April 13, 1971 J. A. RASSENFOSS 3,574,603

METHOD FOR PRODUCING STAINLESS STEEL

Filed Sept. 15, 1967 3 Sheets-Sheet 1

Fig. 1.

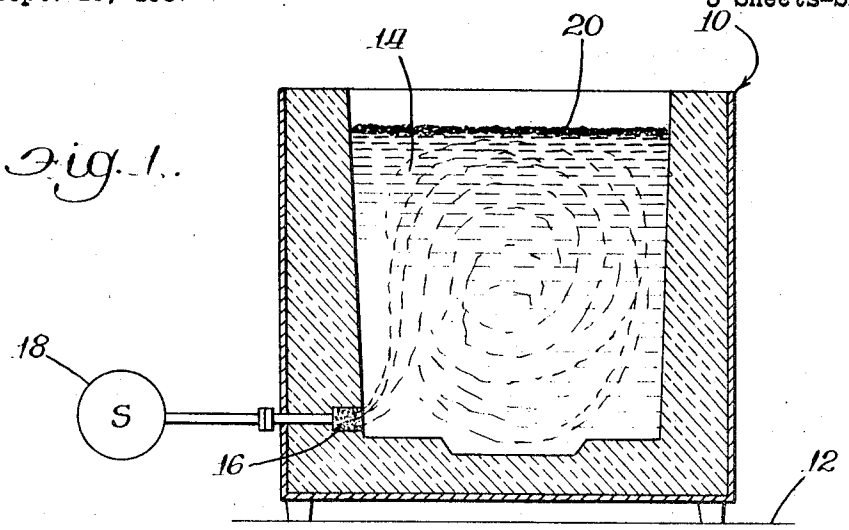
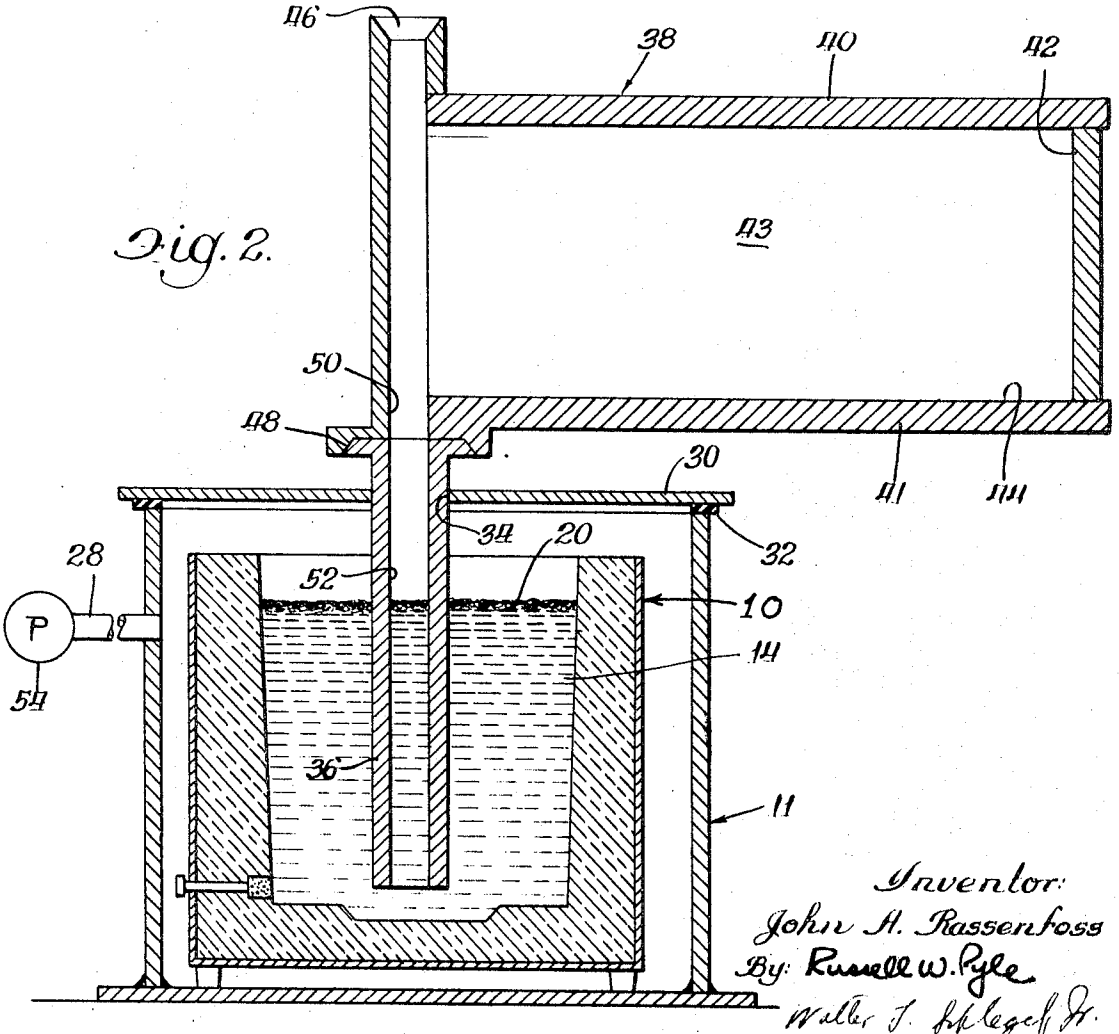


Fig. 2.



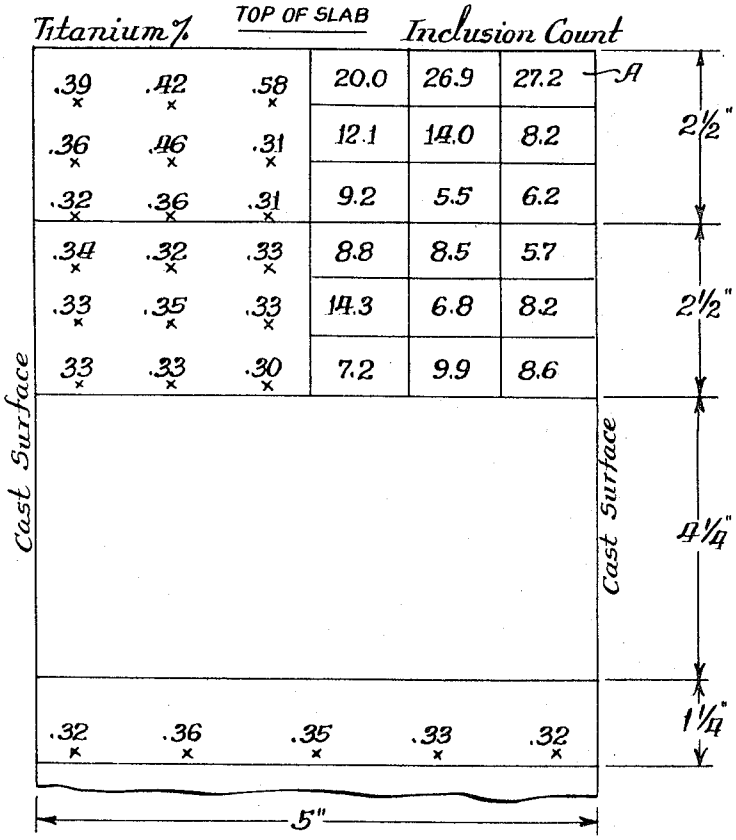
Inventor:
John A. Rassenfoss
By: Russell W. Pyle
Walter J. Schlegel Jr.
Attys.

April 13, 1971 J. A. RASSENFOSS 3,574,603

METHOD FOR PRODUCING STAINLESS STEEL

Filed Sept. 15, 1967 3 Sheets-Sheet 2

Fig. 3.



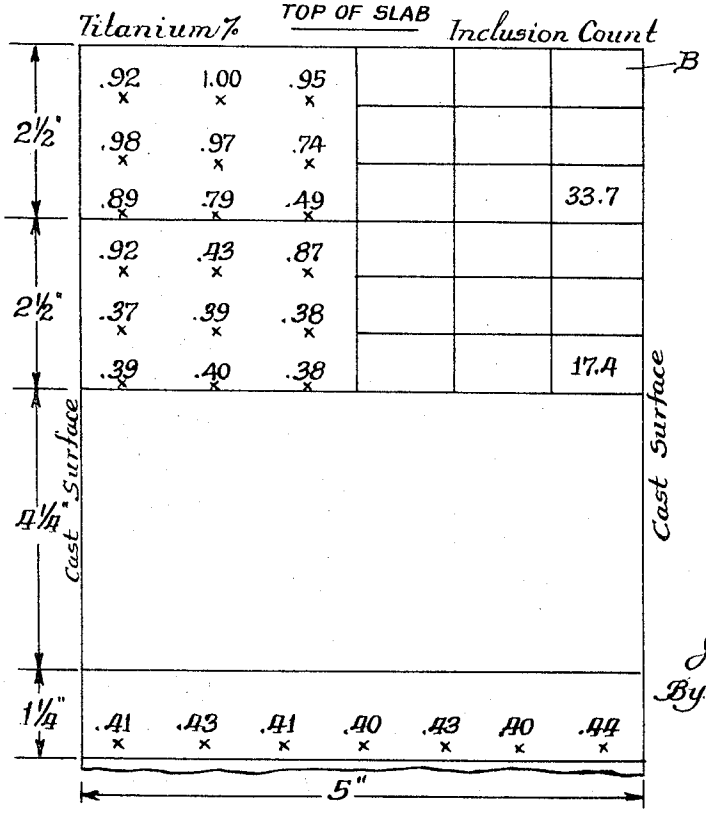


Fig. 4.

Inventor:
John A. Rassenfoss
By: Russell W. Fyle
Walter P. Schlegel, Jr.
Attys.

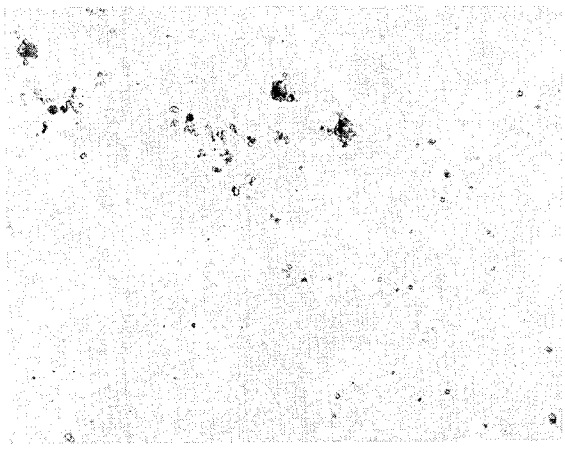


FIGURE 5

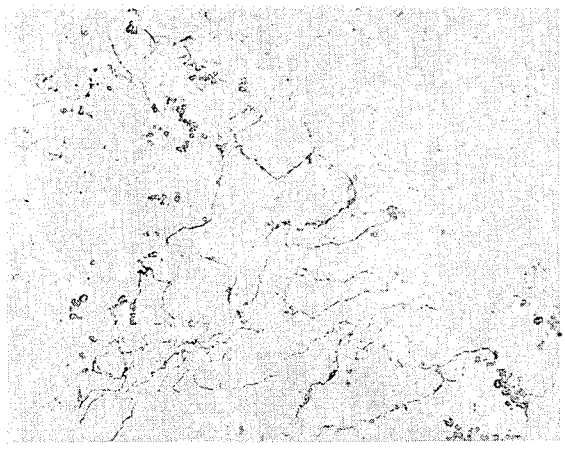


FIGURE 6

JOHN A. RASSENFOSS
Inventor

By Russell W. Pyle
Walter J. Schlight Jr.
Attorneys

United States Patent Office 3,574,603
Patented Apr. 13, 1971

3,574,603

METHOD FOR PRODUCING STAINLESS STEEL

John A. Rassenfoss, Park Ridge, Ill., assignor to AMSTED Industries Incorporated, Chicago, Ill.

Filed Sept. 15, 1967, Ser. No. 667,977
Int. Cl. C21c 7/00; C22c 33/00
U.S. Cl. 75—129 5 Claims

ABSTRACT OF THE DISCLOSURE

In the production of stainless steels involving additions of titanium, columbium or tantalum, the molten steel is agitated in the ladle by the introduction of an inert gas from a lower portion of the side of the ladle, while maintaining a layer of slag on the melt. The melt is cast into a slab or other suitable form by pressure pouring, which involves disposing the ladle in an enclosure with a pouring tube between a mold and a lower portion of the melt, and applying superatmospheric pressure within the enclosure. Preferably, an inert gas atmosphere is maintained in the casting cavity of the mold during the pouring operation.

This invention relates to methods for producing stainless steel and more particularly to a method for reducing inclusions normally found in certain grades of stainless steel.

In the production of those stainless steels containing additions of titanium, columbium, or tantalum, the formation of carbonitride inclusions with these elements presents a serious deterrent to wide commercial usage. During the casting operation, such inclusions tend to rise and concentrate near the top of the slab or other article being cast and impart undesirable properties to the final product. For example, upon the rolling of a stainless steel slab produced by conventional methods, defects such as slivers and scratches occur due to the carbonitride inclusions. Moreover, since these inclusions tend to concentrate in one portion of the slab, a majority of the defects will be concentrated in a relatively small area, resulting in a highly unsatisfactory product.

Very few solutions have been offered to avoid the problems stated above. One proposed solution invloves a reladling technique, wherein the alloying material is added during tap. The melt is then slagged off and poured back into another ladle to achieve some degree of mixing. This technique is generally inefficient and may result in substantial heat losses, thereby necessitating reheating. Another method involves the removal of the inclusion-enriched portion of the slab which may result in considerable loss of material.

Accordingly, an object of this invention is to provide a method of reducing the amount of carbonitride agglomerations normally found in stainless steels containing titanium, columbium or tantalum.

Another object of this invention is to provide a combination method for treating and casting iron-base melts that will be effective to minimize atmospheric recontamination subsequent to treatment.

The above and other objects will become apparent to those skilled in the art from the following description and appended claims, and in connection with the accompanying drawings wherein:

FIG. 1 is a cross-sectional schematic illustration of the apparatus used in conjunction with the first portion of the presently described process;

FIG. 2 is a cross-sectional schematic illustration of the apparatus used in conjunction with the remainder of the presently described process; and

FIGS. 3, 4, 5 and 6 represent results of experiments described herein.

With reference to the drawings, FIG. 1 illustrates a ladle **10** resting upon a support **12** and containing molten steel **14**. The chemical composition of the molten steel will, of course, be dependent upon its intended application. For example, in the production of type 321 stainless, the steel will contain the following approximate maximum percentages of constituents: 0.08 carbon; 2.00 manganese; 1.00 silicon; 0.045 phosphorus; and 0.030 sulphur. In addition, the steel will contain from about 17 to 19 percent chromium, 9 to 12 percent nickel, and an amount of titanium equal to at least five times the carbon content. In the practice of the presently described invention, the necessary amounts of titanium, columbium, or tantalum are added as the molten steel is tapped from the furnace (not shown) into the ladle **10**.

In conventional operations, the above constituents are melted in the furnace and transferred by ladle to a mold. Due to the dissolved nitrogen in the molten bath, however, the titanium, columbium, or tantalum may react to form carbonitride agglomerations that are only partially absorbed by the slag. Ideally, these agglomerations should be minimized by removing nitrogen from the melt or by fluxing the carbonitride particles out of the bath, in order to insure a final product of consistent and uniform quality. However, as mentioned before, such a result has not been sufficiently attainable by utilizing presently known methods.

As shown in FIG. 1, a porous plug **16** is positioned in an interior wall of the ladle **10** in a lower portion thereof, and communicates with a source **18** of pressurized inert gas, such as argon or helium.

As the molten steel **14** is tapped from the furnace (not shown) into the ladle **10**, a sufficient amount of furnace slag is allowed to enter the ladle to provide a slag layer **20** of about one or more inches in thickness on the top of the molten bath. The slag layer **20**, among other things, serves to prevent atmospheric contamination during the agitation of the molten steel **14**.

After the ladle **12** has been substantially filled with molten steel **14**, the inert gas is introduced for a period of about from three to twenty minutes. The required rate and time of flow of gas will be dependent upon the size of the ladle and the amount of molten steel therein, but it has been found preferable to introduce the inert gas at such a rate that only a slight rolling action is noticeable at the top of the bath, in order to prevent break up of the slag layer.

The inert gas agitation herein described has been found to be effective to thoroughly mix the titanium, columbium, or tantalum additions and also to enhance equilibrium between such alloys and any dissolved nitrogen in the melt. Moreover, the bath agitation causes the carbonitride particles to agglomerate into larger particles that more readily rise to the surface of the melt, to be absorbed or retained by the slag layer present at the top of the bath. Also, as indicated in FIG. 1, a rolling motion of the melt is created by the introduction of inert gas near the bottom and at one side of the ladle, which motion is effective to expose successive portions of the melt to the slag layer. In this manner, carbonitride agglomerations are removed or otherwise inhibited because of their absorption by the slag layer, thereby providing a melt that is relatively free of inclusion-forming materials upon subsequent casting.

It will be understood that a plurality of porous plugs located in or near the bottom of the ladle **10** may replace the single plug described herein, and other means may be substituted for stirring the melt in the ladle, such as induction or mechanical stirring.

After the inert gas flushing and mixing has been completed, the ladle **10** is transferred to a pouring station

as shown in FIG. 2. As shown, the ladle is disposed in a substantially sealed tank **11** connected by a line **28** to a regulated source **54** of pressurized pneumatic fluid, such as compressed air.

The top of the tank **11** is closed by a removable cover **30** seated on a resilient seal ring **32** and secured to the tank by releasable clamps or other suitable means (not shown) to afford a substantially sealed enclosure. Cover **30** has an opening **34** adapted to receive a pouring tube **36** that extends through the cover into a lower portion of the ladle **10**. In order to prevent slag **20** from entering the pouring tube **36** during its insertion, it has been found preferable to either remove as much slag from the ladle as possible or to close the lower end of the pouring tube during insertion. A mold **38** is provided above the cover **30** of the tank **11** and is mounted on the upper extremity of the pouring tube **36**. Molten metal **14** may be forced upwardly through the pouring tube **36** into mold **38** by the application of superatmospheric pressure on the molten metal in ladle **10**.

The mold **38** shown in FIG. 2 is a slab mold and comprises a plurality of graphite blocks including a top block **40**, a bottom block **41**, an end block **42** and two side blocks, one of which is indicated at **43**. The blocks are held in engagement by suitable means (not shown) to define therebetween a casting cavity **44**. An upper portion of the mold **38** is provided with a riser opening **46** between the atmosphere and the casting cavity **44**, and a lower portion of the mold is seated on the upper surface of a flange **48** formed on the upper end of the pouring tube **36**. A gate **50** in the mold **38** communicates with casting cavity **44** and is substantially aligned to communicate with the bore **52** of the pouring tube **36**. In operation, pressurized pneumatic fluid is forced from a convenient source **54** through line **28** and into tank **11**, which raises the molten metal **14** upwardly through the pouring tube **36** to fill the casting cavity **44**.

In the practice of the presently described process, it has been found preferable to maintain an inert gas atmosphere in the casting cavity **44** during the pouring operation, in order that there will be little or no harmful contamination or recontamination of the melt by the nitrogen or oxygen in the atmosphere. It may thus be seen that the present method in its entirety affords a continuous procedure by which the melt may be cast efficiently while minimizing harmful carbonitride inclusions therein.

In summary, titanium, tantalum or columbium is added as the molten steel is tapped from the furnace into the ladle, along with sufficient furnace slag to provide a cover for the surface of the melt. Thereafter, an inert gas, such as argon, is passed upwardly from a lower portion of the ladle, in order to stir the melt. The molten metal is then immediately pressure poured, which comprises forcing the molten metal generally upward through a pouring tube and into a mold by the use of superatmospheric pressure imposed against the molten steel in the ladle. Preferably, an inert gas atmosphere is maintained in the casting cavity of the mold during the pouring operation.

In order to further illustrate the present invention, the following examples are given:

EXAMPLE 1

An iron-base charge of about 17,000 pounds was melted and finished in an electric furnace, in the normal manner for producing 300 series stainless steels. The heat was tapped at 3110° F. and 0.60% titanium as ferro-titanium was added in the ladle. Sufficient furnace slag was also admitted into the ladle with the heat, in order to provide a slag layer of over one inch thickness on the melt in the ladle. Argon was introduced by means of a porous plug at a line pressure of 45 p.s.i., to provide a smooth rolling action of the metal-slag interface without splashing and without leaving the metal surface exposed to the atmosphere. The argon bubbling was continued for a total of eight minutes, at which time the temperature of the bath reached 2940° F. The slag was then removed and a slab was pressure poured at a temperature of 2850° F.

The analysis of the steel before and after argon flushing is shown below:

	C	Mn	Si	P	S	Cr	Ni	Ti
Before tap	.05	[1] 1.53	1.61	.026	.010	18.01	10.71	----
After argon	.05	[1] 1.60	1.67	.025	.010	17.72	10.65	.36

[1] CaMnSi alloy added at tap.

A full width section was cut at about ten inches from the back of the resultant slab for the purpose of microexamination and chemical analysis. The area of one-half of the section was analyzed for titanium, and an inclusion count was performed on the other half. The inclusion count was obtained by using a microscope with a 16× objective and ASTM grain size eyepiece. The number 8 grain size was employed, giving 144 squares in the grid. The number of micro-inclusions that intersected an individual square was counted to evaluate the relative number of such inclusions in a given area of the slab. The average result, along with corresponding titanium chemical analyses, are illustrated in FIG. 3, which illustrates a width section of the slab tested from the top downward.

As shown in FIG. 3, the titanium analyses were fairly uniform from the top of the slab downward, with a range of about 0.30 to 0.58 percent. The total average of inclusions was found to be 11.5.

A photomicrograph, reproduced as FIG. 5, was taken of the area A of FIG. 3 at 100×. As may be seen from this figure, the inclusions were relatively few in number and were evenly dispersed over the entire area.

EXAMPLE 2

In order to compare the results stated in Example 1 with other methods, a similar experiment was performed without the use of argon stirring or flushing, but with pressure pouring. A charge of steel was melted and finished in a manner similar to that stated in Example 1. In this instance, however, the melt was then slagged off and poured into another ladle in accordance with the conventional reladling technique. Pressure pouring of slabs was then commenced.

FIG. 4 illustrates the inclusion count and titanium analyses on a width section of the resultant slab corresponding to that section shown in FIG. 3. As shown in FIG. 4, the number of inclusions was found to be very high near the top of the slab as compared to the lower portions, and much higher in total average, which was determined as 25.5. The titanium analyses showed a much higher concentration near the top of the slab and an overall range of 0.38 to 1.00 percent.

A photomicrograph, reproduced as FIG. 6, was taken of the area B of FIG. 4 at 100×, in order to further compare this slab with the one discussed in the previous example. As shown, massive titanium carbonitride agglomerations were found, which would ordinarily render this portion of the slab unsuitable for further use.

It may thus be seen that an improved method for producing certain grades of stainless steel has been discovered, which affords a substantial and unexpected improvement over presently known methods, especially in terms of the prevention of excessive and concentrated areas of carbonitride inclusions.

Having thus described the invention, what is claimed is:

1. In a method of producing stainless steel with a minimum of carbonitride inclusions wherein at least one of the elements selected from a group consisting of titanium, columbium, and tantalum is added to the steel as an alloying material, the steps of melting iron-base materials to provide a melt, tapping the melt into a ladle while

adding at least one of said elements, providing a slag layer on the melt in the ladle, agitating the melt in the ladle to promote carbonitride particle agglomeration and absorption by the slag, and thereafter pressure pouring the treated melt by applying superatmospheric pressure against the slag on top of the melt to force a portion of said melt spaced from the slag through a pouring tube into a mold.

2. The method according to claim 1 wherein the melt is agitated in the ladle by introducing an inert gas for about from three to twenty minutes at a rate such as to cause a smooth rolling action of the metal-slag interface.

3. The method according to claim 1 wherein the step of pressure pouring said melt further comprises disposing a pouring tube within said melt near the bottom thereof, the upper end of said tube communicating with a mold, disposing said ladle and said pouring tube with an enclosure, and applying superatmospheric pressure within said enclosure, whereby said melt is forced upwardly through said tube and into said mold.

4. The method according to claim 3 wherein an inert gas atmosphere is maintained within the mold during the pressure pouring of said melt.

5. A method of minimizing carbonitride inclusions in stainless steeel melts having an undesirably high nitrogen level wherein the steel contains at least one of the elements

selected from the group consisting of titanium, columbium, and tantalum, which comprises the steps of melting iron-base materials to provide a melt, adding at least one of said elements, maintaining a slag layer on the melt, and agitating the melt by bubbling an inert gas upwardly therethrough to promote carbonitride particle agglomeration and absorption by the slag layer.

References Cited

UNITED STATES PATENTS

2,255,482	9/1941	Daeves	75—123X
2,738,267	3/1956	Pakkala	75—124
2,806,782	9/1957	Faber	75—58X
2,745,740	5/1956	Jackson	75—130.5
3,283,369	11/1966	Sylvester	164—133X
3,392,009	7/1968	Holmes	75—59

FOREIGN PATENTS

1,097,862	1/1968	Great Britain	75—128.8

L. DEWAYNE RUTLEDGE, Primary Examiner

JOSEPH. E. LEGRU, Assistant Examiner

U.S. Cl. X.R.

75—49, 61; 164—62, 133