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G. HAGEDORN
METHOD AND APPARATUS FOR ELECTRICAL RESISTANCE WELDING

Filed June 22, 1938

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3 Sheets-Sheet 1

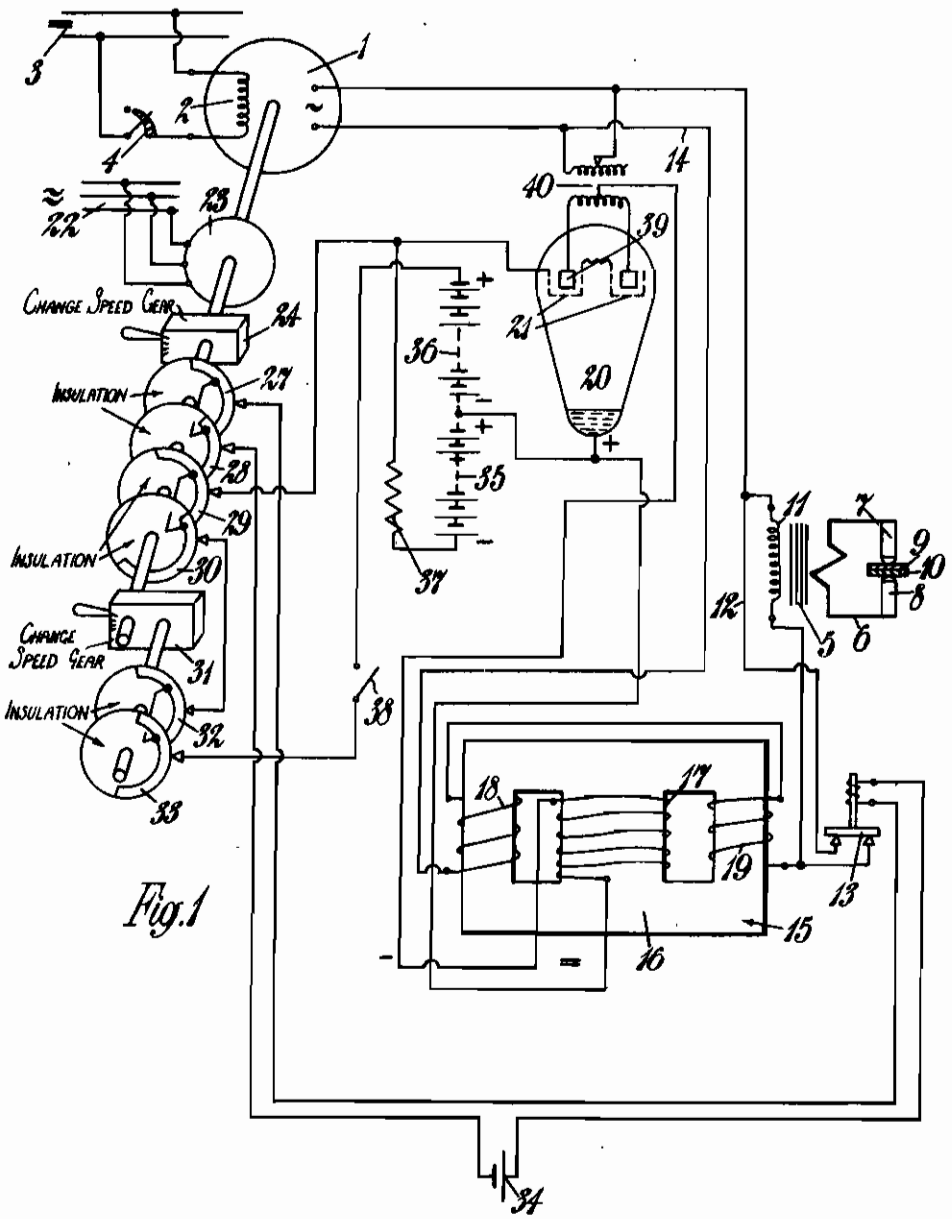

Fig. 1

G. Hagedorn
Inventor

By: Glascock Downing & Seebold
Attys.

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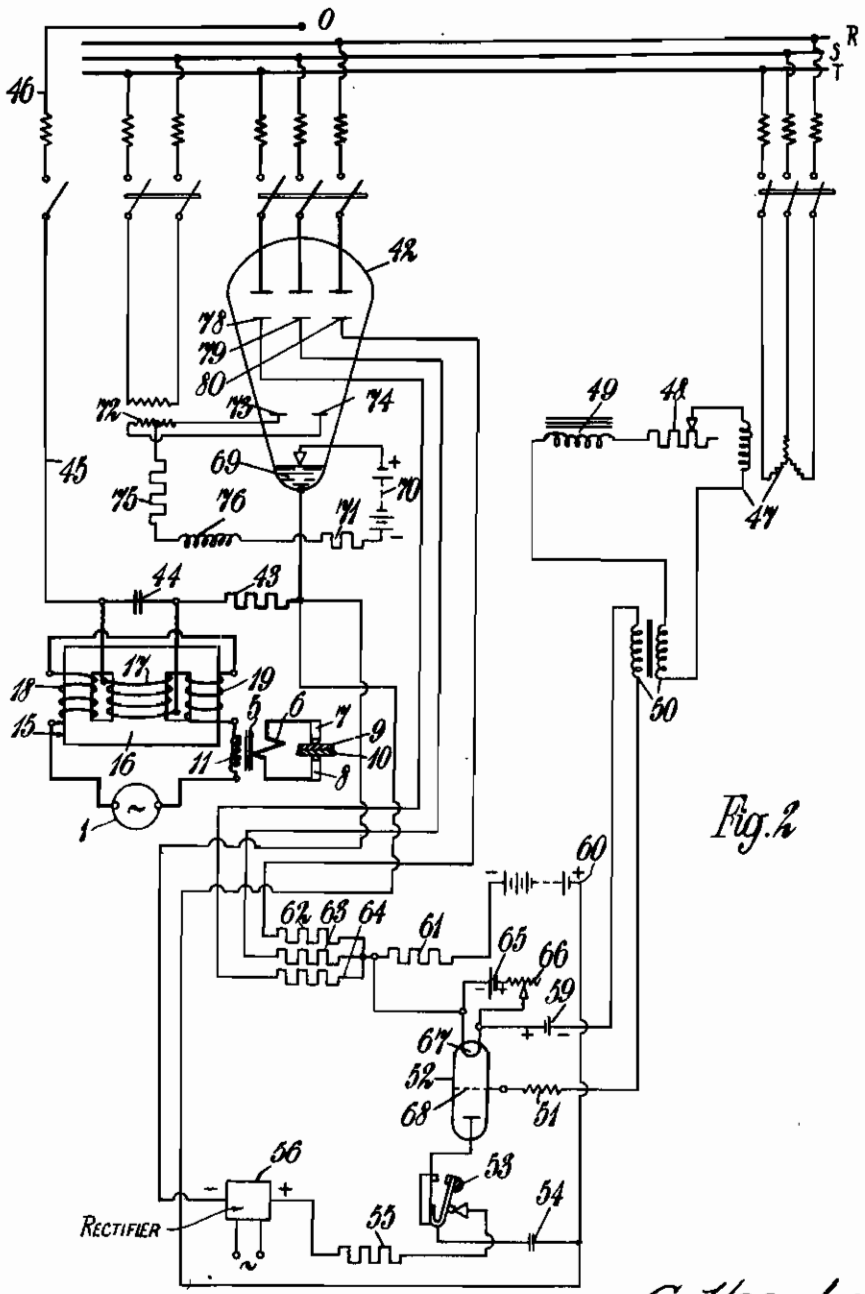

Fig. 2

G. Hagedorn
Inventor

By Glascock Downing & Seabold
Attys.

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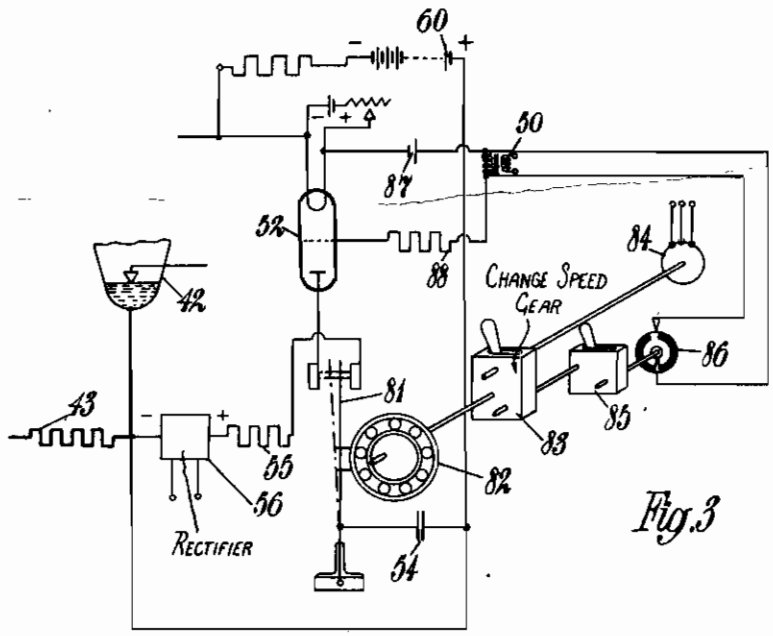

Fig. 3

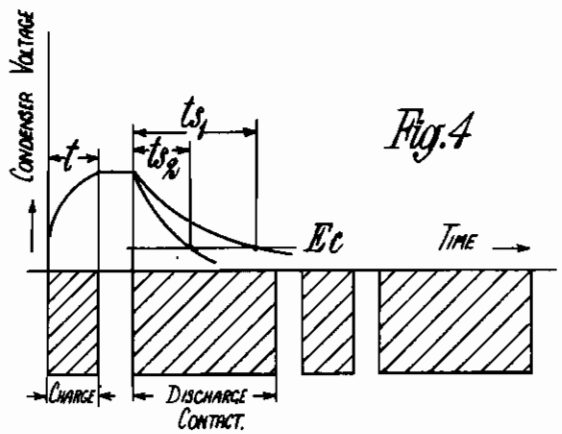

Fig. 4

CLOSED

G. Hagedorn
Inventor

By: Glascock Downing & Seabold
Attys

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ALIEN PROPERTY CUSTODIAN

METHOD AND APPARATUS FOR ELECTRICAL RESISTANCE WELDING

Gerhard Hagedorn, Berlin-Halensee, Germany; vested in the Alien Property Custodian

Application filed June 22, 1938

For the short period connection of resistance welding machines, use is made at the present time of large mercury vapour switching vessels which are connected directly or indirectly in the primary circuit of the welding transformer. These large switching vessels are very expensive and, owing to their great sensitiveness to shaking, are suitable only for stationary installations. The object of the present invention is to avoid the use of these expensive switching vessels in the primary circuit of the welding transformer, which vessels are moreover not very reliable.

The invention relates to a method of electrical resistance welding and it consists in that the temporarily short connections and regulation of the intensity of the welding current is effected by means of a choking coil with iron core inserted between the source of welding current and the welding transformer for the resistance welding, the choking capacity of which choking coil is due to a magnetic flux produced by a continuous current coil mounted on the iron core. The continuous current is controlled as regards its intensity and duration by a current or voltage regulator and a time regulator. Preferably a short circuiting switch connected in parallel with the welding transformer, or a cut out connected in series with the welding transformer, is used for the purpose of reducing the current in the transformer completely to nil during the intervals of rest between the welding periods.

The welding transformer may be operated by an alternating current of 50 or 60 periods. However, it is an advantage to supply a current of middle or high frequency to the transformer, more particularly an alternating current of, for instance 300 to 20,000 Hz.

The invention also relates to an apparatus for carrying into effect the method hereinbefore referred to, which apparatus comprises a source of welding current, a welding transformer for resistance welding connected to the said source, a pre-magnetised choking coil operated by direct current and inserted in the primary circuit of the welding transformer and a source of direct current with a regulating device for the intensity of the current and the period of connection of the said direct current choke.

A further feature of the apparatus is that it comprises a short circuiting switch connected in parallel with the welding transformer or a cut out connected in series therewith. The source of welding current may consist of a generator driven by a motor, preferably a generator of middle or high frequency currents, and the driving motor may operate at the same time the switching means controlling the direct current for the control of the choking coils and switches.

The use of the choking coil pre-magnetised by direct current as a short time switch for the resistance welding machines also offers substantial technical advantages. Thus, for instance, results may be obtained, such as are obtained by the known expensive switching devices, but which are cheaper and in a more reliable manner. Only a small fraction of the welding output has to be switched on and off.

Moreover, the direct current side of the choking coil receives current, preferably from a rectifier, the grid of which is controlled by mechanical controlling means, such as switching cylinders mechanically coupled with the generator. The slip rings of the switching cylinders are coated with the material of the brushes when used for some time, which, owing to the small value of the grid currents, may cause disturbances. Also this disadvantage is avoided by the present invention. Moreover the manipulation of the installation, more especially as regards time adjustments, is considerably facilitated, so that the series of welding spots is quickly produced.

A further feature of the invention consists in that the mechanical control of the grids of the rectifier feeding the direct current side of the choking coils is replaced by a purely electric short period control arrangement by which a grid voltage, which is positive with respect to the cathode, is supplied for a selected period of time to the grids of the rectifier having two or more anodes. The positive gradually dropping grid voltage is produced by the discharge of a condenser, which discharge may preferably be controlled by an auxiliary tube, the grid of which is controlled synchronously with the network feeding the rectifier. The discharge of the condenser may be effected by a hand-operated key. In the case of seam-welding the key may be operated mechanically, so that any desired series of spots may be obtained. A synchronously-operating interrupter for producing the intervals of rest of the welding may be arranged in the grid circuit of the auxiliary tube.

The invention is illustrated diagrammatically and by way of example in the accompanying drawings and showing three different arrangements.

Fig. 1 is a diagram of connections of a resistance spot welding installation in which a choke switch premagnetised by a direct current is in-

serted in the primary circuit of the welding transformer,

Fig. 2 is a diagram of connection of a resistance spot welding installation with a choke switch pre-magnetised by a direct current inserted in the primary circuit of the welding transformer, as well as the controlling device for the rectifier which supplies the direct current for the choke switch,

Fig. 3 shows a portion of a diagram of connections in a resistance seam welding installation, and

Fig. 4 shows the relationship between the grid voltage and the welding time and the position of the controlling contact in the case of seam welding.

Referring to Fig. 1, 1 is a welding generator, for instance for middle or high frequency currents, the field 2 of which is supplied with current from a direct current network 3, through a switch and regulator 4. The excitation current can be adjusted to the necessary requirements. The welding generator 1 is connected to the welding transformer 5, the secondary 6 of which is connected to the welding electrodes 7 and 8 between which the welding material, for instance two metal sheets 9 and 10 to be welded, is placed. The primary coil 11 of the welding transformer is connected in parallel with a short circuiting circuit 12 containing a short circuiting switch 13. A choke switch 15 is inserted in the connection 14 between the welding generator and the welding transformer, which switch comprises, for instance, a three-limb magnetic core 16 and a direct current excitation winding 17. 18 and 19 are the alternating current coils. The direct current winding 17 is energised by rectified alternating current through the mercury vapour rectifier 20 receiving current, for instance, from the generator 1. The control of the rectifier is effected through the grid 21.

The welding generator 1 is driven by means of a motor 23 energised from the three-phase network 22, which motor drives through a change speed gear 24, the controllers 27, 28, 29 and 30, and through a further change speed gear 31, the controllers 32 and 33.

The controllers 27 and 28 are connected through a source of current 34 to the electromagnetically operated short circuiting switch 13. The choking coil is small if the inductivity is not chosen too high for the zero value of the direct current. On the other hand the minimum value of the alternating current increases therewith. Therefore it is an advantage during the interval of rest of the welding to short circuit the transformer or disconnect it by means of a switch. The switch which has to deal only with a small output and may be constructed as a dry switch, controller, or as a switching vessel, is preferably coupled to the controlling shaft for the direct current circuit as shown. Instead of the short circuit switch use may be made of a cut out which is opened in the intervals of rest of the welding. The controllers 29, 30, 32, 33 operate one of the known grid control arrangements consisting of a source of direct current voltage 36 for the positive and 35 for the negative grid voltage and a protecting resistance 37. Moreover the switch 38 can be used to stop the operation of the installation. 39 are the two anodes of the rectifier. The connection is effected, for instance, over the step transformer 40 to the generator 1. In addition to the step transformer the regulation of the voltage may also be effected by suitably choosing the ignition angle for the grids 21.

The controllers 29 and 30 may be used for adjusting the time of welding, for instance, by displacing the one controller 30. Further, the adjustment may be effected by varying the speed, by means of the change speed gear 24. The controllers 27—28, which are constructed and arranged in the same way as the controllers 29—30, disconnect the switch 13 during the welding periods, whereby the short circuit of the transformer is removed. The controllers 32, 33 adjust the periods of rest of the welding. If the number of revolutions of 32, 33 is half that of 27, 28, then one welding period is left out. If it is one-third thereof, then two periods are left out, and so on. The greater the ratio of transmission of the change speed gear, the greater is the interval between the individual welding spots. With increasing transmission ratio the segment covering of the controllers 32, 33 must be made so small that the period of closure coincides with the period of welding.

In this way, welding periods below $\frac{1}{100}$ths of a second can be obtained, so that this method is useful, also for light metal welding.

A further advantage of the method consists in that the intensity of the welding current can also be easily varied, for instance, in the example shown in Fig. 1, by regulating the direct current voltage of the rectifier by means of the grids.

Since the output to be dealt with is small, any desired switches may be used, for instance, relays, cam switches, controllers etc. Use may also be made, for energising the direct current coil, of a separate small direct current generator, the excitation of which is controlled.

The method described is especially suitable for high frequency welding installations, since the magnetic flux of the choke and, therefore, the choke itself, are small. In the case of high frequency currents therefore it is possible to obtain very short periods of welding. Also the direct current output for the magnetising coil is reduced, which results again in a reduction in the size of the whole of the direct current circuit.

Referring to Fig. 2, the source of alternating current supplying the welding current, for instance an alternating current generator 1, is connected to the primary coil 11 of the welding transformer through the choke switch 15, which is pre-magnetised by direct current, the said switch being, for instance, provided with a three-limb magnetic core 16 and alternating current coils 18 and 19. The choke switch is also provided with a direct current excitation winding 17. The welding transformer is provided with an iron core 5 and a secondary core 6, which is connected to the two welding electrodes 7 and 8 arranged to spot weld the metal sheets 9 and 10.

The rectifier 42, provided with controlling grids 79, 79 and 00 supplied with current from a three-phase network 41 over protecting resistances and switches, supplies current over a resistance 43 to the direct current winding 17 of the choke switch 15, the ends of which are connected to a condenser 44. The conductor 45 leads through a switch and protecting resistance to the star point 46 of the network.

The three-phase network 41 supplies current through protecting resistances and switches through a phase shifter and an adjustable resistance 48 and a highly saturated choking coil 49 to the grid transformer 50, which supplies the

grid voltage through a resistance **51** for the gas or vapour discharge path, for instance of an incandescent cathode tube **52**. The contact key **53** connects, in the position illustrated in the drawing, the condenser **54** supplying the positive grid voltage for the rectifier **42** over a resistance **55** to the positive pole of an auxiliary rectifier **56**. By operating the key **53**, the condenser **54** is discharged through the tube **52**, so that a positive grid voltage is imparted to the rectifier **42**, whereby the direct current of the choke switch **15** is switched on.

59 and **60** are batteries which supply the negative grid voltage biases. **61**, **62**, **63** and **64** are resistances. The battery **65** supplies the heating current for the cathode **67** of the grid controlled auxiliary tube **62** with the grid **68** over an adjustable resistance **86**.

The starting anode **69** of the rectifier **42** is supplied with current, for instance from a starting battery **70**, over a resistance **71**. Further, an auxiliary transformer **72** receives current from the three-phase network **41** over protecting resistances and switches, which transformer in its turn supplies current to two continuously working auxiliary electrodes **73** and **74** of the rectifier **42**. **75** is a resistance and **76** a choking coil.

As regards the operation of the installation, the following is further to be pointed out:

In the improved method, a voltage dropping in the selected period of welding from a value which is positive with respect to the cathode down to a stopping value is supplied to the grids **78**, **79**, **80** of the rectifier **42** by the discharge of an energy accumulator, for instance a condenser **54**.

By using the choke switch supplied with current from the rectifier **42**, the great advantage is attained that the rectifier installation is very small and that, therefore, a switching device according to this principle is useful, even for transportable welding plants.

A very simple way consists in charging a condenser and discharging it through resistances, grids and cathodes. In this very simple form the principle is suitable only for a long duration of welding, since the latter depends on the moment of switching on. In the case of three-phase rectifiers and 50 Hz the difference may, for instance, be up to 6.6/1000 seconds. It is possible to use the arrangement also for short periods of welding, by discharging the condenser through a gas or vapour auxiliary path of discharge, for instance the tube **52**. When the key **53** is in the position of rest, the condenser **54** is charged by a source of direct current **56**. When the key is pressed down, the condenser **54** is discharged through the auxiliary path of discharge, viz. the tube **52**, and through the current path leading to the cathode, but only from the moment when, by means of the grid transformer **50**, the stop potential of the battery **59** is rendered ineffective. The grid transformer **58** is fed from the network **41** feeding the rectifier, over a phase shifter **47** and a highly saturated choking coil **48**. The first measure causes that the starting always takes place at the same moment with respect to the alternating current voltage, and thus always starts the same anode of the rectifier with the same angle of phase. The saturated choke acts in the known manner. The secondary voltage of the grid transformer is greatly distorted and becomes very pointed. One thus obtains sharp points of intersection with the starting core line of the auxiliary tube **52**.

The adjustment of the time of welding is best effected by properly choosing the size of the condenser. In the case of welding times below half a wave, the starting and therefore the period of welding can be adjusted by means of the phase shifter.

By means of the new switching method, the switching of the time can be carried out exactly and regularly. Moreover a very quick series of spot welds can be obtained, since, after the key has been released, the plant is again quickly ready for operation since the charging of the condenser takes only a very short time. Besides the simple key one does not require any parts which are movable or subject to wear. By means of a mechanical drive of the key the arrangement may be rendered useful for seam welding.

Fig. 3 shows the modification of the arrangement according to Fig. 1 for electrical seam welding. The rectifier **42** feeds the choke switch, which is not shown, over the resistance **43**. The condenser **54** and the parts **55** and **56** are the same as in Fig. 2, but the hand key **53** shown in Fig. 2 is replaced by a swinging lever **81**, which is driven mechanically by an eccentric, for instance an eccentrically mounted ball bearing **82**, over a change speed gear **83** operated, for instance, by a two pole synchronous motor **84**. With each step of the change speed gear one obtains a certain range of welding period. A contact roller **88** is rotated by a further drive, which contact roller closes and interrupts the grid circuit of the auxiliary tube **54** over the battery **87** and the resistance **88**. The same serves for the introduction of periods of rest for the welding, as is required in the case of stitch welding, that is to say, great spark distance. If the gear ratio is 1:3 for instance, then the contact is opened only once, when the ignition reaches its apex, but the auxiliary tube **52** is not ignited twice, since the ignition (starting) transformer is short circuited.

Fig. 4 shows how, in the closed time of the charging contact, the charging time t of the condenser **54** and, in the closed time of the discharge contact, the welding time ts determined by the size of the condenser, are distributed. As soon as the condenser voltage reaches a definite value E_c, the negative voltage bias of the battery **60** is preponderant and the rectifier works after the corresponding alternating current wave is terminated.

GERHARD HAGEDORN.