Peer Review of "Tier 3 Certification Fuel Impacts Test Program" – Final Report

EPA Contract No. EP-C-16-020

Work Assignment No. 0-06

September 22, 2017

Submitted to:
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I. Introduction

When certification test fuel properties change, EPA must make the proper test procedure adjustments to maintain the intended level of stringency for existing emission and fuel economy standards. It is important to properly evaluate the effects of the changes on the fuel properties for emissions and fuel economy in order to make those adjustments.

The recent Tier 3 regulations for light duty vehicles introduced a new certification fuel designed to be more characteristic of current market fuels. A laboratory test program was conducted to measure differences in carbon dioxide (CO_2) and fuel economy between the current ("Tier 2") and future ("Tier 3") certification fuels. The goal of this program was to rigorously and methodically quantify the impacts on CO_2 emissions and fuel economy for vehicles tested on both Tier 2 and Tier 3 certification fuels. This information will be used in a rulemaking for making adjustments to the test procedures to ensure a consistent stringency of the greenhouse gas (GHG) and Corporate Average Fuel Economy (CAFE) requirements when changing to the new Tier 3 test fuel.

The testing was completed over Spring and Summer 2016. The "Tier 3 Certification Fuel Impacts Test Program" report describes the study's design – including test fuels, vehicles, emission measurements, test procedures and analyses; the results for CO_2 emissions, fuel economy, and testing parameters; and presents a discussion of the results.

EPA guidelines state that all scientific and technical work products intended to inform or support agency decisions are encouraged and expected to undergo independent peer review per specific agency protocols to assure the use of the highest quality science in its predictive assessments and assure stakeholders that each analysis/study has been conducted in a rigorous, appropriate, and defensible way. This document reports the findings of the external peer review of the report.

The peer review was conducted in December 2016 and January 2017, in accordance with the current version of EPA's *Peer Review Handbook.*[1] At the conclusion of the review, ICF collected all unedited peer review comments and provided them to EPA. This document presents the unedited comments and conclusions presented by each peer reviewer along with a brief summary by charge question. Supporting documentation collected from the reviewers, including their curriculum vitae (CV) and conflict of interest (COI) statements is also provided in Appendix A and Appendix B.

The following materials are included in this Task 3 Technical Report.

1. Description of the peer review process (Section II)
2. Reviewer Responses to Charge Questions (Section III)
3. Reviewer Supporting Documentation (Appendix A and Appendix B)

[1] U.S. Environmental Protection Agency, Peer Review Handbook, 4th Edition, October 2015. Prepared for the U.S. EPA by Members of the Peer Review Advisory Group, for EPA's Science Policy Council, EPA/100/B-15/001. Available at http://www.epa.gov/osa/peer-review-handbook-4th-edition-2015-0, including OMB's Information Quality Bulletin for Peer Review (Handbook, Appendix B) provisions for the conduct of peer reviews across federal agencies.

4. Notes from mid-review meetings with EPA, ICF, and the contracted peer reviewers (Appendix C).

II. Peer Review Process

ICF conducted the peer review in three stages. We first identified a qualified set of reviewers. ICF then contracted with all reviewers, conducted the review, and collected reviewer feedback on the report. We assembled this information and provided it to EPA. ICF then documented the peer review process, including responses to the review comments collected from EPA. No responses from EPA to the peer reviewers' comments are included in this draft report, although they will be included in the final version.

The following sections provide detail on these steps.

1. Selecting Reviewers

ICF first identified a pool of independent subject matter experts from which to select three peer reviewers that represent the best qualified candidates. Qualifications included two technical considerations. The first is any actual or apparent conflict(s) of interest or lack of impartiality that would preclude an independent review. The second is that the combined expertise cover this analysis' focus area on expertise in the field related to vehicle emissions testing programs, particularly fuel effects.

EPA requested one reviewer from three categories:

- Industry,
- Government, and
- Academia.

ICF identified thirteen potential reviewers for the report based on a combination of individuals originally suggested by EPA and those identified through our own research. ICF performed an initial screening of these individuals to select three peer reviewers that were available and represented the best qualified candidates, including consideration of any actual or apparent conflict(s) of interest or lack of impartiality that would preclude an independent review. ICF contacted each by e-mail and/or telephone and ascertained their availability and qualifications to perform the peer review within the allotted schedule. This initial contact was designed to assess each potential reviewer's expertise in the field, their ability to perform the work during the period of performance, any association they have with the work that would preclude them from being independent and reasonably expected to be objective. We also collected a CV or resume for each peer reviewer that expressed an interest in participating.

Based on these initial contacts, ICF selected three qualified independent reviewers to conduct the peer review, with the goal that the combined expertise of the selected reviewers would cover all technical aspects of the report. ICF suggested the following reviewers in our December 27, 2016 Peer Review Selection Memo to EPA[2]:

1. Doug Fisher (Industry group)
   Independent consultant and former laboratory and operations manager for vehicle, engine, emissions and fuel economy testing
   5726 Windermere Ln.
   Fairfield, Ohio 45014
   dwfishmail@gmail.com
   (513) 785-9138

2. Jim Kemper (Government group)
   Manager, Aurora High-Altitude Emissions Research Laboratory
   Colorado Department of Public Health and Environment
   15608 East 18th Avenue
   Aurora, Colorado 80011
   jim.kemper@state.co.us
   (303) 364-5334

3. Dr. Kent Johnson (Academics group)
   Associate Research Engineer, College of Engineering-Center for Environmental Research and Technology, University of California Riverside
   University of California Riverside
   Riverside, CA 92521
   kjohnson@cert.ucr.edu
   (951) 781-5791

These selected reviewers each possess the experience and technical expertise required to conduct the review. ICF anticipated that no areas of the peer review will lack based on this selected group of reviewers. ICF's Peer Review Selection Memo documented this process. EPA concurred with all selected reviewers.

2. Administering the Review and Receiving Comments

ICF composed and delivered a charge letter to the three selected reviewers, along with the "Tier 3 Certification Fuel Impacts Test Program" report. The charge letter included instructions on how to complete the review, a timeline of when comments were due to ICF, and a conflict of interest (COI) form. ICF sent the charge letters to each of the three selected reviewers on January 12, 2017.

ICF then arranged and hosted a mid-review teleconference between the selected peer reviewers, EPA, and ICF staff. During this 1 hour meeting, extended discussions occurred on the nature of the review, background information on the review itself, introduction of the various entities involved, and technical issues for consideration. The mid-review meeting was held the afternoon of January 18, 2017. A second, brief, and informal teleconference was also held on

[2] Draft peer reviewer selection memo (Revised), to Connie Hart, US EPA from Seth Hartley and Andie Fritz, ICF, December 27, 2016.

January 25, 2017 requested by one reviewer to answer additional questions. ICF's notes from these meetings are attached to this report as Appendix C.

The reviewers were allowed two weeks to prepare their responses. All peer reviewer comments, cover letters, and completed COI forms were provided to ICF by January 25, 2017. ICF compiled all unedited peer review comments and charge letter information, and attachments into a peer review report. This report organized all comments into tables so that the individual comments could be easily grouped and compared for review purposes. A Draft Peer Review Summary Report was composed assembling raw reviewer comments and delivered to EPA on January 26, 2016.

3. Difficulties Encountered

No significant difficulties were encountered while performing this review.

III. Responses to Charge Questions

Subsection 1 presents a brief summary overview of the feedback received on the seven charge questions. This is followed by Subsection 2 that provides the direct, unedited reviewer responses to each of the charge questions on each report. Within this subsection, the detailed responses are organized by reviewer, with responses to each of the applicable charge question. Each appears in the same table format. In those tables, the left-most column lists the charge question and the right column provides the reviewer comments. A row follows each paired charge question-response, which was populated with EPA's response to the question.

1. Comment Overview and Summary

The following overview of the peer reviewers' comments to the charge questions is a brief summary of the broad, general themes among the comments for each question. It does not rewrite the responses or supersede the more detailed, direct comments presented in Section 2. The questions have been abbreviated for presentation here.

1.1 Does the Report Meet its Primary Goal

All three reviewers agreed that the report met its primary goal of determining the emissions and fuel economy differences between Tier 2 and Tier 3 certification fuels.

1.2 Statistical Approach and Methods

Overall, the reviewers agreed that the statistical approach and methods used for the test program were appropriate.

1.3 Methodical Manner of Testing

All three reviewers approved and agreed that the testing was conducted in a rigorous, methodical manner to achieve high quality results.

However, Johnson commented that there was not much clarity on vehicle selection, which should be expanded upon.

1.4 Description of Analytic Methods and Procedures

All reviewers commented positively, but provided specific caveats and suggestions for improvements. Please see the following tables for discussion.

1.5 Methods and Procedures

Overall, the three reviewers agreed that the methods and procedures employed were technically appropriate and reasonable. Fisher noted an issue with the equation not being included in the final CFR, which was addressed in the follow-on teleconference. None of the reviewers suggested alternate approaches.

1.6 Methodology, Data, and Analyses

All three reviewers agreed that the methodology, data, and analyses supported the report’s conclusion. Kemper did raise the issue of hybrid electric vehicles (HEV) from vehicle selection and influence on results. This was also discussed in the reviewer follow-on teleconference.

1.7 Other Comments

Only Kemper and Johnson provided general comments in the “Other Comments” section. Kemper’s comments regarded the Tier 3 ethanol content, which he felt was reasonable, while Johnson suggested including additional statistical metrics in an appendix.

1.8 Additional Comments

All reviewers provided further feedback in the “catch-all” sections. Please refer to the tables below for details.

2. Comments by Reviewer

2.1 Comments by Doug Fisher

CHARGE QUESTION	COMMENTS
1. Does the report meet its primary goal?	**Yes, I believe the report sufficiently meets the primary goal to quantify the impact on GHG emissions and fuel economy between Tier 2 and Tier 3 certification fuels.**
Author Response: **Thank you**	
2. Were the statistical approach and methods used for this test program appropriate for determining the emissions and	**Yes I believe the statistical approach and methods used for this program were appropriate.**

<table>
<tr><td>fuel economy differences for each test vehicle tested on both Tier 3 and Tier 2 test fuels?</td><td></td></tr>
<tr><td colspan="2">Author Response:

Thank you</td></tr>
<tr><td>3. Was the testing conducted in a rigorous, methodical manner to achieve high quality results?</td><td>The authors of this report have outlined a well thought out test plan in an attempt to generate a tight data set. Great detail was invested in a thorough fuel changeover procedure; as a fuel performance effect is the main driver in this study.

The outline in Table 3.4.2: Vehicle test procedure to be performed during one work week. This also shows a well thought out approach with which to start the project.</td></tr>
<tr><td colspan="2">Author Response:

Thank you</td></tr>
<tr><td>4. 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 differences shown in Section 4?</td><td>With respect to this charge question, the report is missing some detail which will help document the overall plan execution.

Examples Section 3.4

This section includes great detail on the overall test procedure. However, early in this section (page 8) it is noted that excessive testing variability drove the program team to make a change.

“In addition, we made an adjustment to run the same test sequence and number of tests each day. At the beginning of the program we maximized the number of tests run in a day, but this led to a different number of tests conducted on a daily basis. We observed a higher variability with this approach. Therefore, we then required the same sequence on each day and the test data became more repeatable”

This seems reasonable, and a good decision. However the reader doesn’t have any idea what data was affected. How many tests, what vehicles; or was the data included in the sets? The note below regarding additional section 3.5 data tables helps to address this comment.

The test plan includes text indicating the intent to collect fuel samples from the fuel rail after fuel change, including subsequent analysis. It also mentions monitoring of emissions test cell background and dilution air. However, the report discussion section includes no mention if this data was collected, scrutinized and deemed appropriate. It is understandable these are sanity checks for the program team to monitor for assuring a consistent laboratory environment and procedural adherence.

Suggest that similar to the driver metrics (which were missing from the plan), the discussion section should mention to what extent these data points were reviewed.</td></tr>
<tr><td>- Are examples selected for</td><td>Tables 3.4.5 and 3.5.5 are complicated and seem to beg more</td></tr>
</table>

<table>
<tr><td>tables and figures well-chosen and designed to assist the reader in understanding the approach and methods?</td><td>questions than they answer.

For this section, I believe individual vehicle specific tables with a more chronological approach, and fewer statistics, would lead to a better understanding of overall test flow. In particular, lending to a clearer understanding of what vehicles required repeats due to statistical power criteria and when that occurred; and what repeats were due to procedural or schedule issues.

Such an approach would also answer what order vehicles were tested. How long the program actually took to execute. Were any tests performed and rejected completely, if so why?

This would mean a more lengthy report, but would paint a more complete picture of the performance, as all test data summarized and averaged in subsequent summaries would be presented.

The section 4 summary tables and retrospective statistics do a good job of summarizing the results and answering the test of significance questions.</td></tr>
<tr><td colspan="2">Author Response:

Tables 3.4.4. and 3.4.5, and their counterparts in Tables 4.1.1 – 4.2.2 are designed to illustrate the steps in the analyses portrayed, rather than the chronological flow of the testing. As such, these tables contain the inputs and results for these calculations, arranged in logical order from left to right. We believe that a portrayal of results by vehicle in chronological order is more appropriate in sections describing methods or quality assurance than in the sections describing analysis of results. However, to expand on content that describes the performance of measurements for the different vehicles in chronological order, we plan to make modifications as described below.

To provide a comprehensive listing of all tests, a new appendix will be prepared for the revised report, to contain two tables. The first table will show all tests included in our analysis. An additional table showing tests excluded from our analyses for specific reasons shall also be provided. These tables shall list tests by vehicle and in chronological order.

In addition, we will amplify the discussion in the body of the report covering the various procedural and logistical issues we encountered that affected the quality and variability of tests. Resolution of these issues led to modifications in the conduction of the program. Such modifications included a reemphasis on adhering to the original test plan, which specified that the same sequence of cycles would be run on each testing day.

Fuel rail samples collected during fuel changes were analyzed for a few key properties that could indicate a misfueling event. These results were reviewed on a weekly basis by a member of the testing team, and archived in case questions were to arise about suspicious results during data analysis. No evidence of misfueling was suspected or found. Background and dilution air samples were also checked on a weekly basis as a screen for anything unexpected that could influence results. None of these results raised any concerns. These data have not been tabulated or formatted for publication so will not be included in the report.

More discussion will be added to Section 4.4 on Drive Quality Statistics on how we looked at these data and how we used it to confirm the validity of our results.</td></tr>
</table>

5. Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics?	**Page 7. Equation 3.1 FE calculation references 40 CFR Part 1066.870(b)2 In effort to revisit the fuel economy calculations, this reviewer was unable to locate the section noted here in the current online version of the CFR.** **As this question was answered on the 1/25/17 conference call, I removed my question to check this reference.** **I do believe the authors should further elaborate on the appropriateness of using equation 3.1 for both Tier 2 and Tier 3 fuels.**
- 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.	
Author Response: **We are revising the report text to insert the proper CFR fuel economy equation and citation.**	
6. Do the methodology, data, and analyses support the report's conclusion?	**Yes, I believe the methodology data and analysis support the conclusion.**
Author Response: **Thank you**	
7. Other Comments	

Outlined here are some minor questions that came to mind as I read the report. The authors may consider these issues if any further rewrite is considered.

Section 3.2 Vehicles.

The vehicles were well chosen. It's a very good cross section of the varying engine and drivetrain technologies the industry is now employing and in use. The suggestion here is for the authors to consider adding some additional information such as usage data of each vehicle; total odometer miles, is it known how the bulk of mileage accrual occurred, how did EPA procure each vehicle? It could be this information is available in the EPA's Advanced Light-duty Powertrain and Hybrid Analysis model (ALPHA) program. If so, can it be included by reference?

VIN# might be helpful if anyone wanted to look up certification emissions and fuel economy values for each vehicle.

Section 3.3.1 Test Cycles. The HWFE (or HWFET) is shown as a single cycle. This is routinely performed with a double drive of this cycle. The second drive being sampled. The chart only

shows a single drive. For the reader it would be important to confirm this was done as a "double highway" ? Also on Altima six HWFE tests were performed while just three FTP's were done. How and when were extra HWFE data points performed relative to the rest of the data.

Section 3.3.2 Emission Measurement. Did the authors mean the site was compliant to 40 CFR 1065 or should this read 40 CFR 1066?

I believe additional supporting text should be included, either in the body or appendix, to aid in understanding what testing hardware technologies were employed for this study. In particular; the gaseous emissions analyzers , CVS design features for dilution factor optimization, and the dynamometer. Again, this might be included in other published EPA testing or on the EPA web site; if so could be referenced via internet link. Also, if NDIR analyzers were used for CO_2, a particular interest would be detail on the analyzer range or ranges used for CO_2 measurement. Was it possible a single range was adequate for all vehicles? Address any preventive maintenance, calibration or standard gas changes performed prior to starting testing, to ensure consistency over the length of the study.

Table 3.4.1 Step 6. Triple LA4 test cycles performed to allow vehicle to "learn" the next candidate fuel. Was the Vehicle put through a Key Off and restart between LA4 cycles?

Table 3.4.1 Step 7. Were these vehicle coast down data tabulated. Same comment as above regarding background air checks and fuel samples. Might mention it in discussion section that all was normal?

Figures 4.3.1 and 4.3.2. What are the error bars units?

For all Tables, please check the statistic assumption footnotes and make sure footnote numbers are present and on the correct parameter.

Section 4.4

Drive Quality Statistics

This is interesting data. It was not mentioned in the test plan section, but shows up at the end of the document. It would be helpful to the reader to know how this data was collected. Was it from the dynamometer control software, vehicle OBDII port, EPA test site data acquisition, drivers aid system software, or a combination of them all?

The table shows a column array per vehicle, but what units are we looking here. % of what.

Section 4.5

This section goes into some detail but to the reader it is unclear what results are tabulated. It is inferred from the chart 4.5.1 at the end of the section, that it is FTP data only. Why just the FTP?

Author Response:

It is mentioned in the vehicle section of the report that the vehicles were selected based on the presence of emerging vehicle technologies and were recruited as part of EPA's mid-term GHG emissions evaluation. We can add a column in the vehicle table for odometer. It is unknown to us in most cases how the miles were accrued before being recruited by our lab for testing.

We did run a double HFET with the first unsampled. Step 3 in Table 3.4.2 will be clarified as will the data tables in Appendix. There was a key off and re-start between cycles.

The report will be changed to reference that the site was compliant to 40 CFR part 1066. 40 CFR part 1066, testing hardware will be added to Emissions Measurement section along with information on calibration and maintenance. The NDIR analyzers had a range of 0-2.5 volume% for measurement of CO_2 which was used to measure CO_2 emissions for all vehicles in the test program.

Yes, there were separate tests for LA4 cycles in the fuel preparation procedure and Table 3.4.1 shall be updated that there was a key off. **Coastdown data was collected as part of weekly calibration/maintenance.** **A sentence will be added that the background and dilution air checks were normal and in range and did not appear to affect the data.** **In Figures 4.3.1 and 4.3.2, the error bars show 95% confidence intervals for the means shown in the bars, and as such, are portrayed in the units shown on the y-axis, i.e., g/mi for Figure 4.3.1 and mpg for Figure 4.3.2. We will clarify meaning of the error bars in the revised report.** **More discussion shall be added to Section 4.4 on Drive Quality Statistics on how these data were collected and calculated. The percentages are calculated for each metric by the total driven minus the target divided by the target times 100 for a percent. This will be explained in the report.** **In Section 4.5, we have added an analysis for the HFET cycle, and have clearly identified results by cycle in text, tables and figures.**

2.2 Comments by Jim Kemper

CHARGE QUESTION	COMMENTS
1. Does the report meet its primary goal?	**Yes**
Author Response: **Thank you**	
2. Were the statistical approach and methods used for this test program appropriate for determining the emissions and fuel economy differences for each test vehicle tested on both Tier 3 and Tier 2 test fuels?	**Yes** **Using test equipment and analytical methods as defined in the CFR and related SAE J standards should yield consistent measurement results. Therefore, comparing test-to-test CO2 and fuel economy values can be a kind of "rationality test" for control consistency of the entire test sequences. In this report, observed test-to-test variations of these values generally indicate good control of vehicle test conditions and support conclusions that differences are truly due to fuel properties and not some other unaccounted factor(s).**
Author Response: **Thank you**	
3. Was the testing conducted in a rigorous, methodical manner to achieve high quality results?	**Yes**
Author Response: **Thank you**	
4. Is the description of analytic methods and procedures clear and detailed enough to allow the	**Yes, with minor comments:**

reader to develop an adequate understanding of the steps taken and assumptions made to develop the differences shown in Section 4?	**1) Pages 22, 23, & 24 - Description of drive quality statistics. I assume these statistics were calculated using J2951methods or similar. Most values seem like very small deviations. However the casual observer may notice what appear to be large deviations with Malibu 1 on page 24 regarding absolute speed change and inertial work; especially when compared to most other values in the two tables. A short discussion may be helpful, or perhaps reference J2951 or related documents so the reader can review how these statistics are calculated, used, and compared.** **2) Page 9. I'm assuming step 4 is only performed once and at the second refill step 4 is ignored and moved on to step 5. Seems intuitive.**
- Are examples selected for tables and figures well-chosen and designed to assist the reader in understanding the approach and methods?	**Yes.** **See comment above**
Author Response: **More discussion shall be added to Section 4.4 on Drive Quality Statistics on how these data were collected and calculated. Also on how we looked at these data and how we used it to confirm the validity of our results. We will also comment on the Malibu1 and other patterns in the statistics. Reference to SAE J2951 will also be made.** **We will clarify the test procedure in Table 3.4.1.**	
5. Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics?	**Yes**
- 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.	**No**
Author Response: **Thank you**	
6. Do the methodology, data, and analyses support the report’s conclusion?	**Yes** **The mix of vehicles seems appropriate given recent estimations of technology penetrations. Numerous work in**

	this area such as *SAE 2012-01-0360, 2015-01-1683, 2015-01-0972*, *Automotive 2030*, etc., seem to agree that GDI, engine downsizing and turbocharging, variable valve timing, and cylinder deactivation technology will dominate for the foreseeable future. **One possible exception to this is a hybrid electric vehicle (HEV). None of the vehicles were identified in the report as including that technology and it does have a fairly large market penetration. However, I can think of no technical or hypothetical reason why an HEV internal combustion engine (ICE) would be more or less sensitive to fuel properties than the ICE of a non-hybrid incorporating similar technologies. Nor have I come across research suggesting this.** **The large number of variables present with light-duty vehicle testing in general can yield moderate test-to-test variations (yet absolute values are small) in emissions and/or fuel economy; even adhering to test protocols in the CFR. The comparative consistency of fuel economy and related CO2 values between tests in this report indicate good control of those variables. Additional evidence of that control are driver statistics on pages 23 and 24. Therefore, based on the observed consistency in general, and the statistical analyses in particular, it is reasonable to conclude variations in fuel economy and CO2 values are mostly attributable to fuel properties.**

Author Response:

Similar to why we avoided stop/start operation, we did not include a hybrid electric vehicle because slight differences in when the hybrid control logic turns the engine off and on would introduce an additional variable to this program that is unrelated to the goal of quantifying differences from the fuels. Additionally, hybrids have historically been a challenge to repeatedly end the test at the exact same battery state of charge as what the state of charge was at the start of the test. Any differences compound the challenge of reducing variability in the CO_2 and fuel consumption levels. We are trying to capture fuel effect differences between 1 and 2 % and engine off operation and state of charge differences does not help tease out an effect of the fuel.

7. Other Comments

The Tier 3 ethanol content at 9.9% seems a reasonable value for representation of in-use fuel. Local testing in Colorado, using gas chromatography, yields concentration levels at ≈9.5 +% range, but less than 10%.

I found it interesting that the Tier 3 fuel had a slightly lower AKI, and slightly lower net heat of combustion in the ≈3% range, yet overall reduction in fuel economy was in the ≈2% range. It appears these technologies may generally have the ability to take added advantage of the Tier 3 fuel properties, even with the somewhat lower AKI. Perhaps a portion of the difference is the greater thermodynamic efficiencies of the ethanol fraction.

1) **Page 1, item 2 – Should the reference to "section 3.2" be section 3.1?**
2) **Page 9. Page 20, 4th paragraph, "between" used twice. Also "with": used instead of "within."**

Author Response:

The introduction of the ethanol compound into the Tier 3 test fuel likely brings on a new combustion related impact not observed in the Tier 2 fuel. Ethanol has a high latent heat of vaporization which may result in cooler temperatures of the mixture in the cylinder impacting the pumping efficiency. A similar observation has been seen in E85 fueled vehicles where the lower energy E85 is not entirely reflected in the FE loss. **Clarifications on page 1 and 20 shall be made in final report.**

2.3 Comments by Dr. Kent Johnson

CHARGE QUESTION	COMMENTS
1. Does the report meet its primary goal?	**Yes I believe the report meets its primary goal of quantifying there is and the magnitude of the CO2 and FE differences between Tier 2 and Tier 3 fuels. I would only want to add one detail to make the structure of the report read better. I would add to the ES:** **1. Add two sentences on the approach (11 vehicles, 2 main cycles, and obviously 2 fuels).** **2. Add the main findings. I like the last sentence on Page 27/28. I also like the last sentence in the first paragraph. That could be a good tie in for the findings to physical observations.**
Author Response: **Additional discussion shall be added in the report on the approach of the test program. The main findings on pages 27 and 28 shall be included in the Executive Summary*.***	
2. Were the statistical approach and methods used for this test program appropriate for determining the emissions and fuel economy differences for each test vehicle tested on both Tier 3 and Tier 2 test fuels?	**Yes I believe the rigorousness of the experimental setup for statistical analysis was performed. This included rigor for the following:** **1. Utilizing mean fuel properties from various fuel sources.** **2. Setup of the experiment design with a power analysis to determine how many tests to run. To quantify differences at the expected 1.5%.** **3. Statistical evaluation of the means CO2, FE for both test cycles per point.** **4. Statistical evaluation of the means by test group as a whole** **5. Then two statistical evaluations of the test setup (driver repeatability and fuel order). These were both shown to be not significant contributors.** **In general these selected statistics are well selected and represent the main comparisons needed for a A/B comparison for a fuel properties change.**
Author Response:	

<table>
<tr><td colspan="2">Thank you</td></tr>
<tr><td>3. Was the testing conducted in a rigorous, methodical manner to achieve high quality results?</td><td>Yes the tests performed were rigorous and needed. I agree with the experimental design and would have used a similar setup for the task at hand. I like the detail added to the report:
1. Vehicle time needed to have the ECM learn the fuel properties. Very important these days.
2. Rigorous prep times.
3. Reasonable and representative test cycles
4. Consistent driver, facility, and day operations.
The following were some observations regarding test design that were not clear or were may have been part of the design, but not explained:
1. Vehicle selection: According to the report eleven vehicles were selected. It is not clear that they were selected randomly, based on largest inventory, or by their unique design. Stating this would add to the clarity of the methodology. There was a clear discussion that unique designs were considered, but it wasn't said that that was the plan.
2. Selecting a vehicle for its emission certification seems like a good item to target and to describe (I suggest adding the emissions tier and bin to Table 3.2). Was this part of the vehicle selection?</td></tr>
<tr><td colspan="2">Author Response:
Vehicle selection was based mainly on emerging vehicle technologies that target improvements in CO_2 and fuel economy. All of the LD vehicles tested were part of the EPA mid-term evaluation fleet and are considered to have some of the most advanced technologies in production at this time. Emission levels were all current required levels under the Tier 2/LEVII programs and specific emission certification level was not a target for the vehicle selection.</td></tr>
<tr><td>4. 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 differences shown in Section 4?</td><td>The descriptions are clear. They:
1. Correctly reference appropriate standards (40 CFR Part 1066 and 1065)
2. If not a standard then appropriate equations provided such as for all the statistical calculations.
3. The table of fuel properties is provided and their methods of determination. Additionally it is included that the values are averages. I would also suggest providing the range of uncertainty (1 sigma or other) since it is available and would provide the reader a sense of complication in future application of these results for the user.</td></tr>
<tr><td>- Are examples selected for tables and figures well-chosen and designed to assist the reader in understanding the approach and</td><td>I don't see the need for example. There were tables and figures that were well organized and designed to show the comparison. I especially liked Figure 4.3.1 and 4.3.2. These showed the differences in CO2 and FE for both test cycles. It was surprising to see how the values varied in relationship to each other (I didn't expect this). Also that relationship changed between the two cycles. Interesting.</td></tr>
</table>

<table>
<tr><td>methods?</td><td></td></tr>
<tr><td colspan="2">Author Response:

We are adding standard deviations for fuel property averages calculated from two or more measurements.</td></tr>
<tr><td>5. Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics?</td><td>Yes the methods (vehicle selection, calculations, statistics, measurements, laboratory methods) were technically appropriate, reasonable, and expected for CO2 and FE type of experiments.</td></tr>
<tr><td>- 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.</td><td>I am not able to suggest any other method for conducting such an experiment. I feel the experiment was performed with minimal effort (size of experiments) and achieved the goals of its intent (a percent difference in changing Tier fuels).</td></tr>
<tr><td colspan="2">Author Response:

Thank you</td></tr>
<tr><td>6. Do the methodology, data, and analyses support the report's conclusion?</td><td>Yes the methods, data, and analysis support the report conclusion that:
1. The Tier 3 fuel has a -1.76% FE and -1.78% CO2 emission difference compared to the Tier 3 for the FTP cycle
2. The Tier 3 fuel has a -1.02% FE and -2.42% CO2 emission difference compared to the Tier 3 for the WHFE cycle</td></tr>
<tr><td colspan="2">Author Response:

Thank you</td></tr>
<tr><td colspan="2">7. Other Comments</td></tr>
<tr><td colspan="2">I would like to see additional data (means, 1 stdev, P10 and P90s) added to the appendix. This would include:</td></tr>
</table>

1. **Test cell conditions (Temp, Pres, and RH)**
2. **Other pollutants (as available) THC, CH4, NMHC, CO, PM (if collected) and NOx.**

The following are type-o's and other specific details to fix in the report:

- **Pg 2, 2nd Para. There is a reference to an Appendix, but I didn't see one.**
- **Pg 2, 3rd Para. ASTM reproducibility values. Are these larger variations in the values or larger standard deviations? The word choice was confusing for me.**
- **Table 3.1… If possible add the stdev of the measurements and the sample size to the foot note.**
- **Pg 7, 1st Para. The references is to only 1065. I suggest adding 1066 since there were updates for the calculations specific to 1066 (I was on the ASTM committee).**
- **Pg 7, 1st Para. The methane reference. Could you suggest methane contribution are low and specific a value to show how little that plays a role. I looked in a few of our publications (I can provide a reference if this would be of value) for GDIs and PFIs and found it was around 0.02 g/mi with E10 and Gasoline which is a factor of 0.01% for CO2.**
- **Pg 7, 1st Para. The N2O does show a change between gasoline and E20 as statd by a 2012 study published in Climate Change. The value went from 68 mg/km to 17 mg/km. Maybe you could add the fact there may be a change here, but it wasn't done in this study.**
- **Pg7 2nd Para. The reference 1066.80(b)2 does not exist. I looked in the eCFR for both 1066 and 1065. Please update or clarify.**
- **Pg7, 5th Para. Fuel drain procedures were very nice. From your table I estimate the vehicle gets about 1 hr to learn to adapt to the new fuel. That seems reasonable. Good job.**
- **Pg 11, 2nd Para. Second sentence seems to read strange. Please check.**
- **Pg 11, 4th Para. The "as for a one-tailed" seems to be worded strange. Please check.**
- **Pg 13, 2nd Para. You should say the two-sample t-test is the retrospective test since it is referred to in the next couple of sentences and bullets.**
- **Pg 15, Para 1, 2 and Pg 16 Para 2 and 3. You state what the statistics are suggesting. Ca you say that the statistically significant mean differences suggest the change from Tier 2 to Tier 3 is real and the value observed reasonable?**

The following question and answer were discussed as part of this review. In summary my question was answered and the report/data is valid as prepared and not additional discussion is needed for its clarification.

Simple Question: How could the ratio CO2/FE change (1-2%) when all the inputs to the FE equation are mostly constant or very small (usually < 0.2%) in comparison to CO2. If one of the variables causes the change what was the value for CO or CH4 or NMOG?

Detailed Question: The report shows, as expected, a difference in CO2 emissions and fuel economy (FE) for all the vehicles and the data is very tight and well done. The ratio of CO2/FE is plotted nicely in Figure 4.3.1 and 4.3.2 (great figures). CO2 emissions are directly measured and I understand that. The FE is calculated from equation 3.1 (see below) which I've seen and used before. What I'm not sure is how could the ratio CO2/FE change so much when CWF and SG are constants for each fuel so that will be a fixed ratio and NMOG, CH4, and CO are usually less than 1% of the FE and CO2 is 99% of the FE. Let me know what is causing the values to move around.

In summary this won't impact the overall average you reported and I agree with all the methods. I just didn't understand this so it is a minor point, but one to help me understand the results. The answer to this might be by providing supporting data in an appendix in case other have it as well.

From Section 3.3.2 Emissions Measurements:

Fuel economy values reported here were calculated using NMOG as indicated in 1066.870(b)2 and reproduced here in Equation 3.1. In this calculation the carbon weigh

$$FE = \left[\frac{CWF_{fuel} \cdot SpecificGravity_{fuel} \cdot 3781}{CWF_{exh} \cdot (NMOG + CH_4) + 0.429 \cdot CO + 0.273 \cdot CO_2} \right] \qquad \text{Eq. 3.1}$$

Author Response:

Thank you for highlighting these omissions and other corrections. These are being addressed with adjustments to the final report document. Below are some additional responses and clarifications.

The test cell conditions such as temperature, pressure and relative humidity were monitored and remained stable throughout the program as per CFR 1065 and 1066 requirements. A sentence will be added in section 3.4.

We will include raw data for additional pollutants in the appendix but will not complete additional analysis for them in the report as they were not the focus of the study and were not the priority. Measurement equipment for some non-target emissions was offline for some tests, resulting in incomplete datasets for these emissions. They have also not undergone as much quality assurance and validation as the CO_2 and FE data.

Additional detail was added to the report regarding how missing methane emissions were handled. Methane emission rates were below 0.005% of CO2 across the dataset.

Because of our lack of usable N_2O data for this program we do not feel it is appropriate to elaborate certification fuel impacts of N_2O.

Sample size and other statistics for the fuel properties would add significant complexity to Table 3.1 so we are adding these to the other detailed fuel info in Appendix A.

Simple/Detailed Question:

Response and clarified with a short conference call: The reviewer's statement that CO_2 and fuel economy values should have a fixed relationship across the dataset is reasonable for the reasons he stated. Before going any further, we should clarify that Figures 4.3.1 and 4.3.2 do not show such ratios, but absolute differences in test results by fuel and vehicle. We did not include plots of the ratios in the report, as we were keeping the scope focused on the measured results.

To make ratios that come out consistently across the data, we must use a consumption number like gallons per 100 miles instead of MPG. Plotting these ratios by test fuel and cycle produces four relatively tight groupings of points, with a clear separation of about 3% between fuels and very little difference between cycles. This should be reproducible using the values in the report, e.g., Tables 4.1.1 and 4.2.1.

Appendix A. Resumes of Selected Reviewers

1. Doug Fisher

Douglas W. Fisher

5726 Windermere Ln. Fairfield, Ohio 45014
Cell: 513-985-7138 dwfishmail@gmail.com

Project Engineer

Profile

Project Engineer with BS degree in Electrical Engineering Ohio State University. 17+ years in industry with proven ability to design, implement and manage complex research and development test programs for transportation and fuel and lubricant industry. Expertise in, light vehicle emissions and fuel economy test systems, underlying regulations, and laboratory procedures including, but not limited to the automotive, off-road engine and fuels & lubricants industry.

Key Expertise

Laboratory Management – Over 10 years of experience as Laboratory and Operations Manager for Vehicle and Engine Emissions and Fuel Economy Testing Laboratory. Key competencies include resource, budget and staff management and technical reporting. Held accountable for the success of assigned business subgroup as defined by internal business metrics and customer relationship successes. Identified potential process improvement topics, equipment and facility acquisition and upgrades, and employee cross-training opportunities toward future customer needs and business challenges.

Research Project Engineer – Experienced in managing both projects focused on both internal and external clients. Key expertise in laboratory process improvement, facility and on-road data acquisition, and data processing automation. Test stand development involving custom control software development for specialized test platforms and sampling systems.

Quality Systems Implementation - Led transition team assigned to implement emissions laboratory inclusion into existing TRC ISO 9001 Quality Management System and ISO 14001 Environmental Health and Safety System. This was necessary after TRC purchased laboratory operations of Automotive Testing Laboratories (ATL) in 2003. Team member of TRC ISO internal auditing, procedural Fault/Root Cause Analysis and program steering committee.

Career Highlights

As Project Engineer (1998-2007):

At TRC, in 2007, I was lead engineer to develop an indoor chassis dynamometer test platform to perform a modified version of ASTM D5598 Test Method for Evaluating Unleaded Automotive Spark-Ignition Engine Fuel for Electronic Port Fuel Injector Fouling. This main system requirement was to maintain consistent vehicle operation over 30 continuous test days. The hardware platform was based on National Instruments Fieldpoint with a Labview automation front end for user friendly control and monitoring. It was programmed to include safety interlocks with existing proving ground support services, facility alarm systems, and dynamometer control systems.

In 2004 I was the lead test engineer for integrating laboratory operating procedures into the existing TRC ISO-9001/14001 quality system. I Implemented a Microsoft Excel/Access relational database for maintaining vehicle and engine emissions and fuel economy test results, quality assurance records. This system was very effective at generating audit reports and preventive maintenance schedules and tracking analyzer quality and performance.

In 2002 I lead a team of engineers and technicians in the design, fabrication and control implementation of several gasoline LDV evaporative carbon canister evaluation systems. These systems were used in research and development of new activated carbon recipes for use in production vehicle evaporative emissions control canisters. Our approach allowed for rapid evaluation of the carbon working capacity benchmarking as well as durability aging of both production stage and development stage activated carbon canisters. This system utilized both gasoline vapor and 50/50 butane/nitrogen blends for either multi-day aging or overnight heel and capacity benchmark determination.

Lead project test engineer for USMC combat platform engine efficiency and fuel system improvement. A research study focused on a two-cycle diesel light infantry support engine was evaluated across multiple fuels both with and without abrasive flow machining of intake manifolds.

Lead test engineer for fuel efficiency evaluation of improved low friction wheel bearings for All-Wheel Drive Ford F150 Pickup Truck. This project was one of the first efforts to explore the sensitivity of the carbon balanced fuel economy test method when using a new state of the art light/medium duty All-Wheel drive chassis dynamometer.

In support of the ATL evaporative emissions testing group, I designed, programmed and packaged a custom in-vehicle driver’s aid and data acquisition system for collection of EPA/CARB fuel tank temperature profile data sets. The system allowed a single technician to duplicate the FTP transient drive profile over an outdoor on-road circuit while simultaneously capturing the fuel tank liquid and vapor temperatures and tank head space pressure. This system was heavily used during the initial introduction of the multiday diurnal evaporative emissions certification test for light duty gasoline vehicles in the late 1990’s.

The most significant technical project at ATL was the implementation of a PC based emissions test automation platform which allowed ATL to cut the test technician workforce by a factor of three. The system was completed in 1994 and optimized over the subsequent two years as it was deployed in Arizona and Indiana ATL locations. This system was utilized extensively at all three test sites for evaluation emissions and fuel economy of in use flex fuel and standard configuration vehicles in evaluation of alcohol gasoline blends and EPA directed oxygenated fuel blends. One highly trained technician/driver could prepare the vehicle, analyzer, driver’s aid and CVS system and execute the complete sample event and test execution from a single automated platform. This included time aligned modal emissions capture for three raw and dilute sample trains; CVS grab bag sample for regulated pollutants and chemistry lab samples for GC speciation of exhaust Hydrocarbons. This program utilized Horiba and Rosemount emissions analyzers, and PASCAL based software and some custom hardware for signal conditioning and serial communications integration.

All of the test equipment in these laboratory test cells was certified to meet the regulatory requirements of US Code of Federal Regulations Part 40, sections 86,89,90 as well as related but slightly different procedures such as US MSHA (Mining certifications), and European/ECE emissions and fuel economy protocols. I am familiar with all the measurement techniques and quality guidelines for validation and reporting of collected data sets. I have everyday experience in troubleshooting emissions sampling systems, including Constant Volume Samplers (CVS), particulate sampling tunnels, standard and non-standard pollutant analytical sample trains and analyzers, including Horiba, Fisher-Rosemount, Varian, and California Analytical.

As Laboratory Manager (1998-2007):

Starting in 1998 I began taking on an increasing role as the laboratory director. This added to my current project and systems engineering responsibilities, and included oversight of the bulk of the laboratory staff: mechanical, chemical, and electrical engineers (PHD, MS and BS), test technicians and certified automotive mechanics. The staff size varied from as high 20 to as low as five. I stressed the importance of cross training of non-professional staff to become indispensable to a business plan based on short duration vehicular research projects and regulatory scoping studies. Several significant facility installations were pursued during my tenure: including two electric chassis dynamometers, six engine test emissions analyzer systems and all laboratory particulate sampling and weighing equipment. In early 2003 the day-to-day aspects of running the business also included the role of transitioning the operation from ownership and management by Automotive Testing Laboratories, to Transportation Research Center (TRC). During my time under TRC ownership I also took on oversight of the chemistry laboratory portion of the research center. This included management of two chemistry lab technicians.

Employment Chronology

2007-current:	Aperiodic engineering consulting projects, web site development Self employed – Fairfield, Ohio
2003-07:	Project Engineer & Operations Manager of Emissions and Fuel Economy Laboratory: (TRC) Transportation Research Center Inc. – East Liberty, Ohio
2000-03:	Project Engineer and Ohio Director of Site Operations: (ATL) Automotive Testing Laboratories Inc. – East Liberty, Ohio
1996-00:	Corporate Lead Facilities Engineer: Corporate software and hardware Automotive Testing Laboratories Inc. – Ohio, Indiana & Arizona
1991-96:	Ohio Laboratory Site Manager: Manage Day to Day test operations Automotive Testing Laboratories Inc. – East Liberty, Ohio
1990-91:	Staff Engineer: Systems Automation Automotive Testing Laboratories Inc. – East Liberty, Ohio
1987-90:	Project Engineer Communications Systems United States Dept. of Defense -Fort Meade, Maryland

Education

1990	Loyola College Maryland : Graduate Classes : Programming of Government Systems
1982– 1987	Ohio State University, Columbus, Ohio : Graduate: BS Electrical & Computer Engineering

2. Jim Kemper

James M. Kemper

1280 Holland St., Lakewood, Colorado 80215
Phone: 720 363-1437
E-mail: jim.kemper@state.co.us

Biography

For the past eight years Jim Kemper has managed the Aurora High-Altitude Emissions Research Laboratory (AEL) for the Colorado Department of Public Health and Environment (CDPHE) researching vehicle emissions behavior at high altitudes in a certification-level laboratory. Most recently he has worked closely with EPA and other research staff to develop a unique method of identifying vehicle evaporative system problems using a remote sensing device. This multi-year project was used to calibrate a portion of the USEPA MOVES emissions model.

He is also coauthor of a journal article in E*nvironmental Science & Technology* on the emissions effects of mid-blend ethanol fuels on newer model vehicles.

Prior to working at CDPHE he was a research associate for eight years at the National Center for Vehicle Emissions Control and Safety at Colorado State University performing primary and secondary research on vehicle emission systems and fuels in a certification-level laboratory. He used knowledge gained in the laboratory to design and deliver training courses to various state emissions program staff and manufacturers on test program design and implementation issues.

Education

- **Colorado State University**
- **Bachelor of Science, Industrial Sciences**

Experience

Manager, Aurora High-Altitude Emissions Research Laboratory (2008 – present)
Colorado Department of Public Health and Environment (15608 East 18th Ave., Aurora, Colorado 80011)

- Provide technical support to the mobile sources program including primary and secondary research on development and/or modification of effects of I/M program design changes.
- Develop, design and implement research projects and supervise writing of reports.
- Provide testimony and advice to the Air pollution Control Division (APCD) and Air Quality Control Commission (AQCC) regarding development and courses of action with I/M program rules and regulations.
- Supervise four full-time professional staff and one administrative staff position.
- Provide on-site supervision and guidance of the Aurora Emissions Technical Center activities and programs.
- Establish unit goals and objectives to support overall program objectives. Create and supervise budgets including fiscal management and tracking processes for the Aurora laboratory.

Environmental Protection Specialist III (2001 – 2008)
Colorado Department of Public Health and Environment (4300 Cherry Creek Dr. South, Denver, Colorado 80246)

- Manage remote sensing device (RSD) operations including acceptance testing and software revisions.
- Co-authored the primary document in Colorado (COVERS) establishing technical standards and quality assurance and control methods for remote sensing device (RSD) emissions equipment.
- Compose the I/M program's Annual Report for the public, AQCC, and EPA by compiling and analyzing various program performance data and organizing it into report form.
- Create both simple and complex data queries for analysis of I/M inspection and RSD data.
- Provide testimony and support to the Air Quality Control Commission regarding environmental protection principles and state emissions inspection regulations.
- Provide presentations to repair technicians on technical aspects of automotive emissions and regulations.
- Draft regulations for action by the AQCC.

Research Associate (1994 – 2001)
Colorado State University, Fort Collins, Colorado 80523)

- Perform primary and secondary research of automotive emissions and equipment.
- Develop and implement study goals and designs.
- Produce technical reports and documents based on study results.
- Calibrate, maintain, and repair various laboratory emissions equipment including IR, FID, Chemiluminescence, constant volume samplers, and inertia dynamometers.
- Develop curricular materials to communicate complex technical information to both technical and non-technical audiences.
- Author of a legislator's guide to automotive inspection programs.
- Develop and present implications of inspection programs for the repair industry.
- Develop and present quality assurance and quality control design within emissions inspection programs.

Professional Experience

- National/International Conferences:

Speaker, *Annual Mobile Sources/Clean Air Conference*	1994-2006
Speaker, *OBD conference*, Ogden, UT	2000
Speaker, *I/M Solutions Conference*	2011-2016
Speaker, *NACE/CARS*	2013
Speaker, *Automotive Technical Expo*	2014
Speaker, *Workshop: Technical Basics of an Emissions Fee and Fuel Economy Standards for Imported Vehicles*, US State Dept. and Costa Rica	2015

- Projects and/or Co-Author:

Determine Percent of High Evaporative Emissions Vehicles in Fleet (Coordinating Research Council, E-77-3)	2008
Evaluation of Evaporative Leaks Using RSD and Inventory Implications	2010

Impact of Adaptation on Flex-Fuel Vehicle Emissions When Fueled with E-40, *Environmental Science & Technology* 2013

CRC, Preliminary Analysis of Long-Term Deterioration of Tier II Vehicles 2014

CRC, Emissions Deterioration Trends for Light-Duty Vehicles With Declining Emissions Standards 2015

CRC, Assessing the Differential Contributions of Age and Mileage On Emissions Deterioration 2016

- Completed the Leadership Development Program at CDPHE 2007-2008
- Professional Organizations
  Society of Automotive Engineers 1991-present

3. Dr. Kent Johnson

Kent Johnson
Associate Research Engineer, Emission and Fuels Group, CE-CERT
University of California, Riverside, CA 92521-0434 kjohnson@cert.ucr.edu (951) 781 5786

Education

PhD.	2009	University of California, Riverside	**Chemical and Environmental** Engineering
M.S.	2003	California State University, Pomona	**Electrical Engineering**, Controls
B.S.	1992	California State University, San Luis Obispo	**Mechanical Engineering**

Professional Experience

2015 – Present Associate Research Engineer, Step II, Emissions and Fuel Research, University of California, Riverside College of Engineering Research and Technology

My primary interests as a Research Engineer are studying the impact of primary source on local and regional air quality and greenhouse gas impacts. The programs I am PI or Co-PI have annual budgets of approximately $2,000,000. My responsibilities are creation and execution of budgets, proposal, report, and publication. I also supervise and mentor multiple graduate and undergraduate students in addition to professional staff. I also oversee the development, execution, and design of project testing, and the analysis and interpretation of test results, and the analysis needed for the preparation final reports and final publications. Recently one of my proposals included a cooperative project with the Mechanical Engineering department for the assessment of aerodynamics on heavy duty tractor trailers to broaden CE-CERT's collaboration with campus faculty.

2011 – 2015	Assistant Research Engineer, Step IV Emissions and Fuel Research, University of California, Riverside College of Engineering Research and Technology
2009 – 2011	Assistant Research Engineer, Step II Emissions and Fuel Research, University of California, Riverside College of Engineering Research and Technology
2008 – 2009	Principle Development Engineer, Emissions and Fuel Research, University of California, Riverside College of Engineering Research and Technology
2004 – 2008	Senior Development Engineer, Emissions and Fuel Research, University of California, Riverside College of Engineering Research and Technology
1998 – 2004	Associate Development Engineer, Emissions and Fuel Research, University of California, Riverside College of Engineering Research and Technology
1995 – 1998	Assistant Development Engineer, Emissions and Fuel Research, University of California, Riverside College of Engineering Research and Technology
1993 – 1995	Junior Development Engineer, Emissions and Fuel Research, University of California, Riverside College of Engineering Research and Technology
1990 – 1990	Mechanical Engineering Inter, Costa County Sanitation District, Martinez, CA
1989 – 1989	Engineering Inter, Badishe Stahl Werk (BSW) GmbH (Steel Factory), Kehl, Germany
1988 – 1988	Land Surveyor, Delmar Fults Civil Engineering, Modesto, CA

Grants/Contracts/Agreements – PI or CoPI

- California Air Resources Board (ARB) "Ocean-going Vessel Fuel and On-board Technologies Testing and Evaluation", 6/15 – 1/18 $225,000
- California Maritime Academy "Baseline Emissions Emulation of the Golden Bear Ocean Going Vessel" 6/15 – 10/15, $48,000.
- Matson "Evaluation of an Exhaust Gas Scrubber System on a Slow Speed Ocean Going Vessel", 2/16 – 9/16 $78,000
- Carnival Corporation "Measurement of Criteria Pollutant Emissions from a Cruise Ship's Exhaust Gas Reduction System:" 8/15 to 6/16 $78,000
- International Council on Clean Transportation (ICCT) "Marine Black Carbon Emissions Testing" 6/15 – 3/17 $350,000.
- Foss "Characterization Benefits of a Hybrid Tug Improvements, 5/15 – 10/15, $25,000

- ARB, “Evaluation of the impacts of emissions averaging and flexibility programs for all Tier 4 Final off-road diesel engines”, 7/14 – 6/16 $300,000
- ARB, “Evaluation of the feasibility, cost-effectiveness, and necessity of equipping small off road diesel engines with advanced PM and/or NOx aftertreatment”, 7/14/6/16 – 800,000
- ARB “Aerodynamic GHG Emissions Reduction Assessment of Non 53-foot Trailers Pulled by Heavy-Duty Tractors”, 7/14 – 6/16, $500,000
- AQMD “On-Road Heavy-Duty Development, Integration, and Demonstration of Ultra-Low Emissions Natural Gas Engines”, partnership with Cummins Inc. 5/14 – 6/ 17, 5,000,000 total project with 400,000 to UCR.
- ARB “Emissions Testing and Evaluation of Promising Control Technologies for Ocean-going Vessels and Other Port Equipment, 7/13 – 5/15 250,000
- ICCT “Measurements of Black Carbon Emissions from Ocean Going Vessels with Scrubbers” 7/13 – 3/15. $35,000
- ARB “Collection of Activity Data from On-Road Heavy-Duty Diesel Vehicles”, 10/13 – 10/15, $371,321
- Coordinating Research Council and ARB combined “Very Low PM Measurements for Light-Duty Vehicles (E-99)”, 10/12 – 6/14, $436,558
- Southeast Missouri Regional Planning Commission “Emission Benefits from Repowering the MV Daniel W. Wise” 10/12 – 7/15, Total project 2,570,000 with UCR portion at 120,000. Funded by MARAD
- TransPower “IKEA Electric Yard Truck Performance and Evaluation”, $1,000,000 + total project with $100,000 to UCR
- CEC “Plug-in LNG Hybrid Heavy-duty Truck (PLHT)” $1,632,268 total project with $200,568 to UCR 4/2012 – 3/2014
- Council SCAQMD “In-Use Emissions Testing and Demonstration of Retrofit Technology for Control of On-Road Heavy-Duty Engines”, 11/2/2011 – 12/01/2013, $708,534.
- EmiSense, PM Sensor: Research and Development, 11/12 – 1/13, $19,747
- EmiSense, Analysis and Testing of the EmiSense Electronic PM Sensor on various Heavy Duty Diesel Vehicles, Fundamental research and Graduate Student Direction, 16,154 8/1/2011 – 12/31/2012
- CalTrans, Developing a Model to Quantify Emissions from Heavy-Duty Construction Equipment as Related to Job Site Activity Data 11/2011 – 11/2013, $200,000
- ENVIRON International Corporation, Demonstration of Battery-Powered, Heavy-duty Truck, 6/1/2012 to 12/31/2012, $11,977
- ARB, Hybrid Off-Road Equipment In-Use Emissions Evaluation, 7/1/2011 – 6/2013, $2,000,000
- ARB, Gravimetric PM measurement system, 12/3/2010, 300,000
- AVL’s M.O.V.E. 1065 Audit and Correlation Evaluation, 5/2011 – 6/2013, $250,000
- Tetra Tech “Comparing Criteria and Greenhouse Gas Emissions from a Conventional Diesel and a Prototype Hybrid Yard Tractor, 2009 - 11/2010, $80,000
- ARB, “PM PEMS Measurement Allowance Program”, 3/09-6/10, $650,000
- South Coast Air Quality Management District (SCAQMD), “Assessment of Emissions from Use of Biodiesel as a Motor Vehicle Fuel in California: Biodiesel Characterization and NO_x Formation and Mitigation Study,” 8/08-11/09, $150,000.
- ARB, “Assessment of Emissions from California Air Resources Board Qualified Diesel in Comparison with Federal Diesel,” 6/08-5/10, $1,280,000.
- URS Inc in cooperation with Burlington Northern Santa Fe (BNSF), San Bernardino Intermodal Rail Yard “Truck Activity and Emissions for the BNSF Facility in San Bernardino”, 6/08 – 6/09, $50,000
- Miratech Corporation and SCAQMD, “Selective Catalytic Reduction combined Diesel Particulate Filter Efficiency and Durability Evaluation on a In-Use Metrolink Locomotive Auxiliary Engine”, 3/08-12/09, $100,000
- Johnson Matthey, “Continuously Regenerative Particulate Trap Efficiency and Durability Evaluation”, 11/07 – 11/08, $127,000.
- Engine Manufacturers Association (EMA) “PM Measurement Allowance Phase 1: On-Road Testing Using the CE-CERT Mobile Emissions Laboratory.” 11/07-6/09, $192,770.
- ARB with contributions from EMA and EPA, “In-Use Evaluation of PM PEMS pre Measurement Allowance Characterization”, 6/07-2/09, $284,667.
- ARB, “Assessment of Emissions from Use of Biodiesel as a Motor Vehicle Fuel in California: Biodiesel Characterization and NOx Formation and Mitigation Study,” 6/07-6/09, $1,280,000.
- ARB, “Evaluation of the Proposed New European Methodology for Determination of Particle Number Emissions and its Potential in California for In-Use Screening”, 6/06-9/07, $250,000.

- ARB with contributions from EMA and EPA, "Gaseous Measurement Allowance Project", 6/06 – 6/07 $550,000.
- O2 Diesel, "Emissions Testing Related to the 0$_2$DieselTM Demonstration Program at the Nellis Air Force Base," 11/05-12/06, $400,000.
- California Energy Commission (CEC) "Methodology to Assess Air Quality Impacts of Distributed and Backup Generation", 6/02-6/03 $1,500,000 of which $700,000 is testing and demonstration.
- Miratech Corporation, "Catalyzed Diesel Particulate Retrofit Trap Efficiency and Durability Evaluation on a Back-up Generator", 4/05 – 2/06, $125,000.
- ARB, "Evaluation of Portable Emissions Measurement Systems (PEMS) for Inventory Purposes and the Not-To-Exceed Heavy-Duty Diesel Engine Regulation", 6/04-6/06, $250,000
- Cummins Inc, "Program for the Study of Diesel Engines, Fuels, and Emissions", 6/00, 6/02, $600,000.
- ARB "ARB M-17 Program for Heavy-Duty Truck Emission Reduction" 6/03 – 6/04, $180,000.
- ARB, "Development of a Secondary Dilution System for measuring PM and Toxic Emissions from Diesel Engines", $150,000.
- EPA "Evaluation of Emissions from On-Road Heavy Duty Mobile Sources", $380,000.
- EPA "Study of On-Road Diesel Engines, Fuels and Emissions", $200,000.
- EPA "Evaluation of Emissions from On-Road Heavy Duty Mobile Sources", $250,000
- ARB "Portable Diesel Engine Cycle Development & Control", $208,000.
- ARB "Stationary Source Diesel Particulate Matter Control Technology Demonstration Program", $230,000
- Department of Energy, "Evaluation of an Oxygenated Diesel Fuel", $1M of which $220,000 is at UCR.
- Strategic Environmental Research & Development Program, "Characterization of Off-road Diesel Vehicle Emission of Criteria Air Pollutants from Military Vehicles", $2.5M of which UCR is ~$1,000,00 for 4 years
- Wright-Patterson AFB, "Ethanol-Diesel Research and Analysis Program, Phase 1, Work at Nellis AFB", $1M of which $400,000 is at UCR

Honors and Activities

- 2014 – Invited tutorial speaker for AAAR Conference
- 2012 – **Present** Intermediate Referee for Riverside's American Youth Soccer Organization (AYSO)
- 2012 – **Present** Advanced Coach for Riverside's American Youth Soccer Organization (AYSO)
- 2008 – 2012 Referee for Riverside's American Youth Soccer Organization (AYSO)
- 2007/08 University of California Transportation Center (UCTC) fellowship award
- 2007 – 2009 Particulate Matter In-Use Measurement advisory panel
- 2007 – **Present** Emissions Measurement and Testing Committee (EMTC) participant
- 2006/07 University of California Transportation Center (UCTC) Fellowship Award
- 2005 – 2012 Coach for Riverside's American Youth Soccer Organization (AYSO)
- 1998/1999/2000 Department of Energy Ethanol Challenge staff supervisor (4th, 3rd, and 2nd place respectively)
- 1997 Department of Energy Propane Challenge staff supervisor
- 1995 Certificate in applied programmable logic controllers Cal State, Fullerton
- 1995 ASME Certificate in Applied Controls/Mechatronics
- 1994 Finite Analysis Certificate in COSMOS/M + Optimization
- 1994 through 1998, 2003, and 2005 University of California professional development awards
- 1994 Department of Energy Solar Challenge staff supervisor (1st place)
- 1994 Certificate in TIG and MIG welding
- Member of Society of Automotive Engineering and American Society of Mechanical Engineering

Journal Articles (Refereed)

- Tanfeng Cao, Robert L. Russell, Thomas D. Durbin, David R. Cocker III, Andrew Burnette, Joseph Calavita, Hector Maldonado and **Kent C. Johnson**,, 2015, A Generalized Approach for Characterizing Emissions Benefits of Hybrid Off-Road Equipment via Physical Activity and Engine Work: A Case Study for Bulldozers, submitted 2016.
- Tanfeng Cao, Robert L. Russell, Thomas D. Durbin, David R. Cocker III, Andrew Burnette, Joseph Calavita, Hector Maldonado and **Kent C. Johnson**,, 2015, A Generalized Approach for Characterizing Emissions Benefits of Hybrid Off-Road Equipment via Physical Activity and Engine Work: A Case Study for Excavators, submitted 2016.

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Papers in preparation

- E-99-1 Main program
- E-99-1 Filter survey
- Tier 0 repower benefit
- NTE paper in-use HDV
- Heavy duty all electric GHG benefit
- Ultra-low NOx NG HDV
- Marine PM scrubber impacts

Invited Technical Expert

- Discovery MythBusters Episode "Hypermilling" September 2012
- Discovery MythBusters Episode "Cars Vs Motorcycles" November 2011
- ASTM PM methods for light duty vehicles

Invited Presentations

- MECA Annual Washington Meeting 2014
- AAAR Tutorial on "Emerging Engine Technologies" 2014
- Invited presenter to ICCT 2014 on Black Carbon Short Lived Climate forcing measurements
- Clean Air Tech Initiative, November 14, 2013
- Cal Baptist Engineering Class 2011

Hosted Workshops

- 2016 Portable Emissions Measurement Systems Workshop (attended by 200 + people, 8 nations, 60 institutes)
- 2015 Portable Emissions Measurement Systems Workshop (attended by 145 + people, 7 nations, 53 institutes)
- 2014 Portable Emissions Measurement Systems Workshop (attended by 150 + people, 8 nations, 54 institutes)
- 2013 Portable Emissions Measurement Systems Workshop (attended by 150 + people, 7 nations, 55 institutes)
- 2012 Portable Emissions Measurement Systems Workshop (attended by 175 + people, 8 nations, 60 institutes)
- 2011 Portable Emissions Measurement Systems Workshop (attended by 135 + people, 5 nations, 46 institutes)

Presentations

- Presentations every year at CRC, AAAR, DEER, AWMA, and UCR-PEMS. Averages 2-3 presentations at each conference.
- Additionally I present once per year to ARB and AQMD

Technical Reports (Selected) where I averaging 10 per year.

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- Durbin, T.D., Miller, J.W., **Johnson, K.C**., and Hajbabaei, M. (2011) Assessment of the Emissions from the Use of California Air Resources Board qualified Diesel Fuel in Comparison with Federal Diesel Fuels, Draft final report for the California Air Resources Board by the University of California at Riverside, June.
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Appendix B. Conflicts of Interest Declarations

1. Doug Fisher (Industry group)

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-16-020, Work Assignment 0-06

Subject Report: Tier 3 Certification Fuel Impacts Test Program

Subcontractor/Peer Reviewer: Doug Fisher

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.

Douglas W. Fisher

Subcontractor/Consultant

1/13/2017

Date

100 Cambridgepark Drive, Suite 500 — Cambridge MA 02140 — 617.250.4200 — 617.250.4261 fax — www.icfi.com

2. Jim Kemper (Government group)

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-16-020, Work Assignment 0-06
Subject Report:	Tier 3 Certification Fuel Impacts Test Program
Subcontractor/Peer Reviewer:	Jim Kemper, Colorado Department of Public Health

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.

Jim Kemper
Subcontractor/Consultant

1-25-17
Date

100 Cambridgepark Drive, Suite 500 — Cambridge MA 02140 — 617.250.4200 — 617.250.4261 fax — www.icfi.com

3. Dr. Kent Johnson (Academics group)

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-16-020, Work Assignment 0-06
Subject Report:	Tier 3 Certification Fuel Impacts Test Program
Subcontractor/Peer Reviewer:	Kent Johnson, University of California, Riverside

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

1/18/2017
Date

100 Cambridgepark Drive, Suite 500 — Cambridge MA 02140 — 617.250.4200 — 617.250.4261 fax — www.icfi.com

Appendix C. Peer Reviewer Mid-review Meeting Notes

1. Mid-Review Meeting Notes, January 18, 2017

SUMMARY NOTES:
PEER REVIEW FOR TIER 3 CERTIFICATION FUEL IMPACTS TEST PROGRAM REPORT
MID-REVIEW MEETING
JANUARY 18, 2017 – 3:30 PM

Attendees:

Connie Hart, EPA
Kent Helmer, EPA
Aron Butler, EPA
Angela Cullen, EPA
Tony Fernandez, EPA
James Warila, EPA
Seth Hartley, ICF
Andie Fritz, ICF
Doug Fisher
Kent Johnson, University of California, Riverside
Jim Kemper, Colorado Department of Public Health and Environment

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Welcome, Introductions, and Roles

Seth Hartley, ICF gave an overview of the peer review program generally, and as applies to the report, "Tier 3 Certification Fuel Impacts Test Program." He then confirmed that the reviewers received their technical packages. Each package included a charge letter, conflict of interest form, and report for review.

All participants then gave brief introductions of themselves and their background.

Seth asked reviewers to respond to all charge questions and maintain the tabular format. Also to submit a cover letter that includes their name, name and address of their organization, if applicable, and a statement of any real or perceived conflict(s) of interest. A completed conflict of interest form is also required. All were provided in the reviewer package.

Schedule

Seth gave an overview of the project's schedule. Last Wednesday, January 11 ICF sent the charge letter, COI forms, and report to all reviewers. The review deadline is Wednesday, January 25, 2017. All reviews will be returned to ICF (to Andie Fritz). ICF will then compile all comments and share with EPA.

Overview of the Project and Report

Connie Hart, EPA, gave a brief overview of the report. The study was developed to identify differences between Tier 2 and Tier 3 certification fuels. The test program attempted to control all known variables. The same cycle sequences were tested on a daily basis, at the same site, using the same driver. The vehicles were prepared for fuel with triple drain and given initial driving time for the vehicle to adapt to the new fuel. The study compared carbon dioxide (CO_2) with typical criteria. An acceptance variable of 3% is common, but was considered too high for this study.

Reviewers asked about the peer review process. EPA noted that the peer reviewers' comments and EPA's responses, will be documented and filed.

Open Discussion and Questions

The meeting then turned to open discussion to answer the reviewers' questions.

Jim Kemper, CDPHE asked if the ~3% variable was determined from test to test. EPA responded yes and that the compliance division accepts this range, but that percentage was too large for this study.

Doug Fisher asked about the overall peer review process. He asked if the report for review is considered the first draft and if it is typical to incorporate comments from a peer review into the final version of the report. EPA explained the process. EPA responded that it is required to respond to all peer review comments. If EPA feels that a comment is valid, they will incorporate it into the final version. If a reviewer comments that they did not understand certain content, the report will be modified to clarify that content. If EPA feels that the reviewer misunderstood certain content, EPA would also clarify that content. Additionally, if EPA fully disagrees with a reviewer's comment, then EPA would state their reasoning for not modifying the report.

A reviewer asked if hybrid vehicles were included in this study. EPA responded that only conventional vehicles were used to ensure that the fuel effect signal was not masked in a hybrid's start-stop application.

Jim Kemper, CDPHE, asked about barometric pressure effects, noting that they have seen pressure's influence on PM testing. EPA responded that barometric pressure was recorded daily but they did not use it as a criteria for additional testing or delay testing. However, it would be of interest if it has an effect on CO_2 or fuel economy. The study involved lighter duty test cycles and the vehicles never reached peak power or peak flow exhaust. Jim responded that he agreed with the earlier comments and that this is a narrow consideration for fuel economy.

Jim Kemper asked if all base fuel was taken from the same batch to avoid differences in base fuel energy content. EPA responded yes, that two fuels were used and taken from the same batch. The fuels were also sampled weekly to ensure all properties were consistent.

Doug Fisher asked if EPA considered any additional studies to determine the course of this test plan. EPA noted its reliance on studies for EPACT. EPA used this study to review changes in criteria emissions and develop a test program focused on CO_2. EPA did not design the fuels as they were already certified, but put the two fuels into the EPACT model.

A reviewer asked if the study considered the US06 cycle test. EPA responded that it was not included in the report because US06 is not required for certification.

Doug Fisher asked if EPA will be preparing appendices to the report and suggested specific items, such as equipment used. EPA responded that they did not plan to add appendices, but it is possible to include them. They have this information, but it is not in publishable form at this time.

Next steps

During the review period, the reviewers will send any questions to ICF. ICF will forward the questions to EPA. ICF will then share all questions and responses with the entire review team.

The review deadline is Wednesday, January 25, 2017. All reviews will be returned to ICF.

2. Follow-On Reviewer Teleconference Notes, January 25, 2017

SUMMARY NOTES:
PEER REVIEW FOR TIER 3 CERTIFICATION FUEL IMPACTS TEST PROGRAM REPORT
MID-REVIEW MEETING
JANUARY 25, 2017 – 1:15 PM

Attendees:

Connie Hart, EPA
Kyle F., EPA
James Warila, EPA
Seth Hartley, ICF
Andie Fritz, ICF
Doug Fisher
Kent Johnson, University of California, Riverside

Open Discussion and Questions

Doug asked about the CFR reference for equation 3.1. He could not find the section in the CFR. EPA responded that it was from an earlier draft version and has not been added to the CFR yet. EPA noted could redo the calculations using the current CFR equation, but would not affect results significantly. EPA will fix in the report. EPA also noted the same equation was used for both fuels to allow comparison. Finally, EPA noted heating value is not included in this version of the equation. Doug suggested that EPA explain the equation better in the report. EPA to consider how to implement.

Kent asked if fuel economy is calculated from the equation or measured. EPA clarified it is calculated from the equation and that Kent's question was on the right track. The ratio of CO2 emissions in gram/mile, divided by fuel economy in consumption space, clusters by fuel and by test cycle. There is a fixed and repeatable ratio between CO2 and fuel economy, so long as fuel economy is represented as gallons/100 mi instead of mpg. However, this is not what's shown by the figures, which come directly from the emission tests.

Also, two minor questions were clarified. First, that the report under review is considered a draft, even though it is not marked as such. EPA will be making updates to the report based on the peer reviewer's comments. Second that email submission of reviews, any time tonight, is adequate. Reviews can be submitted to either or both Seth (Seth.Hartley@icf.com) and/or Andie (Andie.Fritz@icf.com).