: "Development of a Fully-Suspended, Multi-Stage Bioreactor System for Trichloroethylene Degradation Based on Soluble Monooxygenase Cometabolism."
1991	B.S. Chemistry, Wake Forest University

PROFESSIONAL EXPERIENCE

1996 – present MeadWestvaco Corporation, Specialty Chemicals Division

2007-present	Business Development
2003-2007	Product Development Manager, Carbon Technologies
2000-2003	Sr. Applications Specialist, Carbon Technologies
1997-2000	Process/Project Engineer, Chemical Division Engineering
1996-1997	Research Chemical Engineer, Corporate Research

MEMBERSHIPS

Member of ACS (1996-present)
Member of AIChE (1996-present) – President, Low Country local section
Member of TAPPI (1996-present)
Member of SAE (2000-present)

PUBLICATIONS

Galtress, C.L.; P.R. Morrow; S. Nag; T.L. Smalley; M.F. Tschantz; J.F. Vaughn; D.N. Wichems; S.K. Ziglar; and J.C. Fishbein, "Mechanism for the Solvolytic Decomposition of the Carcinogen N-Methyl-N'-nitro-N-nitrosoguanadine in Aqueous Solutions," *Journal of the American Chemical Society*, **114**, 1992.

Herbes, S.E.; A.V. Palumbo; J.L. Strong-Gunderson; M.F. Tschantz, "Innovative Bioreactor Development for Methanotrophic Biodegradation of Trichloroethylene", Report to The Armstrong Laboratory, Environics Directorate, Tyndall AFB, FL, Project No. EV-14-117-1341-A, 1994.

Tschantz, M.F., "Development of a Fully-Suspended, Multi-Stage Bioreactor System for Trichloroethylene Degradation Based on Soluble Monooxygenase Cometabolism," M.S. Thesis, University of Tennessee, 1994.

Sayler, G.S.; A. Heitzer; J.P. Bowman; M.F. Tschantz; and B.M. Applegate, "Molecular Site Assessment and Process Monitoring in Bioremediation and Natural Attenuation," *Frontiers in Bioprocessing*, Proceedings of the Symposium, Boulder, CO, Humana Press, 1994.

Tschantz, M.F.; J.P. Bowman; T.L. Donaldson; P.R. Bienkowski; J.L. Strong-Gunderson; A.V. Palumbo; S.E. Herbes; and G.S. Sayler, "Methanotrophic TCE Biodegradation in a Multi-Stage Bioreactor," *Environmental Science and Technology*, **29** (8), 1995.

G.S. Sayler; A. Layton; C. Lajoie; J. Bowman; M. Tschantz; and J.T. Fleming. "Molecular Site Assessment and Process Monitoring in Bioremediation and Natural Attenuation." *Appl. Biochem. Biotech.* 54:277-290. 1995.

Tschantz, M.F.; J.P. Bowman; F. Evans; P.R. Bienkowski; T.L. Donaldson; and G.S. Sayler. "Development of a Fully Suspended, Multi-stage Bioreactor System for Trichloroethylene Degradation Based on Soluble Monooxygenase Cometabolism." *Environ. Sci. Health*, A31(1), p. 249-266. 1996.

Tschantz, M.F.; H.M. Haskew; and R.S. Williams, "Activated Carbon and the Control of Evaporative Emissions in Air Induction Systems," American Filtration and Separations Society Diesel and Gas Engine Emission Conference, Ann Arbor, MI, September 29 – October 2, 2003.

PRESENTATIONS

Tschantz, M.F., "Development of a Fully-Suspended, Multi-Stage Bioreactor System for Trichloroethylene Degradation Based on Soluble Monooxygenase Cometabolism," ACS Emerging Technologies in Hazardous Waste Management V, Atlanta, GA, September 27-29, 1993.

Bowman, J.P.; M.F. Tschantz; P.R. Bienkowski; J.M. Strong-Gunderson; A.V. Palumbo; and G.S. Sayler, "Optimization and Performance of a Fully-Suspended, Multi-Stage Bioreactor for Methanotroph-Mediated Trichloroethylene Removal," ASM Annual Meeting, Las Vegas, NV, 1994.

Tschantz, M.F., "Modeling and Performance of a Multi-Stage Bioreactor for TCE Biodegradation," ACS Emerging Technologies in Hazardous Waste Management VI, Atlanta, GA, September 19-21, 1994.

Tschantz, M.F., "Bioremediation and the Use of Methanotrophs for the Biodegradation of Trichloroethylene", Tennessee Society of Professional Engineers, Knoxville, TN, August 29, 1995.

Tschantz, M.F.; P.R. Bienkowski; and G.S. Sayler, "Kinetic Processes Affecting the Performance of sMMO for TCE Degradation by *Methylosinus trichosporium* OB3b," ACS Emerging Technologies in Hazardous Waste Management VII, Atlanta, GA, September 17-20, 1995.

Tschantz, M.F.; P.R. Bienkowski; and G.S. Sayler, "Kinetic Based Model Development for Methanotrophs Utilizing Soluble Methane Monooxygenase for Trichloroethylene Degradation," IGT Symposium on Gas, Oil, and Environmental Biotechnology, Colorado Springs, CO, December 11-13, 1995.

Tschantz, M.F., "Fundamental Description of Adsorption of Gasoline Vapors in AIS Systems onto Activated Carbon," General Motors Corp., May 2001.

Tschantz, M.F., "Effect of Honeycomb Diameter on EAI Emission Control Performance," Mahle-Germany, October 9, 2001.

Tschantz, M.F., "AIS Evaporative Emissions Phase II Update," General Motors Corp., Milford, MI, February 2002.

Tschantz, M.F. and R.S. Williams, "Activated Carbon and EAI Applications," Toyota and Honda Corporations, March 2002.

Tschantz, M.F., "EAI Emissions and Causes," Visteon Corp. and Ford Motor Co., Detroit, MI, June 5, 2002.

Tschantz, M.F., "Description of EAI Emissions Causes and Control," General Motors Corp., Detroit, MI, June 2002.

Tschantz, M.F., "Characterization of Carbon Dusting," Helsa Corp., Germany, July 2, 2002.

Tschantz, M.F., "Development of Novel Materials for EAI Applications," USCAR, Milford, MI, July 22, 2002.

Tschantz, M.F., "Performance Testing of Carbon Liners for Controlling Evaporative Emissions in Air Induction Systems," USCAR Symposium, Milford, MI, October 2002.

Tschantz, M.F., "Air Induction System Evaporative Emissions Control Technologies, "Delphi Corporation, Flint, MI, November 2002.

Tschantz, M.F., "Improved Carbons at Low Purge," Delphi Corporation, Krakow, Poland, May 2002.

Tschantz, M.F. and R.S. Williams, "Air Induction Systems and Evaporative Emissions," Hyundai Motors, Korea, February 2003.

Tschantz, M.F., "Effect of Particle Diameter on Rates of Adsorption," PSA/Renault, February 24, 2003.

Tschantz, M.F., "Evaporative Emissions Control for Air Induction Systems," General Motors Corp., March 25, 2003.

Tschantz, M.F., "SHED Evaluation of AIS Emissions Reduction," General Motors Corp., June, 2003.

Tschantz, M.F., "Small Off-Road Engine Workshop – Evaporative Emission Program," Monitoring and Laboratory Division, California Air Resources Board, Sacramento, CA, July 2, 2003.

Tschantz, M.F.; H.M. Haskew; and R.S. Williams, "Activated Carbon and the Control of Evaporative Emissions in Air Induction Systems," American Filtration and Separations Society Diesel and Gas Engine Emission Conference, Ann Arbor, MI, September 29 – October 2, 2003.

Tschantz, M.F., "Advanced Carbon Solutions for Automobiles," BMW, Germany, November 12, 2003.

Tschantz, M.F., "Treatment of Emissions from Small Off-Road Equipment (SORE)," California Air Resources Board, January 2004.

Tschantz, M.F., "Activated Carbon for Use in Marine Evaporative Control Applications," NMMA Meeting, Miami, FL, January 14, 2004.

Tschantz, M.F.; R.S. Williams, "Evaluation of Activated Carbon and Carbon Canisters for Evaporative Emissions Control," SAE 2004 India Mobility Conference, New Delhi, India, January 16-18, 2004.

Tschantz, M.F., "Control of Small Off-Road Emissions," US EPA, Ann Arbor, MI, July 2004.

Tschantz, M.F., "Activated Carbon for use in Marine Evaporative Control Applications," IBEX Conference, Miami, FL, October 11, 2004.

Tschantz, M.F. and R.S. Williams, "Effect of Purge on Hydrocarbon Emissions from Vehicles," Toyota, Japan, November 2004.

Tschantz, M.F., "Effect of Purge on Carbon Aging," Jaguar Motors, England, January 18, 2005.

Tschantz, M.F., "Adsorption of Gasoline Vapors Using Activated Carbon," California Air Resources Board, Sacramento, CA, October 2005.

Tschantz, M.F., "Summer Test Program Carbon Analysis," IBEX Conference, Miami, FL, October 18, 2005.

Tschantz, M.F., "Novel Form of Carbon for Recovering Acetone in Filter Tow Process," Celanese Corp., Narrows, VA, December 16, 2005.

Tschantz, M.F., "Improved Role of Activated Carbon for Treating Gasoline Emissions," Delphi Corporation, Luxemburg, May 9, 2005.

Tschantz, M.F., "Control of Venting Emissions from Above Ground Storage Tanks and Characterization of Passive Purge," California Air Resources Board, Sacramento, CA, October 17, 2005.

Tschantz, M.F., "Opportunities for Controlling Evaporative Emissions in Northeast States," NESCAUM, Boston, MA, December 6, 2006.

Tschantz, M.F., "Honeycomb Diameter Optimization to Control Bleed Emissions," Toyota, Japan, March 1, 2006.

Tschantz, M.F., "Use of Carbon for Controlling UST Venting Emissions," California Air Resources Board, Sacramento, CA, March 17, 2006.

Tschantz, M.F., "Saturation of Vapors in UST Ullage and Effect on Venting Losses," Chevon, San Francisco, CA, April 25, 2006.

Tschantz, M.F., "Advanced Catalyst Substrate Development and Design," Delphi Corp., Tulsa, OK, June 8, 2006.

Tschantz, M.F., "Design of Spraying System for Controlling UST Vent Losses," Chevron, San Francisco, CA, August 28, 2006.

Tschantz, M.F., "Desiccant Systems Regenerated by Waste Heat," Hussman Corp., Minneapolis, MN, October 3, 2007.

Tschantz, M.F., "Determination of Hydrocarbon Venting Volume from USTs," California Air Resources Board, Sacramento, CA, October 16, 2006.

Tschantz, M.F., "Effect on Gasoline Vaporization Rate by Spraying of Fuel in USTs," BP-Amoco, Brea, CA, July 9, 2007.

Tschantz, M.F., "Activated Carbon and Enhanced Vapor Recovery at Gasoline Dispensing Facilities," South Coast Air Quality Management District Meeting, Diamond Bar, CA, October 10, 2007.

Tschantz, M.F., "Use of Activated Carbon for Enhanced Vapor Recovery," CARB/CAPCOA Joint Meeting, South Lake Tahoe, CA, October 17, 2007.

PATENTS – SUBMISSIONS, APPLICATIONS, AND PENDING

Soper, Hall, Burres, Tschantz, Polymer Film Laminated Activated Carbon Paper, US 60/786,514, Filed Mar. 28, 2002

Tschantz, M.F., Carbon-Containing Shaped Cylinders for Engine Air Induction System Emission Reduction, US 10/621,946, Filed Jul. 15, 2003

Tschantz, M.F., Use of Activated Carbon in Particulate Air Filters to Reduce Evaporative Hydrocarbon Emissions for Small Off-Road Engines, SCD 04-14, Disclosed Apr. 16, 2004

Tschantz, M.F., Thermoplastic Bound Activated Carbon Pellets, SCD 20490, Disclosed Nov. 25, 2005

Clontz, Hiltzik, Leedy, McCrae, Rook, Tschantz, Williams. Activated Carbon Honeycombs for Evaporative Emissions Canisters. SCD 20518. Disclosed Dec. 13, 2005

Tschantz, M.F., Control of Fermentation VOC Exhaust Using Activated Carbon and Activated Carbon Honeycombs. SCD 20550, Disclosed Jan. 31, 2006

Tschantz, M.F., Regenerative Adsorption/Absorption System Using a Liquid Purge Media, Disclosed Mar 2, 2006

Tschantz, M.F., Use of Activated Carbon to Improve the Energy Efficiency for Removing Hydrocarbons from Contaminated Groundwater, SCD 20587, Disclosed Mar. 29, 2006

Tschantz, M.F., Control of Vapor Emissions from Gasoline Stations, SCD 20547-1 Prov/US 60/744,615, Filed Apr. 11, 2006

Tschantz, M.F., Electrically Conductive Adsorptive Honeycomb for Drying of Air, SCD 20609 Prov/US 60/828,694, Filed Oct. 9, 2006

Tschantz, M.F., Compact Check Valve for Spray Nozzle, SCD 20737 Prov/US 60/864,485, Filed Oct. 9, 2006

Tschantz, M.F., Activated Carbon for Odor Control on Food Packages, SCD20589 Prov/US 60/828,801, Filed Oct. 10, 2006

Tschantz, M.F., Voltaically Enhanced Separation of Ionic Species Using Activated Carbon Honeycombs in Liquid Systems, SCD 20819, Disclosed Mar. 6, 2007

ICF INTERNATIONAL

ORGANIZATIONAL CONFLICT OF INTEREST CERTIFICATE

Customer: U.S. Environmental Protection Agency

Contractor: ICF Incorporated, LLC, 9300 Lee Highway, Fairfax, VA 22031

Prime Contract: EP-C-12-011

Subcontractor/Peer Reviewer: MeadWestvaco Corporation

In accordance with EPAAR 1552.209-70 through 1552.209-73, Subcontractor/ Consultant certifies to the best of its knowledge and belief, that:

__X__ No actual or potential conflict of interest exists.

_______ An actual or potential conflict of interest exists. See attached full disclosure.

Subcontractor/Consultant certifies that its personnel, who perform work on this Contract, have been informed of their obligations to report personal and organizational conflict of interest to Contractor and Subcontractor/Consultant recognizes its continuing obligation to identify and report any actual or potential organizational conflicts of interest arising during performance under referenced contract.

[signature]
Subcontractor/Consultant

8/16/2013
Date

REVIEWED AS TO LEGAL FORM
MWV LEGAL
By Alison Bols at 2:58 pm, Aug 15, 2013

Michael Tschantz
Designated Peer Reviewer

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LEELA E. RAO

EDUCATION

DOCTOR of ENVIRONMENTAL SCIENCE, December 2008
University of California, Riverside, CA
Advisor: Edith B. Allen
Thesis: Nitrogen deposition and its effects on the soils, annual vegetation, and fire risk in Southern California deserts.
Areas of Emphasis: Biogeochemistry and ecosystem ecology.

MASTER OF ENVIRONMENTAL MANAGEMENT, May 1999
Nicholas School of the Environment
Duke University, Durham, NC
Master's project: Abundance of seagrass and macroalgae in a Pacific Northwest Estuary.
Concentration: Conservation biology with an emphasis in marine systems.

BACHELOR OF ARTS, *magna cum laude*, May 1997
Scripps College, Claremont, CA
Major: Environmental Studies.
Honors: Phi Beta Kappa, Sigma Xi, Rosalyn Yallow Science Award, departmental honors.

PROFESSIONAL EXPERIENCE

Air Pollution Specialist, Mobile Source Control Division, California Air Resources Board
Primary responsibility is as lead staff on the motor vehicle air conditioning (MAC) efficiency portion of the Advanced Clean Cars regulation. Related duties include working with industry and the federal government to develop a test procedure to measure MAC efficiency, analysis of additional off-cycle technologies such as solar load reduction, and preparing regulatory documents. Other duties include monitoring and assisting with motor vehicle toxics activities, lead staff on fuel fill pipe issues, and assisting with evaporative emission and off-cycle emission testing and regulatory development. Previous duties included lead staff evaluating motor vehicle efficiency gains through use of low friction lubrication oils, support staff for the Cool Cars measure that aimed to reduce MAC usage through advanced glazing, and acting manager (July 2010 through March 2011) supervising staff in developing evaporative emission and Supplemental Federal Test Procedure II regulations for the Advanced Clean Cars regulation. March 2009-Present.

Postdoctoral Researcher, Center for Conservation Biology, University of California Riverside
Determined the change in fire risk across creosotebush scrub and piñon-juniper woodlands in Joshua Tree National Park based on variations in nitrogen deposition and precipitation. Fire risk was determined by modeling annual biomass production with the biogeochemical process model, DayCent, under increasing nitrogen deposition and precipitation regimes and across multiple soil types. September 2008-March 2009.

Environmental Protection Specialist, National Center for Environmental Assessment, US EPA
Assisted a team in designing a causal analysis decision support tool to aid investigators in diagnosing the causes of impairments in aquatic systems. Specific duties included coordinating an EPA/State workshop for design conceptualization, co-authoring a system design strategy, and developing a prototype for training and user needs assessment. Other projects included evaluating and proposing changes to the Wildlife Contaminant Exposure Model, and gathering information for the preparation of a report to synthesize toxicodynamic and toxicokinetic data for methylmercury in avian species. September 2001 – September 2003.

Environmental Protection Specialist, Office of Research and Development, US EPA
Participated in a series of developmental assignments both within and outside of the Office of Research and Development (ORD) as a participant in the EPA Intern Program. Projects included research for and writing of a USEPA document on the development of a Terrestrial Index of Ecological Integrity by working on the section on initial indicator development; creation of a web database to catalog journal articles on effects of contaminants on fish-eating birds; and assisting with the "Assessment of Cruise Ship Wastewater Discharges" by participating in working group meetings, preparing testimony for the Deputy Division Director, updating the cruise ship web site, and developing report recommendations. September 1999 – September 2001.

Physical Science Research Assistant, ORD Coastal Ecology Branch, US EPA, Newport, OR
Assisted in groundtruthing of Yaquina Bay Estuary for remote sensing of seagrasses and algae. Analyzed water samples for presence of silica using spectrophotometric techniques. Analyzed continuous sampling data to determine relationships between irradiance and depth, and total suspended solids and turbidity. Summer 1998.

OTHER EXPERIENCE

Teaching Assistant, University of California, Riverside
Developed discussion section curricula, led discussion sections, and graded assignments and exams for ENSC 001, Intro. to Environmental Science: Natural Resources. Gave one lecture on fossil fuels in 2007. Dr. Brian Lanoil (Professor) Fall 2007 & 2005; Dr. William Jury (Professor) Fall 2004.

Graduate Student Research Assistant, Duke University, North Carolina
Inventoried and maintained marine invertebrate and fish specimens as a Marine Science Museum aide, at the Natural History Resource Center in Beaufort, NC. Monitored flow meters, changed filters, cleaned tanks and assisted with experiments as a fish caretaker in the ecotoxicology laboratory. Fall 1997-Spring 1998.

Biomechanics Research, Claremont Colleges Joint Science Center, Claremont, CA
Determined effects of brooding on the centers of gravity and buoyancy of Caridean shrimp as a Keck Fellowship recipient. Developed protocol for measurement of the centers of gravity and buoyancy using video imaging downloaded into a Macintosh computer for graphical analysis. Summer 1995.

ADDITIONAL EDUCATIONAL EXPERIENCE

Society of Automotive Engineers Coursework
Fundamentals of Modern Vehicle Transmissions e-Seminar, 11/01/2012 (1.50 CEU)
The Basics of Internal Combustion Engines e-Seminar, 07/01/2012 (1.00 CEU)
Turbocharging for Fuel Economy and Emissions Webinar, 05/30/2012 (0.40 CEU)
Diesel Engine Technology, 02/10/2010 (1.3 CEU)
ARB Leadership Development Training Series, completed 05/10/2011

GRANTS, FELLOWSHIPS, AND HONORS

Hilda and George Liebig Environmental Sciences Summer Fellowship – 2007 ($3,500)
Community Foundation of Riverside and San Bernardino Counties Grant – 2007 ($3,970)
Canon National Parks Science Scholars Program 2006 Honorable Mention
U.C. Riverside Graduate Dean's Dissertation Research Grant – Winter 2006 ($999)
U.C. Riverside Dean's Fellowship – 2003 ($29,665)

JOURNAL and BOOK PUBLICATIONS

Rao, L.E., J.R. Matchett, M.L. Brooks, R.F. Johnson, R.A. Minnich, E.B. Allen. *In prep.* Relationships between annual plant productivity and fire size in low elevation California desert scrub. *International Journal of Wildland Fire.*

De Vita, J., J. Wagner, S. Wall, and L.E. Rao. 2012. Determining the frequency of asbestos use in automotive brakes from a fleet of on-road California vehicles. *Environmental Science and Technology*, 46(3): 1344-1351.

Rao, L.E., R.J. Steers, and E.B. Allen. 2011. Effects of natural and anthropogenic gradients on native and exotic winter annuals in a southern California desert. *Plant Ecology*, doi: 10.1007/s11258-010-9888-5.

Rao, L.E. and E.B. Allen. 2010. Combined effects of precipitation and nitrogen deposition on native and invasive winter annual production in California deserts. *Oecologia*, 162: 1035-1046.

Rao, L.E., E.B. Allen, and T. Meixner. 2010. Risk-based determination of critical nitrogen deposition loads for fire spread in southern California deserts. *Ecological Applications,* 20(5): 1320-1335.

Fenn, M.E., E.B. Allen, S.B. Weiss, S. Jovan, L.H. Geiser, G.S. Tonnesen, R.F. Johnson, L.E. Rao, B.S. Gimeno, F. Yuan, T. Meixner, A. Bytnerowicz. 2010. Nitrogen critical loads and management alternatives for N-impacted ecosystems in California. *Journal of Environmental Management*, 91 (12): 2404-2423.

Rao, L.E., D.R. Parker, A. Bytnerowicz, and E.B. Allen. 2009. Nitrogen mineralization across an atmospheric nitrogen deposition gradient in Southern California deserts. *Journal of Arid Environments,* 73(10): 920-930.

Allen, E.B., L.E. Rao, R.J. Steers, A. Bytnerowicz, and M.E. Fenn. 2009. Impacts of atmospheric nitrogen deposition on Mojave Desert vegetation and soils. *in* R.H. Webb, L.F. Fenstermaker, J.S. Heaton, D.L. Hughson, E.V. McDonald, and D.M. Miller eds. University of Arizona Press, Tucson.

Allen, E.B., P.J. Temple, A. Bytnerowicz, M. J. Arbaugh, A. G. Sirulnik and L.E. Rao. 2007. Patterns of understory biodiversity in mixed coniferous forests of southern California impacted by air pollution. In: A. Bytnerowicz, M. Arbaugh, M. Fenn, N. Grulke, and R. Heath, editors. Proceedings "Impacts of Air Pollution and climate Change on Forest Ecosystems." *TheScientificWorldJOURNAL,* 7(S1): 247-263.

Norton, S.B., L. Rao, G. Suter, S.M. Cormier. 2003. Minimizing cognitive errors in site-specific causal assessments. *Human and Ecological Risk Assessment*, 9(1):213-229.

GOVERNMENT PUBLICATIONS

U.S. EPA. (2002) Summary report for the workshop on the Causal Analysis/Diagnosis Decision Information System (CADDIS). National Center for Environmental Assessment (NCEA), Washington, DC; EPA/600/02/078. (Rao: co-author and project officer).

U.S. EPA. (2002) Waquoit Bay watershed ecological risk assessment. National Center for Environmental Assessment, Washington, DC; EPA/600/R/02/079. (Rao: 5th author)

SELECTED POSTERS AND PRESENTATIONS

Rao, L.E. Technologies for Reducing MAC Indirect Emissions: From AB 1493 Credits to a LEV III Standard. Presented at the Society for Automotive Engineers Mobile Air Conditioning System Efficiency Workshop, Scottsdale, AZ , July 14, 2010.

Zhan, T., L.E. Rao, D. Shimer, S. Lemieux, and T. Huai. Update on California's Regulatory Efforts to Reduce Greenhouse Gas Emissions from Mobile Air Conditioning (MAC). Presented at the Society of Automotive Engineers Automotive Refrigerant and System Efficiency Symposium, Scottsdale, AZ, July 13, 2010.

Rao, L.E., and E.B. Allen. Production of two exotic grasses and one desert native annual under altered precipitation and nitrogen regimes: implications for fire in the desert. Presented at the Ecological Society of America Conference, San Jose, CA, August 6, 2007.

Rao, L.E., D.R. Parker, A. Bytnerowicz, and E.B. Allen. Nitrogen mineralization across an atmospheric nitrogen deposition gradient in Southern California deserts. Presented at Soil Ecology Society Conference, Moab, UT, May 2, 2007.

Rao, L.E., E.B. Allen, R.J. Steers, A. Bytnerowicz, and M.E. Fenn. Impacts of atmospheric nitrogen deposition on Mojave Desert vegetation and soils. Presented at Coachella Valley Association of Governments Biological Monitoring Workshop, Palm Desert, CA, April 6, 2005.

ORGANIZATIONAL CONFLICT OF INTEREST CERTIFICATE

Customer: U.S. Environmental Protection Agency

Contractor: ICF Incorporated, LLC, 9300 Lee Highway, Fairfax, VA 22031

Prime Contract: EP-C-12-011

Subcontractor/Peer Reviewer: Leela Rao

In accordance with EPAAR 1552.209-70 through 1552.209-73, Subcontractor/ Consultant certifies to the best of its knowledge and belief, that:

__X__ No actual or potential conflict of interest exists.

______ An actual or potential conflict of interest exists. See attached full disclosure.

Subcontractor/Consultant certifies that its personnel, who perform work on this Contract, have been informed of their obligations to report personal and organizational conflict of interest to Contractor and Subcontractor/Consultant recognizes its continuing obligation to identify and report any actual or potential organizational conflicts of interest arising during performance under referenced contract.

____
Subcontractor/Consultant

08-13-13
____
Date

9300 Lee Highway — Fairfax, VA 22031-1207 — 703.934.3000 — 703.934.3740 fax — icfi.com

RESUME

Eur.Ing. **Stephen J. Stewart** PhD., MSc., BSc., P.Eng., CEng., MRAeS.

36328 Carrington Lane, Abbotsford, British Columbia V3G 2M7 --- tel 604 556 8260 --- email stejste@shaw.ca

SUMMARY

Dr. Stewart studied Aeronautical Engineering at the University of Bristol, then worked as an Airframe Systems Engineer for British Aerospace. He completed graduate work at the University of Manchester; in Mechanical Engineering for MSc, and Computer Graphics and Flight Simulation for PhD. After teaching Thermodynamics and Fluid Mechanics at Salford for seven years he moved to Canada, and has since specialised in vehicle emissions and their control. He has extensive experience in motor vehicle emission related air quality issues and in the design, operation and evaluation of Inspection and Maintenance programs as well as other emission control initiatives.

He has completed many projects for the British Columbia inspection and maintenance program as well as for the Ontario Ministry of Environment, and for Environment Canada. In 2004 he travelled to Urumqi, P.R.China to help develop the air quality monitoring, motor vehicle emission control and air quality improvement project funded by the World Bank. He is an Honorary Research Associate in the Department of Statistics at the University of British Columbia.

Dr. Stewart is a private pilot and Past-President of the Abbotsford Flying Club, as well as a Treasurer of the Abbotsford International Airshow Society. He is the Canadian representative on the Environment Committee of the Guild of Air Pilots and Air Navigators and a member of the North American Section Board.

EMPLOYMENT HISTORY

Operations Manager, BC AirCare Program 2012 to present
President, SBA Consulting, 1998 to present
Senior Project Engineer, BC AirCare Program Oct 1994 to 2011
Manager of Emission Testing and Standards (Acting), BC AirCare Program Aug 1998 to Dec 1998
Emissions Testing Specialist, BC AirCare Program Apr 1993 - Sep 1994
Honorary Research Associate, UBC Department of Statistics Sep 2000 to present
Instructor, BCIT School of Transportation Apr 1998 to Jun 2003
Instructor, Columbia College, Burnaby, BC Jan 1993 - Apr 1993, 1994 and 1996
Continuing Education Instructor, University College of the Fraser Valley Jan 1995 - Mar 1995
Substitute Teacher, Abbotsford School District (#34), BC Oct 1992 - Mar 1993
Consultant to Monodraught Ltd., High Wycombe, England 1988 to 2007
Senior Lecturer, University College Salford, School of Engineering, Salford, England Jan 1986 - Aug 1992
Airframe Systems Engineer, British Aerospace, Woodford, England Aug 1978 – Aug 1982

EDUCATION

PhD. Flight Simulation, University of Manchester Oct 1983 - Dec 1985
MSc. Mechanical Engineering, University of Manchester Oct 1982 - Oct 1983
BSc.(Hons) Aeronautical Engineering, University of Bristol Oct 1975 - Jun 1978

OTHER TRAINING

- **Robotics** levels I and II UK Regional Staff Development Prog June 1987
- **Computer Integrated Manufacture** levels III and IV UK Regional Staff Development Prog June 1987
- **German** language course G10: Elementary, Goethe Institut Manchester, UK 1991 to 1992
- **Teaching Adults** levels I and II School District 43 BC Continuing Education Certificate, , September 1993
- **Transportation of Dangerous Goods** – Road Mode Certification , from 1996
- **Private Pilot** Licence (# 793974) Transport Canada, April 2002; Night Rating 2004; Float Rating 2009
- **Project Management** short course, Simon Fraser University, October 2002
- **Managing Building Projects**, APEGBC Professional Development Seminar, June 2004
- **Visual Smoke Assessment,** EPA Method 9 Initial Certification, November 2004
- **Macro Programming** SAS Institute, May 2005
- **Transportation Land Use Impacts** APEGBC Professional Development Seminar, June 2006
- **Expert Witness** APEGBC Professional Development Seminar, February 2008
- **Opportunities for Engineers in GHG Trading** APEGBC Professional Development Seminar Feb 2010

AFFILIATIONS

- **Royal Aeronautical Society** Member 1987
- **Chartered Engineer** UK, 1989
- **European Engineer** FEANNI, 1992
- **Professional Engineer** APEG British Columbia, 1995, Division of Environmental Professionals 2008
- **Society of Automotive Engineers** Member, 1993, BC Section Board, 1995-2005; Chair 1998-99
- **Western Canada Group of Chartered Engineers**, 2003
- **Abbotsford Flying Club**, 2004, President 2008-2012
- **Abbotsford International Airshow Society**, Director 2008-2011, Treasurer 2011-2013
- **Guild of Air Pilots and Air Navigators** Freeman, 2010, Director North America Section 2010-present
- **BC Scrap-it Program Society,** Director 2005-present

PROJECT EXPERIENCE

Automotive Emissions Testing and Repairs

Light-duty gasoline vehicles

- SS reviewed and developed ASM and idle test standards for the BC AirCare program starting in 1995. The final version was created in 2000, and is still used for 1991 and older vehicles. These standards are a function of vehicle weight for ASM tests, and of engine size for idle tests, as well as accounting for vehicle model year. Also implemented in 2000 was reporting of average passing readings which give motorists an indication of what is normal for their vehicle. These readings were implemented for IM240 as well as for ASM and idle.
- In 1996 SS created a system for evaluating every individual repair reported to BC AirCare administration by the certified repair industry. It took account of the emission reduction achieved, how bad the initial failure was, and how good was the final result, as well as what repair actions were taken. This was implemented in September 1996 for ASM and idle tests and was used to determine technicians eligibility for automatic re-certification. This was probably the first time anywhere in NA that repair technicians had been continually assessed on all of their eligible repair work by an independent organisation. SS expanded the methodology for IM240 tests in 2000 and for OBD tests in 2007.
- In 1998 to 1999 SS ran two projects to test gas caps on in-use vehicles in BC. In the first project the gas caps of vehicles undergoing regular inspection were tested in order to assess the incidence of leaking caps on in-use vehicles. This project provided new caps for all vehicles that showed any leakage, and the old caps were retained for the second project. The second project measured mass flow leakage rates as a function of pressure differential, using a custom-built system.
- From 2002 to 2008 SS ran a series of projects to establish the efficacy of subsidizing emission repairs that would otherwise not be performed because of repair cost limits. The projects achieved emission reductions by providing repair subsidies for light-duty vehicles that had failed emission inspections, and which would otherwise receive a Cost Waiver. Administration of the program required accurate assessment of individual potential benefits from diagnostic information, and the specification of appropriate repairs. With these controls in place it is a cost-effective policy.
- Working with faculty and graduate researchers in UBC Dept of Statistics during 1999 to 2001, SS developed a knowledge-based expert system that can assist repair mechanics in selecting the repair actions that are most likely to reduce a vehicle's emissions to below allowable I/M maxima. The expert system is based on inspection and repair data collected by the British Columbia AirCare I/M program. The system is an observational model based on what was done, and appeared to work, in real reported cases. It does not use the type of rules-based approach which could be developed from a failure modes and effects analysis. Its most efficacious implementation is as part of an overall package which also includes this other type of information. Access to is via a www interface, and allows its responses to incoming queries to be generated from the most up-to-date data available.
- From 2003 to 2005 SS developed a method to report CO2 emission rate and fuel consumption from IM240 tests. The difficulty is that existing IM programs do not all use a standardized test duration or test method and only a mass-emissions test, driven over a specific cycle can be considered. The calculation of fuel consumption from

the quantities recorded in a complete IM240 test is a simple function of the masses of CO2, CO and HC, the carbon weight fraction of the fuel, and the distance driven. A problem arises when trying to compare results from tests which have fast-passed and have been terminated at different times, because the rate of fuel consumption is not constant through a test. So when a test terminates early the actual measured rate of fuel consumption could be much less than, or much more than the rate that would be achieved if the test had gone to full duration. This project developed methods to project full-duration fuel consumption from tests which actually fast-passed.

- In 2006 and 2007 SS led a multi-stakeholder team to develop the communications strategy and formats for reporting CO2 emission rate and fuel consumption for every vehicle tested by the BC AirCare program. The result was successfully implemented in June 2007

- From 2007 onwards SS has organised and run vehicle emissions clinics at various locations in BC, YT and AB in response to requests by local air quality organizations. These clinics introduce motorists to the need for proper emissions maintenance and repair, as well as establishing a picture of the in-use emissions performance of vehicles in non-IM areas.

- In 2003 SS developed a method that used total exhaust carbon to identify IM240 test problems where exhaust was being lost from the sampling system. This enabled invalid tests to be identified and aborted when they reached 30 seconds into the test cycle. The method was implemented for all IM240 tests in BC in 2004. It saved operational time and avoided many errors of omission.

- In 2003 and 2004 SS assisted in developing the Motor Vehicle Emissions Control Strategy for the Urumqi Urban Transportation Improvement Project in Xinjiang Autonomous Region, China. This work was sponsored by the World Bank and undertaken in partnership with DLEX Corporation. Two weeks of training were provided to staff from the Environmental Protection Department, the City bus company, and the Traffic Police. This covered a complete summary of the technologies used to control vehicle emissions; a review of the strategies that can be adopted by a city or other jurisdiction to control vehicle emissions. The existing Motor Vehicle Emissions Control Strategy was reviewed. In depth discussions covered what improvements could be made, and what new strategies are suitable for use in Urumqi. From this we developed a new and improved MVECS which includes an Inspection and Maintenance program, on-road enforcement, old vehicle retirement, parking and access controls, alternative fuel conversion, diesel retro-fit upgrades, and creation of a Motor Vehicle Pollution Control Centre. The Urumqi Urban Transportation Improvement Project environmental requirements include establishing networks for ambient air quality monitoring and ambient noise monitoring, as well as the MVECS. The third aspect of the project was to develop detailed specifications for the equipment required for ambient air quality monitoring; ambient noise monitoring; and the vehicle emissions inspection program.

- SS led two projects to study Repair Cost Limits, Repair Effectiveness, and the Potential for Increased Program Benefits for the Ontario Ministry of Environment Drive Clean Office in 2001 and in 2003. These projects included detailed surveys of the cost of vehicle repair work in 5 US states and 2 Canadian provinces. They included pricing strategies, hourly labour rates, parts prices and the regulatory constraints within which repairs are performed. The survey analyses were combined with inspection and repair data to synthesise a model of the overall fleet repair costs, and to project the effects of various regulatory and administrative options on what repairs would be performed, what they would cost, and how effective they would be.

- From July 2006 to March 2009 SBA produced 7 issues of a technical newsletter for the Ontario Drive Clean Program Repair Industry. The newsletter was aimed at improving the technical knowledge and diagnostic and repair abilities of the repair technicians, inspectors and service writers employed at Drive Clean Facilities. Two copies of each issue were distributed to each of almost 2000 DCFs. SBA also created, and maintained, a website which DCF personnel could access to download the newsletter, find out about training opportunities, complete a prize quiz, and follow links to other sources of relevant inspection, diagnostic and repair information.

Light-duty diesels

- In 1999 SS created a new transient light-duty diesel test that was implemented by the BC AirCare program in 2000. The test used the second phase of the IM240 driving cycle and looked for peaks in exhaust opacity. It was subsequently adopted by KOTSA for all diesel vehicle inspections in South Korea as a replacement for their lug-down test

Heavy-duty diesels

- In 1996 SS was part of the team that launched the BC on-road heavy-duty diesel inspection program. This was the first program anywhere to use the SAE J1667 test. This project included everything from specifying, purchasing and commissioning equipment, to policy making, establishing a network of independent repair facilities, industry communication and liaison, and regular analysis of inspection data after implementation.
- In 2010 SS was a member of the industry advisory working group for Metro Vancouver's development of regulations for off-road heavy-duty diesels. These are primarily construction equipment.
- From 2012 SS has been a member of the Diesel Vehicle Sub-Committee, which was formed as a multi-stakeholder response to the BC Environment Minister's declared interest in shifting the focus of in-use vehicle emissions control towards diesel trucks.

Analysis of Vehicle Population and Use Data

- In 1996 SS developed a method for assessing in-use annual kilometres travelled from odometer readings recorded during annual inspections, and which tracked the readings of individual vehicles. Previous estimates were limited by database considerations to comparing average values from different calendar years and vehicle model years. SS has used this method for all subsequent vehicle annual kilometre estimates.
- Starting in 2002 and continuing into 2012 SBA has undertaken a series of analyses for Environment Canada Pollution Data Branch to define a detailed fleet profile, by GVWR, by fuel type, by model year, for all the vehicles in Canada, separated by jurisdiction and down to the level of FSA. The projects have drawn on various available data sources, including provincial registration files, Drive Clean data, AirCare/ACOR data, and Polk and DesRosiers summary data. From these data sources, the vehicle fleet can be defined by province/territory, by Gross Vehicle Weight Rating (GVWR), by fuel type, by model year, by postal code, at quarterly intervals from 1980 on.
- As an adjunct to the above work for Environment Canada, SBA has used ON Drive Clean data and BC AirCare data to monitor annual kilometre accumulation rates for both light-duty and heavy-duty vehicles. When combined with vehicle counts from the fleet profiles the result is a collection of estimates of vehicle kilometres

travelled by vehicle type, age and calendar year. Comparison of light-duty results from ON and BC shows a different typical pattern of annual kilometres as vehicles age.

- In 2000, working with GWT Consulting, SS created an on-board system to log in-use driving behaviour. The purpose of this study was twofold: to create a driving trace representative of typical commuter driving; and to develop better estimation techniques for cold-transient fuel use and emissions. Study data was collected from a combination of rental and volunteer vehicles. Collected data comprised vehicle position, elevation, speed and heading information from an on-board Global Positioning System (GPS); and a list of vehicle parameters extracted from the vehicle data-stream via the On-Board Diagnostics (OBDII) connection. This project highlighted the amount of 'off-cycle' operation that is included in normal driving, and its contribution to overall emissions, with specific emphasis on cold-start fuel consumption.

Reporting Emission Reductions

- Since 1995 SS has performed biennial analyses of the emission reductions achieved by the BC AirCare program. The first evaluation in 1994 was by dKC and subsequent evaluations built on and expanded this initial work. The particular feature of the approach is the use of in-program data which includes very robust datasets of mass emission data that define the emission performance of vehicles that pass and fail the IM tests and those that are repaired. The approach and the biennial reports were heavily referenced (although anonomously because they were not a US source) by Eastern Research Group in their report to the US congressional committee on IM program effectiveness reporting in 2004.
- Each year since 1999 SS has performed emissions reduction evaluations of the Light-Duty Component of Drive Clean Vehicle Emissions Inspection and Maintenance Program. Sub-sections of this work involve data analysis covering different aspects of the Drive Clean program. There are almost 7 million vehicles registered in Ontario, and each year approximately 3 million inspections are performed. We have analysed and modeled failure rates, effects of program policies, fleet characteristics, repair effectiveness, and program benefits. The emission reduction estimates use mass emission factors derived from BC datasets.
- In conjunction with GWT Consulting from 2001 to 2011, and with dKC since 2012, SS has undertaken analyses of Dive Clean heavy-duty diesel test data for input to the malperformance model. The vehicle counts and SAE J1667 opacity reading frequency distributions define the probable occurrence of different types of malperformance, and these are then related to PM and other emission rates, with the overall result being an evaluation of the emission reductions attributable to the heavy-duty inspection program.
- In 2005 SBA did an evaluation of the suitability of NOx reductions from motor vehicle emission reduction projects for use under Ontario Regulation 397/01 which is an emissions offset regulation. The overall context was Ontario regulation 397/01 which governs annual limits for nitric oxide and sulphur dioxide emissions from the electricity generating sector. To satisfy the requirements of these limits a power producer must submit Emission Reduction Credits (ERC) which match actual annual emissions tonne for tonne. The ERCs are derived from reduction projects undertaken by non-regulated facilities and proponents. The purpose of this project was to review the potential for NOx emission reductions from transportation sources through programs that address human behaviour.
- In 2004, for Environment Canada, SS developed a detailed method for assessing and reporting the emission reductions achieved from old vehicle retirement programs. The need for this project was identified from the

different methods being used by the various retirement programs in Canada. A standard method was required that used emission factors which take into account the type of vehicle being retired, its age, and condition; the annual kilometres travelled for scrapped vehicles, and their expected remaining life; and information on the selected replacement travel options For each vehicle retired the benefit is calculated, then aggregated to derive the total program benefit. Implementation is using an interactive, software application which was created as part of the project.

- SS has been on the Board of the BC Scrap-it Program since its inception in 1996. In 2008 it received a major injection of funds from the provincial government together with the mandate to achieve CO2 emission reductions. SS created the process whereby each transaction was evaluated in terms of the scrapped vehicle and its replacement travel option and the resultant benefit in fuel use and CO2 reduction. This benefit determined the value of the incentive provided.
- In 2010 SS led a project for Retire-Your-Ride (the Canadian national vehicle retirement program) to test the emissions of a 150 scrapped vehicles and compare with the emissions from a range of new vehicles that were typical of those being chosen as replacements. This project included PM measurements as well as HC, CO, NOx and CO2, and confirmed that the claims made for the benefits of vehicle retirement as an emissions reduction approach were more than reasonable.

Other Vehicle Emission Reduction Projects

- SS did significant work with the BC alternative fuel conversion industry throughout the 1990s, after uncovering the major problems conversions were experiencing in the inspection program. This included writing the BC Alternative Fuel Conversion Policy; a series of projects to establish the causes of poor emissions performance and how it could be remedied; and ongoing comparison testing for various public fleets. This led to some innovative work in conjunction with the Workers Compensation Board of BC and with UBC Environmental Health on remediating problems with indoor equipment such as forklifts and ice-resurfacers.
- For the Vancouver Airport Authority, in 2005 SS created a simple method to determine which taxis qualified for licensing incentives based on their environmental performance.

PUBLICATIONS

Society of Automotive Engineers Technical Papers

1. "British Columbia Vehicle Emissions Inspection and Maintenance Program Experience of Alternative Fuel Vehicle Conversions" S.J.Stewart, D.I.Gourley, S. Loo SAE 941913
2. "The Certification and Monitoring of Technicians and Repair Centres in British Columbia's Aircare Program" S. Loo, S.J.Stewart, D.I.Gourley, SAE 950483
3. "An Evaluation of the Effectiveness of Repairs in British Columbia's AirCare Program" S.J.Stewart, S.Loo , D.I.Gourley SAE 950482
4. "Correcting Emissions Problems in Existing Propane and Natural Gas Vehicles in British Columbia" S.J.Stewart, D.I.Gourley, S. Loo SAE 952380
5. "Repair Effectiveness Indices for the British Columbia Vehicle Emissions and Maintenance Program" S.J.Stewart, S.Loo SAE 961700

6. "Study of In-Use Alternative Fuel Vehicle Emission Performance under EPA and BC AirCare Test Cycles" A.Inglis, C.Prakash, S.J.Stewart SAE 961709
7. "The Development of Advanced Technician Training to Meet the Demands of Enhanced Vehicle Emissions Inspection and Maintenance Program Implementation' D.Horrobin, R.MacGregor, T.Wood, R.Plett, J.Marchant, S.Loo, S.J.Stewart SAE 961701
8. "A Study of Mileage Accumulation Rates of Light-Duty vehicles in the Lower Fraser Valley" S.J.Stewart SAE 961702
9. "Quantification of Evaporative Emissions from Defective Fuel Filler Caps" S.J.Stewart, J.Wong, L.Jang, C.Hui, D.Meggy. SAE 2000-01-1171
10. "Cold Start Impact on Vehicle Energy Use" G.W.R.Taylor, S.J. Stewart SAE 2001-01-0221
11. "Emissions Performance of In-Use Alternative Fuel Vehicles" J.Wong, D.Gourley, S.J.Stewart, SAE 2001-01-3678

Conference Presentations

1. "The 2+2 BEng/HND course in computer aided manufacturing engineering at Salford College of Technology and the University of Salford" S.J.Stewart, 3rd Int. Conf. on the Freshman Year Experience, Cambridge England July 1988
2. "Combustion Emissions: measures for and against" S.J.Stewart, Ann. Conf. of Inst. of Domestic Heating and Environmental Engineers. London England May 1991
3. "Converting non-science A-level students into manufacturing engineers" S.J.Stewart, R.Rigby & J.Sharp. Int. Conf. on Engineering Education, Portsmouth England Sept 1992
4. "AirCare, the British Columbia In-Use Vehicle Inspection and Maintenance Program" S.J.Stewart, First North American Conference Emerging Clean Air Technologies And Business Opportunities, Toronto, September 1994
5. "Inspection and Maintenance of Natural Gas Vehicles in British Columbia" S.J.Stewart, 5th Biennial IANGV International Conference and Exhibition on Natural Gas Vehicles. Kuala Lumpur, Malaysia Sept-Oct 1996
6. "Exhaust Emissions from Indoor Vehicles and Small Utility Engines" S.J.Stewart AIHA BC-Yukon Section Annual Meeting Richmond. March 26, 1997
7. "Leaking Gas Caps on Light-Duty Vehicles in the Lower Fraser Valley" S.J.Stewart, L.Jang AWMA PNWIS '97 Annual Conference, Vancouver November 1997
8. "Initial Experience with a Heavy Vehicle Smoke Prevention Program in the Lower Fraser Valley of British Columbia" J.Newhook, D.Gourley, S.J.Stewart AWMA PNWIS '97 Annual Conference, Vancouver November 1997
9. "GVRD 1995 Mobile Source Emission Inventory" C.G.Voigt, S.J.Stewart, C.Lim, K.Krajczar, S.Sidi AWMA PNWIS '97 Annual Conference, Vancouver November 1997
10. "Cost, Effectiveness and Longevity of Vehicle Emission Repairs" S.J.Stewart, S.Loo AWMA PNWIS '97 Annual Conference, Vancouver November 1997
11. "AirCare: Vehicle Emission Inspection and Air Quality Management" Asia Institute of Technology, Bangkok, short course. June 22nd, 2000
    "Motorcycle Emissions, the Real Story" S.J.Stewart First Canadian Conference on Motorcycling. Kamloops, B.C. August 2000
12. "Controlling CO from Powered Industrial Trucks" S.J.Stewart. NorthWest Occupational Health Conference, American Industrial Hygienists Association. Bellingham Washington October 2000
13. "British Columbia AirCare IM Program" S.J.Stewart 11th CRC On-Road Vehicle Emissions Workshop, San Diego. March 2001
14. "Full-Duration IM240 Results For Pre-1981 Vehicles" Stephen Stewart and Jimmy Wong 12th CRC On-Road Vehicle Emissions Workshop, San Diego. April 2002
15. "Two British Columbia Inspection Innovations: New IM240 Fast-Pass Standards, and D147 – A New Transient Inspection Procedure For Light-Duty Diesels" Stephen Stewart, Jimmy Wong and Dave Gourley 12th CRC On-Road Vehicle Emissions Workshop, San Diego. April 2002

16. "AirCare; British Columbia In-Use Vehicle Emissions Inspection and Maintenance Program" Canada-China Experience Sharing Workshop on Regional AirShed Management, Shenzhen, China September 2003
17. "The Effect of Emission Repairs on Fuel Consumption and CO_2 Emissions" Stephen Stewart, Jimmy Wong 14th CRC On-Road Vehicle Emissions Workshop, San Diego. April 2004
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ICF INTERNATIONAL

ORGANIZATIONAL CONFLICT OF INTEREST CERTIFICATE

Customer: U.S. Environmental Protection Agency

Contractor: ICF Incorporated, LLC, 9300 Lee Highway, Fairfax, VA 22031

Prime Contract: EP-C-12-011

Subcontractor/Peer Reviewer: Stephen J. Stewart

In accordance with EPAAR 1552.209-70 through 1552.209-73, Subcontractor/ Consultant certifies to the best of its knowledge and belief, that:

__√__ No actual or potential conflict of interest exists.

______ An actual or potential conflict of interest exists. See attached full disclosure.

Subcontractor/Consultant certifies that its personnel, who perform work on this Contract, have been informed of their obligations to report personal and organizational conflict of interest to Contractor and Subcontractor/Consultant recognizes its continuing obligation to identify and report any actual or potential organizational conflicts of interest arising during performance under referenced contract.

[signature]

Subcontractor/Consultant

August 19th 2013

Date

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Appendix B. Charge Letter

Peer Reviewer Charge

<u>Charge to the Peer Reviewers of "Estimated Summer Hot Soak Distributions for Denver's Ken Caryl IM Station Fleet"</u>

Gasoline vehicles are equipped with evaporative emissions control systems that control vapor from the fuel storage system while a vehicle is sitting or driving. When these systems or the vehicle's gasoline delivery system malfunction, excessive evaporative emissions can be emitted. Few estimates of the frequency of vehicles with evaporative emissions malfunctions, or leaks, in the fleet exist. These vehicles can have a significant impact on the hydrocarbon (HC) emissions inventory.

The Coordinating Research Council - Real World Group through its E-77 and E-77-2 permeation evaporative emission testing programs has confirmed that leaks, both liquid and vapor, can be a significant part of any fleet HC inventory. EPA partnered with the Colorado Department of Public Health and Environment (CDPHE) in 2008 to collect data at the Lipan I/M Station in Denver, Colorado as a pilot test program for recruiting higher evaporative emission vehicles and testing them in large volumes in a portable SHED (PSHED) which was temporarily set up at the I/M station. The following summer the CDPHE collected more data at the Ken Caryl I/M station in Denver using lessons learned from the pilot study. Through the CRADA relationship with the CDPHE, EPA acquired the data for analysis by their contractor, Eastern Research Group (ERG). EPA's primary goal of the Ken Caryl project was to estimate distributions of hot-soak emission levels for gasoline-fueled light-duty vehicles and light duty trucks, using a quick and inexpensive procedure to conduct a survey of an in-use fleet. Innovative strategies were used to measure evaporative emissions data on 175 vehicles representative of the fleet entering Ken Caryl station. The report details the sampling protocol utilizing a screening system to recruit higher percentages in the higher evaporative emissions range and also a field measurement methodology with a PSHED to assess hot soak emissions from these vehicles.

This report has been revised from its original form and title, *Estimates of the Fraction of the Fleet with High Evaporative Emissions based on the Ken Caryl Station (Denver, Colorado) Field Study*, which was sent out for peer review in late 2011. The comments were so extensive as to require a complete reworking of the premises and analysis, including extensive report revisions. With the new title and analysis, it has been deemed appropriate for another round of peer review.

In their comments, reviewers should distinguish between recommendations for clearly defined improvements that can be readily made based on data or literature reasonably available to EPA and improvements that are more exploratory or dependent on information not readily available to EPA. Your written comments should address all aspects of the report (methodologies, analysis, conclusions, and narrative) and should be sufficiently clear and detailed to allow readers to thoroughly understand their relevance to the subject report. Further, each peer reviewer should address whether appropriate conclusions and implications can be drawn from the analysis and the available data.

All materials provided to the reviewers, as well as their comments, should be treated as confidential and should neither be released nor discussed with others outside of the group of reviewers. The Agency requests that the reviewers not release the peer review materials or their comments to anyone else until EPA makes its report and supporting documentation public.

If the reviewer has questions about what is required in order to complete this review or needs additional background material, please contact Lou Browning at ICF International (Louis.Browning@icfi.com or 831-662-3683). If the reviewer has any questions about the EPA peer review process itself, please contact Ms. Ruth Schenk in EPA's Quality Office, National Vehicle and Fuel Emissions Laboratory (schenk.ruth@epa.gov or 734-214-4017).

Some specific areas of focus include the following:

1. Does the report meet its primary goal?

2. Was the sampling methodology using the probability proportional to Index (ppEI) appropriately applied for the situation, allowing for appropriate distribution of the fleet in the end product?

3. Is the description of analytic methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made to develop the Fractions in Table 4-11? Are examples selected for tables and figures well-chosen and designed to assist the reader in understanding the approach and methods?

4. Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics? Are you able to suggest or recommend alternate approaches? In making recommendations please distinguish between cases involving reasonable disagreement in adoption of methods as opposed to cases where you conclude that current methods involve specific technical errors.

5. Is the use of hot-soak as a surrogate for elevated evaporative emissions a reasonable premise? Is it reasonable to conclude that there is potentially a link between fuel/evaporative control system leaks and high hot soak emissions?

6. Is stratification of the results by model year group a reasonable approach to distinguish fuel system and emission control technology changes?

7. Does the methodology, data, and analyses support the report's conclusion?

Appendix C. Michael Tschantz Review Comments

"Estimated Summer Hot-Soak Distributions for Denver's ken Caryl I/M Station Fleet, Report Draft"
Invited Review Response and Comments
September 3, 2013

Michael F. Tschantz, Ph.D.
Business Development Manager, MeadWestvaco Corporation
5255 Virginia Avenue, North Charleston, SC 29406
T: 843-740-2334
Email: michael.tschantz@mwv.com

1. Does the report meet its primary goal (to estimate distributions of hot-soak emission levels for gasoline fueled light duty vehicles and light duty trucks, using a quick and inexpensive procedure to conduct a survey of an in-use fleet)?

   Yes, the report met its primary goal. The report presents a sound and reasonable methodology to effectively and efficiently obtain necessary data and construct a distribution of hot soak emissions. The authors correctly point out the limitations of extrapolating the data across the entire annual vehicle fleet. However, I think the report and its utility -- towards a presumed end-goal of extrapolation to an annual leak-emissions inventory – could be improved by adding a paragraph or section that summarizes the specific work that would be necessary or recommended to construct an inventory.

2. Was the sampling methodology using the probability proportional to Index (ppEI) appropriately applied for the situation, allowing for appropriate distribution of the fleet in the end product?

   Yes, the methodology was appropriately applied to redistribute the sample to be representative of the fleet.

3. Is the description of analytic methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made to develop the fractions in Table 4-11? Are examples selected for tables and figures well-chosen and designed to assist the reader in understanding the approach and methods?

   Appendix A and section 2.3.1 provide the critical information to understand the methodology and calculations used to generate EI23, bin assignments, etc. While I could eventually reconstruct the methodology, Appendix A seemed disjointed and difficult to follow. Some attention should be made to editing this section to make it easier to follow. Some specific issues identified include:
   - A significant amount of effort was spent describing the differences between Method A and Method B using an RSD3000 and RSD4000. Section 2.3.1 mentions that the overall result was the quantity "A minus B." But after review of Appendix A, it does not appear

there is any subtraction of Method B estimates from A. In fact, it appears that Method A is not used in the analysis at all. If Method A is used, then there should be clarification on how. If Method A is not used, then the report might be improved by reducing or eliminating the discussion surrounding Method A.

- On page A-11, the authors describe how the bins were established, but it was unclear where the equations came from until reading through following sections. Appendix A might be improved by rearranging the sections (e.g. relocating the section starting on page A-14 to a location prior to the equations on page A-11).
- On page A-16, the second to last paragraph states "Since exhaust Method B HC concentration [is] known ...the equation cannot be rearranged to estimate the propane release rate from the measured EI23 …" It looks like the equation being referred to is the one at the top of the page (EI23 = 78.536 + …). Why can't this be rearranged and solved for Propane_scfC3?
- On page A-17, the values 1.291 and 2.157 are what established the terms "+/- 2*0.091" (e.g 1.47-2*0.091 = 1.291). A few sentences could be added to help the reader see the connection.
- The terminology for Method B HC was inconsistent. Attention should be made to making terminology for this and all terms consistent.
- Section 3.6 discusses how 21 vehicles were chosen for repair to compare with as-received hot-soak emissions. Since this work is outside the scope of this report, maybe section 3.6 can be omitted.
- The 95% confidence intervals for the model year groupings of hot soak emissions are provided. I think it would be helpful to show how the limits could affect the overall distribution shown in Figure 4-7. I would recommend adding the 95% confidence intervals to Figure 4-7.

4. Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics? Are you able to suggest or recommend alternate approaches? In making recommendations please distinguish between cases involving reasonable disagreement in adoption of methods as opposed to cases where you conclude that current methods involve specific technical errors.

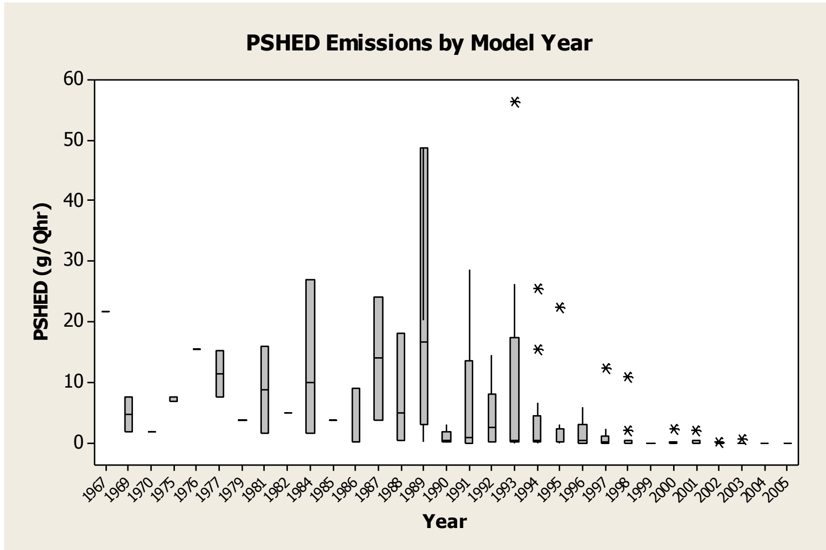
   In my view, the methods and procedures are reasonable and appropriate.
5. Is the use of hot-soak as a surrogate for elevated evaporative emissions a reasonable premise? Is it reasonable to conclude that there is potentially a link between fuel/evaporative control system leaks and high hot soak emissions?

   I feel the relationship between high EI23 and high PSHED emissions is made obvious by the authors. One familiar with fuel systems and evaporative systems should also assume there would be a link. One thing to consider when comparing running loss emissions with engine-off hot soak emissions, however, is that the pressure of the fuel system can fluctuate between positive and negative pressures during various driving and parking situations. When a vehicle is driven and purge is being pulled through the evaporative system by the engine, it is possible that the fuel tank and evaporative system could operate under slight vacuum (it is also possible that the fuel tank is under slight positive pressure when there is no purge and sometimes when purge is being pulled). When the fuel tank or canister is slightly evacuated, air should leak <u>into</u> the system through small openings (and not leak out) and canister breakthrough would not occur; there would be no vapor emissions from the fuel tank or canister during these conditions. When the vehicle is placed hot in the PSHED with the engine off, the vehicle fuel tank likely warms and develops a very slight positive pressure (although it might be possible that the fuel tank could cool and develop a very slight vacuum). The PSHED temperature data show an average of about +10°F temperature rise over the 15 minutes of hot soak, suggesting the fuel tank temperature would increase slightly. In this case of positive tank pressure, vapor would leak out of small openings. One might argue that this tank pressure effect must be accounted for when extrapolating hot soak emissions to driving/running-loss emissions to avoid over-estimating emissions. Perhaps the consideration could take the form of reducing the estimate based on some average proportion of time that the fuel tank is operated under vacuum versus when operated under pressure. This proportion would vary by technology grouping. Purge rates (and range of engine operating conditions that purge air is being pulled) have generally increased since the addition of the 48-hour diurnal test in 1996. In addition to technology improvements, the higher average purge rates could reduce running loss emissions even if leaks exist.

The description of the RSD test states that the test vehicle comes to a stop at a location 40 ft before the RSD test beam and is then accelerated past the beam. Depending on the calibration of the vehicle, the evaporative system may not be purging during this acceleration and could be under slight positive pressure; or, the fuel tank might be under vacuum since the vehicle was first idled at a stop and manifold pressure is at maximum vacuum. This effect might explain why some vehicles with low EI23 had high PSHED emissions and vice versa. Nonetheless, the data certainly show that a high EI23 is most often predictive of high hot-soak emissions.

6. Is stratification of the results by model year group a reasonable approach to distinguish fuel system and emission control technology changes?

   I think that grouping the vehicles is a reasonable approach, because technology advancements necessary to meet more stringent evaporative requirements and powertrain efficiency should have a positive impact on hot-soak and running loss emissions. I feel the effect of vehicle aging needs to be addressed to strengthen the argument that gross technology advancements are the primary reason for lower hot soak emissions. Since this study was a single snapshot in time, it is not possible to directly track how emissions for a single model year of vehicles (or a specific set of vehicles) will or will not increase with time. I plotted the PSHED emissions for the 175 vehicles by model year (below). It certainly appears that emissions from vehicles manufactured since 1998-1999 are much lower in emissions than those manufactured before 1994. Without using any statistical analysis, emissions for vehicles manufactured from 1994 to 1997 appear to be transition years. The transition could be due to early program implementation and phase-in of enhanced evap and ORVR enabling technologies. Since these vehicles were 12-15 years old at the time of the test, one might argue that the vehicle is approaching its design life and components are simply wearing out. The report could be improved by strengthening the argument that vehicle technology plays a larger role in reducing hot-soak emissions than vehicle age.

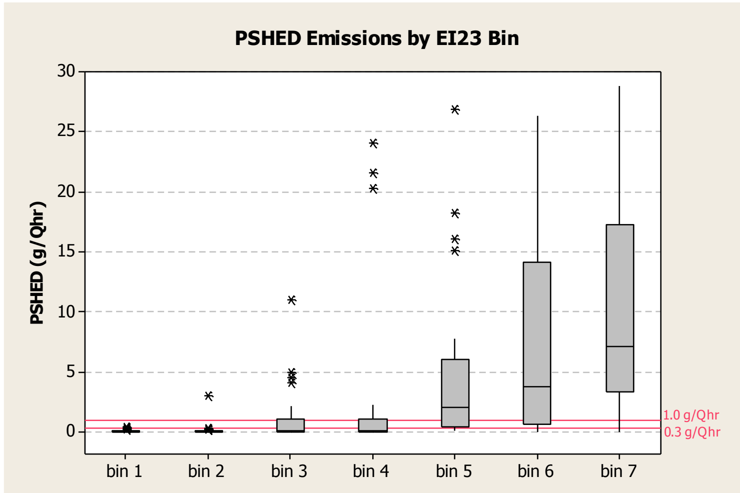


The authors provide some insight on how one might interpret what a bin represents. In summary, bins are broadly considered groupings of vehicles with common expected severities of leaks. One might first assume that a brand new vehicle would be cast into a certain bin based upon the technology applied on that vehicle and the quality of workmanship. One might then envision two paths by which that vehicle may migrate to or towards higher bin levels as the vehicle ages: (1) step change increases from individual failure events (e.g. a connection fails, purge valve fails), or (2) a relatively slow degradation of components that causes the vehicle to slowly pass from one bin to another across a continuum (e.g. slow fatigue of a hose or joint, hose connection slowly opening up).

If we assume that both sets of failure processes are occurring simultaneously, then it might help explain why the comparison of model year emissions is challenging. A step-change failure would likely mask any slow fatigue that could simultaneously be occurring and would not occur on every vehicle. If one could track the hot soak emissions from a large model year sample, one might expect to see the distribution in emissions widen and shift towards higher values with age. Step change failures would cause the distribution to widen on the high end of emissions; aging would cause the low end to shift towards higher emissions. In aggregate, the mean should shift higher with age. The variation in failures and severity would likely blur the distribution.

We see this trend in the figure above. With small samples, one "high" emissions data point can have a significant impact on the distribution and interpretation of results. Also, variation in vehicle design and in-use histories will result in variability of in-use hot soak emissions.

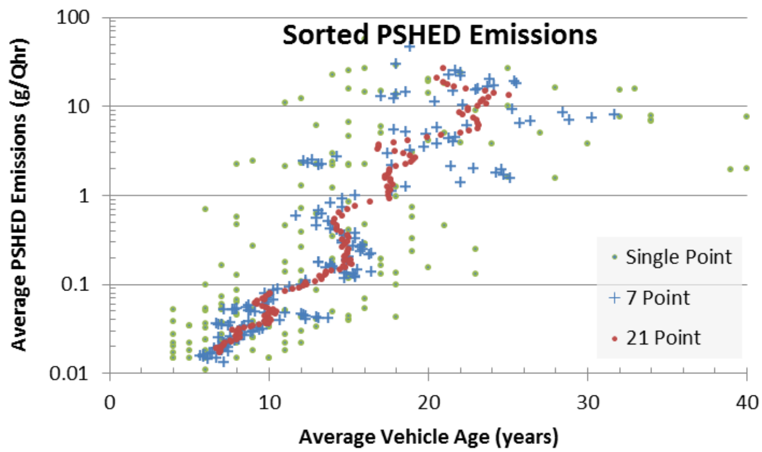
The seven bins assigned by EI23 are clearly shown in the report as being suitable to distinguish between high and low hot-soak polluters. Distributions for each bin are made up from an average of 175/7=25 vehicles spanning many model years and the variation can be very large, as shown below.



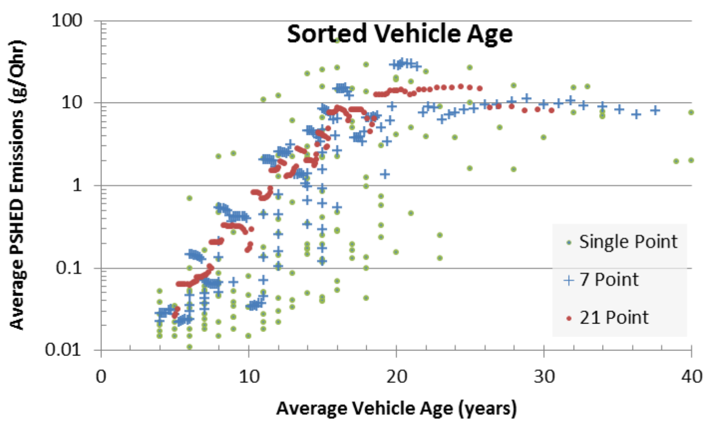
A way to possibly get around these issues is to expand the bin concept and analyze these bin levels of PSHED emissions as a function of the average vehicle age within that bin. That is, for a given level of PSHED emissions, the average age of vehicle that would produce that level of emissions can be calculated. This would, in practice, be a way to sort those vehicles that experience very high emissions (presumably from a step-change causing failure) from the lower-emissions, normally aged vehicles.

The issue with variation can be resolved by removing the large variation by making the bins very small (e.g. one, seven, or 21 vehicles) and permitting the bins to overlap one another to compare the incremental change of the average response.

I sorted the PSHED data from lowest to highest and maintained tags to model year. I then took single point, seven-point, and 21-point running averages for both PSHED emissions and vehicle age and plotted them (shown in the top figure below) against one another; this effectively made 175, 169, and 155 overlapping bins, respectively. The results suggest that a step-change in emissions occurred for vehicles with an average age of about ten years (increasing from 0.04 g/Qhr to 0.08 g/Qhr), and a second step change occurred for vehicles with an average age of about 15 years (increasing from 0.2 g/Qhr to 0.8 g/Qhr). Between these time frames, the emissions increased rather smoothly with increasing average vehicle age. These step-change increases might be corresponding to enhanced evap, OBD, and ORVR. The moderate changes might be caused by aging. A cursory glance suggests that hot soak emissions could be increasing at a nominal rate of about 1-fold per two years. It is just that new vehicles with state-of-the-art technology may start in lower bins than their predecessors.



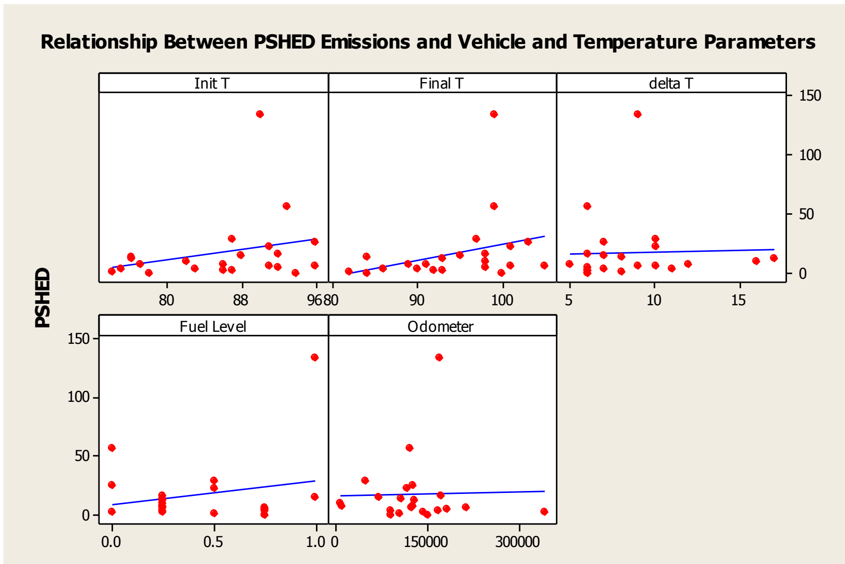
For comparison, the plot below was produced by sorting the PSHED data by vehicle age, then plotting single-point, seven-point, and 21-point running averages. It appears to be much more difficult to interpret. I recommend the authors spend some time trying to address and differentiate effects of aging and technology advancements based on the data available.



7. Does the methodology, data, and analyses support the report's conclusion?

I think the methods used to generate EI23 and assign to a bin are clearly appropriate and useful for an efficient and cost-effective evaluation of hot soak emissions. I think the use of the PSHED and the general tie between running loss and hot soak emissions is appropriate (although as mentioned earlier, data and analysis or an explanation addressing in-use driving tank pressure versus parked hot-soak pressure is needed). I think the authors suitably tied the sample population to a fleet population using appropriate proportioning. Therefore, I think the authors did a reasonable job developing a distribution of hot soak emissions, under the conditions evaluated in Denver during the summer of 2009. I also think that the authors clearly showed where a large number of leaks were arising, particularly from the pre-1996 vehicles.
The authors also suggest that temperature, pressure, fuel RVP, etc. can also impact the results. On page 4-15, the authors report that these factors were not controlled but recorded. If the authors can show correlations or lack of correlations, then the findings might usefully be applied

outside of summer 2009 Denver. I quickly plotted PSHED emissions and EI23 versus various factors below. Again, without any formal analysis, there doesn't appear to be any strong correlation. I think the authors might consider identifying whether any correlations can be identified. The correlations (or lack thereof) would provide the reader with a better sense on how the findings can be extrapolated and what data should be collected during future evaluations.



Appendix D. Leela Rao Review Comments

Peer review of "Estimated Summer Hot-Soak Distributions for Denver's Ken Caryl I/M Station Fleet"

The draft report "Estimated Summer Hot-Soak Distributions for Denver's Ken Caryl I/M Station," prepared by ERG under contract for the U.S. Environmental Protection Agency, details the results of testing that was conducted to evaluate evaporative emissions on a selection of the vehicle fleet. Vehicles were prescreened using remote sensing in order to more heavily sample vehicles with elevated evaporative emissions. Once accepted into the test program, vehicle hot soak emissions were measured using a portable SHED (PSHED). Based on the sample and response weights, the measurements from the PSHED were then used to estimate the distribution of hot-soak emissions for the entire sampled fleet. The analysis was also broken down by model-year group, with model year (MY) used as a surrogate for fuel-system and emissions-control technology.

The results showed that all 1981 MY and older vehicles are expected to have emissions corresponding to cumulative leak of 0.020 inches. In contrast, 26% of 1981-1995 MY vehicles and 3.3% of 1996-2003 MY vehicles are expected to have a leak of that size. In addition to characterizing the hot soak evaporative emissions, a physical inspection of the major fuel system components was conducted and the sources of vapor emissions identified where possible. In 66% of the cases, vapor sources were identified as the fuel tank, fill pipe, and canister.

While the results from this study demonstrate the ability to characterize hot soak emissions from the population of vehicles entering the Ken Caryl I/M station, the ability to generalize these results to larger fleet is limited due to the fact that controlling variables such as ambient temperature, fuel volatility, and barometric pressure were not standardized. Despite this, the hot soak emission characterization combined with the inspection results can provide some insight into the level and sources of evaporative emissions from the local area fleet.

In general, the report is well written and the analyses clearly described. There do not appear to be any major flaws in the methodology given the relatively narrowly defined project goals, and potential biases and sources of uncertainty have been identified. Throughout the analysis description examples are provided to illustrate the methodology, and figures and tables used well to assist the reader in understanding the approach taken. The conclusions drawn are conservative in that they are limited to the narrowly defined project goals.

The project goals were identified as estimation of the cumulative distributions of evaporative emissions in the light-duty fleet and utilization of a cost-effective and efficient method of identifying vehicles with elevated evaporative emissions with subsequent measurement of those emissions. While it is tempting to extrapolate the results from the fairly limited testing conducted to the fleet at large, the researchers recognized the limitations of the test program (e.g., only one population sampled, ambient testing conditions not controlled, test fuel conditions not controlled) and avoided this trap. From the descriptions of the methods and results it appears that the project and methodological goals were achieved.

Sampling was conducted using a "probability proportional to evaporative index" (ppEI). The index is well described and seems appropriately applied as a method to strategically sample vehicles that are likely to have elevated evaporative emissions. Given the sampling fractions and the response rate, it was then possible to estimate distribution of evaporative hot soak emissions from vehicles visiting Ken Caryl I/M station. Because sampling was limited to one location with a possibly unrepresentative population of vehicles, it is difficult to extrapolate these results to the fleet at large.

Hot soak emissions were used as a surrogate measure of evaporative emissions from each vehicle. As discussed in the report, hot soak emissions are just one part of a vehicle's evaporative emissions, but nonetheless should identify those vehicles with fuel system leaks and possibly even purge issues. Measurement of hot soak emissions will also correctly identify those vehicles with low overall evaporative emissions. However, vehicles with moderate fuel system defects, such as bleed emissions that only are observable on the second day of a multi-day diurnal test, will not be identified by a single hot soak test. Despite this, the use of a hot soak as a quick screening tool for identifying vehicles with fuel system leaks seems appropriate and cost effective.

The primary concern I have is with the use of model year as a surrogate for emission control technology. While it is true that on a gross level vehicles manufactured prior to 1981 had no controls, those manufactured between 1981 and 1995 had basic evaporative emission controls, and 1996 and subsequent vehicles had enhanced evaporative emission controls in addition to OBD monitoring, the reality is not as straightforward. Each regulatory action contains a phase-in period during which only part of the vehicle fleet must comply with the new standards. As such, it may be 2-4 years after the start of a new rule until all vehicles contain the newest emission control technology. A second issue is that some 2001-2010 MY vehicles may have been partial zero emission vehicles (PZEVs), with additional emission control technology above and beyond that found on vehicles with enhanced evaporative emission controls. Thus, rather than using model year as a surrogate for emission control technology, a better approach would have been to determine the certification classification of each tested vehicle. While this may not have appreciably affected the results, it is more accurate than the approach taken, which is more of an approximation of emission control technology based on model year. If it is overly burdensome to reanalyze the results based on actual emission control technology, a brief discussion of why model year is likely a simplification, along with any possible ramifications of this simplification, should be added to the report.

In summary, the distributions of hot-soak emissions estimated from vehicles sampled at Ken Caryl station were combined with mechanic's inspection information to characterize evaporative emissions and determine the primary sources of those emissions. The vehicle testing was conducted with a portable SHED, with test vehicles pre-screened using remote sensing. This methodology was a cost-effective way of characterizing the evaporative emissions from this fleet.

Appendix E. Stephen Stewart Review Comments

"Estimated Summer Hot-Soak Distributions for Denver's Ken Caryl IM Station Fleet"

Peer Review – Prime Contract EP-C-12-011

Stephen J Stewart

August 28th 2013

Primary and Secondary Goals

The primary goal was to estimate the cumulative distributions of evaporative emissions in the light-duty vehicle and light-duty truck fleets.

There were also two secondary goals. One was to apply a cost effective and efficient method of measuring evaporative emissions, and this was by measuring hot-soak emissions using a PSHED. The other was to use RSD screening and a probability index to improve efficiency of sampling vehicles with elevated evaporative emissions.

The report meets its primary goal in presenting the fleet fractions that are shown in Table 4-11

It also meets both its secondary goals, and this is demonstrated through the process and analysis necessary in order to reach to primary goal.

Possible Limitations

One limitation is that the project did not include any full-size light-duty trucks, because of the physical size of the PSHED, but it would be reasonable to assume that the results presented would be valid for LDT3 and LDT4 because their evaporative emission standards and control technology is the same as for LDV, LDT1 and LDT2.

The study did not include vehicles that had been exempted from the IM program by the clean-screening provisions. The report shows that high evaporative emissions would be unlikely to have affected the clean-screening results because of the vehicle speed during clean-screening. So clean-screening should not have biased the sampling process.

There were no participating vehicles of model year 2006 or newer, but evaporative problems with these vehicles should be even less probable than with the thirteen 2004-2005 vehicles that did participate, so even though there must be some vehicles in this age group in the fleet that have evaporative emission problems, this is unlikely to have caused any significant error in the overall estimate of the incidence of high evaporative emitters.

At the other end of the age scale, there were few participating vehicles older than model year 1981, and all had high PSHED results, leading to the conclusion that the entire fleet of 1980 and older vehicles have hot-soak emissions over 1g/Qhr. In reality there must be some vehicles in this age group that do not have evaporative emission problems. However, the order of magnitude comparison of age groups is more important here than a comparison to an absolute value of 1g/Qhr, so for these vehicles it is more important to look at their fractions above 2, 5, 10 or 20 g/Qhr.

Sampling and ppEI

This approach increases the chances of selection for vehicles that are likely to have higher evaporative emissions. It therefore reduced the total number of vehicles that needed to participate compared to completely random selection. The probability of selection is inverted during analysis to become part of the weighting used to apply test results to the overall fleet. This is an efficient approach. It is valid even though the screening index is much less useful for identifying vehicles with high evaporative emissions than for identifying those with low evaporative emissions. A second stage of sampling probability was created by the response rate of vehicle owners to selection. This too was inverted during analysis to provide a weighting.

Analytic Methods and Procedures

The testing process and methods are all logical and are well explained in the report. The technical bases for the methods are described step by step, and the appendices provide additional information.
The sampling approach and response rates are sound and the report explains how these carry through into the analysis of results as weightings to be used in applying the sample data to the overall fleet. The examples help in understanding what was done.

RSD for Evaporative Emissions

The way that RSD can be used to look for high evaporative emitters is explained in an appendix, and the main report considers how well high and low values of the EI23 index match up with actual high and low PSHED results. It does show that low values of the EI23 index are indeed likely to correspond to low PSHED results. However, high values of the EI23 index are almost equally likely to have high or low PSHED results, but this is a much higher likelihood than would come from a completely random sample and therefore the EI23 value is an effective way to screen for sampling.

Modified California Method

MCM was used to look for the source of evaporative emissions. The results are interesting and will be relevant to later consideration of how to identify or inspect vehicles in order to find and repair high evaporative emitters. They are also the only data that links high hot-soak emissions to the overall condition of the vehicle's evaporative control system.

Hot-Soak

An appendix details a comparison of hot-soak emissions from PSHED and LSHED testing, and shows that PSHED results tend to be a little lower than LSHED results, and the analysis supports use of PSHED results as a good surrogate for LSHED. However, this is only for the hot-soak evaporative emissions. No measured data is presented that would allow examination of the validity of using hot-soak as a surrogate for elevated evaporative emissions in general, and as the report mentions, there are also running losses, permeation and diurnal emissions that need to be considered. However, these are convenient testing categorisations rather than being completely separate emission issues. The MCM results show some problems that are likely to cause both running losses and hot-soak emissions, and some that are likely to cause both diurnal and hot-soak emissions. I would speculate that in most cases permeation is a relatively minor part of high evaporative emissions, but it too contributes to hot-soak results. Overall, I believe that it is very reasonable to assume that there is a link between fuel and evaporative leaks in general and high hot-soak emissions, and therefore hot-soak is a reasonable surrogate for elevated evaporative emissions.

Stratification by Model Year

The certification standards for light-duty vehicles are almost completely related to vehicle model year, and the evaporative standards for light-duty trucks have been the same as light-duty vehicles. This has meant that the evaporative control technology and its ongoing performance as vehicles age also continues to be tied to vehicle model year. It is therefore completely appropriate to stratify the light-duty fleet by model year as a surrogate for evaporative emission control technologies.

Conclusion

The report describes a project that used a multi-stage testing process, some parts of which yielded data that was not used in this report's analysis. The stages of testing were logical and sequential. The analysis of results was also logical and sound.

The methodology, data and analyses support the report's conclusions.

Other

The page numbering in Appendix D has gone somewhat awry

The picture chosen for Figure 3.1 makes the RSD vehicle look like it has a chemical refinery loaded onto it.