

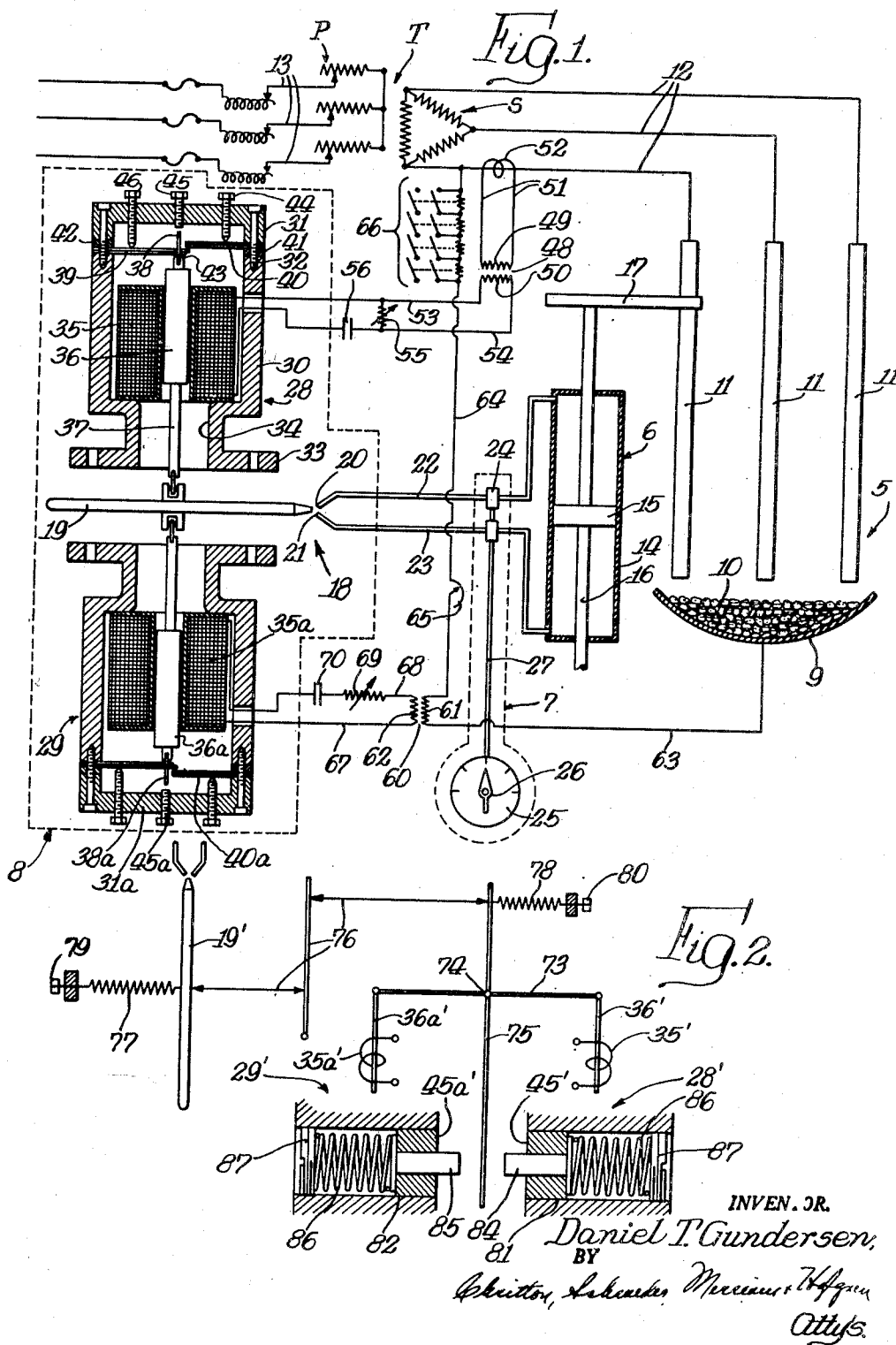
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MULTIPLE SPEED CONTROL SYSTEM

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MULTIPLE SPEED CONTROL SYSTEM

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1

The invention relates generally to a control system for governing the direction and rate of operation or movement of a variable speed motor or motor driven device to obtain a plurality of predeterminable speeds in either direction of operation of the motor or motor driven device. More particularly, the invention relates to such a control system utilized to control a variable condition or factor and thus including means responsive to the condition calling for the changes in direction or rate of operation of the motor.

In a variety of fields it is necessary or at least desirable that a device or element be driven at a plurality of definite but different rates in both a forward and a reverse direction, and that each of the several speeds be independently adjustable. An electric arc furnace is mentioned purely by way of example as typical of a situation requiring such a plurality of speeds of operation. During the melt-down period a rapid movement of the electrodes is required in order that the arc may be held while burning down through thin or poor scrap and, conversely, in order that the electrodes may be rapidly withdrawn and thus guarded against injury in the event of a cave-in of poorly arranged scrap. For what might be referred to as normal operation, by that is meant operation once a pool of metal has been formed, a slow rate of movement of the electrodes is not only satisfactory but desirable because such a slow rate of movement adds to the stability of operation, whereas a high rate of movement would tend to induce oscillation or hunting of the electrodes.

The need for different rates of operation during normal and abnormal operating conditions is apparent from the foregoing. It is also frequently desirable and particularly true in an electric arc furnace that the rates of operation within the normal and within the abnormal range also vary. Thus while during a melt-down period the electrodes should be capable of rapid movement toward the melt, so as to hold the arc while burning down through thin or poor scrap, the rate of movement should nevertheless be tempered so that the electrodes will not be broken by striking the scrap with too much force. On the other hand, withdrawal of the electrode to escape a cave-in can and should be made at a very high rate. During normal operation, that is, when a pool of molten metal has been formed, the rate of withdrawal of the electrodes is preferably less than the rate of feed-in of the electrodes for the possibility of breaking the arc is greater. In the case of an electric arc furnace,

2

and undoubtedly parallel circumstances would exist in other applications of the control system, a third speed in one direction is desirable, namely, a withdrawal of the electrodes in the event of power failure to the electrodes.

It is an object of this invention, therefore, to provide a control system of new and improved construction, operable to obtain such a plurality of predeterminable speeds in a more facile manner and with a more simplified construction than heretofore.

Another object is to provide a control system having means acting as a breachable, low range speed limit and additional means acting as a positive and high speed limit.

Another object is to provide a speed control system for a reversible motor having for each direction of operation of the motor a first means acting as a breachable, low range speed limit, and a second means acting as a positive and high speed limit, and means biasing the system in one direction to obtain a fifth speed.

Another object is to provide a system for controlling the speed of a motor operable for either direction of operation of the motor to permit operation at any speed up to a certain predetermined limit and further operable to permit, under proper conditions, breach of the above mentioned limits and operation at predetermined higher speeds, each limit being independently adjustable.

A further object is to provide a control system having means responsive to a condition, power means for effecting an adjustment of the condition, and means controlled by the responsive means governing the power means, the last named means including adjustable, low range limits determining the rate of operation in either direction in response to ordinary changes in the condition and adjustable high range limits, the low range limits being breachable upon extraordinary changes in the condition to permit operation of the power means at the high rate determined by the high range limits.

Still a further object is to provide a control system for the electrode of an electric arc furnace which operates to adjust the electrode in response to current in and voltage across the arc, normal variation in current and voltage causing movement of the electrode toward or from the melt at certain predeterminable low rates, extraordinary variation in current or voltage causing breach of the low rate limits and movement of the electrode at certain predeterminable higher rates, the system in event of power failure to the

electrode operating to withdraw the electrode from the melt.

Yet a further object is to provide a control system for the electrode of an electric arc furnace having a solenoid responsive to the current in the arc and a solenoid responsive to the voltage across the arc, the solenoids acting in opposition on a rate and direction of movement determining means for the electrode, a yieldable, adjustable stop for each solenoid providing a limit to a normal rate of movement, an adjustable, non-yieldable stop for each solenoid coming into play, upon extraordinary current or voltage conditions causing a breach of the yieldable stop, to provide a nonbreachable maximum rate of movement limit, and means biasing the electrode movement determining means in a direction to cause withdrawal of the electrode from the melt in the event of power failure to the electrode.

Other objects and advantages will become apparent from the following detailed description taken in connection with the accompanying drawing, in which:

Fig. 1 is a diagrammatic illustration of a control system embodying the features of my invention, herein by way of example shown as applied to the control of an electric arc furnace.

Fig. 2 is a fragmentary view showing a modified form of a portion only of the system of Fig. 1.

While the invention is susceptible of various modifications and alternative constructions, it is shown in the drawing and will hereinafter be described in a preferred embodiment and one modification of a part thereof. It is not intended, however, that the invention is to be limited thereby to the specific constructions disclosed. On the contrary, it is intended to cover all modifications and alternative constructions, uses and adaptations falling within the spirit and scope of the invention as defined by the appended claims.

The control system disclosed herein is adapted, broadly speaking, to govern the rate and direction of operation of a power means such as a motor. Control of the direction of operation of the power means is a mere obtaining of forward or reverse operation. Control of the rate of operation, however, is such that for any given adjustment five definite speeds may be obtained, and these speeds may be varied by a different setting of the adjusting means. More particularly, the system is adapted to control a condition in response to the state of that condition, with the power means controlled by the system operating at a low range of rates for normal variations in the condition and at a high range of rates for extraordinary or abnormal changes in the condition.

Turning now to the exemplary embodiment of the invention in the control system of Fig. 1, as there adapted for the control of an electric arc furnace, the system comprises generally an electric arc furnace 5, power means 6 for effecting movement of the electrodes of the furnace toward or from the melt therein, and control means for the power means comprising manual means 7 and automatic means 8, the latter being operable to maintain the electrodes of the furnace in desired position. Like the majority of the system, the electric arc furnace 5 is shown diagrammatically only with 9 representing a main portion of the furnace holding the melt 10. The furnace is of the three-phase type and thus has three electrodes 11 each mounted for independent movement toward or from the melt. Power is supplied to the electrodes through a transformer T

having a Y-connected primary P and a delta-connected secondary S with a lead 12 extending from each point of the delta-connected secondary to one of the electrodes 11. Preferably taps are provided either on the secondary or on the primary of the transformer to obtain different power inputs to the arc. Herein such taps are provided on the primary winding P and designated by the reference character 13.

Each of the electrodes 11, as already stated, is movable independently of the other electrodes and to that end each has its own power means 6 and its own control system 7, 8. Inasmuch as the power means and the control system are the same for each of the electrodes 11, only one such power means and one such control system is herein shown in the drawing and will hereinafter be described. It is not to be overlooked, however, that actually three such power means and control systems are employed. Though the power means might take a variety of forms, it is herein disclosed as a hydraulic motor of the reciprocatory type having a cylinder 14 with a port opening to each end thereof and a piston 15 reciprocable therein. A piston rod 16 extends in both axial directions from the piston 15 and through both ends of the cylinder 14 in order that there may be no difference in volume between opposite ends of the cylinder. At one end, herein the upper end as viewed in Fig. 1, the piston rod 16 is through the medium of a bar 17 or other suitable means connected to one of the electrodes 11 so as to impart with movement of the piston 15 a feeding of the electrode toward the melt or a withdrawal of the electrode from the melt. Conventionally, but not here shown, a counterweight is provided to offset the weight of the electrode.

The fluid supplied to the cylinder 14 during automatic regulation of the electric arc furnace is governed by a regulator, generally designated 18, which is of the "Askania" pivoted jet type. Such a regulator comprises generally a pivoted jet pipe 19 from which fluid under pressure is discharged in the form of a jet and directed against a plate having a pair of closely adjacent orifices 20 and 21 formed therein. As is customary and known, the fluid employed is preferably oil and is the same oil that is supplied to the cylinder 14 in order to obtain more direct and immediate response to any movement of the jet pipe 19. The regulator functions in well known manner to hold the power means 6 stationary when the jet pipe 19 is in neutral or normal position, that is, with its jet impinging equally against both orifices, and functions with any slight departure from this neutral position to cause movement of the power means, the rate of movement of the power means varying with the degree of departure of the jet pipe from neutral or normal position. There is, accordingly, connected to one of the orifices, herein the orifice 20, a conduit 22 leading to the top end of the cylinder 14 and connected to the orifice 21 a conduit 23 leading to the bottom end of the cylinder 14. It will be understood, of course, that fluid in suitable volume and under suitable pressure is supplied to the jet pipe 19 by means not herein shown. Such means usually have provision for a supply of fluid sufficient to raise the electrode from the melt in the event of complete and total power failure including failure of the means driving the fluid source. Apparatus of that character is more particularly disclosed and claimed in the application of Daniel T. Gundersen and

Paul Glass, Serial No. 512,520, filed December 2, 1943.

At times manual control of the power means 6 is desirable. To that end, there is interposed in the conduits 22 and 23 a rotary main control valve 24 of any well known construction. Such a valve should be capable either of rendering the power means automatically controlled, that is, by the regulator 18 under the influence of the balance of the control means 8, or to cut off the regulator and cause fluid to be supplied under pressure either to the upper end of the cylinder 14 to lower the electrode or to the lower end of the cylinder 14 to raise the electrode 11. Herein the valve 24 is shown as regulated from a remote point at which there is located a dial 25, a handle or pointer 26, and suitable means represented at 27 for connecting the handle 26 and the valve 24.

As previously generally indicated, the system is adapted to control a condition and, therefore, includes means responsive to the condition. Herein this condition, of course, is the arc of the electric furnace. Measurable characteristics of the arc, and, moreover, characteristics which must bear a certain relationship to one another for satisfactory operation of the furnace are the current in the arc and the voltage across the arc. Accordingly, means 28 and 29 are provided acting in opposition to one another on the jet pipe 19 of the regulator 18 with one of these means, herein 28, made responsive to the current in the arc and the means 29 made responsive to the voltage across the arc. Herein the means 28 and 29 are solenoid devices each comprising a generally cylindrical housing composed of a main portion 30 and a closure cap 31 removably secured as by means of screws 32. At the end opposite the closure, the main body portion 30 is provided with an apertured flange 33 to adapt the housing for mounting adjacent the regulator 18 and at that same end is provided with an opening 34 through which operative connection may be effected between the parts within the housing and the jet pipe 19.

Within each housing is a coil 35 disposed with its axis axially of the housing and reciprocable within the coil is a core 36. The coil 35 is so wound and so connected in circuit that when energized it urges the core 36 inwardly, that is, downwardly as viewed in Fig. 1. An extension 37 of one end of the core 36 projects through the opening 34 in the housing and engages the jet pipe 19 while an extension 38 of the opposite end of the core 36 projects through and is supported by a leaf spring 39, the core thus being floatingly suspended within the coil. The leaf spring 39 is supported by being clamped between the closure cap 31 and the main portion 30 of the housing and projects radially inwardly. A second leaf spring 40 is similarly clamped between the closure cap 31 and the main portion 30 of the housing and again projects radially inwardly terminating slightly short of the extension 38 of the core and preferably is approximately diametrically opposite the spring 39. Washers 41 and 42 are utilized to offset the leaf springs 39 and 40 from one another longitudinally of the housing, the washer 41 being interposed between the main portion of the housing and the spring 40 and the washer 42 being interposed between the closure cap 31 and the spring 39. Inwardly of the leaf spring 39 the extension 38 of the core is provided with a shoulder 43 so that as the core 36 moves outwardly, that is, upwardly as viewed in Fig. 1, the inner end of the leaf spring is moved with it

and thus after predetermined movement engages the leaf spring 40 which then overlaps sufficiently to make this contact. The spring 40 constitutes the adjustable and breachable stop, above generally described, constituting the limit of the low rate of movement which may be imparted to the electrode. The spring 40 is designed to have such strength that during what may be referred to as normal operation of the system, that is, when a pool of molten metal has been formed, the spring 40 is strong enough to prevent shifting of the core 36 outwardly beyond the point of contact of the spring 39 with the spring 40. Since the position of the core 36 bears a definite relationship to the position of the jet pipe 19 and since the position of the jet pipe determines the rate at which the power means 6 is driven, the spring 40 thus serves to determine the limit of the low rate of movement of the electrode 11 in one direction. This limit is variable and is determined by a manual adjusting means which herein takes the form of an adjusting screw 44 which projects through the closure cap 31 into contact with the spring 40. It will be appreciated that as the screw 44 is adjusted inwardly or outwardly the inner end of the leaf spring 40 will be moved to vary the low range, breachable stop position.

It will be appreciated that the spring 40 is yieldable and thus does not form a positive stop but, on the contrary, is, under extraordinary conditions, breachable and thus permits additional movement of the core 36 with resultant further pivoting of the jet pipe 19 and the increased rate of operation of the power means resulting therefrom. To provide a limit for the movement of the core 36 when the limit formed by the spring 40 is breached, there is mounted in the closure cap 31 a second screw 45 disposed coaxially of the housing so as to be abutted by the extension 38 of the core 36 when the stop formed by the spring 40 is breached. The screw 45, like the screw 44, is adjustable so as to vary the permissible extent of shift of the core 36 and hence the pivoting of the jet pipe 19 and the resultant rate of movement of the power means 6. For a purpose which will later be more fully described, the housing of the means 28 is provided with a third adjustable screw 46 which bears against the leaf spring 39. The spring 39 and the screw 46 are normally adjusted to provide a slight bias to the control system, tending to maintain the jet pipe 19 slightly to one side of rather than in strictly neutral position. The object, as will presently be more fully made known, is to cause the system to withdraw the electrode from the melt in the event of total power failure.

Except for the screw 46 which need not be present, the means 29 is identical with the means 28. Therefore, to avoid purely repetitious description while at the same time applying a distinguishing reference character in subsequent reference to the various elements in the description of the operation and the like, the corresponding number plus the letter *a* has been given to the elements of the means 29 in the drawing. It will thus be appreciated that the spring 40 and the adjustable screw 45 of the means 28 actually form the stops limiting movement of the core 36a under actuation by the coil 35a. Conversely, the spring 40a and the screw 45a serve as the stops limiting movement of the core 36 upon energization of the coil 35.

As already stated, the means 28 is responsive to the current in the arc and to that end the

coil 35 is connected to be energized in proportion to the current flowing in the arc. This energization is preferably effected through a transformer 48 having a primary 49 and a secondary 50. The primary 49 is by leads 51 connected to the coil 52 of a current transformer associated with one of the leads 12 extending between the main power transformer and the electrode. The secondary winding 50 is by leads 53 and 54 connected to the coil 35. Connected across the leads 53 and 54 and parallel with the coil 35 to adjust the response thereof to the current flowing in the arc is a variable resistance 55 while connected in the lead 54 to be in series with the coil 35 is a condenser 56. The value of the condenser 56 is so chosen as to balance out the inductance of the coil 35 and thus reduce the voltage that is required for energization of the coil 35.

The means 29 is, as stated, responsive to the voltage across the arc and to that end the coil 35a is connected to be energized in proportion to the voltage across the arc. This energization is preferably effected through the medium of a transformer 60 having a primary winding 61 and a secondary winding 62. One terminal of the primary winding 61 is by a lead 63 connected to the metallic shell forming a part of the main melt-holding portion 9 of the electric furnace. The other terminal of the primary winding 61 is connected to the lead 12 serving the electrode here under consideration by a lead 64 which has incorporated therein an adjustable rheostat 65 and a plurality of tap switch resistors 66. The tap switch resistors 66 are provided to permit adjustment of the circuit for the coil 35a in accordance with the voltage applied to the power transformer as determined by the changing taps 13. By means well known in the electrical art, these resistors may be cut in or out of circuit by the same means which changes the taps of the power transformer T. The rheostat 65 actually serves as a means for regulating the current that will flow in the electric arc.

The secondary winding 62 of the transformer 60 is by leads 67 and 68 connected to the terminals of the coil 35a, the lead 68 having interposed therein a variable resistance 69 and a condenser 70. The resistance 69 and the resistance 55 serve to vary the sensitivity of the control and to a degree the limit of the low speed range jointly with the breachable stop limits 40 and 40a. The condenser 70 is provided in order again to balance out as much as possible the inductance of the coil 35a so as to lower the voltage that is required to energize the coil.

Turning now to Fig. 2, there is there disclosed a modified form for a portion of the control system disclosed in Fig. 1. Should it not be feasible for some reason or other to have the solenoid devices act directly on the pivoted pipe 19 of the jet pipe regulator, or should it be desired to convert a single or at best two-speed installation into a multiple speed installation, the construction disclosed in Fig. 2 may be employed. As shown in Fig. 2, the control system still includes means 28' and 29', respectively responsive to the current in and the voltage across the electric arc. These means include solenoid coils 35' and 35a' with their cores 36' and 36a'. In place, however, of being directly associated with the jet pipe 19', the cores are here connected to a beam balance 73 which is pivoted at 74 and has rigid therewith a rod 75 extending at right angles to the beam in both directions therefrom. The

upper portion of the rod, as viewed in Fig. 2, is through a suitable linkage system 76 operatively associated with the jet pipe 19', the jet pipe actuating system being completed by compression springs 77 and 78, the first being interposed between jet pipe 19' and an adjustable abutment 79 and the latter being interposed between the upper portion of the rod 75 and an adjustable abutment 80. It is possible that the springs 77 and 78 be so adjusted as to bias the system in such manner as to cause a withdrawal of the electrode from the melt upon power failure to the furnace.

Also present are means providing the breachable stops determining the low rate of movement limits, and nonbreachable stops determining the maximum or high speed rate of movement limits. The high speed, nonbreachable stops here take the form of a pair of cylinders 81 and 82 disposed on opposite sides of the depending portion of the rod 75 with the inner ends 45' and 45a' of the cylinders corresponding to the high speed limit stops 45 and 45a. The breachable stops forming the limits for the low range or rate of movement of the electrode are again in the form of yieldable spring means herein comprising plungers 84 and 85 projecting through and somewhat beyond the ends 45' and 45a', respectively. Each of the plungers is backed by a compression spring 86 housed within the cylinders 81 and 82 and abutting adjustable closures 87 for the cylinders to vary the extent of projection of the plungers 84 and 85, in turn to vary the limits of the low rate of movement imparted to the electrode. As in the form of the invention shown in Fig. 1, the low rate limit stops are so designed as to limit the extent of pivoting of the beam balance 73 and hence the extent of pivoting of the jet pipe 19 so long as the coils 35' and 35a' are subjected only to normal variations in current and voltage variations in the arc. Upon any abnormal or extraordinary variations, such as might occur during melt-down of the scrap, the plungers 84 and 85 will yield and permit the beam balance 73 to swing a greater extent and will be limited only by abutment of the lower portion of the rod 75 with the ends 45' and 45a' constituting the positive, nonbreachable stops.

While it is believed that the operation of the system will be readily understood from the foregoing description, a brief résumé of the operation may help to clarify understanding of the invention and particularly the importance of certain features or phases thereof. Let it be assumed, therefore, that the control handle 26 has been rotated to automatic position whereby the power means 6 is under the control of the regulator 18 and the electrical portions of the system. Let it be further assumed that the taps 13 have been adjusted to provide the desired power to the furnace but that no power is as yet being supplied; that the resistors 66 have been correspondingly adjusted; that the rheostat 65 has been adjusted to give the desired current value in the electric arc; and that the resistances 55 and 69 have been adjusted to provide the desired sensitivity of control. Also assume that fluid is being supplied to and discharged from the jet pipe 19 of the regulator under pressure. Inasmuch as there is no power being supplied neither the current coil 35 nor the voltage coil 35a is energized and thus the system is controlled by the bias imposed on the system by the spring 38. The action of this spring is to pivot the jet pipe 19 clockwise as viewed in Fig. 1, thereby causing the jet to impinge to a

somewhat greater extent upon the orifice 21 and thus to cause upward movement of the piston 15 withdrawing the electrode 11 or maintaining it withdrawn.

If now power is supplied to the primary of the transformer T, the voltage coil 35a will be strongly energized, in fact, will be extraordinarily energized, for the full voltage of one phase of the secondary system of the transformer T is now impressed across the arc. The current coil 35, however, remains deenergized because as yet no current is flowing. The result, of course, is a pivoting of the jet pipe 19 in a counterclockwise direction with the differential of the forces acting on the cores 36 and 36a now being great enough to flex the leaf spring 40, thereby breaching the low range limit and coming to rest only upon abutment with the high speed limit stop 45. This means that the jet from the pipe 19 is impinging to a greater extent upon the orifice 20 than upon the orifice 21 and the piston 15 is moved downwardly to feed the electrode toward the melt. The rate of movement of the electrode while higher than the rate determined by the leaf spring 40 is preferably still tempered so that the force with which the electrode strikes the melt is not so great as to break the electrode.

Upon contact of the electrode with the melt, an arc is established and thus temporarily a short circuit is created resulting in a large flow of current in the arc and a correspondingly very low voltage across the arc. The tables are now reversed with the current coil 35 being extraordinarily energized and the voltage coil 35a being very weakly energized, and hence the differential of the forces acting on the cores 36 and 36a will be such as to pivot the jet pipe 19 in a clockwise direction. This force will again be enough to overcome the leaf spring 40a and thus the withdrawal of the electrode 11 from the melt will be at the high rate determined by abutment of the extension 38a of the core 36a with the positive, nonbreachable stop 45a. This rate of withdrawal is normally adjusted to be higher than the rate of feed-in movement of the electrode though, of course, it should not be so rapid as to cause extinction of the arc. As the electrode is withdrawn, the voltage across the arc, of course, increases while the current in the arc decreases and, with such changes, the energization of the coils 35 and 35a will correspondingly be changed until at some point the desired current voltage relationship of the arc will be attained and the forces of the coils 35 and 35a and the bias of the spring 39 will balance out and the jet pipe 19 will come to rest in its neutral position.

Should the scrap be thin or poorly arranged, it is conceivable that conditions might arise requiring rapid feed-in of the electrode to avoid extinguishment of the arc or rapid withdrawal of the electrode to prevent injury thereto as a result of a cave-in. Thus it might be that after burning through a layer of scrap a large space is encountered. As a result the voltage across the arc would again rise to a high value while the current in the arc is materially reduced if, in fact, the arc is not extinguished. A condition simulating the first above described condition would thus exist, namely, low energization of the current coil 35 and high energization of the voltage coil 35a, with resultant pivoting of the jet pipe 19 counterclockwise and most likely a breach of the low speed limit stop 40 with a high rate of feed-in of the electrode 11. Conversely, poorly arranged scrap might result in

a cave-in. This would mean a shortening of the arc, lower voltage and higher current, bringing about a withdrawal of the electrode, and if the cave-in is severe enough such extraordinary changes in current and voltage as to breach the limit stop provided by the leaf spring 40a and resultant high speed withdrawal as determined by the nonbreachable, high speed limit stop 45a. Again at some point in the withdrawal the current-voltage relationship in the arc would be that desired and the forces of the means 28 and 29 would again balance and the regulator return to neutral position and the electrode come to rest.

Once a pool of molten metal has been formed, the variations in current and voltage are likely to be less pronounced. Under these circumstances, though there will be such variations, the force differential will not be enough to breach the limit stops provided by the leaf springs 40 and 40a and hence the movements of the electrode in either direction will not exceed the comparatively slow rate determined by adjustment of the springs 40 and 40a. This is desirable for it tends to stabilize the system and avoid hunting. It will be appreciated that if at any time during the operation of the electric furnace there should be a power failure to the furnace the spring 39 will take control and urge the jet pipe 19 in such direction that the electrode will be withdrawn at the rate determined by adjustment of the screw 46. It will be appreciated that the operation of the modified form of control means shown in Fig. 2 will be the same as that above described.

It is believed apparent from the foregoing that I have perfected an improved control system particularly applicable to the control of an electric arc furnace and also applicable to the control of any device or element desired to be moved in opposite directions at different speeds, especially when the control for such movements is to be derived from the device itself or some condition or factor varying with the position of the device. An important advantage of the system is the simplicity in design while still obtaining five separate and different speeds. There is in this system, particularly the control portion thereof, a total absence of rotating parts, a minimum of pivoted parts, and a minimum of mass in any moving parts, to increase accuracy, sensitivity and quickness of response of the system. In addition, the system has great flexibility to meet a variety of operating conditions.

I claim as my invention:

1. In combination with the electrode of an electric arc furnace adapted to have melt therein and power means for moving the electrode toward and from the melt, means for controlling the power means to determine the rate and direction of movement of the electrode including means responsive to the current in and the voltage across the arc of the electrode operating to cause a positioning of the electrode relative to the melt to maintain a desired current-voltage relationship in the arc, a first pair of means providing limits for the rate at which the electrode may be moved under normal variations in the current-voltage relationship of the arc, and a second pair of means providing nonbreachable higher limits of rate of movement of the electrode, the limits established by said first pair of means being breachable upon extraordinary changes of the current-voltage relationship in the arc.

2. In combination with the electrode of an

electric arc furnace adapted to have melt therein and power means for moving the electrode toward and from the melt, means for controlling the power means to determine the rate and direction of movement of the electrode including means responsive to the current in and the voltage across the arc of the electrode operating to cause a positioning of the electrode relative to the melt to maintain a desired current-voltage relationship in the arc, a first pair of means providing limits for the rate at which the electrode may be moved under normal variations in the current-voltage relationship of the arc, a second pair of means providing nonbreachable higher limits of rate of movement of the electrode, the limits established by said first pair of means being breachable upon extraordinary changes of the current-voltage relationship in the arc, and means for adjusting each of said limit-forming means independently.

3. In combination with the electrode of an electric arc furnace adapted to have melt therein and power means for moving the electrode toward and from the melt, means for controlling the power means to determine the rate and direction of movement of the electrode including means responsive to the current in and the voltage across the arc of the electrode operating to cause a positioning of the electrode relative to the melt to maintain a desired current-voltage relationship in the arc, a first pair of means providing limits for the rate at which the electrode may be moved under normal variations in the current-voltage relationship of the arc, a second pair of means providing nonbreachable higher limits of rate of movement of the electrode, the limits established by said first pair of means being breachable upon extraordinary changes of the current-voltage relationship in the arc, and means biasing said control means in a direction to effect withdrawal of the electrode from the melt upon power failure to the electrode.

4. In combination with the electrode of an electric arc furnace adapted to have melt therein and power means for moving the electrode toward or from the melt, control means for determining the rate and direction of movement imparted to the electrode by said power means including a primary governing element for the power means, a first solenoid device responsive to the current in the arc of the electrode operating upon increase of the current in the arc to tend to actuate said primary governing element in a direction to effect withdrawal of the electrode from the melt at increasing rates, a second solenoid device responsive to the voltage across the arc acting on said primary governing element in opposition to said first solenoid and tending with increases in voltage across the arc to actuate said primary governing element in a direction causing movement of the electrode toward the melt at increasing rates, a pair of means operatively associated one with each solenoid device to provide an intermediate limit for the rate of movement of the electrode in either direction under normal changes of the current voltage relationship of the arc, a second pair of means associated one with each solenoid device providing a nonbreachable limit for the rate of movement of the electrode in either direction, said first pair of means being yieldable to provide limits that are breached upon extraordinary changes of the current-voltage relationship of the arc.

5. In combination with the electrode of an electric arc furnace adapted to have melt therein

and power means for moving the electrode toward or from the melt, control means for determining the rate and direction of movement imparted to the electrode by the power means including a primary governing element for said power means, a first solenoid device responsive to the current in the arc of the electrode operating upon increase of the current in the arc to tend to actuate said primary governing element in a direction to effect withdrawal of the electrode from the melt at increasing rates, a second solenoid device responsive to the voltage across the arc acting on said primary governing element in opposition to said first solenoid and tending with increases in voltage across the arc to actuate said primary governing element in a direction causing movement of the electrode toward the melt at increasing rates, a pair of resiliently yieldable elements associated one with each of said solenoid devices acting to interpose an obstruction to movement of the cores of said solenoid devices after predetermined movements thereof to constitute intermediate limits for the rate of movement of the electrode in either direction, each of said yieldable means being independently adjustable and having sufficient strength to resist movement of the cores of said solenoid devices beyond the predetermined limits so long as said solenoid devices are subjected to normal changes in the current-voltage relationship of the arc but yielding to permit further movement of the cores of said solenoid devices when said solenoid devices are subjected to extraordinary changes in the current-voltage relationship of the arc, and an adjustable but nonyielding stop for each of said solenoid devices providing a maximum limit to the rate of movement of the electrode under such extraordinary changes of arc current or voltage.

6. In combination with the electrode of an electric arc furnace adapted to have melt therein and power means for moving the electrode toward or from the melt, control means for determining the rate and direction of movement imparted to the electrode by the power means including a primary governing element for said power means, a first solenoid device responsive to the current in the arc of the electrode operating upon increase of the current in the arc to tend to actuate said primary governing element in a direction to effect withdrawal of the electrode from the melt at increasing rates, a second solenoid device responsive to the voltage across the arc acting on said primary governing element in opposition to said first solenoid and tending with increases in voltage across the arc to actuate said primary governing element in a direction causing movement of the electrode toward the melt at increasing rates, each of said solenoid devices having a coil and a core, a variable resistor connected in parallel with the coil of said first solenoid device, a variable resistor connected in series with the coil of said second solenoid device, a pair of means operatively associated one with each solenoid device to provide an intermediate limit for the rate of movement of the electrode in either direction under normal changes of the current-voltage relationship of the arc, a second pair of means associated one with each solenoid device providing a nonbreachable limit for the rate of movement of the electrode in either direction, said first pair of means being yieldable to provide limits that are breached upon extraordinary changes of the current-voltage relationship of the arc.

7. In combination with the electrode of an electric arc furnace adapted to have melt therein and a reversible hydraulic motor for moving the electrode toward or from the melt, a regulator for governing the motor comprising a pair of orifices connected one to each side of said motor and a pivoted jet pipe discharging fluid under pressure impinging against said orifices, and means for actuating said regulator comprising means responsive to the current and voltage of the arc of the electrode acting on said jet pipe to cause a positioning of the electrode to maintain a desired current-voltage relationship in the arc, a first pair of stops providing limits for the rate of adjustment of the electrode for normal variations in the current-voltage relationship of the arc, said stops being breachable upon extraordinary departure from the desired current-voltage relationship of the arc to permit more rapid adjustment of the electrode, and a pair of nonbreachable stops providing limits for the rate of adjustment at the higher speeds.

8. In combination with the electrode of an electric arc furnace adapted to have melt therein and a reversible hydraulic motor for moving the electrode toward or from the melt, a regulator for governing the motor comprising a pair of orifices connected one to each side of said motor and a pivoted jet pipe discharging fluid under pressure impinging against said orifices, and means for actuating said regulator comprising means responsive to the current and voltage of the arc of the electrode acting on said jet pipe to cause a positioning of the electrode to maintain a desired current-voltage relationship in the arc, a first pair of stops providing limits for the rate of adjustment of the electrode for normal variations in the current-voltage relationship of the arc, said stops being breachable upon extraordinary departure from the desired current-voltage relationship of the arc to permit more rapid adjustment of the electrode, a pair of nonbreachable stops providing limits for the rate of adjustment at the high speeds, means for adjusting each of said stops independently, and means biasing said regulator in a direction to cause withdrawal of electrode upon power failure to the electrode.

9. In combination with the electrode of an electric arc furnace adapted to have melt therein and a reversible hydraulic motor for moving the electrode toward or from the melt, a regulator for governing the motor comprising a pair of orifices connected one to each side of said motor and a pivoted jet pipe discharging fluid under pressure impinging against said orifices, and means for actuating said regulator comprising a pair of solenoid devices acting in opposition on said jet pipe, each of said devices comprising a coil and a core one end of which is in operative engagement with said jet pipe, means supporting the remaining end of the core for axial movement of the core, a resilient element interposed in the path of movement of the core in one direction, adjustable means associated with said resilient element forming of said resilient element a stop obstructing further movement of the core in one direction, and an adjustable, nonyielding element forming a final stop for movement of the core when excessive force on the core overcomes the resistance offered by said yieldable element, the coil of one of said solenoid devices being connected to be responsive to current in the arc, the coil of the other of said solenoid devices being connected to be responsive

to the voltage across the arc, and means biasing said regulator to effect withdrawal of the electrode upon power failure to the electrode.

10. In combination with the electrode of an electric arc furnace adapted to have melt therein and a power means for moving the electrode toward and from the melt, means for controlling the power means to determine the rate and direction of movement of the electrode including means responsive to the current in and the voltage across the arc of the electrode operating to cause a positioning of the electrode relative to the melt to maintain a desired current-voltage relationship in the arc, a first limit means predetermining a normal rate of withdrawal of the electrode, a second limit means predetermining the normal rate of feed-in of the electrode, a third limit means determining the rate of withdrawal of the electrode under conditions approximating short circuit of the electrode, a fourth means determining the rate of feed-in of the electrode under conditions approximating no current flow in the arc, and a fifth limit means determining the rate of withdrawal of the electrode upon power failure to the electrode, each of said limit means being adjustable to vary the rate determined thereby.

11. In a control system for governing the rate and direction of operation of a motor or the like, a primary element determining by the direction and the extent of its adjustment the direction and the rate of movement of the motor, a pair of solenoid devices acting in opposition to control said primary element, and means associated with said solenoid devices providing stops limiting the extent of adjustment of said primary element comprising a first pair of spring devices providing limits to the adjustments of said primary element for normal energizations of said solenoid devices, said spring devices yielding under the force of extraordinary energization of said solenoid devices, and a pair of nonyielding abutments coming into play upon yielding of said spring devices.

12. In a control system for governing the rate and direction of operation of a motor or the like, a primary element determining by the direction and the extent of its adjustment the direction and the rate of movement of the motor, and a pair of solenoid devices acting in opposition to control said primary element, each of said devices comprising a housing, a solenoid within the housing having a coil and a core, one end of the latter being in operative engagement with said primary element, a leaf spring mounted within said casing and extending transversely of the axis of said core and into the path of movement of said core, an adjustable screw engaging said leaf spring to determine the position of the end thereof projecting into the path of the core, and a second adjustable screw positioned to be abutted by means carried by said core positively to limit movement of said core when the force on said core is sufficient to overcome the resistance offered by said leaf spring, and a second leaf spring in at least one of said solenoid devices operating to shift said primary element away from neutral position when the coil of neither solenoid device is energized.

13. In a control system for governing the rate and direction of operation of a motor or the like, a primary element determining by the direction and extent of its adjustment the direction and the rate of movement of the motor, and a pair of solenoid devices acting in opposition to control

said primary element, each of said devices comprising a cylindrical housing composed of a main portion having a restricted opening at one end and a closure cap for the remaining end of the housing, a solenoid within the housing having a coil and a core extending with their axes longitudinally of the housing, an extension on one end of the core in operative engagement with and supported by said primary element, a leaf spring clamped at one end between the parts of said housing and projecting radially inwardly, an extension on the remaining end of said core projecting through the free end of said leaf spring to be supported thereby for longitudinal floating movement, a second leaf spring clamped at one end between the parts of said housing and projecting radially inwardly to be engaged by means on said core upon movement of said core toward said closure cap, a first adjustable screw carried by said closure cap and engaging said last named leaf spring to adjust the position of the free end thereof axially of said housing and a second adjustable screw carried by said end closure and adapted to be abutted by the extension on said core upon movement thereof beyond the limit determined by said last named leaf spring, and means in one of said solenoid devices acting to bias said primary element away from neutral position.

14. In a control system for governing the rate and direction of operation of a motor or the like, a regulator of the jet type having a pivoted jet pipe determining by the direction and extent of its pivoting the direction and the rate of movement of the motor, and a pair of solenoid devices acting in opposition to control said jet pipe, each of said devices comprising a housing, a solenoid within the housing having a coil and a core, one end of the latter being in operative engagement with said jet pipe, means for supporting the remaining end of the core for floating movement axially, a leaf spring mounted in said casing and extending transversely of the axis of said core and into the path of movement of said core, an adjustable screw engaging said leaf spring to determine the position of the end thereof projecting into the path of said core, and a second adjustable screw positioned to be abutted by means carried by said core positively to limit movement of said core when the force on said core is sufficient to overcome the resistance offered by said leaf spring.

15. In a control system for maintaining a desired condition, power means operable at variable speeds and in opposite directions to influence the condition and control means for said power means comprising a pair of means responsive to some measure of the condition acting in response to changes in the condition to cause said power means to operate in one direction or the other at different rates, a pair of means constituting stops providing limits for the rates of movement at which said power means operates during normal changes in the condition being controlled, each of said stop elements being separately adjustable to permit of a difference in the limit of the rate of movement in opposite directions, said stop elements being breachable upon extraordinary changes in the condition being controlled, and a pair of positive nonbreachable stop elements providing maximum limits for the rate of operation of said power means, said positive stop elements also being independently adjustable to vary the maximum rate of operation of the power means in opposite directions and thus permit

of obtaining four separate limits of rate of movement of said power means.

16. In a control system for maintaining a desired condition, power means operable at variable speeds and in opposite directions to influence the condition and control means for said power means comprising a pair of means responsive to some measure of the condition acting in response to changes in the condition to cause said power means to operate in one direction or the other at different rates, a pair of means constituting stops providing limits for the rates of movement at which said power means operates during normal changes in the condition being controlled, each of said stop elements being separately adjustable to permit of a difference in the limit of the rate of movement in opposite directions, said stop elements being breachable upon extraordinary changes in the condition being controlled, a pair of positive nonbreachable stop elements providing maximum limits for the rate of operation of said power means, said positive stop elements also being independently adjustable to vary the maximum rate of operation of the power means in opposite directions and thus permit of obtaining four separate limits of rate of movement of said power means, and bias means operative when neither of the pair of means responsive to some measure of a condition is effected to cause movement of the power means in one direction and at a rate determined by said bias means.

17. In a control system for governing the rate and direction of operation of a motor or the like, means for governing the motor including means responsive to magnitude of current flow, means responsive to the voltage producing said current flow, said current and voltage responsive means acting to cause operation of the motor to maintain a desired current-voltage relationship and operation of the motor in turn adjusting the current-voltage relationship, a first pair of means providing limits for the rate of operation of the motor under normal variation in current-voltage relationship, and a second pair of means providing nonbreachable higher limits for the rate of operation of the motor, the limits established by said first pair of means being breachable upon extraordinary changes in the current-voltage relationship.

18. In a control system for governing the rate and direction of operation of a motor or the like, means for governing the motor including means responsive to magnitude of current flow, means responsive to the voltage producing said current flow, said current and voltage responsive means acting to cause operation of the motor to maintain a desired current-voltage relationship and operation of the motor in turn adjusting the current-voltage relationship, a first pair of means providing limits for the rate of operation of the motor under normal variation in current-voltage relationship, a second pair of means providing nonbreachable higher limits for the rate of operation of the motor, the limits established by said first pair of means being breachable upon extraordinary changes in the current-voltage relationship, and means for adjusting each of said limit forming means independently.

19. In a control system for governing the rate and direction of operation of a motor or the like, means for governing the motor including means responsive to magnitude of current flow, means responsive to the voltage producing said current flow, said current and voltage responsive means acting to cause operation of the motor to

maintain a desired current-voltage relationship and operation of the motor in turn adjusting the current-voltage relationship, a first pair of means providing limits for the rate of operation of the motor under normal variation in current-voltage relationship, a second pair of means providing nonbreachable higher limits for the rate of operation of the motor, the limits established by said first pair of means being breachable upon extraordinary changes in the current-voltage relationship, and means biasing said control means to cause operation of the motor in a particular direction upon failure of power producing the current and voltage to which said current and voltage responsive means are responsive.

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