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EXAMINATION OF PNEUMATIC CAPSULES FOR CONTAINING COBALT 60

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Several used and one unused pneumatic capsule were submitted for chemical analysis and examination of welds and effects of service.

The capsules were found to be made of Type 316 stainless steel.

The welds were satisfactory although there was precipitation of intergranular carbides in thin sections of the inner capsule.

The ends of the service-tested capsule were superficially hardened to an extent equivalent to 40% cold reduction. Minor cracks were formed during service in both the outer and inner capsules. The sidewalls of the inner capsule were worn to 0.045 inches below the minimum original wall thickness.

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INTRODUCTION

Mr. C.E. Makepeace, Atomic Energy of Canada Limited, requested that the Physical Metallurgy Division examine some pneumatic capsules, used to contain Cobalt-60 pellets, to determine

(i) whether or not the capsules were made of Type 316 L stainless steel
(ii) whether or not the welds and the heat-affected zones were satisfactory
(iii) the effect of service testing on hardness and
(iv) the effect of service testing on wear.

MATERIAL SUPPLIED

It was explained that the outer capsules had been developed through four stages of design. Design #1 was a straight cylinder with welded ends. None of these were submitted. Design #2 was a straight cylinder welded at mid-length. One of these was submitted. Design #3 was a barreled cylinder. Five were submitted. Design #4 was the same as Design #3 with the addition of hard chromium plating. One design #4 was submitted.

Exhibit No. 1 Chromium plated pneumatic capsule. Design #4. Unused. Stamped T. Inner capsule empty. Refer to Figure 1.

Exhibit No. 2 One longitudinal half of an unused capsule. Design #3. Not photographed.

Exhibit No. 3 Capsule sectioned longitudinally into four quarters. Design #2. Not photographed. Analyzed chemically.

Exhibit No. 4 Carbon steel slug machined to the size and shape of an outer capsule of Design #3. Service tested for an unknown period. Analyzed chemically. Refer to Figure 5.

Exhibit No. 5. One longitudinal half of a pneumatic capsule. Design #3. Cycled 100,000 times (inactive). Whole inner capsule, partly sectioned. Envelope dated Dec. 17, 1965. Refer to Figure 3.

Exhibit No. 6 Pneumatic capsule. Design #3. Solid inner capsule (dummy). Not used. Not photographed. Analyzed chemically.

Exhibit No. 7 Pneumatic capsule. Design #3. Unused. Solid inner capsule (dummy). Refer to Figure 2.

Exhibit No. 8 Pneumatic capsule. Design #3. Unused. Solid inner capsule (dummy). Not photographed.

EXAMINATION

Chemical Analysis

Four of the exhibits were chemically analyzed. The results are shown in Table 1, along with the compositional limits for AISI Type 316 and 316 L stainless steels.

TABLE 1

Chemical Composition of Exhibits No. 3, 4, 6 and 8, Along With Specifications for AISI Type 316 and 316 L

Material	C, %	Ni, %	Cr, %	Mo, %	Mn, %	Si, %
AISI Type 316	0.08 max	10.00 -14.00	16.00 -18.00	2.00 -3.00	2.00 max	1.00 max
AISI Type 316 L	0.03 max	10.00 -14.00	16.00 -18.00	2.00 -3.00	2.00 max	1.00 max
Exhibit No. 3	0.08	10.42	17.81	2.20		
Exhibit No. 4	0.19	0.11	0.05	0.01	0.43	
Exhibit No. 6	0.05	13.62	17.99	2.55		
Exhibit No. 8	0.05	13.72	17.13	2.55		

Macrostructure and Microstructure

Features of the shape, construction and macrostructure of the pneumatic capsules are shown in Figures 1 to 4 inclusive. Due to the shape of these capsules it was not possible to electrolytically etch them uniformly.

Figure 1 shows the capsule of Design #4. The welds were well-formed. The general microstructure was that of quench-annealed austenite. There was no apparent carbide precipitation in the vicinity of the weld.

Figure 2 shows a capsule of Design #3, with and without a sectioned inner capsule. The welds were well-formed. The general microstructure was that of quench-annealed austenite. There was no apparent carbide precipitation in the vicinity of the weld.

Figure 3 shows the inner surface of the capsule of Design #3 which had been cycled in a pneumatic tube for 100,000 cycles; and, views of the accompanying inner capsule. The girth weld in the outer capsule was entirely satisfactory. As indicated, the side surface of the outer capsule was worn smooth. A small crack is visible in each of the four corner re-entrant angles of the cavity of the outer capsule. Two of these cracks are shown more clearly in Figure 4. The general microstructure of this capsule was that of quench-annealed austenite. The ends of this capsule were noticeably work hardened.

Figure 5 shows a longitudinal cross-section of the carbon steel dummy capsule which had been service tested. The profile of the ends indicate the severity of hammering in service.

Figures 6 and 7 show features of the structure of the inner capsule from the capsule of Design #3 which had been service tested for 100,000 cycles. The end plugs of the inner capsule were in the quench-annealed condition. The walls of the inner capsule were of quench-annealed austenite; however, the end lengths showed intergranular carbide precipitation in the vicinity of welds "A" and "B". Small underbead cracks were also observed in sections of weld "B".

Tukon Hardness Surveys

Figures 8 and 9 show the hardness gradient measured on each end of Exhibits No. 5 and 4 which had been service tested. The maximum increases in hardness due to service correspond to approximately the increases of hardness developed by 40% reduction in cold rolling.

Dimensions of Capsules

The thickness of the end and sidewalls and the maximum diameter of the capsules was measured by micrometer and compared with tolerances on AECL Drawing CD-C-8, dated 26 July 1961. The measurements and tolerances are shown in Table 2.

Table 2 shows that after 100,000 cycles of operation in a pneumatic tube the sidewalls of Exhibit No. 5 had been worn to 0.103 inches. The tolerances on Drawing CD-C-8 for the sidewalls are 0.1075 to 0.111 inches.

TABLE 2

Thickness of Endwall and Sidewall of Outer Capsules

Capsule	Endwall, in.	Sidewall, in.	Diameter, in.
Drawing CD-C-8	0.142 min 0.161 max	0.1075 min 0.111 max	0.689 min 0.691 max
No. 5	0.150	0.103	0.666
No. 2	0.162	0.120	0.704
No. 6	0.159	0.121	0.694
No. 7	0.157	0.120	0.700
No. 8	0.157	0.122	0.697

DISCUSSION

The outer capsules which were analyzed were made of AISI Type 316 rather than Type 316 L stainless steel. This was in accordance with AECL Drawing CD-C-8.

The girth welds in the outer capsules were all satisfactory, having good penetration, well-formed fusion zones and no harmful precipitation of carbides in the vicinity of the welds.

The cracks which formed around each end of the cavity of the outer capsule which had been service tested were not apparently critical.

However, they could easily be avoided by filleting the inside edges of the ends of the capsule cavity.

The inner capsule was from the capsule which had been service tested. As shown in Figures 6 and 7 the welds and heat-affected zones leave something to be desired. However, despite variable penetration, underbead cracking and sensitization the capsule survived intact. The inner capsule was noticeably deformed by repeated impacting during service. The severity of the impacts may have been due to the nature of the load of cobalt pellets. If the load of pellets was loose the impacts would be greater than if the load was tightly packed.

It was not possible to determine the extent of wear satisfactorily. In the first place, prior to wear testing the capsules should have been measured and weighed. In the second place, the wear-tested capsule had not been chromium plated. It is understood that the capsules in service have all been plated with hard chromium.

CONCLUSIONS

1. The capsules were made of AISI Type 316 stainless steel.

2. The welds were completely satisfactory in the outer capsules but not in the inner capsule.

3. The sidewalls of the wear-tested capsule were reduced to slightly less than the minimum specified on AECL Drawing CD-C-8.

4. The ends of the wear-tested capsule had been subjected to moderately heavy impact.

5. Small cracks were present at the ends of the cavity of the outer capsule and beneath the end welds of the inner capsule.

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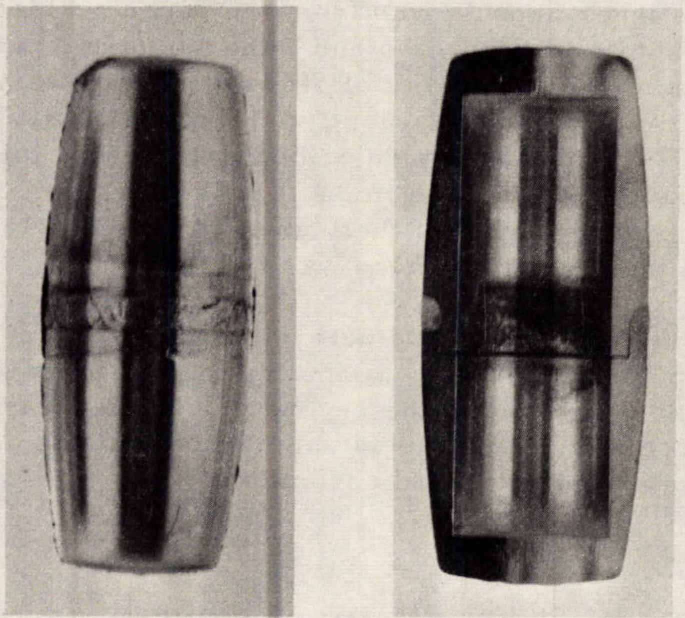


Figure 1. Outer Capsule No. 1. Unused. (X1.6)

Left: Outer surface showing the chromium plating and the girth weld.

Right: Polished section. The midlength of the section was electrolytically etched to reveal the structure of the weld and the heat-affected metal.

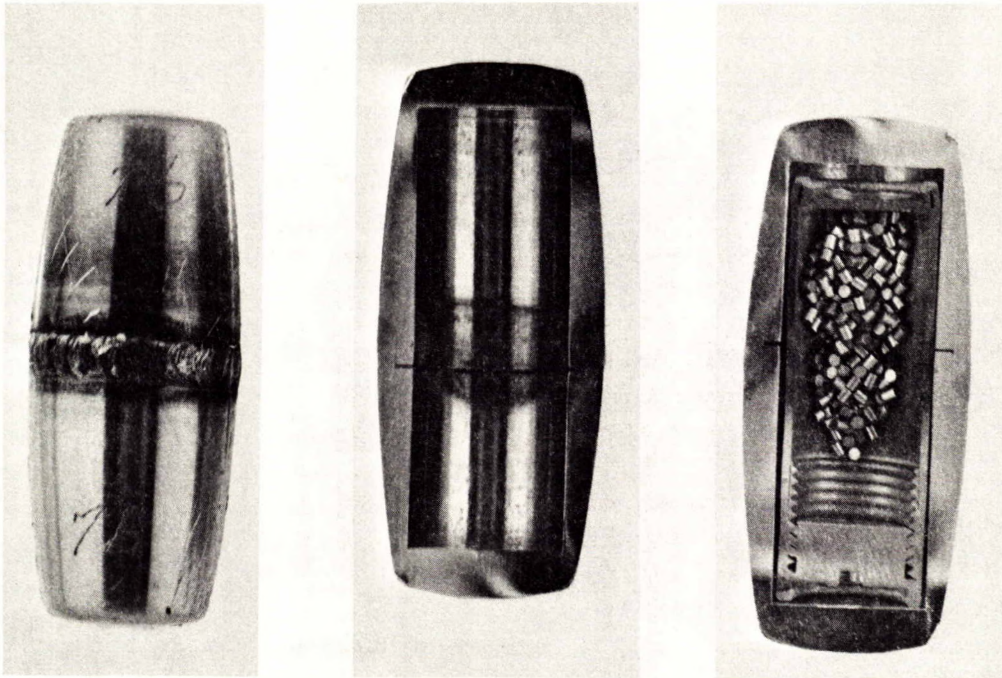


Figure 2. Outer Capsule No. 7 (and Inner Capsule No. 5). (X1.6)

Left: Outer surface showing the chromium plating and the weld.

Centre: Inner surface, electrolytically etched at midlength, to reveal the structure of the weld and heat-affected metal.

Right: Cobalt pellets, half of inner capsule No. 5 and half of outer capsule No. 7.

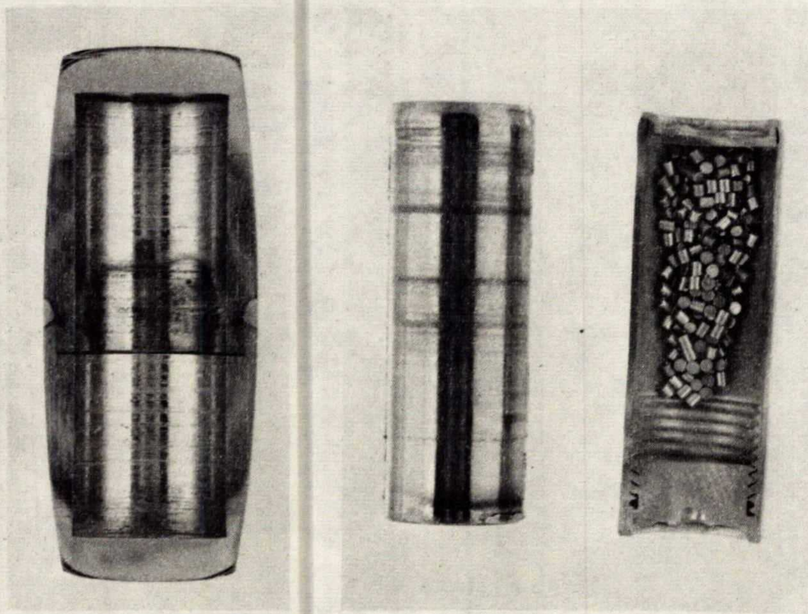


Figure 3. Outer and Inner Capsule No. 5 (after 100,000 cycles). (X1.6)

Left: Inner surface of outer capsule. The midlength zone has been electrolytically etched in oxalic acid.

Right: Outer and inner (after electrolytic etching) views of inner capsule.

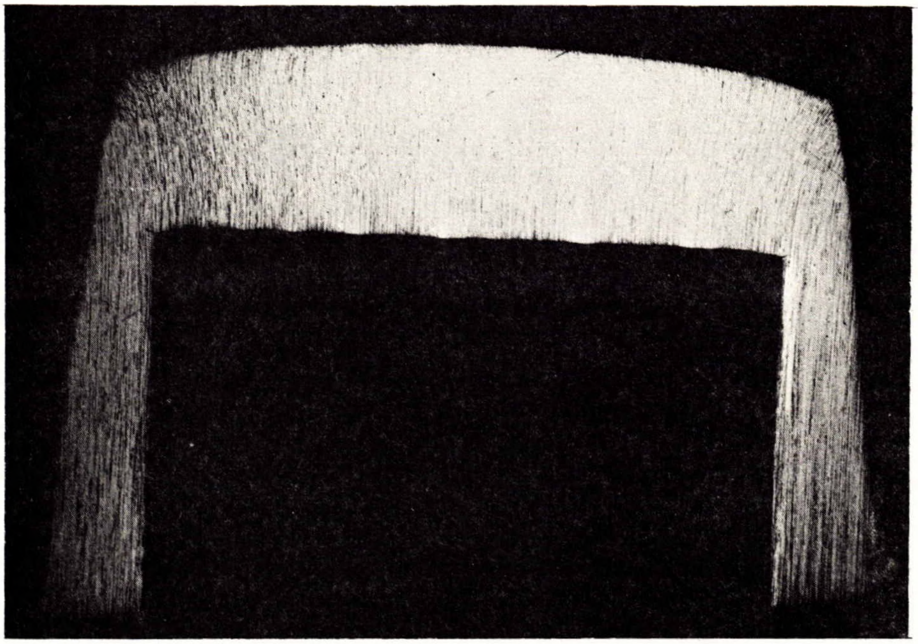


Figure 4. Longitudinal Cross-Section of One End of Outer Capsule No. 5.

The structure is heavily etched in oxalic acid to show how the pattern of parallel flow lines has been deformed in service by impact. Cracks developed, in service, at the sharp internal edges of the body cavity. (X5)

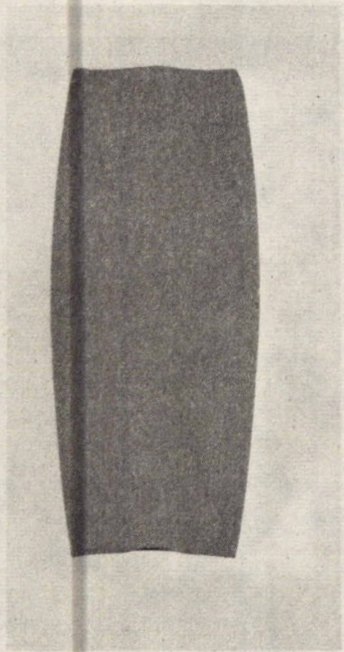


Figure 5. Cross-Section of Exhibit No. 4.

Carbon steel dummy capsule, service tested for an unknown period. Etched in nital. (X1.6)

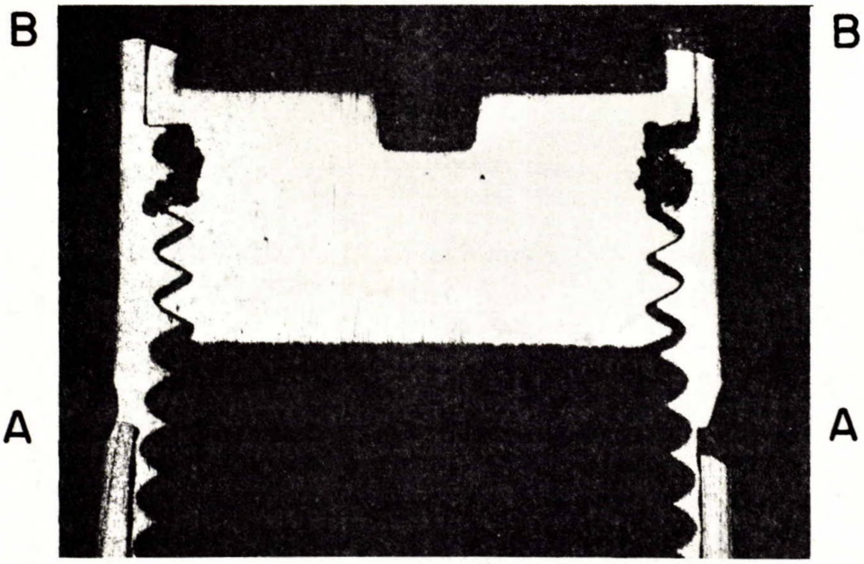
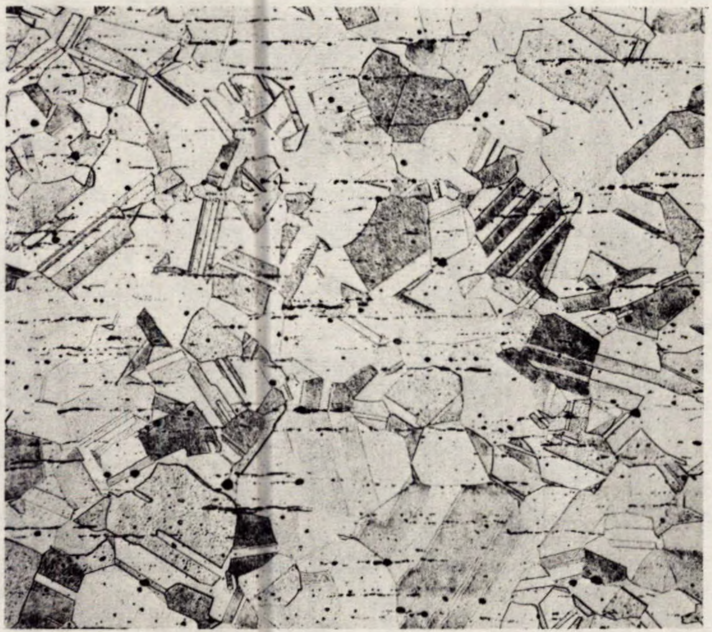


Figure 6. Structures of Inner Capsule No. 5.

Upper: Cross-section of one end showing circumferential welds at "A" and "B". Electrolytic oxalic etch. **(X5)**

Lower: Section of the "B" weld showing root cracks. The weld metal has a dendritic structure. The capsule body at left shows some precipitation of grain boundary. The capsule plug, at right, shows a fully annealed austenitic structure. Electrolytic oxalic etch. (X100)



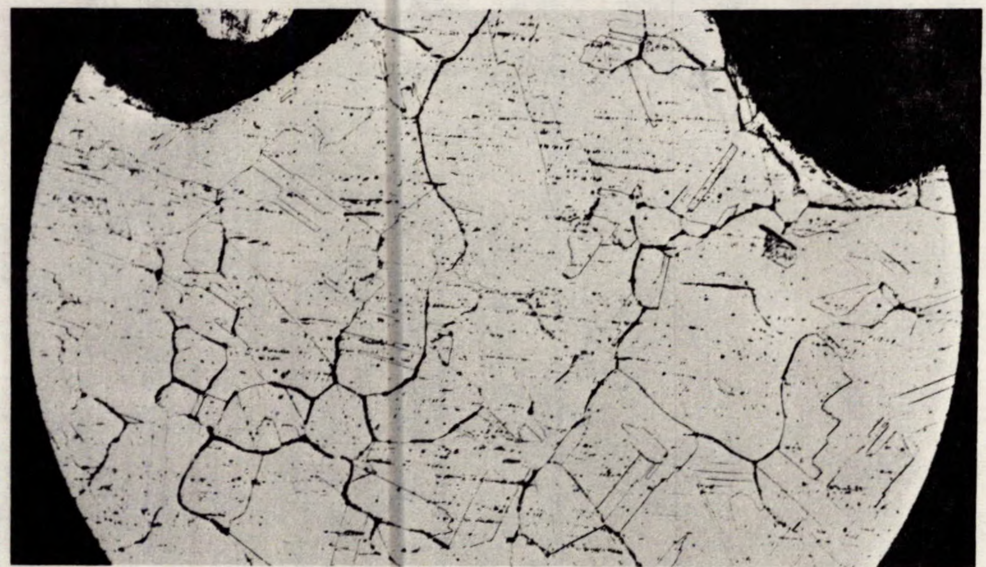
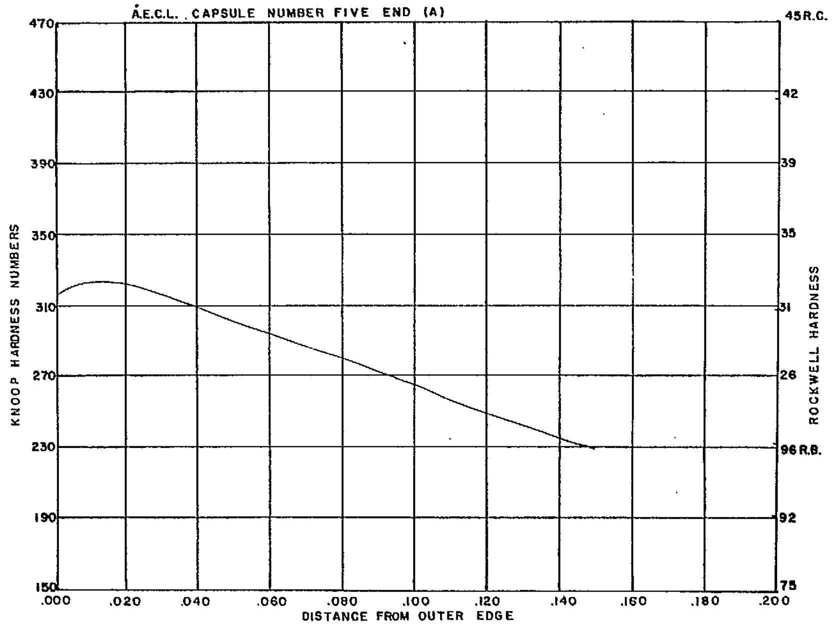


Figure 7. Structures of Inner Capsule No. 5. Electrolytic oxalic etch. (X100)

Upper: Annealed structure of the main part of the inner capsule.

Lower: Sensitized structure of the end-length of the body ("A" - "B" in Figure 6) near weld "A".



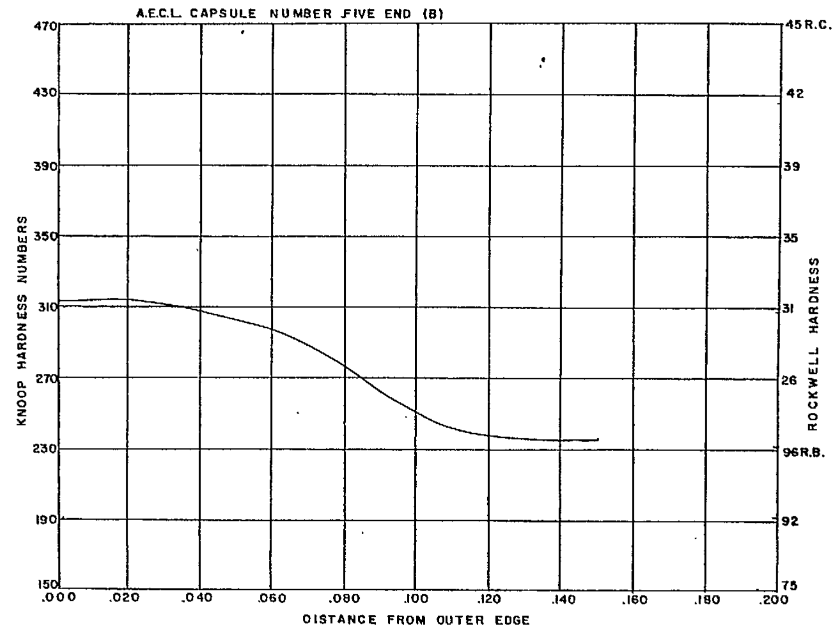


Figure 8. Tukon Hardness Surveys of Impacted Ends of Exhibit No. 5 (stainless steel cycled 100,000 times) (see Figures 3 and 4).

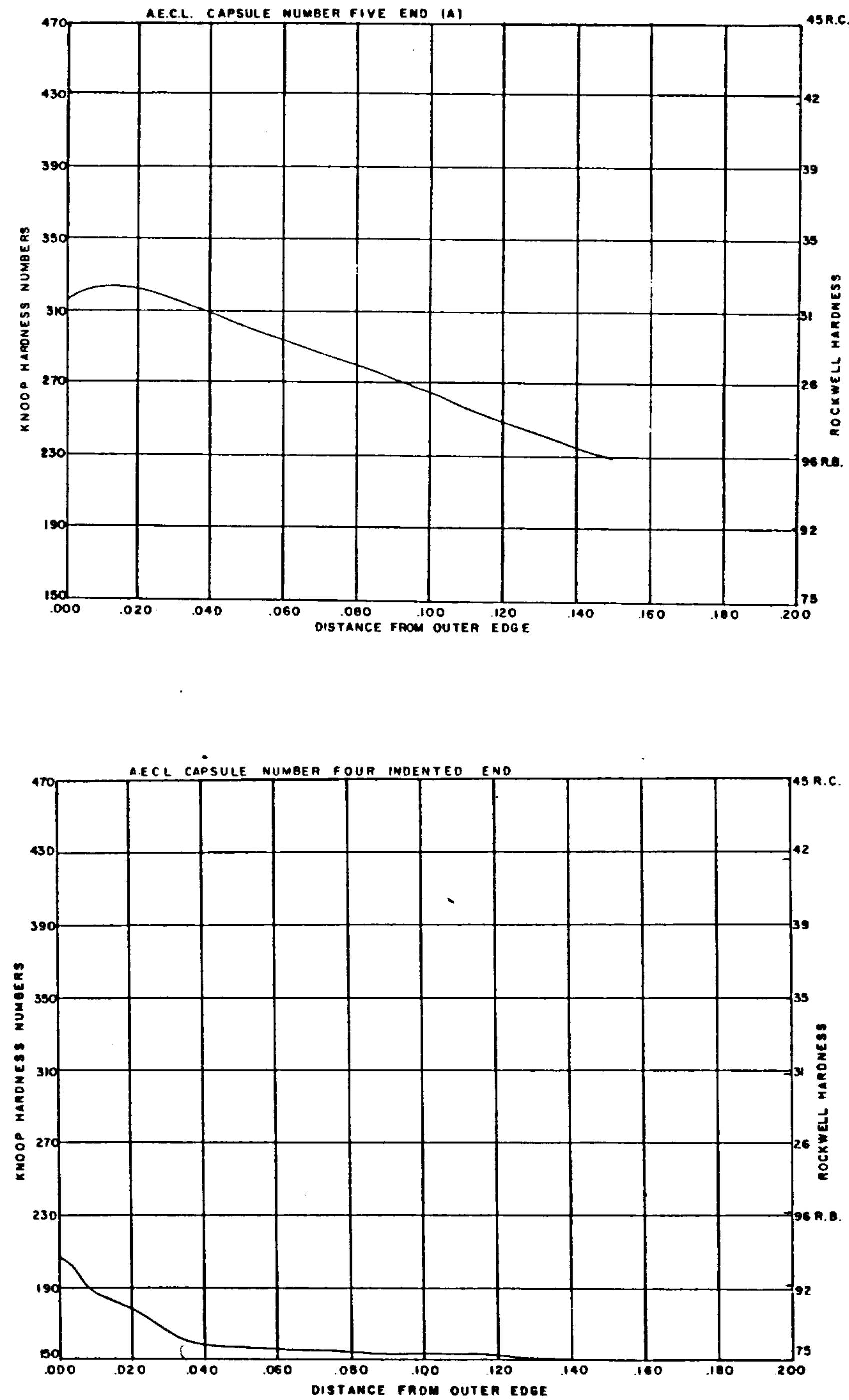


Figure 9. Tukon Hardness Surveys of Impacted Ends of Exhibit No. 4 (solid carbon-steel capsule) (see Figure 5).