Dmytro Lysenko

OPTIMIZATION OF AUTOMOBILE ENGINES – FUEL EMULSIONS

Optimization of internal combustion engines using high-water fuel emulsions; engine and fuel system testing results

2026

Arrow Science & Technology

DOI: 10.29013/OAEFE.LysenkoD.33.2026

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Optimization of Automobile Engines – Fuel Emulsions / Lysenko D., – Urbana : Arrow Science & Technology, LLC – 2026. – 33 p.

ISBN 978-1-967596-43-0

This book addresses technological aspects of the operation and comprehensive restoration of automobiles from the 1940s, as well as the integration of the latest engineering and design solutions that have recently emerged in automotive engineering and related fields into their structural elements.

The materials presented in the book's sections include original innovative solutions for modernizing the fuel system of internal combustion engines, involving the implementation of non-contact monitoring and measurement equipment within fuel pipelines. This equipment is based on electromagnetic resonance spectroscopy and incorporates elements of artificial intelligence and artificial neural networks.

As the primary basis for optimizing internal combustion engines, the book presents linear homogenization of the fuel mixture, built on the principles of modern pioneering inventions that enable dynamic homogenization in parallel with the mixing of fuel components. As a result, a homogeneous fuel emulsion is formed after mixing, in which the water content can be increased up to 50%.

Keywords: *Optimization of internal combustion engines; Optimization of diesel engines; Fuel emulsions; Modernization of the fuel system of internal combustion engines; Paradoxes in emulsions; Description of a unique paradoxical system; A new version of technology for preparing emulsions in general and fuel emulsions in particular; Components of organic origin; Stability of particle or droplet sizes of liquids of organic origin; Preservation of geometric size consistency over a certain period of time; Methodology for designing fuel mixture activation devices using advanced techniques and methods, including active computer modeling and simulation of operating processes; Components of organic origin may include hydrocarbon liquids, liquids with high concentrations of fats, oils, aromatic hydrocarbons, etc*

Subscribe to print 25/08/2026. Format 60×84/16.
Offset Paper. Arno Pro. Pec. liter. 14. Circulation of 300 copies.
Typeset in Arrow Science & Technology, LLC, USA.

Publishing by Arrow Science & Technology, LLC
805 Silver St., Urbana, IL 61801

ISBN 978-1-967596-43-0

Contents

Introduce

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The book sections present, for the first time, the results of testing internal combustion engines using a fuel mixture with the properties of a homogeneous encapsulated fuel emulsion. This emulsion exhibits a hydraulic memory of shape within nanoscale capsules, which take the form of spherical cores of water or liquid condensed in real time from exhaust gases, sur-

rounded by a shell of gasoline or diesel fuel. The thickness of this shell is represented within the nanoscale range.

The book also examines design variations of linear activation devices that utilize the principles of Bernoulli's theorem to create a coaxial zone of localized low pressure within the fuel pipeline. It is within this zone that nanoscale fuel capsules are formed, determining the unusual thermodynamic results of fuel injection and combustion processes.

In addition, the book sections present materials related to the methodology for designing fuel mixture activation devices using the latest techniques and methods, including advanced computer modeling and simulation of operating processes.

Since paradoxical phenomena with unique positive overall results for the entire supersystem were identified in the emulsion during testing, the book also provides descriptions of these paradoxical effects.

Emulsions in which components of organic origin are mixed with water; in these emulsions, components of organic origin are introduced into water. Components of organic origin may include hydrocarbon liquids, liquids containing high concentrations of fats, oils, aromatic hydrocarbons, etc.

In emulsions of this type, the content of organic components in water does not exceed 50% of the total weight of the emulsion, but in most cases it is 10–20% of the total weight.

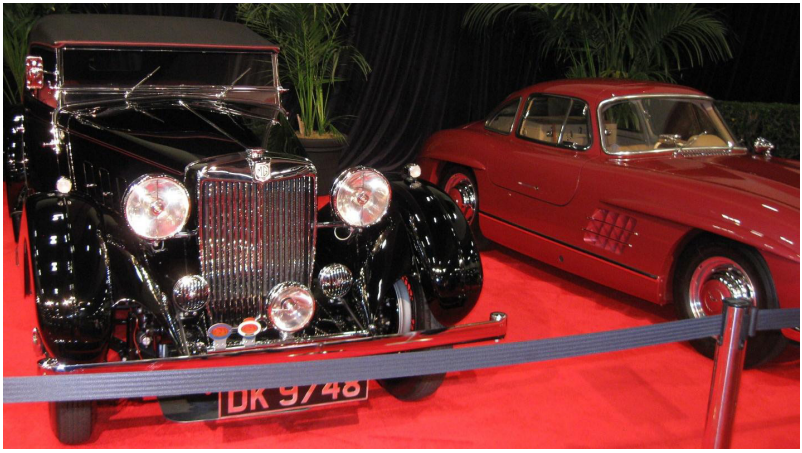
The most important parameters of such emulsions:

- The size of particles or droplets of liquids of organic origin in water;
- The uniformity of distribution of organic-origin particles in water;

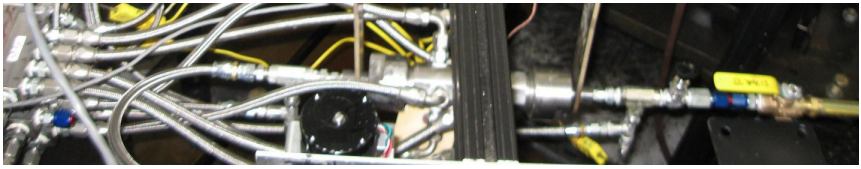
- The stability of particle or droplet sizes of organic-origin liquids, the repeatability of these sizes, and the period of time during which the uniform distribution of these particles within the volume of water is maintained.

Testing of emulsions of this type may involve direct measurement, in which the emulsions are formed using an Emulsion Formation Device, and the resulting emulsion is examined to measure.

- The size of particles or droplets of the liquid component of organic origin in water;
- The uniformity and homogeneity of the distribution of particles of organic origin in water;
- The duration of stability of particle or droplet sizes of the liquid component of organic origin, the preservation of geometric repeatability of these sizes over a certain period of time, and the period during which the uniform distribution of these particles within the volume of water is maintained.



Technical Proposal for Testing the Method of Mixing No. 2 Diesel Fuel with Water in Various Proportions



The ideal mixing ratio is expected to be 50% water and 50% diesel fuel.

It is advisable to begin testing with a ratio of 10% water to 90% diesel fuel, gradually increasing the water content step by step by 5%, while correspondingly decreasing the diesel fuel content in the mixture by 5% at each step.

To prepare the mixture of No. 2 diesel fuel with water, it is proposed to use regular tap water without предварительной обработки или фильтрации; such practice was tested in Livonia (Detroit) with total water mineralization not exceeding 200 mg per liter.

Given that our company possesses the necessary baseline technical solutions, at later stages of testing it is proposed to use the same tap water, the alkalinity of which will be increased to a level of pH 11 in an electrochemical reactor (an invention of our company).

Considering the importance of evaluating the combustion quality of the resulting diesel-water mixture, as well as analyzing the level of exhaust gas pollution by nitrogen oxides and soot, it is proposed to begin testing the obtained emulsion by using it in a boiler (with operating characteristics specified in the responses to our inquiries).

Our company has devices for comprehensive mixing and activation of fuel mixtures with an operating diameter of 25 mm, with a capacity of:

- Maximum: 7.5 gallons per hour;
- Minimum: 2.5 gallons per hour.

To achieve significantly lower output levels required for the boiler proposed for testing, our company's specialists suggest implementing a system on the existing device to divert excess emulsion into an additional tank or reservoir.

To determine the nature of the process, the technology, and the resulting emulsion, the same set of equipment and devices will be required, including measurement instruments and tools.

It is particularly important to measure the flame temperature during the combustion of the emulsion, which must necessarily be provided for.

In case of agreement with the proposed testing procedure, our company will propose and coordinate with you a testing protocol, as well as a detailed working design of the testing equipment or test bench.

General Characteristics of Emulsions Obtained Using a Device for Dynamic Mixing and Hydrodynamic Activation of Liquids in a Developed Turbulent Flow:

Emulsions can be produced within a dynamically active flow of one of the liquids forming the emulsion; no process tanks are required, as the emulsion preparation device is integrated into the pipeline.

– The preparation of emulsions does not require high or ultra-high pressure;
– The production of emulsions does not require the use of ultrasonic technologies;
– The emulsion preparation time does not exceed fractions of a second;

- The parameters of the emulsion, including the size of its component particles, are determined by the geometry of the corresponding sections and elements of the device for dynamic activation of liquids in a developed turbulent flow;
- The emulsion preparation process occurs simultaneously with homogenization, not only in terms of particle size distribution but also in terms of the flow's turbulence level.

General properties of emulsions in which the content of organic components exceeds the content of inorganic components, obtained using a device for dynamic activation of liquids in a developed turbulent flow.

General properties of emulsions in which the content of organic components is lower than the content of inorganic components, obtained using a device for dynamic activation of liquids in a developed turbulent flow.

General properties of emulsions in which the content of organic and biological components exceeds the content of inorganic components, obtained using a device for dynamic activation of liquids in a developed turbulent flow.

General properties of emulsions in which the content of organic and biological components is lower than the content of inorganic components, obtained using a device for dynamic activation of liquids in a developed turbulent flow.

A New Version of Emulsion Preparation Technology in General and Fuel Emulsions in Particular

The main difference of the proposed method of emulsion production is that:

- The emulsion is formed in a device for dynamic mixing and activation of liquids and gases, within a dynamic flow of 60% of one of the emulsion components, into which an additional 40% of the same component is introduced in the form of a dynamic flow. After that, at the junction of the 60% and 40% flows of this component, the second component of the emulsion is introduced, also in the form of a dynamic flow;

The 60% and 40% flows of one of the emulsion components are coaxial and aligned: alondimensional space in which these flow fragments move.

- At the same time, the linear velocity of the 40% flow of one of the emulsion components is at least four times higher than the linear velocity of the 60% flow of the same component;
- The physical conditions at the junction of these flows, including concentric Bernoulli effects within each flow, ensure homogenization of the turbulence of the combined flow (turbulent homogenization);
- The dynamic flow of the second emulsion component is introduced into the zone where turbulent homogenization has been achieved;

- The integrated flow of the resulting emulsion acquires a state of homogenized turbulence level throughout the entire volume of the flow, at all cross-sectional points;
- The duration of this process of forming an emulsion homogenized by turbulence level is, according to calculations, no more than 0.1 seconds;
- The outlet of the device for dynamic mixing and activation of liquids and gases in the integrated (invented) system is directly connected to the inlet of a standard high-pressure pump (used in any modern internal combustion engine, both diesel and gasoline);
- The time required for the primary emulsion with a homogenized turbulence level to enter the working cylinders of the high-pressure pump does not exceed 0.1 seconds, according to calculations;
- In the high-pressure pump, the emulsion with a homogenized turbulence level is compressed to pressures exceeding 2000 bar, which suggests that, according to the definition of a nano-emulsion, such compression results in an additional homogenization cycle within a confined volume. This may be classified as the formation of a nano-emulsion with all its properties and advantages;
- Since no more than 0.2 seconds pass between the onset of turbulence-level homogenization and compression-induced homogenization, and considering the inertia of these processes in a liquid flow, the overall homogenization process can be considered fully uniform.
- The specified integral process of forming double and three-dimensional homogenization within a continu-

ous dynamically uniform turbulent flow of liquids being mixed into an emulsion can thus be considered a sequential process of emulsion homogenization, culminating in its transition into the category of nano-emulsions.

Using this method, we formed an emulsion of diesel fuel and tap water in a flow, which, when burned in the combustion chamber of a diesel engine, demonstrated unusual performance characteristics not found in publications and not previously reported in scientific experiments and studies. This allows us to assume that a nano-emulsion was indeed obtained, which is indirectly confirmed by microscopic analysis of the emulsion images.

The integrated device, consisting of a system for mixing and homogenizing the turbulence level of the emulsion, directly connected to a high-pressure pump as an element of geometric dimensional homogenization under pressure, within an extremely short time interval between stages of homogenization, and ensuring maximum uniform distribution of particles of one component within the volume of the second component homogenized by turbulence level, makes it possible to classify the sequential emulsion formation process as a new method. This method enables double homogenization of the emulsion with its transition into the category of nano-emulsions, but with new criteria of uniformity both in terms of geometry and turbulence level.

These facts indicate that the described process and the integrated device for its implementation are novel and non-obvious to a specialist of average qualification in this field.

What has been invented:

- A new type of nano-emulsion with double three-dimensional homogenization in a dynamic flow, both in

terms of turbulence level and particle geometry within its volume;

- A new type and configuration of an apparatus for sequential homogenization in a developed dynamic flow of liquid components of the emulsion.

Emulsions

Emulsions in which components of organic origin are mixed with water; in these emulsions, components of organic origin are introduced into water. Components of organic origin may include hydrocarbon liquids, liquids containing high concentrations of fats, oils, aromatic hydrocarbons, etc.

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Testing of emulsions of this type may involve direct measurement, in which emulsions are formed using an Emulsion Formation Device, and the resulting emulsion is examined to measure:

- The size of particles or droplets of the liquid component of organic origin in water;
- The uniformity and homogeneity of the distribution of particles of organic origin in water;
- The duration of stability of particle or droplet sizes of the liquid component of organic origin, the preservation of

geometric repeatability of these sizes over a certain period of time, and the period during which the uniform distribution of these particles within the volume of water is maintained.

Emulsions and Their Differences Depending on Size Factors

The particle size of the liquid components of emulsions determines their main properties and characteristics. The smaller the particle size, the higher the quality of the emulsion. Production of emulsions using a device for dynamic mixing, homogenization, and activation makes it possible to achieve minimal particle sizes. This parameter is fundamental in classifying an emulsion as a mini-emulsion, micro-emulsion, or nano-emulsion.

During the initial testing of the emulsion preparation process using a device for dynamic mixing, homogenization, and activation, indications of a multi-level arrangement of capsules and autonomous particles of the components were observed. This factor requires more detailed investigation in subsequent tests.

Emulsions and Their Differences Depending on the Uniformity of Particle Distribution

Emulsions also differ based on the uniformity of distribution of particles of the additional (non-dominant) component within the volume of the dominant component.

Emulsions and Their Differences Depending on the Homogenization Method

In classical emulsion preparation technologies, various chemical reagents are used for homogenization. When using a device for dynamic mixing, homogenization, and activation, both stages of homogenization are achieved solely through the geometry of the device, without the use of any chemical reagents, while improving the main properties and quality of the emulsion.

Emulsions and Their Differences Depending on Sequential Homogenization Stages

Classical emulsions do not include homogenization based on the level of turbulence.

In a device for dynamic mixing, homogenization, and activation, a unique feature and advantage is the ability to simultaneously achieve homogenization by turbulence level during the emulsion preparation process.

Importance of Homogenization by Turbulence Level

One of the key features in the operating cycle of a device for dynamic mixing, homogenization, and activation is the ability to create a uniform turbulence background across the entire cross-section of the emulsion component flows in the emulsion formation zone.

In addition to forming a uniform particle size distribution, a uniform turbulence background creates consistent hydrodynamic conditions in the emulsion preparation zone, which reduces the time required for complete emulsion formation. This is especially important when forming an emulsion within a dynamic flow of its components.

Importance of Homogenization by High Pressure

The ability of the device for dynamic mixing, homogenization, and activation to operate sequentially with a high-pressure pump makes it possible to create exceptionally uniform conditions for homogenization under high pressure, since the emulsion entering the high-pressure pump has a uniform turbulence background throughout its entire volume.

Originality of Emulsion Processing Under High Pressure in Flow

Importance of Minimizing the Time Interval Between Sequential Homogenization Cycles

The time interval between turbulence homogenization and pressure-based homogenization, due to the properties of the device for dynamic mixing, homogenization, and activation, does not exceed 10 milliseconds.

Such a short time interval allows the sequential homogenization process to be considered continuous and ensures the stability and quality of the double homogenization process.

Importance of Multiplying Flow Velocity or Pressure Between Sequential Homogenization Cycles

As demonstrated in the initial tests of the device for dynamic mixing, homogenization, and activation during emulsion formation, introducing a hydraulic resistance stimulator into the channel through which the emulsion exits the device makes it possible to intensify the emulsion preparation process.

Feasibility Study Test Concepts

New invention: Integrated system for nano-fuel emulsion from gasoline and ethanol producing in gas station

In Diagram 1 presented conceptual version of use of fuel nano-emulsion production system in: or gas station or in fuel manufacturing plant

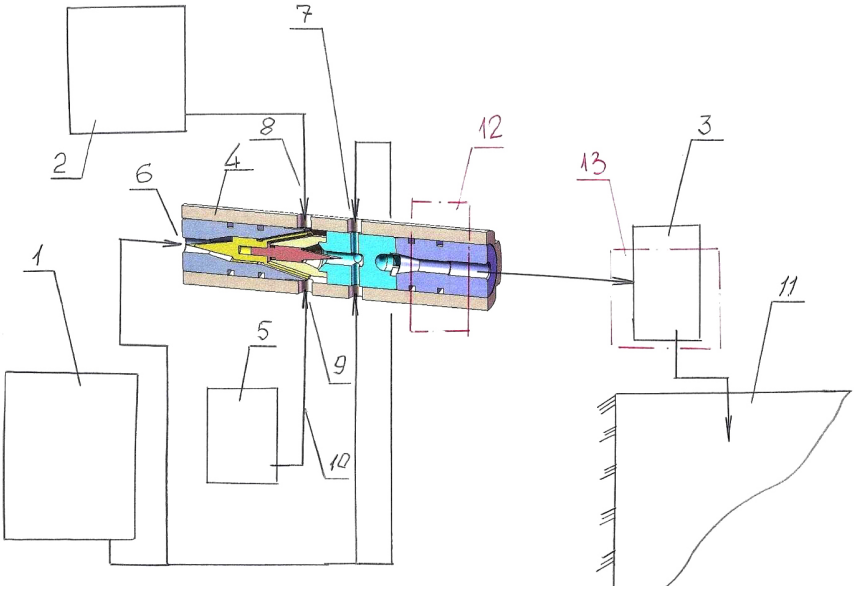

Diagram 1.

1 – gasoline or diesel fuel tank;

2 – ethanol (or methanol with water, or ethanol with water) tank;

3 – high pressure pump (from regular diesel engine);

4 – TEI fuel mixing and activation device (current prototype, 25 millimeters diameter size);

5 – optional, – water tank;

6 – main input of gasoline or diesel fuel to fuel mixing and activation device;

7 – second group (4) of inputs to fuel mixing and activation device;

8 – input of ethanol (or methanol, or ethanol-methanol blend with water, or water);

9 – optional, – input of water;

10 – water line (optional);

11 – gas station tank of gasoline/diesel fuel with ethanol (methanol or water) mix;

12 – first stage of fuel mix homogenization, – turbulent level homogenization (novel operation);

13 – second stage of fuel mix (micro-emulsion) high pressure homogenization and producing of nano-emulsion (novel operation).

The advantages of the technology:

- result of the operation – nano fuel emulsion, that have estimated better octane number, low detonation level, low emissions and estimated fuel economy;
- simple and not expensive equipment for implementation of the operation;
- equipment can been adapted to present gas stations or production plant equipment w/o any modifications of the present equipment;
- production of nano – emulsion don't need a operational tank,
- all operations is produced in dynamic conditions of the fuel flow in a pipe.

Configuration according to Diagram 1 can been use like feasibility study and demonstration test set-up.

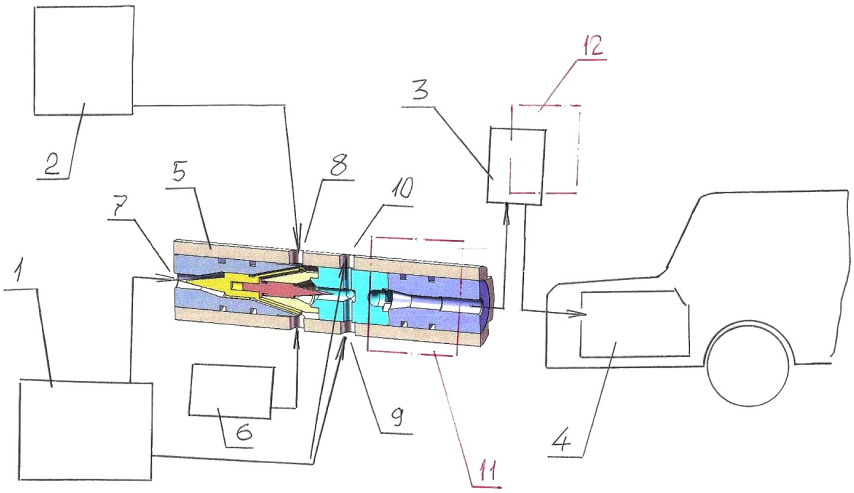

Diagram 2.

Diagram 2 demonstrate the second version of invention with supply of the nano-emulsion direct to tank of the car (in regular gas station) or to the boiler burner.

1 – gasoline or diesel fuel tank;

2 – ethanol tank;

3 – high pressure pump (regular high pressure pump of a diesel engine);

4 – fuel tank of the car;

5 – fuel mixing and activation device;

6 (optional) – water tank;

7 – main gasoline or diesel fuel input;

8 – ethanol input;

9, 10 – second group of gasoline or diesel fuel inputs (4);

11 – first stage of turbulence homogenization (new);

12 – second stage of high pressure nano-homogenization (new)

Additional option for retro-market demonstrate on the Diagram 3.

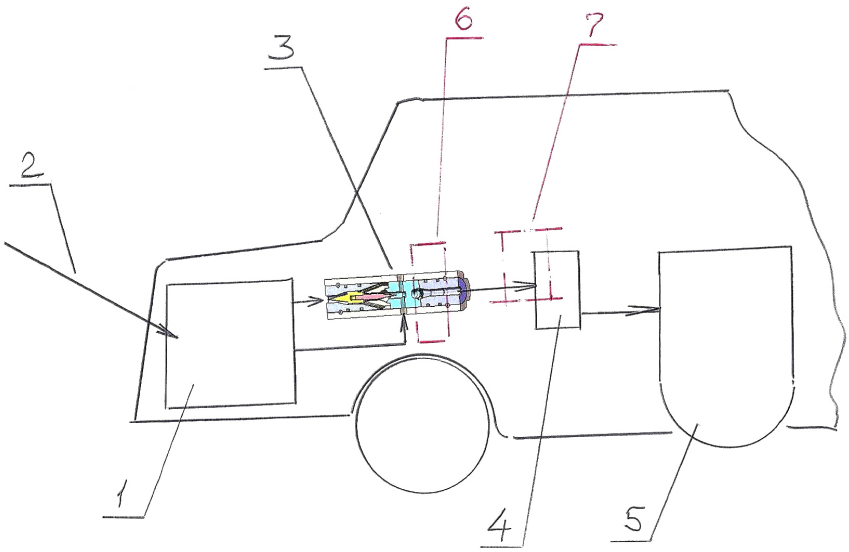

Diagram 3.

1 – fuel tank of the car (regular w/o any modifications);

2 – input of gasoline or diesel fuel nano-emulsion from gas station;

3 – fuel activation device with inputs only for nano-emulsion from the car fuel tank (pressure ~ 45 psi;

4 – high pressure pump of the car;

5 – gasoline or diesel engine of the car;

6, – first additional of nano emulsion homogenization stage (homogenization only w/o mixing);

7,-second additional nano-emulsion homogenization stage with regular engine high pressure pump, before injection.

Figure 1.

Appendix 1.

Results of Initial System Testing

Emulsion/Blend Combustion (Objective #2)

Data was collected from the test cell and combustion analysis system while running the engine at the pre-determined speed and load/timings (see table below). The test points for the baseline data and with the emulsions were selected such that there was sufficient room to adjust the fuel pulse width to account for the additional content of water (when water was used in the emulsions/blends) without reaching the maximum output of the fuel injectors and high-pressure pump. Although the engine used in the testing has on-highway applications, an off-road test cycle set of points were used in the testing as a suitable surrogate and method of reducing the number of speed/load points. The points below were chosen to emulate the most heavily weighted areas of the emissions test cycle for a small off road diesel engine.

RPM	BMEP	Injection timing °BTDC (Final Testing Timing)
2000	5 Bar	4, 8, 12, 14, 16 (8, 12)
2000	10 Bar	4, 8, 12, 14, 16 (8, 12)
2000	15 Bar	4, 8, 12, 14, 16 (8, 12)

Baseline Combustion Testing

No water or other fuel type was introduced for this part of the testing and the bypass fuel from the engine was returned to the

dynamometer float bowl to simulate normal vehicle operation. The calibration used was the same one from previous engine testing with the exception of running main injection only for fueling. The engine coolant temperature, oil temperature, inlet air temperature, fuel rail pressure, and intake manifold pressure were held at fixed values, which can be seen in the supplied data files. Next, a sweep of injection event timing was performed. For most of the points tested, the main injection timing was set to a minimum value of 4 ˚BTDC and was advanced in increments of 4 degrees until reaching a maximum of 12 ˚BTDC. Some of the points were increased in timing to 14 & 16 ˚BTDC to see if the additional timing showed further improvement. At each of these injection timing points, the commanded fuel value "throttle %", as indicated in the dynamometer data, was modified to maintain a constant BMEP (normalized torque) value. Baseline data were recorded each day and at times multiple times during the day to ensure the engine was always operating within normal and expected parameters.

Emulsion Combustion Testing

At each speed and load point, the blend fuel and/or water was introduced to the system with percentages controlled with needle valves. The total flow of diesel was monitored with a Micro-motion flow meter to achieve the target flow supply for the FAD. The side inlet flow was monitored with a separate flow meter to calculate the 60/40 percentages being supplied to the FAD center/side inlets. Flow meters for the blend fuels or water were used to calculate the percentages for the mixtures. A set-up using a combination of 3-way and straight ball valves were used to be able to switch from the FAD and the float bowl

fuel supply systems "on the fly" for more efficient testing. This allowed the baseline with No.2 diesel to be performed every day prior to any emulsion testing. When an emulsion was introduced, if the torque output of the engine decreased, then the commanded fuel value was increased to achieve the set BMEP value. This was done to ensure a valid comparison between the baseline and the various fuel mixtures. The injection timing sweeps were performed and the data was collected at each point. Each baseline and emulsion percentage point was performed like this, and afterwards the engine was run for a short period of time with No.2 diesel with the float bowl to flush the system. This also allowed a re-checked with 0% water and with the original base calibration to watch for any degradation in engine performance, or change in emissions values. Essentially, this also allowed for re-verification of the baseline data.

One issue that was encountered during testing with the emulsions was that the flow meter, which was intended to measure the excess FAD emulsion and engine return fuel, could not properly measure the flow into the waste collection barrel. With Diesel fuel only, the flow meter worked as designed, but with the emulsion fuel blends, the flow signal was erratic which resulted in variations in the overall calculated engine fuel flow. This, in turn, caused inaccurate BSFC calculations. A sight tube was installed after the waste flow meter and before the waste barrel to view the mixture coming out of the flow meter. It was found that the emulsion had variations of bubbles and was causing fluctuations in the flow meter readings. To correct this problem, a 10 gallon drum was placed on a scale and the waste fuel was diverted to it using a bypass solenoid operated valve. When taking a data point, the valve was switched to divert the

waste flow to the drum/scale for mass measurement of fuel flow over time. Although the data is thought to be accurate, some degree of error may have been introduced due to the difference in measurement equipment between the baseline data and the emulsion testing.

The combustion testing went through three phases. The first phase was designed to be broad and cover all the various speed/load points shown above and multiple blend percentages. The objective in the first phase was to determine a smaller sampling of points for further testing and analysis. After running approximately 300 different tests in the first phase, 12 were selected for Phase 2. The results of Phase 1 are not specifically discussed in this report. During the second phase, more time was spent running the 12 select points and validating the results from Phase 1. In our view, the Phase 2 results (tests 1–4 summarized in the table below) were consistent with Phase 1 findings and Turbulent's FAD exhibited consistency in its operation and the resulting performance. The table below includes a summary of the Phase 2 results. The table provides a comparison of the test results versus a baseline. Positive percentages are an improvement and negative percentages are a reduction in performance. It should be noted that the results might not depict what could be achieved if the FAD were put through an optimization process. It is possible that the results might improve further if a calibration effort with the FAD was under taken. The combustion testing was also done with two different injector sizes. Both injector sizes delivered similar results. Phase 3 of the combustion testing is the subject of the "re-blending" tests discussed later in this report.

Table below is a summary of Phase 2 and 3 test results:

Test#	Blend Components	Variables/Results	5 Bar (~70lb/ft)	10 Bar (~140lb/ft)	15 Bar (~210lb/ft)
1.	No. 2 Diesel / Methanol	Blend % Methanol	22.6%	22.3%	24.6%
		BSFC	–17.9%	–14.1%	–18.0%
		Net Cost Benefit/unit	–0.7%	3.0%	0.9%
		Nox (ppm)	1.6%	6.4%	15.5%
		Smoke (FSN)	85.7%	81.5%	35.1%
		Brake Thermal Efficiency	–3.9%	–0.8%	–2.8%
		THC	–230.0%	–2.8%	16.1%
		Injection Timing (BTDC)	12	8	8
2.	No. 2 Diesel / Methanol / Water (Pre–Mix)	Blend % Methanol	18.9%	20.0%	19.6%
		BSFC	–17.1%	–13.4%	–13.8%
		Net Cost Benefit/unit	–2.7%	1.9%	1.2%
		Nox (ppm)	3.3%	27.8%	38.8%
		Smoke (FSN)	73.7%	62.5%	17.6%
		Brake Thermal Efficiency	–5.3%	–1.6%	–2.1%
		THC	–40.0%	8.5%	9.4%
		Injection Timing (BTDC)	12	12	12

3.	No. 2 Diesel / Water	Blend % Water	20.1%	20.4%	19.7%
		BSFC	3.5%	0.6%	–0.4%
		Net Cost Benefit/unit	3.5%	0.6%	–0.4%
		Nox (ppm)	19.8%	25.6%	26.9%
		Smoke (FSN)	86.2%	87.9%	67.4%
		Brake Thermal Efficiency	3.6%	0.6%	–0.4%
		THC	3.9%	8.5%	0.0%
		Injection Timing (BTDC)	12	8	12
4.	No. 2 Diesel / Ethanol	Blend % Ethanol	30.5%	40.4%	–
		BSFC	–19.5%	–19.3%	–
		Net Cost Benefit/unit	3.8%	11.5%	–
		Nox (ppm)	–7.7%	17.1%	–
		Smoke (FSN)	86.4%	86.7%	–
		Brake Thermal Efficiency	–6.2%	–2.1%	
		THC	–117.0%	–11.9%	–
		Injection Timing (BTDC)	12	12	–

5.	No. 2 Diesel / Methanol (Re–blending w/o FAD – Same Day)	Blend % Methanol	–	20.0%	–
		BSFC	–	–12.9%	–
		Net Cost Benefit/unit	–	2.4%	–
		Nox (ppm)	–	7.8%	–
		Smoke (FSN)	–	66.7%	–
		Brake Thermal Efficiency		–1.1%	
		THC	–	0.0%	–
		Injection Timing (BTDC)	–	8	–
6.	No. 2 Diesel / Methanol (Re–blending with FAD – Same Day)	Blend % Methanol	–	20.0%	–
		BSFC	–	–9.7%	–
		Net Cost Benefit/unit	–	5.6%	–
		Nox (ppm)	–	8.7%	–
		Smoke (FSN)	–	70.4%	–
		Brake Thermal Efficiency		1.8%	
		THC	–	–16.9%	–
		Injection Timing (BTDC)	–	8	–

7.	No. 2 Diesel / Methanol (Re–blending w/o FAD – Next Day)	Blend % Methanol	–	20.0%	–
		BSFC	–	–10.1%	–
		Net Cost Benefit/unit	–	5.2%	–
		Nox (ppm)	–	7.8%	–
		Smoke (FSN)	–	73.1%	–
		Brake Thermal Efficiency		1.4%	
		THC	–	4.5%	–
		Injection Timing (BTDC)	–	8	–
8.	No. 2 Diesel / Methanol (Re–blending with FAD – Next Day)	Blend % Methanol	–	20.0%	–
		BSFC	–	–11.9%	–
		Net Cost Benefit/unit	–	3.4%	–
		Nox (ppm)	–	7.4%	–
		Smoke (FSN)	–	57.7%	–
		Brake Thermal Efficiency		–0.2%	
		THC	–	10.4%	–
		Injection Timing (BTDC)	–	8	–

Note: Assumes No. 2 Diesel Cost $1,900/MT, Methanol and Ethanol Cost $450/MT

Engine Brake Thermal Efficiency

Brake Thermal Efficiency is the measure of how efficiently the engine utilizes the fuel energy for crankshaft power out-

put. The methanol and ethanol fuel emulsions had slightly less brake thermal efficiency as compared to 100% diesel #2. After analyzing the combustion pressure data and noticing a delayed start of combustion, one might expect the efficiency to improve similar to baseline through an effort to optimize the engine calibration for the emulsion. The water emulsion was better, in most cases, than the 100% diesel. Water content was not included in engine fuel flow as it was not considered a fuel due to a lack of energy content. With the emulsion having a similar or same brake thermal efficiency as the baseline, it would tell us the emulsion did not adversely affect the combustion process and that these fuels could be utilized in a modern diesel engine in terms of not impacting the thermal efficiency.

Combustion Analysis

To understand the combustion process during the testing and to be able to compare the emulsion to baseline diesel combustion, the engine was fitted with in-cylinder pressure sensors located in the glow plug ports of cylinder #1 and cylinder #4. High speed cylinder pressure data was recorded vs. engine crank angle for all test points performed. Cylinder #1 data was used for the analysis. The following analysis will look at the test points with diesel #2 and methanol. Graphs for the other fuel blends are available in the Appendix.

Diesel #2 and Methanol 2000 rpm and 5 bar BMEP

Graph 1 depicts a comparison of the average of 300 cycles of cylinder pressure during the compression and combustion events taken while running the engine at 2000 rpm and 5 bar BMEP and with 100% diesel (baseline) and 22.5% Methanol.

Both were run with the same start of injection as shown in the injector firing trace. The pressure plot shows a delayed start of combustion for the methanol blend.

Graph 2 depicts a comparison of the burn characteristics of the baseline and 22.5% methanol blend for the same data test points. This graph also shows the delay in start of combustion for the same start of fuel injection. Of significant note is the faster burn rate for the methanol blend once combustion was initiated. 90% of the combustion completed 1.4 degrees sooner than the baseline even though the 5% mass fraction burn was delayed by 5.6 degrees. The 22.5% methanol blend had ~50% increase in maximum burn rate when compared to the baseline.

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