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THE WAYS OF INCREASING ENVIRONMENTAL-ECONOMIC EFFICIENCY OF TECHNOLOGICAL SYSTEMS (BASED ON MARINE TRANSPORT)

ABSTRACT

The modern industrial systems are selectively developing on one vector – economic efficiency, profits – to the damage of the second vector – environmental safety. This gives rise to the World Global problems:

1) limitations and depletion of non-renewable nature resources;
2) environmental issues to the environment, biosphere and human life.

For the operating conditions of marine transport there are considered the ways of solving environmental and economic problems of unidirectional action.

As a result of conducted scientific and experimental researches, the technology, that allows to increase economic efficiency and environmental safety of shipping, is developed.

Relatively to a particular ship, techno–economic performance of the suggested technology is calculated, the absolute and prevented environmental and economic damage to the air are defined, the layout for installation of the complex systems on board is designed.

It should be noted, that the proposed concept of the unidirectional action, that consists of the two main vectors – economic and environmental – can be used in other technological systems as well.

Keywords: technological systems, raw material resources of non-renewable nature, sea transport, economic efficiency, environmental safety, absolute, prevented damage, installation, vessel, concept.

The era of non-renewable hydrocarbons passed its "peak" and maximum in the 70-ies of the 20th century and steadily goes to its end.

The area of gas and oil production moves to Maritime shelves, deep sea developments, the Arctic latitudes. Production of the shale oil, gas and processing of bituminous sand are developing quiet fast and productively.

In article [4] the World's reserves of oil and natural gas, their duration of work and operation are characterized.

At the General Assembly of the United Nations (29.09.2015) the idea of an uncontested transition to non-hydrocarbon raw materials was promoted by the heads of the major leading world countries to meet the growing needs of technological systems.

In article [4], the conceptual problems of the transfer of technological systems from hydrocarbon to non-hydrocarbon, a hypothetical strategy of gradual transition to non-hydrocarbon raw materials are proposed and a model of obtaining non-hydrocarbon energy, using raw materials with a large number of stock that is available and cheap is developed.

At the International Energy Congress in Turkey (Istanbul, 10.10.2016) the current structure of the distribution of the World's energy resources is given (Fig.1).

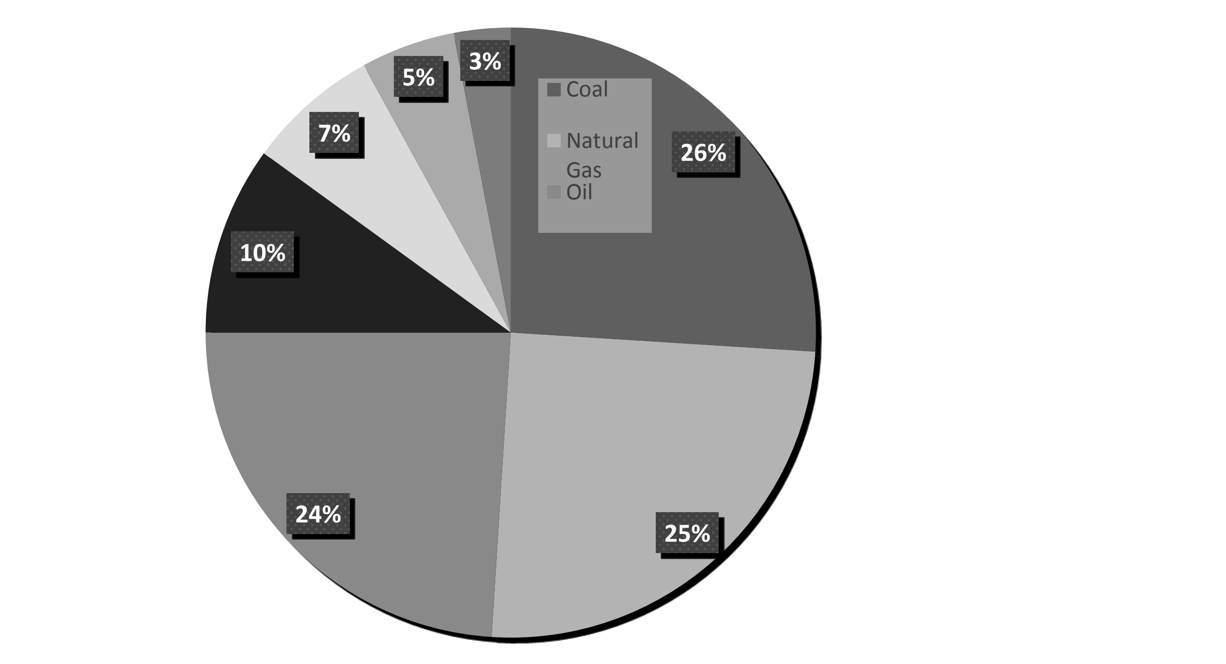


Figure 1—Global energy balance

From Figure 1 it follows that at present non-renewable energy resources (82%) are dominated compared to renewable one (18 %).

Forty years ago the structure of the World's resources was described in a following way (%):

Coal – 26%; Oil – 32%; Natural gas – 17% (Total 75%);

Biofuels – 15%; Nuclear energy 4%; the Eternal energy – 0.5%; Hydro energy – 5,5%.

It must be noted, that in the intervening period (1976-2016) the share of eternal energy has been increased in 10 times, the share of nuclear energy has been increased in 1,75 times, while the total contribution of primary energy non-renewable nature has been remained at the same level—75%. It must be noted, that during this period the total mass of produced and manufactured energy has been increased.

Nowadays, air pollution by emissions of man-made systems is one of the main environmental problems.

A progressive increase in the volume of sea transportation leads to the high level of toxic compounds emissions into the air. The International Convention MARPOL 73/78 of the International Maritime Organization (IMO) contains Annex VI, which prescribes the "Regulations for the prevention of air pollution from ships", which are compulsory for all vessels, fixed and float drilling rigs and production platforms established over the boundary of the territorial waters of coastal countries [7]. "Regulations..." are tightening the requirements of reduction exhausted gas toxicity of ship power plants (further EG SPP).

The aim of this article is to systematize and analyse modern methods of neutralization EG SPP, find advantages and disadvantages of these methods, choose the most effective method for purifying EG SPP.

To reduce the concentration of harmful components in the EG SPP to the maximum permissible limits, there are following methods of the clean-up, neutralization and disposal of EG SPP [8]:

1) physical cleaning (condensation, membrane separation);
2) physical-chemical purification (absorption, adsorption, pyrolysis);
3) heterogeneous catalytic deactivation;
4) transfer of SPP to using gaseous fuels (LNG – Liquid Natural Gas);
5) using of the water-fuel emulsion as the fuel;
6) the use of hydrogen, alcohols, ethers as ship fuel.

Condensation method is used to remove impurities from gases by cooling them to a temperature below the dew point of the removed substance. This method is effective at cleaning EG SPP from hydrocarbons and other organic compounds with a high boiling temperature under normal conditions and a high concentration. The advantage of this method is simplicity of hardware design and operations with the installation. The disadvantages of this method are the high costs of refrigerants and electricity. Condensation method is considered to be cost-effective only then, when the concentration of hydrocarbon vapours in the EG SPP ≥ 100 g/m^3, which significantly limits the scope of application of condensing type installations.

Absorption is the partitioning of the gas-steam-air environment by absorbing one or more components of this mixture by liquid absorbent. The absorbent is selected from the conditions of solubility of the absorbed gas therein, temperature and pressure, the rate of gas flow.

Adsorption methods for gas purification are used for removal of gaseous and vaporous contaminants. Methods are based on the adsorption of impurities by porous solid materials such as adsorbents. The most widely used adsorbent is activated carbon, which is used for purification of gases from organic vapours, removing unpleasant odours and gaseous contaminants contained in industrial emissions and volatile solvents. The advantage of adsorption method is high degree of purification. The disadvantages of the adsorption method are – frequency processes and the impossibility of purification gases, that containe dust, aerosols.

Pyrolysis is a special type of cracking, carried out at high temperatures (650-800˚C).

Heterogeneous catalytic cleaning methods are designed to transform toxic compounds in low-toxic, neutral compounds which are characterized by a high degree of purification α≥99,99%. While catalytic neutralizing of the harmful toxic compounds of the EG SPP catalysts, which should have the following properties – high activity, developed porous structure, resistance to catalyst poisons, mechanical and thermal stability, high selectivity and low hydraulic resistance, are used. The oxidation process intensively proceeds in the presence of copper-chromium, copper-zinc, copper-manganese catalysts. At a temperature of 350 to 400˚C the most of the organic matter are undergone full oxidation, the degree of conversion is α=98.5-99.99% [2].

Nowadays, the search for constructive solutions in the SPP, alternative fuels, additives to reduce pollution of the air EG SPP continues. When choosing the best and the most effective method for purifying EG SPP from toxic substances, it is necessary to pay attention to the type of diesel power, the mode of its operation, type of fuel and impurities therein in it, that each element, used of such a combined system, contributes to increasing of the propulsion efficiency (PE) of SPP, the reducing of thermal pollution of the air, reducing damage to the marine environment, air during the operation of the ships. On the bases of analysis, it is suggested to use reactors of catalytic neutralizatin of toxic components on vessels [2].

There are two types of catalytic neutralisation EG SPP [2,8]:

1. Oxidation.
2. Reduction.

The main toxic compounds (CO – carbon monoxide, CH_x – hydrocarbons, SO_2 and NO_x – the oxides of sulphur and nitrogen) contained in the EG SPP, as a result of catalytic reactions are transformed into neutral, harmless substances (carbon dioxide, water, nitrogen, gaseous elementary sulphur).

Processes occur in the following equimolar reactions [8]:

$$CO^G + 0,5O_2^G \xrightarrow[t,c,p,\tau]{[K]oxi} CO_2^G + Q_1 \tag{1}$$

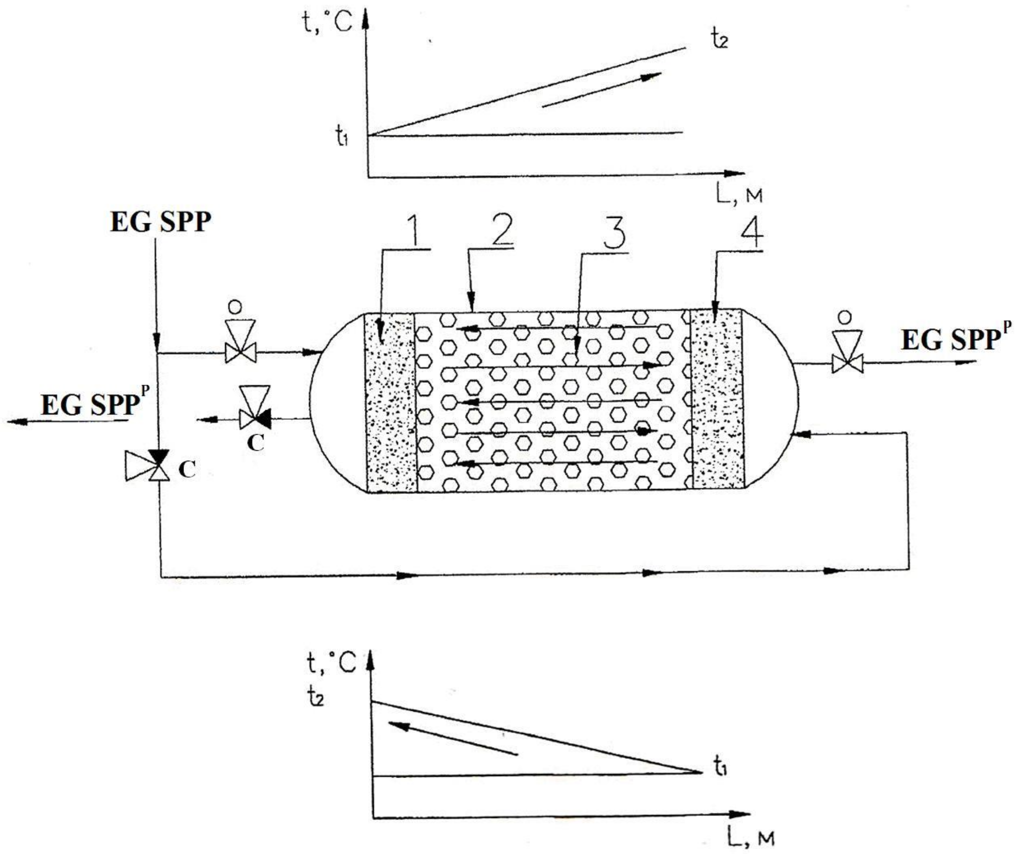
$$CH_x^G + \frac{3}{2}O_2^G \xrightarrow[t,c,p,\tau]{[K]oxi} CO_2^G + H_2O^V + Q_2 \tag{2}$$

$$CO^G + H_2O^V \xrightarrow[t,c,p,\tau]{[K]oxi} CO_2^G + H_2^G + Q_3 \tag{3}$$

$$SO_2^G + 2H_2^G \xrightarrow[t,c,p,\tau]{[K]Red} S^{SP} + 2H_2O^V + Q_4 \tag{4}$$

$$2NO_2^G + 4H_2^G \xrightarrow[t,c,p,\tau]{[K]Red} N_2^G + 4H_2O^V + Q_5 \tag{5}$$

An efficient catalytic method of neutralization of harmful components of the EG SPP in the transient regime has been developed, the essence of which is to change the input / output stream at certain time intervals [8]. The cold gas with the temperature t_1 enters the heated zone of a catalyst at a temperature t_2. The cold gas, while progressing through the catalyst bed be means of exothermic reactions (1-3) of oxidation is heated and reaches temperature t_2 (the process is described from left to right) (Fig.2). Further, the flows change [8].



1, 4 – inert packing;
2 – reactor;
3 – catalyst;
EG SPP and EG SPP^P are accordingly the contaminated and purified gas;
– shut-off and regulating valve: O – open, C – closed;

Figure 2 - The non-stationary reactor [8].

The non-stationary type reactor allows to conduct catalytic neutralization of harmful toxic compounds in EG SPP by method of oxidation reactions (1-3), to exclude from the scheme regenerative heat exchanger, which is one of the most important benefits of the suggested process [8].

In Annex VI of MARPOL 73/78, IMO provides stringent measures to limit the content of sulphur compounds in marine fuel. The concentration of sulphur compounds in marine fuel in Special Control Areas (SECA, ECA) must not exceed 0.1% by weight. (since 01.01.2015) [7,8].

In result of performed calculations, it was determined firstly, that material costs for the purchase of low sulphur marine fuels far exceed the amount of the prevented damage to the air from EG SPP, and therefore, the proposed way of taking the ship on low-sulphur fuels is not productive [1].

The Wartsila company (Finland) suggested a method for purifying EG SPP from sulphur dioxide in scrubber installations by fresh water running. However, the proposal of the Wartsila company has several disadvantages, which don't allow this technology to be considered as promising for practical implementation in the vessels, particularly [8]:

1. Soot, contained in EG SPP, scores a scrubber installation until the complete stop of the cleaning process.
2. It is low absorption capacity of fresh water relatively to the sulphur dioxide.
3. Large overall dimensions of the scrubber installation for purifying EG SPP does not allow it to be placed on the board.
4. Transfer of sulphur dioxide from gas phase to liquid phase has no practical meaning at protection of the marine environment.

The complex scientific works on toxic compounds neutralizing and extra-heat recycling of EG SPP are conducted [3,4,6]. Based on these works, patent of Ukraine for useful model No. 100295 from 27.07.2015 is developed. It demonstrates the most comprehensive and effective protection of air from sulphur compounds [5]. In the integrated process for purifying EG SPP toxic compounds are transformed into marketable products of high quality and low cost [5]:

1. Carbon soot.
2. The monohydrate of sulphuric acid, which concentration may vary in a wide range – 35-95% by weight at the request of the consumer.
3. Disposal of high-potential heat of EG SPP.

Process for purifying EG SPP from sulphur dioxide takes place in three stages according to the reactions [5]:

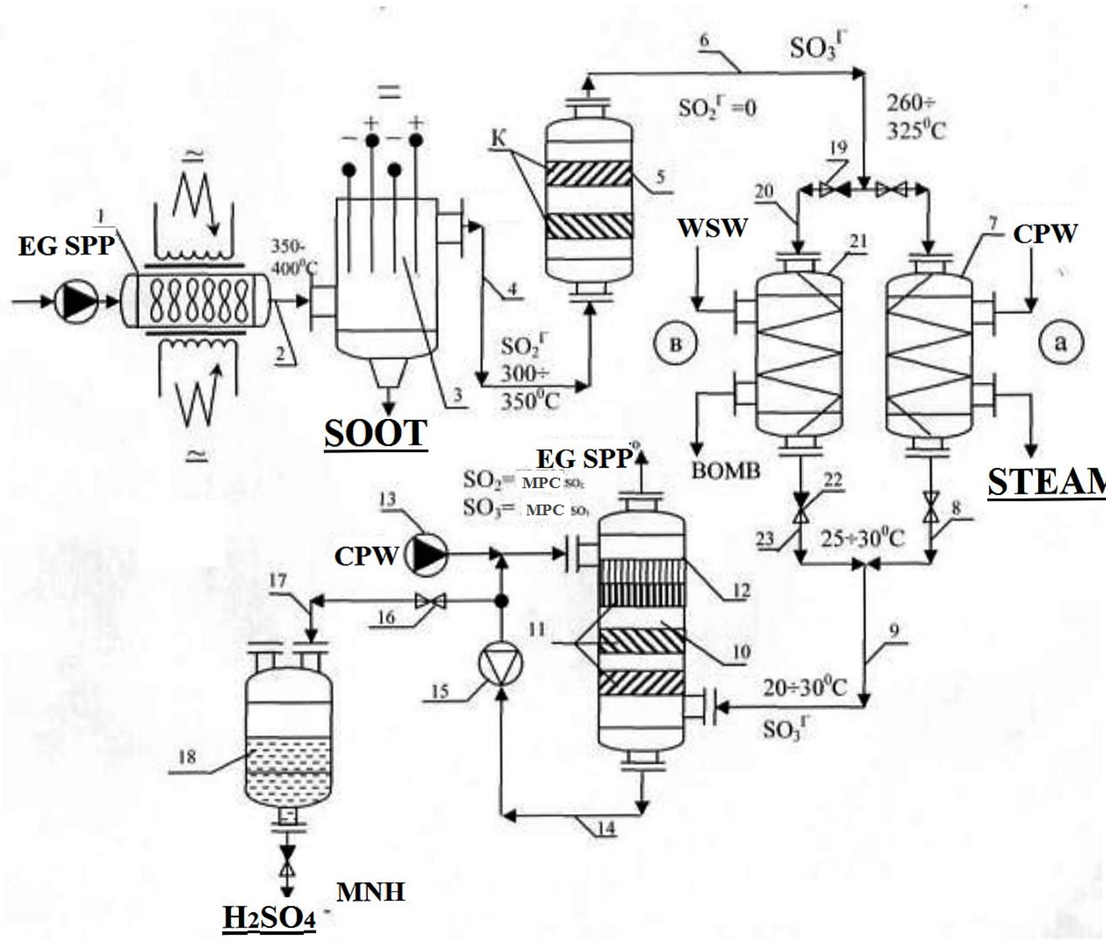
$$EG\ SPP^{C} + \text{electrofilter} \xrightarrow[450^{\circ}C]{t=350-} EG\ SPP^{P} \quad (\uparrow \text{soot}) \tag{6}$$

$$SO_2^{G} + 0{,}5O_2^{G} \xrightarrow[t=300\text{-}350^{\circ}C]{[K]BAV} SO_3^{G} + Q_2 \tag{7}$$

$$SO_3^{G} + H_2O_{XOB}^{L} \xrightarrow[t=20\text{-}30^{\circ}C]{absorption} H_2SO_4^{L} \tag{8}$$

where EG SPP^{C} and EG SPP^{P} - EG SPP, accordingly, containing the soot and purified from soot, L-liquid phase.

The method is carried out according to the integrated installation [5,9] (Fig. 3)



CPW – chemically purified water;
WSW, BOMB - respectively sea and wasted sea water.
MNH – monohydrate;
MPC – maximum permissible concentration;
EG SPP – contaminated gas;
EG SPP° - purified gas;

Figure 3 - Neutralization installation of EG SPP [5].

Conclusions. Analysis of methods for the purification of exhaust gases of ship power plants, their advantages and disadvantages shows, that the development and usage of effective purification installations (patent of Ukraine for useful model No. 100295) is simple and economical in reducing emissions of oxides of carbon, sulphur, nitrogen and other toxic organic substances of the EG SPP, which allows to implement the requirements of "Regulations for the prevention of air pollution from ships", The International Convention MARPOL 73/78 of the IMO, European directives on air protection from vehicle engines EURO – 3,4,5. Moreover, it helps to increase ecological and economic efficiency of the vessel, to obtain the target products on board.

Serdyuk A.D. - the cadet of the Navigation specialty of Kherson State Maritime Academy, Ukraine, is involved in writing this article.

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USING THE LINEAR MODELS IN COMPLEX SYSTEMS

ABSTRACT

This article is a summary of the standard linear units of the classical theory of automatic control in the form of typical models of dynamic systems, which simplifies the modeling of complex systems in the early stages of their research and the mathematical description.

Keywords: modeling, the standard linear units, frequency characteristics, complex systems.

The vast majority of dynamical systems including control systems are characterized by non-stationary and non-linear processes. Methods of mathematical modeling of such systems are quite complex, it is also aggravated by the presence of many controllable and uncontrollable external factors. Using this approach important in building an adequate model. However, in the early stages of the development of control systems is necessary to form a general idea of the subject area, of the processes in the control object.

Using model-based approach, it becomes reasonable detail of complex systems by function and sub-elements, up to the standard linear units, known in classical control theory. The modeling of the typical processes can only be piecewise into linear intervals for a short duration of time (e.g. equal to the time cycle of the process) where the object has linear portions of the static characteristic.

In classical control theory there are six standard linear circuits to describe linear systems. This paper are generics the standard models based on the relevant standard linear circuits with display of dynamic characteristics inherent physical processes with the ability to model of processes and systems in various spheres of human activity [1].

1) The transfer model (proportional circuit) describes the ratio of output and input information and material flows without time-consuming processes of transformation:

$$y(t) = k_n \cdot v(t)$$

where *v(t)* - input information and material flow; *y(t)* - output flow; k_n - coefficient of the transfer characterizes the change in the output flow to the change of the input flow, $k_n = \frac{\Delta y}{\Delta v}$.

Examples of the typical processes are the ratio of volume of the finished product to the raw materials, the production productivity.