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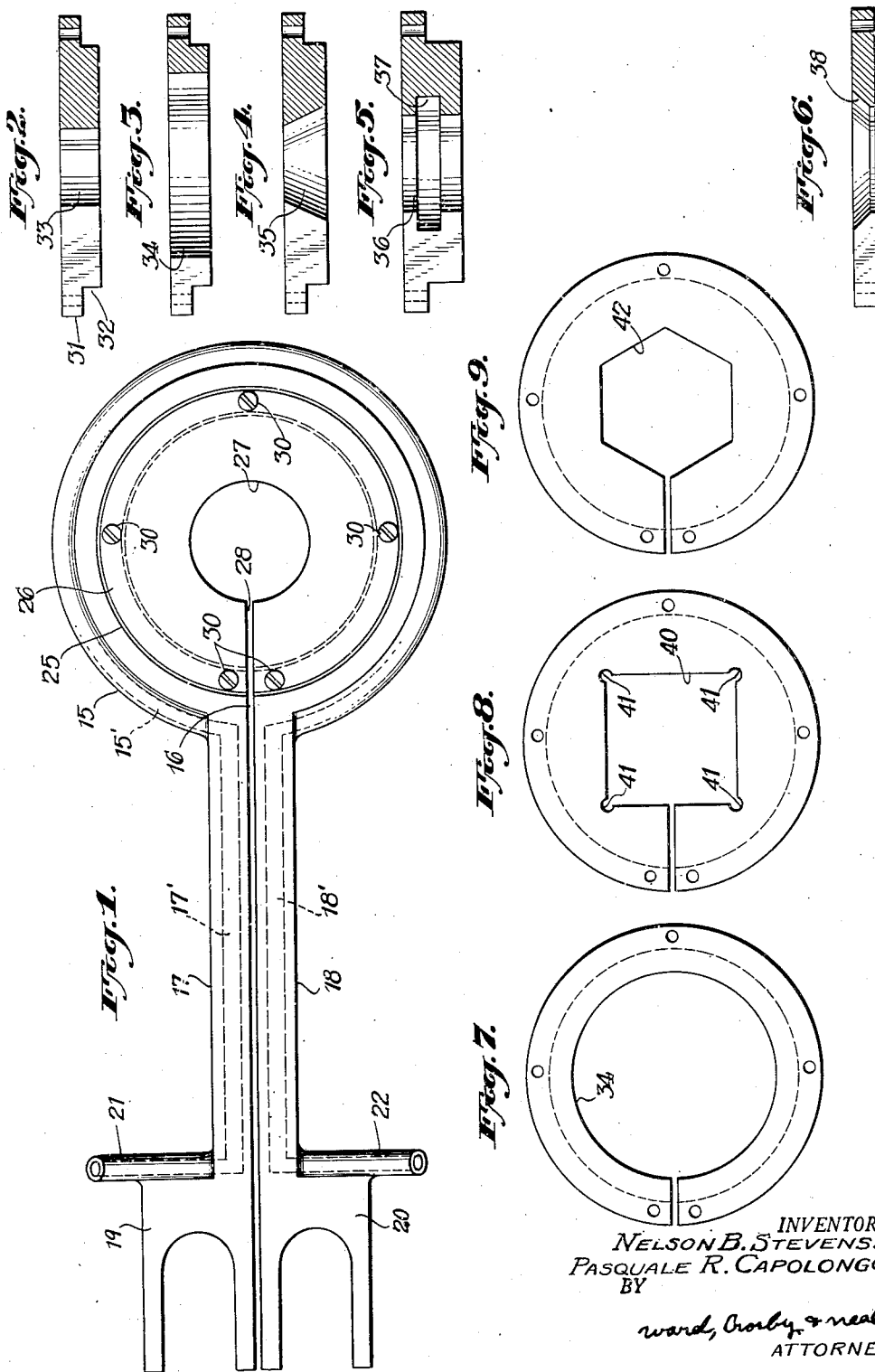
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INDUCTOR FOR HIGH-FREQUENCY INDUCTION HEATING

Filed March 12, 1945

2 Sheets-Sheet 1



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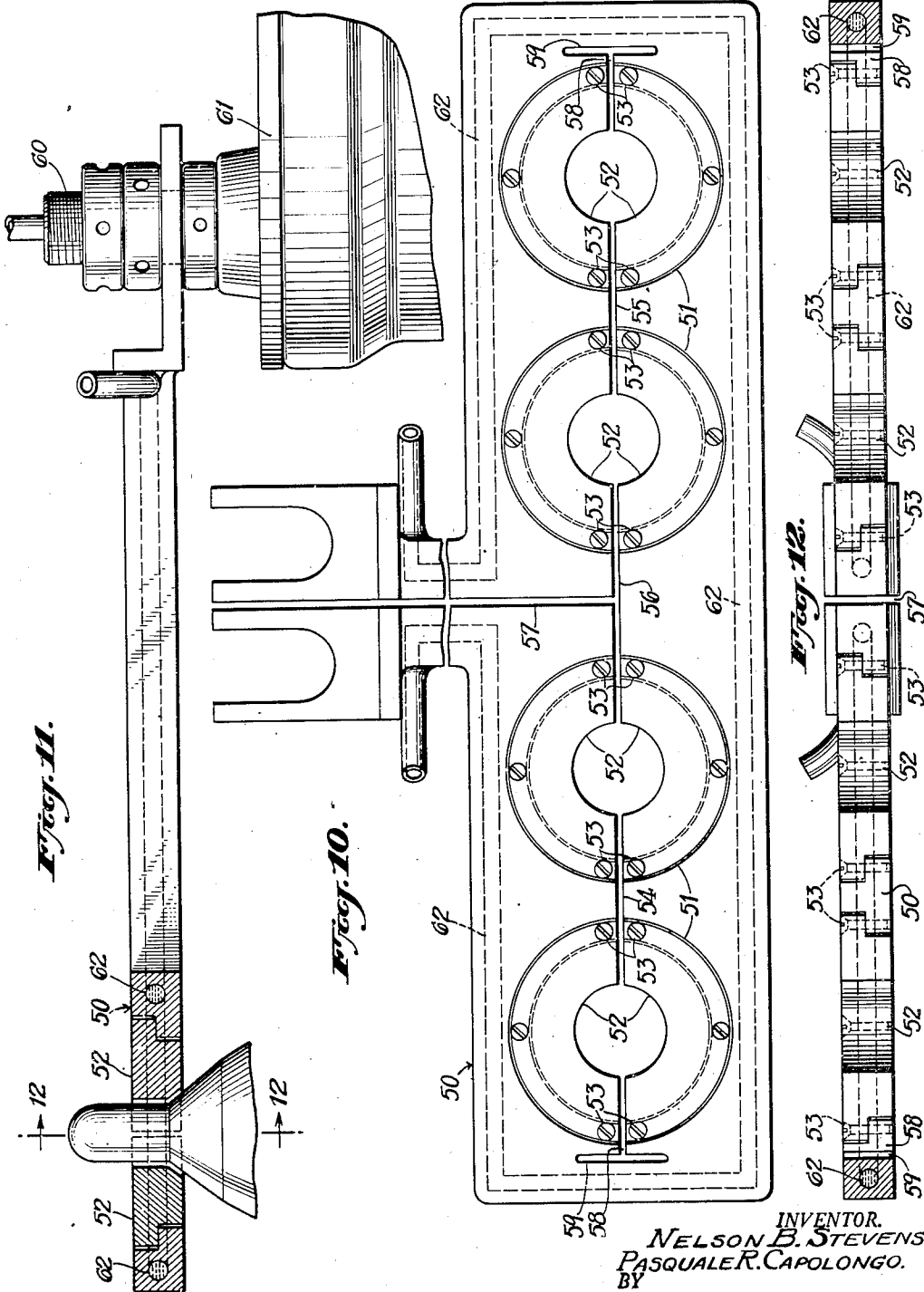
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UNITED STATES PATENT OFFICE

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INDUCTOR FOR HIGH-FREQUENCY
INDUCTION HEATING

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4 Claims. (Cl. 219—47)

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This invention relates to inductors for high frequency induction heating purposes.

In high frequency induction heating it is common practice to provide an inductor or "coil" having a single turn for surrounding an object to be heated in spaced relation thereto and with close inductive coupling therewith. For example, several forms of such inductors are disclosed in the patent to Paul E. Dravneek 2,353,130, granted July 11, 1944. Such inductors may be formed with one or more apertures depending upon the number of work pieces to be heated at one time, and the structure is adapted to be rigidly and substantially permanently mounted in conjunction with terminal connections for a source of high frequency current and also connections for circulating cooling water through the inductor to prevent the same from becoming heated. In the production and heat treating of large numbers of like objects, inductors such as shown in said patent have proven highly successful. However, once the equipment is built and set up to heat-treat objects of a certain shape and size, modifications cannot be easily or quickly made to accommodate objects of other sizes or shapes. It has generally been necessary to construct a special inductor having the proper dimensions and other characteristics for each type of work to be treated, and in shifting from one job to another the inductors of one form have to be disconnected from the supporting structure and from the source of power and water connections so as to be able to replace the whole inductor structure by another one of appropriate design.

The present invention provides an improved inductor construction comprising a frame member having cooling fluid and electrical connections adapted to remain permanently in position, together with any necessary supporting structure, and such frame member is constructed to receive readily interchangeable and replaceable adaptor members or inserts having apertures of shapes preselected for appropriate close inductive coupling with work pieces of different shapes or sizes. Thus, after finishing one job, the induction heating machine may be quickly prepared for another type of job merely by removing and replacing such adaptor means and without the necessity of disconnecting the electrical and water circuit connections or any of the supporting structure necessary for the inductor.

In accordance with this invention, the cooling fluid conduits for the inductor may be all located within the frame portion which may be of a standardized and inexpensive design and does not

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have to be altered to suit work pieces of various shapes and sizes. Also, since the adaptor means may be shaped and constructed independently of the parts of the inductor which include the terminals and cooling fluid conduits, it will be apparent that adaptors of numerous shapes may be made easily, quickly and inexpensively without special tools.

Various further and more specific objects, features and advantages of the invention will appear from the detailed description given below taken in connection with the accompanying drawings which form a part of this specification and illustrate merely by way of example, certain preferred forms of the invention. The invention consists in such novel features, arrangements and combinations of parts as may be shown and described in connection with the apparatus herein disclosed.

20 In the drawings:

Fig. 1 is a plan view of a preferred form of inductor for heating a single work piece;

Figs. 2-6 inclusive are sectional views of several forms of adaptor members suitable for use in the device of Fig. 1;

Figs. 7-9 inclusive are plan views of adaptors also suitable for use in the device of Fig. 1;

Fig. 10 is a plan view of an inductor made according to a preferred embodiment of the invention and of a type adapted for simultaneously heating a plurality of objects;

Fig. 11 is a vertical sectional view of the device of Fig. 10 and showing the device as mounted in connection with the terminals of a high frequency transformer; and

Fig. 12 is a sectional view taken substantially along line 12—12 of Fig. 11.

Referring now to Fig. 1 in further detail, the inductor there shown may comprise a ring-like frame portion 15 formed with a narrow gap 16 at one side, terminal connection and supporting members as at 17 and 18 being secured as by brazing at the respective sides of said gap. The members 17 and 18 may be supported respectively by terminal lugs as at 19 and 20 of the same type for example, as disclosed in the above-mentioned Dravneek patent. Cooling fluid connections may be provided as at 21, 22 and the members 17, 15 and 18 may be formed with communicating cavities as at 17', 15' and 18' whereby the cooling fluid may enter for example through connection 21 and pass around the inductor back to connection 22. If desired, the cavity 15' may be provided by way of a sheet metal tube surround-

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ing and brazed to the periphery of frame member 15.

It will be noted that the frame member 15 is formed with a central aperture as at 25 adapted to receive the removable and replaceable adaptors or inserts, one of which is shown at 26 in Fig. 1. The adaptor 26 for example is formed with a central circular aperture 27 for receiving a work piece of circular outline. One side of this adaptor is slotted as at 28 in alignment with the slot 16, so that the adaptor will not short-circuit the terminal connections. As shown in Fig. 1, the adaptor may be secured in place as by screws 30 located at spaced points around the outer periphery of the adaptor and adjacent the inner periphery of the frame.

As shown in Figs. 2-5, the adaptors may preferably be formed with peripheral flanges as at 31, or, stated in another way, the lower peripheral edges of the adaptors may be recessed as at 32. It will be understood that the inner walls of the aperture 25 in the inductor frame may be formed with a complementary flange or recess whereby extensive contact areas are provided between the adaptors and the frame. To insure good electrical and heat conductive contact, the abutting surfaces of the frame and periphery of the adaptors should preferably be plated with silver or other material of high conductivity.

The adaptor shown in section in Fig. 2 is similar to the one shown in plan view in Fig. 1 except that a smaller central aperture as at 33 is provided to accommodate a smaller work piece. The adaptor of Fig. 3 is also the same except that a larger central aperture 34 is provided. In the adaptor of Fig. 4 a central aperture 35 is provided having downwardly and outwardly tapered side walls for accommodating, for example, a work piece having a generally conical surface. The adaptor of Fig. 5 has a central aperture 36, the walls of which are formed at the mid portion with an annular cavity 37. With an aperture of this shape, for example if the work piece therein is of cylindrical shape, two spaced annular areas thereon may be heated, viz., areas which come into close inductive coupling with the portions of the wall surfaces of apertures 36 which are above and below the channel 37.

In Fig. 6 an adaptor is shown having an aperture 38 which is tapered inwardly and downwardly, at least part way. From the sectional views of Figs. 2-6 it will be noted that the adaptors may be formed of plate-like material of varying thickness, depending upon how far it is desired to have the heated area extend axially along the work piece. That is, if only a narrow heated band is required, then a relatively thin adaptor plate may be selected. On the other hand, if a wide band is to be heated on the work piece, one may select an adaptor formed of a relatively thick plate, and regardless of the thickness of the adaptor plate, within reasonable limits, the same inductor frame or ring of standardized construction may be used therewith.

Fig. 7 shows in plan view an adaptor substantially like that shown in section in Fig. 3. Fig 8 shows in plan view an adaptor having an aperture 40 of square shape to receive a work piece of square cross section. As shown in this figure, the metal adjacent the vertices of the angles at the corners of this aperture is cut away as at 41 for a short distance. The purpose of this is to avoid excessive concentration of the magnetic flux in the work piece immediately adjacent

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such vertices. That is, if for example the aperture 40 is made with substantially true square corners corresponding to a work piece of slightly smaller size having square corners, then the concentration of the flux will be such at the corners that excessive heating and injury of the corners of the work piece may occur. On the other hand, by forming the cut-out portions as at 41, the heating of the metal around the corner portions and elsewhere adjacent the periphery of the inductor aperture may be made substantially uniform. It will be understood that similar principles may be followed as indicated by Fig. 8 in constructing adaptors having apertures of other polygonal shapes. In Fig. 9 an adaptor with an aperture 42 of hexagonal shape is shown. Since the angles of this aperture are not so abrupt, the cut-out portions as at 41 of Fig. 8 may be omitted here if desired.

Referring now to the construction of Figs. 10-12, a rectangular plate-like frame member 50 is here shown formed with a series of openings as at 51, each of which corresponds in function to the opening or aperture 25 of Fig. 1. Semi-annular adaptor plate members as at 52 are secured as by screws 53 in each of the apertures 51. Certain principles of construction of this form of inductor may be the same as of the T form of inductor disclosed in connection with Fig. 1 of the above-mentioned Dravneek patent. That is, in order to form a circuit around all of the apertures collectively, the body portion of the inductor is formed with a T-shaped slot with slot portions as at 54, 55, 56 along the cross portion of the T, serving to interconnect each adjacent pair of apertures, and a slot portion as at 57 serving to separate the terminal connections or supports. Also at each end of the device, slots or notches as at 58 may be formed, opening into the end apertures for purposes of securing more uniform heating of the objects within said apertures in a manner more fully explained in said Dravneek patent. In the example shown in Figs. 10 and 12, the outer ends of the notches or slots 58 may open into transversely extending slots as at 59. With these transverse slots 59, a uniform heating effect may be obtained around within the adjacent work piece apertures without making the notches 58 as long or extended as would be desirable for such uniform heating effect in the absence of slots 59. Thus, with the slots 59 the overall length of the device may be reduced due to the possibility of considerably reducing the length of the slots or notches 58. The combined effect of the notches or slots 58 and 59 so far as concerns the uniformity of heating around within the adjacent work piece apertures, is substantially the equivalent of that obtainable if there were another work piece aperture in place of each slot 59. Yet this effect is obtained without the inductance increase which would occur if the device were equipped with empty or unused apertures of circular form at the ends.

The device of Figs. 10-12 may be formed with a terminal connection and supporting structure including cooling fluid inlet and outlet connections, the same or equivalent to that described in connection with Fig. 1. In Fig. 11 the terminal and supporting structure is shown as applied to the secondary terminals at 60 of a high frequency transformer 61 serving as the source of supply of current for the inductor.

As is best shown in Fig. 10, the peripheral portions of the frame or plate member 50 may be

formed with a cooling fluid cavity as indicated by dotted lines at 62. This cavity may for example be formed by drilling holes inwardly from the edge surfaces at the corners of the plate and then plugging the undesired drill hole openings, for example, with pieces of metal plugs brazed in place. With the fluid cavity formed in this way the construction is rigid, permanent and relatively inexpensive, and externally the frame plate presents the appearance of a solid plate member with unobstructed smooth external surfaces which may be easily cleaned.

As in the case of the structure of Fig. 1, it will be understood that the insert or adaptor members in Figs. 10-12 may be shaped internally in various ways depending upon the dimensions and shape of the objects to be heated. Any of the shapes of adaptors shown in Figs. 2-9 for example may be used in the device of Fig. 10 except that it will be understood that because of the necessity of interconnecting adjacent openings by slots as in Fig. 10, the adaptors for this device have to be formed of two parts separated by a narrow slot or gap at each side. Also as shown in Fig. 12, the adaptors may be formed at their peripheries with flanges and/or recesses as in the case of the construction of Fig. 1 or otherwise formed in a manner such that the walls of the apertures 51 will be more restricted at the lower side of the frame plate to thus afford support against which the screws 53 may retain the adaptors in firm reliable contact for good heat and electrical conduction purposes uniformly around the peripheries of the adaptors except for the gaps.

It will be apparent that the invention provides a construction in which the main frame parts of the inductors, including the electrical connections and cooling fluid connections may be maintained in permanent assembly with the remainder of the high frequency induction heating apparatus. Yet by the use of the interchangeable inserts or adaptors, any one or more of the work piece apertures may be quickly modified to accommodate work pieces of a variety of shapes and dimensions. Also it will be apparent that if any of the adaptors should become injured, as for example due to arcing effects, same may be quickly replaced with no more than a moment's interruption of operations. Also if the adaptors of these slotted gap regions should become clogged with flux or brazing material or need cleaning for other reasons, they may be quickly removed and more readily and effectively cleaned than may be the constructions heretofore available.

Since the inductor frame remains stationary, the interchanging of the inserts will not affect the alignment of the work piece apertures in the frame relative to the axes of fixtures, etc. for supporting the work pieces. The invention also provides a construction convenient for experimental, trial and laboratory work. For example, if it is desired to make a series of tests as to the heating effect on a given work piece using apertures of different sizes or configurations, such tests may be made in rapid succession using a single standardized inductor frame. In that case, if desired, instead of attaching the inserts by ordinary screws, it will be understood that wing nuts, thumb screws or quick-detachable locking means might be provided.

While the invention has been described in detail with respect to certain preferred example, it will be understood by those skilled in the art after understanding the invention, that various changes and further modifications may be made

without departing from the spirit and scope of the invention, and it is intended therefore in the appended claims to cover all such changes and modifications.

What is claimed as new and desired to be secured by Letters Patent is:

1. An inductor for high frequency induction heating, comprising a pair of adjacent supporting and terminal connection members, a ring-like frame portion fixed thereon for completing a circuit connection therewith, said members and frame portion being formed with cavities for circulation of cooling fluid therethrough, and readily removable and replaceable plate-like adaptor means mounted to extend over the space within said frame portion, and formed with a central aperture of size and shape preselected to receive the object to be heated with close inductive coupling therewith, the periphery of said adaptor means and the interior of said ring member being formed with complementary interengaging flanges, and said adaptor means and frame portion being correspondingly slotted adjacent said terminal connections to avoid short-circuiting same, the said interengaging flanges providing effective electrical and heat conducting contact therebetween substantially continuously around the frame portion except at the slot.

2. An inductor for high frequency induction heating, comprising a conductive frame portion formed with at least one aperture, the walls of which are adapted to extend substantially around at least one object to be heated, in a widely spaced relation thereto, a narrow gap being formed in at least one side of said frame portion and opening into said aperture, means connected respectively at each side of said gap for applying high frequency current, said means and said portion being formed with a cooling fluid cavity therein extending from one current connection around said frame portion to the other current connection, removable disc-like conductor means formed with a smaller aperture of size and shape preselected to receive the object to be heated with close inductive coupling therewith, said latter means also being formed with a narrow gap adapted for alignment with said first mentioned gap, the inner aperture walls of said frame portion and the peripheral edges of said removable conductor means respectively being formed with overlapping flange surfaces, a plurality of screw means being provided for removably retaining said removable conductor means in position on said frame portion with said overlapping surfaces in effective electrical and heat conducting contact substantially continuously around the aperture borders of the frame portion.

3. An inductor for high frequency induction heating comprising a conductive frame formed with a plurality of apertures each adapted to receive a work piece in widely spaced relation with the aperture walls, said frame being formed with narrow slots including slots interconnecting each adjacent pair of apertures and all arranged whereby a current path in the frame is provided extending around all of the apertures, said frame also being formed with a cavity for circulating cooling fluid along said path, and pairs of semi-circular plate-like complementary adaptor members which are removably and replaceably fixed to extend over the space within each of said apertures, each pair being separated by narrow gaps forming continuations of said interconnecting slots, and each pair of adaptor members serving jointly to form a smaller aperture of size and

shape preselected to receive the work piece to be heated therein with close inductive coupling therewith, the inner aperture walls of the frame and the peripheral edges of said adaptor members being formed with complementary interengaging flanges providing effective electrical and heat conducting contact between the adaptor means and the frame substantially continuously around each of the frame apertures except at said slots.

4. In apparatus for high frequency induction heating, an inductor member for extending around a work piece to be heated, the work-receiving space within said member being of a generally polygonal shape and the metal being cut away for a short distance about the vertices of the angles of the polygon to which the space corresponds whereby excessive concentration of magnetic flux is avoided in the work piece immediately adjacent such vertices.

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