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Electromagnetic Devices for the Study of Liquids Behavior

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Abstract—**The paper presents five models of electromagnetic devices designed as sources for the study of liquids behavior in alternative magnetic fields. From the construction point of view, these devices are made using one single working air gap, of fixed or adjustable volume, or two or more air gaps of parallelepipedic, toroidal or adapted to the form of the liquid container. The intensity of the magnetic field in the work load has been measured with two specially designed sensors and an electronic multimeter. The purpose of the obtained experimental data was to determine the possibility of adjusting the intensity of the magnetic field by the field current, as well as the solutions to level it inside the work unit. The final part of the paper presents the benefits of using this type of electromagnetic devices on the basis of experimental characteristics.**

Index Terms - **Non-magnetic and magnetic liquids, electromagnetic devices, alternative magnetic field sources, magnetic field strength.**

I. INTRODUCTION

The study of liquids behavior in alternative magnetic fields requires various sources: electromagnetic devices, transformer-type constructions, adapted inductors for electric rotary or linear machines, special solutions.

Electromagnetic devices have one, two or more working gaps of high volume, parallelepipedic shape or required geometry. The vessels or liquid pipes subject to the activation processes within variable magnetic field are introduced in the gaps.

Liquids can be magnetic or not and the present paper takes this fact into consideration. Non-magnetic liquids positioned in alternating magnetic field are apparently not influenced by it. In fact, there are magnetic effects through the interaction between the magnetic field and the rotational currents induced to the liquid, also thermal effects due to the conversion of electric energy produced by the electric resistance into thermal energy, supplementary heating from the thermal sources of the device (electric windings, ferro-magnetic core, etc.), mechanical effects (liquids' vibration, rotation or displacement).

Liquids that contain water, microorganisms, benefit by the effects of the alternating magnetic field, which are only partially known and explained.

Characteristic sizes of the alternating magnetic field of interest in this case are the following: strength of magnetic field, power and magnetic energy dissipated in the liquid unit, frequency and wave shape (sinusoidal with or without continuous component). The electromagnetic devices for the study of liquids behavior within magnetic field must fulfill the following conditions:

- strength of the magnetic field adjustable within limits as wide as possible and distributed as evenly as possible within the work unit;
- adjustable frequency within the limits of the used materials properties;
- modifiable volume of the working gap to the required domain;
- modular construction able to provide economic benefits, both qualitative and functional.
- sizes which require measurements to be made.

The device operation is complex because the following type of sizes interferes: electrical, magnetic, thermal, mechanical, physical and chemical sizes must be measured.

II. CONSTRUCTION OF DEVICES

There are various electromagnetic devices which can be adapted to the above-mentioned purpose. Figure 1 shows examples of magnetic field sources:

a) electromagnetic device with fixed δ gap, having magnetic field made up of pressed U-type sheets. The magnetic current field is achieved with 2 identical coils, b_1 and b_2 , with the following technical data: N_1=N_2= 800 coil whirls of CuEm of 1mm diameter, which can be assembled in series or in parallel, occupying more than half the air gap's height (75mm), so that the volume of the working air gap is given by equation:

$$V = \delta \cdot L \cdot h \tag{1}$$

b) electromagnetic device with δ working air gap adjustable by moving armature A_d towards the fixed one (A_f); the device has only one magnetizing coil named b located on the fixed armature A_f;

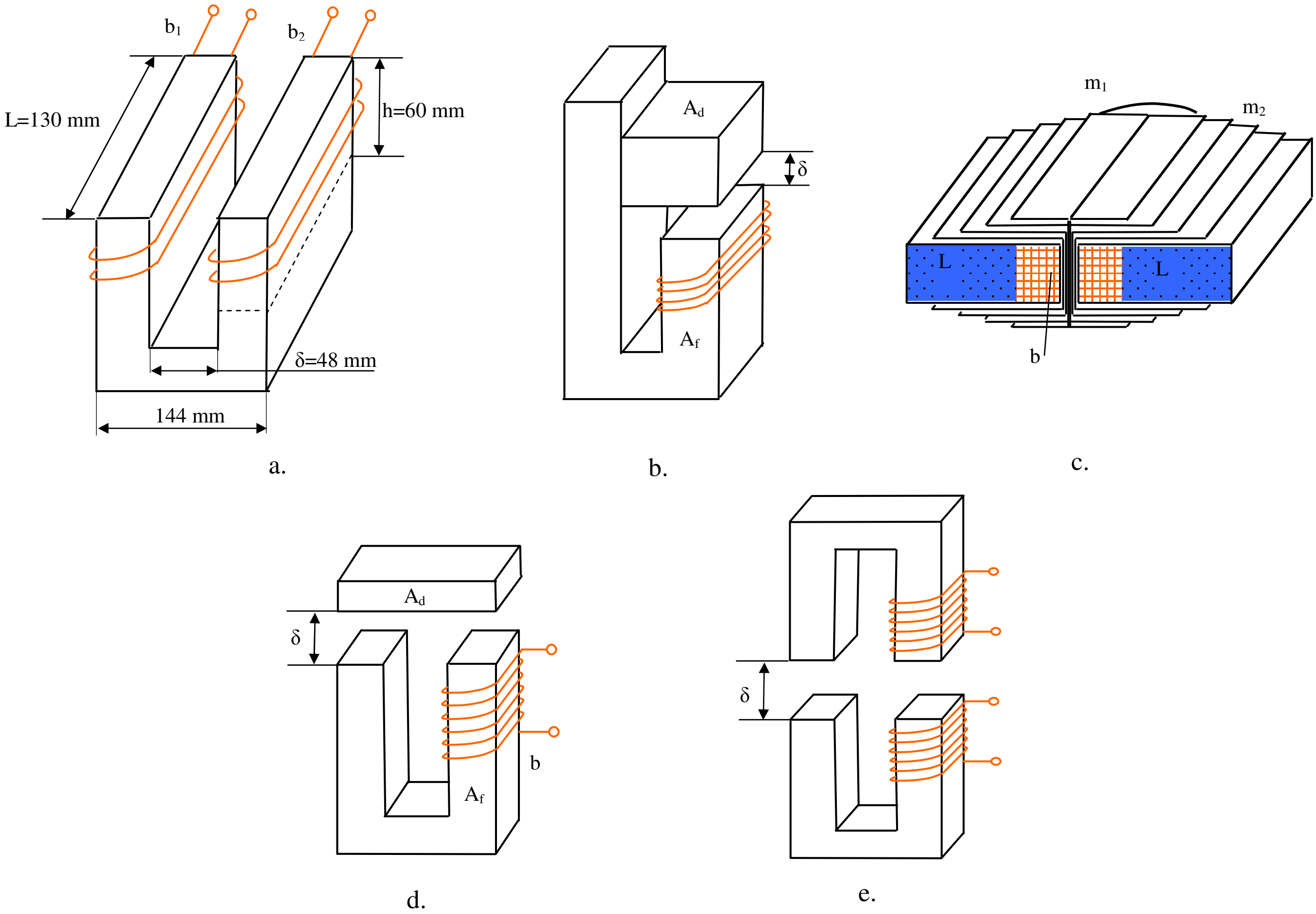
c) electromagnetic device with a single magnetizing coil b and toroidal working gap with rectangular section, obtained by combination of toroidal core m_1 with two cores m_2 made of pressed disc plates.

d) electromagnetic device with two working gaps δ_1 adjustable by A_d armature moving towards fixed armature A_f;

e) electromagnetic device made of two identical U-type cores which insure a maximum magnetic energy within the working air gaps if there are 2 magnetizing coils, located on one side and on the other side, as close as possible to the δ working air gaps.

III. THEORETICAL CONSIDERATIONS

The design and construction of electromagnetic devices to generate controllable magnetic fields may be achieved based on the theory of electromagnets and their applications using equivalent patterns adapted for electric



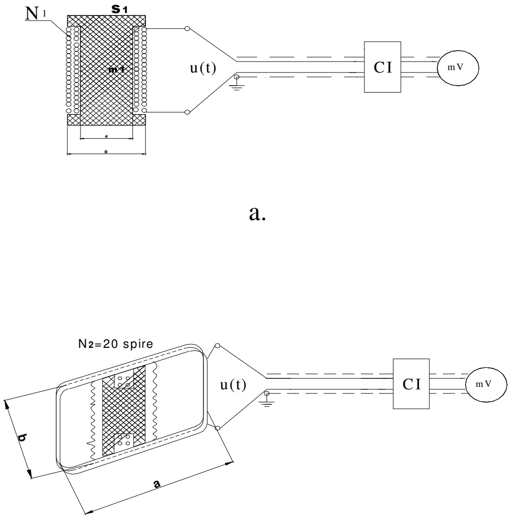
a. b. c.

d. e.

Fig. 1 Construction variants for electromagnetic devices

and magnetic circuits. Figure 2 shows the specially designed sensors made to measure the intensity of the magnetic field.

The miniature S_1 sensor was used to take local measurements of the actual value and sensor S_2 was used for measurements of medium values on relatively extanded areas.



a.

b.

Fig. 2 Magnetic field sensors:
a. for local measurements; b. for extended areas

Sensor S_1 has winding excitation with N_1 whirls coiled on an insulating cylindrical core m_1. Tension (u)t induced in the excitation coil is transferred by a flexible link to the CI integration circuit and the output signal from the integrator circuit is measured by the electronic millivoltmeter mV. By analogy measurements are made similarly with sensor S_2, which has excitation winding N_2 coiled in a channel of a non-conductive part m_2, made up in the form of a rectangular pattern with an area equal to the surface of liquid L located in container V positioned in magnetic field within the working air gap, according to Fig. 3.

The construction data for the S_1 sensor are the following:

D = 8mm, d = 6mm ; $d_m = \frac{D+d}{2} = 7mm$, N_1 = 89 whirls of CuEm, diameter Φ=0,35mm. The sensor's active measurement surface is given by the following formula:

$$S_{m1} = \frac{\pi d_m^{\ 2}}{2} = 38{,}465 mm^2 \qquad (2)$$

The construction data for the S_2 sensor, made up in the form of a rectangular pattern with rounded corners, are the following: a = 118mm, b = 60mm, N_2 = 20 whirls of CuEm with a diameter of Φ = 0,35mm. The sensor's active measurement surface, after subtracting the rounded corners, is given by the following formula:

$$S_{m2} = a \cdot b = 118 \cdot 60 = 7.080\ mm_2$$

$$S_r = d_r^2 - \frac{\pi d_r^2}{4} = 3^2 - \frac{3{,}14 \cdot 3^2}{4} = 1{,}935\ mm^2 \qquad (3)$$

$$S_{m2} = S_m - S_r = 7.078{,}065\ mm^2$$

As:

$$NI = Hl_m;\ \Psi = BS = \mu_0 HS \qquad (4)$$

it results that the strength of the magnetic field H is proportional with the field current I (RMS values) in the case of sinusoidal measurements (N – the number of whirls on the excitation coil, l_m – medium length of the magnetic field line, Ψ- total flux, B – magnetic induction, S – the surface covered by the magnetic flux, $\mu_0 = 4\pi 10^{-}7$ [H/m] – air permeability.

Tension u(t) at the induced magnetizing coil's terminals is:

$$u(t) = \frac{d\Psi}{dt} = \omega \Psi_{\max} \cos \omega t = \omega N \mu_0 H_{\max} S \cos \omega t \qquad (5)$$

which shows that the measured tension signal $u(t) = U_{\max} \sin \omega t$ is in phase quadrature to the signal H(t), meaning that a CI integration circuit is required but not necessary in the case of sinusoidal measurements when phase difference is not a matter of interest.

Therefore we can conclude the following:

$$U_{\max} = \omega \Psi_{\max};\ U_{(RMS)} = 2\pi f NBS \qquad (6)$$

where result:

$$H_{(RMS)} = \frac{1}{2\pi f N \mu_0 S} U_{(RMS)} = kU_{(RMS)} \qquad (7)$$

where $k = \frac{1}{2\pi f N \mu_0 S}$ is the sensor's constructive constant.

In the case of S_1 sensor, the k_{S1} constructive constant results form the following:

$$k_{S1} = \frac{1}{2 \cdot 3{,}14 \cdot 50 \cdot 89 \cdot 38{,}465 \cdot 10^{-6} \cdot 1{,}256 \cdot 10^{-6}} = 740{,}67 \left[\frac{A}{m \cdot mV}\right] \qquad (8)$$

when measured tension U is expressed in milivolts.

For S_2 sensor we obtain:

$$k_{S2} = \frac{1}{2 \cdot 3{,}14 \cdot 50 \cdot 20 \cdot 7078{,}065 \cdot 10^{-6} \cdot 1{,}256 \cdot 10^{-6}} = 17{,}916 \left[\frac{A}{m \cdot mV}\right] \qquad (9)$$

The permeance of the working air gap for electromagnetic device presented in Fig. 1.a is:

$$\Lambda = \mu_0 \cdot \frac{L \cdot h}{\delta} \qquad (10)$$

The total outflow produced inside the columns of the magnetic circuit by the magnetizing coils connected to a power supply U_a = 102 V is:

$$\Phi_T = \frac{U}{N \cdot \omega} = \frac{U}{2\pi \cdot f \cdot N} = \frac{102}{2 \cdot 3{,}14 \cdot 50 \cdot 800} = 4{,}06 \cdot 10^{-4}\ [Wb] \qquad (11)$$

The effective flux through liquid L, measured by S_2 sonde for the magnetizing coils connected to the power supply is the following:

$$\Phi_u = \frac{U_{S_2}}{\omega \cdot N_{S_2}} = \frac{0{,}63V}{2 \cdot 3{,}14 \cdot 50 \cdot 20} = 0{,}0001 Wb \qquad (12)$$

The ratio of the two fluxes is the following:

$$\frac{\Phi_T}{\Phi_u} = \frac{4{,}06 \cdot 10^{-4}}{1 \cdot 10^{-4}} = 4{,}06 \qquad (13)$$

and it shows that the effective flux in this case represents only 25% of the total flux.

Since permeances are in inverse ratio to the fluxes, then the dispersion permeance Λ_{sr} is 4 times higher than Λ_δ air gaps permeance. The two permeances are parallel.

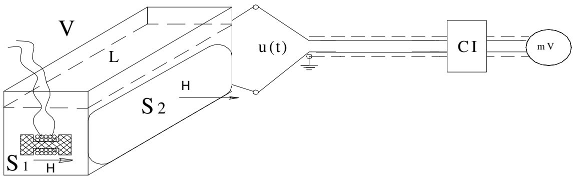


Fig. 3 Location of magnetic field sensors on the electromagnetic device

In order to activate some physical phenomena and chemical reactions during the study of liquids behavior in magnetic fields, the complex interdependencies between the sizes that can influence the process must be known: the value of the electrical and magnetic sizes specific for the device and the fluid (the strength of the magnetic field, the power and energy in the volume unit), the distribution of the main thermal outflows, the hydromechanical effects in the fluid.

IV. EXPERIMENTAL DATA

Experimental attempts were performed with the magnetic field generator presented in the Figure 1.a. Figure 4 presents two sets of characteristics:

a) the set of three characteristics magnetic field – electric current, H(I), which proves the linear dependency of H magnetic field's effective instensity to the effective value of I current;
b) the set of characteristics H(x), at three current values (1; 2; 2,5 A) which indicates a relatively regular magnetic field for $x \in [0 \ldots \delta = 48mm]$.

For the medium effective value of H magnetic field's intensity, we considered the surface of the work unit volume V as $S_V = h \cdot L$, on which the H field phasers (H_x, H_y, H_z) are perpendicular.

The characteristics in Fig. 4 and Fig. 5 have been drawn using a S_1 miniaturized sensor for measuring and a positioning device on three axes, considering the magnetic field intensity in effective value, theoretically in every point of the V volume unit.

Fig. 5.a presents the characteristics of H(x), Fig. 5.b, the ones for H(y), Fig. 5.c, for H(z), Fig. 5.d, the O3 point, Fig. 5.a, with the following coordinates:

$$x=\frac{\delta}{2}=24mm;\ y=\frac{L}{2}=60mm;\ z=0 \qquad (14)$$

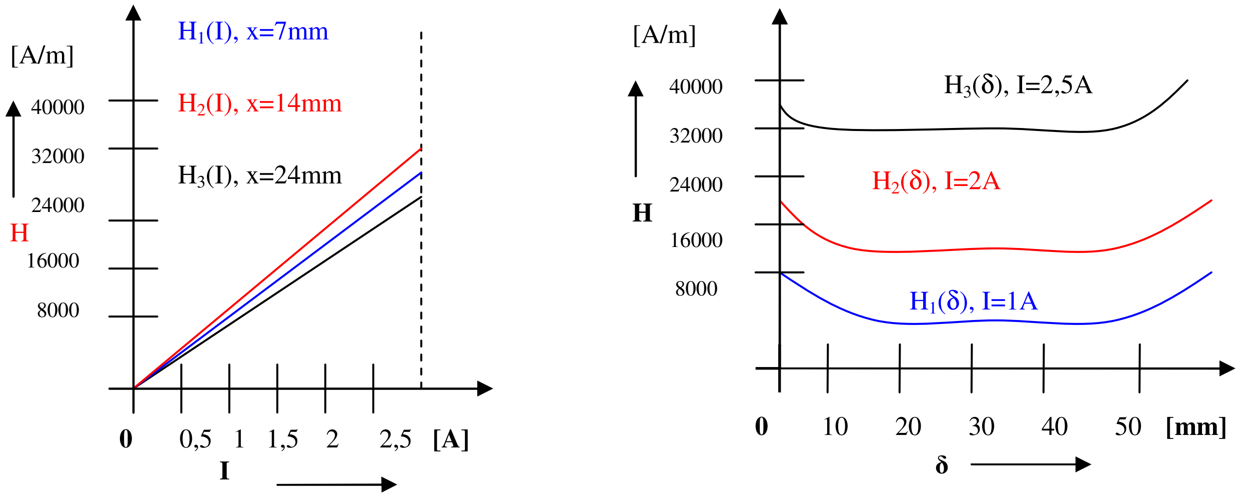
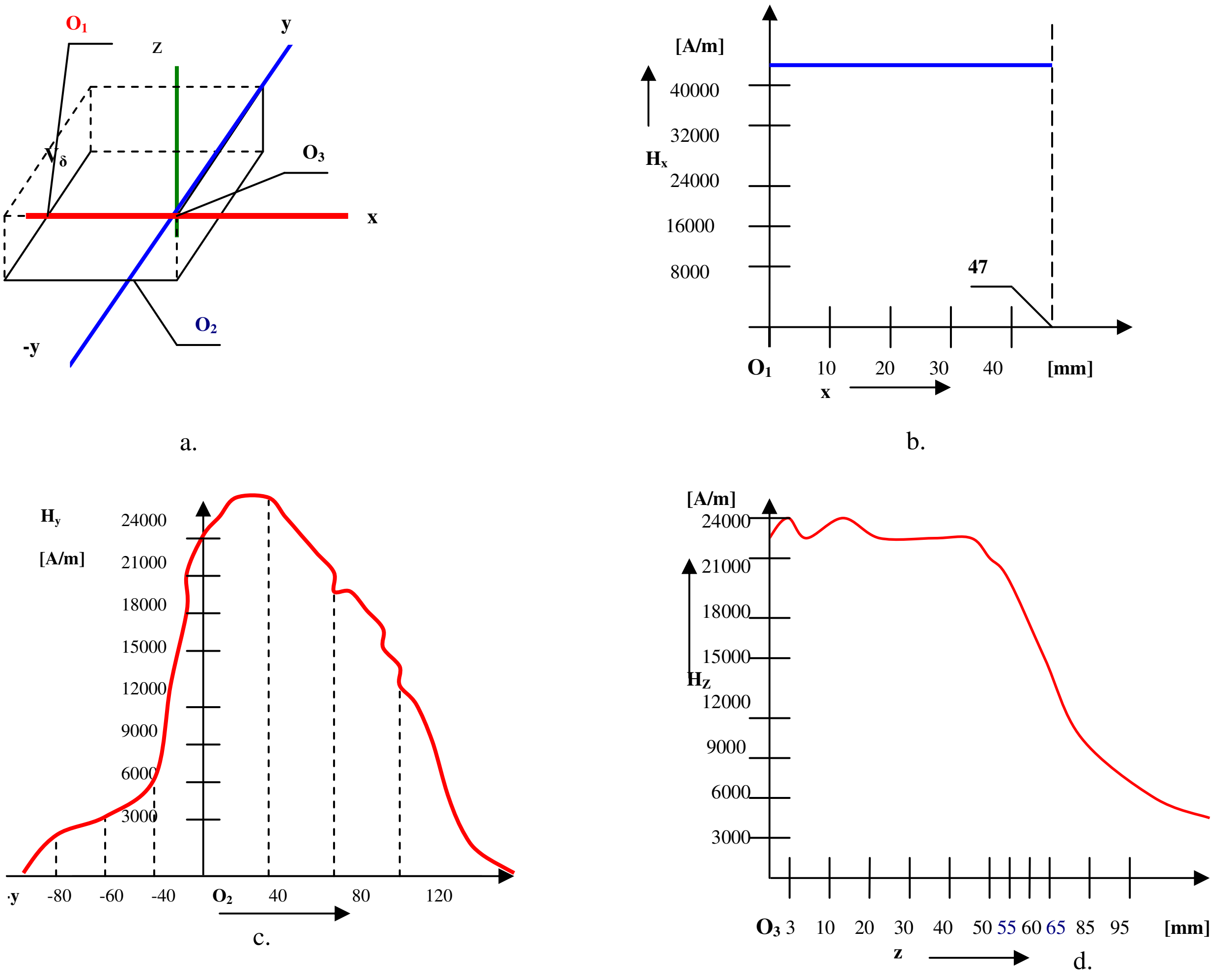


Fig. 4 Influence of field current on the instensity and distribution of the magnetic field in the working air gap

The characteristics of H(x), H(y) and H(z) are the following:

- on the $x \in (-0 ... \delta=48$mm direction, field H variation is rather low;
- on the direction $y \in 0\text{-}L=120$mm, H(y) characteristic touches a maximum value and lightly declines at the edges tending to 0 outside the working gap on both ways;
- on the z direction, H(z) characteristic declines lightly and continuously within the working gap z= 0 ...50mm < h=60mm then decline is important until annulment (H=0).



a.

b.

c.

d.

Fig. 5 Distribution of magnetic field intensity in the air gap on three spatial coordinates

Fig. 6 presents the H(x,y) characteristic for the z = 3mm coordinate, which can be assigned for any value of z coordinate in a suggestive image regarding the variation mode in the air gap' volume. The H(x,y) characteristic is represented by a curvilinear surface which demonstrates that the magnetic field H in the air gap is relative uniform; outside the air gap the intensity of the magnetic field declines relatively quickly to 0.

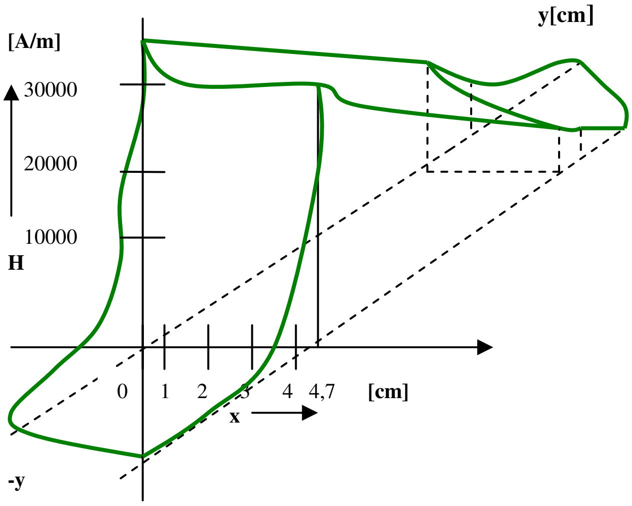


Fig. 6 Spatial distribution of magnetic field intensity in the gap for the electromagnetic device with U-type core for z=3mm, I=2A

V. CONCLUSION

The analysis of experimental data allowed the following conclusions:

1. Electromagnetic devices can represent sources of magnetic field for the study of liquids behavior in the presence of the magnetic field.

2. The effective value of the magnetic field in the work air gap shows a linear dependency on the current field (effective value) so that the latter one can offer correct indirect information on the intensity of the magnetic field.

3. The intensity of the magnetic field in the working air gap volume unit can be adjusted within acceptable limits without saturating the magnetic circuit.

4. The modular construction of the presented electromagnetic devices allows construction of variable magnetic field source systems for long containers or pipes with moving liquids inside.

5. Electromagnetic devices which have the working air gap made up of readjusted pole pieces offer a more regular magnetic field and the working air gap can be bigger.

6. By combining the solution presented above, the working air gap can be adapted to the majority of usual containers forms.

REFERENCES

[1] Ovidiu Centea, Horia Gavrilă. Teoria modernă a câmpului electromagnetic, Editura ALI, 2002.

[2] P.Andea. Electromagneți, Editura Helicon, Timişoara, 1999.

[3] H. Rosman, C. Petrescu. Bazele teoriei câmpului electromagnetic, vol. III Electromagnetismul, Universitatea Tehnică Gheorghe Asachi Iaşi, 2007.

Patents

[4] A/00331/07.05.2008, Sursă de câmp modulară monofazată pentru tratarea lichidelor din vase şi conducte cilindrice, Donceanu Gheorghe, Dangă Mihai Vlad, Pleşca Adrian, Leonte Petru, Cotea D.Valeriu, Cotea V. Valeriu

[5] A/00333/07.05.2008 Dispozitiv electromagnetic liniar modular pentru tratarea în câmp magnetic a lichidelor care circulă în conducte cu secțiune circulară, Pleşca Adrian, Belousov Vitalie , Leonte Petru , Dangă Mihai Vlad, Căruntu Vasile, Buburuzanu Cristinel

[6] A/00332/07.05.2008, Dispozitive electromagnetice pentru tratarea în câmpuri magnetice a lichidelor, Adrian Pleşca, Donceanu Marilena, Dangă Mihai Vlad, Leonte Petru, Zănoagă Cristinel, Niculaua Marius

[7] A/00330/07.05.2008, Sursă electromagnetică de vibrații mecanice pentru tratarea lichidelor, Donceanu Gheorghe, Dangă Mihai Vlad, Pleşca Adrian, Leonte Petru, Ilaşi ionela , Niculina Marius

[8] A/00334/07.05.2008, Sursă de câmp magnetic modulară monofazată pentru tratarea lichidelor din vase şi conducte cilindrice, Leonte Petru, Niculaua Marius, Pleşca Adrian, Dangă Mihai Vlad, Donceanu Marilena, Belousov Vitalie, Coteav Valeriu

[9] A/00335/07.05.2008, Surse de câmp magnetic modulare pentru tratarea lichidelor în pături subțiri, staționare sau în mişcare, Donceanu Gheorghe, Căruntu Vasile, Pleşca Adrian, Dangă Mihai Vlad, Leonte Petru,Acatrinei Cornel, Nichita Bogdan

[10] A/00336/07.05.2008, Convertor triplu a energiei electrice tip transformator pentru lichide, Leonte Petru, Nichita Bogdan, Pleşca Adrian, Dangă Mihai Vlad, Donceanu Gheorghe, Neacşu Ioan

[11] A/00337/07.05.2008, Surse electromagnetice de vibrații mecanice pentru tratarea lichidelor, Dangă Mihai Vlad, Nichita Bogdan, Pleşca Adrian, Leonte Petru, Donceanu Gheorghe, Odageriu Gheorghe

[12] A/00338/07.05.2008, Plonjoare magneto-termo-mecanice, Leonte Petru, Căruntu Vasile, Donceanu Gheorghe, Pleşca Adrian, Zamfir Ioan Cătălin

[13] A/0033/907.05.2008, Dispozitive electromagnetice modulare pentru tratarea lichidelor în câmp magnetic, termic şi de forțe mecanice, Donceanu Gheorghe, Dangă Mihai Vlad, Pleşca Adrian, Leonte Petru, Căruntu Vasile, Cotea V. Valeriu, Zănoagă Cristinel.