# United States Patent

**Babel**

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[45] **Nov. 21, 1972**


[54] **LADLE FOR INDUCTIVE TREATMENT**


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[73] Assignee: **Creusot-Loire**, Paris, France



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[30] **Foreign Application Priority Data**

June 16, 1970 France....................7022041

[52] **U.S. Cl.**..................................**13/27,** 219/10.49

[51] **Int. Cl.**..........................................**H05b 5/12**

[58] **Field of Search** ......219/10.49, 10.79; 13/26, 27, 13/32, 35


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[57] **ABSTRACT**


A ladle for inductive treatment, having a non-magnetic metal casing and a refractory lining, the metal casing being made up of a plurality of elements each forming an open circuit, each of small section relative to the inductive vector and each insulated from its neighbors.

**1 Claim, 10 Drawing Figures**

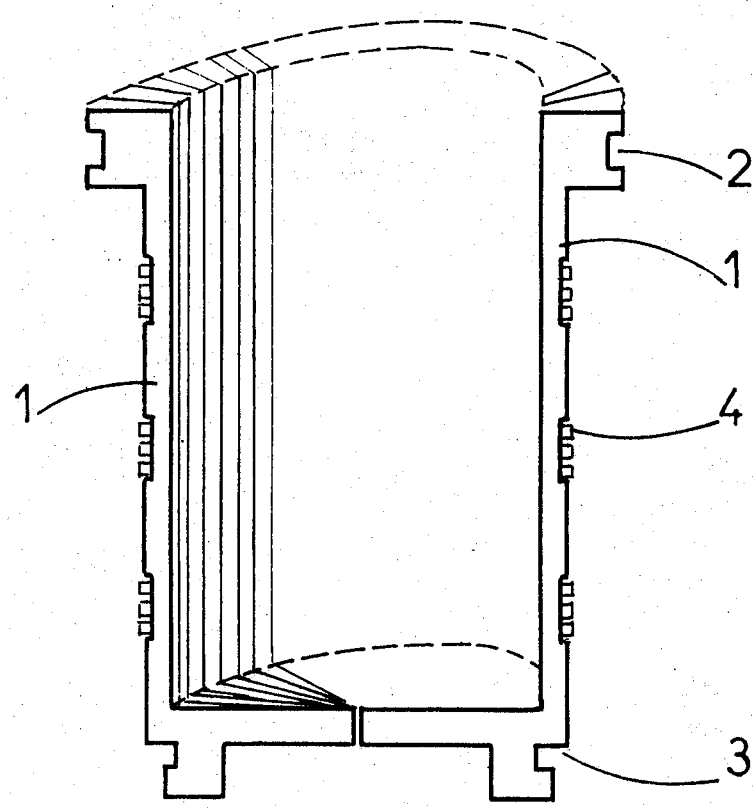



FIG:1

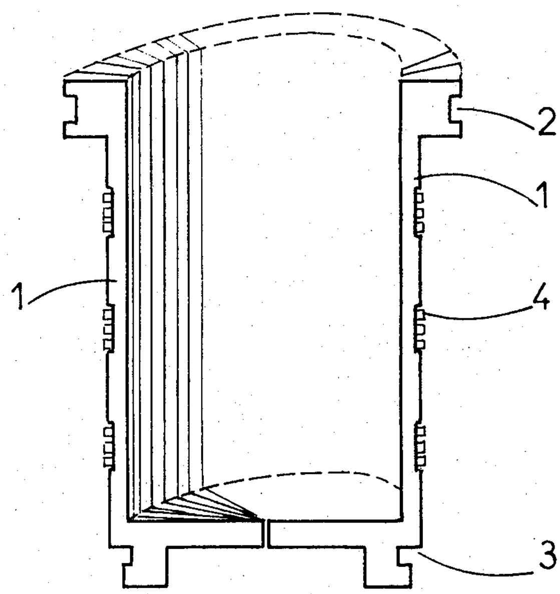



FIG:2

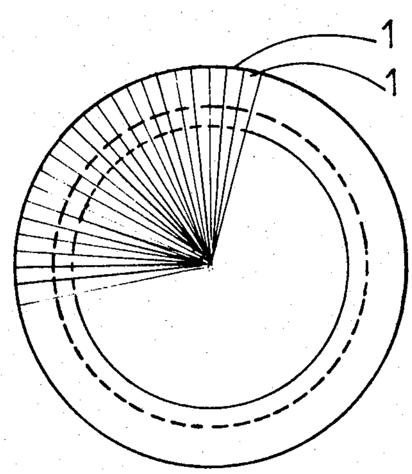


FIG : 3

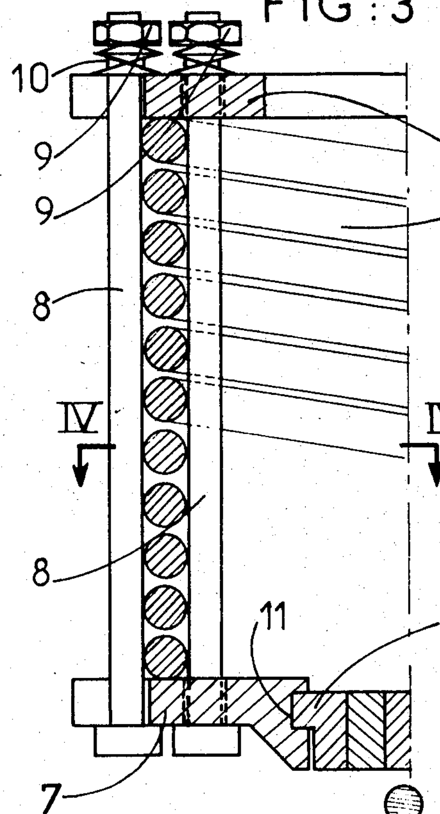
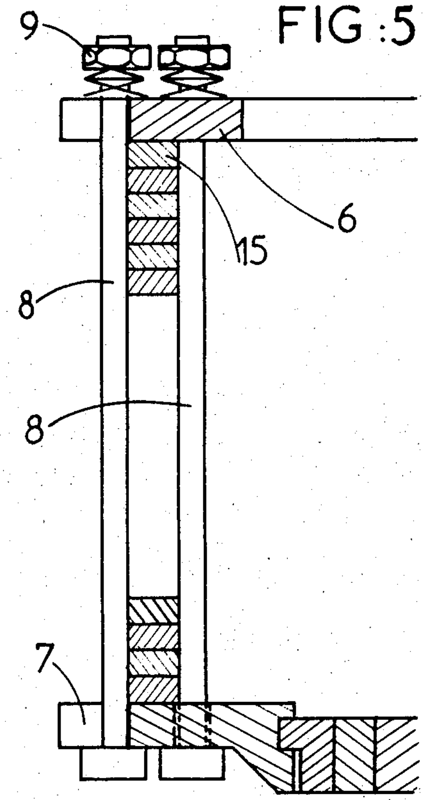



FIG : 5



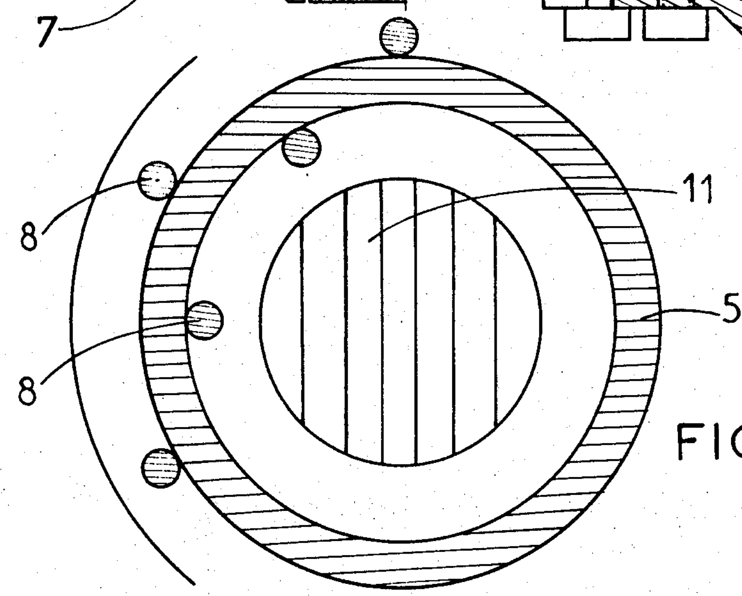




FIG : 4

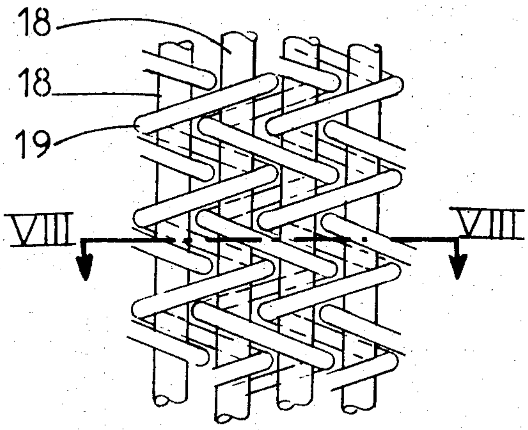



FIG 7

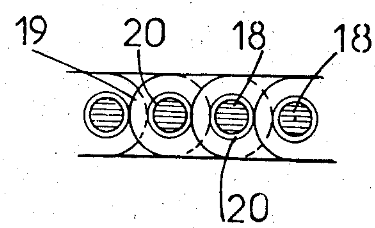



FIG:8

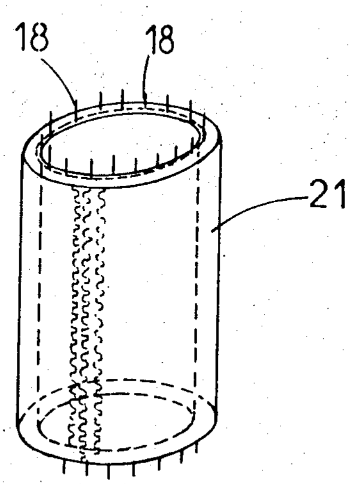



FIG:6

FIG:9

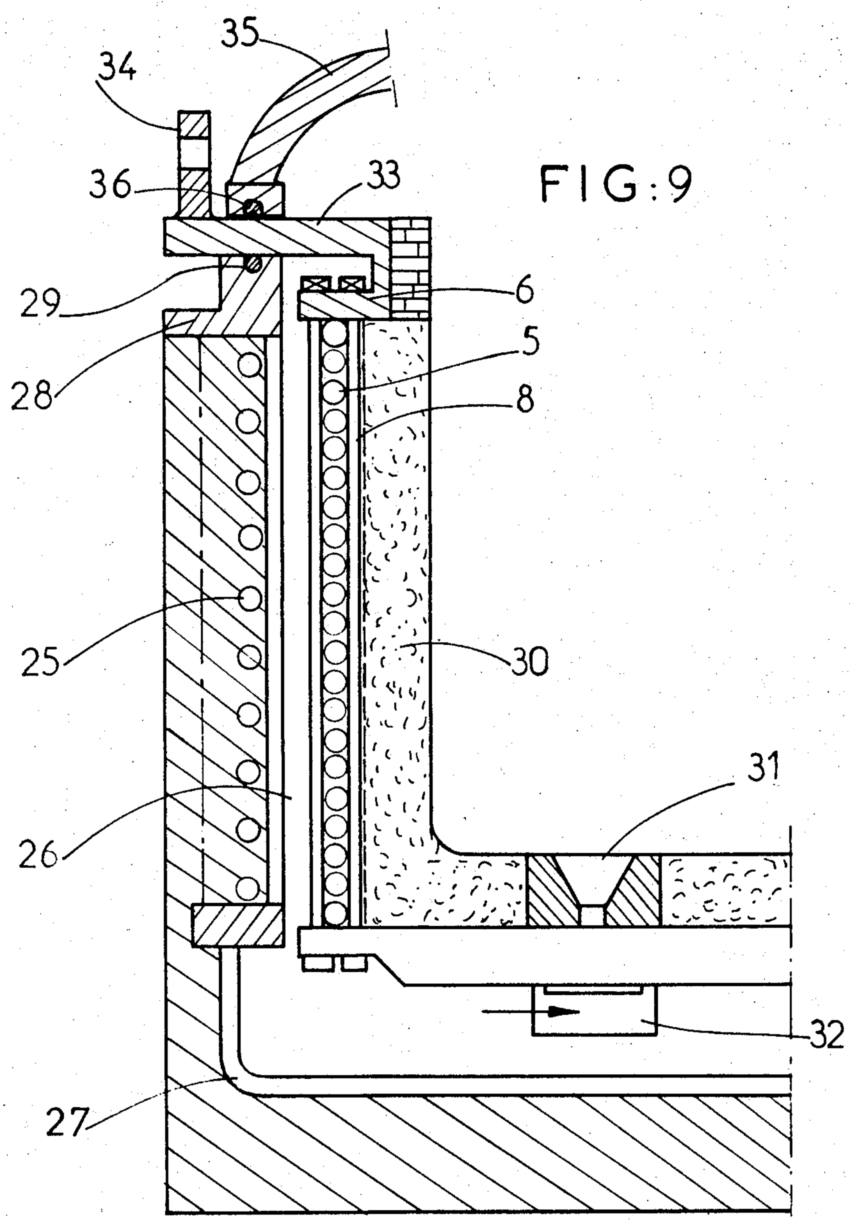
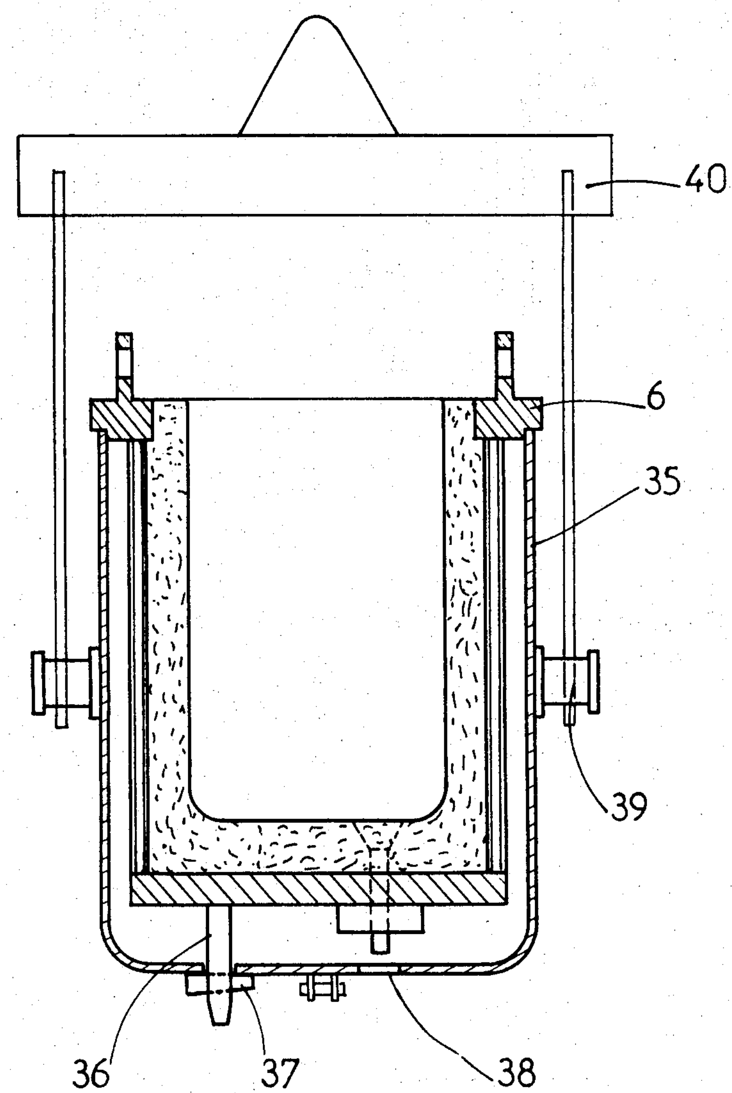


FIG: 10



## LADLE FOR INDUCTIVE TREATMENT

This invention relates to a ladle for inductive treatments, more particularly for the treatment of metals and alloys in the molten state by means of very low, low and medium-frequency inductive alternating fields (5 Hz to 2,500 Hz).

Ladles for inductive treatments are known, which consist of a refractory lining inside a non-magnetic metal cylindrical casing which, in the heating zone, is formed by an assembly of metal elements connected by mortise and tenon joints and electrically insulated from one another by an insulating and refractory gasket consisting of a thermosetting cement injected in the liquid state into continuous interstices between the connected metal elements. An arrangement of this type has been described more particularly in French Patent No. 1,509,043.

If the ladle capacity decreases, the metal inside the ladle must be heated with frequencies above 60 cycles and as high as 2,500 cycles (10 to 15 kg ladles). The known ladles defined hereinabove have the disadvantage that they cannot be used in practice when the frequency of the inductive current is above 60 cycles. The reason for this is that with higher frequencies the heating produced in the metal casing of the ladle as a result, more particularly, of eddy currents (eddy current losses proportional to the square of the frequency), very rapidly cause the ladle to become unusable.

The invention obviates this disadvantage and enables frequencies of as high as 2,500 Hz to be used with a ladle consisting of a cylindrical non-magnetic metal casing which can receive a refractory lining. According to the invention, the metal casing consists of metal elements each forming an open electrical circuit and each having a very small section in relation to the inductive vector, an electrical insulator being interposed between each element.

The invention will now be described in greater detail with reference to a number of specific embodiments given by way of example and illustrated in the drawings.

FIGS. 1 and 2 are a simplified view of one embodiment in which the casing elements are radiating elements. FIG. 1 is a perspective view in diametric section and FIG. 2 is a top plan view.

FIGS. 3 and 4 show another embodiment with spirally wound metal elements. FIG. 3 is a diametric section of the metal casing of the ladle. FIG. 4 is a section on IV—IV in FIG. 3.

FIG. 5 is a variant of the preceding embodiment in which the elements are wound flat.

FIGS. 6, 7 and 8 relate to an embodiment in which the metal casing consists of a braiding acting as a framework or reinforcement for the refractory concrete. FIG. 6 is a simplified perspective of the body of such a ladle, FIG. 7 is a detail of the metal braiding and FIG. 8 is a section on the line VIII—VIII in FIG. 7.

FIG. 9 shows a ladle according to the invention in position at an inductive heating station.

FIG. 10 illustrates possibilities for transporting the ladle and shows a system providing protection during transport or pouring.

Referring to FIGS. 1 and 2, the metal casing of the ladle is formed by juxtaposing a large number of identical elements 1. The shape of each element 1 is a radial section of the cylinder required to form the metal casing of the ladle. In plan view as shown in FIG. 2, each element 1 is in the form of a very thin segment of adequate but very limited width. It will be seen that the juxtaposition of all the elements 1 forms the cylinder making up the ladle and its base. The elements are held in clamped engagement by hoops fitting in grooves 2 and 3 formed by the juxtaposition of identical notches on all the elements 1. The interconnection of the elements 1 is completed by electrically insulated fasteners 4 which connect the elements in groups of 4 or 5.

The elements 1 are made, for example, from a non-magnetic alloy (nickel base, cobalt, chromium, titanium and aluminum) i.e., a super refractory precipitation hardened alloy of high electrical resistivity. Each element is electrically insulated by a surface coating of chromium oxide.

FIGS. 3 and 4 illustrate another embodiment of the metal casing of a ladle which in this case consists of a circular-section wire 5 wound spirally after the style of a spring and held between two rings 6 and 7. The turns of the spring 5 are held in contiguous relationship by means of a number of tie-rods 8 regularly distributed around the wall formed by the spring and alternately inside and outside said wall. Clamping is provided by nuts 9 with the interposition of resilient washers 10.

The spring 5 may consist of a single wire wound over the entire height of the ladle and preferably (no-load tension) by a plurality of super-posed unit springs. The springs 5 and the tie-rods 8 may, for example, be made from a super refractory alloy as defined hereinbefore.

The bottom non-magnetic ring 7 is made in two parts which are connected by bolts. The ring 7 has an annular groove 11 to receive the matching elements of juxtaposed rectilinear metal bands 12 which are held in the groove 11 when the two parts of the ring 7 are connected. The bands 12 are laminations made from non-magnetic alloys generally used for resistors. The assembly of elements formed by the turns of the spring 5, the tie-rods 8 and the metal bands 12 are electrically insulated by a chromium oxide surface coating.

The structure shown in FIG. 5 is very substantially similar to that shown in FIGS. 3 and 4 but the spiral winding in this case is replaced by a superimposition of flat circular rings 15 clamped in the same way between annular elements 6 and 7 by means of tie-rods 8 and nuts 9. The rings 15 are not continuous but are split rings. As in the previous Figures, they are of a super refractory alloy and are electrically insulated by a layer of chromium oxide.

Referring now to FIGS. 6, 7 and 8, the metal framework of the ladle consists of a series of tie-rods 18 uniformly spaced and disposed along generatrices of the cylinder forming the body of the ladle. The tie-rods 18 are connected in pairs by a wire 19 wound as an open spiral around two consecutive tie-rods 18. The turns of each spiral 19 are interlaced with the turns of the adjacent spirals, thus forming a resilient braiding which is closed on itself in the form of a cylinder. The tie-rods 18 and the spirals 19 are of a non-magnetic super refractory alloy like the elements in the embodiment described hereinabove. Each tie-rod 18 is enclosed by a sheath of silico-alumina fibers which form an insulator, while the spirals 19 are electrically insulated by a chromium oxide coating.

The braiding consisting of the tie-rods **18** and the spirals **19** is embedded in a layer of refractory concrete **21**. The concrete cylinder **21** together with the metal braiding as a reinforcement will preferably be prestressed. For this purpose, the braiding will be disposed at the periphery of an expansible mandrel and be tensioned, the system being disposed in a mold into which refractory concrete is then poured. After the concrete has set and the expansible mandrel has been withdrawn, the resilient shrinkage of the braiding will provide the prestressing for the concrete.

The resulting cylinder will then be completed by a base which can be of the type shown in the previous FIGS. **3**, **4** and **5**, and some of the tie-rods **18** will be longer than the others and their ends will project beyond the actual cylinder to enable the base to be fixed.

Of course the descriptions given concern only the metal casing of the ladle, which in every case will receive a bottom refractory lining formed in conventional known manner.

In all the above-described embodiments, the metal elements forming the mechanical resistant element of the ladle all have a very small section in relation to the induction vector and never form a closed electrical loop. The currents directly induced in the framework are thus zero and the eddy currents are reduced to a minimum by reduction of the passage section for the inductive flux in the metal parts forming the framework. Also, since the metal frameworks are non-magnetic they do not interfere with the action of the effective induction vector on the charge contained in the ladle.

The advantage of a ladle of this kind constructed according to the invention is that it provides, for example, a readily replaceable detachable crucible for an induction furnace in which only the inductive winding is a fixed element, and a furnace of this type can use relatively high current frequencies (up to 2,500 Hz) despite the presence of a metal framework in the ladle. The use of such a ladle also enables elementary metallurgical sequences (vacuum melting, super-heating, holding) to be separated, by transferring the ladle successively to fixed working stations each corresponding to a specialization of the fixed induction equipment.

FIG. **9** is a simplified view of an induction furnace comprising a fixed inductive winding **25** disposed at the periphery of a tank **26**. The latter, closed at the bottom by a base **27**, is open at the top and is bounded by a collar **28** provided with a cooled gasket **29**. The ladle used here is of the type described in FIG. **3**, with a spiral framework **5** and tie-rods **8**. It is lined on the inside by a refractory lining **30** and has in the base a taphole **31** with a valve-controlled nozzle **32**. The top annular collar **6** is connected to a projecting collar **33** provided with lifting lugs **34**. When the ladle is in position in the tank **26**, the collar **33** rests on the collar **28** of the furnace. When the metallurgical operation is to be carried out in a vacuum or in a controlled atmosphere, the assembly can be completed by a bell **35** resting on the collar **33** with the interposition of a cooled gasket **36**.

FIG. **10** shows equipment for transportation of the ladle from one treatment station to another or for supporting the ladle during a pouring operation. The equipment comprises a tank **35**, on the edge of which the top collar **6** of the ladle rests. If this equipment is used to tilt the ladle, the latter is also connected to the tank **35** by three rods at least, e.g., **36**, which are connected to the base of the ladle, extend through the base of the tank **35**, and are locked on the base **35** by a key **37**. The tank **35** also has an orifice **38** in register with the ladle taphole. The tank **35** has trunnions **39** on which engage the hooks of a handling yoke **40** and about which the ladle can be tilted for filling or emptying operations.

Of course the invention is not limited solely to the embodiments described hereinbefore, but also covers other embodiments differing therefrom only in detail. Thus the mechanical resistance of the ladles shown in FIGS. **3** and **5** could be reinforced by a concrete lining as described in connection with the framework in FIG. **7**. The spirally wound elements forming the framework of the ladle shown in FIG. **3** could be tubular and form a peripheral cooling circuit for the ladle, such circuit being connected to an external fluid circulation circuit.

I claim:

**1**. A ladle for inductive treatments, consisting of a non-magnetic cylindrical metal casing, a refractory lining for said casing, said metal casing consisting of metal elements each forming an open electrical circuit and each having a very small section in relation to the inductive vector, an electrical insulator interposed between each of said elements, said metal elements including a first series of rectilinear elements regularly disposed along generatrices of the cylinder, and a second series of elements wound spirally between two consecutive rectilinear elements, the turns of each spiral interengaging between the turns of the adjacent spirals, a cylindrical wall of refractory concrete enclosing said series of elements, and metal elements forming the base of said casing being juxtaposed non-magnetic electrically insulated strips in a flat annular element and connected to those of said rectilinear elements projecting beyond said cylindrical body.

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