



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>5</sup> :</b>  <b>B32B 15/01, B23K 9/00</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 93/16873</b>  <b>(43) International Publication Date:</b> 2 September 1993 (02.09.93)
<b>(21) International Application Number:</b> PCT/US93/01220 <b>(22) International Filing Date:</b> 11 February 1993 (11.02.93)  <b>(30) Priority data:</b> 07/838,361                      19 February 1992 (19.02.92)      US  <b>(60) Parent Application or Grant</b> (63) Related by Continuation US    07/838,361 (CIP) Filed on                                      19 February 1992 (19.02.92)  <b>(71) Applicant (for all designated States except US):</b> ARNCO TECHNOLOGY TRUST [US/US]; 5915 Brittmoore, Houston, TX 77041-5619 (US).		<b>(71)(72) Applicant and Inventor:</b> ARNOLDY, Roman, F. [US/ US]; 225 Millbrook Lane, Houston, TX 77024 (US).  <b>(74) Agent:</b> WEILER, James, F.; 1 Riverway, Suite 1560, Hous- ton, TX 77056 (US).  <b>(81) Designated States:</b> AU, CA, KR, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.</i> <i>With amended claims.</i>
<b>(54) Title:</b> DEEP COAT FACED PLATE AND METHOD		
<b>(57) Abstract</b>  <p>Disclosed are methods of facing a surface of a weldable iron based material with a consumable iron based electrode and alloy forming elements by creating an electric arc between the electrode and the surface of the weldable base material effective to form a weld puddle of which the weldable base material provides from about 35 % to about 80 % by weight, and preferably a major portion, of the weld puddle formed by the electrode and the base plate and by depositing and melting a predetermined quantity of alloy forming elements in the weld puddle to form an alloy abrasion resistant or corrosion resistant facing. Also disclosed are plates having abrasion or corrosion resistant surfaces in which from about 35 % to about 80 % and preferably a major portion of the weld puddle formed by the electrode and the base material is the weldable iron based material.</p>		

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DEEP COAT FACED PLATE AND METHODField of the Invention

5 The present invention is in the field of  
hardfacing and providing wear or corrosion resistance to  
industrial equipment.

Background of the Invention

10 Hardfaced plate is a product manufactured to  
resist the abrasion of bulk materials such as earth, rock,  
ores, and other silicious materials. It is used in the  
construction and the protection of fabrications of many  
kinds.

15 It consists of a base plate of any suitable  
analysis which has been weld overlaid with an alloy which  
contains typically up to 40% chromium carbide.

20 Depending upon the alloy content and method of  
application, the overlay can contain several types of  
chromium carbides. Only the primary type of carbide has the  
high abrasion resistance needed to make this product outwear  
other overlays or hard metals of a low cost type. This is  
identified by the formula  $M_7 C_3$  where M is an alloy of iron  
and chromium.

25 Analysis of the individual carbides cannot be done  
with any common commercial equipment, but the carbide can be  
identified by its form and shape in a micrograph of the  
deposit.

30 Common mild steel plate is used as the base plate  
for nearly all manufacture of this product as it is  
sufficient to supply whatever strength and shock resistance  
are needed and is most cost effective.

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The preferred method of manufacture uses the bulkweld process wherein alloy powder and wire are melted together in a welding arc and simultaneously welded to the base plate while melting an amount of base plate to obtain a weld bond, such as set forth in U.S. Patent No. 3,076,888. Other patents illustrating hardfacing are U.S. Patent Nos. 3,000,094; 3,060,307; 3,062,948; 3,407,478; 3,494,749; 3,513,288; 3,517,156; 3,588,432; and 3,609,292.

As the overlay is made by welding, it is not capable of precise parameters. There will be a typical variance between melting of about 20% or less base metal on the one hand and a lack of bond (no melted base metal) on the other hand. With lack of bond the overlay can break off, and with the heavier melting of base metal there is dilution of the overlay material with iron with the result that the type of carbides formed are low in abrasion resistance. In prior art processes, over 15% melted base material is not acceptable.

In the present state of the art all of the iron intended to produce the alloy is supplied by the electrode, usually a wire but it can be a strip. Whatever amount of base metal is melted is for the purpose of producing a bond only.

In the present art the unintentional melting of base plate (beyond the small amount needed for bond) progressively reduces the formation of primary chromium carbides which are the principal constituents which give the product its high abrasion resistance.

In a typical operation the welding parameters are critical within a narrow range. Because of the nature of a welding process, the operation is difficult to control within that range. A relatively small heat input above the desired level will cause greater base metal melting and undesirable structure while a relatively small reduction in current will cause lack of bond allowing the overlay to break off.

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In the present invention, the base metal is intentionally melted and intentionally forms part of the alloy surface being produced. This insures bonding of the alloy surface to the base, and the metal supplied from the metal base to be part of the alloy produced is of much lower cost than that supplied by the electrode wire.

In the manufacture of hardfaced or corrosion resistant plate the most efficient application and easiest to produce quality is obtained when employing the bulkweld system of welding as described above. More particularly, in this system the arc which does the melting and the iron required of the alloy facing are supplied by steel (iron) electrode (wire) continuously fed by automatic welding equipment. The carbide or corrosion resistant forming elements required and the other elements needed are supplied by powder metered into the weld zone in a precalculated ratio to the amount of wire used. As these elements fuse and mix in the weld puddle, they together produce the desired facing alloy.

In order to melt a greater amount of base metal, a larger current is needed than in current overlay welding. In utilizing a larger current in the current prior art processes, a greater amount of base metal is melted, but the greater current overloads the electrode wire (3/32") and causes it to melt very fast and thus still supply most of the iron needed in the weld.

It would be highly advantageous to increase the quality of the abrasion resistant surface to provide assurance of a weld bond, to increase the speed of application, and to decrease the cost of materials and labor.

#### Summary of the Invention

The present invention utilizes the bulk welding process such as disclosed in U.S. Patent No. 3,402,459, but a major part of the iron required in the overlay is the melted base plate rather than the electrode, and the carbide

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structure or corrosion resistance needed is produced by adding those elements needed to form that structure in the resulting iron rich weld puddle.

5 Electrode melting is a function of polarity, current at the arc, and electrode preheating before it reaches the arc. The electrode preheat is a function of the current, the resistance of the electrode (wire), and the time of heating. To prevent increased electrode melting when current is increased to melt more base metal, the electrode size is increased. This does two things: It decreases the resistance to lessen the preheat, and it provides a larger cross section at the arc to decrease current density on the electrode and thus lower electrode melting rate.

10 The needed extra alloy is provided by adding only the kind and amounts of elements actually needed to produce the primary carbide structure at a 4-5% carbon level in the deposit in hardfacing. This avoids having to manage and melt an over-large bulk of powder with the difficulties it produces in welding.

15 Any combination of parameters which cause from about 35% to about 80% by weight of the combined metal of electrode and weldable base metal (almost always iron) to be supplied by the melted base metal meets the requirements for the present invention. Preferably, at least 50% of the metal of the combined base metal and the electrode required to produce the overlay alloy is the weldable base material.

20 Accordingly, it is an object of the present invention to provide a bulkwelding process which overcomes the disadvantages of the prior art processes mentioned above.

25 A further object of the present invention is the provision of a bulk welding process in which the quality of the abrasion or corrosion resistant facing is improved to provide an assured weld bond in which the speed or rate of

30

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application of the facing applied is increased and in which the cost of materials and labor is decreased.

It is a further object of the present invention to supply a major part of the iron required in the overlay with melted base plate, and the carbide or corrosion resistance structure needed is produced by adding only those elements required to that structure in the resulting iron rich weld puddle.

A further object of the present invention is to produce the highest levels of primary carbides while drawing up at least one-half of the iron required in the hardfacing from melted base metal.

A further object of the present invention is to produce hardfacings in which the desired thickness is in its more inexpensive form and to eliminate the problems as between missed bond on the one hand and excessive dilution on the other that are inherent in the present state of the art processes.

It is a further object of the present invention to produce a product of higher and more consistent quality than prior art hardfacings or corrosion resistant facings while at the same time requiring less precision in welding parameters.

A further object of the present invention is the provision of an abrasion or corrosion resistant surface, such as abrasion resistant plate, in which preferably at least 50% of the metal of the base material and the electrode used to produce the overlay alloy will come from the base material.

A further object of the present invention is the provision of a hardfaced or corrosion resistant surface welded to a weldable base material, such as hardfaced plate, in which about 35% to about 80% by weight of the metal of the base metal and the electrode is supplied by the base metal.

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A further object of the present invention is the provision of an abrasion resistant alloy surfaced plate which has a primary carbide structure at a 4-5% carbon level in the deposited alloy.

5 Other and further objects, features, and advantages of the present invention appear throughout the specification and claims or are inherent therein.

Description of Presently Preferred Embodiments

10 Briefly, the method of this invention of hardfacing or corrosion resistant facing a surface of weldable base material comprises creating an electric arc with a consumable electrode between the surface of the weldable base material to form a weld puddle in the base while depositing and melting a predetermined quantity of  
15 alloy forming particles in the weld puddle so that at least about 35% to about 80% by weight and preferably at least one half of the iron based material required in the final weld provided by the weldable base metal and the electrode is the weldable base metal. Thus, preferably a major part, such as  
20 at least 50% by weight of the iron required in the overlay supplied by the base metal and the electrode is melted base plate rather than electrode. The alloy structure, such as carbide structure, or the corrosion resistant structure needed is produced by adding only those elements, which  
25 include some iron to form that alloy structure in the resulting iron rich weld puddle.

In order to melt a greater amount of base metal, a larger electric current is needed. In the prior art processes, such as disclosed in U.S. Patent No. 3,076,888,  
30 more alloy addition is required to produce the alloy composition needed to form the desired level of hardfacing components, such as primary carbides or corrosion resistant components, such as alloys of chromium, nickel, carbon, and iron. More wire can be melted as wire melting is directly  
35 proportional to the current for a given set of parameters. The result will be too much iron in the deposit, low alloy



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content, and lack of primary carbide. The present invention provides increased base melting without significantly increasing electrode melting. Electrode melting is a function of polarity, current at the arc, and electrode preheating before it reaches the arc. The electrode preheat is a function of the current, the resistance of the electrode or wire, and the time of heating. To prevent increase electrode melting when the current to melt more base is increased, the electrode size, that is its cross sectional area, is increased. This does two things: It decreases the resistance to lessen the preheat, and it provides a larger cross section at the electric arc to decrease current density on the electrode and thus lower electrode melting rate. In the present invention, the extra alloy is provided by adding only the kind and amounts of elements actually needed to produce the hardfacing or abrasion resistant structure, for example, a primary carbide structure of about 4-5% carbon level in the deposit. In this manner having to manage and melt an over large bulk of powder with the difficulties it produces in welding is avoided.

By way of example, in the prior art, such as disclosed in U.S. Patent No. 3,076,888, a thin skin of the base plate is melted, that is not more than about 15% by weight to provide the bond. In the present prior art methods, the electrical current rate to the electrode averages about 15.7 kw for an electrode or wire having a 3/32 inch diameter and a current density of 66195 amperes per square inch of electrode cross section. By increasing the electrode cross sectional area to a 1/8 inch diameter, the heat input rate to the electrode can be 24.5 kw with a current density of 57000 amperes per square inch of electrode cross section. The larger cross section at the arc decreases the preheat and current density on the electrode and thus provides a lower electrode melting rate and more base metal melting. While current densities over

57000 amperes per square inch of electrode cross section will melt more base metal, it also melts more electrode.

The following examples and tables provide a comparison of prior state of the art manufacture of hardface plate in the open arc mode to the present invention manufacture of hardfaced plate in the open arc mode. The subarc modes are substantially the same.

Example 1

In this example the following input parameters are for present state of art manufacture of hardface plate in the open arc mode.

Table 1

Elemental Content of Powder - Percents

Fe	Cr	C	Mn	Mo	Si
Bal (av. 26.25)	55-58	9.75-10.25	5-6.5	.5-1.0	.5-1.0

Elemental Content of Wire - Percents

Fe	C	Mn	Si
Bal (av. 98.9)	.05-.15	.85-1.35	.05-.35

The overlay weld was made in which the target percents were 62% of the input to the weld was powder and 38% was wire. After losses and allowances for up to 15% dilution by the base metal, the final target overlay content was as follows:

Table 2

Fe	Cr	C	Mn	Mo	Si
Bal (av. 35.8)	27-29	4.5	2.5-3.5	.2-.5	.2-.4

This target content in the overlay gave a primary carbide content of approximately 40% by weight.

Example 2

In this example the input parameters were for the production of hardface plate in accordance with this

invention in open arc mode. Listed below in Table 3 are the input parameters.

Table 3

5	Elemental Content of Powder - Percents					
	Fe	Cr	C	Mn	Mo	Si
	Bal	63-66	11.2-11.7	6-7.5	.5-1.0	.5-1.0
	Elemental Content of Wire and Plate - Percents					
	Fe		C	Mn		Si
	Wire Bal		.05-.15	.35-1.35		.05-.85
10	Plate Bal		.1-.2	.2-.5		.05-.85

The overlay weld was made in which the target percents were 41% of the input to the weld was powder, 26% of the weld was electrode, and 33% of the weld was fused based metal.

15 The material inputs and overlay analysis of the hardface plate of the present invention, as set forth in Table 3, are set forth in the following Table 4.

Table 4

	Typical Elemental Input - This Invention - in Portions					
20	Fe	Cr	C	Mn	Mo	Si
	Powder 10.7	26.8	6.4	2.5	.3	.3
	Wire 26	0	0	.2	0	0
	Plate 33	0	0	0	0	0
25	Total 69.7	26.8	6.4	2.7	.3	.3
	Portions Stoichiometric					
	Losses -	2.	1.7	-	-	-
30	Total 69.7	24.8	4.7	2.7	.3	.3
	Portions After Losses					
	Per Cents 68	24.2	4.6	2.6	.3	.35

35 The material inputs and overlay analysis set forth in Table 4 provide a primary carbide content of approximately 40% However, the welding labor required was

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1/3 of that required for the prior art process described above at the same rate of deposition.

Example 3

5 In this example, the input parameters were for the production of a corrosion resistant surface in accordance with this invention in sub arc mode. Listed below is Table 5.

Table 5

10		<u>Fe</u>	<u>Cr</u>	<u>Ni</u>	<u>Mo</u>	<u>Mn</u>	<u>C</u>
	Powder	7.4	21.2	9.8	.7	2.0	.03
	Wire	26.0				.2	.02
	Plate	32.6					
15	Total Portions Stoichiometric	66.0	21.2	9.8	.7	2.2	.05
	Losses	----	.4	.1	----	.2	---
20	Total Portions After Losses	66.0	20.8	9.7	.7	2.0	.05
	Per Cents	66.5	21.0	9.8	.7	2.0	.05

25 The material inputs and overlay analysis set forth in Table 5 provide a satisfactory corrosion resistant surface with a good bond.

The following Table 6 compares the welding parameters of the prior art and of this invention as set forth above.

30 Table 6  
Welding Parameters - Present and with this Invention

	Prior Art Overlay Parameters	This Invention
35 Nominal Overlay Thickness	1/8"	3/16"
Added Metal	1/8"	1/8"
Bead Width	1 3/8 - 1 1/2"	1 3/8 - 1 1/2"
Travel Speed	8 1/2 - 9" min.	8 1/2 - 9" min.
Heat Input Rate	15.7 kw avg.	26 kw
Wire Size	3/32" dia.	1/8" dia.

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Advantageously, automatic or semiautomatic welding equipment can be used in practicing the process of the present invention. The electrodes or wire may be in generally circular cross section or may be strips or may be in tubes. Any desired facing or cladding materials can be utilized. The electrode is fed substantially normal to the surface to be faced and supported by automatic or semiautomatic welding of any known and available type in which the feed of the electrode is held substantially constant at a predetermined rate so that a predetermined quantity of electrode is deposited and melted. Similarly, a predetermined quantity of the alloy forming elements is deposited and melted in the weld base puddle. As previously mentioned, the welding may be open mode or submode, such as covered with flux which is readily available on the market.

The method can be used for cladding surfaces or making plate with a cladded surface in which the plate is secured to a surface to be cladded.

Any desired alloy composition can be made according to the invention. For example, representative alloy compositions which can be made according to the invention are set forth in U.S. Patent Nos. 3,000,094; 3,076,888; 3,407,478; 3,494,749. Also, the alloy composition can have a cracked pattern such as disclosed in the last two patents mentioned above.

The present invention therefore is well suited and adapted to attain the objects and ends and has the advantages and features mentioned above as well as others inherent therein.

While presently preferred embodiments of the invention have been given for the purposes of disclosure, changes can be made within the spirit of the invention as defined by the scope of the appended claims.

What is claimed is:

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Claims

1. A method of providing an abrasion or corrosion resistant alloy facing on a surface of a weldable iron based material comprising,

5                   creating an electric arc between an iron based electrode and the surface of the weldable iron based material, the electric arc and cross-sectional area of the electrode being effective to form a weld puddle in which the iron based  
10                   material provides from about 35% to about 80% by weight of the weld puddle,

                  depositing and melting an alloy forming powder in the weld puddle sufficient to form the alloy facing with the weld puddle.

15                   2. The method of Claim 1 where,  
                  the iron based metal provides at least a major portion of the weld puddle.

                  3. The method of Claim 1 where,  
                  the electric arc is created with an electric  
20                   current having a current density in the iron based electrode of not in excess of 57000 amperes per square inch cross section of electrode but sufficient to form about 35% to about 80% by weight of the weld puddle with the iron based  
25                   material.

                  4. A plate having an alloy abrasion resistant surface where,  
                  the plate is relatively ductile, sheet like, and weldable iron based, and  
30                   the alloy abrasion resistant surface is welded on the plate and comprises alloy material, weldable iron based electrode and the iron based metal plate in which about 35% to about 80% by

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weight of the weld formed by the iron based electrode and iron based metal plate is the iron based metal plate.

5                   5. The abrasion resistant plate of Claim 4 where,  
                    the iron based metal plate comprises at least  
                    one-half of the weld formed by the iron based  
                    electrode and the iron based metal plate.

                    6. A plate having an alloy corrosion resistant  
10                   surface where,  
                    the plate is relatively ductile, sheet like,  
                    and weldable iron based metal, and  
                    the alloy corrosion resistant surface is  
                    welded to the iron based plate and comprises an  
                    alloy corrosion material, weldable iron based  
15                   electrode and the iron based metal plate in which  
                    about 35% to about 80% by weight of the weld  
                    formed by the electrode and the iron based metal  
                    plate is the iron based metal plate.

                    7. The corrosion resistant surfaced plate of  
20                   Claim 6 where,  
                    the iron based metal plate forms at least  
                    one-half of the weld formed by the iron based  
                    electrode and the iron based metal plate.

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## AMENDED CLAIMS

[received by the International Bureau on 1 July 1993 (01.07.93);  
original claims 1-7 replaced by amended claims 1-7 (2 pages)]

1. A method of providing an abrasion or corrosion resistant facing on a surface of a weldable iron based material comprising,

5                   creating an electric arc between an iron based electrode and the surface of the weldable iron based material, the electric arc and cross-sectional area of the electrode being effective to form a weld puddle in which the iron based  
10                   material provides from about 20% to about 80% by weight of the weld puddle and the balance the iron based electrode,

                  depositing into and melting a quantity of alloy forming powder in the weld puddle sufficient  
15                   to form with the electrode and the iron based material the facing.

2. The method of Claim 1 where,  
                  the iron based material provides at least a major portion of the weld puddle.

20                   3. The method of Claim 1 where,  
                  the electric arc is created with an electric current having a current density in the iron based electrode of not in excess of 57000 amperes per square inch of electrode cross section but  
25                   sufficient to form the 20% to 80% of the weld puddle with the iron based material.

4. An abrasion resistant surfaced plate comprising,

30                   a relatively ductile, sheet like, iron based metal plate, and

                  a surface of abrasion resistant material welded on the iron based metal plate comprised of alloy material, a weldable iron based electrode and the iron based metal plate in which about 20%  
35                   to about 80% by weight of the weldable iron based



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electrode and the iron based metal plate is the iron based metal plate.

5 5. The abrasion resistant plate of Claim 4 where,  
the iron based metal plate comprises at least  
one-half of the weldable electrode and the iron  
based metal plate.

6. A corrosion resistant surfaced plate  
comprising,  
10 a relatively ductile, sheet like, weldable  
iron based metal plate, and  
corrosion resistant alloy powder deposited on  
and welded to the iron based metal plate by a weld  
comprising a weldable iron based electrode and the  
15 iron based metal plate in which about 20% to about  
80% by weight of the weld is the iron based metal  
plate, the weld and the alloy powder forming the  
corrosion resistant surface.

7. The corrosion resistant surfaced plate of  
Claim 6 where,  
20 the iron based metal plate forms at least  
one-half of the metal in the weld.

## INTERNATIONAL SEARCH REPORT

PCT/US93/01220

<b>A. CLASSIFICATION OF SUBJECT MATTER</b>		
IPC(5) :B32B 15/01; B23K 9/00 US CL :219/137WM; 219/137R; 428/682; 428/683 According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b>		
Minimum documentation searched (classification system followed by classification symbols) U.S. : 219/137WM; 219/137R; 428/682; 428/683 228/256; 228/263.14; 428/610; 428/648		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A, 4,426,426 (Muhlberger) 17 January 1984 See Abstract.	4-7
A	US,A, 4,110,514 (Nicholson) 29 August 1978 See claim 1, column 2, lines 30-40.	4-7
X	US,A, 4,515,870 (Bose et al.) 07 May 1985 See Abstract, column 1, lines 25-30.	4-7
X	US,A, 4,122,817 (Matlock) 31 October 1978 See claim 1, column 1, lines 45-50.	4-7
X	US,A, 4,160,066 (Szumachowski et al.) 03 July 1979 See Abstract, column 1, lines 9-17.	4-7
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be part of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search 29 MARCH 1992		Date of mailing of the international search report 27 MAY 1993
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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US93/01220

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A, 5,010,225 (Carlin) 23 April 1991 See claim 1.	1-3
A	JP,A, 59-78774 (Nishikawa) 07 May 1984 See Abstract.	1-3
A	JP,A, 60-228650 (Riken) 13 November 1985 See Abstract.	1-3
A	US,A, 3,062,948 (Arnoldy) 06 November 1962 See claims 1-4, column 1, lines 45-55.	1-3.
X	US,A, 3,076,888 (Arnoldy) 05 February 1963 See column 7, lines 20-55, column 8, lines 47-65.	1-7
A	US,A, 3,060,307 (Arnoldy) 23 October 1962 See column 1, lines 55-70.	1-3
X	US,A, 2,965,746 (Cresswell) 20 December 1960 See column 3, lines 5-30, column 2, lines 40-45	1-7