May 25, 1965 G. JAHN 3,185,909

ELECTROMAGNET SYSTEM FOR LIFTING AND LOWERING A ROD STRUCTURE IN A TUBULAR HOUSING

Filed May 31, 1962 2 Sheets-Sheet 1

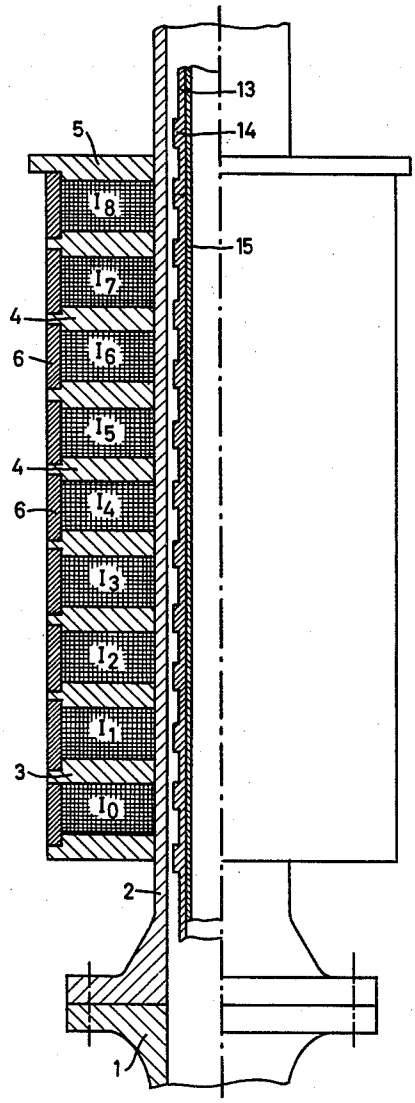


FIG. 1

May 25, 1965 G. JAHN 3,185,909
ELECTROMAGNET SYSTEM FOR LIFTING AND LOWERING A ROD STRUCTURE IN A TUBULAR HOUSING
Filed May 31, 1962 2 Sheets-Sheet 2

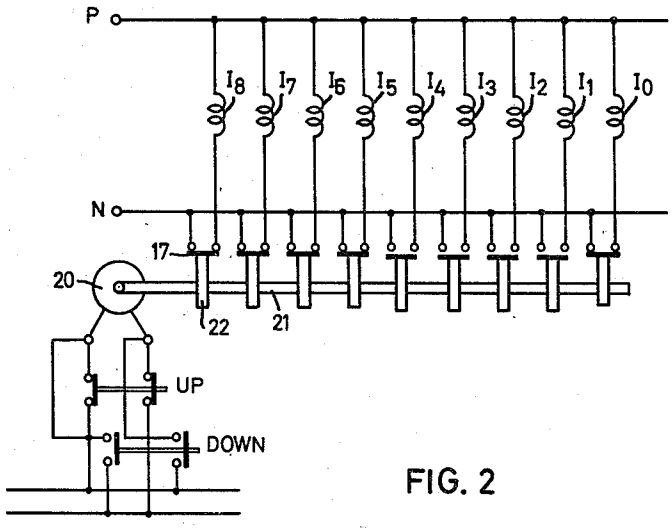


FIG. 2

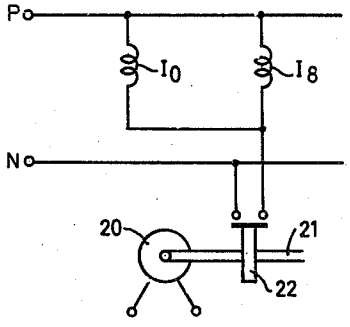


FIG. 3

United States Patent Office 3,185,909 Patented May 25, 1965

3,185,909
ELECTROMAGNET SYSTEM FOR LIFTING AND LOWERING A ROD STRUCTURE IN A TUBULAR HOUSING

Günther Jahn, Erlangen, Germany, assignor to Siemens-Schuckertwerke Aktiengesellschaft, Berlin-Siemensstadt, Germany, a German corporation

Filed May 31, 1962, Ser. No. 199,005
Claims priority, application Germany, June 6, 1961, S 74,217
2 Claims. (Cl. 318—135)

My invention relates to electromagnetic apparatus for lifting and lowering a rod-shaped structure in a tubular housing by magnetic force acting from the outside through the housing wall. Such apparatus are applicable particularly in nuclear reactor plants for shifting the regulating and shut-off rods.

In a more particular aspect my invention relates to improvements of electromagnetic apparatus according to the copending application of F. Schreiber and H. Kumpf, Serial No. 127,374, filed July 27, 1961 and assigned to the assignee of the present invention. According to the principles disclosed in the copending application, the rod-shaped structure within the tubular housing is provided with rack-like teeth in vernier relation to a number of magnet poles that are axially aligned on the outside of the housing. Such a system, for example, may comprise nine magnet poles along an axial distance occupied by ten teeth of the rod structure. By energizing and de-energizing the excitation windings in a progressing sequence the rod structure is lifted or lowered, depending upon the direction of the sequence. Each two adjacent excitation coils are so wound or electrically interconnected that the resulting magnetic fluxes in the pole common to the two windings have the same direction and thus augment each other. The uppermost and lowermost magnet poles, however, are each traversed only by the magnetic flux induced by a single excitation coil. Consequently, the proportion of stray flux passing through the housing without being active upon the rod structure is greater at the uppermost pole and the lowermost pole than at any of the intermediate poles. This manifests itself unfavorably when during the progressive excitation of the coils the excitation is switched from the uppermost coil to the lowermost coil. Then there occurs an interval of time in which the lifting force temporarily drops to a lower value than obtained during the preceding period of time in which the other coils of the group of electromagnets are sequentially energized. As a result, the lifting force may be temporarily insufficient or unreliable for producing the desired continuity of lifting operation, or it is necessary to overdimension the electromagnets in order to make certain that the lifting power always stays above the required minimum value.

It is an object of my invention to minimize or obviate these disadvantages.

To this end, and in accordance with a feature of my invention I provide the group of magnets, axially aligned along the tubular housing in which the teethed rod structure is displaceable, with additional magnetizable means which are joined with the lowermost pole of the group of electromagnets, the additional magnetizing means being poled in flux-augmenting sense relative to the lowermost pole and active simultaneously with the uppermost electromagnet of the group.

According to another more specific feature of my invention, the additional magnetizing means joined with the lowermost pole of the sequentially energized electromagnets of the group consists likewise of an electromagnet except that its excitation coil is switched on simultaneously with the excitation coil located between the two uppermost magnet poles of the group.

The invention will be further described with reference to an embodiment illustrated by way of example on the accompanying drawings in which:

FIG. 1 is a partly sectional view of an electromagnetic apparatus for lifting and lowering a moderator rod or similar structure in a nuclear reactor.

FIG. 2 is the circuit diagram of appertaining sequencing means.

FIG. 3 shows a portion of a modified circuit diagram also applicable with such apparatus.

As shown in FIG. 1, an enclosure 1, such as the tank of a nuclear reactor, is flanged together with a tubular housing 2 consisting of a pressure-resistant tube of magnetizable material. Mounted on the pressure tube 2 is a group of electromagnets comprising for example, eight excitation coils I_1 to I_8 with appertaining magnet poles 3, 4, 5, and ring-shaped yoke pieces 6 of magnetizable material. Attached to the lowermost electromagnet with coil I_1 of the above-mentioned group is another electromagnet whose excitation coil is denoted by I_0. The coil I_0 is electrically connected in parallel to the uppermost coil I_8 of the sequentially energized electromagnets so that coils I_8 and I_0 are always switched on and off simultaneously, as will be further explained with reference to FIGS. 2 and 3.

The structure 13 to be displaced is located in the interior of the tubular housing tube. The structure 13 consists of a tubular rod formed essentially of magnetizable material and provided with rings 14 that constitute rack teeth and are uniformly distributed over the entire lifting stroke of the rod structure. The number of tooth rings 14, counted along the axial extent of the nine poles 3, 4, 5 that form part of the sequentially energized electromagnet with coils I_1 to I_8 differs from the number of magnet poles in accordance with a given vernier ratio as explained in the above-mentioned copending application, Serial No. 127,374. Thus, in the embodiment illustrated in FIG. 1, ten teeth 14 occupy the same axial length as the above-mentioned nine poles. As a result, the rod structure 13 is gradually and uniformly lifted or lowered when the coils I_1 and I_8 are successively energized in a cyclical sequence.

The inner surface of the tubular rod structure 13 is coated with neutron-absorbing substance 15 such as boron, for example.

For increasing the pulling force, several adjacent excitation coils, for example four coils, are preferably switched on simultaneously. For progressively displacing the rod structure, one coil at a time is added to the energized subgroup and the previously first-energized coil of the subgroup is simultaneously switched off. Also for increasing the pulling force, one or more additional groups of electromagnets can be added, each comprising eight individual electromagnets (or generally the same number of electromagnets as the first-mentioned group), the excitation coils of the individual groups being switched on and off in the same sequence as the corresponding coils of the first group. In these cases too, it is advisable to provide the additional magnet means, for example the additional coil I_0. When the groups of electromagnets are spacially separate from each other, each group is preferably provided with an additional electromagnet I_0.

An energizing circuit for coils I_1 to I_8 and for the additional coil I_0 is schematically illustrated in FIG. 2 together with a sequence controller of the cam-type. A reversible electric motor 20 drives a cam shaft 21 with a separate cam switch 22 for each of the respective excitation coils in the illustrated embodiment. The cams are so set that four coils of the group are simultaneously energized, except that the additional I_0 is always switched on and off simultaneously with the coil I_8. The con-

dition shown in FIG. 2 relates to operation of the motor 20 for lifting the rod structure and represents a moment when coils I_5 to I_8 are switched on together with the additional I_0. This moment is just prior to the transfer of excitation to coil I_1. That is, at the next switching stage the coil I_5 is switched off and the coil I_1 is switched on. At that moment the additional coil I_0 is still energized, thus augmenting the magnetic flux in the lowermost pole 3 then jointly traversed by flux from coils I_1 and I_0. At the next stage the coil I_6 is switched off and the coil I_2 is switched on, and so forth.

A simultaneous excitation of coils I_8 and I_0 can also be effected by means of a single control contact and a direct parallel connection of the two coils as shown in FIG. 3, the rest of the circuit diagram being in accordance with FIG. 2.

It will be obvious to those skilled in the art that my invention is applicable in various modifications and together with such varieties of magnetic-jack apparatus as described, for example, in the above-mentioned copending application, Serial No. 127,374 or in the copending application, Serial No. 199,004 of Franz Schreiber filed conjointly with the present application and based upon the same German priority of June 6, 1961. My invention can therefore be given embodiments other than particularly illustrated and described herein, without departing from the essential features of my invention and within the scope of the claims annexed hereto.

I claim:

1. Electromagnetic apparatus for lifting and lowering a rod structure within an enclosure by magnetic force applied from the outside, comprising a tubular housing and a rod structure longitudinally displaceable therein in lifting and lowering directions, a multiplicity of electromagnets axially aligned along said housing at the outside thereof and having uniformly spaced magnet poles, said rod structure having magnetizable teeth forming armatures for said respective magnets, the number of said teeth along the length of said multiplicity of aligned magnets differing from the number of said poles in accordance with a vernier ratio, energizing electric circuit means connected with said electromagnets and having sequence switch means for progressively energizing a given subgroup of cyclically adjacent ones of said electromagnets at a time to selectively cause displacement of said rod structure in one of said respective directions through successive unit distances corresponding to the spacing between two adjacent poles as each new lead magnet of said progressively energized subgroup is energized in direct sequence, and additional magnetizing means joined with the lowermost one of said poles of said group and poled in flux-augmenting sense relative to said lowermost pole for magnetically increasing the displacing force exerted by said lowermost pole on said rod structure, said additional magnetizing means being active simultaneously with the uppermost one of said electromagnets of said multiplicity of electromagnets.

2. Electromagnetic apparatus for lifting and lowering a rod structure within an enclosure by magnetic force applied from the outside, comprising a tubular housing and a rod structure longitudinally displaceable therein in lifting and lowering directions, a multiplicity of electromagnets axially aligned along said housing at the outside thereof and having uniformly spaced magnet poles, said rod structure having magnetizable teeth forming armatures for said respective magnets, the number of said teeth along the length of said multiplicity of aligned magnets differing from the number of said poles in accordance with a vernier ratio, energizing electric circuit means connected with said electromagnets and having sequencing switch means for progressively energizing a given subgroup of cyclically adjacent ones of said electromagnets at a time to selectively cause displacement of said rod structure in one of said directions through successive unit distances corresponding to the spacing between two adjacent poles as each new lead magnet of said progressively energized subgroup is energized in direct sequence, and an additional electromagnet joined with the lowermost one of said poles of said group for augmenting the magnetic flux in said lowermost pole for magnetically increasing the displacing force exerted by said lowermost pole on said rod structure, said additional electromagnet and the uppermost one of said multiplicity of electromagnets being in jointly controlled connection with said switch means so as to be energized simultaneously.

References Cited by the Examiner

UNITED STATES PATENTS

668,978	2/01	Carlson	310—14 X
1,132,445	3/15	Conrad	310—14
1,817,638	8/31	Morris	310—14 X
2,752,546	6/56	Frisch	310—14 X

MILTON O. HIRSHFIELD, *Primary Examiner.*

DAVID X. SLINEY, *Examiner.*