A magnetic lift device includes a permanent magnet and a pair of pole members disposed to provide first and second magnetic circuits respectively through the load end and the keeper end of the device. A control winding switches the magnet flux between the two magnetic circuits. A movable keeper plate contacts a non-magnetic safety member during a lift operation. Spacer rods extend from the keeper plate to the load end over a predetermined distance chosen to facilitate the separation of light magnetic loads from the lift device.

9 Claims, 8 Drawing Figures
ELECTRO-MECHANICALLY SWITCHED PERMANENT MAGNET HOLDING DEVICE

This invention relates to an electro-mechanically switched permanent magnet holding device which is suitable for lifting or holding magnetic loads, and in which the magnetic attraction to the load may be simply switched on or off.

Hitherto magnetic loads have been lifted using electromagnets. Significant disadvantages of electromagnets are the high consumption of electric energy, the stringent precautions which must be taken to prevent the load from dropping on account of a failure of the normal electric supply to the electromagnet and the hazard of trailing leads which are used for the power supply. Difficulty has been encountered using known electromagnets in releasing light weight loads.

A permanent-magnet load lifting device has been proposed in which the attractive magnetic force of a permanent magnet is bistably switched between different magnetic circuits of the device. These circuits are typically a circuit path operating at the load end and a similar path at the opposite or keeper end. A lift mode exists when a majority of the flux is transferred to the load end by decreasing its reluctance and correspondingly increasing the reluctance at the keeper end. In a converse manner a release mode exists when a majority of the flux is transferred to the keeper end with consequent reluctance changes in the respective circuits. Switching the permanent magnet flux between the magnetic circuit including the keeper end plate and the magnetic circuit including the load is accomplished by applying a low energy control signal to an electromagnet coil integrated with one or more of the magnetic circuits. When load lifting is desired, the control winding is energized so as to transfer a majority of the flux to the load end by decreasing its reluctance. As the load is lifted with the device in the lift mode, the keeper end plate is raised to create an air gap to further increase the reluctance of the keeper end circuit and drive even more of the flux through the load. Inadvertent switching to the release mode when the device is operating in the lift mode and the keeper plate is in a position of maximum air gap is prevented since the energized control winding is not of a sufficient energy level to decrease the reluctance in the keeper circuit such that the majority of the flux can be transferred to the keeper plate. Only when the device carrying the load is lowered such that the keeper plate abuts the pole-pieces and the control winding is approximately energized will the reluctance at the keeper end become sufficiently small to allow a transfer of the majority of the magnetic flux through the keeper plate.

These proposed permanent-magnet load lifting devices employ a flux transfer principle for switching the magnetic flux from the keeper circuit to the load circuit and vice versa. This switching depends wholly upon the hysteresis properties of the material forming the pole pieces, keeper and load, and on the extraneous air gaps in each magnetic circuit. During the investigations which led to the present invention, it was found that when the surface of the load is flat and when there is no non-magnetic gap occasioned by mill-scale, rust or paint on the surface of the load, these flux transfer load-lifting devices performed very well. It is generally necessary in practice to handle loads which are not "perfect" and with a flux transfer load-lifting device which has mild steel pole pieces, an air gap of only 0.1 mms was found to be sufficient to impair the operation, the flux immediately switching back to the keeper after termination of the control current pulse intended to switch the flux from the keeper circuit to the load circuit. The capability of this device to be used with larger air gaps could be extended by using pole pieces which have a coercivity greater than that of mild steel but less than the coercivity of the main magnet, but this would be at the expense of the lifting force of the device and the switching current requirements. The external field of the modified device would be greater than that of the originally proposed device having mild steel pole pieces.

The present invention provides a magnetic device comprising a permanent magnet disposed between a pair of pole members which provide a first and a second magnetic circuit respectively through a load and a keeper end of the device. A control winding is disposed about one of the pole members and a keeper plate is disposed on the pole faces and is movable a distance therefrom limited by a stop portion of a non-magnetic safety member. Spacing means are provided which extend from the keeper plate to the load end of the device for a distance which is equal to the length of the pole members plus the maximum air gap as hereinafter defined. The device also includes means for passing a current pulse through the control winding in either direction. The expression "maximum air gap" is used throughout this specification to mean an air gap which is just greater than the largest non-magnetic gap at the load end which the magnetic device will encounter in use. The spacing means in particular simplify separation of loads which are light in comparison to the mass of a lifting magnet.

Preferably the spacing means consist of spacer rods which slidably extend through bores in the pole members. In order to prevent the minimum non-magnetic gap between the keeper plate and the upper faces of the pole members from being increased to an unacceptable value by the ingress of dirt into the space between the keeper plate and the upper faces of the pole members, the keeper plate may be provided with a cover which surrounds the upper periphery of the magnet and pole members, and wherein sealing means may be located between the cover and the said upper periphery. Current pulse switching through the control winding may be conducted manually but is preferably performed automatically.

An embodiment of the present invention will now be described with reference to the accompanying diagrammatic drawings in which:

FIG. 1 is a sectional front elevation of a lifting magnet,

FIG. 2 is a simplified circuit diagram of an automatic magnet control circuit used to operate the lifting magnet,

FIGS. 3 to 7 show front elevation views of the lifting magnet in a sequence of operations of lifting and unloading a load, and

FIG. 8 is a graph on which the attractive force between a magnet together with its pole members and a keeper plate are plotted against the length of the air gap.

A lifting magnet 1 comprises strontium ferrite permanent magnets 2 which are sandwiched between pole members 3, 4, 5 and 6 which consist of mild steel plates. A control winding 7 surrounds an upper portion
3,798,581

3 of the pole members 4 and 5. L-shaped safety members 8 which are made of stainless steel and have stop portions 9 are secured to the pole members 3 and 6, the stop portions 9 limiting movement of a mild steel keeper plate 10 away from the pole faces. A lifting eye 11 extends from one main face of the keeper plate 10 and non-magnetic spacing rods 12 extend from the opposite main face of the keeper plate 10, for a distance which is equal to the length of the pole members 3, 4, 5 and 6 plus a maximum air gap length of 0.9 mms. These spacing rods 12 are a sliding fit in bores 13 in the pole members 3 and 6. A non-magnetic control rod 14 having a stop 15 slides in a bore 16 in the pole member 4. The upper end of the control rod 14 operates a single pole monostable microswitch S1 and a bistable change-over switch S2. The switches S1 and S2 are mounted on top of the keeper plate 10 and are arranged so that S2 operates before S1. These switches are operated by the control rod 14 whenever a load 17 and the keeper plate 10 are at a certain separation which is just greater than the length of the spacing rods 12.

Referring to FIG. 2, the magnet control circuit comprises two 13 volt rechargeable nickel-cadmium batteries 18 and 19. The microswitch S1 switches a capacitor C from a charging position to the base of a transistor 20. The switch S2 reverses the connections to the control winding 7.

Upon lowering the magnetic device 1 to the floor, either to pick up or to release a load, the capacitor C discharges into the base of transistor 20. The transistor 20 conducts during this discharge which lasts for about 100 milliseconds, the control winding 7 is energised, and the magnet switches from a first condition to a second condition. When the magnetic device 1 is lifted, switch S1 connects C to the battery 19 so that it is charged for the next operation, while S2 remains closed in the same position. When the magnetic device 1 is lowered for the next operation, S2 first operates reversing the connections to the control winding 7, then S1 discharges the capacitor C and the magnet switches from the second condition to the first condition.

The function of the spacing rods will now be described with reference to FIGS. 3 to 7. FIG. 3 shows the magnetic device 1 being lowered in order to pick up the load 17 immediately before the capacitor discharges so as to permit a current pulse to pass through the control winding in a direction which will provide magnetic attraction between the pole members and the load 17, and a decreased magnetic attraction between the pole members and the keeper plate, during the application of the current pulse. Provided the current pulse is of sufficient amplitude, the discharge of the current pulse through the control winding results in the force of attraction between the pole faces and the load exceeding that between the pole faces and the keeper plate 10, so that the keeper plate 10 is lifted from the upper pole faces of the device as the ends of the spacing rods 12 abut against the load 17 and hence mechanically push the keeper plate 10 away from the upper pole faces. When the current pulse has ended, the majority of the flux from the magnet passes through the load 17 due to the non-magnetic gap which has been created between the upper pole faces and the keeper plate 10.

FIG. 4 shows the magnetic device 1 and load 17 immediately after a hoist (not shown) has begun to lift the keeper plate 10, at the instant when the switch S1 connects the capacitor C to the battery 19 so that it is charged for the next operation. FIG. 5 shows the system after the load has been lifted clear of the ground, the keeper plate 10 then bears against the under side of the stop portions 9.

FIG. 6 shows the system after the load has been lowered to the ground, as the keeper plate 10 is being lowered towards the upper pole faces and immediately before the switch S1 is closed to discharge the condenser C through the transistor 20. FIG. 7 shows the system immediately after the capacitor C has been discharged through the transistor 20. The force of attraction between the upper pole faces and the keeper plate 10 is now greater than the attraction between the lower pole faces and the load 17 as a result of the electromagnetic force produced in the control winding 7 and the load 17 is pushed away from the lower pole faces by the spacer rods 12. The magnetic device 1 can now be lifted away from the load 17.

The lifting magnet described with reference to FIGS. 1 and 2 weighed 9 lbs and with no gap between the pole faces and the load could lift 40 lbs. FIG. 8 shows a graph on which the maximum load L which could be lifted varies with the length G of the non-magnetic gap between the pole faces and the load.

The remanence of the magnets 2 was 3,600 gauss and the coercivity was 3,000 Oe. The control winding consisted of 350 turns of 24 gauge copper wire and had a resistance of 7.5 ohms. The batteries 18 and 19 were each 3.5 inches long and 1 inch in diameter with a capacity of 200 m.A. hours. The voltage was 26.5 volts, falling on load to 23 volts. This arrangement gave approximately 1,100 amperes-turns from the control winding. A pulse duration of 100 milliseconds was used. This is longer than the minimum duration required, but results in a sufficiently low current consumption for there to be no problem with regard to battery life. A test was conducted in order to determine the number of lifting operations which could be performed between battery charges, in which 1,400 switching operations were conducted at 4 second intervals, representing the carriage of 700 loads, and the batteries had not been discharged at the end of the test.

What we claim:

1. An electro-mechanically switched permanent magnet holding device comprising a permanent magnet disposed between a pair of pole members which provides a first and second magnetic circuit respectively through a load and a keeper end of the device, a control winding disposed about one of the pole members for switching the permanent magnet flux between said first and second magnetic circuits, a keeper plate disposed on the pole faces at the keeper end of the device and movable a distance therefrom limited by a stop portion of a nonmagnetic safety member, spacing means which extend from the keeper plate to the load end of the device for a distance which is equal to the length of the pole members plus the maximum air gap to be encountered in normal use at the load end of the device, and means for passing a current pulse through the control winding in either direction.

2. An electro-mechanically switched permanent magnet holding device as claimed in claim 1, wherein the spacing means comprises spacer rods which slideably extend through bores in the pole members.

3. An electro-mechanically switched permanent magnet holding device as claimed in claim 1, wherein the keeper plate is provided with a cover which sur-
3,798,581

rounds the upper periphery of the magnet and pole members, and wherein sealing means are located between the cover and the said upper periphery so as to prevent dirt from entering the space between the keeper plate and the upper faces of the pole members.

4. An electro-mechanically switched permanent magnet holding device as claimed in claim 1, comprising one or more pairs of permanent magnets, each permanent magnet being disposed between a pair of pole members, said control winding being disposed about central pole-members which are disposed between the two magnets of a pair of magnets.

5. An electro-mechanically switched permanent magnet holding device as claimed in claim 1, wherein the means for passing a current pulse through the control winding include a non-magnetic control rod which retractsably extends from the load end of the device so as to abut against the load, the control rod being adapted to operate a switch which controls a current pulse to the control winding when the space between the keeper plate and the load is just greater than said distance by which the spacing means extend from the keeper plate.

6. An electro-mechanically switched permanent magnet holding device as claimed in claim 1 wherein said maximum air gap is approximately 0.9 millimeters.

7. A magnetic lift device for transporting a magnetic load comprising, a permanent magnet, a pair of pole members with the permanent magnet disposed between said pole members so as to provide a first and a second magnetic circuit through a load end and a keeper end, respectively, of said device, a control winding magnetically coupled to at least one of said magnetic circuits for controlling the attractive force at said load and keeper ends of the device in response to a current pulse applied thereto, a non-magnetic safety member secured to said device at the keeper end and having a stop portion, a keeper plate disposed at the keeper end of the device adjacent one pair of faces of the pole members and displaceable therefrom until engaged by the stop portion of said safety member, means for selectively applying a current pulse to the control winding, and spacer means coupled to the keeper plate and extending therefrom to the load end of the device, the length of said spacer means being equal to the length of the pole members plus a predetermined length equal to the maximum expected air gap at the load end of the device in normal operation.

8. A lift device as claimed in claim 7 wherein the spacer means comprises a rod slidably extending through a bore in a pole number with one end secured to the keeper plate and the other end freely movable to contact a load member at the load end and retractsably therefrom when the keeper plate is moved in a direction away from the load end of the device.

9. A lift device as claimed in claim 8 wherein current pulse applying means comprises a switch secured to the keeper plate and a non-magnetic control rod retractably extending from the load end of the device so as to contact a load when in place, said control rod extending to the keeper plate so as to operate said switch at a predetermined separation between the keeper plate and the load.

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