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United States Patent and Trademark Office

November 11, 2020

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APPLICATION NUMBER: *62/931,084*
FILING DATE: *November 05, 2019*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US62/931,084*

Certified by

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

Electronic Acknowledgement Receipt	
EFS ID:	37665791
Application Number:	62931084
International Application Number:	
Confirmation Number:	1000
Title of Invention:	METHOD AND SYSTEM FOR IMPROVING EFFICIENCY TO ENHANCE FUEL CONSUMPTION RATES AND EMISSIONS REDUCTIONS
First Named Inventor/Applicant Name:	Joao Carlos Fernandes Serodio
Correspondence Address:	Joao Serodio - 27 Cherry Grove Swansea OT SA2 8AT GB +447412686918 joaoserodio@hotmail.com
Filer:	Joao Serodio
Filer Authorized By:	
Attorney Docket Number:	
Receipt Date:	05-NOV-2019
Filing Date:	
Time Stamp:	19:47:43
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$170

RAM confirmation Number	E2019A5J51286749
Deposit Account	
Authorized User	

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	WebADS.pdf	122120 a4b4eb010711c0323709247a61669c8ba896c6421	no	7
Warnings:					
Information:					
2	Certification of Micro Entity (Gross Income Basis)	WFE_SB15A_submit.pdf	120208 07ba3470ae15ab67f3d89f66f2425df52ef18a15a	no	2
Warnings:					
Information:					
3	Specification	WFE_PPA_v1_Specification_Full.pdf	8899353 71f224cd176d6523d92a91776a2863a0a5e1b5f8	no	131
Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	30808 b6f8235df5c4cfae2eacc6f63713893d48070ac6	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	9172489		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	
	Application Number	
Title of Invention	METHOD AND SYSTEM FOR IMPROVING EFFICIENCY TO ENHANCE FUEL CONSUMPTION RATES AND EMISSIONS REDUCTIONS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
Mr.	Joao	Carlos	Fernandes Serodio	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

City	Swansea	State/Province	OT	Country of Residence [i]	GB

Mailing Address of Inventor:

Address 1	27		
Address 2	Cherry Grove		
City	Swansea	**State/Province**	OT
Postal Code	SA2 8AT	**Country** [i]	GB

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☒ **An Address is being provided for the correspondence Information of this application.**

Name 1	Joao Serodio	**Name 2**	
Address 1	27		
Address 2	Cherry Grove		
City	Swansea	**State/Province**	OT
Country [i]	GB	**Postal Code**	SA2 8AT
Phone Number	+447412686918	**Fax Number**	
Email Address	joaoserodio@hotmail.com	Add Email	Remove Email

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	
	Application Number	
Title of Invention	METHOD AND SYSTEM FOR IMPROVING EFFICIENCY TO ENHANCE FUEL CONSUMPTION RATES AND EMISSIONS REDUCTIONS	

Application Information:

Title of the Invention	METHOD AND SYSTEM FOR IMPROVING EFFICIENCY TO ENHANCE FUEL CONSUMPTION RATES AND EMISSIONS REDUCTIONS		
Attorney Docket Number		**Small Entity Status Claimed**	☒
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	47	**Suggested Figure for Publication (if any)**	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number			

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix	Remove

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	
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Title of Invention	METHOD AND SYSTEM FOR IMPROVING EFFICIENCY TO ENHANCE FUEL CONSUMPTION RATES AND EMISSIONS REDUCTIONS	

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Registration Number					

Additional Representative Information blocks may be generated within this form by selecting the **Add** button.

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status			Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) the information[i] will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)
	GB		

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	
	Application Number	
Title of Invention	METHOD AND SYSTEM FOR IMPROVING EFFICIENCY TO ENHANCE FUEL CONSUMPTION RATES AND EMISSIONS REDUCTIONS	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	
	Application Number	
Title of Invention	METHOD AND SYSTEM FOR IMPROVING EFFICIENCY TO ENHANCE FUEL CONSUMPTION RATES AND EMISSIONS REDUCTIONS	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

◉ Assignee	○ Legal Representative under 35 U.S.C. 117	○ Joint Inventor
○ Person to whom the inventor is obligated to assign.	○ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix
Mr.	Joao	Carlos	Fernandes Serodio	

Mailing Address Information For Applicant:

Address 1	27		
Address 2	Cherry Grove		
City	Swansea	**State/Province**	OT
Country[i] GB		Postal Code	SA2 8AT
Phone Number	+447412686918	Fax Number	
Email Address	joaoserodio@hotmail.com		

Additional Applicant Data may be generated within this form by selecting the Add button.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	
	Application Number	
Title of Invention	METHOD AND SYSTEM FOR IMPROVING EFFICIENCY TO ENHANCE FUEL CONSUMPTION RATES AND EMISSIONS REDUCTIONS	

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix
Mr.	Joao Carlos		Fernandes Serodio	

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1	27		
Address 2	Cherry Grove		
City	Swansea	**State/Province**	OT
Country i	GB	Postal Code	SA2 8AT
Phone Number	+447412686918	Fax Number	
Email Address	joaoserodio@hotmail.com		

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	
	Application Number	
Title of Invention	METHOD AND SYSTEM FOR IMPROVING EFFICIENCY TO ENHANCE FUEL CONSUMPTION RATES AND EMISSIONS REDUCTIONS	

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e. g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/joao carlos fernandes serodio/			Date (YYYY-MM-DD)	
First Name	Joao	Last Name	Serodio	Registration Number	

Additional Signature may be generated within this form by selecting the Add button.

PROVISIONAL APPLICATION FOR UNITED STATES PATENT

TITLE: Method and system for improving efficiency to enhance fuel consumption rates and emissions reductions.

INVENTOR: Joao Carlos Fernandes Serodio

FIELD OF THE INVENTION

[0001] The present invention relates to the field of emulsified fuels, information technology, energy and performance management for improving efficiency, of engines, machinery and/or equipment's, such as, of those of internal, continuous and open flame combustion type, to enhance specific fuel consumption rates and/or reduce the emissions produced from the consumption and burning of hydrocarbon, biodiesel and alcohol-based fuels, other fuels and blends.

BACKGROUND OF INVENTION

[0002] "The market is faced with the demand for novelty alternative solutions capable of promoting a significant impact in the reduction of the use of carbon-based fuel and a reduction of the emissions produced from the consumption those fuels. Considering, the uncertainty about future trends & development, and considering a moderate 'Reform Scenario', where Energy Markets adopt a future trajectory by moderate, coordinated policy intervention, that delivers energy-related emission reductions that significantly contribute to the global warming target. This means that there will be significant changes, as forecasted by many experts in the field, however, in general terms, the figures for the target market will, at least, remain the same, due to the increase market demand, driven by robust GDP growth. New stricter legislation leading to increased emission taxation and restrictions imposed on the use of dirty carbon-based fuels for certain applications, consequently increasing fuel price tend to lead consumers seeking new alternative technologies and promoting opportunities. *e.g.* the reduction of sulphur content for residual fuels in the marine sector. However, despite global effort by government, organizations, companies and experts, promoting opportunities for changes, investment in new and cleaner fuels technologies the forecasted targets and the alternative technologies goals are far from being met, with the exception of electrical vehicle (EV) technology, hence enhancing the opportunity for

alternative technologies and innovative environmentally-friendly ideas capable of significantly increase efficiency of current technologies".

[0003] "The total emissions from fossil fuels represent 83.51% of the emissions from total energy, where the solid fossil fuel energy sector accounts for 45% due to its heavy carbon content per unit of energy released, which compared to Oil, coal is 50% higher as emission on average. The oil sectors account for 30.35%, led by the road transports representing 16.33%, followed by marine with 2.05% and aviation with 1.78%. The transport sector is also a key contributor to the climate change and emitted 7.8 Gt of carbon dioxide (CO2) in 2015, about 22% of the global total energy-related CO2 emissions, led by diesel road transport accounting for 30.17% of the total oil sector and 12.4% of the total fossil fuel".

[0004] "The total oil consumption corresponds to 94.84 million barrels per day (mb/d), led by the transport sector accounting for more than half of global oil demand, at around 52 million barrels of oil per day (mb/d). It has grown rapidly, at 1.9% per year, faster than all other energy demand sectors and contributing to 80% of the total global oil demand growth, between 2000 and 2015. The primary target market for water in fuel emulsion technology (WFE) is the 'transport sector', more specifically, road diesel consumers of the road transport sector and distillate and residual fuel consumers of the marine sector, accounting for just over one third (33.9%) of the world total oil consumption and 90.1% of primary target market".

[0005] "Diesel engines are more robust and efficient than petrol engines resulting in lower fuel consumption rates and longer life span, consequently, just a third of the road fuel used is now petrol, a reversal of the pre-1990 share when just a third of road fuel was diesel, and most of this was used by vans, trucks and buses, however diesel engines are noted as major emission contributor to the environment, which is dangerous to human health.. Europe is responsible for 21.26% of the total road diesel transport sector, accounting for 70% of world sales in diesel cars and vans. The demand for diesel is projected to decrease, albeit very slowly, such that by 2020 it will continue to make up a significant share of road transport fuel. The industrial, power plants, off-road, gensets and agriculture sectors represent the 3.72% of the of total oil consumption".

[0006] "NOx emissions from diesel cars, limits were reduced by 68% from Euro 4 to Euro 6; however, recent analyses indicated that 'real-world' performance-on-road driving under normal conditions – is much worse than a typical performance measured by 'official' laboratory tests using the NEDC driving cycle. The amount of CO2 (which is linearly correlated with fuel consumption) produced on the road can be 20-30% higher than the figure indicated by official measurements, and the differences are even greater for NOx emissions, especially for diesel

vehicles. real-life measurements show that NOx emissions can be, on average, as much as four or five times higher than shown in laboratory measurements. A complete CO2 reduction strategy should include a "diesel focus" in order to fill in the gap, and investments in R&D will be required. The European Commission wants to introduce the new mandatory RDE test procedure for type approval of light duty vehicles by 2017, where emissions will be measured on the road by a Portable Emission Measurement System (PEMS). Diesel powertrain efficiency improvement will be an important lever for European OEMs that want to fulfil EU emissions targets, either for CO2 or NOx. Diesel will remain attractive to consumers because TCO will become a strong buying criterion. TCO cost models (including depreciation, fuel costs, insurance, maintenance, fees and taxes, repairs) show that diesel vehicles can have lower TCO than their respective gasoline counterparts in a three-to five-year time frame".

[0007] "Currently, numerous alternative technologies are available in the market capable of offering reduction of emissions, however with limitations and at a cost, *e.g.* alternative and cleaner fuels (electric, natural gas, propane, renewable diesel, biodiesel, ethanol, etc); fuel and lubricant technology (lubricant oil, Alternative fuels and fuel additives); in cylinder control systems (fuel injection systems, intake boosting, air-handling technologies, exhaust gas recirculation – EGR, combustion chamber design and water in fuel emulsion); aftertreatment systems (diesel oxidation catalyst - DOC, selective catalyst reduction - SCR, diesel particle filters - DPF, exhaust gas cleaning system – EGCS and system integration, NOx storage catalyst - NSC); and control, diagnostics & powertrain technologies (hybridization, diagnosis, controls, gearbox design and powertrain matching)".

[0008] "Current reviews acknowledge water in fuel emulsion (WFE) technology as a the most economical solution incorporated in diesel engines without requiring engine modification. decreasing in temperature of the combustion leading to a drop in NOx formation in diesel engines due to an endothermic reaction of water particles in WFE emulsion fuel during combustion. The presence of water also reduces the rate of formation of soot particles and enhances their burnout characteristics by increasing the concentration of oxidation species. The use of nanoparticle size water in fuel emulsions enhance the combustion and emission characteristics (SureshVellaiyana, 2016). However, the complexity of analysing the combustion behaviour associated with micro-explosion, physical path of emulsion and soot formation leads to inconsistent reports in terms of SFC, BTE, CO and HC emissions. In addition, engine operating variables and ambient conditions also affect atomization and general combustion process and restrict drawing a general conclusion of the source of the WFE efficiency. The reviews also highlight that the comparative advantage

of water in fuel emulsions to diesel fuel are not precisely known and understood, due to insufficient knowledge on micro-explosion phenomenon and the associated combustion phenomenon, resulting from confinement of the research to engine tests on water in diesel emulsions only, which are inconsistent, with no much concentration on influence of water concentration, surfactant concentration, HLB of surfactant on the emulsion stability" (Kiran Raj Bukkarapu, 2017).

[0009] "Emulsions are dispersions made up of two immiscible liquid phases which are mixed using mechanical shear and surfactant. Particle size of this conventional emulsion grows continuously with time and hence finally separation occurs at gravitational force thus these emulsions are thermodynamically unstable. Theories: According to the surface-tension theory of emulsification, the emulsifiers or stabilizers lower the interfacial tension between the two immiscible liquids, reducing the repellent force between the two liquids and diminishing the attraction between the molecules of the same liquid. The oriented-wedge theory assumes the formation of monomolecular layers of the emulsifying agent which are curved around the droplet of the internal phase of an emulsion. This theory is based on the presumption that certain emulsifying agents orient themselves around a liquid droplet in a manner reflective of their solubility in that particular liquid. The plastic-or interfacial-film theory describes that the emulsifying agent is located at the boundary between the water and oil, forming a thin film by being adsorbed onto the surface of the internal phase droplets. The film avoids the contact and subsequent coalescence of the dispersed phase; a tougher and more pliable film will result in greater physical stability of the emulsion (Santosh Nemichand Kale, 2017).

- Surface tension theory - this theory assumes that, when surface tension between two phases lessens then emulsion can be formed
- Repulsion theory - this theory explains a phenomenon by which emulsifying agent forms a film containing globules on one of the immiscible phases with ability to repel each other. Thus, immiscible globules remain suspended in the dispersion medium due to these repulsive forces.
- Viscosity modification - according to this theory emulsifying agents raises viscosity of the medium and thus miscible viscous suspension of globules is formed".

[0010] In general emulsions can be classified based on their morphology, *i.e.* a 'water-based', or oil-in-water (O/W), emulsion has water as the continuous phase and oil as the dispersed phase, whereas the inversed condition yields an 'oil-based' or water-in-oil (W/O) emulsion. Multiple emulsions can be subdivided as single emulsions in two categories, oil in water in oil (o/w/o) and

water in oil in water (w/o/w). They can be characterized accordingly to their properties and behaviour as macro, nano or microemulsions.

[0011] "Macroemulsions have been known for thousands of years. The survey of ancient literature reveals that the emulsification of beeswax was first recorded in the second century by the Greek physician, Galen. Macroemulsions are mixtures of two immiscible liquids, one of them being dispersed in the form of fine droplets with diameter greater than 0.1 □m in the other liquid. Such systems are turbid, milky in colour and thermodynamically unstable, *i.e.* the macroemulsion will ultimately separate into two original immiscible liquids with time. Since the early 1890s, extensive and careful studies have been carried out on macroemulsions on various aspects of formation and stability of these systems. Macroemulsions are normally produced by starting with two immiscible liquids and by applying mechanical energy, which deforms the interface to such an extent that it generates droplets. The large excess of energy required to produce emulsions can only be supplied by very intense agitation, which needs much energy" (SHAH, 1985).

[0012] "Microemulsions have resulted in a detailed understanding of the properties of surfactant films and progress have been made with respect to both experimental methods and theoretical concepts. Microemulsions were first introduced by Schulman et. a l in 1943. The various properties of these systems were studied during the following years, and in 1955, the systems were called both swollen micellar solutions and transparent emulsions. The microemulsions are defined as the clear thermodynamically stable dispersions of two immiscible liquids containing appropriate amounts of surfactants or surfactants and cosurfactants. The dispersed phase consists of small droplets with diameter in the range of 5 to 100 nm. The small droplet size in microemulsions also leads to a large surface-to-volume ratio in an oil-water system. This is important for chemical reactions in which the rate of reaction depends on the interfacial area" (SHAH, 1985).

[0013] "The active ingredients in the form of nanoparticles have a high surface-to-volume ratio, which promotes dispersibility in the emulsion, and are better adapted for multiple functions. As a result of reduced gravity force and Brownian motion, premature destabilisation of this emulsion system is averted; hence, the zero sedimentation during storage. Another destabilisation factor, i.e. flocculation, is also prevented by the minuscule size of nanoemulsions, which prolongs the shelf-life of products. The small droplet size of nanoemulsions allows uniform deposition and penetration of active ingredients through the skin surface. Nanoemulsions exhibit better penetration efficacy of the ingredients due to the large surface area and low surface tension of the whole emulsion system, thus requiring only 3–10% of surfactants during preparation (Nur

Haziqah Che Marzukia, 2019). Nanoemulsions are very similar to microemulsions that are dispersions of nano scale particles but obtained by mechanical force unlike to micro-emulsions which forms spontaneously. The combination of two theories, turbulence and cavitation, explain the droplet size reduction during the homogenization process of nano emulsions" (Santosh Nemichand Kale, 2017):

[0014] "Some commonly known preparation methods are (Santosh Nemichand Kale, 2017):

- High energy emulsification method: ultra-sonication and high-pressure homogenization
- Low energy emulsification: Phase inversion temperature method, solvent displacement method and phase inversion composition method.
- High-Pressure Homogenization: specially designed high- pressure homogenization instrument is used to produce nano sized particles. At very high pressure (500 to 5000 psi), oil phase and water phase are allowed to force through small inlet orifice. Hence extremely small size particles are created due to strong turbulence and hydraulic shear. But this method requires high temperature and energy. Pressure, homogenization cycles are directly responsible for particle size. Higher the pressure and higher the homogenization cycles, smallest is particle size. This method is easy to scale up.
- Microfluidization: In this method also specially, designed device called as micro fluidizer is used to create high-pressure (500 to 20000psi). Initially prepare coarse emulsion of by mixing oil and water phase. This device consists of interaction chamber of small micro channels through which coarse emulsion is forced to an impingement area to form nano size fine particles followed by filtration to obtain uniform particles.
- Ultrasonication: This method is based on principle that when coarse emulsion is in ultrasonic field and external pressure is increased, cavitations threshold also increases to limit where fine nano size particles are formed.
- Phase inversion method: This method uses principle of phase inversion temperature which is the temperature at which phase transition occurs. Low temperature favours O/W emulsions and high temperature favours W/O emulsion. Rapid cooling and heating cycles produces fine particles. Non-ionic surfactant like polyoxyethylene becomes lipophilic at high temperature and hydrophilic at low temperature due to dehydration of the polymer chain.
- Spontaneous Emulsification: This method is simple and uses volatile organic solvent composition of oil, water, lipophilic and hydrophilic surfactant. This composition is allowed

to mix homogenously by magnetic stirring. Then evaporate the water-miscible solvent under vacuum to obtain nano-emulsion.

- Solvent Evaporation Technique: In this technique, initially mix drug with organic solvent using suitable surfactant and prepare O/W emulsion by mixing continuous phase. Then evaporate organic solvent under vacuum or heating or at atmospheric conditions to obtain microspheres loaded with drug followed by centrifugation or filtration.
- Hydrogel Method: This method shares similarity with solvent evaporation method. High shear forces are used to form nano-emulsion of drug- solvent which is miscible with the drug anti-solvent".

[0015] The differences between water in fuel (or oil) nanoemulsions when comparing to macro and/or microemulsions are often difficult to distinguish due to numerous and indistinct definitions characterizing nanoemulsions. Macroemulsions distinguish from all other emulsions due to their very low stability properties, hence defined as of high polydispersity. The main differences between the various water fuel emulsions are defined and shown in table below:

Properties	Macro	Nano	Micro
Particle size (vol.)	>0.1 □m (as much as 1 to 20mm)	0.001* to ~0.3 □m	<0.1 □m (usually 0.01 – 0.05 □m)
Polydispersity (PdI)	>0.30	>0.05* <0.10 (max <0.3)	<0.10
Phase	Biphasic	Monophasic	Monophasic
Aspect	Turbid (Milky/White)	Translucent or Semi-transparent (Yellow/Clear)	Semi-transparent or Transparent (Bluish/Clear)

Properties	Macro	Nano	Micro
Stability	Thermodynamically unstable, kinetically Stable	Kinetically stable/ metastable and thermodynamically unstable or of relatively low stability	Thermodynamically stable
Shel-life	Very Short/ Short	Middle /High	Very High
Free water tendency	Within time	N/A	N/A
Surfactant concentration	Low to High	Low/ Middle	Very High
Interfacial tension	High	Low/Ultra-low	Ultra-low
Energy required to emulsify	High/ Very High	Middle/Low	Ultra-low/Low
Preparation cost	High	Middle /Low	Low
HLB***	Low/ Middle	Middle/High	Low/Middle/High
(Fn/W) Surfactant to water ratio (m/m)	>0.2	0.2 to 0.5	>>1 (~2)
Corrosiveness (WFE)	Middle/High	N/A	N/A
Behaviour (Rheology)	Newtonian and No-Newtonian	No-Newtonian	Newtonian
Optical isotropy	Anisotropic	Isotropic	Isotropic

Properties	Macro	Nano	Micro
Combustion efficiency	Poor	Middle/High	Middle/High
Diesel to WFE fuel consumption rates (mass/mass)	<0.90	>0.90 to ~1.2**	Results < 1 Potentially >0.9
Theories	Surface tension, Repulsion, Viscosity modification, Oriented-Wedge, or Interfacial film	Thermodynamic, Solubilisation or Interfacial	Surface tension or Interfacial

** - based on laboratory tests performed and Dynamic Light Scattering (DLS) results using Malvern Zetasizer and Anton Paar Litesizer. Particle sizer greater than >99% for WFE with 22 and 28 % water content @ Fn/W 0.375 and PdI for 8% water content at Fn/W 0.375, by mass. The greater the % W the higher the polydispersity of the WFE.*

*** - based on chassis dynamometer test performed on a Jaguar X-type, 2.2D, 2005.*

*** - Not as a guideline but as a reference for those using the HLB as a guide.*

Table One (1) – Comparison between typical macro, nano and microemulsions.

[0016] "A surfactant is an amphiphilic molecule consisting of a nonpolar hydrophobic part, usually a hydrocarbon chain, attached to a hydrophilic portion. A schematic representation of a surfactant is given figure Thirty-Six (36). The hydrophilic and hydrophobic portions within the molecule are commonly referred to as the head and tail groups respectively. The hydrocarbon tail group may be linear or branched and may consist of more than one chain and may contain an aromatic group. Surfactants are classified according to the nature of their head group. Anionic surfactant

head groups include sulphonate, sulphate, carboxylate, etc. Cationic surfactants, in which the head groups are positively charged, are generally molecules derived from substituted ammonium compounds. Most commonly used non-ionic surfactants are polysorbate and sorbitan ester surfactants, specifically and respectively, Tween 80 and Span 80, both registered trademarks of Croda International PLC. Finally, surfactants in which the head group comprises of both anionic and cationic groups are termed zwitterionic surfactants. The special properties of surfactant molecules in solution have made them of major industrial importance and they are now used extensively throughout many different areas of the chemical industry. Most of the oil in water emulsions, specifically water in fuel nanoemulsions are non-ionic surfactants. When a surfactant is added to water at low concentrations, the molecules exist in solution as monomers. Some surfactant also resides at the air-water interface such that the hydrophobic tail groups protrude out of the water surface, which upon increasing the concentration of surfactant, a concentration can be reached at which aggregates are formed. These aggregates are called normal micelles and the minimum concentration at which they are formed is called the critical micelle concentration (cmc). The cmc can be determined from abrupt changes in most solution properties which include surface tension, conductivity, dye solubilisation, light scattering, osmotic pressure, etc. Formation of micelles in solution is a direct consequence of the amphiphilic nature of the molecule. In solution at low concentrations, the hydrophobic tail group of the surfactant interacts with the solvent producing an increased ordering of the water molecules around it. This entropically unfavourable process, known as the hydrophobic effect, leads to a tendency to minimise the hydrocarbon chain-water contact. One way this may be achieved is through adsorption at the air-water interface with orientation of the hydrophobic groups away from the solvent. Alternatively, the surfactant molecules may aggregate into micelles with their hydrophobic groups directed towards the interior of the structure and the hydrophilic groups forming the exterior surface. In this way, the hydrophobic tails again minimise their contact with water. In contrast to surfactants in water aggregation in oils generally occurs over a wide concentration range because of much lower aggregation numbers. However, for oils containing significant quantities of water, the aggregation numbers are dramatically increased and consequently a cmc can usefully be defined" (Horsup, 1991).

[0017] Standard emulsion technology tends to use the concept of Hydrophilic-Lipophilic Balance (HLB) when choosing the surfactants to define the best chemical compositions. The principle is based on the HLB of a surfactant and their water loving and water hating nature. Surfactants with different ranges of HLB and their applications are shown in **Table Two (2)**.

Ref.	HLB	Surfactant function
1	2 – 3	antifoaming agent
2	3 – 6	water in oil (w/o) emulsions
3	7 – 9	wetting and spreading agents
4	8 – 16	oil in water (o/w) emulsions
5	13 -15	detergents

Table Two (2) – Surfactant HLB and applications

[0018] Another method used to select the surfactants, not commonly known, and normally adopted for microemulsions is the hydrophilic lipophilic difference or deviation (HLD). "HLD is what HLB should have been: a generally useful, scientifically meaningful approach to surfactant formulation. Countless formulators have found, these, the only numbers that are generally mentioned in the surfactant literature, are largely useless for most purposes. Given that we want to use our surfactant most efficiently, we want to ensure that the head and tail are nicely balanced within the whole formulation so that the surfactant resides mostly at the interface. At the point of perfect balance there is no difference between the hydrophilic tendency and the lipophilic tendency so the HLD = 0. The starting point for all surfactant formulations is the identification of the HLD = 0 point. For those who want Type III microemulsions, identifying HLD = 0 is the end of the journey. For those who want conventional emulsions the point where HLD = 0 is absolutely the worst place to be (emulsions will separate with maximum speed!) but by knowing where it is makes it possible to move the formulation to just the right spot to give you a stable Type I o/w or Type II w/o emulsion. In basics, the point of the HLD equation is to juggle the key parameters. Here they are with their usual units: EACN - Effective Alkane Carbon Number, i.e. the oiliness of the oil; T - the Temperature, in °C; S - the Salinity g/100ml and Cc - a characteristic value for the hydrophobic/lipophilic nature of the surfactant NAC" (Abbott, 2018).

[0019] However, "**HLD is not enough.** The surfactant community for having wasted decades by not working with the best available surfactant theory, and therefore not having the time or the clarity to investigate the extra questions for which formulators really wanted answers. Most academia and industry perpetuated the myth that armed with critical micelle concentration, CMC, and with hydrophilic lipophilic balance, HLB, one could formulate wisely. After having said so

many good things about HLD, and having shown how poor its simpler competitors are, it might seem strange to announce that it is not enough. The truth is that all those Cc and EACN measurements have been done with nice 50:50 O:W mixes and the idea that anything different might happen at other O:W ratios is inconceivable within the HLD equation – there are only terms for the surfactant (blend), the oil (blend), salinity and temperature. HLD, therefore, is an excellent starting point for navigating through the complexities of surfactant space. It is necessary but very far from sufficient. To increase its power requires some deeper insights into the meaning of curvature. For that we need to add the idea of Net Average Curvature" NAC (Abbott, 2018). When HLD is higher than 0 (>0) emulsions with water as the continuous phase can be produced with amounts as high as 70% by mass

[0020] "The table below provides some characterisation parameters for various emulsions following are various parameters useful to evaluate micro emulsions used for comparative analysis of emulsion, micro emulsion and nano-emulsion in the pharmacy industry" (Santosh Nemichand Kale, 2017), but not limited to:

Parameter	Description
Visual Inspection	Appearance, homogeneity, transparency, optical clarity, and fluidity.
Cross-polarizing Microscope testing	To exclude liquid crystalline systems, it is necessary to confirm absence of birefringence by cross polarizing microscope
Limpidity Test	Limpidity is defined as an acceptable level of visible impurities. Spectrophotometeric determination of percent transmittance directly proportional to limpidity
Globule size	The globule size is very essential aspect to differentiate emulsion, micro emulsion and nano emulsion. It can be determined by light scattering method and or photomicroscope method.
Viscosity	The rheological properties play an important role in stability as viscosity is immediately affected by storage conditions. It can be determined by Brookfield digital viscometer.

Parameter	Description
pH	The pH of the formulation not only affects the stability of the emulsions but also alters the solubility and bioavailability of the drug through micro emulsion at the site of permeation. PH meter is useful to determine PH of emulsions.
Specific gravity	Determine the specific gravity by a capillary gravity bottle method. Gravity settling can be used alone only to treat loose, unstable emulsions; however, for stronger emulsions, gravity settling separates water from oil only when used with other treating methods that increase water droplet size by destabilizing the emulsion and creating coalescence
Study of microstructure	Electron Microscopy is the most important technique for the study of microstructures of micro-emulsions because it directly produces images at high resolution, and it can capture any co-existent structure and micro-structural transitions.
Identification test for type of micro emulsions	Dilutability test: emulsion can be diluted in 1:10 and 1:100 ratios with double distilled water to check if the system shows any signs of separation. (O/W)
Zeta potential measurement	Electrical charges on particles influence the rate of flocculation and as well as bioavailability. Negative, positive or neutral nature depends on excipients and drug's own charges. Zeta potential between + 30 to -30 is acceptable. Not measurable in WFE.

Parameter	Description
Phase Behaviour Studies	Phase behaviour studies are essential for the study of efficiency of different surfactant systems which can be determined by phase diagram. Oil phase, water phase and surfactant/co-surfactant mixture ratios by keeping concentration of one component or the ratio of two components constant provides useful structural organization of final emulsion. One approach to characterize these multicomponent systems is by means of pseudoternary diagrams that combine more than one component in the vertices of the ternary diagram.
Polydispersity	Size, shape and dynamics of the components can be determined by small-angle X-ray scattering (SAXS), small-angle neutron scattering (SANS), static and dynamic light scattering techniques. Modification of the structure and the composition of the pseudophases due to dilution can be overcome by measuring intensity of scattered light at different angles. In dynamic light scattering (DLS) the size distribution of molecules or particles is the property of interest. Here, the distribution describes how much material there is present of the different size "slices." Traditionally, this overall polydispersity has also been converted into an overall polydispersity index PDI which is the square of the light scattering polydispersity. For a perfectly uniform sample, the PDI would be 0.0.
Interfacial Tension	Use to determine the force between oil and water. The interfacial tension is useful tool to determine the Critical Micelle Concentration (CMC). Generally studied at ambient pressure but cutting-edge technology allows the study at high pressures.

Parameter	Description
Conductivity	O/W emulsions are more conductive, whereas W/O emulsions are non-conductive.
Nuclear Magnetic Resonance Studies: Stability study	Self-diffusion measurements by Fourier transform pulsed-gradient spin-echo (FT-PGSE) technique provide information on the structure, dynamics and mobility of the particles. Self-diffusion coefficients vary in the range of 9 to 12 m2 /s
Centrifugal DLS: Stability Study	Cutting-edge technology for determining stability (LUM Global). The LUMiSizer is an evolutionary development based on the LUMiFuge platform with some significant additional capabilities that instantaneously measures the extinction (space- and time-resolved) of the transmitted light across the entire length of your sample using the STEP-Technology.

Table Three (3) – Various useful parameters to evaluate emulsions

BRIEF BACKGROUND OF INVESTIGATION

[0021] The investigation relates to the field of application of water in fuel emulsion nanotechnology (WFE), to determine the surfactant selection method, the chemical composition, the behaviour on and production of WFE and the effect when applied to internal combustion engines fitted with a high-pressure fuel injection, return less feeding systems and/or common rail, but not limited.

[0022] The investigation relates to the study of fuels, fuel blends and/or water in fuel nanoemulsion to design and define a chemical formulations, methods, systems and device, for improving the overall efficiency, when applied to engines, machinery and equipment, of internal, continuous and/or open flame combustion type, to further enhance fuel consumption rates and reduction of emission from the consumption of hydrocarbon, biodiesel and alcohols-based fuels and fuel blends.

[0023] Water in fuel emulsions (WFE) are generally formed by at least: a hydrocarbon, biodiesel, alcohol-based fuel and/or fuel blends, as the continuous phase; tap water normally treat by

deionisation, as the dispersed phase; and one or more surfactants, generally non-ionic, as the emulsifier and/or agent.

[0024] In water in fuel nanoemulsions (WFE) the continuous phase is a hydrocarbon, biodiesel, alcohol-based fuels and/or fuel blends. HYDROCARBON FUELS are chemical compounds made up of hydrogen and carbon, e.g. petroleum-based fuels (residuals and distillates) that are non-renewable sources of energy composed of a liquid mixture found underground that can be used to make diesel fuel, fuel oil and many other products; renewable diesel is a hydrocarbon diesel fuel produced by hydro processing of fats, vegetable oils, and waste cooking oils, also called "green" diesel biomass-derived transportation fuel suitable for use in diesel engines. BIODIESEL FUELS are those produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil by transesterification process. ALCOHOL FUELS (methanol, ethanol, propanol, and butanol) are biofuels, *e.g.* ethanol which is an ethyl alcohol commonly used to blend with gasoline (petrol). FUEL BLENDS typically consist of a hydrocarbon petroleum fuel as the continuous phase and a renewable diesel, biofuel and/or alcohol as the dispersed phase, depending on the application (*e.g.* road diesel EN590).

[0025] Fuels also contain additives, such as, contain nitrates, nitro, and nitroso compounds to increase the cetane number (CN) to enhance cold start; dispersants and detergents to improve engine cleanliness; ethylene-vinyl ester copolymers, polyolefins, kerosene and chlorinated hydrocarbons, to lower the formation of crystal wax to improve the cold flow; rapeseed oil methyl ester to improve fuel combustion; amines and other nitrogen containing compounds as antioxidants to improve colour and sedimentation stability; which needs to consider to determine those that may have significant impact on the production fuel emulsions.

Materials & Methods

Hydrocarbon, biodiesel and alcohols-based fuels and fuel blends

[0026] The method, system and chemical composition for the production water in fuel nanoemulsion (WFE) are mainly dependent of e.g. the pilot fuel; fuel blends; type of application; and the ambient and operational conditions. For the purpose of the invention the hydrocarbon, biodiesel and alcohols fuels and blends have been grouped based on invention interest, as follows:

- Middle petroleum distillate fuels and/or fuel blends, such as, diesel and heating oil.

- Heavy and residues petroleum distillates fuels and/or fuel blends, such as, heavy fuel oil (HFO), intermediate fuel oil (IFO), low sulphur fuel oil (LSFO), ultra-low sulphur fuel oil (ULSFO) and other fuels consisting mainly of residues from crude-oil distillation.
- Light petroleum distillate fuels and/or fuel blends, such as, gasoline and kerosene.
- Liquid gaseous fuels, such as, liquid petroleum gas, particularly butane and propane.
- Other hydrocarbon liquid fuels.
- Renewable diesel (hydrocarbon biofuel) and/or fuel blends, such as, hydrotreated vegetable oil (HVO).
- Alcohol-based fuels, such as, ethanol and methanol.
- Biodiesel (non-hydrocarbon biofuel) and fuel blends, such as, Fatty Acid Methyl Esters (FAME).
- Other renewable fuels and non-hydrocarbon liquid fuels.

Solvents, additives and other chemical compounds

[0027] Method, system, chemical composition, and device adopting low and/or high energy, batch, continuous flow and/or dilution production methods to produce fuels blends, water in oil (W/O), oil in water (O/W), water in oil in water (W/O/W), and oil in water in oil (O/W/O) and water fuel micro and nanoemulsions. For the purpose of the invention hydrocarbon, biodiesel and alcohols fuels, blends and/or other liquids from petroleum, vegetable and/or animal source, and/or other chemical compounds, may be used as solvents, and/or improvers for pilot fuel and/or specially produced blends, e.g. to dilute the chemical formulation (Fn) for onboard production applications. For the purpose of the invention they have been grouped as follows:

- Solvents:
- Additives:
- Other chemical compounds.

[0028] Method, system and raw materials for improving the properties of WFE and/or fuel blends to improve the combustion efficiency, to enhance the fuel consumption rates and reduction of the emissions form hydrocarbon, biodiesel and alcohols-based fuels consider the reduction of the sulphur content of those fuels, blends and/or WFE, at temperatures between 10ºC to 50ºC, at ambient pressure to 8 Bar, specially of those fuels and blends of medium to high sulphur content (<250ppm) and/or restructuring of the liquid fuels, blends and/or WFE, grouped as follows:

- Nanoparticle ceramics filters comprising materials, such as, activated carbon, alumina, metal oxides, zeolite, etc.

- Rare-earth magnets fitted e.g. to the external housing of the low energy mixing and/or emulsification device.

Surfactants

[0029] The choice of surfactants, method and system to formulate the chemical composition, i.e. chemical composition or chemical formulation (Fn), to produce water in fuel nanoemulsion (WFE) are mainly depends of e.g. the nature of the fuel and/or fuel blend; the amount of water (%W) and formulation (%Fn); the surfactant batch; the production method; and the application, ambient and operational conditions. For the purpose of the invention the surfactants have been group as follows:

[0030] Non-ionic surfactants represent 40% of the total surfactant production worldwide. The main, however the market is dominated by polyethoxylated products, i.e., those whose hydrophilic group is a polyethylene glycol chain produced by the polycondensation of ethylene oxide on a hydroxyle or amine group. ((SALAGER, 2002).

- Amine and Amide Derivatives, representing 10% of the total non-ionic surfactant production worldwide.
- Ethoxylated Linear Alcohols, representing 40% of the total non-ionic surfactant production worldwide. The main alcohols selected nowadays are from the linear alkyl groups. Primary alcohols have their -OH group at the end of the chain. They are generally prepared by moderate hydrogenation of fatty acids, so called catalytic hydrogenolysis (150 ºC, 50atm H2, copper chromite catalyst). For example
- Ethoxylated Alkyl Phenols, representing 15% of the total non-ionic surfactant production worldwide.
- Fatty Acid Esters, representing 20% of the total non-ionic surfactant production worldwide.

[0031] Other surfactants (agents)

- other non-ionic,
- anionic,
- cationic,
- zwitterionic

Water

[0032] Water properties may affect the production and/or application of the emulsion, e.g. temperature, hardness, metals and minerals content. Therefore, it is good particle and/or sometimes required to the use of e.g. deionised and/or demineralized water, to avoid increasing the variables and/or *e.g.* damaging mechanical parts when applied to engines. For the purpose of the invention water has been group as follows

- Tap water
- Deionized and/or demineralized
- Desalinised
- Water vapour

EXAMPLE AND RESULTS

[0033] The selection of the pilot fuel and application was based on market share and opportunity, hence a middle petroleum distillate fuel, specifically road diesel (EN590 standards). The initial stage of the investigation was to define a selection of surfactants and various chemical formulation (Fn), analyse the behaviour of chemical formulation and water in fuel in fuel emulsion and a define potential correlations between the diesel, water, chemical formulation other and other key variables. The investigation also focuses on determining the key factors and the correlation between the variables that significantly affect the overall efficiency when applied to engines, machinery and/or equipment of internal, continuous and/or open flame combustion type.

[0034] The first stage of the investigation was to observe the behaviour of a wide number of non-ionic surfactants with the object to reduce the number of surfactants to five (5), capable of producing nanoemulsions by preparing 50g samples of water in fuel emulsion, where the amount of each component (diesel, water and chemical formulation) was defined as a percent of the total mass of the water in fuel emulsion (100%), where the total mass is the sum of the mass of diesel (%D) plus the mass of water (%W). The samples were prepared at room temperature (~20ºC) using approximately 8% of denoised water (%W), 92% diesel (%D) containing 5.9% FAME (of an unknown source) and ~0.6% to 6.0% of several surfactants combined to produce various chemical formulation (%Fn), comprising one (1) to three (3) non-ionic surfactants. The samples were prepared using 3ml plastic pippetes to add one (1) to ten (10) drops of surfactants (~0.3g per drop) to a 100ml glass pot. Approximately, 55ml of diesel was added to the Fn in the 100ml glass pot, measured in a 100ml glass beaker, marked to the equivalent 46g level, and mixed by hand shaking the pot for approximately 10 to 15 seconds, with 100mm strokes and at a rate of 4

to 5 cycles per second. Approximately, 4ml of water added to the Fn and diesel in the 100ml glass pot, measured in a 10ml glass beaker, marked to the equivalent 4g level, and mixed by hand shaking the pot for approximately 20 to 30 seconds, 200mm strokes and at a rate of 2 to 3 cycles per second. Finally, the samples were poured into three (3) 20ml glass test tube for visual observation using a white light source of around 10 lumen, to observe the turbidity and left standing for stability analyses, to eliminate all those samples that presented e.g. separation, sedimentation and/or fluctuation.

[0035] The results of the latter investigation, clearly demonstrated that the HLB system is not a suitable method for, at least, selecting the surfactants to produce water in fuel emulsion, and may be useful as reference for those that use the HLB system, to indicate the nature of the chemical formulation (Fn) and/or the amount of a specific surfactants, as long as all, expect one, amount of surfactants comprising the chemical formulation (Fn) are known. The results indicated a potential correlations between the mass of lipophilic surfactant (%EL) over the mass of hydrophilic surfactant (%EH) ratio comprising the total mass of chemical formulation (%Fn), i.e. EL:EH, and a correlation between the mass of total chemical formulation (%Fn) over the mass of water (%W) ratio, comprised in the water in fuel emulsion, i.e. Fn:W; when considering that the total mass of the water fuel emulsion (100%) is equal to the sum of the mass of diesel (%D), mass of water (%W) and chemical formulation (%Fn). Five (5) surfactants selected and defined as: two (2) hydrophilic non-ionic surfactants (EL) from group a) one (1) lipophilic non-ionic co-surfactant (EL) from group d), and two (2) other amphiphilic non-ionic co-co-surfactants, or agents (EA) from group b) and c), to further investigate the chemical formulation (Fn) behaviour and the capability to produce water in fuel nanoemulsions (WFE).

[0036] In the following stages of the investigation a range of 50g water in fuel emulsions where the amount of each component (diesel, water and chemical formulation) was defined as a percent of the total mass of the water in fuel emulsion (100%), where the total mass is the sum of the mass of diesel (%D), the mass of water (%W) and chemical formulation (%Fn). The samples were prepared at room temperature (~20ºC) using the same reference diesel (%D) containing 5.9% FAME (of an unknown source) and 8% to 15% of denoised water (%W), in steps of 2%W and 3.5%W, at formula to water ratios (Fn:W) between 0.250 and 0.500 in intervals of 0.0625. The 5 (five) surfactants chosen to form several different chemical composition, i.e. formulations (Fn), comprised by 2 (two) hydrophilic surfactants from group a) with a HLB higher than ten (>10), specifically polyoxyethylene sorbitan monooleate commercially known as Tween 80 and a coconut fatty acid amide of ethanolamine commercially known as Cocamide DEA; 1 (one)

lipophilic co-surfactant from group d) with a HLB lower than nine (<9), specifically sorbitan monooleate commercially known as Span 80; and 2 (two) co-co-surfactants, or agents, from group c) and d) with mid-range HLB (HLB >9 and <10), specifically ethoxylated linear alcohols and alkylphenols commercially known as nonylphenol NP6 and alcohol ethoxylate. After several preliminary tests 3 (three) non-ionic surfactants were defined for further detailed investigation, where a matrix for the chemical formulation (Fn), in 5% (five percent) intervals, comprised, cocamide DEA, between 20% and 70%, nonylphenol, between 20% and 60% and Span 80 between 10% and 25%. The samples were prepared using an analytical precision scale (0.0001g) to measure the chemical compounds of the formulation (Fn), with an error between 0% and 2% using a 100ml glass pot. The diesel was then measured into the 100ml glass pot and stirred using a magnetic stirrer for approximately 3 minutes at 500 rpm. The mixed diesel and formula were then stirred using a Hielscher Silent Crusher M Homogenizer for 3 minutes while pouring the water drop by drop, in relatively evenly spread intervals. Finally, the samples were poured into three (3) 20ml glass test tube for visual observation using a turbidimeter (1000 NTU) to determine the surface area of the suspended particles and left standing for stability analyses, to identify the pattern between those samples that presented e.g. separation, sedimentation and/or fluctuation. Further tests using one percent (1%) intervals were performed to refine the results, define the behaviour and determine the best chemical formulation followed by increasing the Cocamide DEA between 70% to 100%.

[0037] The results from investigation indicated that the lipophilic surfactant (EL) played an important role for adjusting the formulation, which amounts as low as one percent (1%) could had a significant impact on the turbidity and minimal spread (~3%). It was also noticeable that maintaining the amount of the hydrophilic surfactant (%EH) constant, the change in %EL vs the change in %Fn, i.e. EL/Fn ratio, had an impact of ~0.300 on the total mass of chemical formula (%Fn) at constant amount of water (%W), the change %EL vs to the change in %W, i.e. EL:W ratio, had an impact between ~0.4 to 1.4 at constant amount of Fn:W, later determined to be correlated to the amount of FAME content comprised in the pilot fuel. It was also notice that the Fn:W ratio could be slightly reduced when increasing total mass of water (%W) by approximately one percent per percent of water increase (~1% Fn/W). The previous suspicion that the HLB method was not suitable was also confirmed due to the higher the amount of the hydrophilic surfactant in the formulation the clear and more stable was the emulsion. The hydrophilic surfactant and the correlation between the lipophilic and hydrophilic surfactants (ratios) proved to be key factors for selecting a chemical formulation capable to produce monodispersed water in fuel nanoemulsions. Other tests were also performed to verify the potential of the chemical

formulation, such as, freezing the WFE at temperatures between -13 to -18ºC for 24 hours and left return to it liquid stage at ambient temperature demonstrating that they would return to its normal state without any free water and/or undesired state, e.g. separation. A centrifugal test was also performed well above the indicated standards, at 50ºC, which remained visually the same with no indication or tendency to separate and the same turbidity readings. Tests also indicated that emulsion could be produced with similar quality when prepared by hand and/or the magnetic stirrer at low rotational speeds (500 rpm), hence indicating that a low energy emulsification method would be suitable for producing WFE.

[0038] Further tests were performed prepared in a similar way as described in paragraph [0035], but only using a magnetic stirrer, extending the amount of water up to 28%, and the %EH up to 100%, and combining the other remaining surfactants, provided further correlation and determination Fn composition for WFE. Tests to be produced 8 and 15% WFE using a continuous flow production method, by using a pilot plant designed for a nominal pressure of 25 Bar, varying between 8 Bar and 40 Bar, consisting of pumps, no-return valve, 4 (four) different circuits, where 3 (three) were fitted with different length static mixers, 200 mm to ~500mm, with 6 to 16 elements, designed to provide a pressure differential of around 5 Bar, and on the outer end a pressure regulator valve. The samples were prepared by mixing the Fn to the pilot fuel pumped to mix with water and flown through the different circuits including by passing the static mixers direct to the pressure regulator valve. The tests showed that at lowest pressure (8 Bar) direct to the pressure regulator the was possible to obtain the best and desirable results which proved the potential of low energy continuous flow production method the most adequate.

[0039] Various emulsion and nanoemulsion were tested in a small diesel generator and a heavy duty 5.9L 12V 6CYL Cummins diesel engine, without any modification, fitted to a frame and using an electric brake retarder as a dynamometer. The tests indicated the potential application of WFE for internal combustion ignition compression type engines, for improving combustion efficiency, to enhance the reduction of smoke, PM and NOx and reducing the consumption rates when comparing hydrocarbon to hydrocarbon, hence a slight increase in the consumption rates when comparing WFE to pilot fuel. Extensive hour testing was performed using the Cumming Diesel engine which should no mechanical failure, significant loss of power or any other adverse symptoms. Tests were also performed in a drivable vintage double deck bus which verified the potential application of WFE. Various test using earth magnets were conducted in the engine test bench and onboard vehicle which indicated potential reduction of fuel consumption.

[0040] Advanced testing considering a potential "partnership" with a UK company consisted on testing batches of WFE using with 8%, 12% and 15% water content, by mass, at Fn:W of 0.375, a high quality road diesel (%D) containing 3.3% FAME (of an unknown source), The first problems was detected when attempting to reproduce the WFE using the chemical formulation used for the road diesel containing 5.9% FAME, which clearly didn't work. Investigation demonstrated that maintaining the amount of EH the amount of EL had to be adjusted to approximately half. Hence the Fn used for 8%, 12% and 16% Water content, comprised 75% Cocamide DEA (%EH), 13% to 8% Span 80 (%EL) and the remaining Nonylphenol NP6 (%EL), prepared using a pilot plant by continuous flow production method as described in paragraph [0037]. The tests were performed, at a major research & development facility, using a heavy-duty diesel JCB Diesel common rail IC engine installed to cutting-edge engine bench test equipment, at ambient temperatures below freezing (~-5ºC), however under undesirable and uncontrolled conditions for WFE. The test had to be suspended due to inconclusive circumtances, at the time. Later it become clear that the issue was most probably due to the lack of control of the quality of WFE prior and during testing where no access to the facilities was authorised. Since the WFE had been designed to be stable at temperatures above 16ºC it required the heating jacket supplied to be on, constant monitoring of the WFE and depending on the circumtances, recirculation prior priming the system or during testing may have been required. This clearly demonstrates that producing WFE for storage purposes is not desirable and that highly skilled labour is required, hence an alternative model was defined and is most recommended.

[0041] This investigation focused on the defining the quality and properties of the WFE as a fuel and defining the potential key variables that have significant impact when applying for engines, machinery and/or equipment of internal, continuous or open flame combustion type. Many tests were performed to define various properties of WFE, e.g. the lubricity, increasing approximately two and a half micrometres (2.5 □m) per percent of water content in WFE at constant Fn:W 0.375 compared to the reference diesel; %FAME dilution rate of approximately zero point three percent (0.3%) of FAME per one percent of Water; oxygen content, by mass, in the WFE at constant Fn:W 0.375, presenting approximately an one percent (~1%) increase per one percent (1%) of water content; in flash point, for 8%W and 15%W, at constant Fn:W 0.375, respectively, 93ºC and 98ºC; CFPP, for diesel -20ºC and for 8% W WFE at Fn:W 0.375 -2ºC; stability for 8%W WFE at Fn:W 0.375 using dynamic light scattering centrifugation method supported by test tubes left on rack at room temperatures showing a shelf life greater two years (>2); particle size and polydispersity using dynamic light scattering and acoustic particle sizing presenting particle sizes as low as one nanometre (1nm) at room temperature and polydispersity index (PdI) as low 0.048;

and the cetane number test decrease was not representative, due to samples being tested with no correction in viscosity easily done by correcting the temperature of the WFE. Test were also conducted on a renewable diesel, i.e. commercially sold by SASOL, presented similar results to those of petroleum diesel with slight variation of the chemical composition (Fn). Tests for viscosity were tested using a viscometer, equipment available at the time, to indicate the potential degree of variation of the viscosity with the increase of the amount mass of water. The variation indicated that viscosity increase at 20ºC with respect to the reference diesel from 3.114 mm²/s for 8%, 15%, 22% and 28% water, at Fn:W 0.375 to, respectively, 5.163, 12.811, 23.794 and 32.754 mm²/s; and at 40ºC with respect to the reference diesel from 2.012 mm²/s for 8%, 15%, 22% and 28% water, at Fn:W 0.375 to, respectively, 2.619, 3.686, 5.375 and 8.057 mm²/s, which clearly a trend for the WFE at different water content to have the adequate viscosity between 45ºC to 50ºC, coincidently the normal operational temperature of the post high pressure injector once the engine is warmed up. Tests were conducted for residual fuels, i.e. a heavy fuel oil (HFO) and an Intermediate fuel oil (IFO) using only %Cocamide DEA at a FN:W 0.375, using rheometer to measure the viscosity, demonstrated, respectively, lower and higher values, the increased attributed to the mechanical and chemical reactions due to the middle distillate in the residual fuel.

[0042] The latter information allowed to define further testing to be performed in 2 (two) vehicles, an Audi 1.9 TDI, 1998 and a Jaguar X-Type, 2,2D CR, using a chassis dynamometer and emission recording equipment. Test preparation also included the analysis of the injection profile of WFE related to temperature of the WFE. The 3 (three) WFE, contain 8%, 12% and 16% of deionized water, were prepared considering that the sum of the mass of diesel (%D), the mass of water (%W) and chemical formulation (%Fn) equals the total amount by mass of the WFE. The samples were tested in batches of 1 to 2 litres using a glass container fitted inside a 20 litre aluminium container fitted with a resistance connected to an automatic control system, switching on and off, to heat and stop heating the WFE at, respectively, at 15 and 40ºC. The WFE was connected by a hose to the prior to the fuel filter and high-pressure pump and the return to the WFE glass container. The matrix consisted of testing the vehicle between 1000 to 3000 rpm, in 500rpm intervals, in all gears apart form reverse, for 1 to 2 minutes, with 2 (two) different loads, to measure mainly the fuel consumption rate, NOx, PM, $\%CO_2$ and CO. The issues were that the WFE temperature raised up to ~90 at maximum speed and load conditions specially at low gear. However, the behaviour of WFE does present a linear relationship to diesel presenting significant differences at different operational conditions and at different %W. The results surprisingly demonstrated that the fuel rate can be reduced up to 20% comparing fuel to fuel, which indicates

the importance of the properties of the WFE on the combustion efficiency and the particle size and distribution correlation on the micro-explosion phenomenon. PM measurements were also collected following MOT procedures which the recording for Diesel, WFE at 8%W and WFE ate 12% Water were, respectively, 0.88, 0.57 and 0.44 L/m. The same principle applies to the emissions which the results are clearly shown in figures Forty-Two (42) to Forty-Seven (47). The results clearly indicate the need to design a system to attend the need to vary the WFE properties to attend the variable operational conditions.

EXAMPLES

Example One (1) Description: Microemulsion prepared using of prior-art approach vs nanoemulsion based on the results of the investigation.

[0043] Figure Thirty-Eight (38) presents a comparative example between a water in fuel microemulsion (WFE) **302**, produced with 5% water content (m/m) at Fn/W 2.0 (m/m) versus a water in fuel nanoemulsions **30**, produced with 8% water content (m/m) at Fn/W 0.375 (m/m). Figure Thirty-Nine (39) presents the latter water in fuel microemulsion **302** versus a water in fuel nanoemulsion **303** produced with 15% water content (m/m) at a Fn/W 0.375 (m/m). The results were obtained using a DLS at a temperature of 298.21K as presented in table two (2):

Water in Fuel Emulsion Ref.	Hydrodynamic Diameter (nm)	Peak (nm)	Polydispersity Index (%PdI)
302	101.02	101.10	17.1*
301	29.72	30.28	12.9*
303	49.11	53.26	15.7*

** - All three are considered monodispersed due to the %PdI being below 20.*

Table four (4) – Dynamic Light Scattering Data comparison (Malvern Zetasizer)

[0044] Figure Forty (40) presents comparative examples between three water in fuel nanoemulsions, produced with 8% water content (m/m) at a Fn/W 0.375 (m/m) but prepared using different methods. The results were obtained using a DLS at a temperature of 298.21K as presented in table below:

Water in Fuel	Hydrodynamic Diameter (nm)	Peak (nm)	Polydispersity Index (%PdI)
301 (batch using a homogenizer)	31.57	31.00	11.1
304 (continuous flow using regulator valve)	23.39	22.51	9.1
305 (mixed by hand)	32.21	31.96	12.8

Table Five (5) – Dynamic Light Scattering Data comparison (Malvern Zetasizer)

[0045] Figure Forty-One (41) presents a representative result of a water in fuel nanoemulsion produced with 15% water content (m/m) at a Fn/W 0.375 (m/m), presented the following results:

Water in Fuel	Peak 1 in vol. (nm)	Intensity (%)	Peak 2 in vol. (nm)	Intensity (%)
303a (in volume)	1.03	31.31	30.68	0.07
303b (in intensity)	(94.41% in vol)	0.34	(1.04% in vol)	9.42

Table Six (6) – Dynamic Light Scattering (Malvern Zetasizer)

[0046] From the present investigation a method, system, device and chemical formulation was defined capable to produce, on-demand, fuel blends and/or water in fuel nanoemulsions (WFE), using the low energy from main fuel pump, by batch, continuous flow and/or dilution production methods, capable to apply for engines, machinery and/or equipment, of internal, continuous and/or open flame combustion types, for improving the performance, increasing application and combustion efficiencies, to further enhance fuel consumption rates and significantly reducing the emissions from the consumption of hydrocarbon, biodiesel and alcohol-based fuels and blends.

[0047] The investigation object is to define a method, system, device and chemical formulation for water in fuel nanoemulsions, by identifying the key problems believed to derive from the limited and misleading nanoemulsion technology knowledge and the approach research and development for determining the application data. Some of the identified problems are: **(i).** the use of the HLB system as the surfactants selection method used to define the chemical compositions (formulation) which is not the most suitable for fuel nanoemulsions; **(ii).** the use of a single formulation generally designed for a general WFE applications, consequently minimising the

efficiency, limiting the operational conditions and affecting the quality of the WFE due to various conditions, mainly due to the variations of the fatty acid Methyl esters (FAME) found in commercial diesels which are currently compulsory in most commercial fuels (blends); **(iii).** WFE designed to be produced at ambient temperatures, normally 15 to 25ºC, resulting in loss of quality of the WFE at operational temperatures leading to loss in combustion efficiency and a relative increase in fuel consumption rates; **(iv).** poor quality polydisperse emulsions, resulting in low stability, free water, lower combustion efficiency and promoting high fuel consumption rates; **(v).** the use of high energy production methods increasing the production and operational costs; **(vi).** batch production vulnerable to ambient conditions, consequently requiring higher stability control, leading to higher operational production costs and limiting multiple application capabilities.

[0048] It is clear that businesses offering WFE technology are faced with several barriers to overcome, such as, end users low acceptability rates resultant from previous market experience and customers feedback, limited WFE legislation and incentives in place, lack of WFE standards and certification methods, consumers and manufacturers sceptical about the use of water in WFE (lack of knowledge), etc. Hence, the need to innovative methods and systems for producing cost effective high quality WFE to overcome the problems identified problems, hence gaining significant competitive advantage with significant market growth.

BRIEF SUMMARY OF THE INVENTION

[0049] The invention relates to a method and system using low energy continuous flow and dilution production methods, for producing, on-demand, fuel blends and/or emulsified fuels, applied to engines, machinery and/or equipment's, such as those of internal, continuous and open flame combustion types, improving application and/or combustion efficiencies, to selectively enhance the specific fuel consumption rates and/or reduce the emissions produced from the consumption of hydrocarbon, biodiesel and alcohol-based fuels and/or fuels blends.

[0050] The invention relates to a method, system, device and chemical composition for producing automatically, in-line, on-demand and onboard variable types of fuel blends and/or water in fuel nanoemulsions (WFE), comprising, at least, a hydrocarbon, biodiesel and alcohol-based fuel as the continuous phase fuel; a hydrophilic blend (HPB); lipophilic blend (LPB); deionised water; a low energy mixing and emulsification device (LME); and a perfomance management system, connecting the electronic control unit (ECU) and enabling technologies, capable of integrating to other existing alternative fuel and emission reduction technologies.

[0051] It is thus the object of the present invention water in fuel nanoemulsions (WFE) produced onboard and on-demand, comprising at least, but not limited to,

a) from 46% to 95.6% by mass of a pilot fuel, comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends
b) from 4% to 36% by mass of water,
c) from 0.100 to 0.500 by mass of chemical formulation to water ratio, i.e. Fn:W; equivalent to 0.4% to 18% of chemical formulation (Fn),
d) from 1.2% to 90% by mass of solvents,
e) from 0.1% to 5% by mass of additives.

[0052] The invention relates to chemical composition and surfactant selection method, composed of, at least, one or more non-ionic surfactants, with HLB higher than 9, but not limited to, designed to produce monodispersed water in fuel nanoemulsion (WFE) with particle sizes between 1 to 100nm, for and/or at nominal fuel feeding operational temperatures, improving the fuel combustion efficiency, to enhance the specific fuel consumption rates and/or reduce the emissions produced from the consumption of hydrocarbon, biodiesel and alcohol-based fuels and/or fuels blends.

[0053] The invention relates to chemical composition and surfactant selection method, composed of, at least, one or more non-ionic surfactants, particularly a Lauric-acid based surfactant, but not limited to, with HLB between 9 to 15, designed to produce: water in oil (W/O), oil in water (O/W), water in oil in water (W/O/W), and oil in water in oil (O/W/O) micro and/or nanoemulsion; hydrocarbon, biodiesel and alcohol-based hydrophilic blends; and/or hydrophilic solutions using batch, continuous flow and/or dilution production methods.

[0054] The invention relates to chemical composition and surfactant selection method, composed of, at least, one or more non-ionic surfactants, with HLB between 1 and 9, designed to produce: water in oil (W/O) and/or oil in water in oil (O/W/O) micro and/or nanoemulsion; hydrocarbon, biodiesel and alcohol-based lipophilic blends, using batch, continuous flow and/or dilution production methods.

[0055] It is thus the object of the present invention chemical composition, chemical formulation or formulation (Fn), from 0.100 to 0.500 by mass of chemical formulation to water ratio, i.e. Fn:W; equivalent to 0.4% to 18% of chemical formulation (Fn) of the total mass of the WFE, comprising at least, but not limited to,

I. from 25% to 100% by mass of amine and amide derivative non-ionic surfactants, selected from fatty acid alkanolamides, of the total mass of the chemical formulation (Fn);
II. from 1% to 70% by mass of ethoxylated alcohols and/or alkylphenols non-ionic co-co-surfactants, selected from ethoxylated linear alcohols, ethoxylated alkylphenols surfactant and/or ethoxylated thiols, of the total mass of the chemical formulation (Fn);
III. from 1% to 30% by mass of fatty acid esters non-ionic co-surfactants, selected from (Spans) and/or polyoxyethlyene derivatives of sorbitan alkyl esters (Tweens) surfactants, of the total mass of the chemical formulation (Fn);
IV. from 0.1% to 20% by mass of other non-ionic, anionic, cationic, zwitterionic and/or any other co-co-surfactants, of the total mass of the chemical formulation (Fn).

[0056] The invention relates to method, system, solvents, additives, and/or other chemical compounds and/or other raw materials, contained in the pilot fuel and/or used, for improving the quality of fuels blends, and/or single or multiple phase micro and/or nanoemulsions used to produce, onboard and on-demand, fuel blends and/or water fuel nanoemulsions (WFE) to apply to engine, machinery and/or equipment of internal, continuous and open flame combustion type, further improving combustion efficiencies, to enhance the reduction of emissions from the consumptions (burning) of those fuels.

[0057] The invention relates to a modular, single or multi-chamber, low energy mixing and/or emulsifying (LEM, LEE and/or LEME) device, fitted, in-line, of an existing fuel feeding circuit, designed to, by using the low energy produced by the low pressure fuel pump, create multi-directional flow improving vortex and turbulence in the mixing and/or emulsifying chambers, to enhance the fuel blending and/or the emulsification process.

[0058] The invention relates to method, system and production plant, capable to produce offboard and on-demand, or with low energy, by continuous flow production methods, but not limited to, water fuel nanoemulsions (WFE), from a pilot fuel comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends for direct use in engine, machinery and/or equipment of internal, continuous and open flame combustion type, fitted with return and/or return less, low and/or high pressure fuel feeding and/or injection systems, for improving combustion efficiencies, to enhance the reduction of emissions from the consumptions (burning) of those fuels.

[0059] It is thus object of the present invention method and system to produce offboard and on-demand, with low and/or high energy, by batch, continuous flow and/or dilution production methods, but not limited to, baseline products, used to produce, onboard and on-demand, fuel

blends and/or water in fuel nanoemulsions (WFE), resulting in e.g. lowering the production energy required; easing the mixing and emulsification process; providing improved hydrophilic, lipophilic and other blends; ensuring quality of fuel blends and water in fuel nanoemulsions (WFE); securing the intellectually property; promoting commercial advantages; and capability to deliver various types of WFE.

[0060] The invention relates to a method, system and device for producing automatically, in-line, and on-demand, using a low energy continuous flow and dilution production methods, various types and qualities of fuel blends and/or water in oil (W/O) nanoemulsions, further enhancing the combustion efficiency over wider operational range in application, such as in internal combustion engines, continuous combustion engines and open flame combustion machinery or equipment.

[0061] The invention relates to a method and system to

(i) Remotely, manually and/or automatically, onboard and on demand, control and manage the production and quality of pilot fuels and environmental fuels, i.e. fuel blends and water in fuel emulsion nanoemulsions, for improving combustion efficiency, to enhance specific fuel consumption rates and/or reduction of the emissions,

(ii) Manually and/or automatically, onboard and on-demand, select the fuel type, i.e. pilot fuel or environmental fuel, and vary and/or adjust the type of environmental fuel delivered to the engines, machinery and/or equipment's, such as, those of internal, continuous and open flame combustion type, to
   - further improve the specific fuel consumption rates and/or emission reduction rates, by delivering the fuel type with greater specific combustion efficiency,
   - maintain the fuel consumption rates equal and/or below the pilot fuel at any operational condition, i.e. >= 1:1 (fuel to pilot fuel),

(iii) Remotely, manually and/or automatically, control and manage operations of engines, machinery and/or equipment's, such as, those of internal, continuous and open flame combustion type, for improving application efficiency, to further enhance the specific fuel consumption rates and/or reduction of emissions,

(iv) Monitoring and managing the key elements that significantly affect the combustion and/or application efficiency, particularly diminishing the specific consumption rates and increasing the emissions.

(v) Developing environmental fuels for improving combustion efficiency, for specific engines, machinery and/or equipment's, such as, those of internal, continuous and open flame combustion type,

(vi) Develop baseline mathematical models by correlating the variables of significance related the variable fuels, specific engine and/or application (modular),

(vii) Develop self-learning system and/or artificial intelligence capable dynamically adjusting, analysing, correlating and recording, e.g. for improving the baseline mathematical models, for onboard control and management and for technology development and integration.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0062] Some embodiments of the present invention are illustrated as an example and are not limited by the figures of the accompanying drawings, in which like references may indicate similar elements.

Figures Brief Description

[0063] The illustrations of the invention are presented and described by section I to VI: Each element, part and component of the invention, including associated parts and components, have been grouped by sections I to VII and described below to facilitate the understanding of the principles involved.

SECTION I: MODULAR PRODUCTION UNIT FOR WFE BASLINE PRODUCTS.

[0064] The invention relates to a modular production unit for water treatment and/or producing hydrocarbon (HC), biodiesel and alcohol-based blends, water in fuel micro and nanoemulsions (WFE), oil in water (O/W), and/or water in oil in water (W/O/W) micro and nanoemulsions (W/O/W) and/or chemical solutions.

[0065] Figure One (1) Description: Example of a modular production plant, built in a single or multiple 8", 20" or 40" containers, designed to treat water and produce blends, alcohol-based and 'chemical' solutions, and micro and/or nanoemulsions, and treat waste from the latter.

Parts and Components Identification:

REF NUMERAL	PART NAME
90	**Modular production plant for WFE baseline products**
91	BLENDING PRODUCTION SYSTEM
	Raw materials storage and feeding system

REF NUMERAL	PART NAME
1	Tank, pumps, heating elements, sensors and/or actuators for storing hydrocarbons (HC), biodiesel and/or alcohol-based fuels and/or blends.
2	Tank, pumps, heating element, sensors and/or actuators for storing hydrophilic surfactants and/or chemical compositions.
3	Tank, pumps, heating element, sensors and/or actuators for storing lipophilic surfactants and/or chemical compositions.
4	Tank, pumps, heating element, sensors and/or actuators for other surfactants co-cosurfactants.
5	Tank, pumps, heating element, sensors and/or actuators for fuel or WFE improvers and/or other chemicals and products.
	Production unit and/or device for producing blends and/or O/W emulsions.
7	Pre-mixing system of raw materials 1 to 6 (as required). Paddle mixer and/or other mixing equipment, pre-mix tank, heating element, pumps, valves, sensors, actuators, rare-earth magnets and/or control unit.
9	Mixing/emulsifying tank, transfer and/or storage tank and/or desulphurization unit. Paddle mixer, homogenizer and/or ultrasonication equipment. Pump, valves, sensors and/or actuators for HC, biodiesel or alcohol-based blends and/or monodispersed water in oil (W/O) micro and/or nanoemulsions, *i.e.* PdI < 0.1.
	Final products from HC, Biodiesel and alcohol-based materials for producing fuel blends or WFE
10	HC, biodiesel and/or alcohol-based blends for pilot fuel mixing.

REF NUMERAL	PART NAME
11	HC, biodiesel and/or alcohol-based hydrophilic blends and/or monodispersed water in oil (W/O) micro and/or nanoemulsions for WFE production.
12	HC, biodiesel and/or alcohol-based lipophilic blends and/or monodispersed water in oil (W/O) micro and/or nanoemulsions for WFE production.
13	HC, biodiesel and/or alcohol-based blends and/or water in oil (W/O) and/or oil in water in oil (O/W/O) micro and/or nanoemulsions for WFE property improvement, WFE production and/or WFE waste production, and/or waste management.
14	Other oil-based, biodiesel and/or Alcohol based blends for WFE production.
92	<u>WATER TREATMENT SYSTEM & UNIT</u>
6	Tank, pumps, heating element, sensors and actuators for water treatment and storage. Final products: tap water, deionised, demineralised, desalinised and/or any other treated water.
15	'Gray water' and/or tap water treatment unit, *e.g.* membrane filtration, electrolysis, deionisation or demineralisation, desalinisation and/or other treatments.
23	Diesel generator for supply power to the production Plant. Running on Middle distillates and WFE produced from the system waste.
93	<u>'CHEMICAL SOLUTIONS' & EMULSIONS PROD. SYSTEMS</u> Mixing and/or Emulsifying Unit
8	Modular, single or multi-chamber, low energy continuous flow production system for structuring, blending and/or emulsification, *i.e.* low energy mixer and emulsifier (LEME) device, multiple device apparatus and/or production plant. The device comprises: multiple device housing (apparatus body), single device housing (internal

REF NUMERAL	PART NAME
	wall); intake and output nozzle and/or turbulators; static mixer; and/or other mixers or turbulators (spheres); earth magnets; sensors; actuators; valves, solenoid valves, nut and bolt fixing, sealing washer and/or O-rings Refer fig. three (3) to twelve (12).
17	Mixing, emulsifying tank, transfer and/or storage tank. Paddle mixer, homogenizer and/or ultrasonication equipment. Pump, valves, sensors and/or actuators, for alcohol-based and/or chemical solutions, and/or HC, biodiesel or alcohol-based monodispersed oil in water (O/W) and/or water in oil in water (W/OW) micro and/or nanoemulsion, *i.e.* PdI < 0.1.
	Final water-based products for producing fuel blends or WFE
6z	Tap water, deionised, demineralised, desalinised and/or any other types of treated water.
18	Alcohol-based and chemical solutions.
19	O/W and/or W/O/W monodispersed micro and/or nanoemulsions.
20	Other water-based products.
94	*WASTE MANAGEMENT SYSTEM & WFE PRODUCTION FROM WASTE*
8	LEE Device
22	Dual or split tank, pumps, valves, heating element, sensors and/or actuators for waste management and/or WFE production from HC, Biodiesel or Alcohol-based, solutions and/or water emulsions from system waste
	OTHERS
16	Display, transmitter/receiver, modem, manual/automatic remote-control unit, ECU, hard-drive, ports, switchboard, etc..

REF NUMERAL	PART NAME
21	HC, Biodiesel or Alcohol-based, solutions and/or water emulsions cleaning and flushing system - waste line.

[0066] Figure Two (2) Description: The invention relates system and unit for desulphurization, of hydrocarbon (HC), biodiesel and alcohol-based blends, at low temperatures.

Parts and Components Identification:

REF NUMERAL	PART NAME
95	DESULPHURISATION AND FLUSHING SYSTEM
7, 8 and14	As specified in Figure One (1).
9	Mixing/emulsifying tank, transfer and/or storage tank. Paddle mixer, homogenizer and/or ultrasonication equipment. Pump, valves, sensors and/or actuators for HC, biodiesel or alcohol-based blends and/or monodispersed water in oil (W/O) micro and/or nanoemulsions, *i.e.* PdI < 0.1. Paddle mixer, homogenizer and/or ultrasonication equipment. Pump, valves, sensors and/or actuators for HC, biodiesel or alcohol-based blends and/or monodispersed water in oil (W/O) micro and/or nanoemulsions, *i.e.* PdI < 0.1.
9a, 9d & 9e	Intake and output to mixing/emulsifying tank, transfer and/or storage tank. Valves, sensors and actuators for dosing and quality control.
9b	Mixing/emulsifying tank, transfer and/or storage tank. Paddle mixer, homogenizer and/or ultrasonication equipment. Pump, valves, sensors and/or actuators for HC, biodiesel or alcohol-based blends and/or monodispersed water in oil (W/O) micro and/or nanoemulsions, *i.e.* PdI < 0.1.
9c	Twin desulphurisation reusable 'filters'

9f	Desulphurisation bi pass

SECTION II: LOW ENERGY MIXING AND/OR EMULSIFYING DEVICE.

[0067] The invention relates to low energy mixing and/or emulsification (LEM, LEE and/or LEME) device to produce fuel blends and/or water in fuel nanoemulsions (WFE).

[0068] Figure Three (3) Description: Perspective diagram of an example of a robust single chamber LEME device fitted with flat and/or conical shape washer type nozzle at both ends, spheres type turbulator, inspection drainer and baseline product connections for mixing hydrophilic blends, lipophilic blends and/or other blends and water, alcohol-based and/or 'chemical solutions', W/O and/or O/W/O emulsions.

Parts and Components Identification:

REF NUMERAL	PART NAME
81	SINGLE CHAMBER LEME DEVICE FOR IN-LINE PRODUCTION OF WFE

6, 11 & 12	As specified in of figure One (1).
28	Existing pilot fuel feed line from pilot fuel tank
41	Existing pilot fuel feed line to engine and/or other equipment
8a	LEME cylindrical shape housing
8d	LEME drainer
8e	Nozzle, injector or valve
8f	Valve volume control actuator
8g	Flat and/or conical shape washer type nozzle
8i	Spheres type turbulator for enhance tubulation
8z	Mixing and emulsification chamber

[0069] Figure Four (4) Description: Perspective diagram of an example of a robust multiple chamber LEME device fitted with flat shape washer type nozzle at both ends, static mixer and spheres type turbulators, inspection drainer and baseline product connections for mixing hydrophilic blends, lipophilic blends, pilot fuel improving blends and/or other blends and water, alcohol-based and/or 'chemical solutions', W/O and/or O/W/O emulsions.

Parts and Components Identification:

REF NUMERAL	PART NAME
82	MULTIPLE CHAMBER LEME DEVICE FOR IN-LINE PRODUCTION OF FUEL BLENDS AND/OR WFE

6, 11 & 12	As specified in of figure One (1).
28, 41, 8a, 8d, 8e, 8f & 8i	As specified in of figure Three (3).
8gb	Conical washer type nozzle
8j	Mesh type static mixer turbulator
8za	Pre-mixing chamber
8zb	Mixing chamber
8zc	Emulsification chamber

[0070] Figure Five (5) Description: Perspective view of an example of a robust multiple chamber LEME device fitted with flat shape washer type nozzle at middle and ends, static mixer and spheres type turbulators, rare-earth magnet, inspection drainer and baseline product connections for mixing hydrophilic blends, lipophilic blends, pilot fuel improving blends and/or other blends and water, alcohol-based and/or 'chemical solutions', W/O and/or O/W/O emulsions.

Parts and Components Identification:

REF NUMERAL	PART NAME
83	MULTIPLE CHAMBER LEME DEVICE FOR IN-LINE PRODUCTION OF FUEL BLENDS AND/OR WFE

6, 11 & 12	As specified in of figure One (1).
28, 41, 8a, 8d, 8e, 8f & 8gb, 8j, 8i, 8za, 8zb & 8zc	As specified in of figure Three (3) and of figure Four (4).
8zz	Rare-earth magnet for fuel, blends and emulsion structuring

[0071] Figure Six (6) Description: Sketch of an example of a U-shape multiple chamber LEME device fitted with flat shape washer type nozzle at middle and ends, spheres type turbulators, inspection drainer and baseline product connections for mixing hydrophilic blends, lipophilic blends and/or other blends and water, alcohol-based and/or 'chemical solutions', W/O and/or O/W/O emulsions.

Parts and Components Identification:

REF NUMERAL	PART NAME
84	U-SHAPE MULTIPLE CHAMBER LEME DEVICE FOR IN-LINE PRODUCTION OF WFE

6, 11 & 12	As specified in of figure One (1).
28, 41, 8a, 8d, 8e, 8f, 8gb, 8i, 8za, 8zb & 8zc	As specified in of figure Three (3) and of figure Four (4).

[0072] Figure Seven (7) Description: Technical sketch of an example of a single chamber LEME device fitted with multi-directional turbulator nozzle at intake and conical shape washer type nozzle and spheres type turbulators at the output end, with flared tube and threaded type fixings and baseline product connections for mixing hydrophilic blends, lipophilic blends, fuel improvement blends and/or other blends and water, alcohol-based and/or 'chemical solutions', W/O and/or O/W/O emulsions.

Parts and Components Identification:

REF NUMERAL	PART NAME
85	SINGLE CHAMBER LEME DEVICE FOR IN-LINE PRODUCTION OF FUEL BLENDS AND/OR WFE

6, 11 & 12	As specified in of figure One (1).
28, 41, 8a, 8d, 8e, 8f, 8g, 8i & 8z	As specified in of figure Three (3).
8ba	Nut and bolt fixings for flaring pipes and/or tubes.
8c	Sealing washer or O-ring
8h	Turbulator base washer for enhanced turbulence near walls
8ga or 85a	Multi-directional turbulator nozzle
6a, 11a, 12a or 13a	Baseline products feedlines to LEME device
6b, 11b, 12b or 13b	Baseline products low pressure pumps to feed to LEME device from baseline storage tanks
32	WFE main feedline to WFE main and/or buffer tanks

[0073] Figure Eight (8) Description: Technical third-angle orthographic drawing with sectional and rended views of an example of a multi-directional turbulator/nozzle for use in LME, LEE and/or LEME device to enhance the continuous flow mixing and/or emulsification process.

Parts and Components Identification:

REF NUMERAL	PART NAME
85a	MULTI-DIRECTIONAL TURBULATOR NOZZLE & BASE WASHER

8gc	Multi-directional turbulator nozzle
8h	Multi-directional turbulator base washer

[0074] Figure Nine (9) Description: Technical third-angle orthographic drawing with sectional views of an example of a multi-directional turbulator.

Parts and Components Identification:

REF NUMERAL	PART NAME
85a	MULTI-DIRECTIONAL TURBULATOR NOZZLE & BASE WASHER
8gc & 8h	As specified in of figure Eight (8).

[0075] Figure Ten (10) Description: Exploded view of an example of a curved shaped type housing modular LEME device (apparatus), with threaded tube type fixings designed to attend specific applications and baseline product connections for mixing hydrophilic blends, lipophilic blends, and/or other blends and water, alcohol-based and/or 'chemical solutions', W/O and/or O/W/O emulsions.

Parts and Components Identification:

REF NUMERAL	PART NAME
8a or 86	CURVED SHAPED TYPE HOUSING MODULAR SINGLE CHAMBER LEME DEVICE.
28, 32, 41, 8c, 8h & 8gc	As specified in of figure Eight (7).
8ba & 8bb	Female/Male thread nut & Female/Female thread nut
8aa, 8ab & 8ac	Linear type housing modular design
8ad, 8ae & 8af	Angular type housing modular design

[0076] Figure Eleven (11) Description: : Rended view of an example of a spiral shape apparatus assembled from multiple curve shape type housing with multiple modular LME, LEE and/or LEME devices (apparatus) for mixing hydrophilic blends, lipophilic blends, and/or other blends and water, alcohol-based and/or 'chemical solutions', W/O and/or O/W/O emulsions.

Parts and Components Identification:

REF NUMERAL	PART NAME
87	SPIRAL SHAPED MODULAR LEME APPARATUS

28, 32, 41, 8af & 8bb	As specified in of figure Eight (10).
8k	LEME apparatus housing

[0077] Figure Twelve (12) Description: Diagram of the flow pattern in an example of a multiple single chamber LME and LEE devices apparatus, where the chambers are connected by mixing chamber (tubular section) for the mixing hydrophilic blends, lipophilic blends, and/or other blends to water, alcohol-based and/or 'chemical solutions', W/O and/or O/W/O emulsions.

Parts and Components Identification:

REF NUMERAL	PART NAME
88	MULTIPLE SINGLE CHAMBER LME AND LEE APPARATUS

6, 11, 12, 28, 41, 8a, 8d, 8e, 8f, 8i, 8za, 8zb & 8zc	As specified in of figure One (1) and of figure Five (5).
8gb	Conical washer type nozzle
6a	Baseline products feedline to LEE device
11a, 12a or 13a	Baseline products feedlines to LME device
32	WFE main feedline to WFE main and/or buffer tanks

SECTION III: WFE AND/OR MULTIPLE-FUEL CONTINUOUS FLOW PRODUCTION SYSTEMS.

[0078] The invention relates to a modular WFE and/or bi-fuel system adopting low and high energy continuous flow and/or dilution production methods designed to produce and/or supply, on-demand, pilot fuels, fuel blends and/or water in fuel nanoemulsions (WFE) for applications, such

as, of those of internal, continuous and/or open flame combustion types, burning hydrocarbon, biodiesel and alcohol-based fuels, with return and/or return less, low and/or high pressure fuel feeding and/or injection systems and/or produce, on-demand water in fuel nanoemulsions (WFE) for storage purpose.

[0079] Figure Thirteen (13) Description: Block diagram of an example of general bi-fuel system layout adopting low and/or high energy continuous flow and/or dilution production methods designed to produce and/or supply, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE), for use in applications, such as, of those of internal, continuous and/or open flame combustion types, burning hydrocarbon, biodiesel and alcohol-based fuels, with return and/or return less, low and/or high pressure fuel feeding and/or injection systems, including the baseline and/or pilot fuel downstream supply chain.

Parts and Components Identification:

REF NUMERAL	PART NAME
99	**General WFE System Layout**
6z, 10, 11, 12, 13 & 14	As specified in of figure One (1)
24	Oil company and/or pilot fuel supplier (distributor)
25	Pilot fuel storage tank, WFE storage tank and/or 'petrol' station tank.
26	Fuel pump incorporated with a LME device
26a	Hydrocarbon, biodiesel and alcohol-based blend(s) feedline.
27	Main pilot fuel tank, sensors, pre-filters, pump
28	Main fuel feedline for pilot fuel or WFE when batch fed
29	Secondary or system fuel pump
30	Pilot fuel or WFE filter
31	WFE quality control apparatus: instruments (viscometer, thermometer, particle sizer, etc) and sensors.
32	Main WFE parallel circuit feedline

33	Main or daily WFE tank, valves, pumps, actuators, sensors and heating elements.
34	LEE device for mixing the lipophilic blends for on-demand WFE adjustment
35	Single or multiple WFE buffer, daily, and recirculation tank(s).
36	WFE secondary feedline from WFE buffer, daily, and recirculation tank
37	WFE post-emulsification filter, heating or cooling elements and/or WFE quality control apparatus **31**.
38	Engine, burner/boiler and/or any other equipment using fuel as the main energy source and **99** is installed onboard. It can be the main WFE storage tank **25** if the WFE system **99** refers to a prodcution plant.
39	Main pilot fuel and/or WFE return line from the engine, burner/boiler and/or any other equipment using fuel as the main energy source to main pilot fuel tank, WFE main, daily or buffer tank(s).
40	WFE return line to daily or buffer tank(s)
41	Main pilot fuel and/or WFE feedline. Pre-WFE system installation this would be the same feedline as **28**.
42	WFE return line to daily or buffer tank(s)
43	Feedline for mixing the pilot fuel to the lipophilic blends for on-demand WFE adjustment.
47	Switch valve and/or dual solenoid valves

[0080] Figure Fourteen (14) Description: Block diagram of an example of typical WFE system layout adopting low energy continuous flow and/or production dilution methods designed to produce and/or supply, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE), for use in applications, such as, of those of internal, continuous and/or open flame combustion types, burning hydrocarbon, biodiesel and alcohol-based fuels, with return and/or return less, low and/or high pressure fuel feeding and/or injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99a	ONBOARD WFE PRODUCTION SYSTEM
All	As specified in of figure Thirteen (13)

[0081] Figure Fifteen (15) Description: Block diagram of an example of a modular WFE system layout, fitted in 8", 20" and/or 40" containers, for stationary or mobile applications, adopting low energy continuous flow production method designed to produce, 'in situ', water in fuel nanoemulsions (WFE), for local storage purposes.

Parts and Components Identification:

REF NUMERAL	PART NAME
99b	MODULAR WFE PRODUCTION SYSTEM - PLANT
Others	As specified in of figure Thirteen (13)
99z	8", 20" and/or 40" container.

[0082] Figure Sixteen (16) Description: Block diagram of an example of bi-fuel system adopting low energy continuous flow production method designed to produce and/or supply, on-demand, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE) for applications, such as, internal combustion diesel engines burning hydrocarbon, biodiesel and alcohol-based fuels, with return less, low and/or high pressure fuel feeding and/or injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99aa	ONBOARD WFE PRODUCTION SYSTEM – ICE WITH RETURN LESS FUEL SYSTEM
All	As specified in of figure Thirteen (13)

[0083] Figure Seventeen (17) Description: Block diagram of an example of bi-fuel system adopting low and/or high energy continuous flow production method designed to produce or supply, on-demand, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE) for applications, such as, internal combustion diesel engines burning hydrocarbon, biodiesel and alcohol-based fuels, with return less, low and/or high pressure fuel feeding system and high pressure common rail injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99aa	ONBOARD WFE PRODUCTION SYSTEM – ICE WITH RETURN LESS FUEL SYSTEM
Others	As specified in of figure Thirteen (13)
38	Powertrain
38a	High pressure fuel pump
38b	Fuel line from high pressure pump to common rail
38c	Fuel line from WFE system to high pressure pump
38d	Injectors
38f	Common rail
38w	High energy mixing and/or emulsification apparatus: Sensors, actuators, valves, high energy mixing (HEM) and/or emulsification (HEE) device.
38y	Internal combustion engine (ICE)

[0084] Figure Eighteen (18) Description: : Block diagram of an example of a multi-fuel system designed to supply, on-demand, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE) for applications, such as, internal combustion diesel engines burning hydrocarbon, biodiesel and alcohol-based fuels, with return less, low and/or high pressure fuel feeding and/or injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99aa	ONBOARD WFE PRODUCTION SYSTEM – ICE W/RETURN LESS FUEL SYSTEM
Others	As specified in of figure Thirteen (13)
45	Pilot fuel
46	Alternative fuel and/or fuel blend

[0085] Figure Nineteen (19) Description: Block diagram of an example of bi-fuel system adopting low energy continuous flow production method designed to produce or supply, on-demand, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE) for applications, such as, internal combustion diesel engines burning hydrocarbon, biodiesel and alcohol-based fuels, with return, low and/or high pressure fuel feeding and/or injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99ab	ONBOARD WFE PRODUCTION SYSTEM – ICE W/RETURN FUEL SYS.
All	As specified in of figure Thirteen (13)

[0086] Figure Twenty (20) Description: Block diagram of an example of bi-fuel system adopting low energy continuous flow and/or dilution production methods designed to produce or supply, on-demand, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE) for applications, such as, internal combustion diesel engines burning hydrocarbon, biodiesel and alcohol-based fuels, with return, low and/or high pressure fuel feeding and/or injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99ab	ONBOARD WFE PRODUCTION SYSTEM – ICE W/RETURN FUEL SYS
All	As specified in of figure Thirteen (13)

[0087] Figure Twenty-One (21) Description: Block diagram of an example of bi-fuel system adopting a low energy continuous flow and/or dilution production methods designed to produce and/or supply, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE) for applications, such as, internal combustion diesel engines burning hydrocarbon, biodiesel and alcohol-based fuels, with return, low and/or high pressure fuel feeding and/or injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99ab	ONBOARD WFE PRODUCTION SYSTEM – ICE W/ RETURN FUEL SYS
All	As specified in of figure Thirteen (13)

[0088] Figure Twenty-Two (22) Description: Block diagram of an example of bi-fuel system adopting a low energy continuous flow and/or dilution production methods, designed to produce and/or supply, on-demand, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE) for applications, such as, internal combustion diesel engines burning hydrocarbon, biodiesel and alcohol-based fuels, with return, low and/or high pressure fuel feeding and/or common rail injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99ab	ONBOARD WFE PRODUCTION SYSTEM – ICE W/RETURN FUEL SYS.
All	As specified in of figure Thirteen (13)

[0089] Figure Twenty-Three (23) Description: Block diagram of an example of multi-fuel system adopting a low energy continuous flow production method designed to produce and/or supply, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE) for applications, such as, internal combustion diesel engines burning hydrocarbon, biodiesel and alcohol-based fuels, with return, low and/or high pressure fuel feeding and/or injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99ab	ONBOARD WFE PRODUCTION SYSTEM – ICE W/RETURN FUEL SYS.
All	As specified in of figure Thirteen (13) and of figure Seventeen (17)

[0090] Figure Twenty-Four (24) Description: Block diagram of an example of bi-fuel system adopting a low energy continuous flow production and/or dilution designed to produce and/or supply, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE) for applications, such as, internal combustion diesel engines burning hydrocarbon, biodiesel and alcohol-based fuels, with return, low and/or high pressure fuel feeding and/or injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99ab	ONBOARD WFE PRODUCTION SYSTEM – ICE WITH RETURN FUEL SYSTEM
All	As specified in of figure Thirteen (13) and of figure Seventeen (17)

SECTION IV: FLOWDIAGRAM OF KEY OPERATIONS FOR A BI-FUEL SYSTEMS IN A ICE.

[0091] The invention relates to a bi-fuel system, using a low energy continuous flow production method designed to produce and/or supply, on-demand, pilot fuels, fuel blends and/or water in fuel nanoemulsions (WFE), from middle distillate fuels, for direct injection internal combustion diesel engines fitted with high pressure return injection system, such as, used in vehicles and/or stationary equipment.

[0092] Figure Twenty-Five (25) Description: Schematic diagram of an example of a typical layout of a bi-fuel system, middle distillates and WFE, designed produce and/or supply, on-demand, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE), for direct injection internal combustion diesel engines fitted with high pressure return injection system.

Parts and Components Identification:

REF NUMERAL	PART NAME
99aa	ONBOARD WFE PRODUCTION SYSTEM – ICE WITH RETURN FUEL SYSTEM
Others	As specified in of figure Four (4) and figure Thirteen (13)
27a	Pilot fuel drainer
27b	Pilot fuel submerge electric pump
27c	Pilot fuel tank cap
29a	Pilot fuel and/or WFE main filter inspection drainer
35a	WFE buffer tank
35b	WFE buffer tank electric pump
35c	WFE buffer tank maintenance & inspection drainer
35d	WFE buffer tank cap (manhole)
35e	WFE filter
35f	WFE filter inspection drainer
35g	WFE recirculation feedline
35h	Solenoid valves
38a	High pressure fuel pump
38b	Injection system high pressure feedline
38c	High pressure pump excess fuel return line
38d	Injector
38e	Injector return line
38x	High pressure injection system

[0093] Figure Twenty-Six (26) Description: Schematic diagram of an example of a typical layout of a bi-fuel system, middle distillates and WFE, designed produce and/or supply, on-demand, pilot fuel, fuel blends and/or water in fuel nanoemulsions (WFE), for direct injection internal combustion diesel engines fitted with high pressure return injection system. Figure Twenty-Seven (27) shows the typical fuel feeding system while figures Twenty-Eight (28) to Thirty-Two (32) exemplify a typical method for priming, starting the engine, standard operations, varying the WFE and purging the WFE from the fuel feeding and injection systems.

Parts and Components Identification:

REF NUMERAL	PART NAME
99aa	ONBOARD WFE PRODUCTION SYSTEM – ICE WITH RETURN FUEL SYSTEM

Others	As specified in of figure Twenty-Five (25)
31a	Thermometer
31b	Viscometer
31c	WFE quality control instrument – e.g. acoustic particle sizer
35i	WFE tank intake nozzle
35j	WFE tank thermometer
35k	Level sensor (switches)
35l	WFE heating device
35m	WFE cooling device
37a	Thermometer
37b	Viscometer
37d	WFE quality control instrument – e.g. acoustic particle sizer
37e	Pilot fuel and/or WFE heating/cooling device

[0094] Figure Twenty-Seven (27) Description: Schematic diagram of an example of a typical layout of a pilot fuel circuit designed to supply middle distillates fuels for direct injection internal combustion diesel engine fitted with high pressure return injection system.

Parts and Components Identification:

REF NUMERAL	PART NAME
98	PILOT FUEL SYSTEM – ICE WITH RETURN FUEL SYSTEM
All	As specified in of figure Twenty-Five (25)

[0095] Figure Twenty-Eight (28) Description: Schematic diagram of an example of the method for priming the WFE system in typical a bi-fuel system layout for direct injection internal combustion diesel engine fitted with high pressure return injection system.

[0096] Priming is required after installing a WFE system for the first time, onboard a vehicle and/or a stationary equipment and/or when the WFE system requires emptying, *e.g.* thorough cleaning. The electric fuel pump **27b** and/or **30** is powered by the main battery via the priming electric circuit override system, which is controlled by a certified technician. This will pump the pilot fuel through the main fuel feedline **28** to the LEME device **8**, producing the WFE by mixing the hydrophilic blend **11** and water **6z**. The solenoid valves **35h** $\mathbf{S_0}$ and $\mathbf{S_1}$ are activated to, respectively, close and open, allowing the WFE to flow through the WFE feedline **32** to the WFE buffer tank **35a**. The pump will automatically stop when the WFE reaches the sensor **S12** by sending back the signal back to the pump and simultaneously informing the operator via the application installed in the portable device.

Parts and Components Identification:

REF NUMERAL	PART NAME
99aa	ONBOARD WFE PRODUCTION SYSTEM – ICE WITH RETURN FUEL SYSTEM
All	As specified in of figure Twenty-Five (25) and figure Twenty-Six (26)

[0097] Figure Twenty-Nine (29) Description: Schematic diagram of an example of the method for starting an engine in typical a bi-fuel system layout, for direct injection internal combustion

diesel engine fitted with high pressure return injection system, after standard operation and/or engine cut-out (WFE purge).

[0098] For best performance when starting the engine pilot fuel should be used, which avoids the need to change the injection timing (ignition delay), use of cetane and the system left with WFE during longer periods between operations. The electric fuel pump **27b** and/or **30** is powered by the main battery to pump the pilot fuel through the main fuel feedline **28** and **41** to the high pressure injection pump **38a**, to the injectors **38d** through **38b**, returning the unused fuel through the high pressure pump return line **38c** and injectors return line **38e** back to the main pilot fuel tank **27**. Simultaneously, the WFE pump **35b** installed in the WFE buffer tank **35a** is activated pumping the WFE through the WFE recirculation line **35g** through the WFE heating device **35l**, where it is heated, and returning to the WFE buffer tank **35a**. This cycle continuous until the temperature reaches the desired WFE operational temperature monitored by the temperature gauge **35j**. Once the WFE reaches the desired operational temperature the solenoid valves **35h** S_0, S_4 and S_5 are activated to, respectively, close, open and close, stopping the pilot fuel being fed to the high pressure pump, activating the LEME **8**, producing the WFE by mixing a hydrophilic blend **11** and water **6z**, which feeds WFE buffer tank **35a**. A few seconds later (switch delay time), limited time to avoid contamination of the main pilot fuel tank **27**, the solenoid valves **35h** S_2, and S_3 are, respectively, closed and open and WFE tank pump **35b** is turned on, allowing the WFE to be flow to the high pressure pump **38a**, to the injectors **38d** through **38b**, and back to the WFE buffer tank **35a**, through the returns line **38c** and **38e.**

Parts and Components Identification:

REF NUMERAL	PART NAME
99aa	ONBOARD WFE PRODUCTION SYSTEM – ICE WITH RETURN FUEL SYSTEM
All	As specified in of figure Twenty-Five (25) and figure Twenty-Six (26)

[0099] Figure Thirty (30) Description: Schematic diagram of an example of a of the method for WFE standard operations in typical a bi-fuel system layout for direct injection internal combustion diesel engine fitted with high pressure return injection system.

[0100] In a specific operational condition the engine will run with a single type of WFE, *e.g.* with the same content of water which has been designed to achieve best perfomance. In this example,

the solenoid valves **35h** S_0, S_1, S_2, S_3, S_1 and S_5, are activated to, respectively, close, open, close, open, open and close. The electric fuel pump **27b** and/or **30** then powers by to pump the pilot fuel through the main fuel feedline **28** to the LEME device **8**, producing the WFE by mixing the hydrophilic blend **11** and water **6z**. The WFE then flows through **32** directly to the WFE buffer tank **35a** until the maximum operational limit is reached triggered by the level switch **S14**, which simultaneously the WFE tank pump **35b** is turned on, allowing the WFE to be flow to the high pressure pump **38a**, to the injectors **38d** through **38b**, and back to the WFE buffer tank **35a**, through the returns line **38c** and **38e.** If the pilot fuel pump **30** installed in the main pilot fuel line **28** is mechanical a bi-pass valve is required to automatically switch the pilot fuel to flow back to the pilot fuel tank **27** if for any reason the WFE is not being produced.

Parts and Components Identification:

REF NUMERAL	PART NAME
99aa	ONBOARD WFE PRODUCTION SYSTEM – ICE WITH RETURN FUEL SYSTEM
All	As specified in of figure Twenty-Five (25) and figure Twenty-Six (26)

[0101] Figure Thirty-One (31) Description: Schematic diagram of an example of the method to WFE variation in typical a bi-fuel system layout for direct injection internal combustion diesel engine fitted with high pressure return injection system, once the operational condition demands.

[0102] The variation of the type and/or quality of WFE is required to achieve best combustion efficiency at a specific operational which varies depending if the target is to obtain better fuel consumption rates and/or reduction of a specific emission. The variation is achieved by simply changing the mixing rates of the hydrophilic blend and/or water and corrected by the lipophilic blend controlled by the ECU and managed by the intelligent system installed onboard. In a return fuel feeding system, the WFE upper limit, maximum volume should be lower than the operational to avoid the higher volumes of different WFE to be mixed when returning to the baseline WFE or any other changes occur, this is controlled the level switch **S13**. In some cases, multiple tank can be used but ideally the use of the system should use a return less feeding system when possible, by changing to an electric/electronic high-pressure pump. This system works best when the changes are graduate and not frequent, e.g. stationary engines with longer constant periods of power demand.

Parts and Components Identification:

REF NUMERAL	PART NAME
99aa	ONBOARD WFE PRODUCTION SYSTEM – ICE WITH RETURN FUEL SYSTEM
All	As specified in of figure Twenty-Five (25) and figure Twenty-Six (26)

[0103] Figure Thirty-Two (32) Description: Schematic diagram of an example of the method for WFE purging in typical a bi-fuel system layout for direct injection internal combustion diesel engine fitted with high pressure return injection system.

[0104] Purging is required when engine stops after running on WFE to avoid the WFE in the fuel line when engine starts. When engine stops the WFE in the WFE buffer tank can only be at the maximum volume which is controlled by the level switch **S15**. Short time after the engine stops, the electric fuel pump **27b** and/or **30** is powered by the main battery via the priming electric circuit override system, which is automatically controlled ECU and managed by the intelligent system installed onboard. The solenoid valves **35h** S_0, S_1, S_2 and S_3 are activated to, respectively, open, close, close and open, allowing the WFE to flow through the main fuel feed line **41** through the injection system 38a, 38b, 38c and 38e back to the WFE buffer tank, which once finished the solenoid valves will deactivate and go to it normal position.

Parts and Components Identification:

REF NUMERAL	PART NAME
99aa	ONBOARD WFE PRODUCTION SYSTEM – ICE WITH RETURN FUEL SYSTEM
All	As specified in figure Twenty-Five (25) and figure Twenty-Six (26)

SECTION V: BLOCK DIAGRAM INTELLIGENT SYSTEM FOR MULTI-PLE APPLICATIONS.

[0105] The invention relates to a manual and/or automatic, remote control, intelligent management system designed to control, on-demand: the pilot fuels, fuel blends and/or WFE supply; the low and/or high energy continuous flow and dilution production WFE system; and the quality of the water in fuel nanoemulsions (WFE) for applications, such as, of those internal, continuous and/or open flame combustion types, burning hydrocarbon, biodiesel and alcohol-based fuels, with return

and/or return less, low and/or high pressure, fuel feeding and/or injection systems, quality of the WFE; and/or the efficiency of the application and or integrated technologies.

[0106] Figure Thirty-Three (33) Description: Block diagram of an example of bi-fuel system, manual and/or automatic, remotely controlled, intelligent management system, system designed to control, on-demand: the pilot fuels, fuel blends and/or WFE supply; low and/or high energy continuous flow and dilution production WFE system; and the quality of the water in fuel nanoemulsions (WFE) for applications, such as, internal combustion diesel engines burning hydrocarbon, biodiesel and alcohol-based fuels, with return, low and/or high pressure fuel feeding and common rail injection systems; quality of the WFE; and/or the efficiency of the application and/or integrated technologies.

Parts and Components Identification:

REF NUMERAL	PART NAME
201	INTELLIGENT SYSTEM FOR IC DIESEL ENGINE WITH RETURN FUEL SYSTEM AND COMMON RAIL
Others	As specified in of figure Twenty-Two (22)
38t	Common rail
50	Monitoring device: display screen
51	Interface: software (mathematical model), security and alarm system data recording and adjustment
52	Port for data transfer, updates and system control.
53	Wireless connections and positioning system: WIFI, Bluetooth, AIS, VOR, ADF, GPS, etc.
54	Electronic control unit (ECU), original settings, tailored or remapped.
55	Onboard application sensors and/or actuators: for gyroscope, axle-load, tyre pressure, etc
56	External sensors and/or actuators: ambient pressure, altitude, aerodynamic speed, ambient temperature, humidity,

57	Engine sensors and/or actuators: airmass flow; injector pressure and wear; oil and fuel viscosity; engine, fuel, oil, exhaust, air and water temperatures; etc
58	WFE sensors and/or actuators: baseline product dosing; fuel/WFE circuit management; WFE viscosity, temperature; particle size and distribution; etc
59	Fuel injector sensors and/or actuators: pressure, temperatures, etc
60	Common rail sensors: pressure and temperature
61	Injector sensors and actuators: pressure, temperature, volume, etc
62	Engine load and speed sensor
63	Camshaft load and speed sensor
64	Gear box sensors
65	Post treatment technologies and exhaust sensors and/or actuators: e.g. EGR

[0107] Figure Thirty-Four (34) Description: Block diagram of an example of a typical intelligent management system, designed manual and/or automatically, and remotely control, on-demand: the pilot fuels, fuel blends and/or WFE supply; low and/or high energy continuous flow and dilution production WFE system; and the quality of the water in fuel nanoemulsions (WFE) for applications, such as, of those internal, continuous and/or open flame combustion types, burning hydrocarbon, biodiesel and alcohol-based fuels, with return and/or return less, low and/or high pressure, fuel feeding and/or injection systems, quality of the WFE; and/or the efficiency of the application and or integrated technologies.

Parts and Components Identification:

REF NUMERAL	PART NAME
115	TYPICAL INTELLIGENT SYSTEM LAYOUT
All	As specified in SECTION III and SECTION IV.

66	Tyre sensors and actuators
67	Aerodynamic sensors
68	Ambient and external (application) sensors
200	Fuel and emission isocurves (equations)

[0108] Figure Thirty-Five (35) Description: Block diagram of an example of a typical development method for applications, such as, of those internal, continuous and/or open flame combustion types, burning hydrocarbon, biodiesel and alcohol-based fuels, with return and/or return less, low and/or high pressure, fuel feeding and/or injection systems, quality of the WFE; and/or the efficiency of the application and or integrated technologies; and/or development of fuels, fuel blends and/or WFE.

Parts and Components Identification:

REF NUMERAL	PART NAME
113	SYSTEM AND TECHNOLGY CONTROL CENTER
100	Strategical Technical Partners, *e.g.* oil companies; vehicle, engine, equipment, fuel injection, powertrain, plant, chemical manufacturers; software designers; academic institutions; professional consultants; etc. R & D Programme partners.
101	Internal combustion engines, continuous combustion engines and burners/boilers. This includes powertrain design and match. Application technology (AP).
102	Production plant and device design. Production Technology (PT).
103	Chemical formulation, fuel and blends, data collection and development. Fuel Technology (FT).
104	Engine test bench, chassis dynamometer and burner/boiler test bench. Application Technology (AP).
105	Data analysis and database for modelling. Information Technology (IT).

106	Onboard testing. Pilot deployment. Application technology (AT).
107	Advanced data analysis (correlation) and mathematical modelling. Information Technology (IT).
108	Product certification: Fuel Blends, formulations and WFE.
109	WFE legislation and tax incentives: bill proposal (lobby).
110	Technology and application certification: pilot deployment results and/or Trials.
111	Technology software design, integrating to the business software and modules. 'Business franchise format'.
112	Technology, product and system: quality, distribution, management and control.
114	Product A: business software
115	Product B: technology software
116	Product C: technology baseline products: Blends, solutions, plants and devices.

SECTION VI: OTHER FIGURES.

[0109] This section presents: **(i).** examples and data of properties related to WFE, collected from laboratory tests performed during product investigation and development **(ii).** untreated results obtained from preliminary tests performed in a chassis dynamometer on a Jaguar X-Type, 2.2D, 2005, demonstrating the potential combustion efficiency of the WFE and **(iii).** other figures that don't relate to topics of the previous sections.

[0110] Figure Thirty-Six (36) Description: A surfactant is an amphiphilic molecule consisting of a nonpolar hydrophobic (lipophilic) part, usually a hydrocarbon chain, attached to a hydrophilic portion. The hydrophilic and lipophilic portions within the molecule are commonly referred to as, respectively, the head and tail groups.

[0111] Figure Thirty-Seven (37) Description: Photo of a typical water in diesel nanoemulsion **301** containing 8% water content (m/m) at a formula to water ratio (Fn/W) of 0.375 (m/m), produced

at ambient temperature (~20ºC) by initially adding chemical composition (formula) to the diesel and mixed using a magnetic stirrer at 500 rpm for 3 minutes, then adding the deionised water using a pipette, at approximately constant rate, during 5 minutes using an homogenizer (Heidolph, Silent Crusher) at 5000 rpm. The particle size and polydispersity were then measured using Dynamic Light Scattering (DLS – Malvern, Zetasizer ZSP) as presented in Table Two (2) paragraph [00016].

[0112] Figure Thirty-Eight (38) Description: Graph of two emulsions, one a water in diesel nanoemulsion **301** as described in fig. Thirty-Seven (37) and a water in fuel microemulsion **302** produced in the same way but with 5% water content (m/m) at a formula to water ratio (Fn/W) of 2.0 (m/m). The particle size and polydispersity are presented in Table Two (2).

[0113] Figure Thirty-Nine (39) Description: Graph of two emulsions, one a water in diesel microemulsion **302** as described in fig. Thirty-Eight (38) and a water in fuel nanoemulsion **303** produced in the same way but with 15% water content (m/m) at a formula to water ratio (Fn/W) of 0.375 (m/m). The particle size and polydispersity are presented in Table Two (2).

[0114] Figure Forty (40) Description: Graph of three water in water nanoemulsions, **301**, **304** and **305**, produced using different methods, respectively, as described in fig. Thirty-Seven (37), using a 300 litre/hour pilot plant by just flowing through the pressure regulator valve at minimum operational pressure (8 bar) and by hand shaking with short stokes for approximately 5 seconds. The particle size and polydispersity are presented in Table Three (3).

[0115] Figure Forty-One (41) Description: Graph of a representative sample of a water in fuel nanoemulsion **303**, as described in fig. Thirty-Nine (39), with several repeatability's and samples taken from top and bottom of test flask. The particle size and polydispersity were measured using Dynamic Light Scattering (DLS – Anton Paar, Litesizer) are presented in Table Four (4).

[0116] Figure Forty-Two (42) Description: Explanatory example of graphs presented in the figures that follow representing the % reduction (fuel rate and emissions) of the WFE over the pilot fuel Diesel, for WFE with 8% water a Fn/W of 0.375, produced with formulation designed for an operation temperature of 45ºC, using a paddle and electric hand drill, tested in a chassis dynamometer, at 2 different loads, in a Jaguar X-Type 2.2D, 2005, over all six different gears ratios, at engines speeds between 1500 to 3000rpm, in increments of 500 rpm. In brief, the protocol considered measuring the fuel rate directly from the vehicle (ECU) and emissons NOx, $\%CO_2$, PM and CO, from hired reliable calibrated equipment, which both were collected by independent service providers. The graph located on the top relates to the operational zones were

the % reduction of WFE over Diesel is positive at a specific load and WFE, *i.e.* shaded when WFE is more efficient than Diesel at that operational condition. The graph located on the Bottom relates the best results (%reduction) at specific engine speed (rpm), where the top indicated the maximum and the bottom indicated the minimum if over zero, else zero since is not of interest for this analysis.

Parts and Components Identification:

REF NUMERAL	PART NAME
400, 401, 402, 403 & 404	Related to the variable measured, *i.e.* Fuel rate in volume **400**, $\%CO_2$ **401**, NOx **402**, CO **403** and PM **404.**
ab, ax, bx & bz	Related to the type of WFE and load used during test, i.e. 8% water **a**, 15 %water **b**, 159Nm **x** and 317Nm **z**

[0117] Figure Forty-Three (43) Description: Illustrates the operational zones where the vehicle was more economical (fuel) with WFE than diesel and the best results within that engine speed. Comparison is based on the volume of WFE (NOT to the amount of diesel in WFE) to volume of Diesel.

[0118] Figure Forty-Four (44) Description: Illustrates the operational zones where the vehicle $\%CO_2$ emissions were lower for WFE than with diesel and by how much was the best results within a specific engine speed.

[0119] Figure Forty-Five (45) Description: Illustrates the operational zones where the vehicle NOx emissions were lower for WFE than with diesel and by how much was the best results within a specific engine speed.

[0120] Figure Forty-Six (46) Description: Illustrates the operational zones where the vehicle CO emissions were lower for WFE than with diesel and by how much was the best results within a specific engine speed.

[0121] Figure Forty-Seven (47) Description: Illustrates the operational zones where the vehicle PM emissions were lower for WFE than with diesel and by how much was the best results within a specific engine speed.

DETAILED DESCRIPTION OF THE INVENTION

[**0122**] – "The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items. As used herein, the singular forms "a," "an," and "the" are intended to include the plural forms as well as the singular forms, unless the context clearly indicates otherwise".

[**0123**] – "The terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof".

[**0124**] – "Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one having ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and the present disclosure and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein".

[0125] The invention relates to method, system, chemical compositions and device capable of producing, with low and/or high energy, by batch, continuous flow and/or dilution production methods, fuels blends; single or multiple phase micro and/or nanoemulsions, i.e. water in oil (W/O), oil in water (O/W), water in oil in water (W/O/W), and oil in water in oil (O/W/O) and/or water in fuel micro and nanoemulsions (WFE); and/or chemical solutions, for the use therein, but not limited to.

[0126] The invention relates to method, system, chemical compositions and device capable of producing, offboard, onboard and/or on-demand, with low and/or high energy, by batch, continuous flow and/or dilution production methods, fuels blends, single or multiple phase micro and/or nanoemulsions, from a pilot fuel comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends, to apply to engine, machinery and/or equipment of internal, continuous and open flame combustion type, for improving combustion efficiency, to enhance the reduction of emissions from the consumptions (burning) of those fuels.

Products

[0127] It is thus the object of the present invention water in fuel nanoemulsions (WFE) to be produced onboard and on-demand, comprising at least, but not limited to,

a) from 46.0% to 95.6% by mass of a pilot fuel, comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends, of the total mass of the WFE;
b) from 4% to 36% by mass of water, in liquid and/or vapor state, of the total mass of the WFE;
c) from 0.100 to 0.500 by mass of chemical formulation to water ratio, i.e. Fn:W; equivalent to 0.4% to 18.0% of chemical formulation (Fn), of the total mass of the WFE;
d) from 1.2% to 90% by mass of solvents, of the total mass of the WFE;
e) from 0.1% to 5% by mass of additives, of the total mass of the WFE.

[0128] It is thus the object of the present invention fuel blends, to be produced onboard and on-demand, comprising at least, but not limited to,

1st) from 5% to 95% by mass of a pilot fuel, comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends, of the total mass of the fuel blend;
2nd) from 5% to 95% by mass of hydrocarbon, biodiesel, alcohol, and/or other solvents, of the total mass of the fuel blend;
3rd) from 5% to 95% by mass of liquid gas, selected from light naphtha, butane and/or any other gaseous fuel in liquid form between 10 at 50ºC and pressure between ambient to at least 40 Bar, of the total mass of the fuel blend;
4th) from 1% to 20% by mass of additives and/or other chemical compounds, of the total mass of the fuel blend;

[0129] It is thus the object of the present invention modular production plant and modular mixing and/or emulsification device to produce, with low and/or high energy, by batch, continuous flow and/or dilution production methods, fuels blends; and/or single or multiple phase micro and/or nanoemulsions, i.e. water in oil (W/O), oil in water (O/W), water in oil in water (W/O/W), and oil in water in oil (O/W/O), and/or water in fuel micro and nanoemulsions (WFE), comprising at least, but not limited to, homogenizer, static mixer and/or low energy mixing and/or emulsification device, sensors, activators, software, etc, as described, respectively, in figure one (1) to figure two (2) and/or figure three (3) to figure twelve (12).

[0130] It is thus the object of the present invention chemical composition, chemical formulation or formulation (Fn), **c),** from 0.100 to 0.500 by mass of chemical formulation to water ratio, i.e. Fn:W; equivalent to 0.4% to 18% of chemical formulation (Fn) of the total mass of the WFE, used to

produce water in fuel nanoemulsions (WFE), comprising at least, but not limited to, non-ionic surfactants, selected amine and amide derivative surfactant, fatty acid esters non-ionic co-surfactants and ethoxylated alcohols and/or alkylphenols as co-co-surfactants.

[0131] It is thus the object of the present invention methods and systems for producing, offboard and/or onboard, fuel blends, single and/or multiple phase micro and/or nanoemulsion, and/or water in fuel nanoemulsion (WFE); for controlling, remotely and/or in situ, in automatic and manual mode, the production, quality and type of fuel blends, single and/or multiple phase micro and/or nanoemulsion and/or water in fuel nanoemulsion (WFE), the engine, machinery and or equipment operations; for management of the production, fuel and WFE quality and type, the engine, machinery and or equipment operations, maintenance and perfomance; for integrating and managing the fuel, WFE, fuel economy, emission reduction, vehicle and other application technologies; and/or, but not limited to, product, technology and mathematical modelling development, comprising at least, but not limited to; **(i).** new and enabling technologies, e.g. block chain, internet of things, artificial intelligence, SAM learning, etc; **(ii).** production, control and management system for baseline products ,i.e. fuel blends and/or water in oil (W/O), oil in water (O/W), water in oil in water (W/O/W), and oil in water in oil (O/W/O) micro and/or nanoemulsions (WFE), water and/or chemical solutions; **(iii).** an onboard production control and management system for fuel blends and water in fuel nanoemulsions (WFE); **(iv).** an onboard production control and management system, for engine, machinery and or equipment operations, maintenance and perfomance; **(v).** an onboard control and management system, for integrating fuel, WFE, fuel economy, emission reduction, vehicle and other application technologies and other application technologies; **(vi).** data collection, correlation and mathematical modelling method and system for product, technology and software development; and **(vii).** a modular fully integrated systems (software) remotely and/or in situ, automatically and/or manually controlled, connecting the product and technology development system; production control and management systems; onboard fuel blends, WFE quality control systems; onboard application control and management; onboard operational and performance management systems; as well as, but not limited to, technical, security and business management systems; as described in figures thirty-three (33) to thirty-five (35).

Materials

[0132] It is thus the object of the present invention pilot fuel, **a)**, from 46% to 95.6% by mass, fuel and/or fuel blends, of the total water in fuel emulsion (WFE), and/or fuel blend, comprising at least, from but not limited to,

A) Middle petroleum distillate fuels and/or fuel blends (Low viscosity), selected from on-road diesel (D), off-road diesel (D_o), marine gas oil (MGO) – DMX and/or DMA, marine diesel oil (MDO) – DMB and/or DMC) and heating oil.

B) Heavy and residues petroleum distillates fuels and/or fuel blends (high viscosity), selected from, heavy fuel oil (HFO), intermediate fuel oil (IFO), low sulphur fuel oil (LSFO), ultra-low sulphur fuel oil (ULSFO) and other fuels consisting mainly of residues from crude-oil distillation.

C) Light petroleum distillate fuels and/or fuel blends, selected from gasoline, kerosene and/or liquid naphtha.

D) Other hydrocarbon liquid fuels.

E) Renewable diesel (hydrocarbon biofuel) and/or fuel blends, such as, hydrotreated vegetable oil (HVO).

F) Alcohol-based fuels, selected from ethanol, methanol and/or any other alcohol fuel.

G) Biodiesel (non-hydrocarbon biofuel) and fuel blends, e.g. Fatty Acid Methyl Esters (FAME) and any other biodiesel.

H) Other renewable and non-hydrocarbon liquid fuels.

I) Liquid gaseous fuels, selected from butane, propane, and/or any other liquid gaseous fuel.

[0133] It is thus the object of the present invention water **b)**, in liquid and/or vapor state, from 4% to 36% by mass, of the total mass of the emulsion; treated and/or untreated for producing water in oil (W/O), oil in water (O/W), water in oil in water (W/O/W), and oil in water in oil (O/W/O), chemical solutions and water fuel micro and nanoemulsions (WFE), comprising at least, but not limited to, Deionized and/or demineralized water, desalinised water, filtered rainwater, filtered and treated grey water and/or tap water.

[0134] It is thus the object of the present invention chemical composition, chemical formulation or formulation (Fn), **c),** from 0.100 to 0.500 by mass of chemical formulation to water ratio, i.e. Fn:W; equivalent to 0.4% to 18% of chemical formulation (Fn) of the total mass of the WFE, comprising at least, but not limited to,

I. from 25% to 100% by mass of amine and amide derivative non-ionic surfactants, selected from fatty acid alkanolamides, of the total mass of the chemical formulation (Fn);

II. from 1% to 70% by mass of ethoxylated alcohols and/or alkylphenols non-ionic co-co-surfactants, selected from ethoxylated linear alcohols, ethoxylated alkyl phenols surfactant and/or ethoxylated thiols, of the total mass of the chemical formulation (Fn);

III. from 1% to 30% by mass of fatty acid esters non-ionic co-surfactants, selected from sorbitan alkyl esters (Spans) and/or polyoxyethlyene derivatives of sorbitan alkyl esters (Tweens) surfactants, of the total mass of the chemical formulation (Fn);

IV. from 0.1% to 20% by mass of other non-ionic, anionic, cationic, zwitterionic and/or any other co-co-surfactants, of the total mass of the chemical formulation (Fn).

[0135] It is thus the object of the present invention amine and/or amide derivative non-ionic surfactants, from 25% to 100% by mass of the total mass of the chemical formulation (Fn), selected from one or more fatty acid alkanolamide, comprising, but not limited to, for example acetamide MEA, almondamide DEA, apricotamide DEA, avocadamide DEA, avocadamide DIPA, babassuamide DEA, babassuamide MEA, Capramide DEA, cocamide DEA, cocamide DIPA, cocamide MEA, cocamide MIPA, cocoyl sarcosinamide DEA, comamide/cocamide DEA, cornamide DEA, diethanolaminooleamide DEA, disodium cocamido MIPA PEG-4 sulfosuccinate, disodium lauramido MIPA, glycol sulfosuccinate, hydrogenated tallowamide DEA, hydroxyethyl ethylene dipalmitamide, hydroxyethyl stearamide-MIPA, hydroxypropyl bisisostearamide MEA, hydroxypropyl bislauramide MEA, hydroxypropyl bispalmitamide MEA, hydroxystearamide MEA, isostearamide DEA, isostearamide MEA, isostearamide MIPA, lactamide MEA, lanolinamide DEA, lauramide DEA, lauramide MEA, lauramide MIPA, lauramide/Myristamide DEA, lauryl Malamide, lecithinamide DEA, linoleamide DEA, linoleamide MEA, linoleamide MIPA, minkamide DEA, myristamide DEA, myristamide MEA, myristamide MIPA, oatamide MEA, oleamide DEA, oleamide DIPA, oleamide MEA, oleamide MIPA, olivamide DEA, oliveamide MEA, palmamide DEA, palmamide MEA, palmamide MIPA, palmitamide DEA, palmitamide MEA, palm kernelamide DEA, palm kemelamide MEA, palm kernelamide MIPA, pantothenamide MEA, nutamide MEA, peanutamide MIPA, PEG-20 pocamide MEA, ricebranamide DEA, ricinoleamide DEA, ricinoleamide MEA, ricinoleamide MIPA, sesamide DEA, sesamide DIPA, soyamide DEA, stearamide AMP, stearamide DEA, stearamide DEA-distearate, stearamide DIBA-stearate, stearamide MEA, stearamide MEAstearate, stearamide MIPA, tallamide DEA, talloWamide DEA, talloWamide MEA, trideceth-2 Carboxamide MEA, undecylenamide DEA, undecylenamide MEA and/or Wheat germamide DEA.

[0136] It is thus the object of the present invention of ethoxylated alcohols and/or alkylphenols non-ionic co-co-surfactants, from 1% to 70% by mass of the total mass of the chemical formulation (Fn), selected from one or more ethoxylated linear alcohols, ethoxylated alkyl phenols surfactant and/or ethoxylated thiols, comprising, but not limited to, for example comprising, but not limited to, for example nonylphenol ethoxylate and alcohol ethoxylate.

[0137] It is thus the object of the present invention fatty acid esters non-ionic co-surfactants, from 0.1% to 30% by mass of the total mass of the chemical formulation (Fn), selected from one or more sorbitan alkyl esters (Spans) and/or polyoxyethlyene derivatives of sorbitan alkyl esters (Tweens) surfactants, comprising, but not limited to, for example comprising, but not limited to, for example, sorbitan monolaurate (Span 20), sorbitan monopalmitate (Span 40), sorbitan monostearate (Span 60), sorbitan tristearate (Span 65), Sorbitan monooleate (Span 80), sorbitan etrioleate (Span 85), polyoxyethylene sorbitan monolaurate (Tween 20), polyoxyethylene sorbitan monopalmitate (Tween 40), polyoxyethylene sorbitan monostearate (Tween 60), polyoxyethylene sorbitan triestearate (Tween 65), polyoxyethylene sorbitan monooeleate (Tween 80), polyoxyethylene sorbitan trioeleate (Tween 85).

[0138] It is thus the object of the present invention other co-co-surfactants, from 0.1% to 20% by mass of the total mass of the chemical formulation (Fn), selected from one or more other non-ionic, anionic, cationic, zwitterionic (amphoteric) and/or any other surfactants, comprising, but not limited to, for example almondamidopropyl betaine, Alkyl polyethylene glycol ether, apricotamidopropyl betaine, capryl/capramidopropyl betaine, canolamidopropyl betaine, cetearyl Alcohol, cetrimonium bromide, cocamide betaine, cocamidoethyl betaine, cocamidopropyl betaine, cocamidopropyl hydroxysultaine, coco-betaine, coco- hydroxysultaine, Cocamidopropyl Hydroxysultaine, coconut alcohol, coco/oleamidopropyl betaine, Cocamidopropylamine Oxide, Cocamidopropylamine Oxide, decyl betaine, glyceryl stearate SE, Glyceryl Caprylate/Caprate, hydrogenated tallow betaine, Lauramide Oxide, Lauramidopropylamine Oxide, lauramidopropyl betaine, lauryl betaine, Lauryl/Myristyl Amidopropyl Amine Oxide, lauryl alcohol ethoxylates, myristamidopropyl betaine, oleamidopropyl betaine, oleyl betaine, palm kernelamidopropyl betaine, palmamidopropyl betain, palmitamidopropyl betaine, propylene glycol stearate, sesamidopropyl betaine, soyamidopropyl betaine, stearyl betaine, tallowamidopropyl betaine, trilaneth-4 phopshate, octylphenoxy polyethoxyethanol (triton x-100), tetradecyltrimethylammonium bromide (TTAB), Sodium lauryl sulfoacetate, Sodium cetearyl sulfate and/or sodium dodecyl sulphate.

[0139] The invention relates to method, system, solvents, **d)**, additives, **e)**, and/or other chemical compounds and/or other raw materials, contained in the pilot fuel and/or used, for improving the quality of fuels blends, and/or single or multiple phase micro and/or nanoemulsions used to produce, onboard and on-demand, fuel blends and/or water fuel nanoemulsions (WFE) to apply to engine, machinery and/or equipment of internal, continuous and open flame combustion type,

further improving combustion efficiencies, to enhance the reduction of emissions from the consumptions (burning) of those fuels.

[0140] It is thus the object of the present invention solvents, **d)**, from 1.2% to 90% by mass; and/or an additives, **e)**, and/or other chemical compounds, from 0.1% to 5% by mass, of the total mass of the water in fuel nanoemulsion (WFE) or fuel blend, comprising at least, but not limited to,

Solvents:

i. pilot fuel, **a)**, comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends, selected from **A)** to **D)**.

ii. liquid gas, selected from light naphtha, butane and/or any other gaseous fuel in liquid form between 10 at 50ºC and pressure between ambient to at least 40 Bar, of the total mass of the fuel blend; **I)**,

iii. Other solvents, comprising hydrocarbon, biodiesel and/or alcohols, for example, vegetable oils, methanol, ethanol, isopropyl alcohol (IPA), n-butanol, f-butane, trichloroethane, trichlorethylene, benzene, xylene and toluene.

Additives:

iv. Cetane improvers, for example, Octyl Nitrate (EHN or 2-Ethylhexyl nitrate), biodiesel and or vegetable oils.

v. Corrosion inhibitors, for example, octyl 1H benzotriazole, ditertiary butylated 1H-Benzotriazole, propyl gallate, polyoxyalkylene polyols, octadecyl amines, nonyl phenol ethoxylates, calcium phenolates of hydrogenated pentadecyl phenol and magnesium alkyl benzene sulfonates;

vi. Anti-foaming, for example, silicone oil, polyvinyl alcohol and polyethers,

vii. Cold Flow Improvers, for example, ethylene-vinyl acetate copolymers, ethylene-vinyl acetate-hexene terpolymers, ethylene-vinyl acetate-diisobutylene terpolymers, ethylene/vinyl acetate/isobutyl vinyl ether terpolymers, (meth)acrylate, n-decyl (meth)acrylate, n-dodecyl (meth)acrylate, n-tetradecyl (meth)acrylate, n-hexadecyl (meth)acrylate and n-octadecyl (meth)acrylate;

viii. Lubricity Improvers, for example, octyl phosphates and methyl hydroxy hydro cinnamide;

ix. anti-wear agents, for example, zinc dithiophosphate and zinc dialkyl dithio phosphate tricresyl phosphate, glycerol mono oleate and stearic acid;

x. Biodegradability Inhibitors, for example, phenol and anionic exopolysaccharides;

xi. Antioxidants (zinc compounds), for example, butylated hydroxytoluene, 2,4-dimethyl-6-tert-butylphenol, 2,6-di-tert-butylphenol, p-phenylenediamine and ethylenediamine;

xii. Detergents, dispersants and/or engine cleaners, for example, butylated hydroxytoluene, 2,4-dimethyl-6-tert-butylphenol, 2,6-di-tert-butylphenol, p-phenylenediamine, ethylene-vinyl ester copolymers, ethylenediamine, diethylhexyl adipate, polymethacrylate, polyvinylacrylate, calcium alkyl benzene sulfonate, sodium alkyl benzene sulfonate, propylene teramer succinimide of pentaethylene hexamine and octyl phosphonates;;

xiii. Antiknock agents, Butylated hydroxytoluene, 2,4-Dimethyl-6-tert-butylphenol, 2,6-Di-tert-butylphenol, p-Phenylenediamine and Ethylenediamine;

xiv. Smoke reducing agent, neem oil, mahua oil, ricebran oil, acetylated castor oil, linseed oil, karanja oil, ethyl hexyl ester of neem oil fatty acid, ethyl hexyl ester of karanj oil fatty acid, ethyl hexyl ester of neem oil fatty acid, toluene derivative of vegetable oil/its mono-esters;

xv. Other chemical compounds and/or materials, for example, renewable diesel, hydrogen peroxide, poly-glycols, polybutene's, dibasic acid esters, fluoropolymers, polyol esters, phosphate esters, silicones and/or poly-alpha olefins. alcohol oxygenates (methanol, ethanol, isopropyl alcohol, n-butane and f-butane) ether oxygenates (methyl tert-butyl ether, tertiary amyl methyl ether, tertiary hexyl methyl ether, ethyl tertiary butyl ether, tertiary amyl ethyl ether, diisopropyl ether, other fuel improvers and marker dyes.

[0141] The invention relates to method, system, for improving the quality properties of the fuel, fuel blends, single or multiple phase emulsions, e.g. water in oil (W/O), oil in water (O/W), water in oil in water (W/O/W), and oil in water in oil (O/W/O) micro and/or nanoemulsions (WFE), to improve fuel consumption rates and/or enhance the reduction of emissions.

[0142] It is thus the object of the present invention 'sulphur-free' renewable fuels, as solvents to produce the baseline products, i.e. fuel blends and/or water in oil (W/O), oil in water (O/W), water in oil in water (W/O/W), and oil in water in oil (O/W/O) micro and/or nanoemulsions (WFE).

[0143] It is thus the object of the present invention other raw materials comprising at least, but not limited to, nanoparticle ceramics filters comprising materials, selected from activated carbon, alumina, metal oxides, zeolite, and any other porous ceramic-based adsorbent, for reducing sulphur content of fuels, fuel blends, single and/or multiple phase micro and/or nanoemulsions,

where oil is the continuous phase, at temperatures between 10ºC to 50ºC, at ambient pressure to 8 Bar, specially of those containing fuels and/or blends of medium to high sulphur content (<100ppm), to further enhance the reduction of emissions form hydrocarbon, biodiesel and alcohols-based fuels and/or water in fuel nanoemulsions (WFE).

[0144] It is thus the object of the present invention other raw materials comprising at least, but not limited to, rare-earth magnets (lanthanide), selected from neodymium type magnets of grades N35 to N52, and/or samarium–cobalt type magnets, for restructuring, water, fuel blends, single and/or multiple phase micro and/or nanoemulsions, where oil is the continuous phase, at temperatures between 10ºC to 50ºC, at ambient pressure to 8 Bar, specially of those containing fuels and/or blends of medium to high sulphur content (<100ppm), to further enhance the reduction of emissions form hydrocarbon, biodiesel and alcohols-based fuels and/or water in fuel nanoemulsions (WFE).

Application (Methods, systems, chemical formulation and device):

[0145] The invention relates to method, system, device and chemical formulation capable to produce, offboard, onboard and/or on-demand, with low and/or high energy, by batch, continuous flow and/or dilution production methods, fuels blends, single or multiple phase micro and/or nanoemulsions, from a pilot fuel comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends, to apply to engine, machinery and/or equipment of internal, continuous and open flame combustion type, for improving combustion efficiency, to enhance the reduction of emissions from the consumptions (burning) of those fuels, as described in figure thirteen (13) to thirty-two (32).

ONBOARD METHOD AND SYSTEM

(i). Water in fuel nanoemulsion (WFE):

[0146] It is thus object of the present invention onboard method, system, chemical formulation and device capable to produce, with low and/or high energy, onboard and on-demand, by continuous and/or dilution production methods, fuel blends and/or water fuel nanoemulsions (WFE), from a pilot fuel comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends to apply to engine, machinery and/or equipment of internal, continuous and open flame combustion type, fitted with return and/or return less, low and/or high pressure fuel feeding and/or injection systems, for improving combustion efficiencies, to enhance the reduction of emissions from the consumptions (burning) of those fuels, as described in figure thirteen (13) and fourteen (14).

WFE Production method and system:

[0147] In the embodiments present several variations, but not limited to, of water in fuel nanoemulsion (WFE) systems, designed to be produced, onboard and on demand, with low and/or high mixing and emulsification energy, by continuous and/or dilution production methods, from a pilot fuel comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends, applied to engine, machinery and/or equipment of internal, continuous and open flame combustion type, fitted with return, low and/or high pressure fuel feeding and/or injection systems, comprising parts and components as described in the figures in reference, as shown in the following table:

WFE System Embodiment	Figure Reference	Buffer Tank	Production Energy		Combustion Type			Injection Pressure		Injection System		Production Method	
			Low	High	Internal	Continuous	Open Flame	Low	High	Return	Return Less	Continuous Flow	Dilution
1 (One)	sixteen (16)		X		X	X	X	X	X		X	X	
2 (Two)	seventeen (17)		X	X	X			X	X		X	X	
3 (Three)	nineteen (19)	X	X		X	X	X	X	X	X		X	
4 (Four)	twenty (20)	X	X		X	X	X	X	X	X		X	X
5 (Five)	twenty-one (21)	X	X		X	X	X	X	X	X		X	X
6 (Six)	twenty-two (22)	X	X		X			X	X	X		X	

WFE System Embodiment	Figure Reference	Buffer Tank	Production Energy		Combustion Type			Injection Pressure		Injection System		Production Method	
			Low	High	Internal	Continuous	Open Flame	Low	High	Return	Return Less	Continuous Flow	Dilution
7 (Seven)	twenty-four (24)	X	X		X	X	X	X	X	X		X	X
8 (Eight)	twenty-five (25)	X	X		X				X	X		X	X
9 (Nine)	twenty-six (26)	X	X		X				X	X		X	

Table Seven (7) – Water in fuel nanoemulsion (WFE) onboard production System

Pilot fuel:

[0148] It is thus object of the present invention method, system, device and chemical formulation, capable to produce, with low and/or high energy, onboard and on-demand, by continuous and/or dilution production methods, water in fuel nanoemulsion (WFE), from at least, pilot fuels, selected from groups **A)**, **B)** and/or **C)**.

[0149] The method and system of the embodiments presented in table six (6) are suitable for all pilot fuels from groups **A)**, **B)** and **C)**, however the low energy mixing and emulsification device and the chemical formulation require minor adjustments, e.g., respectively, the number of and the diameter of the holes in the multiple directional turbulator fitted to the low energy missing and emulsification device (apparatus) and the changes in the amount of each surfactant comprised in the chemical formulation. These adjustments are needed to attend the variation pilot fuel properties and the WFE quality properties produced onboard, i.e. pilot fuel source, FAME content, viscosity, WFE particle sizing and distribution, etc.

[0150] The method and system for all pilot fuels of group **A)**, **B)** and **C)** require adjustments in the chemical formulation due to variations in the pilot fuel source and solvents used in blends. The most significant variations in the systems described in the figure shown in table 6, are related to the viscosity of the fuels at 40ºC, particularly fuels from group **B)**, which need e.g. additional heating system, centrifuge system and settling tanks installed. Fuels from group **C)**, most injection systems are not of return type and the use of WFE may be limited to specific operational conditions, e.g. during engine warmup to minimise 'knocking', hence may not be used as extensively as for the ones in group **B)** and **D)**.

Low energy mixing and emulsifying device and apparatus:

[0151] It is thus object of the present invention method, system, device, capable to produce, onboard and on-demand, with high and/or low energy, by continuous flow method, at least, but not limited to, monodispersed water in fuel emulsion (WFE), from at least, but not limited to, pilot fuels, selected from groups **A)**, **B)** and/or **C)**, with water particle sizes ranging between 1nm to 500nm, preferentially, particle sizes ranging between 1nm to 50nm, at normal operational temperatures, i.e. typically around 50ºC for internal combustion engines. The device and apparatus are described in figures three (3) to twelve (12), particularly, the device described in figure seven (7) to figure nine (9) and the apparatus in figures ten (10) to eleven (11).

[0152] It is thus object of the present invention modular, single or multi-chamber, low energy mixing and/or emulsifying (LEM, LEE and/or LEME) device, fitted, in-line, of an existing fuel feeding circuit, designed to, by using the low energy produced by the low pressure fuel pump, create multi-directional flow improving vortex and turbulence in the mixing and/or emulsifying chambers, to enhance the fuel blending and/or the emulsification process.

[0153] In the embodiments present several variations, but not limited to, of a device and/or apparatus designed to produce, onboard, water in fuel nanoemulsion (WFE) with low energy, by continuous flow production method. **Embodiment 10 (ten)** of the present invention relates to a robust design as shown and described in figures three (3), have multiple chambers and fitted with multiple turbulators as shown and described in figures four (4) and/or incorporated with additional features as shown and described in figures five (5), **embodiment 11 (eleven)** a device designed with different shapes as shown and described in figures six (6), modular with linear or angular sections as shown and described in figure ten (10) and/or more sophisticated comprising several modular sections (devices) incorporated in a single apparatus as shown and described in figure eleven (11) and **embodiment 12 (twelve)** a multi-directional turbulator designed to fit embodiments 10 (ten) and 11 (eleven).

Chemical formulation (Fn)

[0154] It is thus object of the present invention chemical formulations capable to produce, onboard and on-demand, with high and/or low energy, by continuous flow and/or dilution methods, at least, but not limited to, monodispersed water in fuel emulsion (WFE), from at least, but not limited to, pilot fuels, selected from groups **A)**, **B)** and/or **C)**, with water particle sizes ranging between 1nm to 500nm, preferentially, particle sizes ranging between 1nm to 50nm, at fuel, fuel blends and/or WFE system operational temperatures, i.e. typically around 50ºC for internal combustion engines; as described in figures shown in table six (6).

[0155] In the embodiments present several variations, but not limited to, of chemical formulations (Fn), capable to produce, with low energy, onboard and on-demand, by continuous and/or dilution production methods, monodispersed water fuel nanoemulsions (WFE), from at least, but not limited to, pilot fuels, selected from groups **A)**, **B)** and/or **C)**, with water particle sizes ranging between 1nm to 500nm, preferentially, particle sizes ranging between 1nm to 50nm, at fuel, fuel blends and/or WFE system operational temperatures, to apply to engine, machinery and/or equipment of internal, continuous and open flame combustion type, fitted with return and/or return less, low and/or high pressure fuel feeding and/or injection systems, for improving combustion efficiencies, to enhance the reduction of emissions from the consumptions (burning) of those fuels, as shown is table 8.

[0156] In the embodiments presented various examples of, but not limited to, chemical formulations (Fn) capable to produce, with low energy, onboard and on-demand, by continuous and/or dilution production methods, water fuel nanoemulsions (WFE), from at least, but not limited to, pilot fuels, selected from groups **A)**, **B)** and/or **C)**, as shown in the following table:

Chemical Formulation (Fn) Embodiment	Hydrophilic Surfactants (HLB >10)		Lipophilic Co-surfactants (HLB <10)	Amphiphilic Co-co-surfactants (HLB >9, >11)	Other Surfactants
	Surfactant amount in mass and group				
	25% to 100%		1% to 30%	1% to 70%	0.1% to 20%
	I	III	III	II	I and IV
13 (thirteen)	X				
14 (fourteen)	X		X		
15 (fourteen)	X		X	X	
16 (sixteen)	X		X		X
17 (seventeen)	X		X	X	X
18 (eighteen)	X	X	X	X	X
19 (nineteen)	X	X	X		
20 (twenty)	X	X	X		X

Table Eight (8) – Chemical Formulations (Fn) for water in fuel nanoemulsions (WFE)

[0157] The chemical formulation (Fn), **c),** according to the present invention comprises, at least:

(01). **Embodiment 13 (thirteen),** 100% by mass of a hydrophilic amine and amide derivative non-ionic surfactants, selected from fatty acid alkanolamides, of the total mass of the chemical formulation (Fn); selected among, but not limited to, group I, for example, almondamide DEA, cocamide DEA, cocamide DIPA, cocamide MEA, cocamide MIPA, lauramide DEA, lauramide MEA, lauramide MIPA, palm kernelamide DEA, palm kemelamide MEA and palm kernelamide MIPA particularly, cocamide DEA, lauramide DEA, palm kernelamide DEA and palm kemelamide MEA more particularly, cocamide DEA.

(02). **Embodiment 14 (fourteen),** from 25% to 99% by mass of a hydrophilic surfactant, as defined in (01) in embodiment 13 (thirteen), particularly from 50% to 99%, more particularly, above 75% and from 1% to 30% by mass of a lipophilic fatty acid esters non-ionic co-surfactants, particularly from 1% to 20%, of the total mass of the chemical formulation (Fn); selected among, but not limited to, group III, specifically sorbitan alkyl esters (Spans), for example, sorbitan monolaurate (Span 20), sorbitan monopalmitate (Span 40), sorbitan monostearate (Span 60), sorbitan tristearate (Span 65), Sorbitan monooleate (Span 80), sorbitan etrioleate (Span 85), particulary sorbitan monostearate (Span 60), sorbitan tristearate (Span 65), Sorbitan monooleate (Span 80), more particularly, Sorbitan monooleate (Span 80).

(03). **Embodiment 15 (fifteen),** from 25% to 99% by mass of a hydrophilic surfactant and from 1% to 30% by mass of lipophilic co-surfactants, as defined in (02), in embodiment 14 (fourteen), and from 1% to 70% by mass of an amphiphilic ethoxylated alcohols and/or alkylphenols non-ionic co-co-surfactants, particularly from 1% to 40%, more particularly from 1% to 25%, selected from ethoxylated linear alcohols, ethoxylated alkyl phenols surfactant and/or ethoxylated thiols, of the total mass of the chemical formulation (Fn); selected among, but not limited to, group II, for example, nonylphenol ethoxylate and/or alcohol ethoxylate, particularly, nonylphenol ethoxylate EO-6.

(04). **Embodiment 16 (sixteen),** from 25% to 99% by mass of a hydrophilic surfactant and from 1% to 30% by mass of lipophilic co-surfactants, as defined in (02), in embodiment 14 (fourteen), and from 0.1% to 20% by mass of other non-ionic, anionic, cationic, zwitterionic and/or any other co-co-surfactants, particularly from 1% to 10%, more particularly from 1% to 5%, of the total mass of the chemical formulation (Fn); selected among, but not limited to, group II and/or IV, for example, almondamidopropyl betaine, apricotamidopropyl betaine, capryl/capramidopropyl betaine, canolamidopropyl betaine, cocamide betaine, cocamidoethyl betaine, cocamidopropyl betaine, cocamidopropyl hydroxysultaine, coco-betaine, coco- hydroxysultaine, Cocamidopropyl Hydroxysultaine, coconut alcohol, coco/oleamidopropyl betaine, Cocamidopropylamine Oxide, Cocamidopropylamine Oxide, decyl betaine, hydrogenated tallow betaine, Lauramide Oxide, Lauramidopropylamine Oxide, lauramidopropyl betaine, lauryl betaine, myristamidopropyl betaine, oleamidopropyl betaine, oleyl betaine, palm kernelamidopropyl betaine, palmamidopropyl betain, palmitamidopropyl betaine, sesamidopropyl betaine, soyamidopropyl betaine, stearyl betaine, tallowamidopropyl betaine, octylphenoxy polyethoxyethanol (triton x-100), tetradecyltrimethylammonium bromide (TTAB), Sodium lauryl sulfoacetate and/or sodium

dodecyl sulphate, and /or acetamide MEA, apricotamide DEA, avocadamide DEA, avocadamide DIPA, babassuamide DEA, babassuamide MEA, Capramide DEA, cocoyl sarcosinamide DEA, comamide/cocamide DEA, cornamide DEA, diethanolaminooleamide DEA, disodium cocamido MIPA PEG-4 sulfosuccinate, disodium lauramido MIPA, glycol sulfosuccinate, hydrogenated tallowamide DEA, hydroxyethyl ethylene dipalmitamide, hydroxyethyl stearamide-MIPA, hydroxypropyl bisisostearamide MEA, hydroxypropyl bislauramide MEA, hydroxypropyl bispalmitamide MEA, hydroxystearamide MEA, isostearamide DEA, isostearamide MEA, isostearamide MIPA, lactamide MEA, lanolinamide DEA, lauramide DEA, lauramide/Myristamide DEA, lauryl Malamide, lecithinamide DEA, linoleamide DEA, linoleamide MEA, linoleamide MIPA, minkamide DEA, myristamide DEA, myristamide MEA, myristamide MIPA, oatamide MEA, oleamide DEA, oleamide DIPA, oleamide MEA, oleamide MIPA, olivamide DEA, oliveamide MEA, palmamide DEA, palmamide MEA, palmamide MIPA, palmitamide DEA, palmitamide MEA, pantothenamide MEA, nutamide MEA, peanutamide MIPA, PEG-20 pocamide MEA, ricebranamide DEA, ricinoleamide DEA, ricinoleamide MEA, ricinoleamide MIPA, sesamide DEA, sesamide DIPA, soyamide DEA, stearamide AMP, stearamide DEA, stearamide DEA-distearate, stearamide DIBA-stearate, stearamide MEA, stearamide MEAstearate, stearamide MIPA, tallamide DEA, talloWamide DEA, talloWamide MEA, trideceth-2 Carboxamide MEA, undecylenamide DEA, undecylenamide MEA and/or Wheat germamide DEA.

(05). **Embodiment 17 (seventeen),** from 25% to 99% by mass of a hydrophilic surfactant, from 1% to 30% by mass of lipophilic co-surfactants and from 1% to 70% by mass of an amphiphilic co-co-surfactants, as defined in (03), in embodiment 15 (fifteen) and from 0.1% to 20% by mass of other co-co-surfactants, of the total mass of the chemical formulation (Fn), as defined in (04), in embodiment 16 (sixteen).

(06). **Embodiment 18 (eighteen),** from**),** from 25% to 99% by mass of a hydrophilic surfactant, from 1% to 30% by mass of lipophilic co-surfactants, from 1% to 70% by mass of an amphiphilic co-co-surfactants and from 0.1% to 20% by mass of other co-co-surfactants, of the total mass of the chemical formulation (Fn), as defined in (05), in embodiment 17 (seventeen) and from 1% to 70% by mass of a hydrophilic fatty acid esters non-ionic co-surfactants, particularly from 1% to 50%, more particularly from 5% to 40% of the total mass of the chemical formulation (Fn); selected among, but not limited to, group III, specifically polyoxyethlyene derivatives of sorbitan alkyl esters (Tweens), for example,), polyoxyethylene sorbitan monolaurate (Tween 20), polyoxyethylene sorbitan

monopalmitate (Tween 40), polyoxyethylene sorbitan monostearate (Tween 60), polyoxyethylene sorbitan triestearate (Tween 65), polyoxyethylene sorbitan monooeleate (Tween 80), polyoxyethylene sorbitan trioeleate (Tween 85), particularly, polyoxyethylene sorbitan monopalmitate (Tween 40), polyoxyethylene sorbitan monostearate (Tween 60), polyoxyethylene sorbitan monooeleate (Tween 80) and more particularly, polyoxyethylene sorbitan monooeleate (Tween 80).

(07). **Embodiment 19 (nineteen)**, from 25% to 99% by mass of a hydrophilic surfactant, from 1% to 70% by mass of a hydrophilic co-surfactants and from 1% to 30% by mass of a lipophilic co-surfactants, of the total mass of the chemical formulation (Fn), as defined in (06), in embodiment 18 (eighteen).

(08). **Embodiment 20 (twenty),** from 25% to 99% by mass of a hydrophilic surfactant, from 1% to 70% by mass of a hydrophilic co-surfactants and from 1% to 30% by mass of a lipophilic co-surfactants, of the total mass of the chemical formulation (Fn), as defined in (06), in embodiment 18 (eighteen) and from 0.1% to 20% by mass of other co-co-surfactants, of the total mass of the chemical formulation (Fn), as defined in (04), in embodiment 16 (sixteen).

[0158] In the embodiments present several variations, but not limited to, of water in fuel nanoemulsion (WFE) systems, designed to be produced, onboard and on demand, with low and/or high mixing and emulsification energy, by continuous and/or dilution production methods, from a pilot fuel comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends, applied to engine, machinery and/or equipment of internal, continuous and open flame combustion type, fitted with return, low and/or high pressure fuel feeding and/or injection systems, comprising parts and components as described in the figures in reference.

Water:

[0159] It is thus the object of the present invention water (W), water, **b)**, in liquid and/or vapor state, from 4% to 36%, by mass, of the total water in fuel nanoemulsions (WFE), used to produce baseline products for, onboard and on-demand, production of WFE.

WFE onboard continuous flow production method:

[0160] It is thus object of the present invention onboard method, system, chemical formulation and device capable to produce, with low energy, onboard and on-demand, by continuous flow production methods, water fuel nanoemulsions (WFE), from at least, but not limited to, pilot fuels, selected from groups **A)**, **B)** and/or **C)**, to apply to engine, machinery and/or equipment of internal, continuous and open flame combustion type, fitted with return and/or return less, low and/or high

pressure fuel feeding and/or injection systems, for improving combustion efficiencies, to enhance the reduction of emissions from the consumptions (burning) of those fuels, as described in figure thirteen (13) and fourteen (14); and embodiment 1 (one) to embodiment 9 (nine).

WFE onboard dilution flow production method:

[0161] It is thus object of the present invention onboard method, system, chemical formulation and device capable to produce, with low energy, onboard and on-demand, by dilution production methods, water fuel nanoemulsions (WFE), from at least, but not limited to, pilot fuels, selected from groups **A)**, **B)** and/or **C)**, to apply to engine, machinery and/or equipment of internal, continuous and open flame combustion type, fitted with return and/or return less, low and/or high pressure fuel feeding and/or injection systems, for improving combustion efficiencies, to enhance the reduction of emissions from the consumptions (burning) of those fuels, as described in figure thirteen (13) and fourteen (14); and embodiment 4 (four), embodiment 5 (five), embodiment 7 (seven) and embodiment 8 (eight). Figure Twenty-Three (23) and figure Twenty-four (24) describe an examples of a method and system capable to produce, with low energy, onboard and on-demand, by dilution production methods, various types of water fuel nanoemulsions (WFE), from WFE produced offboard, for further improving combustion efficiencies, to greatly enhance the reduction of emissions from the consumptions (burning) of those fuel.

(ii). Fuel Blends:

[0162] It is thus object of the present invention onboard method, system and device capable to produce, with low energy, onboard and on-demand, by continuous flow and dilution production methods, fuel blends, from at least, but not limited to, pilot fuels, selected from groups **A)**, **B)** and/or **C)**, to apply to engine, machinery and/or equipment of internal, continuous and open flame combustion type, fitted with return and/or return less, low and/or high pressure fuel feeding and/or injection systems, for improving combustion efficiencies, to enhance the reduction of emissions from the consumptions (burning) of those fuels, as described in figure thirteen (13), fourteen (14) and fifteen (15) and/or embodiment 2 (two) and six (6).

[0163] It is thus object of the present invention onboard method, system and device capable to produce, with low energy, onboard and on-demand, by continuous flow and dilution production methods, from pilot fuels and baseline fuel and/or blends, comprising one or more solvent, selected from groups I. to III., and one or more additives, selected from groups IV. to XV.

[0164] An example of a the production of water in fuel nanoemulsions is shown and described in figure Twenty-Eight (28) to Figure Thirty (30), describe the key operations for a WFE system,

respectively, priming the system, starting the engine, standard operations, varying the type WFE and purging the system.

(v). Onboard production, application and operations control and perfomance management system:

[0165] The invention relates to a manual and/or automatic, remote control, intelligent management system designed to control, on-demand: the pilot fuels, fuel blends and/or WFE supply; the low and/or high energy continuous flow and dilution production WFE system; and the quality of the water in fuel nanoemulsions (WFE) for applications, such as, of those internal, continuous and/or open flame combustion types, burning hydrocarbon, biodiesel and alcohol-based fuels, with return and/or return less, low and/or high pressure, fuel feeding and/or injection systems, quality of the WFE; and/or the efficiency of the application and or integrated technologies.

[0166] The invention relates to a method and system to

(i) Remotely, manually and/or automatically, onboard and on demand, control and manage the production and quality of pilot fuels and environmental fuels, i.e. fuel blends and water in fuel emulsion nanoemulsions, for improving combustion efficiency, to enhance specific fuel consumption rates and/or reduction of the emissions,

(ii) Manually and/or automatically, onboard and on-demand, select the fuel type, i.e. pilot fuel or environmental fuel, and vary and/or adjust the type of environmental fuel delivered to the engines, machinery and/or equipment's, such as, those of internal, continuous and open flame combustion type, to

   a. further improve the specific fuel consumption rates and/or emission reduction rates, by delivering the fuel type with greater specific combustion efficiency,
   b. maintain the fuel consumption rates equal and/or below the pilot fuel at any operational condition, i.e. >= 1:1 (fuel to pilot fuel),

(iii) Remotely, manually and/or automatically, control and manage operations of engines, machinery and/or equipment's, such as, those of internal, continuous and open flame combustion type, for improving application efficiency, to further enhance the specific fuel consumption rates and/or reduction of emissions,

(iv) Monitoring and managing the key elements that significantly affect the combustion and/or application efficiency, particularly diminishing the specific consumption rates and increasing the emissions.

(v) Developing environmental fuels for improving combustion efficiency, for specific engines, machinery and/or equipment's, such as, those of internal, continuous and open flame combustion type,

(vi) Develop baseline mathematical models by correlating the variables of significance related the variable fuels, specific engine and/or application (modular),

(vii) Develop self-learning system and/or artificial intelligence capable dynamically adjusting, analysing, correlating and recording, e.g. for improving the baseline mathematical models, for onboard control and management and for technology development and integration.

[0167] The method, system, device and chemical composition is dependent on the application design, type and working conditions, more specifically: type of engine, machinery and/or equipment; mobility; type of output energy; type of combustion; type of fuel feeding and injection systems; type of post-combustion technologies installed; powertrain design (matching); gearing type; steadiness and magnitude of power demand; type of fuel and fuel blends; operational and ambient conditions; enabling technologies available; manufacturers technical specifications; etc.

[0168] Examples of embodiment for application system are presented and described in figure Thirty-Three (33) and Thirty-Four 34 and for technology development, baseline mathematical model and control and management systems in figure Thirty-Five (35).

OFFBOARD METHOD AND SYSTEM

[0169] The invention relates to method, system and production plant, capable to produce offboard and on-demand, or with low energy, by continuous flow production methods, but not limited to, water fuel nanoemulsions (WFE), from a pilot fuel comprising hydrocarbon, biodiesel and/or alcohol-based fuels and/or fuel blends for direct use in engine, machinery and/or equipment of internal, continuous and open flame combustion type, fitted with return and/or return less, low and/or high pressure fuel feeding and/or injection systems, for improving combustion efficiencies, to enhance the reduction of emissions from the consumptions (burning) of those fuels,

[0170] It is thus object of the present invention modular production unit capable to produce, offboard and on-demand, with low energy, by continuous flow production methods, but not limited to, water fuel nanoemulsions (WFE). An example of a typical embodiment of a modular WFE system layout, fitted in 8", 20" and/or 40" containers, for stationary or mobile applications is

described and shown in figure Fifteen (15), which is ideal, at least, for when using WFE systems as described in figures Eighteen (18), Twenty-Three (23) and/or Twenty-Four (24).

[0171] It is thus object of the present invention method and system to produce offboard and on-demand, with low and/or high energy, by batch, continuous flow and/or dilution production methods, but not limited to, baseline products, used to produce, onboard and on-demand, fuel blends and/or water in fuel nanoemulsions (WFE), resulting in e.g. lowering the production energy required; easing the mixing and emulsification process; providing improved hydrophilic, lipophilic and other blends; ensuring quality of fuel blends and water in fuel nanoemulsions (WFE); securing the intellectually property; promoting commercial advantages; and capability to deliver various types of WFE.

[0172] The invention relates to a method, system, chemical formulation, device and production plant, capable to produce, offboard and on-demand, with low and/or high energy, by batch, continuous flow and/or dilution production methods, but not limited to, baseline products, i.e. oil blends; single or multiple phase micro and/or nanoemulsions, i.e. water in oil (W/O), oil in water (O/W), water in oil in water (W/O/W), and oil in water in oil (O/W/O) and/or water in fuel micro and nanoemulsions (WFE); and/or chemical solutions; required to produce, onboard and on-demand, fuel blends and/or water in fuel nanoemulsions (WFE).

(i). Production Plant:

[0173] The invention relates to method, system, chemical formulation, device and production plant, capable to produce, with low and/or high energy, by homogenization, sonication, high pressure and/or shear stress, continuous flow and/or dilution methods, but not limited to, baseline products, i.e. oil blends; single or multiple phase micro and/or nanoemulsions, i.e. water in oil (W/O), oil in water (O/W), water in oil in water (W/O/W), and oil in water in oil (O/W/O) and/or water in fuel micro and nanoemulsions (WFE); and/or chemical solutions; required to produce, onboard and on-demand, fuel blends and/or water in fuel nanoemulsions (WFE).

[0174] It is thus object of the present invention method, system, chemical formulation and production plant to treat water and produce other baseline products required for the onboard and on-demand production of fuel blends and/or water in fuel nanoemulsions (WFE). The production plant comprises, at least, seven units, as shown and described in figure One (1) and Two (2).

- Water treatment unit,
- Water-based products, i.e. Chemical solutions and nanoemulsion unit (water based)
- Oil-based products, i.e. fuel Blends and nanoemulsion unit

- Desulphurization unit,
- Waste treatment unit,
- Power generation unit,
- Production control & management unit.

Water-based products

[0175] The present invention relates to water (W) and single and/or multiple phase nanoemulsions, where the continuous phase is water, i.e. water in oil (O/W) and/or for oil in water in oil fuel micro and/or nanoemulsion (O/W/O), used to produce baseline products for onboard applications for producing of water in fuel nanoemulsions (WFE).

(i). Water

[0176] It is thus the object of the present invention water in liquid and/or vapor state, from 4% to 99% by mass, of the total mass of the emulsion; treated and/or untreated, for producing single and/or multiple phase nanoemulsions, where the continuous phase is water, i.e. oil in water (O/W) and/or water in oil in water (W/O/W), chemical solutions and water fuel micro and nanoemulsions (WFE), comprising at least, but not limited to, deionized and/or demineralized water, desalinised water, filtered rainwater, filtered and treated grey water and/or tap water.

(i). Chemical solutions

[0177] It is thus the object of the present invention chemical solution, used to produce, with low and/or high energy, by batch and/or continuous flow production methods, various types baseline products, comprising at least, but not limited to,

- from 4% to 99%, by mass, of water of the total mass of chemical solution, selected from deionized and/or demineralized water, desalinised water, filtered rainwater, filtered and treated grey water and/or tap water, and
- from 1% to 50%, by mass, of chemical formulation of the total mass of chemical solution, comprising one or more surfactant selected from group I to IV.

[0178] It is thus the object of the present invention chemical formulation, from 1% to 50%, by mass, of the total mass of chemical solution, to produce, with low and/or high energy, by batch and/or continuous flow production methods, various types chemical solutions, used to produce baseline products, comprising at least, but not limited to,

- from 1% to 90%, by mass, of at least, one or more hydrophilic amine and amide derivative non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group I, as defined in embodiment 13 (thirteen), and/or
- from 1% to 70%, by mass, of at least, one or more hydrophilic fatty acid esters non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group III, as defined in embodiment 18 (eighteen), and/or
- from 1% to 30%, by mass, of at least, one or more lipophilic fatty acid esters non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group III, as defined in embodiment 14 (fourteen), and/or
- from 1% to 50%, by mass, of at least, one or more amphiphilic other non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group IV, as defined in embodiment 16 (sixteen).

(iii). Water based, single and/or multiple phase nanoemulsions

[0179] It is thus the object of the present invention single and/or multiple phase micro and/or nanoemulsion to produce, with low and/or high energy, by batch and/or continuous flow production methods, various types of single or multiple phase nanoemulsions, where the continuous phase is water, i.e. oil in water (O/W) and/or water in oil water fuel micro and/or nanoemulsion (W/O/W), with particle sizes ranging between 1nm to 50nm, at operational temperatures of around 50ºC, used to produce baseline products, comprising at least, but not limited to,

- from 50% to 99% by mass, of water, in liquid and/or vapor state of the total mass of the emulsion, selected from deionized and/or demineralized water, desalinised water, filtered rainwater, filtered and treated grey water and/or tap water, and
- from 1% to 30% by mass, of solvent, of the total mass of emulsion, comprising one or more solvent selected from group i. to iii., and
- from 1% to 11% by mass, of chemical formulation, of the total mass of emulsion, comprising one or more surfactant selected from group I to IV, and/or
- from 0.1% to 5% by mass, of additive, of the total mass of emulsion, comprising one or more additives selected from group iv to xv;

Oil-based products

[0180] The present invention relates to blends and/or single and/or multiple phase nanoemulsions, where the continuous phase is oil, i.e. oil based blends, water in oil (O/W) and/or oil in water in oil

(O/W/O), used to produce baseline products for onboard and on-demand application of water in fuel nanoemulsions (WFE).

(i). Oil based, single and/or multiple phase nanoemulsions

[0181] It is thus the object of the present invention single and/or multiple phase micro and/or nanoemulsion to produce, with low and/or high energy, by batch and/or continuous flow production methods, various types of single or multiple phase nanoemulsions, where the continuous phase is oil, i.e. oil in water (O/W) and/or oil water in oil (O/W/O) micro and/or nanoemulsions, with particle sizes ranging between 1nm to 50nm, at operational temperatures of around 50ºC, used to produce baseline products and/or water in fuel nanoemulsions (WFE), comprising at least, but not limited to,

- from 40% to 70% by mass, of water, in liquid and/or vapor state of the total mass of the emulsion, selected from deionized and/or demineralized water, desalinised water, filtered rainwater, filtered and treated grey water and/or tap water, when HLD >0, and/or
- from 4% to 36% by mass, of water, in liquid and/or vapor state of the total mass of the emulsion, selected from deionized and/or demineralized water, desalinised water, filtered rainwater, filtered and treated grey water and/or tap water, when HLD=<0, and/or
- from 26% to 95.6% by mass, of solvent, of the total mass of emulsion, comprising one or more solvent selected from group i. to iii., and
- from 1% to 15% by mass, of chemical formulation, of the total mass of emulsion, comprising one or more surfactant selected from group I to IV, and/or
- from 0.1% to 5% by mass, of additive, of the total mass of emulsion, comprising one or more additives selected from group iv to xv;

(ii). Chemical formulation for micro and/or nanoemulsions

[0182] It is thus the object of the present invention chemical formulation, from 1% to 15%, by mass, of the total mass of multiple phase micro and/or nanoemulsion, to produce, with low and/or high energy, by batch and/or continuous flow production methods, various types multiple phase micro and/or nanoemulsion, used to produce baseline products and/or water in fuel nanoemulsions (WFE), comprising at least, but not limited to,

- from 1% to 90%, by mass, of at least, one or more hydrophilic amine and amide derivative non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group I, as defined in embodiment 13 (thirteen), and/or
- from 1% to 70%, by mass, of at least, one or more hydrophilic fatty acid esters non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group III, as defined in embodiment 18 (eighteen), and/or
- from 1% to 30%, by mass, of at least, one or more lipophilic fatty acid esters non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group III, as defined in embodiment 14 (fourteen), and/or
- from 1% to 50%, by mass, of at least, one or more amphiphilic other non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group IV, as defined in embodiment 16 (sixteen).

(iii). Oil-based blends

[0183] It is thus the object of the present invention blends, to produce, with low and/or high energy, by batch and/or continuous flow production methods, various types oil blends, with and/or with chemical formulation, where the continuous phase is oil, and the total mass of the blend is considered to be the sum of the amount in mass of the solvent and the amount of chemical formulation, used to produce baseline products, comprising at least, but not limited to,

- from 75% to 83.3% by mass, of solvent, of the total mass of blend, comprising one or more solvent selected from group i. to iii., i.e. where the solvent to Fn ratio (HBA:Fn) varies from 3:1 to 5:1, and/or
- 100% by mass, of solvent, of the total mass of blend, comprising one or more solvent selected from group i. to iii., i.e. for blends without adding chemical formulation; and
- from 16.7% to 25% by mass, of chemical formulation, of the total mass of blend, comprising one or more surfactant selected from group I to IV, i.e. where the solvent to Fn ratio (HBA:Fn) varies from 3:1 to 5:1, and/or
- from 0% by mass, of chemical formulation, of the total mass of blend, comprising one or more surfactant selected from group I to IV, i.e. for blends without adding chemical formulation; and
- from 0 % to 35% by mass, of additive, of the total mass of blend, comprising one or more additives selected from group iv to xv;

(ii). Chemical formulation for oil-based blends

[0184] It is thus the object of the present invention chemical formulation, from 16.7% to 25%, by mass, of the total mass of blend, to produce, with low and/or high energy, by batch and/or continuous flow production methods, various types oil-based blends, used to produce baseline products and/or water in fuel nanoemulsions (WFE), comprising at least, but not limited to, as defined in figure one (1),

for hydrophilic blend, **11**, (HPB)

- from 50% to 100%, by mass, of at least, one or more hydrophilic amine and amide derivative non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group I, as defined in embodiment 13 (thirteen), and/or
- from 30% to 70%, by mass, of at least, one or more hydrophilic fatty acid esters non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group III, as defined in embodiment 18 (eighteen), and/or
- from 1% to 30%, by mass, of at least, one or more lipophilic fatty acid esters non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group III, as defined in embodiment 14 (fourteen), and/or
- from 1% to 50%, by mass, of at least, one or more amphiphilic other hydrophilic non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group IV, as defined in embodiment 16 (sixteen).

for hydrophilic blend, **11**, (LPB)

- from 1% to 20%, by mass, of at least, one or more hydrophilic amine and amide derivative non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group I, as defined in embodiment 13 (thirteen), and/or
- from 1% to 10%, by mass, of at least, one or more hydrophilic fatty acid esters non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group III, as defined in embodiment 18 (eighteen), and/or
- from 50% to 100%, by mass, of at least, one or more lipophilic fatty acid esters non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group III, as defined in embodiment 14 (fourteen), and/or
- from 1% to 50%, by mass, of at least, one or more other lipophilic non-ionic surfactants, of the total mass of the chemical formulation, for example, selected from group IV, as defined in embodiment 16 (sixteen)

ABSTRACT OF THE DISCLOSURE:

[0185] In accordance to the investigation, it is thus the object of the present invention method, system, device, apparatus, production plant and chemical formulation (Fn) capable of producing remotely, manually or automatically, in-line, on-demand, offboard and/or onboard, emulsified fuels and fuel blends, in particular, water in fuel monodispersed micro and nanoemulsions (WFE), with particle sizes ranging between 1nm to 50nm, at operational temperatures of around 50ºC, from a pilot fuel, comprising a hydrocarbon, biodiesel, alcohol and/or fuel blends, to apply to engines, machinery and/or equipment's, stationary or mobile, such as, those of internal, continuous and open flame combustion type, for improving the combustion efficiency, to selectively enhance the specific fuel consumption rates and/or reduction of emissions produced from the consumption and burning of those fuels, over wider operational range. The method consists of producing, at least, of a hydrophilic and lipophilic oil-based blends, comprising at least a pilot fuel, as the continuous phase, and/or one or more non-ionic surfactant, consisting of, at least, a lauric faty acid based amine and amide derivative, specifically alkanolamides and a sorbitan alkyl ester, at Fn to water ratios (Fn:W) between 0.1 and 0.5, by mass, for mixing to the pilot fuel with water, from 4% to 36%, by mass, with low energy, by continuous flow and/or dilution production methods, to produce various types and quality fuel blends and/or WFE. It is also the object of the invention method and system, in particularly, to remotely, manually and/or automatically, onboard and on demand, control and manage: the production and quality of pilot fuels and emulsified fuels; select, vary and/or adjust the type of fuel, fuel blend and/or emulsified fuel to deliver to the engines; deliver the fuel with greater efficiency; maintain the fuel consumption rates equal and/or below the rates of the pilot fuel at any operational condition; by which it is capable for further improving the combustion efficiency, to enhance the specific fuel consumption rates and/or emission reduction rates. The system is also designed for monitoring and managing the key elements that significantly affect the combustion and/or application efficiency; developing environmental fuels for improving combustion efficiency, for specific engines, machinery and/or equipment's, such as, those of internal, continuous and open flame combustion type; develop baseline mathematical models by correlating the variables of significance related the variable fuels, the specific engine and/or application, self-learning system and/or artificial intelligence, hence capable dynamically adjusting, analysing, correlating and recording the data for, e.g. improving the baseline mathematical models, onboard control and management and technology development and integration.

DRAWINGS:

SECTION I - MODULAR PRODUCTION UNIT FOR WFE BASLINE PRODUCTS

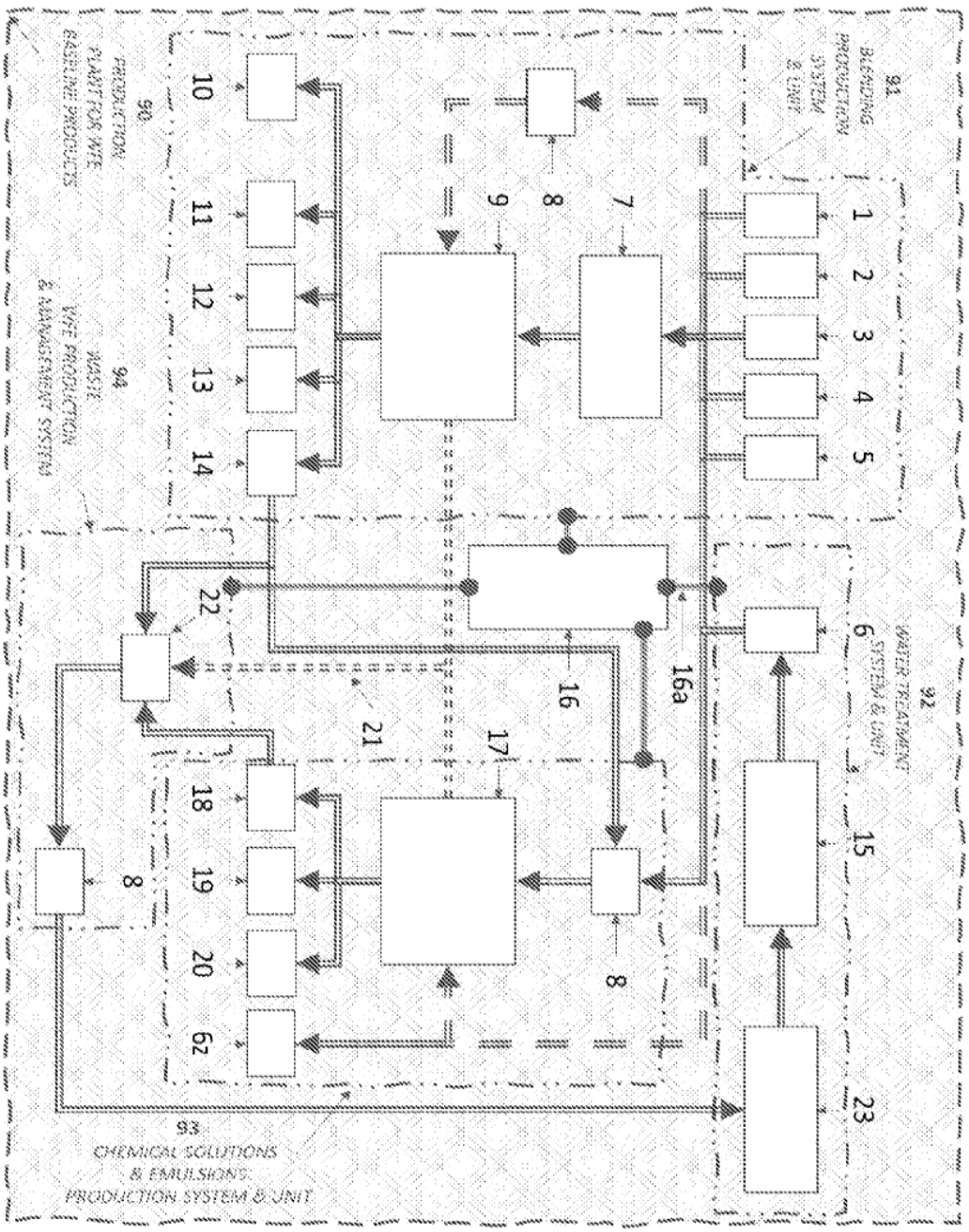


Fig. One (1)

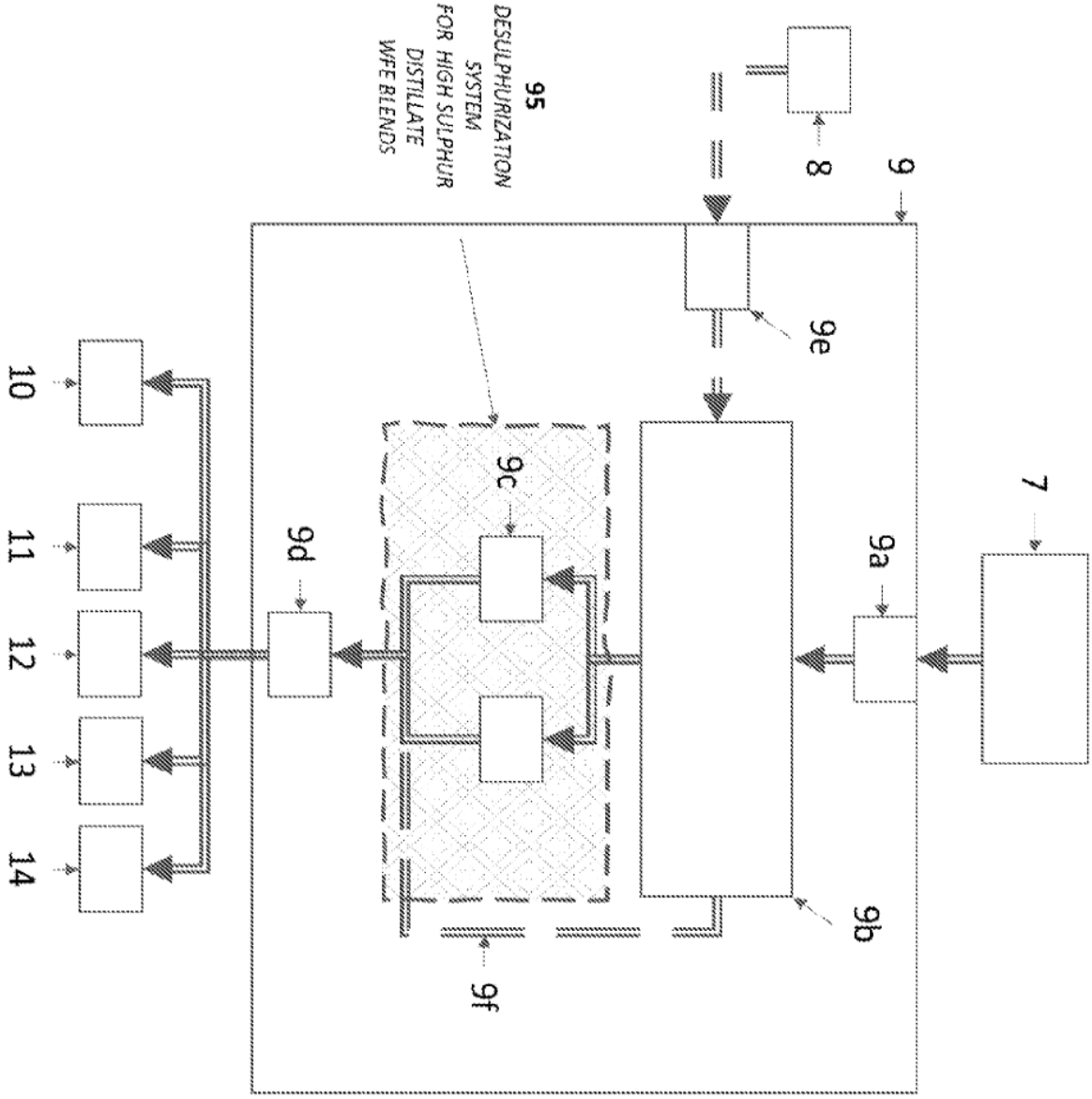

95
DESULPHURIZATION
SYSTEM
FOR HIGH SULPHUR
DISTILLATE
WFE BLENDS
8
9
9e
7
9a
9c
9d
9b
9f
10
11
12
13
14

Fig. Two (2)

SECTION II – LOW ENERGY MIXING AND/OR EMULSIFYING DEVICE

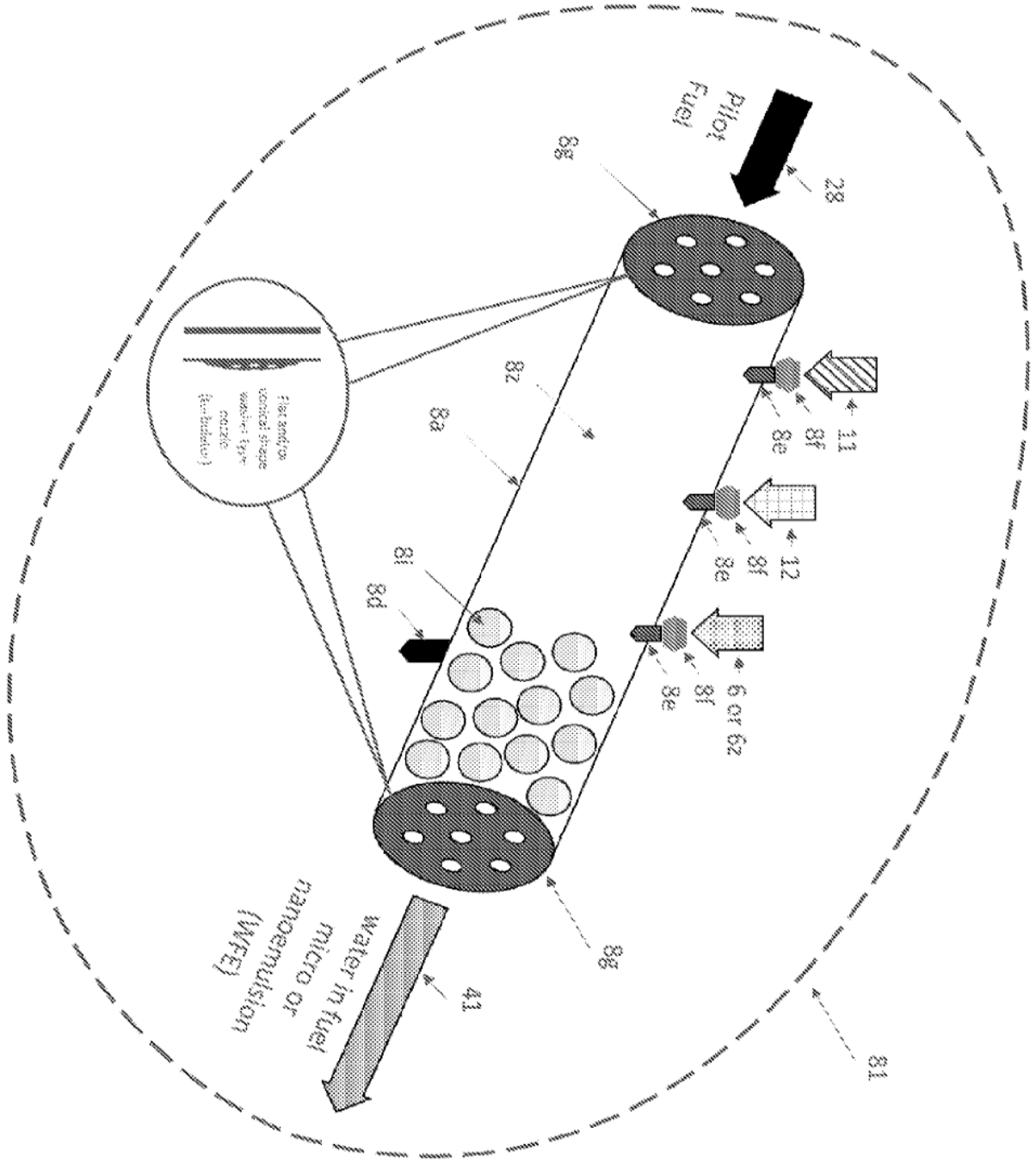


Fig. Three (3)

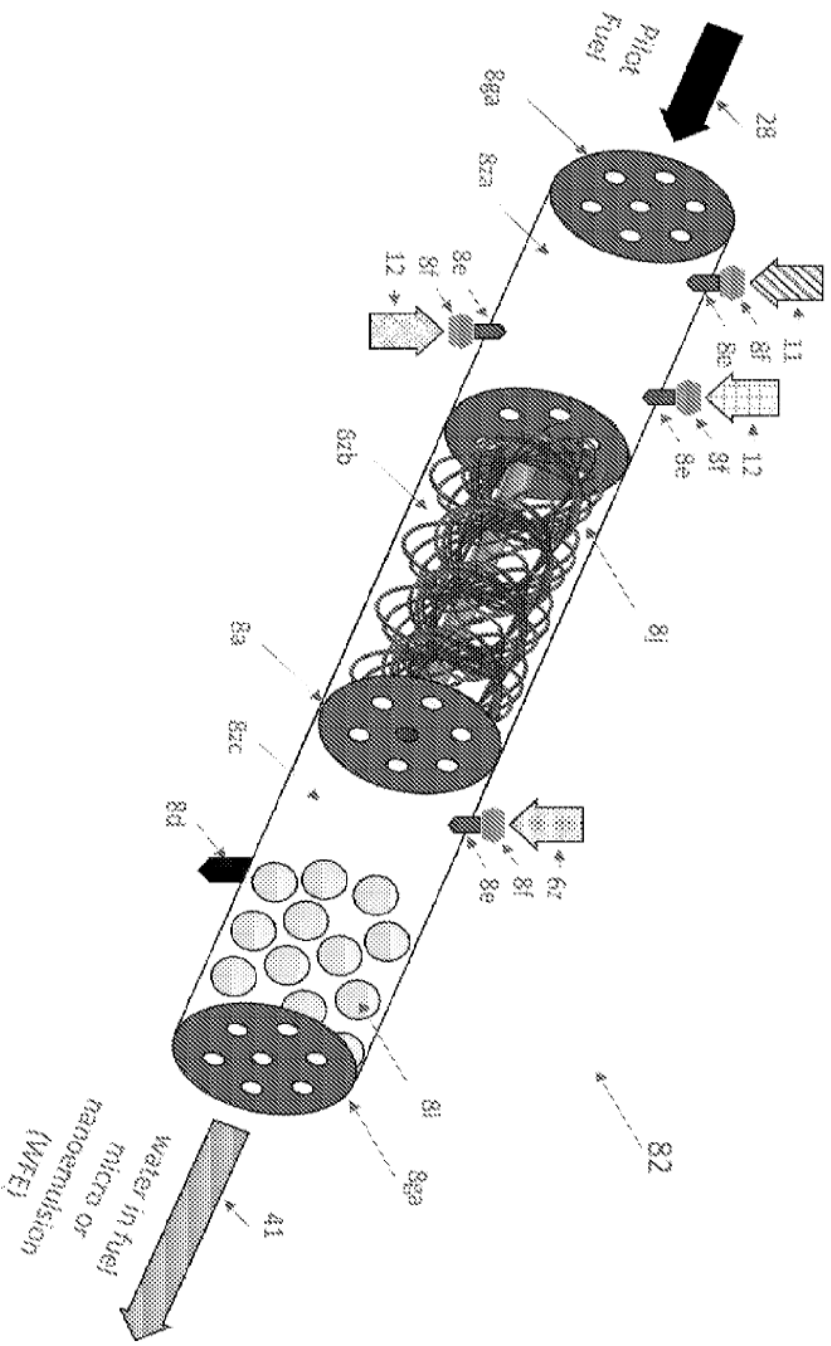

Pilot Fuel
28
8ga
8za
8e
8f
12
11
8as
8zb
8j
8a
8zc
8d
6z
8gb
82
41
Water in fuel micro or nanoemulsion (WIFE)

Fig. Four (4)

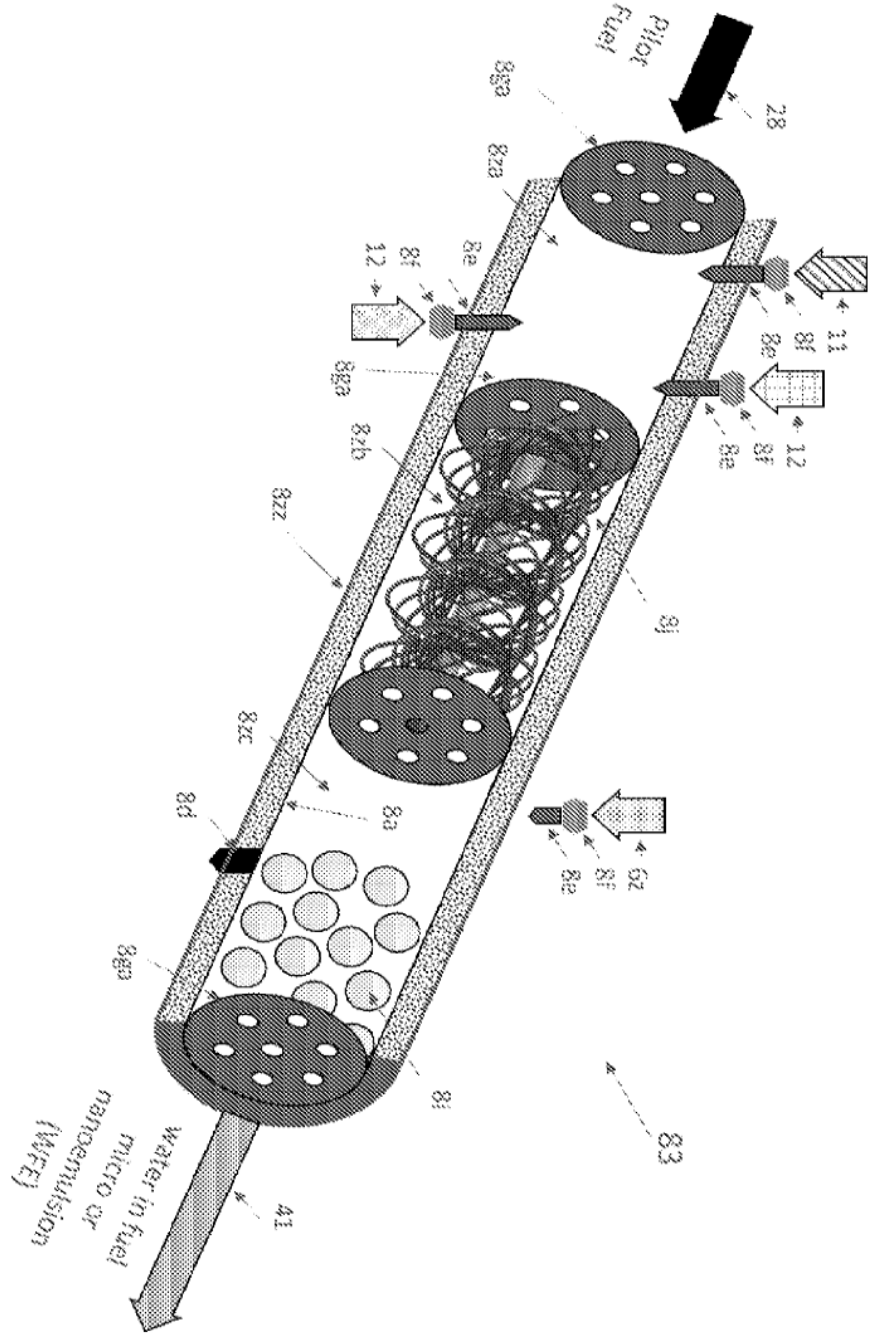

Pilot Fuel
28
8ga
8za
8f
12
8e
11
8f
8e
12
8f
8a
8ga
8zb
8zz
9j
8zc
8a
8d
62
8f
8e
8ga
8i
83
41
water in fuel micro or nanoemulsion (MFE)

Fig. Five (5)

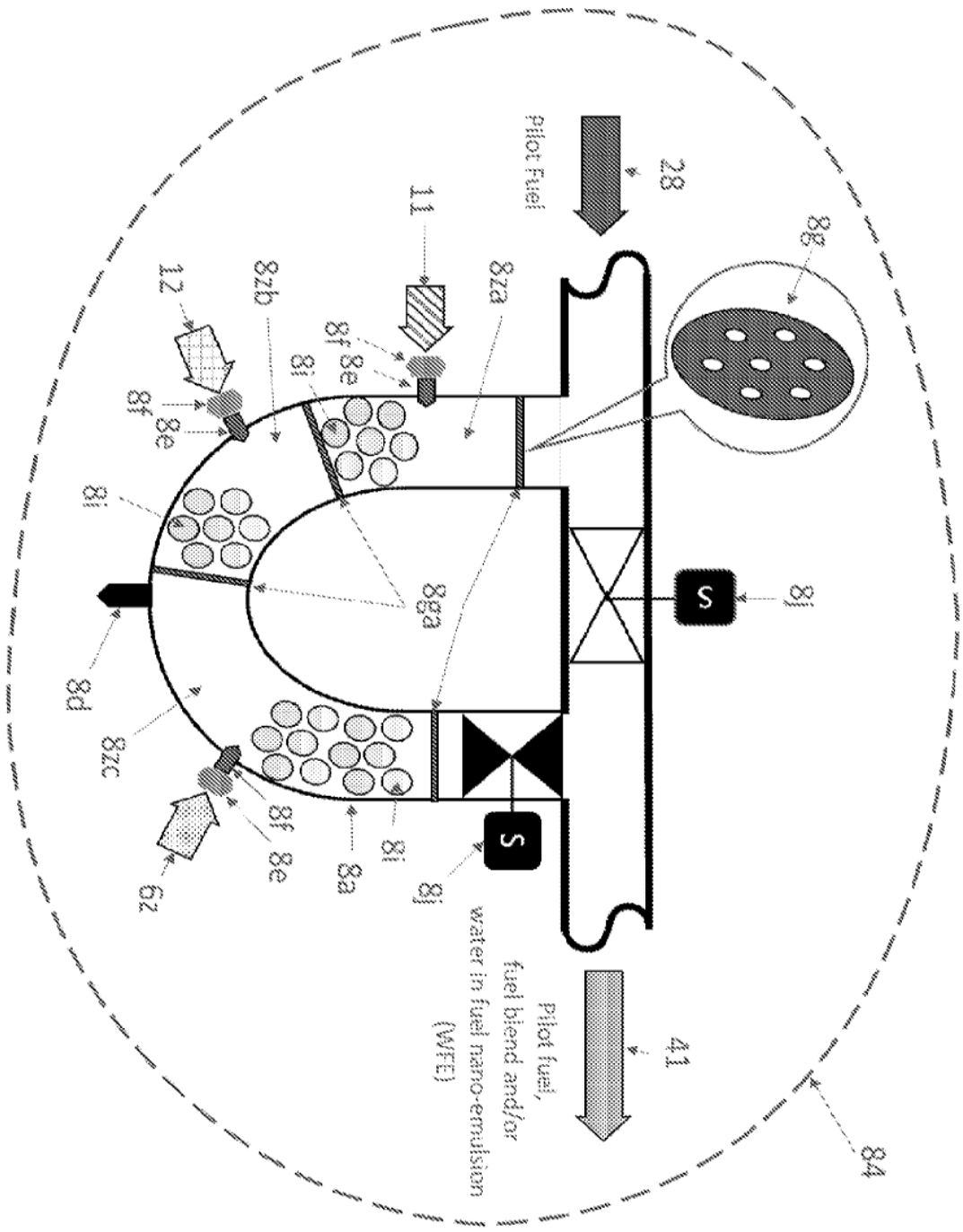

Pilot Fuel
28
11
12
8g
8za
8zb
8f
8e
8i
8ga
8d
8zc
6z
8a
8j
S
8l
Pilot fuel,
fuel blend and/or
water in fuel nano-emulsion
(WFE)
41
84

Fig. Six (6)

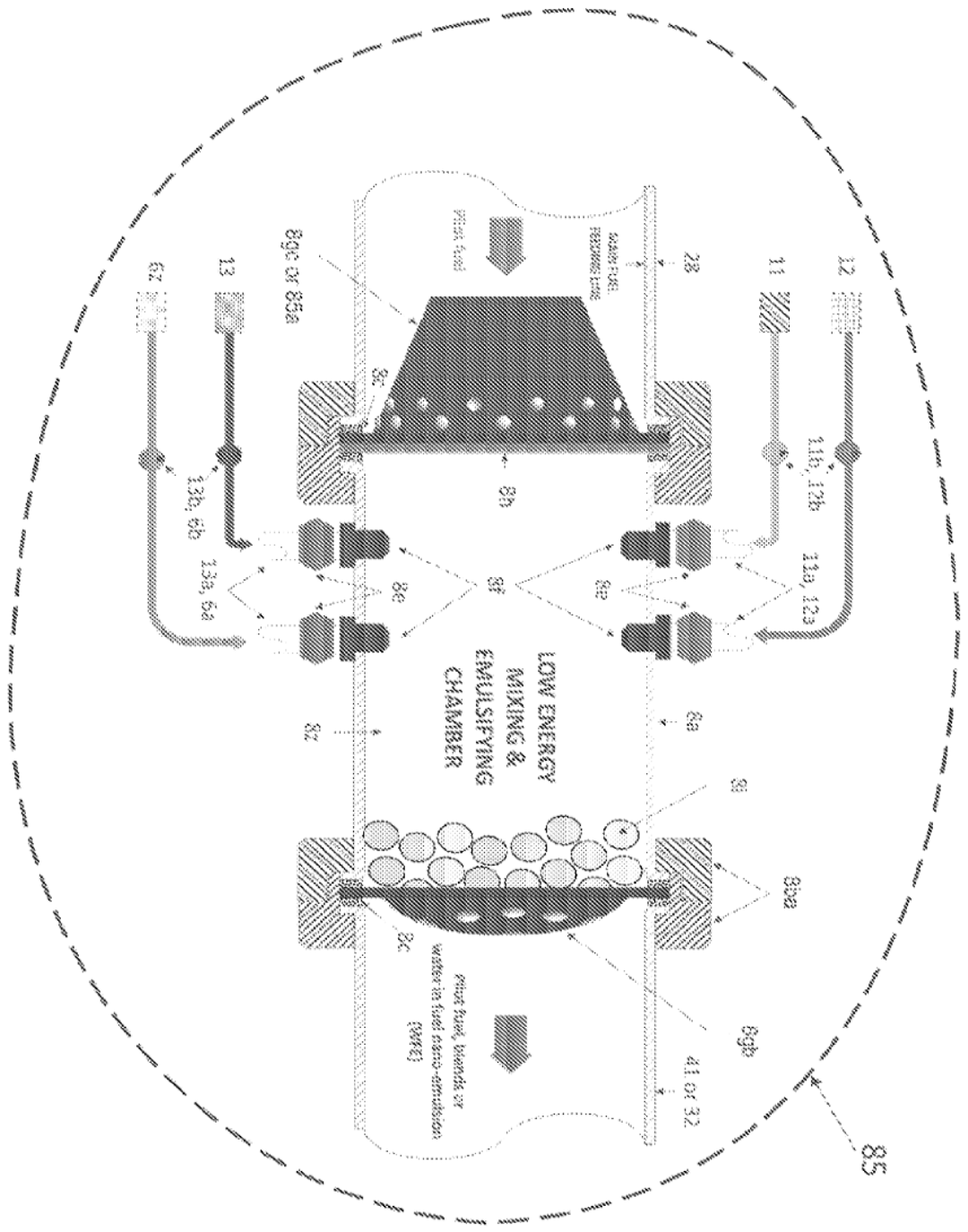

LOW ENERGY
MIXING &
EMULSIFYING
CHAMBER
85
8gc or 85a
13
6z
13b, 6b
13a, 6a
2a
11
12
11b, 12b
11a, 12a
8b
8e
8f
8d
6a
8a
8c
8gb
41 or 32

Fig. Seven (7)

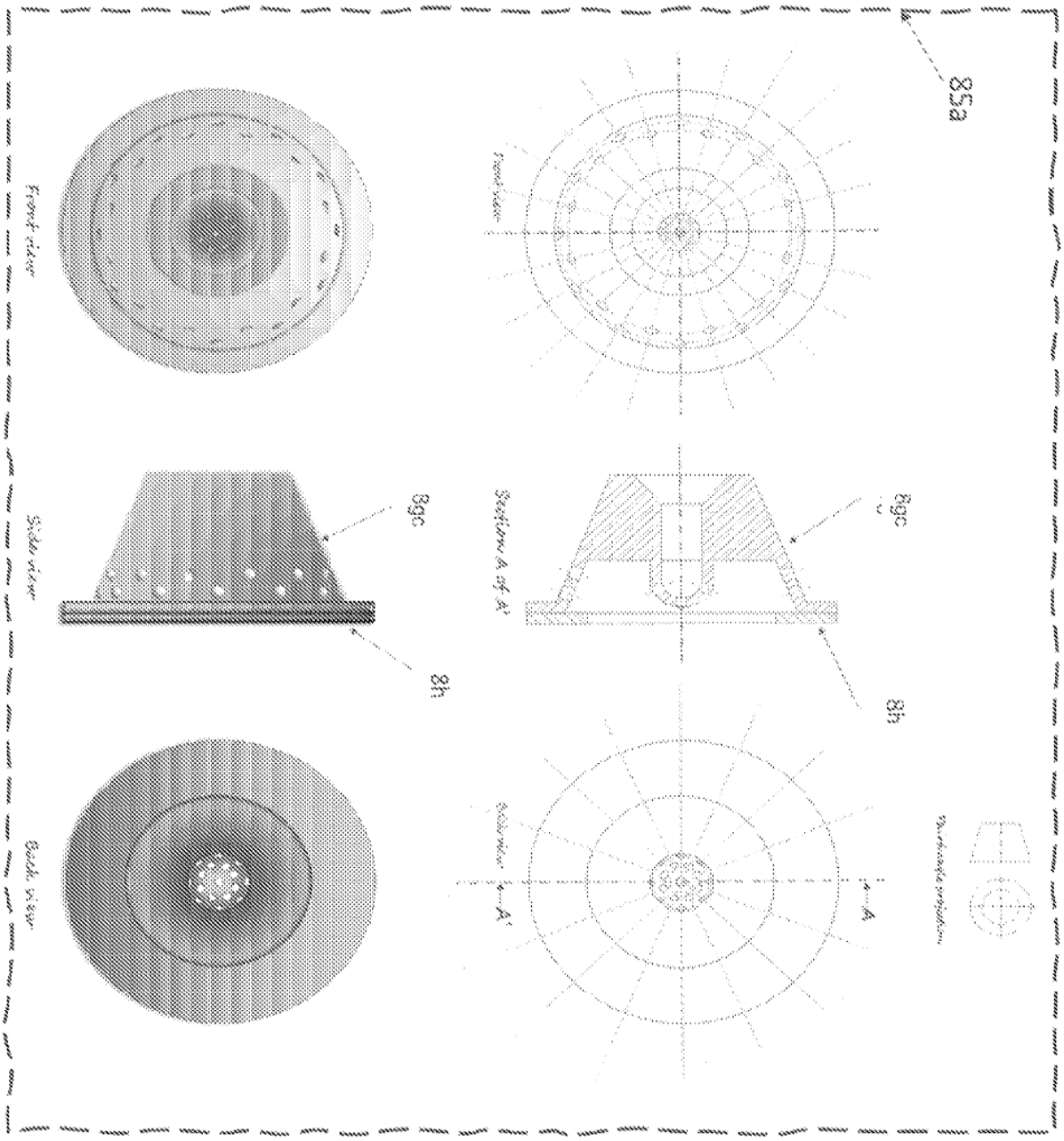

85a
Front view
Side view
Back view
8gc
8h
Section A-A'
Isometric
A
A'

Fig. Eight (8)

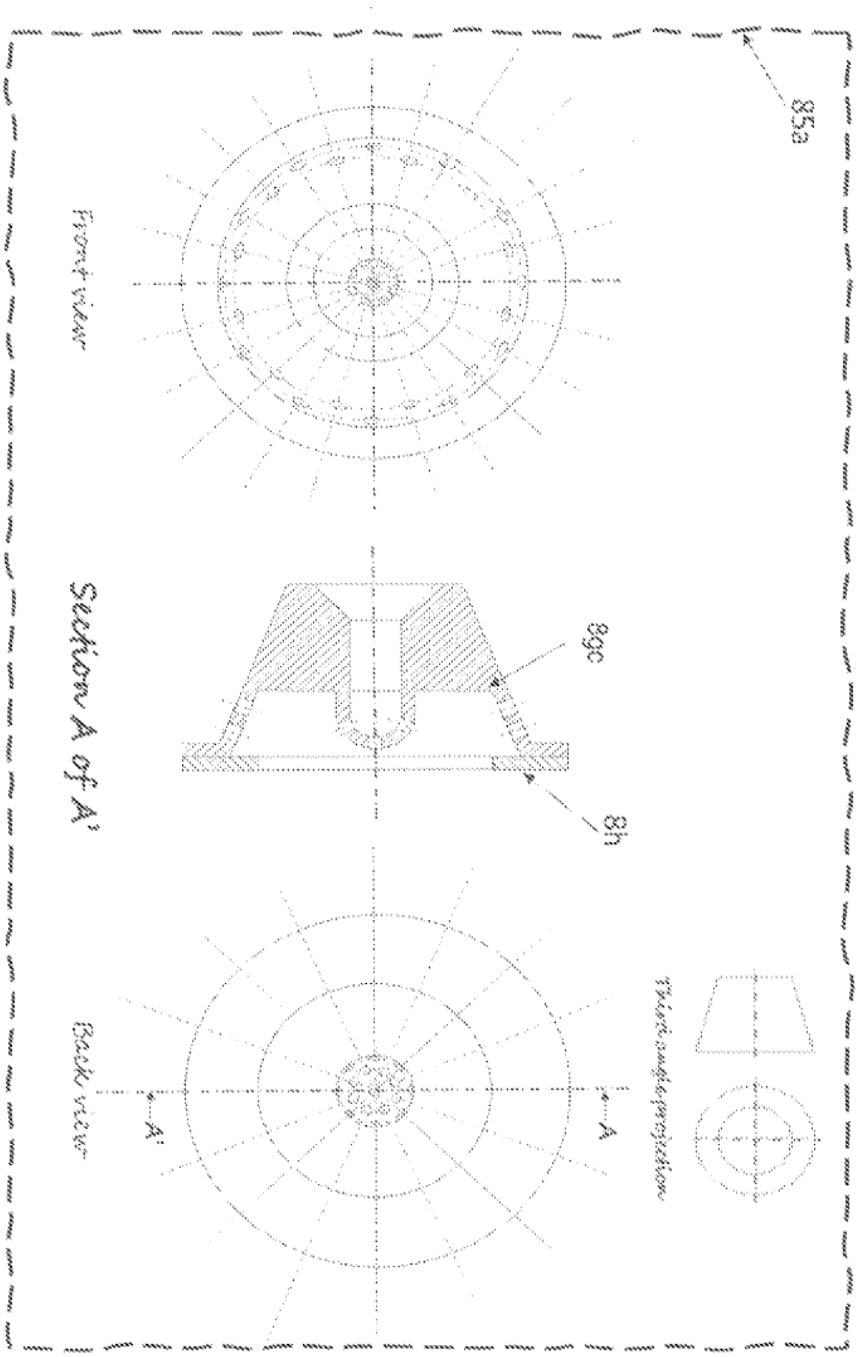

85a
Front view
Section A of A'
8gc
8h
Back view
A'
A
Third angle projection

Fig. Nine (9)

28
8bb
8c 8h 8c
8ac
8c 8bb
MODULAR SECTIONS TYPE (8a)
A - Linear
B - Angular
Short
8aa
30° Bend
8ad
Medium
8ab
45° Bend
8ae
Long
8ac
90° Bend
8af
8af
8bb
8bc
41 or 32
86

Fig. Ten (10)

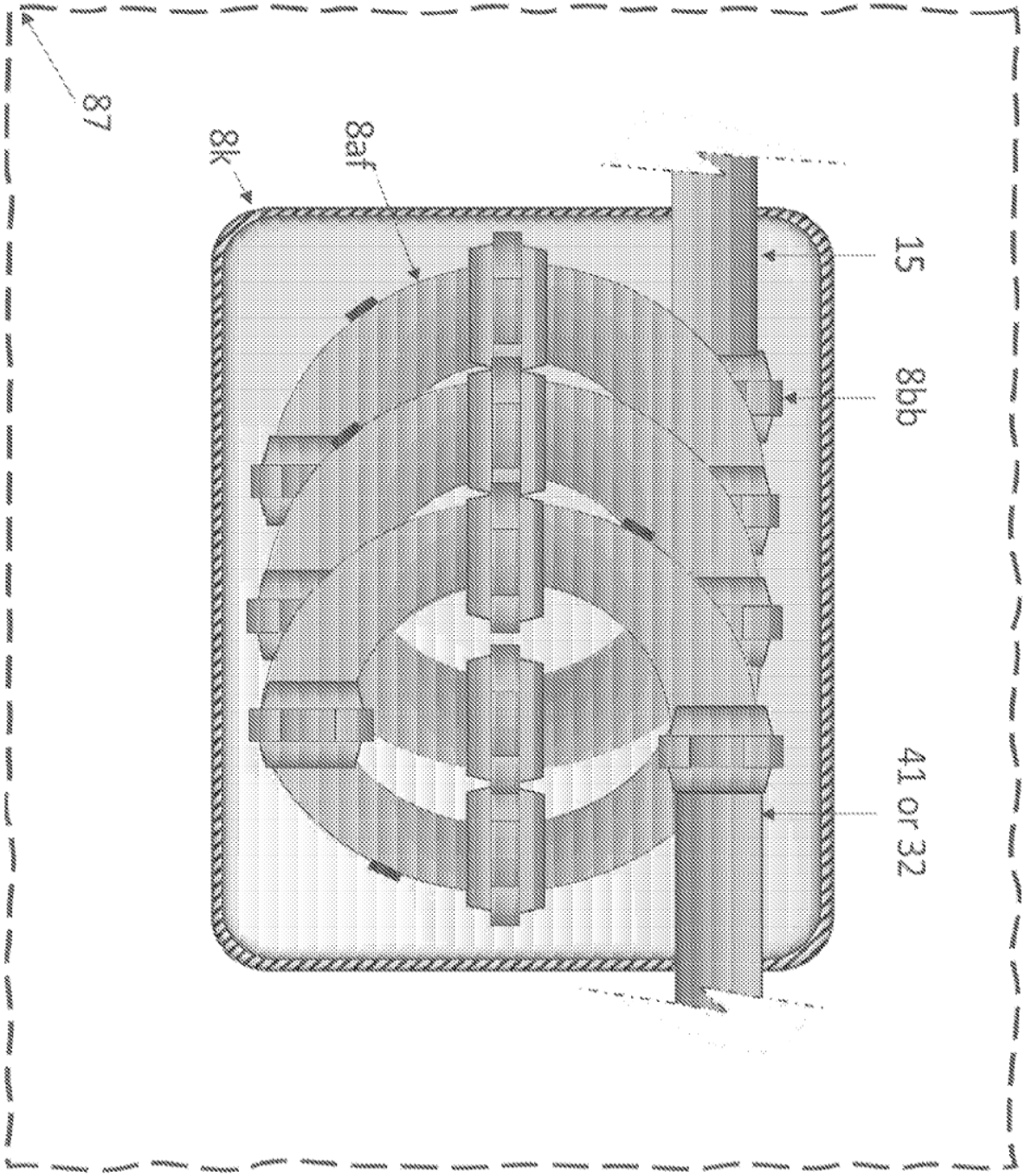


Fig. Eleven (11)

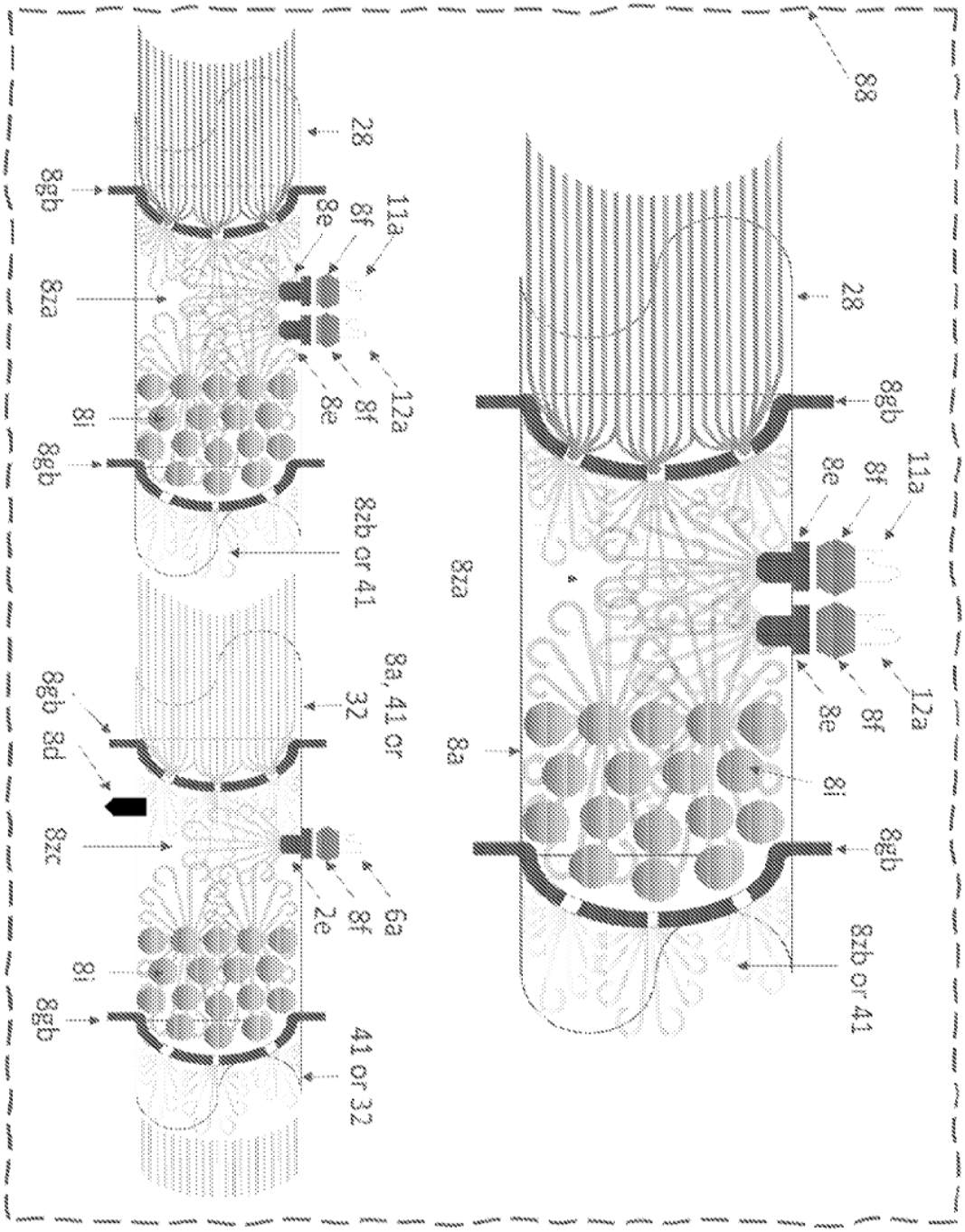


Fig. Twelve (12)

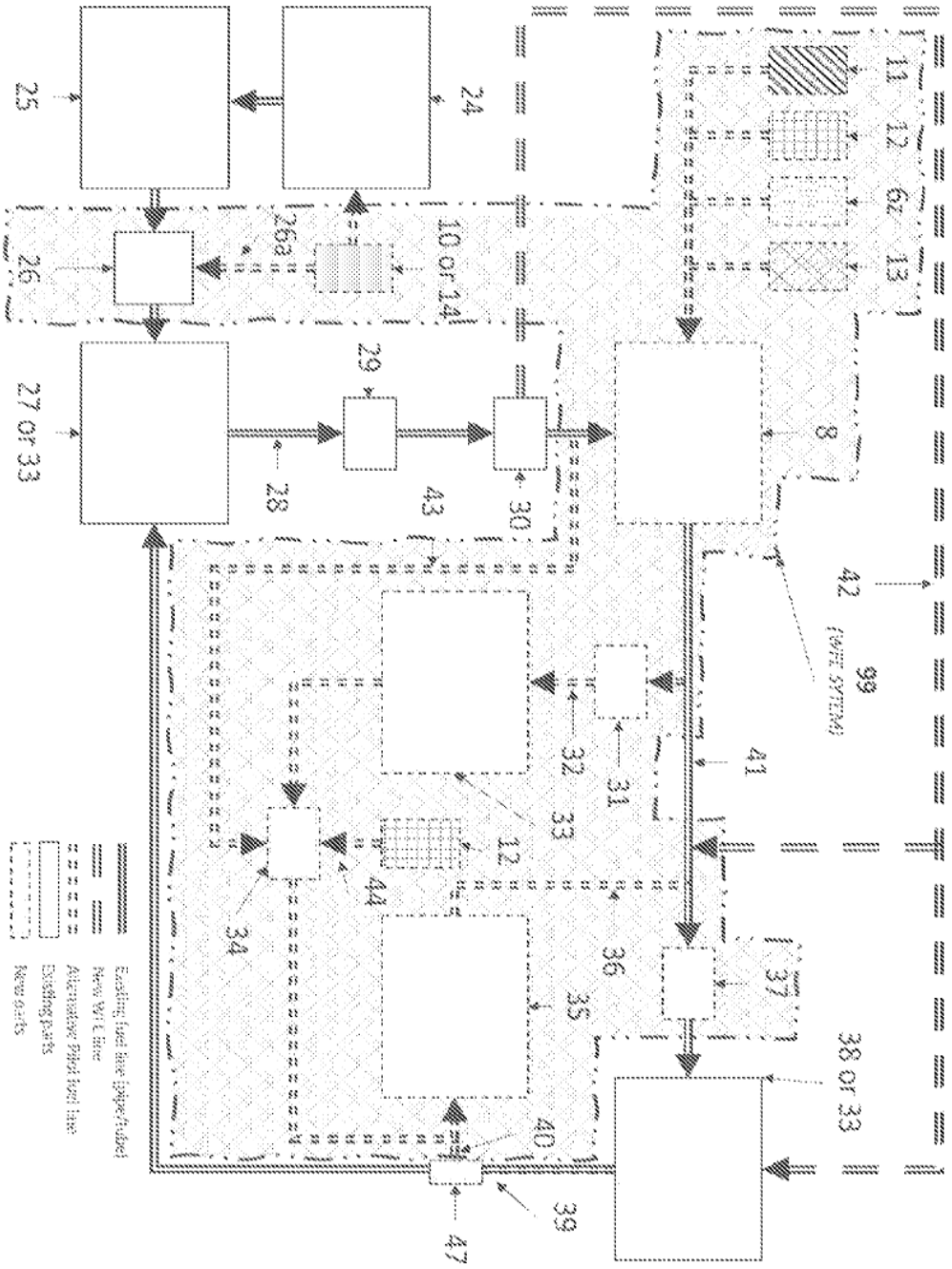


Fig. Thirteen (13)

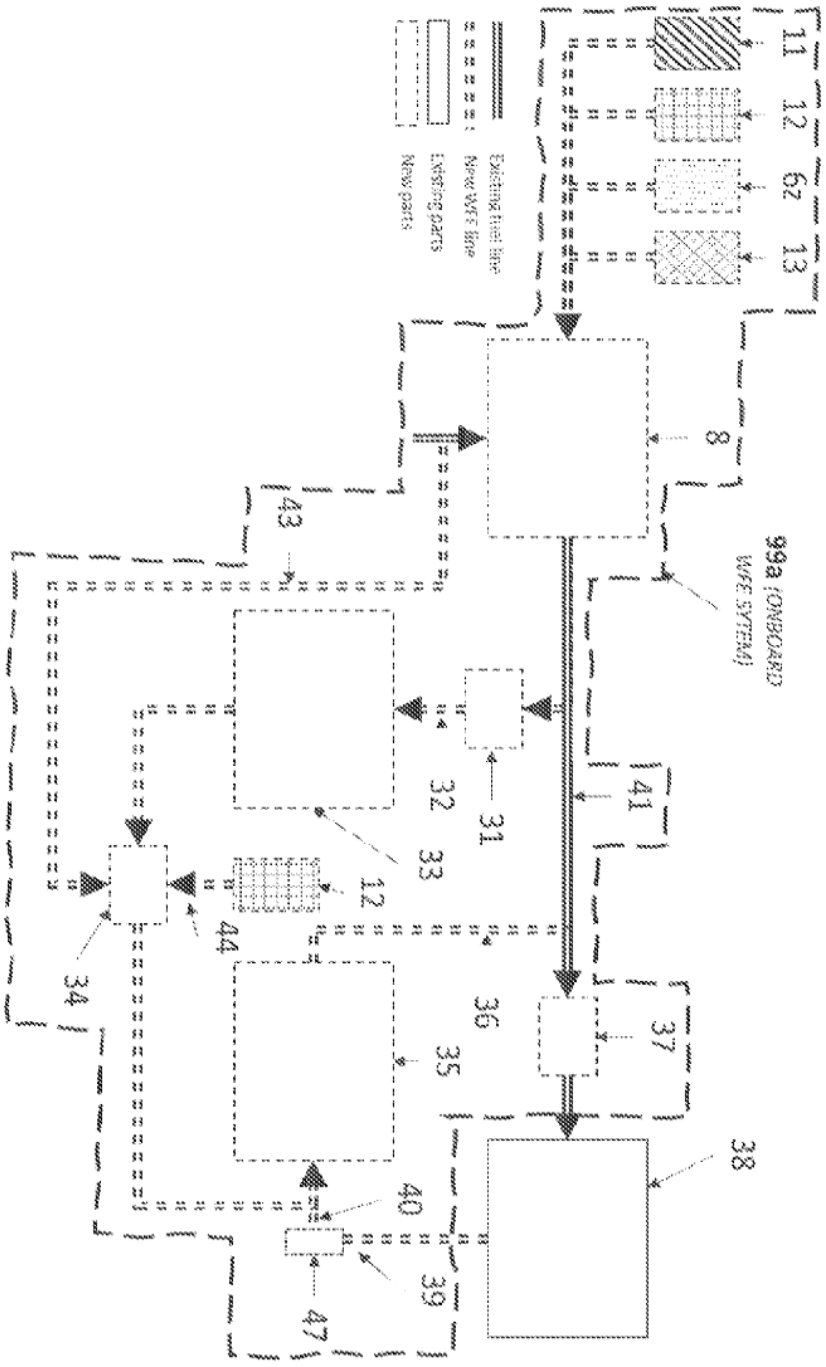


Fig. Fourteen (14)

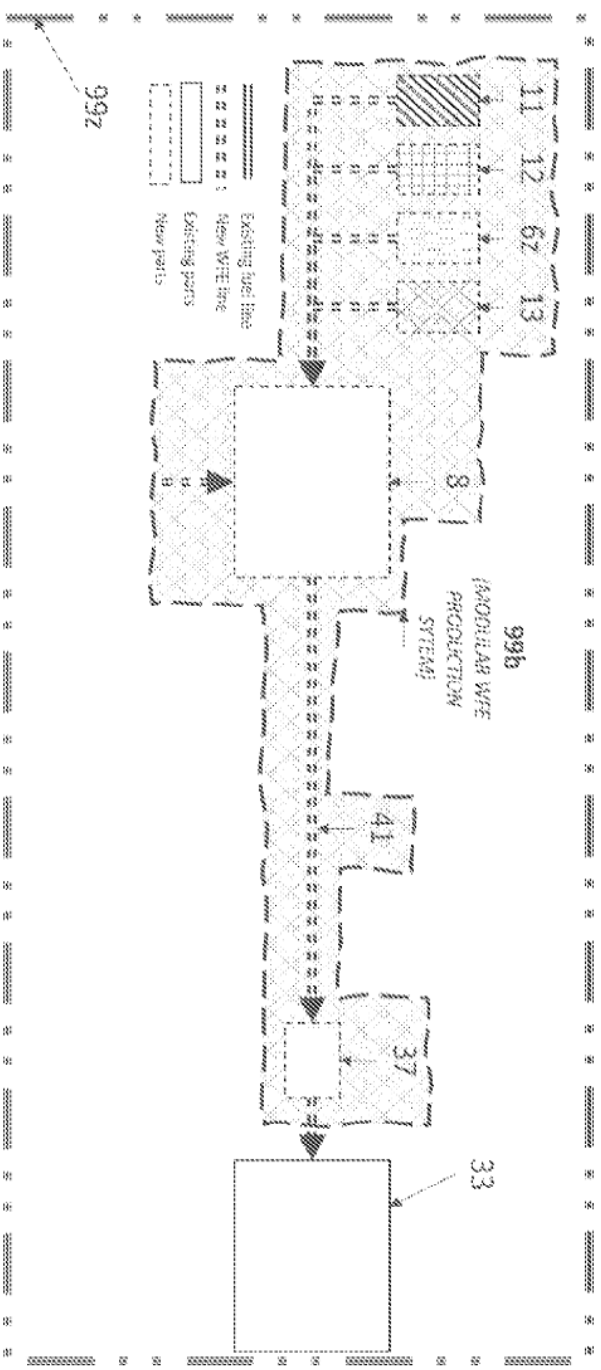


Fig. Fifteen (15)

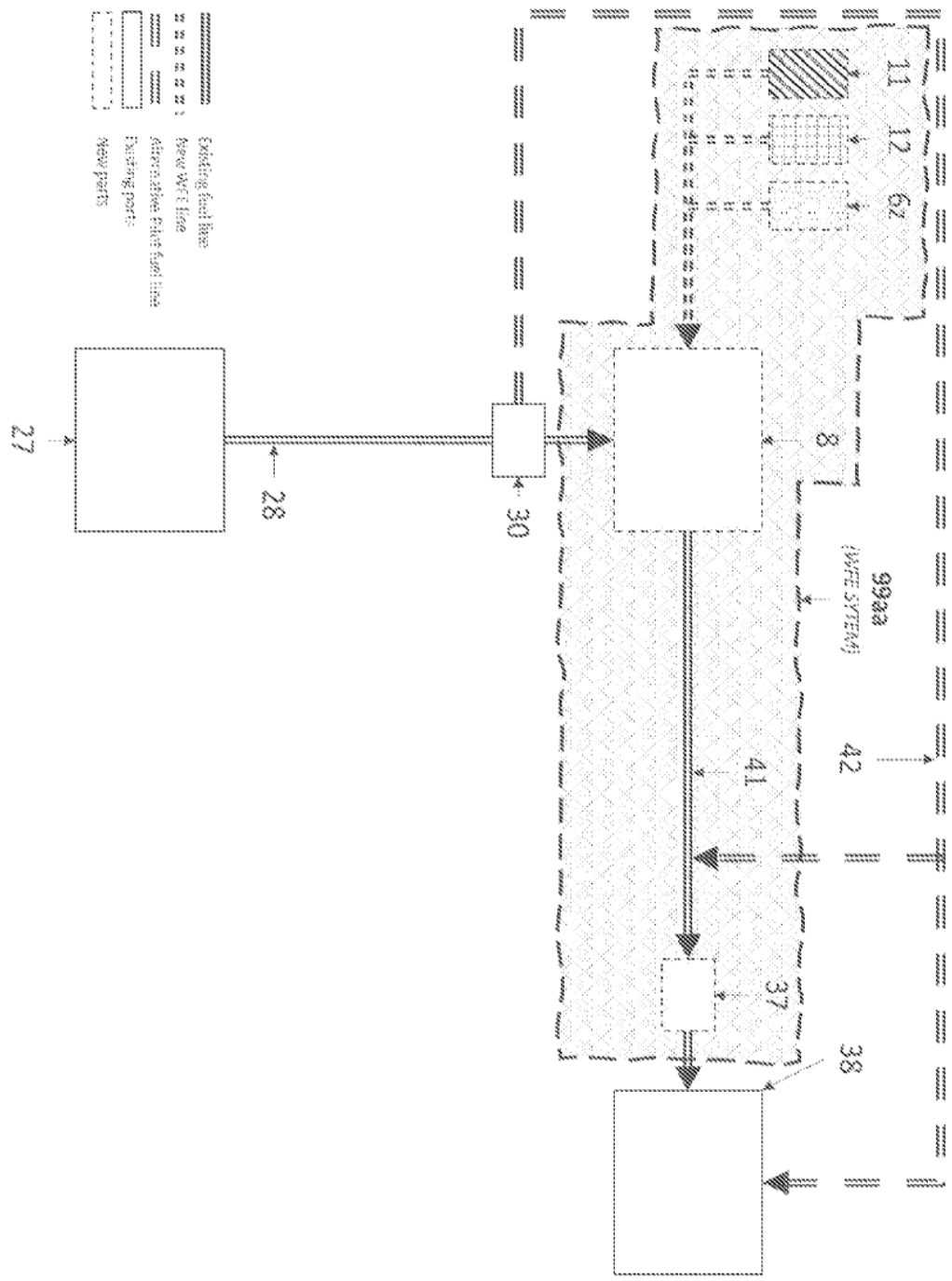


Fig. Sixteen (16)

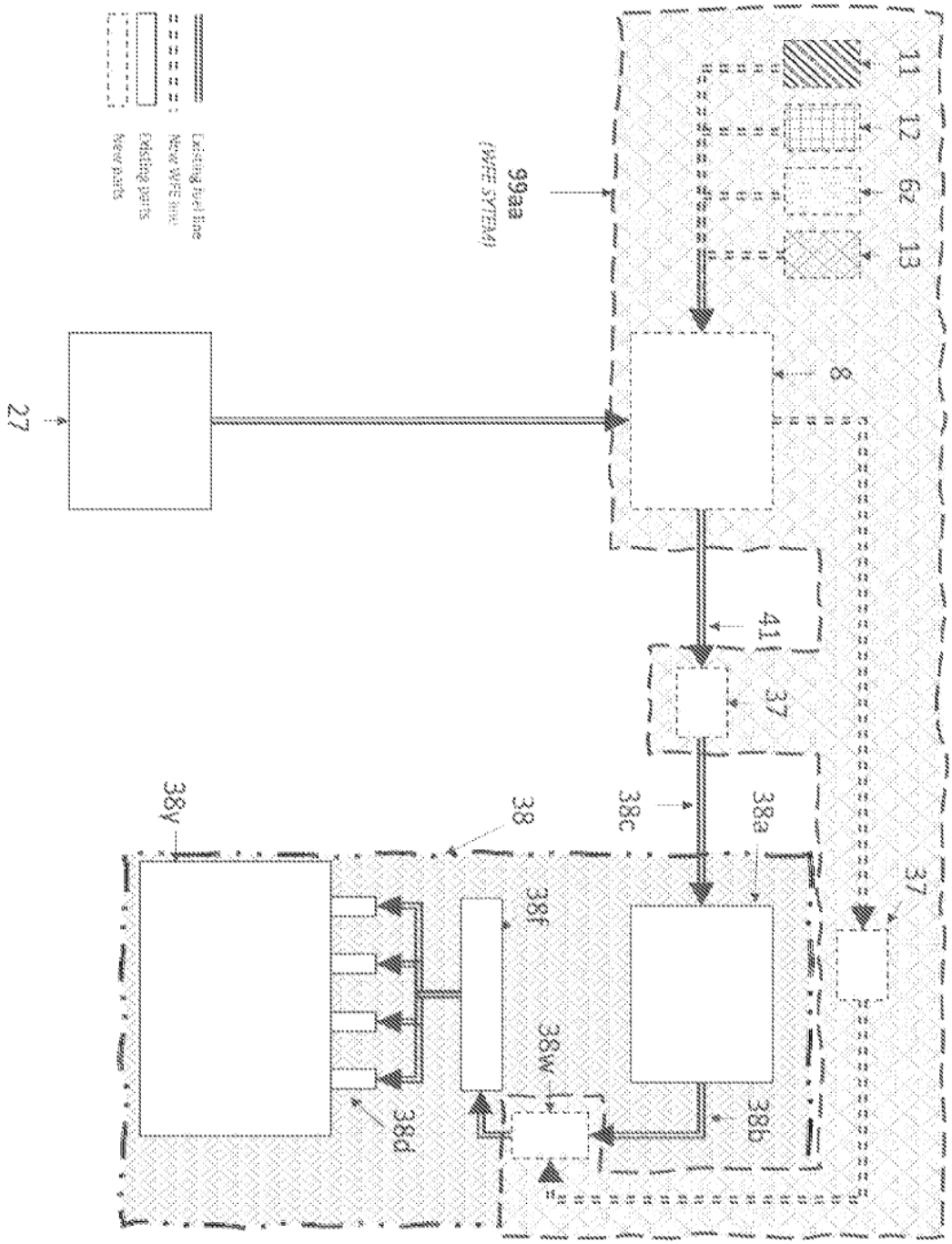


Fig. Seventeen (17)

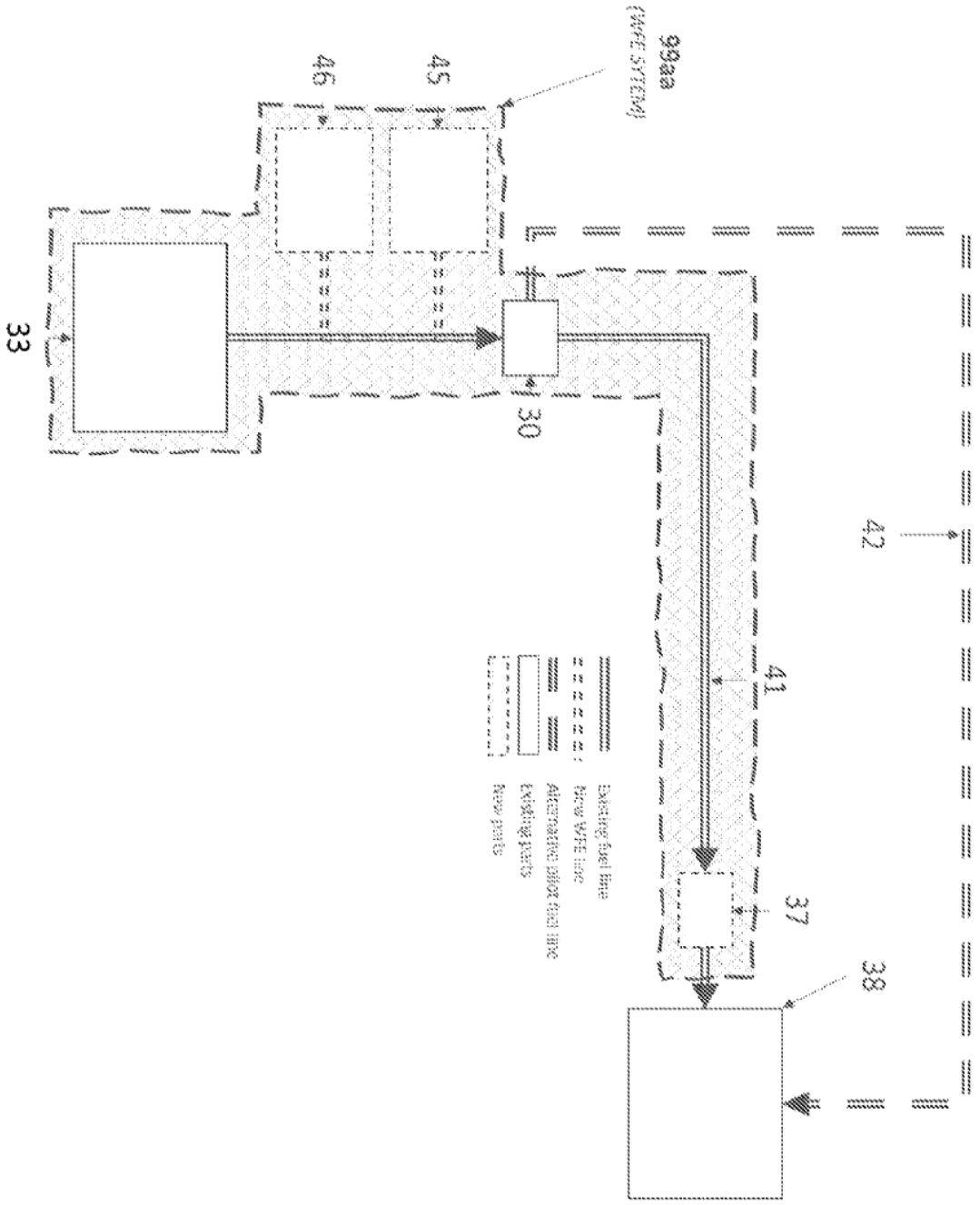


Fig. Eighteen (18)

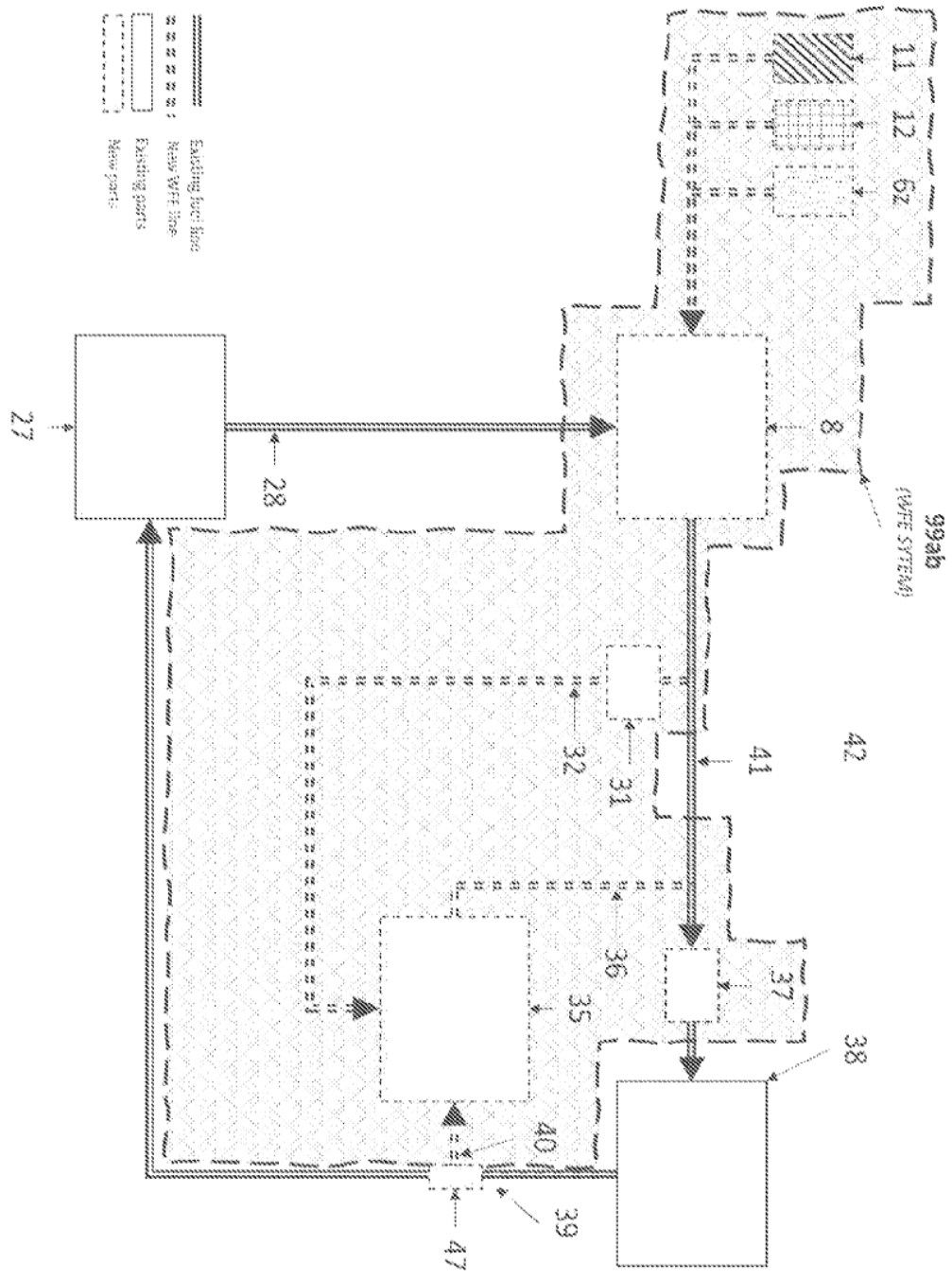


Fig. Nineteen (19)

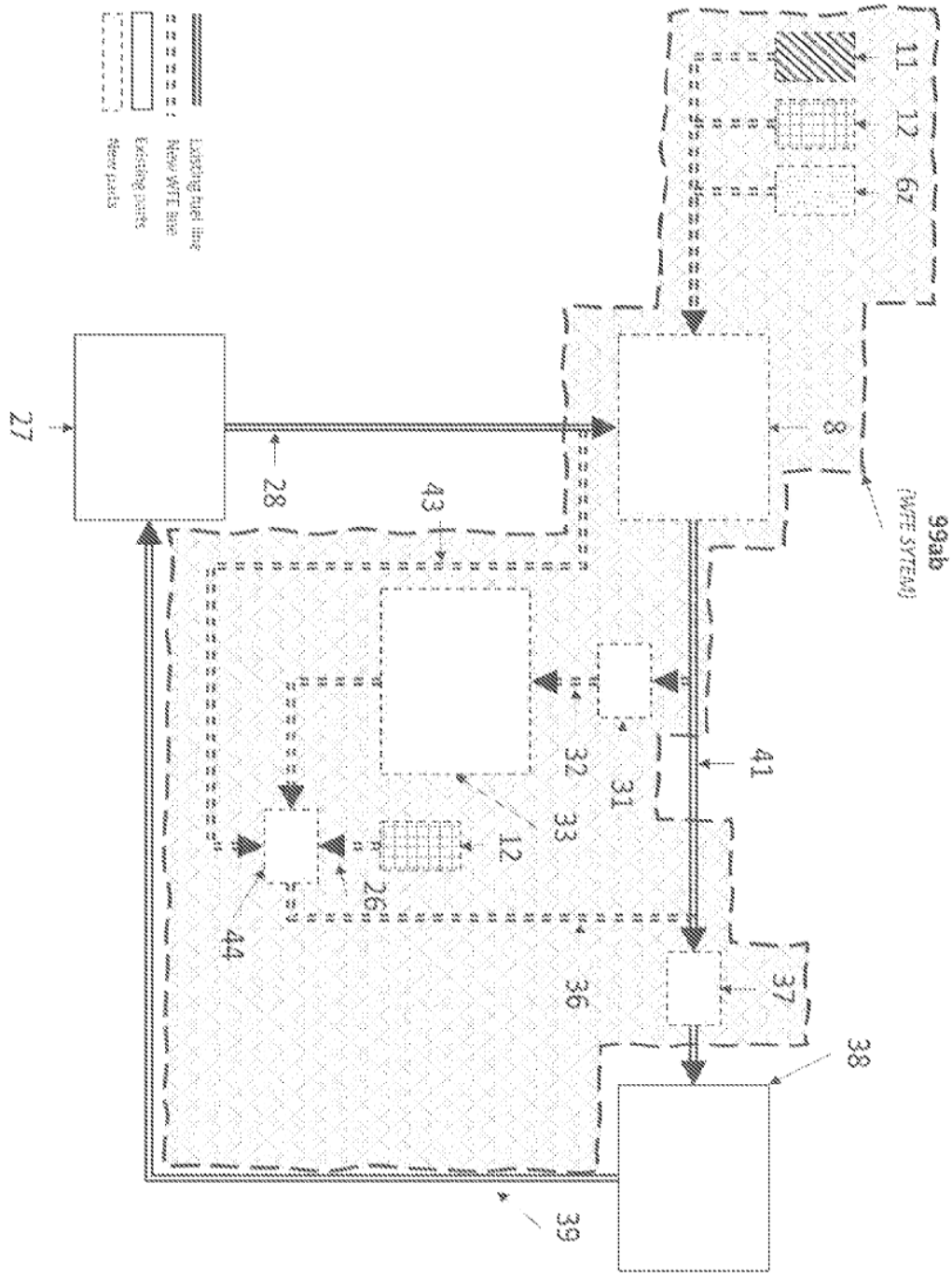


Fig. Twenty (20)

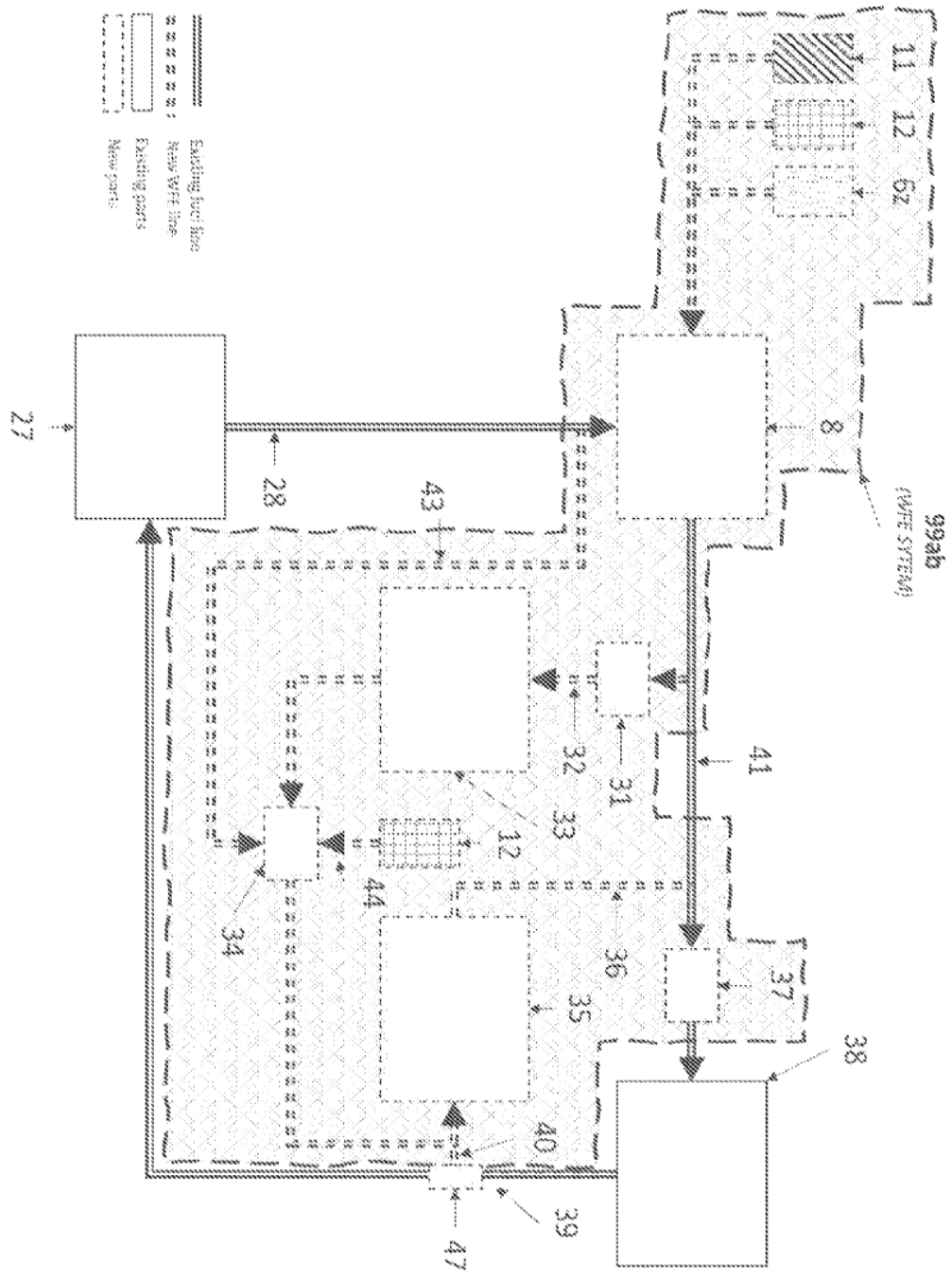


Fig. Twenty-One (21)

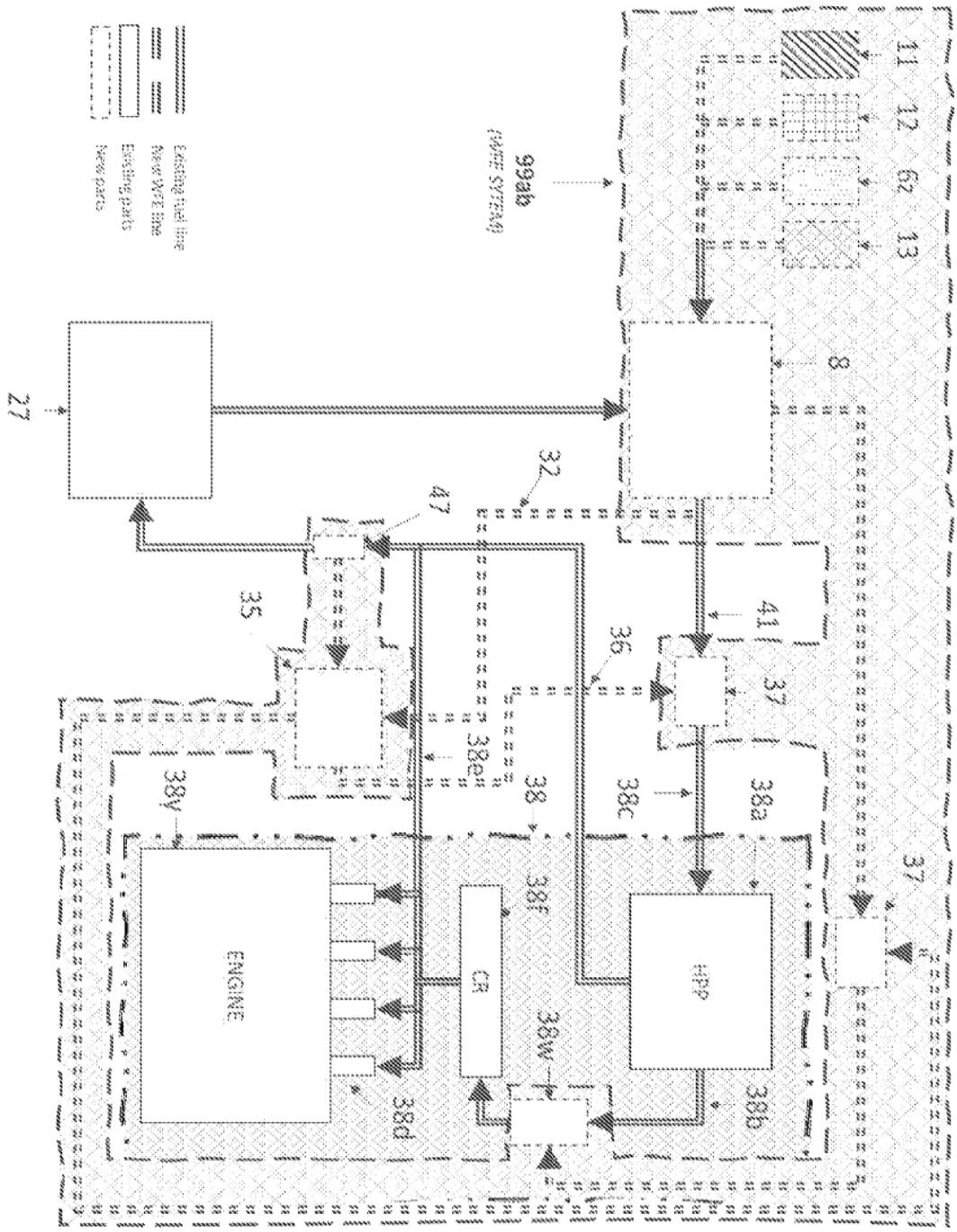


Fig. Twenty-Two (22)

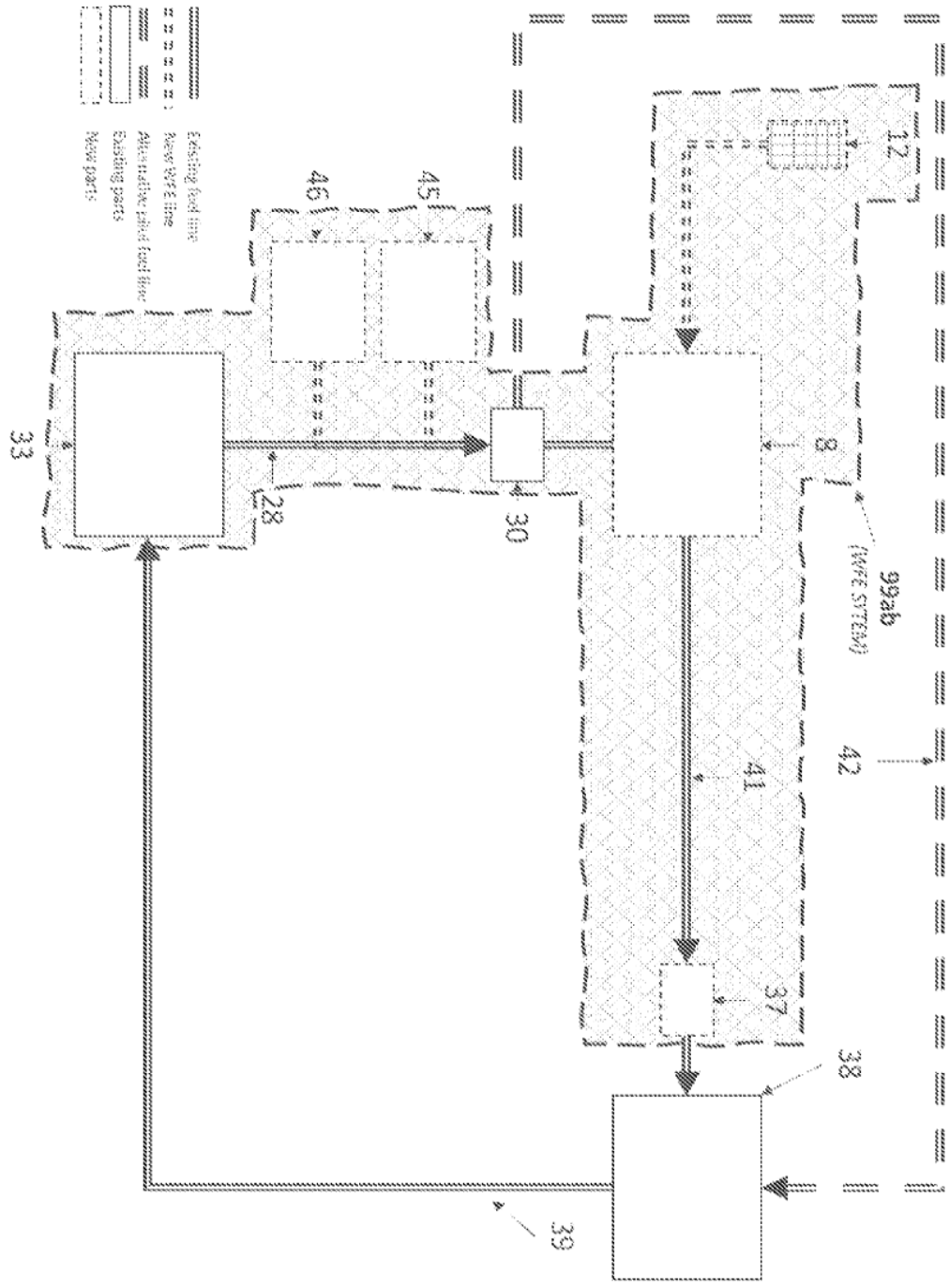


Fig. Twenty-Three (23)

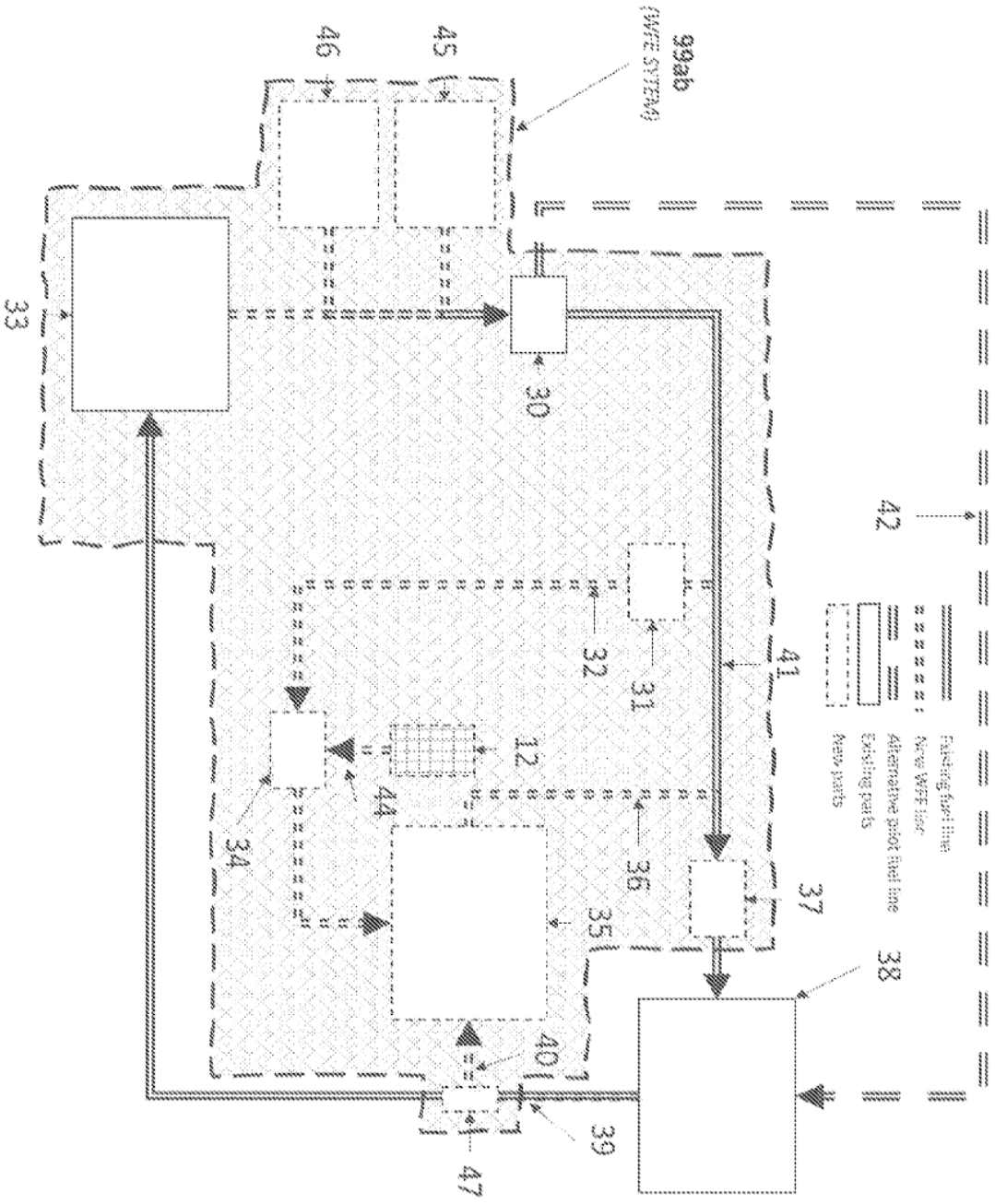


Fig. Twenty-Four (24)

SECTION IV: FLOWDIAGRAM OF KEY OPERATIONS FOR A BI-FUEL SYSTEMS IN A ICE.

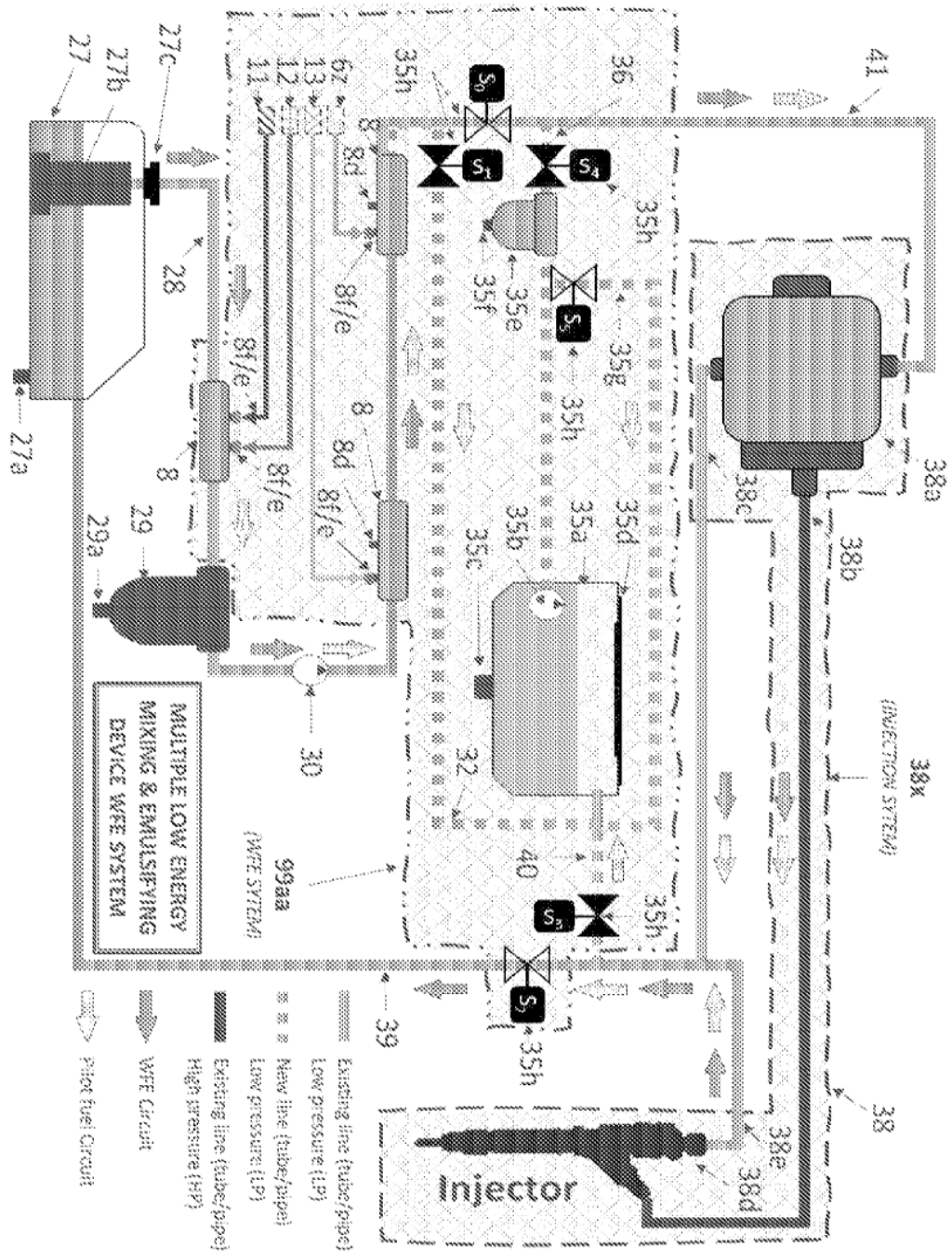


Fig. Twenty-Five (25)

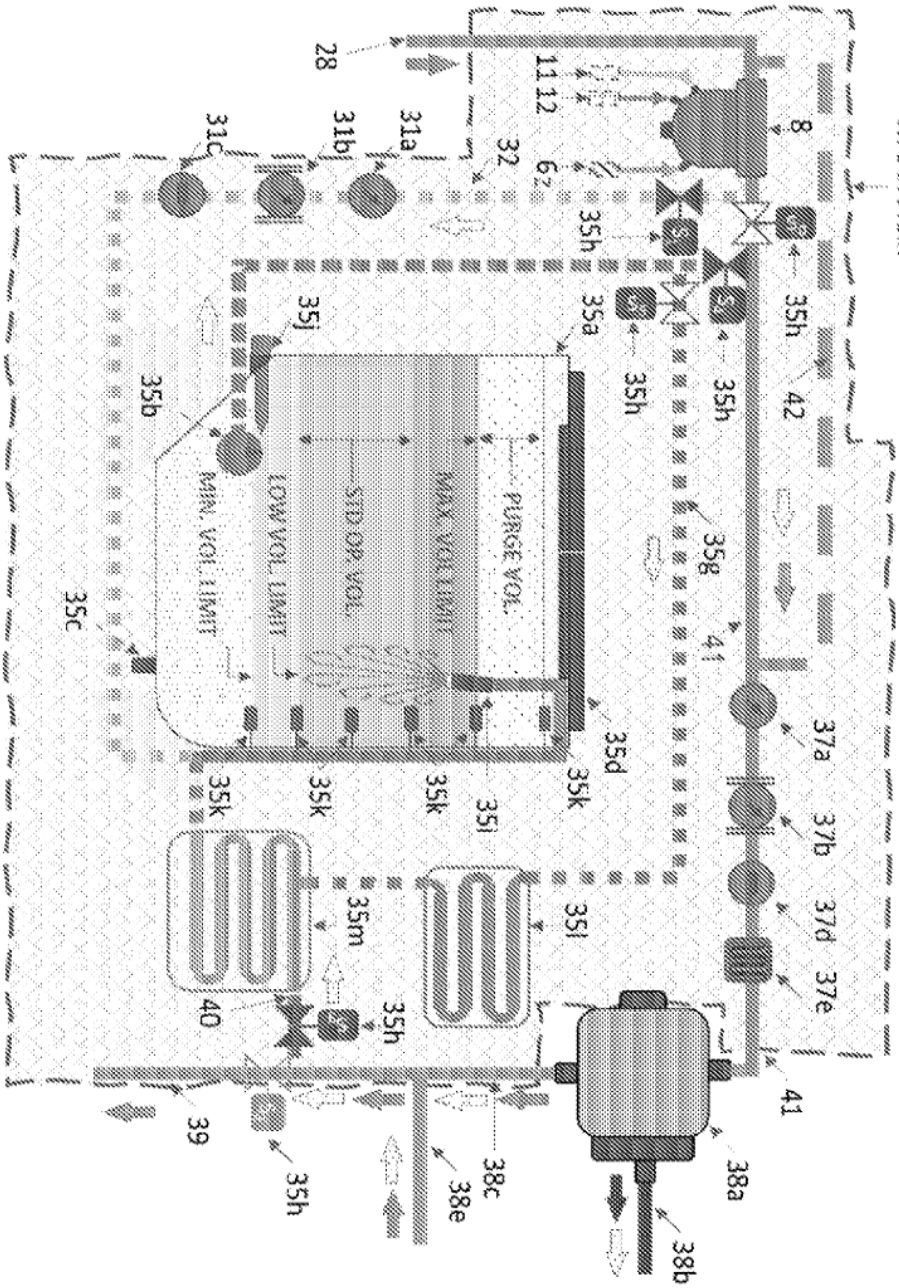


Fig. Twenty-Six (26)

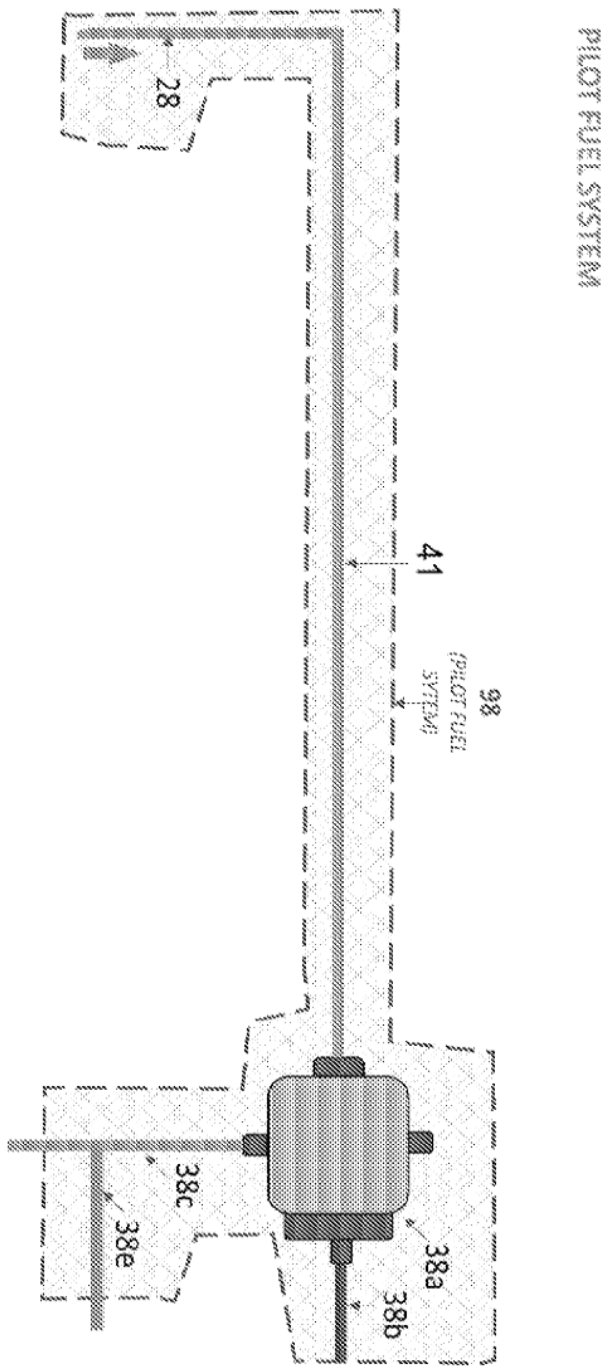


Fig. Twenty-Seven (27)

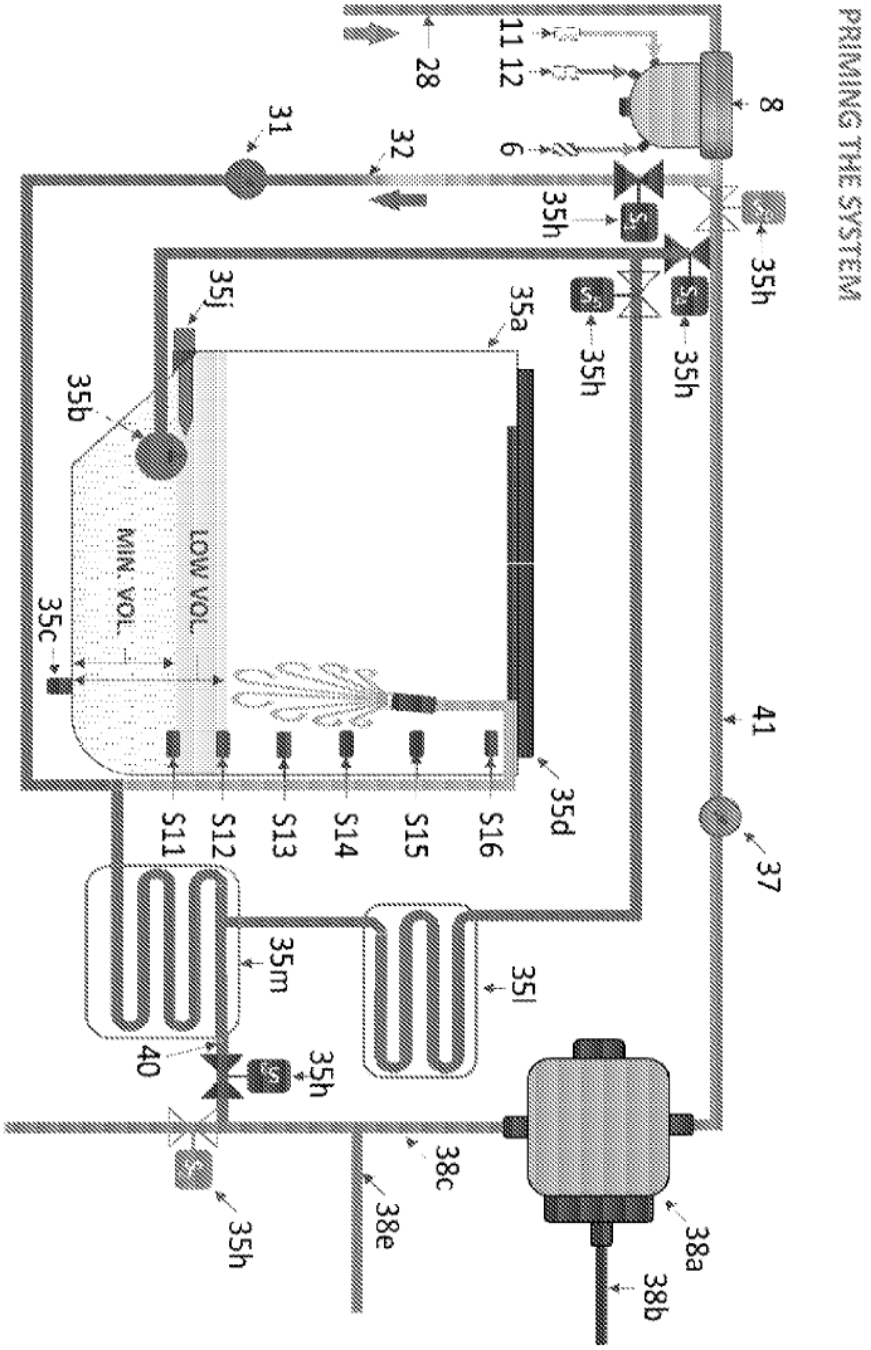


Fig. Twenty-Eight (28)

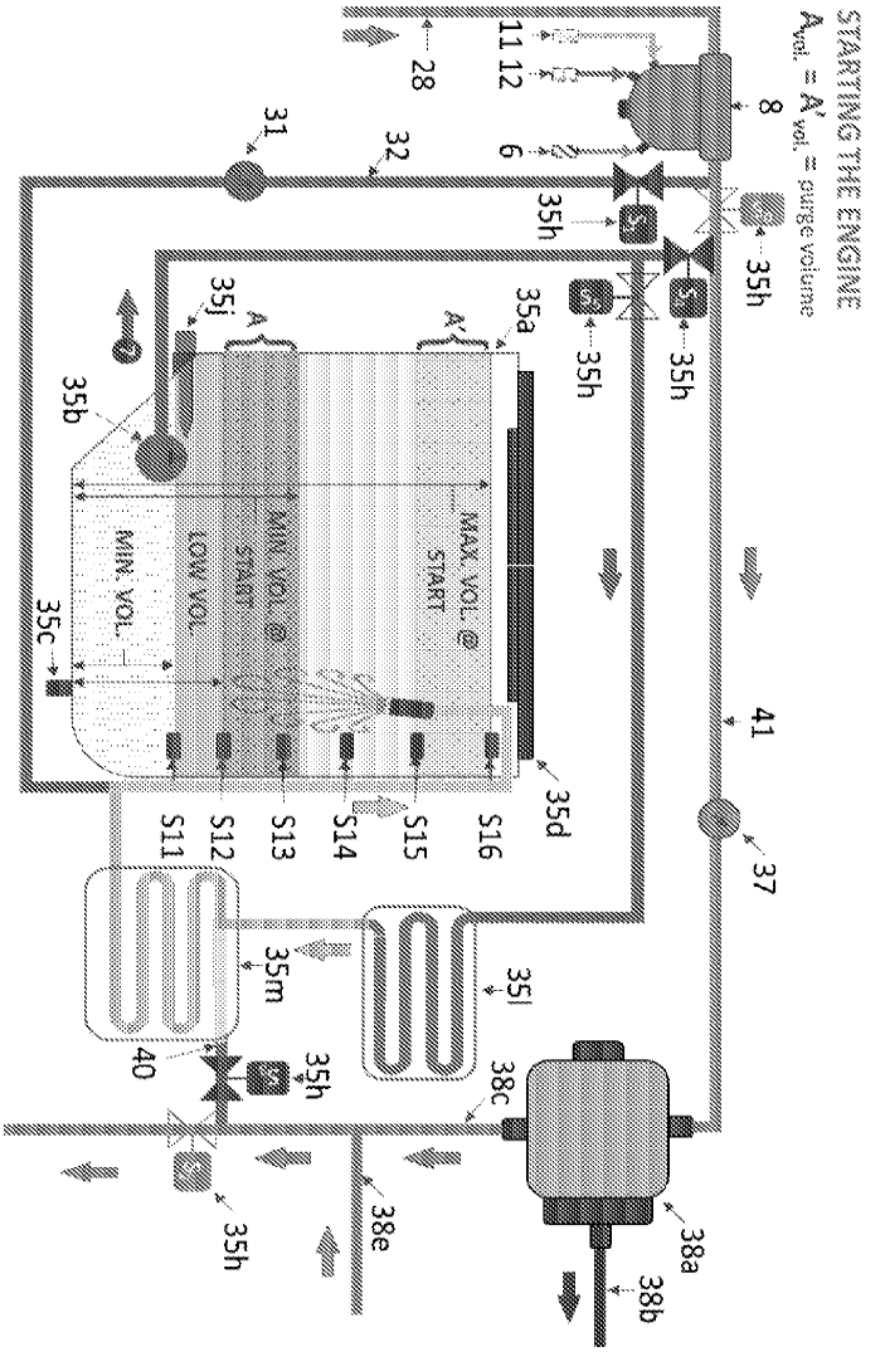


Fig. Twenty-Nine (29)

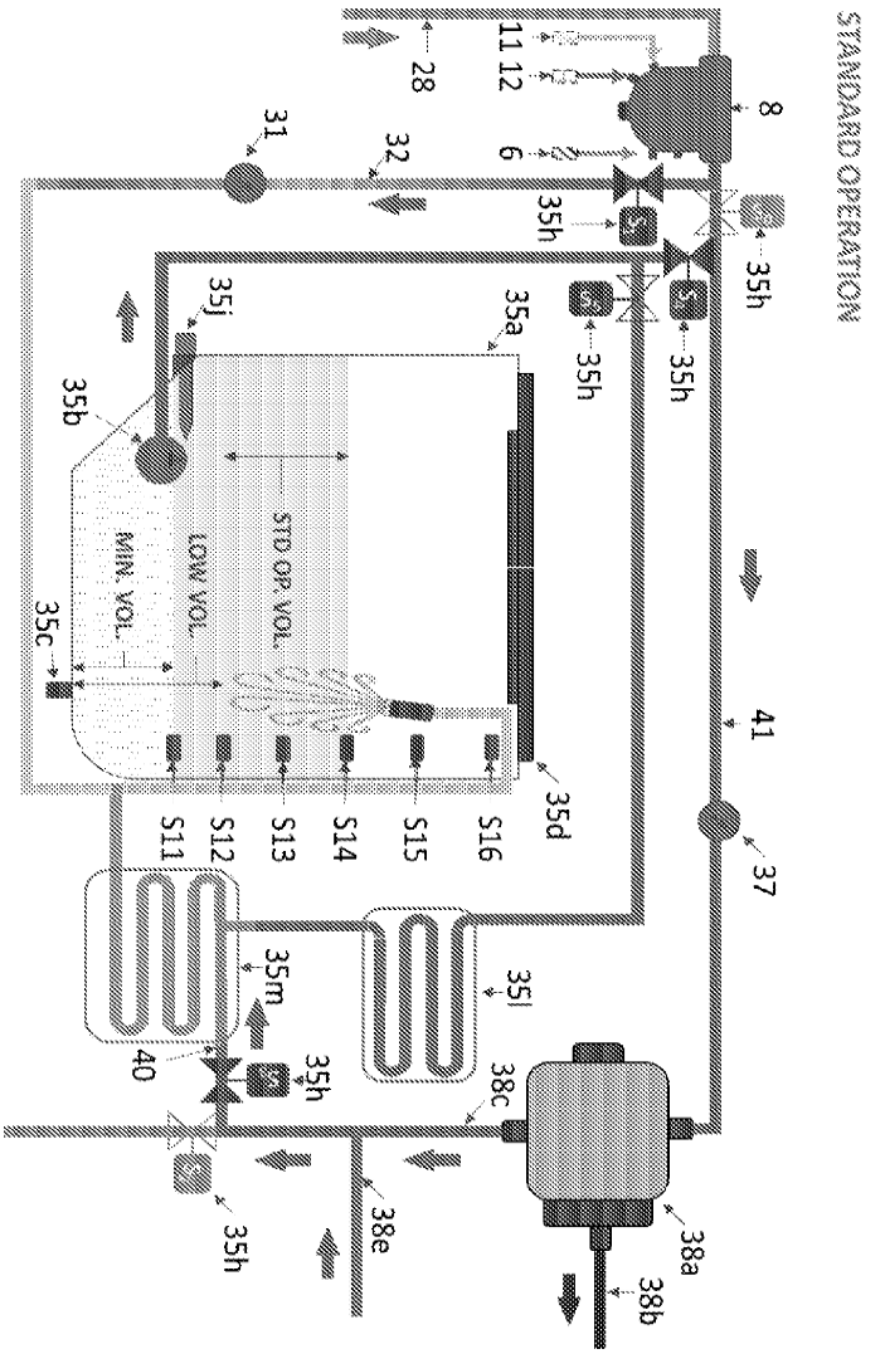


Fig. Thirty (30)

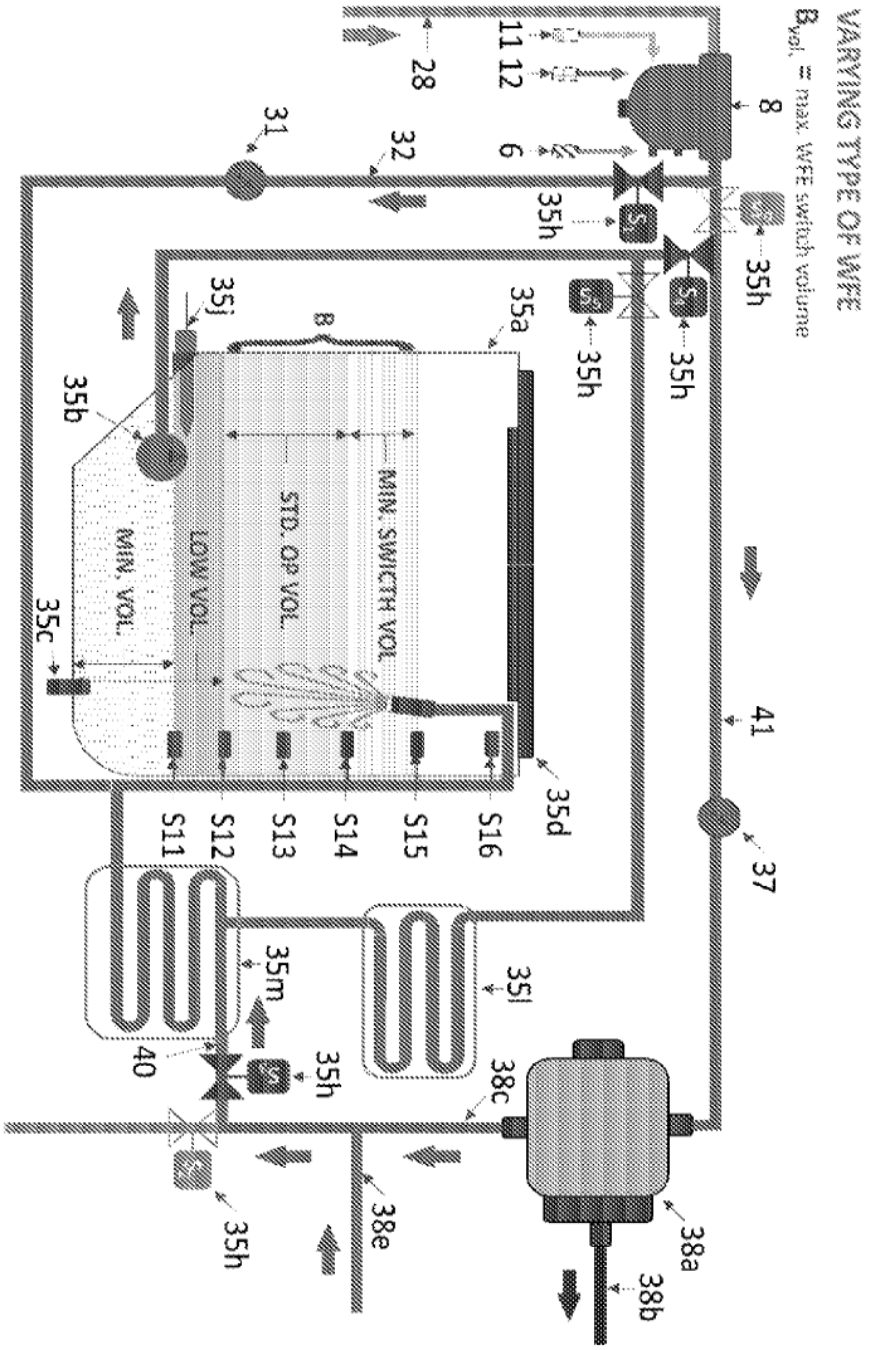


Fig. Thirty-One (31)

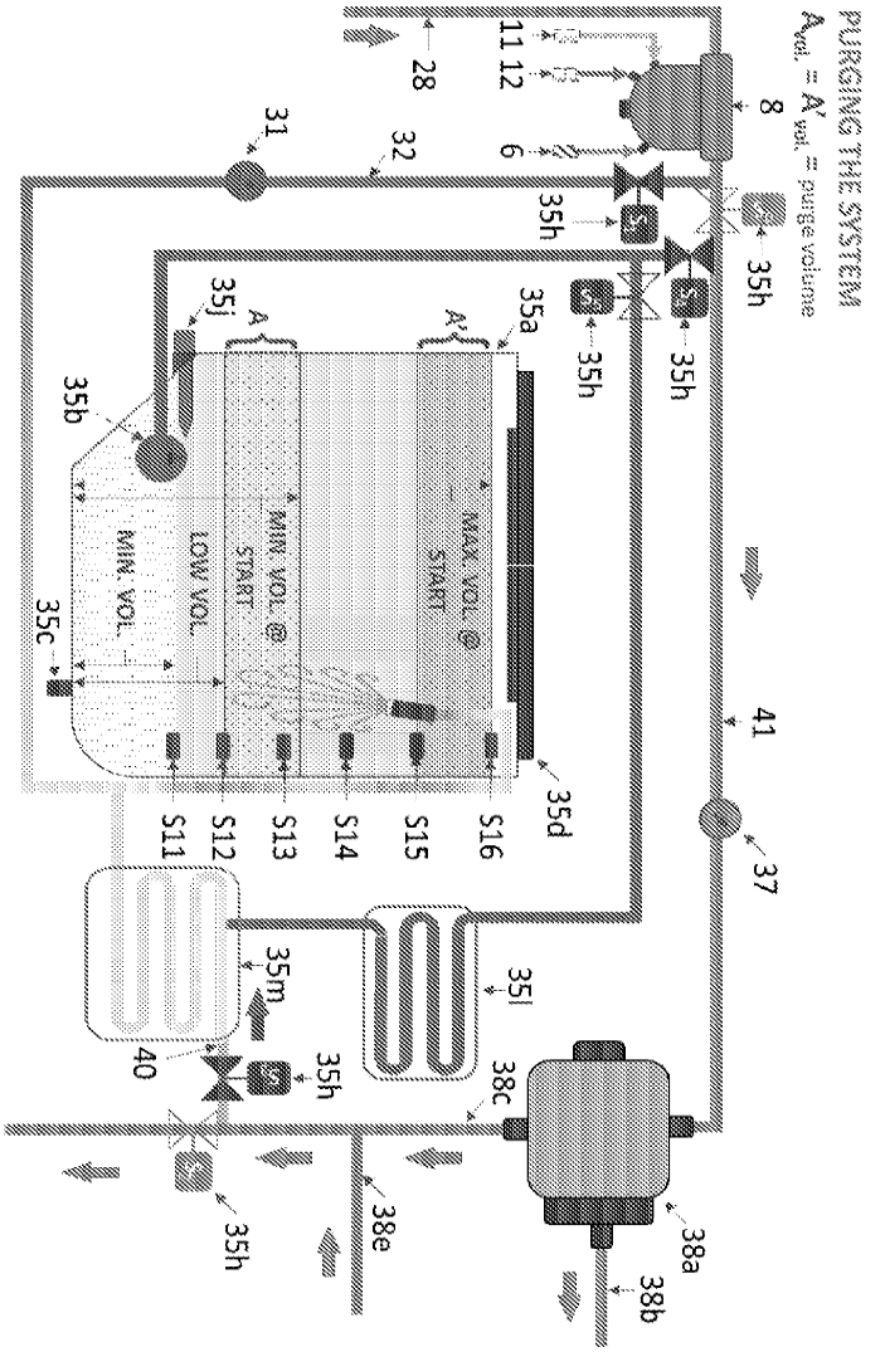


Fig. Thirty-Two (32)

SECTION V: BLOCK DIAGRAM FOR MULTIPLE APPLICATIONS INTELLIGENT SYSTEM

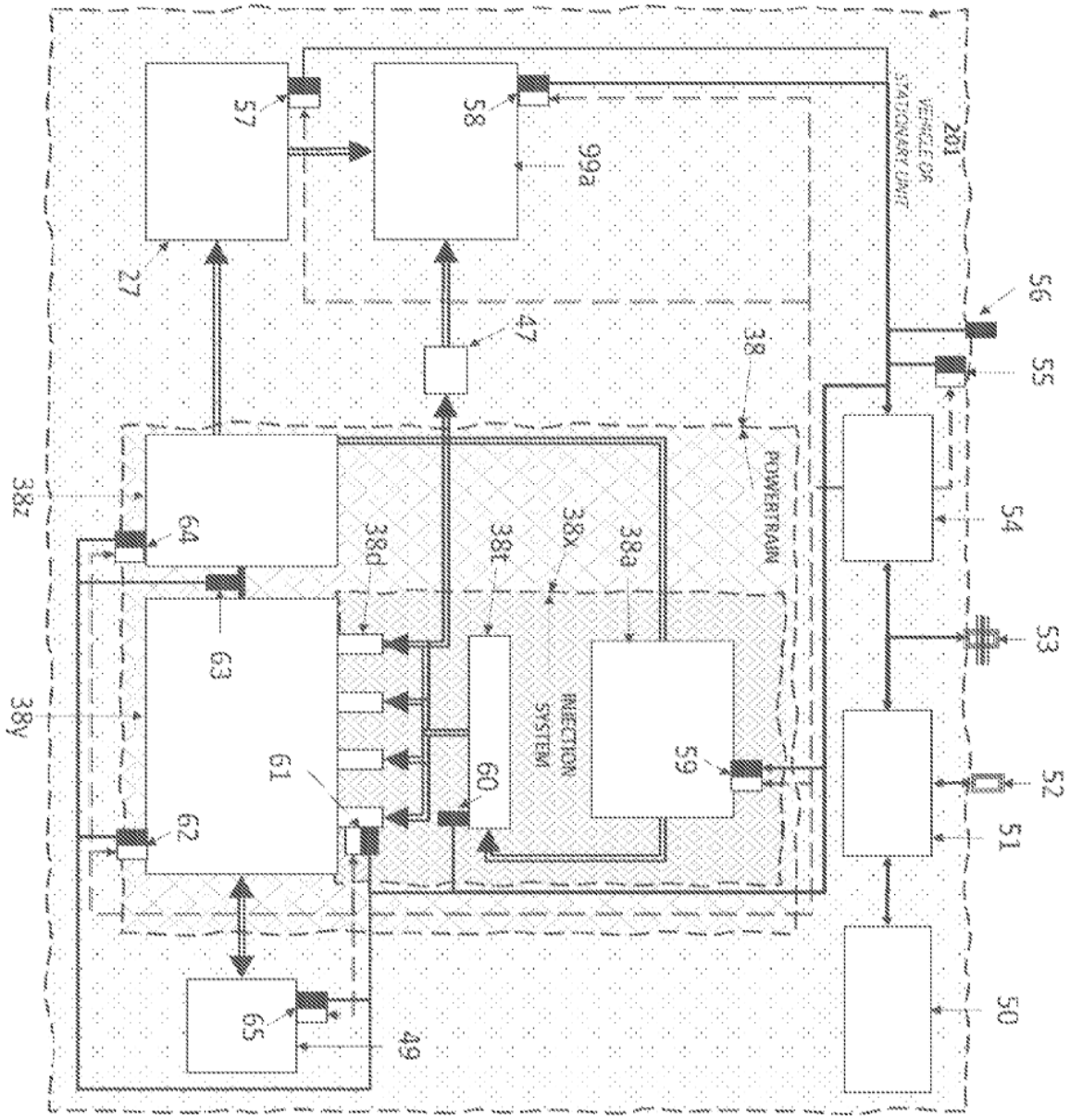


Fig. Thirty-Three (33)

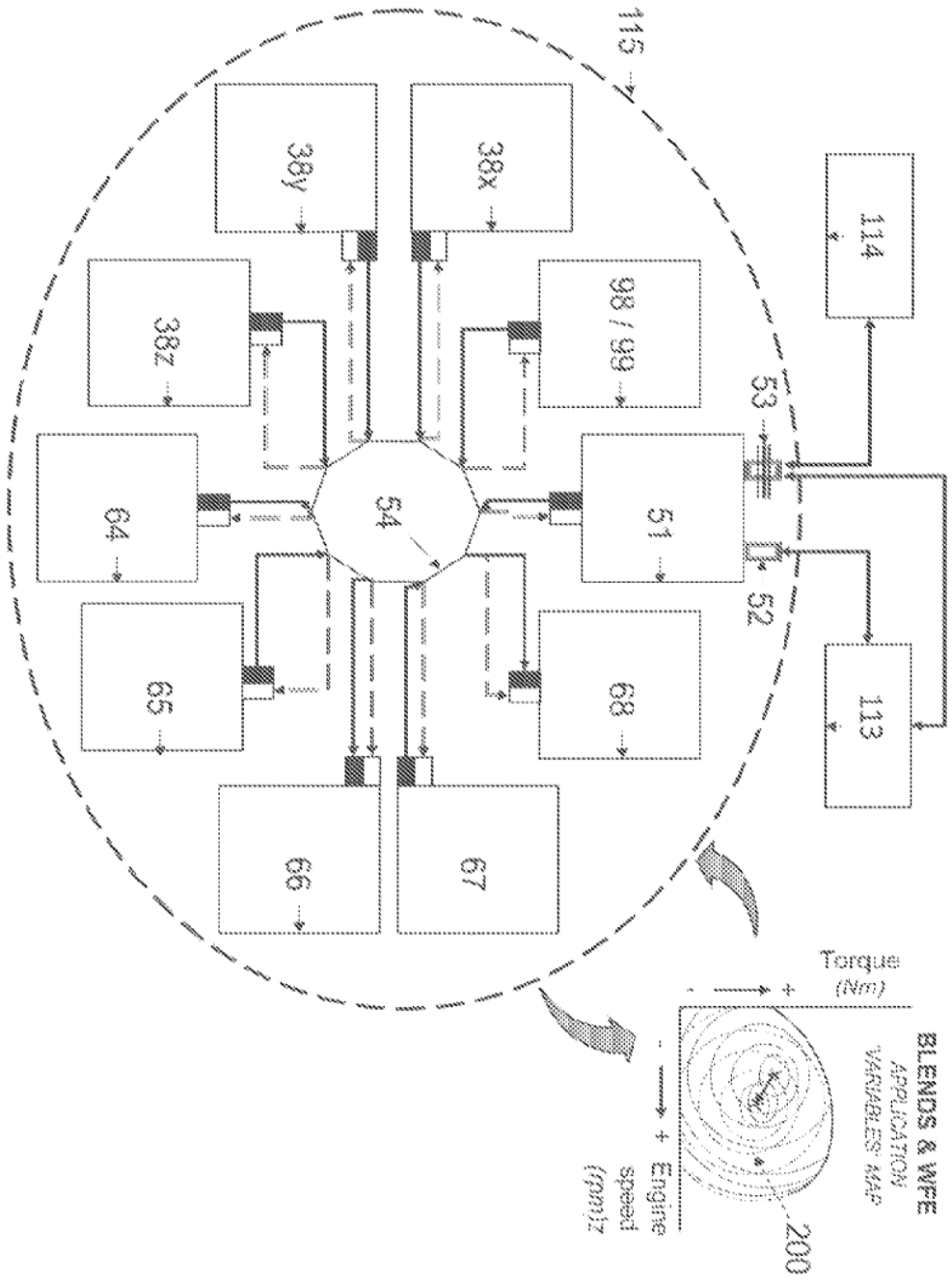


Fig. Thirty-Four (34)

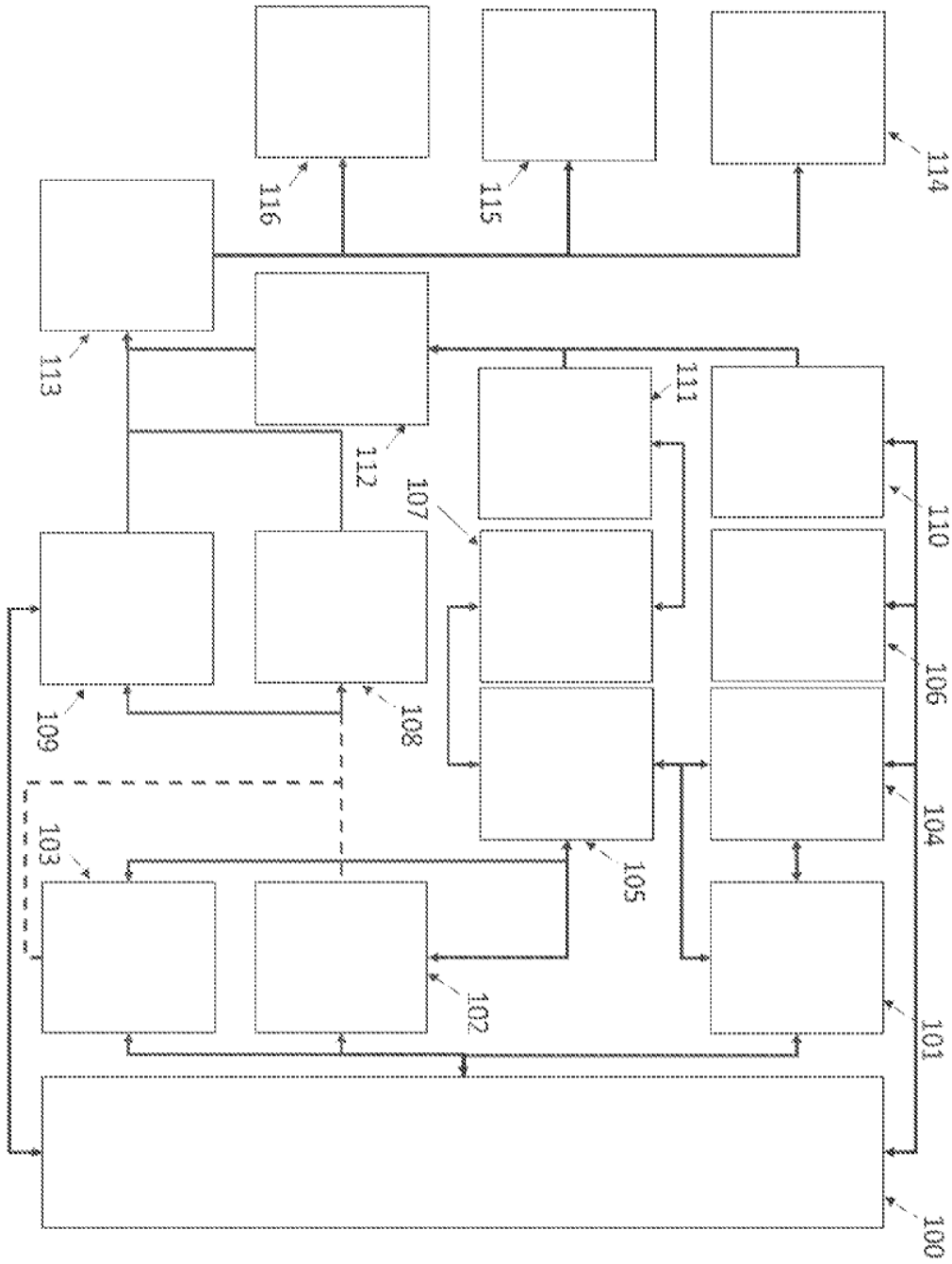


Fig. Thirty-Five (35)

SECTION VI: OTHER FIGURES.

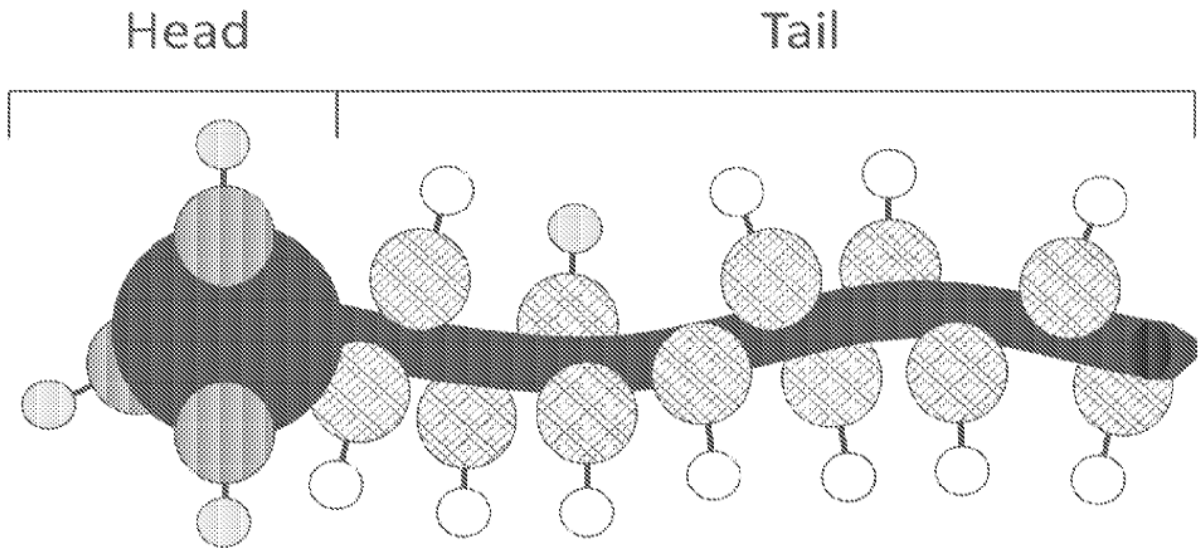


Fig. Thirty-Six (36)

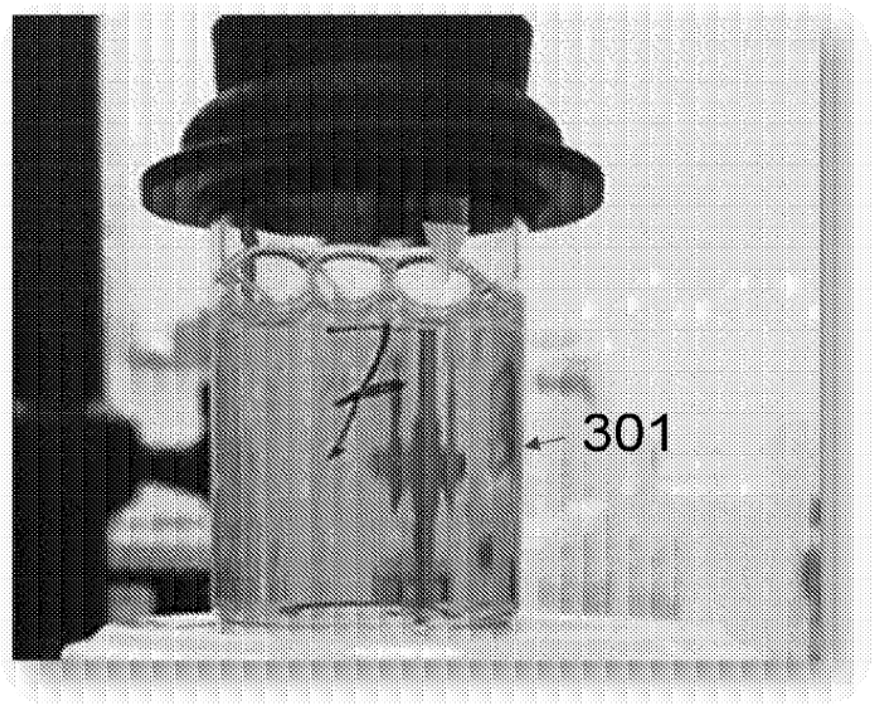


Fig. Thirty-Seven (37)

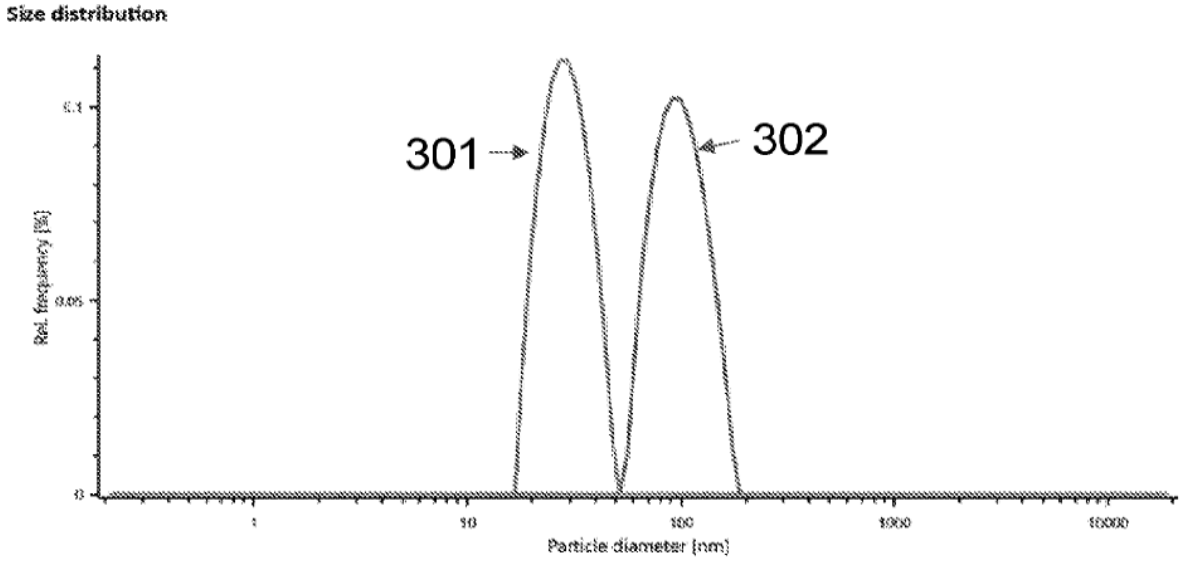


Fig. Thirty-Eight (38)

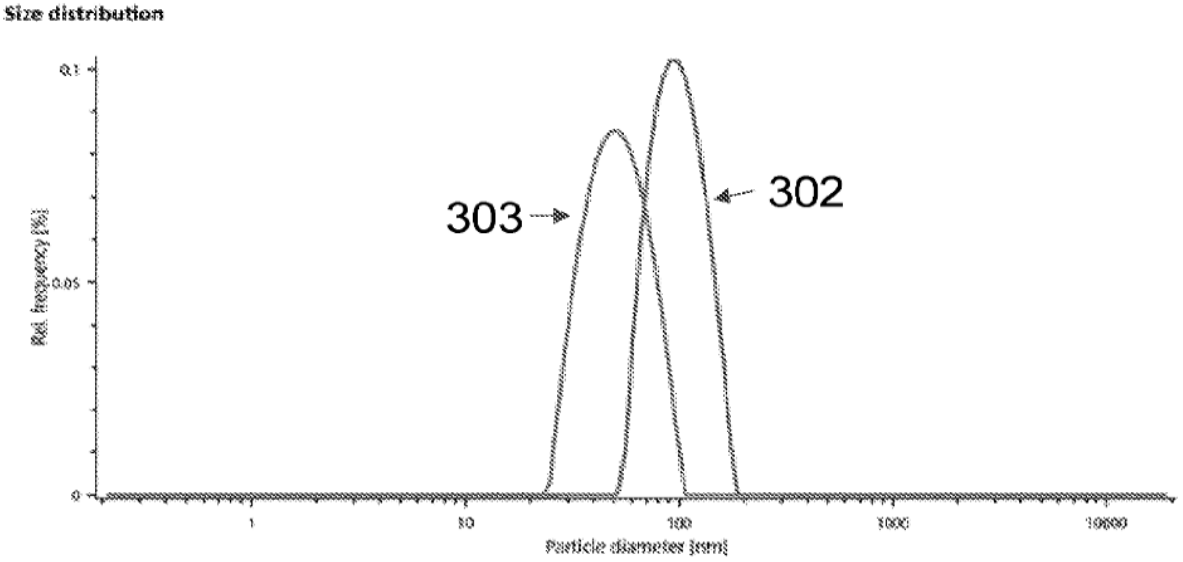


Fig. Thirty-Nine (39)

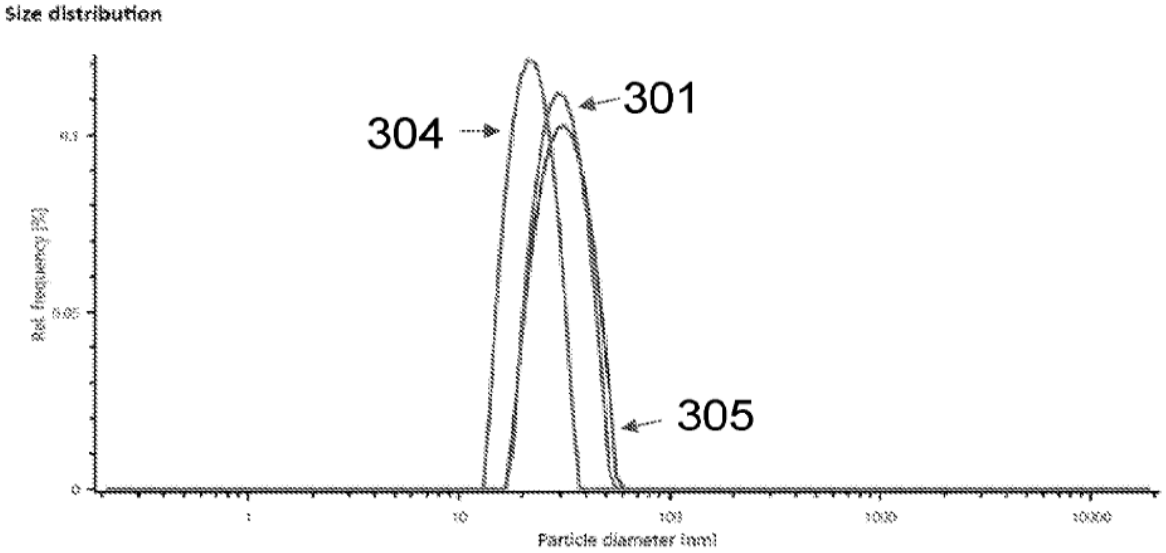


Fig. Forty (40)

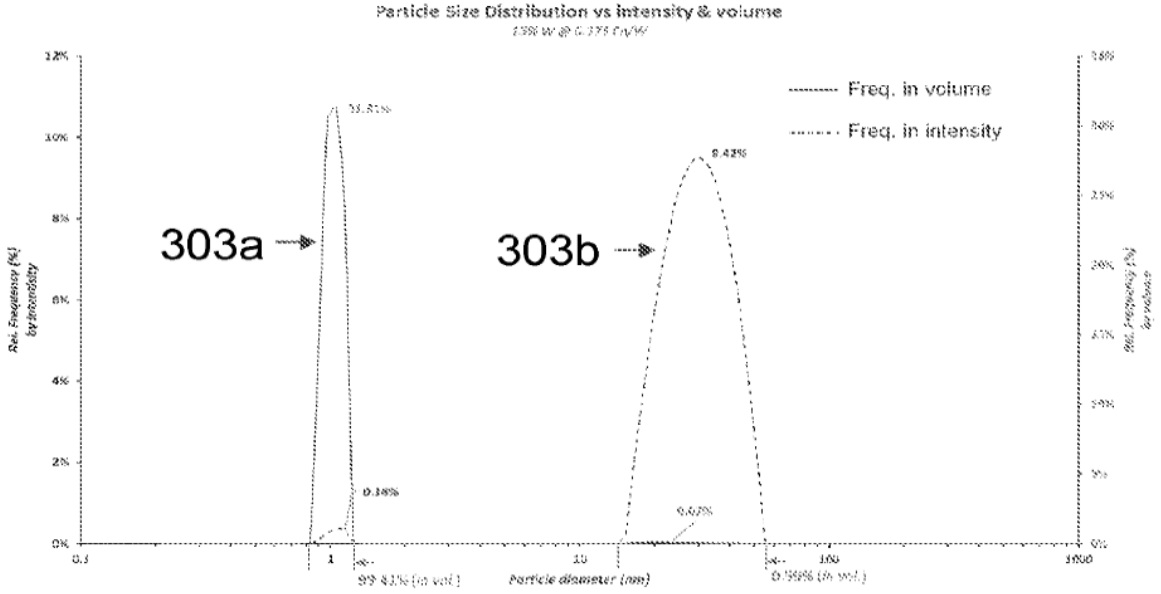


Fig. Forty-One (41)

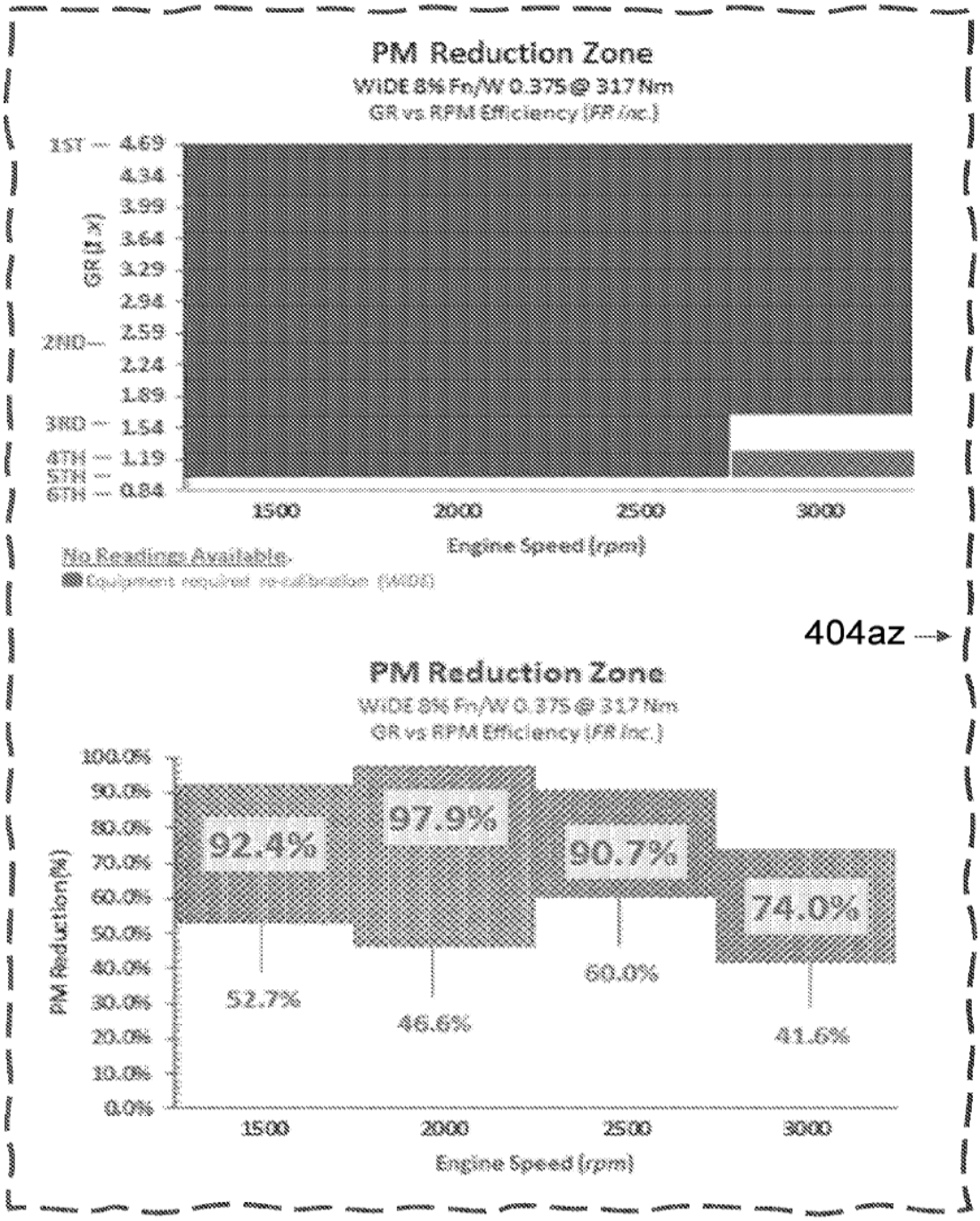


Fig. Forty-Two (42)

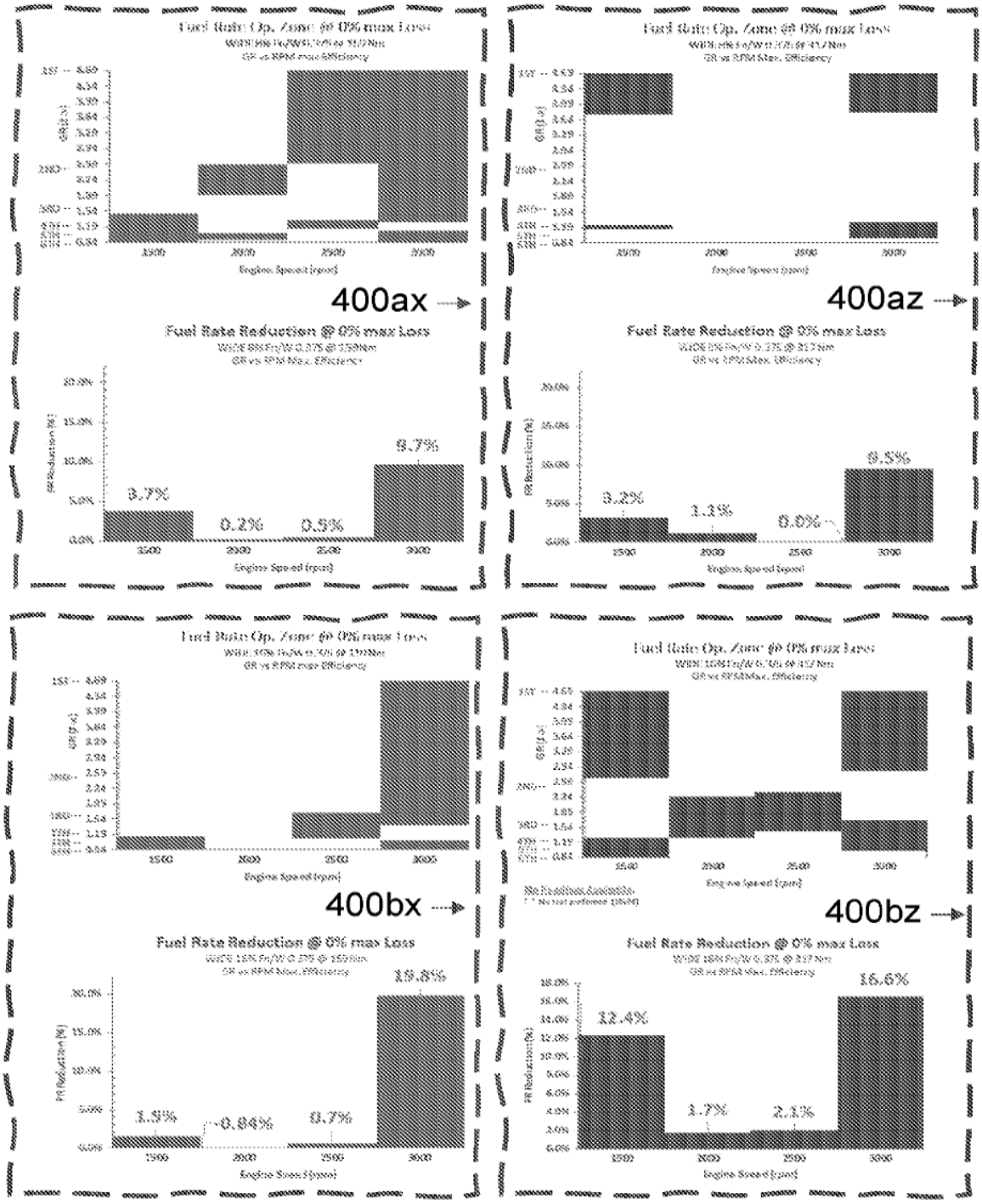


Fig. Forty-Three (43)

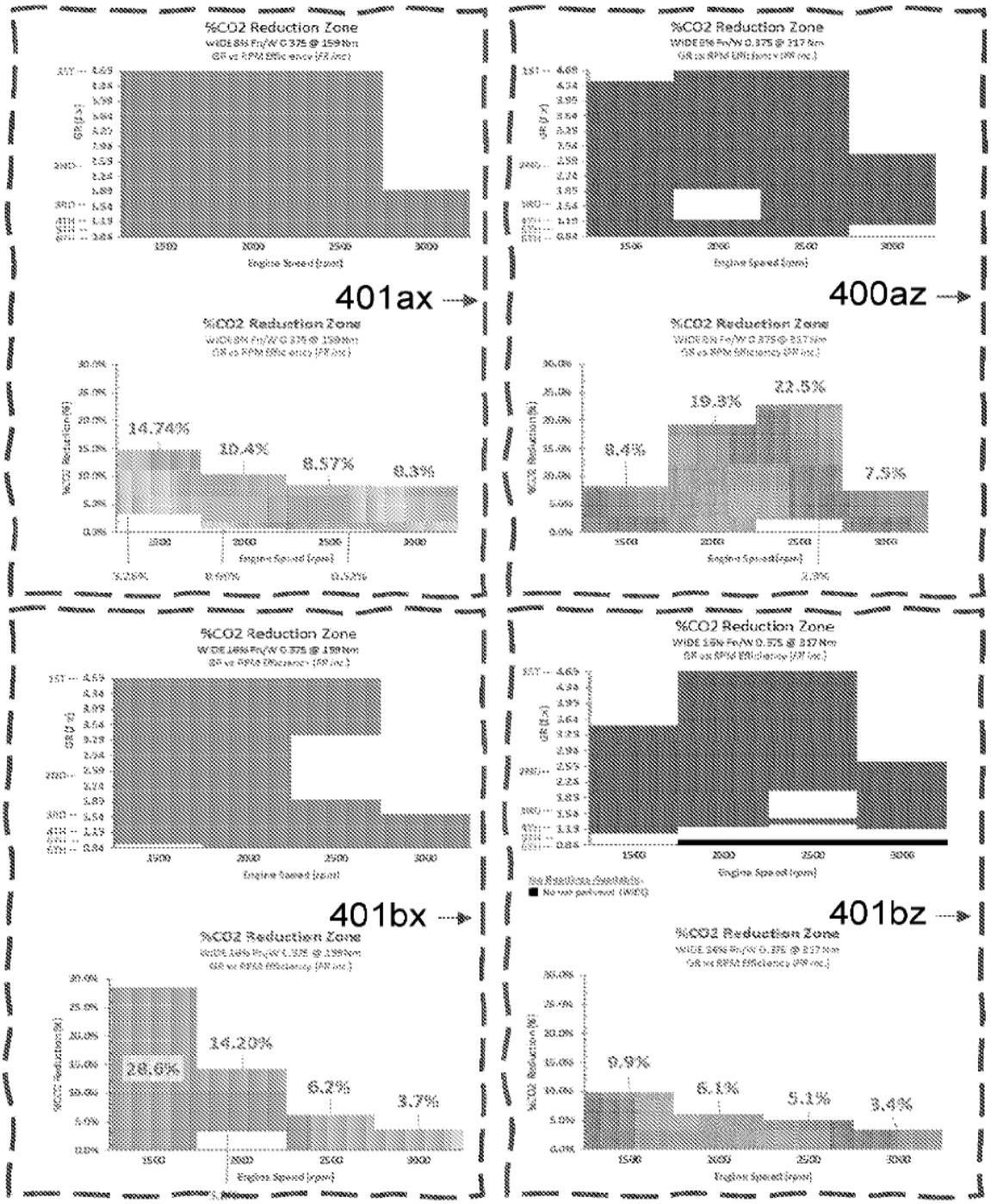


Fig. Forty-Four (44)

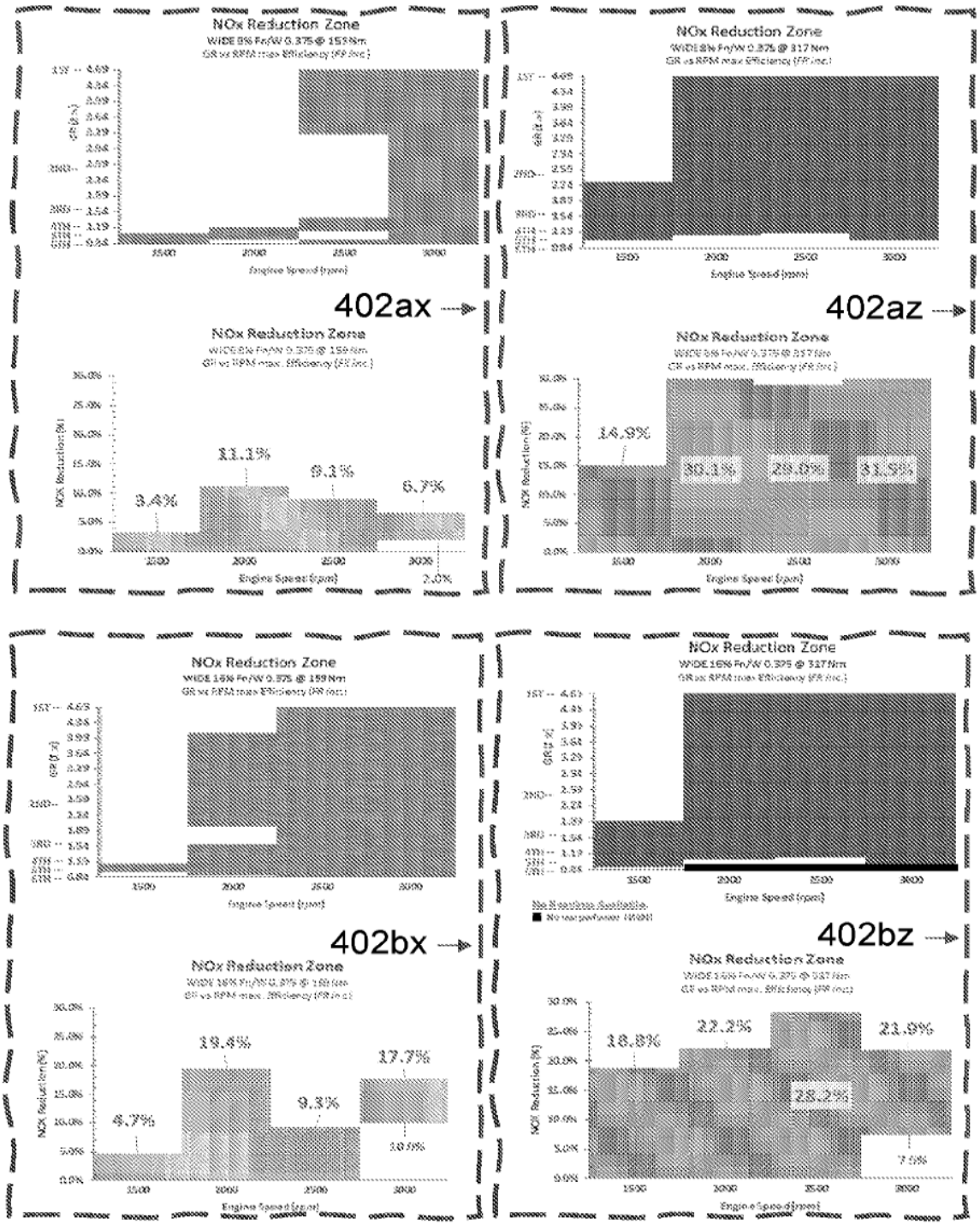


Fig. Forty-Five (45)

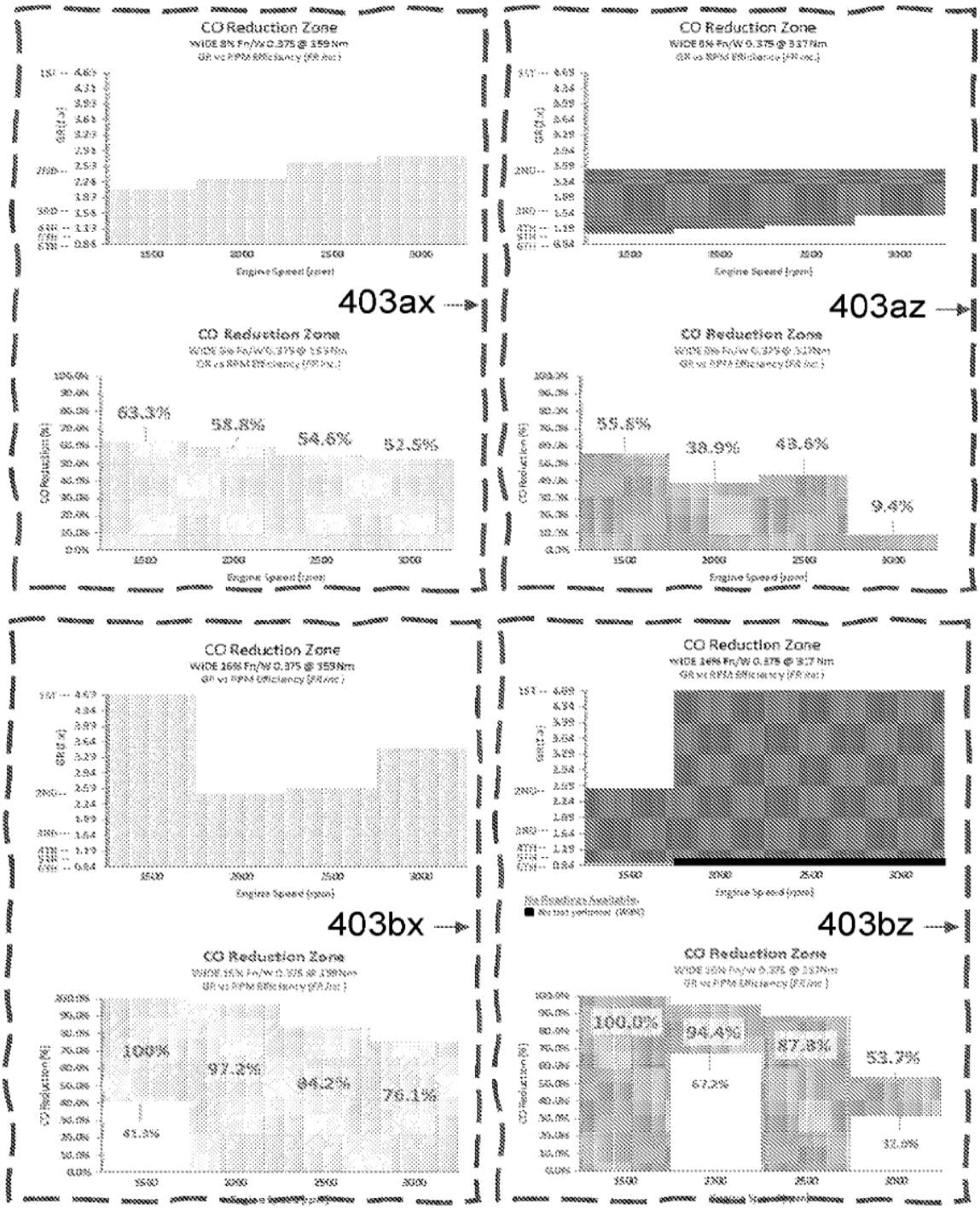


Fig. Forty-Six (46)

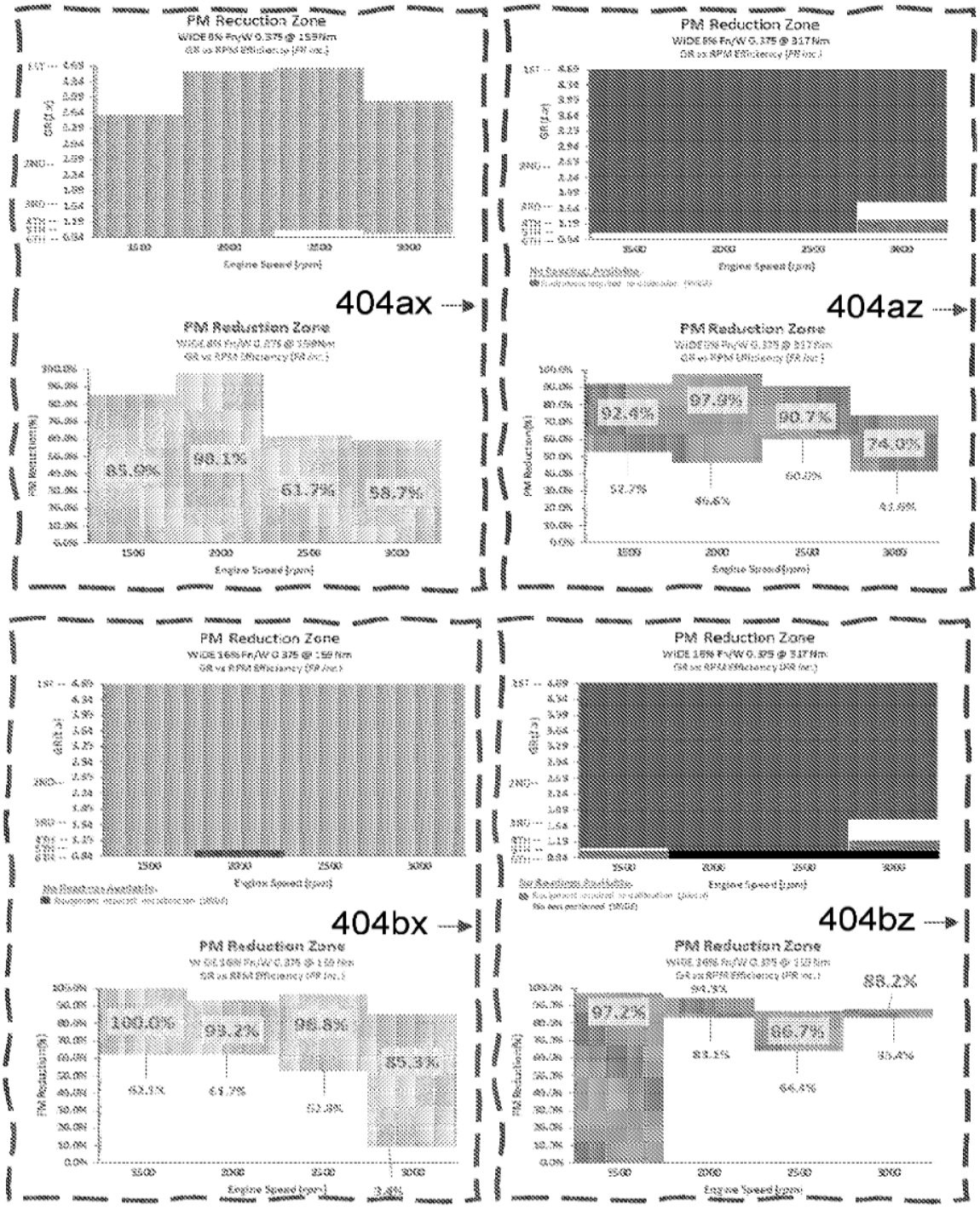


Fig. Forty-Seven (47)

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