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TITLE

Effect of Impurity Elements on the Mechanical Properties of Aluminum Bronze Alloy C95800

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Effect of Impurity Elements on the Mechanical Properties of Aluminum Bronze Alloy C95800

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ABSTRACT

At present there is no consensus on the maximum allowable limits for impurity elements such as Pb,Zn,Sn,Cr,Be,Bi and Se in aluminum bronze castings. These impurities could adversely affect mechanical properties and promote cracking during welding and heat treatment. This project was undertaken to evaluate the effect of such impurity elements on the mechanical properties, heat treatment and weldability of the most popular aluminum bronze, alloy C95800. To date, mechanical properties of single and two element additions have been completed. UTS and Ys values were in excess of the minimum specified in ASTM B148. However, the % elongation was reduced to below or just above the specified minimum in a few cases. Weldability evaluation and addition of three element combination are in progress.

Effect of Impurity Elements on the Mechanical Properties of Aluminum Bronze Alloy C95800

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Introduction

- Three year project (Dec. 1996 - Dec.1999)
- Sponsored by U S Department of Energy, through Cast Metal Coalition (CMC)
- The limits on impurity elements to be included in ASTM specification

Current Standard

CDA C95800 and ASTM B148-95

Limits for major alloying elements

Al	Fe	Ni	Mn
8.5 - 9.5	3.5 - 4.5	4.0 - 5.0	0.8 - 1.5

Limits for impurity elements

Pb	Si
0.03 max	0.10 max

Literature Review

- Si, Pb, Sn, Mg, Bi, Sb and Cd reduce ductility.
- Only Si and Sn increase strength.
- No agreement on safe limits.
- Zn has no significant effect on mech. properties.
- Some elements promote cracking in heat affected zone of weld or during heat treatment.

Experimental Ranges

- C95800 9%Al - 4.5%Fe - 4.5%Ni - 1%Mn
- Impurities

Lead	0.01 - 0.2%	Zinc	0.1 - 1.0%
Tin	0.01 - 0.25%	Bismuth	0.005 - 0.1%
Selenium	0.005 - 0.1%	Silicon	0.01 - 0.25%
Chromium	0.01 - 0.1%	Beryllium	0.01 - 0.1%

Two Element Combinations

- Combinations selected by the monitoring committee:

Lead-Zinc	Lead-Bismuth
Lead -Tin	Bismuth-Selenium

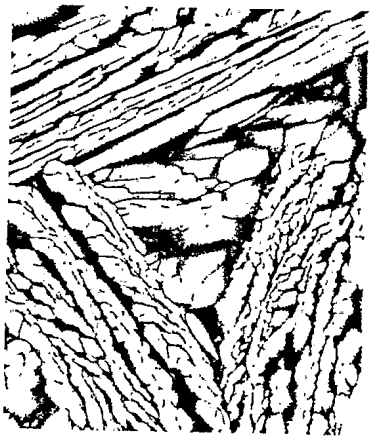
Evaluation

- Microstructure
- Properties
  - Tensile strength, Yield strength
  - Ductility (% Elongation and Reduction in Area)
  - Hardness
- Heat Treatment
  - C95800, 700C for 6hrs, air cool
- Weldability
  - Gleeble analysis

Procedure

- 100kW, 3000Hz pushup type induction furnace
- Charge material: pure copper, aluminum, Cu-10%Fe, Cu-28% Ni and Cu-35% Mn
- Degassed with dry nitrogen
- Pouring temperature 1160 - 1180°C
- Green sand molds
  - Keel blocks for tensile testing
  - 12"x6"x0.75" plate castings for weldability testing

C95800 - Base Composition



As - cast 100x

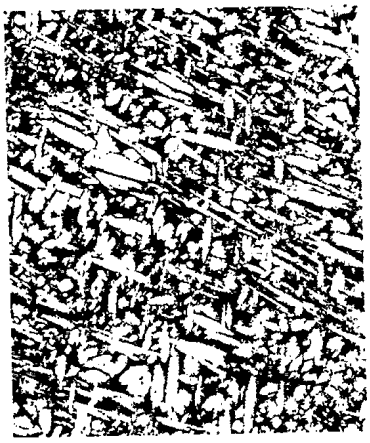
Heat treated 100x

C95800 - Cr added

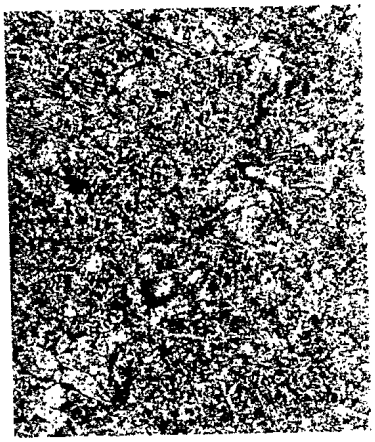
As - cast 100x

Heat treated 100x

C95800 - Si added

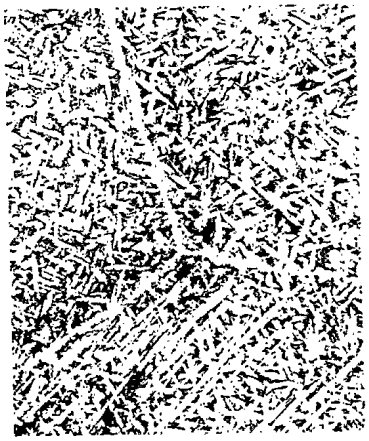


As - cast 100x

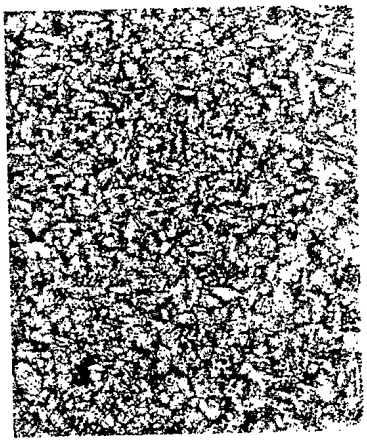


Heat treated 100x

C95800 - Be added

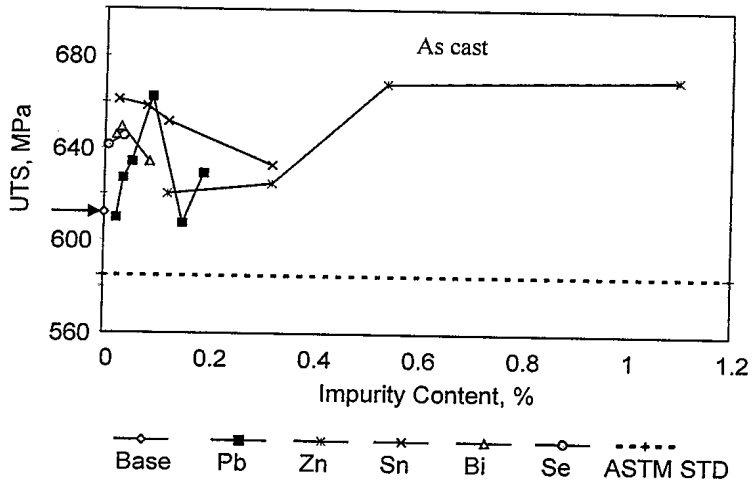


As - cast 100x

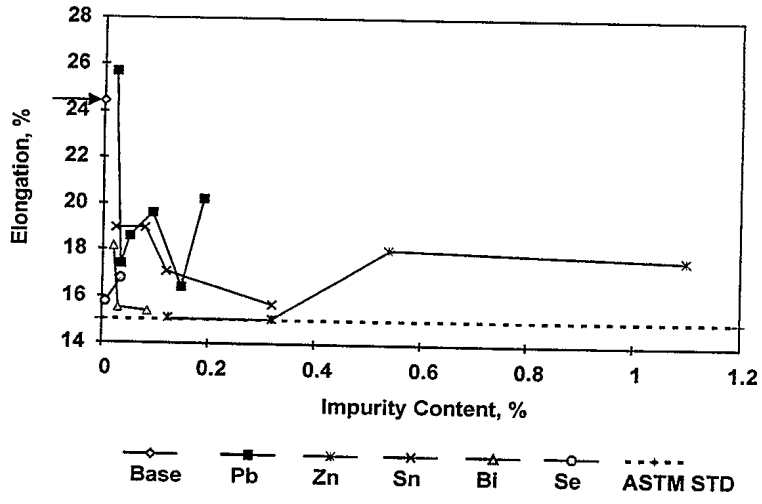


Heat treated 100x

C95800 - Tensile Strength Single Element



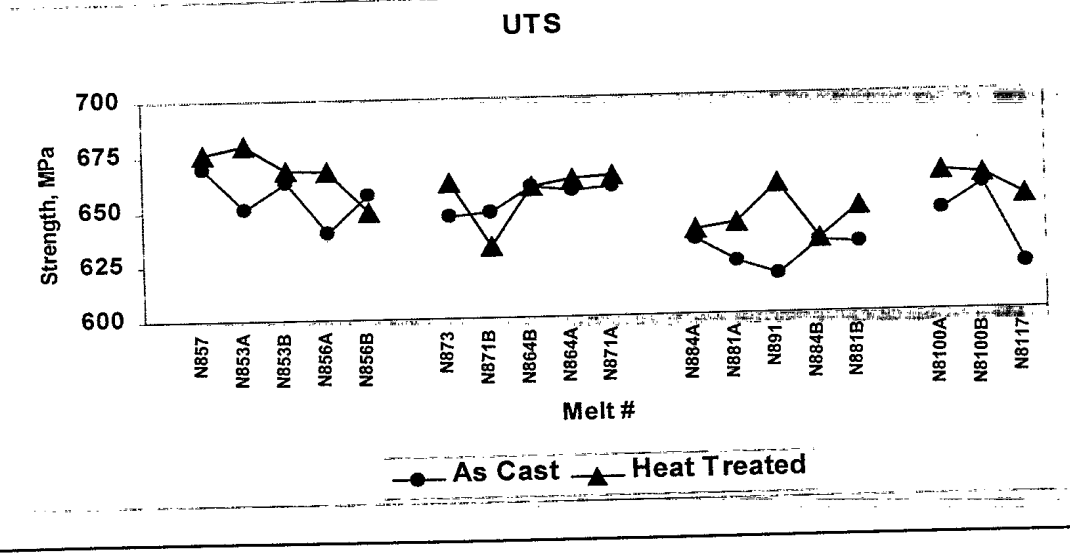
C95800 - Elongation Single Element

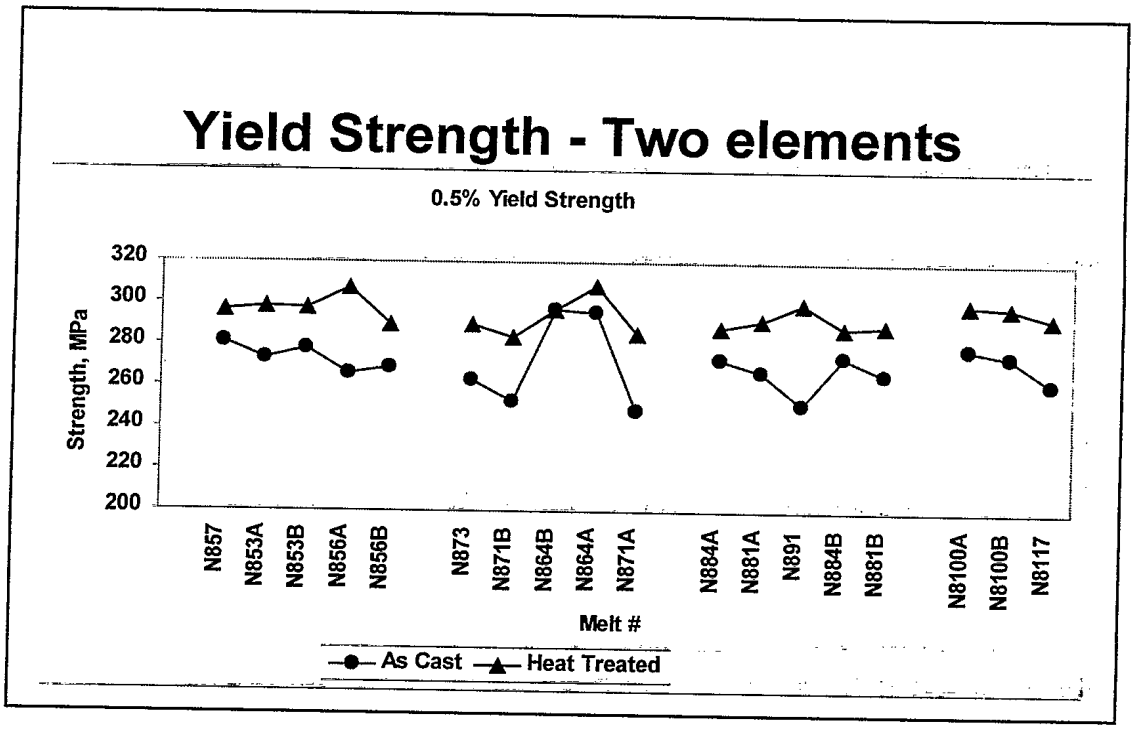


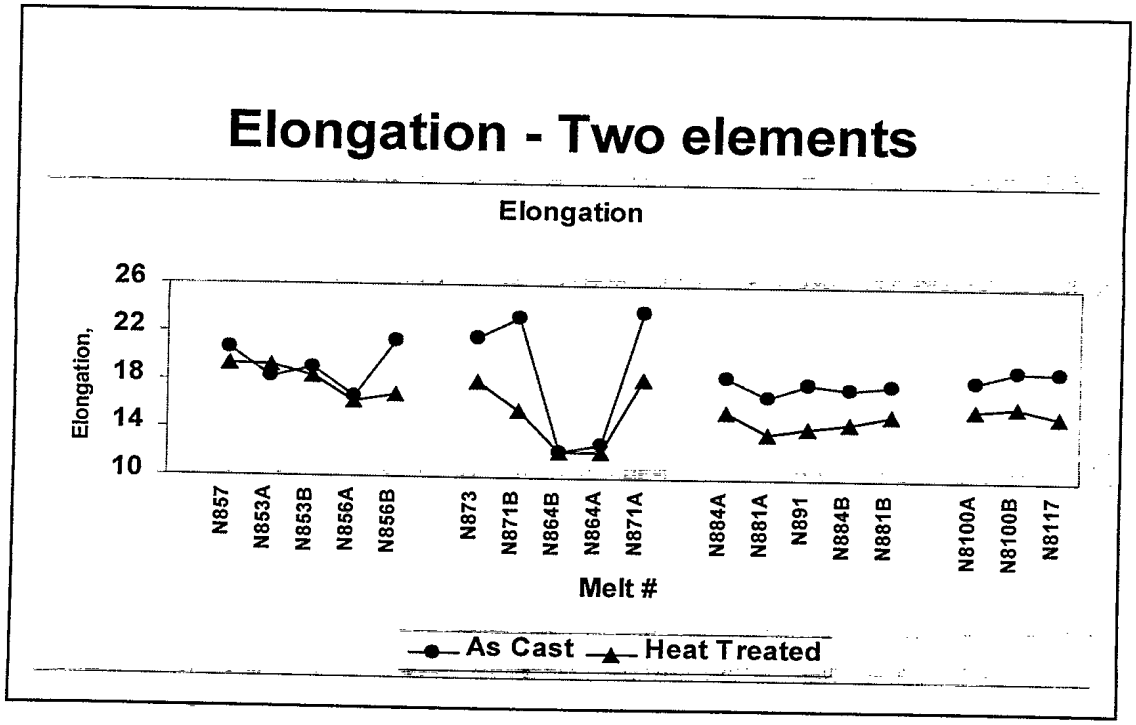
Composition - Two elements

Melt #	Al	Fe	Ni	Mn	Impurities	
N853A	9	4	5	1.1	0.01% Pb	0.18% Zn
N853B	9	4	5	1	"	1.5% Zn
N856A	9	4	4	1.1	0.07% Pb	0.5% Zn
N856B	9	4	4	1	"	1.2% Zn
N857	9	4	5	1	0.005% Pb	0.5% Zn
N864A	9	5	5	1	0.2% Sn	0.05% Pb
N864B	9	5	5	1	"	0.045% Pb
N871A	9	5	5	1	0.06% Sn	0.08% Pb
N871B	9	5	5	1	"	0.035% Pb
N873	9	4	5	1	0.15% Sn	0.025% Pb
N881A	9	4	5	1	0.08% Bi	0.008% Pb
N881B	9	4	5	1	"	0.05% Pb
N884A	9	4	5	1.2	0.05% Bi	0.005% Pb
N884B	9	4	5	1.2	"	0.04% Pb
N891	9	5	5	1	"	0.03% Pb
N8100A	9	5	5	1	0.005% Bi	0.02% Se
N8100B	9	5	5	1	"	0.02% Se
N8117A	9	4	5	1.2	0.06% Bi	0.025% Se

Tensile Strength - Two element




Yield Strength - Two elements
0.5% Yield Strength
Strength, MPa
320
300
280
260
240
220
200
N857
N853A
N853B
N856A
N856B
N873
N871B
N864B
N864A
N871A
N884A
N881A
N891
N884B
N881B
N8100A
N8100B
N8117
Melt #
As Cast
Heat Treated


Elongation - Two elements
Elongation
Elongation,
26
22
18
14
10
N857
N853A
N853B
N856A
N856B
N873
N871B
N864B
N864A
N871A
N884A
N881A
N891
N884B
N881B
N8100A
N8100B
N8117
Melt #
As Cast
Heat Treated

Weldability

- Cracking in the heat affected zones during welding
- Impurities such as lead, silicon and bismuth are considered to be the cause of cracking
- The lead content is restricted to 0.03% to prevent cracking

Weldability

- Bend tests to evaluate the weld strength
- The plate specimen for testing is selected to be 175x25x15mm.
- The mandrel diameter was 50mm.
- The thickness reduced to 9.8mm and the mandrel daimeter was increased to 62.5mm to obtain as cast specimens free of cracks.

Weldability

- Three weld beads were deposited on the plate using stick electrodes (Ampco Trode 10)
- Bend test specimens were machined with the weld beads in the center of the plates.
- All the welded specimens were broken during testing
- It was necessary to develop a test method to evaluate the weldability

Weldability - Testing

- Heat affected zone simulation using Gleeble
- Specimens were of 75x10x10 mm size
- Preheat the specimen at 140C for 5 seconds
- Heat to the required operating temperature, in this case 950, 980 and 1020C.
- Cool the specimen - air cool and water cool
- analyze the specimen for cracking in the HAZ

Weldability - Results

- Lead and bismuth containing alloys reveal cracks even when heated to 900C and air cooled
- Heating to higher temperatures, some of these specimens rupture
- All other elements, Zn, Sn, Se, Si, Cr or Be have no effect and the HAZ remain crack free.
- In two element combination melts, alloys having Pb-Zn, Pb-Sn and Pb-Bi, show cracking.

Conclusions

- The UTS of C95800 was above minimum ASTM value - 585 MPa.
- All impurity elements improved yield strength in as-cast condition (except low Pb, 0.028%).
- Yield strength improved after heat treatment.
- Ductility was reduced by impurity elements but remained above the 15% minimum in most cases.

Conclusions

- Ductility will be the deciding factor for setting limits.
- When tin and lead occur together, the limit can be set at 0.2% and 0.045% respectively.
- When bismuth and lead occur together, they should be restricted to 0.05% and 0.01% respectively.

Conclusions

- Silicon and berillium were the only two elements to modify the microstructure.
- Lead and bismuth were found to cause cracking in weld heat affected zone.