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Detailed Study of the Removal of Copper Jackets from Jacketed Bullets

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ABSTRACT: The often-used method of removing copper jackets from jacketed bullets (or fragments thereof) with nitric acid has been studied in some detail. It was found that 8*M* nitric acid is not satisfactory but that concentrated nitric acid works very well, removing the jacket completely in 5 min at room temperature with no measurable dissolution of the lead and with no measurable change in the concentrations of antimony, silver, or copper at the surface of the lead core (compared with their interior concentrations). The method was tested on commercial hardened-lead bullets (4.7% antimony) and on commercial soft-lead bullets (16 to 1078 ppm antimony). Instrumental neutron activation analysis was used to measure the concentrations of antimony, silver, and copper in specimens.

KEY WORDS: criminalistics, ballistics, radiography

In forensic science investigations of gunshot cases, it is often necessary or desirable to compare the elemental compositions of one or more bullet fragments or intact bullets, recovered from a living person or a dead body, with those of bullets recovered elsewhere or from unfired cartridges found in the possession of one or more suspects. In different laboratories, various methods of elemental analysis are used, emission spectrography, atomic absorption spectrophotometry, X-ray fluorescence, and neutron activation analysis being the most widely used methods.

In some instances, in which "copper-jacketed" bullets[4] are involved, jacket material adhering to the lead may be adequately removed by cutting, sawing, or drilling. However, the first two of these procedures frequently contaminate resulting lead-core samples with imbedded particles of jacket material, and drilling is not suitable for obtaining samples at the jacket/lead-core interface. Frequently, it is also important to analyze various samples of the lead taken from different locations in the interior and from various parts of the outer surface to establish by analysis the degree of homogeneity of the bullet lead. In such instances, and particularly if one wishes to measure the trace levels of copper in the bullet lead, a procedure sometimes used is to dissolve the copper jacket with nitric acid.

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[4] Commercial copper jackets are usually either a 95% copper/5% zinc alloy or a 90% copper/10% zinc alloy.

Of course, such complete jacket removal is not acceptable when the jacketed bullet (or an appreciable portion of it) is an evidential specimen that contains identifying striations on the land and groove markings that must be examined microscopically, photographed, and preserved. Removal of the lead core by melting the lead is effective, but then all information on the original compositional homogeneity or heterogeneity of the lead is lost. A suitable method of dissolution by acid is thus of value for the removal of imbedded jacket material from evidential bullet fragments and for the preparation of uncontaminated lead samples from intact retainer or exemplar bullets to determine the degree of intra-bullet homogeneity.

In connection with several criminal investigations in this laboratory involving copper-jacketed bullets, it became necessary to establish which nitric acid procedure, if any, was capable of rapidly removing all of the jacket material without (1) dissolving any significant amount of the bullet lead or (2) resulting in any change in the elemental composition of the lead at the surface of the lead core. To accomplish this, different concentrations of nitric acid were tested, and the apparently best one—16*M* nitric acid—was tested in greater detail. Two commercial brands of heavily copper-jacketed bullets (both 160-grain, 6.5-mm bullets) were investigated: (1) a hardened-lead type (Hornady 0.264 round nose, 4.7% antimony) and (2) a soft-lead type (Western Cartridge Co. Mannlicher-Carcano, 16 to 1078 ppm antimony). The latter type (WCC/MC) was investigated particularly because of its involvement in the assassination of President Kennedy. The Hornady bullets are completely jacketed except for lead exposed at the nose; the WCC/MC bullets are completely jacketed except for lead exposed at the base.

All resulting bullet-lead samples were analyzed for antimony, silver, and copper by means of reactor flux (thermal neutron flux $\Phi_{th} = 2.5 \times 10^{12}$ n/cm^2·s) nondestructive instrumental neutron activation analysis (INAA), using the 250-kW TRIGA Mark I nuclear reactor regular pneumatic tube at the University of California at Irvine and the rapid-scanning bullet-lead INAA procedure developed earlier [*1*]. In this procedure, antimony is measured via the 498-keV γ-ray of the induced 93-s first metastable isomer of ^{124}Sb activity, silver via the 658-keV γ-ray of the induced 24.4-s ^{110}Ag activity, and copper via the 1039-keV γ-ray of the induced 5.10-min ^{66}Cu activity. With the Hornady specimens, the regular scanning procedure (40 s each for irradiation, decay, and counting) was used for antimony and silver. However, it was modified to a longer decay period (300 s) and a longer counting period (300 s) for copper to measure copper more precisely. With the WCC/MC specimens, the regular scanning procedure was used for all three elements. Antimony and copper were then determined more precisely in a second, longer irradiation (1 h at 1.0×10^{12} n/cm^2·s) in the rotary specimen rack of the reactor, followed after a few hours decay by a 200-s counting of each activated sample. In these more precise measurements, antimony was measured via the 564-keV γ-ray of 2.80-day ^{122}Sb, and copper via the β^+ annihilation 511-keV γ-ray of 12.8-h ^{64}Cu.

Experimental Procedures and Results

Weight Loss

Given sufficient time, heating with nitric acid of various concentrations will dissolve both copper (or copper/zinc alloys) and lead. For example, Guy and Pate [*2*] report that room-temperature treatment with concentrated nitric acid for a matter of minutes, followed by similar treatment with 3*M* nitric acid at 60°C, effectively removes copper jackets from jacketed bullets, but in the process it also dissolves about half of the lead in a 400-mg sample. In the present study, it was soon established that fairly concentrated nitric acid could be effective at room temperature alone. When whole copper-jacketed bullets (Hornady 6.5 mm, 160 grain, round nose) were individually treated with 40 ml of

8*M* nitric acid at room temperature, reaction of the copper was slow, not all of the jacket being dissolved even in 60 min. An additional 30 min in 20 ml of fresh 8*M* nitric acid succeeded in dissolving most of the remaining jacket material, but this procedure also dissolved about 10% of the lead.

Concentrated nitric acid (40 ml of 16*M*), however, gave a vigorous reaction at room temperature, removed all of the jacket material in about 5 min, and did not detectably dissolve any of the lead. Even an additional 10- to 15-min treatment with 20 ml of fresh, concentrated nitric acid did not detectably dissolve any of the lead.

To determine the mean weight of the lead cores of these Hornady bullets, six of the bullets were carefully weighed, the lead cores removed by melting (leaving no visually detectable lead in the now-hollow jackets), the resulting jackets carefully weighed, and the weights of the lead cores determined by subtracting, in each case, the weight of the jacket from the weight of the original whole bullet.

As shown in Table 1, the mean weight of the whole individual bullets was 10.375 ± 0.008 g and the mean weight of the individual jackets was 3.072 ± 0.015 g, resulting in a mean weight for the individual lead cores of 7.303 ± 0.017 g. When six more Hornady bullets from the same box were each treated with 40 ml of 16*M* nitric acid at room temperature for 5 min, washed with distilled water, dried, and weighed, the mean weight of the resulting individual lead cores was found to be 7.318 ± 0.005 g. After an additional 10- to 15-min treatment with 20 ml of fresh 16*M* nitric acid, the mean weight of the individual lead cores was 7.315 ± 0.005 g. These results are also shown in Table 1. The 5-min treatment appeared (visually) to remove all of the copper jacket material, with no detectable loss in weight of the lead core.

Elemental Composition of Bullet Lead

The 5-min room-temperature treatment with 16*M* nitric acid described in the preceding section was further studied to ascertain (1) whether or not such a treatment did indeed remove all of the jacket material and (2) whether or not it changed the elemental composition of the bullet lead at the lead surfaces, where the lead was in direct contact with the nitric acid. Two somewhat different approaches were used—one with jacketed Hornady bullets, the other with jacketed WCC/MC bullets.

Studies with Hornady Bullets—The jackets were removed from seven Hornady bullets by cutting and from three Hornady bullets by the room-temperature 16*M* nitric acid dissolution method. A small sample for analysis (5 to 15 mg) was then cut from the interior of each of these bullets, as was a small sample from the outside surface of the lead. Each of these 20 samples was activated in the reactor for 40 s (at $\Phi_{th} = 2.5 \times 10^{12}$ n/cm^2·s), allowed to decay for 40 s (with transfer to a fresh polyethylene vial), and then

TABLE 1—*Measurement of possible bullet-lead weight loss resulting from the dissolution of copper jackets in concentrated nitric acid (Hornady 6.5-mm jacketed bullets).*

Mean weight of six whole bullets, g	10.375 ± 0.008
Mean weight of six copper jackets (lead removed by melting), g	3.072 ± 0.015
Mean weight of six lead cores (whole bullet weight minus jacket weight), g	7.303 ± 0.017
Mean weight of six lead cores (jacket removed by 5-min treatment with 40 ml concentrated nitric acid), g	7.318 ± 0.005
Mean weight of six lead cores (after an additional 10 to 15 min in 20 ml concentrated nitric acid), g	7.315 ± 0.005

counted for 40 s on the Ge(Li)/4096-channel γ-ray spectrometer to measure its antimony and silver content. Each 40-s count was followed by a longer count (300 s) after a longer decay period (300 s) to measure the copper content. Each sample was analyzed four times. The results of these analyses are shown in Table 2.

One sample of Hornady lead, after the copper jacket had been removed by concentrated nitric acid, was studied in more detail. The lead core was sampled in five places for analysis: three samples were taken from the interior of the bullet (near the nose, center, and base) and two from the surface (at the nose and the base). These five samples were then analyzed by INAA in the same way as the previous 20 samples except that each was analyzed three times (not four times), and the results are shown in Table 3.

It is evident from the data shown in Tables 1 to 3 that the concentrated nitric acid method rapidly removes all of the copper jacket without measurably dissolving any of the lead and does not change the concentrations of antimony, silver, or copper at the surfaces of the lead core.

Studies with WCC/MC Bullets—An extensive study of WCC/MC copper-jacketed 6.5-mm bullet lead (to be reported in full separately) was carried out. Its purpose was to provide the statistical background for the interpretation of the INAA results obtained by one of the authors (V. P. G.) on the bullet-lead evidential specimens involved in the assassination of President Kennedy (to be reported separately). In this study, 16 WCC/MC bullets were treated with concentrated nitric acid, and each was then cut to give four interior and six surface samples for analysis. The 16 bullets so treated, sampled, and analyzed (160 analytical samples) consisted of four each from the four production lots made by WCC: Lots 6000, 6001, 6002, and 6003. The bullets involved are 160-grain bullets (including jacket weight) of soft lead (specified to be at least 99.85% lead), heavily jacketed with 90% copper/10% zinc, and with lead exposed only at the base of the bullet.

The results of the analyses of these 160 portions from 16 WCC/MC bullets whose jackets had been removed by concentrated nitric acid are summarized in Table 4, which shows the mean ratios of the concentrations of antimony, silver, and copper found in the four inside portions to the respective concentrations found in the six outside (surface) portions. It is evident from the results that the nitric acid treatment did not result in any statistically significant change in the concentration of any of these three elements at the surface of the lead cores compared to the concentrations in the bullet interior, none of the ratios being statistically significantly different from 1.00. The WCC/MC bullet lead is much lower than the Hornady bullet lead in antimony (16 to 1078 ppm versus 4.7%), being soft lead rather than hardened lead; lower in silver (4.6 to 14.3 ppm versus about 43 ppm); and much lower in copper (12 to 33 ppm versus about 400 ppm).

Discussion and Conclusions

A 5-min treatment of copper-jacketed bullets (or bullet fragments) with concentrated nitric acid (16*M*) at room temperature is effective. It dissolves all of the jacket material without measurably dissolving any of the lead core and without measurably changing the concentrations of antimony, silver, or copper at the surface of the lead core. Quantitative removal of the jacket material is important because (1) it permits measurement of the true concentration of copper within the lead (copper, along with antimony and silver, is important in comparisons of trace elements in bullet-lead specimens to determine the probability of common origin [*3*] (brand, production lot) and (2) it avoids the analyzer dead time/pulse pileup problems encountered with the INAA of lead samples that contain adhering particles of copper. Pulse pileup problems become severe with a 50-mg lead sample containing more than about 1 or 2% copper by weight.

TABLE 2—*Measurements of possible changes in elemental composition of bullet lead resulting from the dissolution of copper jackets in concentrated nitric acid (Hornady 6.5-mm jacketed bullets).*

	Antimony, % by weight[a]		Silver, ppm[a]		Copper, ppm[a]	
	Outside	Inside	Outside	Inside	Outside	Inside
Mean of seven bullet leads, jacket removed by cutting	4.73 ± 0.11	4.61 ± 0.19	43.2 ± 1.6	43.0 ± 1.3	429 ± 16	. . .[b]
Mean of three bullet leads, jacket removed by nitric acid	4.77 ± 0.21	4.69 ± 0.10	44.4 ± 1.6	42.6 ± 3.2	401 ± 27	425 ± 25

[a] Each sample was analyzed four times.

[b] These samples, as well as two of the seven outside samples, were heavily contaminated with jacket material from the cutting (giving copper values in the range of 0.20 to 1.8% in the lead), and hence were excluded from calculations of the mean values.

TABLE 3—*Measurements of the homogeneity of Hornady 6.5-mm bullet lead after removal of copper jacket in concentrated nitric acid.*[a]

Portion of Bullet	Antimony, % by weight	Silver, ppm	Copper, ppm
Inside, top	4.52 ± 0.16	39.8 ± 1.3	407 ± 25
Inside, center	4.83 ± 0.16	38.9 ± 1.4	357 ± 53
Inside, bottom	4.58 ± 0.18	40.0 ± 1.3	444 ± 32
Outside, top	4.71 ± 0.14	42.3 ± 1.5	401 ± 24
Outside, bottom	4.74 ± 0.16	45.5 ± 1.3	405 ± 23
Means, inside	4.64 ± 0.16	39.6 ± 0.6	403 ± 44
Means, outside	4.72 ± 0.02	43.9 ± 2.3	403 ± 3
Ratio, inside/outside	0.983 ± 0.034	0.902 ± 0.049	1.000 ± 0.109

[a] Each of the five samples was analyzed three times; the mean values ± 1 standard deviation are shown in each case.

TABLE 4—*Measurements of the homogeneity of WCC Mannlicher-Carcano 6.5-mm bullet lead after removal of copper jacket in concentrated nitric acid.*

	Antimony	Silver	Copper
Mean ratio, inside/outside	1.026 ± 0.042	1.004 ± 0.031	1.009 ± 0.163

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