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## **THERMODYNAMIC APPARATUS WITH AN INTEGRATED DYNAMIC MIXING SYSTEM. (Thermodynamic apparatus with an integrated dynamic system for real-time mixing and homogenization of fuel components using elements of artificial intelligence and artificial neural networks)**

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### **Abstract**

Any type of liquid hydrocarbon fuel, and especially fuel compositions based on liquid hydrocarbon fuels, tends to lose its homogeneity during storage. As a result, agglomerates and sediment formations occur, predominantly at the bottom of storage tanks containing the fuel or fuel mixture.

***The elimination of such heterogeneity can be most efficiently achieved through the innovative homogenization process developed by Kristina Bessarabenko, implemented by means of an innovative dynamic homogenization device that performs homogenization directly within the pipeline through which the fuel or fuel mixture flows.***

The homogenization process is carried out at a stable temperature or, under certain ratios and operational conditions, with a decrease in the temperature of the combustible liquid or fuel mixture.

The entire dynamic homogenization process is achieved by generating specific turbulent hydrodynamic conditions within the flow of liquid fuel or fuel mixture, without disrupting the chemical and physical equilibrium among its components.

**Keywords:** *Thermodynamic apparatus; integrated dynamic mixing system; homogenization process; hydrodynamic vortex tube; homogenization based on turbulence level; vortex generator; accelerating hydrodynamic section; coaxial Bernoulli effect*

## **Dynamic Fuel Homogenization Device for Internal Combustion Engines Necessity of the Homogenization Process**

Any type of liquid hydrocarbon fuel, and especially fuel compositions based on liquid hydrocarbons, loses its homogeneity during storage. As a result, agglomerates and deposits are formed, predominantly at the bottom of storage tanks containing the fuel or fuel mixture.

The elimination of this heterogeneity can be achieved most efficiently and conveniently by applying a homogenization process using an innovative dynamic homogenization device that performs the homogenization directly within the pipeline through which the fuel or fuel mixture flows.

### **Dynamic Homogenization Process**

**First, a brief overview of the proposed technology developed by Kristina Bessarabenko, including its distinctive features, novelty, and degree of innovation:**

The device for dynamic homogenization of liquid fuel and fuel mixtures consists of an accelerating hydrodynamic section transitioning into a second, coaxially aligned hydrodynamic section with an integrated vortex generator, which in turn transitions into a hydrodynamic turbulence amplification unit connected to the inlet of the high-pressure pump of an internal combustion engine.

Within the dynamic homogenization device, the entire flow of liquid fuel or fuel mixture is divided into two streams:

- The first stream (60% of the total flow), under a pressure of 3 bar (45 psi), is directed into the accelerating hydrodynamic section, where acceleration is achieved through system elements that initiate the formation of coaxial Bernoulli effects;
- The second stream (40% of the total flow), also under a pressure of 3 bar (45 psi), is directed into the second hydrodynamic section, coaxial with the first.

The device performs a dynamic process of sequential homogenization of the liquid fuel or fuel mixture flow.

At the first stage, homogenization is carried out based on the turbulence level with-

in the pipeline. Such a process is not implemented in any known homogenization devices or technologies and constitutes one of the core elements of the technological novelty, as confirmed by the foundational intellectual property documentation of the developer and technology owner.

Subsequently, the homogenized flow of liquid fuel or fuel mixture is transformed into a hydrodynamic vortex tube (due to the integrated vortex generator) and directed to the high-pressure pump of the internal combustion engine (operating at 2,000 to 3,000 bar, or 29,000–43,500 psi).

At this stage, a second phase of dynamic in-flow homogenization occurs, resulting in the reduction of particle size within the homogenized stream to below one micron. According to the key flow parameters, the medium is thereby converted into a homogenized liquid equivalent in properties to a nanoscale emulsion.

The homogenization process takes less than one second and does not disrupt any natural physicochemical interrelationships within the homogenized liquid fuel or fuel mixture.

The homogenization process is carried out at a stable temperature or, under certain ratios and operating conditions, with a decrease in the temperature of the combustible liquid or fuel mixture.

The entire dynamic homogenization process is achieved through the creation of specific turbulent hydrodynamic conditions within the flow of liquid fuel or fuel mixture, without disturbing the chemical and physical equilibrium among its components.

It should be noted that in advanced innovative projects – not only in fuel blending and dynamic homogenization processes, but also in analogous processes of mixing and homogenization, for example, of liquid food components – the above-mentioned positive effects manifest even more distinctly.

**Several years ago, Kristina Bessarabenko was among the first to successfully initiate work in this direction. She is a multidisciplinary specialist and a well-known international initiator of startup projects in which dynamic homogenization processes constitute the technological foundation for pro-**

**ducing new environmentally friendly products with fundamentally enhanced performance characteristics.**

**Based on the unique qualitative indicators of homogenized tea-and-milk blends invented by Kristina Bessarabenko, the implementation of dynamic homogenization methods in their production processes enabled these innovative products to enter global markets within a remarkably short period of time.**

**Due to the exceptional level of technological refinement of the group technology developed by Kristina Bessarabenko, a number of additional advantages of the process have been achieved.**

**Advantages of the Dynamic Homogenization Process Developed by Kristina Bessarabenko Compared to Existing Technologies**

- Existing technologies do not include a stage of dynamic homogenization based on turbulence level; therefore, they do not enable homogenization to be carried out directly within the fuel pipeline of an internal combustion engine;
- The second stage of homogenization in the proposed process is performed under pressure at least twice as high as that required for homogenization at the nanoscale particle level;
- The particle (globule) sizes in the liquid fuel or fuel mixture homogenized according to the proposed technology are uniform, ranging within 70–120 nanometers, and exhibit no tendency toward agglomeration. In contrast, existing technologies demonstrate a particle size distribution exceeding a ten-fold range – from approximately 0.2 to 2 microns;
- All stages of dynamic homogenization can be carried out directly within the fuel pipeline of an internal combustion engine, for example, between the fuel pump and the high-pressure pump, and do not require any special modifications to the engine design;
- During the dynamic homogenization process, the temperature of the ho-

mogenized liquid fuel or fuel mixture does not increase;

- The dynamic homogenization device enables the simultaneous introduction of additional components into the homogenized liquid fuel or fuel mixture (for example, water, methanol, or ethanol) during the homogenization process;
- The dynamic homogenization device has compact dimensions, is more convenient in operation than known analogues, and provides optimal conditions for installation and maintenance;
- The dynamic homogenization device for liquid fuels and fuel mixtures is significantly more cost-effective than existing equipment of similar purpose;
- The device may also be used for technological homogenization prior to introducing the fuel or fuel mixture stream into technological equipment for the production of other hydrocarbon-based products.

#### **Original Device for Dynamic Homogenization**

An original device for the dynamic homogenization of liquid fuels and fuel mixtures has been developed, manufactured, and repeatedly tested.

The device is extremely compact, with dimensions allowing its integration into virtually any internal combustion engine, including stationary engines (for example, marine engines) as well as engines installed in transport vehicles (such as automobiles of all types).

The device does not require any additional elements or components for operation and can be installed directly in the fuel pipeline of an internal combustion engine – after the fuel pump and before the high-pressure pump.

All inlet and outlet connection elements are standardized. Installation of the device on an internal combustion engine does not require special preparation, tools, or equipment.

The device contains no moving parts and may be manufactured in any required dimensional scale.

It can be produced using standard serial production equipment with numerical control (CNC). No special technologies, materials, or tools are required for manufacturing, assembly, or quality control.

### **Thermodynamic Effect of Using Homogenized Fuel**

(Obtained by Means of the Dynamic Homogenization Device)

After homogenization, the fuel combusts uniformly; following injection, no local zones with larger dispersion fractions are formed within its volume.

As a result, the combustion process proceeds 35–40% faster, and effective heat release is accelerated in the same proportion. These results have been confirmed in more than 60 test cycles conducted on a modern production diesel engine with a displacement of 2.5 liters.

The homogenization technology operates equally effectively in standard engine configurations as well as in engines equipped with exhaust gas recirculation (EGR) systems.

In the event of accidental water ingress into the fuel tank, dynamic homogenization – within milliseconds prior to the fuel entering the high-pressure pump – ensures the formation of a stable micro-emulsion and completely eliminates any harmful effects of water contained in the fuel emulsion on engine operation. These results have been confirmed in more than 60 test cycles on a modern production diesel engine with a displacement of 2.5 liters.

The resulting micro-emulsion, while maintaining effective engine power output, significantly reduces soot concentration in exhaust gases (reduction of 97%) and nitrogen oxide ( $\text{NO}_x$ ) concentration (reduction of 12%), shortens the complete combustion cycle duration, and accelerates heat release. These results have been confirmed in more than 60 full reversible test cycles on a modern production diesel engine with a displacement of 2.5 liters.

### **Environmental Effect of Using Homogenized Fuel**

The application of a dynamic liquid fuel homogenization device within the fuel system of internal combustion engines significantly reduces exhaust gas toxicity and may enable compliance with environmental standards in previously manufactured vehicles, including those that have been in long-term operation.

### **Sequential Dynamic Homogenization Process in a Modern Diesel Engine**

The dynamic fuel and fuel – air mixture homogenization device in a modern diesel engine is installed in the fuel line downstream of the fuel pump and upstream of the high-pressure pump.

The fuel flow after the fuel pump is divided into two streams. One stream, accounting for 60% of the total fuel flow, is directed to the central axial inlet of the dynamic homogenization device. The second stream, accounting for 40% of the total fuel flow, is introduced through an integrated inlet consisting of four radial channels.

After homogenization, the fuel combusts uniformly. Following injection, no localized zones containing larger dispersed fractions are formed within the fuel volume.

As a result, the combustion process occurs 35–40% faster, and effective heat extraction is accelerated proportionally. These results have been confirmed through more than 60 test cycles conducted on a modern production diesel engine with a displacement of 2.5 liters.

The homogenization technology operates equally effectively in engines with standard configurations and in engines equipped with exhaust gas recirculation (EGR) systems.

### **Sequential Dynamic Homogenization Process in a Modern Gasoline Engine**

In a modern gasoline engine, the dynamic fuel and fuel–air mixture homogenization device is installed in the fuel line downstream of the fuel pump and upstream of the high-pressure pump.

The fuel flow after the fuel pump is divided into two streams. One stream, accounting for 60% of the total fuel flow, is directed to the central axial inlet of the dynamic homogenization device. The second stream, accounting for 40% of the total fuel flow, is introduced through an integrated inlet consisting of four radial channels.

The homogenization technology operates equally effectively in engines with standard configurations and in engines equipped with exhaust gas recirculation (EGR) systems.

### **Application of the Dynamic Homogenization Process in Internal Combustion Engines Using an Ethanol – Gasoline Fuel Blend**

Ethanol, even of high purity, contains a certain amount of water.

Prior to blending (for example, with gasoline), ethanol is a sufficiently stable substance in which phase separation between water and alcohol does not occur.

However, an ethanol–gasoline mixture is not completely stable. Under certain conditions (for example, at reduced temperatures), water may separate from the gasoline – ethanol mixture.

If a dynamic homogenization device is incorporated into the engine fuel system, the water that has separated in the fuel tank from the primary hydrocarbon fraction of the fuel blend may, under specific conditions, be dynamically re-mixed with the hydrocarbon fractions within the homogenization device. As a result, the mixture is converted into a micro- or nano-scale emulsion.

Combustion of such an emulsion generally occurs in a stable thermodynamic regime, without detonation, and with reduced levels of soot and nitrogen oxides ( $\text{NO}_x$ ) in the exhaust gases.

### **Application of the Dynamic Homogenization Process in Internal Combustion Engines Using a Methanol–Gasoline Fuel Blend**

Methanol, even of standard commercial grade, contains virtually no water.

Prior to blending (for example, with gasoline), methanol is a sufficiently stable substance and, after mixing, does not significantly separate from gasoline.

Nevertheless, the methanol – gasoline mixture is not completely stable and, under certain conditions (for example, at reduced temperatures), may exhibit a tendency toward agglomeration or phase irregularities.

Combustion of homogenized fuel generally occurs in a stable thermodynamic regime, without detonation, and with reduced soot and nitrogen oxide ( $\text{NO}_x$ ) emissions in the exhaust gases.

### **Application of the Dynamic Homogenization Process in Internal Combustion Engines Using Gasoline Blended with Biological Fuel Compositions or Organic Fuel Components**

In such thermodynamic systems, the fuel consists of a mixture containing gasoline along with heavier biofuels and various types of viscous combustible biological materials. In these composite fuels, agglomeration and the formation of fuel clusters occur more intensively.

If a dynamic homogenization device is incorporated into the thermodynamic system, fuel clusters that have formed in the fuel tanks – consisting primarily of the main hydrocarbon fraction of the fuel blend – are dynamically re-mixed within the device with the remaining hydrocarbon fractions. This process converts the agglomerated mixture into a homogeneous system composed of micro- or nano-scale particles.

Combustion of the homogenized fuel generally proceeds in a stable thermodynamic regime, without detonation, and with reduced soot and nitrogen oxide ( $\text{NO}_x$ ) emissions in the exhaust gases.

### **Application of the Dynamic Homogenization Process in Fuel Supply Systems for Boilers, Turbines, and Other Thermodynamic Devices**

In the above-mentioned thermodynamic systems, heavier diesel fuels and various types of fuel oil are typically used as fuel. In such fuels, the formation of agglomerates consisting of heavier, high-viscosity fractions occurs more intensively.

If a dynamic homogenization device is incorporated into the fuel supply and injection system of the combustion chamber, fuel agglomerates that have formed under certain conditions in the fuel tanks – primarily consisting of the main hydrocarbon fraction of the fuel mixture – are dynamically re-mixed within the device with the remaining hydrocarbon fractions. As a result, the agglomerated structures are transformed into micro- or nano-scale particles.

Combustion of the homogenized fuel generally proceeds in a stable thermodynamic regime, without detonation, and with reduced

soot and nitrogen oxide ( $\text{NO}_x$ ) emissions in  
the exhaust gases.

In certain cases and under specific oper-  
ating conditions, significant fuel savings may  
also be achieved.

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