

Nov. 24, 1953

D. VON LUDWIG
ELECTROMAGNETIC VIBRATOR APPARATUS
FOR TREATING MOLTEN METAL

2,660,414

Filed Dec. 16, 1949

2 Sheets-Sheet 1

FIG. 1

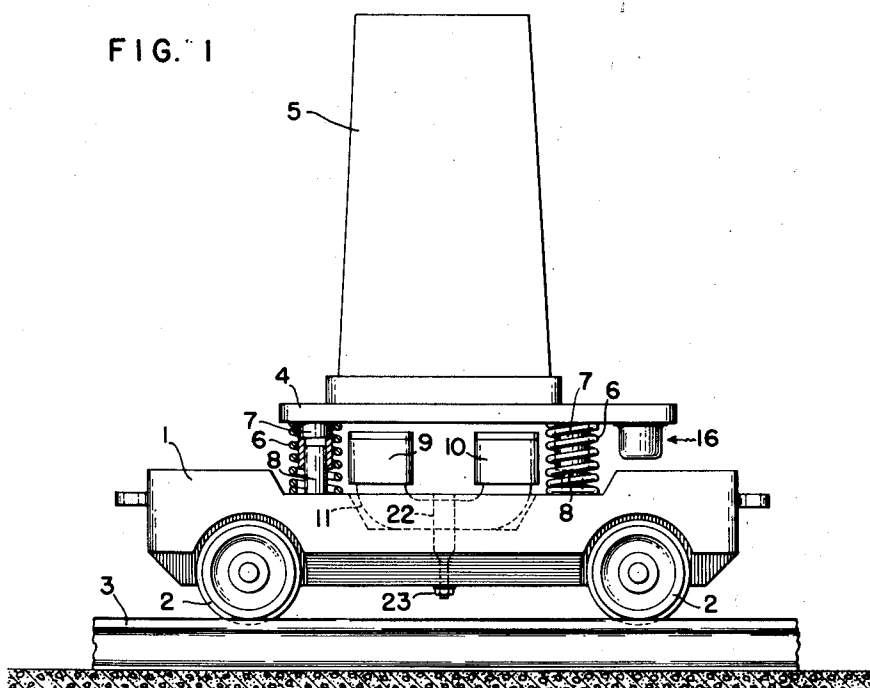
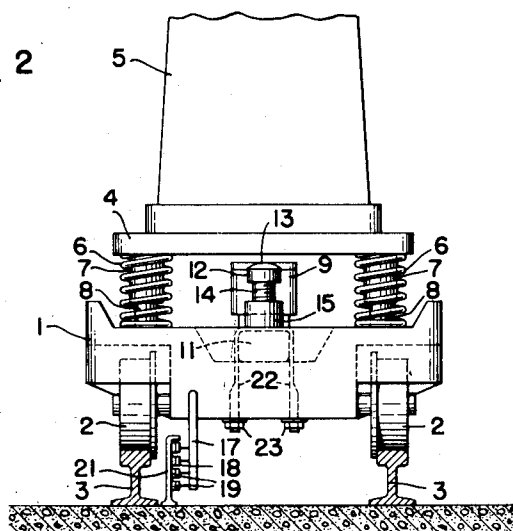


FIG. 2



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2 Sheets-Sheet 2

FIG. 3

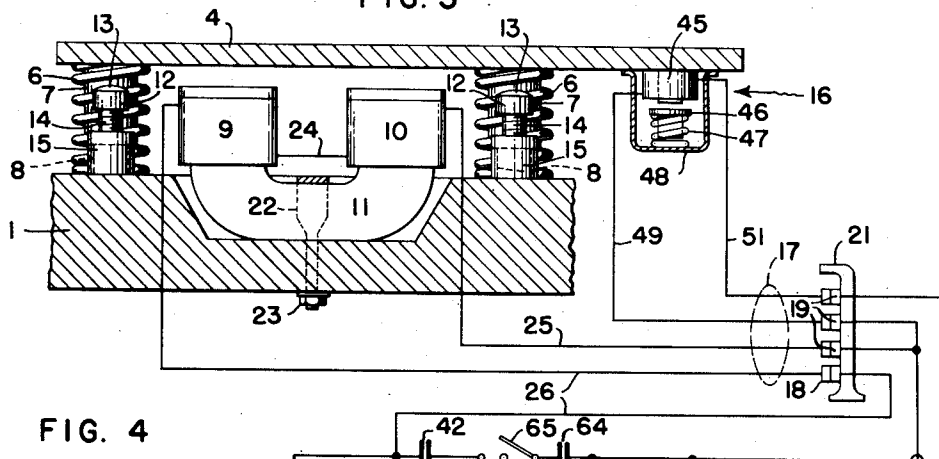


FIG. 4

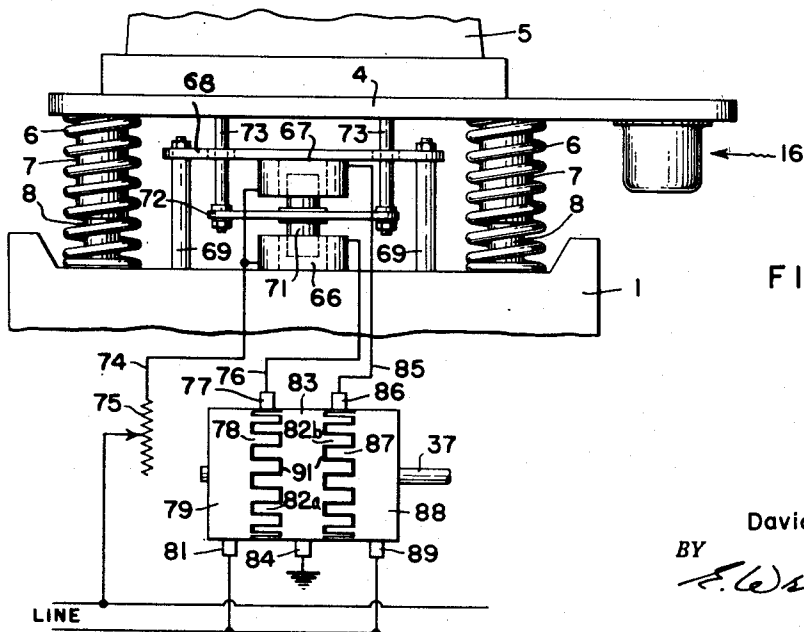
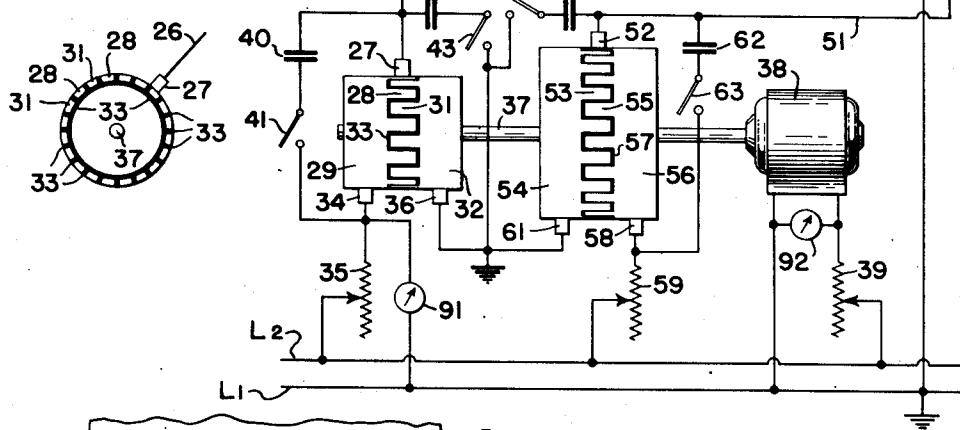


FIG. 5

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UNITED STATES PATENT OFFICE

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ELECTROMAGNETIC VIBRATOR APPARATUS
FOR TREATING MOLTEN METAL

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9 Claims. (Cl. 259—72)

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The present invention relates to the refining of metals by the use of vibration and to apparatus which is used to impart to the metal vibrations of the desired frequency and amplitude.

It has been known for some time that various physical and metallurgical characteristics of metals could be improved if they were subjected to vibration while in their molten state. To this end apparatus of different types have been developed for jarring or shaking ingot molds, for example, while the metal was being poured into them. Such apparatus, however, was cumbersome and required a large amount of power to operate. In addition the apparatus could not easily be adjusted to vary the amount and type of vibration that was imparted to the ingots as they were being poured.

In most cases jarring or vibrations as above described were not commercially successful. There are a number of reasons for this, the main one being that the results obtained were entirely too unreliable to be of any practical value. In some cases the structure of the ingot was improved. In many cases, however, no improvement was obtained, while in other cases flaws were produced in ingots to such an extent that they had to be scrapped. It was impossible to foretell exactly what results would be obtained.

As a result of my experiments I have determined that the vibration of ingots to remove impurities and gases as well as to improve the grain structure can be accurately controlled. This control is predicated upon determining empirically the type of vibration that is required for each metal or family of metals being treated. This type of vibration is then applied to the ingot during the time that it is solidifying as well as during the time it is being poured to obtain predictable results.

I have discovered that various metals or alloys must be treated differently. The type of treatment that will produce beneficial results in one metal will produce faults in another. I have also determined that it is desirable if not necessary to apply more than one type of vibration to the ingot at the same time. The first of these, known as the primary vibration, is of relatively low frequency and high amplitude and is applied in a vertical direction. The second or secondary vibration is of relatively high frequency and low amplitude which is applied in an unoriented plane.

The apparatus that I have devised to impart the desired vibrations to the ingots both during the time that they are being cast as well as dur-

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ing the time that they are solidifying is electromagnetically operated. The apparatus is compact and readily adjustable so that the amplitude and frequency of the vibrations may be readily adjusted to any value which is necessary for the particular metal being treated. Furthermore, the apparatus may be mounted on an ingot car or buggy so that the ingot may be moved from the place of pouring to the place in which it is stored while the ingot is solidifying and during the time it is being treated.

It is an object of the invention to provide a method of treating metals to cleanse them and to improve their physical structure. In following the invention it has been found that various contaminants such as slag may be caused to separate from the body of metal, and that the metal will be degassed. More important, however, is the fact that the grain size may be controlled to produce a dense and small grained metal with its inherently desirable characteristics.

It is a further object of the invention to provide an electromagnetically operated vibrating mechanism that is compact and rugged. The mechanism is provided with means for supplying electric current thereto in such a fashion that the amplitude and frequency of the vibrations may be altered at will by means of simple adjustments.

It is a further object of the invention to provide a method and apparatus for cleansing and refining metals by the use of vibration during the time that the metal is being cast and is solidifying.

The invention of the present application is equally as applicable in the casting of metals in final shape or in the casting of metal in ingots that are subsequently to be rolled or forged. The invention has been used to advantage for both non-ferrous metals such as aluminum, for example, and for ferrous metals and alloys including stainless steel. For purposes of description only, and not by way of limitations, the invention will be described in connection with the casting of steel ingots.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages and specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the invention.

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In the drawings:

Figure 1 is a side view showing the invention when used with an ingot car;

Figure 2 is a view from the right of Figure 1;

Figure 3 is an enlarged view, partly in section, showing the details of the vibrating mechanism and the circuits thereon;

Figure 4 is a sectional view of one of the commutators; and

Figure 5 is a view of a modified type of vibrating mechanism.

Referring to Figures 1 and 2, there is shown an ingot car or buggy 1 that is mounted upon wheels 2 and which runs on a track 3. This car has mounted upon it a platform 4 at least a portion of which is made of magnetizable metal that carries an ingot mold 5. The platform is supported on the carriage by means of spring 6, one of which is placed at each corner of the carriage. It is to be understood, however, that a larger or smaller number of springs may be used, depending upon the weight of the ingot mold or other factors. The platform 4 is guided for vertical movement only on the car 1 by means of cylinders 7 located within the springs and which are attached to the platform. Each of these cylinders receives a post 8 that is attached to and projects upwardly from the car itself. Thus, as the platform is moved up and down against the force of the springs it is guided for vertical movement only. The fit between the cylinders 7 and posts 8 is such that free sliding movement may be obtained, but that no sidewise component is present in the said movement.

In following the present invention it is necessary to vibrate the ingot carrying platform and mold in a vertical direction during the time that the ingot is poured and while it is solidifying. This vibration is accomplished in accordance with the present invention by means of an electromagnet that is attached to the car and which is used to attract the platform 4 downwardly against the force of the springs. As shown herein, the magnet includes a pair of coils 9 and 10 that are wound around an armature 11 which is mounted on the car. As best shown in Figure 2, there are also provided a pair of stops which can be used upon occasion to limit the downward movement of the platform in response to the attraction of the magnet. These stops each include a head 12 that is provided with a cap 13. The cap may be of some resilient material such as rubber or it may be of a solid material such as metal, depending upon the type of damping of the vibration which is required for the specific metal being poured. This will be described in detail below. The cap 12 has attached to it a threaded stem 14 received in a socket 15 attached to the carriage 1. By rotating the stops in the socket, their height and the amplitude of the vibration may be adjusted. There is also attached to the platform 4 a secondary vibrating mechanism 16.

In modern steel mill practice it is customary to move the mold carrying cars to a pouring station and from there to a storage space in which the molten metal can solidify before the mold is stripped from the ingot. Since it is necessary to continue the vibration during the time that solidification is taking place as well as while the ingot is being poured, terminals from the magnet coils extend through a trolley 17 to a plurality of contacts 18 on the end thereof. These contacts bear against elongated stationary contacts 19 that are located adjacent to the path through which the car 1 moves. As shown herein, con-

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tacts 19 are mounted upon supports 21 that are placed between the tracks 3 where there is less likelihood of them being damaged due to activity on the pouring floor.

The details of the magnets and the means for operating them are best shown in Figure 3, and reference is now made to that figure. The armature 11 is fastened to the body of the car 1 by means of a strap 22 and is held in place by nuts 23 threaded over the ends of the strap. Coils 9 and 10 are connected together by means of wire 24. The other end of coil 10 is connected by a wire 25 through one pair of contacts 18 and 19 to one conductor L^1 of a suitable direct current power line which side is also grounded. The second terminal of coil 9 is connected by a wire 26 through another pair of contacts 18 and 19 to a brush 27 which bears against the surface of a commutator. This commutator is so formed that the brush bears alternately against projections 28 formed on a conducting ring 29 and projections 31 formed on a conducting ring 32. These rings are separated by insulation 33 as is shown in Figures 3 and 4 of the drawing. Ring 29 is engaged by a brush 34 which is connected through a variable resistance 35 to the other conductor L^2 of the power line. Bearing on the surface of ring 32 is a brush 36 which is connected through a suitable wire with the ground. It will be seen that as the commutator is rotated the brush 27 bearing alternately on projections 28 and 31 will connect the magnets alternately with the source of power and with the ground, thus intermittently energizing the magnets so that the platform will be intermittently attracted toward the same against the force of springs 6. The commutator is mounted on a shaft 37 and the latter is rotated by a suitable variable-speed motor 38. As shown herein, one of the motor leads is provided with a variable resistance 39, adjustment of which will adjust the speed of rotation of the motor. In some cases it may be desirable to provide a condenser across the lines leading from the magnet to the source of power and from the magnet to the ground in order to dampen arcing. To this end there is provided a condenser 40 extending between wire 26 and one side of the variable resistor 35. The connection for the condenser has in it a switch 41 that can be closed when conditions make it advisable. In a like manner a condenser 42 is connected between the wire 26 and the ground, which connection includes a switch 43.

The secondary vibrator 16 is best shown in Figure 3 and includes a magnet coil 45 that is attached rigidly to the bottom of platform 4. Co-operating with this magnet and attracted thereto when the magnet is energized is a weight 46 which is rigidly attached to a spring 47. This spring is of such a length that it holds the weight separated slightly from the armature of magnet 45. The lower end of spring 47 is attached to a casing 48 which is in turn mounted upon the platform 4. Electrical energy is supplied to magnet 45 by means of a wire 49 connected through contacts 18 and 19 with one side of the line. The other terminal of the magnet is connected by a wire 51 through contacts 18 and 19 with a brush 52 bearing on the surface of a second commutator that is attached to motor shaft 37. The brush 52 is so positioned with respect to the commutator that it bears alternately on projections 53 extending from a conductor ring 54 and projections 55 extending from a conductor ring 56. These rings are mounted in a manner similar to that

described in connection with the first commutator so that the projections are separated from each other by insulation 57.

When brush 52 is engaging a projection 53 it is connected through a brush 61 with the ground. When the brush is engaging a projection 55 it is connected through ring 56, brush 58 and a variable resistance 59 with the other side of the line. Thus, when the commutator is rotated, magnet 45 is connected alternately with the source of electrical energy and with the ground so that it will attract weight 46 with a frequency depending upon the frequency with which it is connected to the power supply. As was the case in connection with the first-described magnet, it may at times be desirable to connect a condenser between the magnet and the ground and between the magnet and the line. To this end there is provided a condenser 64 in the circuit extending between brush 52 and the ground. This circuit has a switch 65 in it. In a like manner there is provided a condenser 62 in a circuit extending from brush 52 to one side of the line. This circuit has switch 63 in it which may be opened or closed as occasion demands.

The main vibrating mechanism that was described above produces motion of the platform 4 by pulling it in one direction against the force of the springs and permitting the springs to move the platform in the opposite direction. In some cases it may be of advantage to have the table vibrated by moving it positively in both directions as a result of the action of a pair of magnets. Mechanism to accomplish this is disclosed in Figure 5. The movement of the table downwardly in this case is imparted by a magnet 66 that is attached directly to the carriage 1. Movement of the platform upwardly is produced by a second magnet 67 that is attached to a support 68. This support is mounted rigidly with respect to the carriage 1 and in spaced relation thereto by means of posts 69. As the magnets are energized an armature 71 of magnetizable material is moved in one direction or the other. This armature is attached to a support 72 that is in turn attached rigidly to the platform 4 by rods 73. Since the vibration is imparted to the armature 71 by alternate energization of the magnets 66 and 67, a slightly modified type of commutator is necessary. Referring to the figure, it will be seen that one terminal of each of the magnets is connected by a wire 74 and the variable resistance 75 to one side of the line. The other terminals of the magnets are connected to the opposite side of the line through the commutator. To this end the second terminal of magnet 66 is connected by a wire 76 to a brush 77. This brush engages alternately projections 78 on a contact ring 79 that is connected by brush 81 to the opposite side of the line, and projections 82a extending from the contact ring 83 that is connected by a brush 84 to the ground. The second terminal of magnet 67 is connected by a wire 85 to a brush 86. This brush bears alternately on contacts 82b extending from the opposite side of contact ring 83 and projections 87 of a contact ring 88 that is connected by a brush 89 to the opposite side of the line. It will be noted that the various contact rings and projections are separated by insulation 91. It will also be noted that the projections 82a and 82b are so aligned with respect to each other that when magnet 66 is energized magnet 67 is connected to ground, and vice versa.

The vibration imparted to platform 4 by elec-

tromagnet 9, 10 is oriented in a vertical plane due to the fact that the platform is confined to movement solely in a vertical direction. The frequency of this vibration is determined by the number of projections 28 and 31 formed on conductor rings 29 and 32, respectively, and by the speed of rotation of motor 38. Adjusting resistance 39 will change the speed of the motor and, therefore, the frequency. It will be noticed from an inspection of Figure 4 that the brush 27 is of such a size that it will bridge the insulation 33 between projections 28 and 32 so that the current is momentarily flowing to ground before and after each energization of the magnet. In this way any counterelectromotive force that is built up in the coil is discharged to relieve sparking across the projections. It is sometimes advisable to connect the condensers 41 and 43 across the leads from the three brushes to help relieve any sparking that might occur. For most applications the proper proportional width of the brush, the projections and the insulation between the projections is 3 to 4 to 1 respectively.

The amplitude of the vibrations produced by magnet 9, 10 is varied by adjusting resistance 35 and, therefore, the current flow through the magnet. The springs 6 are of sufficient strength to support the platform 4 and the load thereon and always return the platform to a predetermined position. When the magnet is energized the platform is pulled downwardly from this position against the force of the springs for a distance depending upon the current flowing through it. Ordinarily the platform 4 does not descend far enough to engage the stops 13. Thus the acceleration of the platform is the same in both directions and a smooth movement rather than a jarring of the platform is obtained with its motion simulating somewhat a sine wave. In some instances a shock wave may be necessary to obtain the desired refining of the metal being treated. When such is necessary, the stops 12 are elevated to a point where they will be engaged by the platform in its downward movement. The platform will, therefore, be stopped suddenly, thus producing a different wave form for its motion.

At this point it might be mentioned that the acceleration of the ingot platform in both directions determines the exact shape of the vibration curve. This acceleration can most easily be altered by varying the stiffness of the springs 6 upon which the casting platform is mounted. When the stops 12 are used, changing from rigid to resilient caps 13 will also vary the acceleration or type of vibration obtained.

The vibrations produced by the secondary vibrating mechanism 16 are of a higher frequency and lower amplitude than those produced by the magnet 9, 10. The vibrations in this case are produced as a result of the blow made by weight 46 hitting against the bottom of the armature of magnet 45. The frequency of the vibrations produced by device 16 is at least ten times that produced by magnet 9, 10 and an uneven multiple thereof. To this end there are at least ten times as many projections 53 and 55 plus one on the commutator of which they are a part as there are projections 28 and 31 on the other commutator. The amplitude of these vibrations is usually substantially the same for all metals, but can be changed by adjusting resistance 59. As the force exerted by magnet 45 is changed the acceleration of weight 46 is changed to vary the blow imparted by it.

The vibrating mechanism of Figure 5 per-

forms in the same manner as that described above in connection with magnet 9, 10 except that the platform 4 is positively moved both upwardly and downwardly. The various projections on the commutator of Figure 5 are so arranged that one magnet is energized while the other is connected to ground. The magnets are adjusted to compensate for the effect of the springs on the platform.

In the operation of the apparatus to carry out the applicant's method, an ingot car containing an ingot mold is moved along the tracks 3 to the pouring station. While it is there the ingot is poured, and the car is then moved along the tracks to a point where it can be held during the time that the ingot is solidifying. Prior to the time that the actual pouring commences the vibrating mechanism of both the primary and secondary vibration producing devices is started into operation. This mechanism including the commutators and motor can be located at some point remote from the pouring station and connected with the conductors 19 on supports 21 by suitable wires. Current for energizing the various magnets is then carried through contacts 18 and the trolley to the magnets themselves. Therefore, the vibrating mechanism can be operated at any position of the cars during the time that the ingot is being poured, while it is being moved, and during the time that it is solidifying.

The vertically oriented vibrations that are given to the platform and mold by magnet 9, 10 is what is known as the primary vibrations, and are of relatively low frequency and high amplitude. The frequency and amplitude of this vibration has been determined previously for the particular metal that is being poured. The secondary or high frequency, low amplitude vibration imparted to the platform and the mold by the secondary vibrating device 16 is, as stated above, at least ten times the frequency of the first-mentioned vibration and it is applied in an unoriented plane. The latter statement means that the vibrations are imparted to the platform 4 without necessarily being directed in any specific direction. If it is possible due to the temperature of the metal being cast, the vibrating device 16 may be attached to the side of the mold rather than to the platform 4. In this case the high frequency vibration would also be superimposed upon the low frequency, vertically oriented vibration.

As indicated above, the current supply should be direct current so that only the frequency which is desired is applied to the magnet. If alternating current was used the fluctuations in this current when combined with the action of the commutator would impress upon the magnets an indeterminate frequency of operation since various resonant conditions would be created in the current supply. If desired, a suitable meter 31 calibrated in terms of amplitude can be connected across the line from one side of resistance 35 as shown in Figure 3 of the drawing. The amplitude is determined by the amount of energization of the magnet so that this meter can be very readily calibrated in terms of amplitude, or the position of the adjusting knob for resistor 35 can be calibrated in terms of amplitude. The frequency can also be determined by means of a suitable meter calibrated in revolutions per minute or frequency which is connected across the leads of motor 38, or the adjusting knob for resistance 39 can be calibrated in terms of frequency. The readings given by the two meters

permit easy adjustment of the amplitude and frequency of the vibrations that are to be imparted to the ingot mold for any given set of conditions.

It was stated above that the frequency and amplitude of the primary and secondary vibrations applied to the ingot mold would vary depending upon the metal or family of metals being treated. This need only be determined once for the metal being poured; after that the adjustments of the system can be made from time to time as the analysis of the material is changed. The process is equally as beneficial on non-ferrous metals as it is on ferrous metals. It has been used to advantage in the production of aluminum ingots, for example.

The primary or low frequency, high amplitude vibrations serve primarily the purpose of removing impurities, degassing the metal and reducing the size of the pipe. The vertically oriented vibrations cause the impurities to separate by rising to the top or settling to the bottom of the ingot depending upon their relative specific gravities. The frequency of the vibration can be in the range of from 1000 to 5000 impulses per minute, depending upon the composition of the metal being treated. The amplitude of the vibrations can be in the range from 0.02 to 0.125 inch.

The secondary or high frequency, low amplitude vibration is primarily to insure uniformity of grain size and to prevent excessive segregation due to the effects of the primary vibration. This vibration should have a frequency approximately ten or more times that of the primary vibration, and should not be an even multiple thereof. The amplitude of the secondary vibration should be from 0.01 to 0.005 inch. While the primary vibration is applied or oriented in a vertical direction, the secondary vibrations do not necessarily have to be applied in any particular plane or direction. For this reason the vibrating mechanism 16 can be mounted on the platform 4, as shown, or may be mounted at any other point, even on the side of the ingot mold itself if the heat thereof is not too excessive.

As an example, when treating low carbon steel alloys the primary vibration should be from 2000 to 3000 vibrations per minute at an amplitude of one-eighth inch. The secondary vibrations will be at a frequency of from 20,000 to 30,000 vibrations per minute with an amplitude of 0.01 inch.

If the metal being treated is to be recast from its ingot form to a final shape only the primary vibration is needed. If, however, the ingots are to be used as rolling or forging stock, or for other purposes, both the primary and secondary vibrations are required to obtain the desired metallurgical characteristics. The cleaning of the metal that is obtained predominately by the primary vibrations is of advantage no matter what use the metal is put to. On the other hand, the refinement of grain that is obtained predominately by the secondary vibrations is lost to a great extent when the metal is remelted. Similar vibrating mechanism can be used to obtain grain refinement when the metal is recast into its final shape.

From the above it will be seen that I have disclosed a self-contained vibrating mechanism that can be mounted on an ingot car. The electrical mechanism for imparting the energizing impulses to the magnets on the car can be mounted in any convenient location and connected to

the car in any position thereof without the use of mechanical linkages of any kind.

The invention also describes a method and apparatus whereby metals of various kinds, both ferrous and non-ferrous, may be treated by the use of vibration to cleanse and degas them, as well as to refine their metallurgical structure.

While in accordance with the provisions of the statutes, I have illustrated and described the best form of embodiment of my invention now known to me it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit and scope of the invention, as set forth in the appended claims, and that in some cases certain features of my invention may be used to advantage without a corresponding use of other features.

What is claimed is:

1. In apparatus for treating metal, the combination of a carriage, a platform including magnetizable means, to mount said platform on said carriage for vertical movement thereon, resilient means to maintain said platform a predetermined position above said carriage, means mounted on said carriage to vibrate said platform vertically relative thereto, separate means on said platform to vibrate said platform, and mechanism to operate said vibrating means at different frequencies and amplitudes, said carriage being provided with wheels for movement along a track, said vibrating means being electromagnetically operated, means extending along the track to carry electric power, and a trolley on said carriage engaging said last named means through which power can be transmitted to said vibrating means regardless of the position of said carriage on said track.

2. The combination of claim 1 including means to supply power intermittently to said vibrating means.

3. In apparatus for treating metal, the combination of a carriage a platform including magnetizable means upon which a mold is to be placed mounted for vertical movement on said carriage, resilient means operative to hold said platform a predetermined distance above said carriage, electromagnetic means mounted directly on said carriage to impart vibrations to said platform, means to energize said electromagnetic means periodically at a predetermined frequency, a second electromagnetic vibrating means on said platform to vibrate said mold, and means to energize said second electromagnetic vibrating means intermittently at a frequency higher than the frequency at which said first-mentioned electromagnetic means is energized.

4. In apparatus for treating metal, the combination of a support, a platform including magnetizable means mounted for vertical movement on said support, means to control said movement, electromagnetic means rigidly mounted on said support having a first and a second terminal to vibrate vertically said platform on said support within limits determined by said control means, means to connect said first terminal to one side of a suitable power supply, said side also being grounded, and means to connect said second terminal alternately to the other side of said power supply and to ground.

5. In apparatus for treating metal, the combination of a support, a platform including magnetizable means upon which a mold is to be placed mounted on said support for movement vertically with respect thereto, means engaging

said platform to hold it normally a given distance from said support electromagnetic means mounted rigidly on said support and operative upon energization thereof to move said platform with respect to said support in opposition to said holding means, said electromagnetic means having a first and a second terminal, means to connect said first terminal to one side of a power supply, said side also being grounded, and means to connect said second terminal alternately to the other side of said power supply and ground.

6. The combination of claim 5 including means to adjust the amount of power supplied to said electromagnetic means.

7. The combination of claim 6 including means to control the acceleration of said platform as it is being moved.

8. In apparatus for treating metals, the combination of a movable support, means to mount said support for movement along a predetermined path, a platform including magnetizable means, means to mount said platform for vertical movement only on said support, electromagnetic means mounted on said support to move said platform relative thereto, a trolley on said support having thereon the terminals of said electromagnetic means, conductor means located adjacent to said mounting means and engaged by the terminals on said trolley in every position of said support, and means located at a distance from said support to supply electrical energy intermittently to said electromagnetic means through said conductor means and said trolley.

9. In an apparatus for treating metal, the combination of a support, a platform including magnetizable means mounted for vertical movement on said support, electromagnetic means having a first and a second terminal and operable to vibrate vertically said platform on said support, means to connect said first terminal to one side of a suitable power supply and the means to connect said second terminal alternately to the other side of said power supply and to ground, said second mentioned means to connect including a first ring having spaced projections extending axially from one side thereof, a second ring having spaced projections extending axially therefrom, means to mount said rings with the projections of one ring received between the projections of the other ring, means to insulate said rings and projections from each other, means to rotate said rings, a first brush on said second terminal positioned to engage said projections as they rotate, a brush connected to said other side of said power supply and engaging one of said rings, and a brush connected to ground engaging the other of said rings.

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