OTTAWA July 30th, 1942.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1275.

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Examination of the Heat Treatment of Brass Fuze Bodies.

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Origin of Problem:

In a letter dated June 10th, 1942, Mr. C. C. Pettet, for Inspector General, Inspection Board of U. K. & Canada, Ottawa, Ontario, requested the examination of brass forgings and machined fuze bodies, and an investigation on the heat treatment of these parts to increase their strength.

It was stated that difficulties have been found in the manufacture of fuze bodies (Fuze 221) from hot stampings made from material covered by B. S. S. 218. Apparently the neck of the fuze is not strong enough to stand graze action and collapses, trapping the inertia pellet and preventing it from moving forward and hitting the detonator, resulting in blinds.

(Origin of Problem, cont'd) -

Similar difficulties have been found in England, where experiments were made with manufacture of such fuzes from steel, and no blinds occur.

In Canada fuzes were successfully manufactured from bar stock B. S. S. 249. It was only when the manufacture of fuzes bodies from hot pressings started that blinds resulted.

In England trials were carried out to harden the material and some improvement was obtained. The steel bodies, however, still gave more satisfactory results. The hardening treatment for the brass bodies consisted of heating the bodies to 725°C., quenching in water, reheating to 260°C., and cooling in air. This increased the hardness from about 100 to about 130 Vickers Hardness Numbers.

Twelve forgings and six finished (machined) fuze bodies were submitted.

It was requested that mechanical tests be carried out both on the forgings and the machined bodies. It was suggested that a tensile test specimen be obtained from the neck of the fuze between the central bore and the outside diameter in order to compare this with B. S. S. 249.

Experimental heat treatments to improve the mechanical properties and the effect of heat treatment upon dimensions of machined parts were requested.

A copy of a letter from the Coulter Copper & Brass Co. Ltd., Toronto, describing the manufacturing process of the brass forgings, was enclosed.

Descriptions of Samples:

Twelve brass forgings were marked from "1" to "12" in these Laboratories for identification purposes.

Six machined fuze bodies were marked "1" to "6".

(Continued on next page)

(Description of Samples, cont'd.) -

Figure 1 shows one forging and one finished fuze body - as received.

Figure 1.

Samples as Received.
(Approx. 4/5 size).

Chemical Analysis:

	Forging No. 4.	Specifications. B. S. 218 1940	Specifications. B. S. 249 1942
	-- Per cent --		
Copper	59.34	56.0 -60.0	55.0 - 60.0
Lead	2.34	1.0 - 2.5	2.0 - 3.5
Zinc	38.25	remainder	remainder
Iron	0.02		
Tin	None detected	Other elements: 0.75	0.75
Aluminium	" "		
Manganese	" "		
Antimony	" "		

Mechanical Properties (As Received):

Tensile Tests:

For the examination of tensile strength in the "as received" condition two forgings and two machined fuze bodies were used.

From each forging two small test specimens (0.159" diameter, 10 mm. gauge length) were obtained. From the

(Mechanical Properties (as received),) - machined parts it was possible to obtain only two small specimens (0.159" diameter, 10 mm. gauge length), taken from the neck of the fuze bodies.

The small specimens were tested in a Hounsfield tensometer, the larger specimens in a normal tensile test machine.

The yield point on the larger test specimens was determined by the dividers method.

The results of the tensile tests are given in Table I.

Table I

Sample No.	Sample Size, in inches	Yield Point, p.s.i.	Ultimate Tens. Str., p.s.i.	Elong'n in 1" per cent	Elong'n in 10 mm., per cent
F3⊕	0.282 dia.	25,600	56,900	37	
F3	0.159		58,000		25
F3	0.159		56,000		27
F4	0.282	31,200	59,300	40	
F4	0.159		60,000		30
F4	0.157		60,000		22
M1	0.159		59,000		21
M1	0.158		56,000		26
M2	0.159		57,000		25
M2	0.159		56,000		22
Average			58,000		25

⊕ F= Forging
M= Machined fuze body.

Hardness Tests:

Hardness was determined by the Vickers method, using a 10-kg. load. Hardness tests were carried out on the flat surface of a section of the forging cut longitudinally through the axis.

The results of twenty-five hardness determinations on the surface of this section were:

Average - 85 V.H.N.
Minimum - 78.5 V.H.N.
Maximum - 91.6 V.H.N.

Heat Treatment:

The effect of quenching on the mechanical properties of $\alpha+\beta$ brasses has been examined by many investigators. According to the equilibrium diagram the fundamental process is of the precipitation type and consists of an incomplete transformation of the β phase into α phase on cooling.

Brasses containing between 38 and 46% zinc solidify as β and change during subsequent cooling (the range of this change - depending on the composition - varies from 850 to 450°C.) to a mixture of $\alpha+\beta$. By quenching from within the β range this constituent may be retained completely unchanged at atmospheric temperature. This result is only obtained, however, when the rate of cooling, as determined by the size of the specimen and the nature of the cooling medium, exceeds a certain critical value, and when the quenching temperature is well within the β range.

✓ Owing to the fact that β can be retained by quenching, the properties of such an alloy may be modified by heat treatment. After quenching the tensile strength and hardness values are pronouncedly higher, accompanied by a decrease in elongation and resistance to impact.

Further changes in the properties of quenched $\alpha+\beta$ brasses can be obtained by accelerated ageing (reheating and air cooling) at temperatures between 200 and 400°C. This treatment increases hardness and tensile strength (maximum at about 300°C.), while elongation remains constant and the shock resistance decreases (mimimum at 300°C.). The change in the mechanical properties after ageing is due to precipitation hardening caused by the deposition of α .

If other elements are added to the composition of $\alpha+\beta$ brass, the range of the transition zone between the β and $\alpha+\beta$ phase is altered.

(Heat Treatment, cont'd.) -

This is especially true for the alloy tested which contains about 2.5% lead, as this lead addition has the effect of raising the transition temperature by about 50°C.

The submitted material was given the following experimental heat treatments:

Quenching temperatures: a) 1450°F (788°C.)
b) 1340°F (727°C.)
Heating period at quenching temperature: 1½ hours.

Quenching medium: cold water.

Ageing temperature: a) 500°F (260°C.)
b) 570°F (300°C.)

Ageing period: 1½ hours, and cooling in air.

All samples were heat treated in the full dimensional size as submitted. After the heat treatment the samples were divided longitudinally through the axis. One section was used for macro-etching and hardness tests, while the tensile specimens were obtained from the other.

The main dimensions of the machined fuze bodies were measured before and after each heat treatment. No dimensional changes were found (using ordinary workshop gauges).

It has been suggested that the quench and ageing treatment could be given to the finished fuze body. This certainly would not be a satisfactory procedure unless the bodies were heat treated in special atmospheres. Under normal furnace conditions the body tarnished badly in heat treatment.

Mechanical Properties (After Heat Treatment):

Tensile Tests:

Results of the tensile tests with details of the heat treatment of each sample are given in Table II.

Certain specimens broke during preparation in the machine shop owing to the presence of fire-cracks. Figure 2 shows the nature of these failures.

(Mechanical Properties ((After Heat Treatment), cont'd.) -

Figure 2.

Specimens Broken Due to Fire-Cracks.
(Approx. 3/4 size.)

The specimens were cut out in a similar manner as used for the previous tests (page 3); the small test specimens were taken from the neck-portion of the forgings and machined fuze bodies respectively.

Table II.

Sample No.	Heat Treatment	Sample Size, in inches	Yield Point p.s.i.	Ultimate Tens. Str., p.s.i.	Elong'n in 1" per cent	Elong'n in 10 mm. per cen
Material "as received"		0.282 dia.	28,500		38.5	
Average from Table I		0.159 "		58,000		25
F5⊠	Quenched from	0.282 dia.	41,700	60,000	32.	
	1450°F	0.159 "		59,600		25
	No ageing	0.159 "		59,000		25
F6	Quenched from 1450°F and aged at 500°F)	specimen broke before finishing				
F7	Quenched from 1450°F and aged at 570°F)	due to fire-cracks.				
M4	Quenched from	0.159 dia.		59,000⊠⊠		2.
	1450°F and aged at 500°F	0.159 "		78,000		2.5
M5	Quenched from	0.159 "		60,000⊠⊠		2.5
	1340°F and aged at 500°F	0.160		78,000		2.0

⊠ F = Forging M = Machined fuze body ⊠⊠ Fracture shows cracks.

Hardness Tests:

Results of the hardness tests are shown in Table III. The hardness was determined on the flat surface of the samples divided longitudinally through the axis.

On each sample, hardness tests were carried out at fifteen locations across the surface.

Mechanical Properties (After Heat Treatment), cont'd.) -

Hardness was determined by the Vickers method, using a 10-kg. load.

Table III.

Sample No.	Heat Treatment	Hardness, in V.H.N. Minimum	 Maximum	 Average. (from 15 tests)
F2⊠	"As received" (without heat treatment)	78	89	85
F5	Quenched from 1450°F., No Ageing	105	130	120
F6	Quenching from 1450°F., Ageing at 500°F.	158	182	170
F7	Quenching from 1450°F., Ageing at 570°F.	146	170	160
				Average (from 10 tests.)
M1	"As received" (without heat treatment)	95	110	100
M4	Quenching from 1450°F., Ageing at 500°F.	160	185	175
M5	Quenching from 1340°F., Ageing at 500°F.	152	165	160

⊠ F = Forging
M = Machined fuze body.

Macrostructure:

Figures 3 to 9 show the macrostructures of the "as received" samples and of samples after the various heat treatments.

A solution of 40% HNO_3 conc. + 20% HCl conc. + 40% H_2O was used as the deep-etching reagent.

The abnormal grain growth produced by the heat treatment is evident and many fire-cracks are visible.

(Continued on next page)

(Macrostructure, Cont'd.)

Figure 3.

Figure 3.

Figure 4.

Figure 4.

Forging No. 2.
"As received"

Forging No. 5.
After Quenching from 1450°F.

Figure 5.

Figure 6.

Forging No.6.
After Quenching from 1450°F.
and ageing at 500°F.

Forging No. 7.
After Quenching from 1450°F.
and ageing at 570°F.

Figure 7.

Machined Fuze Body No. 1
"As Received"

(Macrostructure, cont'd.) -

Figure 8.

Figure 8.

Figure 9.

Figure 9.

Machined Fuze Body No. 4.
After Quenching from 1450°F.
and ageing at 500°F.

Machined Fuze Body No. 5.
After Quenching from 1340°F.
and ageing at 500°F.

Dimension of Results:

Chemical analysis and mechanical properties of the samples as received show that the material conforms closely to British Standard Specifications Nos. 218 and 249.

The experimental heat treatments show that a considerable increase of the tensile strength and hardness may be obtained without marked dimensional changes.

The lead content, added to improve the machinability of the material, causes high sensitivity to any type of heat treatment and danger of fire-cracking.

Such cracks may be observed on Figures 5, 6, 8, and 9. Most of these cracks were observed previous to the macro-etching. The etching reagent, containing a large amount of nitric acid (used also for the detection of excessive internal strains in copper-base alloys), revealed further cracks (season-cracks) and enlargement of the previous detected fire-cracks.

It is obvious that by very closely controlled heat treatment (exact temperatures and cooling rates) it would be possible to overcome the danger of fire-cracking. However, in commercial practice and mass production the average workshop conditions would hardly permit such close

(Dimension of Results, cont'd.) -

control. It is felt that this procedure would not be advisable for fuze manufacture.

In case it is not possible to avoid the present difficulties with fuze bodies, consideration could be given to the use of one of the following suggestions:

a) The use of lead-free brass, which would permit the heat treatment of the fuze bodies. The lead removal would, of course, reduce the machinability of the material, but this difficulty could be overcome by small additions of selenium or tellurium.

b) The use of special brasses, which would not require heat treatment, having higher mechanical properties. As suggested in the literature the best results would be obtained by addition of aluminium, manganese, or possibly also nickel, to the brass.

c) The use of extruded free-cutting brass rods instead of forgings. The use of this type of material would increase considerably the costs and the time of machining.

It is realized that any change in fuze material may prejudice production. The above are mainly offered as tentative suggestions.

<u>Conclusions:</u>

The heat treatment of leaded yellow-brass fuze bodies is not advisable due to the danger of fire-cracking of this material.

If it is not possible to avoid the present difficulties, the use of a different alloy should be considered. Before such a change be made full consideration should be given to the effect of the inevitable change in machinability on production.

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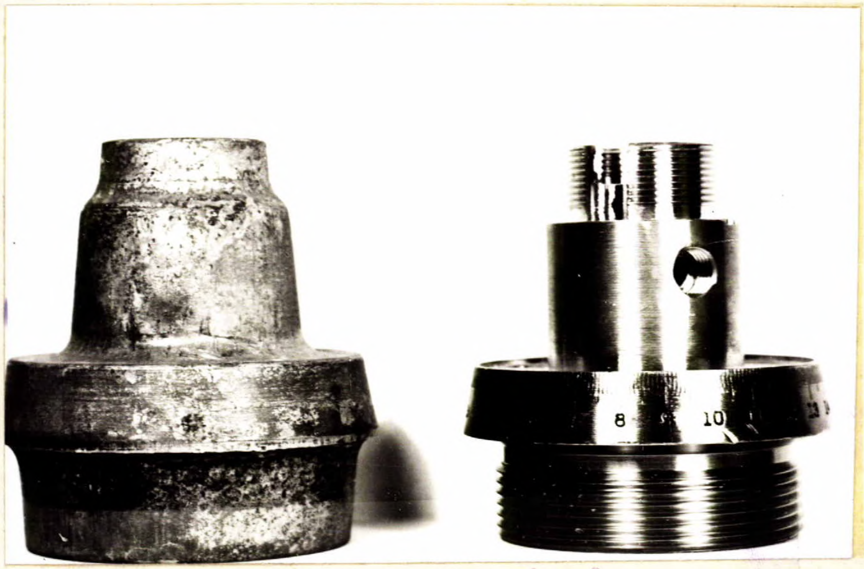
Extra Photo pages

(Description of Samples, cont'd.) -

Figure 1 shows one forging and one finished fuze body - as received.

Figure 1.



Samples as Received.
(Approx. 4/5 size).

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Tin	None detected	Other	
Aluminium	" "	elements:0.75	0.75
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Mechanical Properties (As Received):

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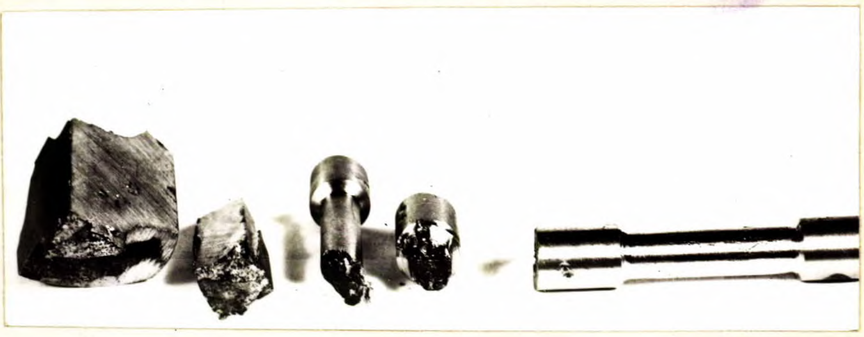
(Mechanical Properties (After Heat Treatment), cont'd.) -

Figure 2.



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(Approx. 3/4 size.)

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		0.159 "		59,000		25
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F7	Quenched from 1450°F and aged at 570°F					
M4	Quenched from 1450°F and aged at 500°F	0.159 dia.		59,000^{xx}		2.
		0.159 "		78,000		2.5
M5	Quenched from 1340°F and aged at 500°F	0.159 "		60,000^{xx}		2.5
		0.160		78,000		2.6

x F = Forging M = Machined fuze body xx Fracture shows cracks.

Hardness Tests:

Results of the hardness tests are shown in Table III. The hardness was determined on the flat surface of the samples divided longitudinally through the axis.

On each sample, hardness tests were carried out at fifteen locations across the surface.

(Mechanical Properties (After Heat Treatment), cont'd.) -

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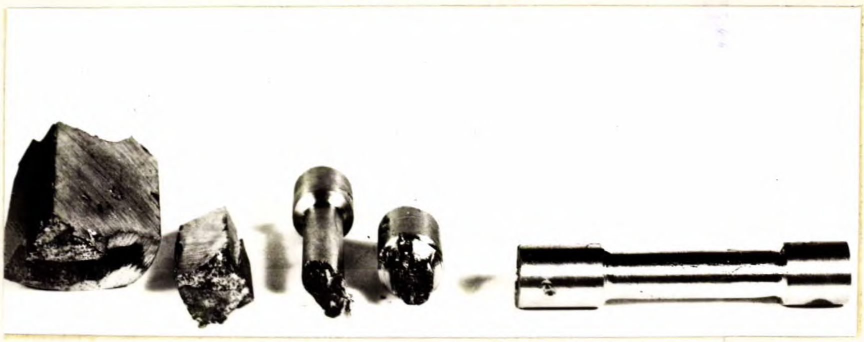

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