United States Patent

[11] **3,622,731**

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[73]	Assignee	**Chisso Corporation** **Kitaku, Osaka, Japan**
[32]	Priority	**July 4, 1969**
[33]		**Japan**
[31]		**44/52916**

[54] **FLEXIBLE HEAT-GENERATING DEVICE**
5 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **219/10.49,** 138/137

[51] **Int. Cl.** **H05b 5/00**

[50] **Field of Search** 219/10.49; 138/137

[56] **References Cited**

UNITED STATES PATENTS

444,477	1/1891	Wright	138/137
3,515,837	6/1970	Ando	219/10.49

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Assistant Examiner—Hugh D. Jaeger
Attorney—Fred C. Philpitt

ABSTRACT: A flexible heat-generating device is constructed by stringing a great number of mutually independent ferromagnetic rings around an insulated conductor line, and heat is generated by the secondary eddy current loss induced upon said rings when an AC current is applied to said conductor line.

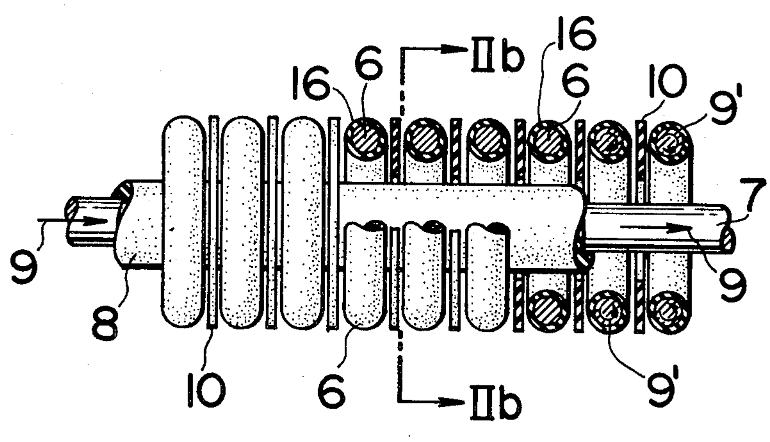


FIG. 1a

PRIOR ART

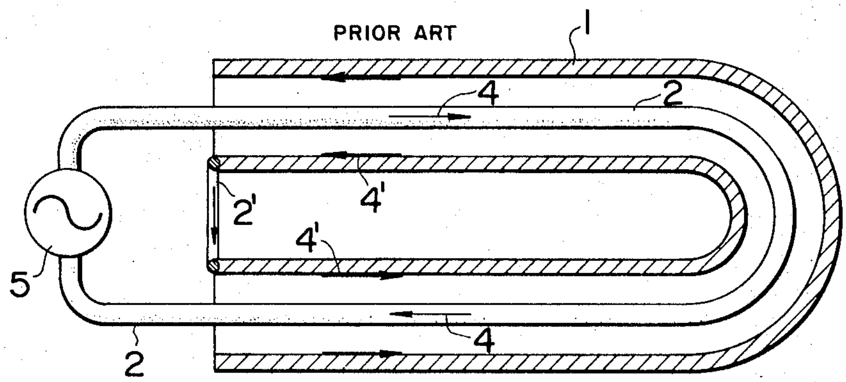


FIG. 1b

PRIOR ART

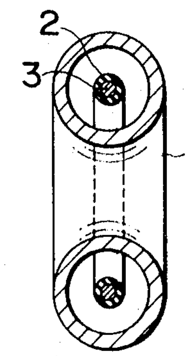


FIG. 2a

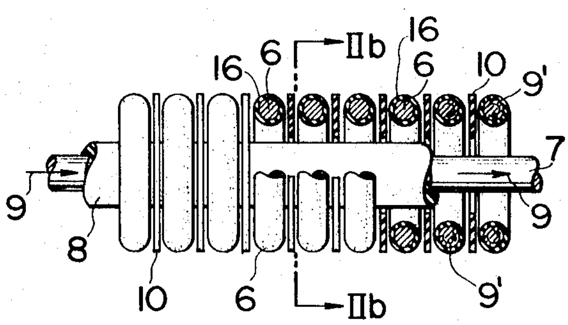


FIG. 2b

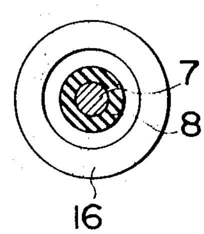


FIG. 3a

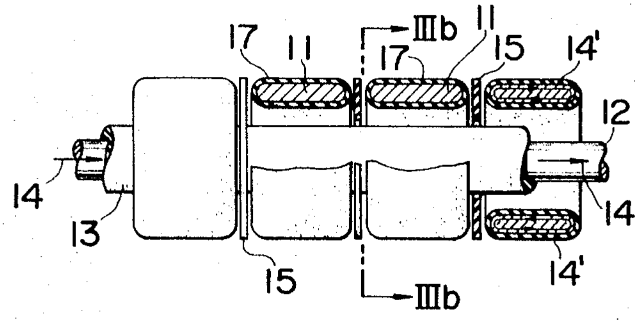
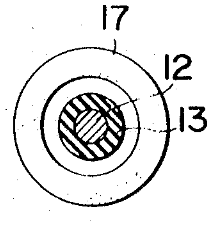


FIG. 3b



FLEXIBLE HEAT-GENERATING DEVICE

BACKGROUND OF THE INVENTION

This invention relates to a flexible heat-generating device which utilizes the eddy current loss of highly magnetic steel mass.

A skin-effect current heat-generating pipe such as that shown in FIG. 1, consisting of a highly ferromagnetic pipe 1, a conductor line 2 which is passed through the inside of said pipe and connected with an AC supply source 5, and another conductor 2' connecting the ends of said pipe together to form an electric circuit whereby current 4' is connected only in the inner skin portion of said pipe, is already known, e.g. by the disclosure of U.S. Pat. No. 3,515,837 filed by the present inventor entitled "Heat Generating Pipe."

The known heat-generating pipe shown in FIG. 1 has been demonstrating superior performance in the pipe line heating and heating of road surfaces or the like but since the heat-generating pipe must be a steel pipe having a thickness greater than a certain definite value, it has almost no flexibility. This often inconvenience e.g. relative to the expansion of the pipe.

Accordingly, it is the object of the present invention to provide a flexible heat-generating device having no such drawback.

The object of the present invention can be attained by a flexible heat-generating device wherein a conductor line is inserted in the inside of a large number of independent ferromagnetic rings in a manner of skewering the rings and AC is passed through said conductor line to generate heat by the secondary eddy current loss in said rings.

BRIEF EXPLANATION OF THE DRAWINGS

FIGS, 1*a* and 1*b* are schematic cross sectional views of a prior art heat arrangement which utilizes skin-effect heating;

FIG. 2*a* is a view, partly in section, of one embodiment of my invention;

FIG. 2*b* is a view along II*b*—II*b* of FIG. 2*a;*

FIG. 3*a* is a view, partly in section, of another embodiment of my invention;

FIG. 3*b* is a view along III*b*—III*b* of FIG. 3*a*.

PREFERRED EMBODIMENT OF THE INVENTION

FIG. 1 is typical of the known skin-effect current heat-generating pipes and shows an insulated conductor 2 that forms a primary closed circuit while a ferromagnetic pipe 1 forms a secondary circuit along with another conductor 2'. A secondary current 4' flows only through the inner wall portion of the ferromagnetic pipe by the induction from a primary current 4 to generate heat therein.

Referring now to FIGS. 2 and 3, numerals 6 and 11 are highly ferromagnetic materials, e.g. steel rings.

Through a number of the rings 6 and 11, conductor lines 7 and 12 having insulation layers 8 and 13 are inserted in a manner of skewering the rings. The cross-sectional area of the ring 6 in FIG. 2 is circular and that of the ring 11 in FIG. 3 is cylindrical but those of various other shapes such as elliptical or polygonal one can also be used.

When AC 9 or 14 are passed through the conductor line 7 or 12 in FIGS. 2 or 3, a secondary induction current (eddy current) 9' or 14' flows in the ring 6 or 11.

By the eddy current 9' or 14', the ring 6 or 11 generates heat but since a large number of rings such as 6 of 11 are independent without being mechanically connected to each other and the conductor line 7 or 12 is naturally flexible, it is possible to give necessary flexibility to the device.

In order to make the heat generation by way of eddy current effective, the diameter d (cm.) in case of the ring 6 having the circular cross section as in FIG. 2, and the thickness t (cm.) in case of the cylindrical ring 11 as in FIG. 3, must be greater than about two to three times the depth S (cm.) of the skin of the eddy current.

If the permeability of the ring 6 is μ, the resistivity of the ring 6 is ρ (ω cm.) and the frequency of AC is f (Hz.), the depth of the skin can be expressed by

$$S=5030\sqrt{\frac{\rho}{\mu f}} \qquad (1)$$

In case of the known heat-generating pipe shown in FIG. 1, if the thickness t (cm.) of the steel pipe 1 is more than twice the S shown in the formula 1, it is a characteristic fact that AC 4' concentrates only on the inner skin portion of the steel pipe 1 and does not practically appear on the outer skin portion of the steel pipe 1.

However, in the apparatus of the present invention, is evident from FIGS. 2 and 3 the eddy current 9' and 14' appear also on the outer skin portion of the rings 6 and 11 because they circulate in the rings.

Seemingly, it is considered to be a drawback of the apparatus of the present invention, but since the electrical potential appearing on the outer surface of the rings 6 and 11 on account of this eddy current is in the order of 0.3–0.8 mv. per 1 mm. surface distance in the direction of the eddy current of the rings 6 and 11 in case of commercial frequency, the potential is 5–15 mv. provided that the diameter d of the cross section of the ring 6 in FIG. 2 can be 5 mm.

Further since such a ring 6 has an oxide coating in its commonly used state, and this oxide coating is a semiconductive substance having a resistivity considerably higher than, e.g. steel, the electric potential of the rings cannot be developed into a cumulative amount by the above-mentioned value of 5 to 15 mv. measured between the mutually neighboring rings. Accordingly, even if the number of rings skewered through the conductor line reaches several hundred, or even several ten-thousands, and they are contacting with a metallic mass e.g. a steel oil transportation pipe, the leakage of electric current to said metallic mass does not occur.

Of course it is possible, if necessary to coat the rings with a thin insulating coating layer 16 or 17 also for the purpose of the prevention of the corrosion of the rings, and in this case, there will be less apprehension as to the above-mentioned leakage of electric current.

Incidentally, the flexible heat-generating device of the present invention may be used in the heating of liquid which is liable to be solidified and being sent through a flexible transportation pipe e.g. a rubber hose. In such a case, since the rubber hose itself is an insulating material, there is no apprehension of the above-mentioned leakage of electric current at all.

As described above, in FIGS. 2 and 3, since there is no leakage of electric current from the heat-generating rings 6 and 11 in the present flexible heat-generating device these heat-generating rings can be placed in the direct contact with a material to be heated without requiring any special electric insulation for the material to be heated, and it is possible to make the temperature difference between the rings and the material to be heated less even when the rings of high heat-generating density are used and there is no need of elevating the heat-resistant grade of the insulation layers 8 and 13 of the conductor lines 7 and 11 higher than the necessary value.

And also in FIGS. 2 and 3, whereas the rings having the same shape and size are shown with the conductor lines 7 and 12 it is possible, in some cases, to skewer two or more rings having different shapes and sizes adequately with a conductor line.

However, in any case, it is preferable to keep the mutual distance between neighboring rings short so long as it is not harmful to the flexibility.

Further, in FIGS. 2 and 3 it is also possible to insert spacers or distance 10 and 15 pieces between neighboring rings such as those made of plastics, elastic rubber, porcelain, asbestos and other electric insulation materials.

As above-mentioned, since there is no leakage of eddy current to other rings or to other metallic mass in the present flexible heat-generating device, it is possible, though not shown in the drawing, to use, as an outside protective cover for the insulation layers 8 and 13, a braided covering of metal wire such as those made of copper, stainless steel, etc.

By the use of the flexible heat-generating device of the present invention, it has now become possible to proceed successfully in the filed of application where the conventional skin-effect heat-generating pipe cannot enter because of the lack of the flexibility.

I claim:

1. A flexible heat-generating device which is characterized by:

a. an insulated conductor line,

b. means for connecting said insulated conductor line to a source of alternating current, and

c. a plurality of separate but closely adjacent highly ferromagnetic rings disposed in side-by-side relationship along the length of said insulated conductor line, said insulated conductor line passing centrally through each of said ferromagnetic rings,

whereby, when alternating current is passed through said insulated conductor line, the resulting eddy currents cause heat to be generated in said rings.

2. A flexible heat-generating device according to claim 1 wherein at least some of said rings are spaced apart by nonconductive spacers.

3. A flexible heat-generating device according to claim 1 wherein each of said rings is covered with a layer of insulation.

4. A flexible heat-generating device according to claim 2 wherein each of said rings is covered with a layer of insulation.

5. A flexible heat-generating device according to claim 1 wherein said rings have a circular cross section.

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