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CAVITATION RESISTANT FLUID IMPELLERS AND METHOD OF MAKING SAME
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- (57) Claim

1. A fluid impeller for use in applications requiring a high degree of cavitation erosion resistance, said impeller ~~comprising~~ including:-

a body fabricated from a castable metastable austenitic steel alloy, said alloy having a chemical composition in the following range:-

	C	Mn	N	Si	Ni	Cr
% min	0.08	14.0		0.3		17.0
% max	0.12	16.0	0.45	1.0	1.0	18.5

the balance comprising iron and impurities.

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I.

I)

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(74) Agents: PALERMO, Robert, F. et al., Patent Dept., Ingersoll-Rand Company, 942 Memorial Parkway, Phillipsburg, NJ 08865 (US).								
(54) Title: CAVITATION RESISTANT FLUID IMPELLERS AND METHOD OF MAKING SAME								
(57) Abstract								
A fluid impeller for applications requiring superior cavitation erosion resistance. The impeller has a body fabricated from a castable metastable austenitic steel alloy which has a chemical composition in the range according to table (I), the balance comprising iron and impurities. The preferred range is 17.5-18.5 % chromium, 0.5-0.75 % nickel, 0.45-0.55 % silicon, 0.2-0.25 % nitrogen, 15.5-16.0 % manganese and 0.1-0.12 % carbon. Quantitative testing has shown cavitation resistance of four to six times that of standard boiler feed pump materials. A method for making cavitation resistant fluid impellers is also disclosed.		C	Mn	N	Si	Ni	Cr	(I)
	% min	0.08	14.0		0.3		17.0	
	% max	0.12	16.0	0.45	1.0	1.0	18.5	

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CAVITATION RESISTANT FLUID IMPELLERS
AND METHOD OF MAKING SAME

BACKGROUND OF THE INVENTION

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This invention relates generally to fluid impellers and more particularly to cavitation resistant fluid impellers made from castable cavitation resistant austenitic chromium-manganese alloy steels.

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Pump impellers frequently suffer cavitation damage for several reasons, including operation outside established hydraulic parameters. This damage is often a limiting factor in the life of the equipment. It may not be repairable by welding for reasons of inaccessibility. With a growing emphasis on enhanced reliability and longer life, there is a need in the pump industry for a casting alloy with significantly better cavitation resistance than the standard materials used to manufacture impellers. Other characteristics required for such a material to be commercially viable include machinability and weldability.

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For high speed applications, relatively high tensile and yield strengths, and elongation will also be necessary. The mechanical properties of commonly used austenitic stainless steels, such as CF8M are: tensile strength 482 N/mm² and yield strength 208 N/mm² minimum. These low mechanical properties render such materials unsuitable for high speed impellers.

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The current state-of-the-art cavitation resistant material which has been used in pumps is a cobalt modified austenitic stainless steel known as Hydroloy (Registered Trade Mark). Hydroloy is described in U.S. Patent No. 4,588,440, entitled "Co Containing Austenitic Stainless

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Steel with High Cavitation Erosion Resistance". One deficiency of Hydroloy is susceptibility to hot short cracking. This characteristic contributes to poor castability. The presence of cobalt is also undesirable for some applications, particularly the nuclear industry.

The foregoing illustrates limitations known to exist in present cavitation resistant alloy steels. Thus, it is apparent that it would be advantageous to provide an alternative directed to overcoming one or more of the limitations set forth above. Accordingly, a suitable alternative is provided including features more fully disclosed hereinafter.

SUMMARY OF THE INVENTION

In one aspect of the present invention, this is accomplished by providing a fluid impeller for use in applications requiring a high degree of cavitation erosion resistance, the impeller having a body fabricated from a castable metastable austenitic steel alloy which has a chemical composition in the following range:-

	C	Mn	N	Si	Ni	Cr
% min	0.08	14.0		0.3		17.0
% max	0.12	16.0	0.45	1.0	1.0	18.5

the balance comprising iron and impurities.

The present invention also provides a method for making a fluid impeller having a high degree of cavitation resistance, comprising the following steps:-

selecting a castable metastable austenitic steel alloy from alloys having the following chemical compositions:-

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	C	Mn	N	Si	Ni	Cr
% min	0.08	14.0		0.3		17.0
% max	0.12	16.0	0.45	1.0	1.0	18.5

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the balance comprising iron and impurities;

fabricating, preferably by casting, said fluid impeller from said castable metastable austenitic steel alloy; and

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heat treating said fluid impeller by solution treating at 1050°C to 1100°C for one hour per inch (25.4 mm) of thickness followed by quenching, preferably by using a water quench.

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The foregoing and other aspects will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

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Figure 1 is a graph showing the cavitation damage versus time for one embodiment of the alloy used in the present invention (known as XM31) and two conventional stainless steel casting alloys: and

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Figure 2 is a graph showing the relationship between the cavitation damage and manganese content.

DETAILED DESCRIPTION

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Embodiments of the alloy used in the invention and described below have demonstrated cavitation resistance several times better than that of existing standard impeller materials. This new alloy also satisfies most

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desirable criteria, including castability, weldability, machinability and low cost.

5 This steel belongs to a class of alloys known as metastable austenitic steels. Both stainless and non-stainless grades of metastable austenitic steels have been produced. Austenite in metastable alloys can transform spontaneously into martensite either in cooling or as a result of deformation. This alloy has an austenitic structure upon
10 water quenching from the solution annealing temperature but will transform to martensite on exposure to impact loading. The transformation which occurs in this class of materials is accompanied by an increase in hardness and has been exploited commercially in steels for wear and abrasion
15 resistant applications. Hadfield manganese steels (a non-stainless type) are the best known of this class.

The ease with which metastable alloys can be induced to transform to martensite is related to a characteristic
20 known as stacking fault energy. Chemical composition can be adjusted to produce an alloy with low stacking fault energy which will readily develop fine cavitation-induced twinning associated with the formation of a martensitic phase. The fine twinning is an efficient means of
25 absorbing the incident cavitation impact energy. The relationship between low stacking fault energy and high resistance to cavitation was first identified by D.A. Woodward in his article entitled "Cavitation-Erosion-Induced Phase Transformations in Alloys" in Metallurgical
30 Transactions, Volume 3, May 1972.

In this class of materials, the element nickel is known to promote a stable austenitic structure, whereas both manganese and nitrogen tend to promote the transformation

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of austenite to martensite. However, nitrogen has a tendency to cause bubbling during solidification.

A known alloy, called Tenelon, produced by United States Steel, has a composition:-

	C	Mn	N	Si	Ni	Cr
% min	0.08	14.5	0.35	0.30		17.0
% max	0.12	16.0		1.0	0.75	18.5

Tenelon is a wrought steel, not previously produced in cast form. Experimental efforts to develop a cast version of Tenelon have not been acceptable due to excessive porosity.

A most preferred cavitation-resistant alloy used in the present invention (designated, generally "XM-31") contains 17.5 to 18.5% chromium, 0.5 to 0.75% nickel, 0.45 to 0.55% silicon, 0.2 to 0.25% nitrogen, 15.5 to 16.0% manganese and 0.1 to 0.12% carbon, the balance being iron and impurities. Preferably, phosphorus and sulfur are less than 0.02%. After the alloy is cast, the article is generally heat treated at 1050°C to 1100°C for one hour per inch (25.4 mm) of thickness, followed by a water quench.

The general preferred range of chemistry for the new alloy is:-

	C	Mn	N	Si	Ni	Cr
% min	0.08	15.0	0.10	0.4		17.0
% max	0.12	16.0	0.30	0.8	1.0	18.5

More preferably the alloy has a specific composition of critical elements as follows:-

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	C	Mn	N	Si	Ni	Cr
% min	0.10	15.5	0.20	0.45	0.5	17.5
% max	0.12	16.0	0.25	0.55	0.75	18.5

5 We have determined that the manganese content is important to cavitation resistance. Figure 2 shows the relationship between manganese content and cavitation resistance. Preferably, the manganese content is 16%.

10 Any conventional fabrication method can be used, but when casting articles using this new alloy, we have determined that olivine sand $[(MgFe)_2SiO_4]$ should preferably be used for the moulds. The metal bath should preferably be kept at 1500°C to limit oxidation. Manganese in steel reduces
15 solubility for nitrogen. Excess nitrogen in high manganese steel, which exceeds the solubility limit, promotes bubbling and gas defects as the casting solidifies. Consequently, nitrogen should be added to the melt just prior to casting.

20 Quantitative laboratory cavitation test data was developed in accordance with ASTM G32-92 for several heats (i.e., samples) of the new alloy. Cavitation resistance was consistently superior, by a factor of about six, compared
25 with the martensitic stainless alloy CA6NM which is the industry standard in boiler feed pumps and other demanding impeller applications where cavitation is a chronic problem. Cavitation resistance of the new material also exceeds by a factor of about four, that of 17-4PH and
30 CA15Cu, both utilized in the pump industry as upgrades for CA6NM. The new alloy combines high mechanical properties, adequate for high energy pumps, with a level of cavitation resistance which far exceeds that of conventional materials.

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Table 1 below and Figure 1 summarise the results of cavitation tests carried out by the Inventors. The Table presents a comparison of the Brinell Hardness Number (BHN) and the Mean Depth of Penetration Rate (MDPR) for several alloys during cavitation testing. The composition of test sample XM31-2 is: carbon 0.11%, manganese 15.3%, silicon 0.49% and chromium 18.39% and test sample XM31-3 is: carbon 0.11%, manganese 15.7%, silicon 0.51% and chromium 17.17%.

TABLE 1
CAVITATION TEST RESULT SUMMARY

	<u>Material</u>	<u>BHN</u>	<u>MDPR</u>
15	XM31-3	260	0.00089
	Cast CA15Cu	388	0.00400
	17-4PH(cond. H1150)	255	0.00469
	Cast CA6NM(Dresser)	262	0.00651
	Cast CA6NM	262	0.00740
20	Cast CA15	217	0.01110

The mechanical properties of the new alloy are: tensile strength 676-745 N/mm², yield strength 410-480 N/mm² and elongation 43.2-53.7%. These properties are based upon testing of five different XM31 samples. It has also been determined that the new alloy can be welded using commercially available filler metals, and machined using standard techniques employed in the manufacture of pump impellers.

The resulting alloy, described above, offers cavitation resistance far superior to that of conventional stainless steel casting alloys. It develops this high resistance by a strain hardening mechanism associated with the formation

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of cavitation induced twinning. This significantly delays the initiation of fatigue cracking.

5 In the foregoing and in the following claims, a blank in the tabulated data means that no minimum of the alloying element is specified and that the element can be absent. All percentages are by weight.

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CLAIMS:-

1. A fluid impeller for use in applications requiring a high degree of cavitation erosion resistance, said impeller

5 ~~comprising:-~~ including:-

a body fabricated from a castable metastable austenitic steel alloy, said alloy having a chemical composition in the following range:-

10		C	Mn	N	Si	Ni	Cr
	% min	0.08	14.0		0.3		17.0
	% max	0.12	16.0	0.45	1.0	1.0	18.5

the balance comprising iron and impurities.

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2. An impeller as claimed in claim 1 wherein the body has been subjected to a heat treatment including a solution anneal at 1050°C to 1100°C for one hour per inch (25.4 mm) of thickness followed by a water quench.

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3. An impeller as claimed in claim 1 or claim 2 wherein the alloy has a chemical composition in the following range:-

25		C	Mn	N	Si	Ni	Cr
	% min	0.08	15.0	0.10	0.4		17.0
	% max	0.12	16.0	0.30	0.8	1.0	18.5

the balance comprising iron and impurities.

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4. An impeller as claimed in claim 3 wherein the alloy has a chemical composition in the following range:-



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	C	Mn	N	Si	Ni	Cr
% min	0.10	15.5	0.20	0.45	0.5	17.5
% max	0.12	16.0	0.25	0.55	0.75	18.5

5 the balance consisting of iron and impurities.

5. An impeller as claimed in any one of the preceding claims wherein the manganese content of the alloy is 16%.

10 6. An impeller as claimed in any one of the preceding claims wherein the body has been fabricated from the alloy by casting.

15 7. A method for making a fluid impeller having a high degree of cavitation resistance, including the following steps:-

selecting a castable metastable austenitic steel alloy from alloys having the following chemical compositions:-

	C	Mn	N	Si	Ni	Cr
% min	0.08	14.0		0.3		17.0
% max	0.12	16.0	0.45	1.0	1.0	18.5

the balance comprising iron and impurities;

25 fabricating said fluid impeller from said castable metastable austenitic steel alloy; and

heat treating said fluid impeller by solution treating at 1050°C to 1100°C for one hour per inch (25.4 mm) of thickness followed by quenching.

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8. A method as claimed in claim 7 wherein the castable metastable austenitic steel alloy has a chemical composition in the following range:-

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	C	Mn	N	Si	Ni	Cr
% min	0.08	15.0	0.10	0.4		17.0
% max	0.12	16.0	0.30	0.8	1.0	18.5

5

the balance comprising iron and impurities.

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9. A method as claimed in claim 8 wherein the castable metastable austenitic steel alloy has a chemical composition in the following range:-

	C	Mn	N	Si	Ni	Cr
% min	0.10	15.5	0.20	0.45	0.5	17.5
% max	0.12	16.0	0.25	0.55	0.75	18.5

15

the balance comprising iron and impurities.

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10. A method as claimed in any one of claims 7 to 9 wherein the castable metastable austenitic steel alloy has a manganese content of 16%.

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11. A method as claimed in any one of claims 7 to 10 wherein the fluid impeller is cast in a mould made from olivine sand $[(MgFe)_2SiO_4]$.

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12. A method as claimed in any one of claims 7 to 11 wherein the fluid impeller is cast from said castable metastable austenitic steel alloy; said alloy having been melted at a temperature not greater than 1500°C.

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13. A fluid impeller substantially as herein before described.

14. A method for making a fluid impeller substantially as herein before described.

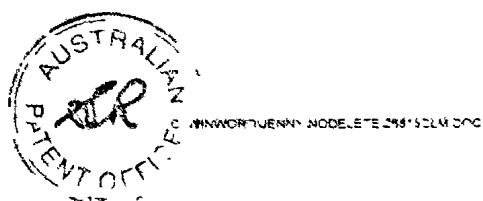
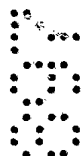
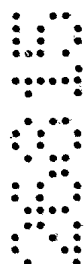
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DATED: 6 August, 1997

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Attorneys for:

10 INGERSOLL-DRESSER PUMP COMPANY



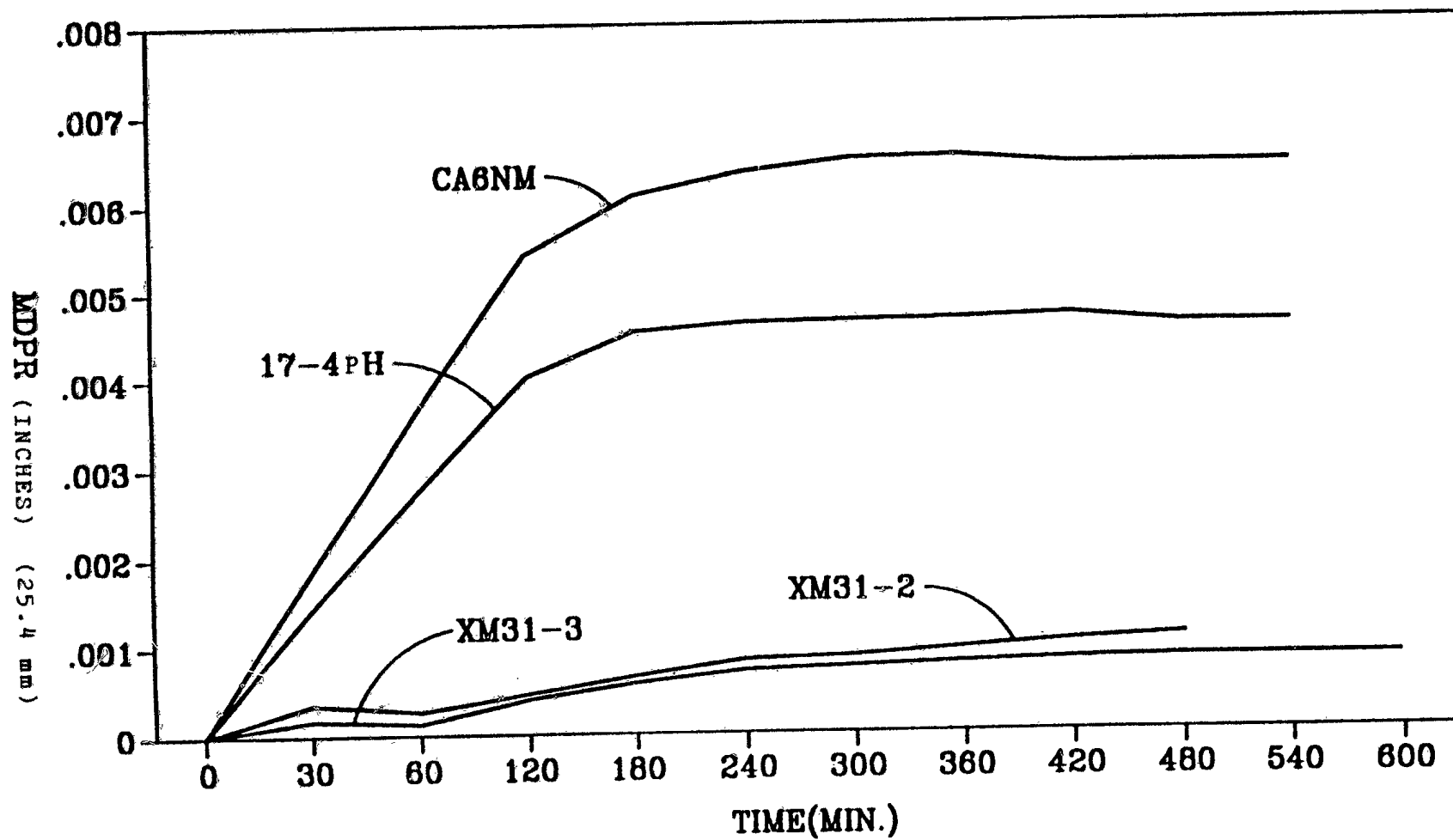


FIG. 1

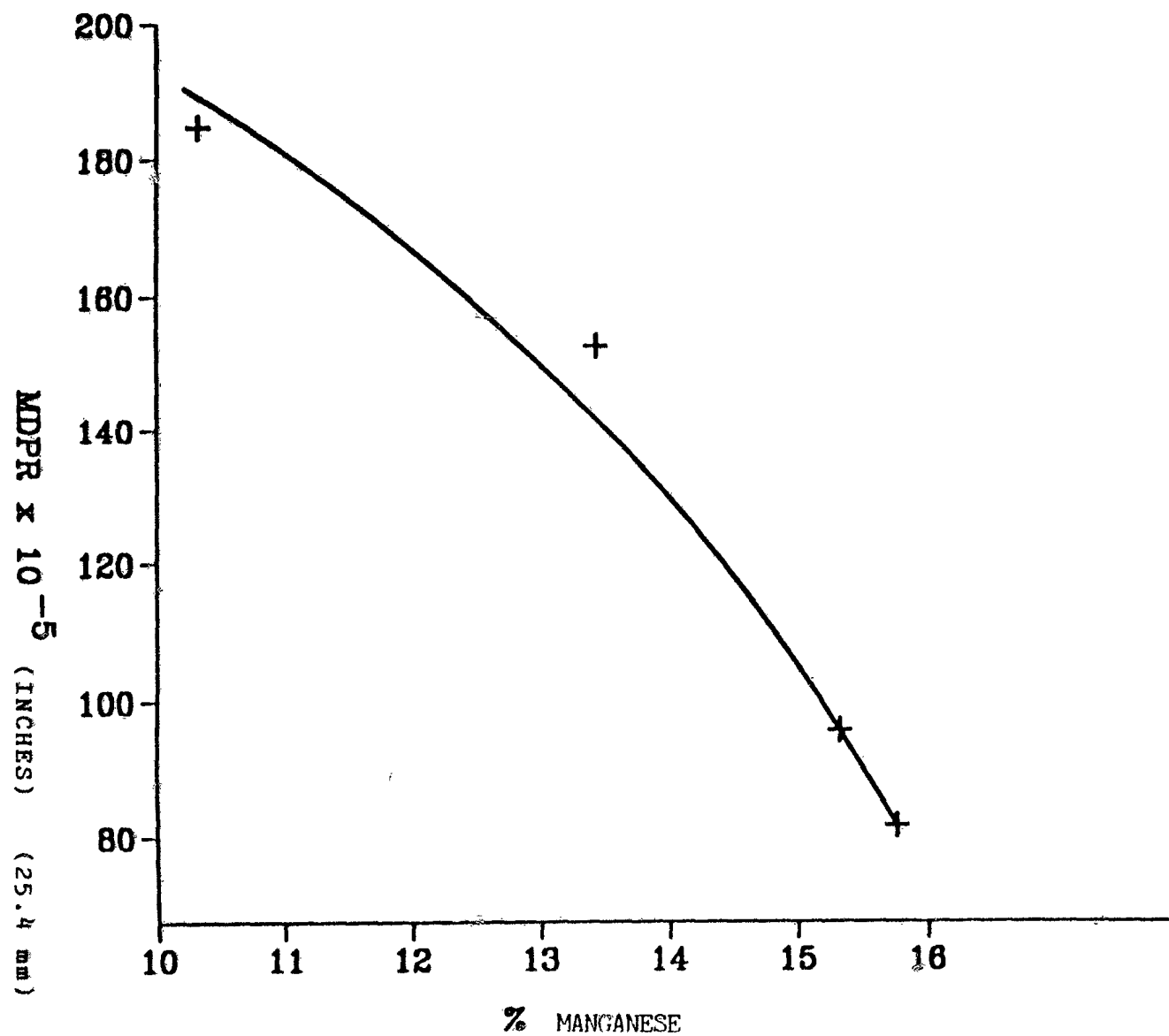


FIG. 2

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IB 95/00512

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C22C38/38 F04D29/22 C22C38/58

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C22C F04D

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 042 180 (TOKYO SHIBAURA DENKI K.K.) 23 December 1981 *Page 5, line 6 - page 7, line 35, Table 1 and claims* ---	1-12
A	GB,A,2 205 854 (AGENCY OF INDUSTRIAL SCIENCE AND TECHNOLOGY OF MITI) 21 December 1988 *Page 4, lines 10-14, page 5, lines 8-15, Table 1 and claims* ---	1-12
A	US,A,3 904 401 (CARPENTER TECHNOLOGY CORP.) 9 September 1975 *Col.3, line 54 - col.4, line 22, Table 1 and claims* --- -/--	1-12

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
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- * & * document member of the same patent family

Date of the actual completion of the international search

20 September 1995

Date of mailing of the international search report

06.10.95

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INTERNATIONAL SEARCH REPORT

Int. l. Application No.
PCT/IB 95/00512

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 12 no. 479 (C-552) ,14 December 1988 & JP,A,63 195224 (NIPPON MINING CO.) 12 August 1988, *Alloy 2 of Table in patent document* see abstract ---	1-12
A	PATENT ABSTRACTS OF JAPAN vol. 12 no. 186 (C-500) ,31 May 1988 & JP,A,62 294130 (SUZUKI KINZOKU K.K.) 21 December 1987, *Table in patent document* see abstract ---	1-12
A	PATENT ABSTRACTS OF JAPAN vol. 12 no. 382 (C-535) ,12 October 1988 & JP,A,63 128157 (KOBE STEEL LTD) 31 May 1988, *Table 1 in patent document* see abstract ---	1-12
A	US,A,5 009 723 (AICHI STEEL WORKS) 23 April 1991 *Examples and claims* ---	1-12
A	ASTM SPEC. TECH. PUBL., vol. 1, 1990 PHILADELPHIA, US, pages 203-220, MAZEY,D.J.,BOLSTER,D.E.J., ET AL. 'Ion Bombardment Radiation Damage Studies of Fusion-Relevant Austenitic and Ferritic Alloys.' *Table 1* -----	1-12

INTERNATIONAL SEARCH REPORT
Information on patent family members

In ternational Application No
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