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(57) Abstract

A steel containing maximum 0.05 weight % C, maximum 0.8 weight % Si, 0.3 – 4 weight % Mn, 28 – 35 weight % Cr, 3 – 10 weight % Ni, 1.0 – 4.0 weight % Mo, 0.2–0.6 weight % N, maximum 1.0 weight % Cu, maximum 2.0 weight % W, maximum 0.010 weight % S and maximum 0.2 weight % Ce, and the balance Fe together with normally occuring impurities and additives, at which the ferritic content is 30 – 70 volume % and the PRE–value is at least 40. Use of such a steel for equipment in contact with seawater.

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NEW USE OF A STAINLESS STEEL IN SEAWATER APPLICATIONS

Introduction

The present invention provides a ferritic-austenitic stainless steel provided for seawater applications and use of this ferritic-austenitic stainless steel in seawater applications and nearby areas, where especially favourable properties for the steel have been pointed out.

Background

Ferritic-austenitic (duplex) stainless steels are today widely used as construction material in a number of industries. The duplex steels are often developed for especially favourable use in special areas. Thus, for example the duplex steel SAF 2507 (UNS S 32750), which is alloyed with 25% Cr, 7% Ni, 4% Mo and 0.3% N and which is described in the Swedish Patent Application SE-A-453 838, concerned to be especially resistant against chloric induced corrosion and finds therefore applications as construction material if the process solution contains chlorides or if the material will be exposed for seawater or chlorine containing cooling water, for example in heat exchangers.

In US-A-5 582 656 (SE-A-501 321) duplex steels are described, which contain maximum0.05 weight% C, maximum0.8 weight% Si, 0.3 - 4 weight% Mn, 28 - 35 weight% Cr, 3 - 10 (3-7) weight% Ni, 1.0 - 3.0 (1.0 - 4.0) weight% Mo, 0.30 - 0.55 weight% N, maximum1.0 weight% Cu, maximum2.0 weight%W, 0.010 weight% S and 0.2 weight% Ce, and a balance Fe together with normally occurring impurities and additives, at which the ferrite content makes 30 - 70 volume%.

The purpose of the present invention is to provide duplex steel for use within seawater applications.

As described in SE-A-453 838 the composition of the alloy is not the most important factor to provide such steel. The balance between the different components of the alloy and structural factors is more important. Furthermore it is wellknown from this patent that high amounts of, for example chromium, improve the tendency of precipitation of intermetallic compounds so strong, that problems in manufacturing and in relation with welding could occur. A high amount of nitrogen is desired in order to stabilize the alloy against precipitation of intermetallic phases and improvement of the corrosion resistance, but is restricted by the limited solubility in the melt, which causes precipitation of chromiumnitrides. By these reasons the content of chromium in this alloy will be restricted to maximum27 % and the content of nitrogen to 0.25-0.40 %.

Short description of the invention

It reveals surprisingly that some of the alloys, which are covered of the in US-A-5 582 656 defined general steelcompositions, have special favourable and in certain cases particular god properties as construction material in the field of seawater applications. This in spite of high content of chromium and high content of nitrogen, that is over the upper limit that according to SE-A-453 838 has to be taken into consideration to avoid precipitation. Especially god properties will be achieved if the PRE-value of the steel is at least 40.

The invention provides consequently to a steel containing maximum0.05 weight% C, maximum0.8 weight% Si, 0.3 - 4 weight% Mn, 28 - 35 weight% Cr, 3 - 10 weight% Ni, 1.0 - 4.0 weight% Mo, 0.2 - 0.6 weight% N, maximum1.0 weight% Cu, maximum2.0 weight% W, maximum0.010 weight% S and maximum0.2 weight% Ce, and the balance Fe together with normally occurring impurities and additives, at which the ferritic content makes 30 - 70 volume% and the PRE-value is at least 40.

Not any of the steelgrades, that are specifically described in US-A-5 582 656 or SE-A-501 321 provides a PRE-value over 40 in both the ferritic and the austenitic phase. Most of the embodiments provide a PRE-value under 40 even calculated on the whole composition.

Characterization of seawater

One has often thought that seawater is relatively the same all over the world. However, the variation is obvious. The total amount of dissolved salt can range from approximately 8000 mg/l (ppm) in the Baltic Sea to ca 7.5 times of this amount in the Persian Gulf. The total amount of salt that artificial seawater is based on is 35 000 mg/l, which can be considered as a typical amount for seawater. In table 1 the mixture of artificial seawater is shown. It concludes that the main share of all salt in seawater is NaCl. Often seawater contains also sand and other solid particles.

The following table shows the mixture of the artificial seawater used for the test of a material suitability for seawater applications.

Table 1

Mixture of artificial seawater

Element	Concentration (mg/l)	% of the total amount of salt
Chlorine	18980	55.0
Bromine	65	0.2
Sulphate	2649	7.7
Bicarbonate	140	0.4
Fluorine	1	0.0
Boric acid	26	0.1
Magnesium	1272	3.7
Calcium	400	1.2
Strontium	13	0.0
Potassium	380	1.1
Natrium	10560	30.6
Total	34486	100.0

The foremost interesting factors for the corrosivity of seawater are: content of chloride, index of pH, temperature, oxidizing ability, biological activity and flowrate. Even impurities in the water can affect the corrosivity. The temperature of the seawater is strongly varying dependent on where one is situated and at which depth the water is taken. The pH-value of seawater is approximately 8.

Detailed description of the invention

In the following the invention is described more detailed regarding to special examples of execution and the enclosed drawings, where Fig. 1 is a schematically description of how the crevice corrosion arises and Fig. 2-11 are diagrams about the measured properties of different steelgrades.

The steel according to the invention contains accordingly maximum0.05 weight% C, maximum0.8 weight% Si, 0.3 - 4 weight% Mn, 28 - 35 weight% Cr, 3 - 10 weight% Ni, 1.0 - 4.0 weight% Mo, 0.2 - 0.6 weight% N, maximum1.0 weight% Cu, maximum2.0 weight% W, maximum0.010 weight% S and maximum0.2 weight% Ce.
The PRE-value, i.e. [%Cr]+3.3x[%Mo]+16x[N], should be at least 40 in the total composition, preferably at least 42 in the total composition. Further, each phase should exhibit a PRE-value over 40, preferably at least 41.

In US-A-5,582,656 it is specified that the additional alloying elements should fulfill the ratio %Cr+0.9%Mn+4.5%Mo-12.9%N<35 in order to minimize the risk for precipitation of intermetallic phases during the production. It has surprisingly appeared, that one could hold the mentioned ratio in the present steel at 35 or more, but still achieve the essential good properties, which are necessary to be able to use the steel in seawater applications. It is advantageous to hold the relation at 35 or more, as it is easier to obtain a higher PRE-value. Thus, present steel fulfills preferably the ratio %Cr+0.9%Mn+4.5%Mo-12.9%N≥35 to obtain a sufficiently high PRE-value. Preferably the result of %Cr+0.9%Mn+4.5%Mo-12.9%N is highest 40 and especially highest 38.

The preferred content of Mn is 0.3-3.0 % and the content of S is suitably maximum

0.005 %. As a result of this a reduced amount of MnS-slag will be obtained in the material. Those slags easily initiate pitting in seawater-environment and it is for these reasons favourable to keep this type of slag on a low level in a ”seawater-steel”.

The content of Mo is preferably 1.5-4.0 %. This gives a higher minimum-level for the PRE-value in the steel. However, for these reasons the risk of precipitation of intermetallic phases the content of Mo should be restricted to maximum 3.0 %, preferably to maximum 2.5 %.

For the maintenance of a sufficient high content of Cr in the austenitic phase and in order to that the PRE-value should be over 40 the lowest total content of Cr is suitably approximately 29 %. In view of the risk of precipitation of intermetallic phases the content of Cr should preferably be maximum 33 %.

Nitrogen increases the relative content of chromium and molybdenum in the austenitic phase. Therefore the content of N should be at least 0.30, but preferably lowest 0.36. High contents of N could cause formation of voids under welding and therefore the alloy according to the invention should contain maximum0.55 % Nitrogen.

The content of Ni is preferable maximum8 % and the minimum content is preferable 5 %.

Important properties of material for seawater applications

An important property for seawater applications is the high strength (high yield point and high fatigue limit). The high strength implies that you can use poorer material (for example thinner wall thickness for tubes) and by that save weight. Often it is important to keep the weight of a construction for seawater applications low, because the construction could often be situated on floating plants, as boats, oil platforms and so on, there you would use the available buoyancy to transport goods.

Another important property of material for seawater applications is a god corrosion resistance in Cl^--containing environments. The types of corrosion, which easily can be initiated in Cl^--containing environments are pitting corrosion, crevice corrosion and stress corrosion cracking. Pitting- and crevice corrosion of the material could be avoided if the “PRE-value” for the same is sufficiently high. The PRE-value is defined as PRE = [% Cr] + 3.3 x [% Mo] + 16 x [% N]. In order to have a god corrosion resistance in seawater the PRE-value should be higher than 40 for duplex steel. As apparent from the definition a high PRE-value could be based on whether a high content of Cr, Mo or N. It is wellknown that a high content of Mo gives a less structural stable material regarding to the precipitation of the sigma phase. It is even wellknown that a high content of N gives a more structural stable material. Therefore it is suitable to base the high PRE-value on a high content of N or Cr, compared with a high content of Mo.

At risk for crevice corrosion it is also desirable with a high content of N, because this neutralises H^+-ions, which will be formed in the cleft and by that avoid the decreasing pH-value that could make the environment worse. The crevice corrosion-course is schematically shown in the Fig. 1.

The third type of corrosion, which can appear in Cl^--environments, is - as mentioned earlier - stress corrosion cracking. This appears mainly in austenitic stainless steel and is treacherous, because it can develop very fast. It is well known that duplex steels have very god stress corrosion cracking resistance because of the advantageous synergy effect between the ferritic and the austenitic phase in the material.

Another property, that is important in some cases of seawater applications, is videlicet the erosion corrosion resistance of the alloy. The erosion corrosion can be defined as acceleration of the corrosion-course as a consequence of rapidly streaming media, which even sometimes can contain solid particles. A strong contributing factor for the erosion corrosion is the turbulent flow in tubes (in difference to laminar). Turbulent flow can be increased by high velocitivity of flow restrictions in the tube (for example valves in the tube etc.), sharp bends etc.

A last factor to be taken into consideration is of course the price of the alloy.

For seawater applications it should be desirable with a material that has a god corrosion resistance, especially in Cl^--environments, at the same time as it has the highest possible strength.

Properties of the steel according to the invention

The steel according to the invention has a very high strength (yield point in tension (0.2) ≥650MPa). In comparison with other typical steelgrades for seawater applications this is considerable higher [SAF 2507: yield point in tension = 550 MPa; 6Mo-steel: yield

point in tension = 300 MPa]. This implies that the present steel can be used with considerable thinner wall thicknesses than these.
However, the high strength is not coincident for all steels of US-A-5 582 656. For example there is steel described (no. 10) with a yield point in tension of only 471 MPa (Table 1 and 2). However, this steel has a PRE-value at only 35.6 and is consequently not in the scope of the present invention.

Fig. 2 shows the effect of the yield point of tension on the wall thickness which is necessary to withstand a certain inner pressure (according to the formula in the Swedish conduit standard 1978, RN78). It appears from this that increasing of the yield point of tension from 550 MPa to 650 MPa allows a reduction of the wall thickness with 15 % and in connection with this a reduction of the total tube weight in the range. A corresponding comparison between 300 MPa and 650 MPa saves about 50 % of the weight.

The pitting and crevice corrosion of the presented steel is good. This depends on that the PRE-value of the alloy is over 40. More precisely the PRE-value is around 42, which is the same level as for the established "seawater steels" SAF 2507 (UNS S 32750) and austenitic stainless steel of the type 6-Mo.

At the acceptance test of the material it is common to use tests for the pitting corrosion, which can be seen as an indicator for the seawater resistance. The most frequent method is to use the modified ASTM G48A-method, where a material is placed in a solution of 6% ferric chloride, whereafter the temperature is stepped with a 24-hour interval and the material will be inspected concerning to the pitting corrosion after every test period. The temperature where pitting corrosion occurs is called as critical pitting temperature. Fig. 3 shows the critical temperature for specimen of the materials 254 SMO, SAF 2507 and according to the invention. From this it can be concluded that all of these materials have high values for the critical pitting temperature, and for this reason it is probable that the materials have equivalent pitting corrosion resistance in seawater.

Corresponding testing in $FeCl_3$ can be made with applicated crevice formers. The steel according to the invention obtains then a critical crevice corrosion temperature of about 40°C. Even this could be seen as being at approximately the same level as for the established "seawater steels". The development of the crevice corrosion after possibly initiation could even be expected to be on a low level because of the high content of nitrogen in the alloy.

Another method to determine the materials pitting resistance that is used, is electrochemical with a steadily applied potential on the material. In order to simulate chlorinated seawater, which is a very aggressive solution, it is tested at 600 mV/SCE. The result of this testing of the steel according to the invention is shown in Fig. 4. It appears from this that the steel passes 70°C in this environment, independent from the content of NaCl.

As mentioned earlier, the reason for good pitting- and crevice corrosion resistance is a high PRE-value. A comparison can be made with SAF 2507, which is optimized in consideration to the PRE-value so that the PRE-value is equal in both phases. This obtains by alloying with a well-balanced composition of Cr, Mo and N, and one has shown that 0.30 % N gives balance between PRE in the ferritic and austenitic phase, when the content of chromium is 25 % and the content of Mo is 4 %. A PRE-value over 40 will then be achieved.

The steel according to the invention is based on the same presumptions - namely PRE-balance - but here is a higher content of Cr and a lower content of Mo is chosen, which makes it possible to alloy a higher content of N. Due to that Mo is considerable more detrimental for the structural stability than Cr, and also that the content of N is higher than in SAF 2507, for this reason a higher structural stability in the steel according to the invention is obtained (see Fig. 5 for TTT-curve) with a sustained PRE-value in the phases.

Fig. 6 shows the influence of temperature on the PRE-value in ferritic (BCC) and austenitic (FCC) phase for the presented steel. PRE-balance will be obtained at about

1080°C, which is the temperature at which the material is heat-treated and the value of the PRE-value is over 40.

The importance of having a high PRE-value in both the ferritic and austenitic phase is shown in Fig. 7, where the CPT according to ASTM G48A is shown as a function of PRE-value for the somewhat weaker ferritic phase in some test variants of the steel according to the invention. A PRE-value over 40 in both phases should for that reason be considered as fulfilled in connection with that the CPT (G48A) is 75 °C for the final alloy.

The stress corrosion resistance of the steel, according to the invention, lies on a level patently over this of austenitic steels of type 316, see Fig. 8. It should even be borne in mind that the duplex steels have a very high strength in absolute figures, which makes that the percentage of the tensile strength, which is possible to take advantage of before the stress corrosion occurs, is very high for these steels.

The impingement attack resistance of the steel is according to the invention with highest reliability very high because of the high strength and the by experience acquired good resistance for duplex steels.

Materials, often used in seawater, are Cu-base alloys. However, these have the big disadvantage to be sensitive for impingement attacks. Other competing materials for seawater applications are Ti- and Ni-based alloys. However, these are considerable more expensive than the present steel.

Example

In the following some embodiments of steel according to the invention will be described.

In the following Table 2 are compositions shown for five alloys according to the invention. These are the examples taken from the big number of different alloys, which were produced and tested during the development of the present invention.

Table 2

Alloy	C	Si	Mn	Cr	Ni	Mo	N	Cu	S
1	0.015	0.19	0.91	29.26	8.00	2.07	0.31	0.025	0.0043
2	0.016	0.16	1.01	28.81	7.48	2.50	0.37	0.035	0.0032
3	0.021	0.27	0.90	28.80	6.62	2.20	0.38	0.081	0.0010
4	0.015	0.15	1.00	29.01	6.66	2.51	0.40	0.037	0.0036
5	0.016	0.16	0.87	30.51	6.20	2.08	0.44	0.034	0.0042

In extruded bars from alloy no. 1, 2, 4 and 5 the content of Cr, Ni, Mo and N measured in the austenitic respectively the ferritic phase with the help of a step by step analysis in a microgroove. The result of those measurements is shown in the following Table 3.

Table 3

Alloy	Phase	Cr (%)	Ni (%)	Mo (%)	N (%)
1	Ferritic	32.59±0.48	5.47±0.18	2.60±0.14	0.00±0.03
	Austenitic	27.88±0.31	9.24±0.20	1.58±0.14	0.62±0.03
2	Ferritic	31.78±0.42	5.27±0.32	3.16±0.12	0.00±0.02
	Austenitic	28.15±0.48	8.48±0.18	1.93±0.08	0.75±0.03
4	Ferritic	31.58±0.34	4.65±0.13	3.21±0.20	0.01±0.03
	Austenitic	28.88±0.28	7.45±0.15	1.93±0.10	0.88±0.04
5	Ferritic	32.31±0.31	4.58±0.13	2.40±0.11	0.00±0.03
	Austenitic	30.16±0.25	6.99±0.20	1.64±0.13	0.98±0.04

The measured contents obtained from those PRE-values ([% Cr] + 3.3 [% Mo] + 16 [% N] for the respectively phase and the comparison for the total composition is show in the following Table 4.

Table 4. PRE-values for austenitic and ferritic phase in test alloys

Alloy	PRE (total composition)	Phase	PRE (for different phases
1	41.1	Ferritic	41.2
		Austenitic	43.0
2	43.0	Ferritic	42.3
		Austenitic	46.5
4	43.7	Ferritic	42.3
		Austenitic	49.3
5	44.4	Ferritic	40.2
		Austenitic	51.3

It appears from this that the PRE-value is higher than 40 in both the austenitic and the ferritic phase in all alloys. This is a condition for a good corrosion resistance in seawater.

The composition and by that the PRE-value in the respectively phase could also be calculated by the help of the computer-program ”Thermo-Calc”. This is made for alloy 1 at different temperatures and is presented in Fig. 6.

The temperature of about 1080°C that is achieved here to obtain the same PRE-value in both phases comes from calculated values and is by that only approximate. The actual values for PRE could divide a little from the equilibrium.

The measured values for the strength of the manufactured tubes of alloy no. 2, 3 and 4 are shown in the diagrams in Fig. 9-11. It appears that the alloys according to the invention have a yield point in tension over 650 MPa in the product application thinwalled tubes (<10 mm), which is the general dimension used in seawater applications.

Summary

It has surprisingly shown that the steel according to the invention has a good suitability to be used in seawater applications. This depends on that the steel has a yield point in tension over 650 MPa, which means that about 15 % of the tubes weight could be saved compared with SAF 2507 and about 50 % compared with 6Mo-steel by reducing the wall thickness. At the same time, the material has a good seawater resistance because it has a PRE-value over 40 in both phases and a high stress corrosion cracking resistance.

Claims

1. Duplex, stainless, ferritic-austenit steelalloy provided for seawater applications, which comprises in weight%:

- C	maximum0.05
- Si	maximum0.8
- Mn	0.3 - 4
- Cr	28 - 35
- Ni	3 - 10
- Mo	1.0 - 4.0
- N	0.2 - 0.6
- Cu	maximum1.0
- W	maximum2.0
- S	maximum0.010
- Ce	maximum0.2

and balance Fe together with normally occurring impurities and additives, at which the ferritic content makes 30 - 70 volume%, **characterized** in, that the PRE-value is higher than 40, where PRE=[% Cr] + 3.3 x [% Mo] + 16 x [% N].

2. Alloy according to claim 1, **characterized** in, that the PRE-value is higher than 40 in both the ferritic and the austenitic phase.

3. Alloy according to claim 1 or 2, **characterized** in, that the PRE-value is at least 42.

4. Alloy according to claim 1-3, **characterized** in, that the PRE-values of the ferritic and austenitic phase are very close to each other.

5. Alloy according to claim 4, **characterized** in, that it is heat-treated at approximately 1080°C.

6. Steel alloy according to some of the prior claims, **characterized** in, that the content of C is maximum0.03 weight%, preferably maximum0.02 weight%.

7. Steel alloy according to some of the prior claims, **characterized** in, that the content of Si is maximum0.5 weight%.

8. Steel alloy according to some of the prior claims, **characterized** in, that the content of Cr is between 29 and 33 weight%.

9. Steel alloy according to some of the prior claims, **characterized** in, that the content of Mo is at least 1.5 weight%.

10. Steel alloy according to some of the prior claims, **characterized** in, that the content of Mo is maximum3.0 weight%, preferably maximum2.5 weight%.

11. Steel alloy according to some of the prior claims, **characterized** in, that the content of N is between 0.30 and 0.55 weight%.

12. Steel alloy according to some of the prior claims, **characterized** in, that the content of N is at least 0.36 weight%.

13. Steel alloy according to some of the prior claims, **characterized** in, that the content of Mn is maximum3 weight%, preferably maximum about 1 weight%.

14. Steel alloy according to some of the prior claims, **characterized** in, that the content of ferrite is between 30 and 55 volume%.

15. Steel alloy according to some of the prior claims, **characterized** in, that the content of Cr in the austenitic phase is at least 25 weight%.

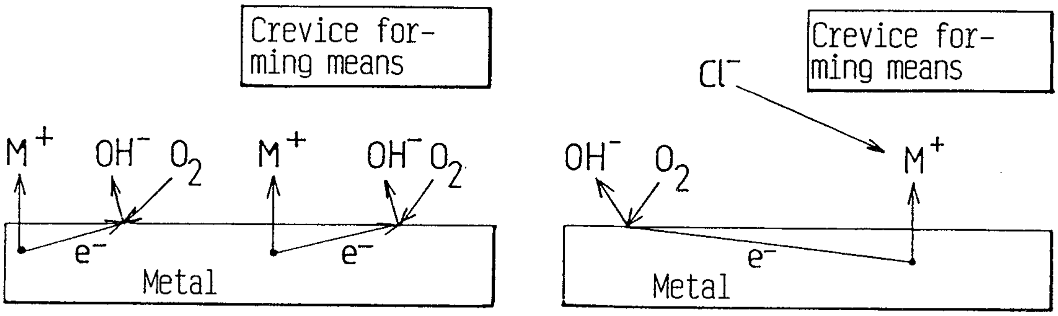
16. Steel alloy according to some of the prior claims, **characterized** in, that the content of Cr in the austenitic phase is at least 27 weight%.

17. Steel alloy according to some of the prior claims, **characterized** in, that it is used for the manufacturing of tubes, bars, heavy castings, forgings, plate, wire or strip.

18. Use of a duplex, stainless, ferritic-austenitic steelalloy, which contains in weight%:

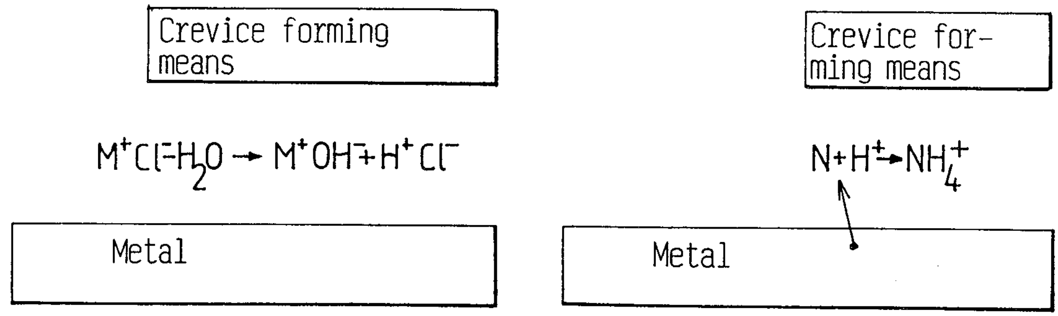
- C	maximum0.05
- Si	maximum0.8
- Mn	0.3 - 4
- Cr	28 - 35
- Ni	3 - 10
- Mo	1.0 - 4.0
- N	0.2 - 0.6
- Cu	maximum1.0
- W	maximum2.0
- S	maximum0.010
- Ce	maximum0.2

and a balance Fe together with normally occurring impurities and additives, at which the ferritic content makes 30 - 70 volume%, **characterized** in, that the PRE-value is higher than 40, at which PRE=[% Cr] + 3.3 x [% Mo] + 16 x [% N], for equipment in contact with seawater, whether clean or with some addition, such as chlorinating.



Step 1: The same reaction inside and outside of the crevice as long as oxygen is available in the crevice.

Step 2: The cathodic reaction moves outside of the crevice when the oxygen has been consumed in the crevice. The anodic reaction gives positively charged metal ions drawing negatively charged chloride ions into the crevice.



Step 3: The salt formed (M^+Cl^-) reacts with water and hydrogen ions are formed and lower the pH.

Step 4: If nitrogen is dissolved into the crevice solution from a high nitrogen content alloy, low pH is counteracted.

FIG.1

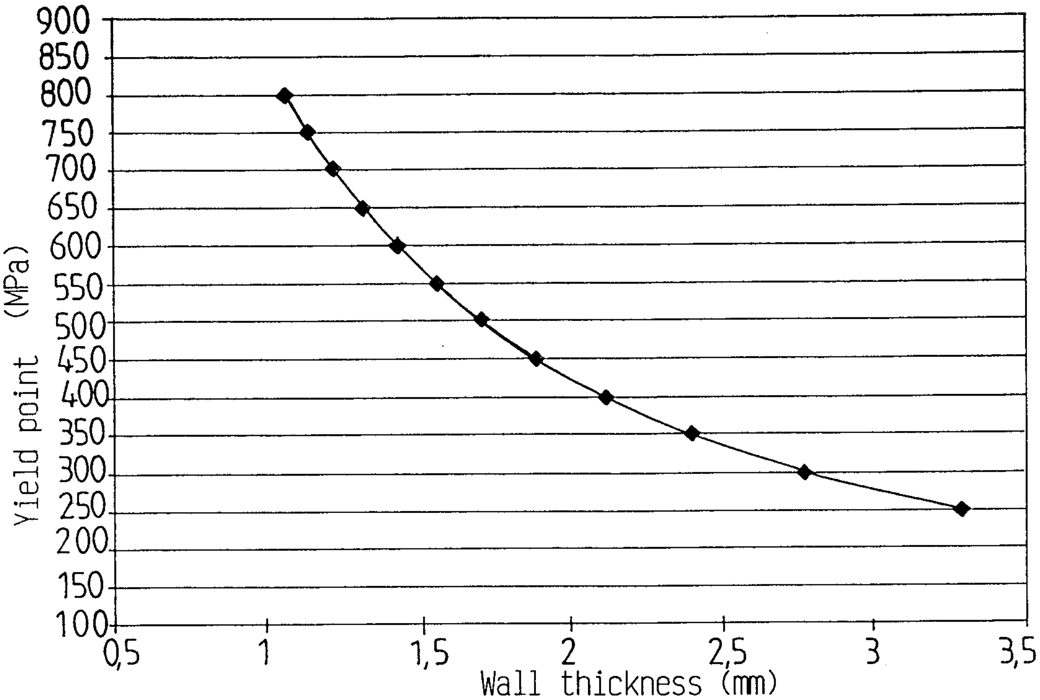


FIG.2 Inner pressure 300 bar above atmospheric (Tube outer diameter: 40 mm)

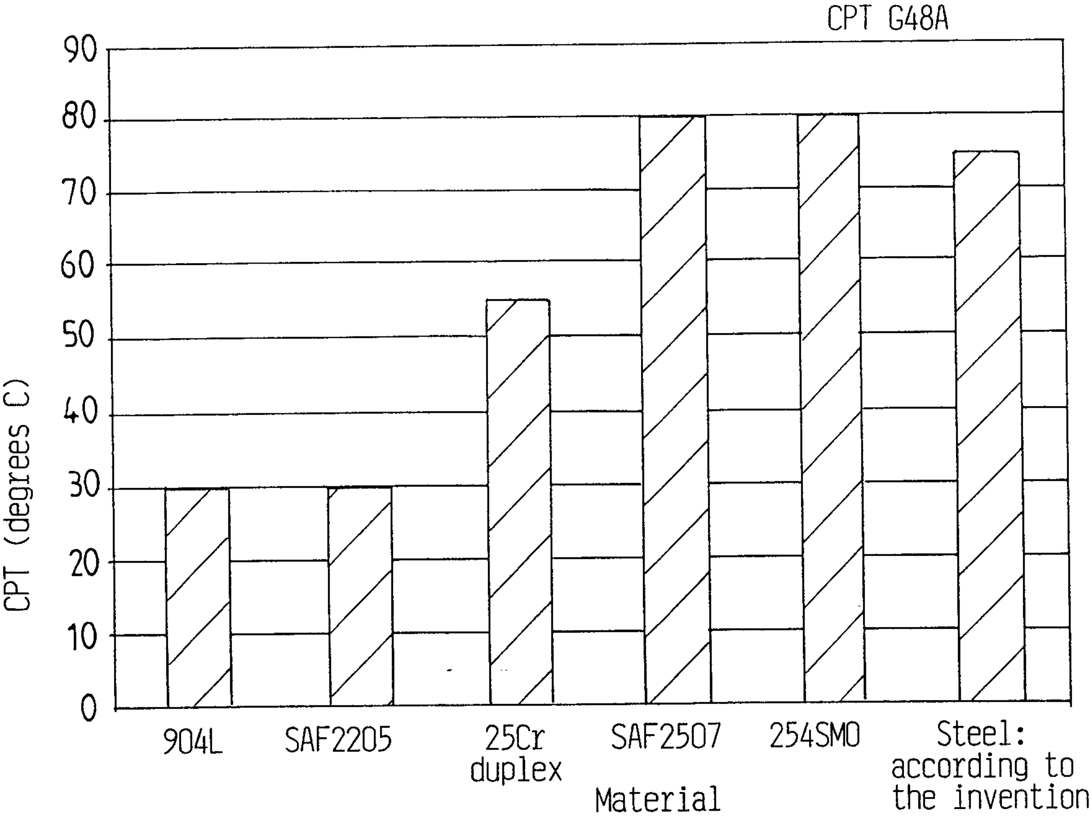


FIG.3 Critical pitting temperature (CPT) in G48 test (iron chloride, 24h)

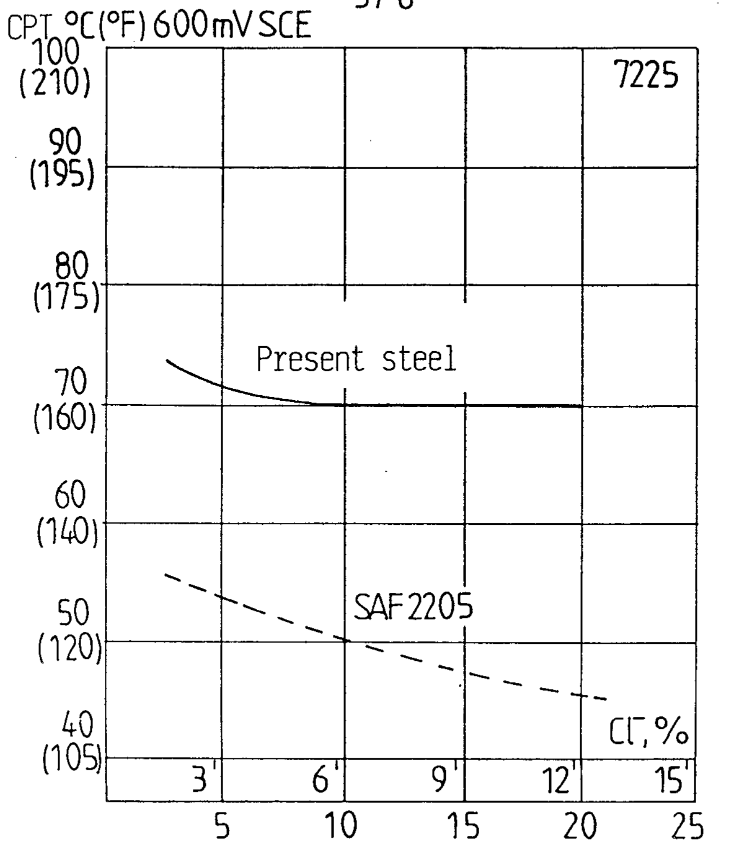


FIG.4

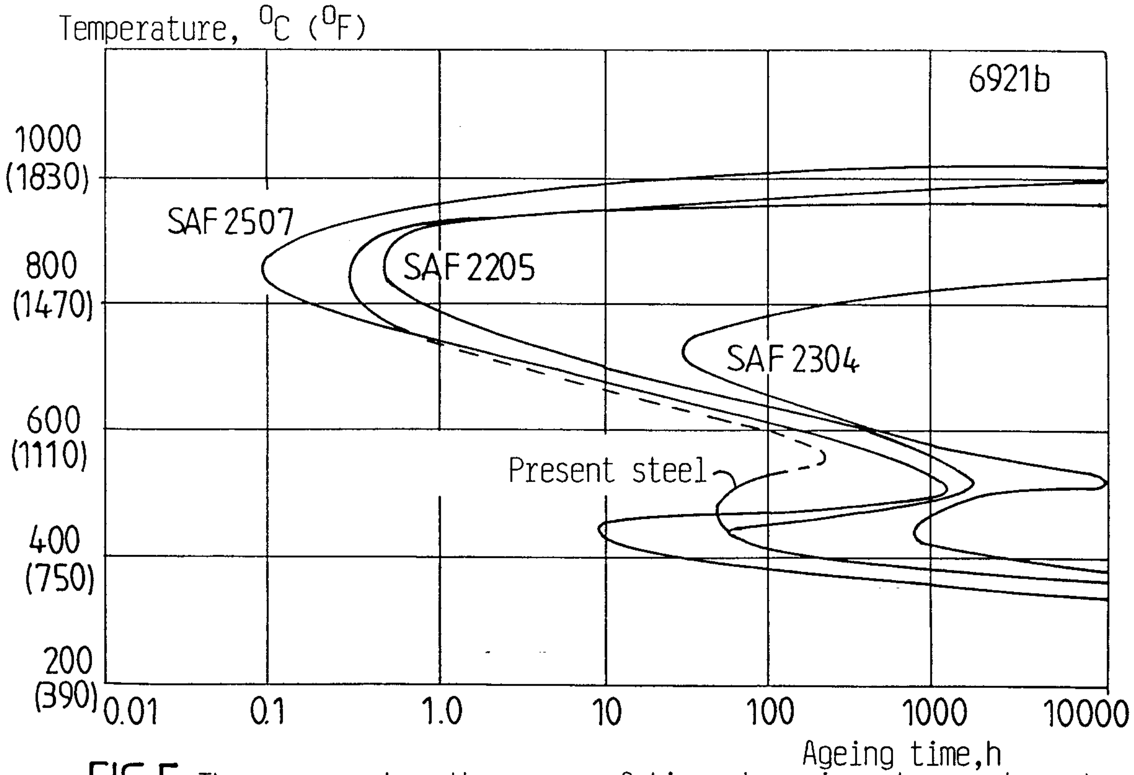


FIG.5 The curves show the space of time at a given temperature to precipitate intermetallic phase in such an amount that an impact value of 27 J is obtained.

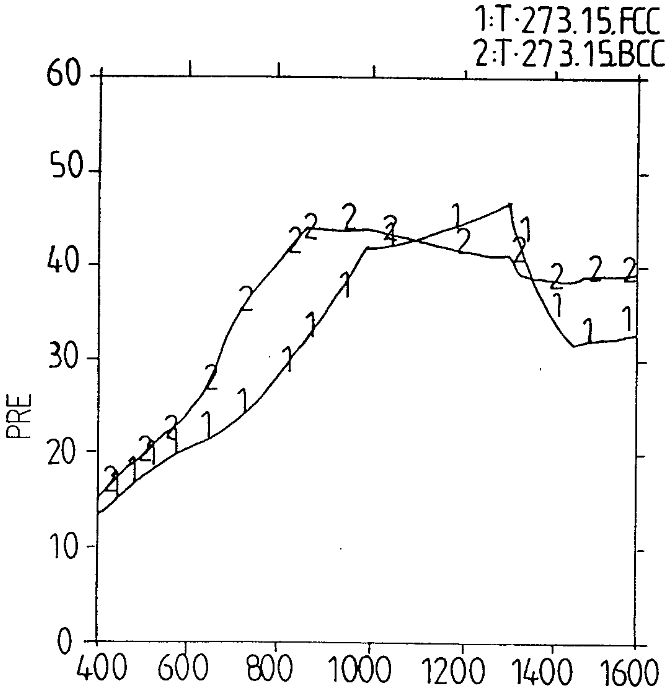


FIG.6 Calculated with Thermo-Calc.

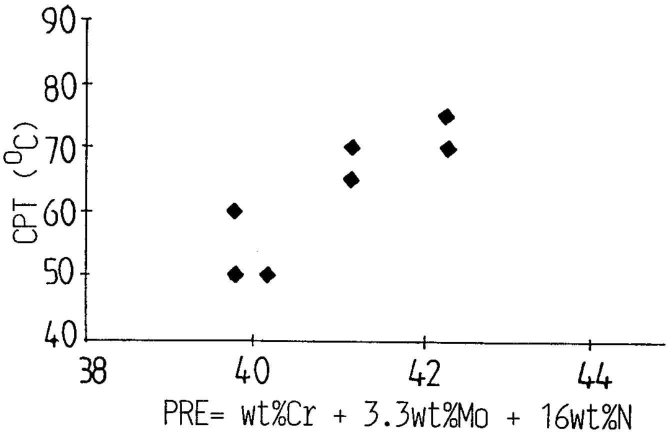


FIG.7

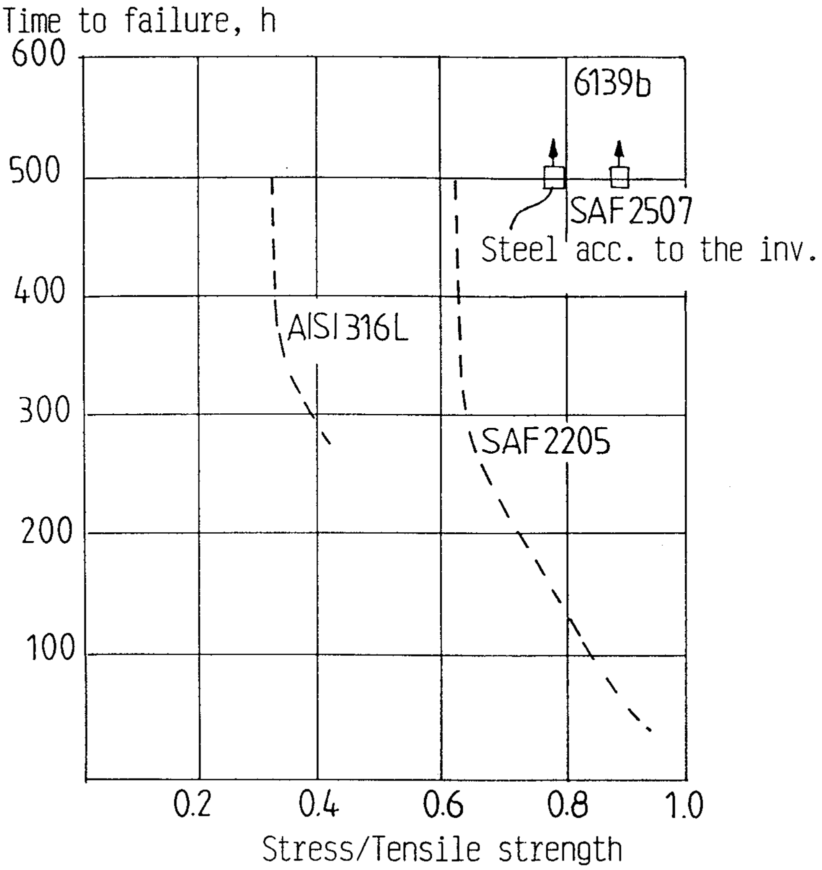


FIG.8 Testing at invariable load in 40% CaCl, at pH 1.5, temperature of 100°C.

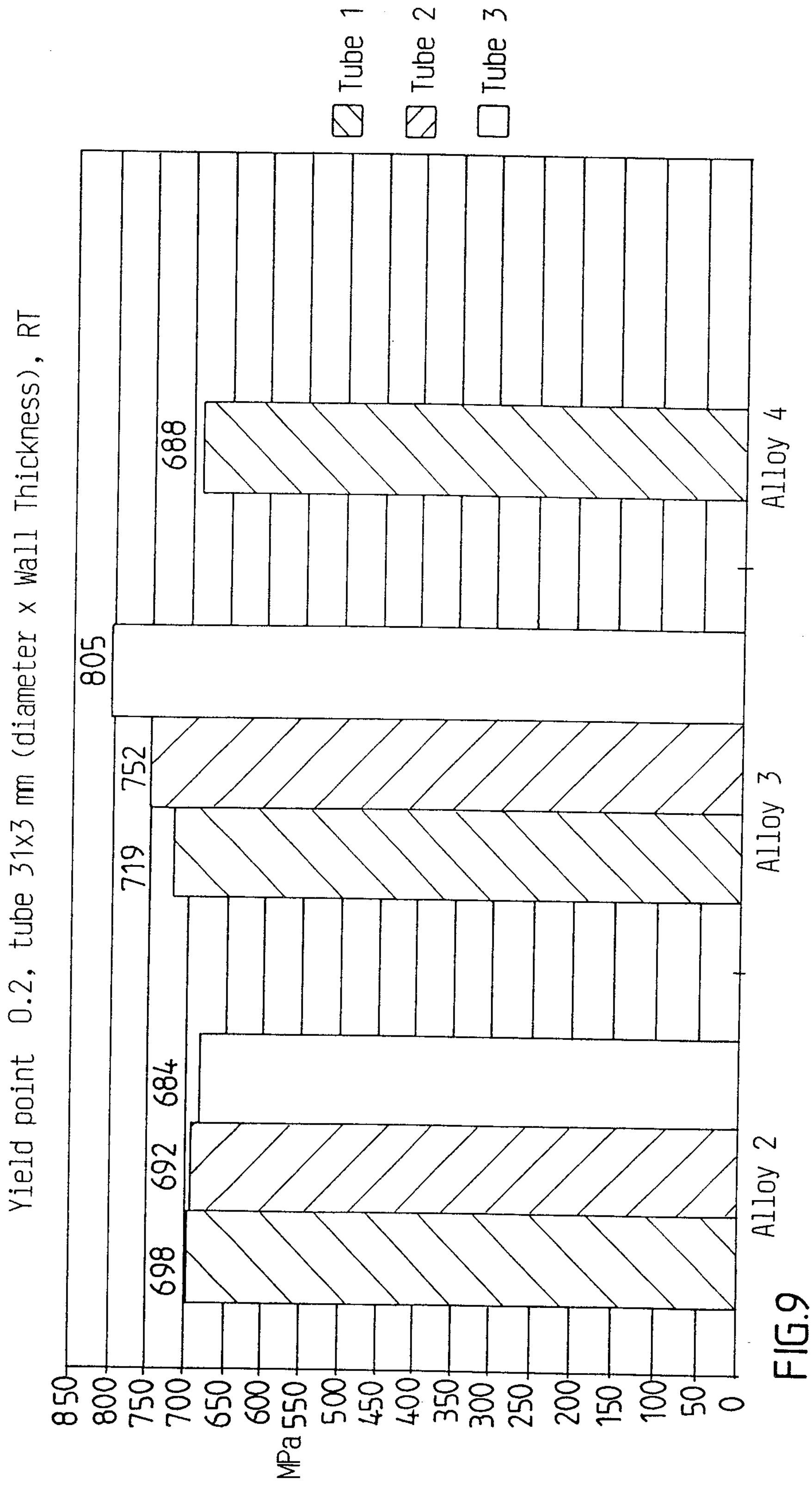

Yield point 0.2, tube 31x3 mm (diameter x Wall Thickness), RT
Tube 1
Tube 2
Tube 3
MPa
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
698
692
684
719
752
805
688
Alloy 2
Alloy 3
Alloy 4

FIG.9

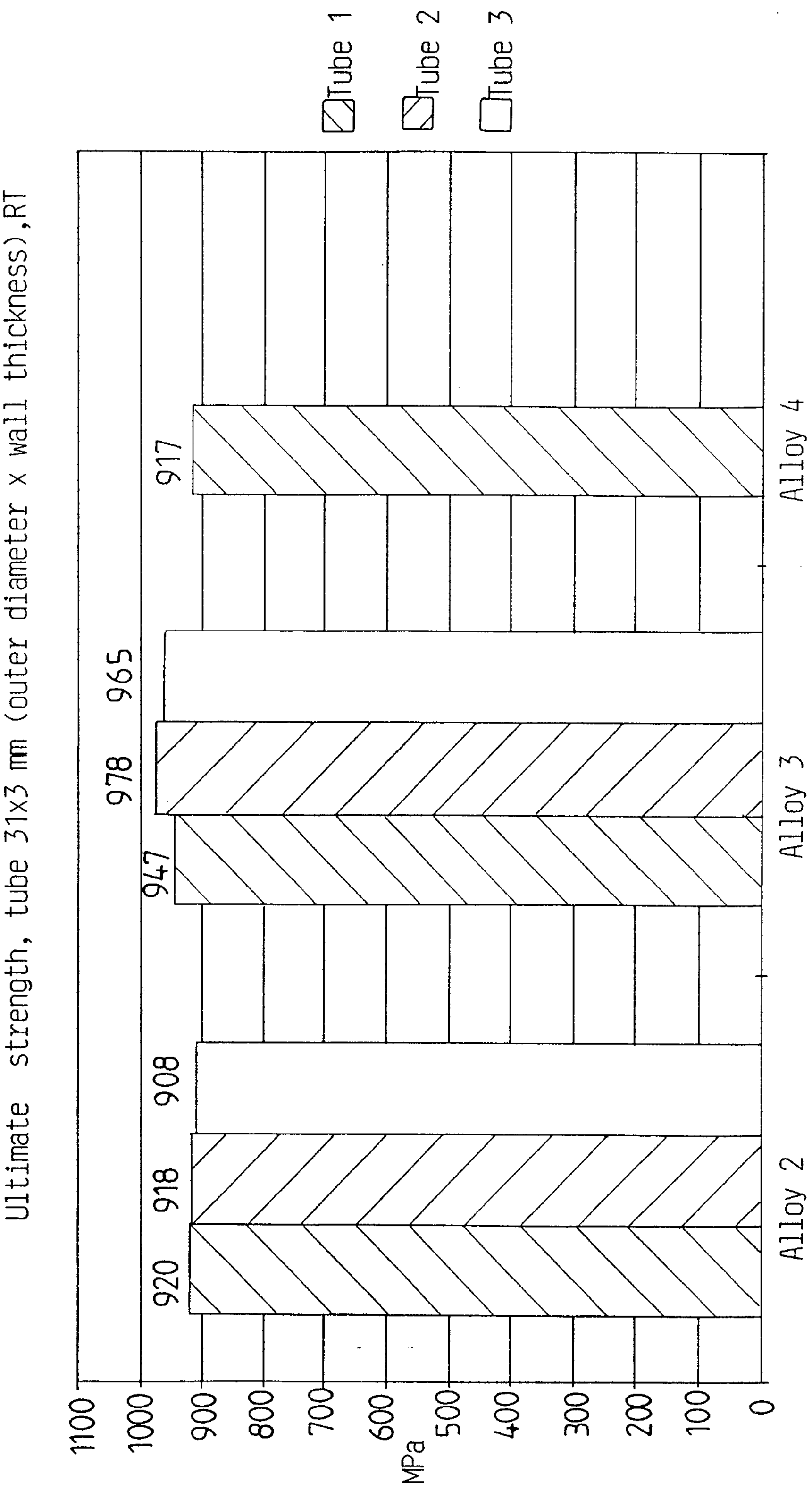

Ultimate strength, tube 31x3 mm (outer diameter x wall thickness),RT
▨ Tube 1
▨ Tube 2
☐ Tube 3
MPa
1100
1000
900
800
700
600
500
400
300
200
100
0
920
918
908
947
978
965
917
Alloy 2
Alloy 3
Alloy 4

FIG.10

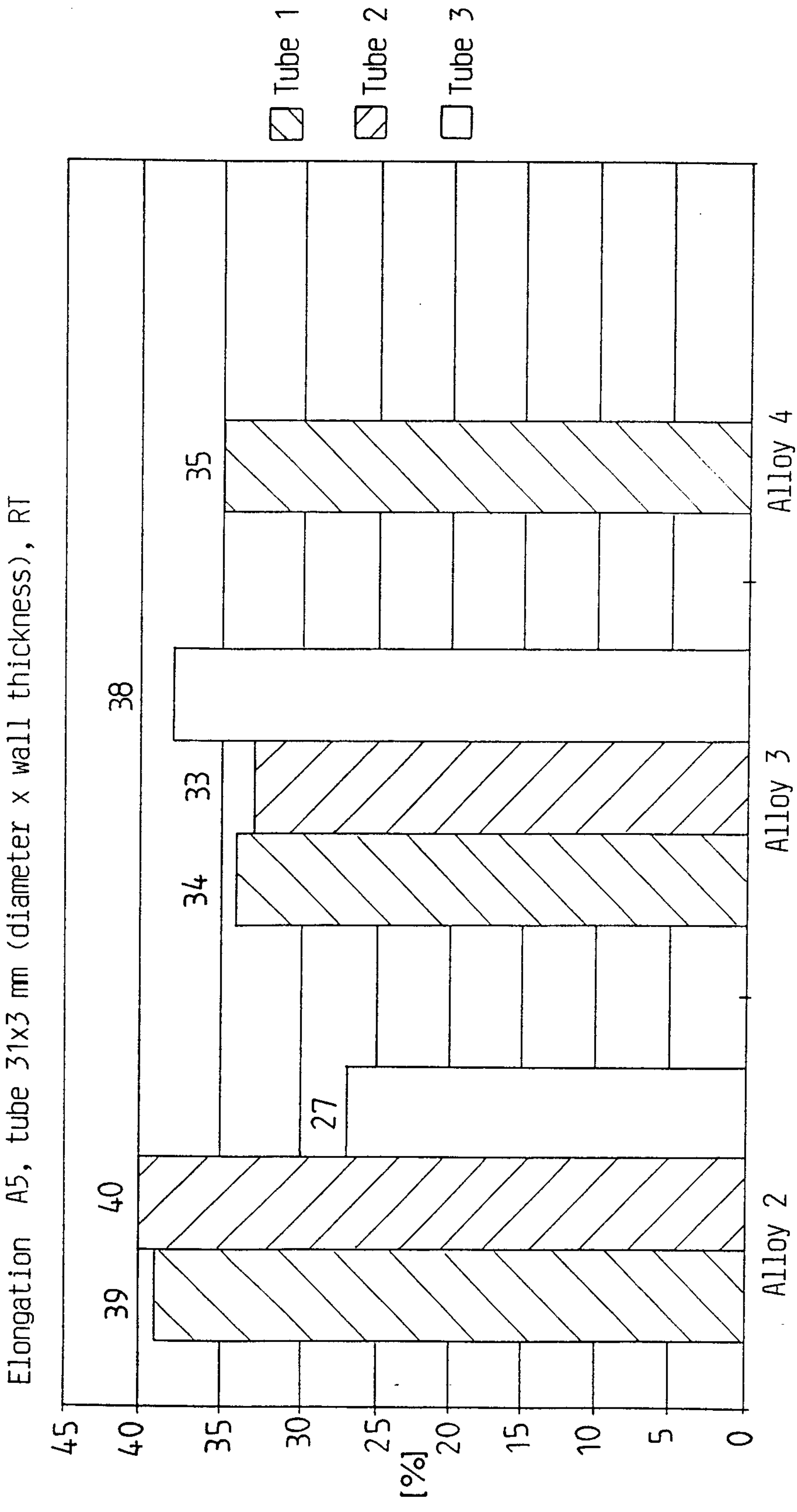

Elongation A5, tube 31x3 mm (diameter x wall thickness), RT
Tube 1
Tube 2
Tube 3
[%]
45
40
35
30
25
20
15
10
5
0
39
40
27
34
33
38
35
Alloy 2
Alloy 3
Alloy 4

FIG.11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/01901

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: C22C 38/44
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)

IPC7: C22C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5582656 A (PASI KANGAS ET AL), 10 December 1996 (10.12.96), column 4, line 53 - line 54; column 6, line 45 - line 47; column 7, line 40; column 10, line 38 - line 40; claim 1	1-16
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" erlier document but published on or after the international filing date	"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 2 February 2000	Date of mailing of the international search report 18 -02- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Anna-Maj Magnusson/MP Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

02/12/99

International application No.
PCT/SE 99/01901

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5582656 A	10/12/96	AT 185854 T	15/11/99
		CN 1125965 A	03/07/96
		DE 69421281 D	00/00/00
		EP 0708845 A,B	01/05/96
		JP 8511829 T	10/12/96
		NO 955204 A	19/02/96
		SE 501321 C	16/01/95
		SE 9302139 A	22/12/94
		WO 9500674 A	05/01/95
		ZA 9404439 A	14/02/95