COORDINATING RESEARCH COUNCIL, INC.
5755 NORTH POINT PARKWAY, SUITE 265
ALPHARETTA, GA 30022
TEL: 678/795-0506 FAX: 678/795-0509
WWW.CRCAO.ORG

June 14, 2016
In reply, refer to:
CRC Project No. AVFL-28

Dear Prospective Bidder:

The Coordinating Research Council (CRC) invites you to submit a written proposal to provide services for "**Gasoline Direct Injection (GDI) Engine Wear Test Development**" (CRC Project No. AVFL-28). A description of the project is presented in Exhibit A, "Statement of Work."

Please indicate by letter, fax, or email on or before **June 28, 2016** if you or your organization intends to submit a written proposal for this research program. If you organization intends to prepare a proposal the project technical panel is requesting that a teleconference be held to discuss the project statement of work and answer questions prior to preparing the written proposal. This teleconference can be scheduled with CRC staff at the time the "intent-to-bid" notification is delivered.

A CRC technical group composed of industry and possibly government representatives will evaluate your proposal. CRC reserves the right to accept or reject any or all proposals.

The reporting requirements will be monthly progress reports and a summary technical report at the end of the contractual period. The reporting requirements are described in more detail in the attachment entitled "Reports" (Exhibit B).

The proposal must be submitted as two separate documents. The technical approach to the problem will be described in Part One, and a cost breakdown that is costed/priced by task will be described in Part Two. The cost proposal document should include all costs associated with conducting the proposed program. The technical proposal shall not be longer than 20 pages in length.

CRC expects to negotiate a cost-plus fixed fee or cost reimbursement contract for the research program but may also elect to conduct the desired work through a fixed price agreement.

Contract language for intellectual property and liability clauses is presented in Exhibit C and in Exhibit D, respectively. Bidders are also advised that government funds may be used to support the research, and therefore certain government contract terms and conditions may apply in this case. However, at this time no government funds are anticipated.

Important selection factors to be taken into account are listed in Exhibit E. CRC evaluation procedures require the technical group to complete a thorough technical evaluation before

considering costs. After developing a recommendation based on technical considerations, the costs are revealed and the recommendation is modified as needed.
Electronic copies of the technical and cost proposals should be submitted to:

Brent K. Bailey
Coordinating Research Council
5755 North Point Parkway, Suite 265
Alpharetta, GA 30022
E-mail: bkbailey@crcao.org

Phone: 678-795-0506
Fax: 678-795-0509

The deadline for receipt of your proposal is **August 5, 2016.**

Yours truly,

Brent K. Bailey
Executive Director

EXHIBIT A
STATEMENT OF WORK

AVFL-28 Gasoline Direct Injection (GDI) Engine Wear Test Development

Statement of Need

Existing engine lubricant wear tests based on ILSAC and ACEA specifications were developed for engines and operating conditions representative of port fuel injection (PFI) engine technology. But the automotive industry is trending away from PFI engines toward GDI technology. Approximately 40% of passenger cars sold in 2014 had GDI engines. In many cases, GDI engines are turbo-charged.

Turbocharged GDI engines often produce more severe operating conditions than PFI engines. Turbo GDI engines operate at higher temperature, higher cylinder pressure, and higher specific torque. Turbo GDI engines are often downsized, causing them to operate at higher load for a larger fraction of operating time. Some modern engines also use alternative combustion cycles (Miller/Atkinson, for example) or stop/start technology which subjects the engine and lubricant to new types of stress compared to conventional PFI engines. Some turbo GDI engines use certain lubricated components not represented in current wear tests based on PFI engines. For example, turbocharger bearings, polymer-coated bearings, and aluminum alloy bearings. For these reasons, a new test for turbo GDI engines is needed to be representative of current and future engine technologies.

Objective

The project objective is to develop a procedure for testing wear performance of engine lubricant (motor oil) for use in turbocharged GDI engines operating in high-fuel-economy duty cycles. Elements of this test protocol include:

- Test engine candidates
- Test engine configuration and component selection
- Test engine operating conditions
- Test methods and criteria to measure engine wear
- Criteria to rate lubricant performance

The goal of the Coordinating Research Council (CRC) is not to set lubricant testing specifications, nor to develop an engine test for lubricant certification, but rather to perform sufficient testing to make recommendations regarding suitability of the test elements listed above. These recommendations would then be provided to existing lubricant standards-setting organizations that may develop lubricant specifications and engine wear tests as they see fit based on project findings.

The purpose of this project to determine general sensitivities of turbo GDI engine technology and develop appropriate operating conditions to test those sensitivities. The purpose is not to point out the sensitivities or weaknesses of any particular engine model.

Engine Selection Criteria and Candidates

The test engine was chosen based on the following criteria. Although not all these criteria will necessarily be met in the chosen test engine, all were considered during engine selection.

- Representative of future direction of engine technology
- Early in product lifecycle
- Wide availability
- High volume of similar engines in production
- Test engine already set up (secondary consideration affecting budget control and timing)
- Manufacturer approves use and provides support
- High brake mean effective pressure (BMEP), high load, high torque, high individual cylinder loading
- Turbo, stop/start, downsized, variable valve timing
- High power density – time at high torque for engine in heavy vehicle
- Twin-turbo (desirable but not necessary)
- High efficiency/dilute technology i.e. cooled exhaust gas recirculation (EGR)
- Low emissions
- Lean burn operation
- Coatings i.e. diamond-like coating (DLC), phosphate
- Low viscosity grade for fuel economy improvement
- Variable displacement oil flow system

Candidate engines and their characteristics were evaluated by the project technical panel and a single test engine was selected for the current test program.

Test Engine

We selected the Ford 2.0 EcoBoost engine. Use of this engine will reduce cost and save time, since this is the same engine used in chain wear and low speed pre-ignition (LSPI) tests.

Types of Wear

The types of wear that are of interest include valve train (valve guides, cams, shims, and timing chain sliding and contact wear), cylinder liner wear, rings, and bearings (connecting rods, main, and turbocharger).

Test Protocol - Engine Operating Conditions

Our approach is to test various types of operating conditions expected to subject the engine oil to severe conditions (especially prolonged time at high temperature) and/or subject the engine to high-wear events. Each of these high-severity operating conditions will be evaluated to determine the effect on engine wear, either alone or in combination. Certain of these operating conditions or combinations thereof will then be recommended for inclusion in future GDI lube oil certification tests based on their effect on wear rates. Operating conditions of interest for this current phase of testing include.

- Transient load
- Wide open throttle (WOT) (steady state and transient)
- High Load (BMEP)
- High torque at low speed
- Boundary lubrication (low speed, high load)

- Hydrodynamic lubrication (high speed, low load)
- Mixed boundary and hydrodynamic (moderate speed, high load)
- Trailer tow/max gross combined vehicle weight (GCVW) (simulation of Davis Dam trailer towing test near Las Vegas, an SAE test procedure)
- Cold start
- Viscosity grade
- Turbo boost active
- Stop/start
- Demonstrate repeatability of high wear operating conditions

Proposed operating conditions are tabulated in Table I and shown graphically in Figures 1 through 5. We expect certain engine operating conditions and test cycles to produce higher wear of certain engine parts. These expectations are tabulated in Table II.

Table I. Test Protocol – Engine Operating Conditions (current scope of work only)

Description	Speed	Load	Temp-erature	Utilization Rate	Comments
1) Baseline – Steady State (SS)	Low Moderate High	Low Low Low	Warm	100%	Low wear Moderate speed - Highway driving
2) Transient Load	Low High High	Low to high Low to high High to low	Warm	100%	
3) Transient Speed	Low to High Low to High	Low High	Warm	100%	
4) WOT SS	Low Moderate High	High High High	Hot	10%	Also represents High Load, Mixed Boundary/ Hydrodynamic Lubrication, and High Torque/ Low Speed
5) WOT Transient	Low to High	High	Hot	30%	
6) Boundary Lubrication	Low to Very Low	High	Hot	10%	Start at 2000 rpm, decrease to 800 rpm
7) Hydrodynamic Lubrication SS	High	Low	Warm	5%	Engine braking down grade, steady-state engine revving
8) Trailer Tow SS	Moderate	High	Hot	20%	Extended time
9) Trailer Tow Transient – Engine Lugging			Very Hot	20%	Start at low speed/max load, decrease load incrementally below max load, increase speed at just below max load curve to high speed/high load, increase load incrementally above max load (causing engine lugging), allow engine to slow to low speed/high load, reduce load to just under max load (to prevent engine stall), repeat for extended time
10) Cold Start	Zero to Moderate	High	Cold to warm	30%	Cold start followed by hard acceleration for 3 minutes, repeat after engine cools
11) Turbo Active – SS Turbo	Moderate	High	Hot	70%	Oil frothing from exhaust gas migration into turbo seals at high turbine temperature
12) Turbo Active – Transient Turbo Wind Up	Low to Moderate	Low to high	Hot	70%	Hard acceleration, onramp merge, promotes oil frothing/ aeration by exhaust gas.
13) Stop/Start – City driving in engine stop-start mode			Hot	50% in vehicles so equipped	Hot start, immediate hard acceleration at high load to moderate speed for 20 sec, drop to low load/ moderate speed for 10 sec, stop engine, hot soak 1 min, repeat for hours
14) Low Viscosity Grade					Repeat high and moderate wear conditions
15) Repeatability					Repeat high and moderate wear conditions

Notes: Utilization Rate is estimated percentage of customers who sometimes use this operating mode. Utilization rate of 70% is assumed for #12 Turbo Active – Transient Turbo Windup operating condition because smaller turbos remain at higher turbine speed longer, especially during highway cruise.

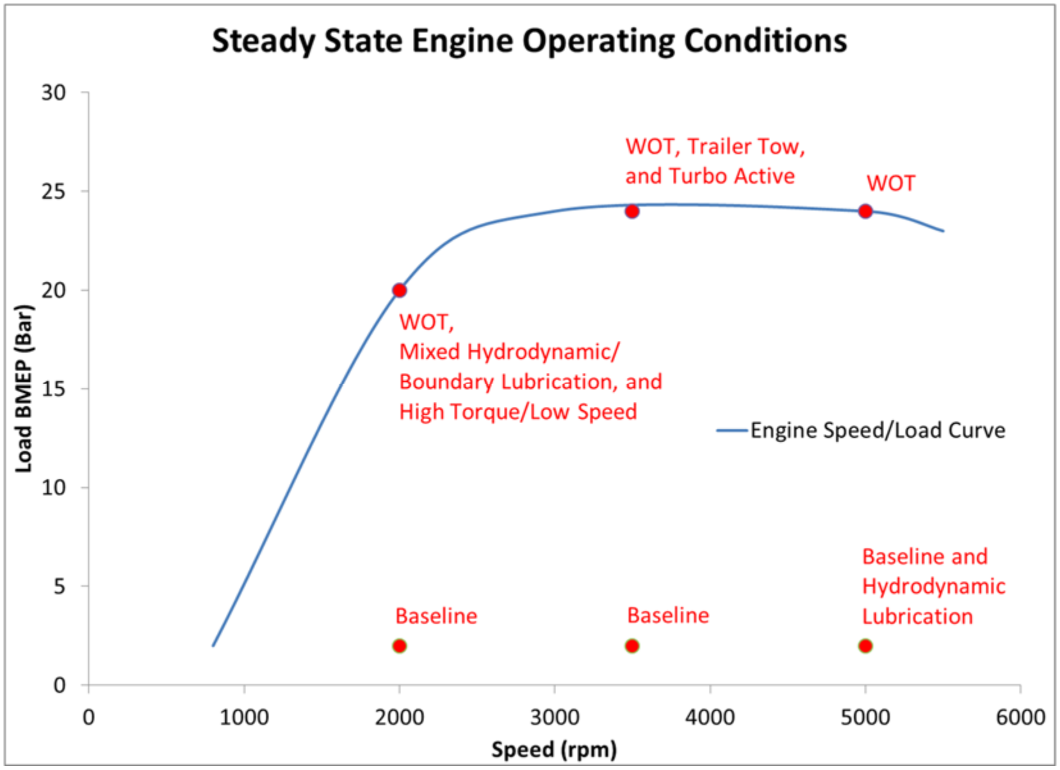

Figure 1. Steady State Engine Operating Conditions

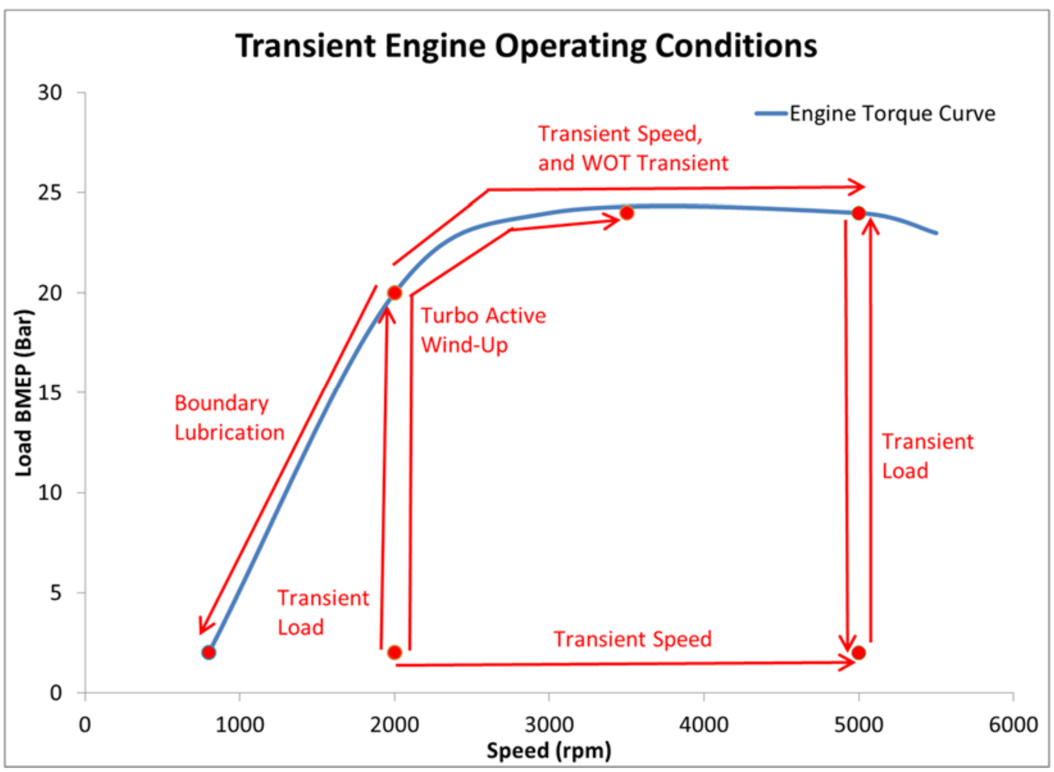

Figure 2. Transient Engine Operating Conditions

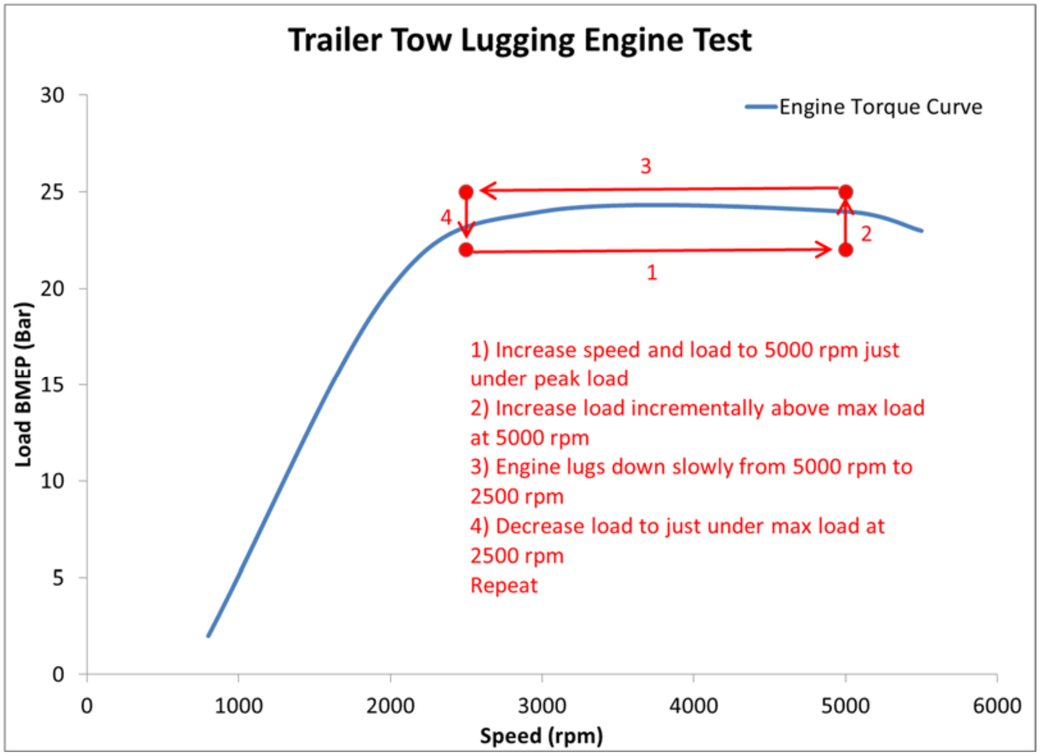

Figure 3. Trailer Tow Lugging Engine Test

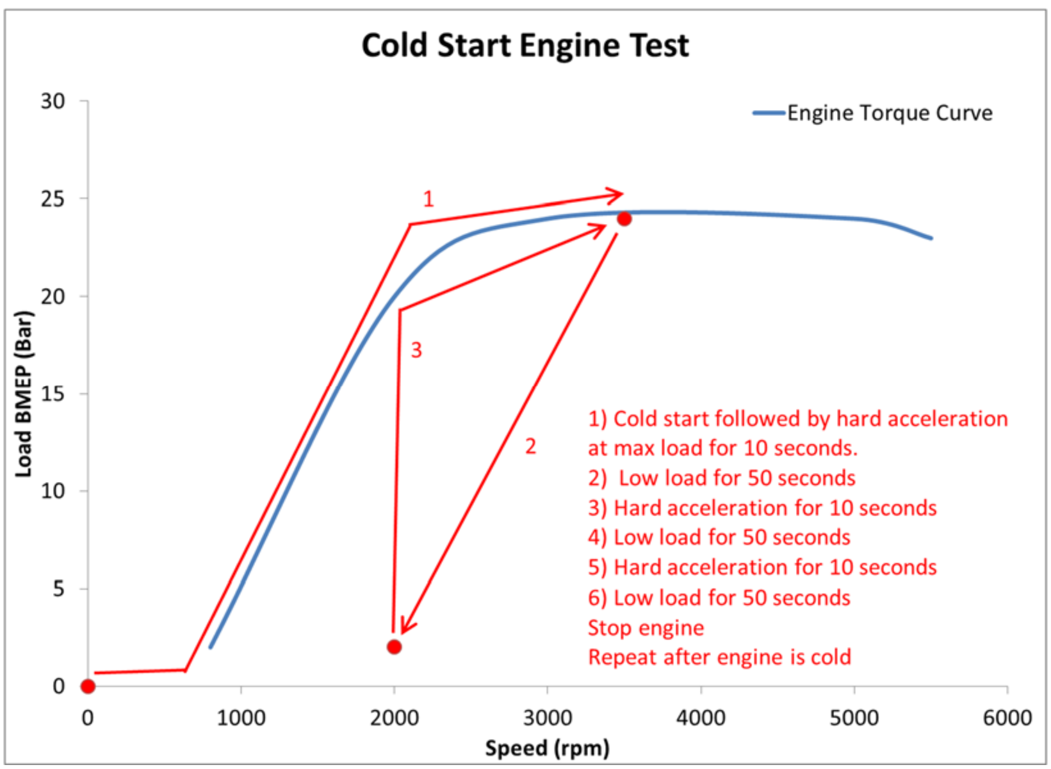

Figure 4. Cold Start Engine Test

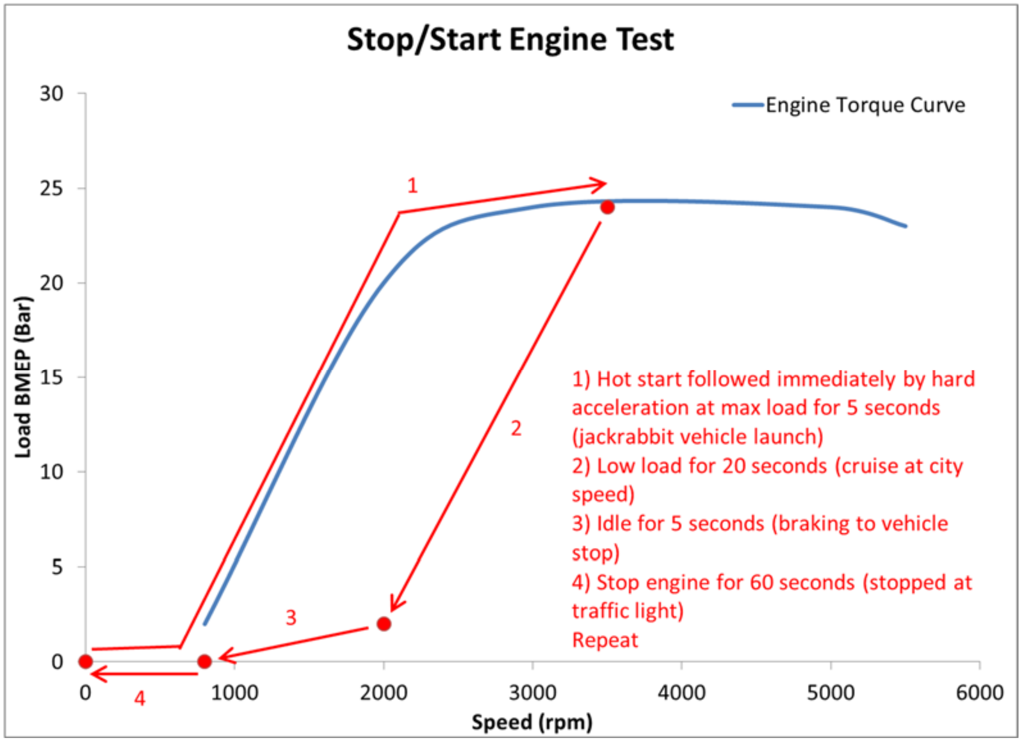

Figure 5. Start/Stop Engine Test

Table II. Operating Conditions Expected to Cause High Wear in Engine Components

Operating Condition (From Table I)	Cams and Shims	Valve Guides	Timing Chain	Cylinder Liner	Piston Rings	Bearings (Con Rod, Journal)	Turbo Thrust Bearings
1) Baseline SS							
2) Transient Load	X (f)		X (f)	X (b)	X (b)	X	X
3) Transient Speed	X (f)		X (f)	X (b)	X (b)	X	X
4) WOT SS	X (f)	X (e)	X (f)	X (b)	X (b)	X (c,h)	X
5) WOT Transient	X (f)	X (e)	X (f)	X (b)	X (b)	X	X
6) Boundary Lube	X (g)			X (b)	X (b)	X (c,g,i)	
7) Hydrodynamic Lube SS	X (f)		X (f)			X (h)	
8) Trailer Tow SS		X (e)				X	X
9) Trailer Tow Trans.	X (f)	X (e)	X (f)	X (b)	X (b)	X (c)	X
10) Cold Start	X (d)	X (d)	X (d)	X (a,b)	X (b)	X (c,d)	X
11) Turbo SS		X (e)					X
12) Turbo Trans.				X (b)	X (b)	X (c)	X
13) Stop/Start	X (d)	X (d)	X (d)	X (a,b)	X (b)	X (c,d)	
14) Low Viscosity	X		X	X	X	X	

Notes: a) Piston skirt to cylinder scuffing at low temperature. (1)
b) Broken lube film at compression ring to cylinder liner at low speed and high load. (1)

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1) S. Tung, G. Totten, Automotive Lubricants and Testing, ASTM International, 2012, Chapters 6, 8, and 19.

c) Broken lube film in bearings under low speed, high load or start/stop. (1)
d) Oil starvation at start-up. (1)
e) Hot operation and high load stresses valve guides. (1)
f) Greater inertial contact loads for valvetrain at high speed. (2)
g) Broken lube film at low speed. (1)
h) High speed increases risk of oil shearing and hot spots in journal bearings. (1)
i) Rod and Journal bearings are subject to wear due to boundary layer lube conditions.

Regarding repeatability testing, we request the bidder make a recommendation regarding statistical design of experiments including the number of repeat tests that will likely be required to produce a statistically significant repeatability determination. Since we don't know ahead of time how many operating conditions will produce moderate or high wear, we request the bidder provide separate cost breakouts for repeatability testing making some simplistic assumptions; 1) Four test operating conditions in Table I produce high or moderate wear and require repeatability testing. 2) Eight operating conditions require repeatability testing, and 3) Twelve operating conditions require repeatability testing. We also request a separate cost breakout for addition of the Low Viscosity Grade study.

More details about the specific values defining "low", "moderate", and "high" speed and load will be determined upon collaboration between the bidder and the CRC project panel.

The test engine will require a break-in period prior to commencement of testing. Break-in is expected to require 50 to 100 hours of engine operation at conditions to be recommended by Ford engineers. Break-in may include operating the engine at conditions representative of test operating conditions.

Test Protocol – Methods and Measurements

We plan to use engine dynamometer testing using Radionuclide Technology (RNT) in order to measure real-time wear rates of various components. In RNT testing, an engine equipped with irradiated components is operated while radiation levels in the lube oil are measured by detectors mounted in the lube oil circuit as shown in Figure 6.

Radionuclides are worn from surfaces of irradiated components and carried to the detector by the lube oil. Wear rates of various components are determined based on the identity of radionuclides detected as well as signal strength.

Advantages of RNT include high sensitivity, good repeatability, real-time wear rate, applicable for short tests, correlation of wear with specific operating conditions, and continuous testing without disassembly for parts inspection. Use of RNT is expected to eliminate the need for end of test (EOT) engine tear-down analysis.

Note that we may not necessarily recommend RNT for routine GDI engine wear testing because RNT is a relatively expensive technique compared to used oil analysis, engine disassembly and metrology wear rating techniques used in traditional engine wear tests. But the RNT technique is

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2) J. Heywood, Internal Combustion Engine Fundamentals, McGraw Hill, 1988, Chapter 13.

well suited for identifying high-wear engine operating conditions. These operating conditions may then be recommended for development of future engine wear tests using less expensive traditional used oil analysis and wear measurement techniques.

RNT uses three basic methods to irradiate parts – bulk activation, surface layer activation (SLA) (also called thin layer activation (TLA)), and ion implantation. Bulk activation irradiates the entire part and is suitable for small parts such as rings. SLA irradiates a thin <100 µm surface layer and is suitable for large parts or parts where you wish to determine wear rates at a particular surface site. Ion implantation implants radionuclide ions in a thin layer near the surface of non-metal parts and is suitable for parts made of or coated with polymers.

Irradiated parts of interest include rings, main bearings, connecting rod bearings, turbo thrust bearings, cylinder liners, camshafts, shims, timing chains, chain tensioners/guides, camshaft support journals, valve seats, camshaft flank vs. nose, oil pumps, balance shaft bearings, thrust washers, and wrist pins.

We are concerned that operating conditions involving high-speed engine and/or turbocharger operation may cause frothing or aeration of oil. Consider the use of an internal standard (such as a Cesium 137 button) to characterize the effect of oil aeration on measured wear rates.

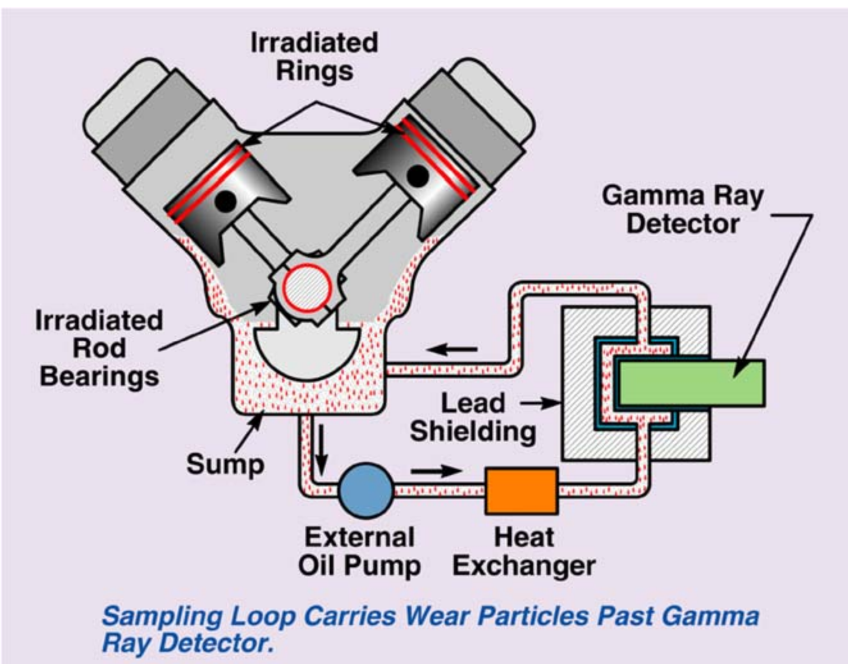

Figure 6. Typical Arrangement for RNT Engine Wear Testing (Figure courtesy of Southwest Research Institute, (3,4)

We expect the use of RNT test methodology may involve potential radioactive hazards. Contractors responding to this request for proposal will be expected to demonstrate expertise in safe use of radioactive materials resulting from RNT testing. This includes controlling human exposure to radioactivity, proper handling and disposal of radioactive hazardous waste, and proper documentation of radioactive materials handling as required by law.

We understand that the RNT test method allows us to combine several components into one single wear test in order to shorten the timeline. We expect the final decision regarding how many components may be tested at once will be made after more in-depth discussions with the test lab.

In order to facilitate the proposal process and avoid misunderstandings, the project panel requests a meeting or call to discuss the project statement of work with contractors interested in submitting proposal before proposals are prepared.

Materials Lost to Combustion Cylinder or Exhaust

The RNT method depends on wear material being entrained in engine oil and recirculated back to the engine oil sump to be measured by the radioactive sensors. Since most of the oil to valve guides is lost to the combustion chamber, RNT may not be a good test method for measuring valve guide wear (1). Similar concerns exist for turbo thrust bearings and ring packs since some of this lube oil containing wear material is lost to combustion cylinder or exhaust as well. For this reason, we delayed valve guide and turbo thrust bearing activation to year 2 scope of work until we can determine the best test method.

Some wear materials that are lost to combustion or exhaust may be deposited onto exhaust system surfaces such as the catalyst. It may be possible to estimate the amount of wear materials and/or lube oil lost in combustion from these various sources by examining the exhaust system components.

We request for contractors responding to this request for proposal to consider and propose methods to measure or estimate the amount of wear materials and/or lube oil lost in combustion to the exhaust system originating from valve guides, ring pack, and turbo thrust bearings.

Test Matrix

The experimental design test matrix for Phase 1 scope of work is shown in Table III. It is expected that the engine will need to be operated for a time period ranging from several hours up to possibly 20-30 hours for each engine operating condition in order to obtain a reproducible steady wear rate. For estimation purposes in Table III, it was assumed that each operating condition requires an average of 12 hours of engine operation time.

Table III. Phase 1 Experimental Design Test Matrix

Irradiated Part	Oil Type	Engine Operating Condition	Test Time (hr)
Rings, Bearings, Cylinder Liners	Reference	1. Baseline SS	12*3=36
Rings, Bearings, Cylinder Liners	Reference	2. Transient Load	12*3=36
Rings, Bearings, Cylinder Liners	Reference	3. Transient Speed	12*2=24
Rings, Bearings, Cylinder Liners	Reference	4. WOT SS	12*3=36

Rings, Bearings, Cylinder Liners	Reference	5. WOT Transient	Included in #3
Rings, Bearings, Cylinder Liners	Reference	6. Boundary Lubrication	12
Rings, Bearings, Cylinder Liners	Reference	7. Hydrodynamic Lubrication SS	Included in #1
Rings, Bearings, Cylinder Liners	Reference	8. Trailer Tow SS	Included in #4
Rings, Bearings, Cylinder Liners	Reference	9. Trailer Tow Transient	12
Rings, Bearings, Cylinder Liners	Reference	10. Cold Start	12
Rings, Bearings, Cylinder Liners	Reference	11. Turbo SS	Included in #4
Rings, Bearings, Cylinder Liners	Reference	12. Turbo Transient	12
Rings, Bearings, Cylinder Liners	Reference	13 Stop/Start	12
			Subtotal 202
Rings, Bearings, Cylinder Liners	Low Viscosity	1	
Rings, Bearings, Cylinder Liners	Low Viscosity	2	
Rings, Bearings, Cylinder Liners	Low Viscosity	3	
Rings, Bearings, Cylinder Liners	Low Viscosity	4	
Rings, Bearings, Cylinder Liners	Low Viscosity	5	
Rings, Bearings, Cylinder Liners	Low Viscosity	6	
Rings, Bearings, Cylinder Liners	Low Viscosity	7	
Rings, Bearings, Cylinder Liners	Low Viscosity	8	
Rings, Bearings, Cylinder Liners	Low Viscosity	9	
Rings, Bearings, Cylinder Liners	Low Viscosity	10	
Rings, Bearings, Cylinder Liners	Low Viscosity	11	
Rings, Bearings, Cylinder Liners	Low Viscosity	12	
Rings, Bearings, Cylinder Liners	Low Viscosity	13	
			Subtotal 202
			Total 404

Test Fuels

The test fuel will be EEE Tier 2 fuel. Only one fuel will be tested in this phase. Fuel interactions, volatility, and ethanol content may be considered for future studies.

Test Lubricants
Test lubricants include a reference oil and a low viscosity oil to test the effect of viscosity on wear rates as shown in Table IV.

Reference Oil – Ford factory fill 5W-30 GF5 engine oil.

Low Viscosity Oil – 5W-20 grade represents a moderate viscosity change. This is not expected to be challenging for wear protection. But 0W-16 represents a more drastic viscosity change. This is expected to be representative of the future direction of engine oils for increased fuel economy. This viscosity grade is expected to be significantly more challenging for an additive package to adequately protect the engine from wear.

We plan to test 0W-16 viscosity grade oil for a more challenging, forward-looking test. But we want to increase wear without destroying the engine. So we plan to be careful, especially early in testing with the low viscosity oil, so as to not to damage the engine. We plan to start out easy and look for signs of wear before moving on to more severe engine operating conditions. In particular, limit the engine speed to no more than 4000 rpm, at least until the effects of low-viscosity oil on wear rates can be established. We may consider higher engine speed upon consultation with test engineers and Ford engineers. This low viscosity oil will be 0W-16 with the same additive package as the reference oil. The only difference is the viscosity.

Table IV. Test Lubricants

Oil Type	Viscosity	Additive Package
Reference	5W-30	Ford factory fill GF5
Low Viscosity	0W-16	Same as Ford factory fill GF5

Project Tasks and Timeline
The project is divided into two phases to be executed across three years. Project tasks and preliminary timeline is as follows.

Phase 1
(Year 2016)
Parts irradiation - cylinder liner, rings, journal bearings, connecting rod bearings, turbocharger thrust bearings
Irradiated parts storage and disposal.
Engine procurement and engine test stand set up
Engine break-in
(Year 2017)
Test reference oil at all 13 operating conditions
Test low-viscosity oil at all 13 operating conditions
Data analysis and reporting

Phase 2

We are only soliciting proposals for the Phase 1 scope of work at this time. But we include tentative plans for subsequent test phases to give context to the Phase 1 test plan. We expect to secure funding and approval for the Phase 2 work upon successful completion of the Phase 1 test plan. We invite suggestions on how to order or divide up the work if there is a better way.

(Year 2017 continued)
Parts irradiation - valve guides, camshafts, valve shims, and timing chain
(Year 2018)
Irradiated parts storage and disposal
Engine break-in
Test reference oil at all 13 operating conditions
Test low-viscosity oil at all 13 operating conditions
Data analysis and reporting

Ideas for Future Testing Beyond Phase 2

Engine operating conditions for consideration in follow-on phases of engine testing include:

- Exceed rated engine load
- Extreme ambient temperature (hot and cold)
- Fuel ethanol content
- Oil aging (performance near end of life)
- LSPI-induced duty cycle
- Low oil sump level
- High fuel dilution loading in lube oil
- High soot loading in lube oil.
-

Consider testing a third test oil, possibly low viscosity 0W-16 oil with modified additive package. Evaluate high-wear operating conditions in other GDI engines for comparison to the Ford test engine.

Acronyms

ACEA Association des Constructeurs Européens d'Automobiles
BMEP Brake Mean Effective Pressure
CRC Coordinating Research Council
DLC Diamond-Like Coating
EGR Exhaust Gas Recirculation
EOT End of Test
GCVW Gross Combined Vehicle Weight
GDI Gasoline Direct Injection
ILSAC International Lubricant Standardization and Approval Committee
LSPI Low Speed Pre-Ignition
PFI Port Fuel Injection
RATT Radioactive Tracer Technology
RNT Radionuclide Technology
SLA Surface Layer Activation
SS Steady State
TBD To Be Determined
TLA Thin Layer Activation
WOT Wide Open Throttle

References

1) S. Tung, G. Totten, Automotive Lubricants and Testing, ASTM International, 2012, Chapters 6, 8, and 19.
1) J. Heywood, Internal Combustion Engine Fundamentals, McGraw Hill, 1988, Chapter 13.
1) Figure courtesy of Southwest Research Institute, http://www.swri.org/4org/ae/rad-wear-meas.htm, accessed Mar. 22, 2016.
1) White paper on Radionuclide Technology (a.k.a. Radioactive Tracer Technology (RATT)) engine testing methodology by Southwest Research Institute, http://www.swri.org/4org/ae/docs/rattpaper.pdf., accessed Mar. 22, 2016.

Appendix A

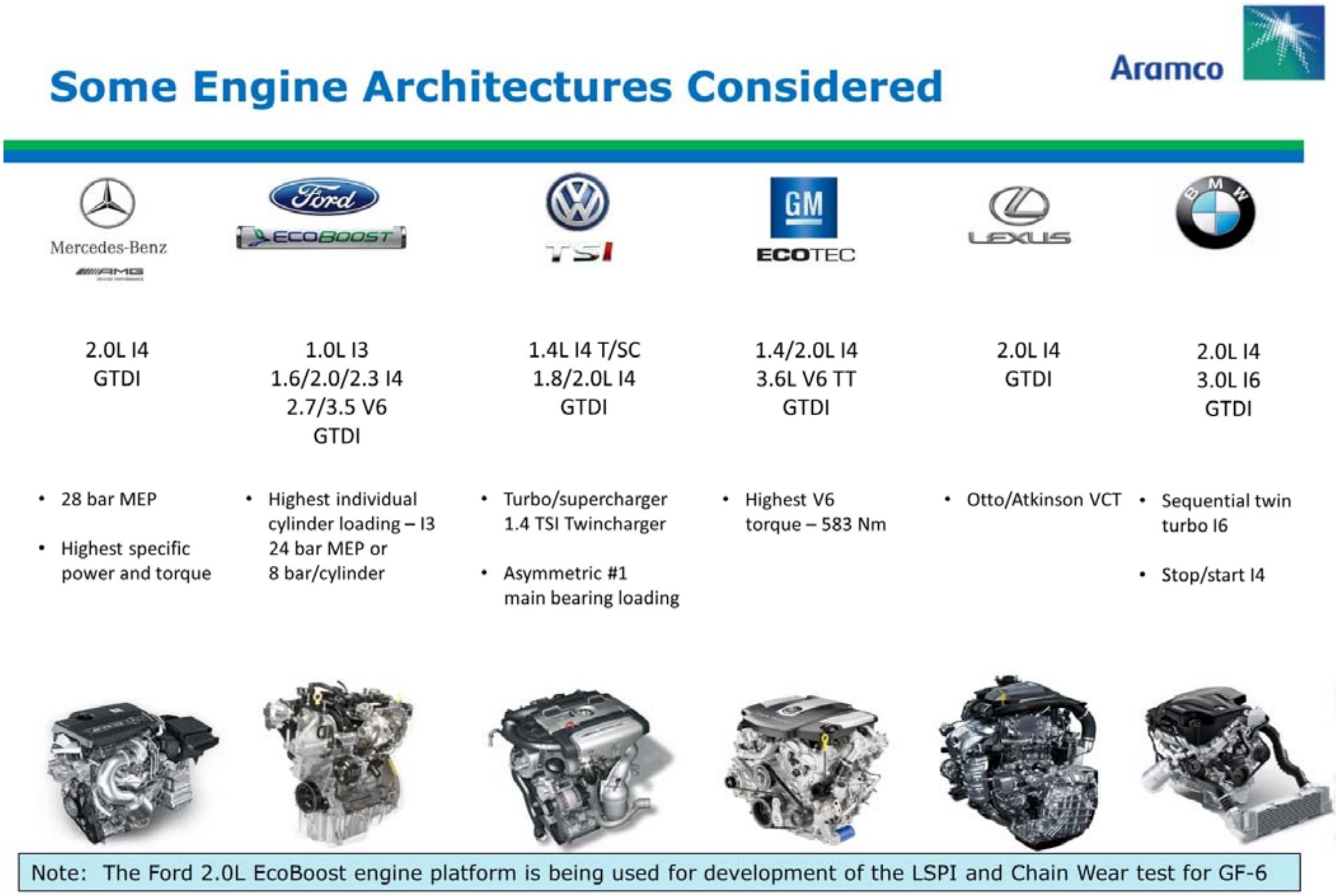

Figure A-1. Candidate Engines and their Characteristics (Courtesy of Bill Woebkenberg, Aramco Services)

EXHIBIT B

REPORTS

MONTHLY TECHNICAL PROGRESS REPORTS

The contractor shall submit a monthly technical progress report covering work accomplished during each calendar month of the contract performance. An electronic Microsoft® Word compatible file (<2 MB) of the monthly technical progress report shall be distributed by the contractor within ten (10) calendar days after the end of each reporting period. The report shall contain a description of overall progress, plus a separate description for each task or other logical segment of work on which effort was expended during the reporting period.

FINAL REPORT

The contractor shall submit to or distribute for CRC an electronic pdf-compatible copy transmittable via email) of a rough draft of a final report within thirty (30) days after completion of the technical effort specified in the contract. The report shall document, in detail, the test program and all of the work performed under the contract. The report shall include tables, graphs, diagrams, curves, sketches, photographs and drawings in sufficient detail to comprehensively explain the test program and results achieved under the contract. The report shall be complete in itself and contain no reference, directly or indirectly, to the monthly report(s).

The draft report must have appropriate editorial review corrections made by the contractor prior to submission to CRC to avoid obvious formatting, grammar, and spelling errors. The report should be written in a formal technical style employing a format that best communicates the work conducted, results observed, and conclusions derived. Standard practice typically calls for a CRC Title Page, Disclaimer Statement, Foreword/Preface, Table of Contents, List of Figures, List of Tables, List of Acronyms and Abbreviations, Executive Summary, Background, Approach (including a full description of all experimental materials and methods), Results, Conclusions, List of References, and Appendices as appropriate for the scope of the study. Reports submitted to CRC shall be written with a degree of skill and care customarily required by professionals engaged in the same trade and /or profession.

Within thirty (30) days after receipt of the approved draft copy of the final report, the contractor shall make the requested changes and deliver to CRC thirty (30) hardcopies including a reproducible master copy of the final report. The final report shall also be submitted as an electronic copy in a pdf or pdf-convertible file format. The final report may be prepared using the contractor's standard format, acknowledging author and sponsors. An outside CRC cover page will be provided by CRC. The electronic copy will be made available for posting on the CRC website.

EXHIBIT C

INTELLECTUAL PROPERTY RIGHTS

Title to all inventions, improvements, and data, hereinafter, collectively referred to as ("Inventions"), whether or not patentable, resulting from the performance of work under this Agreement shall be assigned to CRC. Contractor X shall promptly disclose to CRC any Invention which is made or conceived by Contractor X, its employees, agents, or representatives, either alone or jointly with others, during the term of this agreement, which result from the performance of work under this agreement, or are a result of confidential information provided to Contractor X by CRC or its Participants. Contractor X agrees to assign to CRC the entire right, title, and interest in and to any and all such Inventions, and to execute and cause its employees or representatives to execute such documents as may be required to file applications and to obtain patents covering such Inventions in CRC's name or in the name of CRC's Participants or nominees. At CRC's expense, Contractor X shall provide reasonable assistance to CRC or its designee in obtaining patents on such Inventions.

To the extent that a CRC member makes available any of its intellectual property (including but not limited to patents, patent applications, copyrighted material, trade secrets, or trademarks) to Contractor X, Contractor X shall have only a limited license to such intellectual property for the sole purpose of performing work pursuant to this Agreement and shall have no other right or license, express or implied, or by estoppel. To the extent a CRC member contributes materials, tangible items, or information for use in the project, Contractor X acknowledges that it obtains only the right to use the materials, items, or information supplied for the purposes of performing the work provided for in this Agreement, and obtains no rights to copy, distribute, disclose, make, use, sell or offer to sell such materials or items outside of the performance of this Agreement.

EXHIBIT D
LIABILITY

It is agreed and understood that _____________ is acting as an independent contractor in the performance of any and all work hereunder and, as such, has control over the performance of such work. _______________ agrees to indemnify and defend CRC from and against any and all liabilities, claims, and expenses incident thereto (including, for example, reasonable attorneys' fees) which CRC may hereafter incur, become responsible for or pay out as a result of death or bodily injury to any person or destruction or damage to any property, caused, in whole or in part, by _________'s performance of, or failure to perform, the work hereunder or any other act of omission of Contractor in connection therewith.

EXHIBIT E

PROPOSAL EVALUATION CRITERIA

1) Merits of proposed technical approach.
2) Previous performance on related research studies.
3) Personnel available for proposed study – related experience.
4) Timeliness of study completion.
5) Cost.