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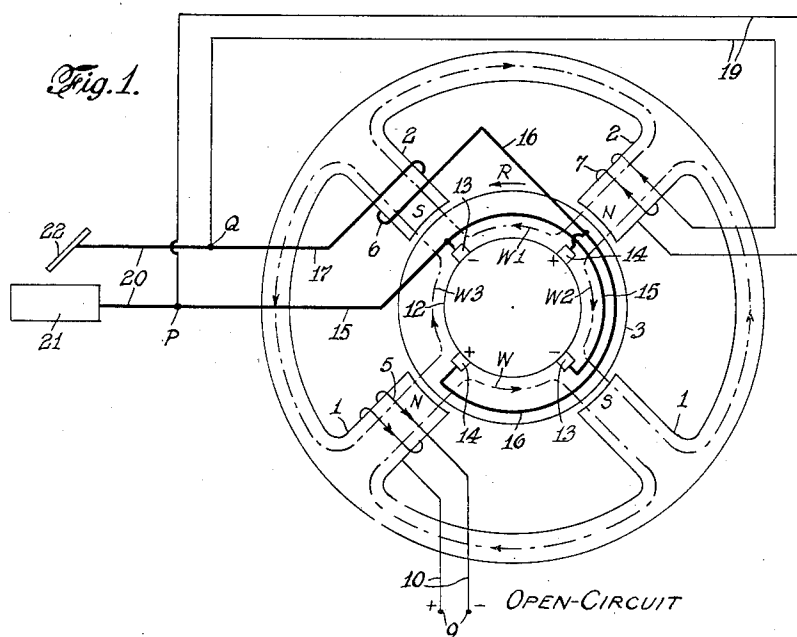
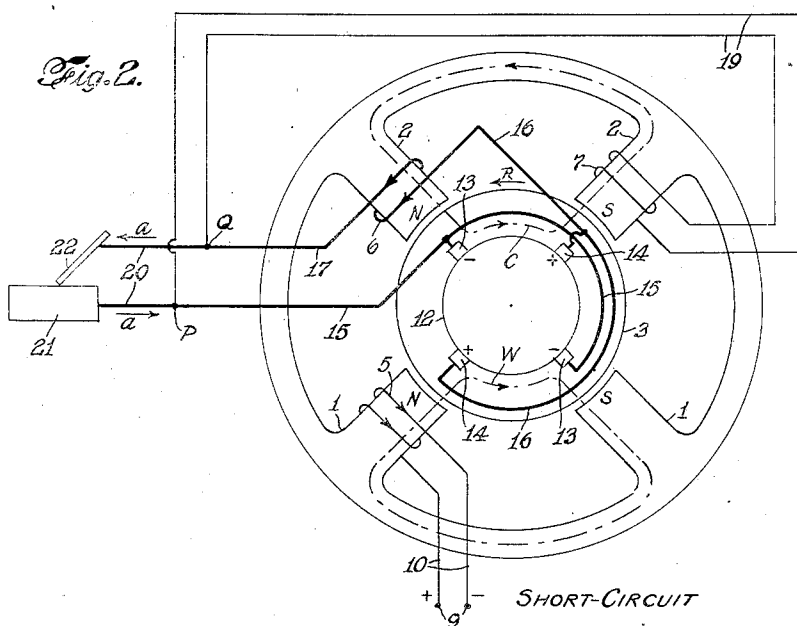
E. E. TISZA ET AL

2,180,700

DIRECT-CURRENT ARC-WELDING GENERATOR

Filed April 16, 1938

3 Sheets-Sheet 1



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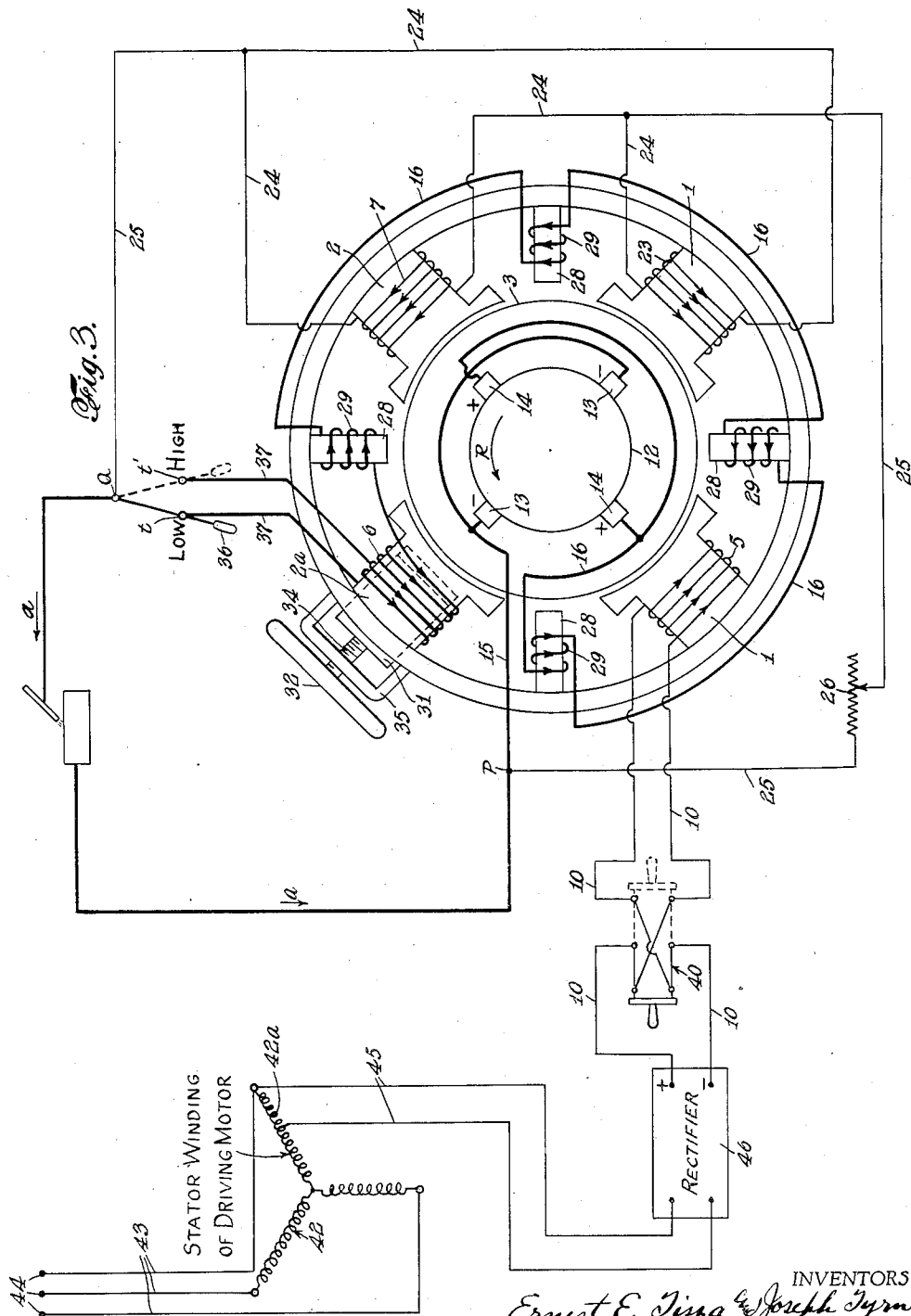
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DIRECT-CURRENT ARC-WELDING GENERATOR

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3 Sheets-Sheet 2



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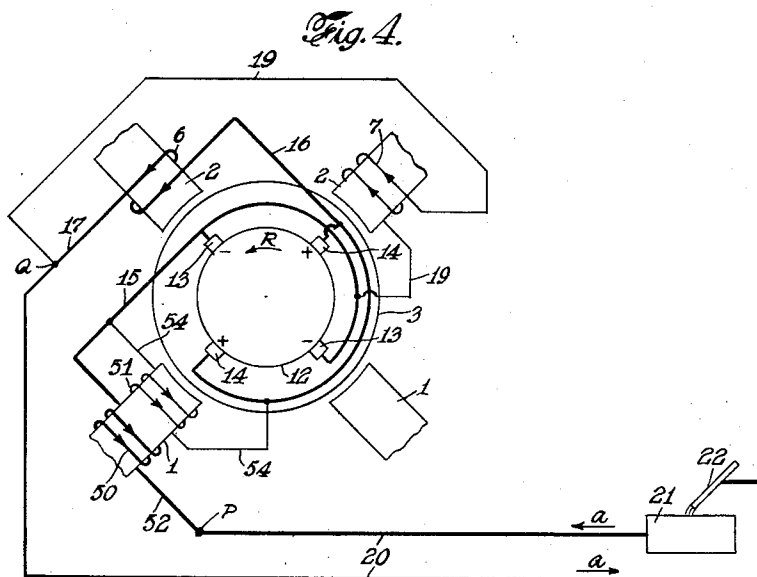
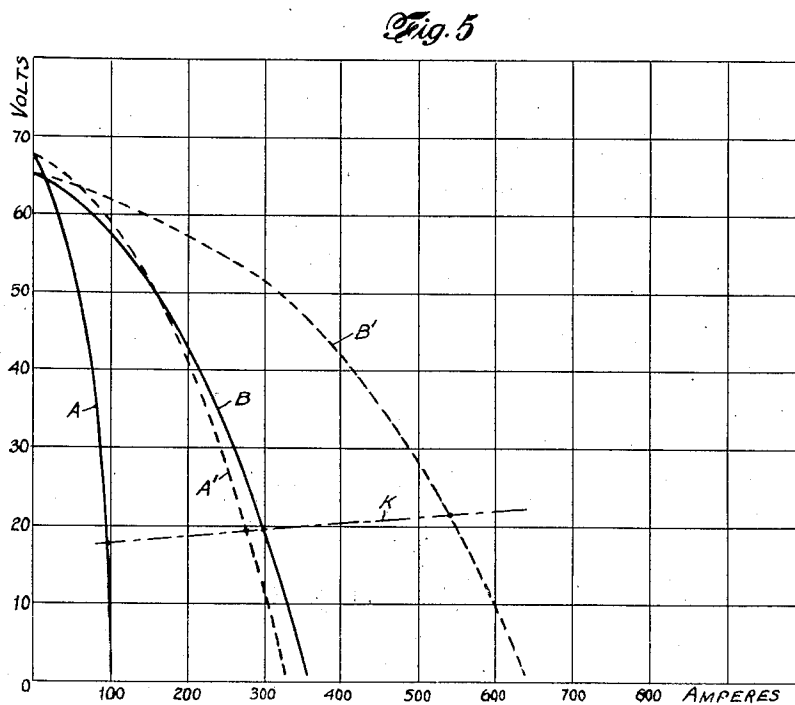
E. E. TISZA ET AL

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DIRECT-CURRENT ARC-WELDING GENERATOR

Filed April 16, 1938

3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,180,700

DIRECT-CURRENT ARC-WELDING
GENERATOR

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Application April 16, 1938, Serial No. 202,456

5 Claims. (Cl. 171-223)

The present invention relates generally to generators for direct-current arc-welding, and particularly to generators intended to effect self-regulation in the armature. In such generators two fields having independent magnetic paths are caused to be produced. One of these is a constant work-field which generates a constant voltage from open-circuit to short-circuit conditions, while the other is a series counter-field which generates an increasing voltage with increase of current in the welding circuit. These voltages oppose one another in the armature, which thus adds them together to a terminal voltage having the drooping characteristic required for self-regulation. Generators of this type will herein be referred to as counter-field generators.

Because of the fact that self-regulation takes place in the armature, the transient characteristics of counter-field generators are very good, the usual current surges occurring in welding operations being reduced to a minimum. On the other hand, it has been found difficult to construct such generators so that these characteristics may be retained and the armature fully utilized for generating purposes. On open-circuit, for example, the terminal voltage has usually been confined for its generation to a particularly small fraction of the armature circumference. This has been a decided disadvantage of counter-field generators from the standpoint of machine size and manufacturing cost.

An important object of the invention is to provide an improved counter-field generator for arc-welding of simple construction, in which the full circumferential extent of the armature is employed to generate the open-circuit voltage, as well as the terminal voltage under all load conditions up to a predetermined load less than the short-circuit current value.

In accordance with the invention, this object is accomplished by making use of a four-pole series-wound armature cooperating with a four-pole field magnet frame with which is associated a special field winding arrangement involving the use of a single constant-field winding for providing the usual work-field through one pair of adjacent pole elements and a single series-field winding for producing the usual counter-field through the opposite pair of adjacent pole elements. The single constant-field winding and the single series-field winding are respectively positioned on two adjacent pole elements, while on the pole element opposite to the pole element carrying the single constant-field winding is lo-

cated a shunt-field winding connected to oppose the single series-field winding, the remaining pole element preferably carrying another shunt-field winding connected to assist the single constant-field winding. By this simple four-pole generator construction, as we have found, not only are the additional work-fields produced through the armature to enable it to be employed to maximum advantage for generating purposes, but at the same time this result is obtained with the counter-field principle of self-regulation carried out in the armature, no appreciable increase in the aforementioned current surges resulting from the production of the additional work-fields, because of the independent location of the single series-field winding.

It is evident, of course, that the single constant-field winding included in the aforementioned field winding arrangement may be replaced by a single group of compound windings operating on a single pole element to produce a field of substantially constant intensity, an example requiring the use of such compound windings in practice being hereinafter described.

In the accompanying drawings, Fig. 1 and 2 are simplified views of an embodiment of the invention, particularly illustrating the field flux paths on open-circuit and short-circuit; Fig. 3 is a detailed view of a more elaborate embodiment of the invention inclusive of means for separately exciting the constant-field winding and for reversing the polarity of the generator; Fig. 4 is a simplified view of still another embodiment of the invention, showing the possibility of entirely depending on the generator armature for excitation purposes, the inner pole portions only of the field magnet frame being shown; and Fig. 5 is a view showing various characteristic curves as may be obtained in practice by the invention. Similar characters refer to similar parts throughout the various figures.

Referring to Figs. 1 and 2, a welding generator is illustrated which comprises a field magnet frame of usual construction having four inwardly-extending pole elements 1 and 2 equally spaced circumferentially about the armature 3. Respectively carried by three of these pole elements are a constant-field winding 5, a series-field winding 6, and a shunt-field winding 7. As will hereinafter become apparent, the use of these single three windings results in the production of fields through the machine enabling the armature 3 to carry out the counter-field principle of self-regulation with maximum usefulness for generating purposes. As shown, the relative positions

of the three windings should be such that the constant-field winding 5 is located on a pole element adjacent to the pole element carrying no winding, and that the series-field winding 6 is located on a pole element intermediate the pole elements carrying the constant-field winding 5 and the shunt-field winding 7. The numeral 1 has reference to the pole element carrying the constant-field winding 5 and to the adjacent pole element carrying no winding, while the numeral 2 has reference to the pole element carrying the series-field winding 6 and to the adjacent pole element carrying the shunt-field winding 7.

Any suitable constant potential source of current may be used to supply the exciting current to the constant-field winding 5, which is shown connected to the terminals 9 of such a source by conductors 10.

The armature 3 comprises a four-pole series-type winding (not shown), i. e., a four-pole two-path wave winding, and is equipped with the usual commutator 12 connected with the armature winding. Four load brushes 13 and 14 are shown positioned on the commutator 12, the arrow R indicating the direction of armature rotation required to cause these brushes to have the polarities indicated. As shown, the two brushes 13 of negative polarity lead directly by a conductor 15 to one output terminal P of the generator, while the two brushes 14 of positive polarity lead by a conductor 16 to the series-field winding 6 and thence by a conductor 17 to the other output terminal Q of the generator.

Preferably, the shunt-field winding 7 is connected as a long shunt across both armature 3 and series-field winding 6, which connection is illustrated as being carried out by conductors 19 leading from the winding 7 to the output terminals P and Q.

In the usual manner the welding current is supplied from the output terminals P and Q, which are shown connected by conductors 20 to a work piece 21 and the welding electrode 22 thereon.

The distinctive manner in which the generator of Figs. 1 and 2 operates will now be fully described.

Although individually positioned on separate pole elements, the three windings 5, 6 and 7 are nevertheless each capable of producing flux in adjacent pole elements. By proper connections of these windings, a work-field W is thus produced by the constant-field winding 5 through the adjacent pole elements 1, while through the adjacent pole elements 2 is produced a work-field W1 (Fig. 1) by the shunt-field winding 7 and a counter-field C (Fig. 2) by the series-field winding 6, the resultant of these two fields W1 and C being the actual field produced through the pole elements 2. Obviously, the work-field W1 is a maximum on open-circuit and substantially zero on short-circuit, while the counter-field C is zero on open-circuit and a maximum on short-circuit. Therefore, since the fields W1 and C oppose one another, their resultant through the pole elements 2 is a varying field reversing in direction with increase of load in the welding circuit, its value on open-circuit being the open-circuit value of the work-field W1 and on short-circuit substantially the short-circuit value of the counter-field C. On the other hand, the work-field W through the pole elements 1 is a constant field unaffected by any change in load conditions, its open-circuit and short-circuit values being the same.

Still other work-fields W2 and W3 are produced as a result of the three windings employed. The field W2 is produced through one pair of adjacent pole elements 1 and 2 by the shunt-field winding 7 alone; while the field W3 is produced through the other pair of adjacent pole elements 1 and 2 by the constant-field winding 5 in conjunction with the series-field winding 6. Since these two windings 5 and 6 oppose one another through their respective pole elements 1 and 2, the field W3 is substantially of the same character as the field W2, which is evident from the fact that the series-field winding 6 increasingly opposes the constant-field winding 5 with increase of current supplied to the welding circuit, the effect of this differential action of the two windings 5 and 6 through their respective pole elements 1 and 2 being obviously to produce a field W3 of substantially the same character as one produced by a single shunt-field winding on either of such pole elements. Therefore, like the field W1, each of the work fields W2 and W3 is a maximum on open-circuit and decreases in value with increase of current supplied to the welding circuit. For reasons hereinafter explained, however, each of the work fields W2 and W3 becomes zero at a predetermined load less than the short-circuit current value.

On open-circuit (Fig. 1), the only fields produced are the four work-fields W, W1, W2 and W3. Since these fields are all working fields produced through the entire four quadrants of the machine, it is clear that the generator of Figs. 1 and 2 is one which on open-circuit assumes the character of a standard four-pole machine having four pole elements successively alternating in polarity about a four-pole machine, the entire circumference of the armature being employed in generating the open-circuit voltage.

Under load conditions the counter-field C superimposes on the work-field W1. The only field which remains constant is the work-field W, a substantially constant working voltage being generated by this field from open-circuit to short-circuit conditions. The work-fields W1, W2 and W3 gradually diminish with increase of load, while the counter-field C gradually increases and eventually overcomes the work-field W1, at which point the work-fields W2 and W3 are both necessarily zero because of reversed polarities in the pole elements 2. Consequently, a working voltage gradually diminishing to zero prior to this polarity reversal is generated by each of the work-fields W2 and W3, during which time a progressively decreasing working voltage also reaching zero is generated by the work-field W1 and counter-field C combined. Subsequently, a counter-voltage is generated by these superimposed fields W1 and C, which counter-voltage gradually increases to a value on short-circuit almost equal to the value of the working voltage generated by the work-field W. Obviously, since the total voltage supplied from the armature brushes is equal at any instant to the algebraic sum of the individual voltages generated, a continuous drop in terminal voltage is obtained from open-circuit to short-circuit conditions, the external characteristic of the generator being necessarily of the usual character employed for self-regulation.

From the foregoing description it is clear that, under increasing load conditions up to a predetermined load less than the short-circuit current value, the generator of Figs. 1 and 2 operates in the same manner as on open-circuit, but

with reducing terminal voltage. Thereafter, a reversal of polarity takes place in the pole elements 2, each of which is caused to assume the same polarity as its adjacent pole element 1.

From this time on up to short-circuit, it is also clear that the generator of Figs. 1 and 2 is simply a machine having two independent electrically opposite fields operating through diametrically opposite portions of a four-pole armature. Obviously, one of these fields is the constant work-field W produced through the pole elements 1, while the other is the reversed field (i. e., the reversed resultant of the work-field W1 and counter-field C) through the pole elements 2, continued terminal voltage reduction with increasing load being obtained as a result of the diminishing difference between these two fields. On short-circuit, of course, the reversed field is substantially the counter-field C alone, which is almost equal to the work-field W, the terminal voltage being caused to assume a value merely in excess of zero to enable it to maintain the required short-circuit current flow.

Since the armature winding is a two-path wave winding, there can be no unbalancing of the armature 3 under load, each of the aforementioned individual voltages generated by the various fields produced through the four armature quadrants being generated in each of the two armature winding paths. For the same reason, only two (a positive 13 and a negative 14) of the four brushes shown on the commutator 12 need be employed, although better commutation results by the use of the four brushes. Also, the three field windings may be so designed that the various working voltages generated on open-circuit are all caused to have the same values, but this is not essential for proper operation of the generator.

As well known in the art, the sudden resistance changes occurring in welding operations are apt to cause the generator to reflect current surges of considerable amplitude in the welding circuit. In the case of self-regulating machines, such surges are in large part due to transformer action of the series-field windings on other windings. It is for this reason that the series-field windings of counter-field generators are caused to establish a field of their own separate from the field established by the constant-field windings.

Again referring to Figs. 1 and 2, the resultant field in part contributed through the pole elements 2 by the series-field winding 6 has no direct influence on the field produced through the pole elements 1 by the constant-field winding 5, since these fields are caused to follow entirely independent magnetic circuits through the machine. The series-field winding 6 may react inductively with each of the other two windings 5 and 7, but the effects of this inductive action of the series-field winding 6 are greatly minimized by its independent location on a pole element separate from those carrying the windings 5 and 7. In this connection it is to be noted that the occurrence of a surge in a welding circuit is accompanied by considerable flux leakage through each of the affected field windings of the generator, the magnitude of the surge largely depending on the extent of mutual induction with reference to these leakage fluxes. Since the three windings 5, 6 and 7 are individually carried by separate pole elements of the field magnet frame, the interlinkage of leakage fluxes between any two windings on adjacent pole elements is practically nil. For this reason the

effects of inductive action of the series-field winding 6 on either of the other two windings 5 and 7 are reduced to a minimum, the transient characteristics of the generator construction of the invention being as good as those of a counter-field generator of the usual construction.

By connecting the shunt-field winding 7 as a long shunt across both armature 3 and series field winding 6, it has been found that appreciable reduction in the short-circuit current value is obtained.

The welding generator illustrated in Fig. 3 contains the same essential elements as described in connection with Figs. 1 and 2, but in addition includes preferred constructional features which for the sake of simplicity have not been shown in Figs. 1 and 2.

Referring to Fig. 3, a fourth winding 23 is now included in the field winding arrangement. This additional winding 23 is a shunt-field winding carried by the formerly unwound pole element 1 and connected to assist in the production of the work-fields through this pole element, all four pole elements being thus utilized for magnetizing purposes. As shown, conductors 24 connect the winding 23 in parallel with the winding 7, while other conductors 25 connect the conductors 24 to the output terminals P and Q. Thus the windings 7 and 23 are each connected as a long shunt across both armature 3 and series-field winding 6. If desired, a rheostat 26 may be inserted in one of the conductors 25 for the purpose of varying the open-circuit voltage.

Since the winding 23 contributes to produce the field through the pole elements 1, this field is no longer constant, but decreases from a maximum on open-circuit to a short-circuit value contributed substantially by the winding 5 alone, although it may be caused to remain substantially constant from open-circuit to short-circuit conditions by the use of pole elements 1 designed to operate at magnetic saturation. As to all other fields produced in the generator of Fig. 3, they are of the same character as the corresponding fields produced in the generator of Figs. 1 and 2, the winding 23 also cooperating with the winding 7 in producing the field through the pole elements 1 and 2 carrying these two windings. Obviously, the field winding arrangement of Fig. 3 has the advantage that the open-circuit voltage value desired may be more economically obtained, which advantage is obtained without altering the transient characteristics obtained with the field winding arrangement of Figs. 1 and 2. The series-field winding 6 has no inductive action on the winding 23. Moreover, any currents induced in the winding 7 are not communicated to the winding 23, the parallel connection of the windings 7 and 23 resulting in a short-circuiting of such currents through the armature.

The welding generator of Fig. 3 has a field magnet frame which includes the usual interpole members 28 disposed to align with the armature commutating zones. Carried by the interpole members 28 are the usual series-excited windings 29, which are all shown connected in the conductor 16 leading from the positive brushes 14 to the series-field winding 6.

For the purpose of varying the current output, the series-field winding 6 in Fig. 6 is carried by a specially constructed pole element 2a comprising an inner core 31 adapted for inward and outward movement through the outer yoke portion of the machine. As shown, the core 31 may be moved by a hand wheel 32 equipped with a screw 34

having its inner end attached to the outer portion of the core 31, a bracket 35 fixed to the outer yoke portion of the machine being provided for cooperative action of the screw 34 therethrough. Movement of the core 31 by the wheel operates to vary the reluctance of the pole element 2a with a resulting variation in the counter-flux produced by the series-field winding 6, which in turn results in a variation of the current delivered by the generator. An inward movement of the core 31 produces a decreased current output, while an outward movement of the core 31 produces an increased current output.

Also included in the generator of Fig. 3 is another current-varying means adapting it for either light or heavy current duty. A switch arm 36 may thus connect the output terminal Q to either one of two switch terminals *t* and *t'*, from which conductors 37 lead to the outer end and to an intermediate point of the series-field winding 6. A throw of the switch arm 36 to one side (contacting it with the terminal *t*) connects the entire winding 6 in circuit, with the result that maximum counter-flux is produced, while a throw of the switch arm 36 to the other side (contacting it with the terminal *t'*) connects a portion only of the winding 6 in circuit, with the result that minimum counter-flux is produced. These two positions of the switch arm 36 are shown in full and dotted lines in Fig. 3, it being apparent that the full line position causes the generator to deliver low current values, while the dotted line position causes it to deliver high current values.

Welding operations are carried out with the current flowing in the arc either in a direction from the electrode or in a direction from the work, depending on the type of welding electrode employed. It is thus for the convenience of the operator that a means is often included in welding equipment by which the polarity of the generator may be controlled.

An important feature of the invention is based on our discovery that the direction of current flow from the output terminals P and Q is positively controlled by the direction of current flow through the constant-field winding 5. In Fig. 3 a simple double-pole double-throw reversing switch 40 is thus shown connected in the conductors 10 supplying the exciting current to the winding 5. The use of this switch has been found to completely reverse directions in all of the aforementioned fields produced through the four pole elements of the field magnet frame (also the directions of the interpole fields), which results in reversing polarities at the generator terminals P and Q. The position of the switch 40 shown in full lines causes the brushes 13 and 14 to assume the polarities indicated, with a resulting direction of current flow in the welding circuit shown by the arrows *a*; while the position of the switch 40 shown in dotted lines causes the brushes 13 and 14 to assume polarities opposite to those indicated, with a resulting direction of current flow in the welding circuit opposite to that shown by the arrows *a*. Obviously, this simple polarity reversing means adds but little to the cost of the equipment.

In the case of alternating-current motor-driven generators, we have also found it possible by the use of simple rectifying means to supply the required exciting current to the constant-field winding 5 from a tapped portion of the motor stator winding. This feature of the invention is also illustrated in Fig. 3. The nu-

meral 42 has reference to the motor stator winding, which is shown as a 3-phase winding connected by conductors 43 to the terminals 44 of an available 3-phase current source. A comparatively small portion 42a of one of the stator winding phases is connected by conductors 45 to the input of a small rectifier 46, the rectified current being supplied to the constant-field winding 5 by the conductors 10 connecting it through the switch 40 to the output of the rectifier 46. Because of the small current required to excite the single constant-field winding 5, the unbalance of the motor caused by tapping into its stator winding does not exceed the usual unbalance of the line. In the case of large machines, however, all three phases of the stator winding 42 may be tapped to avoid any motor unbalance.

Many advantages result from the aforedescribed exciting means. In the first place, the manufacturing cost of the equipment is greatly reduced. Because of the small amount of exciting energy required, the cost of the rectifier 46 is very small as compared to that of the usual exciting generator, the need of a transformer being eliminated by the permitted tapping into the motor stator winding. In the second place, the use of the rectifier 46 positively excludes the possibility of the generator changing its polarity while in welding duty. The generator may thus be used in multiple with another machine without equalizing connections being required. Irrespective of the capacities of the two machines, they conjointly deliver the sum of their respective current output settings, no tendency of a reversal of either by the other being possible.

Fig. 4 illustrates how a substantially constant field may be produced through the pole elements 1 by the use of compound windings deriving their excitation from the generator armature, where no outside source of power is available for excitation purposes, as in the case of gasoline engine driven units. On the pole element 1 formerly carrying the single winding 5, are now carried a series-field winding 50 and a shunt-field winding 51. As shown, the series-field winding 50 may be connected between the conductor 15 leading from the negative brushes and an outer conductor 52 leading to the output terminal P. The shunt-field winding 51 is shown connected as a short shunt, conductors 54 connecting it across the conductors 15 and 16 connecting the two pairs of brushes. As before the shunt-field winding 7 is shown connected as a long shunt across both armature 3 and series-field winding 6, one of the conductors 19 being now connected to the conductor 15 leading to the winding 50.

The two windings 50 and 51 should be connected to assist one another with the view to establishing a work-field through the pole elements 1 from open-circuit to short-circuit conditions. This field on open-circuit is obviously produced by the shunt-field winding 51 alone and under load by the combined action of the two windings 50 and 51. With increase of current supplied to the welding circuit, there is a decrease in the excitation of the shunt-field winding 51, but this is compensated by an increase in the excitation of the series-field winding 50. By the use of pole elements 1 designed to operate at magnetic saturation, the two windings 50 and 51 may thus readily be caused to establish a work-field through such elements of substantially constant intensity from open-circuit to short-circuit conditions.

From the foregoing description it is clear that the generator of Fig. 4 has substantially the same operating features as the generator of Figs. 1 and 2, the two windings 50 and 51 of the former being substantially the equivalent of the single winding 5 of the latter. It is understood, of course, that the generator of Fig. 4 may be additionally equipped with a shunt-field winding on its unwound pole element 1 for more economic production of the open-circuit voltage, as well as with means for varying its current output, as in the case of the generator of Fig. 3.

In Fig. 5 are reproduced four external characteristics of a four-pole frame machine of a construction such as illustrated in Fig. 3. The full line curves A and B were obtained with the switch arm 36 thrown to its low current range position, while the dotted line curves A' and B' were obtained with the switch arm 36 adjusted to its high current range position. The full line curve A and the dotted line curve A' were each obtained with the pole core 31 adjusted to its minimum current position, while the full line curve B and the dotted line curve B' were each obtained with the pole core 31 adjusted to its maximum current position. The full line curves A and B may thus be regarded as limiting characteristics of the machine corresponding to light current duty, while the dotted line curves A' and B' may be regarded as limiting characteristics of the machine corresponding to heavy current duty.

The dot and dash line K in Fig. 5 indicates approximately the voltage values under normal length of arc generally employed in welding operations, the points of intersection of this line with the four characteristics illustrated therefore representing approximately normal current settings of the machine. As noted, the four characteristics illustrated are characterized by considerable drooping causing them to slope steeply at such points. It is this rapid variation in terminal voltage with current change from the normal setting which is especially desired in arc welding in view of the arc stability which is insured; each of the four characteristics illustrated in this respect being excellently suited for arc welding purposes.

Also shown in Fig. 5 are the high open-circuit voltage values permitted by the invention, as well as the considerable current variation over the combined ranges provided for light and heavy current duty.

It has been found that the electrical efficiency of machines constructed in accordance with this invention are exceptionally high.

Having described certain embodiments of the invention, what is claimed is:

1. A direct-current generator for arc welding comprising a four-pole series-wound armature, a field magnet frame having four pole elements circumferentially disposed about said armature, a single constant-field winding for producing a constant work-field through one pair of adjacent pole elements, a single series-field winding for producing a series counter-field through the opposite pair of adjacent pole elements, said constant-field and series-field windings being respectively located on adjacent pole elements, and a shunt-field winding positioned on the pole element opposite to the pole element carrying said constant-field winding, said shunt-field winding opposing said series-field winding.

2. A direct-current generator for arc welding comprising a four-pole series-wound armature, a

field magnet frame having four pole elements circumferentially disposed about said armature, a single constant-field winding for producing a constant work-field through one pair of adjacent pole elements, a single series-field winding for producing a series counter-field through the opposite pair of adjacent pole elements, said constant-field and series-field windings being respectively located on adjacent pole elements, a shunt-field winding positioned on the pole element opposite to the pole element carrying said constant-field winding, said shunt-field winding opposing said series-field winding, and a shunt-field winding on the remaining pole element assisting said constant-field winding.

3. In an apparatus for arc welding, a direct-current generator comprising a four-pole series-wound armature equipped with a commutator provided with load brushes, a field magnet frame having four pole elements circumferentially disposed about said armature, a single constant-field winding for producing a constant work-field through one pair of adjacent pole elements, a single series-field winding for producing a series counter-field through the opposite pair of adjacent pole elements, said constant-field and series-field windings being respectively located on adjacent pole elements, and a shunt-field winding positioned on the pole element opposite to the pole element carrying said constant-field winding, said shunt-field winding opposing said series-field winding; and means for reversing the polarity of said brushes comprising a reversing switch in the exciting circuit of said constant-field winding.

4. In a motor-driven generator unit for arc welding, a direct-current generator comprising a four-pole series-wound armature, a field magnet frame having four pole elements circumferentially disposed about said armature, a single constant-field winding for producing a constant work-field through one pair of adjacent pole elements, a single series-field winding for producing a series counter-field through the opposite pair of adjacent pole elements, said constant-field and series-field windings being respectively located on adjacent pole elements, and a shunt-field winding positioned on the pole element opposite to the pole element carrying said constant-field winding, said shunt-field winding opposing said series-field winding; an alternating-current motor for driving said generator having a stator winding; and means for exciting said constant-field winding comprising a rectifier through which the exciting current to said constant-field winding is supplied from a tapped portion of said motor stator winding.

5. A direct-current generator for arc welding comprising a four-pole series-wound armature, a field magnet frame having four pole elements circumferentially disposed about said armature, a single group of self-excited compound windings for producing a substantially constant work-field through one pair of adjacent pole elements, a single series-field winding for producing a series counter-field through the opposite pair of adjacent pole elements, said group of compound windings and said series-field winding being respectively located on adjacent pole elements, and a shunt-field winding positioned on the pole element opposite to the pole element carrying said group of compound windings, said shunt-field winding opposing said series-field winding.

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