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Section 1. Biology

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ANTIPHYTOPATHOGENIC EFFECT OF TARTARIC ACID SYNTHETIC DERIVATIVES

Abstract. In current paper the effect of 6 compounds from tartaric acid (TA) derivatives 2 new classes on Pseudomonas syringae and Xanthomonas vesicatoria was discussed. Cyclohexyl derivatives of TA are more active than benzyl and phenyl substituted ones and their salts are more effective, than in imides. The absence of resistance transmission by plasmids and their biodegradability by non-pathogenic bacteria of P. chlororaphis group, recommends these compounds for study, as alternative against the multi-resistant pathogens and plant pests.

Keywords: Pseudomonas syringae, Xanthomonas vesicatoria, Resistance, phytopathogens, tartaric acid derivatives.

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АНТИФИТОПАТОГЕННОЕ ДЕЙСТВИЕ СИНТЕТИЧЕСКИХ ПРОИЗВОДНЫХ ВИННОЙ КИСЛОТЫ

Аннотация. В данной статье рассмотрено действие 6 соединений из 2 новых классов производных винной кислоты (ВК) на Pseudomonas syringae и Xanthomonas vesicatoria. Циклогексилпроизводные ВК более активны, чем бензил- и фенил- замещенные и соли более эффективны, чем имиды. Отсутствие передаваемости резистентности к ним плазмидами и биодеградируемость непатогенными бактериями группы P. chlororaphis, рекомендует эти вещества для изучения, в качестве альтернативных в борьбе с мультирезистентными патогенами и вредителями растений.

Ключевые слова: *Pseudomonas syringae, Xanthomonas vesicatoria,* резистентность, фитопатогены, производные винной кислоты.

Введение

Клинически штаммы *Pseudomonas и Stenotrophomonas* известны устойчивостью, обостряемой высокой адаптивностью и повсеместным использованием антибиотиков. Благодаря межвидовому горизонтальному переносу генов, данные микробы передают резистентность с формированием новых, резистентных штаммов патогенов [1, с. 01167–19]. Мультирезистентность фитопатогенов *Pseudomonas* и *Xanthomonas,* определяет малую эффективность антибиотиков для сельского хозяйства и снижает показатели безопасности сельскохозяйственной продукции с их применением в повышенных дозах [2, 482–486]. Поэтому, поиск новых альтернатив классическим способам защиты растений весьма актуален. В данной работе рассмотрено действие 6 новых производных винной кислоты (ВК) на ряд фитопатогенов.

Материалы и методы

Использованы штаммы Национальной Коллекции Микроорганизмов ЦДМ РА. Резистентность определялась селективными средами с 50мкг/мл: Amp/ампициллина, Pcn/пенициллина, Amx/амоксициллина, Amc/аугментина, Cfx/цефиксима, Ctx/цефтриаксона; Kan/канамицина, Stp/стрептомицина, Gnc/гентамицина, Cip/ципрофлоксацина; Tcn/тетрациклина, Azm/азитромицина; Cam/хлорамфеникола (“Astoria”). Производные ВК синтезированы по методу, разработанному в НПУА [3, 8516–8521]. ДНК выделена щелочной экстракцией, бензил хлоридом; исследована PCR и трансформацией, согласно стандартным протоколам [4, 12–19]. Статистическая оценка проведена при помощи стандартных методов [5, 182].

Результаты

Показан разброс спектра устойчивости и мультирезистентность большинства *Xanthomonas* и *Pseudomonas* к различным 13 антибиотикам. Действие новых производных ВК приведены в (таблице 1).

Таблица 1. – Действие производных ВК

Штамм		CAS						CI					
		I	II	III	IV	V	VI	II	III	IV	V	VI	C
8736	A	15	17,2	25	25	L	L	23	23	23	23,8	L	30
8740		11	11	12	20	22	L	9,1	10	11,5	13	17	30
8744		12,1	13	15	14	18	20	14	16,2	19	20,1	22	30
8656		8	8	14,9	15,1	17	L	10,3	11,4	12	12,7	14	30
8647	B	18,2	20	19,7	20,4	22	L	20	20,8	21	21,3	22	30
8651		15	16,1	18,5	20,1	25	L	15	15,5	17,4	18,1	19	30
8843		L	L	L	L	L	L	L	L	L	L	L	30
Штамм		**BAS**						**BI**					
8736	A	+	+	+/–	+/–	+/–	+/–	3	5	L	L	L	30
8740		3	5	6	6,5	7	8	5	6	6,5	7	7,2	30
8744		+	+/–	+/–	4	5,5	6	+	+/–	+/–	3,2	4,2	30
8656		+/–	2	3,8	5,5	6	6,5	3,9	4	4,5	5,6	L	30
8647	B	2,5	3	4,3	5,7	6,2	L	+	+	+	+	+	30
8651		+/–	+	+	+	+/–	3,4	+	+	+/–	+/–	3	30
8843		+/–	+	+	+	+/–	+/–	+	+	+/–	+/–	3,5	30
Штамм		**PhI**						**PhAS**					
8736	A	+	+	+/–	+/–	8	+	+	+	+	+	+	30
8740		+	+	+	+	+	+	+	+	+	+	+	30
8744		+	+	+/–	3,5	8	+	+	+	+	+/–	6	30
8656		+	+	+	+	+	+	+	+	+	+/–	3	30
8647	B	+	+	+	+/–	6	+	+	+	+/–	3	L	30
8651		+	+	+	+/–	5	+	+	+	+	+	+	30
8843		+	+	+	+	+	+	+	+	+	+	+	30

Фенилимид – PhI; бензилимид – BI, циклогексилимид – CI, фенил моноамино соль – PhAS, бензил моноамино соль – BAS, циклогексил моноамино соль – CAS; зоны ингибирования роста представлены в мм; A – P. syringae, B – X. vesicatoria; L – полный лизис зоны роста, C – позитивной контроль на полноценной среде (30мм), "+" – нормальный рост, "+/–" – ингибирование меньше 10%; концентрации веществ: I –50мкг/мл, II – 0.001M, III – 0.01M, IV – 0.05M, V – 0,1M, VI – 0,5M

Как показали данные, наибольший спектр резистентности показали *P. syringae 8736, X. vesicatoria 8647*. Были протестированы: бензилимид, циклогексилимид, фенилимид; бензил, циклогексил и фенил моноамино соли ВК (таблица 1). Минимальная ингибирующая концентрация бензил- и фенил-производных (50мкг/мл) выше, чем у циклогексил- производных (0,01М). Моноамино соли эффективнее имидов. Возможно, это связано с большей биодоступностью, обусловленной гидрофильностью. Ген *blaOXA-10* обнаружен в 1 плазмином штамме *P. syringae*. Согласно негативным данным по трансформации, его локализация нуклеоидная. Обнаружены плазмиды, несущие гены резистентности к β-лактамам и не несущие генов устойчивости. Резистентность к аминогликозидам и амфениколам у всех изученных штаммов представлена нуклеоидными генами. [6, 109–13].

Действие производных ВК не зависит от плазмидности. Фенил- производные ВК не

действуют на штаммы, содержащие β-лактамазу *BlaOXA-10,* а бензил- и циклогексил-производные ингибируют их штаммы [7, 15–27]. В отличие от Tcn-резистентных *P. chlororaphis* и *P. fluorescens*, рост Tcn-резистентных *P. syringae* и *X. beticola* ингибируется бензил- и циклогексил производными ВК [8, 233]. Возможно, это связанно с видоспецифичными отличиями нуклеоидных полифенолоксидаз и других ферментов Tcn-резистентности.

Заключение

Выявлено выраженное антимикробное действие имидов и моноамино комплексных солей ВК. Их эффект не коррелирует с наличием плазмид в клетках *P. syringae* и *X. vesicatoria.* Действие фенил- производных менее значительно. Важной особенностью соединений является невозможность передаваемости резистентности плазмидами. Это делает их рекомендуемыми при разработке новых экологически безопасных антимикробных препаратов.

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Section 2. Medical science

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INFLUENCE OF LOCAL FACTORS OF COLONIZATION RESISTANCE ON VAGINAL MICROBIAL BIOCENOSIS

Abstract

Introduction. Today, there is a problem of improving the diagnostics of BV and establishing the importance of molecular-genetic and immunological parameters of vaginal colonization resistance in the algorithm for diagnostics of dysbacteriosis and bacterial vaginosis (BV). Purpose of the study is to determine the influence of local factors of colonization immune resistance on vaginal microbial biocenosis in normocenosis, dysbiosis and BV. In result the response of vaginal colonization immune resistance with the advance of dysbiosis and BV has evolved from nonspecific resistance to cytokine-induced responses of specific humoral immunity.

Keywords: colonization resistance, microbial vaginal biocenosis.

Introduction. Despite certain advances in the treatment of inflammatory diseases of the female genital organs, the prevalence of these diseases is steadily increasing, ranging from 30% in inpatients to 60–65% in outpatients [1, 3–6; 2].

This is one of the major medical problems and has a significant impact on the health of millions of women of childbearing age. Despite the widespread use of antibacterial medications, anti-inflammatory therapy, immunocorrective therapy, and physiotherapy, inflammatory diseases of the uterus and appendages in 70% of cases acquire a chronic course [2, 70–3].

Along with STIs such as syphilis, gonorrhea, trichomoniasis, chlamydiosis, and others, which are included in the section "Sexually transmitted infections" according to the International Classification of Diseases and Problems (ICD-10), opportunistic pathogenic microorganisms of microbiota of the urogenital tract are becoming of growing clinical importance [3, 30310–9; 4, 36–41].

Optional anaerobic and obligate anaerobic opportunistic pathogenic microorganisms, constituents of the resident microbiota of the urogenital tract, affected by certain external and internal risk factors, can show pathogenic potencies and transform into microorganisms that are the part of the etiologicstructure of infection and inflammatory process [5, 69–75; 6, 859–64].

Changes in the composition of vaginal microbiocenosis can be clinically manifested through various nosological forms of the disease: bacterial vaginitis (BV), nonspecific vaginitis and vaginal candidiasis [7, 21–30].

BV is a general infectious non-inflammatory syndrome associated with dysbiosis of the vaginal

biotope, accompanied by an excessively high concentration of obligate and optional anaerobic opportunistic pathogenic microorganisms and a sharp decrease or absence of Lactobacillus spp. in vaginal discharge [8, 472; 9, 3–4].

The frequency of BV in the last decade has doubled and is, according to various authors, from 26% to 40–45% [8, 472; 10].

In BV, there is a disorder of vagina ecosystem, in which natural protective mechanisms, such as vaginal microbiocenosis, synthesis of antimicrobial substances ensuring local immune protection (both at cellular and humoral level) cease to work and allow the amplification of different species. An important factor in the occurrence of BVis a lack of local immunity – decreasein colonization immune resistance [11, 227–231; 12, 143–148; 13, 1399–1405].

BV is characterized by a lack of systemic and local inflammatory response, although increased levels of proinflammatory cytokines IL1α and IL1β are found in the vagina [14, 1–5], which correlates with an increase ofGarnerella vaginalis and Mycoplasma hominis [15, 481–7].

Emphasizing the importance of the problem of assessment of local immunity, it should be acknowledged that the literature defines the need to improve the diagnostics of BV and to establish the value of molecular-genetic and immunological parameters in the algorithm of diagnostics of BV and mixed infection [16, 231–42; 17, 223–38].

Thus, the urgent task is to study the effect of immunological factors of vaginal resistance and to substantiate the possibility of clinical use of laboratory immunological tests characterizing the condition of local immunity.

Purpose of the study is to determine the influence of local factors of colonization immune resistance on vaginal microbial biocenosis in normocenosis, dysbiosis and BV.

Material and methods

This study examined women aged from 16 to 64 who turnedto gynecologist for a preventive examination or with complaints of genital discomfort of various degrees of manifestation. Subsequent observation excluded patients who had at least one of the definitely pathogenic microorganisms (Trichomonas vaginalis, Neisseria gonorrhoeae, Chlamydia trachomatis and Herpes Simplex Virus 1,2) in the material taken. Presence in the smear of more than 15–20 leukocytes, which indicated of an inflammatory reaction, was also the reason for exclusion from the main stage of study.

298 women were selected for the study. After examination, scraping of epithelium from the posterolateral vaginal parieswas made using a urogenital probe. The material was placed in an Eppendorf tube containing 1 ml of saline. Usingasterile Folkman's spoon, secret from the vaults of the vagina was collected for further immunological and immunoenzymatic studies. Typically, amount of secret collected once did not exceed 180–300 μl. An aliquot of the secretwas brought to 1000 μlusingsaline. The dilution factor was taken into account for each sampling and was used in calculation of the measurement resultsas a correction factor.

Molecular-genetic studies were performedusing polymerase chain reaction (PCR) method. DNA was extracted using a kit of reagents "Proba-GS" ("DNK-Technologiia" LLC, RF). Amplification of tubes with the reaction mixture was performed in the amplifier "DTLite" ("DNK-Technologiia" LLC, RF) using the amplification programs recommended by the manufacturer of the reagent kit. Investigation of vaginal biocenosiswas performed using the Femoflor 16 test system for real-time PCR. The method is based on a complex quantitative assessment of biota using non-cultivation method and comparative analysis of specific representatives of the normo- and conditionally pathogenic flora with the total number of microorganisms in order to detect the imbalance of the microflora and the degree of its manifestation [18, 109–14; 19, 80–4].

Criterion for the distribution of patients into groups was an index of conditionallypathogenic microflora (ICPM), which was calculated as the difference between the sum of all conditionallypathogenic

microorganisms and the number of lactobacilli in lg GE/sample. In normocenosis ICPM was lower than –3 lg GE/sample (n = 53); ingrade I dysbiosisit was from –3 to –1 lg GE/sample (n = 128); and in grade II dysbiosis (BV) itwas more than –1 lg GE/sample (n = 117), which allowed the diagnostics BV [20, 54–7].

According to the PCR results, the following total and derived indicators were calculated: NBI = = lgTBM – lgLB; ΣObA = lg (Σ10ObA); ΣOpA = = lg(Σ10OpA); ΣMP = lg(Σ10MP); ΣFY = lg (Σ10FY); ICPM = lg ((Σ10ObA + Σ10OpA + + Σ10MP + 10FY) – 10LB), where: NBI – normobiota indicator; TBM – total bacterial mass; LB – Lactobacilli; ObA– obligate aerobes; OpA– optional anaerobes; MP – mycoplasma; YF– yeast-likefungi; ICPM – index of conditionally pathogenic microflora. Diagnostic accuracy of PCR studies is not less than 92% [21, 54–7].

Using standard immunological methods, contents of immunoglobulins A (IgA), M (IgM) and G (IgG) in the vaginal fluid (test systems NVL "Granum"; Ukraine), content of immunoglobulin G2 (IgG2) and secretory IgA (sIgA) ("Hema" LLC; RF), content of lysozyme and transforming growth factor 1β (TGF-1β) (DRG; USA)were defined; using the method of selective precipitation in a solution of polyethylene glycol, immune complexes (IK), content of interleukins 1β (IL1β), 2 (IL2), 4 (IL4), 6 (IL6), 8 (IL8), 10 (IL10), tumor necrosis factor α (TNFα) and γ-interferon (γ-INF) ("Vektor-best" LLC; RF), content of components of complement C3 and C4 ("PLIVA-LachemaDiagnosticas.r.o"; Czech Republic) were defined.Leukocyte phagocytic activity (LPA) was defined using yeast cell suspension (Granum NPL, Ukraine); LPA was calculated as the average number of particles absorbed by one active neutrophil per 100 cells; LPA index was calculated as the percentage of phagocytes from the counted neutrophils. Vaginal secretion pHwas defined using the Kolpo-pH test strips manufactured by Biosensor AN LLC (RF).

Regression analysis, method for detecting the effect of one or more independent (factor) variables on a dependent variable (Statistica 10, StatSoft Inc., USA), has been used to determine the relationship between the species of microbial biocenosis and the studied factors of colonization resistance. In medical research, dependent and independent variables reflect the mathematical interdependence of the variables, but not the cause and effect relationship of the parameters.

Results and Discussion

Data on the dependence of microbial biocenosis indicators from the factors of colonization resistance are shown in (Table 1).

In normocenosis, the positive coefficients of β had such indicators as C3 and C4, as well as the index of phagocytosis activity –LPA index ($p<0.05$). In our opinion, this clearly indicates that in normal conditions natural activity of cellular (phagocytosis) and humoral (complement) units of nonspecific immunity is enough for the regulation of biocenosis. Moreover, population of optional anaerobes is controlled by the activity of complement (C4), population of myco- and ureaplasma–by complement (C3) and phagocytosis (LPA index), and conditionally pathogenic microflora –by phagocytosis (LPA has a negative βcoefficient).

In grade I dysbiosis, normal flora was maintained by such colonization resistance factors as sIgA, LPA index, γ-INFand pH due to NBI dependences. Moreover, the first three had negative βcoefficients, while pH was positive. Other local factors of immune resistancewere: sIgA, LPA index and γ-INF, that is, compounds with direct bactericidal action, whereas pH (vaginal laxation) reflects a decrease in colonization resistance.

Optional aerobes were controlled by lysozyme, myco- and ureaplasmsIgA, and yeast-like fungi – bythe increase in IgG levels. In addition, the number of microorganisms in this population inversely depended on the increase of TNFα in vaginal secretion, on the level of which, apparently, depends the

activation of the immune system. ICPMdepended on pH (presumably, a decrease in the acid-producing function of LB was one of determining factors for activation of conditionally pathogenic microflora).

Table 1.– Dependence of group and calculated indicators of microbial biocenosisfrom the factors of vaginal local immunity in normo- and dysbiosis

Biocenosis indicator	Normocenosis			grade I dysbiosis			grade II dysbiosis		
	CRI	β	p	CRI	β	p	CRI	β	p
NBI	–	–	–	sIgA	–0.17	0.008	IL10	–0.18	0.033
				ILPA	–0.22	0.003			
				γ–INF	–0.28	0.000	pH	–0.26	0.030
				pH	1.00	0.041			
OpA	C_4	0.54	0.001	Lyso-zyme	–0.41	0.016	IL1β	–0.28	0.016
ObA	–	–	–	–	–	–	IgG	0.32	0.013
MU	ILPA	–0.11	0.01	sIgA	–0.41	0.007	–	–	–
	C_3	0.20	0.03						
YF	–	–	–	IgG	0.24	0.045	–	–	–
				TNFα	–0.25	0.030			
ICPM	LPA	–0.39	0.024	pH	0.29	0.006	IL1β	–0.20	0.034
							IL10	–0.18	0.038

Remark: CRI–colonization resistanceindicators; ILPA – LPA index; β – regression coefficients; p – the probability of difference from the null hypothesis (accepted at p < 0.05); MU – mycoplasma and ureaplasma

In grade II dysbiosis, negative β coefficientswere noted for the content of IL10 and pH in vaginal secretion. As we have previously established [22, 103–7], the level of this interleukin was of the leading value for the formation of groups according to the analysis of variance. Changing the sign of the β coefficient for pH indicates an uncontrolled growth of pathogenic microflora (pH increased as itgrew and the content of LB decreased). Population of optional anaerobeswas controlled by the proinflammatory cytokine IL1β, population of obligate anaerobes increased in parallel with the IgG level, and the ICPM was inversely dependent on IL1β and IL10 levels. Importance of these cytokines is emphasized in [23, 5–12].

Table 2. – Data of the conclusionis summarized in (table2)

Normocenosis	Grade I dysbiosis	Grade II dysbiosis
1	***2***	***3***
IgM	IgM	IgM
IgA	IgA	IgA
IgG	**IgG (+)**	**IgG (+)**
IgG_2	IgG_2	IgG_2
sIgA	sIgA (–)	sIgA
Lysozyme	Lysozyme (–)	Lysozyme
LPI (–)	LPI	LPI
LPI index (+)	**LPI index (–)**	LPI index
CIC	CIC	CIC

1	*2*	*3*
C_3 (+)	C_3	C_3
C_4 (+)	C_4	C_4
γ-INF	γ-INF (–)	γ-INF
IL1β	IL1β	**IL1β (–)**
IL2	IL2	IL2
IL4	IL4	IL4
IL6	IL6	IL6
IL8	IL8	IL8
IL10	IL10	**IL10 (–)**
TNFα	**TNFα (–)**	**TNFα (–)**
TGF-1β	TGF-1β	TGF-1β
pH	pH (+)	pH (–)

Table 2. Significant indicators (highlighted by gray background) and signs of βcoefficients (+/–) of the dependence of group and calculated indicators of microbial biocenosisfromthe local immunity factors; CIC – circulating immune complexes

It should be noted that, innormocenosis, colonization resistance was determined by two nonspecific effector factors of immune defense – complement and phagocytosis. In grade I dysbiosis, the number of effector factors were joined by lysozyme, sIgA and pH; a factor of specific immunity appeared – IgG, which required the formation of humoral immune response involving T- and B-lymphocytes and was mediated by interleukins, the ones important among which were γ-INF i TNFα. In grade II dysbiosis, levels of regulatory cytokines (IL1β and IL10) and pH acquired the leading value. Innormocenosis and grade I dysbiosisobligate anaerobes were not associated with factors of colonization resistance, but in grade II dysbiosis, IgG levels in vaginal secretions already had regulatory significance. It is likely that a significant increase in the content of obligate anaerobes led to the launch of a specific humoral immune response.

Thus, as dysbiosis progresses, phagocytosis is joined by such protective factors as lysozyme (control of optional anaerobes), sIgA (control of NBI, myco- and ureaplasmas), γ-INF (control of NBI) and IgG formation (triggered by growth of yeast-like fungi); decrease in the number of LB and increase in the ICPM reflected a pH increase. It is noteworthy that the effector factors of nonspecific immunity for grade II dysbiosis do not show any relationship with the biocenosis indicators, which confirms their incapacity, that is, formation of local immunodeficiency. Levels of IL1β and IL10 had regulatory significance.

For a deeper understanding of the relationof individual species of microbial biocenosis with the condition of vaginal colonization resistance, calculation of dependences in regression analysiswas performed (Table 3).

Innormocenosis, amount of LB was regulated, in addition to complement and phagocytosis, by the formation of IC; Streptococcus spp.–by the level of proinflammatory cytokines; and amount of Atopobiumvaginalis, being a marker of BV, increased in parallel with increasing pH.

Number of Eubacterium spp. and Gardnerellavaginalis / Prevotellabivia / Porphyromonas spp. was associated with IgA and IgG, IK and cytokines (γ-INF, IL4, and IL6). Number of Mobiluncus spp. / Corynebacterium spp., being a marker for BV, was controlled by lysozyme and Ureaplasmaurealyticum + parvum by complement and phagocytosis.

Therefore, it can be noted that under normal conditions the balance of proinflammatory cytokines was important for streptococci, and immunoglobulins, IRs and cytokines – for obligate anaerobes.

Table 3. – Dependence of indexes of microbial biocenosisby species on factors of local vaginal immunity innormo- and dysbiosis

Biocenosis indicator	Normocenosis			Grade I dysbiosis			Grade II dysbiosis		
	CRI	β	p	CRI	β	p	CRI	β	p
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
TBM	LPI	0.35	0.027	IC	–0.31	0.005	IgG	0.28	0.039
	C_4	0.56	0.001	C_3	–0.41	0.001	IL8	–0.22	0.025
Normobiota									
Lactobacillusspp.	LPI	0.37	0.019	ILPI	0.30	0.023	–	–	–
	IC	0.36	0.039	IC	–0.22	0.017			
	C_4	0.53	0.001	C_3	–0.26	0.013			
				TNFα	–0.19	0.031			
Optional anaerobes									
Enterobac–teriaceaespp.	C_4	0.397	0.028	lysozyme	–0.34	0.046	γ–INF	–0.46	0.020
				γ–INF	0.44	0.015			
Staphylo–coccusspp.	–	–	–	IL8	0.37	0.007	–	–	–
Strepto–coccusspp.	IL2	–0.37	0.028	IgA	0.27	0.007	–	–	–
	IL6	–0.32	0.050						
	IL8	–0.35	0.046						
	TNFα	0.32	0.049						
Obligate anaerobes									
Atopobiumvaginalis	ILPI	–5.58	0.002	IL2	0.39	0.020	IgG	0.33	0.012
	pH	0.36	0.017	IL6	–0.34	0.033			
Eubacte–riumspp.	IgA	–0.31	0.038	–	–	–	IL8	–0.28	0.004
	IC	–0.39	0.035						
	γ–INF	–0.43	0.008						
	IL4	–0.37	0.034						
Gardn/ Prevot/ Porhphyr	IgG	0.36	0.020	–	–	–	–	–	–
	sIgA	0.35	0.035						
	IL6	–0.41	0.007						
Lachnob/ Clostrspp.	–	–	–	LPI	–0.46	0.028	IgM	–0.25	0.033
				γ–INF	–0.40	0.018	IgA	0.38	0.035
				IL4	0.42	0.020	IgG	0.27	0.042
						sIgA		–0.51	0.034
Meg/Veilon/Dialspp.	C_4	0.44	0.011	IgA	0.22	0.025	IgG	0.35	0.009
Mobilun/Coryneb. spp.	lyso–zyme	–2.57	0.015	ILPA	0.35	0.037	–	–	–
Peptostreptococspp.	IL6	–0.34	0.048	lysozyme	0.45	0.006	–	–	–
				IL6	–0.35	0.023			
Sneathia/Leptotrichia/ Fusob. spp.	–	–	–	IgG_2	–0.27	0.021	IgG	0.27	0.041
				TGF-1β	0.24	0.022			

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Myco-, ureaplasmasand yeast–like fungi									
Ureaplasmaurea+parv	ILPA	–0.50	0.013	sIgA	–0.41	0.007	–	–	–
	C_3	0.39	0.032						
Mycoplas–mahom+gen	–	–	–	IL10			IgM	–0.32	0.005
						0.010	–0.20	0.046	
					–0.43	IgG_2	0.24	0.019	
						IL6	0.19	0.039	
						IL8 TGF1β	–0.26	0.007	
Candidaspp.	–	–	–	TNFα	–0.25	0.030	–	–	–

Notes: ILPA – LPA index; β– regressioncoefficients; p –probabilityofvariation from the null hypothesis (accepted when p < 0.05)

In grade Idysbiosis, amount of LB, in addition to non-specific immune factors, was also determined by the level of TNFα. For conditionally pathogenic microorganismsnon-specific effector factors of colonization resistance (lysozyme, γ-INF, phagocytosis), and modulating immune factors (proinflammatory and regulatory cytokines), were also important.

Interestingly, it is IgG2 was the regulating factor for microorganisms of Sneathia spp. / Leptotrihia spp. / Fusobacterium spp. groups. Representatives of this group were not observed under normal conditions [24, 36–41], appeared only indysbiosis and are pathogenic. The data obtained showed that a specific immune response to this group was formed only in grade I dysbiosis.

Amount of Ureaplasmaurealyticum + parvum was inversely dependent on the level of sIgA, Mycoplasma hominis + genitalium–onthe content of IL10, and yeast-like fungi –on the level of TNFα. It should be noted that for this group of microorganisms, this dependence was the only. Candida spp.was found in 85% of cases in an amount of not exeeding 3,219 lg GE/sample even under normal conditions. Such a prevalence may be a resultof a lack of actual dependenceon the factors of colonization resistance indysbiosis.

In grade II dysbiosis, number of LB decreased sharply and did not show any relation with the factors of colonization resistance. Of all the optional anaerobes, only enterobacteria had γ-INF feedback. Immunoglobulins prevailed among obligate anaerobesrelations, which, in our opinion, testifies to the antagonistic relationship of the forming colony of conditionally pathogenic microorganisms and the defense mechanisms of the immune system. Numerous relations have been demonstrated by the Mycoplasma hominis + genitalium group: inverse – with IgM, IgG2, and TGF1β, and direct – with proinflammatory IL6 and IL8.

We can clearly see the evolution of the immune response in the dysbiosis progression on the example of change of relations ofAtopobiumvaginalis, which is the marker microorganism for BV (see Table 2). Innormocenosis, its number inversely depended on the LPA index and increased with increasing pH (alkalinity); in grade Idysbiosis, it directly depended on IL2 and inversely – on IL6, i.e., its increase caused an immunomodulatory cytokine response; and in degree IIdysbiosisit had a direct relation to IgG – an indicator of specific humoral immunity.

This example, as well as generalizations of other cases, demonstrated that the response of the immune system with progression of BV evolved from nonspecific resistance to cytokine-induced responses of specific humoral immunity. This fits to the classical paradigm of immune reactivity, but it should also be

taken into account, that in grade II dysbiosisBV and, as shown by this study, a local vaginal immunodeficiency, which, in fact, is the cause of BV, are present. This position justified the direction of further research: analysis of the role of the body's immune reactivity at the systemic level and of the state of hormonal regulation.

Conclusions

1. Innormocenosis, vaginal colonization resistance was determined by two nonspecific effector factors of immune protection: complement and phagocytosis.

2. In grade I dysbiosis, the number of effector factors were joined by lysozyme, sIgA and pH; a factor of specific immunity appeared – IgG, which required the formation of humoral immune response involving T- and B-lymphocytes and was mediated by interleukins, the ones important among which were γ-INF i TNFα.

3. In grade II dysbiosis, levels of regulatory cytokines (IL1β and IL10) and pH became of the leading value.

4. Innormocenosis and grade I dysbiosisobligate anaerobes were not associated with factors of colonization resistance, but in grade II dysbiosis, IgG levels in vaginal secretions already had regulatory significance. As dysbiosis progresses, phagocytosis is joined by such protective factors as lysozyme (control of optional anaerobes), sIgA (control of NBI, myco- and ureaplasma), γ-INF (control of NBI) and IgG formation (triggered by growth of yeast-like fungi); decrease in the number of LB and increase in the ICPM reflected a pH increase. Levels of IL1β and IL10 had regulatory significance.

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Section 3. Technical science

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RESEARCH RESULTS OF INTERMEDIATE LEAKS OF A ROTARY ATOMIZER

Abstract. In rod sprayers, the working fluid pumped out of the tank during operation and pumped under pressure is first supplied to a control distribution system, where it regulates the pressure and amount of working fluid per hectare in accordance with the norm.

Keywords: sprayer, tip, boom, rotation, fluid, loss.

As a result, the corresponding part of the working fluid per hectare is directed to the nozzles by means of hoses and pipes leading to the spray nozzles at the selected pressure. The rest of the working fluid is returned and poured into the tank of the sprayer working fluid [1; 2; 3; 4]. Reduced – this selected position of the control valve is maintained throughout the entire spray period. At the same time, the selected working speed does not change during the entire spraying period in order to ensure the rate of working fluid per hectare. In multi-product and multi-section sprinklers, the working fluid pumped from the pump is supplied to a distribution valve installed after the pressure relief valve. The distribution valve block has a common crane at its inlet and a crane block with the number of spray rod sections up to the shoulders at the exit. The output of each branch installed in the distribution block of the branches belongs to one corresponding section. When the pump is running and the valve is open, the working fluid is supplied to the stem in the compartment and its nozzles, and the nozzles are sprayed.

When the valve is closed, the working fluid remaining in the hoses between the valve and the nozzles, as well as the holes in the nozzles, are directly connected to the atmosphere, and the nozzles have not one but several in each section, due to the difference in level between the nozzles, the vibration Due to the centrifugal force on the side, the liquid mass inside the pipe flows through the nozzle holes and is lost. In real life, most of these losses occur during a turn. The determination of the scale of these reliable losses is an important condition for justifying the proposed check valve, which can prevent such losses.

Purpose. Determine and justify the amount of working fluid that is lost in the atomizer due to centrifugal force from the nozzles during rotation in the atomizer.

Work methodology. During rotation of the spraying device – (tractor – spraying machine) at both ends of the field in the headland there is a flow of working fluid from the spray nozzles. However, in this case, the pump does not work and does not create pressure in the system. We conducted theoretical and experimental studies to determine the true amount of additional fluid flow. The slowdown was determined when the device turned on flat asphalt to determine whether there were losses only due to centrifugal force, without the effect of bumps. To do this, the test sprayer was sprayed with plastic cellophane bags on the spray nozzles, then the tractor returned. At the end of the circle, the tractor was stopped, and the amount of fluid collected in the bags of cellophane was divided by the turnaround time and compared with the fluid flow rate for 1 second, where it usually stopped. The experiment was carried out in 5 repetitions. The experiment was repeated in the same way, spraying a cotton field five times. The experiment was conducted on the right and left columns of 1-bar, 3-bar and 5-bar nebulizers. The spraying unit operated at a speed of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 m/s.

Laboratory device and its work.

A laboratory device was developed to determine the legitimacy of a fluid flowing out of nozzles with different speeds under the influence of centrifugal force. Here the Salafan bags 8 were dressed, and experiments were carried out at the ends of the rod, which were driven by two electric motors 1 with a gearbox simulating the rod.

The device has an integrated reservoir 5 on one side of the rotating rod. When the tap "k" is open, the liquid (water) reaches the ends (1, 2, 3, 4, 5) through 6 pipes. Under the influence of centrifugal force during rotation, the fluid tries to move away from the center of rotation of the pipe with inertia from the axis 0–0, and the system is under pressure, and the fluid flows from the ends. The more fluid gets into the bags, the more it moves away from the center of rotation.

Unit unemployment during the working day occurs mainly during the lunch break, when the worker fills the unit tank with working fluid and its preparation, when for some reason there is a malfunction in the sprinkler, when the organization stops and so on.

The intensity and magnitude of the work flow caused by vibration during movement, when the sprayer moves without spraying inside the field, when the sprayer is in the middle of the field, goes to the edge of the field and eliminates the problem. when the layer moves, as well as the centrifugal force at both ends of the field, losses occur both due to vibration and the additional influence of time on movement. occurs throughout the spraying process.

Conclusıon

It was found that:

1. The amount of fluid flowing from the ends during rotation is equal to the algebraic sum of the amount of fluid flowing from each end;

2. The total intensity of the fluid flowing through the nozzles during rotation is the ratio of the amount of fluid flowing per second to the total flow rate and time spent on the rotation process.

3. In an atomizer with the same width, when the speed of rotation of the unit increases during the rotation process, the total average amount of fluid flowing in the void and the flow rate vary depending on the square of the rotation speed.

4. In an atomizer with the same width, when the radius of rotation increases, the total average amount of working fluid flowing from the nozzles and the flow rate increase in proportion to the law of straight lines.

It was determined that the amount of working fluid flow and loss, as well as the average flow rate of the working fluid increase with increasing speed of the device. This occurs both during movement and rotation.

Laboratory, laboratory and field studies show that the amount of liquid flowing out of the spray nozzles increases as the working fluid freely flowing

out of the nozzles in the spray device moves away from the center (on both sides, left and right). In the last rod, the amount of fluid flowing from the end is maximum, and the amount of fluid flowing from the middle end is minimal.

Sprinklers In single-jet, three-beam and five-beam sprinklers, the amount of working fluid flowing from the end closest to the center of rotation of the rod is minimal, and the amount of fluid flowing from the farthest end is maximum.

Since the rotation speed of the spray device increases during rotation at various speed modes (at speeds of 0.5; 1.0; 1.5; 1.0; 2.0 and 3.0 m/s), the amount of fluid entering the total space increases with increasing speed.

As the rotation shifts from the center, the work flow, which flows in vain from the ends, is proportional to the speed of rotation, and the maximum volume of flow occurs at the farthest end (right and left).

In all cases when a check valve is installed on each of the spray nozzles: during stops and turns there is no idle flow of the working fluid. This allows you to effectively use the working fluid. Productivity rises and pollution is prevented.

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RATIONED NATURAL ROW. POLYPARAMETRIC CODING

Abstract. In the work are examined the polyparametric codes, whose verifying combinations are formed on the basis of not one code, but several related codes functional dependence. This dependence between neighboring code words is introduced artificially by rationing elements of the natural series by the preliminarily selected entire natural numbers.

Keywords: normalized natural series, one – and polyparametric codes, aggregate code, dual multiple, identifiers.

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НОРМИРОВАННЫЙ НАТУРАЛЬНЫЙ РЯД. ПОЛИПАРАМЕТРИЧЕСКОЕ КОДИРОВАНИЕ

Аннотация. В работе рассматриваются полипараметрические коды, проверочные комбинации которых формируются на основании не одного кодового, а нескольких, связанных с ним кодов функциональной зависимостью. Эта зависимость между соседними кодовыми словами вводится искусственно посредством нормирования элементов натурального ряда предварительно выбранными целыми натуральными числами.

Ключевые слова: нормированный натуральный ряд, одно- и полипараметрические коды, совокупный код, дуальная кратность, идентификаторы.

Постановка задачи

Многообразие помехоустойчивых кодов делится на два класса: блочные коды и непрерывные коды. В блочных кодах передаваемая информационная последовательность разбивается на отдельные блоки с добавлением к каждому блоку определенного числа проверочных символов. Кодовые комбинации кодируются и декодируются независимо друг

от друга. В непрерывных кодах, называемых также цепными, рекуррентными, конволюционными или сверточными, передаваемая информационная последовательность не разделяется на блоки, а проверочные символы размещаются в определенном порядке между информационными [4]. Процессы кодирования и декодирования также осуществляются в непрерывном режиме.

Блочные коды последние годы стали широко применяться в системах обмена информацией. Поскольку при конструировании проверочных комбинаций используют структуру одного кодового слова, создание их представляет довольно сложную процедуру. Даже для простого кода Хэмминга проверочная комбинации включает в себя четыре этапа: определение необходимого количества контрольных разрядов; определение расположения проверочных бит в результирующей закодированной последовательности; определение группы, которые контролируют проверочные биты; расчет значения контрольных бит. Такое положение объясняется тем, что контрольные биты получаются на основании информации, заложенной только в одном кодовом слове [1; 3].

В данной работе рассмотрена возможность получения проверочных комбинаций не по одной, а нескольким рядом стоящим блоковым кодам, имеющих функциональную зависимость между собой. В этом случае можно классифицировать блочные коды на одно-и полипараметрические. Однопараметрическими блоковыми кодами являются коды, проверочная комбинация каждого блока которых формируется на основании его внутренней структуры и полипараметрическими блоковыми кодами, проверочная комбинация которых формируется по данному блоку и множеством соседних кодовых слов функционально зависящих между собой.

За счет того, что проверочная комбинация строится по нескольким кодовым словам, повышается информативность их выбора и упрощается алгоритм их нахождения [5; 6]. Одновременно их можно представить целым числом без знака. В этом случае они являются элементами отрезка натурального ряда. **Натуральные числа** – числа, возникающие при счёте (например, 1, 2, 3, 4, 5, 6, 7, 8, 9…). Последовательность всех натуральных чисел, называется натуральным рядом. Над элементами натурального ряда могут производиться операции сложения, умножения, возведения в степень, а также вычитание и деление с остатком.

В работе показано, что при нормировании натурального ряда или его отрезков получаются результаты, которые можно использовать при создании полипараметрических блочных кодов.

Нормирование натурального ряда и анализ полученных результатов

Набор кодовых слов, полностью описывающих сообщение составляют его алфавит. Выбрать алфавит сообщения возможно по разным критериям. Одинаковые критерии всех кодовых слов алфавита образуют общий параметр кодовых слов. Если в кодах алфавита присутствует несколько различных параметров, их называют полипараметрическими. Из бесконечного множества различных кодов сообщения следует выбирать такие, параметры которых позволяют проверять правильность каждой кодовой комбинации, а также исправлять канальные ошибки. Иногда одного параметра для этой цели бывает недостаточно и приходится использовать несколько параметров соседних кодов одновременно. Понятно, что набор таких параметров может полностью заменить кодовое слово, которое в данном случае можно не передавать.

Для реализации полипараметрических кодов между соседними кодовыми комбинациями должна существовать функциональная связь, которая в обычном состоянии не наблюдается. Ее надо вводить искусственно. Для кодов, построенных на базе натурального ряда такая связь появляется при нормировании его элементов простыми или составными целыми числами.

Основные свойства рассматриваемых кодов проявляются в случае деления (нормирования)

каждого элемента отрезка натурального ряда (кодовой комбинации) на одно и то же целое число норму (L). Нормой могут служить любые, не только простые числа. После нормирования элементы натурального ряда приобретают свойства, которые можно использовать в качестве параметров полипараметрических кодов.

Результатом нормирования элементов отрезка натурального ряда, получается действительное число, состоящее из двух частей: неполного частного (модуля) и остатка от деления (остатка). Для нормированных элементов в качестве остатка используется только первые три знака после запятой, если они имеются. Возникающие при этом закономерности придают им новые свойства полезные при кодировании дискретной информации:

– элементы натурального ряда превращаются в действительные числа, состоящие из модуля и остатка;

– относительно модуля и остатков нормированный ряд или его отрезки разбиваются на участки одинаковой длины равной размеру нормы, условимся называть их циклами;

– после нормирования модуль становится в L раз меньше исходного целого числа;

– во всех циклах нормированного натурального ряда и в его отрезках остатки повторяются и определяются только размером нормы;

– модули элементов соответствуют порядковому номеру цикла в нормированном натуральном ряду, начиная с первого его элемента;

– друг от друга циклы отделяются нормированным элементом с нулевым остатком.

Эти свойства можно проследить для нормированных кодов.

На (рисунке 1) приведены примеры двух циклов нормированного натурального ряда для двух различных норм и двух разных по длине вырезок.

n = 70..84 k = 56..70

$G(n)=\frac{n}{7}$	$G1(n)=\frac{n}{11}$	$G(k)=\frac{k}{7}$	$G1(k)=\frac{k}{11}$
10	6,364	8	5,091
10,143	6,455	8,143	5,182
10,286	6,545	8,286	5,273
10,429	6,636	8,429	5,364
10,571	6,727	8,571	5,455
10,714	6,818	8,714	5,545
10,857	6,909	8,857	5,636
11	7	9	5,727
11,143	7,091	9,143	5,818
11,286	7,182	9,286	5,909
11,429	7,273	9,429	6
11,571	7,364	9,571	6,091
11,714	7,455	9,714	6,182
11,857	7,545	9,857	6,273
12	7,636	10	6,364
…	…	…	…

Рисунок 1. Циклы нормированного натурального ряда

Здесь $G(n)$ и $G(k)$ – результат нормирования, L= = 7 і 11– размер нормы, n и k – отрезки нормированного натурального ряда, из которых выбраны циклы. Параметры приведенных циклов следующие:

$$G(n),\ L = 7,\ n = 70 \dots 84;$$
$$G1(n),\ L = 11,\ n = 70 \dots 84;$$
$$G(k),\ L = 7,\ k = 56 \dots 70;$$
$$G1(k),\ L = 11,\ k = 56 \dots 70;$$

Элементы нормированного натурального ряда могут быть использованы в качестве полипараметрических кодовых слов. Отметим, что такими же свойствами будут обладать коды, составленные из вариации нормированных элементов натурального ряда [2]. Для проверки этого предположения был рассмотрен несколько экзотичный по структуре числовой «совокупный код». В этом коде каждое кодовое слово является производным от числового натурального ряда и формируется простым сложением его элементов. Например, код с порядковым номером n=5 получается, как результат суммирования десятичных чисел $S(n)$=1+2+3+4+5=15. Таким образом каждое последующее кодовое слово рекуррентно получается из предыдущего посредством добавления очередного элемента натурального ряда.

Рассмотрим два важных свойства совокупных кодов, которые легко проверяются экспериментально.

Первое свойство. Множество кодовых слов на некотором интервале их длин n будучи соотнесёнными к любому целому числу L обязательно дают одну или несколько дуальных кратностей. Дуальные кратности D (парные кратности) – это попарно расположенные результаты деления суммарного кодового слова с количеством элементов n на L без остатка. При делителях L небольшого значения они встречаются достаточно часто. Поэтому такие кодовые слова удобно использовать на практике.

Второе свойство. Для совокупных кодов существует такая закономерность, что, начиная с любой дуальной кратности, остатки от деления целых чисел этих кодов $S(n)$ на делитель L до и после самого числа, по множеству порядковых номеров n являются симметричными и попарно равными между собой. Рекомендуется длину нормы L выбирать равной размеру блока кодового слова. Значения остатков сохраняются по всему множеству номеров кодовых слов n.

Эти свойства являются идентичными для свойств отдельных элементов нормированного натурального ряда. Они позволяют конструировать и другие полипараметрические коды на основании нормированных элементов натурального ряда. Например,

– кодовые слова являются суммой двух или нескольких подряд следующих элементов ряда;

– каждое последующее кодовое слово рекурентно образуется по принципу трех подряд следующих элементов: *123;456…* или *123k;456k…*, где k – некоторый целый или дробный коэффициент. Можно придумать и обосновать и другие алгоритмы получения кодовых комбинаций, которые в работе не рассматриваются.

Идентификаторы полипараметрических кодов

Идентификаторы полипараметрических кодов могут строиться на основании особенностей как одного, так и нескольких функционально связанных кодовых слов. В частности, идентификаторами рассмотренных выше кодов могут служить: 1) целая часть нормированного числа (кода); 2) значения нескольких чисел остатка; 3) соседние разности или соседние линейные преобразования (разности, суммы и т.д.) двух или нескольких соседних слов; 4) линейные вариации указанных параметров. По ним можно обнаружить канальные ошибки и восстановить переданное кодовое слово.

Выводы

1. Исправляющие ошибки комбинации цифровых кодов можно получить, используя внутреннюю структуру только самого кодового слова (традиционный метод) или дополнительно ис-

пользовать функциональные связи с соседними такими же кодами, применяя особенности нормированного натурального ряда.

2. При нормировании вместо целочисленного натурального ряда образуется ряд действительных чисел, имеющих модуль и остаток. Ограничиваются тремя цифрами после запятой. Особенностью нормированного натурального ряда является периодическая повторяемость по всей его длине, а также отдельных отрезков остатков элементов на интервалах нормы. Эти отрезки образуют циклы.

3. Циклы разделяются между собой элементом с нулевым остатком.

4. Целая часть каждого элемента цикла нормированного натурального ряда равна порядковому номеру цикла.

5. Такие коды с исправляющими элементами легко кодируются и декодируются.

6. Вариации нормированного натурального ряда позволяют получить новые кодовые последовательности с новыми или дополнительными свойствами, которые могут использоваться для получения исправляющих ошибки комбинаций. Так в совокупных кодах циклы содержат элементы с симметричными относительно центра цикла остатками. Модули соседних элементов оказываются пригодными для получения дополнительных параметров.

7. Совокупные коды являются полипараметрическими, что может служить важным фактором для их идентификации.

8. Одновременное использование нескольких параметров совокупных кодов увеличивает верность обмена данными.

9. Возможны различные методы реализации кодовых параметров.

10. Полипараметричность совокупных кодов удобно использовать при реализации защиты информации от несанкционированного доступа и могут найти применение для адресации новых процессов.

11. Конкретная реализация каждого параметра определяется пользователями.

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THE USE OF OZONE AND MICRO BUBBLE TECHNOLOGIES FOR CULTIVATING CHLORELLA

Abstract. The article discusses methods for pretreating stagnant water by saturating it with ozone, which provides almost complete disinfection of water from pathogenic factors for the grown chlorella, including Rotatoria rotifers. During the experiments, semi-industrial bubble columns were developed and manufactured for the treatment of chlorella in pools with carbon dioxide and for pretreatment of water with ozone before loading chlorella.

Keywords: Water, ozone, algae, chlorella, purification, cultivation, concentration, minerals.

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ПРИМЕНЕНИЕ ОЗОНОВЫХ И МИКРОПУЗЫРЬКОВЫХ ТЕХНОЛОГИЙ ДЛЯ КУЛЬТИВИРОВАНИЯ ХЛОРЕЛЛЫ

Аннотация. В статье рассматриваются способы предварительной обработки стоячих вод с помощью насыщения её озоном, которое обеспечивает практически полное обеззараживание

воды от патогенных факторов для выращиваемой хлореллы, в том числе от коловраток Rotatoria. В ходе проведенных экспериментов разработаны и изготовлены полупромышленные барботажные колонки, для обработки хлореллы в бассейнах углекислым газом и для предварительной обработки воды озоном перед загрузкой хлореллы.

Ключевые слова: Вода, озон, водоросль, хлорелла, очистка, культивирование, концентрация, минералы.

Огромный исследовательский интерес ученых всего мира к хлорелле определяется, прежде всего, богатейшим составом всего спектра биологически активных веществ, высокой их концентрацией и сравнительно простой технологией получения больших количеств ее биомассы. Эти преимущества давно определили широкое применение хлореллы в различных областях деятельности человека: медицина, сельское хозяйство, пищевая промышленность, парфюмерия, очистка сточных вод и др.

Хлорелла – это одноклеточная зеленая водоросль, найденная в стоячих водах, богатых органическими веществами и во влажной почве. Наиболее распространенными видами являются *Chlorella vulgaris*, обитающая в воде луж, канав и прудов и *Chlorella infusionum,* поселяющаяся в сосудах с водой, покрывая зеленоватым налетом их внутреннюю поверхность. Для процесса фотосинтеза хлорелле требуются только вода, диоксид углерода, свет, а также небольшое количество минералов для размножения.

Благодаря высокому содержанию витаминов, хлорелла во многих странах стала востребованной пищевой добавкой, так как улучшает пищеварение, обеспечивает жирными кислотами, укрепляет иммунитет, а по содержанию белка прекрасно заменяет мясо и даже пшеницу. Существуют также практика использования в медицинских целях при лечении вирусных заболеваний или выведении токсинов. По своей питательности эта водоросль не уступает мясу и значительно превосходит пшеницу. Если в пшенице содержится 12% белка, то в хлорелле его более 50%.

Пятимикронные клетки хлореллы проходят через желудок и кишечник, не расставаясь с половиной белка протеина. Группа ученых из штата Небраска (США) сделала вывод: наш пищеварительный тракт не в состоянии разрушить клеточные стенки хлореллы и взять все полезное, что за ними скрыто. В настоящее время разрабатываются десятки способов разрушения оболочки клеток хлореллы, в том числе с применением озоновых технологий, так что можно рассчитывать на решение этой проблемы в ближайшее время.

Для исследования реакции хлореллы обработку воды озоном, а также её реакцию на насыщение углекислым газом были использованы: распространённый вид хлореллы -*Chlorella vulgaris*, а также планктонный штамм хлореллы ИФР № С-111, который был выделен Богдановым Н. И. в 1977 году из Нурекского водохранилища. Одна из проблем культивирования хлореллы – это защита её от коловраток Rotatoria. Коловратки, попадая в бассейн с культивируемой хлореллой способны полностью уничтожить весь урожай хлореллы. Используя хлореллу в качестве корма, коловратка обретает ярко оранжевый цвет.

Предварительная обработка воды озоно-воздушной или озоно-кислородной смесью приводит к полному уничтожению коловраток, попавших в ёмкость, куда предполагается заселить культуру хлореллы и резко увеличивает объём выращиваемой хлореллы.

Необходимо отметить, что озоновые технологии являются сравнительно дешевыми, практически не требуют расходных материалов (исходным и конечным сырьем является обычный воздух или кислород). Энергетические затраты на генерацию озона незначительны (до 20–30 Вт*час на 1 грамм озона), что является важным техническим

и экономическим фактором. Создание простых, надежных генераторов озоно- кислородных и озоно-воздушных смесей для задач промышленности и мобильных генераторов для полевого применения представляет собой актуальную проблему.

Но, чтобы эффективно растворить озон (или углекислый газ) в воде необходимо разработать специальные колонки, с генерацией пузырьков, размером существенно менее 1 мм. При использовании обычного оборудования, например, диффузных камней, используемых в аквариумах, пузыри получаются размером существенно более 1 мм (до 5 мм). Количество растворённого газа зависит от размеров пузырьков. Чем меньше размеры, тем больше суммарная контактная площадь газа с жидкостью. Поэтому были разработаны устройства с генераторами микропузырьков, позволяющие эффективно растворять озон в воде.

Например, микропузырь с радиусом 10 мкм поднимается со скоростью приблизительно 50 мкм/сек, другими словами, всплывает на 3 мм за минуту. Такая медленная скорость подъёма приводит к большему времени пребывания в воде и, поэтому, к более высокому газовому насыщению, которое связано с большей удельной площадью поверхности раздела.

При уменьшении размеров пузырьков скорость уменьшается вначале пропорционально корню квадратному от размера, а при диаметре пузырька меньше 1 мм, пропорционально квадрату диаметра пузырька. Коэффициент массопереноса обратно пропорционален диаметру пузырька.

Следовательно, эффективность растворения газа в воде прямо пропорциональна третьей степени от диаметра пузыря (Для стоксовых пузырей, движущихся в ламинарном режиме всплытия).

Изменение размеров пузырьков с 2–4 мм до десятков микрон в

поперечнике увеличит растворимость газов в воде в тысячи раз. Без разработки и применения технологии генерации микропузырьков, для того чтобы получит концентрацию озона 0,5–1,0 мг/л, потребуется большой, громоздкий озонатор (в десятки килограммов весом). Для компактного мобильного озонатора получение этой концентрации озона в воде абсолютно недостижимо, если использовать для генерации пузырьков обычный диффузный камень (применяемый в аквариумах).

Были разработаны специальные распылители для генерации микропузырьков.

Следует отметить, что концентрация 0,5 мг/л озона является минимальной, для полного обеззараживания воды от патогенных микроорганизмов.

С использованием технологии микропузырьков можно обеспечить растворение практически 100% углекислого газа, необходимого для микроводорослей (хлореллы, спирулины). Известно, что у водоросли *Chlorella vulgaris* при дефиците CO_2 прекращается фотосинтез, уменьшается количество хлорофилла и запасных веществ, в частности углеводов, более чем в 1,5 раза.

Известно, что пресноводные водоросли, в отличие от морских водорослей, способны поглощать свободную углекислоту. При интенсивном культивировании насыщение суспензии водорослей воздухом, обогащенным углекислым газом (с концентрацией в воздухе – не менее 2,0%), позволяет повышать продуктивность хлореллы до 25–28 г сухого вещества с 1 $дм^3$ в сутки [3].

В нашем случае, в ёмкости с хлореллой подавали баллонный углекислый газ по 5 мин четырежды в день, в течение 6-ти дней, со скоростью 100 $дм^3$/ч, используя насыщение воды углекислым газом, с помощью генераторов микропузырьков. Следует сделать вывод, что при подаче CO_2 интенсивность роста хлореллы увеличивалась более, чем в 3–4 раза.

Для изучения воздействия растворённого в воде озона была разработано устройство (рисунок 1) для изучения обработки озоном микробиологических объектов и хлореллы.

Из баллона с кислородом 1 через редуктор подаётся кислород в реактор озона 3, подключённый к высоковольтному блоку питания.

Из реактора, генерирующего озон в коронном разряде, 3 озоно– кислородная смесь по фторопластовой трубке 4 подводится к распылителю пузырьков озона в воде 6 (например вихревой генератор микропузырьков), размещённому в сосуде 5.

Пузырьки озоново-кислородной смеси поднимаясь в воде, растворяются в ней. При этом они передают в водный раствор часть озона. Кислород и не растворившийся в воде озон по выводной трубке 8 выдувается вытяжным вентилятором 9 наружу лаборатории.

Осветительное устройство 10 обеспечивает достаточное освещение для USB – микроскопа, записывающего на компьютере 12 процессы, происходящие с хлореллой под действием озона. Микроскоп обладает большим рабочим расстоянием (до 50 мм) позволяющим регистрировать физические процессы внутри ёмкости 5.

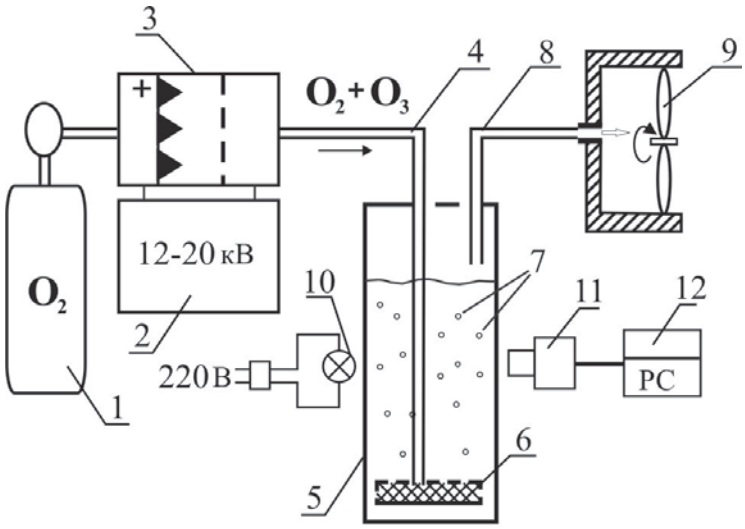

Рисунок 2- Конструкция устройства для изучения обработки озоном микробиологических объектов и хлореллы

1 – баллон с кислородом, 2 – высоковольтный блок питания с обратной связью, 3 – реактор озона, 4 – фторопластовая трубка для подачи в воду озоново – кислородной смеси, 5 – ёмкость с водной взвесью хлореллы, 6 – распылитель пузырьков озона, 7 – пузырьки озона, 8 – выводная трубка, 9 – вытяжной вентилятор, 10 – осветительное устройство, 11 – USB – микроскоп (или скоростная видеокамера), 12 – компьютер

Данное устройство позволяет изучать динамику поведения пузырей в водном растворе и в водной взвеси хлореллы. Естественно для оптической прозрачности водной взвеси, исследования должны проводиться при сильном разбавлении микробиологического препарата.

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Section 3. Electrical engineering

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A METHOD TO IMPROVE EFFICIENCY OF A THERMAL POWER PLANT AND ITS IMPLEMENTATION DEVICE

Abstract. In the modern world, electricity plays an important role. Its consumption increases every year. A significant part is produced at thermal power plants. The average power plant burns about 600 tons of coal per hour. There are thousands of such power plants in the world. Experts know that almost half of the fuel burned is used to pollute the environment and heat the atmosphere without producing useful energy. This is how the existing loop works.

The article provides links to theoretical conclusions of various scientists on statistical thermodynamics, space-time thermodynamics, and kinetic physics. Based on theoretical assumptions, a simple technical solution is proposed that allows you to change the existing cycle. The new cycle will approach the ideal Carnot cycle known since 1824.

This allows you to almost double the efficiency of thermal power plants. As a result, you can burn half as much fuel, reduce emissions of carbon dioxide and combustion products, and useless heating of the atmosphere completely stops. At nuclear power plants there will be half the amount of radioactive waste. This will possibly improve the environment and slow down climate change.

Keywords: heat power engineering; Carnot cycle; increase in efficiency; reduction of air emissions; stabilization of climate change; innovative heat power technology.

The invention relates to the field of heat-power engineering, and can be applied in thermal, nuclear and combined gas turbine power plants.

The flow chart of the classical power generation cycle at thermal power stations is the following (Fig. 1).

Water is supplied to the steam boiler (hereinafter SB) (102) by the feeding pump (hereinafter FP) (101) under pressure P_1(113) and temperature T1 (114). In Russian power plants, the pressure at the inlet of steam boilers is 3.4 MPa, 8.8 MPa, 12.75 MPa, 23.5 MPa or, correspondingly, 35 kg/cm^2, 90 kg/cm^2, 130 kg/cm^2, 240 kg/cm^2. These values are standard. In other countries these parameters may differ.

In the steam boiler SB, the water is heated (heat Q_1 is supplied) and vaporized (heat (Q_2 is supplied), saturated water steam is directed to the steam superheater RH (103), where the steam is superheated up to temperature T 2 ~ 545 °C (heat Q_3 is supplied). The superheated steam is directed to the turbine, the high-pressure cylinder HPC (104), the processed steam, under the temperature higher than the saturation temperature and decreased pressure, is supplied to the intermediate steam superheater SS_1(105). In the

intermediate steam superheater the stem is heated up to temperature ~ 545 °C (heat Q_4 is supplied) and directed to the next turbine stage, the medium pressure cylinder MPC (106). The processed steam in MPC, under the temperature higher than the saturation temperature and even lower pressure, is supplied to intermediate steam superheater SS_2 (107). In SS_2 the steam is again superheated up to the temperature of ~ 540 °C (heat Q_5 is supplied) and directed to the next turbine stages, low pressure cylinders LPC (108). Depending on the plant capacity, there are usually from 2 to 6 low pressure cylinders.

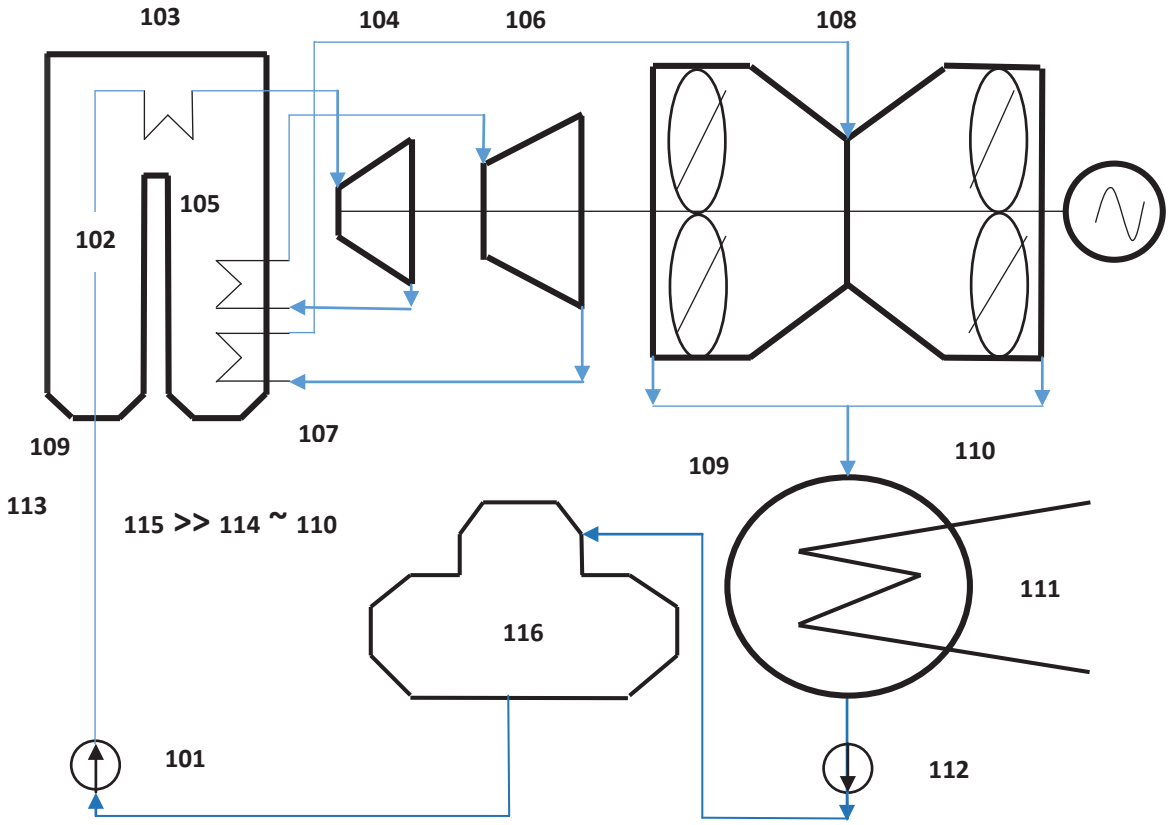

Figure 1.

Intermediate superheating of steam allows to increase the average heat supply temperature, and the process of steam expansion in the turbine ends in the area of higher dryness of steam, therefore the operating conditions for the turbine setting area are lighter.

The Carnot cycle without intermediate steam superheating and the Rankine cycle with intermediate steam superheating are applied.

The steam processed in the turbine, under P_2 (109) from 1.7 kPa to 4.2 kPa, temperature T_3 (110) from 15 °C to 30 °C, (point of the right saturation boundary on T – S diagram, Fig. 2) [3] (under such pressure and temperature the steam has specific volume Vs from 77.97 m^3/kg to 32.93 m^3/kg and condensation heat r from 2465 kJ/kg to 2430 kJ/kg [3]) (these values will be required later for calculations), is supplied to condenser C (111), where it is fully condensed with transition to the liquid phase and giving r (condensation heat from 465 kJ/kg to 2430 kJ/kg, heat $-Q_6$) to the cooling water. The liquid phase remains in the condenser for approximately 20 seconds. Each kilogram of steam requires from 50 to 80 kg of cooling water, the heat of which heats up the atmosphere. Up to 45% of the heat supplied within the cycle is irretrievably lost in the condenser.

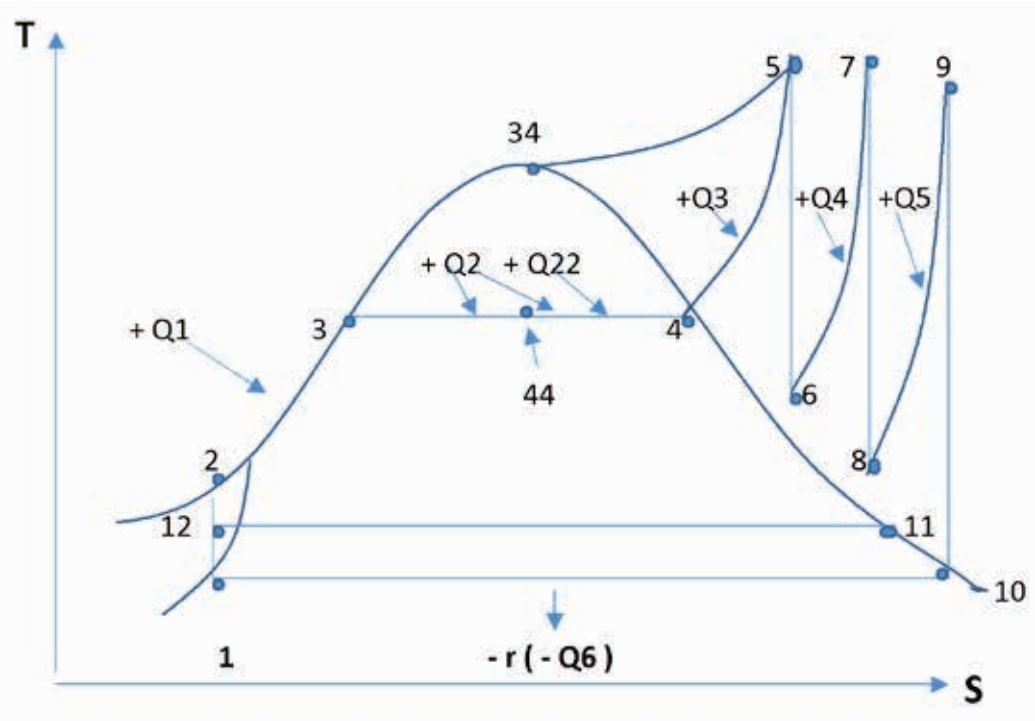

Figure 2.

The condensate pump CP (112) is located approximately 2 m from the condenser. CP pumps water from the condenser, increasing pressure to 1.4 or 1.5 MPa, which water is supplied to de-aerator (116); under this pressure the boiling temperature is 196 °C or 198 °C. The condensate remains in the deaerator approximately for 20 seconds, then it is supplied to the feeding pump FP, which increases pressure up to P_1 (3.4 MPa, 8.8 MPa, 12.75 MPa, 23,5 MPa, the higher the pressure, the higher the water boiling temperature), with T_1 practically being equal to T_3, the cycle is repeated. The distance from the deaerator to the feeding pump is approximately 60 m. If the condensate is fed by-passing the recuperative heads under the average flow speed of 2 m/s, the condensate reaches the feeding pump within 30 seconds. In the equipment rated operating mode, water reaches the feeding pump from the condenser within 70 seconds.

The real flowchart is more complicated, only the basic equipment is described.

Water is a practically incompressible liquid, therefore the energy consumption for pressure increase are insignificant, the equipment is rather compact.

The mechanical work required for increasing water pressure can be calculated using the formula:

$$L = P * dV \quad [1, P. 20] \text{ where}$$

L – is mechanical work.

P – is water operating pressure created by the feeding pump (FP) at the inlet of the steam boiler (SB 3.4 MPa, 8.8 MPa, 12.75 MPa, 23.5 MPa).

dV, change of the water volume, is practically = 0, therefore the work L is insignificant.

According to the second law of thermodynamics, all mechanical work L can be converted into heat [energy] Q, while heat [energy] can be converted into mechanical [energy] only with irreversible losses, therefore L and Q are equal terms with one unit of measurement, i.e. J, representing different forms of the same energy [1, P. 8, 9].

A disadvantage of this cycle is irretrievably lost heat, up to 45% in condenser C, along with cooling water. The diagram of the cycle in question in T-S coordinates is presented in (Fig. 2).

1 – 2 Increasing of water pressure up to the operating level by the feeding pump FP. (3.4 MPa, 8.8 MPa, 12.75 MPa, 23.5 MPa).

The distance between points 1 and 2 is very small due to incompressibility of water. These points practically match.

In the diagram the distance between the points is increased on purpose in order to show that this process exists.

2 – 3 Water heating to the boiling temperature under operating pressure in the steam boiler SB. Heat Q_1 supply, the water boiling temperature depends on the operating pressure.

3 – 4 Water evaporation in SB, area of saturated water steam, boiling process. Heat Q_2 supply.

34 Point 34 on the diagram indicates the point of water transition to steam without boiling, for single-flow units operating at above-critical pressure Pc = 22.1145 MPa.

4 – 5 Superheating of dry steam in steam superheater SS. Heat Q_3 supply.

34 – 5 Superheating of dry steam for single-flow units.

5 – 6 Steam work in the high-pressure cylinder HPC. Decreasing of pressure and steam temperature above the saturation temperature.

6 – 7 Superheating of dry steam in SS_1.Heat Q_4 supply.

7 – 8 Steam work in the medium pressure turbine cylinder MPC. Decreasing of pressure and steam temperature above the saturation temperature.

8 – 9 Superheating of dry steam in SS_2. Heat Q_5 supply.

9 – 10 Steam work in the low pressure turbine cylinder LPC. Decreasing of pressure and steam temperature to the saturation temperature.

10 – 1 Steam condensation in condenser C by cooling water, transition to the liquid phase. Removal of heat – Q_6 = r from 2465 kJ/kg to 2430 kJ/kg. Permanent loss of heat with cooling water giving heat to the atmosphere.

Then, the cycle is repeated.

The work which can be obtained within the cycle is proportional to the area of the pattern limited by lines 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10 – 1.

Patent GB 0002528830 10.02.2016 describes a method of increasing pressure of processed and not yet saturated steam at the turbine outlet using accelerating nozzles together with the compressor followed by superheating without transition to the liquid phase and repeated supply of steam to the turbine for effective work.

A disadvantage of this method is in significant power consumption for pressure increasing of non-saturated steam.

Patent US 6357235 19.03.2002 suggests using pre-compressed atmospheric air to increase pressure of non-saturated steam without transition into the liquid phase followed by superheating, and supplying steam to the turbine.

A disadvantage of this method is in significant power consumption for increasing pressure of non-saturated steam, which will be demonstrated below.

In the T – S diagram, the cycle will be limited by lines 4 – 5 – 6 – 4, and the cycle itself will include:

6 – 4 Increase of non-saturated steam pressure.

4 – 5 Superheating of steam.

5 – 6 Work of steam in the turbine.

Then, the cycle is repeated.

The area of the pattern limited by lines 4 – 5 – 6 – – 4 is by far smaller than the area limited by lines 1 – – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10 – 1 (of the cycles in use), which means that it is impossible to obtain a bigger amount of work.

The work is proportional to the area limited by the cycle's lines.

We will now look at the work needed to be performed for compression of 1 kilo of steam in accordance with patents GB 0002528830 10.02.2016 and US 6357235 19.03.2002.

P_1 = 3.4 MPa (3400 kPa) Lowest operating pressure used in cycles.

V_2 ~ 0.005 m/kg Specific steam volume at t 545 °C

V_1 = 32.93 m^3/kg Specific steam volume at t 30 °C

$L = P_1 * (V_2 - V_1)$. The work needed to be performed for compression of steam using any method [1, P. 20].

$L = P_1 * (V_2 - V_1) = 3400$ kPa $*(0.005$ m^3/kg $- -32.93$ m^3/kg $) = - 111945$ kJ/kg

Work and heat are equal terms [1, P. 8, 9].

The work providing steam compression using any method (irretrievably lost energy), L = 111945 kJ/kg >> r from 2465 kJ/kg to 2430 kJ/kg, greatly exceeds the heat of condensation which is irretrievably lost in the condenser for classical cycles.

Therefore, the efficiency of the cycles presented in the above-mentioned patents will be lower as compared with the existing cycles.

The proposed technical solution is aimed at significant increase of the power generation cycle efficiency at thermal, nuclear and combined gas turbine power plants using Carnot and Rankine cycles by significantly reducing the amount of heat irretrievably lost in the condenser by changing part of the existing cycles with the suggested new cycle.

This aim is achieved by a fundamentally different solution to the technical problem of reducing the heat loss in the condenser and significant improvement of the heat cycle efficiency.

It is found, in particular, that saturated water steam starts to condense if its pressure is slightly increased above the saturation pressure level. In this case, the supersaturated steam transits to the liquid phase [1, P. 215, 256, 257]. In compliance with the invention idea, it is proposed to perform the heat cycle using the existing equipment with the existing parameters up to point 10 in the T – S diagram, where the steam, fully worked off inside all of the turbine cylinders, is directed to the condenser where the pressure level is to be increased above the saturation pressure level and the cooling water circulation through the condenser is to be gradually stopped. Transition of steam into the liquid phase will occur because the pressure in the condenser will be higher than the saturation pressure. The steam condensation heat will remain in the cycle.

The condensation process will be self-adjusting. Saturated water steam is vaporized and condensed at constant temperature and pressure T = const and P = const [1. P. 212, 247; 2, P. 194, 195, 196]. The process is self-adjusting.

The excess pressure needed to be created in the condenser can be determined using the tables of M.P. Vukalovich.

Part of the thermodynamic table for water and water steam properties in saturated condition [3].

Table 1.

t	P	V'	V''	Change of pressure by 1 °C
°C	kPa	m^3/kg	m^3/kg	kPa
15	1.7041	0.0010008	77.970	0.1129
20	2.3368	0.0010017	57.833	0.1487
25	3.1663	0.0010030	43.399	0.1937
30	4.2417	0.0010043	32.929	0.2496

The table shows that the required excess pressure is under 0.2496 kPa, such a small pressure increase will reduce the cycle efficiency by no more than 0.01 %.

The thermodynamic aspects of the proposed invention are corollary of the mathematical proof presented by Nobel prize winner Lars Onsager, who in his work "Thermodynamics of phase transitions" laid the foundation for the 4th law of thermodynamics, which was later confirmed by experiments, and of the fact that the specific heat capacity of components during phase transitions goes to infinity. This means that the condensate specific heat capacity during the phase transition is enough for the steam kinetic energy to transform into the internal energy without significant

temperature increase. A similar proof is presented by M.P. Vukalovich [1, P. 238].

In terms of static thermodynamics, the required amount of condensed steam must have enough latent heat of condensation/vaporization for increasing the condensate temperature and reverse partial evaporation that would create equilibrium under new pressure.

However, the process is not static and must be considered in terms of kinetics physics [4], and as Lars Onsager proposed, thermodynamic processes ought to be regarded within space-time coordinates.

During isobaric-isothermal first-order phase transition (which is the condensation/vaporization process) the Gibbs free energy is minimal, and its change is equal to zero. This means that all the body (condensate) energy is spent on the change of its aggregate state and discontinuous change of the physical parameters, e.g. density is increased by 30,000 times and more, specific heat capacity is increased almost twofold [1, p. 108–150]. The relaxation time for physical parameters of the body (the time it takes for the physical parameters to match the empirical values) [5; 6] can be determined according to the formula

$$Tsec = L^2 / x$$

Where Tsec– relaxation time sec

L – area m^2

x – heat diffusivity ratio under first-order phase transition, for water $0.143*10^{-6}$ m^2/sec

Assuming that the condensation nucleus (condensate droplet) [1, P. 215] has the shape of a ball with a 1 mm radius (0.001 m), its area is

$$L = 4*\pi*R^2$$

$$L = 4 * 3.14 * (0.001)^2 = 12.56 * 10^{-6} \text{ m}^2$$

$$Tsec = 12.56 * 10^{-6} \text{ m}^2 / 0.143*10^{-6} \text{ m}^2/\text{sec} = 87.8 \text{ sec}$$

As calculated above, the condensate travel time to the feeding pump is 70 sec, and the relaxation time of the condensate physical parameters is 87.8 sec.

If the condensate passes through the feeding pump that creates the operating pressure at the steam boiler inlet, before the time of relaxation, the temperature increase and partial evaporation of feeding water start at the inlet or inside the steam boiler. If the relaxation process takes place upstream of the feeding pump, then the process is impossible. However, placing the feeding pump as close to the de-aerator as possible, or finding other technological solutions would allow implementing of the proposed cycle.

Let us review the proposed cycle within T – S coordinates, (Fig. 2).

At the beginning, it is necessary to launch the above-mentioned classical cycle with the loss of latent heat of condensation/vaporization and reach the equipment rated operating mode. The classical cycle will create deep vacuum in the condenser and condensation nuclei [1, P. 215]. During transition to the proposed cycle the process will be fully repeated up to point 10, then it will pass through the following points:

10 – 11 insignificant pressure increase above the saturation pressure level, in the diagram the distance between the points is increased on purpose to show that this process exists [1, P. 215, 256, 257]

11 – 12 phase transition from the vaporous state to liquid phase, points 1 and 12 will practically match because water is uncompressible (points 1 – 2). Removal of heat – Q_6 = r from 2465 kJ/kg4 to 2430 kJ/kg will not occur.

12 – 2 Increasing of water pressure up to the operating level by the feeding pump FP. (3.4 MPa, 8.8 MPa, 12.75 MPa, 23.5 MPa).

The distance between points 1, 12 and 2 is very small because water is uncompressible, they practically match.

2 – 3 Water heating to the boiling temperature under operating pressure in the steam boiler SB. Supply of heat Q_1 is not required as the condensate internal energy $T_{32} >> T_1$, the calculation is given below, the water boiling temperature depends on the operating pressure.

3 – 44 Partial water evaporation, area of saturated water steam, supply of heat Q_2 to point 44 is not required as the condensate internal energy $T_{32} >> T_1$, the calculation is given below.

44 – 4 Complete water evaporation in SB, area of saturated water steam, boiling process. Supply of heat Q_{22} << Q_2, the calculation is given below.

34 Point 34 specifies the point of water transition to steam without process of boiling on the diagram, for single-flow units operating at above-critical pressure Pc = 22.1145 MPa.

4 – 5 Superheating of dry steam in steam superheater SS. Heat Q_3 supply.

34 – 5 Superheating of dry steam for single-flow units.

5 – 6 Steam work in the high-pressure cylinder HPC. Decreasing of pressure and steam temperature above the saturation temperature.

6 – 7 Superheating of dry steam in SS_1. Heat Q_4 supply.

7 – 8 Steam work in the medium pressure cylinder MPC. Decreasing of pressure and steam temperature above the saturation temperature.

8 – 9 Superheating of dry steam in SS_2. Heat Q_5 supply.

9 – 10 Steam work in the low pressure cylinder LPC. Decreasing of pressure and steam temperature to the saturation temperature.

10 – 11 insignificant pressure increase above the saturation pressure level, in the diagram the distance between the points is increased on purpose to show that this process exists.

Then, the cycle is repeated.

The area limited by lines 12 (1) – 2 – 3 – 44 – 4 – – 5 – 6 – 7 – 8 – 9 – 10 – 11 – 12 (1) matches almost exactly with the classical cycle which means that the work will be the same.

The area limited by lines 1 – 12 – 11 – 10 – 1 is proportional to the work needed to be performed for the phase transition of steam into water, irretrievably lost energy. The mechanical work and heat are mutually convertible, presenting different forms of the same energy, one unit of measurement, J [1, P. 8, 9].

"Enthalpy I refers to a single-value function of the system's condition" [1, P. 38].

"Entropy S refers to a single-value function of the system's condition" [1, P. 38].

Maximum mechanical work which can be obtained in the reversible (cyclic) heat process

$$L_{0\,max.} = \mathbf{I}_1 - \mathbf{I}_2 - T' * (S_1 - S_2) = L$$

of expansion [1, P. 91, P. 110] does not depend on the method the process was performed [1, P. 444], as the enthalpy and the entropy do not depend on the process implementation but only depend on the original and final condition of the working fluid, the system's enthalpy and entropy refer to a single-value function of the system's condition [1, P. 38, P. 71, P. 78].

Efficient mechanical work which can be obtained in the reversible (cyclic) heat process will always be less by the value of working fluid compression.

L efficient = L expansion – L compression [1, P. 59]

Mechanical work of compression L = P*dV [1, P. 20].

Efficiency = L efficient / L expansion = (L expansion – L compression) / L expansion

An example of a cycle efficiency calculation for 1 kilo of steam is presented below.

The work needed to be performed for the phase transition of steam into condensate.

The process occurs at constant temperature t from 15 °C 30 °C

Steam saturation pressure P from 1.7 kPa 4.2 kPa

Specific steam volume Vs from 77.97 m^3/kg 32.93 m^3/kg

Specific volume of water (condensate) Vw from 0.001 m^3/kg0.001 m^3/kg

Specific condensation heat r 2465 kJ/kg 2430 kJ/kg

Irretrievably lost work

$$L = P * dV = P * (Vw - Vs)$$

L = 1.7 kPa * (0.001m3/kg – 77.97 m^3/kg) = –133 kJ/kg

L = 4.2 kPa * (0.001 m^3/kg – 32.93 m^3/kg) = –138 kJ/kg

Heat remaining in the cycle

Qc = r – L = 2465 kJ/kg – 133 kJ/kg = 2332 kJ/kg

Qc = r – L = 2430 kJ/kg – 138 kJ/kg = 2292 kJ/kg

The heat lost in the condenser of the classical cycle r is ~ 45%, the lost energy (work) in the proposed cycle L ~ 2.5%.

Thus, the efficiency of the proposed cycle will be higher by ~ 42.5 % (45% – 2.5%) than the efficiency of the classical cycle.

Additionally please find below the calculation for point in T–S diagram for pressure P_1=3.4 MPa (for higher pressure the water boiling temperature will be higher) and for temperature of processed steam t 30 °C.

Operating pressure P_1 3.4 MPa

Water boiling temperature at this pressure Tb 241 °C

Steam generation heat Q_2 Qs 1759 kJ/kg

Water temperature at the inlet of the steam boiler SB T_1 30 °C

Medium water heat capacity Cw 4.2 kJ/(kg*K)

Heat required for heating 1 kg of water to $Q_1 = Cw * (Tb – T_1)$ boiling temperature Q_1 no need to supply$Q_1 = 4.2$ kJ/(kg*K) * (241 – 30) =886 kJ/kg as the heat remaining in the cycle will be enough

T_{32} will correspond to T_b

Heat remaining in the cycle Qc 2292 kJ/kg

Heat remaining for partial evaporation

$$Qe = Qc – Q_1$$

corresponds to point 44 in T – S diagram.

Qe = 2292 kJ/kg – 886 kJ/kg = 1406 kJ/kg

Heat needed for complete evaporation

Q_{22} = Qs – Qe 1 kg of water in the proposed cycle.

Q_{22} = 1759 kJ/kg – 1406 kJ/kg = 353 kJ/kg

Q_{22} = 353 kJ/kg << Q_2 = 1759 kJ/kg

In accordance with the laws of statistical thermodynamics, thermal balance should be kept after a time period required for relaxation of condensate physical parameters.

$$I''_{30} = I'_{241} * (1 – X) + I''_{241} * X$$

Where: I''_{30} – is enthalpy of saturated steam at the saturation boundary at the temperature of 30 °C.

I'_{241} – is enthalpy of feed water at the saturation boundary at the temperature of 241°C.

I''_{241} – is enthalpy of saturated steam at the saturation boundary at the temperature of 241°C.

X – is a steam dryness factor.

The remaining heat Q_3, Q_4, Q_5, required for superheating of steam, is supplied the same way as in the classical cycle.

The calculations presented show that the condensation heat r from -2465 kJ/kg to – 2430 kJ/kg is lost under the classical cycle in the condenser, representing roughly – 45% of permanent loss.

The permanent loss under the proposed cycle (work for compression of fluid L compression). L from –133 kJ/kg to –138 kJ/kg, is significantly lower, representing roughly from –2.4% to –2.6% (~ 0.025) of permanent loss, as the process is developed under very low pressure in the condenser, practically in vacuum, which was preliminary created under the classical cycle.

L efficient = L expansion – L compression [1, P. 59].

Mechanical work of compression L = P*dV [1, P. 20].

Efficiency = L efficient / L expansion = (L expansion – L compression) / L expansion

Assuming that L expansion = 1 (with obtained parameters I S), L compression will be 0,025.

Efficiency = (L expansion – L compression) / L expansion = (1 – 0.025) / 1 = 0.975 (97.5%) < 1.

Thus, the proposed cycle improves the power plant efficiency by 42.5%.

There are many versions of the second law of thermodynamics [1, P. 56, P. 99], "this great principle of nature is still far from being known and, consequently, the story of the second law of thermodynamics is not over yet" [1. P. 97]. However, all agree that heat energy cannot fully be converted to the mechanical energy without loss [1. P. 58], "second-order perpetuum mobile" is impossible, efficiency of the thermal engine shall be < 1 (< 100%) [1, P. 57].

A question concerning thermal efficiency may arise.

In order to answer this question it is necessary to recall the original formulation of the Carnot's theorem known from the only one of his works (the rest Carnot's manuscripts were burnt).

The original formulation of the Carnot's theorem (term "efficiency" was also for the first time applied by Carnot). "Thermal efficiency of a reversible cycle refers to the ratio between the efficient external work L' produced by the engine performing this cycle and amount of heat Q_1 from hot fluid: Efficiency t = L'/Q1» [1, P. 62].

The temperatures are not listed in the original formulation, and are derivative for the cycle with extraction of the latent heat of condensation.

The obtained efficiency is the highest among other known engines [1, p. 376–424), in 1824 Sadi Carnot presented mathematically approved evidence that the efficiency of the reversible thermal engine is the top limit of an action efficiency.

In the 1930 s of the last century, Richard Feynman, a Nobel Prize winner, was among the first scientists to suggest the existence of a monothermal cycle, and in the 1960 s, Lev Landau, a Nobel Prize winner, substantiated theoretically the combined and monothermal cycles.

There have been written a lot of articles about Carnot but his work is still relevant. Only nearly two hundred years after his publication an idea appeared to come as close as possible to his cycle of conversion of heat energy into mechanical, and further, into electrical energy.

Let me remind you of the essence of the cycle proposed by Carnot. The cycle consists of two adiabats and two isotherms, please point out this fact.

In T – S diagram it looks as follows, (Fig. 3).

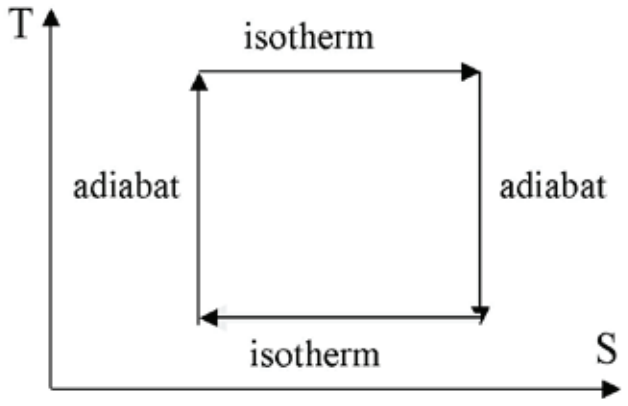

Figure 3.

Two adiabats (without supply and extraction of heat).

Two isotherms (processes with constant temperature).

This is the ideal Carnot's cycle to which it is possible only to approximate.

Let us review, using the T – S diagram, the modern cycles for conversion of heat energy into mechanical energy with water being a working fluid.

Fig. 4 schematically represents the cycle for real conversion of heat energy into mechanical energy without intermediate superheating of steam. The cycle consists of two isotherms and ONE adiabat. For implementation of this cycle, it is required to provide supply of heat Q_1 to heat up the working fluid (water) to the boiling temperature, extraction of boiling/vaporization heat, which reduces the cycle efficiency.

Let us review the cycle proposed in the article, (Fig. 5). The cycle consists of two isotherms and TWO adiabats, which makes it most similar to the ideal Carnot's cycle! Process 1 – 2 does not require heat supply – an adiabat.

The internal heat of condensation/vaporization remaining in the cycle is enough, judging by the calculations, to provide heating of the working fluid (water) up to the boiling temperature and its partial evaporation. An insignificant mechanical work, which is equivalent to heat amount, is spent on condensation of the working fluid (saturated water steam). The ideal Carnot's cycle passes through points 1 – 2' – 3' – 5 – 1, the proposed cycle passes through points 1 – 2 – 3 – 4 – 5 – 1. If the cycle area limited by the lines passing through points 3 – 4 – 3' – – 3 is rotated by 180 degrees along the horizontal and vertical axes, and points 3' and 2' (the areas marked with an asterisk) are aligned, then the area of the proposed cycle will cover the significant part of the area of the ideal cycle limited by the lines passing through points1 – 2' – 2 – 1. Here we can make a conclusion that the work of the proposed cycle will be close to the work of the ideal cycle as in T – S diagram the

area limited by the cycle lines is proportional to the work. In terms of kinetic physics, the process is feasible. The cycle efficiency is rather higher than of the existing cycles and lower than 1, which corresponds to the second law of thermodynamics.

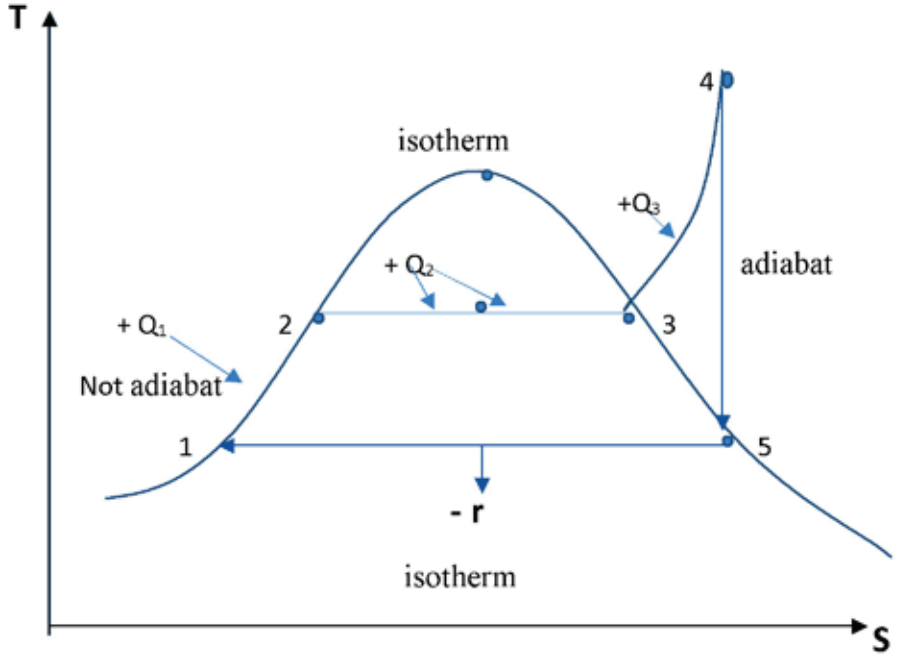

Figure 4.

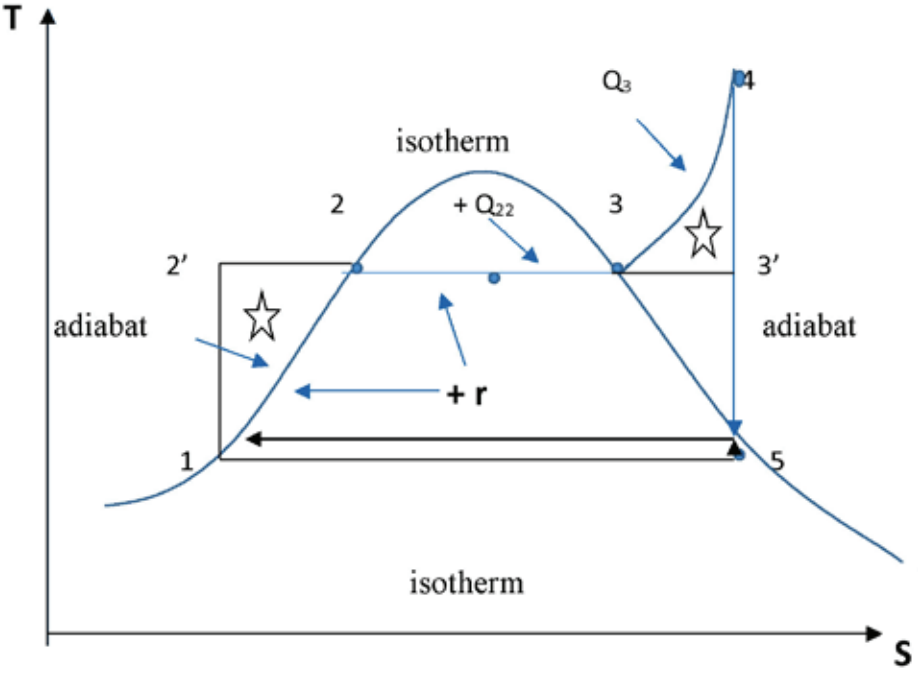

Figure 5.

The cycle is not in contravention of the first law of thermodynamics as the heat is supplied, and is not contradictory to the second law of thermodynamics as a part of energy is irretrievably lost during transition of heat energy to mechanical and the efficiency < 1, is not contradictory to the third law of thermo-

dynamics as the temperatures of absolute zero are not obtained, and is consistent with the fourth law of thermodynamics.

A device designed for pressure increasing can be either external, equipped with a drive from its own electric motor, and mounted on the condenser inlet fitting, or installed (integrated) on the shaft behind the end turbine stages on all LPCs. Under developing of new turbine models this device can be included into the design, it is desirable to use an ionizer.

One of the version will be represented by a device operating as a fan. The fan blade configuration can be different, the optimal configuration shall take into account the steam flow continuity, as well as the integrity of the turbine blade.

It is proposed, during a scheduled preventive repair of the turbine, to replace the blades on the end turbine crown of all the LPCs with the fan blades of the required configuration and, correspondingly, to replace the nozzles. The relevant parts shall be manufactured beforehand. Many designs of turbines implement a symmetric root fixing to the turbine shaft allowing to install it in inversed manner (rotated by 180 degrees) relatively to the working blades.

This modification will allow to create excess pressure in the condenser by the end crowns of the rotating LPC turbine, the turbine power will insignificantly decrease but the cycle efficiency will significantly improve.

The layout of the modified power plant with improved efficiency, with fan blades on the end turbine crown for increasing pressure in the condenser, is presented in (Fig. 1).

For implementation of the proposed technical solution, prior to proceeding to the work with the proposed cycle it is necessary first to launch the existing classical cycle, as described above. With the condenser turned on and irretrievably losing heat with cooling water. When the turbine starts to rotate at the operating frequency, there will be condensation nuclei created in the condenser and rated parameters of processed steam P_2 achieved: pressure from 1.7 kPa to 4.2 kPa, temperature T_3 from 15 °C to 30 °C and condensation heat r from 2465 kJ/kg to 2430 kJ/kg (these parameters refer to points of the right boundary of saturated water steam [3]), then it is possible to proceed to the proposed cycle. With these parameters, the water steam does not follow the equation for ideal gas parameter condition [1, P. 235, 254; 2, P. 194, 195, 196].

The fan under operation will insignificantly influence the condensation process, as the full-flow vacuum will be created by cooling water, and, during the turbine superheating and starting, **when the turbine shaft is rotating for several hours**, there will be no any effect, low parameters of water steam saturation boundary will be achieved.

When the operating parameters are achieved, it is necessary to reduce the flow rate of cooling water smoothly through the condenser C and fully stop its circulation.

The process of steam condensation at the cost of cooling water will be interrupted. This will lead to increase of pressure P_2 in the condenser due to the operating fan. When pressure P_2 reaches the level slightly exceeding the pressure saturation value at the operating temperature, the condensation process will resume [1, P. 215, 256, 257] (See abbreviated as [1]. M.P. Vukalovich was the founder of the first thermodynamical laboratory and experimentally researched thermophysical properties, inter alia, of water and water steam).

There will be no loss of heat in the condenser with cooling water (cooling water circulation through the condenser is stopped), consequently, the heat will remain in the cycle.

In the steam boiler SB heating and evaporation of water require significantly less heat if compared with the classical cycle. This fact allows a substantial efficiency improvement of the cycle proposed.

Prior to proceeding to a new cycle, it is necessary to calculate the thermal balance of the steam boiler taking account to the increased water temperature at its inlet, specifically for single-flow units and NPPs.

Besides, proceeding to the proposed cycle shall cover only one turbine, the next turbine is allowed to be converted to the cycle only after completion of the transition process for the previous one. When calculating the transfer function influencing the reduction of fuel supply to the steam boiler, it is necessary to include a transport delay. Compliance with these requirements will allow to ensure effective and accident-free operation of the power plant.

The practical implementation of the proposed cycle will not require significant expenses, all the necessary components can be manufactured beforehand, using the technology and materials similar to those for the turbine blades. Fixing to the turbine shaft does not change, the modification can be performed during a scheduled preventive repair of the turbine, all the rest equipment and interfaces remain the same. As scheduled preventive repairs and replace of turbine blades are performed constantly at thermal power stations all over the world, transition to a new power plant operating cycle can be implemented in a rather simple manner.

The supposed cycle reduces fuel consumption by nearly 2 times, consequently, decreasing volume of emissions and atmosphere heating by the same number of times, which will benefit the ecology and climate. Radioactive waste produced by nuclear power plants will be reduced by nearly 2 times.

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