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METALLURGICAL COMPARISON OF 5 INCH/54 NAVAL TUBES FIRED WITH NACO AND PYRO PROPELLANT

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U.S. ARMY ARMAMENT COMMAND

BENET WEAPONS LABORATORY
WATERVLIET ARSENAL
WATERVLIET, N.Y. 12189

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The effects of two different types of propellant on the surface damage introduced in the 5 inch/54 cannon tube are compared. Based on metallographic and hardness examination, it is shown that the depth of the damage zone is greater with the Pyro as compared to the Naco propellant. This is related to the higher flame temperature of the former. The type of damage observed is described and discussed.

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INTRODUCTION

Two tubes were examined metallographically as part of the fatigue testing program being conducted at the Watervliet Arsenal for the Naval Weapons Lab (NWL), Dahlgren, VA. One tube, No. 52, was fired 1590 rounds with Naco, while the other tube, No. 7, was fired 1500 rounds with Pyro as the propellant. Naco, which is a propellant designed to reduce the wear rate, has a flame temperature of 2150K as compared to 2650K for the Pyro. Summarized herein are the results of a metallographic examination into the surface and near surface relative damage introduced by the two types of propellant.

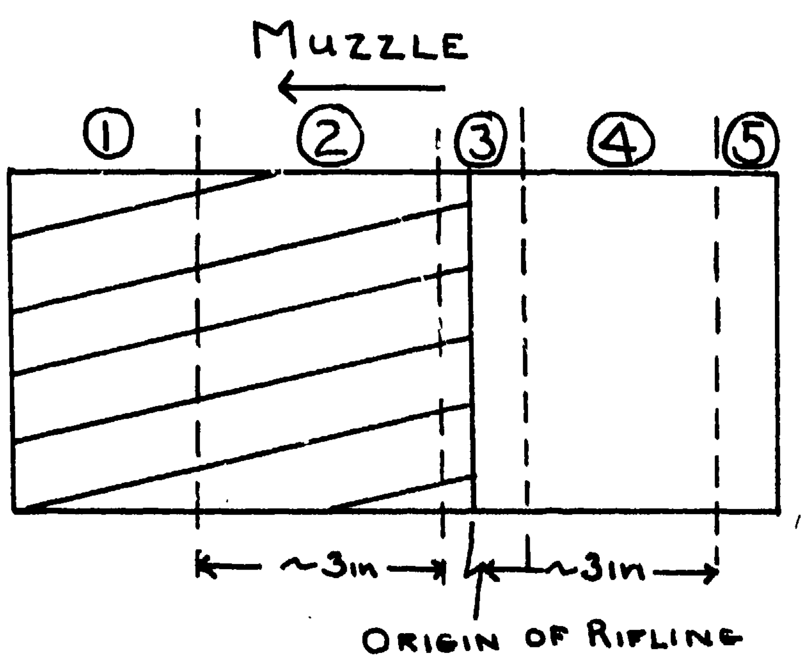
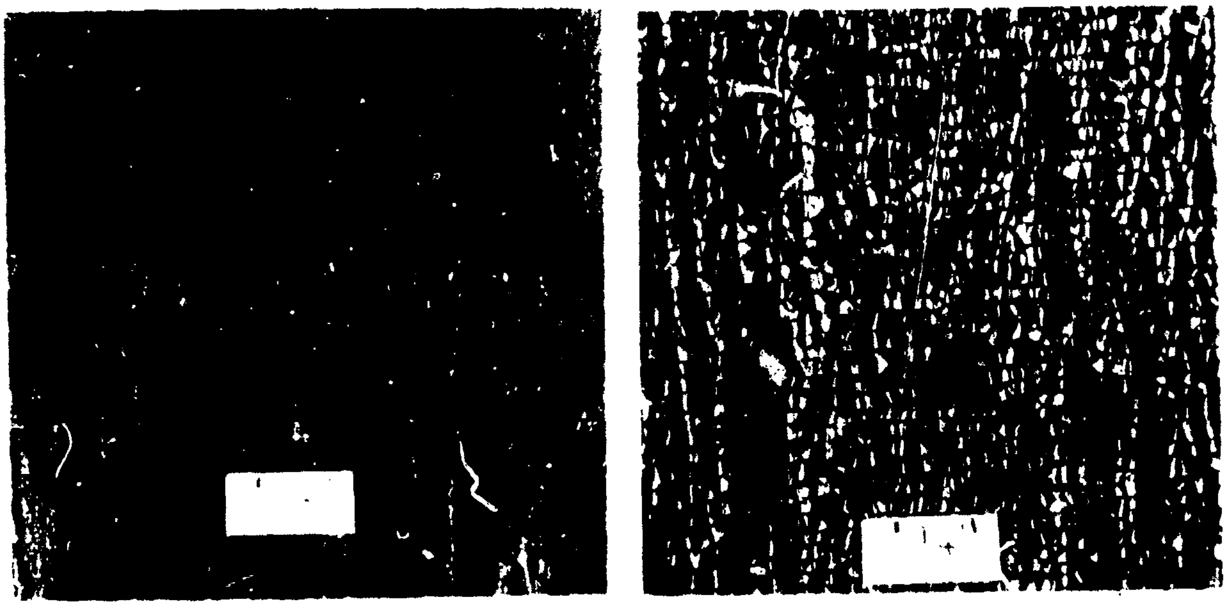


Figure 1. Schematic drawing of the tube and how it was sectioned.

PROCEDURE

The tubes were sectioned so they could be examined in the origin of rifling region, the portion known to exhibit the maximum erosion and structural damage[1]. Figure 1 is a schematic drawing representing the areas from which the specimens were cut. The area examined in this study was the region covering approximately ± 3 inches about the origin of rifling. Samples were polished, etched, and examined optically. Hardness readings were made with a Leitz microhardness tester using a 10 gram load.



a. b.

Figure 2. 15X Macrophotographs taken at the origin of rifling.
a. Tube No. 52 used Naco Propellant
b. Tube No. 7 used Pyro propellant

RESULTS AND DISCUSSION

MACROSCOPIC COMPARISON OF THE TUBES

The macrophotographs, shown in figure 2 were taken from the origin of rifling region and illustrate the marked difference in appearance of

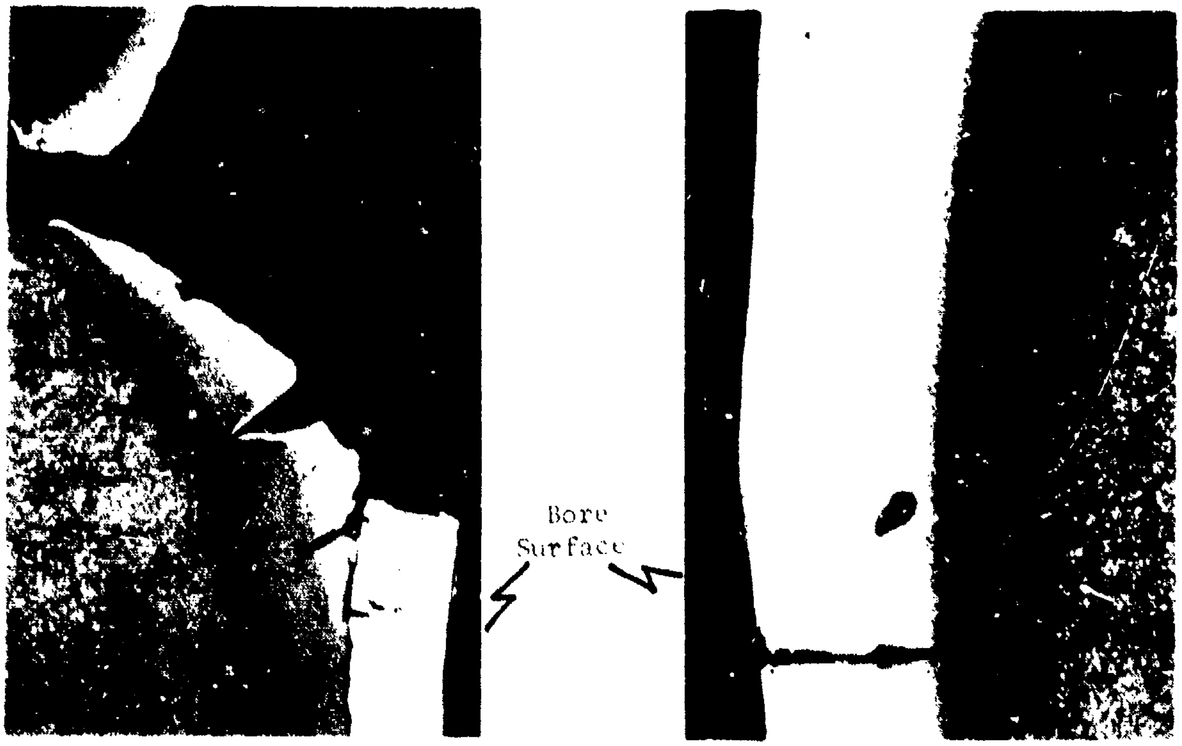
1. Hypervelocity Guns and the Control of Gun Erosion, NDRC, Rpt, Div 1, Vol 1, 1946.

the tubes. With the Naco propellant as shown in figure 2a, the rifling is clearly seen, the heat checking pattern not well defined, and the surface is dark in appearance. However, with Pyro (figure 2b), it is difficult to see where the origin of rifling region begins, the surface shows an extensive heat checking pattern, and it has a shiny pebbled appearance. Both tubes were initially chrome plated; the Naco fired tube having most of the chrome remaining on the surface while it was virtually eliminated in the area examined on the tube fired with Pyro. These differences apparently result from the higher flame temperature of the Pyro as compared to the Naco propellant[2].

MICROSCOPIC COMPARISON OF THE TUBES

Microscopically there are also differences that show up between the two propellants. When the chrome plating stays intact as it generally did in the Naco fired tube, little structural change occurs in the base metal. Figure 3a shows a typical micrograph for a sample sectioned from area 1, 2, and 3 on tube 52, where the chrome was removed. The sample shown in figure 3b for tube 7 was representative of the entire surface examined. Where the total thicknesses of transformed metal can be compared, it is readily apparent the tube fired with the Pyro propellant shows more heat-affected material. The thickest region measured with the Naco propellant was approximately 0.127mm while for the Pyro, it was 0.26mm, or better than twice as thick. In comparing the thickness of the various layers within the heat affected zone, it appears that the tube fired with Naco has an inner white layer that is thicker than the layer produced in the tube fired with Pyro. There were only a few areas available for comparison, so the above statement is very qualitative.

2. C. W. Morris, "Bore Surface Temperature Phenomena in 5 inch/54 Guns", NWLTR-2829, Sep 1973.



a. b.

Figure 3. 200X Micrographs showing representative microstructures for the tubes.
a. Tube No. 52, about 2 in. ahead of the origin of rifling
b. Tube No. 7 chamber section

HARDNESS OF THE LAYERS

Figure 4 plots the hardnesses at various depths below the bore surface for the two tubes and figure 5 shows the location of the hardness readings throughout the heat affected zone. Referring to figure 4, the circles represent the tube fired with Naco. We see a low initial value rapidly rising in the first 0.002cm to 800 KHN and then tailing off to the hardness of the unaffected quenched and tempered martensite. Likewise, the tube fired with Pyro showed a low initial value associated with the inner white layer and a rapid rise to about 700 KHN units where it remained relatively constant from 0.002 to 0.006cm. The hardness increased to 800 KHN units, and finally at about 0.016 or 0.017 cm, it began to decrease to the hardness of the quenched and tempered martensite.

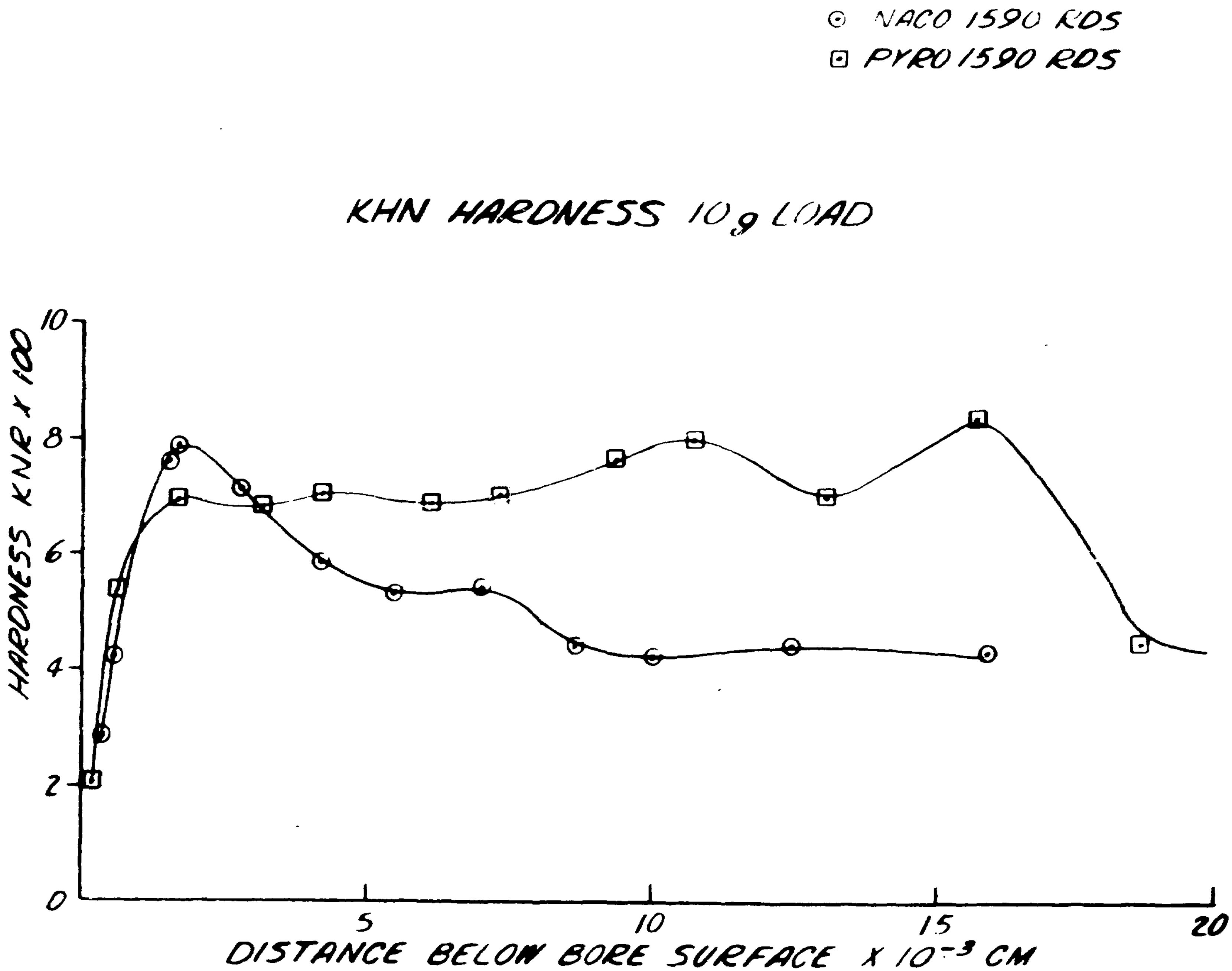


Figure 4. The change in hardness as a function of the distance below the bore surface.

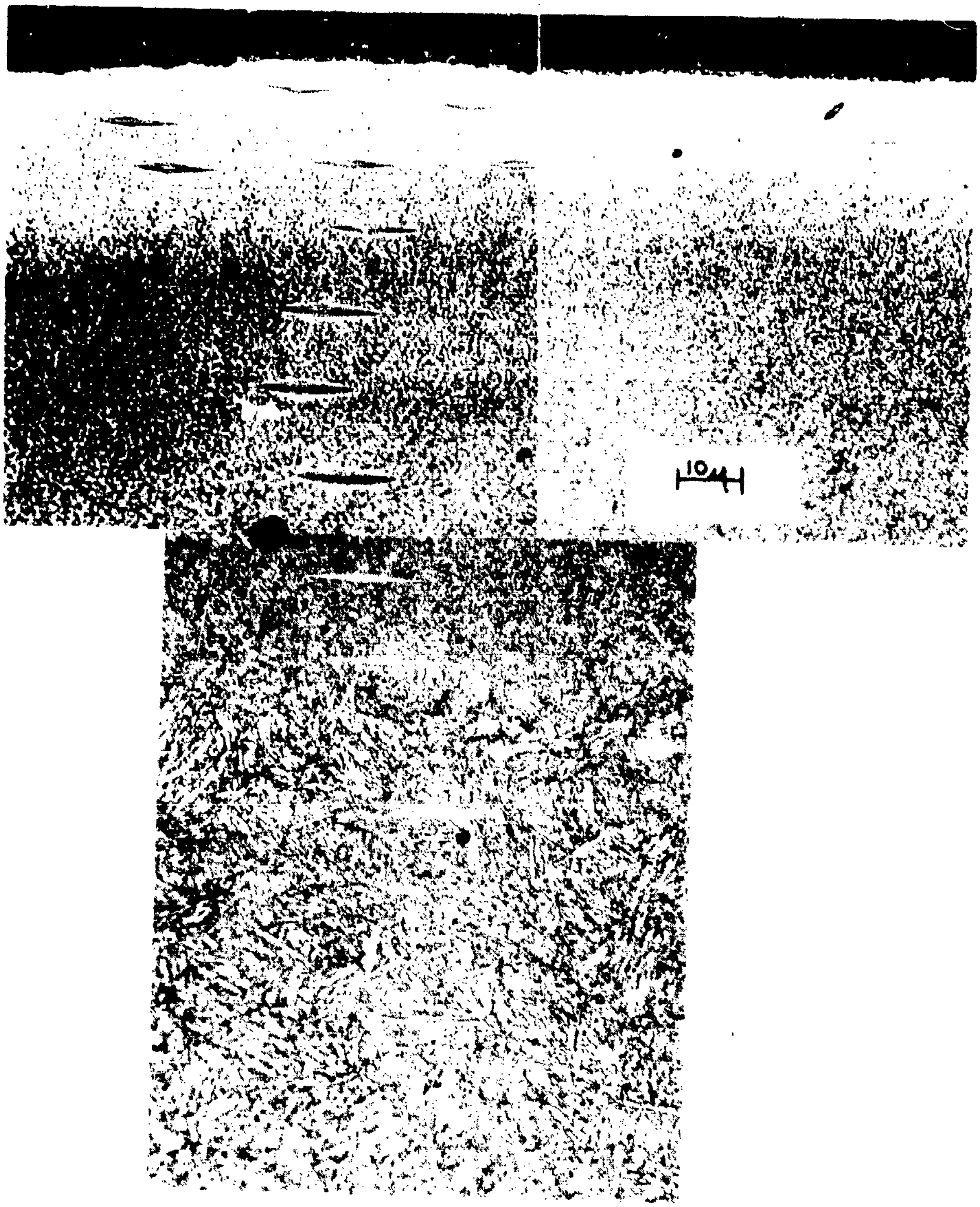


Figure 5a. Tube fired with Pyro, 1500 rounds. Hardness variation across the thermally altered layer. 10g load, KHN indenter, etchant 2% nital.

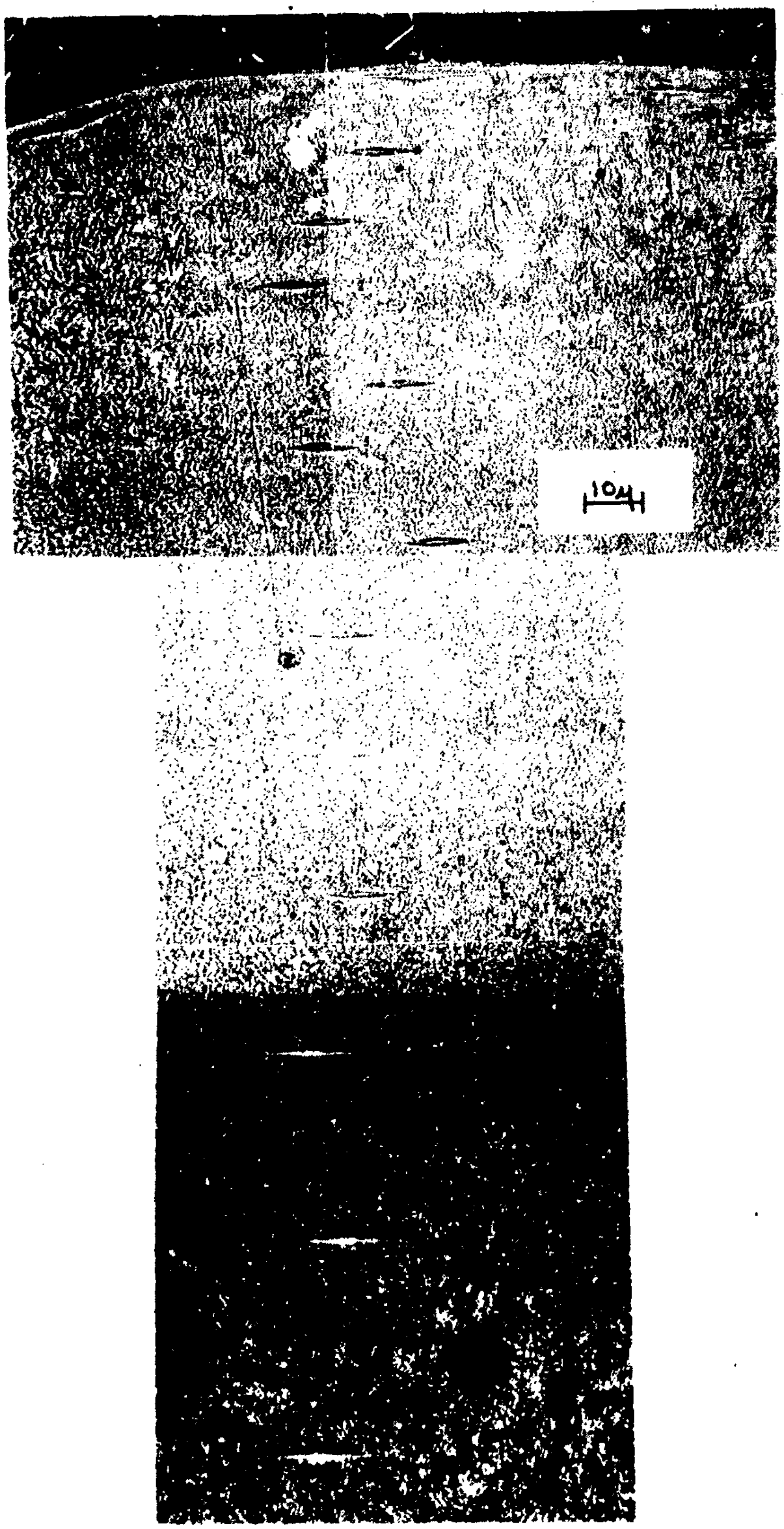


Figure 5b. Tube fired with Naco, 1590 rounds. Hardness variation across the thermally altered layer. 10g load, KHN indenter, etchant 2% Nital.

The larger extent of the heat affected zone of the tube fired with Pyro, shown in figure 5a is immediately apparent when compared with figure 5b. Also, figure 5a shows grain growth near the bore surface as well as a lower hardness value near the surface. This was representative of all the areas examined for the tube fired with Pyro. A possible reason for this may be related to the fact that the Pyro propellant produces a peak temperature in the origin of rifling region of about 1200C, compared to about 870C for the Naco Propellant[2].

CONCLUSIONS

Two 5"/54 Navy weapons were examined metallurgically. One tube was fired with Pyro while the other was fired with Naco propellant.

1. Macroscopically, the Pyro fired tube appeared much more worn than did the Naco tube.

2. The chrome plate was predominately intact for the Naco tubes, while this was not true for the Pyro fired tubes.

3. The depth of metallurgically affected material was about twice as great with the Pyro as with the Naco.

4. The Pyro fired tube showed grain growth just below the inner white layer.

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2. C. W. Morris, "Bore Surface Temperature Phenomena in 5 inch/54 Guns", NWLTR-2829, Sep 1973.