UNDULATIVE INDUCTION ELECTRON ACCELERATOR FOR THE WASTE AND NATURAL WATER PURIFICATION SYSTEMS

***V.V. Kulish*[1], *A.C. Melnyk*[2], *I. V.Gubanov*[3]**
[1] ***Dep. of Physics I, National Aviation University,***
1 Komarova Prospect, Kiev, 03058, Ukraine
[2] ***EH-Accelerator, Inc.,***
801 Bovee Lane, Powell, Ohio 43065, USA
[3] ***Dep. of Theoretical Physics, Sumy State University,***
2 Rymski-Korsakov St., 44007, Ukraine

The project analysis of Undulative Induction Accelerator (EH-accelerator) for the waste and natural water purification systems is accomplished. It is shown that the use of the four-channel design of induction block and the standard set of auxiliary equipment (developed earlier for the Linear Induction Accelerators - LINACs) allow to construct commercially promising purification systems. A quality analysis of the accelerator is done and the optimal parameters are chosen taking into account the specific sphere of its usage.
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1 INTRODUCTION

It is well known that apart from traditional scientific application the electron accelerators are also widely used for purely commercial purposes, including defectoscopy in mechanical engineering, sterilization of medicine and foodstuff products etc. [1, 2]. However, the constructing of purification and disinfecting systems for waste and natural waters [3, 4] should be noted especially in view of topicality of this problem for modern industrial world.

Both: radioactive isotopes as well as the accelerators are used in the mentioned systems as the sources of ionized irradiation. But, it is obviously that the first of these ways is not acceptable for widely social application from the radiation security point of view. On the other hand, the problem of developing the commercially suitable design of an electron accelerator also was rather topical long time. This can be explained by that the traditional accelerator designs (which, as a rule, had been developed in the framework of known nuclear programs) rather often are found to be unacceptable for "usual" industrial applications.

We propose to construct the system of the discussed type on the basis of Undulative Inductional Accelerators (UNIAC or EH-accelerators) [5-7] as a source of ionized irradiation. This allows to increase considerably the commercial attractiveness of such purification systems because of a number of advantages of EH- accelerators, such as a relative compactness, reliability, efficiency in work, etc.

Technological and element basis of the EH-accelerators is the same with Linear Inductional Accelerators (LINACs) [8,9]. But, in contrast to the LINACs the EH-accelerators are found to be essentially "easier" with respect to technological requirements and commercial characteristics. The peculiarity of the EH-accelerators of principle is the use of many accelerative channels, which are connected by special turning systems like to [10].

2 THE EH-ACCELERATOR FOR THE SYSTEM OF WASTE AND NATURAL WATER PURIFICATION

We are oriented at parameters of known accelerators, which are usually used in purification systems. Analogous parameters for the EH-accelerator are given in Table 1.

Table 1. The general parameters of the EH-accelerator.

Parameters	Values
Intensity of the electrical field, [*MV/m*]	0.5
Beam energy at input, [*keV*]	50
Beam energy at the output, [*MeV*]	1.6
Peak current density of beam, [*A*]	10
On-off ratio	10^3
Average current density of the system, [*mA*]	10
Duration of electron bunch, [*nc*]	0.153
Used capacity, [*kW*]	~10
Overall dimension size of the accelerator, [*m×m×m*]	1.5×1.5×0.5

Table 2. Parameters of the electron gun.

Parameters	Values
Current intensity in bunch, [*A*]	10
Frequency of bunch passing [*kHz*]	6.54
Energy of electron bunch	50
Perveance of bunch, [$A\cdot V^{-3/2}$]	0.32
Gun power, [*kW*]	1.5
Diameter of bunch at the output, [*cm*]	1
Current density in the bunch [A/cm^2]	1.41
Gun type	magnetron type

In general, the accelerator is a complex electrical engineering system, which consists of a number of design elements and blocks. Let's discuss some of most important elements and blocks of the EH-accelerator proposed.

The electron gun. In this project it is proposed to use a standard electron gun of a magnetron type which is produced in the modern industry. The parameters of the gun are given in Table 2.

The induction block consists of eight induction subblocks. The arrangement of the eight-channel induction block is shown in Fig. 1. The parameters of the induction block are given in Table 3.

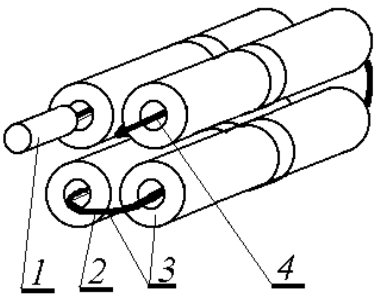

Fig. 1. The arrangement of the eight-channel induction block. Here: 1 - the electron gun, 2 - the electron beam, 3 - the induction channels, 4 - the vacuum channel.

Table 3. Parameters of the induction block and the output parameters of the feed system.

Parameters	Values
Total number of inductors	80
Induction of one inductor [*mkH*]	5.86
Current given to each induction subblock [*кA*]	208.86
Total losses of power to remagnetizing [*kV*]	4.96
Bunch duration [μc]	0.153
Equivalent working frequency [*MHz*]	0.65
A number of work channels	4
General length of the block [*m*]	0.7
Width of the block [*m*]	0.3
Height of the block [*m*]	0.3

The magnetic pulse generator [11] is used as a feeding system. The principle scheme of this feeding system is shown in Fig. 2.

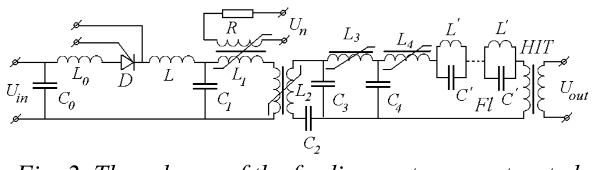

Fig. 2. The scheme of the feeding system constructed on the basis of a magnetic-bunch-generator. Here the four-cascade scheme is used. Fl is the forming line. HIT is the high frequency pulse transformer. D is the thyristor block (commutation block). The first LC is the circuit with resonance frequency.

The thyristor block is used as a commutation element of the system. It allows to make the frequency of bunch passing as the quantity of order ~10 *kHz* [15]. To get the required power we use two pulse generators, each of them feeds four induction channels. The operation of the two generators is done from the main mastering generator.

The parameters of the feeding system are given in Tables 4, 5.

Table 4. Parameters of the feed system of the EH-accelerator.

Parameters	Values
Intensity at the input [*kV*]	0.8
Intensity at the output [*kV*]	20
Systems power in the pulse [*MV*]	4.2
Compression factor	1000
Bunch duration at the output [μ*c*]	0.155
Frequency of bunch repetition [*kHz*]	6.5
Transformation factor	25

Table 5. Elements of the feed system of the EH-accelerator.

Condenser C_0 [μ*F*]	100
Condensers $C_0C_1C_2C_3C_4$ [μ*F*]	0.3
Condenser of the forming line (*FL*) [μ *F*]	0.05
Magnetic throttle L_0 [*mH*] (steel E42)	4.3
Magnetic throttle L_1 [*mH*] (permalloy 50 NP)	0.284
Magnetic throttle L_2 [*mH*] (permalloy 50 NP)	0.91
Magnetic throttle L_3 [*mH*] (permendure 49KF-VM)	0.036
Magnetic throttle L_4 [*mH*] (permendure 49KF-VM)	0.7
Thyristors	ITL1-59 or KU201L

Other systems. The v*acuum system* consists of the forvacuum and turbo-molecular pumps for obtaining 10^{-5}-10^{-6} *Pa*. The system for electron bunch scanning is the C-like electromagnet which is driven by the low frequency source of supply, with a frequency of 200 *Hz*.

3 THE PROJECT CHARACTERISTICS OF THE SYSTEM FOR PURIFICATION OF WASTE AND NATURAL WATERS ON THE BASIS OF THE EH ELECTRON ACCELERATOR

The proposed purification system consists of two subsystems: mechanical water purification (the first subsystem) and the subsystem of radiation purification (the second subsystem). In the case, if it is necessary, the system may contain three subsystems (plus the subsystem for biological purification) that depends on specific requirements to the output water quality. The first and last subsystems are described in detail in the literature.

So we will discuss further the radiation purification only. The general project characteristics of this system are given in Table 6.

Table 6. General parameters of the proposed system of water disinfection.

Parameters	Values
Dose of irradiation (*kGr*)	0.5-3.5
System productivity (*t/day*)	400-2000
Water cost price (*$/m³*)	0.2-1.5

Table 7. Water quality after purification and disinfection in the proposed system.

Parameters	Waste which are directed into the system of the third processing	After purification and disinfection by the radiation method
1.	200.4	24.4
Weighed obj., [*mg/l*]	0.047	0.03
CDO mg [O_2/*l*]	800	40
NO^{-2} [*mg/l*]	3	4
NO^{-3}, [*mg/l*]	2.2	1
NH_3, [*mg/l*]	20	0.8
General Nitrogen, [*mg/l*]	23.2	7.7
2.	7.5	7.05
Transparency, [*cm*]	3.5	30
SO_4^{2-}, [*mg/l*]	842	111
Cl, [*mg/l*]	174.83	28.01
BDO, [O_2/*l*]	96	8
3	1.1 *millions per ml*	4 *units per ml*
E. coli	25000	Full desinfection
Staphylococci	2500	Full desinfection
PO_4^{3-}, [*mg/l*]	75	0.1
K^+, [*mg/l*]	2.7	0.2
Dry sediment, [*mg/l*]	1060	440

It is cleared that the water output parameters after purification and disinfecting, which are given in Table 7, could be really attained. Therein, the first column shows the water parameters, which are entered in the system for radiation purification and disinfecting after the mechanical and biological purification. As it is readily seen, the parameters of the proposed system (see Tables 6, 7) is close to the well-known analogous systems. However, the proposed variant looks more attractive for practice owing to a number of its advantages. Including, relatively small total system dimensions (i.e., the system could be compact), relatively low work voltage (20 *kV* on the inductor and less 1 *kV* on the feeding system, in comparison with ~1-2 *MV* in the traditional systems of the same class). It should be added also that the EH-accelerators are characterized by the low level of the external electrical fields (i.e. they posses good electromagnetic compatibility) without decreasing the intensity within the acceleration channels. All this makes the proposed project very promising for practical application.

It should be mentioned that also the authors had accomplished relevant business-analysis of the project. We have be convinced that the industrial producing the systems on the basis of EH-accelerators, which are designed for purification and disinfecting of waste and natural water, could be regarded as a very promising trend for the investing of capital.

4 CONCLUSION

Thus, as it has been shown above, the systems of a commercial type can be really constructed on the basis of EH-accelerators. Therein, the existing level of modern traditional industrial technologies can provide the required element basis. It is clear also that such systems could be interesting from the practical point of view.

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