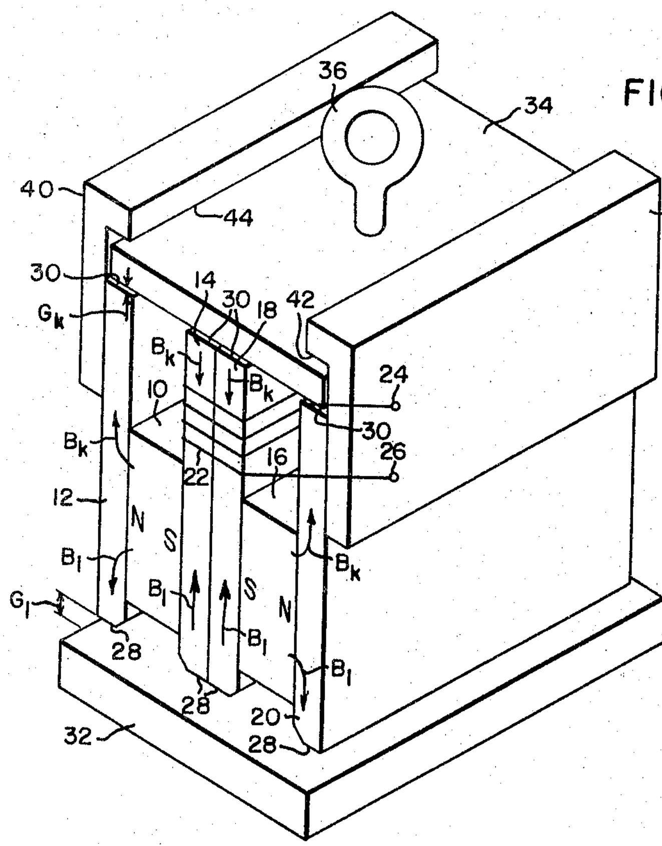
FAIL SAFE ELECTRO-MAGNETIC LIFTING DEVICE WITH SAFETY-STOP MEANS

Filed March 29, 1965

FIG. 1.



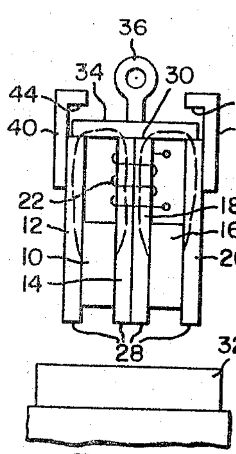


FIG. 2.

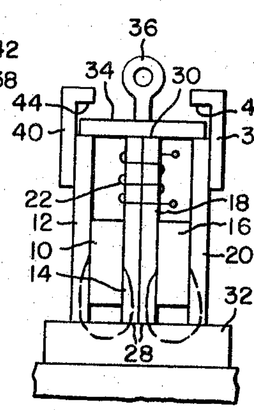


FIG. 3.

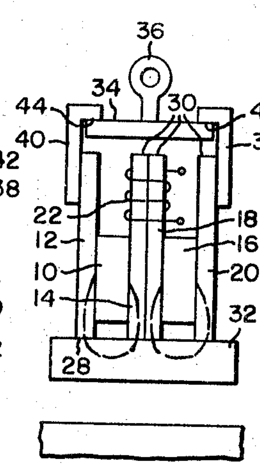


FIG. 4.

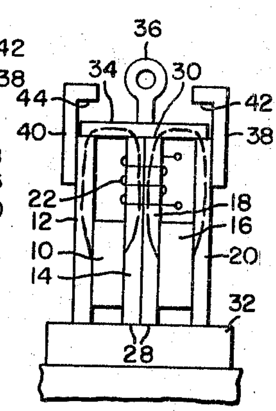


FIG. 5.

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FAIL SAFE ELECTRO-MAGNETIC LIFTING DEVICE WITH SAFETY-STOP MEANS

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The present invention relates to lifting apparatus, and more particularly to lifting apparatus of the permanent magnet type.

Lifting or hoist apparatus utilizing electro-magnets have been in operation for many years. The electro-magnet type of lifting apparatus has two severe disadvantages: (1) a large amount of energy must be supplied to the electro-magnet in order to generate a sufficient magnetic field to provide reasonable lifting weight capacity, and (2) the load will fall if the electro-magnet is deenergized due to a power failure or other interruption of electrical power to a coil of the electro-magnet. The latter disadvantage makes such apparatus dangerous or requires additional safety features to insure the load will not accidentally be dropped. The use of a permanent magnet for the lifting apparatus would be particularly advantageous from an energy standpoint. However, the difficulty of disengaging the load from the permanent magnet must be overcome. Also, safety must be considered if the permanent magnet is to be made fail safe.

In copending applications, Ser. No. 167,360, filed Jan. 19, 1962, entitled, "Magnetic Memory Device," and Ser. No. 283,035, filed May 24, 1963, entitled, "Permanent Magnet Memory Device Using Pulse Control," both by Raymond J. Radus and assigned to the same assignee as the present application, permanent magnet devices are shown in which the attractive magnetic force of a permanent magnet may be bistably switched between different magnetic circuits of the device. The switching between the high and low attractive force circuits of the memory device is accomplished by the application of a low energy electrical signal to an electro-magnetic coil disposed in one or more of the magnetic circuits. The device will remain in one of its bistable states until a control signal is applied to switch another of the magnetic circuits to a higher or lower reluctance than the reference magnetic circuit. Lifting apparatus which could incorporate such a device would be highly advantageous in that the device requires only the momentary use of a very low energy source which is used only for switching. Moreover, if a hoist using permanent magnet devices can be made fail safe such lifting apparatus would overcome both of the serious problems encountered in the electro-magnetic type of lifting apparatus.

It is, therefore, an object of the present invention to provide new and improved lifting apparatus utilizing permanent magnet devices.

It is a further object of the present invention to provide new and improved lifting apparatus utilizing permanent magnet memory devices in which the engaging or disengaging of a load may be accomplished by a low level energy source.

It is a still further object of the present invention to provide new and improved lifting apparatus utilizing permanent magnet memory devices and which incorporates therein a fail safe feature prohibiting the accidental dropping of a load once engaged.

Broadly, the present invention provides lifting apparatus in which a permanent magnet device is provided wherein a high attractive force may be switched from one magnetic circuit of the device to another magnetic circuit of the device through the use of a control winding. When

lifting is desired, the high attractive magnetic force is switched to the end of the device adjacent the load to be lifted. Safety means are provided to prevent the accidental dropping of the load during the moving operation.

These and other objects and advantages of the present invention will become more apparent when considered in view of the following specification and drawings, in which:

FIGURE 1 is a pictorial diagram of the lifting apparatus of the present invention; and

FIGS. 2, 3, 4 and 5 are front elevation views of the present lifting apparatus and are used in the explanation of the operation thereof.

Referring to FIG. 1, lifting apparatus is shown including magnetic memory devices. Only two magnetic memory devices are shown although it should be noted that a larger or smaller number of such devices could be employed. One device comprises a permanent magnet **10** disposed between a pair of substantially planar pole pieces **12** and **14** adjacent respectively the North and the South poles of the permanent magnet **10**. The other permanent magnet device is similar and includes a permanent magnet **16** sandwiched between a pole piece **18** disposed adjacent the South pole of the permanent magnet **16** and a pole piece **20** disposed adjacent the North pole. A control winding **22** having input terminals **24** and **26** is disposed about the center pole members **14** and **18**. Additional control windings could be added of course if desired at different positions if convenient for design purposes. The permanent magnets **10** and **16** may, for example, be the well known ceramic type. The pole piece members **12, 14, 18** and **20** may comprise a soft magnetic material. The magnetic device has two ends at which magnetically attractive forces will develop. These ends will be termed a load end **28** and a keeper end **30**. At the load end **28**, the pole members **12, 14, 18** and **20** are shown tapered to concentrate the magnetic force. The permanent magnets and pole members are secured together by any convenient means.

A load **32** which may comprise any magnetically attractive material such as iron or steel is shown disposed adjacent the load end **28** of the magnetic devices. A keeper member **34** is disposed adjacent the keeper end **30** of the magnetic devices. The keeper member **34** may comprise a soft magnetic material similar to those of the pole members. A lifting loop **36** is secured to the keeper member **34**, for example, by welding. A lifting hook may thus be inserted in the lifting loop **36** and be utilized in conjunction with an external hoist to move and position the lifting apparatus.

A pair of safety members **38** and **40** having an L-shape are secured to the pole pieces **12** and **20** at their external surfaces. The safety members **38** and **40** may be secured to the pole members **12** and **20** respectively by welding, bolting or other convenient methods. The safety members comprise a non-magnetic material, for example, brass or non-magnetic stainless steel. A stop portion **42** and **44** which extends over a portion of the keeper member **34** is provided in the safety members **38** and **40**. Thus, when the keeper member **34** is lifted vertically it will move a distance away from the keeper end **30** of the magnetic devices and then will engage the stop portions **42** and **44** of the safety members **38** and **40**. Other means of securing the safety members to the permanent magnet devices could of course be employed.

In the condition shown in FIG. 1, the lifting apparatus is being positioned over the load **32** and is at the instant pictured a distance G_1 away from the load end **28**. The distance G_1 will be termed the load air gap which will have a minimum value when the load end **28** abuts against the surface of the load **32**. The keeper member **34** is shown abutting against the top surface **30** so that an air gap G_k exists therebetween. When the keeper member **34** and the end portion **30** are abutting, a minimum keeper air gap exists. When the keeper **34** is separated from the end **30** and abuts against the stop portions **42** and **44**, a maximum keeper air gap will exist.

A load magnetic circuit is established from the North poles of the permanent magnets **10** and **16**, through the pole members **12** and **20**, the air gap G_1, the load **32**, the air gap G_1, the center pole members **14** and **18**, to the South pole of the permanent magnets. A magnetic flux B_1 will flow through the load magnetic circuit.

A keeper magnetic circuit is established with a magnetic flux B_k flowing from the North poles of the permanent magnets **10** and **16**, through the outer pole members **12** and **20** in the opposite direction to the magnetic flux B_1, through the air gap G_k, the keeper member 34, the air gap B_k, and back to the South poles of the permanent magnets **10** and **16** through the center pole members **14** and **18** in the opposite direction to the magnetic flux B_1. The magnitude of the attractive force applied to the load **32** or the keeper **34** will depend upon the amount of magnetic flux B_1 or B_k passing through their respective magnetic circuits.

Assume initially that the keeper member **34** is placed adjacent the end **30** of the magnetic device so that there is a minimum keeper air gap G_k, and that the load **32** is separated from the end **28**. The majority of the magnetic flux provided by the permanent magnets will align itself into the keeper circuit so that the keeper **34** will be held by a relatively strong magnetic force to the end **30**. With the lifting apparatus in the state shown, the apparatus may be positioned over the load **32** and may be lowered to abut against the top surface of the load. Since the majority of the magnetic flux had previously been aligned in the keeper circuit including the keeper member **34**, the keeper member will be held against the end **30** of the device still with a relatively high attractive force while the load **32** will only be held to the end **28** with a relatively small attractive force as determined by the amount of flux B_1 which will pass therethrough. The mechanism by which the flux alignment takes place is discussed in full detail in the above copending applications which are incorporated by reference herein.

In order to switch the high attractive force from the keeper **34** to the load **32** so that the load may be lifted, it is necessary that a majority of the flux supplied by the permanent magnets **10** and **16** be realigned to pass through the load **32** rather than the keeper **34**. This may be accomplished by applying a control signal momentarily to the control winding **22** through the terminals **24** and **26**. The control signal may be a unidirectional low intensity signal applied in such a direction as to oppose the flux B_k flowing in the pole pieces **14** and **18**. The induced flux caused by the coil **22** in bucking the flux from the permanent magnet will thereby increase the reluctance of the keeper magnetic circuit. The keeper magnetic circuit having an increased reluctance will cause a large percentage of the flux from the permanent magnets **10** and **16** to be transferred from the keeper magnetic circuit to the load magnetic circuit. This flux transferral will thereby switch the high attractive force to the load end **28** of the permanent magnet device so that the load member **32** will be held thereto with a high attractive force. The load **32** will now be held by a high attractive force while the keeper member **34** is free to move vertically if a mechanical force is applied thereto. It should be noted that all that was required to switch the lifting apparatus from a no lift to lift state was the application of a low energy D.C. signal to the control signal which may be supplied by a low voltage battery. It should also be observed that the control pulse need only be momentarily applied to the control windings and then may be disconnected therefrom. The momentary application of the control signal is effective to accomplish the flux transfer back and forth between the keeper and load magnetic circuits.

When a mechanically lifting force is applied to the lifting loop **36** to move the keeper member **34** vertically, the keeper member **34** will move until its top portion engages the stop portions **42** and **44** of the safety members **38** and **40**. At this point, the air gap G_k is at a maximum. Several advantages result from having maximum and minimum air gap positions for the keeper **34** with respect to the end **30** of the permanent magnet devices. One of the advantages of the variable air gap is that when maximum keeper air gap exists, that is, when the load is being lifted, a high magnitude lifting force will appear at the lifting end **28** of the permanent magnet devices since the load magnetic circuit is of a very low reluctance in comparison to the keeper magnetic circuit having the maximum keeper air gaps G_k. Thus, a larger attractive force is developed to attract the load **32** than otherwise would be provided if the keeper air gap were constant which has the obvious advantage of permitting larger loads to be moved. Also, as shown in FIG. 1, the permanent magnets **10** and **16** may be positioned closer to the load end than the keeper end in order to increase the attractive force at the load end. Another advantage of having a variable keeper air gap G_k is that minimum control power is only required to switch the high attractive forces between the load and the keeper and vice versa when the air gap G_k is at a minimum. This may be seen since when the keeper **34** is adjacent the end **30** a relatively low reluctance path is provided, and, therefore, a relatively low intensity input signal applied to the coil **22** will have a greater effect in either aiding or opposing the permanent magnet flux B_k in the keeper circuit. Thus, during the positioning operation when the keeper magnetic circuit is in its low reluctance state and adjacent the end **30**, when the permanent magnet devices are disposed over the load **32**, a low intensity control signal applied to the control winding **22** in a direction to oppose the keeper flux B_k will readily switch the low reluctance path to that including the load **32** so that the load may be lifted. Alternately, when the moving operation is over and it is desired to disengage the load, with the keeper **34** having been lowered to be adjacent the keeper end **30** at minimum keeper air gap G_k, a low intensity control signal in the opposite direction to the previous signal in a direction to induce a flux which will aid the keeper flux B_k will readily permit the flux supplied by the permanent magnets **10** and **16** to switch from the load **32** to the keeper **34** and thereby permit the load to be disengaged from the lifting apparatus. The lifting apparatus may then be moved to other areas with the keeper **34** being held against the end **30** by a relatively strong attractive force.

Still another advantage of the variable keeper air gap is that when the keeper air gap is at a maximum value during the lifting operation with the keeper member **34** adjacent the stop portions **42** and **44**, the accidental application of switching signals to the coil **22** will not drop the load. Normally, if keeper **34** were abutting the end **30**, the load would drop since the high attractive force would be transferred from the load to the keeper. However, with a maximum air gap G_k existing during the lifting operation when the load is carried above surface level, the normal low intensity switching signal will not be of sufficient strength to effect the transfer of flux from the load circuit to the keeper circuit. The maximum keeper air gap G_k can be so designed to set in a safety factor to insure that even an accidental signal applied to the control winding **22** of several times the normal necessary switching magnitude at minimum air gap G_k will not be effective to transfer the strong attractive force from the load to the keeper and thereby drop the load. It can thus be seen that a fail safe type of lifting apparatus is provided by the apparatus shown in FIG. 1.

In FIGS. 2, 3, 4 and 5, a sequence of the lifting and disengaging operations are shown. In FIG. 2, the lifting apparatus is being lowered over a load **32** resting on a surface. The keeper member **34** is held by a relatively strong attractive force, that is, one at least sufficiently strong to permit the keeper **34** to remain adjacent the keeper end **30** of the permanent magnet devices while the lifting apparatus is being positioned over a load. Under these conditions, a majority of the flux from the permanent magnets **10** and **16** pass through the keeper magnetic circuit. The lifting apparatus is shown disposed over the load **32** in FIG. 3. By the application of a D.C. control signal, for example, from a battery to the winding **22**, a majority of the flux from the permanent magnets is transferred from the keeper magnetic circuit to the load magnetic circuit. Such a transfer of flux may be effected by the application of a low intensive voltage of a polarity as shown on the diagram which will oppose the flux in the keeper magnetic circuit and therefore increase the reluctance thereof so that a majority of the flux may realign itself to pass through the load **32**. A high attractive force having the capability of lifting the load **32** will thus be applied at the end **28** adjacent the load **32**.

In FIG. 4, the lifting apparatus is shown lifting the load **32** above the surface level. At this point, the keeper member **34** has moved away from the keeper end **30** of the magnetic devices since only a relatively small attractive force is applied at that end. By the application of mechanical force through the lifting loop **36** on the keeper member **34**, the keeper will move away from the end **30** until it engages the stop portions **42** and **44** of the non-magnetic safety members **38** and **40**. When the keeper member **34** abuts against stop members **42** and **44**, a maximum attractive force is developed at the end **28** of the permanent magnet devices to strongly hold the load by a strong attractive force thereto. Also at this maximum air gap position, the accidental application of a control signal that would normally switch the flux back to the keeper member will not be effective because of the maximum air gap. Therefore, the load cannot be dropped by the application of a control signal accidentally to the coil **22**. Hence, the device is fail safe.

The load **32** is shown having been moved and ready for disengagement in FIG. 5 after the load **32** has been brought to surface level. The keeper member **34** then drops from its maximum air gap position to its minimum air gap position abutting against the end **30** of the permanent magnet devices. At the minimum keeper air gap position G_k, the application of a low intensity control signal of the polarity as shown in FIG. 5 will induce a flux to aid the flux through the keeper magnetic circuit and thereby reduce its reluctance to a level lower than that of the load **32**. A majority of the flux from the permanent magnets **10** and **16** will align themselves to pass through the keeper circuit now causing a relatively high attractive force to be transferred from the load **32** to the keeper **34**. In this condition, the lifting apparatus may be disengaged from the load and moved to other load positions, with the pickup and dropping operations being repeated.

Although the present invention has been described with a certain degree of particularity, it should be understood that the present disclosure has been made only by way of example and that numerous changes in details of construction and combination and arrangement of parts and elements may be resorted to without departing from the scope and spirit of the present invention.

We claim as our invention:

1. In magnetic lifting apparatus for moving magnetic loads and being operative with control signals, the combination of: a permanent magnet device including a permanent magnet for supplying magnetic flux, a pair of pole members, said permanent magnet being disposed between said pair of pole members for providing a first and a second magnetic circuit respectively through a load and a keeper end of said device, and a control winding disposed in at least one of said magnetic circuits for controlling the attractive force at said load and keeper ends of said device in response to control signals being applied thereto; a non-magnetic safety member connected to said pole pieces and having a stop portion thereon; a keeper member disposed at said keeper end of said magnetic device between said device and the stop portion of said safety member in said first magnetic circuit, said load being movable by disposing said keeper member adjacent said keeper end of said device and disposing said load adjacent said load end thereof in said second magnetic circuit and by applying a control signal to said control winding to transfer a strong attractive force to said second magnetic circuit so that said load is held to said magnet device at said load end thereof by a strong attractive force, said keeper member moving away from said keeper end of said magnetic device until engaging the stop portion of said safety member so that the inadvertent application of a control signal to said control winding will not drop said load.

2. In lifting apparatus for moving loads the combination of: a permanent magnet device including a permanent magnet for supplying magnetic flux, a pair of pole members, said permanent magnet being disposed between said pair of pole members for providing at least two magnetic circuits respectively through a load and a keeper end of said device, and a control winding disposed in at least one of said magnetic circuits for controlling the attractive force at said load and keeper ends of said device in response to control signals being applied thereto; a safety member secured to said magnet device and having a stop portion thereon; said load disposed for moving at said load end of said magnet device in one of said magnetic circuits; a keeper member disposed at said keeper end of said magnetic device, said load being movable by applying a control signal to said control winding to transfer a strong attractive force to the magnetic circuit including said load, said keeper member moving away from said keeper end of said magnet device until engaging the stop portion of said safety member so that the inadvertent application of a control signal to said control winding will not transfer the strong attractive force away from said load.

3. In magnetic lifting apparatus for moving magnetic loads and being operative with a source of control signals, the combination of: a permanent magnetic flux transfer device including a permanent magnet for supplying magnetic flux, a pair of pole members, said permanent magnet being disposed between said pair of pole members for providing a first and a second magnetic circuit respectively through a load and a keeper end of said device, with the magnetic flux dividing between said magnetic circuits according to their relative reluctance, and a control winding disposed in at least one of said magnetic circuits for controlling the reluctance thereof in response to control signals being applied thereto; said load disposed for moving at said load end of said magnetic device in said first magnetic circuit with a load air gap being formed between said load and said pole pieces at said load end of said device; a keeper member movably disposed at said keeper end of said magnetic device, with a keeper air gap being formed between said keeper member and the pole pieces at said keeper end of said device; and safety means connected to said device to prevent the inadvertent dropping of said load; said apparatus operative for moving said load by disposing said load and said keeper members adjacent said load and keeper ends of said device respectively so that said load and keeper air gaps are a minimum and by applying a control signal to said control winding to transfer a majority of the magnetic flux to said first magnetic circuit with said load being held to said magnet device by a strong attractive force, said load being movable by the application of mechanical force to said keeper member so that said keeper member moves away from said keeper end of said magnetic device until being restricted by said safety means, said keeper air gap being a maximum when said keeper member is restricted by said safety means so that the inadvertent application of a control signal to said control winding will not transfer sufficient flux to said keeper member to drop said load.

4. In magnetic lifting apparatus for moving magnetic loads and being operative with control signals, the combination of: a permanent magnetic flux transfer device including a permanent magnet for supplying magnetic flux, a pair of pole members, said permanent magnet disposed between a pair of pole members for providing a first and a second magnetic circuit through a load and a keeper end of said device, with the magnetic flux dividing between said magnetic circuits according to their relative reluctance, and a control winding disposed in at least one of said magnetic circuits for controlling the reluctance thereof in response to control signals being applied thereto; a non-magnetic safety member secured to said pair of pole pieces of said magnetic device and having a stop portion thereon; said load disposed for moving at said load end of said magnetic device in said first magnetic circuit with a load air gap being formed between said load and said pole pieces at said load end of said device; a keeper member disposed at said keeper end of said magnetic device between said device and

the stop portion of said lifting member with a keeper air gap being formed between said keeper member and the pole pieces at said keeper end of said magnetic device; said apparatus operative for moving said load by disposing said load and said keeper member adjacent said load and keeper ends respectively of said device so that said load and keeper air gaps are a minimum and by applying a control signal to said control winding to transfer a majority of the magnetic flux to said first magnetic circuit with said load being held to said load end of said magnet device by a strong attractive force, said load being movable by the application of mechanical force to said keeper member so that said keeper member moves away from said keeper end of said magnetic device until engaging the stop portion of said safety member, said keeper air gap being a maximum when said keeper member engages said stop portion so that the inadvertent application of a control signal to said control winding will not transfer sufficient flux to said keeper member to drop said load.

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