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3,154,017

D.C. INDUCTION PUMP

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3 Sheets-Sheet 1

FIG. 1

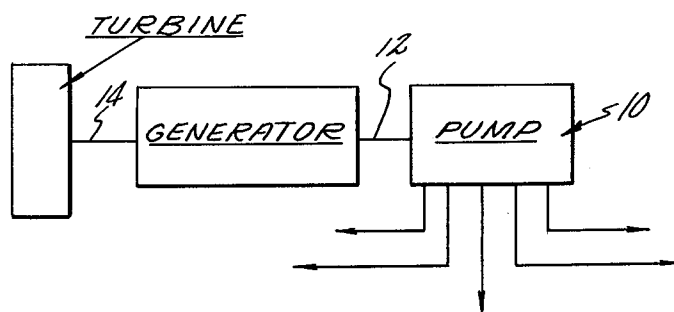


FIG. 2

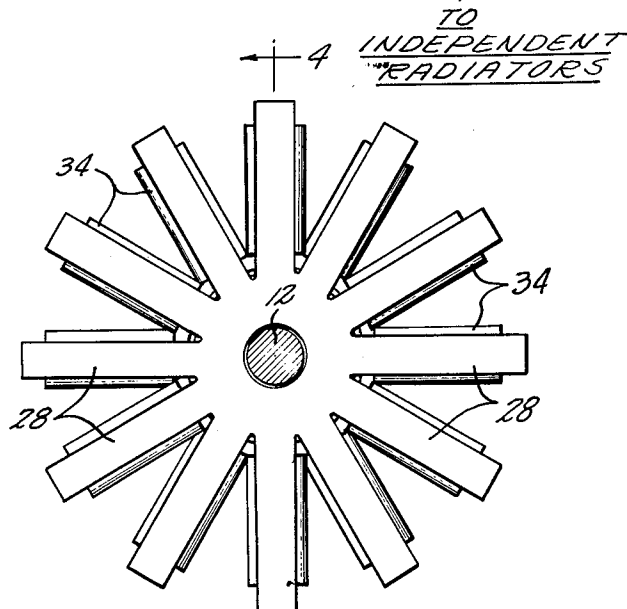
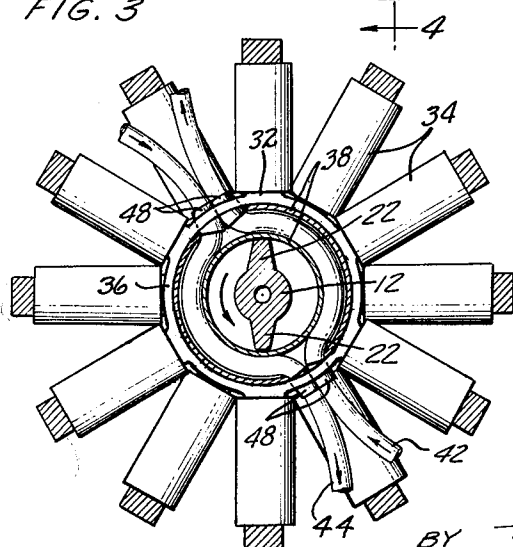


FIG. 3



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FIG. 6

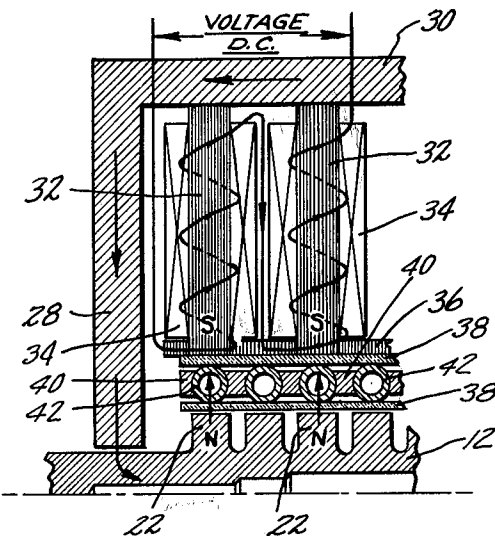


FIG. 7

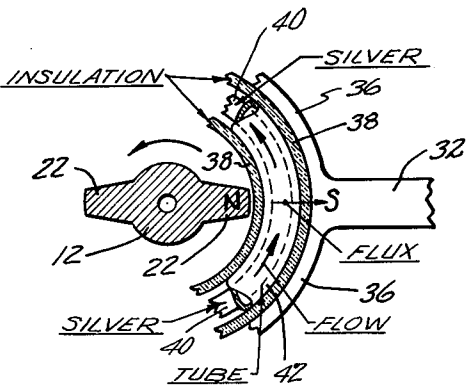
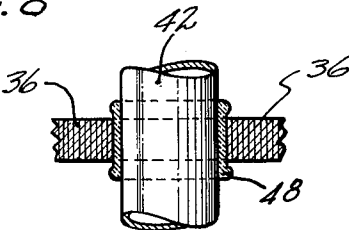


FIG. 8



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3,154,017

D.C. INDUCTION PUMP

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14 Claims. (Cl. 103—1)

This invention relates to mechanically rotated D.C. induction pumps for pumping conductive fluids. More specifically it relates to liquid metal pumps adapted to be driven by extremely high speed prime movers to pump liquid metals, or other conducting fluid, in hermetically sealed systems that require a multitude of electrically and hydraulically independent fluid paths, with or without gravitational effects.

It is an object of this invention to provide a high speed induction pump for pumping electrically conducting fluids.

It is a further object of the invention to provide such a pump directly connected to a high speed prime mover for pumping a large number of independent fluid circuits for a space radiator, utilizing existing power and converting it to direct current at the available line voltage to provide the magnetic field for the pump.

A still further object of the invention is to provide such a D.C. induction pump having rotating parts, light in weight, adapted for direct shaft connection to, for example, a 12,000 r.p.m. turbo generator.

A further object of the invention is generally to improve D.C. induction pumps.

These and other objects and advantages of the invention will be evident or will be pointed out in the following detailed description of one embodiment of the invention shown in the accompanying drawings by way of illustration.

In these drawings FIG. 1 is a diagrammatic showing of the improved pump of this invention, shaft-connected to a turbo generator.

FIG. 2 is a sectional view taken through the drive shaft showing an end view of the pump.

FIG. 3 is a cross sectional view through the pump taken on line 3—3 of FIG. 4.

FIG. 4 is a longitudinal, sectional view through the pump on line 4—4 of FIG. 2.

FIG. 5 is a plan view of the pump illustrating the arrangement of the incoming and outgoing fluid conducting pipes for the liquid metal, a part of the magnetic field structure being broken away to facilitate illustration.

FIG. 6 is a diagrammatic radial section through the pump illustrating a typical magnetic flux path through the pump, and

FIG. 7 is a transverse sectional detail through the shaft and its rotating pole structure and the adjacent stationary pole structure showing the flux path and the flow path of conductive fluid.

FIG. 8 is an enlarged detail view showing a flow tube passing through a protective bushing in the magnetic sleeve.

As herein shown, the pump 10 of this invention has its axial shaft 12 directly connected to the axial shaft 14 of a turbo generator. As a result the pump is driven at shaft speed of the turbo generator which may be in the vicinity of 12,000 r.p.m. or higher. Shaft 12 is journaled in bearings 16 in a frame 18 (FIG. 4). The shaft, which forms a part of the magnetic circuit, is preferably bottle-bored as shown in FIG. 4 at 20 to provide constant flux density at any cross section.

The particular pump shown is designed to pump 16 separate fluid streams, two tubes for each flow tube position, and to that end the shaft 12 is provided with 16 pole pieces 22 arranged in pairs, one pair for each flow tube position, on diametrically opposite sides of the shaft. A pair of

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pole pieces 22 are shown in section in FIG. 3 and in elevation in FIG. 4. The shaft 12 and its pole pieces 22 constitute the sole rotating part of the pump, and it will be evident that the pump by this light weight and compactness of its rotating part is particularly well adapted for high speed operation. Obviously more than two pole pieces may be provided at each tube location, the number depending upon speed of rotation, field distribution, and required performance.

The stationary parts of the pump comprise left and right skeleton frames 24 and 26 which are mounted around shaft 12 with minimum clearance inside the bearings 16 and are held against rotation by fixed structure (not shown). Each of these frames consists of 12 radial arms 28 having longitudinal right angle extensions 30 which extend inwardly toward each other in axial planes. These extensions are of varying length so as to support the outer ends of the radial core pieces 32 of the electromagnets, each extension supporting the cores of two adjacent magnets. It will be noted that the magnets are arranged in 2 banks of four magnets, each of which lie in the same planes as extensions 30. The magnets, however, are staggered in alternate banks which accounts for the variation in the length of the extensions.

Each magnet consists of a coil 34 wound around its radial core 32. From FIG. 6 it will be noted that in this pump all 48 coils are wound in the same direction. The 48 coils may be connected in series or in various groups of parallel connected coils with the groups connected in series, depending on the voltage available.

The inner ends of all of the magnet cores 32 are connected by a magnetic sleeve 36. Herein the sleeve and the 48 cores are made integral. Within the sleeve 36 and insulated from it by sleeve 38 of insulating material is a relatively heavy sleeve 40 of good electrically conducting material supporting, and electrically bonded to, the flow tubes 42 and 44 which are arranged in pairs. Sleeve 40 is preferably made of silver. One pair of tubes 42 and 44 is shown most clearly in FIG. 3. A second insulating sleeve 38 serves to insulate the rotating magnetic pole pieces on the shaft from the heat of the liquid metal flowing in tubes 42 and 44.

From FIGS. 3 and 4 it will be evident that a pair of tubes 42 and 44 is provided for each bank of magnets. It will be recalled that the pole piece locations are staggered in the alternate banks of magnets. As shown in FIG. 3, the tube 42 provides one fluid pass through the pump while the tube 44 provides a separate pass through the pump in the opposite direction, thus providing a total of 16 fluid passes through the pump.

FIG. 5 shows how the tubes 42—44 are brought out between the pole pieces. Also in FIGS. 3 and 8 bushings 48 are shown. These are provided around the tubes 42 and 44 where they pass through the magnetic sleeve 36.

The particular pump shown is intended for use with a space radiator in which one of each of the 16 separate segments of the radiator is connected with a separate flow tube through the pump. As a result, a leak or any injury to one radiator segment will not in any way affect the operation of the other 15 or the operation of the pump.

It will be understood that the sleeve 36 and the pole piece 32 are laminated to reduce the eddy currents therein in a well known manner. It is not necessary, however, to laminate the extensions 30 and the radial arms 28 or the pole pieces 22.

In the operation of the pump, the magnet coils are energized by a suitable D.C. current. The circuit is designed to utilize existing power, converting it to direct current at the available line voltage and connecting the coils in series, or series parallel, to best utilize the voltage available.

Magnetic flux generated in cores 32 of the electromagnet windings 34 is fed into the frame extensions 30 of the left-hand shell 24, for example (FIG. 6). It then flows inwardly along the radial arms 28 and jumps the gap to shaft 12, this gap being maintained as small as feasible. The flux then flows from the North pole 22 of one of the rotating pole pieces formed integral with the shaft, across the gap occupied by the insulating sleeve 46, transversely through the flow tube 42 and the liquid metal in it, across the gap occupied by insulating sleeve 38 to magnetic sleeve 36 and hence back to the core 32 of its origin. For those magnets supported by extensions 30 of the right-hand shell 26 a like flux path is provided. The flow tubes may be made of a metal which is a poor conductor, such as stainless steel. The metal sleeve 40 in which the tubes are embedded is made of a good electrical conductor to provide good return paths for the induced pumping currents.

The relative motion of a pole piece and therefore of a flux concentration relative to a flow tube is illustrated in FIG. 7. Here it will be noted that the rotating pole pieces on the shaft always form a North pole, whereas the magnetic sleeve 36 and the inner ends of the electromagnet pole pieces 32 form a South pole. As a pole piece 22 rotates in a counterclockwise direction (FIG. 7) past the core 32 of a magnet 34, a concentrated flux will flow radially, as represented by the arrow, from the North to the South pole, inducing eddy currents in the section of tube 42 which, interacting with the primary field, tend to move the conducting fluid along tube 42 in the direction of the arrows. Thus the force resulting from the interaction of the two fields and the induced currents will cause the liquid metal to flow along the tube in the direction of pole rotation.

In this way each liquid metal flow path through the pump is independent of all other flow paths so that a leak in one does not affect the operation of the others.

It will be evident from the above that a D.C. induction pump has been provided by this invention which is capable of direct shaft connection with a high speed turbine, the only rotating part of the pump consisting of a shaft carrying short radially extended pole pieces.

It will also be evident that a pump of this type has been provided capable of providing a large number of independent liquid metal lines of flow.

It will be further evident that the pump of this invention is adapted to be operated at various voltages by merely changing the connections to the 48 coils.

While only one embodiment of the invention has been described, it will be understood that various changes may be made in the construction and arrangement of the parts without departing from the scope of the invention as defined by the following claims.

I claim:

1. A D.C. induction pump for pumping a plurality of independent circuits of conductive liquid comprising a shaft of good magnetic material having a plurality of radial projections at spaced points along its length constituting flux concentrating pole pieces, a sleeve of good magnetic material surrounding said shaft in spaced relation thereto, said sleeve having radially directed outward projections forming magnet cores lying in the same transverse planes as said shaft projections, windings on said magnet cores, means forming flux linkage between the outer extremities of said magnet cores and said shaft, and flow tubes, each included in a separate one of said circuits, located in the space between said shaft and said sleeve at said magnet core locations.

2. The induction pump of claim 1 in which two flow tubes are provided at each of said magnet core locations, each occupying half of the annular space between said shaft and said sleeve and each having inlet and outlet connections extended through said sleeve and outwardly between said magnet cores.

3. The induction pump of claim 1 in which the several flow tubes are embedded in a sleeve of good electrical conducting metal.

4. The induction pump of claim 1 in which a sleeve of heat insulating material is provided between said flow tubes and said magnetic sleeve.

5. The induction pump of claim 1 in which a sleeve of heat insulating material is provided between said flow tubes and said shaft.

6. The induction pump of claim 1 in which concentric sleeves of heat insulating material are provided between said magnetic sleeve and said flow tubes and between the latter and said shaft, fluid inlet and outlet connection for said flow tubes extended generally radially through said magnetic sleeve, and insulating bushings surrounding said inlet and outlet connections where they pass through said magnetic sleeve.

7. A D.C. induction pump for pumping conductive liquids comprising a shaft of magnetic material having a plurality of radial projections at spaced points along its length constituting flux concentrating pole pieces, a sleeve of magnetic material surrounding said shaft in radially spaced relation thereto, said sleeve having radially outwardly directed projections forming magnet cores, said magnet cores lying in the same transverse planes as said shaft projections, windings on said magnet cores, means for effecting flux linkage between the outer extremities of said magnet cores and said shaft, and flow tubes in the annular space between said shaft and said sleeve, said tubes being located in the aforesaid transverse planes.

8. The induction pump of claim 7 in which pairs of diametrically opposed projections are provided on said shaft at said spaced points along said shaft and said magnetic sleeve has a pair of diametrically opposed core projections for each pair of shaft projections located in the transverse planes including said shaft projections.

9. In a D.C. induction pump for pumping conductive liquids comprising a shaft adapted to be directly connected to the shaft of a high speed turbo generator, said shaft having a plurality of magnetic pole pieces arranged along its length and constituting the sole rotating element of the pump, a laminated sleeve of magnetic material concentric with and spaced from said pole pieces, said sleeve having a plurality of outward radial extensions along its length arranged in circular banks which are in the radial planes of said pole pieces, a magnet winding on each of said extensions, a flow tube for conductive liquid extended through the space between said shaft-carried pole pieces and said magnetic sleeve, a flow tube being provided for each of said banks and each having an inlet and an outlet extended through said magnetic sleeve, and left and right-hand shell members of magnetic material through which said shaft extends having longitudinal extensions connected with the outer ends of said radial extensions of said magnetic sleeve and linking the latter magnetically with said shaft.

10. In a D.C. induction pump for pumping conductive fluids, a rotatable axial shaft having radial poles of magnetic material projecting therefrom along a substantial extent of its length, a stationary sleeve of magnetic material concentric with said shaft and coextensive with the pole carrying extent of said shaft, said sleeve being spaced from the extremity of said poles, said sleeve having radial extensions of magnetic material about its periphery arranged in circular banks in the transverse planes including said pole pieces, magnet windings on said radial extensions, magnetic means completing a magnetic circuit between the end of each of said radial extensions and said shaft, and a flow tube extending through the space between said sleeve and said shaft carried poles for each of said banks of radial extensions.

11. The pump claimed in claim 10 in which the flow tubes are embedded in a sleeve of good electrical conducting material.

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12. The pump claimed in claim 11 in which a heat insulating sleeve is provided between the magnetic sleeve and the current conducting sleeve in which said tubes are embedded and a second heat insulating sleeve is provided between said current conducting sleeve and said pole pieces on said shaft. 5

13. The pump claimed in claim 12 in which the flow tubes have inlet and outlet connections which extend generally radially outward through the magnetic sleeve and between said magnet windings and an insulating bushing is provided around the flow tube wherever said flow tube extensions pass through said magnetic sleeve. 10

14. In a D.C. induction pump for pumping conductive liquids, an axial shaft adapted to be directly connected with a high speed turbo-generator shaft, a plurality of rigid pole pieces on said shaft projecting radially therefrom, a sleeve of magnetic material surrounding said shaft and spaced therefrom having a plurality of radial exten- 15

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sions forming magnet cores, magnet windings on said cores, magnetic members connecting said shaft with the ends of said pole pieces, flow tubes extending circumferentially about said shaft in the annular space between said shaft and said sleeve, said tubes being located at said pole locations, and inlet and outlet extensions for said tubes passing through said sleeve and outwardly between said magnets.

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