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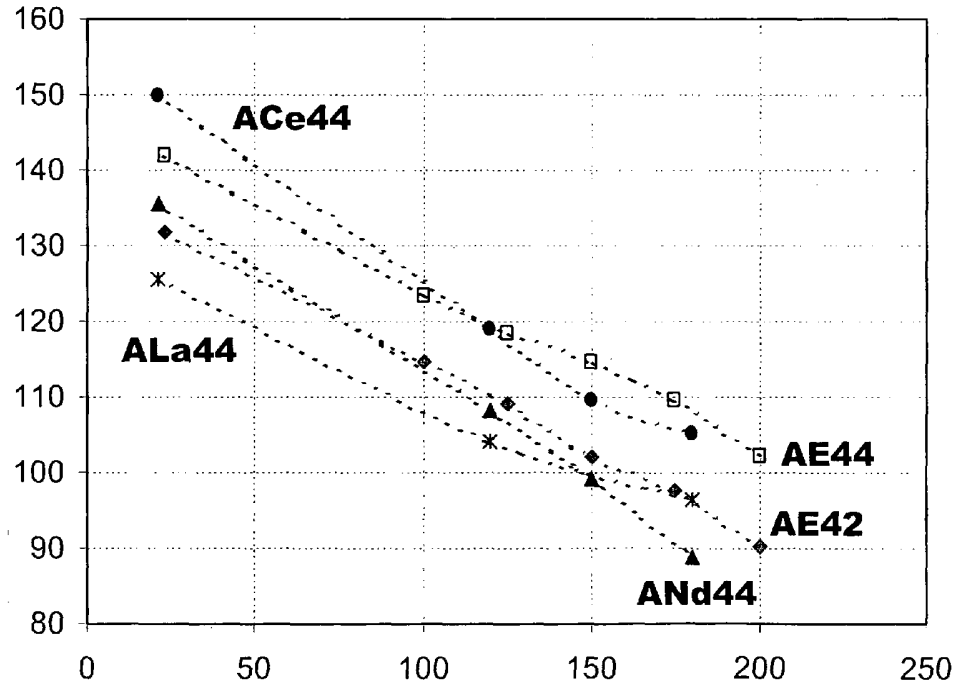
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[Continued on next page]

(54) Title: MAGNESIUM ALLOY HAVING IMPROVED ELEVATED TEMPERATURE PERFORMANCE



(57) Abstract: A magnesium alloy consisting of 1,00 - 10,00 % by weight of aluminium, 1,00 - 8,00 % by weight of rare earth metals (RE-metals), at least 40 % by weight of the RE-metals being cerium, less than 0,5 % by weight of manganese, less than 1,00 % by weight of zinc, 0,00 - 3,00 % by weight of calcium, 0,00 - 3,00 % by weight of strontium and the balance being magnesium and unavoidable impurities, the total impurity level being below 0,1 % by weight.

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MAGNESIUM ALLOY HAVING IMPROVED ELEVATED TEMPERATURE PERFORMANCE

The invention relates to a magnesium alloy having improved elevated temperature performance and more particularly relates to magnesium-aluminum rare earth metals (RE-metals) alloys having good tensile strength and good creep resistance, particularly at elevated temperatures of 150° C or higher.

BACKGROUND OF THE INVENTION

Magnesium-based alloys have been widely used as cast parts in the aerospace and automotive industries. Magnesium-based alloy cast parts can be produced by conventional casting methods, which include die-casting, sand casting, permanent and semi-permanent mold casting, plaster-mold casting and investment casting.

Mg-based alloys demonstrate a number of particularly advantageous properties that have prompted an increased demand for magnesium-based alloy cast parts in the automotive industry. These properties include low density, high strength-to-weight ratio, good castability, easy machinability and good damping characteristics.

Most common magnesium die-casting alloys such as Mg-Al-alloys or Mg-Al-Zn-alloys are known to lose their creep resistance at temperatures above 140° C. Mg-Al-Si alloys and Mg-Al-RE alloys have been developed for higher temperature applications and offer only slight improvement in creep resistance. However there is still a need to have available alloys with better performances.

It is therefore an object of the present invention to provide relatively low cost magnesium-based alloys with improved elevated-temperature performance.

It is a more particular object to provide relatively low cost magnesium-aluminum-rare earth alloys with good creep resistance and tensile yield strength and bolt-load retention, particularly at elevated temperatures of at least 150° C.

CONFIRMATION COPY

SUMMARY OF THE INVENTION

The present invention therefore provides a magnesium-based casting alloy comprising, in weight percent, 1,00 to 10,00 aluminium and 1,00 to 8,00 of rare earth metals (RE metals) at least 30 % by weight of the RE-metals being cerium, less than 0,5 % of manganese, less than 1,00 % of zinc, and further comprising 0,00 to 3,00 % by weight of calcium, 0,00 to 3,00 % by weight strontium with the balance being magnesium and unavoidable impurities, the total impurity level being below 0,1 % by weight.

In general a number of RE-metals can be used as alloying element, such as e.g. Ce, La, Nd and or Pr and mixtures thereof. It is however preferred to use cerium in substantial amounts as this metal gives the best mechanical properties. Mn is added to improve the corrosion resistance but its addition is restricted due to limited solubility.

Preferably the aluminium content is between 2,00 and 7,00 % by weight, more preferably between 2,60 and 6,50 % by weight.

If higher amounts of aluminium are present, this can easily lead to the formation of a Mg17Al12-phases which is detrimental for the creep properties. Too low Al is negative for the castability.

With respect to the RE-metals it is preferred that the RE-content is between 3,00 and 7,00 % by weight.

If more than 3.00 % by weight is present, this gives a significant improvement of the creep properties. More than 7.00 % by weight is not practical because of the restricted solubility of RE-metals in magnesium.

For specific applications the composition of the alloy is selected in such a way that the aluminium content is between 3,6 and 4,5 % by weight and the RE-content is between 3,6 and 4,5 % by weight.

This type of alloys can be used for applications up to 175°C while still showing excellent creep properties and tensile strength. Moreover this alloy does not show any degradation of its properties due to ageing and has a good castability. For applications above 175°C the composition of the alloy is such that the aluminium content is between 2,6 and 3,5 % by weight and the RE-content is greater than 4,6 % by weight.

Apart from the excellent creep properties and tensile strength this alloy does not show any degradation of properties due to ageing.
For high temperature applications below 150°C the alloy can have an aluminium content between 5,6 and 6,5 % by weight and the RE-content is greater than 3,0% by weight. In this temperature range the creep properties and tensile strength of the alloy are maintained, as is the excellent castability.

It has been found that combinations of high content of RE-metals (> 7 % by weight) and low content of Al (< 2,5 % by weight) will make the alloy difficult to cast.

Preferably the RE-metals are selected from the group cerium, lanthanum, neodymium and praseodymium.

The RE-metals as an alloy rather than individual elements are contributing to the ease of alloying, but also increase the corrosion resistance, the creep resistance and improve the mechanical properties.

Preferably the amount of lanthanum is at least 15 % by weight and more preferably at least 20 % by weight of the total content of RE-metals, Preferably the amount of lanthanum is less than 40 % by weight of the total content of RE-metals..

Preferably the amount of neodymium is at least 7 % by weight and more preferably at least 10 % by weight of the total content of RE-metals. Preferably the amount of neodymium is less than 20 % by weight of the total content of RE-metals.

Preferably the amount of praseodymium is at least 2 % by weight and more preferably at least 4 % by weight of the total content of RE-metals. Preferably the amount of praseodymium is less than 10 % by weight. Of the total content of RE-metals.

Preferably the amount of cerium is greater than 40 % by weight of the total content of RE-metals, preferably between 45 and 55 % by weight.

Preferably the amounts of calcium and/or strontium are at least 0,5 % by weight.

Calcium and strontium give an increase in creep resistance, and the addition of at least 0,5 % weight of calcium will improve the tensile strength. Otherwise higher amounts of calcium and strontium will reduce the ductibility and can easily lead to sticking problems thereby influencing the castability of the alloy.

The present invention is described in more detail with reference to the following example which are for purposes of illustration only and are not to be understood as indicating or implying any limitation on the broad invention described herein.

Example 1

In order to compose the influence of the alloying elements and a number of Mg-alloys have been prepared with the compositions as given in table 1.

TABLE 1

Alloy Type	Al wt%	Mn wt%	Zn wt%	Si wt%	Ce wt%	La wt%	Nd wt%	Pr wt%	RE wt%	Ce/RE	La/RE	Nd/RE	Pr/RE
AZ91D	8,93	0,17	0,73						0,09				
AS21B	2,11	0,08		1,01					5,44	45,77	31,80	17,28	5,15
AE35-24	3,23	0,29			2,49	1,73	0,94	0,28	2,64	49,85	30,08	14,15	5,92
AE42-15	3,89	0,15			1,31	0,79	0,37	0,16	4,62	45,67	33,12	16,23	4,98
AE44-24	4,12	0,29			2,11	1,53	0,75	0,23	3,30	43,03	40,91	12,12	3,94
AE63-4	6,31	0,18			1,42	1,35	0,40	0,13	3,90	100,00			
ACe44	3,70				3,90				2,50			100,00	
ANd44	3,90						2,50		3,00		100,00		
ALa44	3,70	0,38				3,00			3,20	28,10	71,90		
ALaCe431	3,70	0,45			0,90	2,30			3,30	72,70	27,30		
ALaCe413	4,00	0,28			2,40	0,90			3,40		76,50	23,50	
ALaNd431	3,90	0,46				2,60	0,80		2,70		40,70	59,30	
ALaNd413	3,70	0,42				1,10	1,60		3,40	76,50		23,50	
ACeNd431	4,70	0,27			2,60		0,80		1,90	47,40		52,60	
ACeNd413	4,40	0,32			0,90		1,00		3,00	50,00		50,00	
ACeNd422	3,60				1,50		1,50						

each alloy a number of test bars has been made with die cast to do the testing scribed in the following examples. Die casting is done on a 400 ton Bühler SC 42 Evolution cold chamber machine. The performed tests are the following :

Tensile strength

Test-bars of 6 mm in accordance to ASTM B557 have been made, and the following

Test conditions has been used :

- 10 kN Instron machine
- Room temperature to 210 °C
- At least 5 parallels at each temperature
- Strain rate
  - 1.5 mm/min up to 0.5 % strain,
  - 10 mm/min above 0.5 % strain
- Testing in accordance with ISO 6892

Tensile creep testing

For this text the following test material is used :

- Diameter : 6 mm
- Gauge length : 32.8 mm
- Radius of curvature : 9 mm
- Grip head diameter : 12 mm
- Total length : 125 mm

The testing is done in accordance with ASTM E 139

Stress relaxation testing

- Test material
  - 12 mm diameter, 6 mm length
  - Cut from arbitrary end of creep bars
- Testing in accordance with ASTM E328-86

Corrosion properties

The corrosion is tested according to ASTMB 117.

Example 2

For a number of compositions the strength has been measured as a function of the temperature.

The results are shown in Figures 1, 2 and 3. In these figures the y-axis is representing the tensile strength expressed in MPa, whereas the x-axis is representing the temperature expressed in degrees Celsius.

Example 3

For a number of compositions the Creep strain has been measured as a function of the time.

The results are shown in Figures 4 and 5. In fig. 4 the measurement is done at 175 °C whit a load of 40 MPa, and in fig. 5 the measurement is done at 150 °C with a load of 90 MPa.

In these figures the y-axis is representing the creep strain expressed in percentage, whereas the x-axis is representing the time expressed in hours.

Example 4

For a number of compositions according to table 1 the stress relaxation has been defined, expressed as the remaining load versus the time. The results are shown in fig. 6, 7 and 8.

In these figures the y-axis is representing the remaining load expressed in percentage, whereas the x-axis is representing the time expressed in hours.

Example 5

For a number of compositions the corrosion properties have been defined in accordance to ASTM B117. In this test a great amount of data has been incorporated in order to define the influence of the RE-contest versus the Al-contest. The results are shown in Fig. 9.

In this figure the y-axis is representing the RE-contest expressed in % by weight whereas the x-axis is representing the Al-contest also expressed in % by weight. The border lines between the zones with different shades are representing lines of equal corrosion resistances.

Claims

1. A magnesium alloy consisting of

1,00 – 10,00 % by weight of aluminium,
1,00 – 8,00 % by weight of rare earth metals (RE-metals),
at least 40 % by weight of the RE-metals being cerium,
less than 0,5 % by weight of manganese,
less than 1,00 % by weight of zinc,
0,00 – 3,00 % by weight of calcium,
0,00 – 3,00 % by weight of strontium

and the balance being magnesium and unavoidable impurities, the total impurity level being below 0,1 % by weight.

2. The magnesium alloy according to claim1, characterising in that the aluminium content is between 2,00 and 7,00 % by weight, preferably between 2,60 and 6,50 % be weight.

3. The magnesium alloy according to claim 1 or 2, characterised in that the RE content is between 3,00 and 7,00 % by weight.

4. The magnesium alloy according to anyone of the preceding claims, characterised in that the aluminium content is between 3,6 and 4,5 % by weight and the RE-content is between 3,6 and 4,5 % by weight.

5. The magnesium alloy according to anyone of the claims 1-3, characterised in that the aluminium content is between 2,6 and 3,5 % by weight and the RE-content is greater than 4,6 % by weight.

6. The magnesium alloy according to anyone of the claims 1-3, characterised in that the aluminium content is between 5,6 and 6,5 % by weight and the RE-content is greater than 3,0 % by weight.

7. The magnesium alloy according to anyone of the claims 1-6, characterised in that the RE-metals are selected from the group cerium, lanthanum, neodymium and praseodymium.

8. The magnesium alloy according to claim 7, characterised in that the amount of lanthanum is at least 15 % by weight of the total content of RE-metals, preferably at least 20 % by weight.

9. The magnesium alloy according to claim 7 or 8, characterised in that the amount of lanthanum is at most 40 % by weight of the total content of RE-metals.

10. The magnesium alloy according to anyone of the claims 7-9, characterised in that the amount of neodymium is at least 7 % by weight of the total content of RE-metals, preferably at least 10 % by weight.

11. The magnesium alloy according to anyone of the claims 7-10, characterised in that the amount of neodymium is at most 20 % by weight of the total content of RE-metals.

12. The magnesium alloy according to anyone of the claims 7-11, characterised in that the amount of praseodymium is at least 2 % by weight of the total content of RE-metals, preferably at least 4 % by weight.

13. The magnesium alloy according to anyone of the claims 7-12, characterised in that the amount of praseodymium is at most 10 % by weight of the total content of RE-metals.

14. The magnesium alloy according to anyone of the claims 7-13, characterised in that the amount of cerium is greater than 40 % by weight of the total content of RE-metals, preferably between 45 and 55 % by weight.

15. The magnesium alloy according to anyone of the preceeding claims, characterised in that the amount of calcium and/or strontium is at least 0,5 % by weight.

Fig. 1

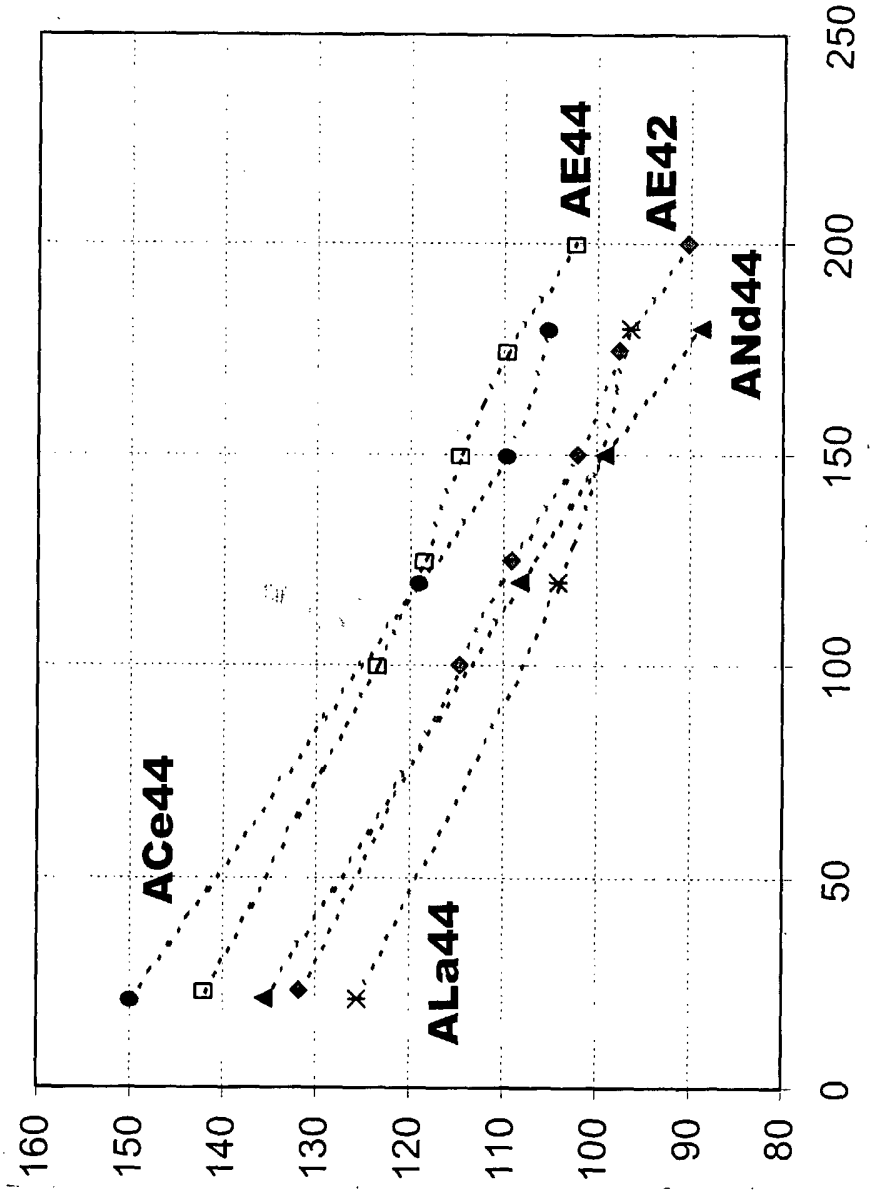

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Fig. 2

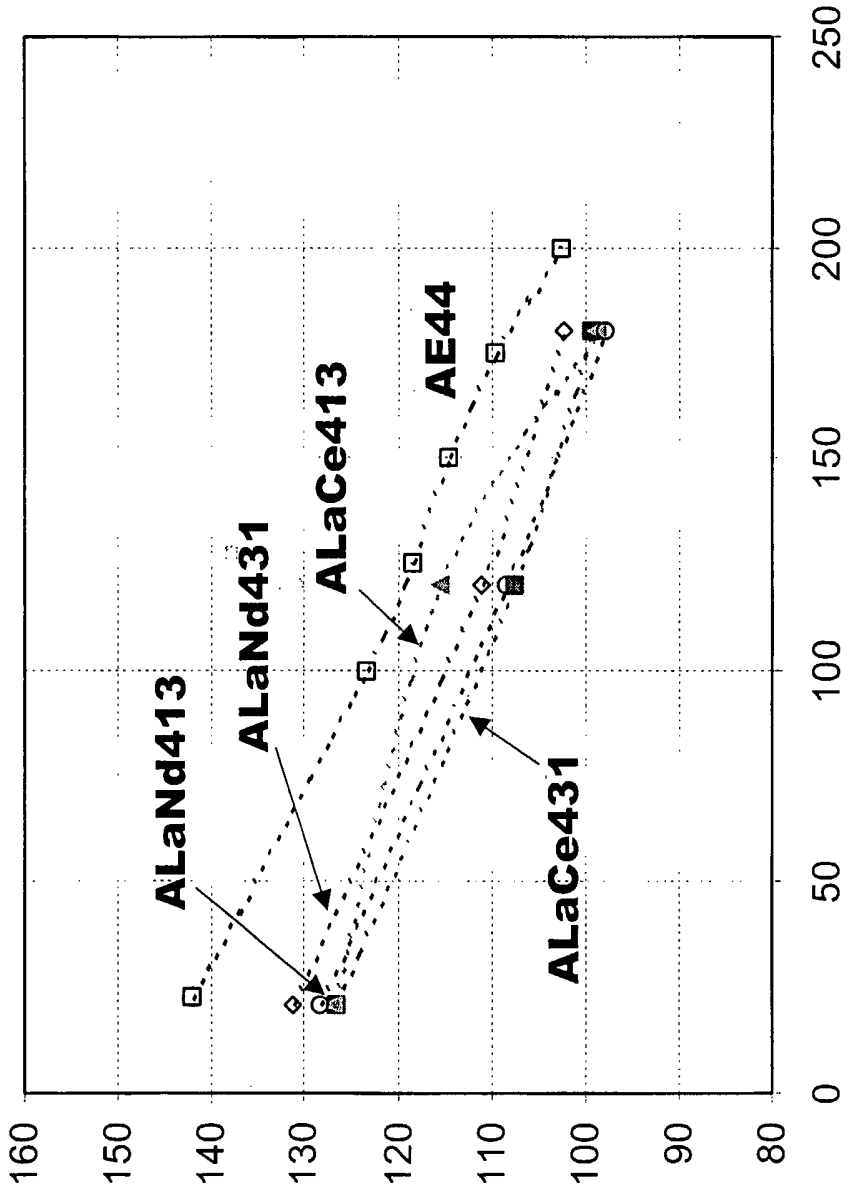

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Fig. 3

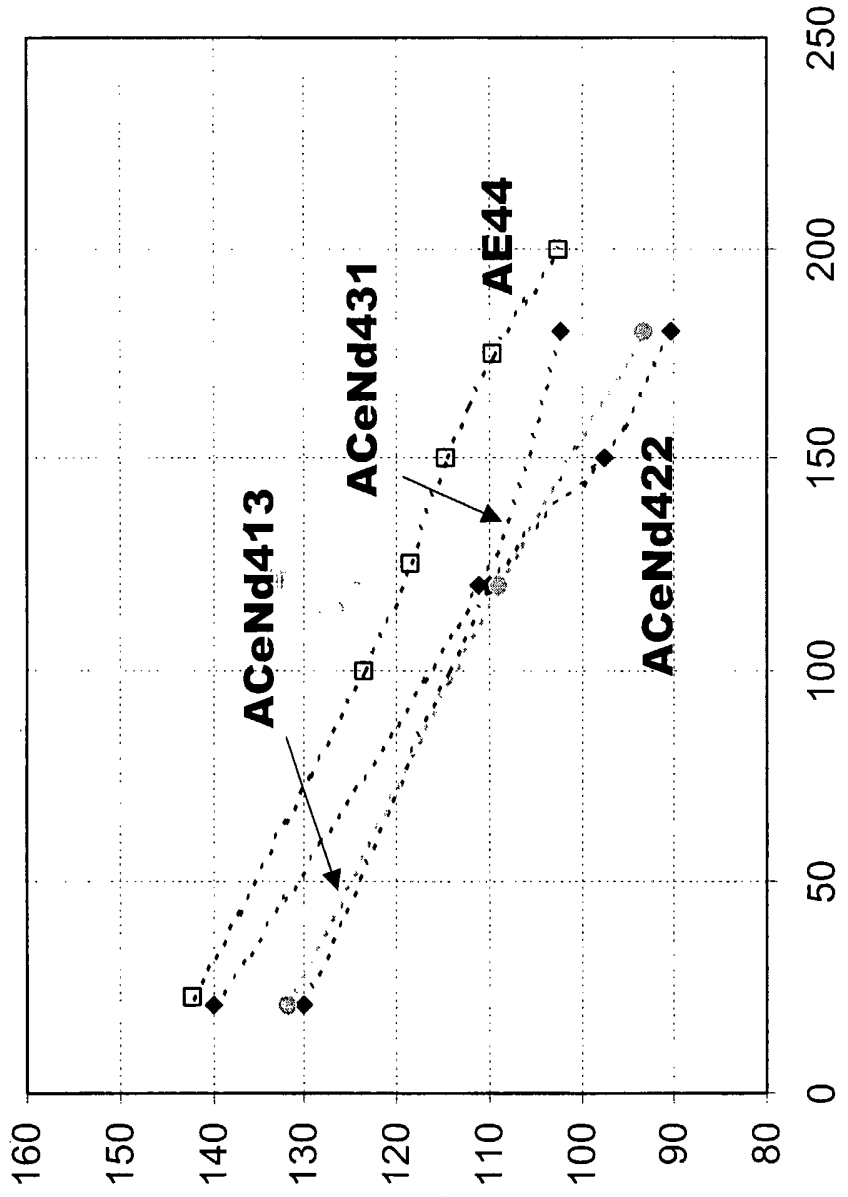

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Fig. 4

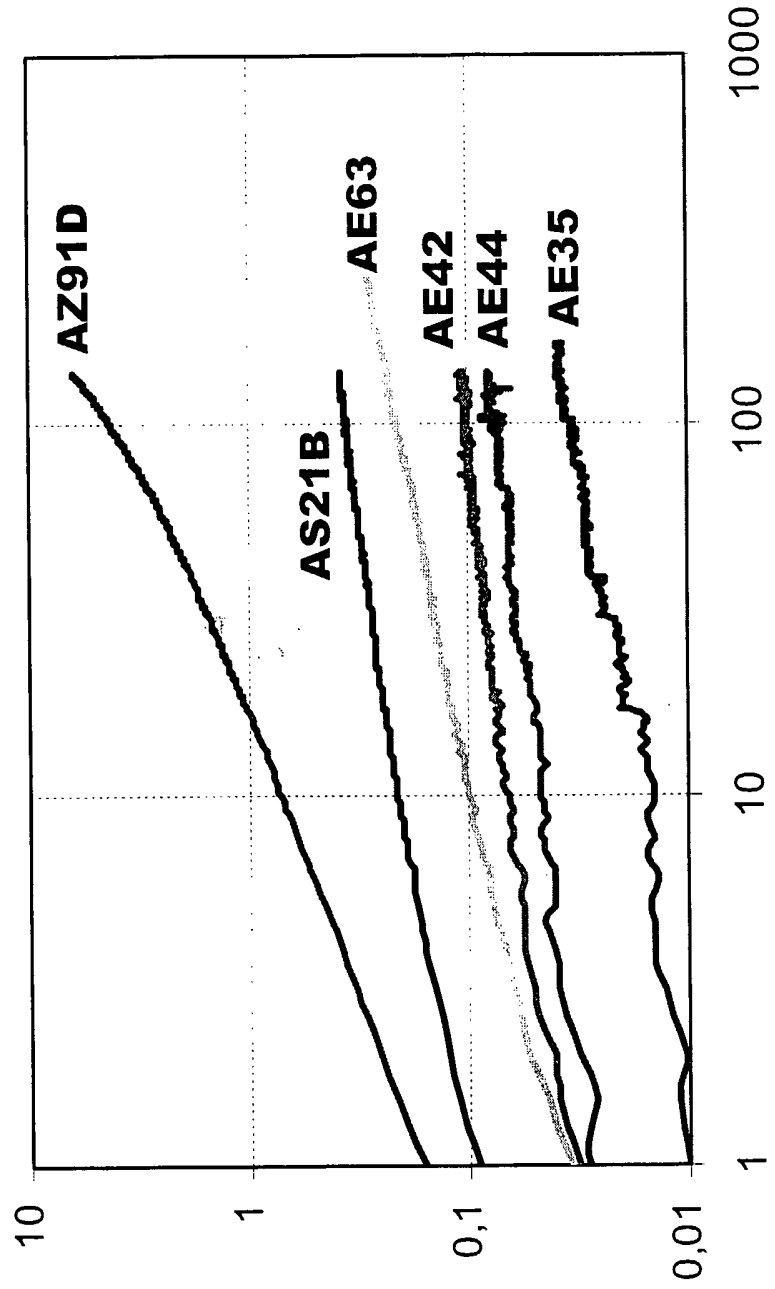


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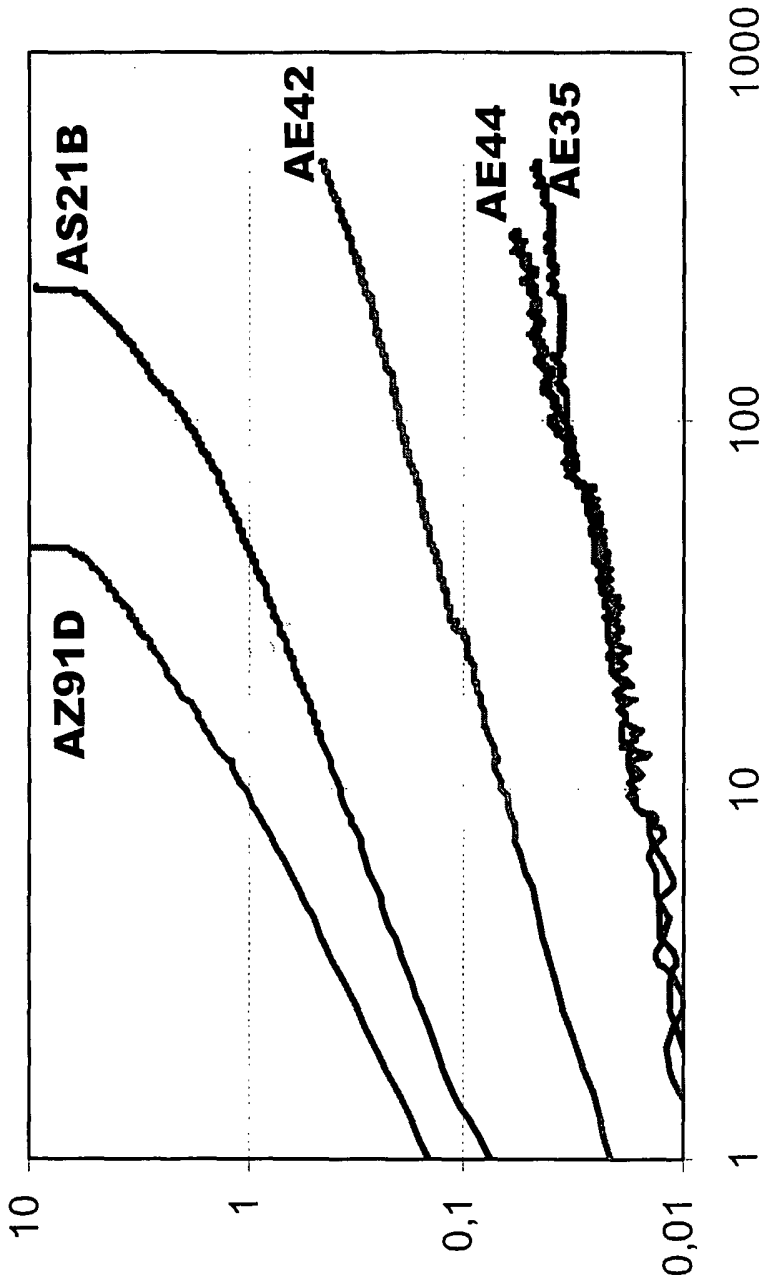


Fig. 6

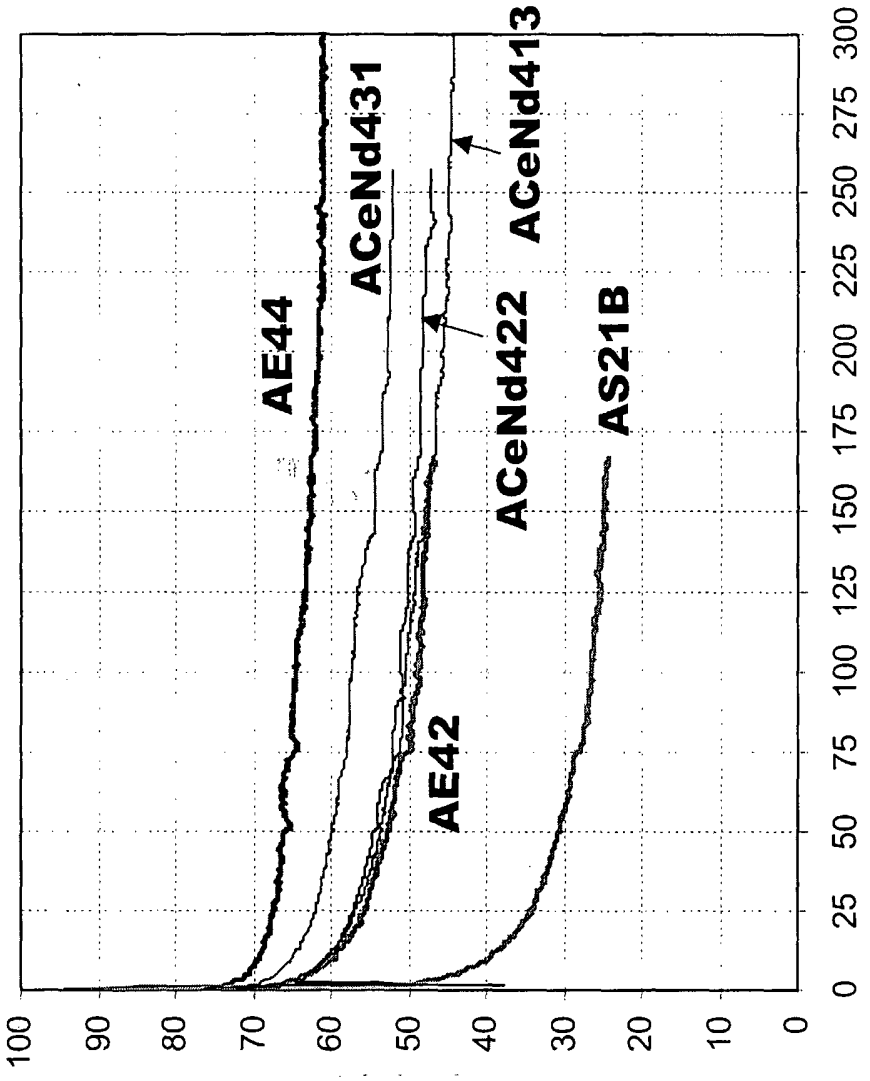

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Fig. 7

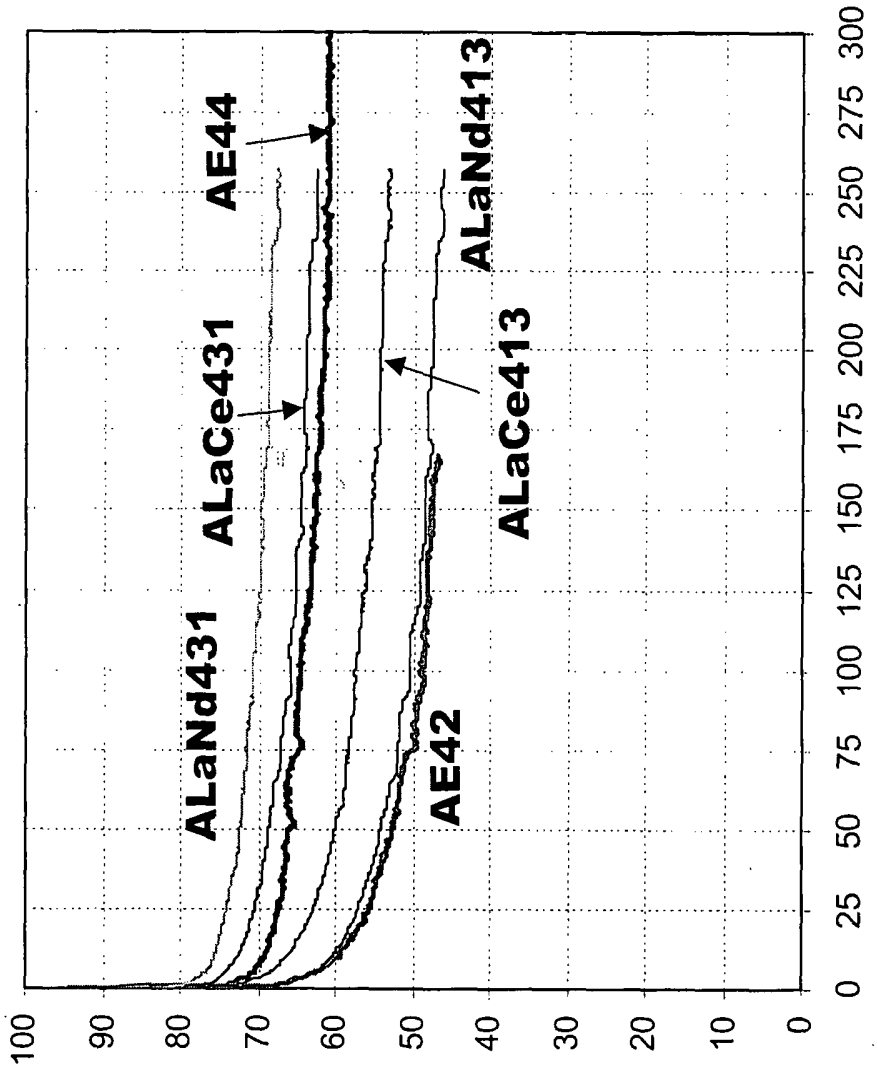

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Fig. 8

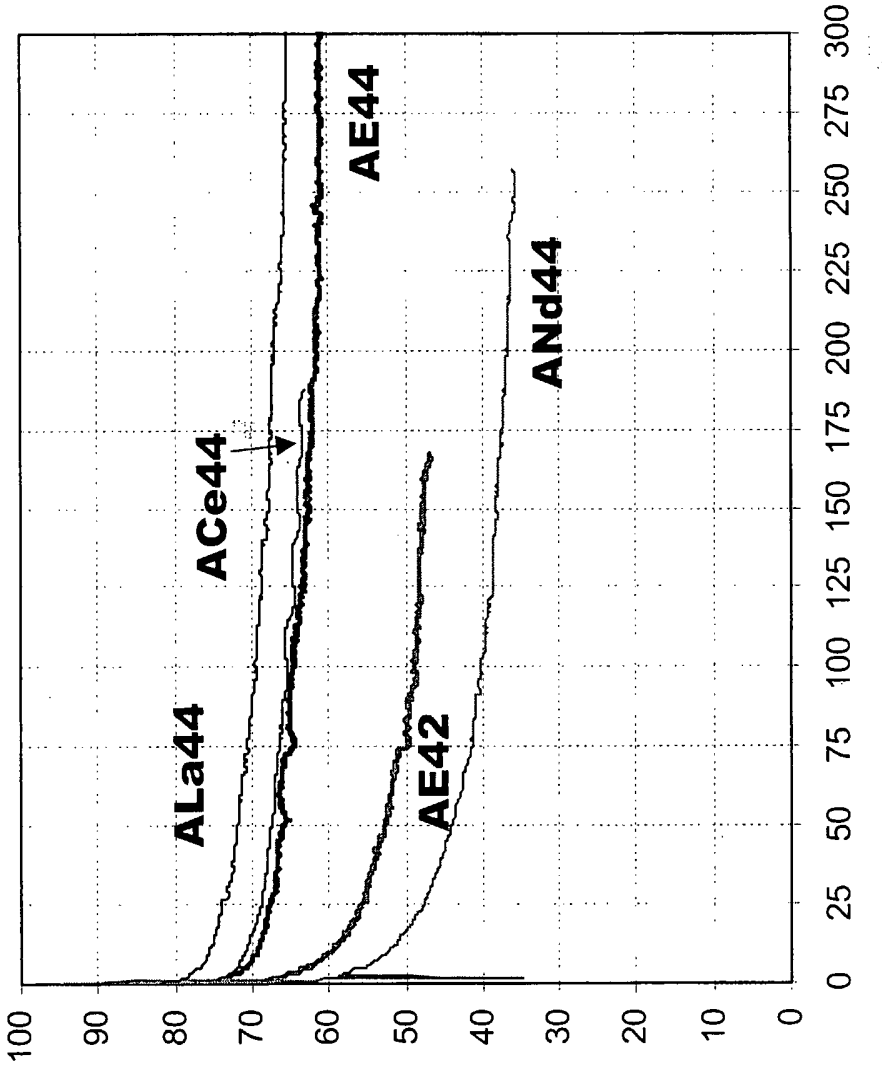
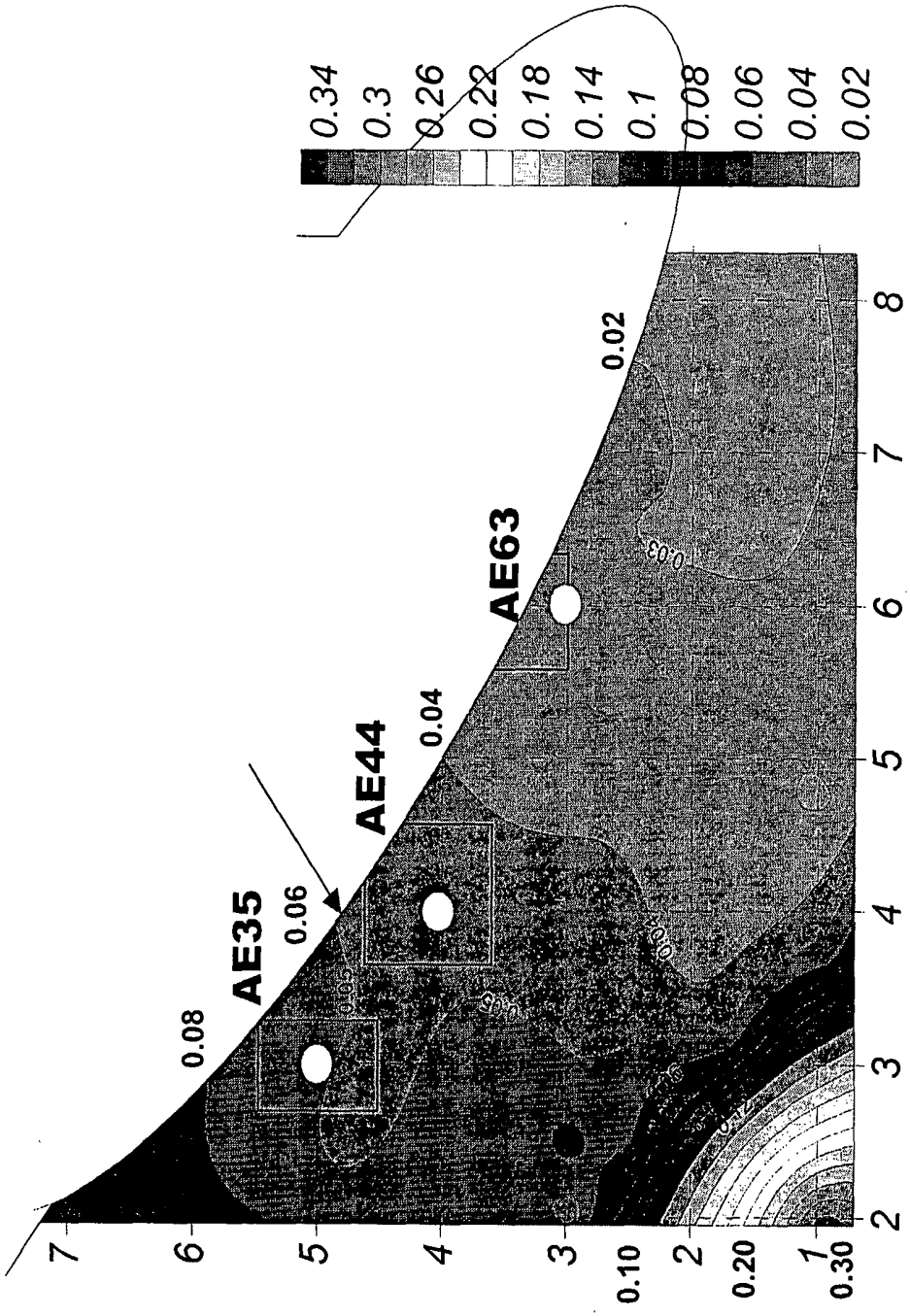

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Fig. 9


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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2005/004990

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 C22C23/02

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 7 C22C

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)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 June 2005	28/07/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Brown, A

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP2005/004990

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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