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(54) **ELECTRIC STEAM GENERATOR**

(57) The invention represents an electrical-to-thermal energy conversion and heat exchange maintenance device and can be used during heating up liquids e.g., in systems of heating and hot steam-water supply systems of industrial and residential facilities, and in other cases requiring heat-up and vaporization of fluids. The electric steam generator includes flat ferromagnetic core with rods to create a closed magnetic field inside them. The primary windings represent coils on rods, and are electrically insulated from them. The total tubular secondary winding is insulated within the magnetic field and embraces all the rods of the ferromagnetic core so that each

rod is wrapped with several closed turns. Tube turns located in the intertube space are electrically-parallelly inextricably externally interconnected in the tube center plane parallel to the magnetic induction vector of the rods. On the intertube space periphery there is at least one distant cylindrical element installed between the secondary tubular winding turns and externally inextricably connected with turns in centerplane of tubes parallel to magnetic induction vector of the rods. The invention enables improvement of reliability and steam production performance of the steam generator.

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Description

Field of invention

[0001] The invention represents an electrical-to-thermal energy conversion and heat exchange maintenance device. It can be used during heating up liquids e.g., in systems of heating and hot steam-water supply systems of industrial and residential facilities, and in other cases requiring heat-up and vaporization of fluids.

Prior art

[0002] Invention background includes electric steam generator involving electric transformer with stacked metal core intended for creation of a closed magnetic field, a primary winding located on the core and electrically insulated from it, a tubular secondary winding insulated within the magnetic field, a link externally connected to the tubular secondary winding turns to short-circuit the tubular secondary winding turns, and necessary aids for forcing liquid through the inner cavity of the tubular secondary winding. (US 1,999,446)

[0003] The common device represents a highly efficient electrical-to-thermal energy conversion device due to the presence of a direct contact between liquid being heated up and the heating surface in the inner cavity of the short-circuited secondary tubular winding. To enable steam generation in the common device, it's necessary either to have the tubular winding heated above 212 degrees, or to preliminarily heat up the feed water prior to its forcing into the tubular winding. The latter action is implemented by way of introduction an extra tubular short-circuited winding intended for pre-heating the liquid prior to its forcing into the main short-circuited tubular winding to enable vaporization. Quantity of thereby generated steam depends directly on the liquid flow rate. Exceedance of the design flow rate through the device disables steam generation because of lack of evaporating energy, and the flow rate reduction below the design value entails insufficient cooling of the secondary tubular winding, and its overheating to the emergency value. Although the common device version is highly efficient, it is too sensitive to control parameters such as amperage, voltage, feed water inlet temperature, flow rate since values of such parameters are subject to a particular design version. Abnormal deviations in value of at least one parameter entail either quality deterioration of steam being generated by the device, or its tripping. Amperage and voltage may be controlled within a relatively narrow range because the heat amount produced by the device is proportional to the squared amperage or voltage. Deviations in values of these parameters entail disfunction of the devices.

[0004] The common device is classified as an once-through steam generator where liquid is forced through tubes by means of a feed pump which ensures overcoming the overall resistance to fluid motion through tubes,

and the preset outlet pressure. General disadvantage of this method implemented in all types of generators consists in a low heat-storage capacity of tubes (see page 266 in "Steam generators: College textbook" by A.P. Kovalev. M.: Energoatomizdat, 1985, 386 p, fig.). This disadvantage is particularly expressed in the common device US 1,999,446 since the tubular secondary winding length is related with its electric impedance, and is often characterised by insufficient heat exchange area because of insufficient length. Therefore, reliable implementation of once-through method of steam generation by means of the common device is possible only through its design revision to elongate the tubes and to concurrently ensure the sufficient heating temperature on account of increasing the heating current rate. These parameters are inconsistent with each other since an increase in current rate under the common design is only possible at decreasing the tube length.

[0005] There is also the fluid heating inductor having been accepted as the prototype and including the flat ferromagnetic core with rods carrying the primary winding connected to an alternating current source, and the electrically conductive secondary winding inductively connected with the primary winding through the core and representing the heat exchanger for a heated fluid; this heat exchanger is equipped with the heated fluid inlet and outlet nozzles and made of tubular elements located within the primary winding turns plane and embodied as a turn forming a closed loop around a respective rod of the core; at that, tubular element sections located within intercoil space are truncated and inextricably connected with coplanar truncated sections of tubular **elements embracing adjacent rods** (RU 2263418 C2)

[0006] This design of fluid heating inductor enables increasing the efficiency and power factor, decreasing the dimensions and materials consumption of the device, makes it possible to use longer tubes.

[0007] However, the heating inductor designed this way is characterised by reduced performance reliability because of truncation of tubular elements integrity, and their subsequent non-detachable interconnection. At that, tubular elements as interconnected forms a common large-volume inner cavity characterised by reduced pressure integrity compared to each separate tubular elements, and its operation becomes explosion-dangerous even without considering the aggravation caused by the non-detachable connection.

[0008] Besides that, the common inner cavity of the heat exchanger is not suitable for designing the once-through steam generator where a heated fluid forced by the feed pump through the inner cavity of the non-detachable tube gets vaporized. This is its operation principle which violation poses the risk of local overheating of tubes in such places of generator where the heat-transfer fluid flow gets slowed. Therefore, the prototypic device cannot be used for efficient generation of steam.

[0009] A particular significant disadvantage of the prototype consists in the design-intrinsic non-detachable in-

terconnection of truncated sections of tubular elements located in the intercoil space and embracing adjacent rods in the same plane. This plane is normal to magnetic induction vector of the primary winding. As for the secondary tubular winding consisting of short-circuited turns around each rod representing tubular electrical conductors, the current flows with its maximum rate just at the tubular conductor sections close to the tubular conductor centerplane normal to the magnetic induction vector direction. The non-detachable connection implemented in the maximum current rate zone is exposed to operation-concurrent destructive action of the current flow, and reduces general reliability of the device.

Essence of the invention

[0010] The claimed invention is to enable creation of reliable electric induction steam generator with increased steam production capability at concurrent reduction of metal consumption and overall dimensions of the steam generator.

[0011] Technical result of the claimed invention consists in increasing the performance reliability and steam generation capability of electric induction steam generator

[0012] The claimed technical result is achieved owing to that the electric steam generator including ferromagnetic rodded core, primary winding located as coils on the rods and electrically insulated from the latter, the common tubular secondary winding insulated within magnetic field and embracing all the ferromagnetic core rods so that each rod is wrapped with closed turns, featured by that the common secondary tubular winding turns located in the intercoil space are inextricably externally electrically-parallelly interconnected in the tube centerplane parallel to the magnetic induction vector of the rods, whereas on the intertube space periphery there is at least one distant element installed between the secondary tubular winding turns and externally inextricably connected with turns in centerplane of tubes parallel to magnetic induction vector of the rods.

[0013] The particular case of the claimed technical solution implementation assumes application of a three-phase ferromagnet core.

[0014] The particular case of the claimed technical solution implementation assumes that the distant elements are cylindrical, and their diameter equals the secondary tubular winding diameter.

Concise description of drawings

[0015] Details, features, and advantages of this invention follow from the below description of design versions of the claimed technical solution with use of drawings demonstrating as follows:

Fig. 1 contains the general view of the three-phase electric steam generator (axonometry);

Fig. 2 demonstrates the tubular secondary winding (axonometry).

[0016] Digits on the Figures indicate the following items:

[0017] 1 - flat ferromagnetic core; 2 - ferromagnetic core rods; 3 - coils; 4 - coil tap; 5 - tubular secondary winding; 6 - inlet nozzle; 7 - outlet nozzle; 8 - non-detachable connection; 9 - distant cylindrical elements.

Invention disclosure

[0018] Feasibility of the proposed design of new electric steam generator satisfying the claimed purpose is justified herein below through this description. This description of the claimed technical solution corresponding to this invention by no means limits its legal protection scope.

[0019] This example contains an illustration of new electric steam generator.

[0020] In this particular example, the electric steam generator is assembled on the basis of a three-phase transformer with flat ferromagnetic core (1) with rods (2) carrying primary winding coils (3). The primary winding coils (3) are connected to an alternating current source through coil taps (4). The common secondary tubular winding (5) is made of a solid tube, and is equipped with inlet nozzle (6) and outlet nozzle (7).

[0021] The common secondary tubular winding (5) of the electric steam generator is insulated within magnetic field, and is coiled around each rods (2) of the flat ferromagnetic core (1). The welded or soldered non-detachable connection (8) of the common tubular winding turns (5) enables creation of short-circuited turns around each rod (2) in the intercoil space.

[0022] It is conceptual that the non-detachable external connection (8) of the common tubular winding turns (5) in the intercoil space is implemented in the tube centerplane parallel to magnetic induction vector in the rods (2). Furthermore, the coil sections of the common tubular winding (5) beyond the intercoil space are spaced apart at the diameter of the tube, and there are distant cylindrical elements (9) installed between them by means of non-detachable connection (8), and ensuring the structure rigidity as well as facilitating the short-circuiting the winding turns. Diameter of the distant tubular elements equals the tube diameter of the secondary tubular winding.

[0023] This way of short-circuiting the secondary tubular winding currents corresponds to physical phenomena being underway in the secondary short-circuited winding; therefore, the device is featured by the design simplicity and absence of unnecessary energy losses entailing overheating and destruction. Besides that, another advantage of the invented device consists in that it is insensitive to feed voltage phase offset parameters.

[0024] The tube length, quantity of short-circuited turns around each rod (2) are preset on the basis of thermo-

technical calculations. Experiments have proven the subject design of the common tubular secondary winding (5) to be efficient in inducing currents in the tube wall to ensure the preset uniform heating of the tube throughout its length.

[0025] The operation concept of the electric steam generator is as follows. Water flow shall firstly be ensured by forcing it through the inlet nozzle (6) into the inner cavity of the common tubular secondary winding (5). Then, the primary winding (3) shall be connected through taps (4) to an alternating current source. This causes the primary winding to induce an alternating magnetic flux in the rods (2). The alternating magnetic flux in the turns short-circuited around each rod (2) of the common tubular winding (5) by means of the non-detachable connections (8) causes induction of a heavy current heating the common tubular secondary winding (5). The thermal energy gets transferred to water flowing through the inner cavity of the common tubular secondary winding (5). And, according to the once-through steam generator operation concept, it is here where water is vaporized, and the obtained steam is released through the outlet nozzle (7).

[0026] The current rate heating the common tubular winding (5), its length, and heat-storage capacity of the device version proposed in accordance with this invention are parameters consistent with each other what ensures designing compact and reliable steam generators. Continuity of the common tubular secondary winding (5) and its electrical heat-up uniformity throughout its length comprehensively ensure implementation of the once-through steam generator operation concept.

[0027] To support justification of the invention feasibility and the claimed purpose achievement, a 30 KW steam generator was implemented on the basis of a flat three-phase core. According to the calculations, each core rod was wrapped around with 3 turns of the secondary tubular winding made of a 19 mm-diameter copper tube. The total length of the tube was 6.3 m, and thermal capacity was 4762 W/m, respectively. Test results of this steam generator having been designed and fabricated in line with this invention revealed a high performance efficiency and power factor of 98% of the device. Performance capability of this steam generator was 100 kg of steam per hour. **Under continuous operation mode, the primary winding temperature increased by 96°C** compared to the initial temperature right before the test. Then, recalculations was run to have implemented a 40 KW steam generator on the basis of the same core so that it had 4 turns of the secondary tubular winding on each rod of the three-phase core, and total length of the copper tube was 10.32 m. Thermal capacity of the tube got reduced to 3876 W/m, steam production performance ranged within 120 to 130 kg of steam per hour. Under continuous operation mode, the transformer primary winding temperature **reached the stable value exceeding by 108°C the initial temperature although remaining** within the range permissible for the primary insulation.

[0028] Thus, it has been determined that the prototype

disadvantages were overcome, and the device can be used as the once-through steam generator within a certain power range without reduction in performance reliability.

Claims

1. Electric steam generator including ferromagnetic rodded core, primary winding located as coils on the rods and electrically insulated from the latter, the common tubular secondary winding provided with inlet and outlet nozzles and insulated within magnetic field and embracing all the primary winding coils so that each primary winding coil is wrapped with closed turns, featured by that the common secondary tubular winding turns located between adjacent coils of the primary winding are inextricably externally electrically-parallelly interconnected in the tube centerplane parallel to the magnetic induction vector of the rods, whereas on the intertube space periphery there is at least one distant element installed between the secondary tubular winding turns and externally inextricably connected with turns in centerplane of tubes parallel to magnetic induction vector of the rods.
2. Steam generator according to claim 1, featured by including a three-phase ferromagnetic core.
3. Steam generator according to claim 1, featured by that all the distant elements are cylindrical with diameter equal to the tubular secondary winding diameter.

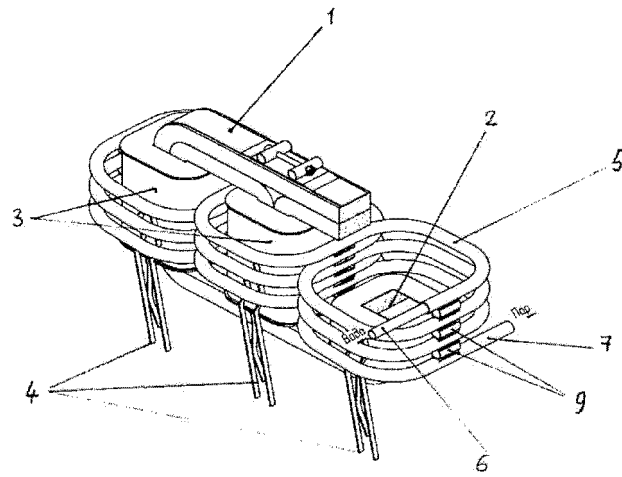


Fig.1

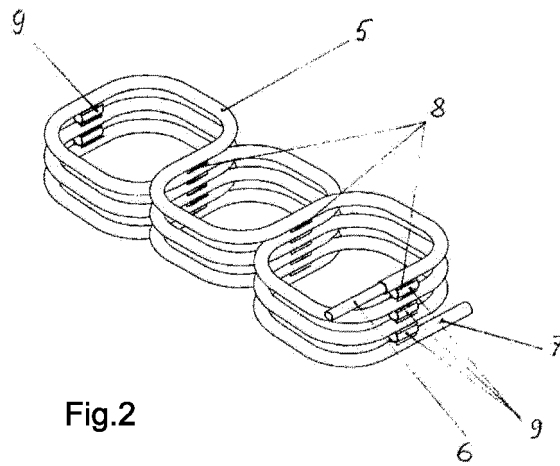


Fig.2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 2017/000721

5	A. CLASSIFICATION OF SUBJECT MATTER H05B 6/10 (2006.01)		
	According to International Patent Classification (IPC) or to both national classification and IPC		
	B. FIELDS SEARCHED		
10	Minimum documentation searched (classification system followed by classification symbols) H05B 6/00-6/02, 6/10, F22B 1/00, 1/28		
	Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
15	Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE		
	C. DOCUMENTS CONSIDERED TO BE RELEVANT		
20	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	A, D	US 1999446 A (J.K.DELANO) 30.04.1935, fig.1, 5, p.2 left-hand column lines 20-41	1-3
25	A	US 4602140 A (MANGELS INDUSTRIAL S.A.) 22.07.1986	1-3
	A	RU 2013125924 A (SHIPILOV VLADIMIR MIKHAILOVICH et al.) 10.12.2014	1-3
30			
35			
40	☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
45	* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
50	Date of the actual completion of the international search 18 May 2018 (18.05.2018)		Date of mailing of the international search report 24 May 2018 (24.05.2018)
	Name and mailing address of the ISA/ RU		Authorized officer
55	Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 1999446 A [0002] [0004]
- RU 2263418 C2 [0005]

Non-patent literature cited in the description

- **A.P. KOVALEV ; M.: ENERGOATOMIZDAT.** Steam generators: College textbook. 1985, 386 [0004]