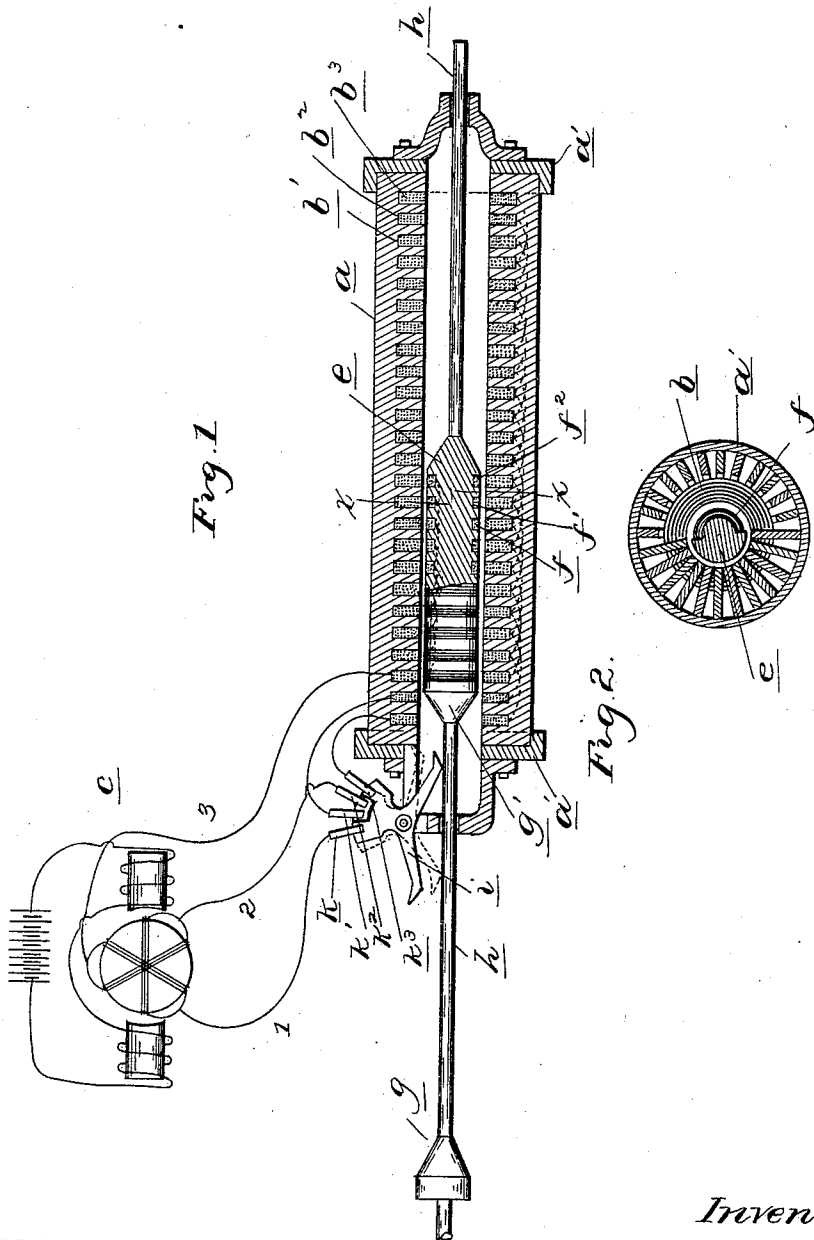


(No Model.)

F. B. RAE.
RECIPROCATING ELECTRIC ENGINE.

No. 547,383.

Patented Oct. 1, 1895.



Witnesses
N. L. Lindop.
M. B. O'Dogherty

Inventor
Frank B. Rae
By M. S. Mague & Son,
Attys.

UNITED STATES PATENT OFFICE.

FRANK B. RAE, OF DETROIT, MICHIGAN.

RECIPROCATING ELECTRIC ENGINE.

SPECIFICATION forming part of Letters Patent No. 547,383, dated October 1, 1895.

Application filed May 31, 1892. Serial No. 434,911. (No model.)

To all whom it may concern:

Be it known that I, FRANK B. RAE, a citizen of the United States, residing at Detroit, in the county of Wayne and State of Michigan, have invented certain new and useful Improvements in Electromagnets, of which the following is a specification, reference being had therein to the accompanying drawings.

My invention relates to that class of electromagnets known as the "coil and plunger magnet," and the object of which is to produce a pull between the coil and plunger.

The direct object of my invention is to produce a magnet of this kind the pull of which has an indefinitely long range and the speed and power of which can be controlled.

The ultimate object I have in view is to utilize the energy produced by its plunger as the motive power for propelling vehicles, operating elevators, reciprocating motors, and doing all other kinds of work for which motive power is required.

It is well known that an electromagnet will suck in an iron plunger, and if the same is about equal to the length of the electromagnet the iron plunger will be drawn in completely; but the shorter the plunger the less will be the range of its movement, and if it is very small it will not be attracted any farther than just into the mouth of the hollow core. Thus to make a long-range magnet of this description it would be necessary to use a plunger of corresponding length. Moreover, the energy derived would be far from uniform, as the plunger is at first but very feebly attracted, the attraction increasing until a maximum is reached, when the plunger is about half-way in, and then it would again rapidly decrease to zero. I am also aware that coiled tubes have been made in a number of separate sections or short tubes associated together end to end and furnished with means for turning on the current into any of the sections separately. The iron core entering into any one section turns the current on in that section, and as the end of the core or plunger passes through it the current is turned on in the next section ahead. The attraction may be kept up along a tube of indefinite length in this way. Instead of operating in this plan of progressively magnetizing the field by the agency of the movement

of the armature, my invention involves a progressive movement of the field itself, brought about by the agency of the current and entirely independent of the movement of the armature.

To this end my invention consists in providing a magnet of indefinite length with two or more sets of magnetizing conductors uniformly distributed along the tube and traversed by currents differing in phase, whereby corresponding sets of magnetic waves are produced in the magnet. This may be regarded as producing in the magnet a set of progressive magnetic waves of constant amplitude. The plunger tending to continually place itself in the maximum field of induction will therefore be carried along by the magnet and travel from one end to the other irrespective of its own length and the length of the magnet. As the direction in which the magnetic waves progress depends upon the direction of the current, it is natural that by a reversal of the current the movement of the plunger will be in opposite direction, and thus a reciprocating movement of the plunger can be obtained.

In carrying out my invention I also wind the plunger in the same way as the magnet, for the well-understood reason of obtaining a higher electromotive force by increasing the magnetic induction in the plunger, all as more fully hereinafter described, and shown in the accompanying drawings, in which—

Figure 1 is a longitudinal section through an electromagnet, illustrating my invention. Fig. 2 is a cross-section on line xx in Fig. 1.

The electromagnet a is made of any length desired to get a required stroke. For shorter length, I preferably build it of soft bar-iron, the bars to be cut of a length with rectangular notches cut at equal intervals along one edge. A series of coils $b^1 b^2 b^3$, separately prepared, are then inserted into these notches, the bars being radially adjusted around the coils, so as to form a tubular jacket with the coils inclosed in the annular grooves formed by the notches in the bars, as shown in Fig. 2, in which one half is a section through the solid portions and the other half through a notched portion, showing a coil. The bars are held together in any desired manner, such as by means of heads a' at the ends, which have

radial recesses formed on their inner sides for the ends of the bars to fit in to hold them in their proper relative positions.

1, 2, and 3 are the three conductors forming the circuit of a dynamo-electric generator *c*, which is of the peculiar type known as a "three-phased-current" generator, in which the current is split up, so that at each phase of the generation the current passes over a different set of conductors. As such generators are well known, I omit a further description thereof. The coils *b* are connected in series with the three conductors 1 2 3—that is, the first, fourth, seventh coil, &c., is connected to conductor 1. The second, fifth, eighth, &c., is connected to conductor 2, and the third, sixth, ninth, &c., is connected to conductor 3. The terminals of the last three coils are connected to each other. The plunger *e*, of soft iron, is preferably provided with annular grooves corresponding in distance apart with the coils on the electromagnet. These grooves receive either copper rings or they receive coils *f*, *f'*, *f''*, which are either short-circuited or preferably connected in series of three in the same manner as the coils *b* into three closed circuits. A switching device for automatically reversing the connection of the coils with two of the conductors is provided. This may be constructed as shown in the drawings, in which *g g'* are two conical collars or tappets adjustably secured upon the plunger-rod *h*. An oscillating lever *i*, with two arms arranged in the path of these collars, is oscillated thereby when the plunger reciprocates to reverse the electrical connection reciprocally between the contact-springs *k k' k'' k'''*, so that at one direction of the stroke the springs *k k''* and *k' k'''* are electrically connected, and then at the stroke in the opposite direction the springs *k k'* and *k'' k'''* are connected. The plunger is supported in any suitable manner to be free to reciprocate. For long magnets this may be done by antifriction-rollers and for short magnets the plunger is preferably suspended within the tubular jacket by plunger-rods supported in bearings, as shown in the drawings. A magnet of this description may be readily adapted for various kinds of work in which reciprocating motion is employed.

The operation of the device will be readily understood from the peculiar action of so-called "multiphase" currents in producing progressive magnetism in the iron bar, in which the windings are so arranged as to receive the phases of the current in progressive order. My device operates on this principle. The parts of the iron jacket inclosed between the coils become strong magnetic poles at certain phases of current of the dynamo if the order of these phases is successively over the conductors 1 2 3. A given pole will therefore travel in the bar the distance of three coils, and as every pole has such a progressive movement there is a constant flow of magnetic stress in one direction, in harmony with the magnetic stress in the revolving armature of

the generating-dynamo, slower or faster, according to the speed of the armature. The plunger will become strongly induced, the more so if provided with coils, and as it always tends to receive the maximum induction it will therefore tend to move in harmony with the field. A movement of the plunger should thus take place at corresponding speed with the field; but as there are retarding forces—such as the work placed upon the plunger—the speed will be of course less; but in the same degree as the speed becomes less the pull increases, and therefore the device is especially adapted to start quick and exercise considerable pull, and as the field in which the plunger moves is constant its pull is well adapted for motive power. As the plunger approaches each end of its travel, it operates the switch and thereby reverses the order in which the current-phases pass through the coils. The magnetism will therefore have a progressive motion in the opposite direction and carry the plunger back.

It will readily appear that my construction of magnet may be adapted for generators having a higher or lower number of phases, provided the electromagnet has as many sets of coils as there are phases.

My invention is capable of a converse operation, which has certain advantages, especially for long magnets. In such application I connect the coils of the plunger in the manner described above to the conductors 1, 2, and 3, either directly or by means of traveling contacts, and the coils of the magnet may then be short-circuited to form corresponding induced circuits therefor.

What I claim as my invention is—

1. The combination in a multiphase reciprocating motor, of an electro-magnet having coils contained in different windings in the conductors forming the circuit of a multiphase generator whereby a progressive field of force is produced in said magnet, a plunger for such magnet and a reversing switch, substantially as described.

2. In a multiphase reciprocating motor, the combination of an electro-magnet having a continuous iron core provided with a plurality of sets of coils contained in the different conductors of the circuit of a multiphase generator, a plunger for said electro-magnet and a reversing switch operated by said plunger, substantially as described.

3. In a multiphase reciprocating motor, the combination of a tubular electro-magnet composed of a series of interiorly notched iron bars concentrically arranged around a common axis, a plurality of sets of coils contained in the annular grooves formed by said notches, and contained in the conductors forming the circuit of a multiphase generator, a reciprocating plunger provided with a plurality of like sets of coils connected into a separate circuit and a reversing switch operated by the plunger, substantially as described.

4. In a multiphase reciprocating motor, the

combination of a tubular electro-magnet composed of a series of interiorly notched iron bars *a*, a plurality of sets of coils *b'* *b*² *b*³ contained in the conductors forming the circuit
5 of a multiphase generator, the reciprocating plunger *e* provided with corresponding coils *f'* *f*² *f*³, the reversing switch *i* having contacts *k* *k'* *k*² *k*³ and the conical tappets *g* *g'* on the plunger rod for operating the switch, sub-
10 stantially as described.

5. In a multiphase, reciprocating motor, a coil and plunger magnet having its magnet and plunger each formed with a series of annular recesses containing magnetizing coils
15 and forming between them a series of corresponding annular magnetic poles, the coils of the magnet being connected in series with the conductors of a multiphase generator in the progressive order of the phases thereof,
20 and the coils of the plunger being connected to form corresponding induced circuits therefor, substantially as described.

6. A multiphase reciprocating motor comprising a series of coils grouped to develop

a series of consequent poles in combination 25 with a differential phase alternating current circuit, means for periodically changing the order of delivery of the differential phase currents and thereby reversing the direction of
30 polar travel, and a plunger controlled by the polar wave, substantially as shown and described.

7. The combination in a reciprocating motor of a tubular electro-magnet composed of a series of bars provided with transverse 35 grooves, a plurality of sets of coils, grouped to form consequent poles, located in said grooves and connected in the conductors forming the circuits of a multiphase generator, means for periodically changing the order of delivery of 40 the currents, and a plunger actuated by said poles, substantially as described.

In testimony whereof I affix my signature in presence of two witnesses.

FRANK B. RAE.

Witnesses:

M. B. O'DOHERTY,
N. L. LINDOP.