Aug. 13, 1968 N. H. JENSEN ET AL 3,396,778

APPARATUS FOR CAST CLADDING

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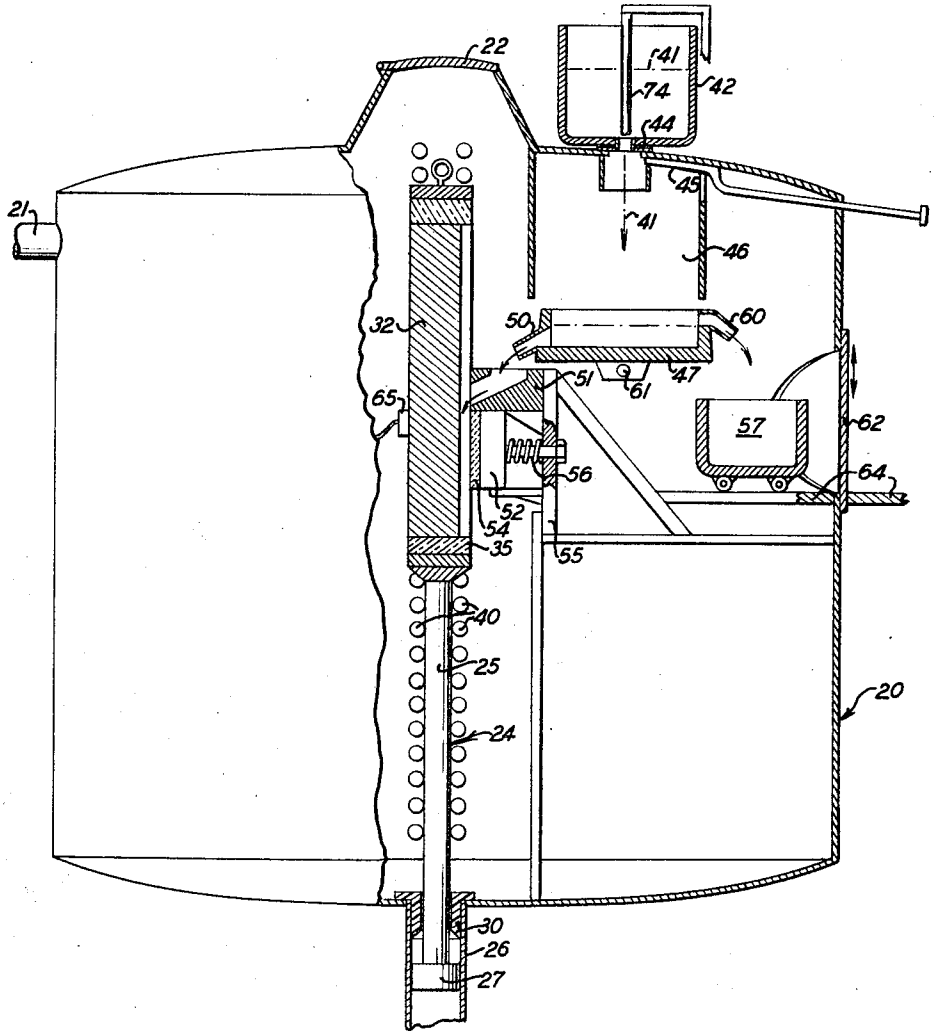



Fig. 1

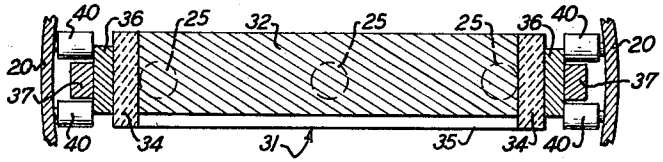



Fig. 3

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APPARATUS FOR CAST CLADDING

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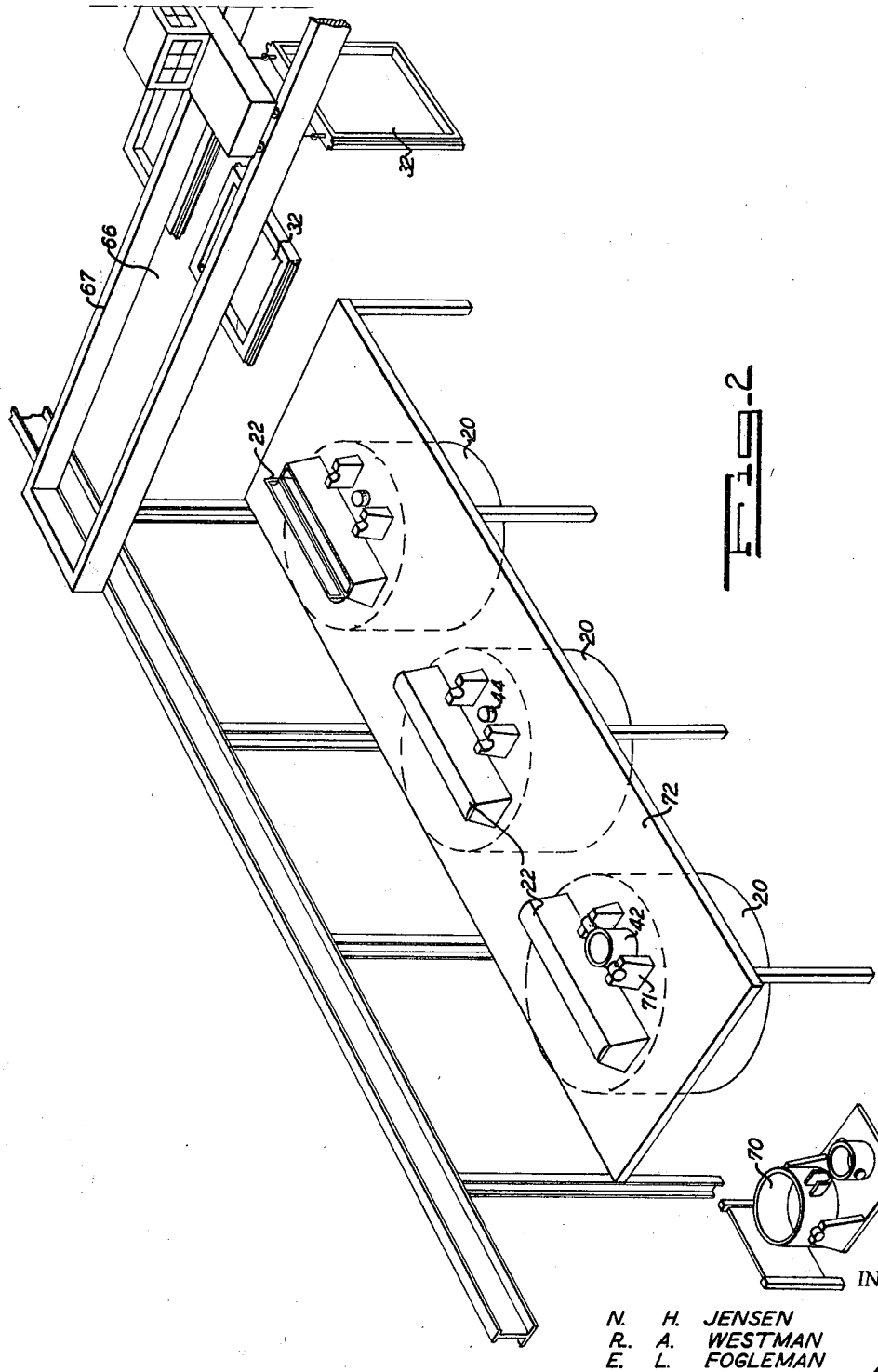



Fig-2

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APPARATUS FOR CAST CLADDING

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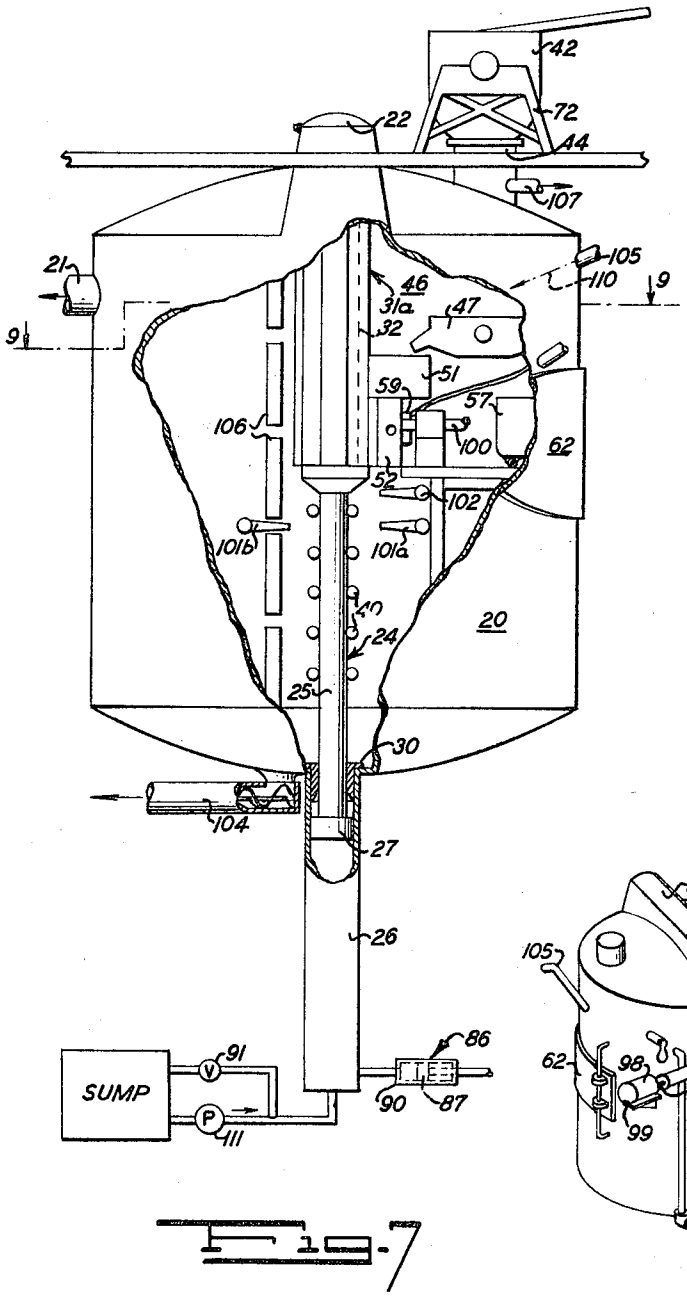



Fig. 7

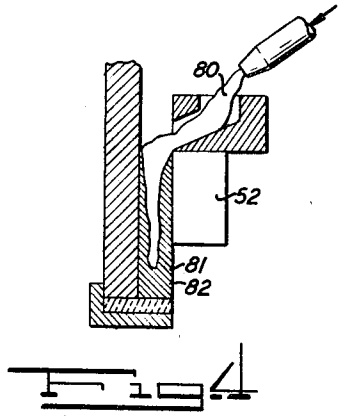



Fig. 4

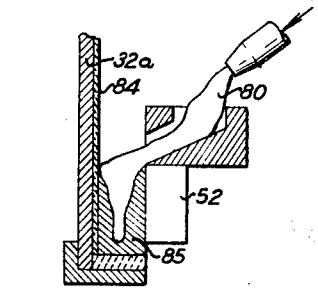



Fig. 5




Fig. 6

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APPARATUS FOR CAST CLADDING

Filed Aug. 24, 1964 6 Sheets-Sheet 4

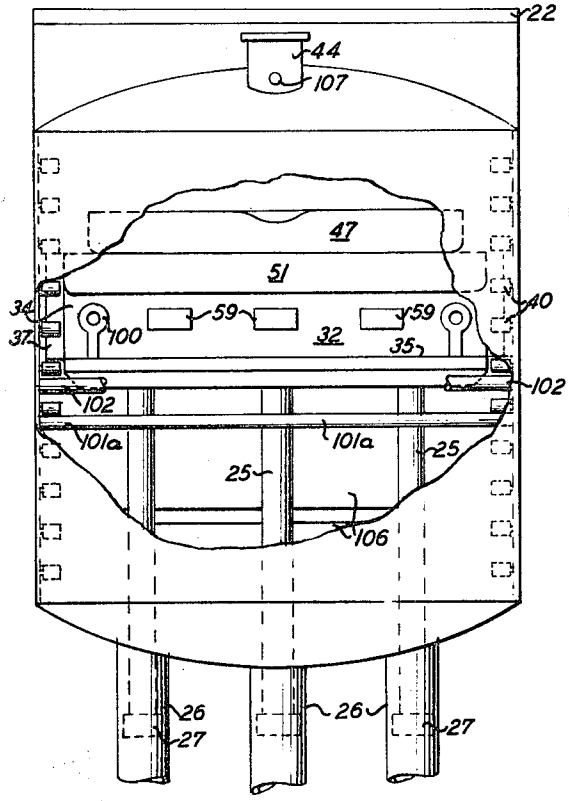



Fig. 8

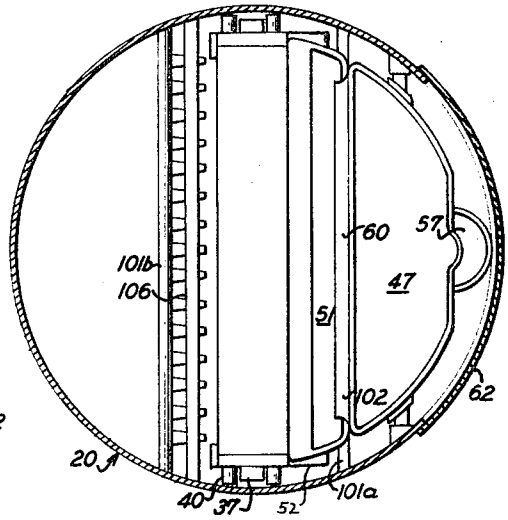



Fig. 9

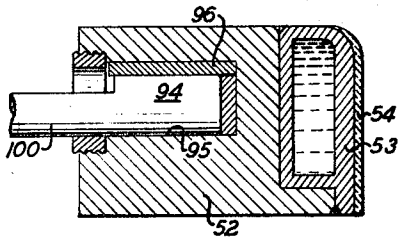



Fig. 11

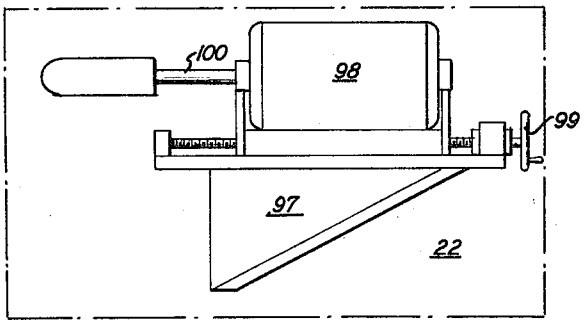



Fig. 10

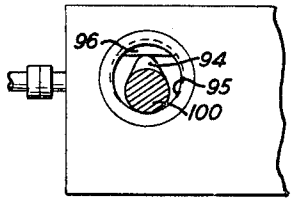



Fig. 12

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APPARATUS FOR CAST CLADDING

Filed Aug. 24, 1964 6 Sheets-Sheet 5

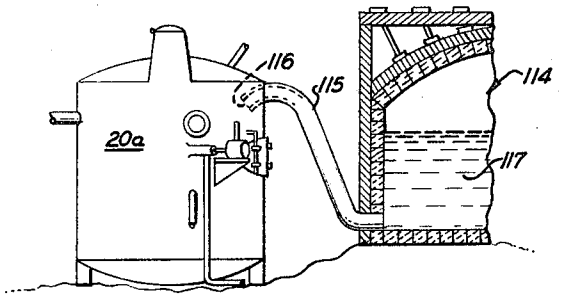



Fig. 13

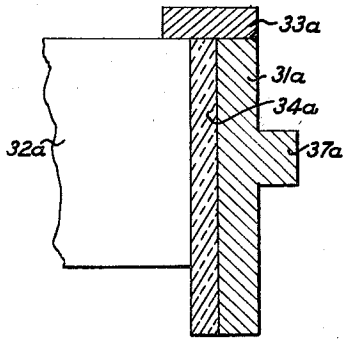



Fig. 15

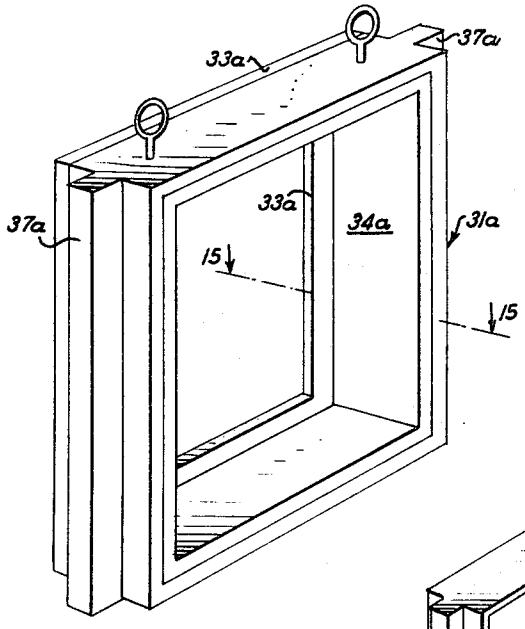



Fig. 14

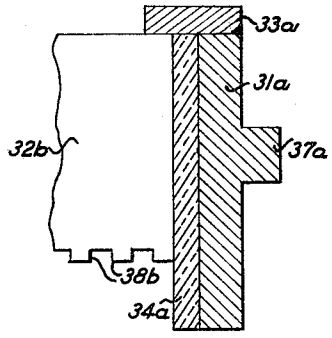



Fig. 16

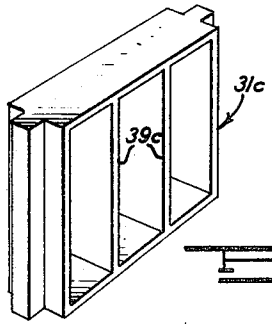



Fig. 17

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APPARATUS FOR CAST CLADDING

Filed Aug. 24, 1964 6 Sheets-Sheet 6

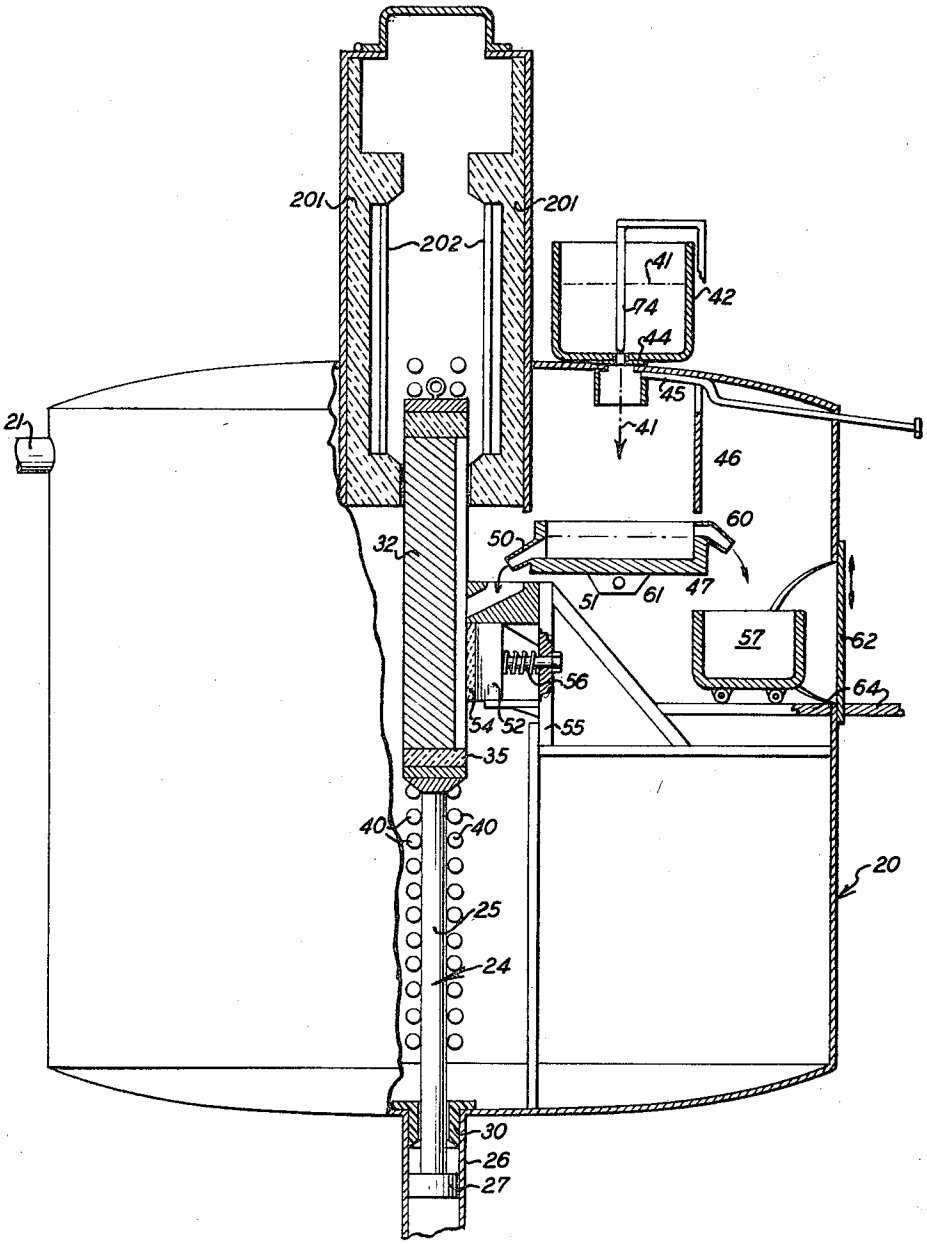



Fig. 1a

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United States Patent Office 3,396,778
Patented Aug. 13, 1968



3,396,778

# APPARATUS FOR CAST CLADDING

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Continuation-in-part of application Ser. No. 349,288, Mar. 4, 1964. This application Aug. 24, 1964, Ser. No. 393,470
13 Claims. (Cl. 164—275)

## ABSTRACT OF THE DISCLOSURE

Cladding apparatus wherein a slab held in a graphite frame is lowered within a vacuum chamber past a horizontal mold which bears against the graphite frame and molten cladding metal is continuously poured between the slab and the mold, solidifying as it moves past the mold to form a cladding surface on the slab. The slab is preheated to promote a bond betwen the slab and the metal and prevent warping. The mold is vibrated to eliminate sticking. Alternatively, the frame with the slab is vibrated by pulsing its hydraulic lift for the same purpose.

*Cross reference to related applications*

This application is a continuation-in-part of application Serial No. 349,288, filed Mar. 4, 1964, now abandoned.

*Summary and objects of the invention*

This invention relates to an apparatus for casting clad on a backing plate which is vertically disposed. More particularly, it relates to such process and apparatus wherein the backing plate together with a frame surrounding at least three sides of the backing plate is moved relative to a continuous casting mold in front of and spaced from the backing plate whereby molten metal entering the mold is continuously cast as clad on the backing plate.

Broadly speaking, cladding is a method or process in which a dissimilar metal or alloy layer is metallurgically bonded to base material in order to produce a metallic surface with special properties not obtainable with the base metal alone, as, for example, corrosion resistance. When the cladding is accomplished on a slab or backing plate which is subsequently to be rolled, it is a usual method to prepare what is known in the art as a sandwich or pack wherein the backing plate and the cladding material are held within a hermetically sealed steel envelope which is heated and rolled to effect a metallurgical bond. Another method is to place a backing plate within a mold and to apply the clad in the form of molten metal directly on the face of the backing plate. When the clad metal is solidified the laminated metal slab may then be rolled.

Practical cladding techniques require that the clad be metallurgically bonded to the backing metal in such a way as to avoid undesirable alloying at the interfaces of the clad and the backing metal. It is also frequently important that the clad metal has substantially uniform chemical and physical properties throughout. The casting of the clad should be carried out at a reasonable rapid rate for the most economical use of the equipment.

Accordingly, it is an object of this invention to provide process or apparatus for cast cladding which is inexpensive, permits rapid cladding techniques, has considerable flexibility in the type and thickness of clad produced, and is adaptable to the casting of slabs, billets, or blooms where desired.

The apparatus of the present invention has many advantages. For example, the cladding metal may be subjected to degassing or treatment under vacuum conditions just prior to its application to the backing plate. The thickness of the clad may be regulated within relatively close tolerances. The backing plate may be cleaned under vacuum or inert gas conditions to free it from contaminants such as scale, rust or other oxides, oils, grease, or other foreign material which might form on the face of the clad. Heating means for preheating the backing plate can be used within the tank.

The system permits considerable versatility in means which may be emplowed to prevent the molten metal from sticking to the moving mold. For example, when the backing plate is lowered relative to the mold in a hydraulic lift, a pulse vibrator in the latter may be employed to keep the relative movement between the mold and the metal which has just been poured so that they are never travelling at the same speed and thus prevent sticking of the mold to the molten metal. Or a sonic vibrator may be incorporated in the mold both to prevent the mold from sticking to the molten metal and to contribute to a fine crystalline structure in the clad metal.

By the utilization of a pressure vessel in the system in which a vacuum can be created, such vacuum may be controlled as means to introduce metal into the system and also to assist in the discharge of treating materials, cooling substances, and the like.

The foregoing advantages are objects of this invention and other objects, adaptabilities, and capabilities will appear as the description progresses, reference being had to the accompanying drawings, in which:

*Brief description of the invention*

FIGURE 1 is a vertical sectional view of an apparatus embodying the invention;

FIGURE 2 is a perspective view showing a plurality of apparatus such as shown in FIGURE 1 arranged with a melting furnace and a gantry crane;

FIGURE 3 is a horizontal section of the backing plate and frame as received in the apparatus illustrated in FIGURE 1;

FIGURE 4 is a vertical section illustrating the process of continuous casting of the clad;

FIGURE 5 is similar to FIGURE 4 except that it shows how the process or apparatus of the invention may be utilized to cast a slab;

FIGURE 6 is a perspective view of a further embodiment of a pressure vessel in accordance with the invention;

FIGURE 7 is a side view of the pressure vessel shown in FIGURE 6, partially broken away to expose the apparatus within the vessel;

FIGURE 8 is a front view of the pressure vessel shown in FIGURE 6, also partially broken away;

FIGURE 9 is a horizontal sectional view of the pressure vessel illustrated in FIGURE 6;

FIGURE 10 shows a vibrating motor such as is used on the pressure vessel illustrated in FIGURE 6;

FIGURE 11 is a vertical sectional view of the mold showing the cooling jacket and the vibrating cam member;

FIGURE 12 is a front elevational view of the mold shown in FIGURE 11;

FIGURE 13 shows a further modification wherein the pressure vessel is connected directly to the melting furnace;

FIGURE 14 is a perspective view showing a frame member as used in the invention carrying a backing plate;

FIGURE 15 is a sectional view taken on lines 15—15 of FIGURE 14;

FIGURE 16 is similar to FIGURE 15 except that it shows a modification wherein the surface of the backing plate to be clad is scored; and

FIGURE 17 is a perspective view of a frame similar to FIGURE 14 except that it has a plurality of spaces for the receipt of the molten metal in the casting process in accordance with the invention.

FIGURE 18 is a vertical sectional view of an apparatus similar to that shown in FIGURE 1 including means for preheating the slab or backing plate.

*Description of the preferred embodiments*

Referring now to FIGURE 1, a pressure vessel comprising a cylindrical tank **20** has an exhaust outlet **21** which leads to a vacuum source such as vacuum pumps (not shown). Disposed on top of the tank **20** is a loading door **22** which is positioned directly over a hydraulic support means **24**. The latter includes a plunger **25** which is received in a hydraulic cylinder **26** by a piston member **27**. A bushing **30** around the plunger **25** guides the plunger and assists in maintaining same in a vertical position. It will be appreciated that by the introduction of a hydraulic fluid and varying the pressure in the hydraulic cylinder **26** under the piston member **27**, the plunger **25** may be reciprocated.

The hydraulic support means **24** provides support for a frame member designated generally **31**. In the embodiment shown in FIGURE 3, the frame member **31** contains a backing plate or slab **32** which has vertical graphite frame parts **34**, one on each vertical side edge thereof. There are further graphite frame parts **33** and **35** on the upper and lower edges, respectively, of the backing plate **32**, whereby such backing plate is surrounded on its lower and vertical sides by the graphite frame parts **35** and **34**. It will be understood that the leading edges of the graphite frame parts **34** and **35** are coplanar. The frame member **31** together with backing plate **32** are carried by a guide jig **36** which incorporates on its sides guide rails **37**. The rails **37** are received between two lines of guide rollers **40** carried by the tank **20**. By such means or other appropriate apparatus as will occur to one skilled in the art, the frame member **31** may be reciprocated by the hydraulic support means **24** along a vertical coplanar path.

Molten metal **41** contained in a ladle **42** enters the tank **20** through a aluminum disc inlet **44**. When molten metal **41** is not flowing, a copper airlock **45** seals the burned down aluminum disc inlet **44**. The molten metal **41** drops through a degassing area **46** into a tundish **47**.

In the cladding process, the metal pours out of the tundish through the production outlets **50** and is received in a channel means or runner **51** which is carried immediately by a spring-loaded copper mold **52** having a graphite face **54**. The mold **52** together with the runner **51** are supported by a framework **55** which is firmly attached to the tank **20**. The mold **52** is spring-loaded by means of a compression spring **56** which urges the mold **52** away from the framework **55**. A spill ladle **57** is disposed under the excess outlets **60** of the tundish **47**. The tundish **47** is carried by a pivot means **61** which may be manually controlled outside of the tank **20** by any suitable means known to the art. It will be understood that pivot means **61** can be tilted in vertical plane in order to compensate for unequal molten metal from one side or the other of runner **51** by any number of means which would occur to one skilled in the art. Accordingly, when desired, molten metal in the tundish **47** may be spilled into the spill ladle **57**. A door **62** in the tank **20** is disposed adjacent to the spill ladle **57** whereby when such door is opened, the spill ladle **57** may be rolled out from the tank **20** on tracks **64**.

An induction heater **65** is provided to compensate for bending and warping due to the heat of the molten metal on one side of the backing plate **32**.

In operation, a frame member **31** containing a preheated backing plate **32** is carried from an assembly area **66** by an overhead crane **67** and deposited through an open loading door **22** onto the hydraulic support means **24** within a tank **20**. The loading door **22** is then secured and a vacuum is pulled within the tank through the exhaust outlet **21**. At approximately the same time the crane **67** deposits a ladle **42** with molten metal **41**, recently poured therein from a melting furnace **70**, onto supports **71** carried on a platform **72** above the tanks **20** except for the protruding loading doors **22** and inlets with discs **44**. When sufficient vacuum has formed within the tank **20**, a stopper rod valve **74** in the ladle **42** is pulled and molten stainless steel or other cladding metal **41** is poured from the ladle **42**, piercing the aluminum disc inlet **44**, through the degassing area **46** and into the tundish **47**. The pouring within a vacuum accomplishes a degassing operation. After the ladle **42** has been emptied, a copper airlock **45** is brought into place to seal the burned out aluminum disc inlet **44**. The tundish **47** is pivoted along its axis so as to pour molten metal **41** from the production outlets **50**. After the production operation is complete, the tundish **47** is tilted in the opposite direction and the excess metal flows into the spill ladle **57**.

The production operation consists of a continuous casting process where the frame member **31** together with the backing plate **32** continually move downwardly between the series of guide rollers **40**, the backing plate **32** being positioned so that the face of the clad is facing the tundish **47**. Thus the hydraulic support means **24** lowers the framed backing plate **32** downwardly opposite the runner **51** together with the mold **52** and the downward motion is correlated with the rate of flow of molten metal from the ladle **42** through the tundish **47** and out of the production outlets **50** onto the face of the moving backing plate **32**. The mold **52** is held into contact with the graphite frame parts **34** by means of the compression spring **56**. As previously noted, the front of the mold **52** is a graphite face **54**. The back portion is a water-cooled copper girder.

When the casting operation is complete, the upper frame part **33** blocks further flow of metal from runner **51**, the valve **74** is moved downward to stop the flow of molten metal **41** from the ladle **42**, and the tundish **47** is pivoted in the opposite direction to discharge excess metal into the spill ladle **57**. The vacuum within the tank **20** is broken by any appropriate means and the hydraulic support means **24** moves upwardly to bring the backing plate **32** together with the frame member **31** in the vicinity of the loading door **22** which is opened. The crane **67** removes the frame member **31** together with the backing plate **32** and, if desired and if further metal is available, places a further frame member and backing plate onto the hydraulic support means **24**.

FIGURE 4 illustrates the solidification of the cladding during the pouring process. Hence it will be noted that as a stream of metal **80** is poured into the water-cooled copper mold **52** it forms a hard skin **81**.

FIGURE 5 illustrates a modification wherein a thin backing plate **32***a* is employed with a thick layer of dividing compound **84** applied thereto. In this modification, the molded section **85** is a slab. Such slab may, while still hot, be placed in a further frame member **31** and cladded.

In the modification shown in FIGURES 6 through 12, the same reference characters have been utilized insofar as applicable. This modification is included to show the adaptability of the system for specialized applications. Accordingly, it will be noted that three distinctive means to vibrate the mold **52** have been provided. The first is a pulse means **86** which consists of a piston **87** which is reciprocated within a cylinder **90** having a fluid connection with the cylinder **26**. Thus when the plunger **25** is lowered by opening valve **91**, the reciprocating piston **87**

will communicate hydraulic pressure pulses to the piston means **27** whereby the piston **27** is vibrated vertically simultaneously with its being lowered, which vibrations are transmitted through the plunger **25** to the backing plate **32** within the frame member **31***a* to prevent sticking between the mold **52** and the solidified metal which has just been poured adjacent thereto.

A second vibrating means comprises a series of magnetostrictive transducer heads **59** attached to the mold **52**. Such heads transmit vibrations in the 1 to 50 kilocycle frequency range or higher and the term "sonic vibration" as used herein is intended to describe that acoustic energy which has a frequency above 1 kilocycle per second and may range from such frequency to many megacycles per second. The magnetostrictive transducer heads **59** have the effect of preventing stickage of the mold to the solidifying metal in the vicinity thereof during operation of the apparatus and, in addition, tend to homogenize the clad metal and cause a finer grain structure therein.

Vibration in the mold **52** may also be produced (FIGS. 11–12) by a rotating cam member **94** received within a bore **95** in the mold member **52**. The cam **94** acts upon a segment **96** disposed at the top of the bore **95**, whereby with each revolution the mold **52** is raised slightly, following which it lowers slightly. The cam is designed and its r.p.m. controlled so that the mold **52** and the adjacent clad never travel at the same speed whereby sticking is prevented.

In this embodiment, the cam member **94** within the bore **95** also acts to support the mold **52**. The position of the mold **52** relative to the frame member **31***a* is determined by the position of the motor **98** on its support stand **97** which is firmly connected to the tank **22**. It will be appreciated that the shaft **100** of the motor **96** connects with the cam **94** and rotates same. By moving a motor **98** horizontally on both sides of the tank **22**, by cranks and screws **99** journaled to stand **97** and threadably received by the mounts of motor **98**, the mold **52** may be brought flush with the graphite frame parts **34**.

The mold **52** has a graphite face **54** and is cooled by the circulation of water in jacket **53**.

In order to cool the clad together with the backing plate, more rapid cooling means comprising water nozzles **101***a* and **101***b* are disposed below the mold **52** (FIG. 7) and to either side of the backing plate and clad metal as it is lowered by plunger **25**. Steam produced by water sprayed on the hot recently solidified metal has the effect of tending to break the vacuum within the tank **20** which is generally a desirable condition at this point. With the breaking of such vacuum the loading door **22** may be opened and the air from the atmosphere is then swept into such door while steam is evacuated through the exhaust outlet **21**. The nozzles **101***a* can also carry fluid and other substances to clean the surface of the backing plate **32** which is to be clad. Since such cleansing takes place in a vacuum, metal once clean tends to stay clean, a circumstance which enhances the metallurgical bond between the cladding metal and the backing plate.

It is, however, sometimes desirable to treat specially the surface of the backing plate **32** to be clad. This may be accomplished through the treating nozzle **102**. Such treatment may consist of shot peening which will both clean and treat such surface or plating by the shot method such as is, for example, disclosed in the patent to N. C. Parrish, No. 2,618,572 of November 18, 1962, for the metal titanium. By such means an intermediary layer may be produced on the surface of backing plate **32** to be clad. Removal means **104** is provided at the bottom of tank **20** for the removal of spent material, debris, liquid, and the like. It will be understood by those skilled in the art that the removed material and liquid can frequently be separated for subsequent re-use.

A gas inlet **105** is provided in the vicinity of the degassing area. Such gas inlet **105** may selectively provide a jet of gas to intercept the stream of molten metal, such gas generally being an inert gas. Where an inert gas is employed, a turbulence may be produced wherein the degassing effect is enhanced.

A bank of radiant heating cells **106** perform essentially the same function as the induction heater **65** of the first embodiment.

In this embodiment a further exhaust outlet **107** is placed in the proximity of the inlet **44** to insure the exhaust of gases which may enter with the poured metals. When the metal stops pouring, an airlock such as airlock **45** in the first embodiment or other appropriate covering means may be placed over the inlet **44** in order to maintain a pressure-tight condition within the tank **20**.

In operation, the frame member **31***a*, together with the backing plate **32**, may be first lowered through the loading door **22** onto hydraulic support means **24**, following which such door is closed and atmosphere is exhausted from the tank **20**. Plungers **25** lower the frame member **31***a* whereby the face of the backing slab **32** to be clad may be thoroughly cleaned by action of the treating nozzle **102** or the water nozzle **101***a* or a combination of both. Plunger **25** is then raised to the position shown in FIGURE 7, mold **52** is brought flush with frame member **31***a*, and, as previously described, molten metal from the ladle **42** is received in the tundish **47**. A stream of argon gas **110** intersects the stream of molten metal to assist the degassing process in the area **46**. The metal is then poured into the runner **51** and at the same time valve **91** is opened and pulse means **86** is started whereby the plunger **25** is lowered and at the same time vibrated through impulses imparted by pulse means **86**. If desired, such vibrations may be augmented by the rotation of the cam **94** by means of the motor **98** in the mold **52** and by actuation of the transducer heads **59**. The heating elements **106** are turned on in order to keep the backing plate **32** from warping or bending due to the heat generated by the poured metal. As the plunger brings the backing slab **32** together with the clad metal past the water nozzles **101***a* and **101***b* and the pouring operation is nearing completion, such nozzles are opened in order to remove the heat from such backing plate and the recently molten metal. When the top of the slab passes the runner **51**, the ladle is stopped and excess metal in the tundish **47** is spilled into the spill ladle **57**. The vacuum pump is now cut off and with the continued lowering of the heated backing plate **32** and the clad past the water nozzles **101***a* and **101***b*, the tank **22** fills with steam to break the vacuum within the tank **20** to permit the opening of loading door **22**. The exhaust pumps may then be again started to evacuate the steam from the tank **20** and the plunger **25** is raised by closing the valve **91** and starting the pump **111**. Pulse means **86** is secured when the backing plate **32** together with the poured metal which is now cladded onto such plate no longer contacts mold **52**.

If desired, following the cooling of the slab, the surface of the slab can be further treated by shot peening, plating by peening, or the like.

FIGURE 13 shows a melting furnace **114** connected to a modified tank **20***a* by means of a conduit **115**. The conduit **115** is made of refractory material or other suitable substances for the conveyance of molten metal, such as steel. The outlet **116** of conduit **115** is higher than the level of the metal **117** in the melting furnace **114**. Consequently, by controlling the degree of vacuum in the tank **20***a*—and hence the pressure differential between the two units—the rate of flow of molten metal **117** through conduit **115** to the inlet **116** may be controlled.

The modified frame means **31***a* is shown in FIGURE 14. In such frame member, the guide rails **37***a* are incorporated in the frame member **31***a* and an inwardly extending flange **33***a* is provided in the after portion of the frame means **31***a*. The graphite frame parts **34***a* and the backing plate **32***a* can be readily assembled in such a frame member.

FIGURE 16 discloses a frame member **31***a* which has a backing plate **32***b* similar to the backing plate **32***a* ex-

cept that its surface 38*b* has been scored to provide an additional surface interlock between the molten metal and the surface 38*b*.

FIGURE 17 shows a frame member 31*c* which in all respects is similar to frame member 31*a* except that a plurality of vertical division plates 39c create a plurality of spaces to receive backing plates in the form of billets for cladding, or, alternatively, by the use of dividing compound as shown in FIGURE 5, billets may be formed, per se.

It will be understood that normally the dividing plates 39*c* will be composed of graphite.

FIGURE 18 illustrates a further refinement wherein the slab 32 is preheated on both or either side, as desired, before and during the casting step when the piston lowers the frame member. The same reference numbers as those seen in the FIGURE 1 device are used insofar as applicable.

It will be noted that the top portion of tank 20 supporting the holding door 22 has been extended to accommodate heating elements 202 which are located between insulating screens 201 and the front and back of slab 32. The preferred heating elements are longitudinally arranged so that substantially the entire front and back surfaces of the slab can be preheated at the same time. Suitable heating elements are silicon carbide rods although alternative arrangements will occur to one skilled in the art.

Induction heater 65 can be eliminated but except for this change and the modification of the tank top, the apparatus and process described in connection with FIGURE 1 are the same.

The heating elements are arranged so that the temperature of at least the front and back surfaces of slab 32 or either of them may quickly be brought to a temperature in the order of 2200° F. or above. Although much lower temperatures down to about 800° F. have some effect in the avoidance of premature freezing of the poured metal, it has been postulated that in the instance of pouring 18–8 stainless steel on a carbon steel backing plate, superior "wetting" and, accordingly, better welding occurs when the surface temperature of the slab is 2200° F. or more with the temperature of the stainless steel melt being above 2650° F. to about 3000° F. Commercially available heating elements of silicon carbide can be heated to about 3100° F. and are capable of heating the slab surfaces to the desired temperatures in a relatively short time. Other ways of raising the temperature of the slab surfaces such as induction heating within or without the tank 20 can also be employed, but if preheating is done it is preferable to carry it out completely within the tank using resistance heating elements.

After cast cladding has been completed the plunger can be moved upwardly until the clad backing plate is again in preheat position. The cladded plate can then be heated to annealing temperatures before being removed from the top of the tank.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, for further modifications will be obvious to those skilled in the art.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. Apparatus for cast cladding which comprises a pressure chamber (20), an evacuation means (21) operatively connected to said chamber, opening means (22) in the upper part of said chamber for admitting a vertically disposed rectangular metallic slab (32), reciprocating means (24) disposed under said opening within said chamber for moving said slab up and down in a vertical plane, horizontally disposed mold means (52) carried in said chamber positioned to be proximate and including a planar surface substantially parallel to the surface of said slab carried by said reciprocating means, said slab being movable past said mold means while maintaining molten metal retaining relationship with said mold means, a molten metal inlet (44) in the upper portion of said chamber and a molten metal receiving and distributing means (47) within said chamber disposed to receive molten metal from said inlet and distribute same to said mold means, said mold means being limited to the region for casting metal on said slab, whereby when said molten metal is so distributed to said mold means and said slab is moved downward by said reciprocating means, a clad is cast from said molten metal on said slab as said slab moves past said mold means.

2. An apparatus in accordance with claim 1 wherein sonic vibrations means (59) are incorporated in said mold means, said sonic vibration means adapted to vibrate said mold relative to metal adjacent thereto to promote stripping of said metal from said mold.

3. An apparatus in accordance with claim 1 wherein heating means (202) is positioned in the upper part of said chamber for preheating said slab while positioned on said reciprocating means.

4. An apparatus in accordance with claim 1 wherein said reciprocating means includes a hydraulic cylinder (26) and piston (27), the fluid in said cylinder under pressure from the weight of said slab, pump means (111) and discharge means (91) to introduce and discharge fluid from said cylinder for reciprocating said slab, and pulse means (86) interconnected with the fluid in said cylinder whereby the downward speed of said reciprocating means is varied by pressure pulsations introduced on said fluid by said pulse means within said cylinder.

5. An apparatus in accordance with claim 1 wherein a gas inlet (105) is provided into said chamber disposed whereby gas may be directed therefrom to said molten metal received within said chamber.

6. An apparatus in accordance with claim 1 wherein a heating means (65) is included within said chamber positioned on the side of said slab opposite said mold means whereby the back of said slab receiving said molten metal may be heated to prevent warping of said slab.

7. An apparatus in accordance with claim 20 wherein cooling means (101*a*, 101*b*) are incorporated in said chamber positioned below said mold means to cool and promote solidification of said clad as it moves past said mold means.

8. An apparatus in accordance with claim 7 wherein said cooling means are positioned to direct fluid on both sides of said slab following the casting of a clad thereon.

9. An apparatus in accordance with claim 1 wherein cleansing means (102) are positioned within said chamber to direct cleansing material against said slab for removing oxides and other impurities therefrom.

10. An apparatus in accordance with claim 9 wherein said cleansing means directs a treating material at a high velocity to impinge upon said slab and a recovery means (104) operatively associated with said chamber to recover therefrom said spent treating material and debris removed from said slab.

11. An apparatus in accordance with claim 1 in combination with a melting furnace (114) containing molten metal (117), conduit means (115) connecting the lower portion of said furnace and said molten metal inlet, the latter having a height above the level of metal in said furnace whereby molten metal is received from said furnace in said chamber only when vacuum is applied in said chamber.

12. A mold for cladding a rectangular vertically disposed slab (32) on one face thereof which comprises a graphite frame (31) receiving said slab and embracing the edges thereof, said frame extending continuously forward of the face of said slab to form the ends of a space extending in front of said face, said space having a horizontally disposed rectangular cross section, a horizontal forming element (52) disposed across said frame opposite said face and in slidable molten metal retaining engagement with two parallel edges thereof, said forming ele-

ment movable contiguous with said space and including a planar surface forming a partial fourth side surface of said rectangular space, and means to move relatively said forming element vertically upward along said space while maintaining said molten metal retaining engagement whereby molten metal introduced into said space between said slab and said forming element forms a clad of a uniform thickness and having the cross-sectional dimensions of said rectangular space on said slab said forming element being limited only to the essential region for casting metal on said slab.

**13.** Apparatus in accordance with claim **12** including a pressure chamber (**2**), an opening (**22**) in the upper part of said chamber for admitting said frame, and reciprocating means (**24**) disposed under said opening within said chamber for receiving said frame and comprising the means for relatively moving said forming element along said space.



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# UNITED STATES PATENT OFFICE

# CERTIFICATE OF CORRECTION

Patent No. 3,396,778 August 13, 1968

Niels H. Jensen et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 60, "reasonable" should read -- reasonably --. Column 2, line 12, "emplowed" should read -- employed --. Column 3, line 49, "a" should read -- an --. Column 7, line 6, the "c" in "39c" should be in italics. Column 8, line 40, "20" should read -- 1 --; line 69, "ends" should read -- sides --. Column 9, line 1, "movable" should read -- movably --.

Signed and sealed this 20th day of January 1970.

(SEAL)
Attest:

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