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REVIEW OF SOVIET ORDNANCE METALLURGY

Paper Presented at Meeting on

Trends in Soviet Metallurgical Developments

Central Intelligence Agency
Washington 25, D. C.

16 April 1953

by

A. HURLICH
Metallurgist

DATE: 10 April 1953

WATERTOWN ARSENAL
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REVIEW OF

SOVIET ORDNANCE METALLURGY

INTRODUCTION

The bulk of the Soviet ordnance materiel which has been examined in this country consists of equipment which was manufactured prior to and during World War II. Whatever equipment which may have been manufactured more recently than 1945 represents designs which were standardized before the end of World War II and were made from materials and by methods used prior to 1945.

The subject paper covers the examination of several Soviet tank and field guns, armor from JS II and T-34 tanks, kinetic energy armor-piercing ammunition of both steel and tungsten carbide core types, and high-explosive ammunition, most of which had been captured in Korea, while a certain amount had been recovered from German battlefields of World War II. The metallurgical and mechanical properties of this materiel will be covered, as will the more significant feature of design and manufacture. Insofar as available information permits, an evaluation will also be made of their performance characteristics.

I. Artillery

Four gun tubes ranging in caliber from 76 MM to 122 MM and representing both tank and field guns presumably manufactured during 1937-1944 have been examined by the Ordnance Corps. Common features of these weapons were simplicity of design and ruggedness. The breech rings and blocks were square cornered, had a minimum number of bosses, and these components as well as the tubes were rough machined on all non-critical surfaces. Critical surfaces such as chambers, forcing-cones, breech ring recesses for the blocks, and rifling were well machined and had surfaces comparable to those found in American equipment.

Generous fillets were observed in the interior re-entrant angles of the breech rings and in the rifling of the gun tubes; a very desirable practice in that it minimizes stress concentrations. All guns had monobloc tubes except for the 122 MM field gun which had a sleeve approximately one-third the length of the tube shrunk on the breech end of the tube. External threads on the sleeve of this weapon screwed into the breech ring, while the sleeve was pinned as well as shrunk to the tube. The 122 MM tank gun was designed so that most of its weight was at the breech end, thus minimizing the equilibration problem. This gun had a massive two piece breech ring, one end of which acted as the collar to hold the breech ring to the tube. The guns are, in general, of conventional design and have locking collars similar to those found in German World War II guns. The 76 MM gun was fitted with a cast steel double baffled muzzle brake, see Figure 1. It is not certain whether this 76 MM gun was a tank or a field piece.

The chemical analyses and mechanical properties of the four guns and their components are listed in Table I. The tubes of the 76 MM, 85 MM, and 122 MM tank guns are made from a Ni-Cr-Mo vanadium deoxidized steel having approximately equal amounts of nickel and chromium as alloying elements. American gun steels of the Ni-Cr-Mo composition generally contain at least twice as much nickel as chromium. The composition of the Soviet 122 MM field gun very closely approximates that of domestic weapons. The breech rings and blocks as well as the locking collars were made of either Ni-Cr-Mo or Cr-Mo alloy steels. The only component made of unalloyed steel (except for residual quantities of Ni, Cr, and Mo) was the cast muzzle brake on the 76 MM gun.

The mechanical properties of the Soviet gun tubes and other components are, in general, comparable to those of domestic weapons which were manufactured during World War II. The notched-bar impact properties of these weapons at low temperatures are quite poor and are considerably below present standards. It must be borne in mind, however, that we had no low temperature toughness requirements in gun steel specifications until after the end of World War II, and American guns manufactured during that period were undoubtedly no tougher than the subject Soviet guns.

In general the components of the Soviet guns were made of steels of somewhat inferior quality as compared to American guns in that the steels contained relatively numerous non-metallic inclusions and more pronounced and coarser dendritic structures. Except for the 76 MM tank gun's muzzle brake, all gun components were forged by conventional practices.

The relatively poor toughness of these weapons as revealed by low temperature notched-bar impact tests resulted from the incomplete quench hardening of the components during heat treatment. Although, in some cases, this was the result of insufficient hardenability because of excessively low alloy content, the incomplete hardening generally was caused by a slow cooling rate during quenching, indicating that the gun components were quenched in oil or warm water rather than drastically quenched in cold water.

The properties of the Soviet gun tubes are such that brittle fractures of the tubes and breech rings may be encountered in service, particularly at reduced operating temperatures, high pressures, and towards the end of the useful service life of the weapons.

II. Tank Armor

The Ordnance Corps's first contact with modern Soviet tank armor was in 1943 when two tanks were provided to this country by the Soviet government for performance tests at Aberdeen Proving Ground. These tanks were the T-34 medium tank and the KV-1 heavy tank. Sections, including welded joints, were cut from the hulls and turrets of these tanks and were sent to the Watertown Arsenal for metallurgical examination. The following observations and conclusions resulted from this study:

1. Four types of alloy steels were encountered in the armor sections; Mn-Si-Mo steels were employed for the thinner rolled armor sections, Cr-Mo steels for the thicker rolled armor sections, Mn-Si-Ni-Cr-Mo steels were employed for both rolled and cast steel components from 2" to 5" in thickness, and Ni-Cr-Mo steels were employed for some of the moderately thick cast armor sections. The silicon content of the Mn-Si-Mo and the Mn-Si-Ni-Cr-Mo steels was high, 1.0-1.5% Si, and there appeared no attempts at alloy conservation except in the case of the element molybdenum; the alloy content of all sections being more than sufficient to provide adequate hardenability.

2. The armor components of the T-34 tank, with the exception of the bow casting which was unheat-treated, were heat-treated to very high hardnesses (430-500 Brinell), probably in an attempt to secure maximum resistance to penetration by certain classes of armor-piercing projectiles even at the expense of structural integrity under ballistic attack. The armor components of the KV-1 heavy tank were heat-treated to hardnesses more nearly approaching American practice (280-320 Brinell).

3. The quality of the armor steels ranged from poor to excellent. Wide variations in production technique were indicated; some rolled armor components were well cross-rolled while others were virtually straightaway rolled. There was an extensive use of armor castings; the cast turret of the T-34 tank was of good quality while that of the KV-1 tank had excessive amounts of shrinkage and hottears in the section examined. The bow casting of the T-34 tank was very unsound and would have been rejected under American standards, see Figure 2.

4. The design of the welded joints was characterized by dovetailing such that the edges of the lighter plates were set into niches machined or flame-cut into the heavier sections so that the surfaces of the lighter plates were approximately flush with the edges of the heavier sections. This resulted in transmission of stresses from one armor section to another without subjecting the weld metal deposits to the full force of stress applications other than compression stresses. In many cases the weld joint designs were such that the weld deposit served more as a glue to hold the members together than as structural, stress-bearing elements. Although the fundamental design of the joints appeared excellent, the fit-up, appearance, and execution of the joint design and welding was generally poor.

5. Shallow penetration, poor fusion, severe undercutting, porosity, and cracking was observed in most of the welds and probably resulted from improper manipulation of electrodes which might not have had suitable operating characteristics. The sloppy appearance of the welds was indicative of poorly qualified weldors. Many of the welds looked as if the weld deposits were hastily thrown in to speed up production. These obvious defects, together with low strength and poor metallurgical structure of ferritic weld deposits, indicate that the welded joints would have poor resistance to severe shock.

6. Ferritic electrodes were used for most of the welding, although austenitic weld deposits were also encountered. In some cases, ferritic and austenitic electrodes were used, apparently indiscriminately, in making some of the weld deposits; some of the beads being laid down with one type of electrode while other beads in the same weld were deposited from the other type of electrode.

The results obtained from the metallurgical examination of these early World War II Soviet tanks have been described in some detail since they are exactly the same as have been obtained from all examinations performed since then on Soviet tanks which were recovered in Germany after the end of World War II, and on Soviet tanks which were captured in Korea during 1950-1952. The Ordnance Corps has examined several Soviet JS-II tanks which were found in Germany and several Soviet T-34 tanks from both Germany and Korea.

The metallurgical and mechanical properties of various armor sections of JS-II and T-34 tanks are shown in Table II and the compositions of both austenitic and ferritic weld metal deposits in these tanks are shown in Table III. Again, we encounter the Mn-Si-Mo, Mn-Si-Ni-Cr-Mo, and Ni-Cr-Mo armor compositions and very high armor hardnesses. Although molybdenum contents as high as 0.38% have been observed in Soviet armor, the bulk of the armor compositions have lower molybdenum contents in the range of 0.15 to 0.30%, with many having no more than 0.25% molybdenum. This element has an important function in reducing the temper embrittlement susceptibility of heat-treated medium to high alloy steels and is used extensively in domestic gun, armor, and projectile steels in amounts of 0.40 - 0.50%. The significantly lower molybdenum content generally observed in Soviet ordnance steels may be taken as a deliberate attempt at conservation of this element which is known to be not plentifully available in Soviet controlled lands.

Some of the armor steels have surprisingly high toughness considering the very high hardness levels; but many of the armor steels, even the softest ones, are very brittle. In several cases, the use of unalloyed and/or unheat-treated steels in such critical applications as turret rings, bow castings, and floor plates has been noted. Such components would be very brittle and are apt to fracture even when not directly impacted by projectiles. Unheat-treated hull floor plates would be very subject to shattering and splintering under mine attack. Since these conditions were observed in Soviet tanks presumably constructed during World War II when much of Soviet industry lay in ruins and when production had to be pushed even at the expense of quality, it cannot be safely assumed that the use of unheat-treated steels in critical tank applications is an approved Soviet practice. The Russians know too much metallurgy to be deliberately guilty of such practices.

The very high hardness encountered in most Soviet tank armor has caused much unnecessary concern regarding the relative ballistic performance of the hard Soviet armor and the softer American armor. Many people associate high hardness with high resistance to penetration. Although this is true, within limits, in the case of attack of armor by undermatching projectiles (i.e. caliber of shot is less than the thickness of the armor) particularly at low obliquities of attack, it is definitely not true when the armor is attacked by larger caliber shot at higher obliquities of impact. Competitive ballistic trials which have been conducted at ordnance proving grounds on both very hard and normally hard domestic armor and Soviet armor have established beyond question of doubt that in many cases, representative of actual battlefield attack conditions, very hard armor is distinctly inferior in resistance to penetration as compared to armor of more conventional hardnesses (280-320 Brinell).

Although welds in Soviet tanks are inferior in quality and much more brittle than corresponding welds in American tanks, this condition has not been a major factor in impairing the battlefield performance of Soviet armor. Poor joint fits, sloppy appearance, jagged and rough finishes should not divert attention from the fact that the Soviet tanks are rugged and battleworthy and require many fewer man-hours of labor and precision machine tools, jigs, and fixtures to construct than American tanks of corresponding offensive capabilities. In battle, the number of armored vehicles which can be fielded by a combatant is a vital factor in the outcome of the conflict - and the Russians seem to have learned this lesson more rigorously than have we. It would be very interesting to compare, for example, the relative man-hours of labor and investment in machine tools to construct equivalent numbers of the American 76 MM Gun Tank T41 and the Soviet T-34/85.

Typical samples of Soviet armor weld joints are shown in Figures 3, 4, and 5, which demonstrate the various evils of poor joint fit, weld cracks, shallow weld penetration, etc. as well as the fundamentally sound joint designs. Figure 5 is particularly interesting in that it shows a typical Soviet weld repair, this time in the welded joint between the lower glacis plate and the bow casting of a T-34 tank. A wide and deep crack several feet in length opened up in this ferritic weld, and repair of the crack was effected by depositing a small bead, using an austenitic rod, over the surface of the crack to hide it from view. It might be pointed out, parenthetically, that this tank did not become a battlefield casualty because of this glaring defect, but because an armor-piercing projectile was driven through its armor.

III. Armor-Piercing Projectiles

A. Steel Projectiles

Soviet steel armor-piercing projectiles which have been captured in Korea as well as those which have been recovered from various localities during World War II are characterized by the wide variety in designs which have been encountered. Basically, almost all of the shot which have been observed are of the monobloc, or AP, type; i.e. a shot without an armor-piercing cap, and the great majority have rather small explosive cavities of rather narrow diameter so that they are more properly classified as APHE projectiles.

Beyond this point, the similarity in design ceases. Some have rather sharp-pointed, ogival noses; some have flat noses; some have knobs of various shapes machined on their relatively blunt noses; some are fitted with windshields made of steel stampings to maintain a good aerodynamic shape; some have single copper rotating bands; some have two rotating bands; some are boat-tailed; some have cylindrical bases; some are deeply notched circumferentially forward of or behind their bourrelets, some have one and some have two such notches, and the notches come in a multiplicity of profiles and depths. Typical shot illustrative of these various design characteristics are shown in Figure 6.

This bewildering array of designs reduce, however, to a few basic concepts. It is postulated that Soviet AP shot are designed primarily for the defeat of highly sloped armor and are believed to be particularly effective against very hard armor of the type produced by the Soviets, as well as effective against armor under conditions of low ambient temperatures; where improperly heat-treated armor tends to be particularly brittle and sensitive to shock impacts.

Highly sloped armor, hard armor, and brittle armor all tend to be penetrated by a mechanism which involves the shearing out of a disc or plug ahead of the attacking projectile. This type of penetration is most effectively achieved by a blunt nosed shot or by one which fractures in such a manner that a roughly cylindrical blunt missile results. Such a projectile tends to plug through armor along a path more nearly normal to the surface of the armor than the original line of flight of the projectile, i.e., the shot tends to straighten up and take a shorter path through the plate than an intact ogival nosed shot which tends to ricochet off the face of the armor. The function of the cap on the APC type of shot is to reduce the forces on the nose of the shot and thus keep it intact; consequently, the Soviet shot are not capped.

It is inferred that the function of the circumferential grooves in the region of the bourrelet is to locate and promote fracture of the shot when attacking sloped armor targets, and thus convert ogival shot into the more effective flat-nosed shot. Against low obliquity armor, on the other hand, ogival nosed shot are more effective than flat nosed shot. Since the bending moment and stress concentration induced by the groove when attacking low obliquity targets is also correspondingly low, the grooved shot will not have a great tendency to fracture against such targets. The groove thus tends to make the shot more versatile; it does not degrade its performance against targets most readily defeated by sharp nosed shot, and improves the performance of the shot against targets most readily defeated by blunt nosed shot.

Information on the design characteristics, chemical compositions, and mechanical properties of typical Soviet steel armor-piercing projectiles is shown in Table IV. We again encounter the use of high silicon Mn-Si-Cr steels quite similar to those which are employed for armor except that the carbon content has been raised from the 0.25-0.30% level used in the armor steels to 0.32-0.38% carbon, and the element molybdenum has either been greatly reduced or eliminated from the shot steels. A Ni-Cr-Mo steel was, however, employed for the 122 MM AP shot which is the largest caliber shot studied, but even in this projectile the molybdenum content was only 0.22%. In several cases, the Soviet AP shot steels have insufficient alloy content to permit full hardening through the section upon quenching.

The shot bodies are heat treated by a quench and temper operation to maximum hardnesses in the range of Rockwell C 50, which is significantly softer than domestic shot which are fully hardened to Rockwell C 60-63, particularly in the forward portions of the shot. In addition, American shot are made from alloy steels containing approximately 0.50-0.60% carbon which permits the attainment of the very high hardnesses sought in domestic practice. Maximum hardnesses are desired in domestic shot to prevent deformation and fracture of projectiles on impact against armor, particularly against thick, low obliquity targets. Against highly sloped armor, it is found that monobloc, sharp ogived projectiles undergo nose fracture regardless of their metallurgical and mechanical properties and thus become transformed to relatively blunt cylindrical shapes which are, as a matter of fact, most effective against highly sloped targets. In view of the fact that ogival nosed shot undergo nose break-up against sloped armor targets, the circumferential grooves used by the Russians are not really necessary since the shot break up without them. The grooves may serve a useful purpose in APHE shot, however, by localizing the fracture in a region away from the explosive cavity and thus permit a high order detonation of the portion of the shot that gets through the armor.

In several cases the Soviet shot are heat treated to a uniform hardness of Rockwell C 50 all over the shot body, although in the case of the 85 MM shot the hardness decreased to Rockwell C 25 at the base. In the domestic practice, it is usual to obtain maximum hardness (R_c 60-63) in the shot nose down through the bourrelet region to approximately Rockwell C 45 at the base. This practice is followed in order to impart sufficient toughness to the body section to keep it intact even though the nose may shatter.

Windshields on Soviet AP shot are generally made by deep drawing or stamping low carbon sheet steel into the desired shapes. Relatively pure copper is employed for rotating bands, which are generally of conventional design, although a copper alloyed with approximately 5% nickel has been observed as a rotating band material. This latter alloy may, however, be accidental rather than intentional.

Like the rest of Soviet ordnance material, steel AP projectiles show evidence of coarse machining and finishing on all non-critical surfaces, while rotating bands and bourrelets have surfaces comparable to domestic practice. Almost all Soviet equipment indicates the careful husbanding of manufacturing processes requiring complex and expensive machine tools and skilled labor. Where needed, however, good practices are employed.

B. HVAP Projectiles

This type of armor-piercing ammunition covers tungsten carbide cored projectiles in which tungsten carbide penetrators are fitted into carriers to permit firing from guns; the carriers accompanying the cores to the target, at which point the cores break out of the carriers to perforate the armor. The carrier generally plays little or no part in the penetration of armor, serving only as a vehicle for the tungsten carbide core in the interior and exterior ballistic stages of flight. When, however, as in the case of Soviet HVAP shot, the carrier is heavy and much of the weight is behind the core, the carrier may act as a piston helping to drive the core through the armor and dishing out a large crater in the face of the impacted plate.

The Soviet HVAP projectiles which have been encountered in Korea are very primitive in design, looking almost exactly like the early German World War II arrow-head projectiles which were encountered in 1942 and possibly earlier. Figure 7 shows photographs of typical Soviet 45 MM, 57 MM and 85 MM HVAP shot. These three shot are similar in most of their design characteristics; all have soft steel bodies machined from unheat-treated low to medium carbon steel bar stock, see Table V. The windshields of these particular rounds are aluminum alloy sand castings whose inside contours fit over the ogive of the tungsten carbide cores and are screwed into the shot bodies, see Figure 8 for cross-sectional views of the carriers of the subject HVAP shot. The aluminum alloy windshields are similar in composition to two commonly used domestic sand-casting alloys, Alcoa 212 and 195. The cores are cemented into position by use of a litharge-glycerol cement.

In the case of a 76.2 MM Soviet HVAP shot, the windshield was made of a low carbon steel stamping attached to the shot body by grooves pressed into cannelures machined in the forward portion of the body. In this projectile the core was fixed into the body by crimping a lip of the body over the ogive of the core. The smaller caliber HVAP shot had integral steel rotating bands machined from the bar stock while the larger caliber HVAP shot had one and two rotating bands made from high purity copper.

Again, machining and finishes on non-critical surfaces are extremely rough; and all materials with, of course, the exception of the tungsten carbide cores, consist of non-strategic metals insofar as possible. The tungsten carbide cores are of uniform composition, containing approximately 90% tungsten, 6% carbon (sufficient to combine with all the tungsten to form WC), and approximately 4% nickel as the binder. It has been found in this country that cobalt is better than nickel as the binder in tungsten carbide cores; providing somewhat greater toughness and resistance to fracture. The use of nickel by the Russians may indicate a shortage of cobalt in the Soviet zone, or else an attitude that nickel bonded cores are good enough and the use of cobalt does not provide sufficient improvement to justify the use of the more strategic metal in this application.

American tungsten carbide cores have been made with as high as 16% cobalt as the binder, but recent research has shown that lower binder contents result in better overall penetration performance, with possibly 5 to 8% cobalt being optimum. The Soviet tungsten carbide core composition is thus not too far away from what we are evolving to.

A significant difference between Soviet and American HVAP shot is in the size and weight of cores used in the various calibers of shot. As seen in Table V, the Soviet 45 MM HVAP shot has a core weighing approximately 1/2 pound, while the 57 MM, 76-2 MM, and 85 MM HVAP shot have cores weighing between 1 and 1 1/3 pounds; while the core to total projectile weights range from as low as 13% to a high of 30%. By way of contrast, the American 76 MM HVAP M93 shot has a 4 pound core and the 90 MM HVAP M304 shot has an 8 pound core, with the cores weighing 45% to 50% of the total weight of the shot. The very small size of the cores in the Soviet HVAP shot is well illustrated in Figure 8, which shows cross-sections of the bodies and windshields of the 45 MM, 57 MM, and 85 MM HVAP shot such that the cavities for the cores are revealed. The tungsten carbide cores for these shot are shown in Figure 9.

Photomicrographs of a typical Soviet tungsten carbide core are shown in Figure 10. The material is very porous and the grain size is extremely non-uniform, the structure containing scattered large grains interspersed with fine grains of tungsten carbide. The poor quality customarily observed in Soviet tungsten carbide cores is indicative of sloppy manufacturing practice.

In view of the light weight and arrow-head designs of Soviet HVAP shot, the range-velocity characteristics of these projectiles would be expected to be poor. Also, because of the low weight and consequent low kinetic energy of the tungsten carbide cores, the armor penetration performance of Soviet HVAP shot should be far inferior to that of domestic HVAP shot. Nevertheless, at short ranges the Soviet HVAP shot can readily perforate American tanks as we have learned in Korea.

IV. High Explosive Ammunition

The general appearance of Soviet high explosive ammunition is similar to that of comparable American munitions. In many instances, however, the Soviet shell have thicker walls than American shell, presumably to provide a greater mass of metal for fragmentation. As a matter of fact, the design of and materials employed in Soviet high explosive ammunition seems to stress fragmentation rather than blast effect; both mortar and artillery H.E. shell often having thicker walls and heavier weights of metal than corresponding types and calibers of American rounds.

A very noteworthy aspect of Soviet high explosive ammunition is the use of cast iron in both mortar and artillery H.E. shell as seen from the data shown in Table VI. The extreme brittleness of cast iron enhances the fragmentation characteristics of this material; a shell of cast iron may produce up to 20 times as many fragments upon detonation as a similar shell made from forged steel. The fragments recovered from one detonated 82 MM mortar shell are shown in Figure 11. This shell, for example, produced more than 10,000 fragments upon detonation. Although, of course, a very large proportion of these fragments are fines weighing less than 2 grains (approximately 7500 fragments are in this classification), a very large number of these fragments may be effective as casualty producing agents. Even very tiny fragments are capable of producing severe casualties as well as deaths as attested to by the surveys made by medical teams in Korea during the periods when field trials of experimental body armor garments were conducted prior to the standardization of this type of equipment.

The 82 MM Soviet mortar shell also produced approximately 1600 fragments weighing from 2 to 5 grains, 850 fragments weighing from 5 to 10 grains, 700 fragments weighing 10 to 25 grains, and 100 fragments weighing 25 to 50 grains. Fragments in these weight ranges are particularly effective against personnel.

Competitive firing tests of the Soviet 82 MM cast iron and the American 81 MM M43A1 forged steel mortar shell have been conducted at Aberdeen Proving Ground where the shell were detonated in the center of 1" pine boards arranged in semi-circles of 20 foot and 40 foot radii. The following results were obtained:

	82 MM Soviet Mortar Shell	81 MM American M43A1 Mortar Shell
	20' radius	
Total hits	5891	734
Total perforations	1435	333
	40' radius	
Total hits	2513	277
Total perforations	824	102

From these data, the Russian shell is shown to produce:

at 20 feet

8 times more total hits
4.3 times more total perforations

at 40 feet

9.1 times more total hits
8.1 times more total perforations

Number of Fragments or Density
Per Square Yard From Main Spray

	82 MM Soviet Cast Iron	81 MM American Forged Steel
20' radius		
Total hits	93.8	11.7
Total perforations	22.8	5.3
40' radius		
Total hits	20.0	2.2
Total perforations	6.6	0.8

The above data were extracted from an Aberdeen Proving Ground Memorandum Report by Colonel G. B. Jarrett, Chief of Library and Museum Branch, dated 28 November 1950.

The very neat trick employed by the Soviets in the selection of calibers should be pointed out at this time. If they capture stocks of our 81 MM mortar shell, they can return them to us by firing them from their 82 MM mortars. On the other hand, their 82 MM mortar shell will not fit our 81 MM mortar tubes.

To further belabor the point of the excellent fragmentation characteristics of cast iron shell, the Soviet 120 MM Mortar Shell, Mod. 0Ø843A produces approximately 23,000 fragments upon detonation; approximately 10,000 being up to 2 grains in weight, 6,000 - 2 to 5 grains in weight, 3000 - 5 to 10 grains in weight, 2300 - 10 to 25 grains in weight, 900 - 25 to 50 grains in weight, 300 - 50 to 75 grains in weight, and 200 - 75 to 100 grains in weight. Truly an anti-personnel weapon of terrifying capabilities.

The low strength (see Table VI) of cast iron does, of course, limit the performance of shell made from this material; and probably confines their use to lower pressure and hence lower velocity and shorter range gun and mortar tubes. Cast metal does, on the other hand, have the desirable characteristic of breaking up into chunky, almost cubic, fragments as can be seen in Figure 11. Fragments of this general shape have the most desirable range-velocity characteristics and are to be greatly preferred to long splinters such as are often produced from the sidewalls of forged steel shell.

As with all other Soviet materiel, the high-explosive ammunition shows rough surface finishes and coarse machining except on critical areas such as bourrelets and rotating bands.

GENERAL CONSIDERATIONS

It must be borne in mind that the Soviet ordnance materiel described in this paper was mostly of World War II manufacture and represents design concepts which, for the greater part, were established as early as 1940-1942. It cannot be said with any certainty that these design concepts are, in all cases, still adhered to by the Soviets.

There have been recurrent rumors of the up-gunning and up-armoring of Soviet tanks, including the addition of more or less complex spaced armor on tanks designed to defeat chemical energy armor-defeating ammunition.

From a metallurgical point of view, it would appear that the Soviets have attained equality with this country in the matter of technical information but not in technological development or in skill and training of metals workers such as weldors, foundrymen and machinists.

The use of high silicon steels for many ordnance applications is unique with the Soviets. American ordnance steels rarely have more than 0.4% silicon, while the Russians use steels with as much as 1.5% silicon as one of the alloying elements. In one case where a high silicon bearing armor steel was produced by an American steel mill under Lend-Lease during World War II, the steel was very dirty, containing high concentrations of silicate inclusions, whereas the Russians have developed methods to produce reasonably sound high silicon alloy steels. Silicon is not a particularly desirable alloying element in steel, having only a moderate effect on hardenability and it has been found, in many cases, to embrittle steel which is tempered in the range of 250-300 Brinell. Its effect in very high strength steels (400-450 Brinell) may not be detrimental and may even be beneficial, witness the high silico-manganese spring steels. In any case, most of the high silicon alloy steels had sufficient quantities of other alloying elements such as manganese, nickel, and chromium present to provide adequate hardenability, so that the use of silicon did not seem necessary.

There appears to be a definite tendency to conserve molybdenum in Soviet ordnance steels, even though this element is almost a specific for temper embrittlement. Of course, very high hardness steels such as Soviet armor and AP shot are not tempered at temperatures in which the embrittling precipitate forms, so that the need for molybdenum to cope with temper brittleness is greatly lessened as compared to American practice.

In many cases, the total alloy content of Soviet ordnance steels has not been too wisely selected; some components having more alloy than needed to provide adequate hardenability for the section sizes involved, and some not having sufficient alloy content. The same remark also applies, however, to many American ordnance steels employed in the early stages of World War II, but by 1943 most ordnance steels in this country were designed with attention to hardenability requirements in order to conserve the more strategic alloying elements.

In closing, it should be emphasized that this country could do well to emulate the Soviet practice of employing finely machined finishes only where needed. The same applies to high quality, carefully prepared welded joints, castings, and other metal products. Detailed attention to aesthetic appearances is costly, time consuming, and, throughout the history of man, is not known to have won a single war.

SECRET

TABLE I

Metallurgical Properties of Soviet Artillery Materiel

Gun Size (FMAR No)	Component	C	Mn	Si	S	P	Ni	Cr	Mo	Va	Y.S. .1% Offset†	T.S. psi†	Elon. %	R.A. %	Impact (ft-lbs) +70°F	Impact (ft-lbs) -40°F
122mm Tank Gun Model 1943 (1404)	Tube	.35	.59	.27	.025	.031	1.27	1.61	.44	.04	B-114.0	141.6	15.2	40.8	15.2	9.4
											M-128.0	150.5	12.2	33.1	11.8	6.4
	Br. Ring (Rear)	.39	.46	.19	.026	.032	1.32	1.55	.21	.045	95.4	125.9	17.7	51.6	15.3	8.3
	Br. Ring (F'wd)	.36	.73	.36	.019	.031	.42	.25	.09	Tr.	50.0	89.1	18.6	27.2	22.2	4.8
	Br. Block	.35	.54	.24	.027	.028	1.31	1.49	.24	.045	81.3	110.9	19.0	52.9	29.2	14.1
85mm Tank Gun Model 1944 (1403)	Tube	.345	.81	.40	.037	.032	1.38	1.29	.23	.04	B- 95.2	123.8	15.6	39.7	19.5	6.4
											M*-99.3	128.2	21.8	61.5	19.5	7.2
	Br. Ring	.37	.67	.34	.046	.020	.66	1.30	.26	Nil	91.5	121.2	15.0	36.7	8.3	—
	Br. Block	.41	.57	.28	.044	.042	1.43	1.52	.26	Nil	87.8	119.6	18.6	47.0	25.4	8.8
	Locking Collar	.31	.51	.22	.027	.021	.22	1.14	.25	Nil	77.0	115.0	24.0	65.2	45.0	6.1
122mm Field Gun Model 1931/37 (504A)	Tube	.345	.51	.37	.025	.022	3.63	1.71	.29	.03	B-136.0	159.0	16.0	41.2	19.1	10.5
											M-136.0	158.2	13.3	37.4	16.8	9.4
	Br. Ring	.30	.52	.35	.020	.018	2.31	1.39	.35	.03	90.3	119.9	18.6	52.5	26.3	15.5
	Br. Block	.31	.54	.27	.023	.013	2.20	1.25	.31	.06	94.9	122.2	18.0	50.4	36.5	14.4
	Sleeve	.365	.56	.33	.026	.021	.29	1.35	.24	.03	92.8	121.8	20.3	53.0	44.1	18.2
76mm Gun Model 1942 (1261A)	Tube	.40	.60	.38	.023	.022	1.48	1.47	.22	.03	B-106.8	136.3	16.2	44.1	30.8	10.6
											M*-116.0	142.8	20.5	60.6	27.3	16.8
	Br. Ring	.36	.49	.24	.017	.033	.30	1.23	.30	.16	104.3	123.4	19.7	59.8	29.5	7.7
	Br. Block	.395	.53	.27	.026	.029	1.43	1.45	.25	.03	106.5	124.6	20.4	60.3	39.1	18.1
	Locking Collar	.33	.45	.26	.023	.029	.30	1.33	.34	.135	*86.9	108.9	22.5	69.2	59.8	33.2
	Muzzle Brake	.38	.90	.35	.035	.020	.20	.14	.07	—	*64.0	92.8	23.2	48.7	58.7	11.9

NOTE: * Longitudinal tests. All other tests are transverse to flow lines.
** Castings.
† Yield Strength and Tensile Strength X1000 PSI.

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TABLE II

Metallurgical Properties of Soviet Tank Armor and Tank Components

Soviet Tank	Location of Armor	Thickness and Type of Armor	Chemical Composition C	Mn	Si	S	P	Ni	Cr	Mo	V	Mechanical Properties: Brinell Hardness	Yield Strength 0.1% psi	Tensile Strength psi	Elong. %	R.A. %	Impact Energy V-Notch Charpy Ft.Lbs. at -40°F
JSII	Hull, side plate	5" Cast	.20	.83	1.18	.029	.027	2.72	1.56	.29	.06	444	142,000	142,000	0	3	18
JSII	Hull, lower side	3.4" Cast	.34	.40	.35	.026	.016	1.54	2.35	.38	.04	285	113,500	145,000	18.3	56.0	31.3
JSII	Turret	4" Cast	.20	.75	1.59	.037	.021	2.86	1.58	.33	.04	447	157,400	211,000	2.1	6.0	14
JSII	Turret, roof	1.25" Rolled	.275	.40	.35	.025	.018	.43	2.26	.33	.04	290	117,500	137,400	17.9	55.9	36.1
JSII	Gun Mantlet	3" Cast	.265	.83	1.80	.024	.017	1.91	1.79	.20	.04	444	174,000	217,000	5.5	12.5	19
T34	Hull, side	1.75" Rolled	.24	1.29	1.55	.014	.026	.08	.08	.28	.01	450	163,000	225,000	10.7	39.4	16.1
T34	Hull, lower side	1.75" Rolled	.255	1.16	1.84	.013	.021	1.26	1.09	.28	.04	477	196,500	229,800	11.4	43.6	4.2
T34	Sponson floor	0.8" Rolled	.26	1.36	1.54	.020	.025	.09	.10	.23	—	212-241	87,000	119,000	16	47.6	2.5
T34	Turret	3.25" Cast	.22	.77	1.41	.019	.022	1.72	1.33	.19	.04	444	175,000	206,000	7.0	5.8	15.5
T34	Turret, roof	0.9" Rolled	.285	1.75	1.16	.022	.030	.04	.10	.18	.01	444	192,000	218,000	0.7	0	5.5
T34	Bow casting	5" Cast	.24	1.21	1.51	.014	.020	.91	.90	.07	.04	192	67,000	103,500	18.5	33	2.2
T34	Upper glacis	1.8" Rolled	.245	1.23	1.56	.024	.024	.99	.81	.16	.03	429	163,000	225,000	11.5	42	12
T34	Lower glacis	1.8" Rolled	.24	1.22	1.42	.022	.028	1.08	.86	.20	.01	444	170,000	225,000	12	42	11.5
T34-85	Track shoe	Casting	1.24	13.90	.98	.007	.105	.91	.73	.22	--	---	59,000	119,000	34.5	35.0	----
SU-76	Track shoe	Casting	.32	.75	.36	.035	.043	.23	.14	.05	--	---	63,300	90,900	24.0	42.0	----

TABLE III

Chemical Analyses of Weld Deposits in Soviet Tanks

Tank	Weld Joint Location	Chemical Composition C	Mn	Si	S	P	Ni	Cr	Mo	V
JSII	Hull Side-wall to upper glacis	.205	1.07	.80	.022	.032	11.55	19.53	.09	--
JSII	Roof plate to turret	.24	.98	.95	.029	.032	9.68	15.81	.11	--
T34	Glacis Plates to Bow Casting (Exterior)	.08	.85	1.32	.04	.029	.34	.25	.05	--
T34	Glacis Plates to Bow Casting (Interior)	.125	.86	1.12	.039	.023	.40	.31	.06	--
T34	Sponson side-wall to upper glacis	.12	.88	.66	.03	.03	.63	.54	.25	--
T34	Roof plate to turret	.165	.90	.64	.037	.032	.16	.13	.08	--

TABLE IV

Metallurgical and Design Characteristics of Soviet AP Shot

Projectile	Components	Material	Chemical Composition C	Mn	Si	S	P	Ni	Cr	Mo	Hardness	Design Characteristics
45 MM APHE-T	Body	Steel Bar Stock	.365	.93	1.37	.018	.037	—	1.32	.06	49-52 Rockwell C	Blunt nosed shot with steel windshield knurled to shot nose. Two V-notches around shot body at bourrelet. Single rotating band.
Mod UBR-243Z	Windshield	Steel Stamping	.115	.47	--	.027	.023	—	—	—	159 Brinell	
	Rotating Band	Copper			- - - - - -						108 Brinell	
57 MM APHE-T	Body	Steel Bar Stock	.38	.98	1.64	.027	.022	.09	1.42	.03	50-55 Rockwell C	Knob-headed blunt shot with steel windshield knurled to shot nose. Two wide V-notches around shot body, one above and one below bourrelet. Two rotating bands.
Mod UBZR-271	Windshield	Steel Stamping	.09	.29	.01	.035	.018	.09	.18	.03	123 Brinell	
	Rotating Band	Copper	95.03 Cu, 4.48 Ni, .13 Mn								114 Brinell	
85 MM APHE	Body	Steel Bar Stock	.32	.92	1.41	.034	.029	.22	1.17	.03	50 Rockwell C at nose 25 Rockwell C at base	Sharp pointed ogival nosed shot with deep V-notch around body below bourrelet. Two rotating bands.
Mod UBR-365K	Rotating Band	Copper	99.90 Cu								100 Brinell	
122 MM APHE-T	Body	Steel Bar Stock	.35	.36	.29	.024	.009	1.19	2.35	.22	50 Rockwell C	Same as 57 MM shot except for single rotating band.
Mod BR-471B	Windshield	Steel Stamping	.07	.35	.004	.034	.009	—	—	.03	110 Brinell	
	Rotating Band	Copper	99.92 Cu								118 Brinell	

TABLE V

Metallurgical and Design Characteristics of Soviet HVAP Projectiles (Arrow-Head Design)

Projectile	Component	Weight - Lbs. Total	Weight - Lbs. % of Total	Material	Chemical Composition	Hardness
45 MM HVAP-T Mod UBR-243P	Complete Shot	1.84	100	- - -	- - - -	- - -
	Carrier	1.15	63	Steel Bar Stock	.13 C, .56 Mn, .23 Si	115 Brinell
	Carbide Core	.56	30	Tungsten Carbide	89.23 W, 5.86 C, 4.01 Ni, .07 Co	86 Rockwell A
	Windshield	.13	7	Aluminum Alloy Casting	1.90 Si, 9.76 Cu, .30 Fe, Bal. Al	115 Brinell
57 MM HVAP-T Mod UBR-271P	Complete Shot	3.78	100	- - -	- - - -	- - -
	Carrier	2.44	65	Steel Bar Stock	.13 C, .51 Mn, .23 Si	117 Brinell
	Core	1.11	29	Tungsten Carbide	89.53 W, 5.94 C, 3.50 Ni, .26 Co	85 Rockwell A
	Windshield	.23	6	Aluminum Alloy Casting	1.84 Si, 8.26 Cu, 1.28 Fe, 1.18 Mg, Bal. Al	115 Brinell
76.2 MM HVAP-T	Complete Shot	6.71	100	- - -	- - - -	- - -
	Carrier	4.96	73.9	Steel Bar Stock	.39 C, .76 Mn, .27 Si	177 Brinell
	Core	1.07	15.9	Tungsten Carbide	88.64 W, 5.81 C, 4.45 Ni	84-88 Rockwell A
	Follow-Thru Plug	0.33	4.9	Steel Bar Stock	.81 C, .23 Mn, .11 Si	385-675 Brinell
	Windshield	0.18	2.7	Steel Stamping	.08 C, .46 Mn, .002 Si	65 Brinell
	Rotating Band	0.17	2.6	Copper	99.94 Cu	89 Brinell
85 MM HVAP-T Mod UBR-365P	Complete Shot	10.78	100	- - -	- - - -	- - -
	Carrier	8.73	81	Steel Bar Stock	.345 C, .57 Mn, .25 Si	156 Brinell
	Core	1.38	13	Tungsten Carbide	89.77 W, 5.95 C, 3.37 Ni, .21 Co	88 Rockwell A
	Windshield	.67	6	Aluminum Alloy Casting	.42 Si, 2.27 Cu, .40 Fe, Bal. Al	55 Brinell
	Rotating Band	--	--	Copper	99.89 Cu	78 Rockwell 15-T

TABLE VI

Metallurgical Properties of Soviet High Explosive Ammunition

Shell	Method of Manufacture	Chemical Composition								Mechanical Properties					
		C	Mn	Si	S	P	Ni	Cr	Mo	Brinell Hardness	Yield Strength psi	Tensile Strength psi	Elong. %	R.A. %	Impact Energy V-Notch Charpy ft.lbs. at +70°F
76 MM HE Shell, Mod. O-354	Cast	2.94	1.14	1.58	.067	.099	--	--	.05	200	25,000	37,000	2.0	1.8	2.8
76 MM HE Shell, Mod. O-353	Cast	3.03	.92	1.87	.055	.070	—	—	.05	180	34,000	35,000	2.0	—	1.4
76 MM HE Shell, Mod. Unidentified	Forged	.295	.53	.23	.036	.062	--	--	.03	--	73,000	103,000	22.0	57	29.9
122 MM HE Shell, Mod. ZH-462	Forged	.68	.99	.20	.023	.027	--	.01	—	250	53,000	118,000	14	20	5.5
82 MM Mortar Shell, Mod. 0832D	Cast	3.25	.49	2.32	.081	.311	.09	.09	—						
120 MM Mortar Shell, Mod. 0Ø843A	Cast	3.51	.51	1.70	.069	.207	.09	.11	—						

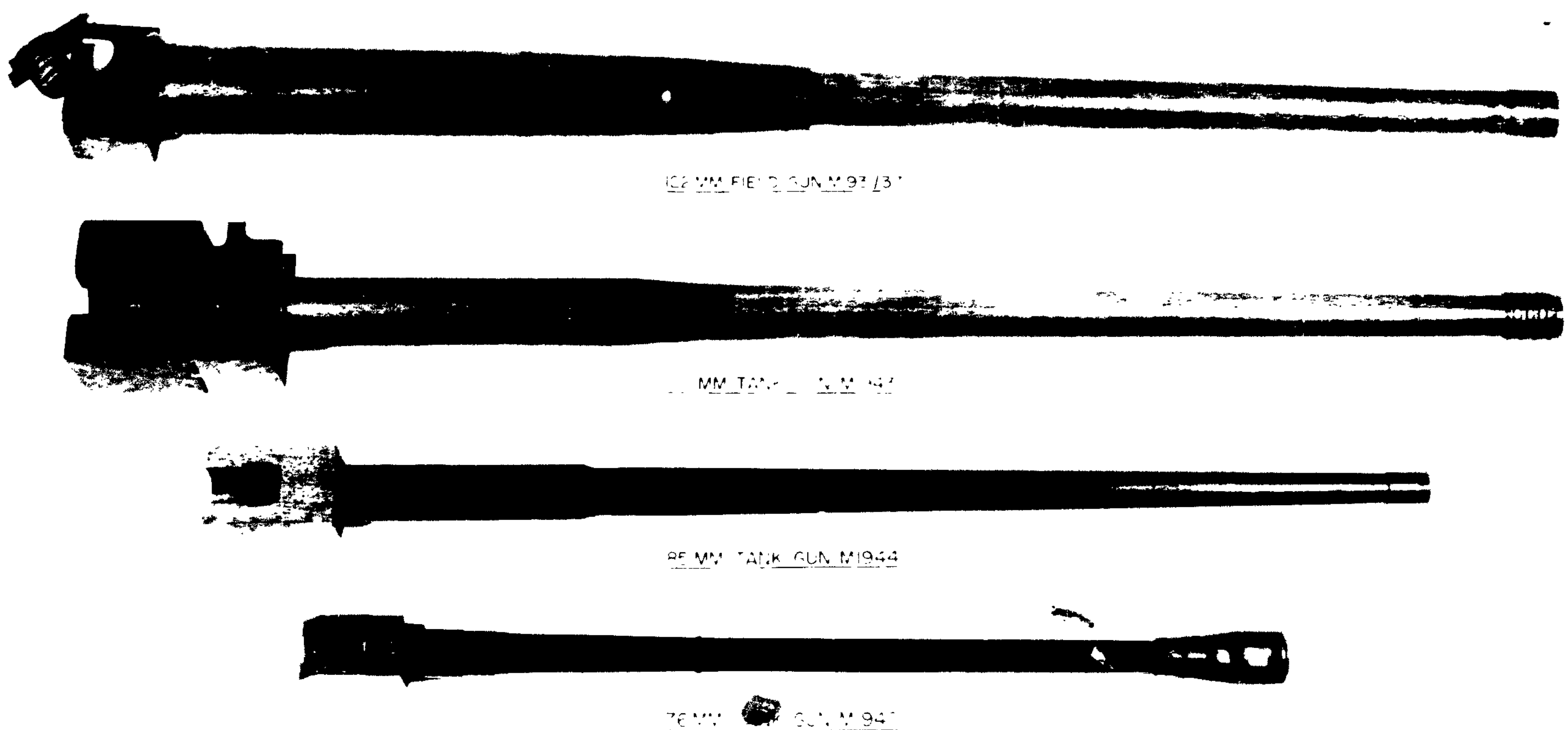

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FIGURE I

WOODEN MODELS OF SOVIET TANK AND FIELD GUN TUBES

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WTN.710–3134

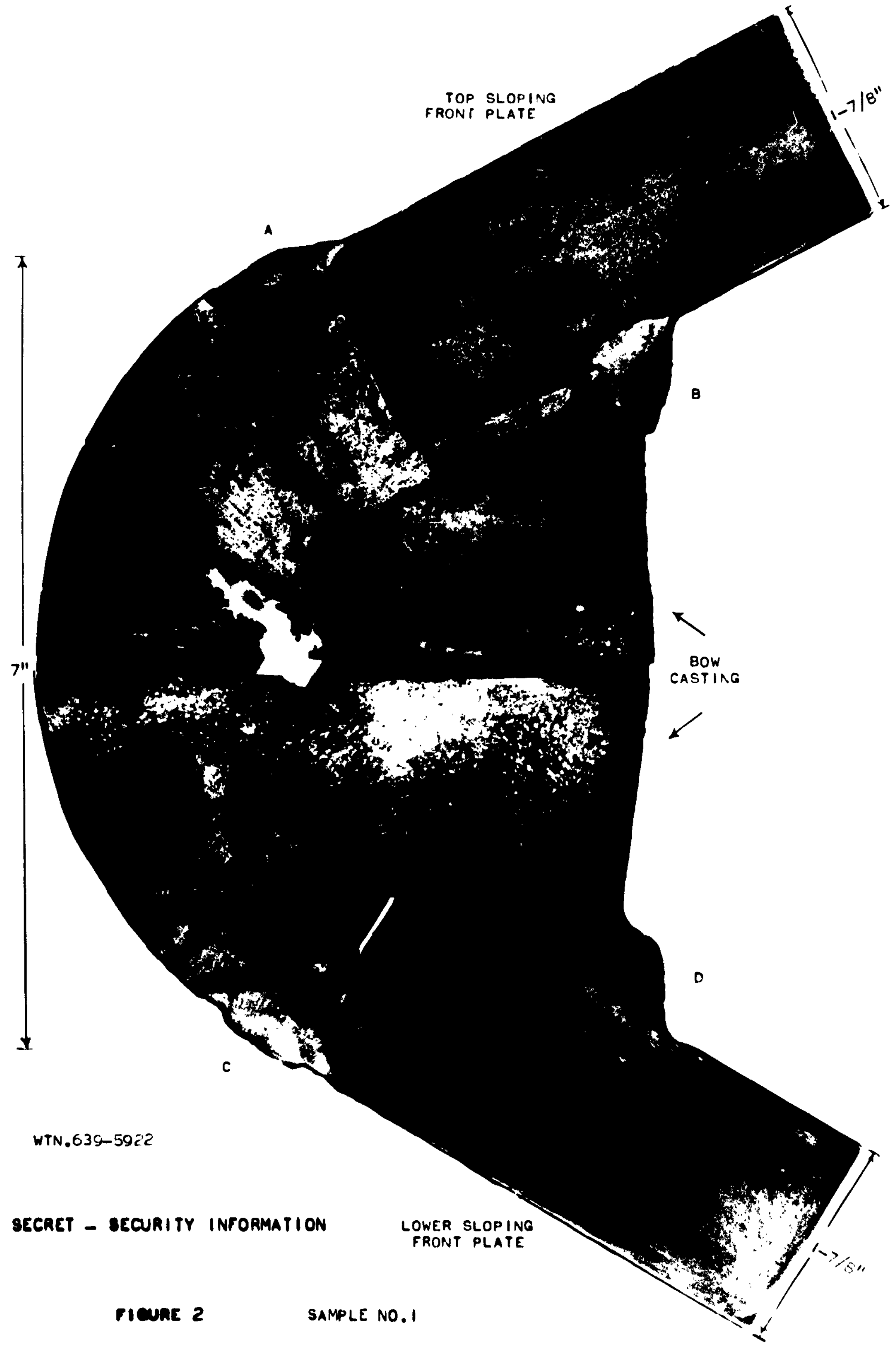

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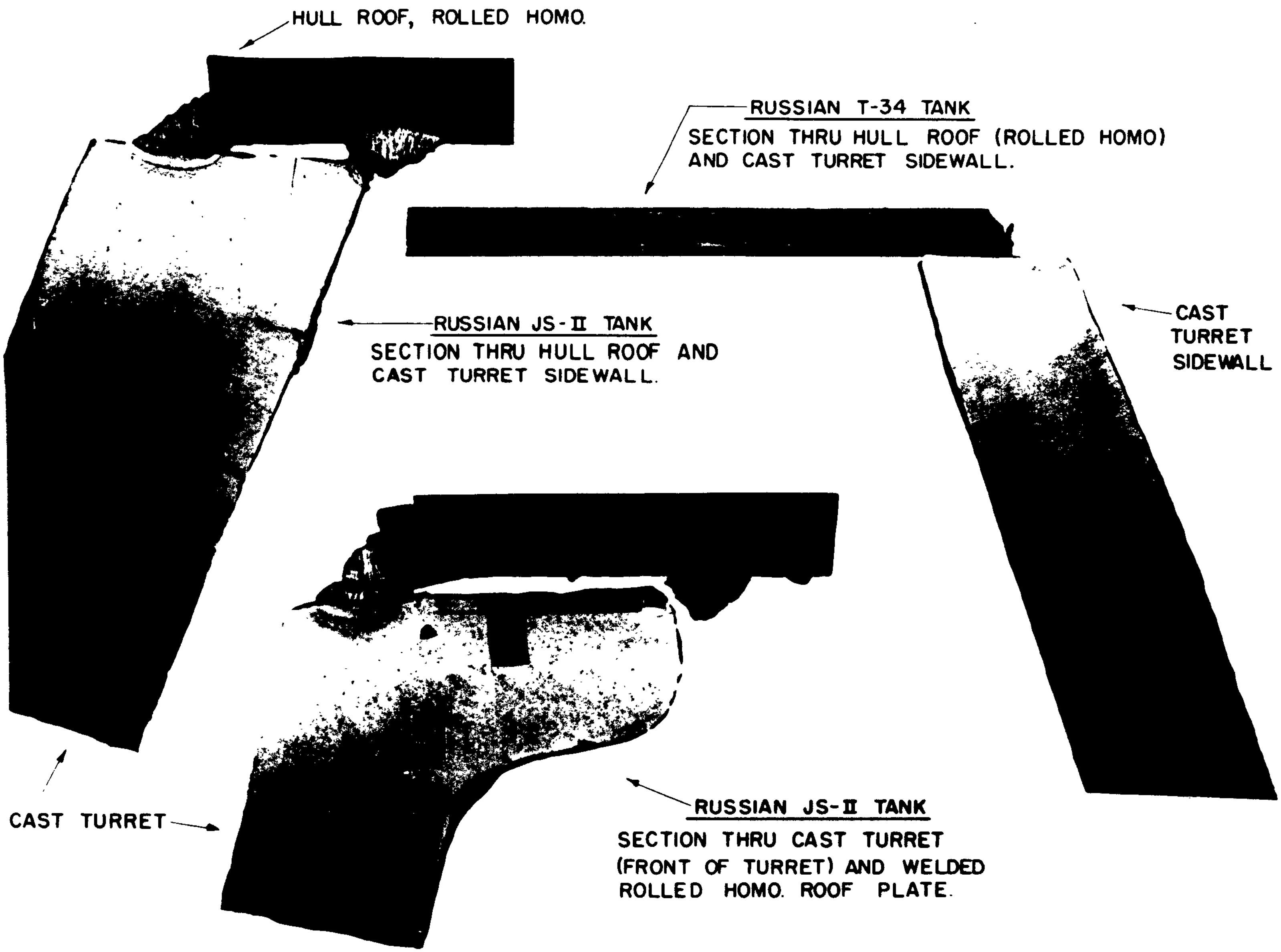
FIGURE 2 SAMPLE NO. 1

MACROETCHED TRANSVERSE SECTIONS THROUGH WELD JOINTS IN HULL OF RUSSIAN MEDIUM TANK T-34. SEE SKETCH A (APPENDIX A) FOR LOCATION OF JOINTS IN TANK STRUCTURE.



SECTIONS OF WELDS FROM SOVIET TANKS

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FIGURE 3

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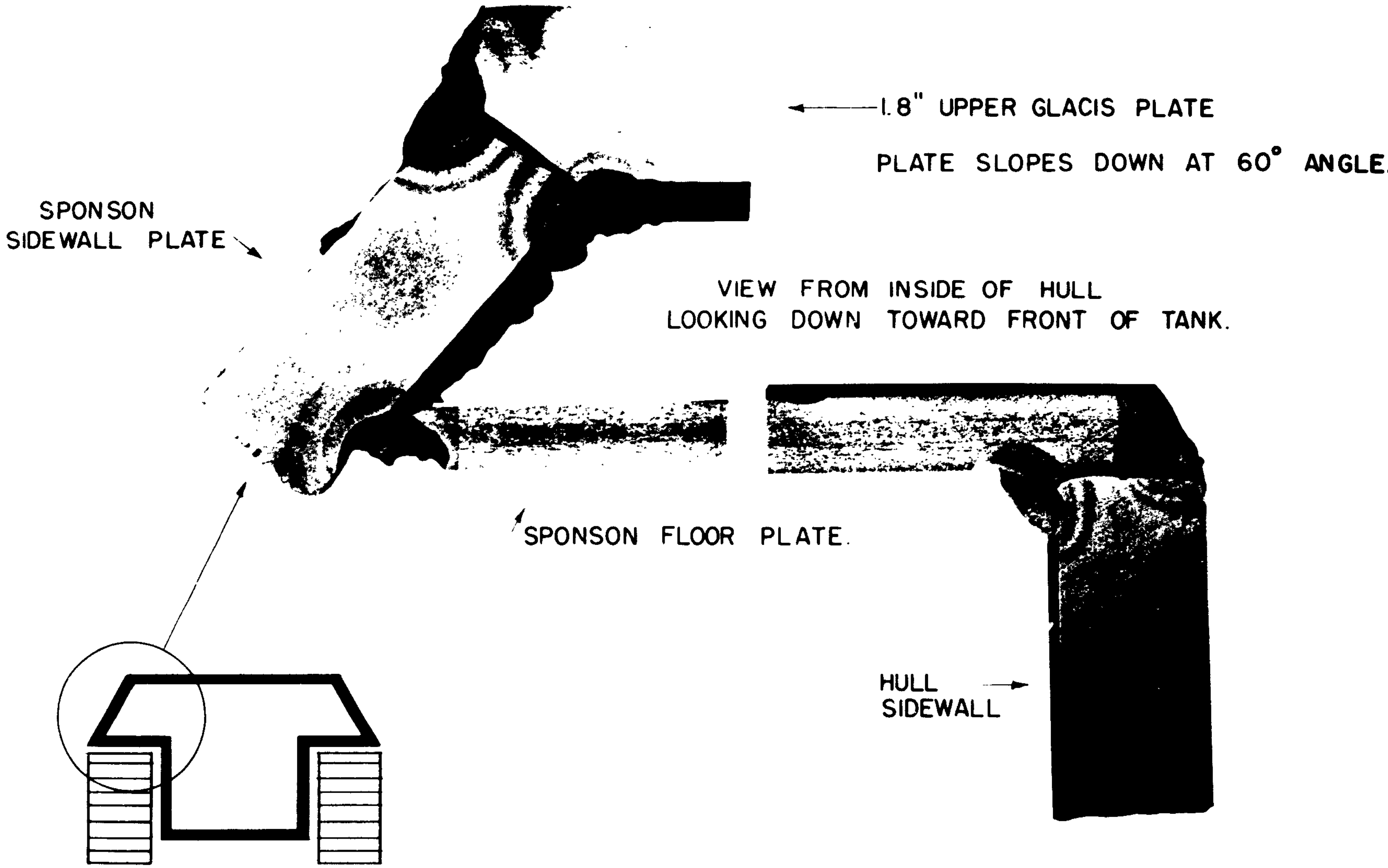
WTN.710-3136



WELDED SECTION OF HULL OF RUSSIAN T-34 TANK.

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FIGURE 4

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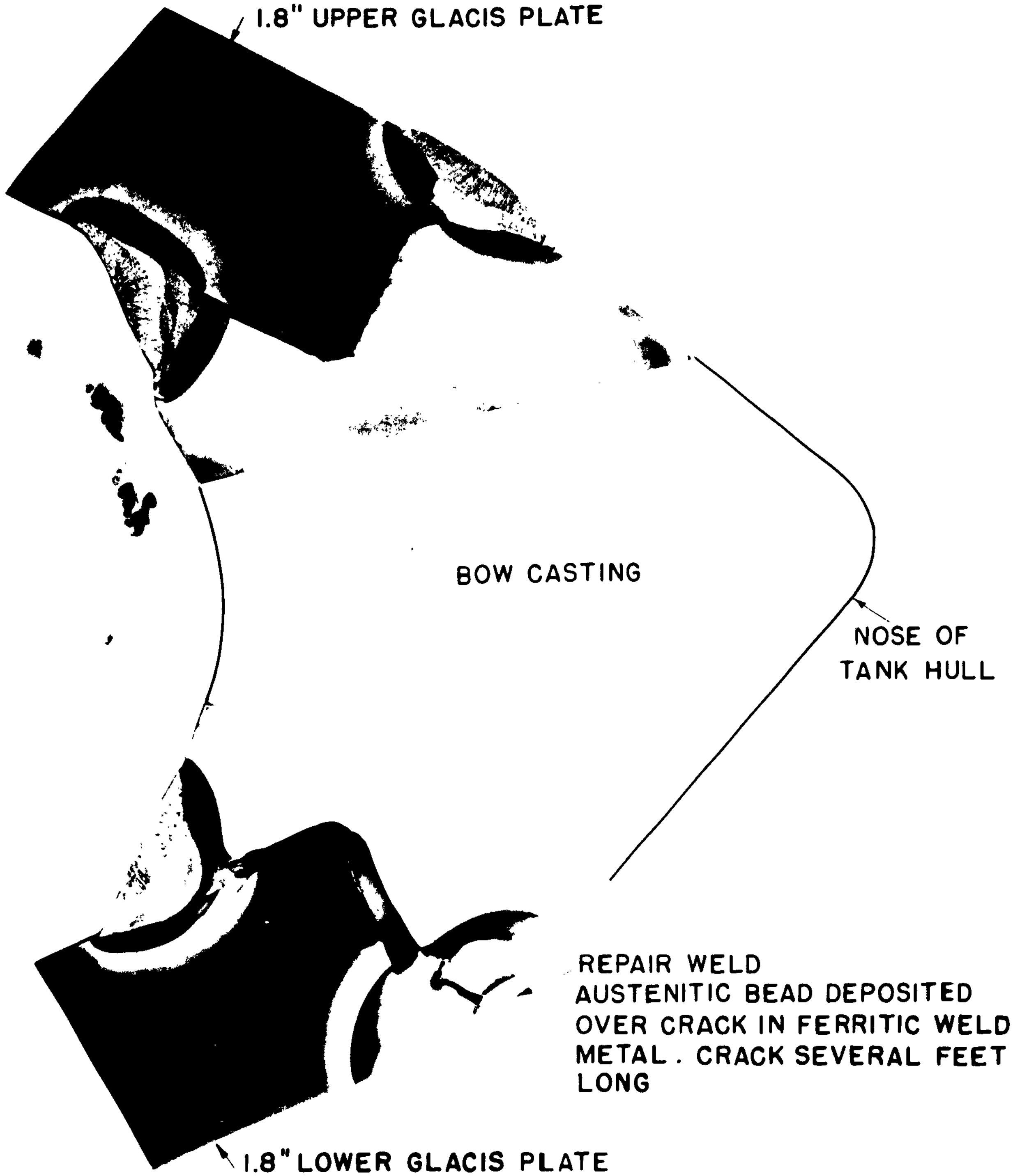
WTN.710-3135



WELDS AND WELD REPAIR
IN SOVIET T-34 TANK

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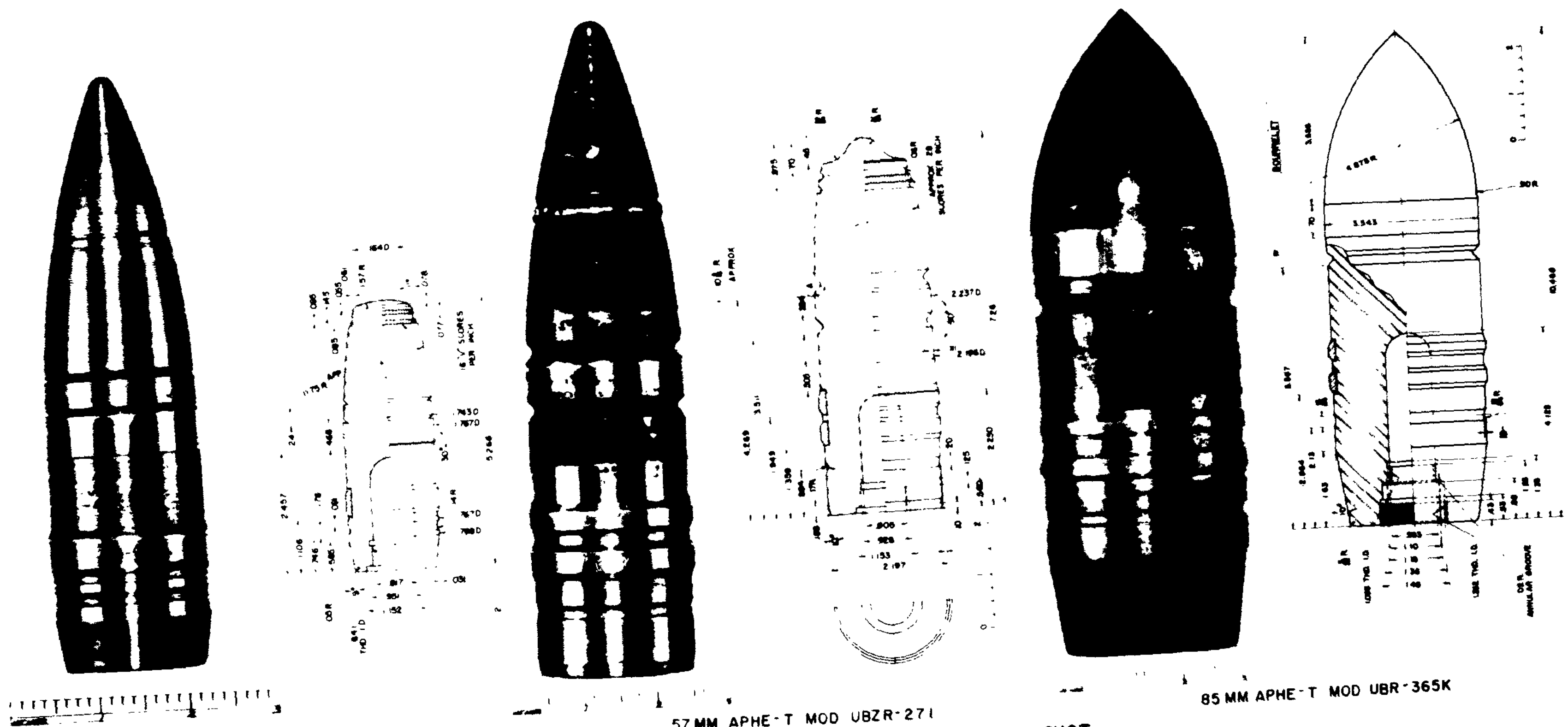
WTN. 710-3137 SECRET - SECURITY INFORMATION FIGURE 5



45MM APHE-T MOD. UBR-243Z

57 MM APHE-T MOD UBZR-271

85 MM APHE-T MOD UBR-365K

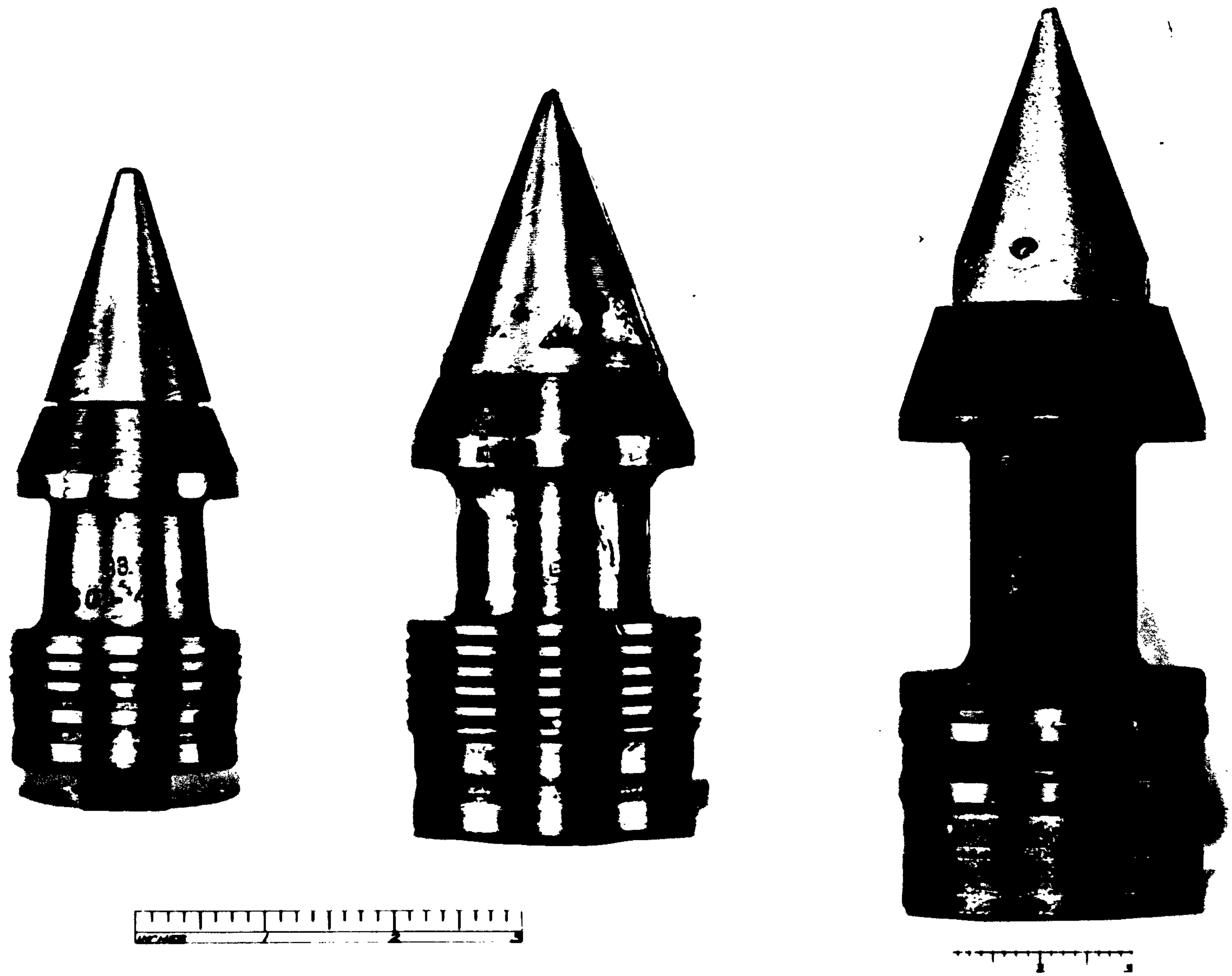
SOVIET 45 MM, 57 MM, AND 85 MM ARMOR-PIERCING SHOT

W A T E R T O W N   A R S E N A L   L A B O R A T O R Y

WTN.71C-3140

SECRET - SECURITY INFORMATION

FIGURE 6



45 MM HVAP-T MOD. UBR-243P   57 MM HVAP-T MOD. 271P   85MM HVAP-T MOD. UBR-365P

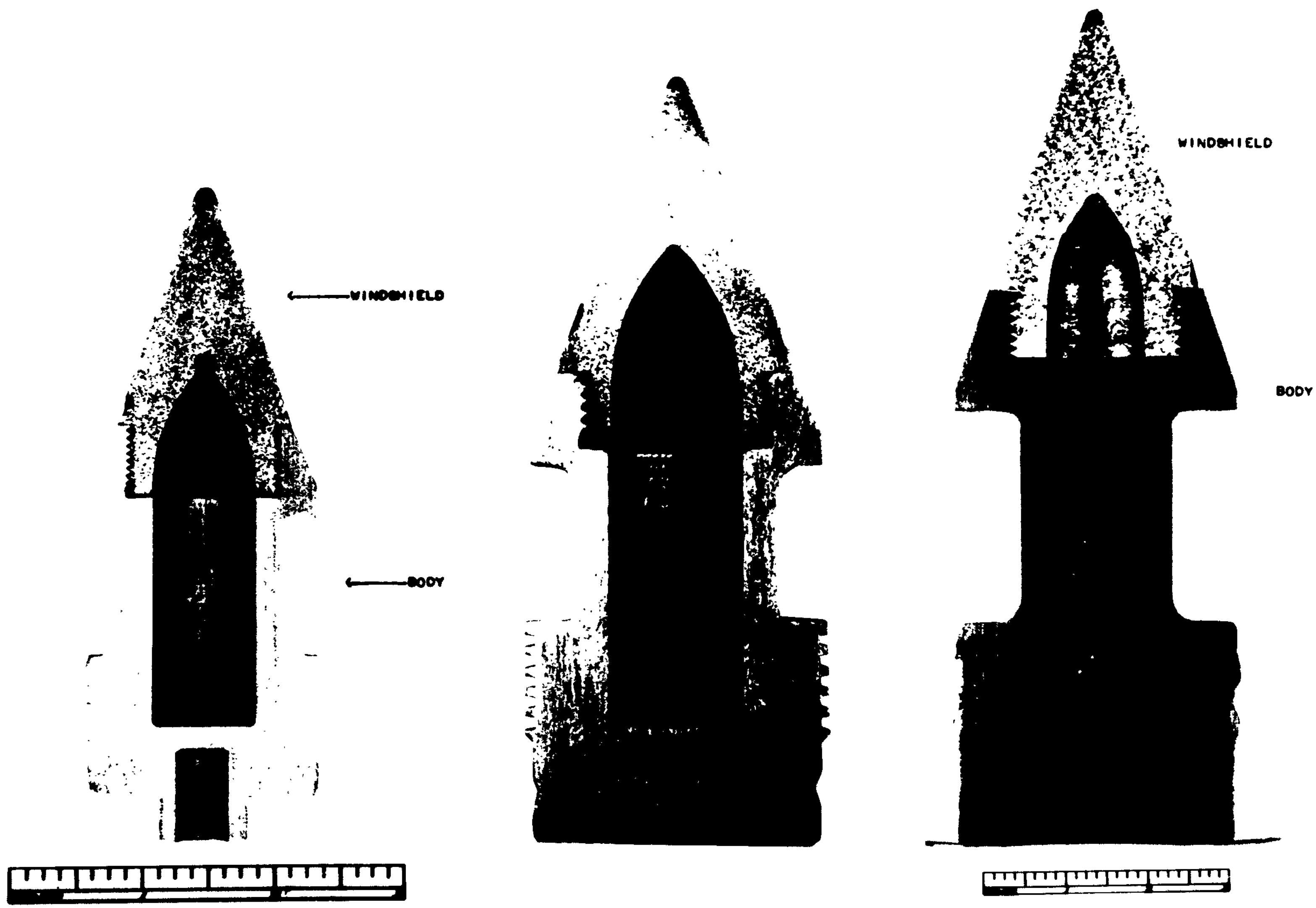
SOVIET HVAP PROJECTILES

WATERTOWN ARSENAL LABORATORY

FIGURE 7

SECRET – SECURITY INFORMATION

WTN.710-3139

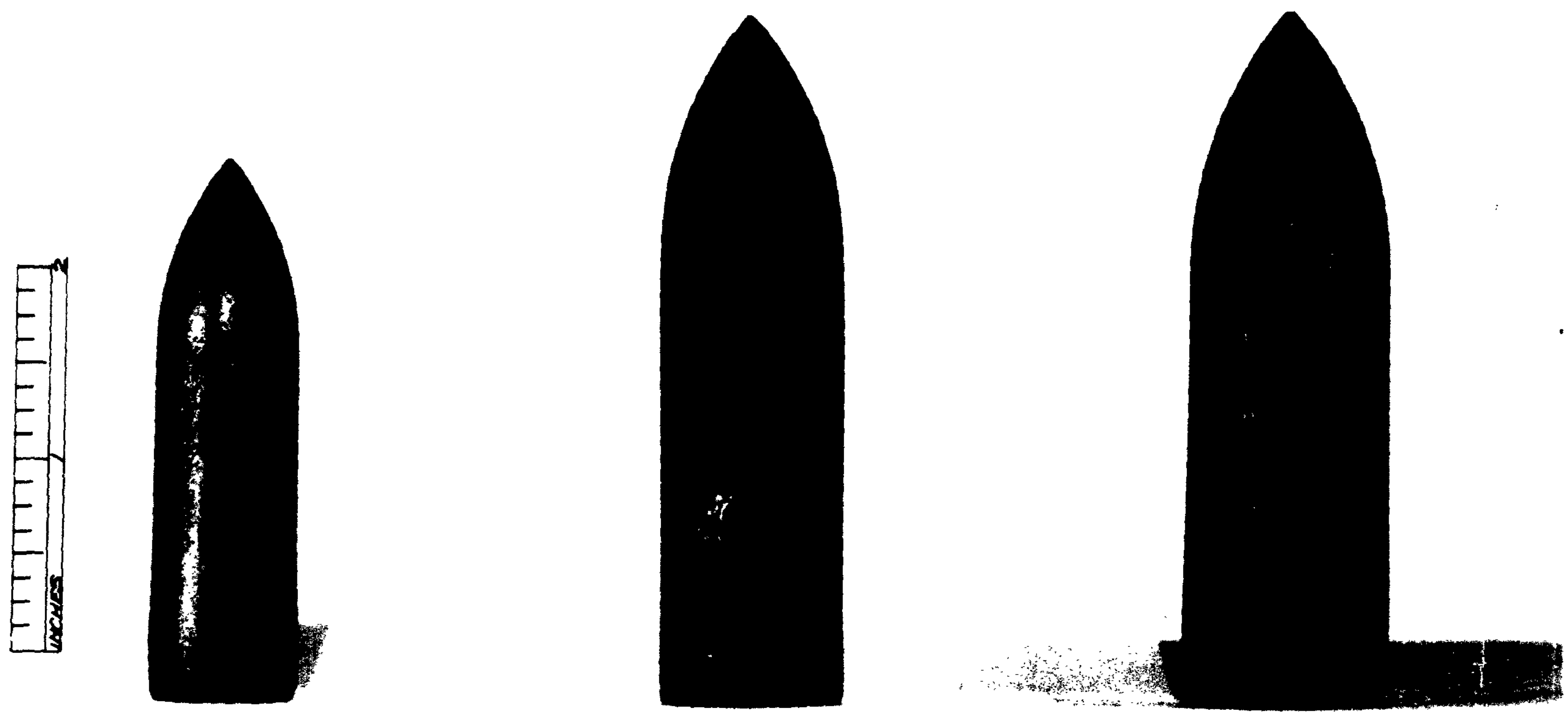


45 MM HVAP-T MOD UBR-243P   57 MM HVAP-T MOD. 271P   85 MM HVAP-T MOD. UBR-365P

MACROETCHED CROSS-SECTIONS OF SOVIET HVAP PROJECTILES
SHOWING SIZES OF TUNGSTEN CARBIDE CORES

WATERTOWN ARSENAL LABORATORY

FIGURE 8   SECRET – SECURITY INFORMATION   WTN.710-3138



TUNGSTEN CARBIDE CORE FROM SOVIET 45MM HVAP-T MOD. UBR-243P PROJECTILE.

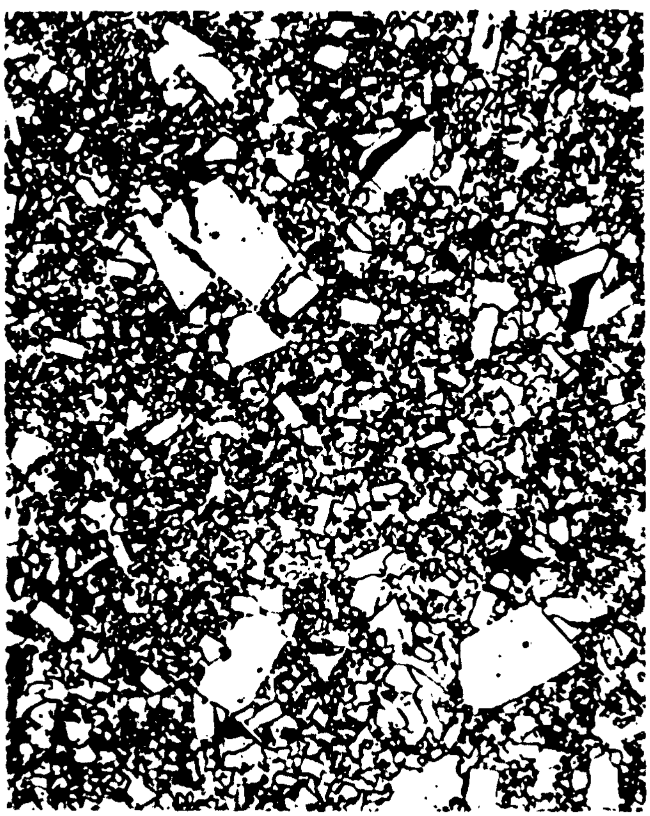
TUNGSTEN CARBIDE CORE FROM SOVIET 57MM HVAP-T MOD. UBR-271P PROJECTILE.

TUNGSTEN CARBIDE CORE FROM SOVIET 85MM HVAP-T MOD. UBR-365P PROJECTILE.

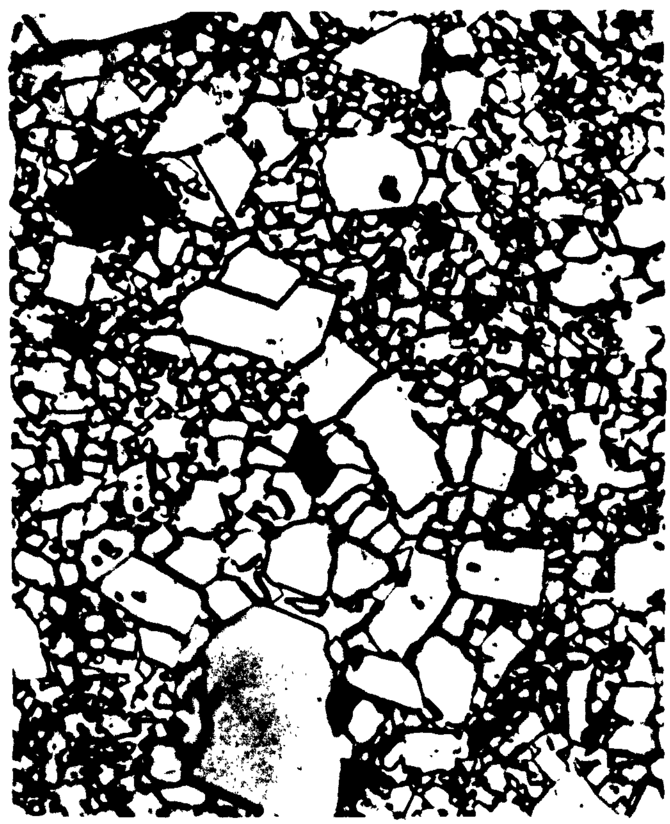
W A T E R T O W N   A R S E N A L   L A B O R A T O R Y

FIGURE 9 SECRET – SECURITY INFORMATION WTN.751-1950

3A



3B



3C

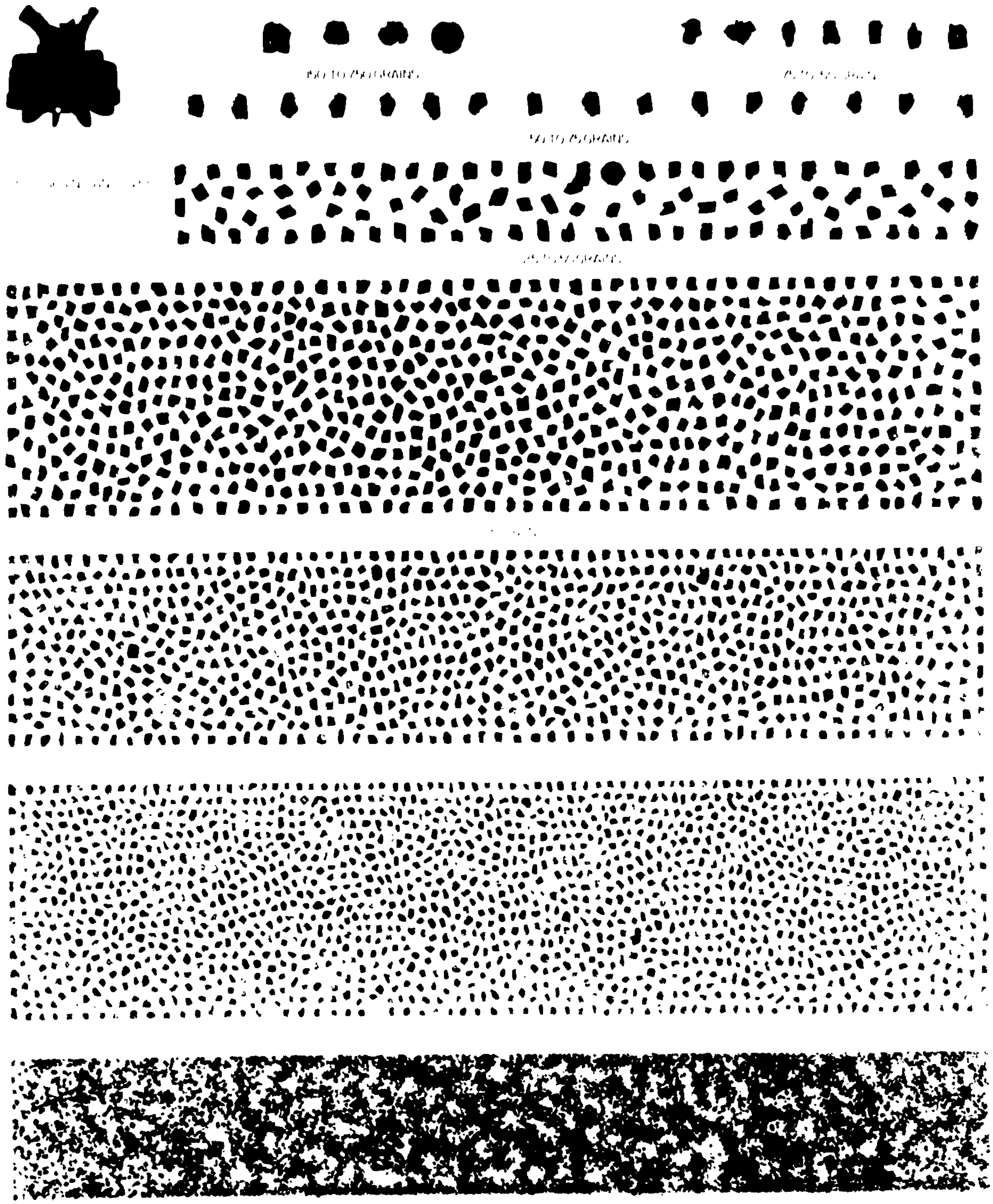
W A T E R T O W N   A R S E N A L   L A B O R A T O R Y

CEMENTED CARBIDE CORE FROM SOVIET 76.2 MM HVAP SHOT – PHOTOMICROGRAPHS OF CORE NO. PM243-3

WTN.639-10,955

SECRET – SECURITY INFORMATION

FIGURE 10



UNFRAGMENTED SHELL

WATERTOWN ARSENAL LABORATORY

SECRET – SECURITY INFORMATION

WTN.639-11,692

FIGURE 11