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**НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ ЦИВІЛЬНОГО ЗАХИСТУ УКРАЇНИ**

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## CALCULATED SUBSTANTIATION OF CHOICE OF UNITS OF MONETARY EQUIVALENTS OF COMPLEX FUEL AND ECOLOGICAL CRITERIA COMPONENTS

This article describes results of calculated choice substantiation of monetary equivalents units complex fuel and ecological criteria components on example of autotractor diesel engine 2Ch10.5/12. The study found that difference in the values of monetary equivalents of these ctiteria components, expressed in the selected currency – USD and UAH, can reach one order for the present value of their ratio and close to two orders when compared their values for 2003 and 2016 years, due to different economic and political factors. But the study also shows, that USD as a world reserve currency due to inflation can not be an absolute monetary equivalent of such ecological criteria components. It was propose to use mathematical apparatus of Consumer Price Index for taking into account inflation phenomenon. Scientific novelty of the research results is that for the first time carried out calculated substantiation of choice of prof. Parsadanov complex fuel and ecological criteria components monetary equivalents. Practical value of the research results is that with modified mathematical apparatus can be carried out assessment of ecological safety level of exploitation process of emergency and rescue equipment, which powered with piston ICE of different years of release.

**Keywords:** technogenic and ecological safety, complex criterial assessment, fuel and ecological efficiency, monetary equivalents, emergency and rescue equipment, diesel engine.

**Problem statement.** *Relevance of the study.* Exploitation process of any power plants (PP) units, which are in commercial or personal use and equipped with diesel piston internal combustion engines (PICE), as it can be seen in article [1], may be characterized by certain ecological safety (ES) level [2–4] with the prof. Parsadanov complex fuel and ecological criteria $K_{FE}$, described in [5] and taking into account legislative established on Ukraine territory requirements, contained in [6]. ES factors for such objects is pollutants mass hourly emissions with its engines exhaust gas (EG) flow, which produces in large quantities during normal (with no accident) exploitation process. Values of that criteria may be used for calculated assessment of functioning effectiveness of ecological safety management system (ESMS) and described in [2] in accordance with evaluation conception which was developed in study [3]. Also values of that criteria may be used for calculated assessment of activities for increasing of PP with PICE ES level [1].

**Analysis of the recent researches and publications.** But monetary equivalents of $K_{FE}$ criteria components in monograph [6] are expressed in UAH, that associated with some problems described in article [7], where was some hypotheses have been put forward. In present paper that hypotheses will be find its confirmation by the results of calculated study. It will be carried out for example of autotractor diesel engine 2Ch10.5/12, description and technical characteristics of which are given in [6]. Initial data for calculated assessment were obtained in studies [8, 9].

*Purpose of the study* is calculated choice substantiation of monetary equivalents units of prof. Parsadanov complex fuel and ecological criteria components.

*Object of the study* is mathematical apparatus of prof. Parsadanov complex fuel and ecological criteria.

*Subject of the study* is monetary equivalents units of components of object of the study.

*Tasks of the study* is:

1. Analysis of methodic and mathematical apparatus of prof. Parsadanov complex fuel and ecological criteria taking into account the essence of put in study [2] forward hypotheses.
2. Modification of mathematical apparatus of $K_{FE}$ criteria in order to be able assess its value for the individual representative modes of the diesel operation in its exploitation model as well, as in study [1], based on the initial data obtained in studies [6, 7].
3. Calculated choice substantiation of monetary equivalents units of prof. Parsadanov complex fuel and ecological criteria components on example of autotractor diesel engine 2Ch10.5/12 for regimes of 13-mode standardized steady testing cycle.
4. Analysis of results of the study.

*Methods of the study* is analysis of specialized science and technical literature, processing of motor bench experimental testing data, calculating of middle exploitation values of technical, economical and ecological diesel engine operational indicators, mathematical apparatus of prof. Parsadanov complex fuel and ecological criteria, instruments for analysis of the dynamics of exchange rates, the mathematical apparatus of Consumer Price Index.

**Statement of the problem and its solution.** Mathematical apparatus of prof. Parsadanov complex fuel and ecological criteria $K_{FE}$, which described in [5] and modified in [1] for separately taken individual representative *i*-th operational regime of exploitation model can be and described by following formulas.

$$K_{FEi} = \eta_{ei} \cdot (1 - \beta_i) = \eta_{ei} \cdot \left(1 - Z_{ei} / \left(Z_{fi} + Z_{ei}\right)\right), \quad (1)$$

$$Z_{fi} = g_{ei} \cdot P_f \,, \quad (2)$$

$$Z_{ei} = G_{fi} \cdot U_{Ei} = G_{fi} \cdot \delta \cdot P_f \cdot f \cdot g_{pri} \,, \quad (3)$$

where $\eta_e$ – effective efficiency coefficient of diesel engine; $g_{pr}$ – specific effective mass hourly pollutant emis-

sion by diesel engine, kg/(kW·h); $G_f$ – mass hourly fuel consumption by diesel engine, kg/h; β – coefficient of relative exploitation ecological monetary costs; $Z_e$, $Z_f$ and $Z_{fe}$ – ecological damage compensation monetary costs, motor fuel monetary costs and total fuel and ecological monetary costs, \$/(kW·h); $g_e$ – specific effective mass hourly fuel consumption by diesel engine, kg/(kW h); $U_{Ei}$ – ecological damage compensation monetary valuation, \$/kg; δ – dimensionless index of relative dangerous of pollution for various territories; $f$ – dimensionless coefficient, which taking into account the character of EG dispersion in atmosphere; σ – dimension coefficient for converting scoring assessment of damage in the monetary (σ = $P_f$ [5]); $P_f$ – price of motor fuel mass unit (results of choice of monetary equivalents units of $K_{FE}$ criteria components given in [2], $P_f$ = 0,871 \$/kg at $P_f$ = 20,0 UAH/l, $\rho_f$ = 0,85 kg/m$^3$ and currency exchanging course at December 2016 27,0 UAH/\$).

Features of engine test bench and methodic of experimental researches with it, which are used for determination of 2Ch10.5/12 diesel engine and its DPF operational characteristics, described in articles [1, 7, 8]. Operational characteristics of autotractor diesel engine 2Ch10.5/12 described in [7]. Parameters of 13-mode standardized steady testing cycle as an autotractor diesel engine exploitation model described in UNECE Regulations № 49 [5]. Legislative established on Ukraine territory requirements to PP with PICE ES level indicators in historical dynamic shown in article [1].

Results of calculated assessment of $K_{FE}$ criteria values, which based on experimental data obtained in articles [8, 9], for autotractor diesel engine 2Ch10.5/12, that operates on 13-mode standardized steady testing cycle, as well for its individual regimes as for whole cycle, shown in article [1].

Verbal justification and logical substation of measurement units choice for $K_{FE}$ criteria as an as the nearest of the known analogues of ESMS of PP with PICE exploitation process functioning efficiency criteria $\Omega_{ESMS}$ – US Dollars (\$, USD) as a freely convertible global reserve currency units, whose history completely covers the history of PICE – in form of hypothesis proposed and presented in [4].

This decision is due to the following circumstances.

Firstly, by definition, money is the commodity of maximum liquidity and the universal equivalent of the value of goods and services [10].

Secondly, the presence of the successful experience of applying well-known approach to assessment of technical, economic and ecological indicators of PICE developed by prof. I.V. Parsadanov as part of the methodology of calculation of the fuel and ecological criteria $K_{FE}$ [6].

Thirdly, not all of monetary expenses components is possible to bring to form the dimensionless quantity β and, moreover, give them a physical meaning of average operational efficiency specific mass hour fuel consumption $g_{eme}$, as in the case $K_{FE}$ [6].

In monograph [6] monetary expenses, which included in $K_{FE}$ criteria structure, expressed in Ukrainian Hryvnia (₴, UAH). But in this case there is the problem of assessing the effectiveness of measures to ensure the ES level of PP with PICE which are in operation for a long time. So, for the case of raising the ES level of diesel 2Ch10.5/12 by equipping it exhaust system with DPF, developed in Piston Power Plants Dept. of A. M. Podgorny Institute for Mechanical Engineering Problems of NAS of Ukraine with the participation of staff members of the Applied Mechanics Dept. of Technogenic and Ecological Safety Faculty of National University of Civil Defense of Ukraine [6, 8 – 10], a direct comparison of $K_{FE}$ criterion values for the basic (diesel without DPF) and modernized (diesel with DPF) version to perform in the UAH difficult. This is due to the following circumstances.

Firstly, diesel 2Ch10.5/12 (D21A1), which was used as a generator of aerosol of PM in the EG in these studies, released in the middle of the 80-years of the XX century, modern its modification produced by the Vladimir Tractor Plant (Russian Federation) and has significant constructive differences (e.g., electronic fuel supply control system). In this case to accurately estimate total operating time and the residual motoresource, prehistory and features of its exploitation, maintenance and repair measures and also, accordingly, its current technical condition and correlate it with any value indicator is extremely difficult.

Secondly, at the time of its release, such monetary unit as the UAH did not exist, and the unit in which to express it cost parameters – USSR Ruble – do not exist at present; monetary unit in which its cost was estimated at the time, when motor test bench was equipped with this diesel engine – Ukrainian Coupon-Karbovanets – also no longer exists; and the current modification of this diesel engine is estimated in Russian Rubles (RUB).

Thirdly, for some reason the UAH exchange rate against major freely convertible (so-called hard) currencies is very unstable. So, at the time of introduction into circulation UAH (1996), its rate against the USD amounts to less than 2 ₴/\$, at the beginning of development of DPF concept (2008) – about 5 ₴/\$, at the time of obtaining experimental data for the study [6] (2013) – about 8 ₴/\$, at the time of mathematical models [8–10] creation (2014) – about 12 ₴/\$, at the moment (October 2016) – about 26.5 ₴/\$. To predict behavior of this macroeconomic indicator with reasonable accuracy for at least six months in advance is impossible, not to mention the longer term.

It confirmed the above by the history of official National Bank of Ukraine average monthly currency exchange rate UAH against USD in the period from 1998 to 2016, shown on figure 1. The same holds true for rate UAH against EUR and UAH against RUB in the same period, presented on figure 2 and 3 [11].

This is most clearly be demonstrated by the example of official National Bank of Ukraine average annual currency exchange rate UAH against USD, against EUR and against RUB in the period from 1998 to 2016, shown on figure 4 [11].

In connection with the above considerations, it seems rational to express the monetary expenses values $Z_e$, $Z_f$ and $Z_{fe}$ in the formula (1)–(3), that forming $K_{FE}$ criteria value, in one of the widely used in Ukraine freely convertible world reserve currencies – Euro (€, EUR) or USD. However, only USD has a history, that complete-

ly covering the PICE history from birth of the idea (1807 de Rivas engine, 1860 Lenoir engine, 1863 two-stroke Otto engine,1876 four-stroke Otto engine, 1880 Kostovich engine, 1897 Diesel engine) and to the present day. EUR as the currency was introduced in cashless transactions in 1999 alone, and in the cash trade turnover – in 2001. In 1785 USD approved as an USA national currency, in 1794 USD begun to mint in USA, accepted for payment any banknotes and coins issued since 1861, but since 1971 it canceled USD backed by gold reserve.

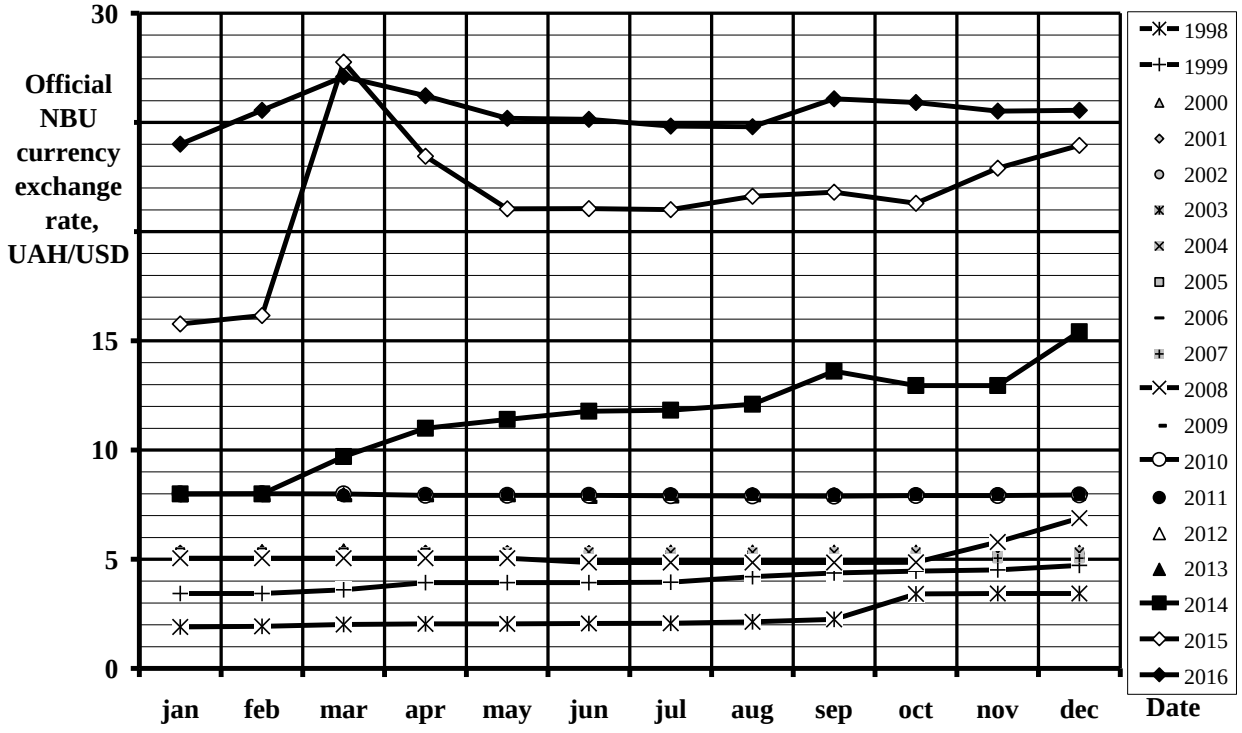


Figure 1 – Official National Bank of Ukraine average monthly currency exchange rate UAH against USD in the period from 1998 to 2016

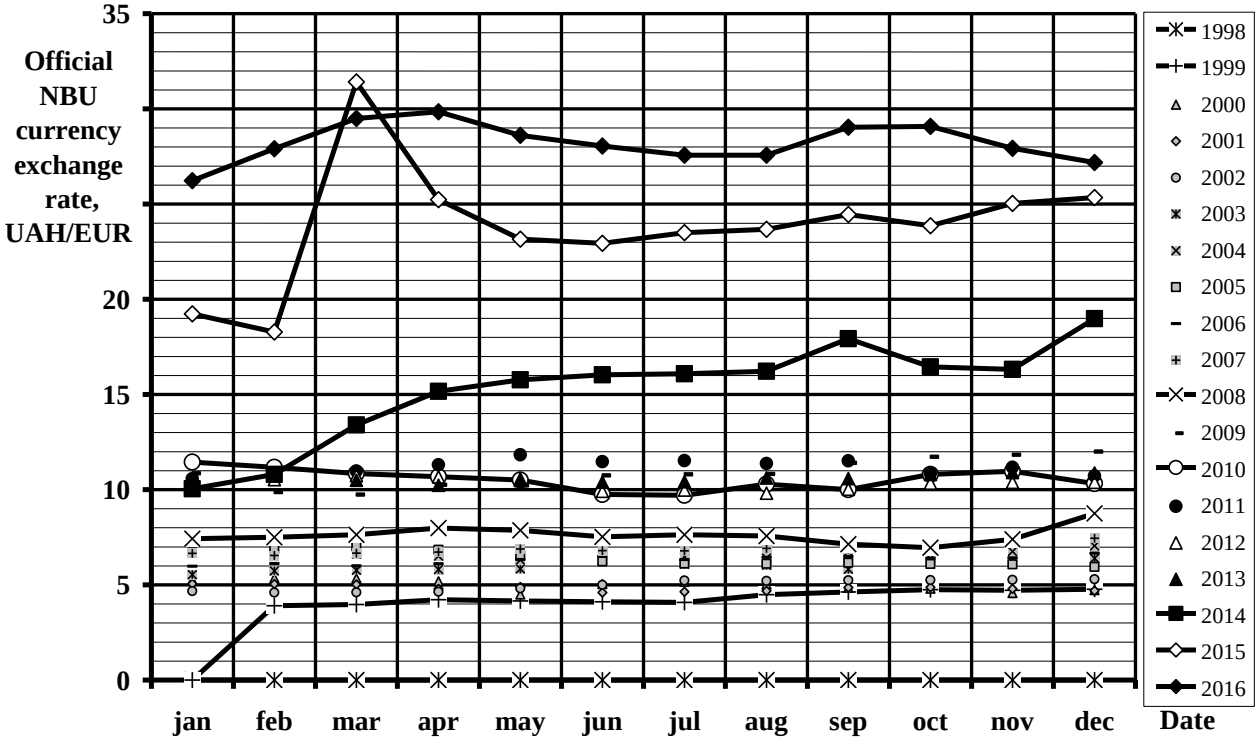


Figure 2 – Official National Bank of Ukraine average monthly currency exchange rate UAH against EUR in the period from 1998 to 2016

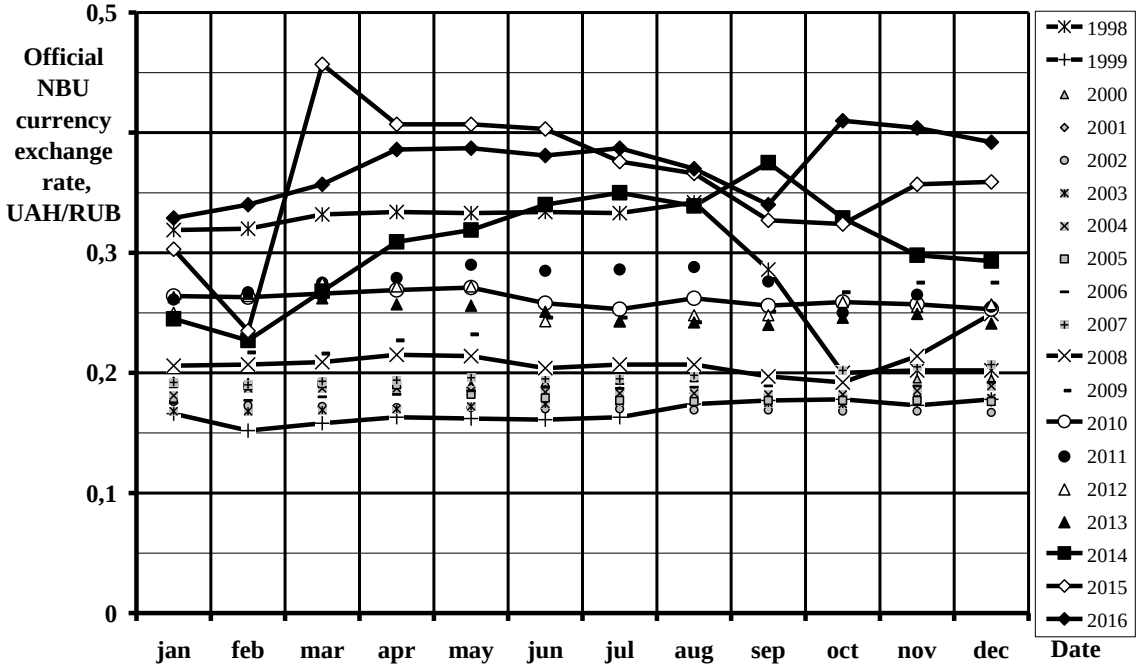


Figure 3 – Official National Bank of Ukraine average monthly currency exchange rate UAH against RUB in the period from 1998 to 2016

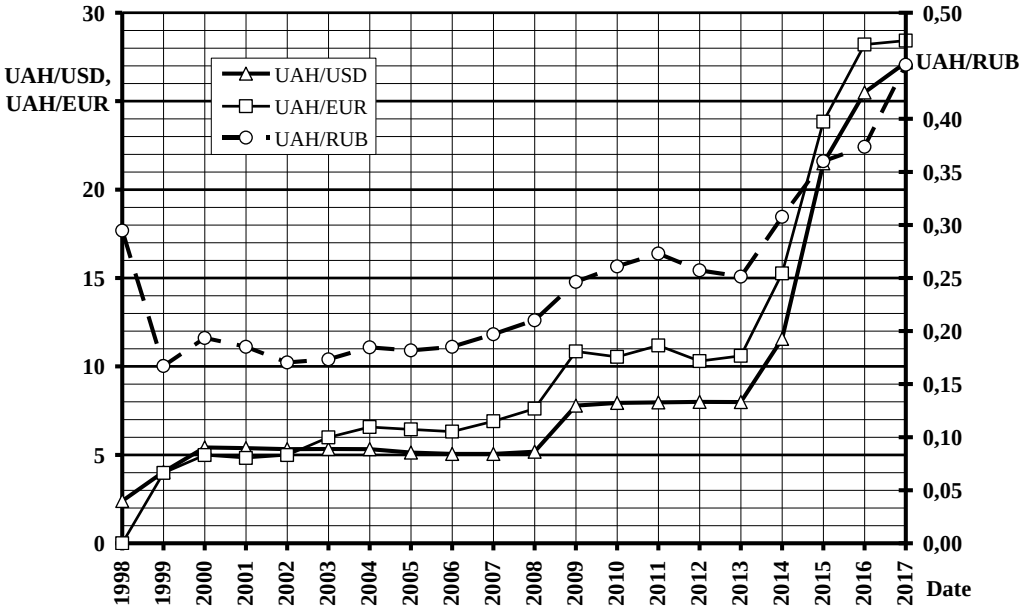


Figure 4 – Official National Bank of Ukraine average annual currency exchange rate UAH against USD, against EUR and against RUB in the period from 1998 to 2016

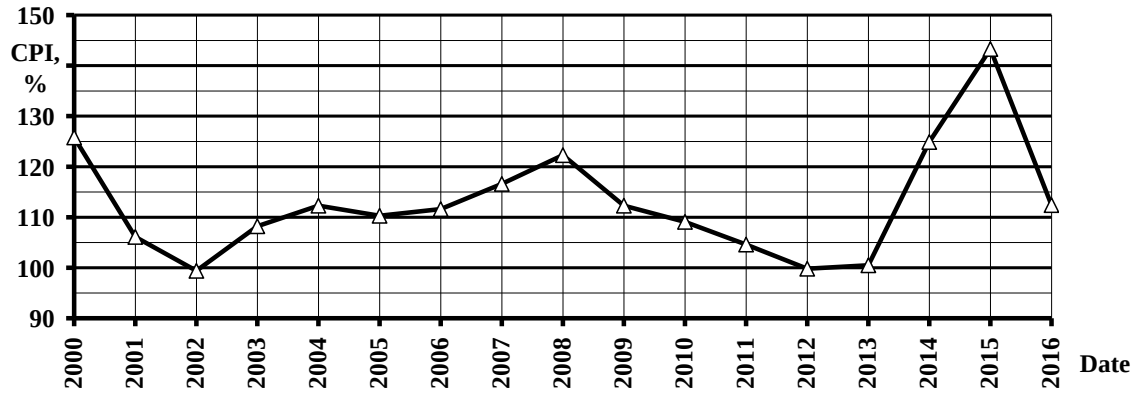


Figure 5 – CPI annual values for Ukraine in 2000 – 2016

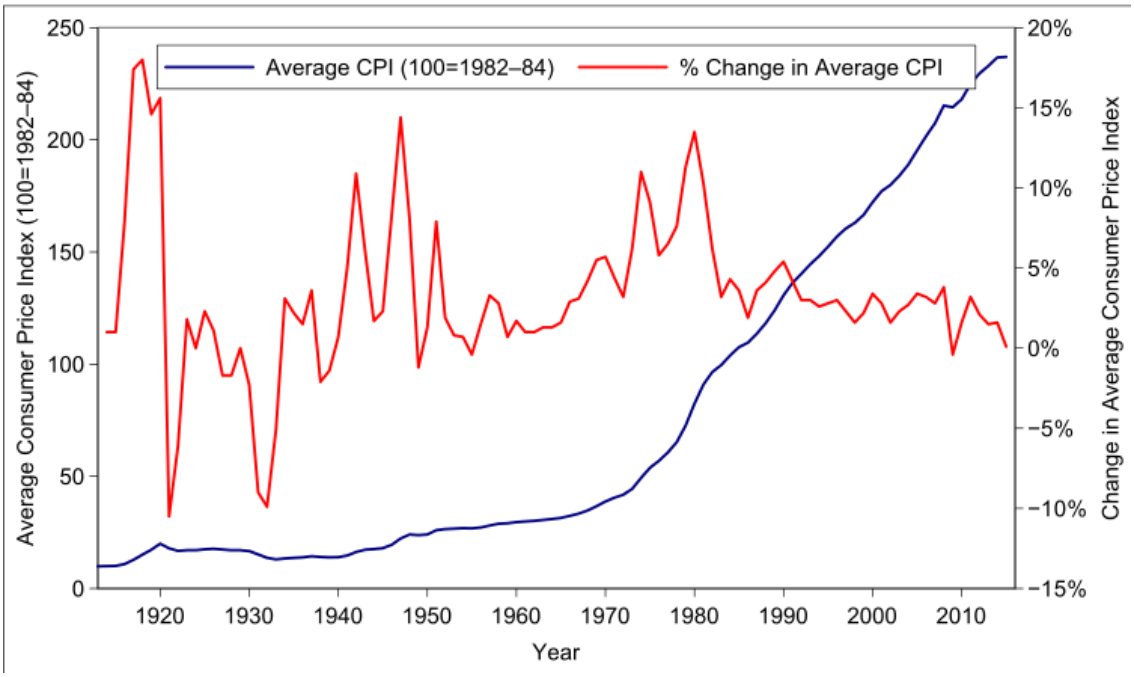


Figure 6 – CPI annual values for USA in 1913 – 2015 [13]

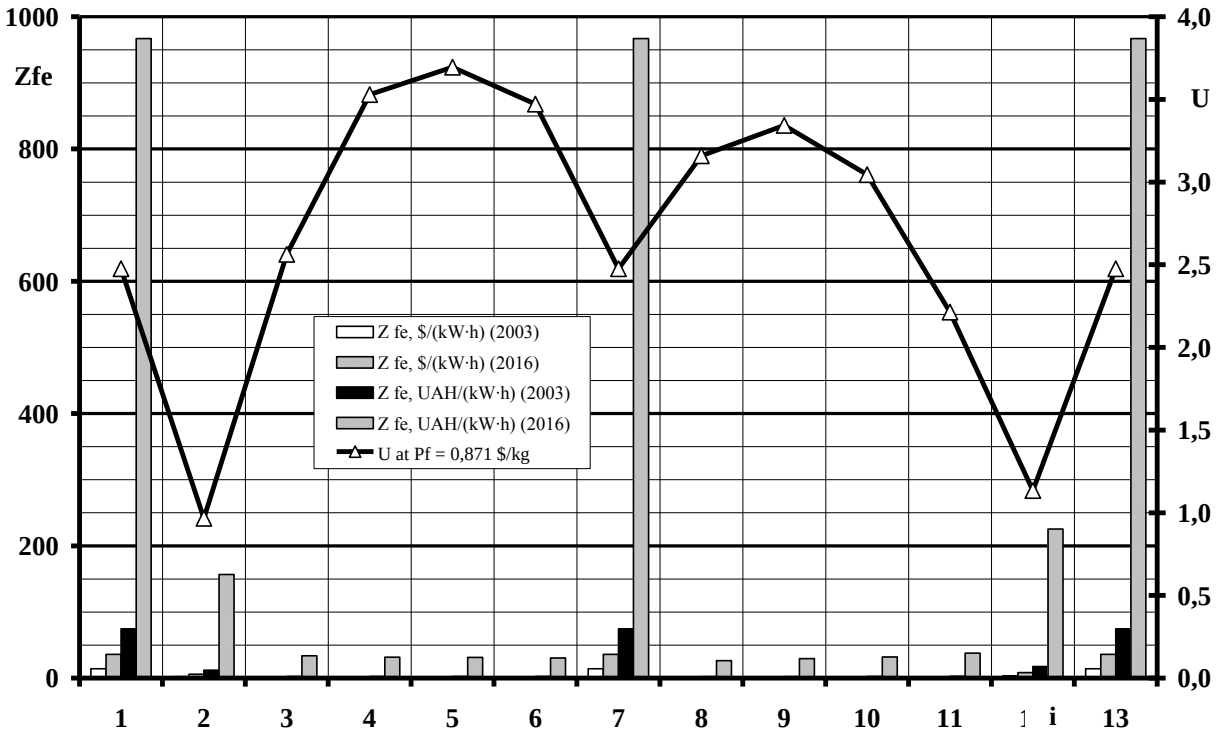


Figure 7 – Distribution of values of fuel and ecological monetary costs $Z_{fe}$ and ecological damage compensation monetary valuation $U$ as a $K_{FE}$ criteria components by regimes of 13-mode standardized steady testing cycle for different values and units of fuel price $P_f$

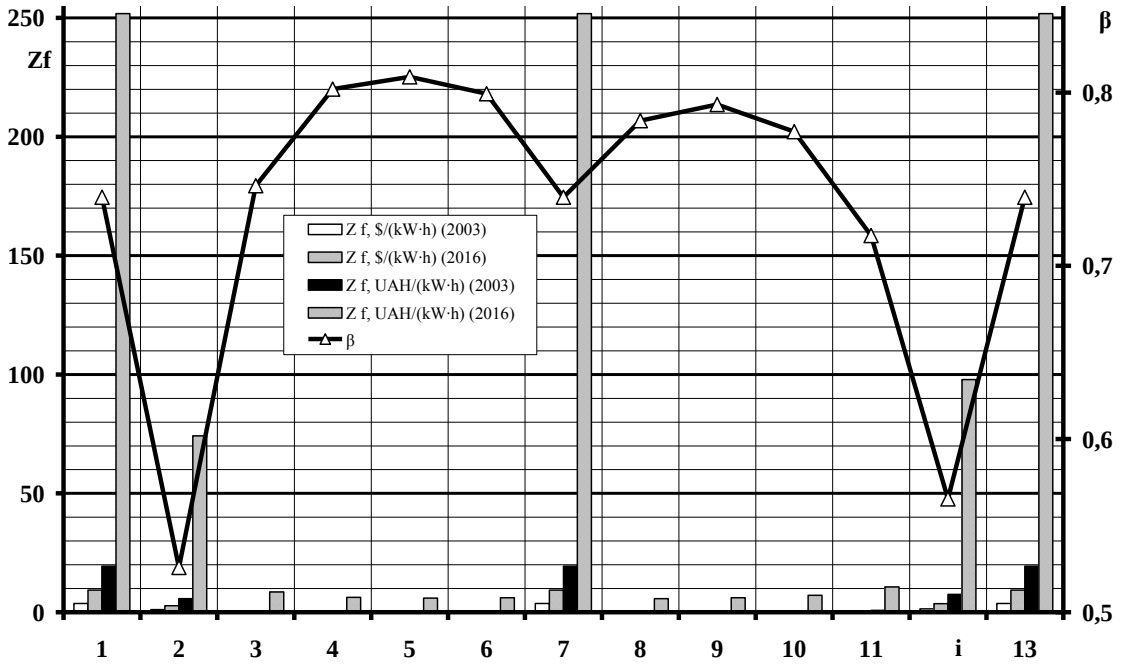


Figure 8 – Distribution of values of fuel monetary costs $Z_f$ and coefficient of relative exploitation ecological monetary costs β as a $K_{FE}$ criteria components by regimes of 13-mode standardized steady testing cycle for different values and units of fuel price $P_f$

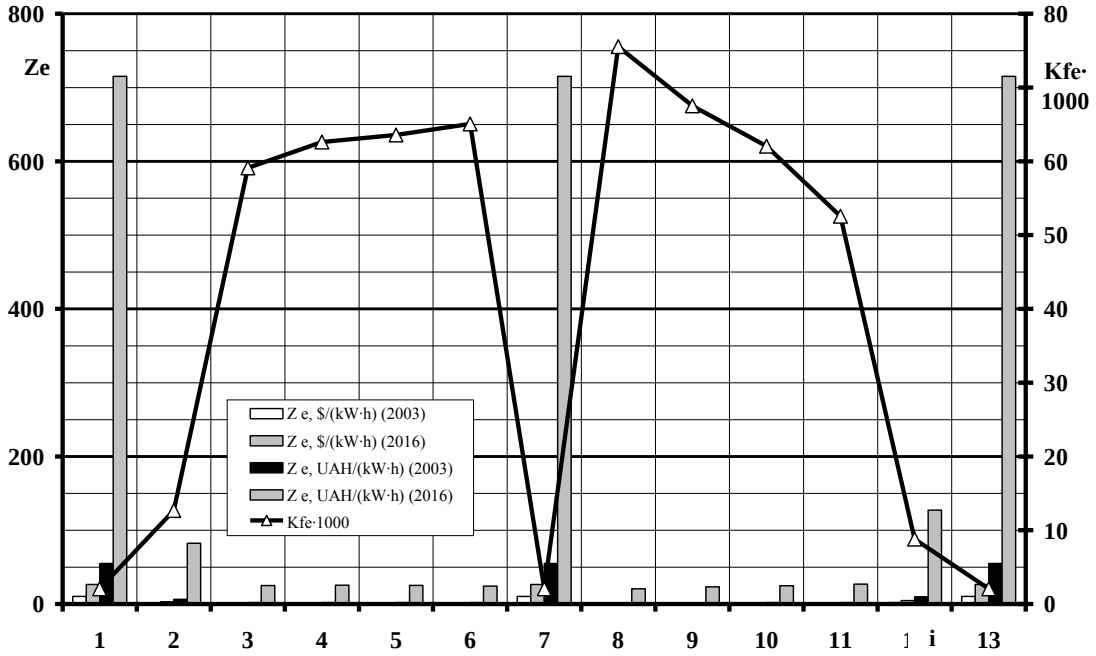


Figure 9 – Distribution of values of ecological monetary costs $Z_e$ and $K_{FE}$ criteria by regimes of 13-mode standardized steady testing cycle for different values and units of fuel price $P_f$

In this case should take into account that purchasing capacity of the USD throughout its existence since the creation of the first PICE to the present day was not constant due to manifestations of inflation phenomenon, which can be accounted by applying the Consumer Price Index CPI [10]. CPI described by following formula.

$$CPI = \sum\left(Q_i^t \cdot P_i^t\right) / \sum\left(Q_i^0 \cdot P_i^0\right) \cdot 100\%, \qquad (4)$$

where index $i$ marked types of products, index 0 marked base year (forUSD it is 1982 – 1984); index $t$ marked current year; $Q$ – amount of products issue; $P$ – price of products.

Then $Z_e$, $Z_f$ and $Z_{fe}$ values with taking into account inflation phenomenon – non-inflationary monetary costs $z_e$, $z_f$ and $z_{fe}$ – described by following formula

$$z_j = Z_j(t) \cdot CPI_{\$}(t)/100, \qquad (5)$$

where index $j$ marked types of monetary costs ($j = e, f$ of $fe$); $t$ – date; $Z_j$ – monetary costs as a part of $K_{FE}$ criteria, $.

Annual values of CPI for Ukraine, based on data from [12], shown on figure 5. Annual values of CPI for USA shown on figure 6 [13].

In present study carrying out calculating assessment values of $K_{FE}$ criteria components for autotractor diesel engine D21A1 for 13-mode stationary standardized test cycle.

Calculation investigated following cases of expression of weight unit cost of diesel fuel $P_f$.

– 1.81 UAH/kg (value at the moment of monograph [5] publication –2003);

– 0.34 $/kg (value at the moment of monograph [5] publication – 2003);

– 23.53 UAH/kg (current value);

– 0.871 $/kg (current value).

The results of this assessment calculation shown in Fig. 5–7.

From the figure 5 follows, that the difference in the monetary of value equivalent of these variables, expressed in the currency selected above (USD and UAH), can reach one order for the present value of their ratio and close to two orders when compared their values for 2003 and 2016 years. This is due to the instability of their course relative one to another, caused by external and internal economic and political factors, as well as the phenomenon of inflation, and can not be unaccounted.

In addition, in figures 7–9 shows that the correlation between variables $Z_f$, $Z_e$, $Z_{fe}$ and is not constant over different modes of the test cycle.

As it can seen on figures 5 and 6, USD as a world reserve currency due to manifestations of inflation phenomenon can not be an absolute monetary equivalent of $K_{FE}$ criteria components. Than in further studies it necessary to pay attention to changes in the cost of banking gold and oil.

**Conclusions.** Thus, in present study for the first time carried out calculated substantiation of choice of prof. I.V. Parsadanov complex fuel and ecological criteria components monetary equivalents and in what is *scientific novelty* of results of the study.

The study found that difference in the values of monetary equivalent of these variables, expressed in the selected currency – USD and UAH, can reach one order for the present value of their ratio and close to two orders when compared their values for 2003 and 2016 years, due to different economic and political factors. But the study also shows, that USD as a world reserve currency due to inflation can not be an absolute monetary equivalent of prof. Parsadanov complex fuel and ecological criteria components. It was propose to use mathematical apparatus of Consumer Price Index for taking into account inflation phenomenon.

With modified mathematical apparatus can be carried out assessment of ecological safety level of exploitation process of emergency and rescue equipment, which powered with piston ICE of different years of release, and in what is *practical value* of results of the study.

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**РАСЧЕТНОЕ ОБОСНОВАНИЕ ВЫБОРА ЕДИНИЦ СТОИМОСТНЫХ ЭКВИВАЛЕНТОВ СОСТАВЛЯЮЩИХ КОМПЛЕКСНОГО ТОПЛИВНО-ЭКОЛОГИЧЕСКОГО КРИТЕРИЯ**

В этой статье описаны результаты расчетного обоснования выбора единиц выражения стоимостных эквивалентов составляющих комплексного топливно-экологического критерия на примере автотракторного дизеля 2Ч10,5/12. Исследование показало, что разница в значениях стоимостных эквивалентов составляющих этого критерия, выраженные в избранных для исследованиях валютах – украинская гривна и доллар США, могут достигать одного порядка для современного значения их курса относительно друг друга, и двух порядков в случае сравнения их значений для 2003 и 2016 гг. из-за влияния определенных экономических и политических факторов. Однако исследование также показало, что доллар США, как мировая резервная валюта, в силу проявления инфляции не может рассматриваться как единицы выражения абсолютных стоимостных эквивалентов составляющих такого критерия. Предложено использовать математический аппарат индекса потребительских цен для учета явления инфляции. Научная новизна полученных результатов состоит в том, что впервые обоснован расчетом выбор единиц стоимостных эквивалентов составляющих комплексного топливно-экологического критерия проф. И.В. Парсаданова. Практическое значение полученных результатов состоит в том, что с использованием модифицированного математического аппарата становится возможным выполнить сравнительную оценку уровня экологической безопасности процесса эксплуатации энергетических установок с поршневым ДВС разных лет изготовления.

**Ключевые слова:** техногенно-экологическая безопасность, комплексное критериальное оценивание, стоимостные эквиваленты, топливно-экологическая эффективность, аварийно-спасательная техника, дизельный двигатель.

**С. О. Вамболь, О. М. Кондратенко**

**РОЗРАХУНКОВЕ ОБГРУНТУВАННЯ ВИБОРУ ОДИНИЦЬ ВАРТІСНИХ ЕКВІВАЛЕНТІВ СКЛАДОВИХ КОМПЛЕКСНОГО ПАЛИВНО-ЕКОЛОГІЧНОГО КРИТЕРІЮ**

У цій статті описано результати розрахункового обґрунтування вибору одиниць вираження вартісних еквівалентів складових комплексного паливно-екологічного критерію на прикладі автотракторного дизеля 2Ч10,5/12. Дослідження показало, що різниця у значеннях вартісних еквівалентів складових цього критерію, що виражені у обраних для дослідженнях валютах – українська Гривня та Долар США, можуть сягати одного порядку для сьогоднішнього значення їх курсу одне відносно одної, та двох порядків у випадку порівняння їх значень для 2003 і 2016 рр. через певні економічні й політичні фактори. Однак дослідження також показало, що Долар США, як світова резервна валюта, через інфляцію не може розглядатися як одиниці вираження абсолютних вартісних еквівалентів складових такого критерію. Запропоновано використати математичний апарат Індексу споживчих цін для врахування явища інфляції. Наукова новизна отриманих результатів полягає в тому, що вперше обґрунтовано розрахунком вибір одиниць вартісних еквівалентів складових комплексного паливно-екологічного критерію проф. І.В. Парсаданова. Практичне значення отриманих результатів полягає в тому, що з використанням модифікованого математичного апарату стає можливим порівняльне оцінювання рівня екологічної безпеки процесу експлуатації енергетичних установок з поршневим ДВЗ різних років виготовлення.

**Ключові слова:** техногенно-екологічна безпека, комплексне критеріальне оцінювання, вартісні еквіваленти, паливно-екологічна ефективність, аваріно-рятувальна техніка, дизельний двигун.

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