Dec. 18, 1962 S. J. VICKERS 3,069,535

METHOD AND APPARATUS FOR FORGING

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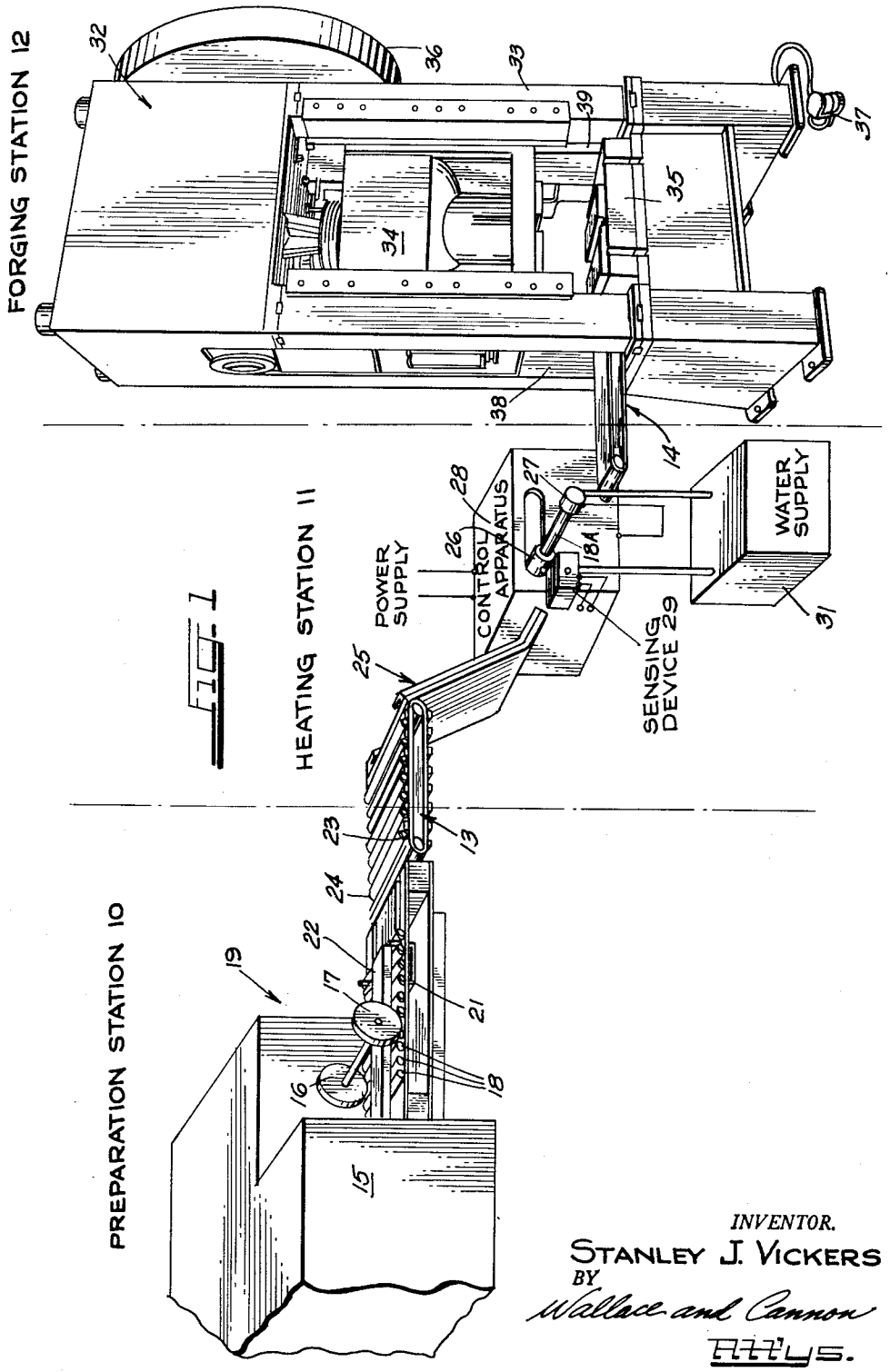


FIG. 1

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FIG. 2

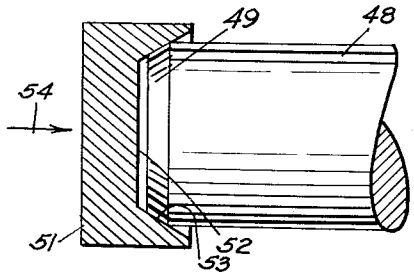


FIG. 3

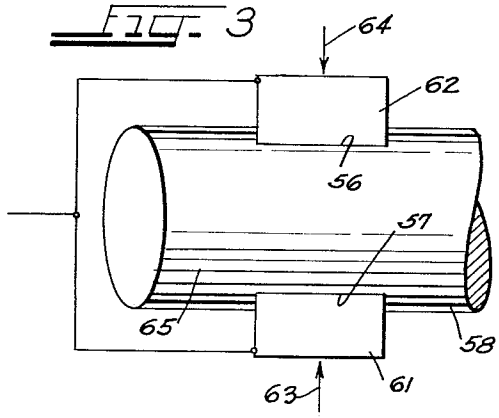


FIG. 4

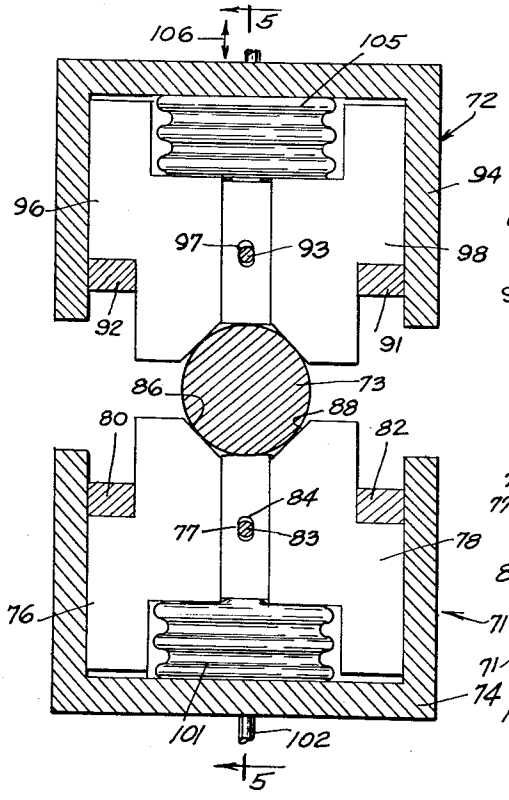
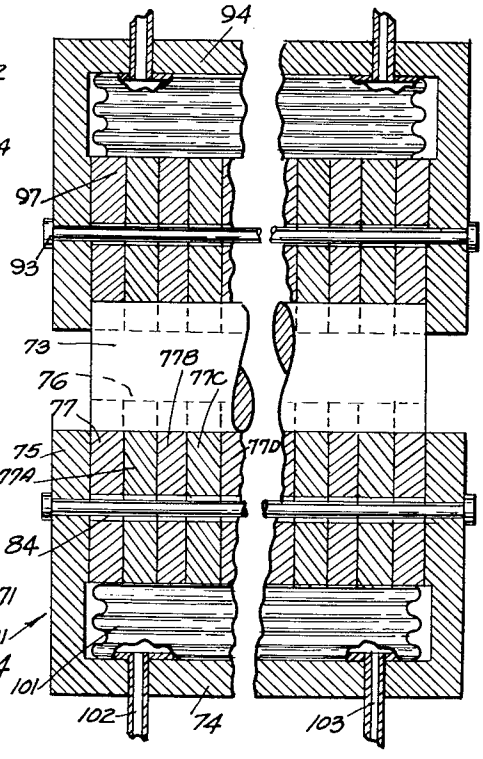


FIG. 5



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METHOD AND APPARATUS FOR FORGING

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5 Claims. (Cl. 219—154)

This invention relates to a new and improved method of forging and to apparatus for carrying out that method. More specifically, the invention relates to a new and improved forging method in which the billet or other metal piece, usually steel, being forged is specially heated before forging, and to a particular form of electrical apparatus employed therefor.

In a conventional forging operation, whether carried out by a press, a hammer, or an upsetter, the billet to be forged is first heated to a relatively high temperature, just short of the melting point, in a furnace. With steel billets, and also other metals, the pre-heating usually forms a relatively heavy scale upon the billet which interferes with the degree of precision to which the forging can be held. In fact, the thickness of the scale becomes the effective limit on tolerances to which the forging may be held. Moreover, extended periods of time are required to assure uniform heating throughout the billet, since the center of the billet is not heated directly, but rather is heated only by conduction from the surface. Indeed, even relatively long periods of pre-heating in conventional furnace arrangements may still fail to achieve uniform heating throughout the billet, with the result that the forging may be defective. Conventional methods are also difficult to adapt to automatic handling of the billets, barring the use of extremely long furnaces, and present substantial problems in instances in which it may be necessary to change the temperature to which the billets are heated before forging, as when there is a change in the kind of steel or other metal being forged.

Many of these difficulties and problems may be overcome by adopting induction heating as a substitute for furnace heating. The formation of scale is virtually eliminated, substantially uniform heating can be obtained, and the time of heating is reduced substantially. On the other hand, the power required for heating is relatively high, and the heating equipment, which operates at relatively high frequencies, is quite expensive. An even greater disadvantage is presented by the coils used for induction heating. Coils which are efficient for a large billet are not efficient for smaller pieces, and, of course, coils used for small billets cannot be employed with large pieces.

It is a primary object of the invention, therefore, to provide a new and improved method of forging, and particularly of pre-heating a billet in the course of a forging operation, which effectively eliminates the above-noted difficulties and disadvantages of previously known methods.

A more specific object of the invention is to provide a practical and effective method of pre-heating a billet, during a forging operation, which avoids the formation of scale on the billet, heats the billet uniformly, and may be accomplished almost instantaneously.

Another object of the invention is to afford a new and improved forging method in which the billet is directly electrically heated, which method is readily and conveniently adaptable to either manual or automatic handling of the billet during all stages of the forging operation.

A further object of the invention is a new and improved forging method in which a billet to be forged is directly heated, by resistance heating, before the final

forging step, which method is applicable to all kinds and types of steel susceptible to forging and may also be applied to other metals.

Another object of the invention is a new and improved automatic forging system for preparing a billet, resistance-heating the billet, and forging the billet, which system is useful in connection with a wide variety of billet shapes formed of substantially different alloys.

The billets used in normal forging operations are not particularly uniform in shape, they may vary substantially in cross-sectional configuration, and the ends are frequently rough and irregular. These variations can be overcome by using special billet stock, and by special cut-off methods, but these expedients are not normally economically feasible. Consequently, it is difficult to pass large electrical currents through such billets without causing substantial damage to the contact electrodes or welding the electrodes to the billet. This presents a substantial problem in direct resistance-heating of the billets, particularly steel billets, as is required in the method of the present invention. This problem can be overcome by machining special contact areas on the billets, in accordance with one aspect of the method of the invention. On the other hand, it is desirable to eliminate this special machining or other preparation operation on the billets if possible, because of the attendant expense and the time required.

A further object of the invention, therefore, is to provide for direct electrical heating of an irregularly-shaped billet, particularly a steel billet, with a minimum of machining or other preparation of the billet.

Another object of the invention is to provide for pre-heating of a billet, in a forging operation, by a multiple-contact electrode structure which eliminates or minimizes contact arcing but is adaptable to automatic handling of billets on a production-line basis.

A further object of the invention is to provide a multiplicity of individually movable contacts, in a single electrode structure, for direct pre-heating of a billet in a forging operation, and at the same time to provide for cooling of all of the contact members by water or other liquid coolant.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings, which, by way of illustration, show a preferred embodiment of the present invention and the principles thereof and what I now consider to be the best mode in which I have contemplated applying these principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

In the drawings:

FIGURE 1 is a partially schematic illustration, partly in perspective, of a forging system constructed in accordance with one embodiment of the invention, and is used to explain the inventive method;

FIG. 2 is a detail view illustrating one technique for securing electrical contacts to a billet for direct resistance heating as a part of a forging operation;

FIG. 3 is a further detail view showing another method of applying electrodes to a billet;

FIG. 4 is a sectional end elevation view of an electrode construction, in accordance with one feature of the invention, providing for direct electrical heating of irregularly shaped billets; and

FIG. 5 is a sectional side elevation view of the electrode fixture of FIG. 4, taken approximately along line 5—5 in FIG. 4.

The forging system illustrated in FIG. 1 comprises

three major stages of operation, the billet preparation station 10, the heating station 11, and the final forging station 12. The three stations are preferably interconnected to form an integrated automated system, the interstage connections comprising the conveyor 13 connecting the preparation station 10 to the pre-heat station 11, and the conveyor 14 connecting the heating station to the final forging station 12.

The billet preparation station 10 is utilized to prepare the billets for the electrical heating to be effected in the station 11. Accordingly, the station 10 includes suitable apparatus for forming a pair of smooth, scale-free, rust-free contact areas on each of the billets before they are fed to the conveyor 13 and thence into the station 11. Preferably, the contact areas are formed at the extreme ends of the billet, in each instance, but other locations may be selected if desired. In fact, in upset forging, it may be desirable in at least some instances to form the contact areas at intermediate points on the billets, so that the end portions, or at least one end portion, of each billet is not heated to the same extent as the central part of the billet. In any event, however, it is necessary to prepare two spaced portions of each billet for contact with the electrodes of the heating apparatus described hereinafter in connection with station 11.

The billet preparation station 10 includes a magazine 15 in which a supply of billets 18 are stored. From the magazine 15, the billets are fed one-by-one to a preparation apparatus 19; any suitable means may be employed to feed the billets into the apparatus 19, depending upon the size of the billets, the rate of feed, and other factors. In the apparatus 19, the billets are advanced past a pair of grinding wheels 16 and 17, which are located at opposite sides of the apparatus in position to engage the end portions of the billets. The preparation apparatus 19 also includes a conveyor 21 or other suitable apparatus for moving the billets through the preparation station and one or more hold-down members 22 for maintaining the billets in alignment with the grinding wheels 16 and 17 during the grinding operation. The grinding wheels may be pivotally mounted, with respect to the conveyor 21, to provide for movement between an inactive position displaced from the billets 18 on the conveyor and a grinding position in which the wheels engage the billets and grind smooth contact surfaces 23 and 24 on the opposite end portions thereof.

From the conveyor 21 of the preparation station 10 the billets 18 are transferred to the conveyor 13 connecting the preparation apparatus 19 to the heating station 11. The conveyor 21 may be operated continuously or intermittently, depending in part upon the particular construction and arrangement employed for the grinding apparatus, and the same may be true of the interstage conveyor 13. Preferably, however, the conveyor 13 is operated continuously and feeds the prepared billets into a storage magazine 25 in the heating station 11 of the forging system.

In the heating station 11, the prepared billets 18 are fed from the storage magazine 25, sequentially, into a heating position in which they are engaged by a pair of electrode structures 26 and 27, as illustrated by the billet 18A. Each of the devices 26 and 27 comprises a relatively large electrode capable of carrying very high heating currents for at least short periods of time. The electrode 27 engages the prepared contact portion 23 of the billet, whereas the electrode 26 engages the prepared contact surface 24. The electrodes should be constructed from an alloy having a relatively high conductivity, but capable of withstanding relatively high temperatures, particularly at the contact faces. Certain beryllium-copper alloys are considered to be suitable for this purpose, but no one alloy is of critical importance in this regard. The electrodes may be faced with a relatively hard metal, including some steel alloys, if desired, to reduce the wear normally experienced at the contact face; in many instances, however, this may not be desirable because it increases the possibility of welding the electrode and billet together in the event arcing occurs during the heating operation. In the illustrated arrangement, each of the electrode structures 26 and 27 is constructed as a movable-jaw clamp, but other constructions may be utilized, including those described hereinafter, in connection with FIGS. 2 and 3.

The two electrodes 26 and 27 are connected to an electrical control unit 28. The control unit is in many respects similar to the control apparatus for a resistance welder, except that provision is made to cut off the current applied to the two electrodes in accordance with the temperature of the billet 18A, instead of being based upon fixed time intervals or other control criteria. A sensing device 29 is provided to actuate the control apparatus 28. The sensing device 29 may be a device which is directly actuated by changes in temperature, or may comprise a photoelectric device sensitive to light of a specific color, in which case the control of the apparatus is made responsive to changes in the color of the billet 18A as its temperature increases. Of course, the control apparatus 28 is connected to a suitable power supply, such as a 220 v. or 440 v. 60 cycle supply.

As noted hereinafter, the billet 18A is heated to a temperature of the order of 2000° or more during the time that it is engaged by the electrodes 26 and 27, with the result that the electrodes tend to heat up to a corresponding high temperature. To hold the electrode temperature as low as possible, the electrodes are preferably provided with internal passageways and are connected to a source of coolant, here shown as the water supply 31. Of course, suitable precautions must be taken to prevent shorting out of the electrical system through the water supply, but this is not a particularly difficult problem since the electrodes are operated at relatively low voltages and the billet 18A is a much better conductor than the stream of water flowing through the electrodes from the water supply 31. Other coolants may be used if desired, or air cooling could be utilized, but water cooling is usually the least expensive and most effective arrangement.

From the heating station 11 the heated billets are transferred along the conveyor 14 into the forging station 12. A typical forging press 32 is illustrated in FIG. 1, and comprises a heavy frame 33 which is used to support a ram 34 above a bolster 35. Suitable forging dies may be mounted upon the bolster in the usual manner. The forging press 32 also includes an operating mechanism, including a flywheel 36, for driving the ram 34 downwardly toward the bolster 35 to effect a forging operation; inasmuch as operating mechanism of this kind is well known in the art, the mechanism is not shown in detail in the drawings. Preferably, an electrical control system is provided for the press 32, including a control treadle 37 for operating the press. On the other hand, in a fully automatic system the press may be arranged for remote control from a distant location or may even be provided with control apparatus capable of actuating the press in response to delivery of a billet to the dies on the bolster 35.

In feeding the heated billets to the forging press 32 at the forging station 12, the conveyor 14 feeds each billet through the window 38 at the left-hand side of the press as seen in FIG. 1. In an automatic system, the completed forgings are usually removed from the press through the window 39 at the opposite side of the press, but the forgings may also be removed from the front or, more usually, the back of the press.

In carrying out the forging method of the invention, three major steps are effected in sequence, one step being completed in each of the three main operating stations 10, 11 and 12 of the system of FIG. 1. In the following discussion, these three major steps are considered in their

order of occurrence, certain variations and modifications in each step being set forth along with the basic requirements of that step.

As noted hereinabove, the first step in the method of the present invention is the preparation of the billet. In most instances, this preparation comprises the formation of a pair of spaced, smooth, clean contact surfaces on the billet. The arrangement illustrated in FIG. 1, in which individual contact areas are formed in the billet by grinding or otherwise machining the billet, is exemplary of this step of the method, and affords clean, smooth surfaces which may be engaged by the electrodes 26 and 27 with a minimum or arcing. In the illustrated arrangement, the contact areas 23 and 24 comprise annular bands located at the ends of the billets, and this is an advantageous technique which provides for convenient engagement by the electrodes and affords uniform current distribution, and hence uniform heating, throughout substantially the entire body of the billet. On the other hand, the grinding or other surface-machining apparatus of station 10 may be arranged to finish the ends of the billets into parallel, smooth, planar surfaces. If this is done, the resulting contact surfaces may be engaged by planar electrodes arranged for reciprocating movement in a direction normal to the planes of the contact surfaces when the billet is disposed in the heating station 11 in position to be heated. Other variations in the configuration of machined contact surfaces, such as the surfaces 23 and 24, are discussed hereinafter in connection with FIGS. 2 and 3.

In some instances, it may not be necessary or particularly desirable to machine the billets in the preparation stage of the forging operation. This is particularly true if the electrodes used in the heating station 11 are constructed to accommodate substantial variations in billet configuration, as with the electrode construction described hereinafter in connection with FIGS. 4 and 5. On the other hand, it is usually necessary to make sure that the billet surfaces to be contacted by the electrodes of the heating station are clean and free from rust or scale. For this purpose, the preparation station 10 may be used primarily to clean the billet, either mechanically as by a light grinding operation or other abrading operation, or by use of solvents and other chemical cleaning means, or both. Thus, the degree of preparation necessary in the initial stage 10 of the forging system is to some extent dependent upon the heating apparatus employed and the particular method selected for applying the heating current to the billets.

In heating the billets, as noted hereinabove, a relatively large current is passed through each billet for a short period of time to heat the billet uniformly throughout its cross-sectional area. For steel billets, the forging temperature is usually of the order of 2000° F. to 2300° F., the optimum forging temperature varying to some extent with different types of steel. It is usually desirable to raise the steel from ambient to forging temperature in a very short time interval, usually of the order of one minute or less. To achieve this result, current densities of the order of 10,000 amperes per square inch must be achieved. Consequently, and as noted hereinabove, it is essential to achieve good contact between the electrodes 26 and 27 and the contact areas 23 and 24 of the billets. Preferably, the electrodes are pressed firmly against the billets, and are made as nearly identical in configuration to the billet contact surfaces as possible.

FIG. 2 illustrates another contact-electrode configuration which may be used in carrying out the method of the invention. In this arrangement, the billet 48 is machined to afford a chamfer 49 on the end thereof, a similar chamfer being formed on the opposite end of the billet (not shown). The bevelled contact surface 49 may also be formed by cold chamfering in a press. The electrode in this instance is constructed as indicated by the electrode 51, which is provided with a recess 52 for receiving the end of the billet 48, the recess 52 having an internal inclined contact wall 53 which matches the chamfer 49. During heating, the electrode is forced against the end of the billet 48 is indicated by the arrow 54 to assure good contact between the contact wall 53 and the billet contact surface 49.

Another electrode arrangement is shown in FIG. 3. Here, the billet 58 is provided with two flat contact surfaces 56 and 57 which are located opposite one another near one end of the billet. Two contact blocks 61 and 62 are engaged with the contact surfaces 57 and 56, respectively, being forced inwardly toward each other and toward the contact surfaces as indicated by the arrows 63 and 64. The two contact blocks 61 and 62 are electrically connected to each other to form a single electrode structure. A similar arrangement may be employed at the opposite end of the billet 58. In this arrangement, it should be noted that the extreme end 65 of the billet 58 carries no current, and therefore is not heated to the same extent as the center portion of the billet, an arrangement which may be desirable in some forging operations, particularly upset forging. On the other hand, if the flat contact surfaces 56 and 57 are located at the extreme end of the billet, the end portion of the billet can be heated to full forging temperature along with the rest of the billet.

In a typical heating installation, the control unit 28 may have a rating of 300 kva., may provide current densities in the steel billets of about 10,000 amperes per square inch, and may be capable of heating 2000 lbs. of steel, to 2300° F., per hour. The heating apparatus may comprise single-phase electrical equipment, but may also constitute a three-phase apparatus. In the latter instance, each phase is connected to a separate pair of electrodes, thus affording three different heating set-ups, which may be employed to feed three different forging stations or may be utilized in heating billets for a single press, upsetter, or hammer. It should be noted that most forging equipment can be maintained in continuous operation on an input of 3000 lbs. per hour or less.

Because the billets fed to the press 32 are all uniformly heated to a controlled temperature, the press may be readily and conveniently made almost wholly automatic in operation. The heated billets are fed through the window 38 into the first die section on the bolster 35. Provision may be made for automatically transferring the billets between dies after a given number of impacts by the ram 34 and for automatically removing the finished forging without any control operation on the part of an operator. In fact, in most instances all variable quantities may be considered to be eliminated.

FIGS. 4 and 5 illustrate a contact construction which may be used to substantial advantage in connection with the forging method of the present invention. The apparatus shown in these two figures comprises a first electrode structure 71 and a second electrode structure 72 which are utilized in heating a billet 73. The billet is effectively clamped between the two electrode structures, which cooperate to pass a heating current through the billet in a transverse direction, instead of lengthwise thereof, as described more fully hereinafter.

The electrode structure 71 comprises a mounting member or base 74 which is substantially U-shaped in cross section, as shown in FIG. 4, and which is provided with a pair of end plates 75 as illustrated in FIG. 5. Within the confined space defined by the base and end members there are mounted a multiplicity of individual electrode or contact elements, and it is these contact elements which engage the billets. In the illustrated construction there are three individual contact elements in each layer, as shown by the contact elements 76, 77, and 78 in FIG. 4. The longitudinal arrangement of the multiple layers of contacts is shown in FIG. 5 by the contact elements 77, 77A, 77B, 77C, 77D, etc.

Lateral movement of the contact elements such as the contacts 76–78 is prevented by engagement of the contact elements with the sides of the base 74 and with each other.

Longitudinal movement within the base is prevented by engagement of the stacks of contacts with the end walls 75 of the electrode structure 71. The contacts are free to move, to a limited extent, in a vertical direction, each contact being independently movable in this direction with respect to the base 74 and each other. Upward movement of the contacts 76 and 78 is limited by a pair of guide rails 80 and 82, respectively, which are mounted on the inside of the opposite side walls of the U-shaped base 74, movement in the opposite direction being limited by engagement with the bight portion of the base. The central contact elements, such as the contact 77, may be held to a limited range of movement by suitable means such as a guide rod 83 extending between the end plates 75 and through a series of elongated apertures 84 in these contact elements.

The two exterior contact elements 76 and 78 are provided with bevelled or inclined contact surfaces 86 and 88, respectively, which extend inwardly toward each other to form a substantially V-shaped notch, the base of which is cut off by the central contact element 77. The billet 73 is disposed within this notch, during heating, and in a notch of similar configuration formed by the contact elements 96, 97, and 98 of the electrode structure 72. The electrode structure 72 is essentially similar to the electrode structure 71, and comprises a base 94 for mounting the contact elements and suitable guide means such as the guide rails 91, 92, and 93 for limiting movements of the individual contact elements with respect to the base and each other.

A bellows 101 is mounted in the base 74 of the electrode structure 71 and engages the base surface of each of the electrode segments such as the contact members 75–78. The bellows 101 is provided with an inlet conduit 102 at one end thereof, and an outlet conduit 103 is connected to the opposite end of the bellows. The bellows 101 is of the type to which fluid may be applied, under pressure, with a restricted flow through the bellows being permitted but, at the same time, a build-up of pressure within the bellows being achieved. Bellows structures of this kind are known in the art, and, therefore, the complete construction of the bellows need not be shown in detail herein. By way of example, the desired effect of permitting fluid flow through the bellows and affording a build-up of pressure therein can be obtained by incorporating a normally-closed pressure-sensitive control valve in the outlet conduit 103, the valve being adjusted to open and permit a flow of fluid from the bellows once a predetermined pressure has been achieved within the bellows. A similar bellows 105 is incorporated in the electrode structure 72.

To facilitate operation of the heating equipment in which the electrode structures 71 and 72 are incorporated, at least one of the electrode structures is preferably mounted for reciprocating movement toward and away from the other, as indicated by the arrows 106 in FIG. 4. In operation, the two electrode structures are first separated from each other by a distance sufficient to permit convenient insertion of the billet 73 therebetween. The electrode structures are then moved together to bring the contact elements of both electrodes approximately into engagement with the billet. Fluid, usually water, is applied to the two bellows 101 and 105, under pressure, building up the pressure within the bellows and forcing each of the contact elements of the two electrode structures into contact with the billet. Since each element of the multi-element contact assemblies is individually movable with respect to the others, each contact element such as the contacts 76–78 and 96–98 is forced into intimate contact with the billet, affording a relatively large total contact area on each side of the billet.

The two electrode structures are then energized, usually from a 60 cycle A.C. source as described hereinabove, to effect a current flow of substantial magnitude through the billet 73. Heating is effected in essentially the same manner as described in connection with FIG. 1, except that the heating current flows across the bar or billet 73 instead of longitudinally therethrough. To achieve the high current densities needed for heating to forging temperature in the desired short time, the total current required with the side or transverse heating arrangement of FIGS. 4 and 5 is substantially higher than with the end-heating arrangement of FIG. 1. On the other hand, the total resistance of the current path is lower, and much lower operating voltages can be employed.

The electrode arrangement of FIGS. 4 and 5 reduces the preparation necessary for adequate heating without excessive arcing to a minimum, since the electrode structures effectively compensate for substantial irregularities in the surface of the billet. The electrodes 71 and 72 can accommodate billets of various sizes, both as regards length, diameter, and cross sectional configuration. The described bellows arrangement provides for cooling of the electrode structures, by means of the water flowing through the bellows, and at the same time affords an effective and efficient pressure or spring-like means for forcing each of the multiplicity of individual contact elements into contact with the billet to be heated. This coupled with the ability of each contact to seat independently on the billet enables the contacts individually to conform to the contour of the billet, thereby assuring effective electrical contact with and heating of the billet. It should be noted that there need not be three contact elements in each layer; two or four or more contacts per layer may be employed, and the ratio of contacts in each row need not be one-for-one, but may be varied if desired. The electrode structures are readily adaptable to automatic handling of the billets as they are fed into and out of the heating station of the forging system. The large number of contact areas provided by each electrode structure reduces arcing to a minimum.

From the foregoing description, it is seen that the method of the invention eliminates the formation of scale, since the billets are heated uniformly throughout the desired portion of their length within an extremely short period. Heating is more uniform than with furnace heating, and also more uniform than with induction heating, since the skin-effect prevalent at the high frequencies used for induction heating does not occur to any substantial extent with direct resistance heating. Further, the invention provides faster heating than is practicable or possible with either furnace or induction heating. The method of the invention is adaptable to a relatively slow, manually controlled forging system, but may be used to best advantage in an automatic high-speed system. Further, it permits the use of a single automatic system for billets of various sizes and shapes with a minimum of changeover in equipment. In the forging of steel, particularly, the method and system of the invention permit improved precision control of the forging operation without material increase in cost and usually at a substantial reduction in cost.

Thus, while I have illustrated and described the preferred embodiment of my invention, it is to be understood that this is capable of variation and modification, and I therefore do not wish to be limited to the precise details set forth, but desire to avail myself of such changes and alterations as fall within the purview of the following claims.

I claim:

1. In a forging system in which steel billets are directly electrically heated to forging temperature by passing large, low-frequency electrical currents therethrough, an electrode structure for engaging a billet to provide for heating the billet, comprising: a base structure defining a confined electrode-receiving space open at one side; a multiplicity of individual contact elements movably mounted within said confined space and externally accessible at said one side of said base structure, said contact elements defining a substantially V-shaped notch for

receiving a billet; means for limiting movement of said contact elements to movement toward and away from said notch; a bellows device, mounted within said base structure in engagement with said contact members; and means for applying fluid under pressure to said bellows device to force said contact elements, independently of each other, into contact with said billet.

2. In a forging system in which steel billets are directly electrically heated to forging temperature by passing large, low-frequency electrical currents therethrough, an electrode structure for engaging a billet to provide for heating the billet, comprising: a base structure defining a confined electrode-receiving space open at one side; a multiplicity of individual contact elements movably mounted within said confined space and externally accessible at said one side of said base structure, said contact elements defining a substantially V-shaped notch for receiving a billet; means for limiting movement of said contact elements to movement toward and away from said notch; a bellows device, mounted within said base structure in engagement with said contact members, including means for limiting the flow of fluid through said bellows; and means for applying water under pressure to said bellows device to force said contact elements, independently of each other, into conductive contact with said billet and to establish a flow of water through said bellows to cool said electrode structure.

3. In a forging system in which steel billets are directly electrically heated to forging temperature by passing large, low-frequency electrical currents therethrough, an electrode structure for engaging a billet to provide for heating the billet, comprising: a base structure defining a confined electrode-receiving space open at one side; a multiplicity of individual contact elements movably mounted within said confined space to form a laminated contact structure externally accessible at said one side of said base structure, said contact elements defining a truncated V-shaped notch for receiving a billet, each layer of said laminated contact structure including at least three individual contact elements; means for limiting movement of said contact elements to movement toward and away from said notch; a bellows device, mounted within said base structure in engagement with said contact members; and means for applying water under pressure to said bellows device to force said contact elements, independently of each other, into contact with said billet, and to cool said electrode structure.

4. In a forging system in which steel billets are directly electrically heated to forging temperature by passing large, low-frequency electrical currents therethrough, an electrode structure for engaging a billet to provide for heating the billet, comprising: a base structure comprising a U-shaped base and end plates defining a confined electrode-receiving space open at one side; a multiplicity of individual contact elements movably mounted within said confined space and externally accessible at said one side of said base structure, said contact elements defining a substantially V-shaped notch for receiving a billet; means for limiting movement of said contact elements to movement toward and away from said notch within a narrow range; a restricted-flow bellows device, mounted within said base structure in engagement with each of said contact members; and means for applying fluid under pressure to said bellows device to force said contact elements, independently of each other, into contact with said billet, and to establish a cooling flow of fluid through said bellows.

5. In a forging system in which steel billets are directly electrically heated by passing large, low-frequency electrical currents therethrough, a pair of electrode structures for engaging a billet to provide for heating the billet, each of said structures comprising: a base structure defining a confined electrode-receiving space open at one side; a multiplicity of individual contact elements movably mounted within said confined space and externally accessible at said one side of said base structure, said contact elements defining a notch for receiving billets of varying sizes and establishing electrical contact therewith at a series of points along the length of any given billet; means for limiting movement of said contact elements to movement toward and way from said notch within a narrow range; a bellows device, mounted within said base structure in engagement with said contact members; and means for applying fluid under pressure to said bellows device to force said contact elements, independently of each other, into contact with said billet.

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