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[54] **INDUCTION HEATING APPARATUS FOR HEATING THE MARGINAL EDGE OF A DISK**

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[30] **Foreign Application Priority Data**
Jan. 31, 1972 Germany............................ 2204343

[52] **U.S. Cl.**............ **219/10.57**, 219/7.5, 219/10.43, 219/10.79, 266/5 EI
[51] **Int. Cl.**.. **H05b 5/08**
[58] **Field of Search**............... 219/7.5, 10.43, 10.57, 219/10.73, 10.79, 152; 266/4 E, 5 E

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Primary Examiner—Bruce A. Reynolds
Attorney, Agent, or Firm—Hill, Gross, Simpson, Van Santen, Steadman, Chiara & Simpson

[57] **ABSTRACT**

Induction heating apparatus for heating the marginal edge of a disk as the latter is deformed to produce a peripheral flange, incorporates ferromagnetic means located on both sides of the marginal edge of the disk, such means being adapted to move as the disk is deformed, for maintaining a relatively constant magnetic path through the marginal area of the disk during its deformation.

13 Claims, 8 Drawing Figures

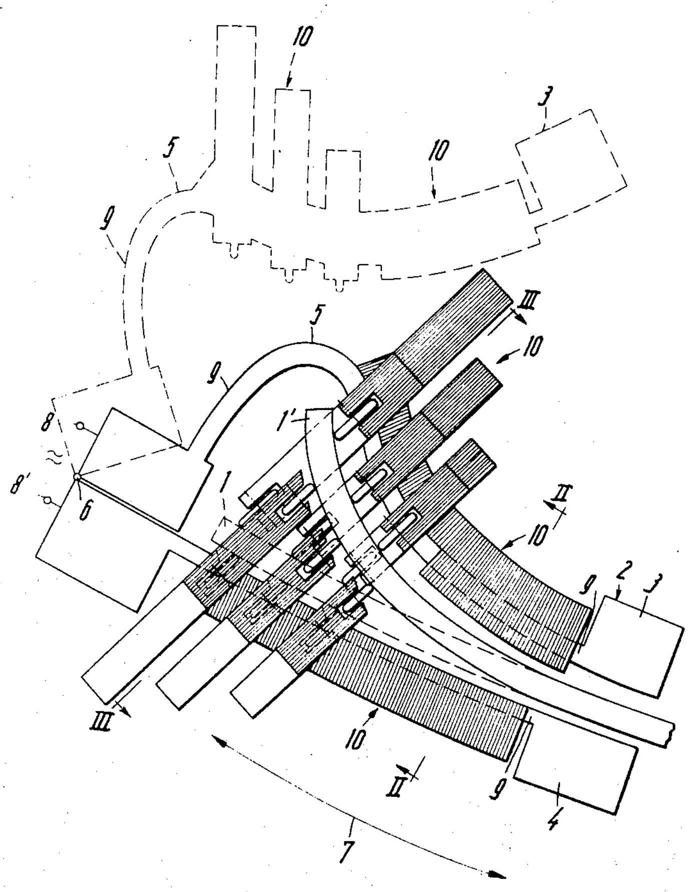


Fig.1

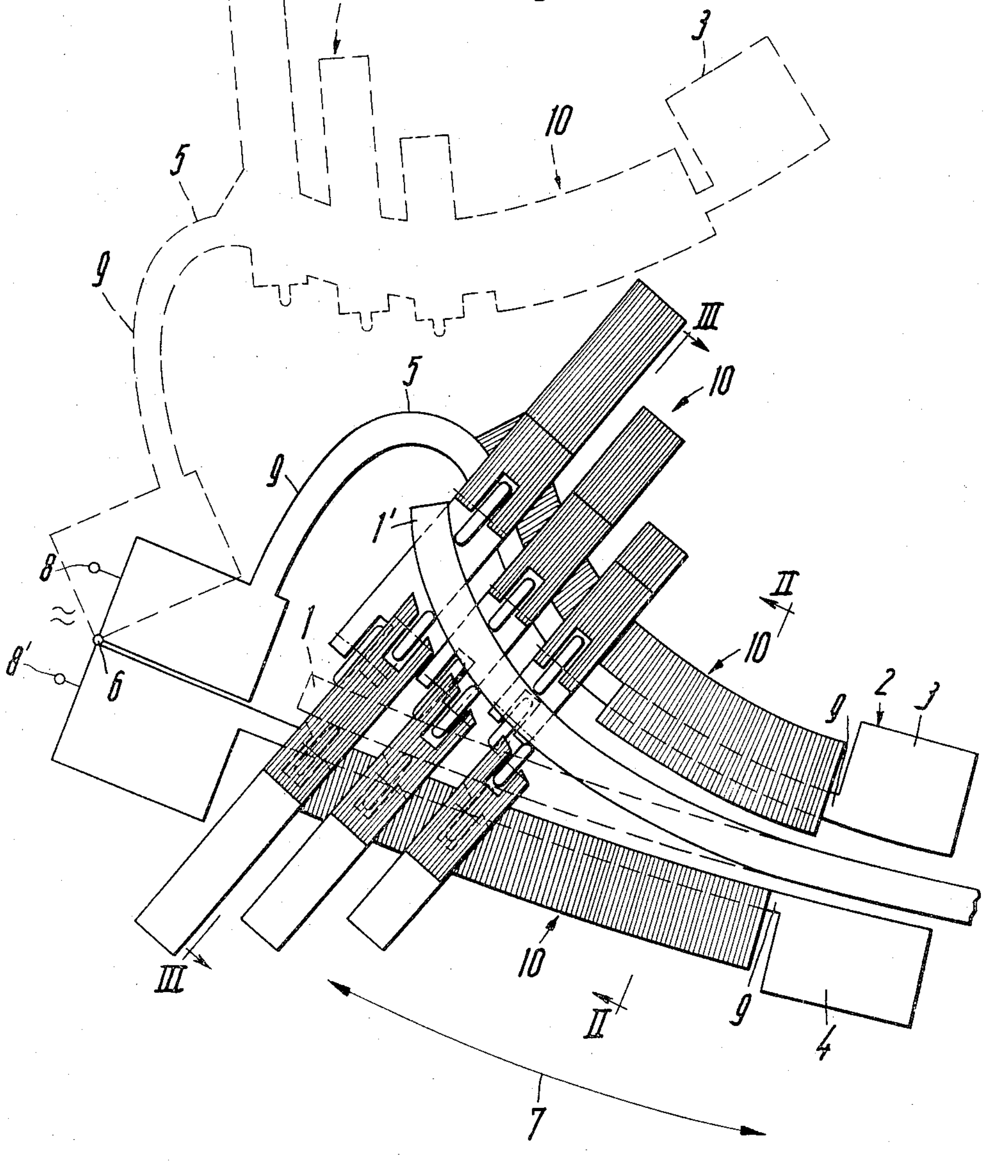


Fig. 2

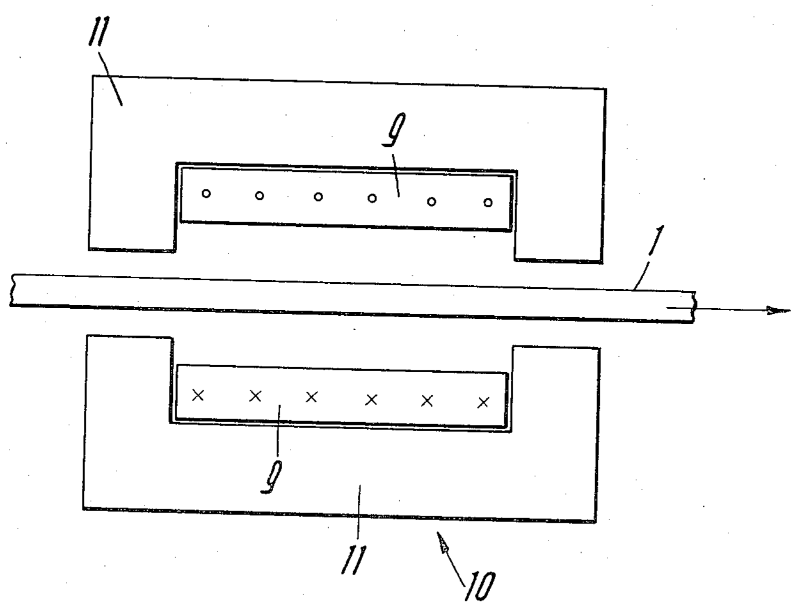


Fig.3

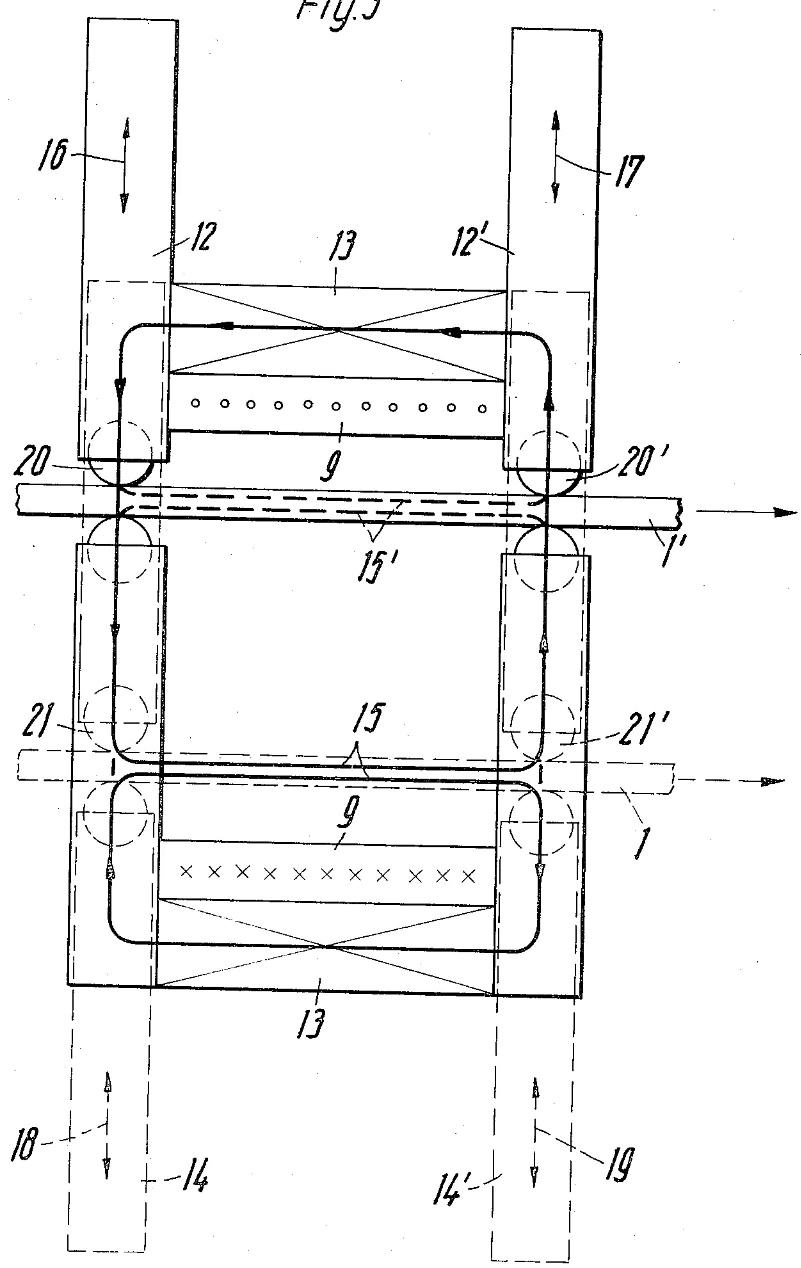
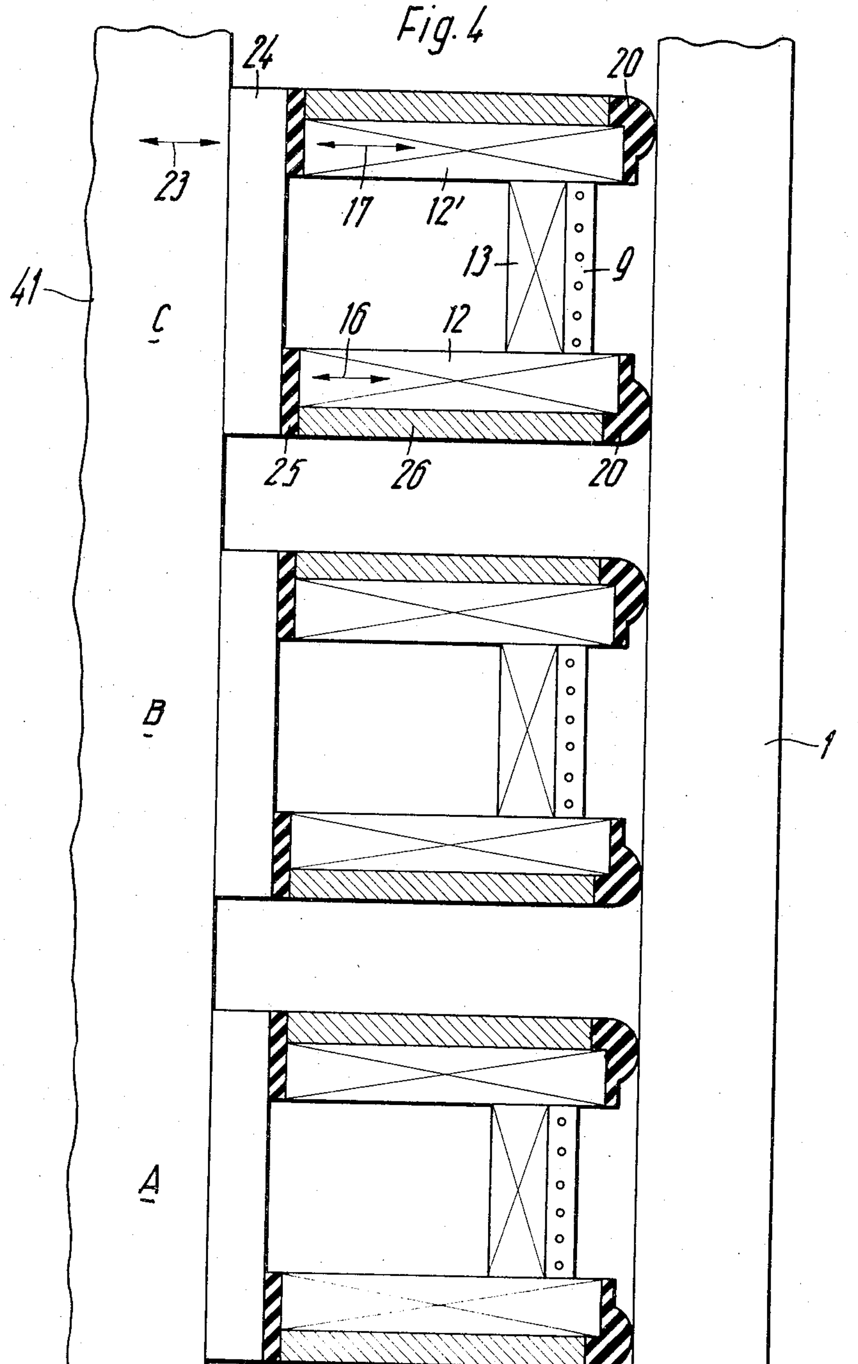


Fig. 4



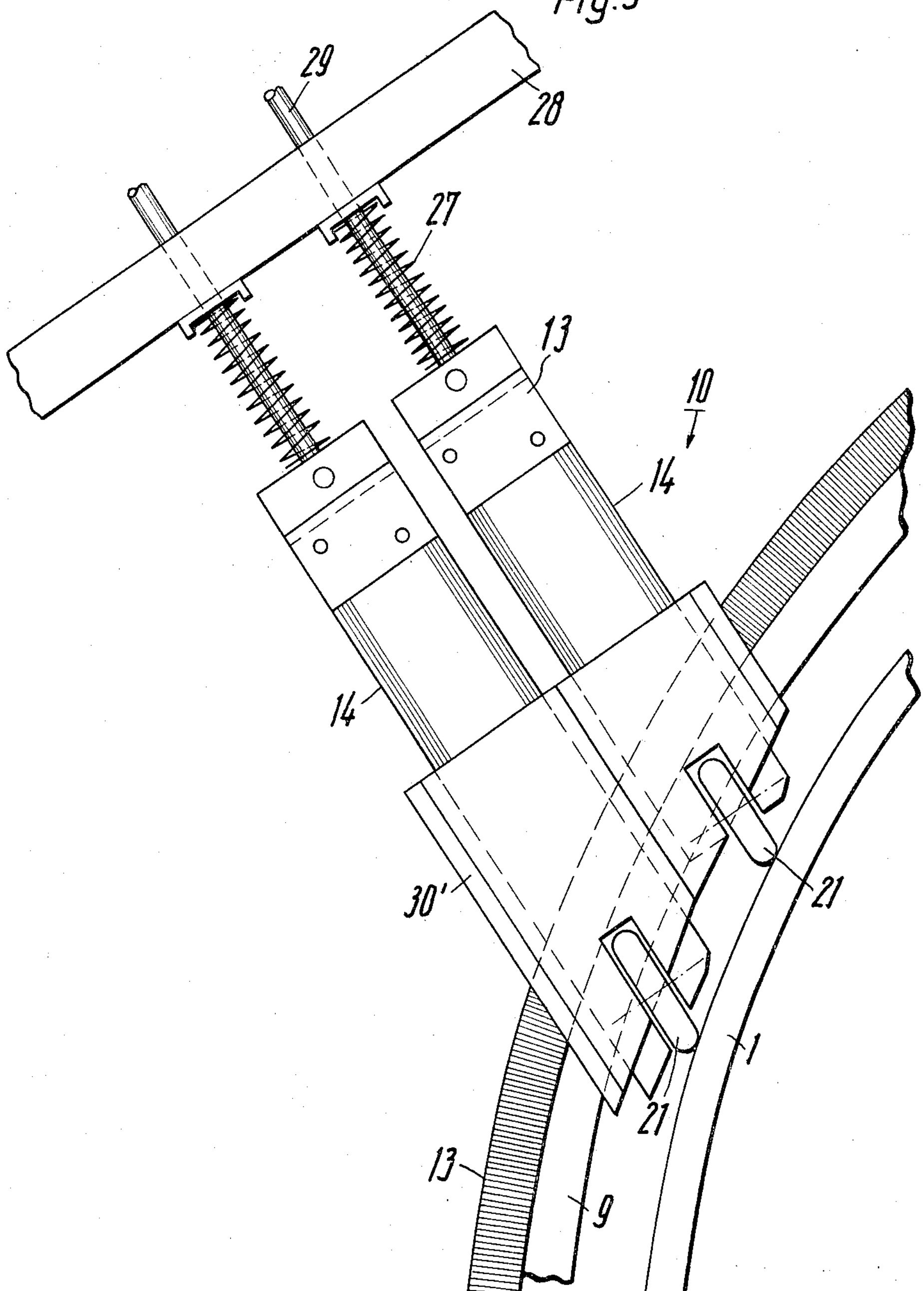


Fig.5

Fig. 6

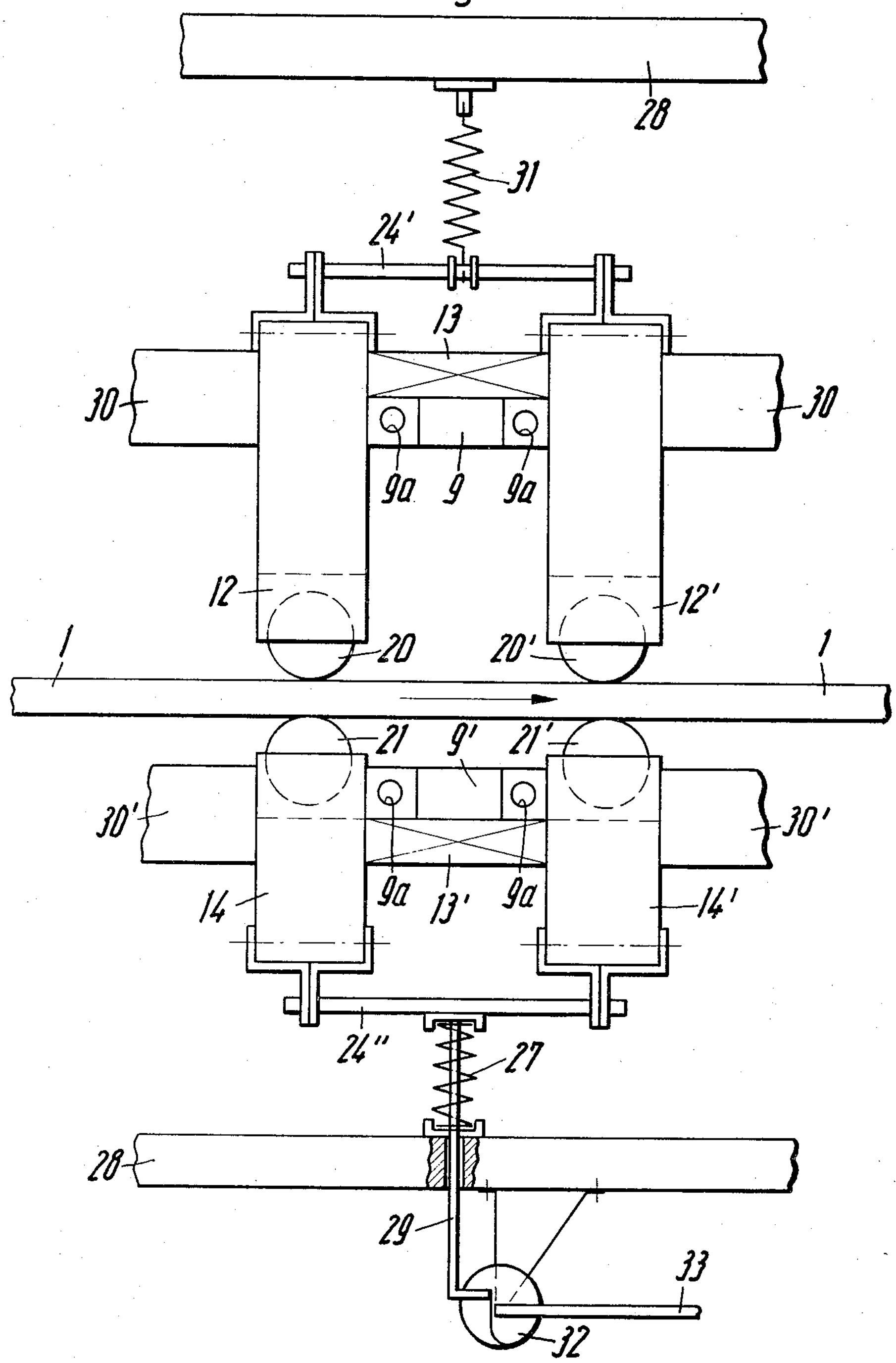

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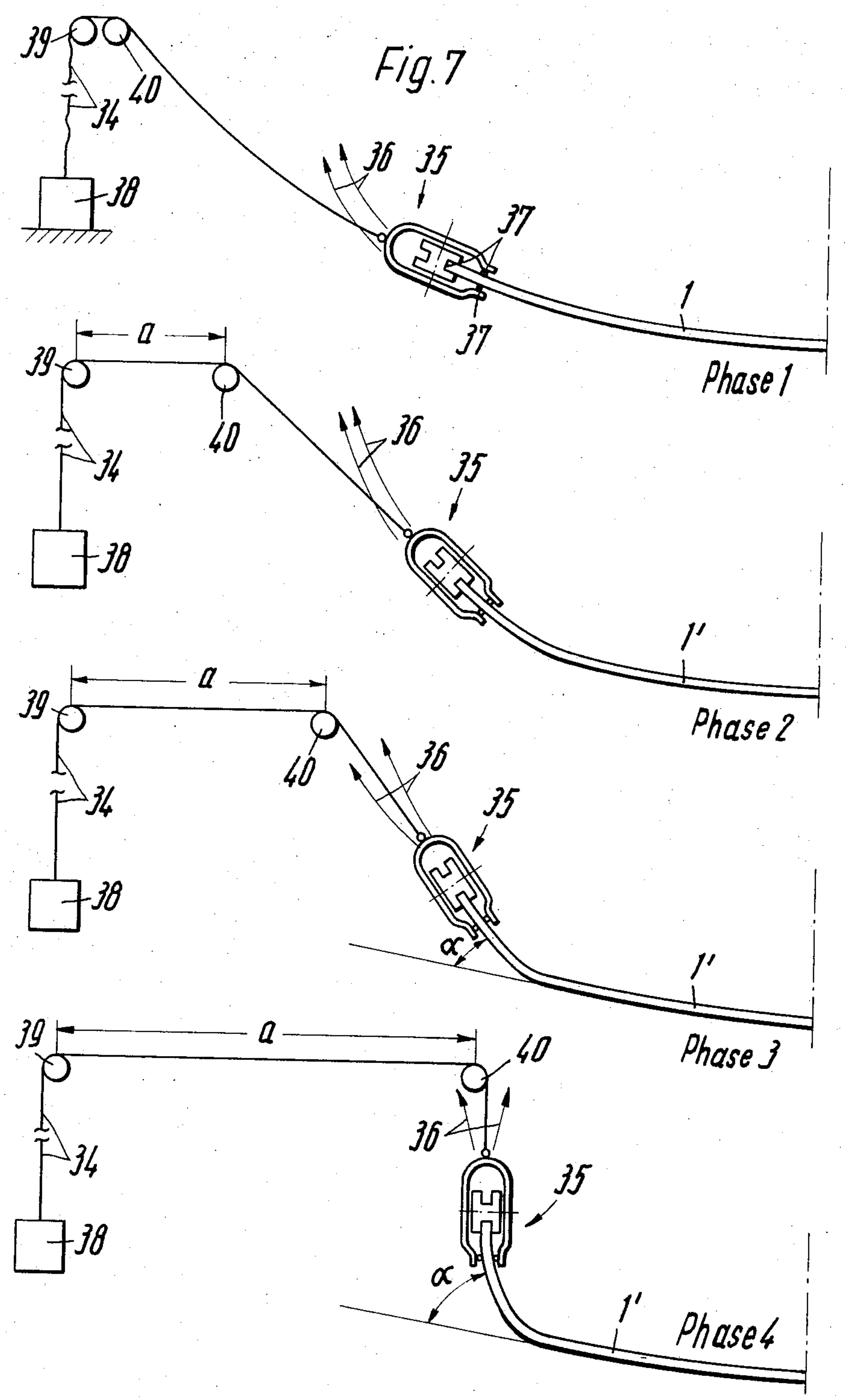
Fig.7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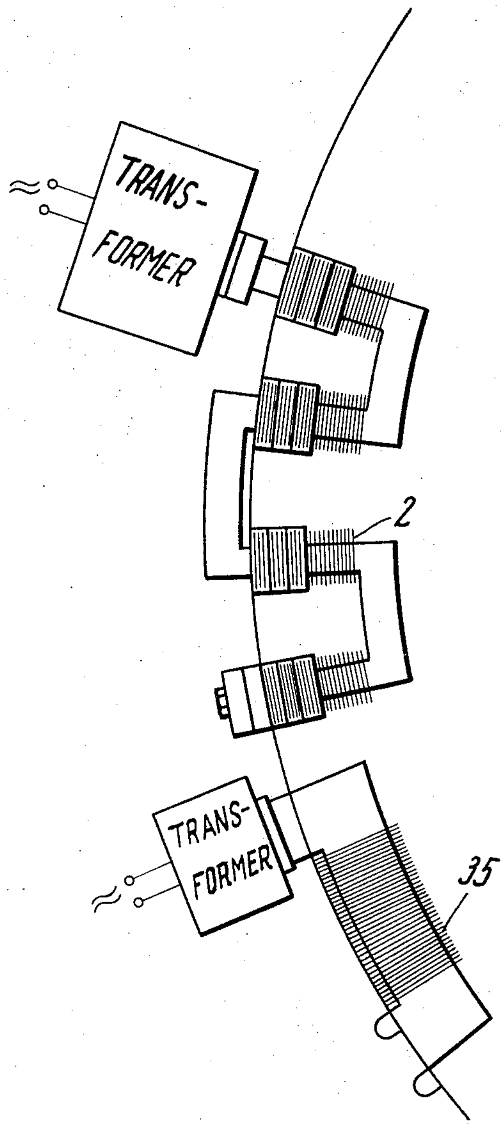
Phase 4

Fig. 8



INDUCTION HEATING APPARATUS FOR HEATING THE MARGINAL EDGE OF A DISK

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to induction heating apparatus and more particularly to such apparatus for heating the marginal area of a circular disk as it is deformed relative to the plane of the disk to provide a peripheral flange.

2. The Prior Art

Electric induction heating apparatus has in the past been employed for the purpose of heating round ferromagnetic disks to the point where they become softened and may readily be deformed under pressure, to form a peripheral flange so that the disks can be used to form the bottom panels of boilers or the like. Such apparatus is disclosed in German patent application P 21 48 519.8. However, such apparatus has not been adapted to heat the disk during the process of deforming the edge. On the contrary, it has been necessary to alternately heat the disk, and then form the flange while the disk is removed from the heating apparatus. Accordingly, the apparatus described in the German patent is not wholly satisfactory because the heat rapidly dissipates during the flanging operation, with the result that the disk is not maintained at the optimum temperature during flanging.

In another known arrangement, described in Austrian pat. no. 105,313, aluminium disks have been heated continuously during flanging, but the method of doing so is restricted to the production of aluminium parts, and is not adapted for use with ferromagnetic materials.

It has not been practical heretofore to continuously heat the edge of a disk by induction, because the bending of the marginal portions of the disk demand a very large area throughout which the heating must be equally effective, if the optimum temperature is to be maintained. However, the provision of a large area is accompanied by a relatively large stray field which severely limit the useful heating energy.

Accordingly, it is desirable to provide an apparatus whereby the marginal edge of a ferromagnetic disk may be heated continuously during the time it is being deformed into a flange.

SUMMARY OF THE INVENTION

A principal object of the present invention is to provide apparatus adapted for continuously heating the edge of a circular disk as it is being deformed to form a flange.

Another object of the present invention is to provide induction heating apparatus incorporating means for maintaining a satisfactory heating relationship with both surfaces of the marginal edge of a circular disk as it is deformed into a flange.

Another object of the present invention is to provide induction heating apparatus for heating a disk, in which the effective heating zone moves as the edge of the disk is deformed.

These and other objects and advantages of the invention will become manifest upon an examination of the following description and the accompanying drawings:

In one embodiment of the present invention there is provided induction heating apparatus having ferromagnetic members located on both sides of the marginal zone of a circular disc, the ferromagnetic members being movable as the disk is deformed for maintaining close magnetic association with the surface of said disk during the deformation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a vertical cross-sectional view of apparatus incorporating an illustrative embodiment of the present invention;

FIG. **2** is a cross-sectional view of a portion of the apparatus of FIG. **1**, taken in the plane II—II;

FIG. **3** is a cross-sectional view of a portion of the apparatus of FIG. **1**, taken in the plane III—III;

FIG. **4** is a cross-sectional view of apparatus incorporating an alternative embodiment of the present invention;

FIG. **5** is a cross-sectional view of apparatus incorporating another embodiment of the present invention;

FIG. **6** is a cross-sectional view of apparatus incorporating a further embodiment of the present invention;

FIG. **7** is a diagramatic view showing, at four different phases, the change in position of apparatus incorporating yet a further embodiment of the present invention during four successive phases in the deformation of a disk; and

FIG. **8** is a plan view of apparatus incorporating yet another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. **1**, the round disk **1** is supported (by means not shown) for rotation about a vertical central shaft (not shown). The disk **1** is shown in undeformed condition, and after the heat deformation it has an upwardly directed flange **1'**. The heating of the marginal zone of the round disk **1** is accomplished before and during the deformation by means of an inductor **2**, having an upper leg **3**, and a lower leg **4**. The upper leg **3** is arched upwardly so as to accommodate in this arch **5** the deformed edge **1'** of the round disk. The upper leg **3** and the lower leg **4** are interconnected by a hinge **6**, so that the inductor can be opened into the position shown in broken lines in FIG. **1**, and thus be moved away more easily from the edge of the round disk when the deformation is concluded, or when an additional deformation is intended for which the arch **5** of the upper leg **3** is insufficient. Such a hinged inductor may be moved out of the area of the marginal zone of the disk **1** after opening in the manner described in German patent application No. P 21 48 519.8.

Alternatively, the inductor **2** may be of rigid design, without the hinge **6**. In that case, it is moved in the direction of the arrow **7** away from the marginal zone, when desired, as described in the aforementioned German patent.

Electrical current is supplied to the inductor **2** through the terminals **8** and **8'**, which are connected to the conductors **9** of the upper and lower legs **3** and **4**, respectively. Each conductor **9** has a generally rectangular cross-section, as seen in FIG. **2**, and is preferably formed of copper and is provided with passages (not shown) for water cooling. The construction of the conductors **9** may be the same as that described in the aforementioned German application. Each conductor 9 is partially surrounded by short circuit panel **10**, for concentration and guidance of the magnetic flux, the short circuit panel **10** comprising, in FIG. **2**, a ferromagnetic U-shaped panel **11**.

The conductors **9** are supported rigidly relative to the center of the disk **1**, and the shape of conductor **9** in the lower leg **4** of the inductor conforms to the plane shape of the undeformed marginal zone. The conductor **9** in the upper leg **3** conforms to the shape of the deformed marginal zone **1'**. The result is that the conductor **9** of the upper inductor leg **3** has, prior to the deformation, a larger distance from the disk **1**, and after the accomplished deformation of the marginal zone of the round disk, a smaller distance, as compared with the conductor **9** of the lower inductor leg **4**. In order to achieve equal heating on both surfaces of the round disk **1**, the ferromagnetic panels **10** are arranged at least in part of an angle of about 45° to the horizontal line. The panels **10** are supported in fixed relation to the inductor body, where the deformation is small, and the upper and lower legs **3** and **4** are not widely separated from each other, especially toward the central portion. The panels **11**, shown in FIG. **2**, which shows the cross section toward the central portion of the disk **1**, are preferably formed of sheets of ferromagnetic material, with adjacent sheets being insulated from each other, to minimize eddy current losses. The panels **11** are preferably about 0.3 mm thick and are positioned closely adjacent each other.

FIG. 3 shows a cross section at a point spaced radially outward relative to FIG. **2**. As shown in FIG. **3**, certain portions of the short circuit panels **10** are movable. In particular, the parts **12** and **12'** and **14** and **14'** are movable toward and away from the disk **1**, while the center parts **13** and **13'** of the ferromagnetic short circuit panels **10** are supported in fixed relation. The round disk **1**, and the movable panels **12, 12'**, **14** and **14'** are shown in broken lines, to illustrate their positions before deformation, while the round disk **1'** and the movable panels are shown in solid lines to illustrate their positions after deformation. Because of the movable panels, the magnetic flux, within the disk **1**, is relatively constant during deformation of the disk **1**. The flux path within the disk **1** is identified by reference numeral **15** before deformation, and after deformation by **15'**. As a result, the disk **1** is heated approximately evenly on both sides, during deformation. The movement of the parts **12, 12'** and **14, 14'** in the direction of the arrows **16–19** is controlled by non-magnetic rollers or sliding parts **20, 20', 21, 21'** which contact the marginal zone of the round disk **1**. The sliding parts are preferably formed of a ceramic material or the like. The deformation of the marginal portion of the disk **1** is performed, during heating, by pressure applied by hydraulic or pneumatic means.

FIG. 4 represents several loop arms A to C of the upper inductor leg **3**, with their ferromagnetic panels in the position they occupy prior to the deformation of the edge of the round disk **1**. The individual parts of the ferromagnetic panels have the same reference symbols as in FIG. 3. A bracket **41** is provided for moving the ferromagnetic panels **12** and **12'**. The bracket **41** is urged rightwardly, as viewed in FIG. **4**, so that projections **20** bear upon the marginal zone of the disk. The bracket **41** is also effective to return the moving parts **12** and **12'**, following deformation and removal of the deformed round disk, back into their starting positions. The bracket **41** is provided with non-ferromagnetic members **24** for supporting the movable parts **12** and **12'**. In addition, an electrical insulation member **25** is provided between the movable parts **12** and **12'** and the member **24**. Water-cooled copper panels **26** are provided for cooling the movable parts **12** and **12'**. The projections **20** and **20'** are preferably formed of ceramic material, and insulate the disk **1** from the copper panels **26**.

FIG. **5** shows a portion of an assembly provided for the lower inductor leg **4**, employing a different arrangement for supporting and guiding the movable parts **14**. The upper inductor leg **3** (not shown) is of analogous design. The stationary parts **13** of the ferromagnetic panels **10** are arranged in arcuate fashion, and the movable parts **14** are provided with rollers **21** formed of non-ferromagnetic material. The movement of the parts **14** is accomplished by the pressure of compression springs **27**, which bear against a bracket **28** made of insulating material. The movable parts **14** can be retracted against the pressure of springs **27** by means of a tension bar **29**, in order to accommodate a new (undeformed) disk. The movable parts **14** are guided by bushing **30'**, made of insulating material, for rectilinear movement toward, and away from the disk **1**.

FIG. **6** shows another embodiment, in which the disk **1** rotates in the direction of the arrow. The conductors **9** of the upper leg **3** and the lower leg **4** are both provided with passages **9*a*** to support a flow of water for cooling, and are disposed adjacent to the stationary ferromagnetic parts **13** and **13'**. The movable parts **12, 12'** and **14, 14'** are preferably covered with water-cooled copper panels such as the panels **26** of FIG. **4**, which panels are insulated by mica foil from the movable parts of the circuit, and which are also used to guide the movable parts **12, 12'**, **14** and **14'**. The movable parts are also guided by bushings **30** and **30'**, which are formed of insulating material.

The movable parts **12, 12'**, **14** and **14'** are interconnected by transverse rods **24'** and **24''**. The rod **24'** is connected to a tension spring **31**, for equalization of the weight of the assembly to relieve some of the weight from the rollers or sliding parts **20** and **20'**. In the lower inductor leg **4**, a compression spring **27** urges the assembly upwardly against the rod **24''**. The movable parts **14** and **14'** can be returned to their starting position by compressing the spring **27** and holding it in compressed condition by means of a latch wheel **32**, having a hook engaging the lower end of a rod **29**, the upper end of which is connected to the rod **24''**. This is done prior to the introduction of the next round disk to be deformed. The latch wheel **32**, the lever **33**, the bar **29** and the compression spring **27** are shown in tensioned position, that is after the return operation. Alternative means may be used in lieu of springs, such as hydraulic and pneumatic actuators, or the like.

FIG. 7 shows a tunnel-like inductor **35** adapted to be placed at the edge of the round disk and slide thereon by means of non-magnetic, sliding parts **37**. Rollers may be substituted for the sliding parts **37** if desired. The inductor **35** is provided at **36** with leads by which electrical power is applied thereto, and it is supported by a line **34** having an end secured to a weight **38** over a pair of rollers **39** and **40**. The roller **40** is displaceable horizontally, over a path a.

A coiled current-bearing conductor is supported within the inductor **35.** The tunnel inductor **35** is maintained at a distance from the surfaces of the round disk by the sliding parts **37,** and stationary ferromagnetic members may be provided to establish a path for magnetic flux through the marginal portion of the disk **1.** The length of the tunnel inductor **35** in the circumferential direction of the round disk **1** may be increased with increasing diameter of the round disk and with decreasing angle alpha of deformation. Several tunnel inductors **35** also may be juxtaposed at different positions on the circumference of the round disk. The four views of FIG. **7** represent the relative positions of the apparatus at four different phases in the deformation of a disk. In the first phase, the deformation is slight, and the position of the roller **40** is adjacent the roller **39.** Then the roller **40** is moved rightwardly progressively, as the deformation is increased, so that the inductor **35** remains aligned with the edge margin of the disk.

FIG. **8** shows an assembly employing two inductors, **2** and **35,** arranged in series on the circumference of the round disk **1.** The central part of the marginal zone is heated with the aid of the inductor **2,** while the tunnel inductor **35** heats the outer marginal area.

The present invention is effective to maintain a constant heating of the marginal portion of a disk while it is being deformed, and it is not necessary for the heating to be discontinued as the deformation is performed. The use of the laminated panels permits the apparatus to operate efficiently, and only a small amount of energy is lost in the ferromagnetic panels. The air gaps between the ferromagnetic panels and the disk are maintained small, so the magnetic flux in the disk **1** is maximized, and little energy is lost due to stray magnetic fields.

If desired, the movable ferromagnetic panels of the present invention may be moved manually, or by the use of motors or the like, instead of by springs as described above.

What is claimed is:

1. Induction heating apparatus for heating the marginal edge of a disk while it is being deformed into a flange, flux generating means for establishing a magnetic flux within said marginal edge, means for maintaining said magnetic flux in approximately the same concentration in said marginal edge throughout said deformation, separate flux generating means disposed on opposite sides of the marginal edge of said disk for uniformly heating both of said sides and means supporting said separate flux generating means for movement in the same relative direction as said edge is deformed.

2. Apparatus according to claim **1,** wherein said supporting means includes a compression spring on one side of said disk and a tension spring on the other side of said disk.

3. Apparatus according to claim **1,** wherein said flux generating means includes a ferromagnetic member and an electrical conductor, and including electrical insulating means interposed between said ferromagnetic member and said conductor.

4. Apparatus according to claim **1,** wherein said flux generating means includes a ferromagnetic member and an electrical conductor, and electrical insulating means interposed between said ferromagnetic member and said disk.

5. Induction heating apparatus for heating the marginal edge of a disk while it is being deformed into a flange, flux generating means for establishing a magnetic flux within said marginal edge, means for maintaining said magnetic flux in approximately the same concentration in said marginal edge throughout said deformation, separate flux generating means disposed on opposite sides of the marginal edge of said disk, for uniformly heating both of said sides, means supporting said separate flux generating means for movement in the same relative direction as said edge is deformed, said flux generating means comprising two separate inductors each juxtaposed with a separate minor proportion of the periphery of said disk, one of said inductors being adapted for heating the central portion of the marginal zone of said disk, and the other inductor being adapted for heating the outer portion of said marginal zone.

6. Apparatus according to claim **5,** wherein said one inductor is provided with a movable ferromagnetic member means for moving said movable member to maintain an end of said movable member juxtaposed with said disk, and wherein said second inductor is a tunnel inductor.

7. A method of heating the marginal edge of a disk while it is being deformed into a flange, comprising the steps of establishing a magnetic flux within said marginal edge, maintaining said magnetic flux in approximately the same concentration throughout said deformation, providing a path for said magnetic flux including a movable ferromagnetic member, moving said member during said deformation to maintain a constant spacing between said movable member and said disk, movable ferromagnetic members being provided on opposite sides of said disk, and wherein the movable members on both sides of said disk are moved during said deformation to maintain a relatively constant separation between said disk and said movable members.

8. An apparatus for heating the edge zone of a disc, for example, a boiler bottom or the like rotating repeatedly about a central normal axis of the disc for the purpose of deformation of the edge zone to form a marginal rim, comprising an edge heating tool, alternating current inductors cooperable with the edge tool which sectorially impinge on both sides of the disc, the inductors including current conductors which enclose the edge zone of the disc before and during the deformation, first means provided for movement on said edge heating tool for the concentration of the magnetic alternating field, and support means for movably guiding said first means in the area of the edge zone in such a manner that in each phase of the deformation the inductors and the disc are operatively coupled.

9. Apparatus according to claim **8** further characterized in that the first means comprises movable short-circuit panels, and rollers supporting said panels on the disc, said support means including means having the panels extended there through.

10. Apparatus according to claim **9** further comprising a pressure equalizer connecting said support means with one another.

11. Apparatus according to claim **8,** characterized in that the first means comprises movable short-circuit panels which are electrically insulated from the windings of the conductors.

12. Apparatus according to claim 11, further characterized in that the movable short-circuit panels are electrically insulated from the disc.

13. Apparatus according to claim 8, wherein said alternating current inductors comprises two inductors and further characterized in that the two inductors are arranged consecutively in the direction of movement of the disc, a first of said inductors being operable to heat the part of the edge zone nearest to the interior of the disc and being further provided with the movable short-circuit panels, said short-circuit panels including iron, said apparatus further comprising rollers and the second of said inductors being constructed as a short tunnel inductor and being movable during the deformation and operable to continuously heat the outer part of the edge zone while traveling on said rollers.

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