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ECOSYSTEM AND INFRASTRUCTURE OF A SMART IRRIGATION SYSTEM FOR DRIP IRRIGATION. (Linear equipment for drip irrigation with pre-saturation of water with oxygen before injection and with the possibility of using the same principle for cleaning and regeneration of linear pipelines of greenhouses and dairy farms)

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Abstract

The article examines the application of dynamic foam generators within integrated technologies for water treatment, regeneration, and recirculation, including their use in smart greenhouse systems and hydroponic complexes. Special attention is given to the influence of the scale factor on process efficiency and to the challenges of selecting optimal technological solutions among numerous existing methods. The study describes a new principle of foam generation based on the use of compressed air introduced into liquid through a device operating according to the Bernoulli principle, enabling precise control of bubble size and improving foam performance.

The paper highlights the simplicity, adaptability, and economic advantages of the proposed equipment, including linear systems for drip irrigation with pre-oxygenation of water and their application in pipeline cleaning and regeneration. It also presents modular and miniaturized water treatment systems suitable for small-scale operations, emphasizing cost-effectiveness and ease of maintenance. In conclusion, the proposed approach demonstrates high efficiency and versatility, contributing to improved performance of modern irrigation and water treatment systems.

Keywords: *Dynamic foam generators; dimensional factor of a foam generator; application of dynamic foam generators; integrated technologies; cleaning, regeneration, and recirculation of water; smart hydroponic system; control of heavy metal concentration; linear equipment for drip irrigation*

Introduction:

Application of dynamic foam generators in integrated technologies for water treatment, regeneration, and recirculation, including their use in smart greenhouse systems and smart hydroponic systems.

There are many different basic technologies for water treatment and regeneration of process water solutions, and a wide range of materials, including composite ones, is available on the market for the same purpose. However, when it becomes necessary to make a final decision on selecting a specific technology and material for a particular case, difficulties arise in comparative analysis.

The latest technological ideas in this and related fields encounter significant challenges during implementation due to the strong influence of the scale factor on the results of various operations in water preparation, purification, and regeneration for recirculation.

As is often the case in engineering, especially in innovative developments, gripping devices of specialized robotics have revealed properties and capabilities that ensure effective foam generation when compressed air from a vacuum gripping device, operating according to the Bernoulli principle, is introduced into a liquid (water).

During the first experiments, it was discovered that the prototype of the future foam generator, due to the air flow thickness being no more than a few microns, can regulate the diameter of air bubbles in the foam by adjusting the gap between the membrane and the housing.

This indicator and technical parameter proved to be extremely important, providing flexibility and a wide range of possibilities for foam generation processes based on a new principle.

In addition, the load-bearing capacity of the foam obtained in this way turned out to be significantly higher than that of conventional foam.

The ease and precision of regulating the diameter of air bubbles in the foam are demonstrated by the fact that the foam structure in the same liquid and in the same container can change when the gap between the membrane and the housing is adjusted.

This simplicity is ensured by the exceptionally simple design of the foam generator.

When forming irrigation systems, the cost factor is of the greatest importance, which in modern conditions of an innovation-driven economy and a market saturated with various types of equipment ultimately becomes decisive.

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Linear equipment for drip irrigation with pre-saturation of water with oxygen before injection and with the possibility of applying the same principle for cleaning and regeneration of linear pipelines in greenhouses and dairy farms.

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The first two photographs show models of a module for water treatment and regeneration for greenhouses.

The capacity of such a module is 2,000 liters per hour, and this value can be increased by adding two-section columns for ion-exchange purification of water or irrigation solutions.

Figure 1.

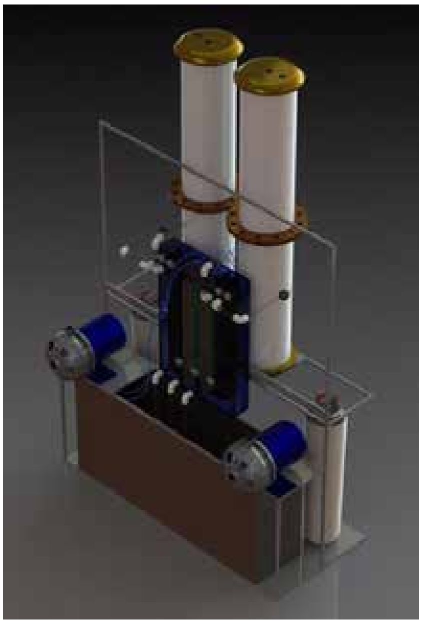
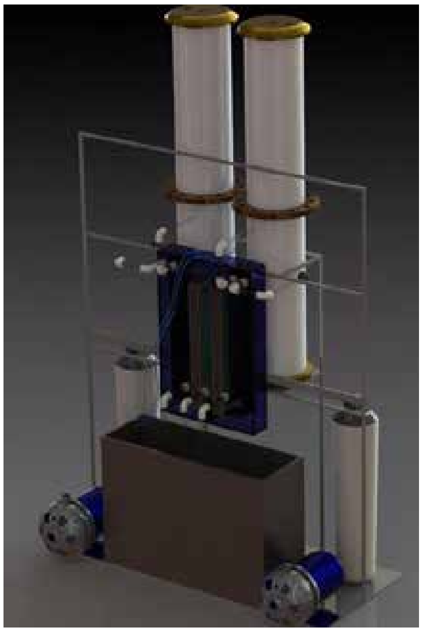


Figure 2.



As can be seen from the model, at least two additional columns can be used as a reserve, which can double the module's capacity. The same applies to increasing the number of electrochemical reactors by a factor of two.

The structure and cost, as well as the cost of operation and maintenance of specialized equipment for water treatment and purification, also play an important role in evaluating the cost factor.

Ultimately, these same factors affect the overall efficiency of greenhouse operations and the final cost of products.

Since the formation of conditions for capsule generation, as well as the mixing and dissolution of air and oxygen, occur directly in the drippers or nozzles, the module is freed from these functions, which makes all processes within the module more efficient and stable.

In order to максимально simplify the operating scheme of the module, a mini-module has been developed for very small greenhouses, the three-dimensional models of which are shown in the following two photographs.

As can be seen from these images, everything in these modules is максимально simplified, and the principle of communicating vessels is used for their operation, which made it possible to eliminate pumps.

Everything in these modules is extremely simple, and they can be serviced even by non-technical personnel; that is, such a module can be installed in a very small greenhouse and achieve maximum efficiency, essentially equivalent to that of a full-scale module.

Despite its simplicity, such a module can perform multifunctional tasks, and its presence in the irrigation equipment market can fundamentally change the situation and significantly increase the efficiency of relatively small greenhouse operations.

Importantly, the design of these modules allows the use of electrochemical reactors of various types and purposes, as well as inlet columns both with different types of fillers and without them.

All of the above can be implemented thanks to the method of electrochemical treatment in an upward flow of liquid, in this case water.

In addition to all the purely technological advantages, it is necessary to note the exceptional cost-efficiency of this type of equipment.

For small greenhouse operations, in order to maintain their competitiveness, the cost of such equipment should have minimal impact on the final cost of products.

In the case of irrigation technologies, the issue of minimizing water consumption and achieving water savings is also of primary importance; however, both in engineering and in agricultural practices, environmental standards make this issue particularly critical.

Figure 3.

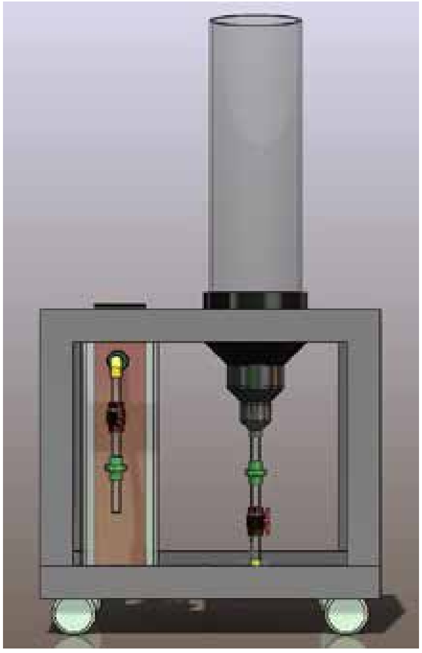


Figure 4.

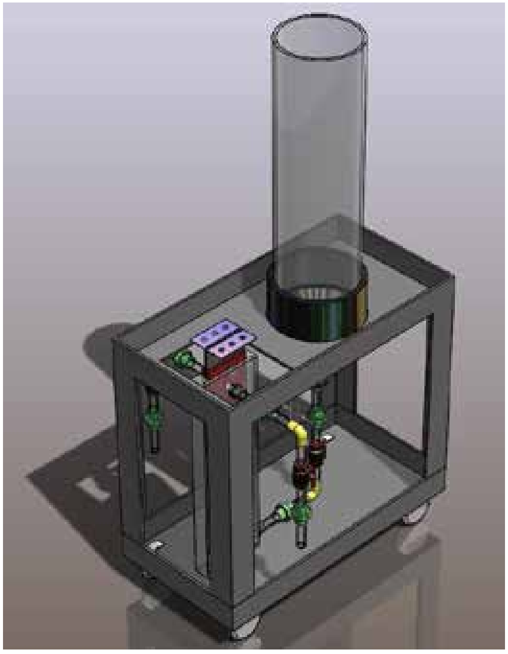
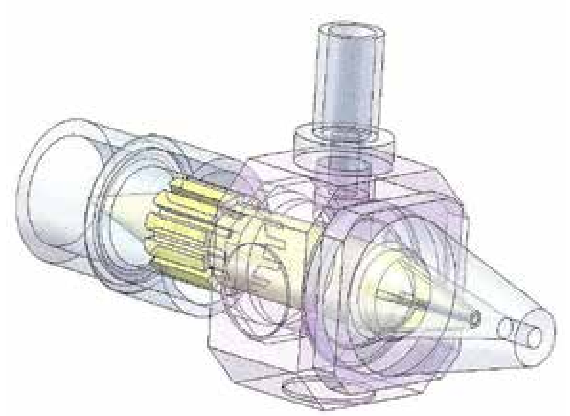


Table 5.



The requirement to comply with environmental standards, in addition to purely technical challenges, imposes additional responsibilities on developers of agrotechnological systems, both in terms of efficient use of water resources and in achieving the most effective application of water from the perspective of modern plant cultivation in specific greenhouses and hydroponic complexes.

One of the key factors in evaluating irrigation efficiency is the time factor, which determines the duration of contact between the root structure of cultivated plants and water.

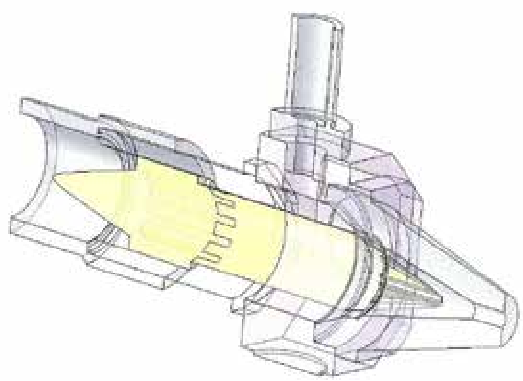
Considering that drip irrigation is currently recognized as the most effective method, the saturation of water droplets with air before they reach the soil is one of the factors determining success.

The presented three-dimensional models show variants and designs of drippers with integrated devices for mixing and saturating water with air bubbles.

When designing such drippers, several limiting factors were taken into account, in particular the requirement for efficient operation at low water and air pressure, as well as the requirement for uniformity of air bubbles within the water capsules.

Given the need for a large number of such drippers, their cost-effectiveness is a key factor in solving the problem.

Table 6.



To substantiate the high economic efficiency of the drippers, it is also necessary to note their exceptional structural simplicity combined with maximum functionality.

What is especially important is that the design of the drippers contains no moving parts, and the structural implementation of the components and the entire device allows for mass production using any production cycle, from a wide range of materials and manufacturing methods.

Extensive possibilities for optimization and modification of the product make it possible to produce several variations of these изделия in parallel on the same production equipment while maintaining the required quality level and with minimal costs for reconfiguration and adjustment of the manufacturing process.

Considering that the main consumers of this range of products will be relatively small enterprises and greenhouses with limited resources, such an approach to design and to defining technical characteristics makes it possible to achieve maximum commercial success while preserving existing production equipment.

All dripper components are easily unified and can be manufactured both by machining and by injection molding.

Figure 7.

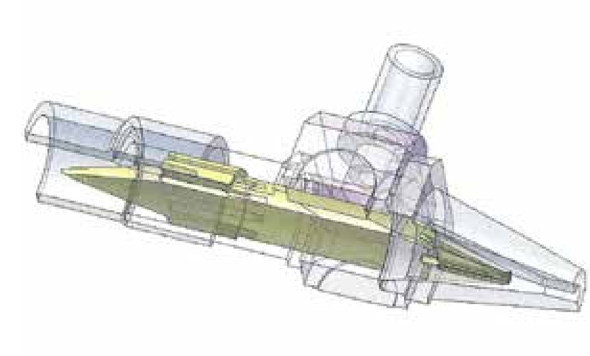
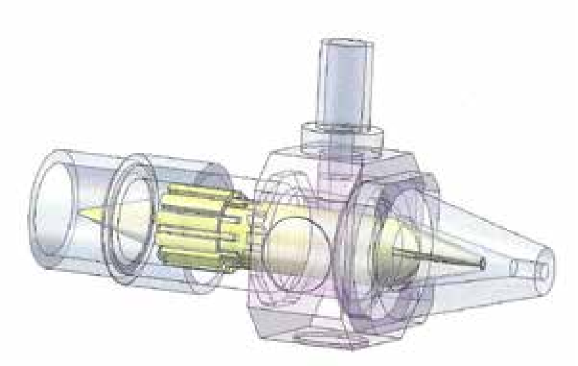
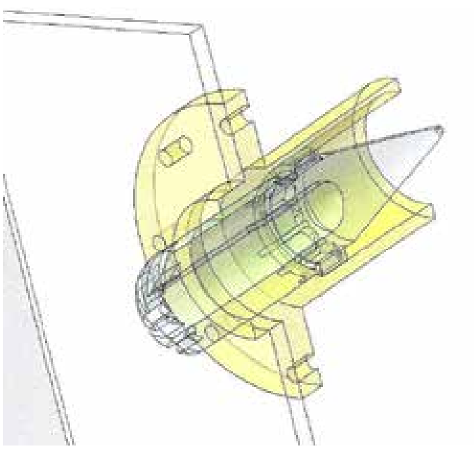


Figure 8.



The same devices can be used with a high degree of efficiency as nozzles and effective mixers for all types of liquids.

Table 9.



In addition to their use in the format of drippers with pre-injection treatment, these same designs can be applied with slight modification as active local mixers.

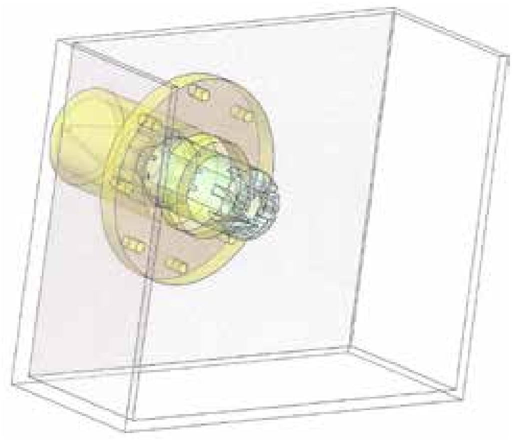
For this purpose, instead of an injector, a vortex generator is implemented on the central element, which injects the supplied liquid into the process vessel in the form of a vortex hydrodynamic stream.

As a result, stagnant zones in the process vessel are eliminated, and the injection process is integrated with the process of hydrodynamic activation of the solution within the process vessel.

In application to the storage of hydroponic solutions in intermediate technological containers of small volume, where standard activators cannot be used, the use of drippers modified with vortex generators for hydrodynamic activation makes it possible to achieve the required level of storage quality for hydroponic solutions, with almost complete unification of technological equipment and a significant reduction in maintenance, adjustment, and operational costs.

The positive properties and capabilities of such equipment also include the ability to combine the process of introducing liquid into the process vessel with the involvement of the introduced liquid in the process of hydrodynamic activation, with minimal costs.

Table 10.

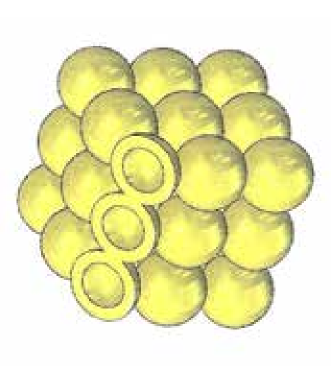


The use of these devices as activating elements in stagnant zones of process baths and vessels makes it possible not only to significantly improve the quality of process solutions, but also to ensure the real possibility of continuous regeneration of these solutions in order to reduce their consumption and lower storage costs for process solutions and liquids.

The dripper designs can also be independently used as both linear and local foam generators.

Analysis of the foam produced by such generators has shown a clearly defined capsule structure, in which numerous microcapsules are present, each containing a compressed air or gas bubble as the core, while the surrounding оболочка is formed by the base liquid of the solution, most often water.

Table 11.



Structural transformation in such foam makes it possible to obtain a so-called compressible liquid.

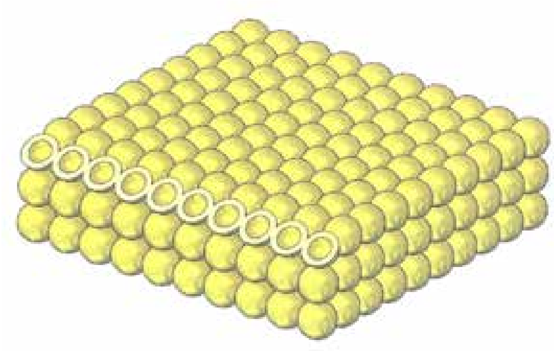
If, in an electrochemical reactor, a liquid with a high level of alkalinity is produced without the use of chemical reagents, then the foam from such a liquid becomes an ideal cleaning and disinfecting agent, especially for cleaning and disinfecting surfaces intended for bonding reinforcing or light-protective films.

In addition, further study of solar energy processes has revealed a significant shortage of silicon for the production of solar panels.

Increasingly, specialists are turning to the application of silicon films onto pre-treated glass surfaces.

Before application, in order to prevent various chemical reagents and heavy metal ions contained in water from reaching the glass surface, it is best to treat the surface using alkaline and acidic solutions that do not contain chemical reagents – that is, foam obtained from water with adjusted acidity or alkalinity.

Table 12.



Use of flexible membranes and thin films:

- instead of conventional structures, use flexible membranes and thin films;
- isolate the object from the external environment using flexible membranes and thin films.

This approach should be divided into micro- and macro-level components.

This method is also an important element, for example, in nanoscale technologies.

Consider, for example, the process of preparing a fuel emulsion. If an emulsion is formed, for instance, from diesel fuel and water, the only guarantee of the success of such a fuel emulsion is its structure, in which micro-droplets of water are surrounded by a thin film of diesel fuel.

After such an emulsion is injected into the combustion chamber, the water, which evaporates earlier than the diesel fuel, breaks the diesel оболочки into nanoscale particles during evaporation, which is far more effective for achieving an optimal combustion process than, for example, a sharp increase in injection pressure that would require strengthening the structural elements of the cylinder-piston group of the engine.

This same approach can form the basis for inventions in which, for example, an electronic board in areas intended for intensive heat exchange is coated with an ultra-thin film of synthetic diamond.

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