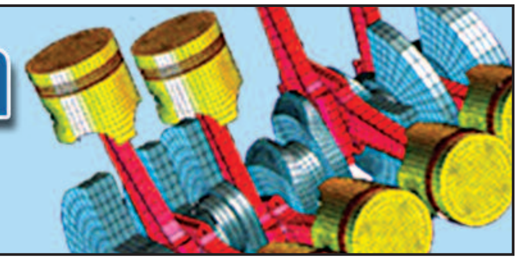
ASME SETTING THE STANDARD

Internal Combustion Engine



From the Editor's Desk

Suri Rajan, Editor

The Internal Combustion Engine Division is always striving to do better from one year to the next, and judging from the activities and events scheduled so far, the level of excitement remains high. The premier event of the year will be the Fall Technical Conference, September 27-30, 2009, in beautiful Lucerne nestled among the Swiss Alps. Do not miss this unique opportunity to attend. This Newsletter also brings you details of past and future events, awards, and a technical article on Long term Emissions Data from NSCR-Equipped Natural Gas Engines.

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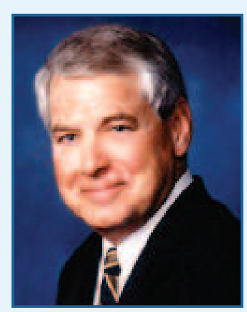
CHAIR'S MESSAGE

Tim Callahan

Since the invention of the internal combustion engine, engineers and manufacturers have sought to improve design, performance, and emissions. The improvements have been driven by expectations of the market for improved reliability, higher power density, and better fuel economy or efficiency, and by regulations demanding lower exhaust emissions for improving ambient air quality. And for eighty-eight (88) years, the ICE Division of ASME has facilitated those improvements by providing engineers a forum for exchanging ideas, networking, and disseminating technical information. Despite over one-hundred (100) years of development, the need to improve the design, performance, and emissions of internal combustion engines still exists in order to meet pending emissions regulations and demands for higher efficiency. In the face of this need, the ICE Division will continue to provide a forum for engineers to gather, share information, and present technical papers.

The ICE Division is a vital part of ASME and the strength and success of the Division over the years has been a result of contributions made by you and other members of our ICE society. The many accomplishments of this group are far too numerous to list and there are far too many people involved in our success story to acknowledge everyone. Granted, there are key people who continually receive recognition, but the real thanks should go to those who make the small contributions that contribute to a much greater result. Having said that, I would like to encourage you to continue making these contributions, whether it is reviewing papers, writing papers, making presentations, organizing events, networking, maintaining an e-mail list, participating in a local section, sponsoring student events, or one of a host of other activities. The collective contribution of each individual activity results in a much stronger ICED organization. In these turbulent economic times, the strength of the Division, as in the past, depends on the participation of the members. If you are not currently active in the ICE division, but would like to get involved, please feel free to email me at tcallahan@swri.org or talk to me at an upcoming meeting.

David Merrion to Receive 2009 Seichiro Honda Award.



David F. Merrion will receive the 2009 Seichiro Honda Award at a formal presentation on Sunday November 15 during the Members and Students Luncheon during the ASME International Mechanical Engineering Congress and Exposition, November 13-19, 2009 at the Walt Disney Swan and Dolphin Hotel.

Fall 2009 ICE Meeting to be held in Lucerne Switzerland, September 27-30, 2009

Frank Aboujaoude and Steve Ciatti

The Fall ICE conference will be held at the Grand Hotel Europe in Lucerne, Switzerland. The Grand Hotel Europe, built in 1872 and renovated during the last three years, is a four star hotel located 10 minutes away from the city centre. It combines a grand past with a contemporary outlook and is distinguished by its subtle elegance, attentive service and warm hospitality.

The Grand Hotel Europe, shown on the far right of the aerial view picture, is located by Lake Lucerne (Vierwaldstättersee) which is surrounded by the impressive panorama of the Alps.

Although Lucerne does not have an airport, the proximity of the Zurich International Airport makes Lucerne very accessible. Lucerne is approximately 1 hour (60 km) by train from the Zurich airport and direct trains are scheduled every hour. Driving from the Zurich airport is about the same distance and takes approximately 1 hour to Lucerne.

The conference will start on Sunday night and conclude with two technical tours on Wednesday late afternoon rather than Wednesday noon. We will tour the facilities of DUAP AG, a diesel fuel injection systems manufacturer in Herzogenbuchsee, Switzerland in the morning. The details for the afternoon tour are being finalized. Busing will be provided and will showcase the nice coutryside.

The conference will officially kick off on Monday morning with the Keynote Address. Following the Keynote Address, we are aiming for three parallel technical sessions on Monday and Tuesday.

Please remember to check the conference website, www.asmeconferences.org/ICEF09/ on a regular basis as more detailed information will be posted as events are finalized.

The ICE Spring 2009 Conference in Milwaukee, Wisconsin

Frank Aboujaoude and Stuart Neill

The Spring Technical conference, which was hosted by Dresser Waukesha, was held at the InterContinental Hotel in Milwaukee, Wisconsin. The conference started on Sunday May 3rd with a welcome reception and concluded on Wednesday May 6th with a technical tour of Dresser Waukesha. Attendees gathered each evening at the Chair's hospitality suite to share snacks and beverages with fellow engine enthusiasts and have a great time.

The conference officially kicked off on Monday with a Keynote Address by David E. Foster, Co-Director of the General Motors - ERC Collaborative Research Laboratory at the University of Wisconsin - Madison. Dr. Foster's presentation titled "Combustion Technologies, Aftertreatment Systems and Alternative Energy Carriers for a Carbon Constrained World." The conference had approximately 75 technical papers presented in four parallel sessions and covered design, development, and application of internal combustion engines. All presented papers were published in the Conference Proceedings. The searchable CD was provided to all registrants and can be ordered from ASME for those unable to attend the conference.

The Ajula Performance Troupe Does a Dance Number

The Honors and Awards Banquet was another highlight of the conference. This is a unique event held annually to recognize and honor the outstanding achievements and service of our colleagues to the internal combustion engine field. This year's Monday evening banquet

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featured a nice dinner at the conference hotel, which was followed by the awards ceremony, and concluded with an outstanding performance by the Ajula Performance Troupe.

Dresser Waukesha hosted Tuesday night a well attended reception at the InterContinental Milwaukee with plenty of delicious hors d'oeuvres.

The conference had several "Table Top" exhibits including those from DieselNet.com, Drivven, Inc., University of Wisconsin-Madison, Geislinger Corporation, Nagel Precision, Heinzmann America, Inc. IR Telemetrics, Inc., and C-K Engineering, Inc. Attendees were able to exchange information with exhibitors during meals and breaks.

The Spouses' Program was held on Monday and Tuesday and showcased the finest attractions in the Milwaukee area which included visits to the Milwaukee Art Museum, shopping at the Bayshore Mall, tours of Holy Hill and the Milwaukee Public Museum.

The conference concluded with the technical tour of Dresser Waukesha manufacturing and assembly facilities.

Former Chair Neil Blythe Receives the Distinguished Service Award

Thanks again to Dresser Waukesha for hosting the conference and sharing their impressive facility with us.

photos continued on page four

Doug Kiesling with his Wife Receiving the Local Arrangements Award

David Foster Receives the Keynote Speaker Award

ICE Spring 2009 Conference in Milwaukee, Wisconsin continued from page three

Kirby Chapman with his Wife receives the Retiring Chair Certificate

Rolf Reitz Receives 2007 Fall FTC Best Paper Award on Behalf of Mark Musculus

Paul LaVigne of IR Telemetrics, Inc. visits with Neil Blythe at Display

Steve Ciatti of Argonne visits with Matt Viele of Drivven, Inc.

Variations in Long-term Emissions Data from NSCR-equipped Natural Gas-Fueled Engine

Sarah Nuss-Warren, Mohamed Toema, and Kirby S. Chapman
Kansas State University, Manhattan, KS, USA

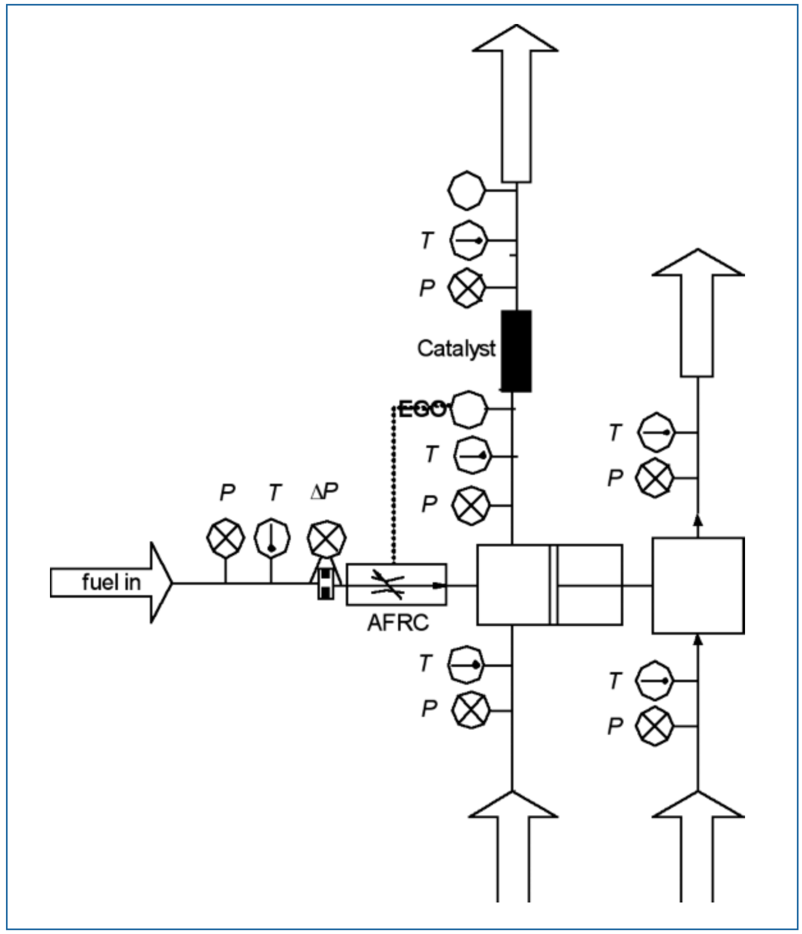

FIGURE 1. PARAMETERS MEASURED IN SEMI-CONTINUOUS DATA COLLECTION

One possible solution for emissions control of four-stroke cycle, rich-burn engines, is to apply an NSCR system to the engine. Such a system relies on three components to control NOx, CO, and unburned hydrocarbon (HC) emissions: a three-way catalyst (TWC), an AFRC, and an exhaust gas oxygen (EGO) or lambda ( ) sensor to determine the oxygen concentration in the exhaust. All three components must function correctly and be tuned properly to successfully reduce emissions to the target level and maintain reliable performance.

Semi-Continuous Data Collection

Three engines at gas gathering sites in the Farmington, NM, and Durango, CO, area were chosen to be continuously monitored. These engines are site-rated at 57 hp (43 kW), 23 hp (17 kW), and 1,467 hp (1094 kW), in the end-user documentation. These continuously monitored engines provide data regarding the stability of the NSCR system and how any changes relate to engine operating conditions and ambient conditions. In order to effectively characterize the day-in, day-out emissions of the NSCR-outfitted engines as typically operated, emissions, engine operating conditions, and ambient conditions were measured, as shown schematically in Fig. 1. Using the data collected, brake-specific fuel consumption, engine power, temperature and pressure changes across the catalyst, and specific emissions rates can be estimated. These values are then examined considering intake and exhaust manifold conditions, ambient conditions, fuel quality, and the conditions of the gas analyzer, sample line, and the EGO sensor output.

Collectively, these parameters characterize the emissions output of the engine, identify how well the engine operates, give insight into the combustion process, and characterize the exhaust gases that enter and exit the catalyst. Monitoring gas analyzer and sample conditions ensures that the analyzer is in proper working condition and not exposed to changes in temperature that could bias or otherwise impact the response of the instrument. The sample line temperature is monitored to determine if the sample gases are maintained at a temperature above dew-point, as any condensed water in the sample line could absorb nitrogen dioxide (NO2). The EGO output signal shows how closely the AFRC is able to maintain the set point and can give insight into EGO sensor health. Emissions are measured using a Testo 350 XL portable gas analyzer with four electrochemical cells that measure CO, NO, NO2, and O2 respectively.

Continuous monitoring began at Engines 1 (57 hp) and 2 (23 hp) in October of 2007, although no emissions data was present at the Engine 2 until November of 2007. Continuous monitoring began at Engine 3 in May of 2008. Data collection was halted at the Engines 1 and 2 in November of 2008.

Results based on data collected at Engine 1 and Engine 2 through August 15, 2008, are reported here. The data indicate that AFRC/catalyst systems are unable to simultaneously control NOx emissions levels below a few hundred ppm and CO emissions below 1,000 ppm CO on a consistent basis. Furthermore, the data show an emissions trade-off. One pollutant may be consistently controlled to a low concentration while the other pollutant tends to vary significantly or remain high. The data also show significant variation of emissions over time spans of a few hours or less, as well as over long-term measurements. Changes in emissions levels often correspond to changes in measured EGO signal or changes to the EGO set point voltage, indicating rich or lean air-to-fuel ratio excursions. This paper attempts to give a general picture of the emissions conditions that have been observed at Engine 1 and Engine 2 during the study.

A graphical representation of the simultaneous control capabilities

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Long-term Emissions Data

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observed for Engine 1 is shown in Fig. 2. In this figure each line represents the percentage of time that the CO level was below a certain value for NO levels below a given value. For Engine 1 when the NO level was below 0.5 g/hp-hr (0.7 g/kW-hr), as shown by the bottom-most curve in Fig. 2, CO was controlled to below 11 g/hp-hr (15 g/kW-hr) almost 50% of the time. When the NO level was below 10 g/hp-hr (13 g/kW-hr), as shown by the top-most curve in Fig. 2, CO was controlled to below 11 g/hp-hr (15 g/kW-hr) approximately 85% of the time. As can be seen by the closeness of the curves for 6 g/hp-hr (8 g/kW-hr) through 10 g/hp-hr (13 g/kW-hr), little additional time with NO controlled to below a given limit would be gained for this particular NSCR/engine system, as it was operated, by relaxing the NO limit to greater than 6 g/hp-hr (8 g/kW-hr). Similarly, the curves begin to flatten

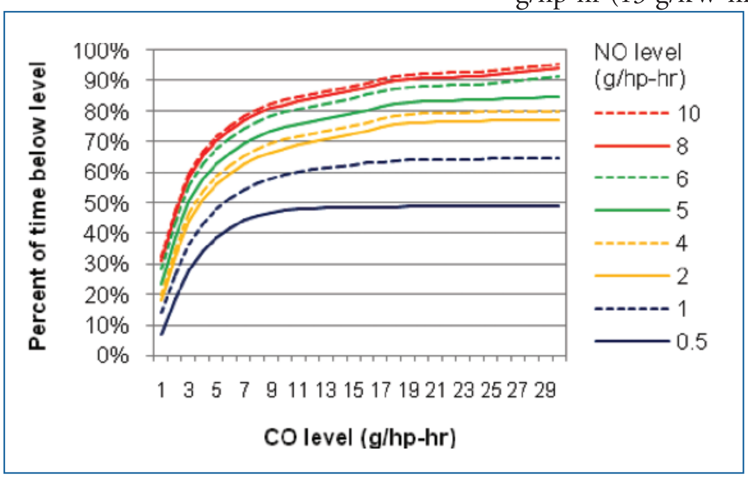

FIGURE 2. CO CONTROL AT VARIOUS NO LEVELS FOR ENGINE 1

for CO levels of approximately 11 g/hp-hr (15 g/kW-hr), and they become even flatter at CO levels of 18 g/hp-hr (24 g/kW-hr). The incremental increase in additional time when CO is controlled to below a given limit gained by relaxing CO limits to above 11 g/hp-hr (15 g/kW-hr) would be insignificant for this particular NSCR/engine system as it was operated. This particular NSCR/engine system operated within levels simultaneously below 6 g/hp-hr (8 g/kW-hr) NO and 11 g/hp-hr (15 g/kW-hr) CO approximately 80% of the time its emissions were monitored.

The graphical representation of the simultaneous control capabilities observed for the Engine 2 is shown in Fig. 3. While these curves have the same basic shape as the curves for Engine 1, the initial slope is steeper for Engine 1, but flattens out more quickly. Additionally, there is decreased spread in the percentage of time that emissions below various NO levels were detected for Engine 2 compared to Engine 1. For instance the curves for 5 g/hp-hr (7 g/kW-hr) and 10 g/hp-hr (13 g/kW-hr) of NO are close in Fig. 3. Thus, in most instances where NO was controlled to below 10 g/hp-hr (13 g/kW-hr), it was also controlled to below 5 g/hp-hr (7 g/kW-hr). Little additional time with NO controlled to below a given limit would be gained for this particular NSCR/engine system, as it was operated, by relaxing the NO limit to greater than 5 g/hp-hr (7 g/kW-hr). Similarly, the curves flatten dramatically for CO levels near 15 g/hp-hr (20 g/kW-hr). The incremental increase in additional time when CO is controlled to below a given limit gained by relaxing CO limits to above 15 g/hp-hr (20 g/kW-hr) would be insignificant for this particular NSCR/engine system as it was operated. This particular NSCR/engine system operated within levels simultaneously below 5 g/hp-hr (7 g/kW-hr) NO and 15 g/hp-hr (20 g/kW-hr) CO approx-imately 95% of the time its emissions were monitored and to below 5 g/hp-hr (7 g/kW-hr) NO and 11 g/hp-hr (15 g/kW-hr) CO for approximately 80% of the time its emissions were monitored.

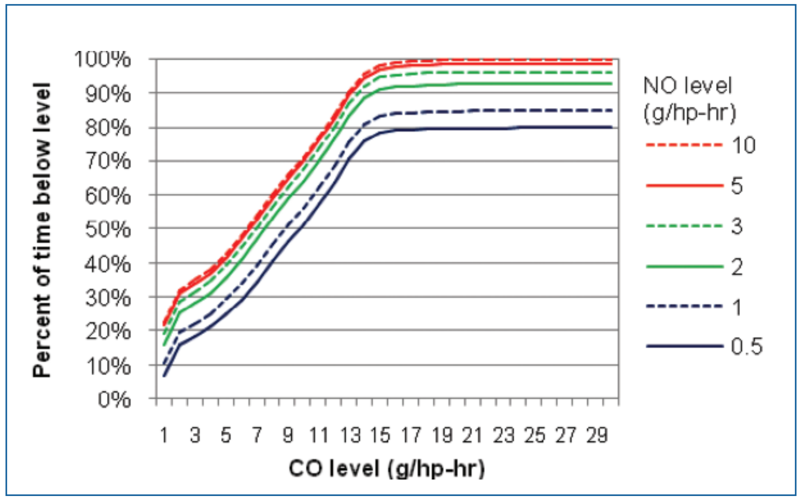

FIGURE 3. CO CONTROL AT VARIOUS NO LEVELS FOR ENGINE 2

Seasonal Variation

Breaking data down by season and emissions level reveals differences in seasonal emissions conditions. These differences in NO and CO emissions levels at Engine 1 are shown in Fig. 4 and Fig. 5 respectively. As shown in Fig. 4, more NO values were above 2 g/hp-hr (2.7 g/kW-hr) than at any other level during the winter season while more measured NO values were below 0.5 g/hp-hr (0.7 g/kW-hr) than at any other level during the fall/spring and summer seasons. The seasonal CO behavior was different, as shown in Fig. 5. During the winter season, more CO values were below 2 g/hp-hr (2.7 g/kW-hr) than at any other level. A similar, though less dramatic trend is seen during the fall/spring season. Conversely, CO levels seem to be almost evenly split between levels below 2 g/hp-hr (2.7 g/kW-hr) and above 4 g/hp-hr (5.4 g/kW-hr) during the summer season.

Data collected from Engine 2 revealed patterns similar to those seen on Engine 1 when broken down by emissions level and season. As shown in Fig. 6, during the winter season, more NO measurements were recorded at levels

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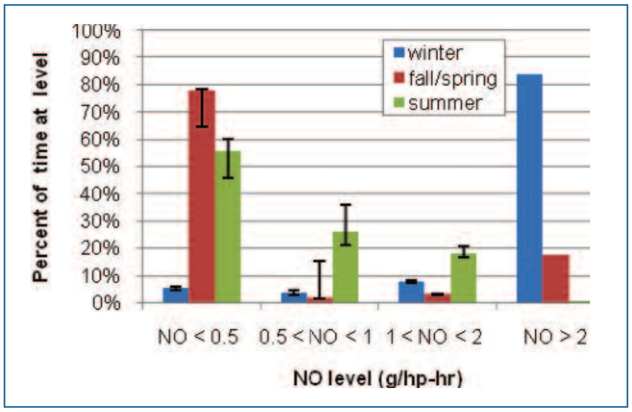

FIGURE 4. SEASONAL EFFECTS ON NO LEVELS FOR ENGINE 1

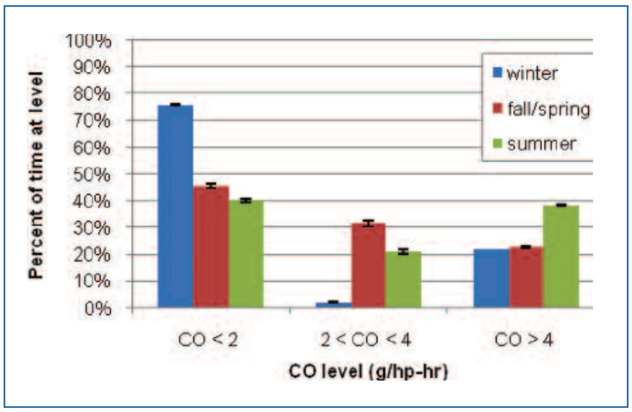

FIGURE 5. SEASONAL EFFECTS ON CO LEVELS FOR ENGINE 1

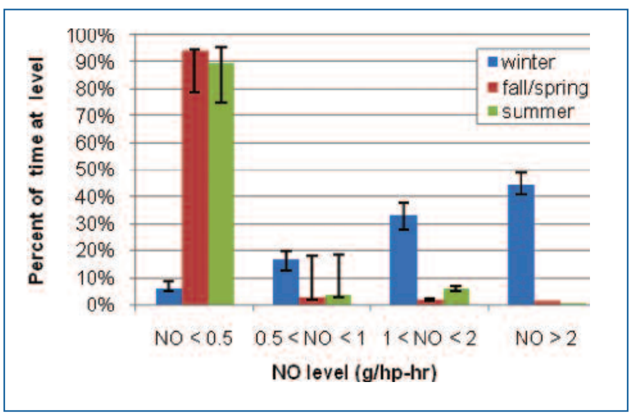

FIGURE 6. SEASONAL EFFECTS ON NO LEVELS FOR ENGINE 2

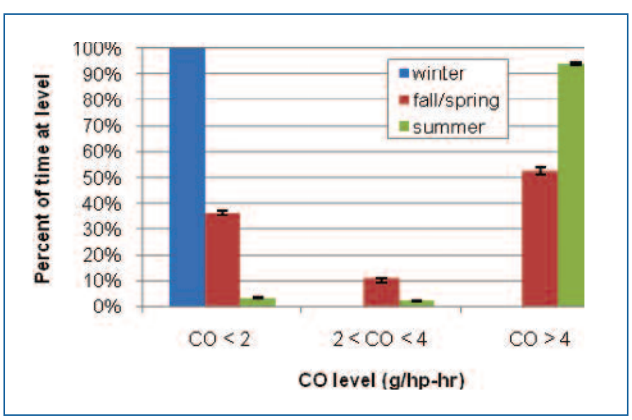

FIGURE 7. SEASONAL EFFECTS ON CO LEVELS FOR ENGINE 2

Emissions Data

continued from page six

above 2 g/hp-hr (2.7 g/kW-hr) than at any other NO level. During the fall/spring and summer seasons, more NO measurements were recorded at levels less than 0.5 g/hp-hr (0.7 g/kW-hr) than at any other NO level. This is the same seasonal NO pattern that was observed for Engine 1, although the degree of variation between bin levels for each season and between seasons is different. As for Engine 1, the CO data for Engine 2 shown in Fig. 7 reveals that during the winter, more data was collected at CO levels less than 2 g/hp-hr hr (2.7 g/kW-hr) than at any other level.

SUMMARY OF CONCLUSIONS

The data indicate a fairly tight operating window for simultaneous control of both NOx and CO to low levels (e.g. < 500 ppm). The NSCR/AFRC systems were able to simultaneously control both species to low levels for a small fraction of the time. Additionally, high emissions levels (e.g. > 500 ppm) drifted back to low emissions levels (e.g. < 500 ppm) with no intervention on a number of occasions. However, for the majority of the monitored operation, one species was much more effectively controlled than the other, suggesting the AFRC was not able to consistently control to the tight operating window.

(Adapted from paper ICES2009-76159, ICE Spring 2009 Technical Conference, Milwaukee, Wisconsin)

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College Station, TX 77843-3123
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Cell Ph. 413-420-0025
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E-Mail: Dan.E.Richardson@ cummins.com

EMISSION CONTROL SYSTEMS

Steven G. Fritz, PE
Manager Medium Speed Diesel Engines
Dept. of Engine and Emissions Research
Southwest Research Institute
6220 Culebra Road
P. O. Drawer 28510
San Antonio, TX 78228-0510
E-Mail: sfritz@swri.org

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Song-Charng Kong
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Iowa State University
3028 Black Engineering Building
Ames, IA 50011
E-mail: kong@iastate.edu

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Dr. Jerald A. Caton
Prof., Mechanical Engineering Dept.
Texas A&M University
College Station, TX 77843-3123
Ph. 979-845-4705
Fax 979-862-2418
E-Mail: jcaton@tamu.edu

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Dr. James S. Cowart, Asst. Professor
Mechanical Engineering Dept.
U.S. Naval Academy
590 Holloway Road
Annapolis, MD 21402
Ph. 410-293-6515
Fax: 410-293-3041
E-Mail: cowart@usna.edu

Dr. Margaret S. Wooldridge
Associate Professor
Department of Mechanical Engineering
University of Michigan
2350 Hayward Street
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Ph.: 734-936-0349
Fax: 734-647-3170
E-Mail: mswool@umich.edu

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LaGrange, IL 60525
Ph. 708-387-3758
Fax 708-387-6164
E-Mail: ramesh.poola@gm.com

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Tim Callahan

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Prof. Suri Rajan
Dept. of Mechanical Engineering and Energy Processes
Southern Illinois University
Carbondale, IL 62901-6603
Ph. 618-453-7010
Fax: 618-453-7658
E-Mail: rajan@siu.edu

PAPER PRESENTATION RATING

Steven G. Fritz, PE
Manager Medium Speed Diesel Engines
Dept. of Engine and Emissions Research
Southwest Research Institute
6220 Culebra Road
P. O. Drawer 28510
San Antonio, TX 78228-0510
Ph. 210-522-3645
Fax: 210-522-3950
E-Mail: sfritz@swri.org

CIMAC U.S. NATIONAL MEMBER GROUP

Tim Callahan, Chair

MEMBERSHIP DEVELOPMENT AND MEMBER INTERESTS

Dr. Frank W. Aboujaoude
Engineering Manager, Pielstick Engines
Fairbanks Morse Engine
701 White Avenue
Beloit, WI 53511
Ph. 608-364-8197
Fax: 608-364-8233
E-Mail: frank.aboujaoude@ fairbanksmorse.com

NOMINATING

Terry L. Ullman
Southwest Research Institute (Ret)
27540 Riata Ranch
San Antonio, TX 78261
Ph. 210-408-0830
E-Mail: tullman27@gmail.com

HONORS & AWARDS

Abnash C. Narula, PE
Manager of Engineering
Wm. W. Nugent & Co.
3440 Cleveland St.
Skokie, IL 60076-0948
Ph. 847-674-7782
Fax: 847-674-0379
E-Mail: a.narula@wwnugent.com

MEETINGS COORDINATING

Frank Aboujaoude

PUBLICITY

Mark McNeely
Publisher and Editor
Diesel & Gas Turbine Worldwide
Diesel & Gas Turbine Publications
20855 Watertown Road
Waukesha, WI 53186-1873
Ph. 262-754-4113
Fax: 262-754-4175
E-Mail: mmcneely@dieselpub.com

OPERATING GUIDE & BY-LAWS

John Hedrick
Principal Engineer
Southwest Research Institute
6220 Culebra Road
P. O. Drawer 28510
San Antonio, TX 78228-0510
Ph. 210-522-2336
Fax: 210-222-2710
E-Mail: jhedrick@swri.org

GOVERNMENT RELATIONS (Open)

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LECTURES

Dr. Kirby S. Chapman
Professor and Director
National Gas Machinery Lab.
Kansas State University
245 Levee Drive
Manhattan, KS 66502
Ph. 785-532-2319
E-Mail: chapman@ksu.edu

INTERNAL COMBUSTION

Engine Award
Raj Sekar
Center for Transportation Research
Argonne National Laboratory
9700 S. Cass Ave., Bldg. 362
Argonne, IL 60439
Ph. 630-252-5101
Fax. 630-252-3443
E-Mail: rsekar@anl.gov

HONDA MEDAL COMMITTEE REPRESENTATIVE

Steven G. Fritz, PE
Manager Medium Speed Diesel Engines
Dept. of Engine and Emissions Research
Southwest Research Institute
6220 Culebra Road
P. O. Drawer 28510
San Antonio, TX 78228-0510
Ph. 210-522-3645
Fax: 210-522-3950
E-Mail: sfritz@swri.org

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Manager of Engineering
Wm. W. Nugent & Co.
3440 Cleveland St.
Skokie, IL 60076-0948
Ph. 847-674-7782
Fax: 847-674-0379
E-Mail: a.narula@wwnugent.com

LONG RANGE PLANNING

Frank Aboujaoude

HISTORY AND HERITAGE LIAISON

Melvin J. Helmich
Technical Director
HELMA'RK
P. O. Box 493
Mount Vernon, OH 43050-0493
Ph. 740-397-5323
Fax 740-397-5323
EMail:mhelmich@columbus.rr.com

STUDENT ACTIVITIES

Dr. Stani Bohac
Assistant Research Scientist
Mechanical Engineering, Univ. of Michigan
2045 W. E. Lay Automotive Laboratory
Ann Arbor, MI 48109-2121

STAFF

Vince Dilworth
Senior Manager,
Engineering Programs
30 Rainbow Bridge Ct.
San Ramon, CA
94582-4534 USA
Ph. 925-244-1360
Fax 925-244-1359
Email: diworthv@asme.org