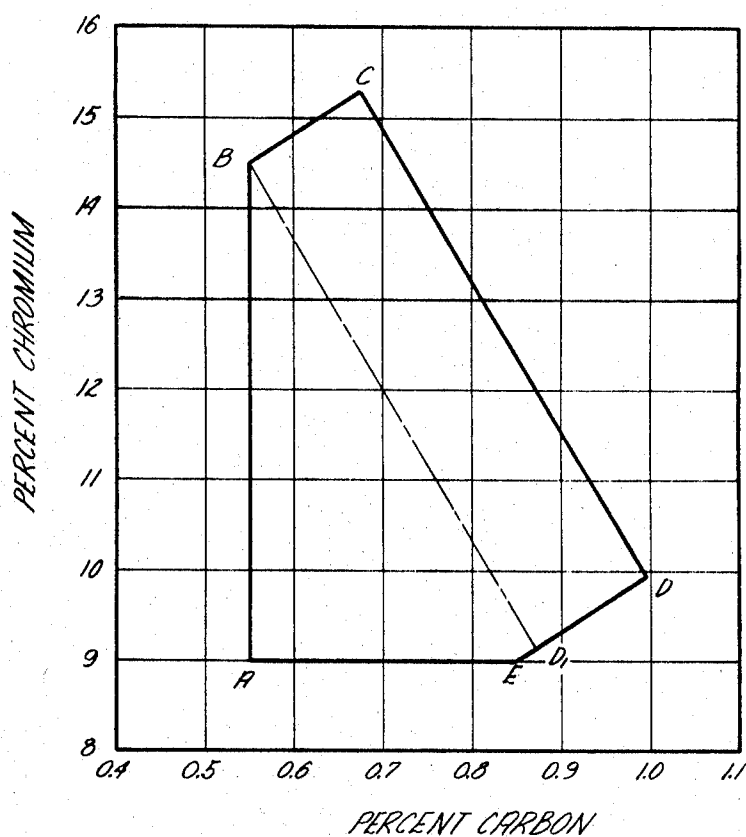


Sept. 30, 1969 **JAN-CHRISTER H. O. CARLEN ET AL** **3,469,972**
RAZOR BLADES AND SIMILAR THIN ELONGATED SHARP-EDGED
BLADES MADE OF A CHROMIUM STEEL
Filed Jan. 4, 1966



1

3,469,972

RAZOR BLADES AND SIMILAR THIN ELONGATED SHARP-EDGED BLADES MADE OF A CHROMIUM STEEL

Jan-Christer Henric Ovesson Carlen, Sandviken, Sweden, and Francis Edward Flaherty, Canton, and Wyman Carrick Tupper, Marblehead, Mass., assignors to Sandvikens Jernverks Aktiebolag, Sandviken, Sweden, a corporation of Sweden

Filed Jan. 4, 1966, Ser. No. 518,583

Int. Cl. C22c 39/18, 39/48; C21d 1/18

U.S. Cl. 75-126

10 Claims

ABSTRACT OF THE DISCLOSURE

Razor blades having a good corrosion resistance and a cutting edge hardness above VPN 700 after tempering up to 500° C., characterized in that the razor blades are made from a steel having good working properties and consisting essentially of carbon and chromium in amounts within the area ABCDEA of the accompanying diagram; 0.70-2.5% silicon; up to 2% manganese; a member of the class consisting of molybdenum, tungsten, and mixtures thereof, the amount of molybdenum when present alone being 0.5-2.5%, the amount of tungsten when present alone being 1.0-5.0%, and the sum of the amounts of molybdenum and one-half the tungsten when both are present being 0.5 to 2.5; 0-1.5% of nickel; 0-1.5% of copper, and 0-0.5% cobalt, the total amount of all nickel, copper and cobalt being at most 1.5%; and the remainder being substantially all iron; and in which the sum of the amounts of chromium, molybdenum and one-half the tungsten is 10-15%. The method of making such blades which includes cold rolling the steel to the desired thin dimension, hardening the cold rolled steel to high hardness by heating it to a temperature within the range 1000° to 1150° C. and subsequently cooling to a temperature below room temperature, the temperature and time of the hardening step being selected to provide substantially maximum hardness of the steel after cooling.

The present invention relates to razor blades, and similar thin elongated sharp edged blades, having a very good corrosion resistance and a hardness above VPN 700 (Vickers hardness, 0.5 kg. load) also after tempering up to 500° C. Of particular importance are the razor blades of the present invention because of their superior shaving characteristics.

Previously such blades have been made from high-chromium steels having a high carbon content and being hardened from a temperature exceeding 1000° C. As an example of this can be mentioned steel alloys containing 0.9-1.25% carbon, 13-15% chromium, the remainder being substantially all iron, possibly with minor additions of one or more further elements such as manganese, copper, molybdenum and cobalt. The blades made of these alloys have in several essential respects been found not entirely satisfactory. Their corrosion resistance is moderate, and they corrode noticeably when in contact with other metals such as in a razor. Their edge smoothness is not of the desired quality. These steels have also a limited temper resistance, i.e. they soften somewhat on tempering, and their hardness after hardening is decreased substantially when they are subjected to temperatures above 300° C., as e.g. in connection with the applying of certain coatings to improve the shaving properties.

The purpose of the present invention is to provide corrosion resistant blades having an improved corrosion resistance, in combination with superior edge sharpness and smoothness and improved temper resistance. By a

2

special heat treatment of the alloy of the present invention a further increase of the temper resistance can be obtained.

The appended drawing is a schematic diagram showing the chromium and carbon contents of the steels of the present invention.

According to the invention the blades are made from a hardenable steel having a high corrosion resistance, good cutting properties and a hardness above VPN 700 (Vickers hardness, 0.5 kg. load) also after tempering up to 500° C. By a special heat treatment the steel can be given a hardness up to VPN 800 and even more after tempering. The steel, which also has good workability, is in the main characterized in that besides iron and such insignificant amounts of alloying elements and impurities normally present in iron it has carbon and chromium contents within the area ABCDE of the accompanying diagram; 0.70-2.5% silicon; up to 2% manganese; 0.5-2.5% molybdenum or 1.0-5.0% tungsten, or a mixture of molybdenum and tungsten in an amount such that the sum of molybdenum and one-half the tungsten is 0.5-2.5%; up to 1.5% nickel, up to 1.5% copper, and up to 0.5% cobalt; the total amount of all nickel, copper and cobalt being at most 1.5%; 2% of niobium, tantalum and/or titanium; and in which the sum of the chromium, molybdenum, half the amount of tungsten, niobium, tantalum and/or titanium is 10-15%, preferably 11-14%. Up to 0.05% of boron may also be present, to improve working characteristics, this material serving as a grain refiner. It is preferred that no other carbide formers be present in addition to chromium, molybdenum and tungsten. However, as a rule the carbon content should be chosen within the narrower range 0.60-0.75%. Further the chromium content should normally be held within the range 9-12.5%, preferably 9.5-12.5%.

The steels previously used for the purposes mentioned have been characterized by a structure having a very large number of rather coarse carbide grains of the order 3-30 microns (maximum linear dimension). These grains are only little influenced by the different steps of treatment of the steel and form a serious disadvantage, as they are easily torn out during the grinding of the cutting edge and give the edge a frayed contour and surface. In order to decrease the number of large carbide grains present in such steels, there have been employed steels having 0.5-0.75% C and 13-15% Cr, but these steels have a limited temper resistance. In the steel according to the present invention the amount of larger carbide grains is substantially reduced or practically completely eliminated whereby a considerable improved quality of the cutting edge is obtained. At the same time the hardness and other desirable properties can be maintained at a high level.

The corrosion resistance of the steel according to the present invention in comparison with conventional steels used for the same purpose is illustrated by the following example in which A represents a steel according to the invention and B and C conventional steels:

	C	Si	Mn	Cr	Mo	Fe
A-----	0.66	1.15	0.48	10.9	1.12	Remainder.
B-----	0.96	0.26	1.00	13.3	-----	Do.
C-----	0.60	0.32	0.43	14.1	-----	Do.

Two sets of the three steels were hardened by heating one set to 1050° and another set to 1100° C. respectively with subsequent deep-cooling of each set to -80° C. The hardening was followed by a tempering at 350° C. Then the corrosion rate of the steels in 0.5% acetic acid at 30° C. and their equilibrium potentials in comparison

with a hydrogen electrode were determined. The following results were obtained:

	Hardened from 1,050° C.		Hardened from 1,100° C.	
	Corrosion rate, mm./year	Equilibrium potential, volts	Corrosion rate, mm./year	Equilibrium potential, volts
A-----	1.1	+0.02	0	+0.06
B-----	41	-0.12	98	-0.05
C-----	1.3	+0.03	5.5	+0.07

As appears from the table and steel A was considerably more corrosion resistant than steel B and approximately equivalent with steel C. In comparison with steel B and C steel A had the advantage of a higher initial hardness, and a higher temper resistance in addition to improved edge properties as will appear from the following.

In order to combine a good corrosion resistance with high hardness, good temper resistance and as small an amount as possible of coarse carbide grains it has according to the invention been found necessary that the steel contains a relatively low amount of carbon at the same time as the amounts of carbide formers are held within rather narrow limits. In this regard steel A is superior to steel B. The amount of carbon should, however, be sufficiently high to provide desired hardness after hardening and subsequent cooling.

The blades which we produce are as previously mentioned made of steel containing 0.55-0.85% carbon and 9.0-14.5% chromium. However, in order to obtain the valuable properties according to the invention we have found it important that the amounts of carbon and chromium are chosen in accordance with the area ABCDEA in the accompanying diagram. Thus steel compositions above and to the right of line CD i.e. contain too coarse primary carbide grains, which would jeopardize the quality of the cutting edge. The preferred range is the area ABD₁EA in said diagram. Thus the limiting condition set by line CD of area ABCDEA gives the relation:

$$\text{Cr} \leq 26.5 - 16.7 \times \text{carbon content}$$

The corresponding limiting relation set by the line BD₁ for the preferred range, the area ABD₁EA in said diagram, will be

$$\text{Cr} \leq 23.7 - 16.7 \times \text{carbon content}$$

The amount of silicon should be relatively high in order to make corrosion resistance high and to give a further improved temper resistance within the range 175°-425° C. but yet limited in order to give good cold rolling properties. In these regards steel A is superior to steel B as well as steel C, both of which have a low content of silicon. By the said relatively high silicon contents according to the invention also a further advantage is gained. Thus the silicon in the amounts used has been found explicitly to add to the corrosion resistance. Furthermore, it is important that the steel have the proper quantities of molybdenum and/or tungsten to obtain a high corrosion resistance. The high corrosion resistance in the steel according to the invention is remarkable with regard to the relatively low content of chromium. Besides depending on the silicon content as mentioned above this depends also on the molybdenum and/or tungsten content. It is believed that this content has influence upon the composition of the carbides so that a greater amount of free chromium, i.e. chromium not bonded in carbides, is obtained than would appear from the relation of carbon-chromium. Moreover, the molybdenum and/or tungsten in itself improves the corrosion resistance and makes the steel especially suitable for a special heat treatment which increases the temper resistance.

The molybdenum and/or tungsten content in the steel is sufficiently high to provide in addition to good corrosion resistance, a secondary hardening when the steel is tempered within the range 450°-600° C. and is in this

regard better than steels B and C. The molybdenum and/or tungsten also contributes to the temper resistance within 175°-425° C. which also is superior to that of the steels B and C. The effects produced by molybdenum are quite similar to those of tungsten except that the amounts (in weight percent) necessary to produce the effects with tungsten are about twice as great as those of molybdenum because of the substantial difference in the atomic weights of these two elements. The molybdenum and/or tungsten content is, however, rather limited as are also the contents of niobium, tantalum, titanium, vanadium; and/or zirconium, when present, in order not to cause large carbide grains in the steel.

It has been found desirable but not essential to manufacture the steel by melting and degassing in a high vacuum electric arc furnace and then casting in a mold cooled by a liquid such as water. Hereby a higher purity from slags is gained. Moreover, the steel solidifies more rapidly in large ingots so that the larger carbides, which normally primarily are formed by segregations during the solidification, hardly appear or at least diminish as well in size as in number. The steel is then hot rolled before being finally cold rolled.

In order to obtain the optimal combination of the desired properties, high corrosion resistance, high hardness, good temper resistance and freedom from large carbide grains it is necessary to balance the composition of the steel within relatively narrow limits. As mentioned the carbon content should be 0.55-0.85%, preferably 0.60-0.75%, at the same time as the sum of the contents of the carbide formers chromium and molybdenum and/or ½ × tungsten and, (when present) niobium, tantalum, titanium, vanadium, and/or zirconium should amount to 10-15%, preferably 11-14%. The silicon content must be 0.70-2.5%, preferably 0.8-2.0% and optimally 0.8-1.4%. In order to obtain the desired high corrosion resistance the content of chromium should not be less than 9.0% and the content of molybdenum and/or half of the content of tungsten not less than 0.5%. At the same time the chromium content should not exceed 15.3%, the carbon content should not exceed 0.99%, the content of molybdenum and/or half of the content of tungsten should not exceed 2.5%, and the content of carbide formers niobium, tantalum and titanium should not exceed 2% as otherwise a large amount of coarse carbide grains would appear in the steel. Up to 0.5% vanadium and up to 0.5% zirconium may also be used, but only when the carbon content is less than 0.65%. As a rule the content of chromium should exceed 10% but not be more than 12% and preferably not more than 11.5%. The chromium content should often be chosen within the range 10-11%. Furthermore, the content of molybdenum and/or ½ × tungsten should exceed 0.6% and preferably 0.8%. A normal upper border for the content of molybdenum and/or ½ × tungsten is 2%, and for the preferred steels according to the invention an upper border of 1.5%, and often 1.3% is chosen. Besides the carbide formers chromium, molybdenum and tungsten there are as a rule no other carbide formers. However, it is possible to include the carbide formers niobium, tantalum and/or titanium, provided the total content of them does not exceed 2% and preferably does not exceed 1%. The content of manganese should preferably not exceed 1%. Nickel, cobalt and/or copper may be present in a total amount not exceeding 1.5%.

As a preferred range of analysis for steels according to the present invention the following can be mentioned: 0.60-0.75% carbon, 0.8-1.4% silicon, up to 1.5% manganese, 10.0-11.5% chromium, 0.6-1.5% molybdenum (if no tungsten is present), 1.2-3.0% tungsten (if no molybdenum is present), mixtures of molybdenum and tungsten in which the sum of the molybdenum and one-half of the tungsten is 0.6-1.5%, the balance being iron with incidental impurities; and the more restricted range: 0.61-0.72% carbon, 0.8-1.3% silicon, 0.4-0.8%

5

manganese, 10.0–11.0% chromium, 0.8–1.2% molybdenum, the balance being iron with incidental impurities.

As examples of steels according to the invention meeting the requirements for a minimum hardness of 700 VPN as hardened and thereafter tempered up to 500° C. and having simultaneously excellent corrosion resistance the following can be mentioned:

	C	Si	Mn	Cr	Mo	Fe
1.....	0.62	0.99	0.29	9.2	1.04	Remainder.
2.....	0.83	1.01	0.47	0.4	1.71	Do.
3.....	0.71	1.28	0.54	10.5	1.07	Do.
4.....	0.58	1.20	0.47	14.2	0.72	Do.

All the steels were hardened by heating to 1100° C. with subsequent deep-cooling to -70° C. The hardening was followed by a tempering at approximately 125° C. about one hour and a subsequent tempering at approximately 500° C. about one hour. The VPN hardnesses after the first and second temperings were:

	Hardness after tempering at 125° C.	Hardness after tempering at 500° C.
1.....	810	755
2.....	815	750
3.....	860	750
4.....	750	725

The following procedure may be used for the manufacture of the blades. The steel is cold rolled in strip form to the desired thin dimension, e.g. 0.05–0.5 mm., after which a shaping as punching possibly is done. The steel is then hardened to a high hardness by heating to a temperature within the range 1000–1150° C., preferably within the range 1050–1125° C. with subsequent cooling to room temperature or lower, e.g. between the range -20° and -120° C., whereby the hardening temperature and the time at said temperature is chosen in such a way that the steel obtains maximum hardness or close to maximum hardness for the steel analysis used. It is thus characteristic for the invention that the steel, when heated for hardening, is not overheated, i.e. heated to a temperature so high that instead of the desired maximum hardness a lower hardness is obtained because of an increased amount of residual austenite. The hardening procedure according to the invention makes the cold rolled steel suitable for the subsequent grinding of the cutting edge or edges, said grinding being difficult to perform in case the hardening is performed in such a way that the steel becomes too soft.

After the hardening to a level in excess of 700 VPN (Vickers hardness, 0.5 kg. load), and a possible subsequent tempering, the cutting edges are shaped by grinding or the like. Finally the material is tempered during a limited period of time, for instance for about a minute up to one or a few hours, at a temperature within the range 275–425° C. preferably within the range 300–400° C. The hardness of the steel after the said final tempering is at least VPN 700.

Between the hardening and the forming of the cutting edges the steel sometimes is tempered at a relatively low temperature, e.g. between 100–275° C.

The steel according to the invention maintains a hardness above VPN 700 even if it during a limited period of time is subjected to a heating up to 500° C. By a special treatment after the hardening it is furthermore possible to give the steel a hardness of up to VPN 800 and more, said hardness being maintained during a final tempering up to 400° C. during a limited period of time, as for instance when applying a coating on the cutting edges to improve the shaving properties. This special treatment for raising the final hardness is an important feature of the invention. The steel is according to this procedure hardened as previously described by heating to a temperature within the range 1000–1150° C. with subsequent cooling to room temperature or lower, preferably between -20° C. and -120° C., in order to achieve maximum hardness

6

or close to maximum hardness for the steel composition used. The steel is then tempered for a short period of time, e.g. some seconds up to one minute or more within the temperature interval 450–600° C., preferably 475–550° C., which results in a hardness above VPN 700 and depending on the composition even above VPN 750. The forming of the cutting edges by grinding or the like can be done before or after said tempering. Finally a tempering is performed to a temperature within the range 275–425° C., preferably within the range 300–400° C. It has been found that the hardness obtained by the first mentioned tempering is maintained unchanged when the steel is subjected to the later tempering. This is a very valuable property, which contributes to the advantageous results achieved by the blades according to the invention.

In order to show the effect of the heat treatment on the hardness of the steel alloys according to the invention, reference may be had to the table below in which A, A1 and A2 represent steel alloys according to the invention and B and C conventional steel alloys used for the same purpose. The chemical analyses of said steel alloys were in percent of weight:

	C	Si	Mn	Cr	Mo	Fe
A.....	0.66	1.15	0.48	10.9	1.12	Remainder.
A1.....	0.72	0.82	0.54	10.4	1.02	Do.
A2.....	0.74	1.38	0.54	10.5	1.07	Do.
B.....	0.96	0.27	1.00	13.3	-----	Do.
C.....	0.60	0.32	0.43	14.1	-----	Do.

Treatment No. 1

Thin strips of the steel alloys A through C were hardened to maximum hardness by heating to a temperature about 1100° C. for 30 seconds and thereafter quenched to -70° C.

Treatment No. 2

Hardening and quenching as under Treatment No. 1. The steel alloy was then tempered at 285° C. for 30 seconds.

Treatment No. 3

Hardening and quenching as under No. 1 above. The steel alloy was then tempered at 350° C. for 30 minutes.

Treatment No. 4

Hardening and quenching as under No. 1 above. The steel alloy was then tempered at 475° C. for 60 minutes.

Treatment No. 5

Hardening and quenching as under No. 1 above. The steel alloy was then tempered at 525° C. for 30 seconds and thereafter tempered at 350° C. for 30 minutes.

The following results were obtained by the treatments 1 through 5 whereby the hardness is measured in Vickers hardness, 0.5 kilogram load.

Analysis treatment No.....	1	2	3	4	5
A.....	810	830	710	780	770
A1.....	850	870	760	820	810
A2.....	840	860	775	825	815
B.....	770	790	620	630	620
C.....	750	760	610	620	610

As is clearly evident from the table above the steel alloys A, A1 and A2 according to the invention will have the very high hardness which is characteristic for the steels according to the present invention.

The procedure for making the blades is further illustrated by the following examples:

A cold rolled steel strip having a thickness of about 0.10 mm. and containing in addition to iron with incidental amounts of impurities approximately in percents of weight 0.66% C, 1.15% Si, 0.48% Mn, 10.9% Cr and 1.12% Mo was hardened by heating to about 1100° C. during approximately a minute followed by cooling to about -70° C. during about 15 seconds. The strip was then tempered at about 150° C. After the forming of the

razor blade cutting edges a tempering at about 350° C. was done in the same way as when applying a coating for the improvement of the shaving ability. The finished razor blade had a hardness of about VPN 710.

According to an alternative method a composition containing 0.64% C, 1.05% Si, 0.5% Mn, 10.4% Cr, 1.08% Mo, the balance iron with incidental amount of impurities was hardened from about 1125° C. with a subsequent cooling at about -80° C. Thereafter the steel was tempered at about 175° C. After forming the cutting edges a tempering at about 485° C. was done. Finally a tempering at about 350° C. was done. The hardness was about VPN 775.

The razor blades according to the invention have been found to have extraordinary shaving properties and excellent edge qualities. They have furthermore a very good corrosion resistance. The process of manufacture is moreover relatively simple and well suitable for mass production.

All the percentages mentioned throughout this specification and the appended claims are percentages of weight. The invention is of course not limited to the described embodiments but comprises any product within the scope of the appended claims.

What is claimed is:

1. Razor blades having a good corrosion resistance and a cutting edge hardness above VPN 700 after tempering up to 500° C., characterized in that the razor blades are made from a steel having good working properties and consisting essentially of carbon and chromium in amounts within the area ABCDEA of the accompanying diagram; 0.70-2.5% silicon; up to 2% manganese; a member of the class consisting of molybdenum, tungsten, and mixtures thereof, the amount of molybdenum when present alone being 0.5-2.5%, the amount of tungsten when present alone being 1.0-5.0%, and the sum of the amounts of molybdenum and one-half the tungsten when both are present being 0.5 to 2.5; 0-1.5% of nickel; 0-1.5% of copper, and 0-0.5% cobalt, the total amount of all nickel, copper and cobalt being at most 1.5%; and the remainder being substantially all iron; and in which the sum of the amounts of chromium, molybdenum and one-half the tungsten is 10-15%.

2. Razor blades as claimed in claim 1 in which the sum of the amounts of chromium, molybdenum, and one-half of the tungsten present in the steel is 11-14%.

3. Razor blades having a good corrosion resistance and a cutting edge hardness above VPN 700 after tempering up to 500° C., characterized in that the blades are made from a steel having good working properties which contains, in addition to iron with incidental impurities, carbon and chromium in amounts within the area ABCDEA of the accompanying diagram; 0.70-2.5% silicon; up to 2% manganese; up to 0.05% boron; a member of the class consisting of molybdenum, tungsten, and

mixtures thereof, the amount of molybdenum when present alone being 0.5-2.5%, the amount of tungsten when present alone being 1.0-5.0%, and the sum of the amounts of molybdenum and one-half the tungsten when both are present being 0.5 to 2.5; 0-1.5% of nickel; 0-1.5% of copper, and 0-0.5% cobalt, the total amount of all nickel, copper and cobalt being at most 1.5%; 0-2% each of niobium, tantalum, and titanium, the total of all niobium, tantalum, and titanium being a maximum of 2%; and 0-0.5% each of vanadium and zirconium, said vanadium and zirconium being present only when the carbon content is less than 0.65%; and in which the sum of the amounts of chromium, molybdenum, one-half the tungsten, niobium, tantalum, titanium, vanadium, and zirconium is 10-15%.

4. Razor blades as claimed in claim 3 in which the sum of the amounts of chromium, molybdenum, one-half the tungsten, niobium, tantalum, titanium, vanadium, and zirconium is 11-14%.

5. Razor blades and similar thin elongated sharp-edged blades having properties and a composition as claimed in claim 3 in which the maximum carbon content is 0.75%.

6. Razor blades as claimed in claim 3 in which the silicon content is 0.8-2.0%.

7. Razor blades as claimed in claim 3 in which the chromium content is 9.5-12.5%.

8. Razor blades as claimed in claim 3 in which the amount of molybdenum when present alone is 0.6-2.0%, the amount of tungsten when present alone is 1.2-4.0%, and the sum of the amounts of molybdenum and one-half the tungsten when both are present is 0.6-2.0%.

9. Razor blades and similar thin elongated sharp-edged blades as claimed in claim 5 in which the carbon content is 0.60-0.75%, the silicon content is 0.8-1.4%, the manganese content is up to 1.5%, the molybdenum content when present alone is 0.6-1.5%, the tungsten content when present alone is 1.2-3.0%, and the sum of the molybdenum and one-half the tungsten when both are present is 0.6-1.5%.

10. Razor blades as claimed in claim 3 in which the chromium content is $\leq 23.7 - 16.7 \times$ the carbon content.

References Cited

UNITED STATES PATENTS

2,513,935	7/1950	Harris.	
2,848,323	8/1958	Harris	75-126
2,934,430	4/1960	Klaybor.	
3,349,488	10/1967	Craig	30-346.53

HYLAND BIZOT, Primary Examiner

U.S. Cl. X.R.

75-128

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,469,972

Dated September 30, 1969

Inventor(s) Jan-Christer Henric Ovesson Carlen 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 2 in the chart under "Si", "0.26" should be "0.27";

Column 3 in the chart under "Corrosion Rate, mm./year", there is a misprinted zero;

Column 3, line 11, "and steel" should be "the steel";

Column 5 in the chart under "Cr", "0.4" should be "10.4".

SIGNED AND
SEALED
MAY 5 1970

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents