

Dec. 13, 1932.

S. B. SANFORD

1,890,752

SWITCHING MECHANISM

Filed Dec. 23, 1930

4 Sheets-Sheet 1

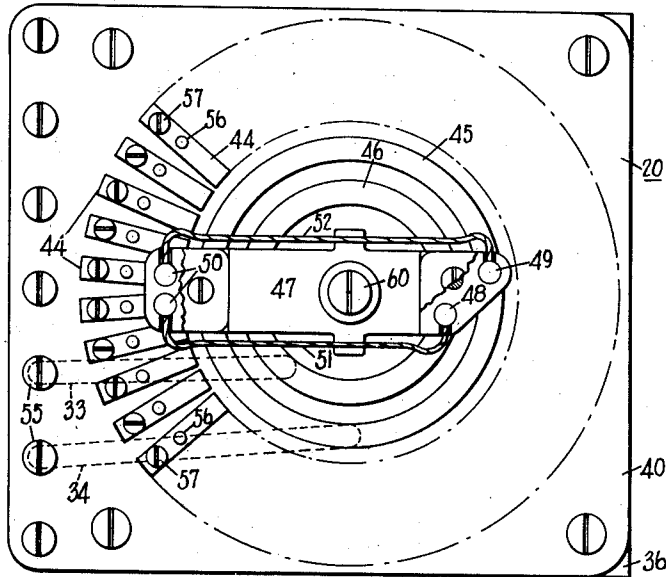


FIG. 1

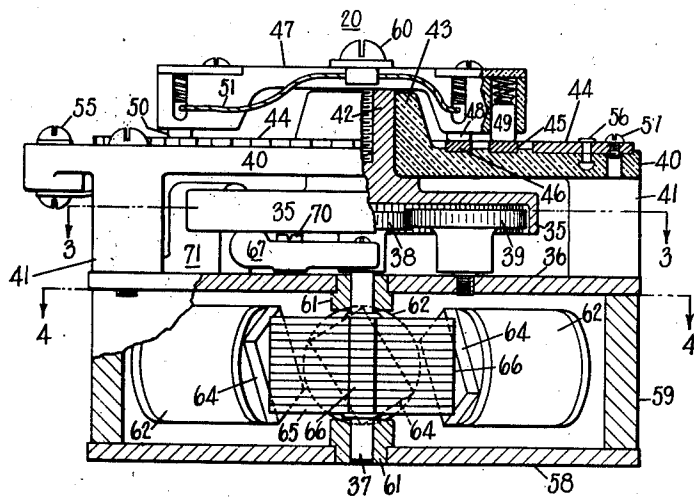


FIG. 2

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4 Sheets-Sheet 2

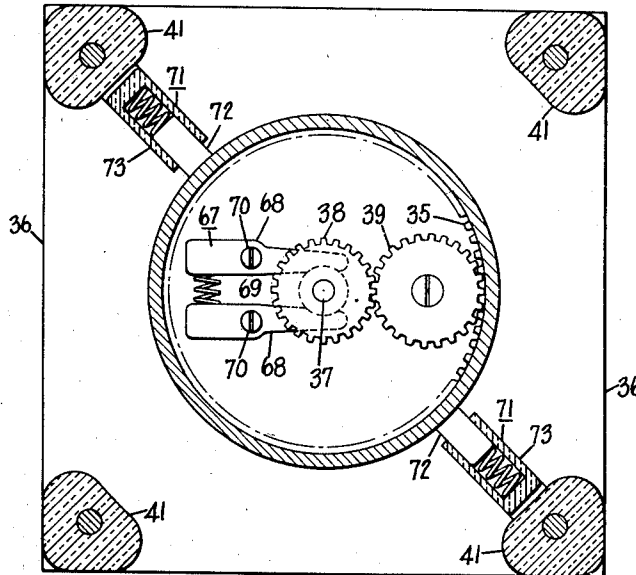


FIG. 3

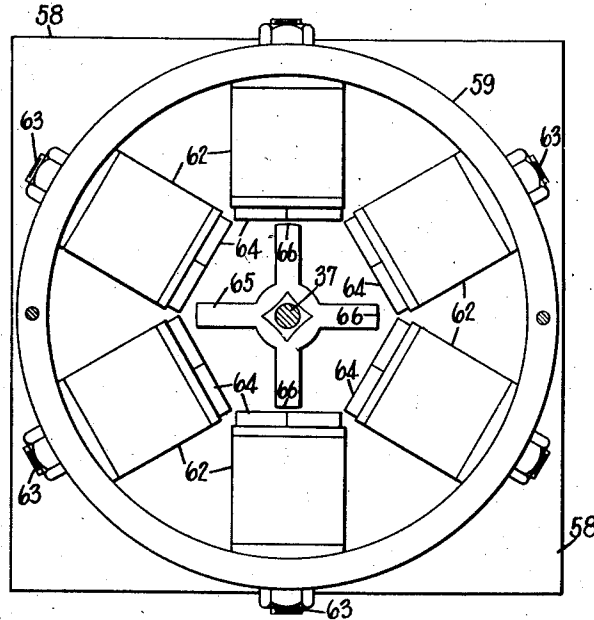


FIG. 4

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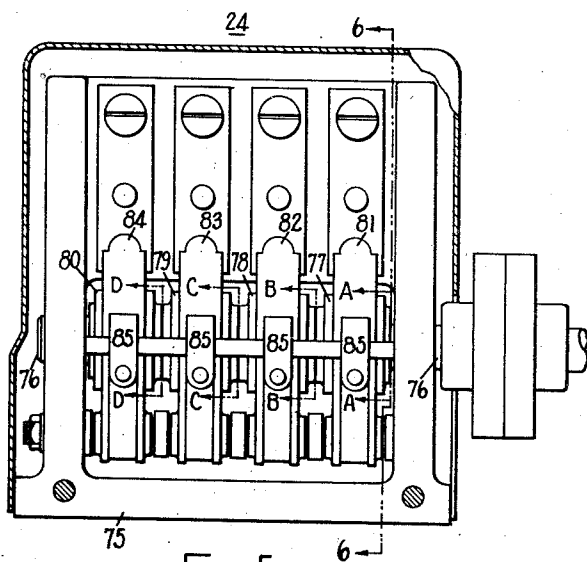


FIG. 5

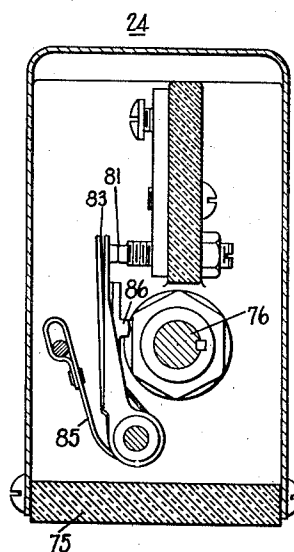


FIG. 6

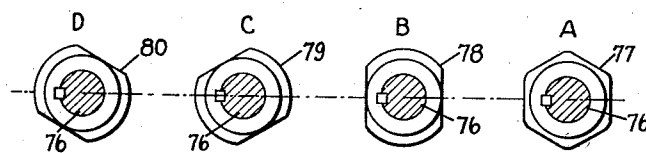


FIG. 7

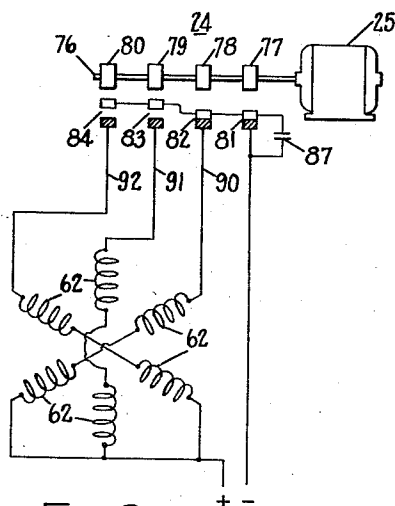


FIG. 8

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ARMATURE POLES (4) - $\frac{3}{16} \times \frac{3}{4}$

STATOR POLES (6) - $\frac{1}{2} \times \frac{3}{4}$ SKEWED AT AN ANGLE OF 30°

N^o OF TURNS PER STATOR POLE = 504

RADIAL AIR GAP = $\frac{1}{64}$

PULL IN OZ.
AT $\frac{7}{16}$ RADIUS

TORQUE REQUIRED TO ROTATE ARMATURE, (FRICTION) = 0.2 OZ.

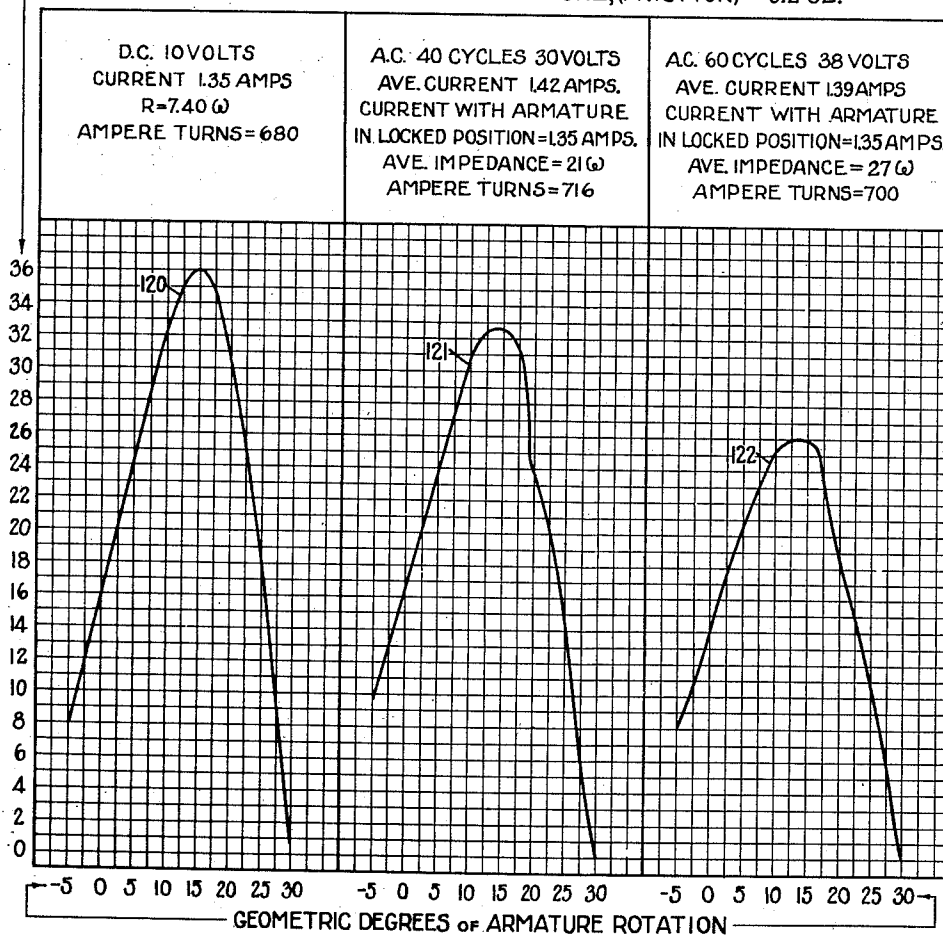


FIG. 9

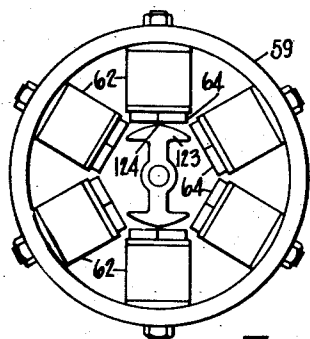


FIG. 10

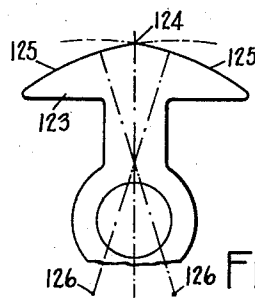


FIG. 11

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UNITED STATES PATENT OFFICE

SELDEN BRADLEY SANFORD, OF YONKERS, NEW YORK, ASSIGNOR TO OTIS ELEVATOR COMPANY, OF NEW YORK, N. Y., A CORPORATION OF NEW JERSEY

SWITCHING MECHANISM

Application filed December 23, 1930. Serial No. 504,230.

The present invention relates to systems of control and especially to systems in which an impulse motor is controlled by switching mechanism from a remote point to operate other switching mechanism.

Such switching mechanisms are useful in the transmission of signals or impulses in various remote control systems. It is advantageous to employ as few of the relatively long transmission conductors as possible. It is especially advantageous in the case of impulse or signal transmission systems for elevator installations to employ very few long conducting wires in the connecting cable between the elevator cars and the control stations therefor arranged at points other than on the car. This effects a saving not only in the cost of such connecting wires but also in a far more important item, the weight of a portion of the connecting cable which is supported by each elevator car and varies in amount as the elevator car travels up and down. It is also important in many signal or impulse transmission systems that the switching mechanisms, which are arranged at points widely removed from each other, each provide a large number of contacts, that circuits through corresponding contacts on each mechanism are accurately established, and that the circuits through each of the different sets of corresponding contacts are speedily made and broken.

One feature of the invention resides in the provision of a switching mechanism that will accurately and rapidly transmit a large number of signals or impulses.

Another feature of the invention is the provision of a simple and compact unit comprising an impulse motor and a switching means having a large number of contacts, in which unit connection is accurately made from a common terminal to one and only one of the contacts at the termination of each step of the impulse motor.

A further feature of the invention lies in providing an impulse motor which has very definite locking positions.

A further feature of the invention lies in the provision of an impulse motor which ex-

erts a strong starting torque in either direction.

Another feature of the invention is the provision of an impulse motor wherein the armature poles stop accurately at locking positions without oscillation or vibration.

Other features and advantages will become apparent from the following description taken in connection with the accompanying drawings.

For the purpose of illustrating the genus of the invention, typical concrete embodiments are shown in the accompanying drawings in which:

Figure 1 is a top plan view of a step-by-step impulse motor and commutator unit employed in a switching system in accordance with the present invention;

Figure 2 is an elevational view with parts in section of the impulse motor and commutator unit shown in Figure 1;

Figure 3 is a sectional view taken along line 3—3 of Figure 2;

Figure 4 is a sectional view taken along the line 4—4 of Figure 2;

Figure 5 is a front view with a portion of the casing broken away of a contactor device employed in the switching system;

Figure 6 is a section taken along line 6—6 of Figure 5;

Figure 7 comprises a number of sections taken along lines A—A, B—B, C—C and D—D of Figure 5 and shows the relative arrangement of the contactor cams and shaft;

Figure 8 is a wiring diagram of a switching system according to the present invention;

Figure 9 is a diagram showing performance curves of an impulse motor constructed in accordance with the invention as illustrated in Figures 2, 3 and 4;

Figure 10 illustrates a modified form of impulse motor; and

Figure 11 is an enlarged detail of a part shown in Figure 10.

The motor operated switching mechanism is illustrated in Figures 1, 2, 3 and 4. This mechanism, designated as a whole by numeral 20, is separated into two compartments by a division plate 36, the lower compartment for the impulse motor and the upper for a set

of reduction gears. The compartments may be joined in any suitable manner, for example, by means of bolts as illustrated.

The lower compartment comprises in addition to division plate 36 which serves as its top plate, a base plate 58 and a ring 59. A shaft 37 for the impulse motor is mounted in suitable bushings 61 which are pressed into apertures cut through the centers of the plates 36 and 58. The shaft 37 extends through the plate 36 and the bearing 61 into the upper compartment.

The upper compartment for the reduction gearing comprises, in addition to division plate 36 which serves as its base, a plate 40 of insulating material and depending spacer lugs 41. The reduction gearing comprises a pinion gear 38, idler gear 39 and internally toothed gear 35. The pinion gear 38 is secured to the projecting end of shaft 37. The idler gear 39 is rotatably mounted on a suitable boss projecting upwardly from plate 36 and meshes with pinion 38. The internally toothed gear 35 engages with idler gear 39 and is rotatably mounted in a bearing 43 at the center of plate 40 through the intermediary of its hub 42. Gears 35, 38 and 39 are preferably of an alloy of zinc and are made with sufficient accuracy to operate without binding and without excessive back lash.

The top portion of the plate 40 is slotted to accommodate a number of contacts 44 which are radially disposed relative to and equidistant from the impulse motor shaft 37. An outer collecting ring 45 and an inner collecting ring 46 are also mounted on the plate 40 concentrically with respect to impulse motor shaft 37. A brush holder 47 is mounted above the plate 40 and fastened to the hub 42 of the internally toothed gear 35 by a screw 60 so as to rotate therewith. Spring pressed brushes 48 and 49 are mounted on one end of brush holder 47 so as to engage the inner and outer rings 46 and 45, respectively. On the opposite end of brush holder 47 other spring pressed brushes 50 are mounted so as to engage two adjacent contacts 44. Conductors 51 and 52 connect each of the brushes 50 with one of the other brushes 48 or 49. Conductors 53 and 54 connect the inner and outer rings to suitable terminals 55 disposed along the margin of the commutator base. The contacts 44 are secured to the commutator base 40 by any suitable means, such as rivets 56. Screws 57 are threaded to each of contacts 44 to provide suitable terminals therefor.

The commutator mechanism is driven through the reduction gearing by the impulse motor. The details of the motor are shown in Figures 2 and 4. The impulse motor field pole structure is illustrated as comprising six poles. These poles, designated 63, are positioned equidistantly around the inside of ring 59. Each pole is provided with a winding 62 and illustrated as in the form of a pool

magnet. Also, each pole is provided with a comparatively large pole shoe in the form of a rectangular plate tangentially disposed relative to the armature and skewed at an angle of approximately 30 degrees with respect to the armature shaft 37. The dimensions of each shoe are such that one diagonal of its rectangular face is disposed parallel with the armature axis. The ring 59, poles 63 and shoes 64 constitute the field structure of the motor.

The armature is formed of a suitable number of laminations 65 pressed on the shaft 37. The laminations are of sheet iron or steel and may be punched from circular discs. Each finished lamination is in the form of a cross having a center opening for the accommodation of the armature shaft 37. These laminations are assembled in superposed position on said shaft to form a four pole armature. The poles are disposed at 90 degrees and present long, narrow pole faces, which are parallel with the armature axis.

In the above construction of the field and armature poles, the armature poles are caused to have very definite positions with respect to the field poles. Assume, for example, that the coils of the top and bottom field poles, as viewed in Figure 4, are energized. Under such conditions, the armature assumes the illustrated position with the longitudinal centerlines of two armature pole faces 66 directly aligned with the diagonals joining opposite corners of the top and bottom field pole faces 64. Similarly the energization of other pairs of oppositely arranged field poles causes the armature to assume positions in which the longitudinal centerlines of two of its diametrically opposite pole faces are in direct alignment with the diagonals of opposed field pole faces.

In each of these positions the magnetic reluctance between the field and armature poles is at a minimum for two reasons: First, because a maximum area of the faces of the field poles is opposed to the faces 66 of the armature poles, and second, because the air gaps between the tangentially disposed field pole faces and armature pole faces are, in this position, reduced to a minimum. This gives a very definite locking position since movement of the armature poles to either side of the locking position reduces the iron path available to the flux threading between the field and armature poles and at the same time increases the length of the air gap between said poles.

The skewed arrangement of the field pole shoes also allows the use of large-areaed, closely-spaced, shoes to effect a strong starting torque for rotating the armature to a succeeding position in either direction. Furthermore, the strong starting torque is obtained without causing excessive magnetic leakage between adjacent shoes, since essentially par-

allel surfaces are presented to one another and points or corners of one shoe are widely separated from those of adjacent shoes.

It is preferred to provide brakes to produce a frictional drag on the armature shaft 37 and on the gear 35 to cause the armature poles to stop in locking positions without oscillation or vibration. Two brakes are illustrated, one of these brakes, designated 67, is shown in the form of a pair of brake arms 68 disposed on either side of the armature shaft 37 and biased into engagement with the hub of pinion 38 by a spring 69. The brake arms 68 are pivotally mounted at intermediate points on screws 70 which thread into the top plate 36. The other brake, designated 71, is shown in the form of diametrically opposed spring-pressed plungers 72 engaging the outer periphery of gear 35 and mounted in guides 73 which are in turn secured to the lugs 41 of the commutator base 40. Brake 71, in addition to assisting brake 67 in preventing vibration, causes the back lash of gears 35, 39 and 38 to be taken up. Other forms of brakes may be employed if desired.

Diametrically opposed magnet coils 62 may be connected either in parallel or in series. Also, the opposed coils are oppositely wound so that their energization produces magnetic poles of opposite polarity. As oppositely disposed magnets are energized, the pair of armature poles separated therefrom by the least angle moves into a position in alignment with the energized magnets. With the three pairs of magnets successively energized in one direction around the ring 59, the armature will rotate in the opposite direction in steps of thirty degrees each. At the completion of each step two oppositely-disposed armature poles are in alignment with two oppositely-disposed field poles so that each locking position is equally definite.

The impulses from a source of current to the impulse motor are transmitted through a contactor device 24 which is driven by a motor 25 as shown in Figure 8.

The details of a preferred form of contactor device are illustrated in Figures 5, 6, 7 and 8. The contactor device is enclosed in a casing and comprises a base frame 75 of insulating material, a cam shaft 76 rotatably mounted in this frame and a number of contact members operable by cams fixed to the shaft 76. These cams comprise a hexagonal master cam 77 and three cams 78, 79 and 80. Master cam 77 and cams 78, 79 and 80 operate a master contact 81 and contacts 82, 83 and 84, respectively, to open position against the closing influence of springs 85. The cams are cut from cylindrical blanks of the same diameter. The master cam 77, as illustrated in Figure 7, is made by removing segmental portions at each sixty degree point around the circum-

ference of the blank and at equal distances from its center to form a hexagonally shaped cam having slightly rounded corners. Cams 78, 79 and 80 are formed by removing from the circumference of each blank two segmental portions one hundred and eighty degrees apart and at equal but slightly less distances from their centers than in the case of the segments removed to form the master cam. Cams 78, 79 and 80 are each keyed to shaft 76 so that its flats are parallel to two flats of cam 77 but at an angle to the flats of each of the other cams. Springs 85 bias each of the contacts to closed position when one flat of its operating cam is adjacent a bearing lug 86 disposed on the movable portion of the contact. Since the flats of the master cam are farther from the shaft center than the flats of the other cams, the master cam during operation of the contactor causes the contact 81 to close after and open ahead of the engagement and separation, respectively, of each of the other contacts.

Referring to Figure 8 it will be noted that one power lead, the negative as illustrated, is connected to the stationary point of contact 81. With contact 81 closed, the movable points of the other contacts will be connected to the negative lead. All the make and break of the power circuit through the contacts will be effected at the points of master contact 81. Therefore, but one condenser 87, shunted around the master contact 81, is used to reduce the arcing at the contact points. If the condenser 87 should burn out or be short-circuited the contacts 82, 83 and 84 continue to make and break their circuits.

The shaft 76 of the contact device as illustrated in Figures 5, 6, 7 and 8 is at a position in which the master contact 81 and contact 82 are closed completing the circuit through conductor 90 to one pair of field magnet coils 62 of the impulse motor. The armature of the impulse motor has two poles aligned with these magnets and the commutator arm completes a circuit to a contact 44. Assuming that the shaft 76 is rotated in steps of sixty degrees each in a clockwise direction as viewed in Figures 6 and 7, then during the first step, master cam 77 opens contact 81, cam 80 allows contact 84 to close, cam 78 opens contact 82 and master cam 77 allows contact 81 to close in the order named, cam 79 continuing to hold contact 83 open during this step. The circuit to the pair of field coils of the impulse motor through conductor 90 has been cut off during this step and a circuit to another pair of field magnets has been established through contacts 81 and 84 and conductor 92 causing the impulse motor armature to advance one step and move the commutator arm to the next contact 44. Rotation of the shaft 76 another step in the same direction causes

master cam 77 to open contact 81, cam 79 allows contact 83 to close, cam 80 opens contact 84 and then master cam 77 allows contact 81 to close, cam 78 holding contact 82 open during this step. During this step the circuit through contact 84 and conductor 92 is severed and a circuit established through contacts 81 and 83 and through conductor 91 to cause the impulse motor to advance another step and the commutator to establish a circuit to the next contact 44. Rotating the shaft 76 still another step in the same direction causes the master cam to open contact 81, cam 78 to allow contact 82 to close, cam 79 to open contact 83, and master cam 77 to allow contact 81 to close in the stated order, cam 80 holding contact 84 open during this step, establishing the same conditions of the contactor as illustrated in Figures 6, 7 and 8. The next three steps of the contactor in the same direction cause a repetition of the above events and will not be described. The impulse motor meanwhile advances three additional steps completing a half revolution of its armature during the full revolution of the contactor shaft. Reversal of the contactor shaft at any time restores the conditions pertaining to the previous step.

Assuming, for example, that the impulse motor and switching mechanism unit is mounted on an elevator car and that the contact device or an equivalent switching mechanism is mounted at some point other than on the car, then but five conductors are necessary to operate signals in the car. These conductors would comprise the three wires, 90, 91 and 92, connecting the contact device or other switching mechanism with stator fields of the impulse motor, and two power leads to the switching mechanism of the unit. This makes possible a marked saving in the weight of the connecting or traveling cable because the connecting cables of a directly wired signal system would ordinarily as a minimum require as many wires plus one as there are signals to transmit. In an eighty story building, for example, with one or two signals for each floor a very material reduction in the weight of the traveling cable is made possible by the present invention.

The impulse motor illustrated in Figures 1, 2, 3 and 4 is operable on either direct or alternating current. For a better understanding of certain characteristics of this motor reference may be made to the performance curves shown in Figure 9. These curves show values of the torque, expressed in ounces at a $\frac{1}{16}$ " radius, obtained for various positions of the armature. The positions of the armature are given in geometric degrees of rotation with respect to locking positions, the zero degree point representing the position of the armature at a pair of deenergized

poles and the thirty degree point the position of the armature at a pair of energized poles or a locking position. Certain details of the motor tested are given at the top of the figure. It will be noted that the usual step of operation is from the 0 degree to the 30 degree position and that in curve 120, for example, with the motor operating on a 10 volt direct current source, the torque expressed in ounces at a $\frac{1}{16}$ " radius increases from 16 ounces at the zero position to 36 ounces at the fifteen degree point and decreases from that point to 0 ounces at the thirty degree point or the active locking position. It is also noted that in the vicinity of the active locking position the torque changes very rapidly as the armature poles rotate toward and away from locking position. For example, the torque required to rotate the armature poles out of locking position increased from 0 ounces at locking position to 3.5 ounces at 1 degree from locking position and to 18 ounces at 5 degrees from locking position. This abrupt change in the opposition to the rotation of the armature poles out of locking position makes this position very definite. Curves 121 and 122 show the torque at various armature positions when the motor is driven by alternating currents of 40 cycles, 30 volts and 60 cycles, 38 volts, respectively. It will be noted that with the alternating current drive practically the same results are obtained as with the direct current source of power.

The motor when driven from any of the above current sources has a starting torque at the 0 degree point on the beginning of each step of from 14 to 16 ounces, a torque of from 26 to 36 ounces at the 15 degree or half way point, a torque of from 10.4 to 18 ounces at the 25 degree point or 5 degrees from the end of the step, and an abruptly decreasing torque from the 25 degree point to zero torque at the 30 degree point or locking position. During operation of the motor the energization of a pair of oppositely disposed field poles will exert a force on a pair of armature poles spaced one step away sufficient to cause very rapid rotation, the total time for the rotation through one step being about $1/320$ of a second.

With such rapid rotation, the inertia of the armature and gears driven thereby would normally cause the armature to rotate through locking position to a point beyond and subsequently to oscillate through locking position several times before coming to rest. In the case of the alternating current drive the armature poles would at time also vibrate back and forth through the locking position at a rate in synchronism with the alternations of the current or some multiple thereof. To avoid the running through locking positions and the possibility of vibrations being set up by alternating current a drag is imposed on the shaft. This drag is afforded

by the brakes 67 and 71. The drag is equal for either direction of shaft rotation and is sufficient to cause the armature poles to stop accurately at the locking positions. The frictional drag applied to the motor tested, for example, was about four ounces and may be adjusted by varying the tension of the springs of brakes 67 or 71.

The importance of definite locking positions increases as the number of signals to be transmitted increases. For example, in a signal system for an elevator installation in a tall building, there are one or two signals to be transmitted for each of nearly a hundred floors. The impulse motors employed in the above transmission systems must have ample torque to be positive in their action and to rotate the reduction gearing and parts of the sending and receiving units rapidly enough for speedy transmission of signals. Also the armature poles must stop at locking positions with sufficient accuracy to give the proper scale indication at the receiver or to make the proper contacts at the signal receiver.

The invention is not limited to the above combination of a six pole field structure and a four pole armature and many of its features may be embodied in systems in which the impulse motors have other combinations of poles. By virtue of the six and four pole arrangement, however, a compact, light and highly efficient motor and switching unit is easily constructed.

Referring to Figures 10 and 11 an impulse motor having a two pole armature and embodying certain features for carrying out the present invention is illustrated. In this embodiment the same field pole structure is employed as before. The armature poles are diametrically opposed and have winged tips 123 for effecting a strong starting torque. Pole faces 124 are formed by cutting back the pole ends and wing tips on curves 125 having centers 126 eccentrically disposed relative to the armature center line and having radii greater than the armature radius but less than its diameter. The armature pole ends thus taper to a line at the center of each pole face. The minimum air gap is reached when this line on an armature pole face is at the center of a plane-surfaced field pole face 64. In this position the line portion affords the equivalent of a narrow armature pole face opposing the maximum width of field pole face as in the case of the first embodiment. Rotation of the armature pole from this position in either direction increases the length of the air gap and diminishes the metal path provided by the field pole and the line portion of the armature pole for the flux threading between these poles thus effecting an abrupt change of torque and a very definite locking position as before.

The two pole armature type motor may be

operated with either six or twelve steps per revolution of the armature according to the manner in which the field coils are energized. For six steps per revolution diametrically opposed poles are energized in pairs in sequence around the field pole structure causing one step for each pair energized. For 12 steps per revolution the poles are energized in pairs as before but in sequence and in multiple around the field poles i. e., assuming that the field poles are numbered 1 to 6 in sequence around the field poles, the poles will be energized in the order: the 1-4 pair; the 1-4 and 2-5 pairs; the 2-5 pair; the 2-5 and 3-6 pairs; the 3-6 pair; the 3-6 and 1-4 pairs; to complete one half a revolution of the armature and a repetition of this order of energizing the field poles will cause the armature to complete the second half revolution.

Although the invention has been described and illustrated in connection with a switching system for elevators, it is to be understood that it is applicable to other transmission mechanisms and impulse transmission systems and that it applies to other types of impulse motors than those herein described.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In combination, a step-by-step impulse motor, a braking means for applying a substantially constant frictional drag directly on the armature shaft of said impulse motor, a rotatable part connected to the armature of said impulse motor by a reduction gearing, and a second braking means for applying a substantially constant frictional drag on said rotatable part.

2. An impulse motor comprising an armature and a plurality of field poles each having a substantially quadrangular shaped pole face having unequal dimensions, each pole face being skewed at an angle with respect to the armature axis to dispose a diagonal dimension of said pole face parallel to said rotor axis.

3. An impulse motor comprising an armature and a plurality of field poles each having a plane-surfaced pole face of substantially quadrangular shape and unequal dimensions, skewed at an angle with respect to the armature axis to dispose a diagonal dimension of said pole face parallel to said armature axis.

4. An impulse motor comprising an armature and a plurality of field poles each having a plane-surfaced pole face of substan-

tially quadrangular shape and unequal dimensions, tangentially disposed with respect to said armature and skewed at an angle with respect to the armature axis to place a diagonal dimension of said pole face parallel to said armature axis.

5. An impulse motor comprising an armature and a plurality of field poles each having a substantially rectangular pole face skewed at an angle with respect to said armature axis to dispose a diagonal dimension of said pole face parallel to said armature axis.

6. An impulse motor comprising an armature and a plurality of field poles each having a plane-surfaced pole face of rectangular cross section disposed tangentially with respect to said armature and skewed at an angle with respect to the armature axis to dispose a diagonal dimension of said pole face parallel to said armature axis.

7. An impulse motor comprising a shaft, a plurality of radially disposed armature poles on said shaft, each pole having a pole face long in the direction of the axis of said shaft and narrow in the direction of rotation of said pole face, a plurality of field poles each having a pole face of rectangular cross section disposed tangentially with respect to the periphery of said armature and skewed at an angle with respect to the axis of the armature shaft to dispose a diagonal dimension of said field pole face parallel to the axis of said armature shaft.

8. An impulse motor comprising a shaft, a plurality of radially disposed armature poles on said shaft, each pole having a pole face long in the direction of the axis of said shaft and narrow in the direction of rotation of said pole face, a plurality of field poles each having a plane-surfaced pole face of rectangular cross section disposed tangentially with respect to the periphery of said armature and skewed at an angle with respect to the axis of said armature shaft.

9. An impulse motor comprising a shaft, a plurality of radially disposed armature poles on said shaft, each pole having a pole face long in the direction of the axis of said shaft and narrow in the direction of travel of said pole face, a plurality of radially disposed field poles each having a plane-surfaced pole face of rectangular cross section disposed tangentially with respect to the periphery of said armature, the dimensions of said pole faces being such that when each pole face is skewed at an angle of 30 degrees with respect to the axis of said shaft, a diagonal of said pole face will be parallel with the axis of the shaft.

10. In an impulse motor the combination of, an armature comprising a shaft, a plurality of radially disposed armature poles on said shaft, each pole having a pole face long in the direction of the axis of said shaft and narrow in the direction of rotation of said pole face, a plurality of field poles each hav-

ing a plane-surfaced pole face of rectangular cross section disposed tangentially with respect to the periphery of said armature and skewed at an angle with respect to the axis of said armature shaft, and a braking means for applying a substantially constant frictional drag on said shaft.

11. An impulse motor comprising an armature, a plurality of field poles each having a plane-surfaced pole face of rectangular cross section, said pole faces being tangentially disposed with respect to the periphery of said armature and skewed at an angle with respect to the axis of said armature to dispose corresponding diagonal dimensions of the pole faces parallel to the armature axis.

12. An impulse motor having a multipole armature, a plurality of radially disposed field poles arranged in a circle about the armature and plane-surfaced pole faces of rectangular cross section, said armature poles having long and narrow faces disposed parallel with the armature axis, said field pole faces being tangentially disposed with respect to the periphery of said armature and skewed with respect to said armature axis to dispose corresponding diagonal dimensions of the field pole faces parallel to the armature axis.

13. An impulse motor including an armature, a plurality of field poles each having a plane-surfaced pole face of substantially quadrangular shape and unequal dimensions skewed at an angle with respect to the armature axis to dispose a diagonal dimension of its pole face parallel to said armature axis, said armature comprising a shaft and a plurality of radially disposed poles each having laterally projecting wings as its outer end and a pole face which recedes uniformly from the center of the pole face toward each of the wing tips on curves having greater radii than that of the armature.

In testimony whereof, I have signed my name to this specification.

SELDEN BRADLEY SANFORD.