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CONCEPT OF SMART HOME INFRASTRUCTURE. (Innovative smart home infrastructure components for energy supply, backup energy storage, water supply, and water treatment)

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Abstract

This article examines innovative smart home infrastructure components designed for energy supply, backup energy storage, water supply and purification, water regeneration and recirculation, clean air provision, air regeneration, and oxygen enrichment, as well as the issues of integrated real-time monitoring and control of these systems. The article emphasizes the importance of integrating advanced technical and software solutions corresponding to the global state of the art in technological and structural innovation in order to enable the implementation of artificial intelligence and artificial neural network elements in smart home design and operational processes. Particular attention is devoted to the logistics of generating innovative technical solutions within the framework of modern smart home, smart building, and smart house infrastructure, as well as to the methodological aspects of developing technical solutions possessing both inventive merit and commercial potential. The article substantiates the necessity of a systematic approach to the evaluation, structuring, and commercialization of new technologies with due consideration of market requirements, investment attractiveness, production constraints, and objective economic factors. It is concluded that the development of modern innovative solutions in the field of smart infrastructure requires a transition from autonomous standalone inventions to comprehensive integrated technological ecosystems capable of ensuring sustainable competitiveness and compliance with contemporary infrastructural, environmental, and social requirements.

Keywords: *Smart home infrastructure; smart home infrastructure components; innovative smart home infrastructure components; innovative smart home infrastructure components for energy supply; innovative smart home infrastructure components for backup energy storage; innovative smart home infrastructure components for water supply, water treatment, regeneration, and recirculation; innovative smart home infrastructure components for clean air supply, air regeneration, and oxygen saturation; comprehensive integrative issues of active real-time monitoring and control of these components and their interconnections.*

Characteristics of the Integrated

Nature of the Proposed Technology

Analysis of the proposed technology with respect to the use of only known and repeatedly tested physical principles and laws embodied in a compact integral engineering or technological solution;

Analysis of the proposed technology and the device (method) for its implementation, allowing their application in real industrial systems without the slightest change or modification of their design or the slightest alteration of their operating principle;

Analysis of the proposed technology with respect to the use of only known and widely utilized components and combinations thereof;

Analysis of the proposed technology with respect to the possibility of integrated use, alongside widely known components, of new components in various combinations with known ones, which are formed within the proposed process due to the properties and characteristics of the device for implementation of the proposed technology;

Analysis of the proposed technology with respect to the level of universality and flexibility allowing flexible technological schemes to be applied within the same device or method for implementation of the technology;

Analysis of the composition of the proposed technology with respect to the possibility of use or presence of a system for control, monitoring, and regulation of parameters based on a minimum number of monitored and regulated process parameters having direct dependence upon and immediate influence on the efficiency level of both the process itself and the device during its operation, taking into account the achievement of required technological, energy, and environmental results;

Description of the process.

Possible components of the proposed technology and device.

Description of design variants of the device taking into account the possibility of integrated activation and increased efficiency of its principal operating principles.

Description of advantages for the process obtained during operation of the proposed device due to the properties and characteristics of the device itself.

Description of known tested technologies preceding the emergence of the proposed technology and of how they positively influenced this technology and its output parameters and characteristics.

Characteristics of the proposed technology.

Sequential description of the technological stages of the proposed process.

Principal schematic of devices and components included in the industrial system utilizing the proposed integrated technology.

Operating procedure of the proposed device based on the example of its implementation in a real industrial system.

Operational characteristics of the proposed technology at the initial stages of application.

Operational characteristics of the proposed technology at subsequent stages of its application.

Methods for regulating the principal operating characteristics of the proposed technology; possibility of remote control of the regulation process; principal regulated parameters; feedback during regulation.

Principal operating parameters of the proposed technology forming its advantages over known alternatives and technologies.

Description of the proposed process or of the comprehensive/integrative nature of the proposed technology; advantages arising from implementation of the proposed process or technology.

Estimated and calculated characteristics of the proposed process.

Technical and commercial advantages of application of the proposed technology; its possible integrated nature and the influence of this aspect.

Work with the block diagram of patent-licensing strategy.

After completion of the above analysis of the situation, a sufficient amount of information may be accumulated for preparation of patent-licensing strategy block diagrams.

Depending on the complexity of the technical solution, the block diagrams may differ substantially; however, such diagrams will certainly be more effective and reliable if, prior to their preparation, a forecast is made regarding the development of the field of technology to which the proposed technical solution or the subject matter of the future invention belongs.

At present, numerous informational tools exist for such forecasting, and their analysis in combination with understanding of the technical and commercial essence of the invented technology allows such forecasting to be carried out with sufficient accuracy.

Thereafter, the initial sections of the block diagram may be completed in accordance with the proposed template and the planned implementation may be carried out.

This article examines innovative smart home infrastructure components relating to water supply, water purification, water regeneration, and water recirculation.

There exists positive global experience in water treatment without the use of chemical materials and reagents.

The installation uses membrane filters in parallel with automatic self-cleaning mechanical filters, and three dual electrochemical reactors are integrated into the installation, which transforms the installation into a relatively large unit requiring significant space for installation and connection, thereby creating substantial difficulties for many residential properties, including those having smart home status.

Figure 1. Shows such an innovative installation for treatment, purification, and regeneration of wastewater



Therefore, during the formation of smart home infrastructure, this issue was taken into account from the earliest stages, and the concept of water treatment, operation, and recirculation for smart home needs was substantially redesigned.

Electrochemical Treatment of Industrial Wastewater for Purification from Heavy Metal Ions and for Enabling Repeated Reuse of Purified Water in Recirculation Mode

This problem arose long ago in the field of industrial wastewater treatment.

Purification of Industrial Wastewater From Heavy Metals

The principal problem in modern industrial production is the necessity of using

water for technological processes and maintaining the required level of water quality throughout the technological process.

Because it is impossible to maintain the required water quality level for prolonged periods, water that has completed its service cycle is removed from the process and replaced with new water possessing the required properties and parameters.

Because the cost of water is constantly increasing, efforts are being made to identify methods for repeated reuse of water resources.

In addition, the requirements for water discharged from technological processes are continuously increasing, and such water must be brought to required standards before discharge into sewage systems.

Informational Materials on Global Industrial Production Associated With Generation of Waste In The Form of Aqueous Solutions Containing Metal Ions

The principal sources of wastewater contamination by metal ions include:

- rinse waters from electroplating facilities of all types;
- water used for cooling hot metal surfaces;
- water used for washing transport and process containers for chemical reagents and materials;
- water used in rinsing after metal pickling;
- water used in metallized paint and coating application processes;
- water used in mining operations.

In general, the volume of water requiring special treatment prior to disposal amounts to no less than 200–250 cubic meters per day for an average enterprise engaged in electroplating operations.

To illustrate the overall volumes of water requiring treatment and purification, annual water consumption for air-conditioning systems with water-cooled heat exchangers in Israel may be cited as an example, amounting to approximately 150,000,000 cubic meters per year.

General Classification of Wastewater; Place of Electrochemical Technologies Within This Classification

Industrial wastewater is classified as follows:

- water not containing metals in ionic form;
- water containing metals in ionic form in concentrations up to 1 gram per liter;
- water containing metals in concentrations up to 5 grams per liter;
- water containing metals in concentrations up to 10 grams per liter;
- water containing metals in concentrations exceeding 10 grams per liter.

In all such cases, metal ions may be present either in pure form or in the form of chemical complexes comprising metals and various non-metallic materials and compounds, including organic substances.

Electrochemical technologies are capable of exerting real influence on all types and classes of wastewater, including water not containing metals, specifically through acidity/alkalinity adjustment and turbo-flotation for separation of conductive and dielectric components of aqueous solutions.

Classification Of Technical Solutions For Wastewater Purification; Methods of Metal Removal From Wastewater

Approximately 16 different technological methods of purification of metal-containing wastewater are known.

The most widespread is purification using chemical reagents, whereby caustic soda is added to water to increase alkalinity until metal hydroxides precipitate.

Artificial coagulation and flocculation methods need not be considered due to their poor economic efficiency resulting from high cost.

The only method capable of competing with chemical reagent treatment in terms of cost and efficiency is electrocoagulation.

This method has recently gained popularity, especially in high-technology industries, but it cannot comprehensively resolve all existing problems.

Transition to electrocoagulation systems at enterprises currently using chemical reagent purification requires substantial capital expenditures while failing to solve all fundamental problems.

All known methods fail to solve the problem of water purification for repeated reuse and, consequently, the problem of reducing water consumption for technological needs.

Popularity of Existing Water Purification Technologies

As noted above, the most common technology remains purification of wastewater using chemical reagents.

Electrocoagulation technology has recently begun gaining popularity.

Market positioning and competitive landscape of the proposed technologies

These technologies are applied at virtually all enterprises using water for technological purposes.

There exists a vast number of local integrator companies which construct purification systems based on general purification principles and customer-specific requirements.

Large consumers such as Intel utilize major companies concentrating broad water purification technologies, but even these companies – such as Vivendi, France – use local integrators as subcontractors.

Thus, major corporations are technology rights holders granting smaller companies rights to use their technologies, while large customers rely upon guarantees of technology holders.

Free Market Niches and How New Smart-Home-Suitable Technology May Occupy Them

The majority of water treatment technologies currently used involve chemical reagent processes.

The niche of non-chemical reagent technologies is practically unoccupied.

Even less occupied is the niche of non-chemical technologies that do not generate difficult-to-dispose waste, which is critically important for smart home applications.

At present, such technologies are practically absent from the market, and seven technological modules derived from electrochemical process specialists' developments, together with all modifications and configurations, provide grounds for occupying market sectors related to comprehensive purification, regeneration, and repeated reuse of water resources, including smart home water infrastructure.

As of today, no technologies have been identified that enable regeneration and repeated reuse of industrial wastewater with minimal economically acceptable costs and near-complete absence of toxic waste.

Furthermore, electrochemical processing modules can be integrated into existing installations and lines utilizing chemical and other technologies.

In such cases, electrochemical processing modules solve local technological tasks while significantly increasing the technical level of existing technologies.

Entry into the smart home market for electrochemical technologies through this category is therefore substantially facilitated.

Current Main Competitors of Electrochemical Processing Technology

At present, technologies proposed on the basis of electrochemical methods are not used anywhere due to the substantial novelty of these technologies.

Once the principal base elements of the technology are implemented, the most likely competitors may become large companies such as Zenon (Canada) and Vivendi (France).

Particularly novel is the method proposed for smart home infrastructure involving aerodynamic foaming and resulting separation of conductive and non-conductive fractions in treated water or aqueous solutions.

This problem currently hinders broader implementation of electrochemical technologies.

This innovative method has been tested and demonstrated promising results.

Comparison of Electrochemical Processing With Similar Technologies

The most advanced currently used technologies for purification of metal-containing wastewater are electrocoagulation technologies.

Despite their advantages over older chemical methods, electrocoagulation does not resolve all critical issues of water purification and possesses substantial disadvantages eliminated by the integrated electrochemical processing technology.

The principal advantages of electrochemical processing technology include:

- absence of need for sedimentation processes;
- absence of toxic waste requiring complex and expensive disposal methods;
- absence of process sensitivity to acidity level of treated water and no need for acidity correction;
- universality of electrochemical reactor modules allowing inexpensive and simple customization for customer-specific conditions while preserving core technological and structural principles, including smart home water treatment principles;
- possibility of broad and deep standardization of electrochemical processing modules;

- possibility of integration into any technological line;
 - possibility of preliminary separation of conductive and non-conductive components of aqueous solutions;
 - possibility of combining electrochemical metal extraction with natural and biological ion-exchange materials.
- Separate consideration should be given to the economic advantages of electrochemical processing technology.

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