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June 5, 2019
In reply, refer to:
CRC Project No. AVFL-36

Dear Prospective Bidder:

The Coordinating Research Council (CRC) invites you to submit a written proposal to provide services for "Impact of MON on Engine Performance" (CRC Project No. AVFL-36). A description of the project is presented in Exhibit A, "Statement of Work."

Please indicate by letter, fax, or email by **June 19, 2019** if you or your organization intends to submit a written proposal for this research program. CRC will answer technical questions regarding the Request for Proposal if they are submitted in writing. CRC will then return written answers to all of the bidders, along with a copy of the original questions.

A CRC technical group composed of industry 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). Contract language for intellectual property and liability clauses is presented in Exhibit C and in Exhibit D, respectively. 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.

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 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 10 pages in length (not including resumes). **The schedule / timeline information should be included in the technical proposal.**

CRC expects to negotiate a cost-plus fixed fee or cost reimbursement contract for the research program.

The technical and cost proposals should be submitted to:
Christopher J. Tennant Email: **ctennant@crcao.org**

The deadline for receipt of your proposal is **July 3, 2019.**

EXHIBIT A

Statement of Work

Background

It is well established that fuels with higher knock (or autoignition) resistance can help elevate spark ignition (SI) engine efficiency by enabling improved combustion phasing and increased compression ratios1. Consequently, for any consideration of improving properties of market gasoline to facilitate higher engine efficiencies it is imperative to understand the impact of fuel knock resistance on engine performance. The knock resistance of fuels is typically expressed in terms of the Research Octane Number (RON)[2] and Motor Octane Number (MON)[3] determined on a Cooperative Fuels Research (CFR) engine. However, due to the significant advancements in engine technology since the development of the CFR engine nearly 90 years ago, the RON and MON test conditions are not representative of modern engine operation. To help better relate engine performance to fuel knock resistance expressed in terms of RON and MON, in 2001, Kalghatgi[4,5] introduced the concept of Octane Index,

$$OI = RON - K \times S, \quad (1)$$

where $S = RON - MON$ is the sensitivity of the fuel and K is a correlation constant determined for a given engine and operating condition. Since the introduction of the OI concept, several studies[6-10] have demonstrated that low speed high load conditions typically associated with knock limited operation correspond to values of K less than zero. Based on Eq. (1), a value of $K < 0$ implies that the OI of the fuel is greater than its RON value in modern engines under typical knock limited operation. Additionally, when $K < 0$, a higher sensitivity S (or lower MON) has been shown to further increase the knock resistance of the fuel[11]. The evidence of $K < 0$ in multiple studies in conjunction with the potential benefit of higher S, has increasingly been used to suggest that knock limited operation of modern engines correlates with fuel RON and that fuel MON should be allowed to decrease as much as possible.

However, most of the studies that have demonstrated values of $K < 0$, have been focused on the most severely knock-limited conditions, namely low speed and high load. Consequently, other operating conditions that may be more representative of MON like conditions have not been investigated systematically. As higher RON fuels, potentially with higher S, are discussed as enablers for improved vehicle fuel economy, it is important to ensure there are no unintended consequences of the reduced significance of MON on engine operation.

Objectives

The primary objective of this study is to investigate the impact of fuel MON on engine performance under a wider range of operating conditions, including those where K may be positive (and potentially greater than 0.5). Testing under a wider range of operating conditions will help establish the relevance of fuel MON for modern engines, especially from the perspective of durability and safe operation. To this end the proposed study will evaluate the impact of MON at multiple operating conditions including but not limited to:

(a) High speed high load (high power) operation with elevated air charge temperatures. This engine operation regime is representative of real world driving conditions such as towing a trailer up a steep grade on a hot day. For future powertrains, this operating regime is expected to become even more challenging as criteria emissions regulations are driving elimination of enriched engine operation as a strategy for managing exhaust gas temperatures.

(b) Knock limited part load operation which is relevant for drive cycle fuel economy. This operating regime is of particular interest for downsized boosted SI engines.

Figure 1 illustrates the aforementioned operating regimes that are of most interest for this study.

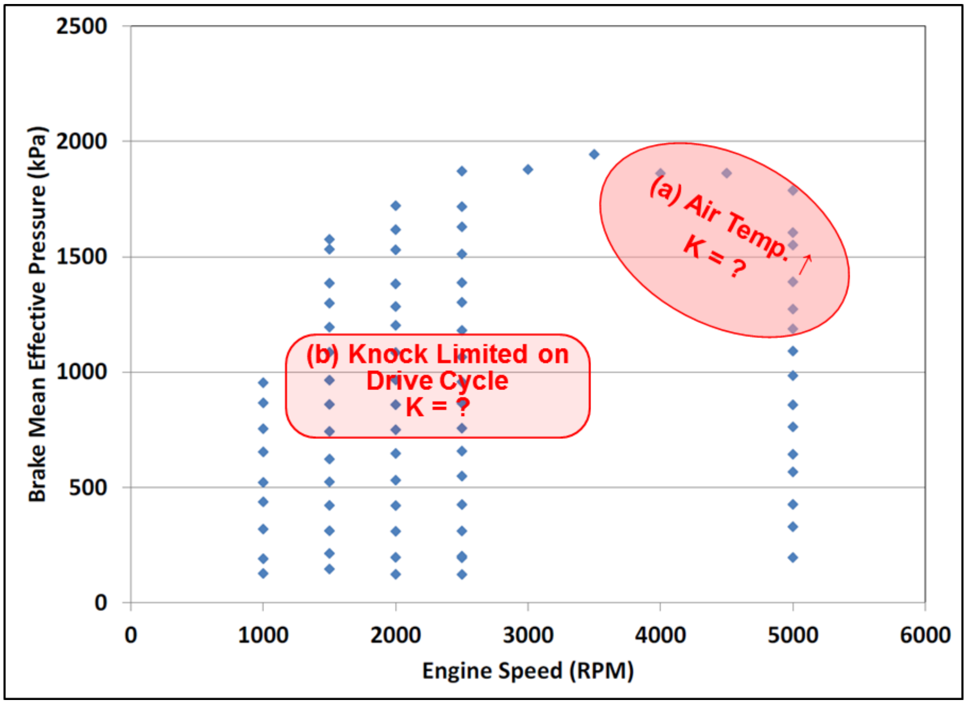

Figure 1: Operating regimes of interest for investigating the impact of fuel MON

Scope of Work

This project will consist of engine dynamometer testing that includes the following elements:

(a) Test Engines: Up to 3 different engines out of which at least one will be Naturally Aspirated (NA) and one gasoline turbocharged direct injection (GTDI). Inclusion of a large bore NA V8 engine and a downsized boosted I4 engine would be preferred.

(b) Fuels: At least 4 different fuels with a fixed RON and varying MON. As an example, for a Premium Recommended/Required engine, the fuel matrix could be as follows:

RON	MON	AKI (R+M/2)	S = RON-MON
95	95	95	0
95	91	93	4
95	87	91	8
95	82	88.5	13

The fuel matrix will be defined by the CRC project panel after taking into consideration test engines and input provided by the selected vendor.

(c) Engine Mapping:
  i. Speed: 1000-5000 RPM in 1000 RPM increments.
  ii. Load: 2 bar BMEP to Full Load in 1 bar increments.
  iii. Air Charge Temperature (ACT): At least 2 different temperatures for the air/charge in the intake runner/manifold, with one temperature representing operation under normal conditions (e.g. 45°C for GTDI engines) and the other representing operation under hot conditions (e.g. 65°C for GTDI engines). The CRC project panel will select the target ACTs in consultation with the vendor.
  iv. Spark Control: The engine shall be operated with manual control of spark timing to achieve MBT or borderline knock at each operating condition, to facilitate better comparison between different fuel maps.
  v. Lambda Control: The engine shall be operated at stoichiometry, except that sufficient enrichment will be used at higher loads to control exhaust temperature to the maximum level observed for that engine with the original "as calibrated" controls.
  vi. Control of EGR, variable valve timing, injection timing, tumble flaps, etc.: The engine shall be operated with all other engine actuators controlled to "as calibrated" settings as closely as feasible.

(d) Minimum Engine and Test Cell Instrumentation:
  i. In-cylinder pressure measurements and combustion analysis.
  ii. Pressure and temperature measurements for engine coolant, engine oil, ambient air, intake air, exhaust gases.
  iii. Engine torque and fuel flow for measuring efficiency.
  iv. Emissions bench for measuring criteria emissions (primarily to be used as a combustion diagnostic tool).

Project Deliverables

The deliverables for this project include:

(a) Post-processed data corresponding to the requested engine maps.

(b) Periodic status updates to the CRC project panel. The cadence for these periodic updates is to be proposed by the vendor based on the overall project timeline.

(c) A Final Report providing the details of the testing and the conclusions drawn based on the collected engine data.

Required Elements of the Quotation

(a) The vendor will provide CRC a list of engines available for testing out of which the CRC project panel will select up to 3 engines.

(b) The cost breakdown should include
   i. Cost of setting up 1 engine
   ii. Cost of completing 1 engine map (fuel + ACT combination)
   iii. Cost (and volume) estimate of fuel required for completing 1 engine map

(c) Detailed project timeline, preferably presented in terms of weeks. The project timeline should also include the schedule for periodic status updates to be provided to the CRC project panel.

References

1. Leone, T., Anderson J., Davis, R., Iqbal, A., Reese II, R., Shelby, M., and Studzinski, W., 2015, "The Effect of Compression Ratio, Fuel Octane Rating, and Ethanol Content on Spark-Ignition Engine Efficiency," Environmental Science and Technology, 49 (18), pp. 10778-10789.
2. ASTM D2699-18a, 2018, "Standard Test Method for Research Octane Number of Spark-Ignition Engine Fuel," American Society for Testing and Materials.
3. ASTM D2700-18a, 2018, "Standard Test Method for Research Octane Number of Spark-Ignition Engine Fuel," American Society for Testing and Materials.
4. Kalghatgi, G. T., 2001, "Fuel Anti-Knock Quality – Part I, Engine Studies," SAE Paper 2001-01-3584.
5. Kalghatgi, G. T., 2001, "Fuel Anti-Knock Quality – Part II, Vehicle Studies – How Relevant is Motor Octane Number (MON) in Modern Engines?" SAE Paper 2001-01-3585.
6. Bradley, D., Morley, C., Walmsley, H., 2004, "Relevance of Research and Motor Octane Numbers to the Prediction of Engine Autoignition," SAE Paper 2004-01-1970.
7. Kalghatgi, G. T., 2005, "Auto-ignition Quality of Practical Fuels and Implications for Fuel Requirements of Future SI and HCCI Engines, SAE Paper 2005-01-0239.
8. Kalghatgi, G. T., Nakata, K., Mogi, K., 2005, "Octane Appetite Studies in Direct Injection Spark Ignition (DISI) Engines," SAE Paper 2005-01-0244.
9. Mittal, V., Heywood, J. B., 2008, "The Relevance of Fuel Ron and MON to Knock Onset in Modern SI Engines," SAE Paper 2008-01-2414.
10. Heywood, J. B., and Mittal, V., 2008, "The Shift in Relevance of Fuel RON and MON to Knock Onset in Modern SI Engines Over the Last 70 Years," SAE Paper 2008-01-2414.
11. Prakash, A., Wang, C., Jansen, A., Aradi, A., and Cracknell, R., 2017, "Impact of Fuel Sensitivity (RON-MON) on Engine Efficiency," SAE Paper 2017-01-0799.

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 (<1 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. Periodic conference calls may also be requested by CRC to update the technical committee overseeing the project.

FINAL REPORT

The contractor shall submit to CRC a draft final report. The report shall document the test procedure, document details of each test iteration, and explain any observations noted. The test data will be recorded and reviewed, and the final report will include a certification that the test procedures were followed, noting any exceptions. The detailed data will also be supplied electronically to CRC.

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. Incomplete draft reports or reports of poor quality requiring additional outside editorial review may have outside editorial services charged back to the project budget.

Comments regarding the report shall be furnished by the CRC committee to the contractor within one (1) month after receipt of the draft copy. Additional rounds of review may be required.

Within thirty (30) days after receipt of comments, the contractor shall make the requested changes and submit an electronic copy of the draft final report in both Microsoft Word and Adobe pdf file format. Once accepted, the contractor shall deliver five (5) hard copies of the final report to CRC. 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 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.