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**VORTEX GENERATOR; GASEOUS MEDIUMS VORTEX
MIXING DEVICE. (Aerodynamic and Hydro-Dynamic
Effective Technology For Vortex Tube Formation In Multi
– Gaseous Medium's; Effective Multistage Cooling and
Water Removing from Compressed Gaseous Stream's)**

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Abstract

This article examines the design, operational principles, and industrial applications of an innovative vortex generator system intended for high-efficiency localized mixing, cooling, turbulence generation, and dynamic gas–air homogenization in industrial and energy-related processes. Particular attention is devoted to the constructive and functional advantages of the vortex generator, including its focused turbulent impact, modular architecture, controllable operational parameters, ease of installation and maintenance, resistance to corrosive and extreme-temperature environments, and capability for integration into existing technological systems with minimal modification. The article further analyzes the application of ring vortex generators for dynamic mixing of natural gas with compressed air, highlighting the formation of controlled vortex channels that enhance diffusion penetration, turbulence intensity, pressure vector stabilization, and kinetic energy accumulation within the mixed gas stream. It is demonstrated that such vortex-induced structural transformations of gaseous media contribute to improved homogeneity of combustible mixtures, enhanced combustion preparation, and increased process efficiency. The article concludes that vortex generator technology constitutes a versatile and commercially valuable engineering solution with broad applicability across modern industrial, thermal, chemical, and energy infrastructure systems requiring advanced fluid dynamic control, precision mixing, and optimized thermodynamic performance.

Keywords: *Vortex Generator, Gas Medium; Vortex Tube, Water Extraction from Compressed Gas Flow, Aerodynamic and Hydrodynamic Technology, Vortex Tube Formation, Series of Vortex Generators, Vortex Generator Functions*

Introduction:

Vortex Generator is the solution to many industrial problems and therefore has a large variety of applications. The device produces rushing fluid that emerges at a high velocity and possesses a high kinetic energy. This creates a highly turbulent and powerful action in the medium where the device is submerged. The Vortex Generator functions aerodynamically or hydro-dynamically, depending whether a compressed gas or a pressurized liquid is utilized as the active fluid.

The modular and mobile construction of the device allows it to be totally flexible and customizable to any relevant industrial application. It consists of a series of Vortex Generators that are arranged specifically, depending on the size and shape of the object being acted on. The shape and size of the Vortex Generators are also variable to fit the shape and size of the operative surface. The tubing on which the Vortex Generators are mounted can be rigid or flexible, and can have many configurations, which makes the device applicable in tight spaces such as pipes and narrow tubes.

Fast-propelled fluids have many industrial applications in cooling, cleaning, rinsing

and mixing processes. When used for rinsing or cleaning, the device can be used on a local area or manipulated over a large area, as the application requires. Since it is light and maneuverable, it can be manipulated manually or automatically to bring it to the local operative surface or specific object. As an alternative, when the operative surface is extensive, a larger assembly consisting of many Vortex Generators can be assembled to operate simultaneously over the broad surface of the object.

The active power is greatest at the heads of the device; being applied locally at locations needed most. As a result, much less active fluid is utilized, reducing energy and time consumption. Another advantage of the device is the cooling. When combined with original Equipment, the Vortex Generator can be used as a more effective mixing and cooling system.

When used as a mixing apparatus, the device's action behaves as a highly efficient agent.

Taking into account its flexibility, maneuverability, and applicability, it becomes evident that Vortex Generator can serve as an extremely useful tool in today's diverse industrial market.

Table 1.

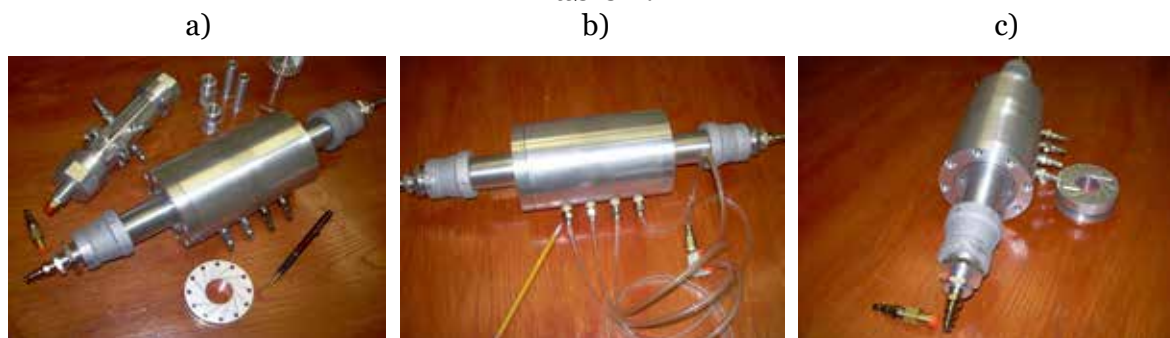
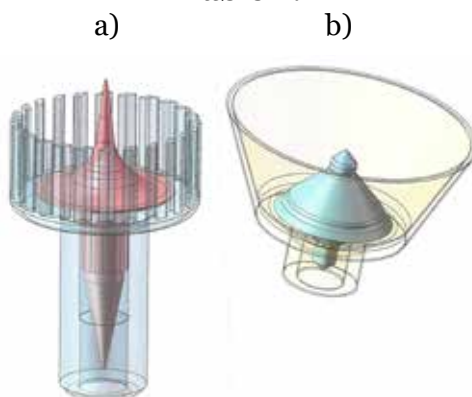


Table 2.



I. Advantages of Vortex Generator

Efficient performance

- The turbulent power of the Vortex Generator is not scattered over the entire medium, rather its full thrust is exerted locally (for cooling, like example) where it is needed most. As a result, much less active fluid is utilized, and less energy and time are consumed.

Complete control

- Since the active power of the Vortex Generator is focused, one can control how much and where to apply it. It can be applied more intensively on densely affected zones or evenly over the entire operative surface. The Vortex Generator also comes with a flow control valve that can be regulated manually or automatically. For example, in an automated system, the Vortex Generator can be mounted onto a robotic immersion arm and can be activated via a valve only while the object is submerged.

Modular design allows for easy customization

- The Vortex Generator System is comprised of multiple Vortex Generating Generators mounted onto tubing. Both the Vortex Generator and the tubing can be arranged in an unlimited number of configurations, each according to the size and shape of the operative surface. The Vortex Generator can thus be used in hard to reach places or tight spaces such as pipes and narrow tubes. The shape and size of the Vortex Generator are also variable to suit the physical parameters of the application. In addition, if process requirements change, the existing configuration can be adjusted accordingly to accommodate those changes.

Easy assembly and installation

- All of the tubing as well as the Vortex Generator's heads are assembled via threaded joints that simply screw into each other. The Vortex Generator's Assembly is provided with a flexible hose that is equipped with a standard hose fitting for easy connection to a source of compressed air.

Interchangeable parts

- All of the components are interchangeable and can be easily replaced even by non-technical operators, without the need for special tools or equipment. This gives the client an option to minimize down time by keeping a stock of replacement parts and servicing the Vortex Generator's System by himself.

Corrosion and extreme temperature resistant

- All of the components including the tubing and the Vortex Generator's are made of durable non-corrosive materials. These materials are resistant to reactive chemicals and temperature extremes, enabling to operate with virtually any active fluid and in any application. This translates into longer-lasting, more reliable performance.

Can be integrated into existing processes

- Vortex Generator's System can be connected into any functioning system with only minor modifications. No redesign or reconfiguration of the existing treatment process or its components is necessary. In many instances, the Vortex Generator can be used in addition to the existing system to supplement and enhance it.

Side benefits at use of a technique of vortex mixing natural gas with compressed air which arise at application of the device for mixing natural gas with air in the ring vortex generators located along one axis, conterminous with a direction of movement of a stream of natural gas;

The constructive device of vortex generators, allows to form a vortex pipe in which around of a stream of natural gas on a spiral the stream of compressed air which limits volume in which stream of natural gas and in which occurs diffusion penetration of compressed air into a stream of natural gas rotates moves;

Thus the vector of linear pressure of a mix in a direction of movement aside chambers of combustion accumulates kinetic energy of the incorporated streams of compressed air

both natural gas and kinetic energy of the vortex channel;

Such combination of energy and the form of the combined streams allows to mix dynamically an organic part of a mix with an oxidizer, keeping a high level of turbulence and uniformity of distribution of volumes of a stream in which the oxidizing agent and the combustible agent moves;

Process of mixing goes in parallel with physical transformations to gas streams which lead to structural changes in character of these streams, passing with reception of phase transformations of a condition of water;

Preliminary tests of a pre-production model of the device for mixing natural gas with compressed air, have shown correctness of these assumptions

So at submission in the device for mixing natural gas with the compressed air, compressed air under pressure in 3 atmospheres it was possible to receive a homogeneous stream of a mix with precisely designated vortex cylinder with pressure, a vector which is directed aside, continuous with a direction of movement of a stream of a mix to the chamber of combustion and the level of the pressure equal to pressure in a stream of compressed air a minus pressure in a stream of natural gas, that is, $-3 - 1.5 = 1.5$ atmospheres;

Thus streams of the compressed air having pressure above than a stream of natural gas, move on a tangential trajectory, compress a stream of natural gas and get into the center of this stream, keeping thus vortex character of movement;

Preliminary tests have shown a high level of controllability of process at the control and change only one parameter of mixing, – pressure in a stream of compressed air;

Process of mixing with use of vortex ring generators, has in parallel with diffusion mixing dynamic effect still a number of physical effects which are based on constructive advantages of system of ring vortex generators;

There is a speech about effects of the adiabatic expansions and movements of streams of the compressed gas in a vortex pipe which render an essential influence on temperature of gas streams;

Thus by results of preliminary tests it is possible to define presence of following ad-

vantages of vortex dynamic mixing of natural gas and compressed air:

- High uniformity of mixing; the level of uniformity between components of a mix on all volume of a mix makes more than 95% from all volume of a mix both in movement, and in static position;

- 100% an opportunity of the full control of proportions of mixing and concentration of components in a mix to within 1.5 milligram of natural gas on one liter of air;

- 100% an opportunity of change and adjustment of concentration and proportions of mixing;

- Low need for energy on process of mixing, due to use of some physical effects;

- 100% an opportunity of the control and regulation of temperature of a mix at all stages of mixing, including and a stage of formation of the vortex channel;

- An opportunity at mixing at the same expenses of energy to reduce temperature of a mix to necessary limits;

- An opportunity at controllable decrease in temperature in streams of components of a mix and in a stream of a mix after mixing to take from gases the water containing in them both simultaneously in regular intervals and homogeneously to distribute this water in the form of bubbles in the size of diameter no more than 10 micrometers on all volume of a mix in dynamic movement;

- 100% an opportunity to supervise and adjust pressure in a stream of a mix and speed of movement of a mix due to the control and changes only one parameter, namely pressure in streams of compressed air and natural gas.

Owing to the specified general parameters, there is a new level of operational advantages:

- A low general level of volume of all exhaust gases; an expected level of decrease more than 25% from volume of all exhaust gases arising at burning, – the reason sharp reduction of quantity of air of combustion directed to the chamber and not had time to take part during burning;

- A low level of toxic substances in exhaust gases, at a level of decrease on 75–95%, due to presence of particles of water in streams gas components of a mix, due to uniformity of a gas mix, due to a high level

of turbulence and dynamic volumetric three-dimensional mobility of a mix including during burning;

- Decrease in a level of the charge of a gas mix on burning, due to sharp reduction of expenses of time for hashing of natural gas with air and reception of a stable gas mix in which is available certain on its volume certain, controllable quantity of air homogeneously distributed on its volume;

- Decrease in the charge of natural gas on creation of a homogeneous gas mix and burning with reception of equivalent quantities of energy not less than on 25–45%, under condition of creation of a mix of a rattling mix not having proportions;

Considering explosion hazard of process, the active control of all elements of process has essential value;

The offered technology and its constructive realization, allow to conduct the control and management of process over a mode of real time with speed of reaction to any changes in parameters of process within the limits of 1 millisecond;

Additional opportunities which are available for system of dynamic vortex mixing streams of two gas environments

The design of the device for vortex mixing has high composition flexibility;

The same vortex generator can have the direction of tangential channels conterminous with a direction of a hour hand or directed counter-clockwise; it defines a direction of a vortex spiral and can serve as the tool for formation of various levels of turbulence in a stream of gases at mixing and after mixing;

At presence in the device for vortex mixing the several consistently located vortex generators, probably to change a direction of tangential channels at two adjacent vortex generators and to receive at the same expenses of energy increase in a level of turbulence of a mix in two and more times;

In the same way it is possible to adjust time in which current there is a process of mixing and formation of a vortex stream of a gas mix;

One of the important reserves of increase of efficiency of process of mixing is the opportunity of adjustment of pressure of gas

environments in a wide range from 2 atmospheres up to 20 atmospheres;

Separate maintenance of each of vortex generators the compressed air and absolutely independent work of each of vortex generators, enable even within the limits of the same devices for dynamic vortex mixing gas environments to establish a various operating mode for each of vortex generators;

As owing to formation on an output from tangential channels of a local zone of adiabatic expansions it is possible to receive decrease in temperature of the gas leaving each channels, increasing or reducing pressure of air it is possible to receive various temperature;

At submission on the vortex generator of air under pressure in 20 atmospheres it is possible to receive negative temperature on an output from the channel and to take water from air in the form of microscopic crystals of an ice which presence at burning improves quality of burning and in addition reduces concentration of toxic substances in products of burning on size of concentration of water in a gas mix;

So, if water borrows in a mix of 10% from weight of a mix it is considered to be, that the level of concentration of oxides of nitrogen and carbon decreases also on 10%;

If in the device for dynamic vortex mixing there are some vortex generators changing pressure of air which moves on each generator it is possible to receive water only in that place which is necessary, keeping thus a consumption level of energy and a level of efficiency of the device for dynamic vortex mixing;

The characteristics of the device for dynamic vortex mixing gas environments and components includes the basic base parameters and additional parameters which are received in addition to the cores due to basic and design features of vortex generators and the device for the dynamic vortex mixing gas environments using vortex generators as the basic technological tool;

The basic attributes of a characteristics:

- Controllable dynamic vortex homogeneous mixing two or more gas environments;

- Controllable and adjustable maintenance of any proportions between mixed gases;

- Controllable and adjustable input of each gas by criteria of the charge, pressure, a level of turbulence, a level of temperature, a level of linear speed of a stream;
- Formation of a vortex pipe from a mix of gases;
- Formation of two basic criteria and base physical effects for decrease in temperature in a stream of gases on all length of a vortex pipe or on local sites of a vortex pipe;
- Controllable and if necessary changeable direction of a spiral in a vortex pipe on its all extent;
- Controllable and adjustable change of a level of turbulence of a stream of gases in a vortex pipe during and after mixing;
- Controllable and adjustable condensation of water in a stream of gases at mixing and after mixing;
- Controllable and adjustable value of linear speed of movement of a stream of gases in a vortex pipe;
- Controllable and adjustable value of pressure in a stream of gases in a vortex pipe and on an output from it;
- Controllable and adjustable change of a direction of a spiral in a vortex pipe without change of a design of the device for dynamic vortex mixing gas environments.

Table 3.



All the specified basic attributes of a characteristics are new and are directed on increase of efficiency of the device for dynamic vortex mixing gas environments

Advantages of technology to dynamic vortex mixing gas environments

Efficiency of technology and the device for dynamic vortex mixing gas environments

The technology of dynamic vortex mixing of gas environments which is based on application of consistently located vortex generators, owing to use simultaneously several dynamic physical effects, has low consumption of energy and has side benefits in the form of two steps of cooling of gases at mixing and at least double increase in a level of turbulence;

All it is carried out due to one energy source, – the compressor which compressed air or any other gas submits, on vortex generators of the device

The full control over a mode of real time above all working parameters of the device for dynamic vortex mixing gas environments

The control over work of the device for dynamic vortex mixing gas environments is carried out by means of the control of the charge and pressure over streams of gas components of a mix;

Such kind of the control does not demand what or special devices and by means of standard reliable decisions pressure can automatic remote be adjusted;

Modular design of the device for dynamic vortex mixing gas environments

The device for dynamic vortex mixing gas environments has a modular design as in one device all vortex generators have the identical sizes and functions both their quantity and combinations can change easily at the customer's request

Convenient change of the basic target characteristics of the device for dynamic vortex mixing gas environments proceeding from conditions of the consumer

Owing to that in the device the unified details and standard components are applied only, performance of changes in performance data of the device does not cause what or difficulties.

Convenient assembly and connection of the device for dynamic vortex mixing gas environments

Owing to a high level of unification and corresponding design of details of the device for dynamic vortex mixing gas environments, assembly of the device at the consumer, connection of the device to the process equipment

at the consumer are extremely simplified and do not demand non-standard decisions.

**High level of interchangeability
of details and components of
the device for dynamic vortex
mixing gas environments**

As a rule in the device for dynamic vortex mixing gas environments 4 types of original details, all which design features are applied, the executive sizes and which principles of assembly are unified and correspond to requirements of operating standards.

**The prevention of influence of
corrosion and high working
temperature; an opportunity of use of
composite constructional materials**

The design of details and components of the device for dynamic vortex mixing gas

environments allows to make them of wide scale of constructional materials including composite materials steady against influence of corrosion and heats.

As in the device there are no mobile parts that and there is no harmful influence of corrosion and a heat on working capacity of the device.

**Integration into any industrial
technological process;**

The device can be integrated into any technological process owing to that its running cycle and a high level of efficiency do not depend on external processes, and can be supervised and be adjusted on the minimal number of parameters in a mode of real time and with use of standard devices and adaptations.

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