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ARMY MATERIEL COMMAND

U.S. ARMY
FOREIGN SCIENCE AND TECHNOLOGY CENTER

MODERN ARTILLERY

by

A. N. Latukhin

COUNTRY: USSR

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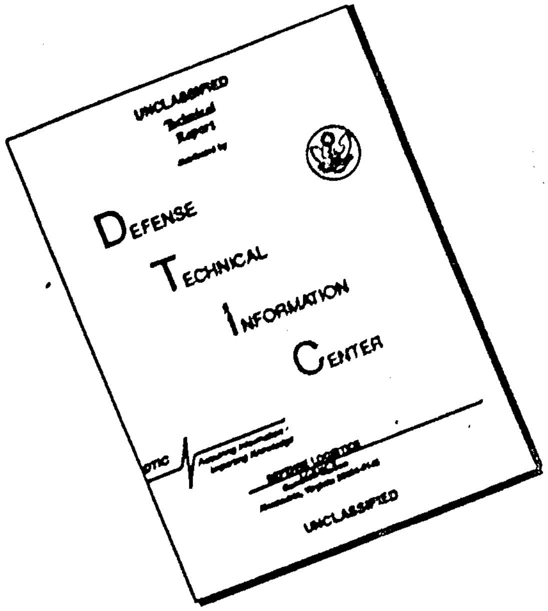

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13. ABSTRACT

Soviet Armed Forces have at their disposal first-rate artillery weapons and artillery cadres that are experienced and devoted to their country. Together with the armies of the other socialist countries they vigilantly guard the peace.

The Soviets tirelessly increase their combat expertise and persistently master their weapons and combat materiel.

In artillery chasti a persistent effort is under way to increase the number of experts in combat and political training, as well as outstanding gun crews, otdeleniya and podrazdeleniya, class-room specialists. Personnel master allied specialties since in modern battle interchangeability of piece crew members is of paramount importance for all artillery combat activity.

The results of exercises, field firing and all-army artillery contests of recent years show the growing tactical, technical and fire training of the troops.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Artillery weapon R and D						
Ammunition						
Field Gun						
Rocket						
Weapon						
Combat vehicle						
Antiaircraft weapon						
Ordnance Production						
Artillery Tactic						
Antitank Missile						
Antiairdraft Defense						
Artillery Weapon Specification						
Armored Warfare						
Artillery Fire Control System						
Weapon Performance						
Projectile						
Gun Component						
Weapon Fuze						
Artillery Rocket Launcher						
Military Tanl						
Armed Helicopter						
Multipurpose Weapon						
Artillery Survey						
Optic Equipment						
Angle Measuring Instrument						
Computer Application						
Distance Measuring Equipment						
Detection Equipment						
Meteorologic Data						
Night Warfare						
IR Detection Equipment						
Radar System						
Fire Control Equipment						
Range Finder						
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Sovremennaya Artilleriya (Modern Artillery)
by A. N. Latukhin. Moscow: Military Publishing House of the Ministry of Defense
USSR, 1970, 320 pp.

The book considers problems in the development of modern artillery, shows the purpose, combat characteristics and construction principles of modern examples of artillery weapons and ammunition, gives a classification of them and their basic tactical-technical data, and gives an account of the questions involved in artillery instrumentation.

The book also acquaints the reader with the basic trends in further development of artillery weapons.

Factual and numerical data included in the book are taken from the Soviet and foreign public press, and prospects for the development of artillery are set forth in accordance with the views of foreign specialists.

The book is intended for the wide circle of readers interested in artillery weapons.

PREFACE

P. N. Kuleshov, Marshal of Artillery

Artillery was long the main striking fire power of decisive significance in combat operations on land and sea. The situation remained thus until the end of World War II.

With the appearance during the postwar period of rocket nuclear weapons, especially tactical and operational-tactical weapons permitting a sharp increase in the depth and force of fire action against the enemy, military specialists in a number of countries began to consider artillery an antiquated and cumbersome means of combat. However, such views have not stood the test of time. Further improvement of tactical rocket weapons and analysis of their combat capabilities have shown that they cannot be employed to perform all the fire missions previously entrusted to artillery. It has been found, for example, that the use of rocket nuclear weapons is practical only against large-sized and strategically important targets.

In recent years the attention paid abroad to questions of improving and developing artillery weapons has increased. This is due to the adoption in the United States and other NATO countries of the military concept of so-called "flexible reaction" and limited local wars. Foreign specialists believe that in comparison with tactical rocket weapons artillery possesses considerably greater precision of fire. It can deliver fire on the enemy without exposing advanced friendly troops to danger. In addition, cannon-type artillery is simpler in construction and more reliable in operation, while mastery of artillery technique presents no special difficulties.

The development of offensive and defensive weapons under modern conditions has led to a clearcut separation of the functional duties of missiles and artillery in the performance of common combat missions.

A traditional type of weapon, artillery in our day occupies a firm place in the armament system of modern armies.

Artillery is rightly regarded as the most reliable, fastest, most flexible and economical fire weapon for influencing the course and outcome of battle.

What has happened to artillery today? The answer can be found in A. N. Latukhin's book Sovremennaya Artilleriya (Modern Artillery).

The reader will find here a great deal of useful information about modern towed and auxiliary propelled guns, self-propelled artillery and recoilless guns, mortars and salvo-fire field rocket artillery, the artillery armament of tanks, aircraft and the navy. The book will also give a familiarity with various types of ammunition used for gunnery and with artillery instrumentation.

The popular treatment of a wide range of questions relating to the artillery weapons of our day will doubtless find an interested reading public made up of soldiers and officers, young civilians preparing to join the ranks of the glorious Soviet Armed Forces, veterans of the Great Patriotic War, and all who want to enlarge or update their knowledge in the field of artillery weapons.

INTRODUCTION

The literature has not cast much light during the past decade on questions of artillery development.

To a certain extent this has been the consequence of an overevaluation of the role of missiles during the period of rapid development of this type of weapon. At the same time experience has shown that the rocket weapon and artillery do not exclude, but mutually complement each other. Artillery has continued to develop, using the latest achievements of scientific and technical thought, and has acquired new characteristics. Auxiliary-propelled and self-propelled artillery, differing from that employed during World War II, have appeared. Developments of light-duty field guns are under way. Something new has appeared in ammunition (combustible shell cases, rocket-assisted projectiles, shells with ready-made elements etc.). The rapid development of electronics has contributed much that is new to artillery instrumentation (electronic computers to prepare initial firing data, laser range finders, radar devices for target acquisition etc.).

At present there is in the literature no generalizing work in print about modern artillery. However, the importance of covering this subject is obvious from the foregoing.

The book offered here is devoted to modern artillery weapons. It considers combat and operating characteristics of pieces, classification of artillery and the fundamental principles of construction of numerous types of artillery weapons and ammunition, instruments and apparatus employed to support artillery firing, and shows the basic trends in the further development and improvement of artillery weapons. The construction of certain specific weapon models is illustrated by the example of foreign artillery systems.

The state-of-the-art of armament and combat materiel is in many respects dependent on the level of development of science and technology in a given country, on the skills of engineers, designers and workers. The development of artillery weapons is itself a complex creative process. General theoretical principles can be properly applied under specific conditions only when newly emerging factors and conflicting trends that objectively are evolving are carefully weighed. Some of these trends are becoming stronger, others are losing strength. What yesterday was of a progressive character may today be depleted of its significance, thus preparing conditions for the emergence and development of new ways of creating armament and combat materiel. What is progressive today may tomorrow prove to be a bygone stage. In order to give full range to the new and indeed progressive, all these circumstances must be duly borne in mind.

The new armament is material proof of scientific and technical progress attained as a result of the development of theory and experience over many years. Years of research and development precede the emergence of new artillery weapons. Then comes a protracted period of tests of a new model, finishing touches on it and further improvement. No wonder it is said that the first generation of arms lives in the troops, the second in firing ground tests, the third in experimental workshops, the fourth in blueprints, while the fifth gestates in the minds of scientists and designers and is adumbrated in service requirements.

Owing to the tireless concern of the Communist Party and Soviet Government our Armed Forces have at their disposal first-rate artillery weapons and artillery cadres that are experienced and devoted to their country. Together with the armies of the other socialist countries they vigilantly guard the peace.

The author conveys his sincere gratitude to Yu. V. Chuyev, State Prize Winner, Doctor of Technical Sciences, Professor and Major General of the Engineering and Technical Service, for his valuable advice during preparation of the book for publication.

Chapter I

HISTORY OF THE DEVELOPMENT OF SOVIET ARTILLERY

1. Development of Artillery 1918-1941

The mighty Soviet artillery in its development inherited the best traditions of the valiant Russian artillery, which had a great history and instructive combat experience. Many times over the span of six centuries Russian artillerymen pounded the enemies of our country.

Significant contributions to the development of artillery have been made by the outstanding and world-famed Soviet scientists N. V. Maiyevskiy, N. A. Zabudskiy, A. D. Zasyadko, K. I. Konstantinov, A. V. Gadolin, A. P. Engel'gardt, D. K. Chernov, R. A. Durlyakhov, and many others.

Russian artillerymen were the first in the world to invent and create rifled rapid-fire guns, field and heavy artillery, combat missiles, mortars and other types of artillery ordnance. Russian gunners were long regarded as excellent masters of accurate fire.

Before the Great October Revolution conditions were unfavorable for the development of artillery. The backward industry of Tsarist Russia, the conservatism of its ruling clique and the servility of its officials towards everything foreign prevented realization in full measure of the technical innovations in the field of artillery weapons suggested by native artillery scientists. The situation changed sharply only after the Great October Socialist Revolution.

From the first days of Soviet power the Communist Party and V. I. Lenin attached tremendous significance to the development and improvement of artillery.

On V. I. Lenin's instruction all armament left by the old army was strictly inventoried and repaired. Directing the combat activity of the fronts, V. I. Lenin was ever concerned that they should be supplied with armament although practical solution of this question in those years entailed great difficulties.

The old Russian army on the eve of the October Revolution had only 10,200 pieces of various calibers. However, not even this number of pieces could be used since most of them were captured by the Germans at the beginning of 1918 or remained on territory occupied by the interventionists and White Guards. Industry, which was in a state of complete collapse, was unable to give the army the necessary amount of arms.

Under these exceedingly difficult conditions our party and government solved the problem of setting up artillery production and supply for the Red Army. Production of guns was started at the Putilovskiy, Obukhov , Sormovskiy and Perm' munitions plants.

In combat with the foreign interventionists the Red Army made successful use of the few models of artillery weapons left by the Tsarist Army. They included the 76-mm gun M1902, 107-mm gun M1910, 122-mm light howitzer M1910, 152-mm heavy howitzer M1909, and 76-mm antiaircraft gun M1915 (F. F. Lender's gun).

A striking example of Communist Party concern for the development of armament was V. I. Lenin's historic visit on 18 June 1920 to the Artillery Committee of the Main Artillery Administration. As busy as he was, he had found time to acquaint himself with the antiaircraft fire adjuster suggested by Bol'shevik inventor A. M. Ignat'yev. A. M. Gor'kiy, who accompanied V. I. Lenin, testifies that Vladimir Il'ich after listening attentively to explanations began to put questions to the inventor and Artillery Committee members about the construction and action of the instrument. The artillery scientists were amazed at Vladimir Il'ich's profound knowledge of military affairs and his extraordinary ability to grasp speedily and in detail the model that was presented.

During this period a Special Artillery Experiment Commission, presided over by famous ballistics expert and designer V. M. Trofimov, was set up in the Artillery Committee of the Main Artillery Administration. It was charged with the task of conducting scientific research and experimental work in all fields of artillery science and ordnance. Active participants in the work of this commission were such scientists as Academicians A. N. Krylov and P. P. Lazarev, Professors N. Ye. Zhukovskiy, S. A. Chaplygin, N. F. Drozdov, G. A. Zabudskiy, S. G. Petrovich and many others. From 1918 to 1924 alone staff members of the commission performed about 100 scientific-research and experimental-design projects and authored 141 scientific works. Scientifically founded ways of developing new artillery weapons were determined in accordance with the results of the commission's work. A beginning was made in founding the Soviet scientific school of ballistics scientists and artillery designers.

The development of Soviet armament proceeded in close association with the development of the economy and the growth and strengthening of our Armed Forces on the basis of the first achievements of the socialist regime.

At the end of the civil war a modest and feasible problem was solved during the reconstruction of the national economy, namely setting to rights and improving the combat materiel inherited from the old Tsarist army. The best models of pieces were selected from the arsenal of weapons of the old army and put into service for the combat training of the young Red Army (period of "small-scale modernization" of the artillery).

During this period intensive preparation was made for the creation of new models of weapons which in their combat and technical characteristics could meet increased requirements. At the same time, use was made of new methods and data obtained as a result of theoretical and experimental investigations.

The first new model of an artillery weapon created by Soviet designers was the 76-mm regimental gun M1927.

During the years of the first five-year plan "large-scale modernization" of the basic models of our artillery pieces was accomplished. It was possible to solve successfully the principal modernization tasks, viz. an increase of 15-50 percent in maximum effective range, improvement in precision of fire, and an increase in weapon mobility. This was achieved by lengthening the barrels, increasing the weight of powder charges, improving the ballistics characteristics of the projectile, and by transferring guns from wooden wheels to metal ones with rubber tires.

Apart from the modernization of old systems, new models of artillery pieces were also created. In February 1931 by order of the Revolutionary War Council the 37-mm antitank gun M1930 -- the first special antitank gun in our artillery -- was adopted for service in the Red Army, and in 1932 the more powerful 45-mm antitank gun M1932. During the years of the first five-year plan our Armed Forces obtained such powerful weapons as the 122-mm gun M1931 and the 203-mm howitzer M1931.

If the preceding period was in the main a period of artillery modernization, 1933-1940 is rightly considered a period in which the artillery was completely reequipped with new materiel and ammunition.

Successfully developed, tested and adopted for service during this brief period were such field artillery models as the 45-mm gun M1937, 76-mm mountain gun M1937, 76-mm mountain gun M1938, 76-mm division guns M1936 and M1939, 107-mm gun M1940, 122-mm and 152-mm howitzers M1938, 122-mm gun M1931/37 and 152-mm gun-howitzer M1937, 152-mm gun M1935, 210-mm gun M1939, 280-mm mortar M1939 and 305-mm howitzer M1939.

The 45-mm gun M1934 and 76-mm casemate gun M1940 were created for service in fortified regions.

The antiaircraft artillery obtained the 25-mm automatic cannon M1940, 37-mm automatic cannon M1939, 76-mm cannon M1938 and 85-mm cannon M1939.

Figure 1. 122-mm howitzer M1938.

The new models were not inferior in their performance to the best models of the analogous class of artillery of foreign armies, while the 122-mm howitzer M1938 (Figure 1), 122-mm howitzer M1931/37 and 152-mm gun-howitzer M1937 (Figure 2) were in many respects superior.

Figure 2. 152-mm gun-howitzer M1937.

The creation of Soviet mortars was an event of fundamental importance for our army during the prewar years. Adopted for service were the 50-mm company mortars M1938 and 1940, 82-mm battalion mortars M 1937, 107-mm mountain pack mortars M1938 and 120-mm regimental mortars M1938.

During these same years new ammunition of varying purpose was developed and put into series production (projectiles, mortar shells, charges, fuzes). The troops obtained more highly improved observation and fire control equipment, as well as topogeodetic survey instruments and artillery instrumental observation devices, which made possible full utilization of the combat capabilities of artillery pieces and mortars. Radio communication facilities were introduced into the artillery.

The necessary measures were taken for artillery motorization. Thus, as early as the second five-year plan the changeover of horse-drawn corps and heavy artillery to mechanical traction was started. The artillery began to receive "Komsomolets" (light), "Komintern" (medium) and "Voroshilovets" (heavy) tracklaying prime movers, as well as STZ-3, STZ-5, S-60, S-65 and other tractors designed for the national economy.

The organizational structure of the artillery was also improved. Thus, whereas at the beginning of the 1920's it was subdivided into division and special-purpose heavy artillery, in the 1930's we already had battalion, regimental, division, corps and general reserve artillery.

On the eve of the Great Patriotic War a formidable new weapon (Figure 3) -- salvo-fire field rocket artillery ("Katyushas") -- was created in the Soviet Union for the first time in the world.

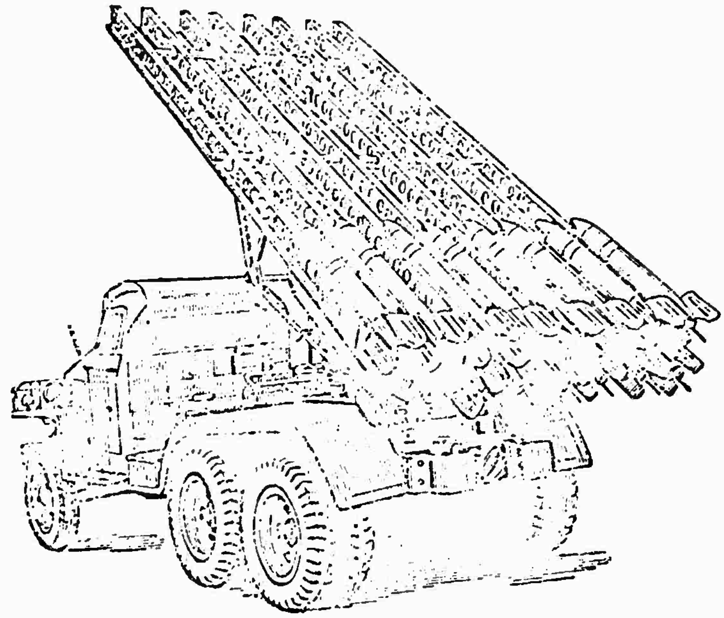

Figure 3. Rocket-artillery combat vehicle BM-13.

Antiaircraft artillery was provided with new antiaircraft directors, as well as two- or four-meter telescopic range finders.

The first Soviet radar models of the type RIS-B-2, RIS-B-3 (search radar) and RUS-2 (air-search radar) began to come into service.

New weapons gave an impetus to further development of artillery tactics. On the eve of the war artillery regulations, manuals and instructions were published. Among the special works on the combat employment of artillery Artilleriya v Osnovnykh Vidakh Boya (Artillery in the Basic Types of Combat) under the general editorship of V. D. Grendal' (1940) and Taktika Artillerii (Artillery Tactics) under the general editorship of A. K. Sivkov (1941) were considered the principal ones.

The Soviet combined-arms and artillery regulations and manuals at the beginning of the 1930's set forth views, progressive for the time, on the combat employment of artillery: massing in most important directions in close coordination with other arms of the service; surprise opening of fire; creation of temporary artillery groups during combat and their decisive employment in counterbattery and antitank fire; organization of reliable artillery reconnaissance of all kinds and of continuous signal communication.

By this time there had grown up in our country remarkable cadres of artillerymen -- scientists, designers, engineers, commanders.

An invaluable role in the development of Soviet armament was played by the major works of Academician A. A. Blagonravov, Professors

Ye. A. Berkalov, M. F. Vasil'yev, D. A. Venttsel', I. P. Grave, N. F. Drozdov, B. N. Okunev, G. V. Oppokov, M. Ye. Serebryakov, V. Ye. Slukhotskiy, K. K. Snitko and many others.

Important contributions to the development of effective techniques of ground and antiaircraft artillery fire were made by the famous artillery scientists P. A. Gel'vikh, V. G. D'yakonov, G. I. Blinov, P. M. Prokhorov, S. N. Kapustin et al.

Successful fulfillment of the plan of socialist industrialization made possible the creation of a mighty defense industry capable of producing all types of artillery weapons. This is graphically indicated by the significant increase in the number of guns of all systems in our army, especially during the years of the prewar five-year plans (Table 1).

Table 1

GROWTH IN THE NUMBER OF GUNS OF ALL SYSTEMS (1917-1941)

Date	Number of guns
October 1917	About 40*
End 1918	About 1700
1 May 1919	2,300
End 1920	3,000
1 October 1928	8,600
1 January 1932	14,000
1 May 1933	15,000
1 January 1934	17,000
1 January 1939	55,790
22 June 1941	67,335**

2. Artillery during the Great Patriotic War and Its Postwar Development

The Great Patriotic War was a grim testing of our artillery. The armed struggle took place under conditions initially extremely disadvantageous for us.

The German-Fascist command, setting their hopes on a "Blitzkrieg," were betting mainly on their highly mobile tank and motorized forces, supported by large forces of aviation.

A fierce struggle was waged against Hitlerite tanks by all arms of the service -- infantry, tanks, aircraft and combat engineers. The main brunt of this struggle, however, fell on the shoulders of artillerymen, on special artillery antitank podrazdeleniya, chasti and soyedineniya.

*In Red Guard detachments.

**Excluding 50-mm mortars, which numbered about 24,200.

Warfare with enemy tanks required of Soviet artillerymen constant readiness, high combat skill, exceptional stamina, endurance, coolness and valor in battle. They had to have the courage to approach Fascist tanks at close range and then fire pointblank at them from the guns.

In the very first engagements artillery heroes were born, dread destroyers of Fascist tanks, whose feats inspired our fighting men to martial deeds for the glory of the fatherland. The heroism of Soviet artillerymen was unparalleled. By fire they smashed breaches through encirclement and covered the passage of friendly infantry, often losing any opportunity of withdrawing with them due to the loss of means of traction and the exhaustion of ammunition. They fought to the last shell and often perished under the tracks of the tanks, but they did not abandon any combat positions.

Thousands of Fascist tanks were wiped out by our guns by direct fire during attacks, by massed artillery fire from concealed positions at points of concentration, on the march and on initial lines prior to attack. This is what happened in the environs of Kiev and Odessa, near Moscow and Leningrad, at the walls of Sevastopol' and Stalingrad.

Soviet artillerymen fought heroically too in the battle of Kursk. The German Fascist command counted on achieving success in this engagement by using new, more powerful tanks and self-propelled guns. However, the much-praised enemy "Tigers," "Ferdinands" and "Panthers" did not help. With precise rounds our valiant artillerymen turned them into heaps of scrap metal.

In all, during the war years the accurate fire of our artillery annihilated tens of thousands of Fascist tanks.

In the crucible of war the skill of the artillerymen grew from day to day, as did the influence of artillery on the course and outcome of operations. The artillery consolidated its role as the main fire and striking power of the Soviet Army and became a veritable "god of war." As a token of gratitude for the great combat services of the artillery in defense of the fatherland the Nineteenth of November has become a tradional holiday -- Artillery Day -- in memory of the heroic feat of the artillerymen in the Battle of Stalingrad, which began the radical change in the course of the Great Patriotic War and of World War II as a whole.

On the defense, artillery was the principal means of combating the enemy's tanks, his fire weapons and manpower. On the offensive, mighty artillery fire cleared a way forward for our troops, and as a result they speedily overcame echeloned defense in depth, successfully repelled enemy counterblows and counterattacks.

During the war not only methods of artillery employment, but also qualitative characteristics of artillery weapons constantly improved. The troops received a sufficient quantity of first-rate pieces and ammunition. This permitted the massing of artillery fire in decisive directions on a hitherto unparalleled scale.

The power and might of Soviet artillery are indicated by figures such as the following. Whereas the counteroffensive of our forces was backed up by 7,985 guns, mortars and field rocket launchers in the environs of Moscow and by 14,200 in the Battle of Stalingrad, already 34,500 guns, mortars and field rocket launchers took part in the Kursk operation, and in the Berlin operation which concluded the war an entire avalanche of fire from 41,600 artillery systems was hailed upon the enemy.

The fire of such large masses of artillery enabled our forces successfully to smash any enemy defense lines, negotiate any water barriers encountered, put mobile forces into a gap and back up their action in operational depth of defense, surround and destroy large enemy groupings and victoriously assault cities and fortresses. Participants in the war remember how devastating artillery preparation before an attack always aroused in our soldiers and officers a feeling of admiration for the might of Soviet arms and inspired them with confidence of success in battle.

Experienced artillery commanders were required to direct vast masses of artillery on battlefields. Our party trained a whole constellation of talented artillerymen. These included Chief Marshals of Artillery N. N. Voronov and M. I. Nedelin, Marshals of Artillery V. I. Kazakov, P. N. Kuleshov, G. F. Odintsov, N. D. Yakovlev, M. N. Chistyakov, K. P. Kazakov, Yu. P. Bazhanov, many generals and officers.

In close cooperation with valiant infantrymen, tankmen, flyers and fighting men of other arms of the service the glorious artillerymen with honor did their duty to the fatherland. For heroism on the battlefield during the past war, for diligence in combat and expert mastery of formidable weapons 515 artillery soyedineniya and chasti were made guards units, and about 800 were awarded the Order of the Soviet Union. The title Hero of the Soviet Union was conferred upon more than 1,800 combat artillerymen, and twice upon two of them, Afanasiy Petrovich Shilin and Vasiliy Stepanovich Petrov; 1,600,000 artillerymen were awarded orders and medals.

Development and improvement in the forms and tactics of conducting combat operations made more and more new demands on weapons in general and artillery in particular. Some models of artillery weapons became qualitatively obsolete. Consequently, artillery weapons had constantly to be improved and developed.

During the Great Patriotic War the following new antitank guns came into service: 45-mm gun M1942, 57-mm gun M1943 and 100-mm gun M1944 (Figure 4).

The 100-mm guns became a threat to the latest German "Tiger" and "Panther" tanks. They refuted the legend of the impenetrability of the Fascist armored monsters. Soviet fighting men had good reason to call these guns "Hunters."

Also adopted for service were the 76-mm regimental gun M1943, 76-mm division gun M1942 (Figure 5), 152-mm howitzer M1943 and 85-mm antiaircraft gun M1944 (Figure 6).

Participants in the Great Patriotic War well remember with what joy each new gun was received at the front, becoming a symbol of the indestructible link between the front and the rear, a symbol of the progressive character of our socialist industry and of our scientific and design thinking.

The significant enhancement of the combat characteristics of Soviet artillery is shown in Tables 2 and 3.

Table 2

CHANGE IN RANGE OF ORGANIC-ARTILLERY FIRE

A Артиллерийские орудия	B Максимальная дальность стрельбы в 1941 г., %	C Изменение максимальной дальности стрельбы к 1944 г., %
1 Батальонная пушка	100	187
2 Полковая пушка	100	181
3 Дивизионная пушка	100	150
4 Дивизионная гаубица	100	139

Keys:

A. Artillery weapons

1. Battalion gun
2. Regimental gun
3. Division gun
4. Division howitzer

B. Maximum range of fire in 1941, %

C. Change in maximum range of fire by 1944, %

Table 3

COMPARATIVE DATA ON ARMOR-PIERCING ABILITY OF GUNS AT RANGE OF 1000 m AND AT 60° ANGLE OF IMPACT WITH ARMOR (FROM THE NORMAL)

A Артиллерийские орудия	B Бронепробиваемость в 1941 г., %	C Изменение бронепробиваемости к 1944 г., %
1 Батальонная пушка	100	215
2 Полковая пушка	100	143
3 Дивизионная пушка	100	185

Keys:

A. Artillery weapons

1. Battalion gun
2. Regimental gun
3. Division gun

B. Armor-piercing ability in 1941, %

C. Change in armor-piercing ability by 1944, %

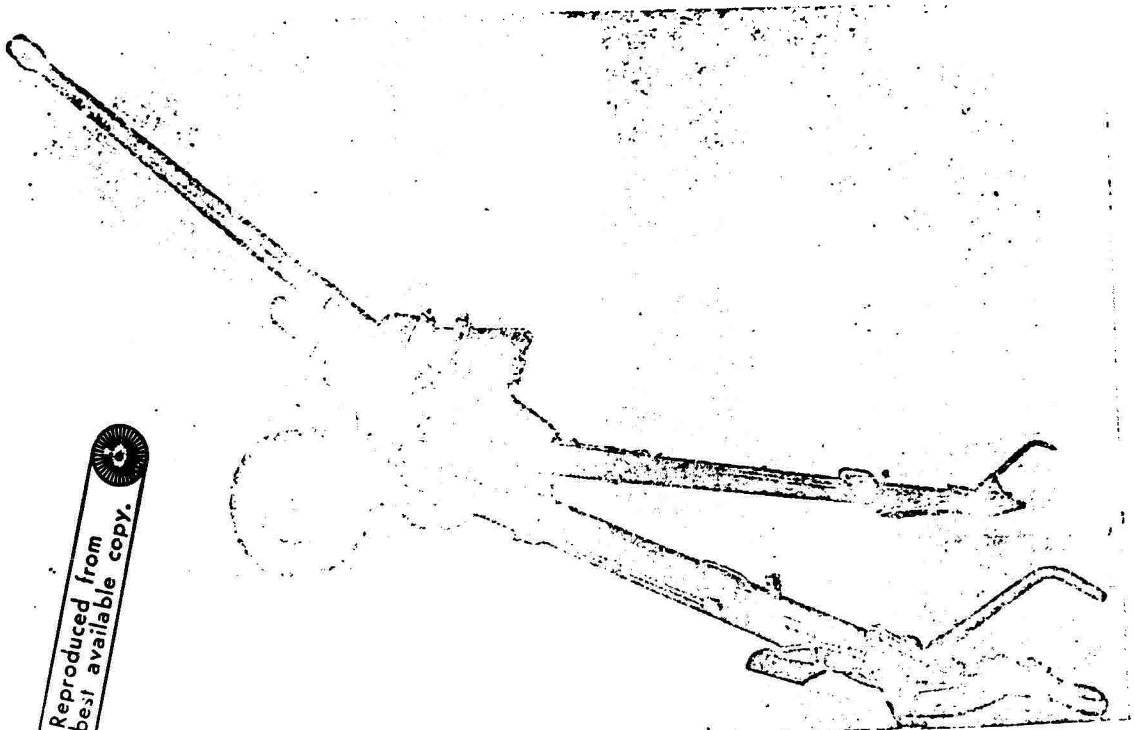

Figure 4. 100-mm field gun M1944.

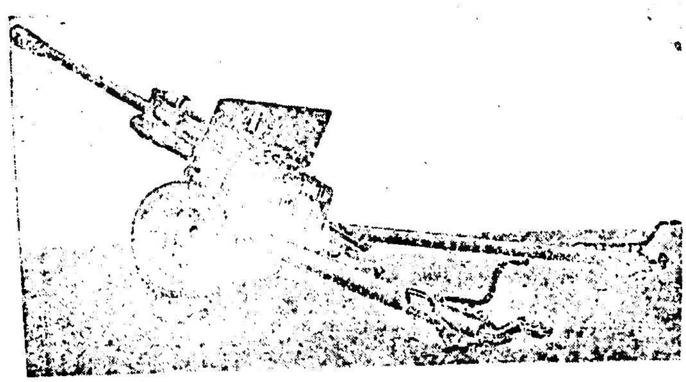

Figure 5. 76-mm division gun M1942.

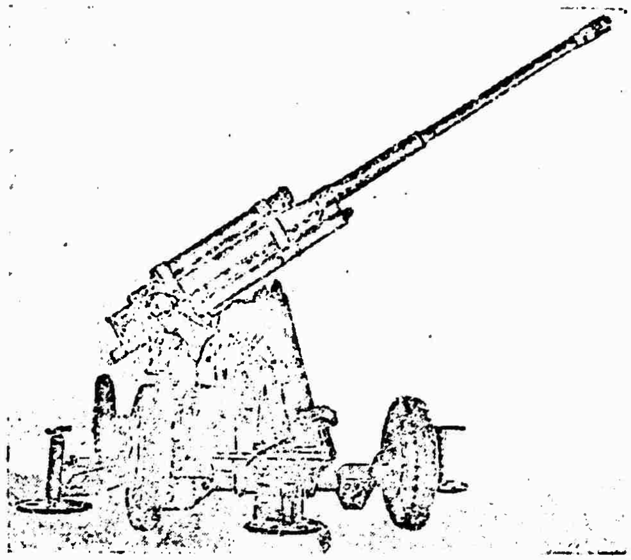

Figure 6. 85-mm antiaircraft gun M1944.

It should be emphasized that, in addition to antitank artillery, artillery of all calibers -- from light battalion artillery weapons to heavy army artillery pieces, and in some cases even general reserve artillery -- were used to combat enemy tanks and self-propelled guns. There were armor-piercing shells in the unit of fire of every artillery piece. In the course of the war subcaliber and shaped-charge antitank shells possessing especially great armor-piercing ability were created and widely used.

The enemy was obliged to acknowledge the high combat characteristics of our antitank weapons and their power, too. The German Fascist General F. Mellentin wrote, "The Russian infantry has good arms, especially a great many antitank weapons. Sometimes you would think there is an antitank rifle or an antitank gun for every infantryman. The Russians place these weapons very skillfully and there doesn't seem to be a spot where they are not to be found."*

The requirements of the front for the creation of ever more efficient weapons of antitank warfare were implemented not only by increasing the power of antitank and tank guns but also by creating a new type of weapon -- self-propelled artillery.

The characteristic feature of Soviet self-propelled artillery was the use of latest tank chassis and the employment of the most powerful artillery pieces. For example, our self-propelled guns were created on the basis of medium tank T-34 (SU-85, SU-100) and heavy tanks KV

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*F. Mellentin, Tankovyye Srazheniya 1939-1945 gg. (Tank Battles 1939-1945), Foreign Literature Press, 1957, p 246.

(SU-152) and IS (ISU-122, ISU-152). The caliber of Soviet self-propelled guns as a rule was a degree higher than that of the tank on whose chassis this piece was mounted. Thus, while the T-34 tank at first had a 76-mm gun, the self-propelled mount on the same chassis had an 85-mm gun; whereas in 1944 the T-34 tank was armed with an 85-mm gun, in the same year a 100-mm self-propelled mount SU-100 was created on the T-34 chassis. The IS heavy tank was successively armed with 85-mm and 122-mm guns, while the self-propelled mounts on the IS base had 122-mm and 152-mm pieces respectively (Figure 7).

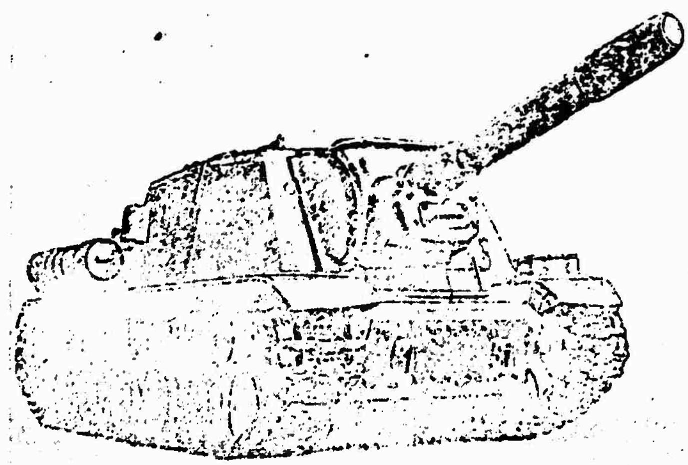


Figure 7. 152-mm self-propelled mount SU-152.

During the war years the 82-mm and 120-mm mortars M1941 and 1943 were adopted for service. They were essentially a modernization of good prewar mortars dictated by operational and production considerations. To make the bodies of mortar shells wide use was made of a less scarce material -- semisteel. This simplified the technology of mortar shell production and speeded up output.

In 1943 an important change in the characteristics of mortar weapons occurred. The 50-mm company mortars, which were not sufficiently effective in combat, were taken out of production, and the 160-mm mortar M1943 (Figure 8) was adopted for service. This mortar had no counterrecoil mechanism, and was distinguished by simplicity of construction, light weight, and ease of service. Loading was accomplished from the breech rather than from the muzzle.

The 160-mm mortars were a very effective offensive weapon and were highly rated by the troops. Reports from the front noted that these mortars were powerful weapons for the destruction of all kinds of field shelters, reliable guns for silencing and annihilating enemy batteries, and a good means of demolishing fortifications under combat conditions in large inhabited localities. During World War II foreign armies did not have mortars comparable with our 160-mm mortars in caliber, fire power and maneuverability.

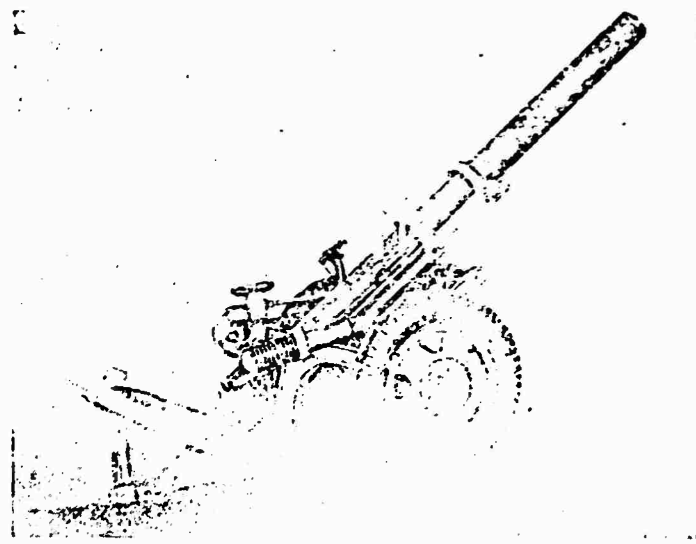


Figure 8. 160-mm mortar M1943.

During the four war years the mortars of the Soviet Army went the route from infantry direct support weapon to means of reinforcement. Suffice it to say that already in 1943 mortars accounted for more than half of all our artillery weapons.

The Great Patriotic War conclusively showed the might and viability of a new type of weapon -- field rocket artillery. Possessing high mobility and the capability of making sudden artillery attacks on personnel and combat materiel, and exerting a literally stupefying effect on the enemy, Soviet field rocket launchers gained the warm sympathies of our troops.

Antiaircraft artillery made a great contribution to assuring our victory in the Great Patriotic War. In coordination with fighter aircraft it provided cover for the large cities and industrial centers, as well as bridges and railways of our country, and supported the operations of friendly forces in defensive and offensive combat. In the region of Moscow alone, antiaircraft gunners shot down 272 Fascist aircraft in 1941. The antiaircraft artillery defending Leningrad destroyed 509 aircraft. In all, during the years of the Great Patriotic War Soviet antiaircraft gunners shot down more than 21,000 enemy aircraft.

The antiaircraft artillery of the Soviet Army had good materiel. Scientifically grounded techniques of aerial gunnery were developed. During the course of the war the antiaircraft artillery grew quantitatively and was supplied with even more highly improved fire direction instruments.

Artillery was widely used in aircraft also. The armament of our fighter aircraft included 20-mm cannons, and that of attack aircraft 23-mm and 37-mm rapid-fire aircraft cannons.

The Navy entered the war with artillery weapons that were rather highly perfected for the time. They included shipboard and coast artillery with appropriate fire control instruments.

In respect of purpose, shipboard artillery was divided into main batteries, multipurpose artillery and antiaircraft artillery. The main batteries, which had guns of the largest caliber aboard, were called upon to perform the principal missions proper to the given class of vessel, viz. waging war on vessels similar to this class. However, during the war they were more frequently drawn upon to perform other missions, for example, to neutralize coastal targets while supporting the seaward flank of ground forces in landing operations.

Main batteries included guns of large caliber (over 180 mm) mounted on battleships and cruisers, medium-caliber guns (100-180 mm) on light cruisers, as well as destroyers and destroyer escorts, and small-caliber guns (less than 100 mm) on small ships.

Multipurpose artillery (76-100 mm) was mounted on certain cruisers, as well as some destroyers and destroyer escorts. It performed main-battery and antiaircraft-artillery missions and at the same time backed up antiboat defense.

Naval antiaircraft artillery was used to fight the enemy in the air. Its fire capabilities against waterborne and coastal targets were limited. In respect of caliber size, antiaircraft artillery was divided into large-caliber artillery (100 mm and over), medium (76-90 mm) and small caliber (less than 76 mm).

Coast artillery was placed in coastal regions and on islands. It defended naval bases, ports and other important installations against enemy attack from the sea. In addition, it was drawn upon to support ground forces operating on the littoral.

The coast artillery had fixed (turret emplacements and open positions) and mobile (railway) mounts with 100, 130, 180 and 305-mm naval guns.

In the heroic battles for Odessa and, especially, for Sevastopol' the artillery of the ships of the Black Sea Fleet inflicted countless losses on the enemy. During the 250-day defense of Sevastopol' the battleship Sevastopol', the cruisers Krasnyy Kavkaz, Krasnyy Krym and other ships delivered fire on Hitlerite troops about 400 times. The antiaircraft gunners of the fleet shot down dozens of enemy aircraft. The 305-mm turret battery at Cape Khersones covering the evacuation of our troops kept firing on the enemy to the last shell.

On the Leningrad front, artillery fire of the battleship Oktyabr'skaya Revolyutsiya, the cruisers Kirov and Maksim Gor'kiy and other fighting ships of the Red Banner Baltic Fleet, as well as of the coastal batteries of Kronstadt, Fort Krasnoflotskiy (Krasnaya Gorka) and others not only helped halt the Germans at the walls of Lenin's city in August 1941, but also played an important part in the rout of Hitlerite troops in the vicinity of Leningrad in January 1944.

The creative thinking of Soviet artillery designers responded briskly to all requirements of the front and swiftly took into account everything new which the war contributed to the principles of artillery employment in combat. Soviet designers mastered the methods of high-speed planning of guns. This made it possible in short periods

-- a few months and even weeks -- to develop and put into production new models of weapons.

The teams of designers, directed by Heroes of Socialist Labor, State Prize Winners andDoctors of Technical Sciences V. G. Grabin, F. F. Petrov, B. I. Shavyrin, I. I. Ivanov et al., made a great contribution to the creation of first-class Soviet artillery weapons.

The Chairman of the Council of Ministers USSR A. N. Kosygin, speaking at a solemn session in the hero city of Volgograd on 11 July 1965, noted, "In the Great Patriotic War our army conclusively showed its superiority over the Hitlerite army, and the arms with which they were equipped were shown to be more highly perfected than German arms."*

During the course of the war a historically unparalleled reorganization of our economy onto a war footing was carried out, and thousands of enterprises were relocated from the western to the eastern part of the country. Under the most complex wartime conditions blue-collar workers, engineers and white-collar workers by their heroic labor not only reestablished, but even significantly expanded artillery production. This made it possible to overtake and surpass Hitlerite Germany in the production of artillery weapons and combat materiel (Table 4).

Table 4

COMPARATIVE DATA ON PRODUCTION OF ARTILLERY WEAPONS IN THE USSR AND GERMANY DURING THE WAR

A Образец орудия	B Произведено			
	C в СССР		D в Германии	
	E с 1.7.1941 г. по 1.7.1945 г.	F в среднем за год	1941—1944	F в среднем за год
1 Минометы, тыс. шт.	347,9	86,9	68	17
2 Орудия, тыс. шт.	188,1	47,0	102,1	25,5
3 Танки и самоходные орудия, шт.	95 099	23 774	53 800	13 450

Keys:

- A. Model of gun
  1. Mortars, in 000's
  2. Guns, in 000's
  3. Tanks and self-propelled guns, each
- B. Number produced
- C. In the USSR
- D. In Germany
- E. From 1 July 1941 to 1 July 1945
- F. Average per year

*Pravda (Truth), 12 July 1965.

It is not amiss to take note of the falsity of the bourgeois propaganda assertion that supplies of arms to our country from the allies allegedly played a decisive role in winning the victory over the enemy. It is known that Lend-Lease supplies of antiaircraft guns amounted to only approximately 2 percent of our production.

The multimillion Soviet Army and our Navy were equipped with Soviet-made artillery weapons. The personnel of enterprises of the People's Commissariats of Armament, Ammunition and Mortar Weapons, headed up by People's Commissars D. F. Ustinov, B. L. Vannikov and P. I. Parshin, made the principal contribution to the performance of this difficult mission. Orders of the Soviet Union embellish the banners of many plants in the artillery industry. For valiant labor tens of thousands of workers, engineers and scientists involved in arms production were awarded orders and medals. The title of Hero of Socialist Labor was conferred on many of them.

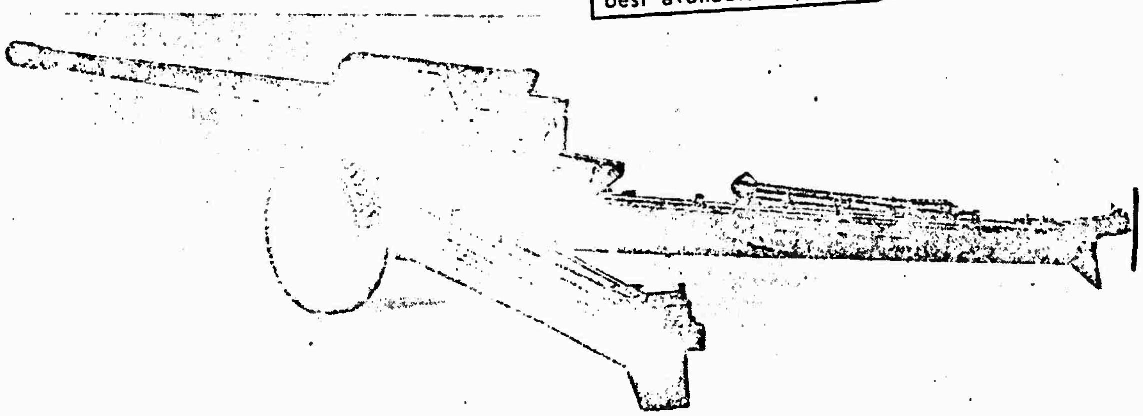


Figure 9. 130-mm gun.

In the postwar period a weapon of tremendous destructive power -- the nuclear missile -- appeared. This revolution in military affairs heralded an upheaval in the methods of conducting combat operations, in the theory of the art of war and in the practice of troop training. A radical reorganization was carried out in the Armed Forces of the USSR. The Strategic Rocket Forces were created. Important organizational reforms took place in other Armed Services also: operational-tactical rocket forces were created, as well as antiaircraft rocket forces, atomic missile-launching submarine forces, aviation chasti armed with missiles of various types.

Apart from the creation of rocket forces, artillery also continued to develop. Artillery ordnance underwent great qualitative changes. New models of guns, howitzers and rocket launchers with increased fire power and high precision of fire, more effective shells, good mobility and maneuverability came into service in the Soviet Army. This increased the fire capabilities of combined-arms soyedineniya by far.

Figure 10. 203-mm howitzer.

In the first postwar years there came into service such weapons as the 85-mm division gun, 85-mm antitank gun, 122-mm gun, 130-mm gun (Figure 9), 152-mm gun, 203-mm howitzer (Figure 10), 160-mm and 240-mm mortars (Figure 11), 82-mm and 107-mm recoilless guns with shaped-charge shells and high-explosive fragmentation shells, as well as many other artillery systems.

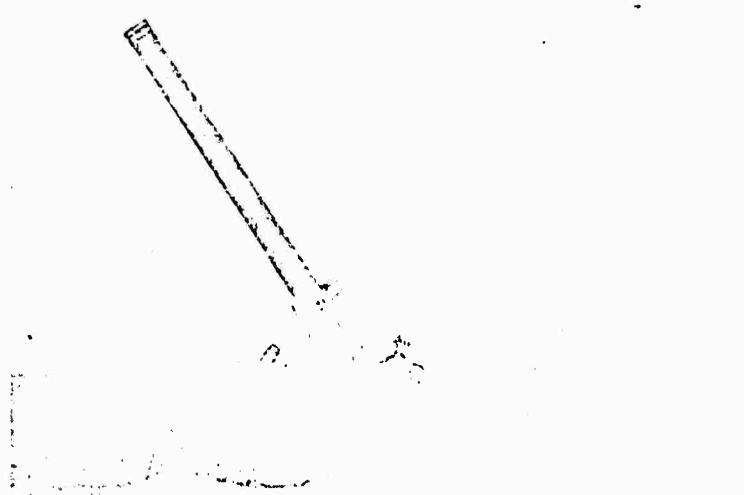


Figure 11. 240-mm mortar.

Field rocket artillery is equipped with modern salvo-fire systems of the BM-14 and BM-24 type.

With regard to the creation of antiaircraft artillery weapons the culmination was the development of the 57, 100 and 130-mm antiaircraft artillery systems which are distinguished by a significant rate of fire and altitude range. In addition, new multiple self-propelled small-caliber antiaircraft artillery mounts (Figure 12), capable while on the move of combating high-speed low-altitude aerial targets, were created and introduced into the forces.

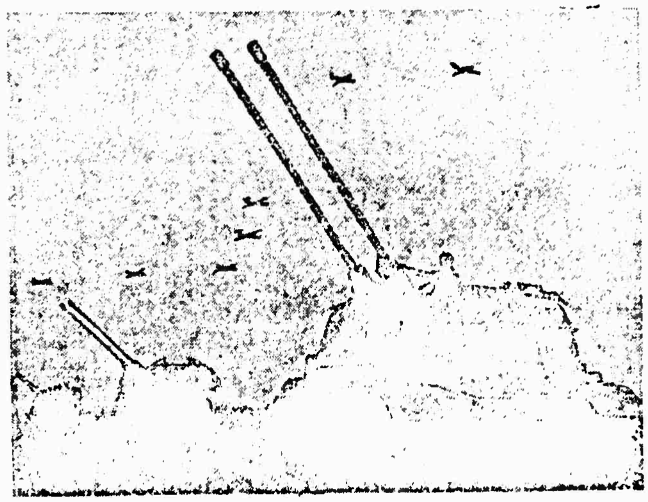


Figure 12. Self-propelled antiaircraft mounts.

Shipboard and coast artillery considerably changed. New ships were equipped with modern gun mounts and fire control instruments making possible successful fire on waterborne, coastal and aerial targets. Both self-propelled and towed artillery systems began to come into service in the coast artillery.

Aviation received new fixed aircraft armament with a high rate of fire and more powerful shells than during the war years.

Radar found wide use in detection, target-designation and fire-support systems, as did remote control (servo systems) in guidance systems.

The Communist Party and the Soviet Government manifest constant solicitude for the further increase of our country's military might. The magnificent military parades on the Red Square in Moscow conclusively show what wonderful combat materiel, including artillery weapons, our Armed Forces have at their disposal at present.

The Secretary General of the CC of the CPSU, Comrade L. I. Brezhnev, observed on 3 November 1967 in his report, "Fifty Years of Great Victories for Socialism," that "The Soviet Army today is a mighty, formidable and invincible force. It is armed with the best weapons in the world. Soviet fighting men -- from soldiers to marshals and from sailors to admirals -- are veritable experts in military affairs, with perfect mastery of military science and of the superb equipment entrusted to them. They are people of boundless devotion to our party and to the cause of communism!"

Chapter II

DOES ARTILLERY HAVE A FUTURE?

1. Appearance of Rockets and Emergence of the "Shell or Rocket" Problem

During World War II artillery was the principal fire striking power. It wiped out and destroyed the enemy's personnel and materiel, demolished his engineer installations, supported infantry and tank offensives.

This function of artillery was in keeping with the then-accepted views on fighting battles and conducting operations, which envisaged the inflicting of powerful coordinated blows on the enemy in the full depth of his operational troop dispositions by aircraft, artillery, tanks and infantry. In these blows artillery was regarded as the decisive weapon of fire for effect.

In the course of World War II a new fire weapon appeared -- field rocket artillery. Priority in the massed employment of rocket shells for the delivery of collective fire goes to the Soviet Army. This is evidenced by the history of the development of the famous Soviet "Katyushas" and their combat employment on the fronts. The Great Patriotic War conclusively demonstrated the might and viability of this new type of weapon. It is important to emphasize that Soviet rocket shells, developed even before the start of the war, had a decisive influence on the development of rocket armament abroad both during the war and in the postwar period.

The sphere of employment of the reaction principle in models of weapons was not limited to the sphere of field rocket artillery alone. Rocket shells came into service in the infantry as a close-combat weapon, as well as in the tank forces, antiaircraft artillery, aviation and the navy.

Long-range guided missiles, used in the concluding stage of World War II, have a special place in the development of rocket armament. The appearance of rockets portended the solution of artillery's touchiest problem -- that of ultra-long-range fire.

As is known, the main obstacle in the path of an increase in the range of artillery fire to several hundreds of kilometers was the physicochemical nature of the existing powders, whose composition, established dozens of years before, had changed little essentially during World War II. For example, the best nitroglycerin powders could provide a theoretically maximum muzzle velocity of a projectile of about 2800 m/sec, but in practice this limit at that time amounted to approximately 1700 m/sec. But even this muzzle velocity of a projectile led to a sharp decline in the life of a gun, and an inordinate increase in size, and a complete loss of maneuverability.

Attempts to solve the problem of ultra-long-range fire by improving rifled artillery were made as early as World War I. The Germans, for example, created the famous "Kolossal" gun with a muzzle velocity of 1600 m/sec and range of fire up to 120 km. The gun barrel was 35 m long, and the weight of the entire system 157 tons. After a few rounds the gun went out of commission.

Calculations show that in order to fire for a distance of up to 250-300 km at a muzzle velocity of 2000 m/sec a piece must have a barrel 150-170 m long, which is unrealistic in practice.

It became clear that the problem of ultra-long-range fire could not be solved with conventional artillery. A new weapon was required. Rockets were such a weapon. Their advantages in the sphere of ultra-long-range fire as compared with ordinary artillery were incontestable. Rockets do not need the powerful initial dynamic thrust to put artillery projectiles into motion.

From among the combat weapons constructed on the reaction principle, field rocket artillery, with a range of fire which was small, had the greatest development during World War II. Not one of the belligerent states used tactical missiles with a range of fire amounting to tens of kilometers in combat operations. Work to create tactical missiles was only in an initial exploratory stage. No scientific and technical solution of this problem had yet been found by the end of the war.

At the same time, operational-tactical missiles with a range of 200-350 km were used in practice. In this case the complexity of design of the missile system was of secondary importance since it was justified by the capability of destroying important strategic targets hundreds of kilometers removed from the front line and strongly defended against air attack.

Combining the rocket with a nuclear warhead led to large-scale revolutionary transformations in military affairs during the postwar years. A fundamentally new weapon of stupendous destructive power appeared.

The problem of "shell vs. rocket" emerged.

Due to the rapid development of the rocket-nuclear weapon military specialists of the capitalists were very skeptical in rating the prospects of further development of tube artillery and mortars. It was asserted that in the nuclear age artillery had had its day and that it had no future. It became modish to talk about the artillery "crisis." It was predicted, for example, that artillery pieces would become as extinct as mammoths. A few even suggested that "artillery be retired without pension or uniform."

In numerous discussions on the subject of "shell vs. rocket" foreign specialists noted that missiles could successfully perform all artillery functions.

These views were reflected in the organizational measures carried out during the 1950's in the ground forces of the principal capitalist states: the number of guns was sharply curtailed. It is known, for example, that in the U.S. Army organic division artillery had been almost halved by the beginning of 1957 (46 pieces instead of 72 remained).

However, the pessimistic forecasts were not vindicated. In recent years the attitude abroad towards artillery has altered drastically. An evolution is evident in the views regarding the role and prospects for development of artillery -- from a denial of its future (at the end of the 1940's) to the practical implementation of a broad program of reequipping armies with modern new artillery pieces and mortars (1960's).

It was found that missiles cannot perform all the functions characteristic of artillery and if they are capable of doing them, performance is costlier and sometimes worse. Specialists began to say that missiles and artillery have their own specific spheres of combat employment where they can be used with maximum effect.

The American command, for example, after a number of troop exercises came to the conclusion that the amount of artillery left in a division after the cutback did not at all suffice to provide direct fire support for troops on the battlefield. It was found that an American division was fit only for nuclear warfare and altogether incapable of operating under ordinary conditions. The decision was made to increase the number of divisional artillery pieces from 46 to 64 at first, and later to 76 pieces, i.e. more pieces per division than prior to the reorganization.

Foreign specialists also note a number of important advantages which conventional artillery has over tactical missiles: high precision of fire; simplicity of construction and combat employment; constant readiness for immediate opening of fire without special preparation; trouble-free operation and dependability under any climatic conditions, in any season of the year and at any time of day; relatively low cost of production etc. It is believed that troops under modern conditions need rapid fire support and concentration of fire on targets against which nuclear weapons cannot be employed. Therefore, ground artillery is characterized as an indispensable means of providing accompanying fire for tanks, of overwhelming antitank weapons and observation posts, and of destroying enemy fire weapons and personnel in the immediate vicinity of friendly troops.

In the sphere of fire weapons for antiaircraft defense it once seemed that antiaircraft missile systems would assume a monopoly position and that the "shell vs. rocket" problem would be settled irrevocably in favor of the rocket. Many foreign specialists thought so when at the end of the 1950's a number of countries developed modern antiaircraft missile systems capable of intercepting subsonic or supersonic aircraft, as well as medium- and high-altitude winged missiles.

However, in the autumn of 1959 an event occurred in the United States which allerted American military specialists. A strategic bomber crossed the entire expanse of North America from east to west at an altitude of 150 m and . . . remained undetected by a single radar station.

In the opinion of foreign specialists, serious shortcomings of antiaircraft missile systems have come to light: their radar apparatus has been found incapable of detecting and tracking low-flying targets. In addition, it takes a comparatively great deal of time to zero mobile antiaircraft missile systems. As a result, the problem of covering troops on the battlefield became especially acute.

Two organic antiaircraft missile systems -- "Chaparral" and "Redeye," equipped with infrared homing devices that are sensitive to the temperature of a target's exhaust gases -- were developed in the U.S. Army to combat aerial targets at low altitudes. However, these missiles too, specially developed to combat low-flying targets, were found to have significant shortcomings. Their homing devices were ineffective in the direction of the sun, and the range of this zone was fairly considerable. Missiles are launched at a target only in an "overtaking direction," i.e. after the target has overflown the rocket-launching site, using its weapons. Hence it follows that the probability exists that both the missile and the personnel launching it will be wiped out before the launch takes place. Antiaircraft missiles of the Chaparral and Redeye type have yet another shortcoming. They have no identification, friend or foe (IFF) system. In this connection, an American flyer has remarked, "Friend or foe will have to be sorted out according to the debris on the ground."

To solve antiaircraft defense problems under field conditions, recourse is again being had abroad to antiaircraft tube artillery. This is dictated by two reasons: the war experience in Vietnam, where the DRV [Democratic Republic of Vietnam] Army has successfully shot down American aircraft with antiaircraft artillery fire; and the shortcomings of existing antiaircraft missile systems. It is noted that the leap from tube artillery to guided antiaircraft missiles was made too quickly and that it is premature to discard tube artillery. In the foreign military press voices have even begun to be heard speaking about the decline of the "missile era."

Some American, West German and other specialists assert that as soon as aircraft swoop towards the ground, there is no more effective weapon to combat them than automatic antiaircraft guns. They are mobile, simple to service, reliable and exceedingly effective in combat.

In this connection, a World War II experiment is recalled when antiaircraft artillery achieved good results at short ranges with massed concentration of fire. The experiment was staged as follows. A battery of 30-mm antiaircraft guns fired on a fighter plane flying at a range of 1000 m at close to sonic speed. The probability of hitting such a target was found to be close to 100 percent. It is also suggested abroad that a return be made to certain old tactical methods: that barrage fire, rather than aimed fire, be conducted against aircraft. This is believed to be quite an effective means of combating aerial targets that are visually invisible and untracked by radar.

Military specialists who are more cautious in their conclusions note that the Vietnam war experience proves only the need to change the disproportion in the development of air-defense ordnance and missilery in favor of antiaircraft guns. The press has reported that the Americans are setting up in their forces mixed antiaircraft divisions, armed with guided Chaparral antiaircraft missiles and 20-mm self-propelled antiaircraft six-barrel Vulcan guns. As a whole, the "Chaparral-gun" system should, according to the concepts of the developers, be effective in combating various low-flying offensive aircraft -- from helicopters to supersonic planes, but under conditions of clear visibility.

Thus, the necessity of employing antiaircraft missile systems and antiaircraft guns in combination in modern air defense is recognized abroad. It is noted that the effectiveness of antiaircraft missiles is not great within a fairly large close-in zone around launching sites, but then it increases to significant effectiveness within the limits of the zone of controllability as distance to target increases. At the same time, it must be borne in mind that it is missiles that "corral" aircraft into low altitudes where the fire of antiaircraft guns is deadliest for them.

Antiaircraft artillery is widely employed on all classes of modern surface vessels and especially on small ones where it is impossible to accommodate antiaircraft missile systems which weigh a great deal and require much space. On small vessels automatic antiaircraft artillery is at present the basic and sole means of self-defense against the enemy in the air.

Thus, artillery and missiles in our day are not regarded as mutually exclusive, but as complementary weapons.

2. Scientific and Technical Progress and Artillery

It should be borne in mind that scientific and technical progress has extended not only to the latest types of missiles, but also to conventional weapons. The tremendous progress of science and technology during the 1950's and 1960's gave rise to a new approach in the evaluation of the role of these weapons and their capabilities. There has e en begun to be talk now of the renaissance and development of artillery on a new technological basis.

For example, in the development of modern artillery pieces and mortars and the ammunition for them it has become possible to use the latest materials, including high-strength light alloys and especially strong alloyed steels, powders and high-strength explosives, high and ultra-high powder gas pressures, completely or partially combustible shell cases, proximity fuzes. There has been an increase in the assortment of casualty-producing ammunition -- new shaped-charge and subcaliber shells, fragmentation and high-explosive fragmentation shells -- as well as special-purpose ammunition -- illuminating shells, smoke projectiles etc. Rocket-assisted projectiles and mortar shells have significantly increased the range of fire of guns and mortars.

Modern artillery instrumentation has changed beyond recognition. This has made possible a significant increase in the precision of fire -- the most important indicator of artillery combat effectiveness.

In our day ground forces and artillery are equipped with ground-search radar, numerous infrared devices -- sights and night-vision devices, laser devices, sound ranging observation sets and weather stations, topogeodetic survey equipment, electronic computers.

All this taken together has raised artillery to a qualitatively new level.

Modern artillery will find wide employment in battle and in operations, above all in combating the enemy's tactical nuclear weapons and artillery, tanks, electronic equipment and many other targets.

The armies of the capitalist states with developed war industry are seeking ways of improving artillery weapons further. Thus, in the United States and other Western countries there has been a significant heightening of the rate of development of new guns and mortars so as to take into account the conditions of nuclear war. The Americans, for example, have twice modernized their artillery in the past decade. A great deal of work along this line is under way in the French, English and West German armies.

The development of tube artillery abroad at present is aimed towards a further rise in the power and effectiveness of ammunition, an increase in the range and precision of fire, an improvement in mobility and cross-country ability. Requirements that guns be air-transportable and buoyant are becoming mandatory.

The problem of increasing the power of guns and of raising the effectiveness of the action of ammunition at the target is being solved by the creation of nuclear ammunition. In the United States, for example, shells with nuclear charges have been developed for the 280, 203, 175 and 155-mm guns, as well as for the "Davy Crockett" recoilless rifle.

Something fundamentally new is the creation of nuclear ammunition in the field artillery. Combining the most powerful means of destruction and mass annihilation (nuclear charge) with the most economical means of delivering this charge to the target (artillery shell) transforms conventional artillery into a qualitatively new type of weapon.

Under study are the possibilities of using light gases (helium, hydrogen etc.) to obtain ultra-high muzzle velocities -- over 3000 m/sec. For example, tests have been made in the United States under laboratory conditions of an experimental 40-mm mount using helium, which is heated in the combustion chamber by hydrogen vapor burning in oxygen. It is known that the heavier the weight of the charge, the greater is the proportion of the inefficient expenditure of the energy from the explosive decomposition of powder for the transport of charge particles and decomposition products along the bore. Therefore, attempts are being made to replace powder with liquid propellants.

Research is under way on problems in the use of electric power. The idea is to create guns which will fire by using the heat and gases generated due to a powerful electric discharge inducing the formation of shock waves.

Aircraft are developing rapidly in our day. Modern aircraft have high performance characteristics and are capable of carrying out combat missions under complex meteorological conditions with diverse variants of armament (cannons and missiles) in a wide range of speeds and altitudes.

Nor are antiaircraft weapons standing still. There are now multi-barreled, rapid-fire mobile systems. They are automated, and have their own reconnaissance radar and computer equipment. For example, Soviet antiaircraft artillery systems with their high precision of fire in any weather by day or night make it possible to cover troops continuously in all kinds of highly mobile combat operations and to combat airborne landings as well as ground and surface targets. Of special importance is the fact that these systems, operating in the prebattle and battle formation of motorized rifle and tank chasti and podrazdeleniya can deliver accurate fire on the move.

The progress in natural sciences, mathematics and technology at the middle of the twentieth century resulted in amazing achievements in the field of radio electronics, which plays a revolutionary role in military affairs. The creation of devices for recording the subtlest variations in the parameters of various processes and phenomena, the development of electrophysical and electrochemical methods of treating materials, the invention of lasers and amplifiers, the use of electronic computers and power semiconductor devices -- all these are the results of the development of radio electronics, which is now widely used in artillery. For example, electronic computers opened up inexhaustible possibilities of replacing many logical functions of man. They not only store a tremendous volume of information and perform mathematical operations immeasurably faster than man, but they also solve exceedingly complex logical problems and select the optimum ways of solving them. Electronic computers are employed in preparing initial firing data.

Soviet artillery weapons incorporate the latest achievements of Soviet science and technology, the fruits of the selfless labor of scientists, designers, engineers and production workers.

Artillery has not only not lost its significance in our day, but as previously it is one of the powerful means of routing the enemy in close combat. It backs up the combat operations of tank and motorized infantry forces. Only artillery fire, supporting the infantry and tanks in direct contact with the enemy, can assure the safety of friendly troops. Even in nuclear missile warfare, artillery will be the basic means of direct fire support of troops, especially in the enemy's tactical depth of defense.

Chapter III

PURPOSE AND COMBAT CHARACTERISTICS OF ARTILLERY PIECES

1. Classification of Artillery

The power of artillery lies in fire. Artillery operates in all types and phases of combat in close cooperation with tanks, infantry, aircraft and other arms of the service, helping them with artillery fire in the performance of common combat missions. Artillery neutralizes the enemy's resistance and clear the way for friendly troops in an attack. It imparts firmness to the defense by interdicting the enemy's path.

Artillery is prized for its might, its constant readiness for immediate opening of fire, and its troublefree operation under any climatic conditions at any season of the year or time of day.

The basis of artillery combat employment is the combining of powerful fire with maneuver. Under modern conditions artillery is capable of performing a wide range of diverse functions in combat and in operations:

combat with the enemy's tactical nuclear missiles;

destruction and neutralization of artillery and mortar batteries, including atomic batteries, and other fire weapons;

annihilation or neutralization of enemy personnel;

combat with tanks, self-propelled guns and other mobile armored combat means;

destruction of manned and unmanned aircraft, helicopters, airborne landings and other aerial targets;

combat with the enemy's electronic weapons;

demolition of fieldworks and permanent defensive installations;

disruption of enemy troop control and neutralization of his rear (interdiction of the moving up of reserves, the bringing up of ammunition, rations etc.).

For reliable performance of these missions modern artillery is armed with many artillery pieces of the most diverse kinds and types, each of them having a strictly defined combat function and distinctive design features.

Kinds of Artillery

In respect of organizational affiliation, the artillery of ground forces is subdivided into organic artillery, which is organizationally part of soyedineniya, chasti and podrazdeleniya, and general reserve artillery, i.e. separate artillery chasti used for the quantitative and qualitative reinforcement of organic artillery.

Whereas organic artillery constantly operates as a part of friendly chasti, general reserve artillery is attached to troops only as needed for the performance of specific combat missions, and after these are executed it reverts to the disposition of the high command.

Organic artillery in turn is usually subdivided into battalion, regimental, division, corps and army artillery.

In respect of place of operation and character of targets, artillery is divided into ground, antiaircraft, aircraft, coast and shipboard artillery.

Ground artillery is intended to strike ground targets, and antiaircraft artillery aerial targets. Antiaircraft artillery is also capable of delivering fire on ground targets. The ground and antiaircraft artillery of land forces is sometimes designated by the common term -- field artillery.

Aircraft artillery serves as the armament of combat aircraft. Aircraft cannons are automatic and have a high rate of fire.

Coast artillery is employed for coast defense. It is capable of engaging enemy ships and preventing seaborne assaults.

Shipboard artillery includes guns for combating waterborne, coastal and aerial targets.

Special-purpose ground artillery includes:

antitank artillery to combat tanks;

self-propelled artillery to accompany and provide fire support for tanks and infantry;

tank artillery for tank armament;

mountain artillery for combat operations in mountainous and very rugged terrain;

casemate artillery for the armament of fortified areas.

In respect of the technique whereby muzzle velocity is imparted to the projectile, a distinction is drawn between tube artillery and rocket artillery; and in respect of bore construction, between rifled and smoothbore.

According to the mode of locomotion, artillery can be classified as:

towed -- borne in a trailer behind prime movers;

auxiliary propelled artillery -- supplied with an engine and necessary apparatus for self-propulsion directly in the combat area; for great distances it is towed by prime movers as a rule;

self-propelled -- on tracklaying or wheeled chassis;

tank artillery -- mounted in tanks;

portée artillery -- transportable in vehicle bodies or in armored carriers (for example, some recoilless guns and mortars);

pack artillery -- carried on pack animals in mountains;

railroad artillery -- mounted on armored trains or special carriers.

The division of artillery into light, medium, heavy and superheavy is now obsolete and is rarely used. Heavy and superheavy artillery have been replaced by tactical missile systems. The classification of tube artillery by caliber remains: small-caliber pieces (20-57 mm), medium caliber (75-155 mm) and large caliber (over 155 mm).

Types of Pieces

Historically there has arisen the division of artillery pieces into the following basic types: guns, howitzers, gun-howitzers (howitzer-guns), heavy mortars (mortira), trench mortars (minomet), recoilless guns, combination guns, and rocket systems.

This diversity of types of artillery armament is due to the variety of targets which have to be hit by artillery fire. There are, for example, vertical and horizontal, moving and stationary targets. Vertical targets are tanks, self-propelled guns, armored carriers, buildings adapted for defense etc. Horizontal targets include foxholes, fire trenches, connecting trenches etc.

To hit a rapidly moving tank, an antitank gun must have a flat (low) trajectory, the height of which does not exceed the height of the tank itself. This requires exceptionally high muzzle velocity of the projectile, for example, 1000 m/sec or more. Such velocity primarily affords high combat effectiveness. Antitank guns can even fire on tanks with dummy shells which have no explosive. The tank in this case will be damaged by the kinetic energy of the shell at the moment of impact with the target. The force of such an impact amounts to one million h.p. or more.

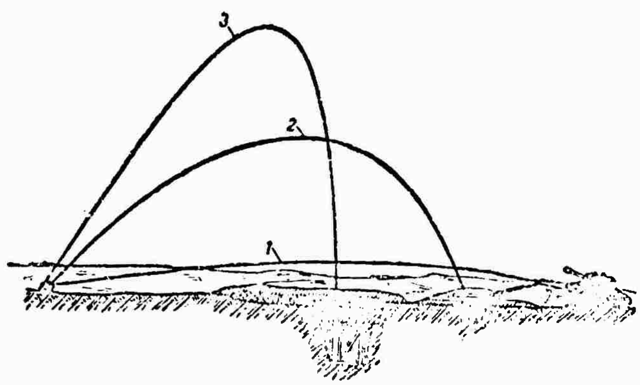


Figure 13. Flight paths of shells fired from a gun (1), howitzer (2) and mortar (3).

The great flatness of trajectory characteristic of guns is disadvantageous in a number of cases. A target can, of course, be safely concealed from a gun in accidents of the terrain, in trenches, trench shelters, foxholes, ravines etc. To hit such targets, one must have a weapon with a steep trajectory, i.e. a howitzer or mortar (Figure 13).

Let us consider the principal characteristics of the basic types of artillery pieces.

Guns serve for the annihilation of open vertical targets, as well as for long-range fire. The characteristic features of guns are long barrels, high muzzle velocities of projectiles, flat trajectory, high rate of fire. They surpass all weapons of other types in maximum effective range and penetration effect of shells. However, given their caliber, guns are the heaviest weapons since their long and heavy barrel and the great recoil on firing necessitate strong and massive carriages.

Howitzers are intended for the destruction of defensive installations and for hitting targets under cover. Therefore, the flight path of howitzer shells is steep and plunging; muzzle velocity is low (400-600 m/sec or less). Howitzer barrels are short; calibers large; shells heavy; maximum angles of elevation 65-75°. Howitzers have a multisection charge, the magnitude of which can be varied immediately before loading. The number of charges for howitzers runs as high as 10-13. Variation in the curvature of the trajectory and range of fire is thus achieved with a constant angle of elevation. The fact that the charge is multisection makes a howitzer round more economical.

Given the same caliber, the weight of a howitzer is a half or a third the weight of a gun, and given the same weight as a gun, a howitzer can have a considerably larger caliber.

Howitzers are inferior to guns in rate of fire. This is due to the difference in the method of loading. Guns, as a rule, are fired with one constant charge. This makes it possible, by means of the shell case, to unite shell and charge into a single whole, i.e. a fixed round. This cannot be done in the howitzer, however, since there are several charges. Whereas no preparation of the charge is required before firing from a gun, before each round from a howitzer the prescribed charge has to be prepared, i.e. the required number of powder sections must be removed from the case. A gun is loaded in one go. A howitzer has separate loading, which is more complicated: first the shell is inserted in the breech of the barrel and forced home just enough to engage the rotating band into the start of the rifling grooves; then the case with the powder charge is put in behind the projectile.

Gun-howitzers (howitzer-guns) are pieces of an intermediate type, capable of performing fire missions of both a howitzer and gun character. Thus, as early as the prewar years one of the best World War II pieces -- the 152-mm gun-howitzer M1937 -- was created in the Soviet Union under the leadership of Hero of Socialist Labor F. F. Petrov. This piece combined with exceptional success the properties of howitzer and gun. The gun-howitzer was able to deliver fire at angles of elevation up to 65° and had 13 multisection charges. These, of course, are obvious howitzer characteristics. However, with the maximum charge it hurled a projectile with muzzle velocity of about 700 m/sec for a great distance. This was its gun quality.

Usually a piece whose characteristics are closer to guns is called a howitzer-gun.

Heavy mortars (mortira) are artillery pieces with howitzer characteristics developed to the maximum. They are intended for the destruction of especially strong defensive installations. They have large calibers, short barrels and a very steep trajectory. Fire from heavy mortars (mortira) is usually delivered at angles of elevation greater than 45° -- hence the term "mortar fire" (mortirnaya strel'ba). Heavy mortars (mortira) have gone out of use in our day. Their role is now filled by trench mortars (minomet).

Trench mortars (minomet) are smoothbore weapons firing unrotative finned projectiles -- mortar shells. They differ from rifled pieces (guns, howitzers and heavy mortars (mortira)) in the simplicity of their construction, light weight, and steep trajectory (angles of elevation from 45 to 85°).

Trench mortars are employed to hit enemy personnel and fire weapons in open country and under artificial and natural cover: in foxholes, trenches, dugouts and ravines, behind reverse slopes, in woods. The great curvature of trajectory makes it easy to select and camouflage firing positions for mortars, and makes it possible to deliver fire from deep cover (ditches, ravines, woods) and over the head of friendly forces.

The most valuable characteristic of the mortar (minomet) is its light weight despite the great power of mortar shell effect. For example, the 120-mm mortar M1943 is nine times lighter than the 122-mm howitzer M1938 which is close to it in caliber, and 22.5 times lighter than the 122-mm gun M1931/37. These same merits, albeit to a somewhat lesser degree, are characteristic of large-caliber mortars as well (160-mm and 240-mm).

Table 5

AVERAGE VALUES OF CERTAIN CHARACTERISTICS OF GUNS, HOWITZERS AND MORTARS

A Образец орудия	B Начальная скорость, м/сек	C Длина ствола, клб.	D Отношение веса орудия к весу снаряда
1 Пушки	650—1000	40—75	180—350
2 Гаубицы	400—600	20—35	100—180
3 Минометы	100—350	10—25	15—30

Keys:

A. Type of weapon

1. Guns
2. Howitzers
3. Mortars

B. Muzzle velocity, m/sec

C. Barrel length, cal.

D. Ratio of weapon weight to shell weight

Table 5 presents generalized data characterizing the various types of pieces. Here it should be borne in mind that in artillery, barrel length is more frequently determined not in measures of length (m, cm, mm), but in relation to the caliber of the piece, i.e. it is indicated how many times the caliber of the piece can be divided into barrel length. For example, if the absolute barrel length of a 76-mm gun equals 3215 mm and its caliber is 76.2 mm, then relative barrel length will be 3215 ÷ 76.2 = 42.2. In such case it is usually said that the barrel length of the gun equals 42 calibers.

Recoilless guns are employed in the main to fire on tanks with shaped-charge or mortar shells. The distinctive feature of the construction is that there are nozzles in the breech of the barrel for the escape of gases to the outside, i.e. in the direction opposite to that of the shell's motion. In the process, dynamic equilibration takes place -- the barrel remains motionless despite the shot. The principal merit of recoilless guns is their light weight.

Combination guns is the name given systems which combine basic design elements of guns of various types. Most frequently the basis of a combination gun is a mortar barrel set on a light howitzer carriage. Caliber and combat effectiveness of fire are significantly increased, and the weight of the entire gun is markedly decreased. For example, a combination gun, the "Howtar," which is a combination of a 106.7-mm mortar barrel and the carriage of a 75-mm mountain howitzer, has been adopted for service in the U.S. marines.

The rocket systems of field rocket artillery are intended, as a rule, for the delivery of salvo fire on comparatively large targets and areas with powerful shells of fragmentation, high-explosive and other effect. Such systems have a rocket shell equipped with a tail unit, which is unrotative in flight, or a spin-stabilized missile which spins in flight. Both types of projectile are of the powder type and are unguided. The rocket engine makes it possible, in principle, to eliminate the effect of recoil and therefore to get rid of cumbersome carriages and barrels made of expensive and scarce steel.

The launcher for rocket-shell salvo fire is simple in its construction: it is a package of launching guides of rail, frame or other design, mounted on a motor vehicle, armored carrier, tank. Packages or individual guides for rocket shells can also be placed on aircraft, helicopters and ships.

It should be noted that accuracy of fire for unguided rocket shells is far worse than for mortars, howitzers and guns. This shortcoming is compensated for by the almost simultaneous release of a large number of shells.

Thus, each type of artillery weapon here considered has its valuable characteristics, but at the same time certain shortcomings. However, none of these types of guns in any wise excludes another. They each merely complement one another in the performance of diverse artillery combat missions. Under modern conditions troops need both guns and howitzers, as well as mortars and recoilless guns and missile systems.

2. Combat Characteristics of Guns

The basis for the evaluation of any artillery weapon is primarily its combat characteristics. These include caliber and power of the shells, maximum effective range, precision of fire, rate of fire, maneuverability of fire, mobility, buoyancy and air transportability.

Caliber and Power of Shells

Caliber is the name given to the interior diameter of the barrel. In rifled guns caliber is customarily regarded as bore diameter between opposite lands.

At present, calibers are measured in millimeters, for example, a 90-mm gun, 120-mm mortar, 155-mm howitzer etc. Isolated countries (the United States, England etc.) retain the inch designation of caliber for old guns. It should be borne in mind that in converting the designations of the commonest calibers from inches into the metric system, rounding off is permitted. Thus, 76-, 122-, 152- and 203-mm calibers are in fact 76.2-, 121.92-, 152.4 and 203.2-mm calibers respectively.

Caliber is the principal and decisive performance characteristic of any piece. The power of a given artillery weapon is judged from its caliber.

The power of a gun depends in significant measure on the power and effectiveness of shell action at target, which are determined by a number of factors, among which shell weight figures decisively. Shell weight is in turn a function of caliber. Obviously the larger the caliber, the greater is shell weight. The weight of a piece grows with an increase in caliber, and its mobility declines correspondingly. An increase in caliber and, consequently, an increase in shell weight cannot fail to affect a piece's rate of fire.

Caliber cannot be considered in isolation from other performance characteristics, apart from the structural solution of the contradictory requirements of power and mobility in the gun. World War II experience showed that guns differing both in purpose and in their characteristics were created with the same caliber. In some guns there was a successful combination of power and mobility; full consideration was given to the numerous pluses and minuses, and a margin of power was provided for the contingency of probable strengthening of enemy armament. Such systems were assured a long combat life. Many Soviet artillery weapons, for example, the 57-mm antitank gun M1943, 122-mm howitzer M1938 etc. rationally combined power and mobility. In particular, during the war these guns served as the basis for the creation of new, even more powerful systems, at the same time preserving high mobility. Thus, a 76-mm barrel was set on the carriage of a 57-mm gun and a new 76-mm division gun was obtained; a 152-mm barrel on the carriage of a 122-mm howitzer and a new 152-mm howitzer was created. In a number of foreign models designers did not succeed in finding a good solution of the central "power-mobility" problem. Such pieces proved shortlived and were doomed to be replaced, something which under wartime conditions involved certain economic difficulties.

Gun calibers increased everywhere during the war, especially in antitank and antiaircraft artillery. Whereas the Germans, for example, at the beginning of the war had only 37-mm and 50-mm antitank guns, during the war they were obliged to adopt for service 75-mm and 88-mm guns, and they developed experimental models of 105-mm and 128-mm antitank guns. An analogous picture was observed in antiaircraft artillery too -- from the 20-mm and 37-mm guns at the beginning of the war to 75-, 88- and 105-mm antiaircraft guns at war's end. In addition, 128-mm and 150-mm antiaircraft guns remains in the stage of unfinished experimental development.

The maximum artillery caliber during World War II was obtained in an experimental model of the American 36-inch "Little David" mortar -- 914 mm.

In the past decade the ground artillery of foreign armies virtually renounced both small and very large calibers. For example, 105, 155, 175 and 203-mm caliber pieces constitute the basis of modern American field artillery. In the antiaircraft artillery the picture is different. Here the functions of medium- and large-caliber antiaircraft guns have been transferred to antiaircraft guided missiles, while automatic small-caliber (20, 30, 35 and 40-mm) antiaircraft guns to combat low-flying aerial targets are under intense development.

Maximum Effective Range

One element of the power of artillery is the maximum effective range of pieces, i.e. the ability to hit targets at a great distance. Sometimes maximum effective range is regarded as the ability of a gun to support combat operations with friendly fire continuously without frequent shift of fire positions.

For ground field artillery maximum effective range is range of fire; for antiaircraft artillery it is range of fire and altitude; for antitank artillery it is the range that is effective for armor-piercing capability and hit probability.

Maximum effective range depends on many factors: design of the piece, shape, weight and distribution of shell mass, size of charge, angle of elevation of barrel. Maximum horizontal range of fire is usually reached at barrel angle of elevation of about 45° (angle of maximum range). In so-called superrange fire (over 40 km) the angle of elevation equals approximately 53°. In this case the shell will enter the stratosphere at an angle of 45°.

Antitank and tank guns are characterized by point-blank range, i.e. maximum range of fire at which height of trajectory does not exceed height of target (2 m as applied to tanks). Firing on tanks at point-blank range (1000-1500 m) significantly raises the probability of hitting them.

During the course of World War II a tendency was observed towards an increase in the range of field artillery pieces. However, this was not the objective purpose, but rather the result of the realization of other more important requirement set for artillery by the troops. During the war it was found that fire from field pieces at a distance of over 10 km was not effective enough owing to the impossibility of arranging for reliable observation of shell bursts. Therefore, such fire did not become widespread. Field artillery, together with special long-range artillery, was used only in special cases, for example, in the organization of counterbattery activities, in fire intended to disrupt enemy troop control and operation of the rear area, when reconnaissance, observation and fire adjustment were provided.

For effective antitank warfare the main aim was to increase the muzzle velocity (velocity of the shell at the moment it leaves the bore) of conventional armor-piercing and subcaliber projectiles, i.e. to enhance the ballistics of antitank guns and provide maximum point-blank range. This was the basic way of improving flat-trajectory field pieces. Incidentally another problem was solved -- that of increasing the range of fire of high-explosive fragmentation shells. For example, our 100-mm field gun M1944 was developed mainly as a powerful antitank gun to combat tanks of the "Tiger" and "Panther" type. However, since it possessed high muzzle velocity (about 900 m/sec), it was able when required to fire high-explosive fragmentation shells for a distance of over 20 km. Once more the old truth was corroborated: good maximum effective range never hurts a gun.

As for special-purpose artillery (heavy and superheavy artillery, siege artillery, railroad artillery), here the problem of maximum effective range coupled with the power of the effect of high-explosive shells became the principal problem. For its barbarous shelling of Leningrad during the Great Patriotic War the Hitlerite Army used 150- to 420-mm caliber siege artillery, some of the pieces (170-mm and 240-mm guns) having a range of fire as long as 28-31 km.

Some models of German railroad artillery had even greater ranges: 36-37 km (203-mm and 283-mm guns), 40 km (806-mm gun "Dora"), 42 km (380-mm gun "Siegfried"), 47 km (283-mm gun "Bruno"), 57 km (283-mm gun "K-5") and even 120 km (210-mm gun "K-12"). The weight of these guns in firing position was extraordinarily great -- from 86 to 308 tons. Of course, these large-caliber weapons, of which there were only a few, were unable to have any appreciable influence on the course or outcome of even individual operations. These guns are of only historical interest, attesting to the persistent, albeit unavailing attempts of the Germans to solve the problem of superrange fire with the methods of classical artillery.

Foreign military specialists believe that the maximum effective range of tube artillery can be increased through the use of high and ultrahigh pressures in gun barrels, through the use of rocket-assisted projectiles (combining the properties of conventional and rocket shells), and through the use of light gases (helium, hydrogen etc.) in order to obtain ultrahigh muzzle velocities of 3000 m/sec or more.

Precision of Fire

This is one of the most important characteristics of any firearms. Precision of fire consists of a close pattern of shooting and accuracy of fire.

Close pattern of shooting is the name customarily given to that property of weapon and ammunition which makes possible the grouping of points of impact of shells in a minimal area. The close pattern of shooting of a specific weapon is characterized by the ratio of longitudinal (P_{long}) and lateral (P_{lat}) probable error to range X. A piece is considered good if the ratio P_{long}/X is a range of $1/300 \div 1/400$, and the P_{lat}/X ratio = $1/1500 \div 1/2000$. The smaller this ratio, the better the close pattern of shooting of the weapon.

For antitank guns firing on vertical targets (tanks, armored carriers etc.) the ratio P_{vert}/X, i.e. the ratio of vertical probable error to range X, is of great importance.

The better the close pattern of shooting, the quicker can the target be hit with less expenditure of projectiles.

It is customarily throught that closeness indicators are the opposite of dispersion indicators. The less the dispersion, the closer the pattern of shooting.

It is known that even with the most careful observance of all rules and conditions of firing from a gun, the projectiles discharged one after another do not fly along the same trajectory. They form, so to speak, a sheaf of trajectories radiating from the muzzle of the piece. Thus shells are dispersed over an area. Dispersion results from the combined action of many causes, which give rise to random deviations in the conditions of the projectile's flight, and these deviations differ for every round. For example, dispersion of muzzle velocities is dependent upon nonuniformity of powder charges and variations in their temperature and moisture content, on deviations in the magnitude of the weight of the projectile etc. Dispersion is significantly affected by the inadequate stability of the piece during firing if the piece is poorly braced in the fire position. Diversity of shell flight conditions is also due to weather conditions during a specific shot, i.e. by variations in wind direction and force, atmospheric pressure, temperature and air density.

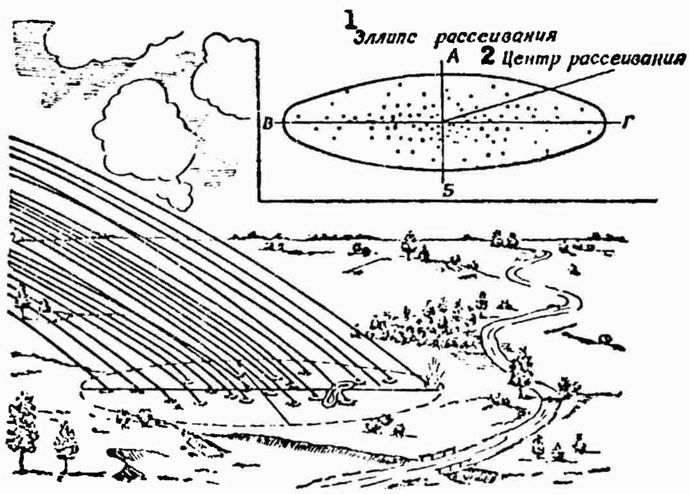


Figure 14. Ellipse of dispersion

Keys:

1. Ellipse of dispersion
2. Center of dispersion

Experience shows that the dispersion of individual shells conforms to a certain law: shells fall within a limited ellipse-shaped area (Figure 14). In the area of the ellipse shells group symmetrically to its axes, but nonuniformly: more closely towards the center of the ellipse and more sparsely towards its edges.

The area of the ellipse of dispersion grows with an increase in range of fire; consequently, the close pattern of shooting deteriorates. Therefore, at close range guns can reliably hit even such pinpoint targets as individual machine guns or grenade launchers. However, we should not be surprised by the fact that artillerymen cannot with their first shots destroy the same machine gun situated 5-7 km from the gun. Tens of shots will be required to fulfill this mission.

Whereas close pattern of shooting is assessed by the deflections of shells from mean trajectory, accuracy of fire is assessed by the deflections of mean trajectory from target center.

Accuracy is sometimes regarded as the ability to bring the center of dispersion of bursts into coincidence with a desired point on the terrain, i.e. with the target. Accuracy depends primarily on marksmanship, precision and teamwork of the combat crew, accuracy of sighting mechanisms and fire control instruments, and other factors. Accuracy is affected by several individual qualities of a given piece, for example, the precision with which the barrel was manufactured, erosion in the bore, curvature of bore.

Rate of Fire

It is defined as the maximum number of rounds that can be fired per minute from a fully serviceable piece without change of laying. A high rate of fire is absolutely necessary in field pieces to repel enemy tank attacks when the outcome of a duel between tank and gun is decided in seconds. The more rounds a gun fires at such a critical moment, the greater is the probability of destroying the tank.

A high rate of fire permits the performance of combat missions with a smaller number of pieces and, in addition, makes possible surprise of artillery attacks and the massing of fire.

An increase in the rate of fire is achieved by mechanization and automation of the loading and firing process, as well as by the rapid teamwork of the gun crew. Rapid-fire guns are loaded with fixed rounds which permit the loading process to be executed in one step.

Automation of the loading and firing process has become very widespread in antiaircraft artillery for both small and medium calibers. But such automation, in view of the increase in caliber, has necessitated the use of a special power unit, has increased the complexity of the gun and added markedly to its weight. Therefore it has been found unacceptable for field artillery.

In field pieces, especially antitank guns, a different trend has prominently appeared, namely the use of the semiautomatic breech mechanism. Here without human participation, by virtue of the energy of the powder gases generated during firing, the breechblock is opened, the spent shell case ejected and the springs compressed, which then, after manual loading, close the breechblock. While automation in the case of antiaircraft guns yields a great gain in the rate of fire, the semiautomation of field pieces by increasing the rate of fire principally conserves the strength of the gun crew. This is the important aspect of semiautomation because handling fixed rounds of great weight (15-20 kg or more) increases a gun crew's fatigue appreciably.

In recent years there has been an effort abroad to increase the rate of fire of antiaircraft guns through multibarreled design, i.e. through the use of several barrels rather than one. For example, the United States and Sweden have developed double-barreled (twin-barreled) 40-mm antiaircraft guns; Switzerland triple-barreled 20-mm guns; the United States triple-barreled 30-mm and six-barreled 20-mm guns of the Vulcan type.

Fire Maneuverability

It includes primarily such elements as speed in the opening of fire and flexibility of fire. For example, division guns and howitzers of the World War II period needed less than one minute to shift from traveling position to firing position. Artillery also possessed good flexibility of fire, i.e. the ability of pieces to transfer fire rapidly and accurately from one target to another. Split-trail carriages permitted large angles of traverse (up to 60°) without moving the gun itself, and large elevation ranges, for example, from -5° (below the horizon) to + 45° for guns and from -3° to + 65° for howitzers.

The design of some modern field pieces and mortars makes possible all-round fire.

The modern antiaircraft gun is a complex system permitting continuous target tracking and almost continuous delivery of fire. Therefore, very high speeds of laying in azimuth (60 deg/sec or more) and elevation (30 deg/sec or more) are especially necessary in this case. This is achieved through the use of guidance systems with special power drives (electric or electrohydraulic).

Mobility

The maneuvering character of modern operations necessitates high mobility of artillery. The mobility of a piece is its capability of rapid long-distance movements, its ability to maneuver on the terrain at high speeds and rapidly occupy fire positions and, finally, its man-handleability during shifts of fire. The principal gauge of mobility is speed of movement, which is dependent on weight of the piece, kind of traction, and design of the carriage from the transport viewpoint.

Obviously the weight of any piece should be the least possible. However, weight reduction inevitably results in a lowering of the gun's power. Therefore, artillery designers are always faced with the central problem: how to provide the necessary mobility simultaneously with the prescribed power, i.e. how to keep the weight of a piece minimal while preserving its power. This complex problem is solved by a reasonable compromise between the various service requirements for a gun of a particular purpose, and the number of requirements that have to be reconciled is large. Usually the most urgent requirements are singled out and the others are reconciled with them as far as possible, an attempt being made, of course, to select the optimum variant.

As early as World War II the trend became widespread to cut down the weight of guns by employing muzzle brakes. Almost all new pieces coming out during and after the war were equipped with muzzle brakes, which make possible absorption of 50 percent or more of the recoil energy during firing, taking a significant load off the recoil mechanism and thus reducing the adverse effect firing on the carriage. Muzzle brakes began to be used in Soviet artillery even before the war, for example, in the 152-mm gun-howitzer M1937 and other pieces. Under combat conditions they proved extremely reliable and effective.

A trend was also marked during the war towards the employment of light alloys in weapon models, but in practice these alloys never became very popular. This was due to the significantly lower mechanical properties of the brands of light alloys used at that time as compared with steels, as well as to the scarcity and high cost of light alloys, which were channeled as first priority into the aircraft industry. The use of light alloys in artillery armament did not usually go beyond the manufacture of secondary parts made thereof (handwheels, boxes, low-load brackets etc.). Aluminum alloys were used in the manufacture of such assemblies as trails in only a certain portion of the Soviet 45-mm guns M1932 and 1937.

In the postwar period, however, special aluminum, magnesium and titanium alloys with high ultimate strength began to be widely employed in mortars for the manufacture of barrels, bipods and base plates (French 81-mm and 120-mm mortars, American 81-mm mortar etc.) and in self-propelled guns for the manufacture of bodies and turrets (light alloys accounted for about 40 percent of the combat weight of the American 105-mm and 155-mm self-propelled howitzers), as well as in other models of armament for those parts not subject to extraordinarily great dynamic loads.

As for the type of traction for gun towing, mechanical traction had already taken a dominant position at the end of World War II. Horse traction, with which the towing speed of even light pieces did not exceed 10-12 km/hr, lost its former significance in artillery. This type of traction by the end of the war had begun to be employed, instead, by way of exception under the specific conditions of certain combat areas, for example, under mountainous conditions. The wheeled and tracklaying artillery prime movers of our day can develop relatively high speed of travel on roads, and in most cases possess completely acceptable cross-country ability over broken terrain.

The mobility of a piece in many respects depends on how rational the design of the carriage is from the transport viewpoint, i. e. how successfully the problems of lightness, cross-country ability, handling ease, stability and accuracy life of the system during movement have been solved. This is very important during travel over bad roads and roadless areas. To assure good cross-country ability of a gun over dirt roads and wooded roads, as well as roadless areas, an effort is under way to make its axle length correspond to the axle length of the prime mover, and the ground clearance of the gun (distance from the road to the lowest point of the carriage) not less than the road clearance of the prime mover.

The best means of protecting guns and their mechanisms from dynamic overloads when towed behind prime movers is acknowledged to be the use of suspension and the bracing of individual mechanisms in traveling position. It is to the credit of Soviet artillery designers that all our guns created back in the prewar years and during the war had spring-type suspension, making possible gun towing at the speeds which the prime movers themselves were capable of developing.

And the 100-mm field gun M1944 employed the most advanced type of suspension -- torsion, which produced an appreciable saving in weight and made the design more compact. The trend towards the adoption of suspension mechanisms into artillery ordnance which became so popular in Soviet artillery was later reflected in other armies too.

A basic trend in the development of modern field tube artillery in the armies of the capitalist countries is a rise in maneuverability -- the development of self-propelled artillery to replace pieces towed by mechanical traction. It is thought that only self-propelled artillery is capable of providing higher speed of travel and better cross-country ability over broken terrain. Self-propelled guns differ advantageously from towed guns in yet another respect. They require vastly less time to be put into firing position with a smaller number of servicing personnel. Depending on the situation, they can be speedily concentrated or dispersed.

Foreign specialists note that self-propelled artillery meets the requirements of nuclear warfare to the maximum degree. Protected against bullets, projectile and mortar-shell fragments and to some degree against the shock wave of a nuclear explosion, self-propelled guns are capable of operating on contaminated terrain. Therefore, the proportion of self-propelled artillery in the armies of the capitalist countries is constantly growing. For example, the artillery of American and French divisions in the new organization consists solely of self-propelled guns.

Apart from the development of self-propelled artillery, towed guns are also being developed abroad to provide direct support of airborne forces and of forces transported by air. For such guns special carriage-mounted power units are under development (for example, for the American 105-mm and 155-mm howitzers).

The result of giving guns self-propulsion is to increase their mobility directly on the battlefield (up to 15 km/hr) and to save the strength of gun crews during a change of fire positions.

Buoyancy

It is known that modern tanks are capable of negotiating water barriers afloat or along the bottom (with complete submersion in the water). Buoyancy is either given tanks by attached equipment or it is deliverately provided for in their design . The armored carriers used for motorized infantry are amphibious in most cases. Hence it follows that modern artillery which cooperates closely in all kinds of combat with tanks and infantry must also possess buoyancy. Self-propelled artillery achieves this characteristic by the use of buoyant chassis. If such a chassis cannot be selected, the self-propelled gun is outfitted with a special attachment, for example, a light folding frame over which waterproof fabric is stretched. Before immersion of the vehicle in water the frame is quickly put up and it assures buoyancy of the entire system.

Air Transportability

Inseparably connected with the problem of gun weight reduction is that of assuring their transportability by air. It is thought that in our time every artillery weapon must in case of need be lifted for long distances (thousands of kilometers) by military transport aircraft and for relatively short distances (tens and hundreds of kilometers) by army helicopters. In the American army, for example, most guns can be transported by one aircraft in completely assembled form. To transport by air such large-caliber self-propelled guns as the 175-mm gun and the 203-mm howitzer takes two aircraft per gun: one aircraft to transport the chassis, the other the tipping parts of the gun.

Abroad, especially in the U.S. Army, a great deal of attention is given to increasing the maneuverability and combat efficiency of ground forces through the use of army aviation, primarily helicopters. In the opinion of American military specialists, army aviation is an important component of the ground forces and has the job of supporting the execution of the missions confronting them. A doctrine of the modern American Army uses the term "flying soldier," which implies ever increasing penetration of the air space by podrazdeleniya of the ground forces together with their arms.

The increased interest in helicopters is due to the fact that, since they possess considerably greater speed of travel than any type of ground transport and are practically independent of the character of the terrain and state of ground communications, they can provide fast and concealed maneuver at low altitudes in approaching a given area. These characteristics of helicopters are especially effective in negotiating wide water barriers, contaminated and flooded areas, as well as terrain sectors impassable to ground transport.

Figure 15. Air transport of gun and ammunition for it in external load of helicopter.

In the foreign military press there has recently been lively discussion of questions relating to the combat employment of helicopters. There has been consideration of the part they play and their significance in "limited wars," i.e. in the drive against the national liberation movement of peoples. There has been careful study of the experience in the use of helicopters in South Vietnam, in particular for the speedy transfer of guns and mortars with ammunition (Figure 15).

In addition to the landing method, the dropping of guns and ammunition by means of special parachute systems is also employed.

Air transportability, and especially parachute dropping, set very rigid requirements to be met by artillery weapons: reduction in size and decrease in weight of pieces; greater compactnese of materiel; removal or sheathing, insofar as possible, of all protruding and brittle parts; ruggedization of ammunition and packing; increase in safety of fuzes.

3. Operating Characteristics of Pieces

Any artillery weapon must be reliable in operation and possess the necessary strength and accuracy life, simplicity and ease of operation, and safety in handling.

Reliability

Reliability is the term applied to the capacity of a gun to perform all assigned functions under specified operating conditions over a specified (given) period of time with values of basic parameters kept within a preestablished range.

The operating conditions of artillery weapons are extraordinarily complex and diverse: heat as high as 40-50°, cold as low as -50°, rain, snow, dust, mud, prolonged firing etc. And under any conditions however adverse, the gun must be reliable and troublefree in operation.

Of course, an artillery weapon is not as complex in its construction as a guided missile. Whereas the breakdown of a few elements of a missile make it useless for combat employment, individual defects in a gun do not disable it for combat. For example, there were instances during the war when our artillerymen successfully engaged enemy tanks using guns with damaged or demolished sights -- they aimed the guns at the target directly through the barrel.

It is known that no technical device (gun, assembly, machine, instrument), however perfect it may be, can perform for its entire service life without a single malfunction. However, some devices get out of order more, others less frequently. The average time of troublefree operation of a technical device (from the correction of one malfunction to the appearance of the next) is considered the basic quantitative reliability indicator of a given device. Since the elimination of every malfunction usually requires repair, the average time of a technical device's troublefree operation between repair jobs is regarded as its reliability indicator.

The operating reliability of artillery weapons depends to a certain extent on their complexity. The more complex a weapon model, the more devices, assemblies and mechanisms there are in it, the greater is the probability that failures will occur.

New models of artillery weapons, replete with automation, hydraulics and electronics, with diverse calibrating and testing equipment and high-precision measuring apparatus, require servicing personnel to use new ways of solving questions of operation, repair and storage. Engineering and technical servicing is becoming an important factor in the operating reliability and troublefree operation of a weapon and its role is constantly growing.

Designers are taking a number of measures to increase the reliability of guns. For example, they duplicate the actions of the mechanisms on which the combat efficiency of a gun depends (manual opening of the breechblock in the event of failure of the semiautomatic device; dual trigger mechanism etc.); they employ locking devices to prevent wrong actions that might lead to breakdowns; they provide warning signs and indicators for timely prevention of defects etc. Unserviceability due to the breakdown of a part is rapidly corrected by simply replacing the damaged element from spare parts on hand.

However, the principal requirement for reliability is proper operation of a weapon. Therefore, the strictest and most scrupulous compliance with all requirements of field manuals, handbooks and instructions setting forth the rules for the use of combat materiel is necessary. To use combat materiel properly, it must be thoroughly studied and known, lovingly protected, mastered to perfection, maintained in complete serviceability and constant combat readiness. Preventive maintenance of all kinds must be performed in a first-rate manner.

As weapons are developed and improved and as various technical devices increase in complexity, the reliability of their operation becomes increasingly a basic and decisive indicator of their quality.

Technical devices, including weapons, have other quality indicators in addition to reliability, primarily accuracy life.

Accuracy Life

Accuracy life is the ability of a piece to withstand wear and fully retain its combat characteristics for as long a time as possible. The measure of accuracylife is the number of rounds fired and the number of kilometers traveled on the road which a gun can take before becoming unserviceable due to wear of its parts.

Wear has an especially marked effect on the condition of the bore. Wear on the barrel leads to a reduction in the maximum pressure of powder gases, a decline in muzzle velocity and therefore to an increase in fire dispersion. The indicator of total wear of a gun is a ten-percent drop in muzzle velocity for field guns, four-percent for antiaircraft guns. In this case the barrel is considered worn out. It is discarded and replaced with a new one.

Experience shows that the accuracy life of a barrel rapidly declines with an increase in caliber and muzzle velocity. For example, medium guns and howitzers have an accuracy life reckoned at several thousand rounds, but large-caliber guns firing at high muzzle velocities only hundreds of rounds.

The attempt is made to reduce the rate of wear of other gun accessories by rational design, choice of wear-resistant materials, use of appropriate lubricants and observance of the rules for care and maintenance.

Simplicity and Ease of Operation

This is an important requirement which every weapon model must meet. In the creation of weapon models designers strive to provide for convenient placement of mechanisms and operators' positions (seats, footboards, platforms, instrument boards and panels etc.), to locate the necessary instruments and accessories rationally, and recommend simple methods of gun operation. The design must provide for special devices to facilitate the work of the crew (jacks, loading devices for heavy-caliber guns, rollers under trails in order to manhandle the piece etc.). Stripping and assembly of basic units and mechanisms must be simple and practicable. Gun mechanisms must not require great exertion. It is considered essential that there be indicators and signs reminding the combat crew of the direction in which to turn a handwheel or handle in performing a necessary operation.

Safety in Handling

This is achieved by the use of safety devices, locking devices, fenders, warning signs, and rational placement of parts and mechanisms to reduce the possibility of bruises, pinching and other injuries to personnel manning the gun.

For example, all Soviet muzzle-loading mortars have special safety devices against double loading to prevent the possibility of a second mortar shell being dropped in the bore if an unnoticed misfire should occur and the first mortar shell is still in the barrel. As is known, double loading results in bursting of the mortar barrel.

Strict observance of safety requirements is necessitated because artillerymen are dealing with explosives which are dangerous to handle. It must be emphasized that exact compliance by personnel with all directions of service manuals, field manuals and instructions regulating gun operating procedure is of decisive importance for the prevention of accidents and injuries.

4. Economic Characteristics of Guns

Weapons are expensive. Vast resources and funds are spent for their development and production. The rate of armament development is constantly rising every year. The process of updating armament and war materiel is accelerating more and more. In the services the number of new models of armament is growing, each of them, as a rule, considerably more complex and therefore more costly than the preceding model.

In the creation of the latest models of artillery armament the point of departure is primarily their anticipated military and economic effectiveness. This means that the optimal variant of a model will be the one which will assure execution of the assigned combat missions with minimal economic inputs and a given system of constraints (for example, on the number of operating personnel, consumption of critical materials etc.), or the one which will assure execution of the maximum number of missions with fixed inputs and a given system of constraints. While making an all-out attempt to cut armament costs, at the same time designers cannot do this by lowering combat and operating characteristics -- power, reliability of action, safety etc.

The most important economic requirement to be met by arms is that they be series-produced at plants from Soviet raw materials.

In the creation of weapons designers try to use materials which will satisfy strength and reliability requirements rather than those of the highest quality. It would be unreasonable, for example, to make the handwheels of gun mechanisms out of expensive alloyed gun-barrel steel.

Serious significance attaches to the use of high-efficiency technology in artillery production. Such economically advantageous technological processes as stamping, shaped casting, arc and gas welding, the broaching of holes, multicutting, high-speed cutting, electric spark machining etc. improve the quality of guns, decrease metal consumption, speed up and cut the cost of production.

Modern technological production processes yield maximum economic effect only when the weapon design itself is technologically efficient. This is achieved by decreasing the number of parts, by simplicity of their shape, by prescribing precision of execution and finishing no greater than required by the conditions under which a part will operate, by using the simplest methods of manufacture with the minimum number of necessary operations during machining etc.

Minimum inputs of labor, time and capital are the criteria of good technological effectiveness of a design.

Table 6

NUMBER OF MACHINE HOURS FOR MANUFACTURE OF 76-mm DIVISION GUNS

A Образец, год изготовления	B 76-мм пушка обр. 1902 г.	C 76-мм пушка обр. 1936 г.	D 76-мм пушка обр. 1939 г.	E 76-мм пушка обр. 1942 г.		
				1942	1943	1944
F Станкочасы	57[illegible]	2634	1300	1029	909	475

Keys:

- A. Model, year of production
- B. 76-mm gun M1902
- C. 76-mm gun M1936
- D. 76-mm gun M1939
- E. 76-mm gun M1942
- F. Machine hours

Many examples of high technological efficiency of guns are known in Soviet artillery armament. Thus, the number of parts in our division guns has systematically been cut from model to model: the 76-mm gun M1936 had 2080 parts, the 76-mm gun M1939 1057, while the 76-mm gun M1942 had only 719. This has permitted a sharp decrease in time input for gun manufacture (Table 6).

A mandatory condition for mass or large series production is interchangeability of parts and assemblies. This is of great importance for the operation and repair of armament. Thanks to interchangeability a damaged part can quickly be replaced under combat conditions with a spare part, especially in such an important assembly of the gun as the breechblock.

Standardization, i.e. the use in different models of identical parts, assemblies, mechanisms and units, is exceptionally important for artillery weapons. The use of standardized elements shortens the time and lowers expenditures for design and planning, development of technology, the production and testing of new models; it facilitates the mastery of new weapons in the services, and simplifies repair and supply of spare parts.

Here are a few examples of standardization from the history of Soviet artillery weapons. Thus, all 76-mm division guns M1902/30, 1936, 1939 and 1942 were supplied with interchangeable ammunition; for the 152-mm gun-howitzer M1937 the same rounds were used as for other 152-mm guns; for 82-mm mortars of all types the ammunition was the same. The significant economic effect of this standardization in wartime can hardly be overestimated. First, the production and storage of ammunition were made cheaper and simplified. Second, troop supply was considerably facilitated, which is exceptionally important in wartime. Third, it became possible to make wide use of ammunition stocks which had been created and accumulated over a long time in a period of peace.

Another example. Soviet artillery ammunition, as a rule, has employed point and base fuzes. It is known that all our fragmentation, high-explosive fragmentation, and high-explosive gun and howitzer shells from 100 to 152 mm in caliber were equipped with RGM [Rdultovskiy membrane-type point detonating] fuzes.

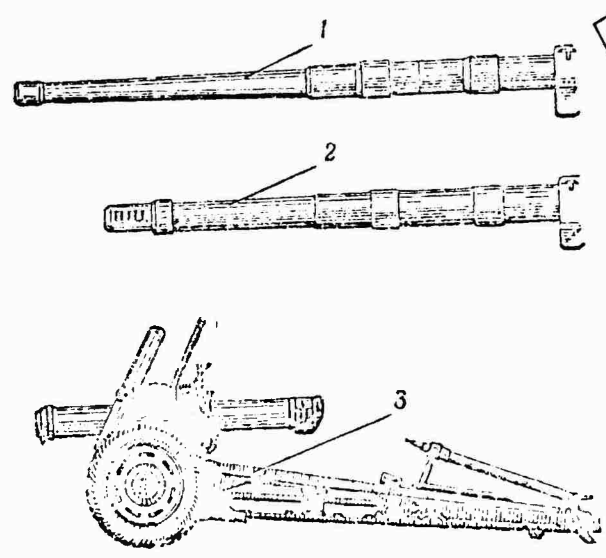


Figure 16. 122-mm gun M1931/37 and 152-mm gun-howitzer M1937 on standardized carriage:

1) gun barrel; 2) barrel of gun-howitzer; 3) standized carriage.

A third example. Three models of Soviet heavy pieces -- 152-mm gun M1935, 203-mm howitzer M1931 and 280-mm mortar (mortira) M1939 -- had the same standardized carriage. Other guns with the most diverse calibers, ballistic characteristics, barrel sizes, many breechblock parts etc. were created to use the same carriage (Figure 16).

Standardized parts and assemblies can be found in wedge- and screw-type breechblocks, the semiautomatic device, sighting devices and recoil mechanism.

During the years of the past war Soviet designers, who had built up solid experience in standardization, were quickly able to solve the complex problem of developing self-propelled artillery. Using the chassis of existing tanks and combat-tested artillery weapons, they created the well-known self-propelled gun mounts SU-76, SU-85, SU-100, SU-122, ISU-122, ISU-152.

A characteristic feature in the development of the foreign self-propelled artillery of our day is chassis standardization, i.e. the use of one chassis for a whole family of guns of varying purpose. Chassis standardization simplifies operations, repair and spare-part supply and facilitates the training of personnel of combat and repair podrazdeleniya. Thus, the standardized chassis in the American Army, for example, is the amphibious and air-transportable tracklaying carrier M-113, on which are based more than ten combat and special vehicles, including the 105-mm and 155-mm self-propelled howitzers. Chassis standardization is a manifestation of the general trend in modern machinery manufacture towards standardization of basic design elements.

Under modern conditions the standardization used in war material contributes to the elimination of diversity of type sizes and brands of particular items. It is essential to standardize fasteners (screws, bolts, nuts), certain elements of parts (threads, holes, recesses, grooves) etc. Standardized parts can be made at different plants according to the same process. This permits timely introduction into production of the most advanced technological processes based on the latest achievements of sciences and technology and, in final analysis, makes possible a rise in product quality.

5. Basic Characteristics of Artillery Pieces

The generalized characteristics of pieces are: muzzle energy E_o, power factor C_{E_o}, and metal utilization factor η.

Muzzle energy is the name given the kinetic energy of a projectile on leaving the bore:

$$E_o = \frac{qv_0^2}{2g},$$

where q is weight of the projectile in kg;

v_o is muzzle velocity in m/sec;

g is gravitational acceleration equal to 9.81 m/sec^2.

Muzzle energy is expressed in kilogram-meters or ton-meters. It determines the basic combat characteristics of a piece -- range of fire and penetration effect of the projectile at the target. For example, for the 120-mm mortar M1943 $E_0 = 60$ tm, for the 122-mm howitzer M1938 $E_0 = 295$ tm, and for the 122-mm gun M1931/37 $E_0 = 800$ tm.

Power factor is expressed as the ratio of muzzle energy in ton-meters to the cube of the gun caliber in decimeters:

$$C_{E_0} = \frac{E_0}{d^3} \left(\frac{\text{tm}}{\text{dm}^3}\right).$$

Power factor makes it possible to judge the power of a piece irrespective of its caliber. It shows the useful work per unit volume of bore for similar gun construction. Power factor ranges from 100 tm/dm^3 (for mortars) to 1000 tm/dm^3 or more (for antitank, antiaircraft and naval guns).

Metal utilization factor is the ratio of muzzle energy to the weight of the piece in firing position:

$$\eta = \frac{E_0}{Q_6} \left(\frac{\text{kgm}}{\text{kg}} \text{ or } \frac{\text{tm}}{\text{t}}\right).$$

This factor characterizes the degree of design perfection in the sense of combining gun power and mobility, i.e. it shows how metal is utilized -- how many kilogram-meters of muzzle energy there are per kilogram of gun weight.

Metal utilization factor tends to increase with an increase in caliber. In addition, it does not reflect certain gun characteristics affecting the weight of the entire design. In particular, automation, which adds to gun weight, lowers the metal utilization factor. But if the schematic diagrams of two or more pieces are similar, metal utilization factor is very convenient for estimating the combination of power and mobility of these guns.

Recoilless guns and mortars have the maximum value of η going as high as 200 kgm/kg or even higher, while four-trail automatic guns have the minimum value.

Table 7 presents values of metal utilization factor for certain pieces.

Table 7

METAL UTILIZATION FACTOR FOR CERTAIN PIECES

A Образец орудия (миномета)	B Коэффициент использования металла η, кгм/кг
1 122-мм пушка обр. 1931/37 г.	112
2 122-мм гаубица обр. 1938 г.	125
3 152-мм гаубица-пушка обр. 1937 г.	130
4 240-мм миномет	175
5 85-мм пушка	177
6 160-мм миномет	188
7 100-мм пушка обр. 1944 г.	191
8 107-мм безоткатное орудие	198
9 120-мм миномет обр. 1938 г.	218
10 82-мм безоткатное орудие	234

64

Keys:

A. Gun (mortar) model

1. 122-mm gun M1931/37
2. 122-mm howitzer M1938
3. 152-mm gun-howitzer M1937
4. 240-mm mortar
5. 85-mm gun
6. 160-mm mortar
7. 100-mm gun M1944
8. 107-mm recoilless gun
9. 120-mm mortar M1938
10. 82-mm recoilless gun

B. Metal utilization factor η , kgm/kg

Chapter IV

PRINCIPLES OF THE CONSTRUCTION OF ARTILLERY PIECES

1. Structural Diagrams of Guns

An artillery piece is a powerful heat machine, unicue in the conditions and character of its operation. The working principle of a gun is based on utilization of the energy of powder gases. During firing, powder gases act upon barrel and projectile with a pressure reaching 3000-4000 kg/sq cm and a temperature of 3000° C. The power of a medium-caliber gun is 400-900 h.p., and that of a large-caliber gun (over 300 mm) 9 to 12 million h.p. For sake of comparison let us recall that the power of the Soviet 122-mm howitzer M1938 is about 130,000 kw (1 kw = 1.36 h.p.), while the power of Dneproges /Dnepr Hydroelectric Power Station imeni V. I. Lenin/ is 653,000 kw. The efficiency of artillery pieces is considered to be very high -- up to 35 percent. This is equivalent to the efficiency of internal combustion engines and considerably greater than the efficiency of steam engines.

Let us consider two most characteristic schematic diagrams which have become classical -- those of the field howitzer and mortar. They have proved themselves in combat. In any modern piece the basic structural elements of these diagrams vary to some extent.

Figure 17. Construction of artillery piece:

1) barrel; 2) muzzle brake; 3) breech ring; 4) breech-block; 5) cradle; 6) recoil mechanism; 7) top carriage with pointing mechanisms; 8) shield; 9) trails; 10) running gear; 11) sighting mechanisms.

A modern artillery piece (in this case the howitzer) consists of the following basic assemblies (Figure 17): barrel with muzzle brake and breech ring, breechblock and carriage. The carriage includes: cradle, recoil mechanism, top carriage, pointing mechanisms and shield, split-trail bottom carriage, running gear, and sighting mechanisms.

The barrel is the basis of a gun. It gives a projectile the prescribed flight direction, rotary motion, and a certain muzzle velocity.

The muzzle brake is screwed onto the muzzle end of the barrel and is intended to absorb recoil energy.

Breech ring is the name given the rear end of the barrel in which the breechblock is located.

The cradle is the trough-shaped or cylindrical part housing the barrel. By means of its trunnions the cradle rests on the top carriage, and by means of the elevating mechanism can rotate in the vertical plane. The cradle also serves to secure the recoil mechanism. At the time of firing the barrel recoils along the guide rails of the cradle and then returns to its initial position.

The recoil mechanism consists of a recoil brake (absorbs the energy of barrel motion during firing) and a recuperator (returns the recoiled barrel to its original position).

The barrel, cradle and recoil mechanism, taken together, are the tipping parts of a gun.

The top carriage is a massive part of complex configuration, which is intended to house all the tipping parts of a gun, the pointing mechanisms, equilibrator, sighting mechanisms and shield. Underneath, the top carriage has a pintle, which goes into a hole in the bottom carriage and serves as the axis of its horizontal rotation. By means of the traversing mechanism the top carriage moves in the horizontal plane.

The bottom carriage with split trails and running gear is the foundation of the entire piece. The trails serve to give the piece stability during firing. In the firing position they are opened out and bear up against the spades, through which stresses are transmitted to the ground during firing. In the traveling position the trails are coupled together and fastened to the hook of the prime mover.

The running gear is intended for movement of the gun and for its support on the ground. It consists of axle, wheels with rubber truck tires and suspension mechanisms. The selection of a piece's running speed depends on its design, weight, and the prescribed speed of travel.

Sighting mechanisms are necessary for precise pointing of a gun at a target. They consist of a panoramic sight and a gun sight. Antitank guns also have optical sights for direct laying fire. Field gun sights are mounted on the bracket of the top carriage and are connected in some manner with the barrel.

The construction of a muzzle-loading mortar of classical design is very simple. The basic parts of the mortar (Figure 18) are: barrel with breech ring, bipod mount, base plate, sight and double-loading safety lock.

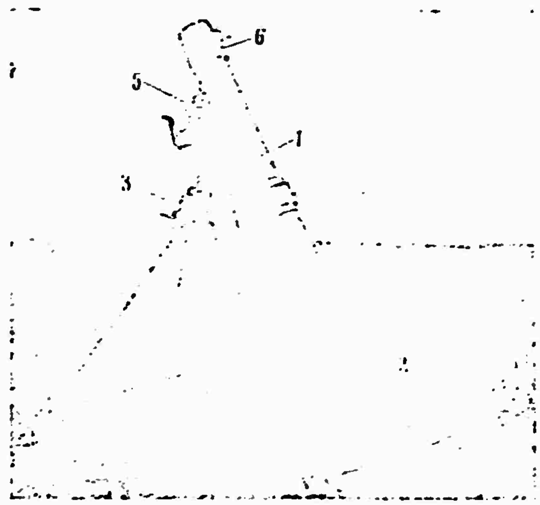


Figure 18. Construction of mortar:

1) barrel; 2) breech ring; 3) bipod mount; 4) base plate; 5) sight; 6) double-loading safety lock.

The barrel, as a rule, is a smooth-walled tube, closed at the rear end by a breech ring.

While in modern guns the maximum pressure of powder gases in barrels reaches 4000 kg/sq cm, in mortars it does not exceed 1000 kg/sq cm, i.e. four times less. Therefore mortar barrels are made thin-walled and, consequently, light.

The breech ring is screwed onto the rear end of the barrel tube. At the bottom of the breech ring is located a firing pin, on which a mortar shell is pinned by its primer element when it is dropped into the barrel. Underneath, the breech ring terminates in a ball pivot, which serves to connect the barrel with the base plate. In the ball pivot a hole is made, through which a jemmy is forced so that it will be easier to screw the breech ring onto or off the barrel tube.

The rigid firing pin screwed into the bottom of the breech ring makes possible simplicity of design and a high rate of fire. 107 to 120-mm mortars often use a firing mechanism which can be cocked. It has two positions: rigid and cocked. In the latter case the firing pin is countersunk until release of the sear, thus eliminating the possibility of spontaneous breaking of the mortar shell primer during loading. Firing with a cocked striker takes place whenever after loading the gun laying has to be checked and the crew then pulled off the mortar for cover.

The bipod mount supports the barrel and gives it the vertical and horizontal angles. Located on the bipod mount are the elevating mechanism, traversing mechanism, leveling mechanism and sight. The bipod mount is connected to the barrel by means of a clamping collar and clamp ring. All guiding mechanisms of a mortar are of the screw type. The leveling mechanism is intended for precise leveling of the mortar in cases where the sight is rigidly fixed on the bipod mount. The need for precise leveling is obviated if an oscillating mortar sight is used.

When a mortar is fired, the recoil absorbed by the base plate is transmitted to the ground. Owing to the elasticity of the ground and plate, the barrel travels along the axis to a certain extent and then returns to its previous position. To prevent damage to mortar mechanisms during sharp recoil of the barrel the bipod mount is fastened to the barrel by means of spring shock absorbers.

The base plate serves as a support for the barrel. It consists of a foundation plate with stiffening ribs welded on the underside. Distribution of the recoil over a large area contributes to a lessing of ground pressure.

Optical and mechanical sights have gained greatest prevalence in mortar designs. Every mortar sight has an azimuth instrument and a sight scale. The azimuth instrument is intended for measuring horizontal angles, and the sight proper for measuring vertical angles.

The double-loading safety lock prevents loading a mortar with a second shell when there is already a live shell in the barrel. It is attached to the muzzle end of the barrel. All Soviet muzzle-loading mortars are equipped with reliable and automatic double-loading safety locks. They operate dependably whatever type of mortar shell is fired, for all charges provided for a given mortar, at any angle of elevation and deflection, at any rate of fire, and from firing sites on any kind of ground.

The construction of large-caliber mortars is considerably more complex. In principle, however, they have the same basic design elements: smooth-walled barrel, wheeled carriage, base plate, sight.

Large-caliber mortars are breech-loading. The long barrel and heavy mortar shell do not permit muzzle loading.

To assure that the barrel opens during loading and closes at the moment of firing the barrel of a large-caliber mortar is divided into tipping parts and breech ring. The tipping parts are a tube open at both ends. In the loading position it is held back by a locking mechanism. The breech ring in the closed position is the base of the barrel. It safely seals the barrel during firing and transmits the force of the recoil to the plate. In addition, the breech ring serves as a foundation on which the tube of the barrel tips and is locked at loading angles, and on which the barrel is connected with the carriage by means of spring shock absorbers.

The carriage is the foundation of the large-caliber mortar in firing and traveling positions. On the carriage are mounted the elevating mechanism, traversing mechanism and equilibrator, running gear with suspension mechanism, and sight. The mortar is towed by a motor vehicle, whose coupling mechanism is connected to the muzzle end of the barrel by means of a muzzle attachment slipped over the barrel in the traveling position.

2. Barrels and Muzzle Brakes

A barrel is a steel tube closed at one end by a breechblock. The interior through cavity is called the bore. In the barrel we distinguish between the front or muzzle end and the rear or breech end, to which is fastened the breech ring (located here are the breechblock, powder charge and shell). If along the gradation marks on the breech and muzzle faces of the barrel we stretch thin cross hairs, an imaginary straight line connecting the centers of these cross hairs will be the axis of the bore.

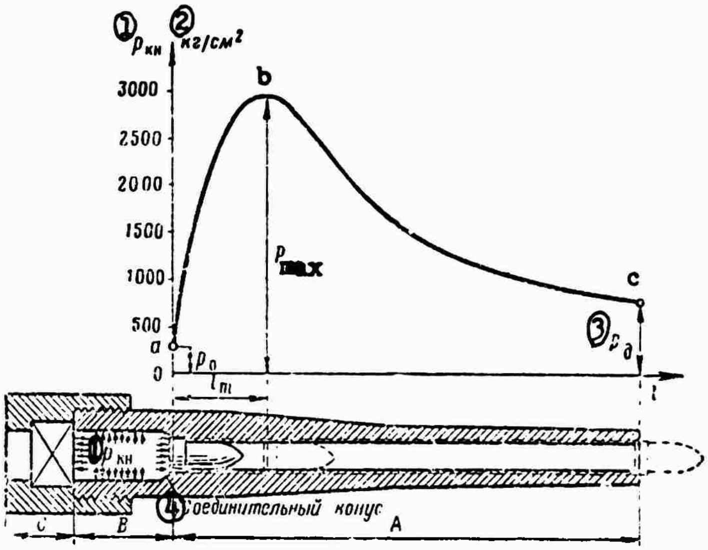


Figure 19. Diagram of construction of artillery barrel and powder-gas pressure curve as a function of projectile path along bore:

A) rifled portion; B) chamber; C) breechblock; P_{bore}) pressure of powder gases in bore; P_{max}) maximum gas pressure on base of projectile; P_o) pressure to overcome inertia of projectile (engravings in rifling); P_{muz}) muzzle pressure; l_m) projectile path prior to attainment of maximum pressure; abc) pressure curve of powder gases in barrel as function of projectile position in bore.

Keys:

1. P_{bore}
2. kg/sq cm
3. P_{muz}
4. Connecting cone

The bore of the gun has the powder chamber (cartridge chamber) and the rifled portion (Figure 19). The sector of the bore between them is called the connecting cone. During loading the projectile is inserted in the rifled portion of the bore, resting with its rotating band against the origin of the rifling. The powder charge (in case or bag) is in the chamber, and the base of the shell is situated here too.

Helical grooves are made on the surface of the bore. They are called rifling.

Shells have securely attached rotating bands made of a metal softer than the metal of the barrel (usually red copper, porous soft iron), or of other materials, for example nylon. When the shell under the action of powder gases at the time of firing begins to move along the bore, the rotating band is engraved by the rifling. Recesses and projections are formed on the band, as a result of which the shell moves in the bore just as the rifling directs it. Thus, in addition to forward motion the shell also receives rotary motion.

In Soviet pieces right-hand rifling has been adopted, i. e. the grooves in the bore run from left to right upwards. Therefore, if we look in the bore from the breech end, the rotation of the shell is clockwise. In some foreign pieces left-hand rifling has been adopted.

All rifling in the barrel of a given piece is the same in width and depth. If too shallow a depth of groove is adopted, the projections on the rotating band of the shell will also be too fine and low. A shell pressing on the edges of the grooves with these fine projections can easily mash them and break loose from the rifling. Then it will not receive the necessary rotation and will fly improperly. Too great a depth of groove is also regarded as disadvantageous.

The gyroscopic effect is skillfully used in rifled artillery. Rotary motion assures the projectile stability in the air, increases the range of flight, and makes the shell fly with tapered head forward without tumbling.

The accuracy of the projectile's flight and hence the accuracy of fire depend on the angular rotational velocity of the projectile, which is determined by the twist of the rifling in the muzzle end and by the projectile's velocity of motion in the barrel. For example, a shell of the 76-mm gun M1942 makes 357 r.p.s. at the moment it leaves the bore, while a shell of the 122-mm howitzer M1938 rotates at a rate of about 210 r.p.s. at this time.

At the time of firing powder gases press against the base of the projectile and on the walls and bottom of the bore. But the walls of the barrel resist this pressure. If the tension of the metal does not reach its elastic limit, after firing the walls contract and recover the dimensions which they had before firing. If, however, the elastic limit is exceeded, the walls do not return entirely to their initial state and remain distended. Such a phenomenon is called barrel dilation. A piece with a dilated barrel is unfit for firing since the movement of the projectile along the bore will be wrong (breakaway from rifling, impacts against walls, escape of gases etc.).

Therefore, the chief problem in the designing and production of any piece is to provide a guaranteed safety factor for the barrel.

Gas pressure in the bore from the start of powder combustion up to departure of the projectile is a variable. At first the pressure increases to a certain maximum, then declines. For every cross section of the barrel it has its maximum value determined according to the pressure curve as a function of the projectile path along the bore (Figure 19). The transverse dimensions of the barrel are likewise not uniform. Therefore, the actual safety factor of a barrel is also a variable. The following minimally necessary safety factor values have been established in practice and verified: for cross sections in the chamber region 1.2-1.25, for rifled portion of bore 1.2-1.35, for muzzle end of barrel 1.5-2.

The safety factor of mortar barrels is higher still: for the entire barrel 2, for the muzzle end not less than 3. This is due to the comparatively small thickness of the barrel walls and their pronounced heating during intense fire.

To heighten the strength of barrel walls, their thickness has to be increased. But such thickening is useful only to a certain limit, after which it becomes simply superfluous and even harmful (adds to barrel weight, results in inefficient use of metal).

The trouble is that when the metal of barrel walls expands under the pressure of powder gases, it does not participate uniformly in the resistance to this tension. The interior metal layers of a barrel expand more vigorously, while the exterior layers expand more weakly. The thicker the barrel, the less and less the part played by the exterior metal layers in breaking strength. Now if a barrel is made very thick, the exterior layers will not exert any resistance at all.

Artillery designers have been able to produce several rational barrel designs, in which all metal layers are more or less uniformly stressed.

The following basic barrel types are known: monobloc barrel, built-up barrel (inner tube with jacket slipped over it under tension), cold-worked (autofretted) barrel, loose-tube barrel, loose-liner barrel (Figure 20).

The unbuilt-up monobloc barrels made of high-grade alloy steels are simplest in construction and the most economical to produce. They are widely favored in all small- and medium-caliber pieces up to 152-155 mm inclusive. The sole significant shortcoming of monobloc barrels is the necessity of replacing the entire tube if the rifled portion wears out.

Large-caliber pieces more often use built-up barrels, as well as loose-tube or loose-liner barrels.

The idea of barrel build-up is as follows: Two tubes are taken, the inside diameter of the outer tube being slightly smaller than the outside diameter of the inner tube. The outer tube is heated to a temperature of 400-500° C and pulled over the smaller cold tube. As it cools, the outer tube will tend to assume its original dimensions and compress the inner tube. But since the inner tube exerts resistance, the outer tube will not assume its original dimensions. Consequently, on cooling to normal temperature the outer tube will prove to be somewhat stretched, the inner tube compressed. This condition is called reciprocal tension.

At the time of firing, under the pressure of the powder gases the inner tube at first returns to its normal state, but then begins

to expand together with the outer tube. The stress of the metal layers of the two tubes is more uniform than in the monobloc barrel.

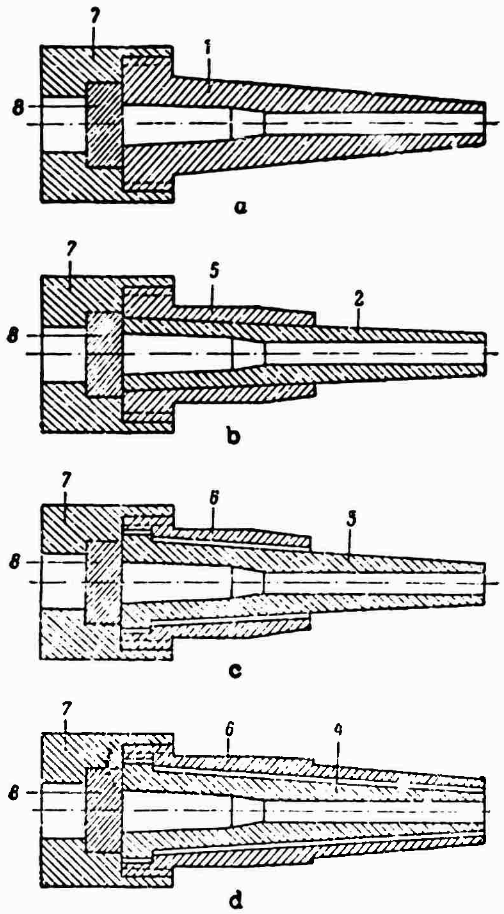


Figure 20. Basic types of barrels:

a) monobloc barrel; b) built-up barrel; c) loose-tube barrel; d) loose-liner barrel; 1) monobloc barrel; 2) tube; 3) loose tube; 4) loose liner; 5) outer tube (jacket); 6) outer tube (jacket); 7) breech ring; 8) breechblock.

Since the gas pressure declines sharply as the shell moves along the bore, the muzzle end is usually not covered by the outer tube, i.e. is not built up. At the muzzle end the barrel operates like a monobloc barrel.

The shortcoming of built-up barrels is the complexity and expensiveness of their manufacture.

Cold-worked (autofretted) barrels do not differ from monobloc barrels in external appearance. The cold-working process consists in increasing the resistance of the inner metal layers to the action of the high pressures of the gases by inducing in the metal stresses analogous to the stresses produced in the barrel built up under tension. This is achieved by means of powerful hydraulic presses creating high pressure (6000-7000 kg/sq cm). In the cold-worked barrel prior to firing the inner layers are compressed, the outer layers expanded. During firing this barrel operates in the same way as a built-up barrel made of two tubes. The modern American 175-mm self-propelled gun M107 has an autofretted barrel.

Loose-tube or loose-liner barrels consist of an outer tube (jacket) and inner thin-walled tube (loose liner) or inner thick-walled tube (loose tube). The inner tube is inserted in the jacket with very small clearance (0.1-0.2 mm). If the jacket overlaps the inner tube for its entire length, such a barrel is said to be lined, and the inner tube is called a loose liner. Liners are made of the best brands of high-strength alloy barrel steel. If the jacket does not overlap the entire length of the inner tube, but only part of it, such a barrel is called a loose-tube barrel.

On firing, the removable liner (tube) expands, takes up the clearance, presses against the inner walls of the jacket and thereafter functions together with it as a single whole. After firing and after the barrel cools, the clearance between liner and jacket is restored.

The principal advantage of the loose tube (liner) is that its extraction from the barrel in case of erosion and its replacement with a new one from reserve stock are very simple to do under field conditions directly in the firing position. For a trained crew this takes 10-30 minutes.

It should be noted that increasing the barrel strength still does not eliminate rapid wear of the bore surface. Even if all other mechanisms and assemblies of a piece are in serviceable condition, a worn barrel entails loss of the combat characteristics of an artillery system. To repair or replace a barrel the piece is sent to the factory and is out of commission for a long time.

The accuracy life of a barrel is the most important problem for artillery. It is known that during combustion of a powder charge high-pressure incandescent gases are generated. Even though firing lasts only several hundredths to tenths of a second, the bore surface has time to heat up to a temperature close to the melting point of steel. In the intervals between rounds the surface cools sharply by virtue of heat elimination into the body of the barrel and heat exchange with the air. The heat causes the thin layer of the bore surface to expand. The adjacent metal layers, however, are not heated. Therefore, they not only do not expand themselves, but even impede the expansion of the surface layer. In the walls of the barrel alternating temperature stresses are generated, the magnitude of which depends on the difference between the temperature of the bore surface and that of the adjacent metal layers. Under the influence of these stresses little cracks begin to appear in the surface layer of the bore, and with time these cracks form an erosion network.

The cracked surface of the bore has lowered strength and fails under the action of the rotating band of the shell and the flow of powder gases. The rate of failure depends on many factors. For example, the higher the temperature of the explosive decomposition of power, the greater the weight of the charge and the higher the rate of fire, the more vigorously does the bore surface heat up, and therefore the more intensely does it wear away. The elevated temperature of the powder charge also accelerates barrel wear since it increases the rate of powder combustion and hence raises the temperature and pressure inside the barrel.

For some makes of powders when the charge is heated from + 15 to + 40° C, the muzzle velocity of the shell increases 4-5 percent, and the maximum pressure of powder gases in the bore 15-20 percent.

To protect bore surfaces from excessive wear, especially in barrels with high ballistic characteristics, a phlegmatizer is introduced into the charge. Its composition usually includes petroleum refining products (paraffin, ceresin etc.). The phlegmatizer is placed around the periphery of the charge. Melting under the action of the hot powder gases, it so to speak forms an interlayer between the burning powder and the bore surface. This reduces heat transfer from the powder gases to the bore surface and thus lowers its heating temperature.

Wear of the bore surface also depends on the method of piece loading. With cartridge loading the initial section of grooves erodes considerably more rapidly than with bag loading or separate-case loading. This is due to the fact that with cartridge loading the rotating band of the projectile does not butt up against the rifling and on firing is engraved by it under impact. As the number of rounds fired increases, erosion of the initial section of grooves progressively increases, since the origin of the rifled portion moves farther and farther towards the muzzle face, and the velocity of the projectile by the time the band is engraved, and hence the force of its impact with the rifling, increase. The clearance between the rotating band of the projectile and the bore surface also increases with barrel wear. More and more powder gases escape into it, which entails an even greater increase of wear. In bag and separate-case guns the projectile is forced home until the rotating band butts up against the rifling, and therefore the band is engraved without impact.

The type of projectiles used also affects wear of the rifled portion of the barrel. For example, in the case of an armor-piercing shell, whose body is made very rigid, the body remains practically undeformed when the rotating band is engraved in the grooves. Therefore, the stress transmitted by the band to the barrel is highest for this projectile. The bodies of fragmentation and high-explosive fragmentation shells, which possess less rigidity, sag somewhat during engraving of the band, diminishing the effect of the band on the barrel. This contributes to a reduction in the wear of the rifled portion of the barrel.

The material of which the rotating band is made has a certain influence on wear of the bore surface.

As the bore surface erodes, muzzle velocity and the penetrating action of projectiles decline, the range of fire decreases, and more and more frequently fuzes fail to arm. At the same time, conditions deteriorate for driving the projectile along the grooves; there are cases of the shearing off of rotating bands and premature action of fuzes in trajectory; the close pattern of shooting markedly deteriorates; and the number of fuze failures increases.

When the rifled portion of the bore erodes so much that the combat characteristics of the piece decline to the established limits, the barrel becomes unfit for further service. Values of maximum permissible wear vary for different barrels. They are indicated in barrel classification documents.

The commonest signs that a barrel has lost its combat characteristics are: a ten-percent decline in muzzle velocity; increase in fire dispersion to a certain limit; complete shearing off of rotating bands of projectiles; when the flight of the projectile is accompanied by a sharp whistling sound; systematically recurrent failures of the point fuze; and premature shell bursts in trajectory during full-charge firing.

If at least one of these signs is discovered during firing, the barrel must, regardless of the extent of the decline in the muzzle velocity of a projectile, be considered as having reached the limit of its accuracy life. For medium- and small-caliber pieces this condition sets in after 5,000-10,000 rounds, for large-caliber pieces after 200-300 rounds. The accuracy life of gun barrels is far [illegible] than that of howitzer barrels (500-2,500 and 5,000-20,000 respectiv[illegible]).

The natural loss of combat characteristics i not the sole reason why a barrel becomes unserviceable. Sometimes barrels which have been damaged during combat employment of the piece (cracks, holes, barrel dilation etc.) are discarded if the extent of dammage exceeds permissible limits as established by repair documents. The life of a barrel can be considerably prolonged if it is protected against accidental damage during firing, transport and storage, and if attentive care is taken to see to it that no sand or dirt gets into the bore during loading of the gun. Ammunition must also be carefully prepared for firing and wiped with a clean rag. No shells must be employed which have rust on the positioning bands, nor any powder charges which have been highly heated by the sun's rays.

The wear of barrels depends in many respects on their overheating. To prolong barrel life, the most rational rate of fire must be selected, and fire must be conducted using the minimum charge which will permit performance of a given fire mission. All lulls in firing must be used for cooling the barrel: the breechblock must be opened, and to increase the air draft, the barrel must be given elevation. After firing, the barrel must be carefully cleaned. Barrel life can be prolonged only by observing all rules of piece servicing and maintenance.

The replacement of eroded monobloc, built-up and cold-worked barrels takes a great deal of time and is expensive. These shortcomings are eliminated to a considerable extent in loose-tube and loose-liner barrels.

The use of a loose tube or loose liner makes possible an increase in a piece's rate of fire and the use of more powerful powders which accelerate barrel wear but at the same time increase the muzzle velocity of the projectile and maximum effective range. Moreover, one need not fear that the piece will become unserviceable for a long time requiring barrel replacement.

The barrels of mountain guns, because of the specific character of their combat employment, are made to be dismountable (into three or more parts), without taking up the clearance between tube and jacket during firing.

Modern artillery most frequently employs barrels with a cylindrical bore. In this case the area of the projectile cross section on which the pressure of the powder gases acts is constant for the entire path of the projectile's travel in the bore. To increase the muzzle velocity of a projectile, the pressure of the powder gases must be increased, or the path over the course of which they act upon the projectile must be lengthened. Gas pressure is increased by increasing the weight of the charge and simultaneously increasing the volume of the powder chamber. The path over which the powder gases act is lengthened by lengthening the barrel. Such methods are widely used in the development and modernization of pieces.

But there is yet another method of significantly increasing the muzzle velocity of a projectile with the barrel length remaining comparatively short, viz. the use of conical bores.

A conical bore gradually tapers to the muzzle face. Usually conical bores consist of three portions: the first one -- a rifled cylindrical section -- has a large diameter and extends from the chamber to approximately the middle of the barrel length; the third portion -- a smooth-walled cylindrical portion -- has a smaller diameter and is located at the muzzle end; between these is situated the second portion -- a smooth-walled portion, which is conical in shape.

In barrels with conical bores the work of the powder gases is utilized more fully and efficiently over the comparatively short path of the projectile along the bore. For this reason, as well as the relatively lighter weight of the projectile, pieces with a conical bore are in principle capable of providing high projectile muzzle velocities -- 1300-1500 m/sec.

From the standpoint of interior ballistics, barrels with conical bores do not differ from the conventional barrels from which subcaliber shells are fired, but "conical character" of bores means that shells of good exterior ballistic shape leave the bore.

The caliber of a piece with a conical bore is indicated by two numbers: in the numerator the larger caliber of the rear portion, in the denominator the smaller caliber of the front (muzzle) end -- for example, the 28/20, 42/28 and 75/55-mm guns of the World War II period.

Conical barrels erode very rapidly owing to the great amount of work in the shrinkage of the driving parts of a projectile, and thus their accuracy life is short. Experience has also shown that fire from such pieces can be more effective only at short ranges since the light shell rapidly loses its velocity owing to great air resistance.

Pieces with conical bores have not gained wide acceptance in our day owing to the complexity of the manufacture of the barrels.

Two types of breech rings are encountered in modern designs: screw-on and screw-in. The use of breech rings offers certain advantages: barrel manufacture is simplified at plants, and the replacement of a removable tube or removable liner in case of damage is facilitated. If the breech ring has great weight because of strength specifications, the tipping parts of the gun can be balanced relative to the axis of trunnions without using special equilibrators (this method is used in naval and coast artillery). The breech ring also serves to connect the barrel with the recoil mechanism.

The muzzle brake is an external sign of modernity of design in many pieces. It is a massive short steel tube screwed onto the muzzle end of the barrel. A muzzle brake has an axial hole for the exit of the projectile and side ports (circular holes) for the escape of powder gases.

The physical nature of the operation of a muzzle brake of any type is as follows. When a shell leaves the barrel, the gases following it strike with force against the walls of the ports or blades of the muzzle brake and push it sharply forward together with the barrel. At the same time, there also appears a reactive force acting in the opposite direction of the recoil. Thus, a muzzle brake decreases the effect of a shot on the gun carriage by reducing the energy of the recoiling parts.

Other things being equal, use of a muzzle brake permits the carriage to be made lighter and the length of recoil to be shortened, which is especially important for self-propelled and tank guns.

Muzzle brakes can absorb from 20 to 70 percent of recoil energy, and in some cases even more. Muzzle brake efficiency is to a significant extent determined by the design of the brake and by ballistic parameters of the piece. Therefore the selfsame muzzle brake may have varying efficiency depending on the amount of the powder charge and, in addition, on variation in barrel ballistics due to the increase in its wear with the increase in the number of rounds fired.

If a muzzle brake is present, the recoil mechanism absorbs only the remainder of the recoil energy, and therefore is compact, small in size, light in weight, and does not encumber the piece as a whole.

According to the commonest classification, there are three types of muzzle brake: positive type, positive-passive type, and passive type (Figure 21).

In the positive muzzle brake, ring partitions are made perpendicular to the axis of the bore. Powder gases strike these and are ejected through the ports.

The passive muzzle brake has no interior partitions. The powder gases escape through side holes which are tilted rearwards. The resultant reactive force is guided in a direction opposite to the recoil. The smaller the hole tilt angle φ, the greater is the efficiency of the muzzle brake (gun crew safety is the constraint here).

In the positive-passive muzzle brake the advantages of both the above-described types are combined. To raise efficiency, deflecting blades tilted rearwards, sometimes at different angles, are added. For example, the West German company Reinmetall several years ago suggested for artillery pieces the muzzle brake schematically depicted in Figure 21,d. Here use was made of the well-known principle of the deflection of powder gases by numerous surfaces. The first deflecting surface 2, situated at the muzzle face, is provided with a number of holes 5. At the time the projectile passes along the barrel at the level of the first deflecting surface, powder gases escaping through the numerous holes 5 encounter the second deflecting surface 3 in their way. Angle α, formed by the first deflecting surface, is less than angle β, formed by the second deflecting surface, in just the same way the outside diameter of the first deflecting surface is less than the outside diameter of the second deflecting surface.

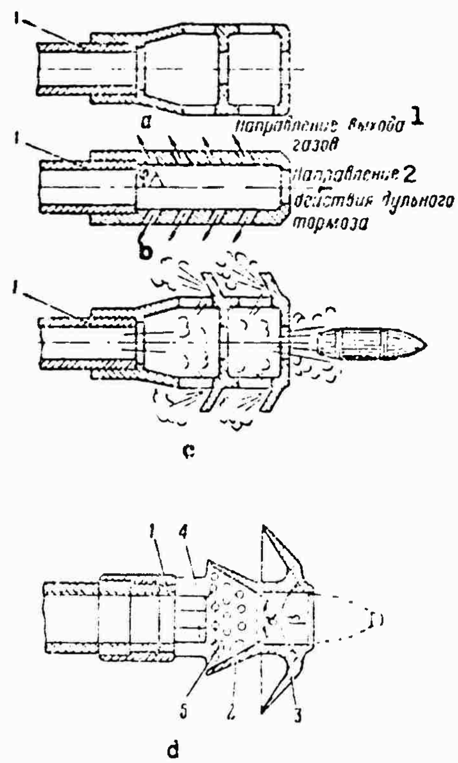


Figure 21. Diagrams of muzzle brakes:

a) positive type; b) passive type; c) and d) positive-passive type; 1) barrel; 2) first deflecting surface; 3) second deflecting surface; 4) muzzle brake body; 5) holes.

Keys:

1. Direction of gas exit
2. Direction of muzzle-brake action

In antiaircraft and tank guns the escape of powder gases is permitted in all directions, in field guns to the left and right.

The use of muzzle brakes also introduces certain complications into the combat servicing of artillery pieces. The zone of increased muzzle-wave pressure moves backwards as the wave propagates in the region of the piece, i. e. towards the gun crew. Protective measures must be taken to reduce the harmful effect of the muzzle wave on the ears of persons in the crew manning field guns (use of helmets, ear plugs etc.). The point is that the harmful action of a muzzle wave on ears in many cases is cumulative in character, adding up from the exposure to individual rounds. The repeated exposure of unprotected ears to muzzle waves may cause the development of irreversible processes, leading to the onset of so-called "hardness of hearing," i.e. irremediable hearing loss. Auditory deterioration more frequently occurs in the perception of frequencies in the 1500-3000 Hz range, i.e. the most frequently encountered frequencies of human speech and music.

3. Breechblocks

The breechblock is the most important part of the piece. It absorbs the great pressure of the powder gases.

Very rigid requirements are set for any breechblock regardless of its design. The breechblock must be strong and safely lock the barrel; it must prevent spontaneous opening during firing; preclude even insignificant escape of powder gases to the rear; assure speedy opening and closing of the bore at all angles of elevation; take up as little room as possible in the open position; prevent firing if the recoil mechanism is not connected to the barrel (for pieces in which the barrel is pulled back in the traveling position) or in cases of failure to return to battery, when the recoiling parts fail to return to their initial position after firing; assure dependable operation of the firing mechanisms and extraction of the case after firing or of the entire cartridge in the event of misfire; must be simple in construction and easy to service. In addition, an essential requirement is that voluntary firing must not be permitted unless the breechblock is completely locked and its opening precluded until firing has taken place.

According to principle of operation, breechblocks are divided into nonautomatic (manually operated), semiautomatic and automatic.

Several types of breechblock are known but modern artillery pieces, as a rule, employ only the sliding-wedge and screw type.

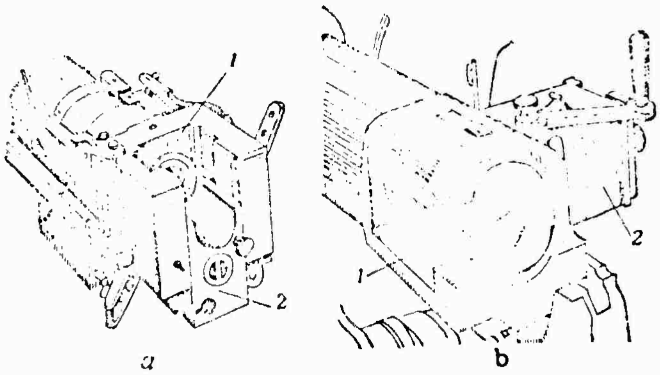


Figure 22. Sliding-wedge type breechblocks:

a) vertical; b) horizontal; 1) breech ring; 2) wedge.

Sliding-wedge type breech mechanisms (Figure 22) are of two kinds -- vertical and horizontal. In vertical wedge-type breech mechanisms the pull on the operating handle is uneven and, if the weight of the wedge is great, may even be beyond the strength of a single person.

This has necessitated the introduction of equilibrators in the form of springs which rise when the breechblock is opened and reduce the energy of the wedge's drop downwards, and conversely when the breechblock is closed, facilitate the wedge's ascent. Horizontal wedge-type breechblocks do not have this shortcoming. In their case the exertion of opening and closing the breechblock is uniform, but room is required for the wedge to move to the side. The foregoing determines the sphere of employment of wedge-type breechblocks: vertical for smaller-caliber pieces, horizontal for larger caliber pieces.

Designs of wedge-type breechblocks differ, but they all have in common a massive wedge in the form of a prism housed in the wedge slot of the breech ring. The front surface of the wedge is perpendicular to the axis of the bore, and the back (bearing) edge forms an angle of about 2° with the front edge. Thus the wedge tapers to one end. This structural execution assures safe locking of the bore.

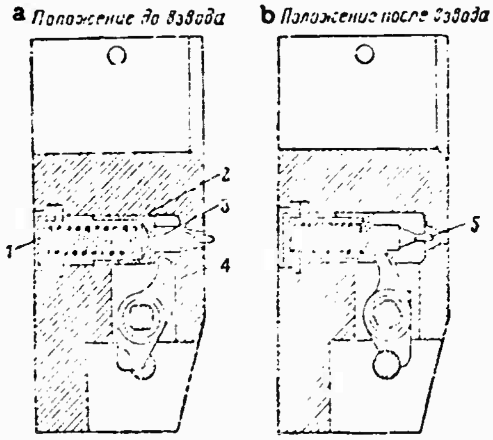


Figure 23. Firing mechanism of wedge-type breechblock:

1) cover; 2) firing spring; 3) firing pin; 4) sear; 5) striker.

Keys:

a. Position before cocking
b. Position after cocking

In addition to the locking mechanism, every breechblock has several more mechanisms, for example, firing mechanism, extractor, safety lock. Figure 23 shows the operation of the firing mechanism. The extractor serves to eject a spent case after firing or to extract a fixed round in its entirety in case of misfire. When the breechblock is opened, the wedge strikes the small shoulders of the extractor, and the latter, turning on its axis, extracts the spent case from the chamber with the catches on the large shoulder.

The simplicity of the opening and closing of sliding-wedge type breechblocks permits automation elements to be widely used in them, which creates favorable possibilities for an increase in the rate of fire and lightens the work of the crew.

Wedge-type breechblocks with a cam plate-type semiautomatic device have gained the widest acceptance. The semiautomatic device usually consists of two parts: closing mechanism, which is situated in the breech ring and participates in recoil, and cam-plate device, which is mounted on the cradle bracket and does not participate in recoil. When the barrel recoils after firing, the cam of the closing mechanism forces the cam plate out with its bevel and moves further to the rear. During counterrecoil the cam runs against the cam plate and rotates the axle of the crank. The energy of the rotation of the crank suffices to cock the firing pin and lower the wedge, which strikes the lower shoulders of the extractor and assures extraction of the spent case. The closing spring is compressed. The piece is ready for the next loading.

Screw-type breechblocks. The basic part of this kind of breechblock is the cylindrical body (breech screw), which is provided with screw threads and screwed into the corresponding recess of the breech ring (Figure 24). The threads of the breech screw, engaging with the threads of the breech recess, assure safe locking of the bore during firing. For speedy operation of the breechblock the threads are not made around the entire circumference of the breech screw and breech recess, but only in sectors, for example, at 90° intervals. When the breechblock is closed, the threaded sectors of the breech screw enter the slotted sectors of the recess and the threads of the recess go into position opposite the slotted sectors of the breech screw. When the breech screw is turned 90°, the threads of the breech screw engage the threads of the breech recess, and the bore is locked.

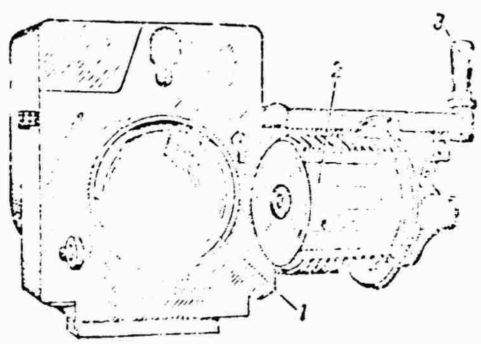


Figure 24. Screw-type breechblock:

1) recess of breech ring; 2) breech screw; 3) operating level of breechblock carrier.

At this point a conflict arises. To make possible speedy operation of the breechblock, the number of threads have to be decreased. But a small number of threads loosens the hold of the breech screw in the recess since the area of engaging surfaces does not suffice . Therefore, designers are seeking optimum solutions (step-thread screws with varying-height sectors and thread of varying diameters etc.).

The breech screw is mounted on a block carrier, which is hinged to the breech ring of the barrel by means of an axle with an operating lever. When the breechblock is opened, the breech screw comes completely out of the breech ring.

Depending on the location of the carrier axle, screw-type breechblocks may be vertical or horizontal, the same as wedge-type blocks.

Screw-type breechblocks are subdivided into two-cycle (first cycle: screw, together with block carrier, moves along an arc until it completely enters the breech recess; second cycle: screw turns on its axle until it completely engages with the threads of the breech ring) and three-cycle (first cycle: screw, together with block carrier, is brought into contact with the breech face along an arc; second cycle: screw moves out of carrier and enters breech recess; third cycle: screw turns until it engages completely with threaded sectors).

Ordinarily screw-type breechblocks consist of the following mechanisms: locking mechanism; firing mechanism; extractor; safety lock; a device to facilitate loading; and a case retaining mechanism.

The locking mechanism includes such basic parts as screw, block carrier, operating lever, bolt stop and rack (Figure 25). The firing mechanism is housed in the central recess of the screw and carrier and consists of firing mechanism and firing hook, and traveling safety lock.

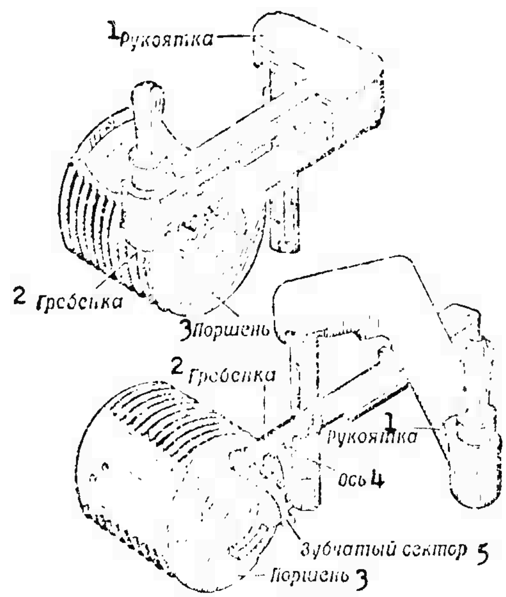


Figure 25. Locking mechanism of screw-type breechblock.

Keys:

1. Operating lever
2. Rack
3. Screw
4. Axle
5. Toothed quadrant

The inertia-type safety mechanism precludes opening of the breechblock without additional manipulations if no shot resulted after release of the firing pin, for example, in the case of hangfire. If, however, a shot did take place, an inertial body under the action of the force of inertia, compressing the spring, sinks into the recess of the breech ring, liberates the rack and permits the breechblock to open freely.

In the breech recess there are projections and grooves in which both the head and the rotating band of a shell can become lodged during loading. A loading facilitator in the form of a regulating plate prevents this. When the breechblock is opened, the plate rises and moves forward. Therefore the shell, traveling over the top of the plate, does not become lodged. When the breechblock is closed, the plate drops into place and does not hinder entry of the breech screw into the recess.

The shell-case retaining mechanism keeps the shell and case from falling out of the chamber when the piece is loaded at large angles of elevation. When the breechblock is opened, the shell-case retaining mechanism under the action of its own weight turns on its own axis and drops down. The shell or case can be moved forward but they can no longer fall backwards. When the breechblock is closed, the screw raises the shell-case retaining mechanism.

In screw-type breechblocks for large-caliber bag pieces (which use no case) plastic obturators are employed.

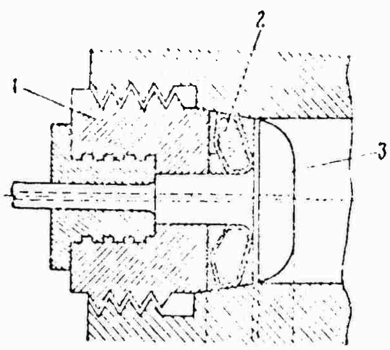


Figure 26. Screw-type breechblock with plastic obturator:

1) breech screw; 2) obturating pad; 3) mushroom-head spindle.

The modern plastic obturator (Figure 26), as a rule, consists of mushroom-head spindle, obturating gas check pad, split rings and filling-in disks. A vent is made along the axis of the mushroom-head obturator spindle in order to communicate the fire power to the powder charge.

During firing, the mushroom-head spindle absorbs the powder-gas pressure and, moving backwards, compresses (so to speak, flattens) the obturator pad. Under the pressure of the mushroom-head spindle the pad, which is made of plastic materials, expands in radial directions and presses against the chamber walls, whereby obturation of powder gases between breech ring and breechblock is achieved. After firing, due to its elasticity the obturating pad recovers its initial dimensions and does not impede opening of the breechblock.

Complex requirements are set for plastic obturators: simplicity and low cost of production; operating reliability under various temperature conditions; the necessary plasticity and at the same time sufficient strength and chemical stability of pad material; elimination of adhesion to chamber walls and breechblock etc. Use of a plastic obturator must not lower the maximum rate of fire technically possible for a given piece.

Although plastic obturators have been in existence for dozens of years, the formula for their plastic and the technology of its production have not yet been finally established. The composition of obturator plastic has included, for example, asbestos, various binders (fats, wax), graphite etc. Therefore, the quality of the operation of a plastic obturator depends not only on its design, but also on the quality of the manufacture of its individual elements.

The question is sometimes asked: Which breechblock is better -- the sliding wedge or screw-type? From the standpoint of strength, both types of breechblock are equal. A comparative evaluation of sliding-wedge and screw-type breechblocks in respect of other parameters is given in Table 8.

Table 8

COMPARISON OF SLIDING-WEDGE AND SCREW-TYPE BREECHBLOCKS

Characteristics	Sliding-wedge breechblock	Screw-type breechblock
Ease of opening and closing	Better	Worse
Weight of breechblock (other things being equal)	Heavier	Lighter
Ease and safety of loading	Better	Worse
Wear/sensitivity of friction surfaces	Less	More
Labor-intensiveness of production	Less	More
Feasibility of automation and maximum rate of fire	More	Less

As regards ease of breechblock opening and closing and the effect of breechblock type on maximum rate of fire, the advantages of the sliding-wedge breechblock are obvious. During the opening and closing of the sliding-wedge breechblock only the wedge is moved in the direction of the breechblock's motion -- the effort expended on this travel in case of horizontal motion being independent of angles of elevation. To open a screw-type breechblock, first the breech screw must be turned and then the breechblock opened. Although both these motions are performed with one turn of the operating lever, it still takes more time than in the case of a sliding-wedge breechblock. This difference in time is insignificant for small-caliber pieces, but it changes to the advantage of the sliding-wedge breechblock with an increase in caliber. The time difference becomes very appreciable if the screw-type breechblock has three-cycle action.

In pieces with a screw-type breechblock the possibility of the loader's hand getting caught between the breechblock and breech face is not out of the question in the event of faulty teamwork between assistant gunner and loader. With the sliding-wedge breechblock such an occurrence is entirely ruled out.

In loading a piece with a sliding-wedge breechblock the round is rammed through a notch in the breech ring. This gives a special advantage, for example, to antiaircraft guns firing at large angles of elevation. The height of the line of fire can be lowered by introducing part of the round during loading into the notch in that part of the breech ring behind the wedge. This contributes to an increase in the stability of a piece in the event of small angles of elevation.

In the sliding-wedge breechblock there are more opportunities for the employment of automation or elements thereof: breechblock opening and closing requires only one rectilinear motion, which makes possible rapidity and simplicity of action in such a breechblock. In screw-type breechblocks this is harder to do since the forward motion of the parts of the semiautomatic device has to be transformed into the rotary and translational motion of the breech screw as it is closed and opened.

When designers are creating a new piece, they base their choice of the type of breechblock primarily on the purpose of the gun, its prescribed maximum rate of fire and the type of ammunition.

In modern artillery sliding-wedge breechblocks are usually employed in fixed-ammunition and separate-case pieces. Here the cartridge case itself serves as obturator. Expanding under the pressure of powder gases during firing, the case presses against the chamber walls and prevents the escape of gases to the outside.

Screw-type breechblocks are used in medium- and large-caliber new pieces. Obturation in screw-type breechblocks is accomplished by the cartridge cases. However, if the charge is inserted in a powder bag rather than a case, only screw-type breechblocks with a plastic obturator are used.

To fire a case gun, the breechblock must be opened, the spent case ejected, loading must take place (a projectile and charge or fixed round inserted), the breechbolt must be closed, the firing pin cocked and released. If all these operations are performed through the energy of powder gases during firing, the breechblock is said to be automatic. Such breechblocks are widely employed in antiaircraft artillery, for example.

If, however, only part of the above-enumerated operations are performed automatically, the breechblock in this case is said to be semiautomatic. Such a breechblock automatically opens after firing, ejects the spent case, and closes after loading. Actual loading and firing, however, are performed manually.

The inventor of the semiautomatic breechblock was our fellow countryman, Engineer of the Putilovskiy Plant F. F. Lender, who in

1914 developed a three-inch gun with this kind of breechblock. F. F. Lender was granted patents in Russian, the United States, England and France for his invention of the semiautomatic breechblock.

Sliding-wedge and screw-type breechblocks were first created in Russia. The following historical fact is of interest. At the end of the nineteenth century the German cannon king Friedrich Krupp came to Saint Petersburg. He visited the Artillery Historical Museum and spent more than an hour looking at a small arquebus which had a horizontal sliding-wedge breechblock with an opening and closing mechanism. Krupp asked to buy the arquebus, but was refused. His manifestation of such great interest in a Russian artillery relic was not fortuitous. It turns out that the Krupp Company in the 1860's contrived to patent the production of sliding-wedge breechblocks and made a lot of money on this deal although the Krupp "invention" was not original. Incontestable priority in the invention of sliding-wedge breechblocks went to the Russian master craftsmen who were more than two and a half centuries ahead of West European craftsmen.

The first screw-type breechblock with self-cocking firing pin, cartridge case extractor and safety lock in the history of artillery was created by the talented Russian inventor V. S. Baranovskiy in 1872, i.e. 25 years earlier than in other countries.

4. Gun Carriage and Its Mechanisms

The carriage of the modern field piece performs two functions: it serves as a combat mount for the entire piece during firing and as a means of transport (vehicle) during movement.

In the broad sense of the word carriages are divided into two basic groups: carriages for mobile guns and carriages for stationary (fixed) guns.

Mobile guns have running gear and can deliver fire directly from the ground.

Stationary pieces are connected permanently to foundations which are constructed beforehand at certain points of the terrain (coast artillery) or which constitute part of some structure (shipboard artillery). Pieces which are subject to specific conditions of combat employment (aircraft, tank, self-propelled, railroad mounts) are regarded as stationary (semistationary).

The carriage of an artillery piece absorbs all the force of the recoil on firing. The force of the recoil is rather great, for example, for 76-mm guns it reaches 115 tons, and for 152-mm howitzers exceeds 400 tons.

Old guns, whose barrels were rigidly attached to the carriage, rolled backwards after every round. To return the piece to its position and restore pointing took precious combat time and much effort. Artillerymen have always tried somehow to inhibit the recoil of a piece and to facilitate rolling it back into its previous position. At first use was made of simple devices in the form of wedges placed under the wheels of a piece. During recoil the piece rolled back onto the wedges and then rolled off them down an inclined plane and resumed its initial position.

Our fellow countryman V. S. Baranovskiy, employing a hydraulic recoil brake and spring recuperator, created a quick-firing gun, whose carriage remained in position during firing and whose barrel first rolled backwards and then returned into initial position. Thus, the first gun carriage with recoil mechanism was created. All tube artillery nowadays uses this principle of recoil-energy absorption during firing.

The carriage of the modern piece includes the following assemblies: cradle with recoil mechanism; top carriage with elevating and traversing gear; equilibrators; bottom carriage with trails, spades and trail handspike; running gear with axle and wheels, suspension and brakes; shield assembly; gun-traveling lock assembly; auxiliary mechanisms (cranes, jacks, rammers, mechanism for bringing a piece to loading angle etc.); sighting mechanisms.

Without going into the details of the complex physical picture of the effect of firing on the carriage, let us note that a properly designed piece is stable and immobile during firing, i.e. during firing it should not move over the ground (immobility), nor should wheels or tracks lose contact with the ground (stability).

Travel of the barrel over the guides of the cradle during firing is called recoil, and the barrel together with the parts participating in recoil are called the recoiling parts.

The recoil mechanism is intended for the smooth braking of the recoiling parts of a piece during firing, for their smooth return to initial position and secure retention in the extreme forward position until firing, whatever the angle of elevation.

The recoil mechanism includes: recoil brake; counterrecoil brake; and recuperator.

The recoil brake retards and limits barrel recoil along the cradle. The counterrecoil brake brakes the recoiling parts during counterrecoil. Both brakes in modern pieces are hydraulic and are structurally united into a single whole.

The recuperator serves to return the recoiled barrel to initial position and hold it in forward position at angles of elevation. In addition, the recuperator takes part in braking during recoil of the barrel, and absorbs 10-15 percent of the recoil energy. Recuperators are of either the spring or hydropneumatic type. Sometimes pneumatic recuperators are used, for example in the design of the 105-mm gun of the new West German Leopard tank.

The recoil brake (Figure 27) consists of a cylinder and piston rod inserted therein. The cylinder is filled with liquid. The front end of the rod is fastened securely to the cradle cap. Small apertures are made in the piston.

During firing, the barrel of the piece rolls to the rear; together with it the recoil brake cylinder and throttling bar also roll to the rear. In drawing to the rear the front lower end of the brake cylinder presses on the liquid, which is practically incompressible, and forces it to spurt through the narrow vents of the stationary piston into the rear part of the cylinder. Since the apertures in the piston are small and the amount of displaced liquid is comparatively large and during recoil flows very rapidly, the liquid exerts a strong resistance, which takes most of the recoil force to overcome. The resistance to the spurting is the greater, the smaller the apertures and the greater the recoil velocity. The remainder of the recoil force goes to compress the springs (or air) in the recuperator and to overcome friction forces.

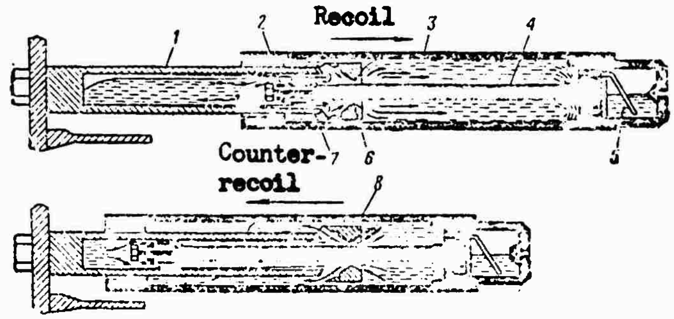


Figure 27. Diagram of operation of recoil brake:

1) rod; 2) buffer valve; 3) cylinder; 4) throttling bar; 5) replenisher; 6) adjusting ring; 7) buffer; 8) piston.

During recoil of the barrel the liquid goes through the apertures in the piston in two directions: to the rear part of the cylinder through the annular space between the adjusting ring and throttling bar, and to the front cavity of the rod through the apertures in the buffer, displacing the valve of the latter. A certain amount of the liquid gets into the front cavity of the rod through grooves of variable depth on the inside surface of the rod. The size of the annular space between the throttling bar and adjusting ring of the piston varies with recoil since the throttling bar has a variable cross section.

When all the recoil force is absorbed and the barrel remains in the rear position, the springs (or compressed air) of the recuperator will begin to expand and counterrecoil of the barrel will take place. The liquid in the brake, passing through the apertures into the piston, will flow back into the front part of the cylinder, but at a far lower rate than during recoil. The reverse flow of the liquid brakes counterrecoil, makes it smooth (without shock) and gradually decelerating. This function is performed by the counterrecoil brake. During counterrecoil some of the liquid, which gets into the space behind the buffer, presses on the buffer valve, moves it and closes the apertures in the buffer. The liquid can now spurt only through the grooves of variable depth located on the inside surface of the rod. Smoothness of counterrecoil is achieved by virtue of the fact that at the end of counterrecoil the grooves of variable cross section diminish until they are nothing.

Some pieces employ the "opposite" design of the recoil brake: the brake cylinder is immovably fixed in the cradle and the rod is connected to the breech ring of the barrel. In this case, barrel and brake rod participate in recoil, but cylinder and cradle remain immobile. The operating principle of such a recoil brake is essentially the same.

The recoil brake is a heat machine transforming mechanical energy into thermal energy. After every round the temperature of the liquid in the brake cylinder increases approximately one degree. Heating of the liquid is accompanied by an increase in its volume. This may result in failures of the barrel to return to battery and even to breaking of rods. To continue firing, the volume of liquid in the cylinder must be decreased by letting some of it out. But then the fluid that has been let out has to be added to the cylinder when the recoil brake cools off.

Special devices -- liquid replenishers -- are employed in modern pieces so that the brake cylinder is always filled with liquid regardless of the heating temperature of the recoil mechanism.

Replenishers automatically regulate the amount of liquid in recoil brakes. Replenishers are of the hydropneumatic or spring type. Their principle of operation is the same.

The body of the replenisher is usually rigidly connected with the brake cylinder (Figure 27). Separating them is a partition, into which a curved tube is welded. There is a certain amount of liquid in the replenisher. During firing as the liquid expands in the brake cylinder, some of it overflows through the tube into the body of the replenisher, compressing the air there. When a lull in firing occurs, the liquid in the brake cylinder cools off and its volume decreases. The air compressed in the replenisher forces out the liquid into the recoil brake cylinder.

The commonest type of recuperator is the hydropneumatic system. It consists of two or three communicating cylinders connected to the barrel. One or two cylinders are filled with liquid. The outer cylinder contains air or nitrogen under 25-40 atm pressure. A rod and piston are housed in the working cylinder and there are no apertures in the piston.

During firing the barrel of the piece, together with the cylinders of the recuperator, is drawn to the rear (Figure 28). The rod, fastened to the cradle, remains stationary. Therefore the liquid is forced from the working cylinder into the outer cylinder where the air (nitrogen) is compressed to 80-100 atm. At the conclusion of recoil the compressed air (nitrogen) expels the liquid from the outer cylinder into the working cylinder. Pressure is transmitted to the piston. The latter, remaining in place, forces the cylinders to move, and the barrel together with them. Counterrecoil takes place.

There are recuperators whose rod recoils with the barrel while the cylinders, fastened to the cradle, remain in place.

To fill the recoil mechanism, anticorrosion and antifreeze liquids are used, for example, spindle oil, steol etc.

The placement of the recoil mechanism relative to the barrel is determined by the general layout of the piece. In some cases both recoil brake and recuperator are side by side under the barrel; in others, the recoil brake is under the barrel, while the recuperator is above the barrel. If a piece has a powerful muzzle brake and consequently a small-sized recoil mechanism, the latter is housed above the breech ring of the barrel.

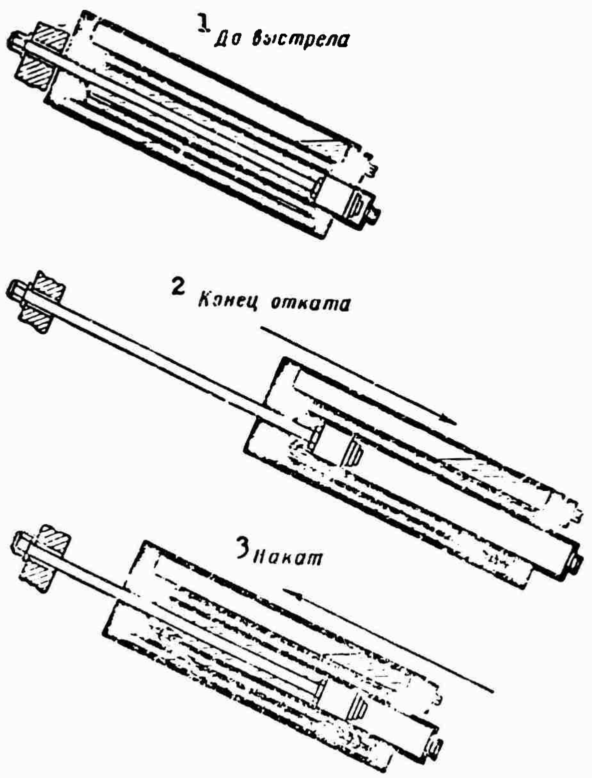


Figure 28. Diagram of operation of recuperator.

Keys:

1. Before firing
2. End of recoil
3. Counterrecoil

In pieces with double recoil the method of recoil resolution used is as follows: first, as in all pieces, the barrel recoils along the cradle and, second, the cradle with barrel and top carriage recoils along the guides of the bottom carriage. In this case, recoil energy is lessened by increasing the weight of the recoiling parts.

In pieces with a reverse recoil cycle, during firing the recoiling parts first roll forward and then roll backwards. To fire a round, the recoiling parts must be released from the locked position, i. e. the gun must be moved forward. When the recuperator speeds up the recoiling parts, the firing pin will automatically be released. In this case the force of the action of the gases on the barrel first brakes counterrecoil and only later imparts motion to the recoiling parts. Compression of the recuperator before the first round is fired is usually effected by means of a pneumatic energy storage device.

Aiming and laying mechanisms -- the traversing and elevating mechanism -- serve to aim the piece at a target. The traversing mechanism makes possible laying for direction, the elevating mechanism laying for range.

The essence of the operation of aiming and laying mechanisms is to impart motion from a manual, mechanical, hydraulic or electric drive to the tipping or rotating parts of a piece.

Aiming and laying mechanisms of modern pieces are of the rack and screw type.

The rack-type elevating mechanism is constructed as follows. On the bottom of the cradle (or on the side) there is a rack which meshes with a spur gear attached to a shaft in the top carriage of the piece. The rotary motion of the handwheel of the elevating mechanism is imparted to the shaft and gear through a gear train. The gear, moving along the rack, turns the barrel around the cradle trunnions, making possible laying in the vertical plane.

The screw-type traversing mechanism consists of a screw hinged to the bottom carriage, housing, and a shaft with a handwheel. The housing is permanently connected to the shaft and is screwed onto or off the screw by turing the handwheel. Since the shaft is hinged to the bracket of the top carriage, moving it will result in turning the top carriage relative to the stationary bottom carriage.

To maintain the direction imparted to the barrel, aiming and laying mechanisms are made to be self-braking. Some pieces use aiming and laying mechanisms with gear-boxes, which permit variation of aiming speed.

The equilibrator is intended to relieve the elevating mechanism and thus facilitate the work of the gunlayer who points the piece in the vertical plane. The need for such mechanisms is due to the fact that artillery pieces nowadays have long barrels, great elevation ranges and high aiming speeds. Under these conditions it is impossible to do without reliable balancing of the tipping parts.

Modern pieces widely use spring, pneumatic and hydropneumatic equilibrators.

A distinction is drawn between equilibrators of the push and pull type according to the site and method of application of the balancing force to the cradle. In the former case balancing is achieved by pushing the cradle upwards, in the latter case by pulling the rear part of the cradle downwards.

A pneumatic equilibrator of the push type consists of one or two symmetrically placed columns, each of which has an outer and inner cylinder, packing, and a valve. The ball pivot of the outer cylinder enters the corresponding cradle bed. The inner cylinder enters the outer cylinder and rests its ball pivot on the top carriage. The air between the two cylinders, compressed to 50 atm, props up the front end of the cradle and thus decreases the influence of the weight of the muzzle end of the barrel on the elevating mechanism.

In spring equilibrators the role of compressed air is performed by springs arranged as a single spring or as two springs of varying diameters.

Pneumatic mechanisms are very compact and light in weight, but their functioning strongly depends on the temperature of the surrounding environment. Therefore they need systematic adjustment.

Spring mechanisms are simple in construction and their functioning is not dependent on air temperature, but they are cumbersome and heavy in weight.

The bottom carriage is a strong cast, welded or riveted structure, which houses the rotating parts of a piece. Trails and running gear are fastened to the bottom carriage.

Modern field pieces employ only split trails. Two trails enable a piece to have maximum traverse up to $\pm$ 25-30° during operation of the traversing mechanism; three or four trails make possible all-around fire. Trails are made of tubes or are welded (riveted) beams of variable cross section. The length of a trail depends on the power of the gun and its weight.

Trails terminate in spades which rest in the ground. For ease of operation spades are made to be collapsible or removable. Beside the spades on some pieces removable or collapsible rollers are installed, which facilitate opening the trails or manhandling the pieces.

An entrenching tool and spare parts are usually attached to the trails. At the rear end of the trails there is a drawbar to connect the piece to the hook of the prime mover.

The running gear of a piece consists of axletree, wheels, suspension with spring disconnecting mechanism, and brake system.

Towed artillery nowadays employs metal wheels of the automobile or streetcar type with rubber tires filled with sponge rubber. Such tires are very elastic and suffer little damage. The wheels of some pieces have caterpillar bands instead of solid tires.

The mobility of a piece depends on the size of the wheels. High wheels easily roll over rough places in its way, small rocks, roots of trees etc. But in this case the entire gun carriage becomes higher and its stability declines. To retain high wheels and at the same time not lose stability of the piece, the axletree of the gun carriage is made with a dropped center.

It is known that a wheel with a wide tire cuts less into the ground and more easily traverses muddy places. However, widening the tire increases wheel weight. Therefore, designers seek the optimum combination of these conflicting parameters. To increase trafficability, sometimes dual wheels are employed.

In movement over hard and rough terrain at elevated speeds a gun experiences sharp bumps and impacts which can shake it up and cause serious damage. To decrease the harmful effect of bumps and shocks on the mechanisms in modern pieces, suspension mechanisms are used.

In essence, suspension consists in the use of an elastic coupling between the running gear and bottom carriage of a piece. The elastic element assures a smooth increment of the force coming from an obstacle on the suspension parts of the piece.

Modern artillery employs three types of elastic suspension elements: laminated springs, coil springs, and torsional suspensions.

A diagram of the commonest torsion-bar suspension is shown in Figure 29. A torsion bar is a long steel rod which is subject to torsion. At the thickened ends of the rod there are splines. One end of the rod is fixed in the bottom carriage, and to the other is attached a rocker arm with a wheel. If the wheel in motion encounters some obstacle, the rocker arm goes up and the torsion bar twists. Since steel possesses elasticity, the torsion bar untwists when the wheel gets by the obstacle. Twisting of the torsion bar takes place within the limits of elastic deformation, and therefore it acts as a spring. To avoid breakage of the torsion bar in the event of overloading, the turning of the rocker arm is limited by a stop with a rubber buffer. Torsion-bar suspension is distinguished by compactness of design and light weight.

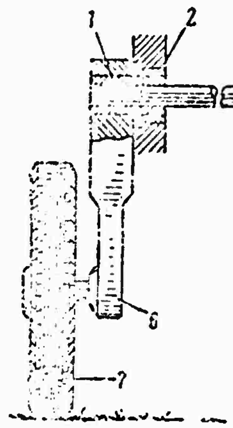


Figure 29. Diagram of torsion-bar suspension:

1), 4) splined sectors; 2) hollow axle; 3) rod; 5) gun carriage; 6) rocker arm; 7) wheel.

During firing the suspension is disconnected. Unless this is done, during firing the top carriage and barrel will vibrate on the springs, and this will impair the stability of the piece. The suspension is automatically disconnected when the trails are opened, and connected when the trails are closed, i.e. when the piece changes from firing position to traveling position. To brake a gun on the march, especially in case of sudden stops, wheel braking devices are used: shoe brakes, band brakes etc. Braking is accomplished by a cable running from the driver's cab of the prime mover.

The shield assembly protects personnel and mechanisms of a piece from hits by bullets and fragments of projectiles and mortar shells. In guns with powerful muzzle brakes, shields lessen the harmful effect of muzzle waves on the gun crew.

The shield assembly of modern field pieces consists of two shields: a fixed shield attached to the top carriage, and a movable one attached to the tipping parts. In the fixed shield an opening is made, through which the barrel and cradle pass. The size of this opening must permit the tipping parts to move up and down. The movable shield covers the opening in the fixed shield.

Gun shields are made of special steels and are from 3 to 10 mm thick.

To decrease the penetrability of shields, screened structures are used. Instead of one shield, two are placed 20-25 mm apart and are rigidly fastened together with braces. The idea of screen construction is that after fragments or bullets penetrate the first shield, they lose some of their energy, are deformed, and change flight direction. Therefore, conditions for penetration of the second shield are appreciably worsened.

The gun-traveling lock assembly protects the most important assemblies and mechanisms of the piece against impact loads while traveling. For example, the elevating mechanism, especially the elevating rack mechanism whose teeth can get bent or broken, suffers from jolts in motion. To prevent this from happening, before traveling the tipping parts of a piece are brought into an approximately horizontal position and fastened to the bottom carriage by means of a beam or by locking devices.

In large-caliber pieces the barrel is pulled back along the cradle and then secured with locking devices. This permits uniform distribution of the weight of the piece over all the wheels.

Auxiliary gun carriage mechanisms are exceedingly diverse. Their purpose and design are determined by the operating peculiarities of the specific piece. If, for example, a piece has a heavy shell, devices and mechanisms are employed to make loading easy and convenient.

One such loading device consists of a chute and a graded runway. Axles are welded on underneath the chute, and wheels are put on the axles. The chute moves freely along the graded runway to the loading tray of the piece.

Some guns have interlock mechanisms which rule out the possibility of firing when assemblies are improperly connected.

Small reaction engines are sometimes used to get speedy and sure adhesion of a piece's spades to the frozen ground. They make it possible to drive the spades into the ground very rapidly.

It is known that when a piece is set up in a fire position, artillerymen try carefully to level the gun platform since a tilt to the left or right of a piece's axis of trunnions sharply worsens the accuracy of fire. To avoid such an undesirable occurrence, horizontal leveling mechanisms (jacks) and counterpoises are made part of some pieces.

The essence of the operation of the counterpoise is to provide a piece with three footings (center of gun-carriage axle, spades of two spread trails).

American forces in South Vietnam use special aluminum platforms to mount pieces, especially the 105-mm M102 howitzer, on muddy and soft ground and on rice paddies. The floor of this platform is made of reinforced glued plywood. The platform itself is set upon four adjustable supports. Weight: 2225 kg; length 6.7 m. The platform is transportable by helicopter. In the opinion of American specialists, such a gun platform assures accuracy of artillery shell fire practically unattainable in firing from soft ground.

To give the barrel the necessary position (angles of elevation), sighting mechanisms are employed whose construction is practically identical for all pieces despite a difference in certain parts and assemblies depending on the type of piece.

The present chapter has considered the principles of construction of towed field artillery pieces and mortars.

Design peculiarities and specific mechanisms of field self-propelled, auxiliary propelled and recoilless guns, tank, antiaircraft and other types of artillery are covered in Chapters VI-VIII.

Chapter V

ARTILLERY AMMUNITION

1. The Artillery Round

In contrast to a round as a physical phenomenon, by "artillery round" is meant the full unit of all the ammunition elements necessary for the firing of a single round. This unit includes (Figure 30): a specific-purpose projectile or mortar shell, a firing device or time fuze, a propelling (powder) charge, a case (bag) in which the charge is placed, and a propelling-charge primer. The artillery round of some pieces includes auxiliary elements to the charge, for example, deterrents, flash detonators, decopperers etc.

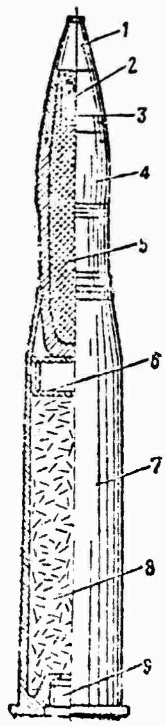


Figure 30. Elements of an artillery round:

1) firing device; 2) detonating cap; 3) detonator; 4) shell; 5) bursting charge; 6) cardboard obturator; 7) shell case; 8) propelling (powder) charge; 9) primer or electrical cup.

Based on their function, rounds are classified as service, practice, blank and dummy rounds.

Service rounds are designed for field firing. Units of fire of guns consist of a certain combination of these.

Practice rounds are used for target practice on artillery ranges. They differ from service rounds in that they have simple and cheap projectiles which make possible only the observation of bursts or holes in practice targets. Reduced charges are used to reduce barrel wear.

Blank rounds are designed for the simulation of fire in troop exercises, for signals and salutes. A blank round has no projectile.

Dummy rounds are used to train gun crews. They are made up of blank elements of service rounds.

Types of artillery rounds based on the manner of loading are shown in Figure 31.

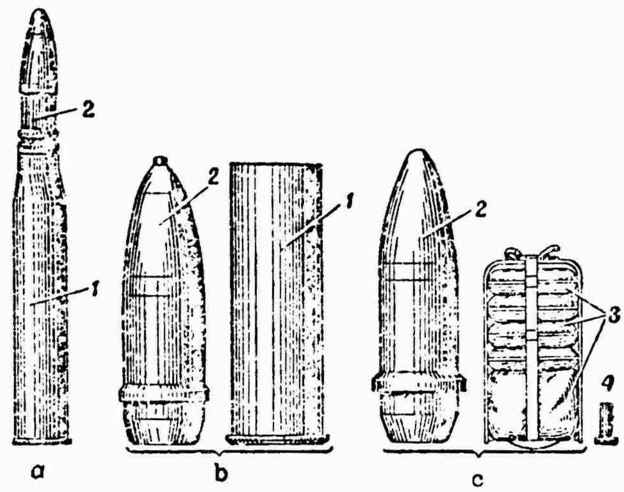


Figure 31. Types of artillery rounds:

a) fixed round; b) separate case-loading round; c) separate bag-loading round; 1) case with propelling charge; 2) shell; 3) propelling charge in bag; 4) charge primer.

Projectiles (mortar shells) are designed for target damage (destruction, demolition, incendiary effect etc.), ranging fire, target designation or for support of the execution of a combat mission (smoke screening, illumination etc.).

Based on combat function, the various types of projectiles (mortar shells) are subdivided into three groups:

basic-purpose shells -- fragmentation, high-explosive fragmentation, high-explosive with ready-made damage elements, armor-piercing (solid, with bursting charges, subcaliber), shaped-charge, concrete-piercing, incendiary, canister;

special-purpose shells -- smoke, illuminating, leaflet;

auxiliary-purpose shells -- practice, dummy.

The unit of fire of any gun or mortar includes several projectiles (mortar shells) with different purposes and working principles.

Firing devices and time fuzes are used for the timely actuation of projectiles (mortar shells) at a target or at a given point of the trajectory.

A propelling charge imparts the necessary muzzle velocity to a projectile (mortar shell). The powder charge is ignited by the force of the fire of the primer cup.

The shell case is designed to accommodate the propelling charge and its primer and to protect the charge from moisture and mechanical damage and obturation of the powder gases during firing. In fixed rounds the case combines charge and shell into a single whole.

2. Explosives

Explosives are the energy source for fire from any type of modern firearms and for target destruction. Explosives acted upon by an insignificant external force are capable of instantaneous chemical transformation -- an explosion.

The essential criteria of an explosion are a tremendous rate of chemical transformation, the generation of a large quantity of high-temperature gases, and a sharp report. The potential energy of explosives during an explosion is converted into the mechanical work of expanding gases, which fragmentize and destroy surrounding objects.

The explosion process itself is brief, lasting from hundredths to millionths of a second.

The volume of gases evolving during the explosion of any explosive is much greater than the volume of the explosive itself. Thus, 1440 liters of gases are evolved in the combustion of a liter of nitrocellulose powder.

The work of an explosion is also determined by the quantity of heat that is emitted. One thousand calories of heat are emitted in the explosion of one kilogram of TNT or in the combustion of one kilogram of smokeless powder.

The temperature of the gases in an explosion reaches 2200-4000° C.

A distinction is drawn between rapid combustion, the explosion proper, and detonation by reference to the velocity of the explosive transformation characterizing the qualitative aspect of an explosion.

Rapid combustion of an explosive is the process of explosive transformation taking place at a velocity of up to several meters a second. In the process gases, as they gradually form, do the work of scattering or throwing. For example, in the rapid combustion of a powder in a bore the gases do the work of throwing. They eject the shell from the bore without destroying the shell or the barrel itself.

The explosion proper is a process with a velocity measured in hundreds of meters a second. In an explosion a sharp pressure jump occurs, there is an impact of gaseous products on the surrounding environment, and destruction of the latter takes place.

The detonation of an explosive is a special type of explosion characterized by the maximum possible velocity for the given explosive -- several thousand meters per second. The detonation rate does not depend on external conditions. It is 6700 m/sec for TNT, and about 8200 m/sec for nitroglycerin. The detonation of the explosive charge in a shell instantaneously fragmentizes its walls.

According to the character of the action and their practical application, explosives are subdivided into initiators, high (blasting) explosives, low (powder) explosives and pyrotechnic compounds.

Initiators (sometimes called primary explosives) are explosives with high sensitivity to various external forces. They are set off by a flame, spark, pinpoint, push, impact, friction, and by their explosion can cause the detonation of other less sensitive explosives. Therefore initiators are used to load various primers, which are the causative agents of explosive processes.

Initiators include mercury fulminate, lead azide, lead styphnate, tetrazene. Initiating mixtures are used which contain, for example, mercury fulminate, Berthollet's salt, antimony trisulfide.

High explosives (secondary) are less sensitive to fire, impact and other external forces. Therefore they are safe in routine handling. The principal form of explosive transformation of high explosives is a detonation, which is set off by the action of initiators. High explosives are designed for the loading of projectiles and mortar shells. Chemically, high explosives are cyclic nitro compounds of the aromatic series (TNT, picric acid or melinite, tetryl), heterocyclic compounds (nitramine group -- hexogen, octogen), acyclic nitro compounds of the aliphatic series (nitroglycerin, pentaerythritol tetranitrate or PETN, tetranitromethane, ethylenedinitramine). The most popular high explosive is trotyl (full name -- trinitrotoluene, abbreviated -- TNT).

Trotyl is a solid crystalline substance, yellow in color. Specific gravity 1.66, melting point 81.6° C. The starting material for its production is toluene, a colorless liquid extracted from the distillation products of coal or petroleum. Trotyl forms as a result of threefold nitration of toluene with a mixture of nitric and sulfuric acids. It is insensitive to shocks, even if bullets are shot through it, and to heating. Trotyl can be cut, sawed, drilled, burned. When ignited in open air, it burns quietly with a strongly smoking flame. Trotyl does not dissolve in water, does not interact with metals under ordinary atmospheric conditions, is very stable in storage (projectiles and mortar shells filled with it can be stored for many years).

Trotyl is not only widely used in artillery; it is used to load hand grenades, blasting charges, aerial bombs, warheads of missiles of various classes.

Trotyl is the measure of the power of nuclear weapons. The generally accepted TNT equivalent characterizes the effect of a nuclear explosion in terms of the weight of a TNT charge with explosive energy equaling the explosive energy of the particular nuclear ammunition.

For example, the TNT equivalent of the nuclear charge in 1 kg of uranium-235 (with complete fission of all its nuclei) amounts to the explosive energy of 20,000 tons of trotyl.

Besides trotyl, hexogen and PETN are also widely used for the active components of ammunition, and tetryl for making detonators. Since hexogen in pure form is sensitive to mechanical forces, it is phlegmatized with paraffin or other substances when projectiles and mortar shells are loaded.

Abroad work is continuing on the synthesis and study of new explosives and compositions possessing higher energy or operating characteristics than explosives already known.

For example, in the United States a series of new high explosives was recently developed under the general designation of "Astrolite" with a detonation rate of 8200 m/sec. "Astrolite-R," for example, is a high-energy plastic explosive. Its structure can vary from gluey pasty to hard rubbery. "Astrolite-R" is most frequently used in the form of a soft mastic, since it is easily molded, retaining the shape imparted to it, as well as readily sticking to a dry surface.

Low explosives (powders) are subdivided into nitrocellulose and mechanical mixtures. Their distinguishing feature is the capacity for explosive transformation in the form of rapid combustion, but without detonation. They are intended for the production of propelling charges or ammunition elements (igniters, retarders, expelling charges etc.).

Powders are smokeless (nitrocotton, nitroglycerin, nitroguanidine, diglycol etc.) or black.

Smokeless powders are made in the form of ribbons, plates, disks, tubes, cylindrically shaped grains with one or seven channels etc. Specific gravity of the powder 1.55-1.63; flash point 180-200° C.

Smokeless powders are subdivided into single-, double- and triple-base. The single-base powders include nitrocotton, the double-base nitroglycerin, the triple-base nitroguanidine powders (nitrocotton + nitroglycerin + nitroguanidine).

The basic ingredient of all smokeless powders is nitrocotton, i. e. a high explosive. Nitrocotton is obtained as a result of treating cotton with nitric acid in the presence of sulfuric acid. This process is called nitration. In order to obtain powder, the nitrocotton is treated with a solvent consisting of an alcohol-ether mixture. As it dissolves, the nitrocotton turns into a homogeneous gelatinous mass, from which powder of the requisite shape is prepared. This is the essence of the production of nitrocotton powder.

In 1890 our great compatriot D. I. Mendeleyev was the first to suggest the diffusion method of dehydrating nitrocotton with ethyl alcohol. This method is now used in all countries of the world.

Nitroglycerin powder is made from nitrocotton and nitroglycerin. A distinction is drawn between powders with a high nitroglycerin content (40-60 percent) and those with a moderate content (20-30 percent). It should be recalled that nitroglycerin is an exceedingly strong blasting explosive, obtained by nitration of glycerol. It possesses the property of dissolving nitrocotton and forming a gelatinous mass, from which powder of the same shapes can be obtained as from nitrocotton.

Depending on the properties of the solvent, nitrocotton powders are also known as volatile-solvent powders, and nitroglycerin powders as nonvolatile-solvent powders.

An advantage of nitroglycerin powders over nitrocotton powders is that they are considerably more powerful, and cheaper to make besides. However, they have a high combustion temperature, which leads to rapid barrel wear. "Cold" nitroglycerin powders are also employed. The accuracy life of barrels in this case is even higher than with the use of nitrocotton powders.

Smokeless powders can be flashless, i.e. give no more than 5 percent flame as compared with a conventional (flash-type) round under average firing conditions. Little or no back blast is observed when the breechblock of tank guns is opened after a round with a propelling charge of flashless powder has been fired.

Black powder, with which everyone is familiar, is a mechanical mixture of potassium nitrate (75 percent), charcoal (15 percent) and sulfur (10 percent).

Black powder is not directly used for firing in modern times. It is three times as weak as smokeless powder, markedly fouls the bore with solid residues, and forms a smoke cloud during combustion, which discloses the fire position and prevents observation of target or aiming point.

But black powder does have some good qualities: it readily ignites, even from a small spark, and burns much faster than smokeless powder. Therefore, black powder is now used as igniter for smokeless powder, in primer cups and impact primers, for powder safety locks, boosters and delay elements, in time fuzes and firing devices, in Bickford fuzes etc. The expelling charges of incendiary, illuminating and leaflet shells are made of black powder.

Pyrotechnic compounds are hot mixtures with weakly manifested explosive properties. The principal type of transformation here is combustion.

Pyrotechnic compounds are used to load incendiary, smoke and illuminating projectiles (mortar shells) and all kinds of tracers and signals. The combustion rate of pyrotechnic compounds is very low because they are intended to produce a flame, light or smoke of varying color rather than for destruction or throwing.

3. Propelling Charges, Metal and Combustible Cases, Primers

In order to fire a piece, it must first be loaded, i.e. a projectile and propelling charge must be inserted in the barrel. For each round a strictly defined quantity by weight of smokeless powder is used, and this quantity of powder is called the propelling charge.

Propelling charges are fixed or multisection. Fixed charges are used in guns loaded with fixed ammunition. In this ammunition the case is closed by the projectile itself, which is connected to the case by crimping or rolling the case neck. Troops are not allowed to make any changes in these charges.

Multisection charges are used for separate loading. They consist of the base package and increments. When firing at less than maximum range, the weight of the propelling charge can be modified by removing the necessary number of powder sections. In this way trajectory curvature is varied when firing at the same range, the gun stands up better with a reduction in charge, and powder consumption is cut.

A propelling charge includes, in addition to smokeless powder, some auxiliary elements: an igniter (made of black powder), a standard cover (obturator), a reinforced closing plug (for hermetic sealing of charge), a flash hider (to reduce muzzle flash), a decopperer (to remove copper particles from the rotating band), and a phlegmatizer (to reduce barrel erosion).

Mortar propelling charges are subdivided into base and increment charges. The base charge is placed in the stabilizer tube and in appearance resembles a shotgun shell: a paper case, a brass base with a cap. The base charge is the minimal charge and it is constant. Firing is impossible without it.

To increase the range of fire, increment charges, which are fitted on the mortar shell stabilizer tube, are used. They are small bags of powder in the form of a ring. The charges are customarily designated by numbers. The number of a charge corresponds to the number of rings added to the base charge: charge No. 1 is the base charge plus one increment ring charge; charge No. 2 is the base charge plus two ring charges etc.

When a round is fired, the powder gases of the base charge, escaping through the fire-transmitting openings of the stabilizer tube, ignite the increment charges. As a result of the combustion of the increment charges the pressure in the bore increases and the mortar shell is ejected from the barrel at a greater speed and, hence, for a greater distance.

The shell case is an element of a fixed or separate round. Its shape conforms to that of the powder chamber of the piece for which it is designed.

The shell case consists of a body, neck, shoulder connecting the neck to the body, base, head and a screw-on eye (<u>navintnoye ochko</u>) for the primer cup. Cases for separate rounds have no shoulder. To facilitate extraction of the case after firing, its body is made slightly conical. In the loaded state the case rests its base against the breech face of the barrel tube. After firing, the ejector of the breechblock catches the case by the base and extracts it from the barrel. Cases for automatic pieces have a circular groove instead of a base or rim to engage the ejector.

In some recoilless guns the case has perforated openings, through which the powder gases enter the chamber of the piece and then pass into the atmosphere through the breechblock. A covering closing the perforated openings in the case and a *bursting* diaphragm prevent the propelling charge from running out and moisture from entering.

Cartridge cases are usually made of brass or low-carbon steel.

In recent years, as a result of the development of automatic cannons with a high rate of fire, increased requirements have begun to be set for cartridge cases: the necessary strength; guarantee of ejection under high barrel-chamber temperature conditions; elimination of the phenomenon of cartridge disintegration in seating a fixed round in the barrel at high speed. Underestimating the great importance of the cartridge case in automatic guns may lead to such undesirable consequences as failure of the breechblock to open, breakage of the ejector mechanism, flange breakdowns, case cracking, nonextraction of cases from the chamber etc.

The experience of artillery combat operation in modern warfare has revealed the deficiencies of metal cases, these deficiencies being especially acute in tanks and self-propelled guns. In the closed turrets of these vehicles spent cases clog the fighting compartments, already crowded to the limit. In addition, the spent cases extracted from the barrel are filled with powder gases. This sharply increases the rate of exposure to gas in the fighting compartments and lowers the working capacity of the crew despite the ventilating system. For tank guns with high powder-gas pressure metal cases have to be made massive so as to facilitate their ejection after firing, and this leads to additional operational inconveniences.

Metal cases are also inefficient from an economic point of view. Many costly and scarce brass alloys and special steels are used for their mass manufacture. The production technology of seamless cases is complicated and requires heavy press equipment.

The salvaging of spent cases for reuse, necessitated by the short supply of brass and special steel, imposes on troops in the combat zone the onerous duty of collecting and transporting used cases to the rear, and at the same time places a burden on communication lines near the front.

These are the principal reasons which have led to the development of a light nonmetal case made of a cheap material which burns on firing.

Despite the clarity, simplicity and attractiveness of the idea itself, the problem of developing combustible cases has proved very difficult. In the United States work on combustible cases began early in the 1950's and it was not until ten years later that the first experimental models of ammunition with combustible cases were developed. Tests showed that combustible cases can perform some of the functions of metal cases, namely be a container for the propelling charge, and be an obturator. However, the latter function was achieved only in fire from guns with a new breech ring design. Therefore, it was decided to develop new artillery pieces which would permit full use of all the advantages of combustible ammunition and at the same time to create breech-ring redesign projects for those pieces already in service in the American army.

The result of this decision was the development of a 152-mm gun -- the launcher for the Sheridan light tank, which fires Shillelagh antitank missiles and conventional ammunition. By the end of 1965 a consumable-case jet engine for the launching stage of the Shillelagh antitank missile was created, as well as combustible armor-piercing rounds. The combustible cases are produced by the "felting" method. Nitrocellulose-impregnated cardboard is the case material, and sawdust, kraft paper and magnesium are also used.

A serious difficulty in the search for a combustible case material has been the problem of the porosity of the material. It is believed that high porosity is an important condition for the production of a fully combustible material, while high porosity is a negative factor for assuring the necessary overall strength of a round.

The American press recently has pointed out the following problems facing developers of combustible artillery cases: operational strength of the case; long storageability under adverse conditions (high and low surrounding temperature, rain, moisture etc.); and, finally, total combustion of the case on firing. It is noted that it is a hardly feasible task to combine the optimal parameters for all three problems. Therefore, the efforts of researchers and designers are now directed towards achieving the proper combination of strength, moisture resistance, and fast and clean combustion. In the view of foreign military specialists, success in choosing the proper combination of parameters will produce great changes in ammunition and artillery as a whole.

It is also thought that it is economically infeasible completely to reequip combat vehicles with new pieces and pieces with redesigned breech rings. Besides, this would make large stocks of ammunition with metal cases unsuitable for use. Therefore, the American army was confronted with yet another problem -- the development of ammunition with a partially combustible case, which can be used without any changes in existing pieces.

The partially combustible case, made mainly of a combustible material, has a shortened metal base 50-60 mm high, which provides obturation of the barrel. Partially combustible cases are light in weight, cut down the penetration of harmful fumes into the fighting compartment of vehicles, and are less bulky than ordinary metal cases.

Combustible and partially combustible ammunition has also been developed for the American 105-mm howitzer and 105-mm and 120-mm guns (Figure 32).

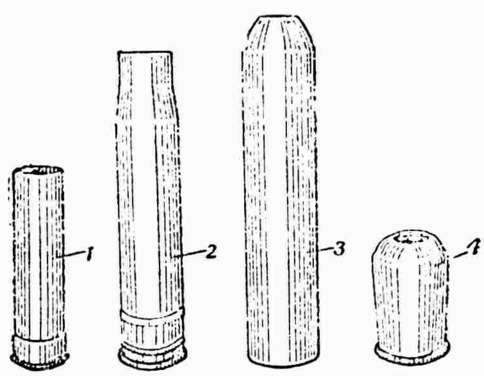


Figure 32. Combustible cases:

1), 2) partially combustible cases for American 105-mm gun; 3), 4) fully combustible cases for 120-mm gun and 152-mm gun of the Sheridan tank.

Primers serve to impart a flame to the propelling charge. They are of the percussion or electric type.

Percussion primers -- percussion caps, primer cups and impact fuzes -- are actuated by the impact of a striker pin.

Percussion caps are used in the basic rounds of mortars, primer cups for case-loading rounds, impact fuzes for bag-loading rounds. There is little difference between a primer cup and impact fuze in interior design (percussion powder, black smoke charge, powder pellet). The primer cup is screwed into the cartridge base; the impact fuze is inserted in a special breech recess.

Electric primers are used in antiaircraft, tank, coast, shipboard and field rocket artillery. The powder is ignited here by means of an electric squib with a "bridge" in the primer composition. The electric primer for combustible cases is made of completely combustible materials. As it is assembled, its parts are glued to the cartridge base.

4. Firing Devices and Fuzes

Fuzes are used for all shells which have a high explosive charge. A fuze is not needed if the shell has no explosive charge (for example, in an armor-piercing shot or hard-core shell).

Fuze designs are quite diverse, but each of them has three essential elements which constitute the igniter train (Figure 33): a primer, upper detonator, and lower detonator. The primer transmits a flame; it is ignited by the impact of the striker or the prick of the firing pin. The upper detonator serves to initiate the explosion (detonation); it is actuated only by the flame of the primer. The lower detonator is a small explosive charge (10-30 g), sensitive to the initial impulse of the detonating cap. It intensifies the detonating action of the upper detonator, since the latter cannot by its own explosion cause the complete explosion of the explosive charge of a projectile (mortar shell).

Sometimes the igniter train also includes a delay element of black powder. It is placed between the primer and upper detonator. In the event of firing without fuze delay the flame goes to the upper detonator past the delay element along an open channel. If the setting sleeve shuts the channel, the flame of the upper detonator goes only through the delay element, whose burning time also determines the delay time.

Fuzes are absolutely safe in routine handling, transport and storage, during firing and in trajectory. This is achieved by locking the moving parts of the fuze by means of mechanical or black powder safety locks. Mechanical safety elements are rigid safety devices, restraining springs, inertia and centrifugal safety devices. The resistance of the safety elements is calculated so as simultaneously to provide good armability of the fuze on firing and to eliminate the possibility of its being armed as a result of shaking and accidental shocks in handling. The safety elements are released when acted upon by inertia or centrifugal force at the time of firing, as well as under the influence of creep force in the initial phase of the trajectory.

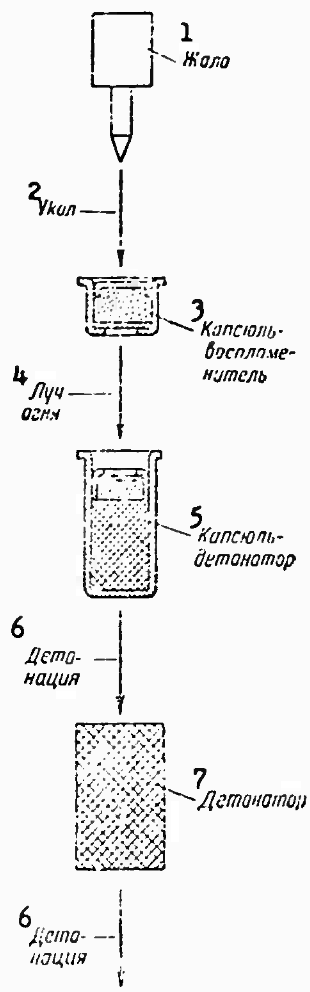


Figure 33. Igniter train of fuze.

Keys:

1) Firing pin
2) Prick
3) Primer
4) Flame
5) Upper detonator
6) Detonation
7) Lower detonator

Fuzes are of the boresafe, semi-boresafe and nonboresafe type, depending on the degree of protection against the premature action of primers and, consequently, against premature projectile (mortar shell) explosions during routine handling or during firing. In the first case the primer and upper detonator are completely insulated from the lower detonator; in the second case the primer is insulated from the upper detonator. In nonboresafe fuzes there is no insulation of the primer or upper detonator.

In the development of fuzes the most difficult thing is to solve the problem of reliably calculating the resistance of the safety devices so as simultaneously to meet two contradictory requirements, viz. assure safety of the fuze in handling and reliable arming of its machinery on firing. This problem was first solved by the well-known Soviet artillery engineer, Honored Scientist and Technician of the RSFSR V. I. Rdultovskiy, who determined the conditions for safety and reliable arming of fuzes and developed engineering methods for calculating the resistance of rigid safety devices and restraining springs. Many fuzes created by V. I. Rdultovskiy, especially the RGM and RGM-2, showed their superior qualities during the Great Patriotic War. They have long remained unsurpassed in safety, reliability of target effect.

Fuzes are classified according to the character of their operation as percussion, time and combination fuzes, and according to their location in the projectile as nose (Figure 34) and base (Figure 35) fuzes. Base fuzes are used in large-caliber armor-piercing, concrete-piercing and high-explosive projectiles. Mortar shells have only nose fuzes.

Fragmentation, high-explosive fragmentation, high-explosive and smoke shells have percussion fuzes, which function on contact with an obstacle. These same shells use time fuzes, which bring about an explosion in air at a certain altitude -- at a predetermined point of the trajectory.

Depending on the speed of response percussion fuzes are subdivided into superquick, inertia, and delayed-action fuzes.

The superquick action of a fuze brings about an explosion of the shell at the moment it encounters an obstacle, before the shell begins to penetrate the obstacle, the duration of this action not exceeding 0.001 sec. Superquick fuzes are used in projectiles and mortar shells designed for firing at enemy personnel.

Somewhat slower (of the order of 0.005 sec) is the inertia action of a fuze, which causes the shell to burst after it has penetrated the obstacle (ground) to some extent. Inertia fuzes are effective for firing on targets offering negligible resistance (light overhead trench covers, wooden shelters etc.).

Delay fuzes are used in high-explosive projectiles and mortar shells in fire for effect on enemy defensive installations. Special black powder delay elements provide a delay time of from 0.01 to 0.2 sec.

Time fuzes are mechanical, with pyrotechnical compositions (powder) and proximity fuzes.

In mechanical fuzes the time is performed by means of a special clockwork called the timing device.

In powder fuzes the time is reckoned from the moment of firing to the moment the shell bursts by means of a powder time-fuze composition burning at a constant rate (0.5-1 cm/sec).

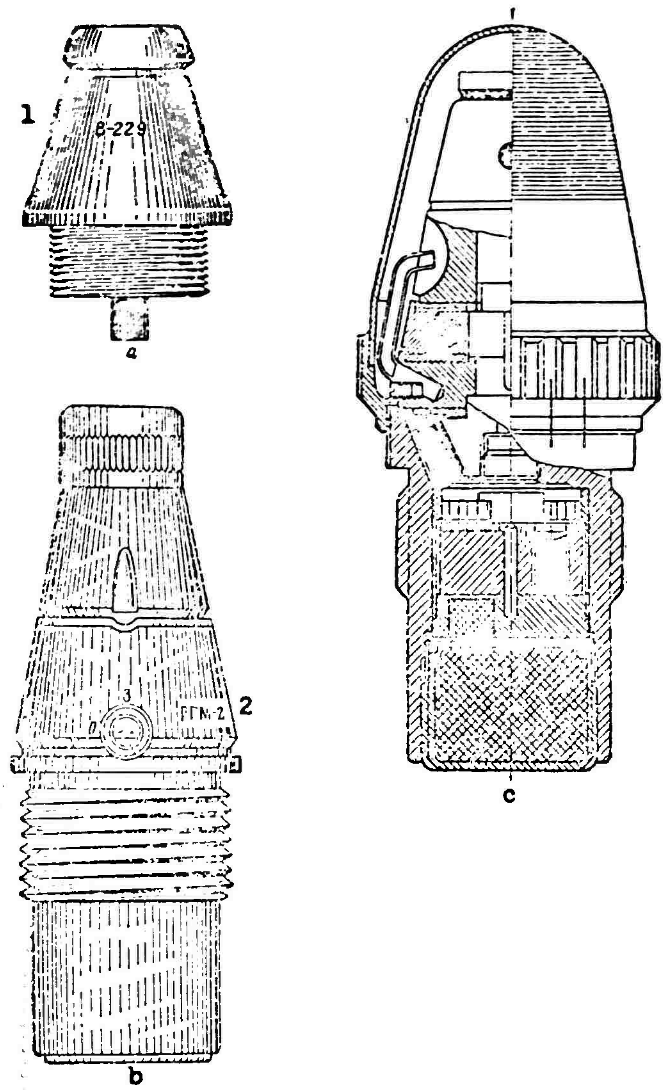


Figure 34. Nose fuzes:

a) superquick fuze; b) fuze with several settings; c) time fuze.

Keys:

1) V-229
2) RGM-2

Figure 35. Base fuze.

Key: 1) MD-7

The time powder fuze operates essentially as follows. On firing a concussion plunger (firing pin), acted upon by inertia, pricks the primer. The fire from the primer is transmitted to the time train of the upper ring, after its combustion is transmitted through a vent to the analogous train of the central ring, then to the lower ring, and thence to the powder train. The latter actuates the upper and lower detonators. The length of the burning part of the time train is changed by appropriate rotation of the rings before firing.

Ground artillery time fuzes also have a setting for percussion action. If for any reason a shell does not go off at a given point of the trajectory, it is certain to go off on striking the ground or an obstacle.

An air burst increases the fragmentation effect of a shell. This method of delivering fire with the use of a time fuze is customarily called high-explosive shell fire.

Illuminating, incendiary and leaflet projectiles and mortar shells use time firing devices rather than fuzes. These resemble time fuzes in their design. The only difference is that the igniter train of the firing device does not have an upper or lower detonator because there is no explosive charge in these projectiles (mortar shells). The igniter train of a time firing device terminates in a powder pellet, which ignites a bursting charge of black powder; the latter in turn ejects the contents of the illuminating, incendiary and leaflet projectiles (mortar shells) into the air.

In the postwar years a new variety -- proximity fuzes -- has been added to the traditional types of artillery fuzes and has gained general acceptance. The appearance of proximity fuzes is dramatic proof of the influence which scientific and technological achievements in the field of electronics and physics have had on widening the combat capabilities of modern artillery.

Proximity electronic fuzes go off automatically at the moment the shell approaches the target at a distance at which the target is sure to be fragmented. They do not need to be preset for burst range. This is their fundamental difference from ordinary time fuzes. The use of proximity fuzes significantly increases the effective operation of artillery projectiles and mortar shells.

In terms of design and operation, proximity fuzes are subdivided into radar proximity fuzes (radio fuzes), optical, capacitance, inductive, magnetic, infrared fuzes etc. Radio and optical fuzes have become the most popular abroad.

A radio fuze generally combines a radio transmitter and receiver into a single unit (Figure 36). During the flight of a projectile the activated fuze emits radio waves. The target-reflected and radiated radio waves interact, resulting in pulsation or a voltage jump. At a certain voltage jump intensity the electron key flips and the electric circuit is closed. The projectile bursts at the optimal distance from the target. If the radio sets of the fuze fail to operate and the projectile meets a solid obstacle, the percussion mechanism of the fuze is actuated and the projectile blows up. In case of a miss a self-destruct mechanism is provided in radio fuzes for antiaircraft shells.

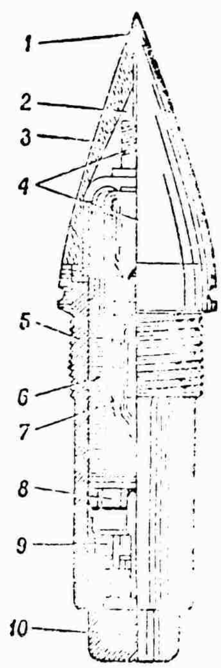


Figure 36. Diagram of artillery radio fuze:

1) antenna; 2) mass of wax; 3) plastic head; 4) radio equipment parts; 5) body; 6) battery; 7) cylinder with electrolyte; 8) safety device; 9) self-destructor; 10) detonator.

A radio fuze consists of a radiotransparent, plastic, conically shaped cap and a metal body. The plastic head houses an electronic unit with an antenna. In the body of the fuze are the power supply and a safety-and-detonating mechanism. The latter is mounted in the lower cylindrical part of the body and is designed to make the fuze safe to handle. The essence of its operation is that the holding devices are removed only at the moment of firing.

The arming system for the radio fuze consists of mechanical and electrical arming.

Mechanical arming is provided by a plunger. In the safe position a spring-mounted rotating disk with a detonator is so locked that the detonator is displaced from the axis, and therefore the igniter train and electric circuit are disconnected. The fuze is safe for routine handling and storage until the stop releasing the rotating disk sinks under the influence of axial inertia at the time of firing. When released, the rotating disk turns and closes the igniter train and electric circuit. This has already happened by the time the shell leaves the gun barrel (in 2-4 sec).

Radic fuzes began to be used at the end of World War II. They were very complex in design, had a large tail and low operating reliability. There was no interference elimination. Despite a number of important deficiencies radio fuzes proved exceedingly effective even then. For example, in the defense of London against raids by the German V-1 buzz bombs 90-mm and 94-mm antiaircraft guns partially supplied with radio fuzes shot down as much as 80 percent of the buzz bombs that were produced.

An optical fuze is constructed on the principle of using target-reflected light rays. It consists of a special lens, photocell and amplifier. The lens, mounted in the fuze head, has a detection cone. When a target intersects the detection cone, there is a sudden increase in the output current of the photocell as a result of light action, and this is the signal for a burst. A shell burst signal is issued only at the moment the shell is in the target destruction zone. This is achieved by appropriate regulation of the detection cone.

An optical fuze responds only to a sudden light flux change due to the passage of a target through the detection cone and does not respond to an absolute light flux value. This permits the use of an optical fuze under conditions where light characteristics vary in a wide range. Important shortcomings of optical fuzes are the impossibility of using them at night, the effect which clouds and fog have on their operation etc.

One of the most important problems in the creation of proximity fuzes is the development of electric power supply sources. For the fuzes of artillery shells use is made of storage batteries with a liquid electrolyte which for safety in handling is put in a special ampoule. As a result of exposure to the impact load at the time of firing the ampoule breaks open and the electrolyte is forced out to the plates of the storage battery.

Various safety measures are provided in proximity fuzes: mechanical separation of the initiating and bursting charges, high charging resistor in the capacitor circuit, a mercury contact, a shunting detonator. The mechanical holding device is removed only at the moment of firing. The value of the capacitor charging circuit time constant is chosen so as to provide a certain time delay for the capacitor charge from the moment the battery is activated. Thus, the capacitor does not possess the requisite electrical energy until the shell is safely away from the piece. The mercury contact opens after firing.

The development of proximity fuzes involves the overcoming of a number of technical difficulties caused by the specific character of fuze operation. It suffices to recall that at the time of firing the parts of proximity fuzes experience overloads of up to 20,000 units, rotation at the speed of several hundred revolutions per second etc. In this connection all parts, including the various electronic instruments, must be durable and provide trouble-free operation.

Foreign specialists note that darkness does not affect the functioning of proximity fuzes. Heavy rain or rain clouds, hail or snow may significantly increase the relative number of cases of improper fuze action of antiaircraft artillery and some models of ground artillery, causing premature response on the trajectory. For example, during firing in heavy rain proximity fuzes either do not respond at all or respond prematurely. This is due to structural damage or microphone effects resulting from rain drops striking the flying projectile. If clouds have such a high reflectivity that they can be fixed on radar, the approximate deterioration in the precision operation of a fuze can be determined. If there are frequent cases of abnormal fuze operation under the influence of clouds or rain, it is recommended that proximity fuzes be replaced with time mechanical fuzes.

Proximity fuzes may also be actuated by close explosions or fragments. An increased number of premature bursts in trajectory may be due to a volley, a salvo or rapid fire from adjacent pieces. This number is reduced by increasing the distance between guns or the time between rounds.

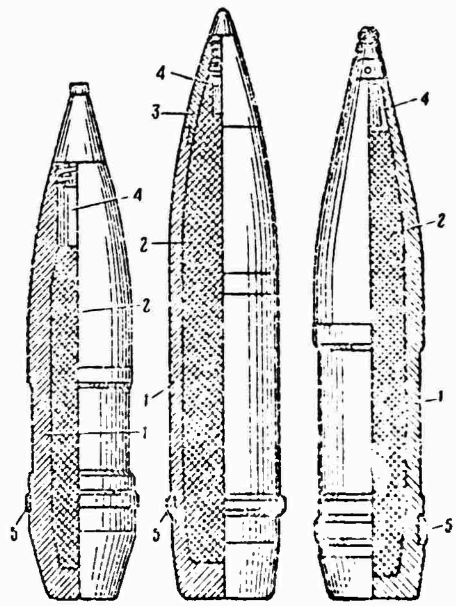
The principal factors influencing the burst height of a projectile with a proximity fuze are the angle of impact with the target and the reflectivity of the target surface. The height of burst declines with an increase in the angle of fall of the projectile. The minimum burst height is afforded by such target surfaces as dry sand and ice. Damp ground, water, dense foliage and dense vegetation cover increase the burst height of a projectile. As they approach elevations, large buildings, towers, trees and other protruding objects, proximity fuzes are actuated at a greater height than when approaching the flat surface of the earth.

The further development of proximity fuzes should, in the view of foreign specialists, take the approach of increasing their noise immunity, microminiaturization and the creation of general-purpose models, with a trend towards standardization applying generally to all fuzes. For example, the United States decided in 1968 to develop standard fuzes which would reduce to a minimum the wide assortment of fuzes of varying purpose. The plan is to have two standard fuzes for ground artillery (for projectiles and mortar shells) and one fuze for naval ordnance projectiles. Plans also call for the development of proximity fuzes whose tail diameter will be the same as in percussion fuzes.

Foreign military specialists believe that proximity fuzes do not replace time fuzes, but merely complement them, especially in long-range fire when the spread in projectile time of flight significantly increases.

5. Fragmentation, High-explosive, and High-explosive Fragmentation Shells

Fragmentation shells (Figure 37,a) are used by antiaircraft artillery to fire on air targets and by ground artillery to fire on personnel and materiel, to destroy light field shelters and to breach wire entanglements and mine fields.



a b c

Figure 37. Shells:

a) fragmentation shell; b) high-explosive shell; c) high-explosive fragmentation shell; 1) shell body; 2) bursting charge; 3) threaded cap; 4) fuze; 5) rotating band

Fragmentation shells destroy a target with the fragments of the burst body and in part by the force of the gases of the bursting charge and the force of impact against an obstacle.

The fragmentation effect of a projectile is characterized by the number of effective splinters, by their distribution in the beaten zone and by the effective casualty radius of shell splinters. An effective splinter is customarily considered one weighing 4-5 g, having a minimum speed of around 200 m/sec and possessing a lethal energy of 8-10 kgm. The number of splinters depends on the wall thickness of the projectile body, the mechanical properties of the body metal, the weight and properties of the explosive, and the character of the detonation of the bursting charge.

Serious difficulties arise in the development of fragmentation shells due to the necessity of implementing contradictory requirements. For example, the main requirement of a fragmentation shell, viz. that it give the maximum number of effective splinters with the maximum effective casualty radius and an adequate damage density, forces an increase in the wall thickness of the shell. But since the deadliness of a splinter also depends on its velocity at the moment of impact, the weight of the bursting charge has to be increased, i.e. the wall thickness of the shell must be reduced, which inevitably involves fragmentation of the body into fine splinters. In the Soviet fragmentation ammunition used in the Great Patriotic War the optimum ratio was found between bursting charge weight and body wall thickness, and therefore our fragmentation shells were distinguished by high target effectiveness.

Fragmentation shells are made of steel or semisteel and loaded with a high explosive. The weight of the bursting charge relative to the overall weight of the shell is 5-14 percent.

These shells use instantaneous nose percussion fuzes or time fuzes. In American fragmentation shells a deep recess with an aluminum cup in it is made in the head of the bursting charge for placement of proximity fuzes. There is an increment explosive charge in this recess for firing with percussion or ordinary time fuzes (mechanical, powder).

Varying splinter densities are created at varying distances from the site of a shell burst. For example, in the vicinity of a burst a target is damaged at any point since it is in the saturation damage range. The number of deadly splinters declines with increased distance from the site of the burst, and they are distributed over a greater area. In this case one no longer speaks of saturation -- but of effective -- splinter damage.

Effective areas for fragmentation shells are: 15 x 30 m for 75- to 76-mm calibers; 20 x 60 m for 120- to 125-mm calibers; 25 x 70 m for 150- to 155-mm calibers.

When a shell with a percussion fuze bursts, some of the splinters fly along the surface of the earth, i.e. they fly flat, and a small number rise upwards or crash into the ground in the vicinity of the burst site. Target damage depends on the magnitude of the angle of fall of the shell: with increased angle the splinters scatter more uniformly in all directions. At angles of fall in excess of 75° almost uniform all-round damage is obtained.

Splinter effect is better, the more rapid the fuze actuation and the harder the ground, i.e. the smaller the shell crater, since in a large crater many splinters are left that turned out to be useless.

To increase the effectiveness of splinter action on ground targets given angles of fall up to 18-22° and sufficiently hard ground, use is made of shell ricochet so as to obtain an air burst at a height of 3-4 m after impact with the ground. In this technique of firing the fuze is set for delayed action. An air burst can also be obtained by firing on underbrush, tree branches and other objects in the vicinity of the target with the fuze set for splinter action.

Fragmentation shells with time fuzes are especially effective. Such means of personnel protection as open trenches, ditches, accidents of the terrain and reverse slopes are no safeguard against casualties from air bursts of shells.

High-explosive shells (Figure 37,b) are used to destroy defensive installations which are not reinforced with concrete, wire, mine and other entanglements. They are used in combined fire with concrete-piercing shells to remove the earth cover from permanent fortifications. In isolated cases high-explosive shells are used to fire on enemy tanks and exposed personnel.

The destructive effect of a high-explosive shell consists of the action of the explosive charge gases which are generated on detonation (high-explosive effect), and in part of the impact and splinter effect of the shell.

The high-explosive effect depends on the weight of the bursting charge and the power of the explosive, as well as on the penetration of the shell into the obstacle before the moment of the burst and the properties of the environment. The volume of the crater is a measure of the high-explosive effect.

High-explosive shells consist of a thin-walled steel body, bursting charge and fuze. The power of a shell is increased either by increasing the weight of the explosive or by using a stronger explosive. Shell capacity can be increased by decreasing the wall thickness of the shell to a limit such as to assure body strength as the shell moves along the bore during firing, as well as by increasing the length of the cylindrical part of the shell. Howitzer high-explosive shells have the thinnest walls since they undergo much less pressure in the bore during firing than do cannon shells. Therefore, the volumetric efficiency of the explosive is 10-15 percent in cannon high-explosive shells, and up to 20-25 percent in howitzer high-explosive shells.

In modern artillery the use of high-explosive shells is considered advisable only in large-caliber pieces (over 152-155 mm) since there is clearly not enough explosive in smaller-caliber shells to destroy field shelters.

To assure the proper high-explosive effect it is necessary that the shell penetrate the obstacle before the moment of its explosion. Therefore, high-explosive shells are provided with nose and base inertia and delay fuzes.

The essence of the high-explosive effect on earth obstacles is that a shell after penetrating the ground to a certain depth bursts there, and a crater is formed at the explosion site. It takes place as follows. The gases of the bursting charge, occupying an initially small volume, press with great force on the surrounding environment, break up the particles directly adjacent to the bursting charge and, squeezing them against the neighboring layers, form a cavity at the site of the shell burst. Then the pressure of the gases is transmitted successively to adjacent layers of the ground, which results in disturbance of the bonds between the ground particles and in their ejection. This space is called the area of destruction. The pressure of the gases gradually decreases. It no longer has enough force to destroy the bonds between the ground particles and they merely receive a vibratory motion. This is the vibration area.

After the explosion some of the ejected earth falls back into the crater, and some of it falls around it to form a bank. The diameter of the crater in the ground averages three times as great as its depth. In stone installations the crater is flat, its diameter averaging six times as great as its depth.

With most advantageous penetration, the explosion of 1 kg of TNT can eject 2.2 to 2.5 cu m of medium-hard ground. In practice, under actual firing conditions each kilogram of explosive accounts for about 1.2 to 1.5 cu m of ground. In excessively porous or marshy earth camouflets sometimes occur, i.e. underground explosions of shells without the formation of an open crater. The shells penetrate the ground so deeply that the bursting charges in exploding do not have force enough to eject the earth above them.

The high-explosive effect is not limited solely to the formation of a crater. The explosion of a shell causes destruction and vibrations in the solid mass of the obstacle, and therefore communication trenches, shelters and installations within the effective zone of the explosion may be demolished and filled in.

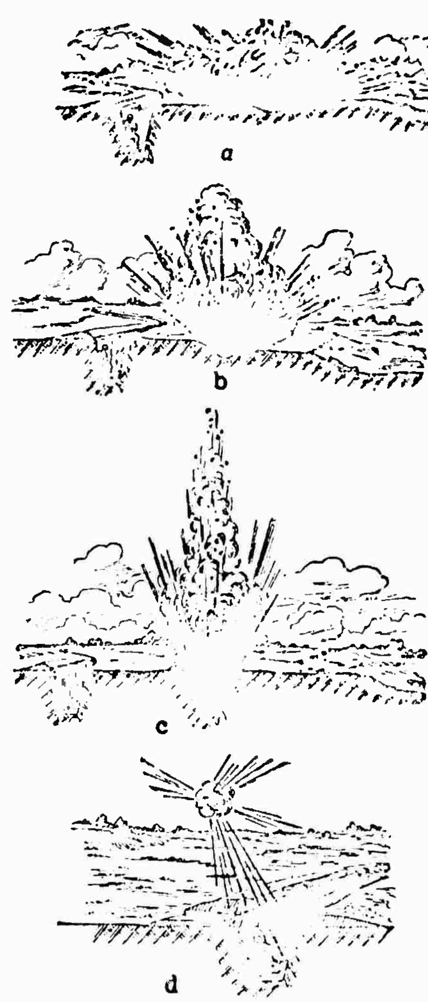


Figure 38. General appearance of shell bursts:

a) splinter effect; b) high-explosive effect;
c) delayed high-explosive effect; d) air burst.

High-explosive action against armored targets leads to the jamming, breakdowns and overturning of turrets, the failure of welds as a result of the dishing of armor plate, breaks in bolts and rivets, the wrecking of machinery behind the armor protection and to the explosion of the unit of fire of the tank or self-propelled gun.

High-explosive fragmentation shells (Figure 37,c) are designed for striking at enemy personnel and materiel, as well as for destroying his defensive installations. These shells function as fragmentation shells in the former event, and as high-explosive shells in the latter. It is known that the fragmentation effect predominates in shells up to 105- to 122-mm caliber, and the high-explosive effect in larger-caliber shells. It has also been established that the fragmentation effect is more pronounced in gun high-explosive fragmentation shells, the high-explosive effect in howitzer shells. The character of a shell's action is determined by setting a percussion fuze for instantaneous or inertia (delayed) action or by using a proximity or time fuze.

High-explosive fragmentation shells are the most successful example of the standardization of varied-purpose shells. Therefore, they have become widespread in field and tank artillery.

High-explosive fragmentation shells are somewhat inferior to fragmentation shells in their splinter effect and to high-explosive shells of the corresponding caliber in their high-explosive effect. The weight of the bursting charge is somewhat greater in high-explosive fragmentation shells than in fragmentation shells, but somewhat less than in high-explosive shells. However, high-explosive fragmentation shells are cheaper to produce in mass manufacture and make ammunition supply to troops simpler.

Figure 38,a,b,c shows the general appearance of a shell burst on impact with the ground when the fuze is set for splinter, high-explosive and delayed action, and Figure 38,d shows an air burst.

6. Shells with Ready-made Damage Agents

Shells with ready-made damage agents are designed for both close- and long-range annihilation of exposed enemy personnel. They include shrapnel, shells with arrow-shaped damage agents, and canister.

There is shot shrapnel, rod shrapnel, stick shrapnel, and shrapnel with covers.

Shrapnel consists of a steel cup with a screw-on head, inside which is placed a bursting charge of black powder separated by a diaphragm from the lead balls which fill the cup. The interstices between the balls are filled below with a smoke-producing composition, and above with rosin or sulfur, which readily dissipate and do not interfere with the spray of shrapnel balls. The smoke-producing composition facilitates observation of the shrapnel burst by creating a cloud of smoke. The filler between the balls prevents their moving about.

A central tube filled with powder runs through the entire cup up to the bursting charge. Screwed into the shrapnel head is a time fuze, which assures a shrapnel burst in the air at a certain distance from the gun.

Despite its high effectiveness of action against exposed personnel targets and its great effective depth shrapnel has lost its former significance in modern times. It has been replaced by fragmentation and high-explosive fragmentation shells. Shrapnel is not effective enough against personnel behind even weak cover, and the effect on morale of a shrapnel burst is much less than that of a high-explosive fragmentation shell. However, the experience gained from the combat use of shrapnel has not been forgotten.

In 1967 the American forces in South Vietnam for the first time used shells with arrow-shaped damage agents (Figure 39) for fire from 105-mm howitzers. In the estimation of the Western press, this so-called "honeycomb" or "dispersing" ammunition is effective for anti-personnel warfare in open country, as well as in jungles, especially in close defense and in direct fire.

The shell is made of steel and aluminum alloys and consists of a body, an adapter with an explosive charge, a mechanical time fuze, an expelling and a spotting charge. There are about 8000 fin-stabilized arrow-shaped steel rods (needles) in the body of the shell. Each arrow is about 25 mm long and weighs 0.5 g.

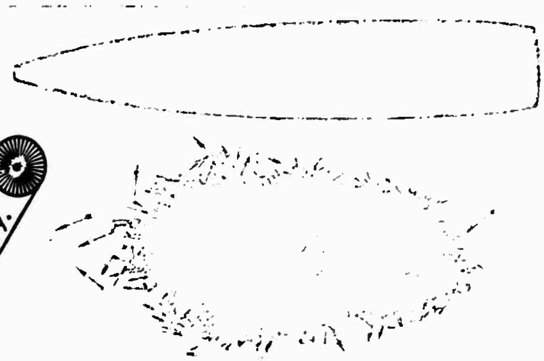


Figure 39. Shell with arrow-shaped damage agents. Below -- arrows.

The fuze is armed as soon as the shell leaves the barrel. To actuate the fuze, the explosive charge in the adapter splits the head of the shell body and ignites the expelling charge. As a result of centrifugal forces and the pressure of the powder gases of the expelling charge the arrow-shaped damage agents are ejected from the shell and disperse in the form of a cone. The aerodynamic shape of the arrows and the fact that they have fins assure that they fly with the point forward. Expelled at the same time is the spotting charge, which indicates the site where the damage agents scatter.

Canister is designed for firing on enemy personnel alongside the weapon and up to 400-500 m from it. The shell consists of a heavy steel base, a thin cylindrical body of steel or sheet iron and a front cover. The body is filled with damage agents -- spherical or cylindrical balls, fin-stabilized steel arrows. Longitudinal notches or grooves are made on the shell body.

Immediately after the emergence of the shell from the bore the pressure of the airstream on the cover and centrifugal forces acting on the body and damage agents split the body along the longitudinal notches. This results in dispersion of the damage agents, the shape of the spray being conical.

If the canister body is made of sheet iron or plastic rather than steel, it opens while still in the bore. This type of canister design cannot be used for firing from pieces with muzzle brakes.

7. Armor-piercing Shells

Armor-piercing shells are designed to hit moving armored targets: tanks, self-propelled guns, armored carriers, ships. They are also used to fire on the embrasures of permanent defensive installations.

Armor-piercing shells are part of the unit of fire of small- and medium-caliber weapons. They are the principal type of ammunition for tank and antitank artillery.

These shells first appeared in shipboard and coast artillery when ships began to have armor protection and armored artillery turrets began to be installed at coastal forts.

The tanks used in World War I in land theaters of operations gave rise to armor-piercing shells in field artillery. The mass-scale use of tanks in World War II led to a sharp increase in the effectiveness of action of armor-piercing shells of all types and designations. The significantly enlarged role of tanks and other armored machines in modern combat led to further improvements in armor-piercing shells.

For more than 50 years now the development of tanks and armor-piercing shells has been marked by a constant effort to raise the antiprojectile resistance of tanks, on the one hand, and to increase the power of the action of shells against armor, on the other.

The main way to increase the resistance of tanks to the damaging effect of armor-piercing shells is to increase armor thickness and the angle of tilt of armor plating and to reduce tank height. For example, by the end of World War II the thickness of tank armor had reached 200 mm.

The power of an armor-piercing shell is characterized by the impact action on armor and is determined by the thickness of the armor to be pierced. The impact action of a shell depends on many causes, but the main ones are: the kinetic energy of the shell at the moment of impact with the obstacle; the shape of the head and the strength of the shell body; the angle of shell-armor impact; the strength and design of the armor. The greater the velocity and weight of the shell and the closer the angle of impact is to 90°, the thicker is the armor that the shell can pierce.

The effectiveness of an armor-piercing shell is evaluated, in addition to its power, by two more characteristics: heavy damage effect behind armor, and high accuracy of fire. Damage behind armor manifests itself as the percussion, demolition, fragmentation and incendiary effect of the shell. High accuracy of fire is necessary because armored targets are small in size (tank length 6-7 m, width 3-3.5 m, height 2-2.5 m) and they can be damaged only with a direct hit.

To facilitate adjustment of fire, armor-piercing shells as a rule are supplied with tracer devices. Therefore, they are sometimes known as armor-piercing tracer shells.

Armor-piercing shells are subdivided into two large groups -- caliber and subcaliber shells.

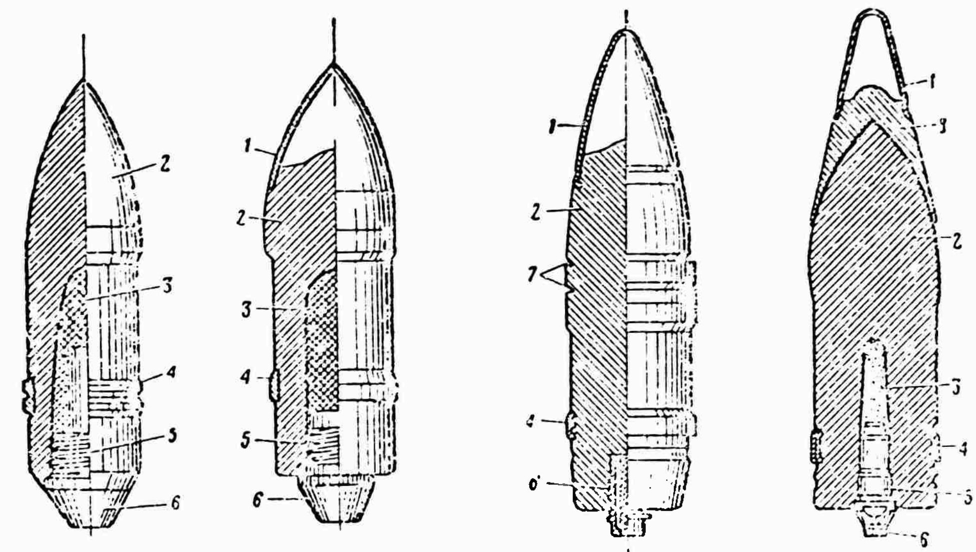


Figure 40. Caliber armor-piercing shells:

a) chambered sharp-nosed shell; b) chambered blunt-nosed shell with windshield; c) solid shell with notches on body and with windshield; d) shell with armor-piercing cap; 1) windshield; 2) body of shell; 3) bursting charge; 4) rotating band; 5) fuze; 6) tracer; 7) notches; 8) armor-piercing cap.

In construction, caliber armor-piercing shells (Figure 40) may be chambered (with a bursting charge) and solid (without an explosive); and, in head design, sharp-nosed, blunt-nosed or have an armor-piercing cap. To give these shells an aerodynamic shape a sharp-pointed windshield is attached to the head.

A chambered armor-piercing shell consists of the body, a screwed-in base, a small bursting charge, a base charge and tracer. Small-caliber shells do not have a screwed-in base.

To prevent the shell from breaking up on impact with armor, its body is made of high-alloy, heat-treated steels. The armor-piercing shell has a massive head and a base charge with a tracer to permit observation of the shell trajectory.

To prevent the shell from sliding off the surface of armor in the event of a small-angle hit, its head is made blunt. To reduce air resistance, the blunt nose is covered with a thin steel or aluminum cap. The windshield is broken up on impact with an obstacle and does not take part in the armor-piercing. Making the shell head blunt assures pressure distribution on impact with armor over a relatively larger sectional area of the shell and armor. With sufficient impact force and shell strength, a "cork" with a diameter close to shell caliber is ejected from the armor, and metal spalling is observed on the outer and inner surfaces of the armor plating.

Shells with armor-piercing caps were first suggested in 1893 by Admiral of the Russian Fleet S. O. Makarov for combating enemy ships protected by face-hardened armor. The armor-piercing cap reduces ricochet, prevents the shell head from breaking up and partially destroys the upper layer of armor. The cap itself breaks up and remains in front of the armor.

On impact with armor very great inertial forces capable of causing premature explosion arise in the bursting charge. To prevent this undesirable phenomenon, chambered armor-piercing shells are supplied with phlegmatized explosives -- TNT, PETN or hexogen. To give a shell incendiary capability too, thermite or aluminum powder is sometimes inserted in the shell chamber housing the explosive.

Sharp grooves -- notches -- are made on the outer surface of some armor-piercing shells. When thick armor is pierced, the notches preserve the shell body as the head of the shell breaks up, and prevent the explosive chamber from opening at the moment of impact with the armor. Stresses are concentrated in sharp notches and therefore, on impact, shearing of the metal takes place along the notches, and cracks do not spread deep inside the body.

A solid armor-piercing shell consists of a strong steel body, windshield and tracer. There is no bursting charge or fuze in such a shell. It penetrates an obstacle only by virtue of its kinetic energy. The crew and vital points of the tank are hit by the body of the shell and by splinters from the armor which the shell has pierced.

Solid armor-piercing shells are used for firing from 37- to 120-mm caliber guns.

Subcaliber armor-piercing shells are designed to destroy all modern tanks.

It is known that the effectiveness of the action of a caliber armor-piercing shell is determined mainly by its kinetic energy at the moment of impact. It is the higher, the greater the weight of the shell and its striking velocity. Consequently, the development of a good tank or antitank gun requires increasing the caliber and bringing muzzle velocity up to 1000 m/sec or more. Only the successful combination of shell weight and muzzle velocity can give the desired results.

The increase in the thickness of tank armor and the need to increase the effectiveness of antitank combat with guns already in service led to the appearance in ground artillery during World War II of a new type of shell known as the subcaliber shell. Subcaliber shells were first developed and adopted for service in the Soviet Union as early as 1938 for a 20-mm aircraft gun.

The armor-piercing part of the subcaliber shell is a core with a diameter approximately one-third the caliber of the gun. Therefore such a shell was called a subcaliber shell.

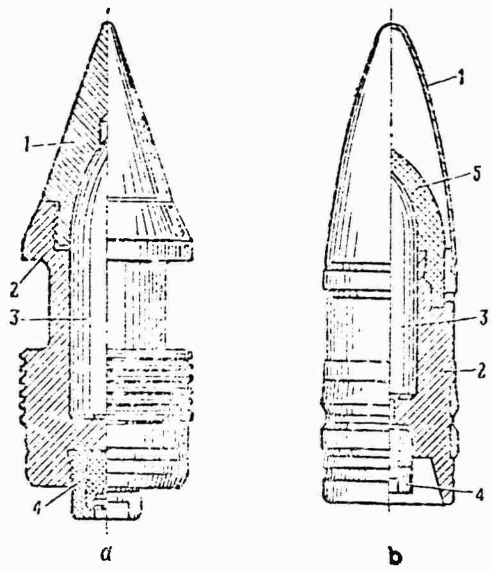


Figure 41. Subcaliber armor-piercing shells:

a) bobbin-shaped; b) streamlined; 1) windshield; 2) sabot; 3) armor-piercing core; 4) tracer; 5) plastic cap.

A subcaliber armor-piercing shell (Figure 41) consists of a body which is coil-shaped or of some other shape. Into the body is inserted a heavy core whose top is covered by a windshield. A tracer is screwed into the bottom of the body. This shell has no fuze or explosive.

The body (it is often called the sabot) is made of mild steel, iron or aluminum alloys; the windshield of plastic or aluminum. On the outside the sabot has an upper positioning band and a rotating band.

The armor-piercing core is made of cermet alloys, which are a mechanical mixture of tungsten, molybdenum, titanium, tantalum, vanadium carbides with the powdered metals cobalt, nickel, chromium, iron. Cores possess exceptionally high strength and are only slightly less hard than diamond. Their specific gravity is a little more than twice that of steel.

The core is inserted into the inside cavity of the sabot with a special putty. This prevents it from spinning at the time of firing or in flight.

When the shell strikes armor, its carrying element -- the body -- is completely destroyed, and the core, which is very heavy, moves forward by reason of inertia and, on emerging from splinters of the shell body, pierces a hole of small diameter in the armor. A great amount of heat is liberated in the process. Inside the tank fragments of the core and armor, heated to a high temperature, fly in a divergent cone. They hit the crew, put the tank machinery and equipment out of commission and set the tank on fire.

At ranges up to 1000 m the armor-piercing capability of subcaliber armor-piercing shells is significantly higher than that of caliber shells. They penetrate armor with a thickness two to three times greater than the shell caliber, while caliber shells penetrate armor with a thickness only 1.2 to 1.3 times greater.

Such high armor-piercing ability is provided primarily by increasing the muzzle velocity of the subcaliber shell. The fact is that a subcaliber shell is lighter than an ordinary shell. And since the powder charge of the gun remains the same, initial shell velocities of 1100-1500 m/sec can be achieved without exceeding permissible pressure in the bore.

In addition, the weight of the active part of the shell -- the core -- is appreciably increased by an overall decrease in the weight of the shell. Since the area of the core is much less than the area of the shell itself, the specific impact energy of the core is several times greater than in ordinary shells of the same caliber. Such a concentration of the impact energy in the comparatively small area of the core, which possesses great hardness besides, assures high armor-penetrating ability.

Subcaliber shells have some shortcomings as well: a disadvantageous ballistic (difficult to streamline) shape, a small transverse load. Therefore they quickly lost their speed in trajectory and lost their advantages in armor-piercing action.

The quest to eliminate the shortcoming due to the bobbin shape of the shell led to the creation of streamline-shaped subcaliber shells (Figure 41,b). Such shells externally are no different from caliber armor-piercing shells; they are merely shorter than the latter. Streamlined shells do not lose their velocity as rapidly as bobbin-shaped shells, so they can be fired effectively at increased ranges (up to 1500-2000 m).

In addition to bobbin- and streamline-shaped shells, there are also discarding subcaliber shells. In shells of this type the core is inside a jacket (steel or of light alloys), which enables good exterior ballistic characteristics to be obtained. This assembly (it is called the active part of the shell) is placed in a sabot having the caliber of the weapon. The sabot is made of steel, aluminum or magnesium-zirconium alloys, as well as plastics. Having a rotating band, the sabot guides the shell in the bore.

After the shell leaves the bore, the sabot and active part of the shell are severed. The sabot, which is light-weight and has a poor ballistic shape, is separated by reason of centrifugal forces and the force of air resistance. The active part of the shell, due to its excellent ballistic shape, continues to fly at a high velocity (over 1000 m/sec) and destroys targets with heavy armor protection. However, the presence of the discardable sabot by itself is a disadvantage of the subcaliber shell.

All the subcaliber shells considered supra are stabilized in flight by rapid rotation. Therefore they are known as rotating shells. This is the predominant, but not the only method of assuring trajectory stability of the shells.

Foreign subcaliber finned shells are known, which can be used for fire from both smooth-bore and rifled guns. An indispensable part of these shells is the stabilizer. It serves to center the shell in the case and as it moves along the bore, and above all to assure flight stability of the shell in trajectory.

Obturation of the powder gases during firing is effected by means of a discardable band fitted to the shell body or by the use of metal or plastic disks of the appropriate configuration or, finally, by means of an obturating sabot which separates after the shell leaves the bore.

Some subcaliber finned shells have ring slots, cams, thread etc. to fasten the sabot and supplementary centering ring. This impairs the aerodynamic characteristics of the shells and increases their production cost.

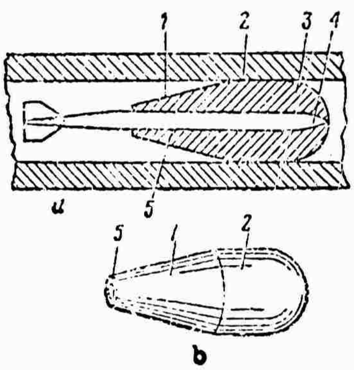


Figure 42. Subcaliber finned shell with sabot:

a) shell in bore; b) sabot; 1) tail cone; 2) cylindrical guiding and obturating surface; 3) sabot; 4) shell; 5) axial duct of sabot for shell.

Under study are the possibilities of finned shell designs which require no fastening elements. One such structural scheme is shown in Figure 42. Here the sabot has an axial duct for the subcaliber shell proper, a cylindrical guiding and obturating surface, a tail cone which elastically encircles the shell body. As the shell moves along the bore, the pressure of the powder gases presses the tail cone to the shell body, and the developing force of friction firmly confines the sabot to the shell. After the shell leaves the barrel, the sabot is discarded in some manner.

8. Shaped-charge Shells

Shaped-charge shells are designed for direct fire on armored targets and vertical walls of defensive installations and, in some cases, to cause casualties among exposed enemy personnel.

Shaped-charge shells differ fundamentally from ordinary armor-piercing or subcaliber shells in their design and mode of target effect. Armor is not penetrated by a powerful shell impact, but rather as a result of destruction by a thin cumulative jet, formed at the moment of the bursting-charge explosion and thickened along the shell axis.

The principle of the accumulation of an explosion, or cumulative effect, was discovered in 1864 by the Russian army engineer General M. M. Boreskov and used for practical purposes in combat engineering.

Numerous experiments have established that the character of the destruction in an obstacle depends not only on the properties of the explosive and the magnitude of the bursting charge, but also on the latter's shape.

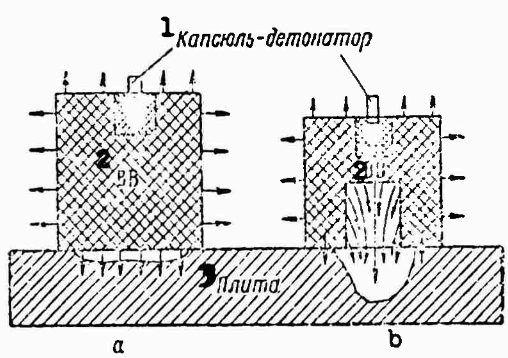


Figure 43. Diagram of the action of explosive charges:

a) without recess; b) with recess.

Keys:

1. Blasting cap
2. Explosive
3. Plate

Let us use an example to consider this phenomenon (Figure 43). It is known that for the demolition of obstacles combat engineers use bursting charges of a regular geometrical shape in the form of different-sized sabers. If a bursting charge is hollowed out on the side contiguous with the obstacle and the blasting cap is placed on the opposite side of the charge so that the detonation wave goes towards the recess, the hollowed-out charge will produce much greater destruction in the obstacle despite a somewhat reduced weight. This is due to the fact that the explosion shock waves which proceed from the surface of the bursting-charge recess acquire a certain directivity towards the obstacle as a result of this recess.

The most advantageous shapes for the recess (depression) of the bursting charge are considered to be semispherical and conical depressions. It is on this principle that shaped-charge projectiles and mortar shells have been developed.

Thus, the essence of the cumulative effect is the focused concentration of the energy of the explosion in a given direction and the creation of compressed gas flow in the region of the cumulative depression.

The collision and compression of the explosion products gives the cumulative flow an exceptionally high density, velocity, temperature and pressure. The velocity of the cumulative jet reaches 15,000 m/sec, and the pressure more than 100,000 kg/sq cm.

Modern shaped-charge shells are subdivided into rotating and finned (nonrotating) shells. The latter can be fired from both smoothbore and rifled guns. Finned shells are stabilized during flight by a caliber or supercaliber tail unit, which opens after the shell leaves the bore.

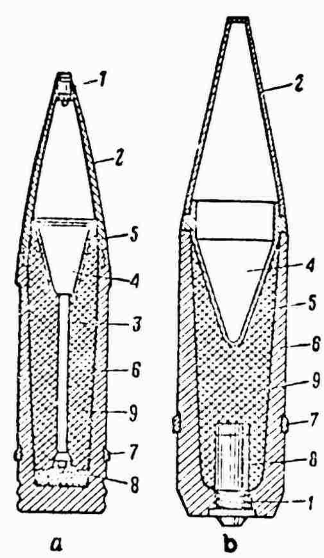


Figure 44. Shaped-charge shells:

a) with nose fuze; b) with base fuze; 1) fuze; 2) head; 3) central duct; 4) charge hollow; 5) metal liner; 6) shell body; 7) rotating band; 8) blasting cap and detonator; 9) bursting charge.

A shaped-charge shell (Figure 44) consists of a body, shaped-charge assembly, nose or base fuze and tracer. Inside the body is a bursting charge, in whose head is made a cone-shaped depression covered with a metal liner. TNT, hexogen and PETN are used in different proportions as the bursting charge.

The metal liner of the depression sharply intensifies the cumulative effect and increases the force of the action of the shell. The damage properties of a metal cumulative jet, above all the kinetic energy and density, are much higher than in a gas jet. The liner is usually made of copper, zinc, iron or sheet steel.

To increase the destructive effect of the shaped-charge shell even more, a two-layer liner for the charge hollow has been suggested abroad. During the explosion of the bursting charge the first layer acquires great speed and, becoming deformed, is transformed into a needle. The second layer forms a beater (a short heavy rod with a round end) which, coming under the influence of the explosive wave right after the needle, also passes through the hole made by the needle.

If a nose fuze is used, a central duct is made along the axis of the bursting charge, and the blasting cap and detonator are placed at the bottom of this duct.

The action of a shaped-charge shell boils down to the following. When the shell strikes armor, the fuze is instantaneously actuated. Its impulse is transmitted to the blasting cap located in the lower part of the shell, and the bursting charge explodes. The front of the detonation wave heads for the nose of the shell. Under its action the metal liner of the charge hollow is compressed and deformed. Thus the cumulative jet comes into being.

The powerful impact of the jet against armor leads to the formation of a hole. Some of the metal of the liner, compressed into a beater, digs its way into the hole after the cumulative jet. The action of the cumulative jet is shown schematically in Figure 45.

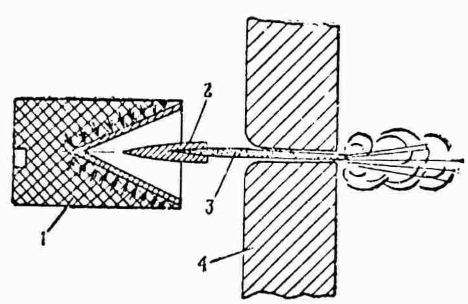


Figure 45. Diagram of action of shaped-charge shell:

1) action of explosion products on liner; 2) liner compressed into beater; 3) cumulative metal jet ejected by compressed liner; 4) armor.

The armor-piercing ability of the shell is in many respects determined by the distance between the armor and the upper section of the bursting charge. The action of a shaped-charge shell is most effective when the bursting charge is directly in front of the armor at the moment of detonation.

The armor-piercing ability of a shaped-charge shell is affected by the power and quality of the explosive, the shape and geometric dimensions of the charge hollow, the angle of impact with armor, the quality of the metal liner of the hollow. A favorable condition for the proper action of shaped-charge shells is a relatively low terminal -- and, therefore, initial -- velocity. This made it possible during the Great Patriotic War to use in antitank warfare not only guns, but also howitzers with initial velocities of 300-500 m/sec.

Shaped-charge shells differ advantageously from ordinary armor-piercing shells in that their armor-piercing ability does not depend on target range, degree of barrel wear and other factors. The effective range of fire with these shells is limited to the probability of a direct tank hit.

It is known that centrifugal force adversely affects the cumulative jet. The more rapidly a shell rotates during flight, the worse the cumulative effect: the jet is poorly focused and scatters. Various measures have been taken to eliminate this shortcoming. For example, there have been attempts to reduce the rotational speed of the shaped-charge assembly of the shell with respect to its body by mounting the shaped-charge assembly on ball bearings. Shaped-charge shells with spinning filler have also been developed.

However, the best way found to increase the cumulative effect has been to use nonrotating finned shells. Such shells are found in the units of fire of present-day American, English, French and West German tanks. The armor-piercing ability of nonrotating finned shells is considerably higher than that of rotating shaped-charge shells.

Another way to increase the cumulative effect is to create a vacuum in the cavity of the charge hollow. It is known that the velocity of the jet is significantly lowered because of the resistance of the air under the windshield. If a cap is placed between the windshield and the metal liner of the charge, and the air is then sucked out from underneath the cap and a vacuum created there, when the shell strikes the obstacle the cumulative jet will for all practical purposes go through the vacuum space, i.e. without a decrease in velocity.

Favorable characteristics of shaped-charge shells: high armor-piercing ability, especially at large angles of impact; the use for antitank warfare of artillery pieces with low muzzle velocities, which are not designed to fire ordinary armor-piercing shells. Shaped-charge shells also have good fragmentation effect.

Shortcomings of shaped-charge shells include comparatively low muzzle velocites and hence low point-blank ranges; high cost; poor effect against targets protected by a shield (for example, a thin metal shield in front of the main armor of a tank causes the shell to be actuated at a distance from the main armor, which may remain undamaged).

9. Concrete-piercing Shells

Concrete-piercing shells are designed to destroy concrete and ferroconcrete structures, as well as strong brick and stone buildings adapted for defense purposes.

In design features these shells are, so to speak, an intermedite link between armor-piercing and high-explosive shells. They possess strength sufficient to be effective against concrete and at the same time are, for all practical purposes, the equal of high-explosive shells in their high-explosive effect.

The body of a concrete-piercing shell is made of high-strength steel, its walls are thick, and the head of the shell is solid. The fuze is located in the base of the shell.

Concrete-piercing shells are used only in large-caliber weapons. They have both an impact and a high-explosive effect. Depending on the strength of the concrete a shell either pierces the obstacle and breaks up beyond it or it penetrates the concrete to a certain depth and breaks up inside it. Impact with a concrete structure, augmented by the high-explosive effect, causes the formation of a crater, cracks, loosening of the entire structure and internal cave-ins, and makes it easy to destroy with subsequent shell hits.

The effectiveness of concrete-piercing shell fire depends on the angle of impact and velocity of the shell at the moment of impact with the concrete. At less than allowable angles of impact the shell ricochets, and at velocities under 300 m/sec it rebounds from the concrete regardless of the angle of impact.

10. Special-purpose Shells

Special-purpose shells include chemical, incendiary, smoke, illuminating and leaflet shells.

In their preparation for new wars the imperialistic aggressors are devoting a great deal of attention to chemical weapons, particularly projectiles and mortar shells.

Chemical shells loaded with poison gases (PG) are designed to produce casualties among enemy personnel and lower their combat ability ("pin them down"), as well as contaminate the atmosphere, terrain, food supplies and water supply sources.

Chemical shells were first used as weapons of mass destruction by the Germans during World War I on 22 April 1915 in France at the Ypres River.

A chemical shell consists of the body of an ordinary high-explosive or high-explosive fragmentation shell, the inner cavity of which is filled with PG, a booster casing with an explosive bursting charge, and a fuze. Actuation of the fuze results in detonation of the burster, opening of the shell body and ejection of its contents.

Chemical fragmentation shells combine the properties of fragmentation and chemical shells. They are loaded with a relatively small amount of PG so as to assure good fragmentation effect of the shell by virtue of filling about 30 percent of the volume of the inner cavity with a burster.

In the view of foreign military specialists guns and mortars with a high rate of fire or rocket systems of collective fire possess maximum combat effectiveness in firing chemical shells. Thus, an American 105-mm howitzer battalion consisting of 18 pieces can fire more than 100 chemical shells in 30 sec and about 1000 shells in a 10- or 15-minute fire assault. American 155-, 175- and 203-mm pieces are also considered effective enough for firing chemical shells, since at a low rate of fire they can hurl large quantities of PG into enemy lines (for example, a 203-mm chemical shell contains as much PG as ten 105-mm shells).

Incendiary shells serve to produce casualties and destroy materiel, military property, transport, fortifications. They are used to burn out the enemy in concealed firing points and control points, clear out trenches and connecting passages, destroy tanks and cause casualties during the rebuff of attacks and counterattacks on the march and in concentration areas.

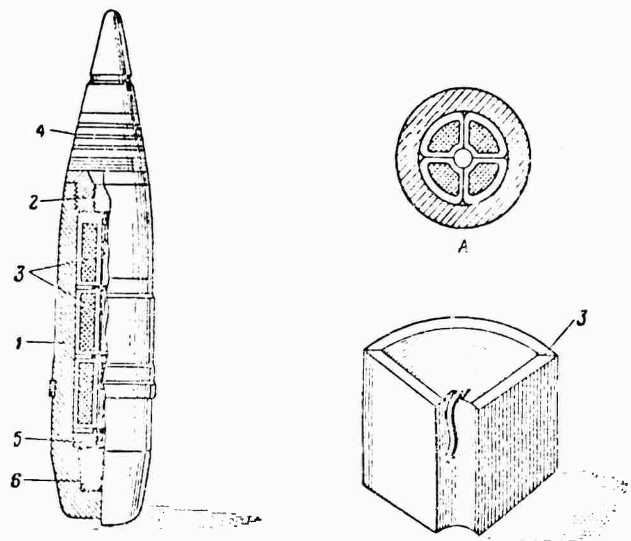


Figure 46. Incendiary shell:

1) body; 2) screw-on head; 3) incendiary elements; 4) time fuze; 5) diaphragm; 6) burster; A) cross section of an incendiary shell.

An incendiary shell is a time shell and resembles shrapnel in its construction. It consists of a body, a screw-on head, incendiary elements (segments), a diaphragm, burster and time fuze (Figure 46). Unlike shrapnel, instead of balls the free space between the head and diaphragm is filled with incendiary elements packed into several rows. Each such element is a metal jacket filled with an incendiary composition, for example, thermit. Depressions in the incendiary elements form a central duct, in which is placed a cord fuze designed to transmit the flame from the time fuze to each element and the burster, with the incendiary elements supposed to ignite first, and the burster next.

When the burster ignites, powder gases press on the diaphragm and incendiary elements, as a result of which the screw-on head is torn off and the burning elements are ejected at a high velocity onto the target under bombardment. A high temperature develops during the burning of the incendiary composition, reaching 2500-3000° C.

Incendiary shells have quite powerful damaging action and great psychological effect. The basic principle of their use is sudden and massive blows. Incendiary shell fire on fortified inhabited localities, airfields, depots, stations etc. is usually accompanied by high-explosive fragmentation shell fire for the purpose of preventing fire fighting.

Smoke shells are used to create a smoke cloud so as to interfere with combat activity of the enemy, i.e. reduce the effectiveness of his fire, conceal the operations of friendly troops from him, hinder his maneuvering of reserves. Smoke shells are fired to blind enemy observation and command posts, fire positions of batteries and individual guns, weapon emplacements and personnel. They are also used for target designation, signaling, adjustment of fire and support of tank attacks, as well as to determine wind direction and velocity in the area of the target.

Smoke shells resemble chemical shells in their construction and operation. In contrast to chemical shells they are filled with smoke agents -- white phosphorus, sulfur trioxide etc.

When the burster explodes, the body of the shell breaks up and white phosphorus, capable of spontaneous ignition in air, is dispersed. The oxidation products of the phosphorus condense into a thick white smoke.

The duration of the smoke-screening of an area depends on the character of the terrain and meteorological conditions. Cool cloudy weather and a wind velocity of 4-5 m/sec are favorable conditions for the use of smoke shells.

Maximum smoke-screen effect is obtained when the shell bursts on contact with the obstacle (the percussion fuze is set for instantaneous action) or in an air burst (if the shell is time-fuzed).

Some smoke shells resemble shrapnel or incendiary shells in their design: they have a burster and a screw-in base. The burster ignites on actuation of the time fuze, the powder gases of the burster expel containers with smoke agents and the screw-in base from the shell. The smoke mixture burning in the container forms a dense cloud of white or colored (green, red, yellow, violet) smoke.

Illuminating shells are designed for the sudden illumination of individual targets and enemy-occupied terrain in night operations and under conditions of reduced visibility. They are also used to illuminate targets under attack by tanks and motorized infantry, indicate the direction of operations of friendly troops, lay down illuminated reference points, counter night vision devices, and also as means of signaling.

Illuminating shells resemble incendiary shells in design and consist of a body, screw-in base, burster, a container with an illuminating composition, a parachute device and a time fuze.

The illuminating composition for the shells usually includes three components: a fuel (powdered aluminum and magnesium), an oxidizer (sodium nitrate, barium nitrate), and a binder (rosin, camphor, resin, boiled oil).

In the flight of the shell the flame from the time fuze is transmitted after a prescribed time interval to the burster, which ignites the illuminating composition in the container. The force of the pressure of the gases which form on combustion of the burster cuts off the base of the shell and forces out the container and parachute. The parachute opens immediately and fills with air, while the body of the container is stabilized by an antirotation braking device, which also prevents twisting of the parachute lines.

Depending on the parachute design, the burning flare descends at a speed of 2-7 m/sec. The terrain is illuminated for 40 to 120 sec. The luminous intensity of the various shells ranges from 400,000 to 1,000,000 candles.

In parachuteless illuminating shells the illuminating segments (stars) are arranged in the body in the same way as the incendiary elements of incendiary shells. The terrain illumination obtained in this case is uneven, and the burning time is not great (20-25 sec), since the illuminating elements fall at a great speed (40-50 m/sec). Dark night, clear air, flat terrain are considered favorable conditions for the use of illuminating shells. Moonlight reduces the visibility of targets illuminated by a shell, and fog and rain rule out the use of illuminating shells altogether.

Leaflet shells serve to hurl propaganda literature and leaflets into enemy lines.

They resemble illuminating shells in their design. The rolled-up literature is placed in two or three metal containers. The distinguishing feature of leaflet shells is that the burster is situated in their head and the literature is ejected backwards through the tail unit of the shell body. Once it has left the shell, the roll unwinds and the literature scatters over a wide area.

Shells can be loaded with propaganda literature directly among troops under standing operating procedure.

Unfavorable conditions for the use of leaflet shells are rain, fog, updrafts and strong wind.

11. Mortar Shells

Mortar shells are nonrotating finned shells designed for fire from mortars and smooth-bore recoilless guns.

The combat purpose, classification and action of mortar shells are analogous to the combat purpose, classification and action of the corresponding artillery shells.

Used for mortar fire are basic-purpose mortar shells (fragmentation, high-explosive fragmentation, high-explosive shells), and special-purpose mortar shells (chemical, incendiary, smoke, illuminating, leaflet shells). The unit of fire of recoilless guns includes shaped-charge and high-explosive fragmentation mortar shells.

A mortar shell as finally filled (Figure 47) consists of a drop-shaped or projectile-shaped body, stabilizer, fuze, a main charge and increment powder charges. The body is made of steel or semisteel and serves as a jacket for the bursting explosive or other type of filler, depending on the purpose of the mortar shell. The fuze is screwed into the head of the body, the stabilizer into the base.

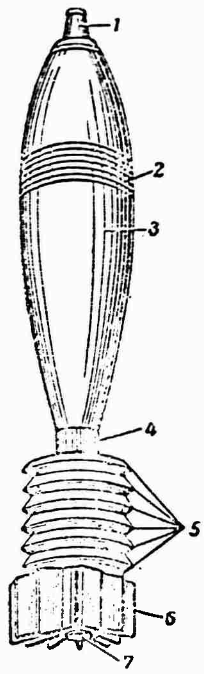


Figure 47. Mortar shell as finally filled:

1) fuze; 2) centering bulbs; 3) body; 4) stabilizer tube; 5) increments; 6) stabilizer wings; 7) main charge.

In order for the mortar shell to fit the bore snugly with a slight clearance rather than hit against it, the outside surface of the body of the shell has one or two centering bulbs. The wings of the stabilizer have centering shoulders. The centering bulbs and shoulders assure proper movement of the shell along the bore.

To reduce the escape of powder gases between the mortar shell and inside surface of the barrel there are cannelures of a triangular, rectangular, semicircular or trapezoidal profile made on the centering bulb of the shell. In them powder gases expand, eddy and decelerate, losing pressure and velocity. Therefore the quantity of gases escaping through the clearance in modern mortar shells is not great (10-15 percent of the total quantity of gases).

The stabilizer (steel or aluminum) gives the mortar shell flight stability and serves to position the propelling charge and center the shell as it moves along the bore. It consists of a tube with holes and wings welded onto the tube. After the ignition of the main charge in the stabilizer tube, powder gases rush towards the bore through the fire-transmitting holes. The increments in the stabilizer tube are ignited in the process.

There are stabilizers with a tail unit that opens up, for example in the new French 120-mm rocket-assisted mortar shell. In routine handling and loading the diameter of the tail unit of such a stabilizer does not exceed the diameter of the mortar bore. On firing, after the shell leaves the bore, the wings open up and the diameter of the tail unit becomes considerably greater than the bore diameter -- the stabilizing moment of the mortar shell increases.

In the American 106.7-mm rifled mortars stabilization of the projectiles (they can arbitrarily be called mortar shells) is effected by rotation as they move along the bore. For this purpose a clamping disk and a spinning disk are mounted in the tail of the shell. These disks enter the rifled part of the mortar barrel and perform the function of a rotating band, communicating rotatory motion to the shell, and the function of an obturator, preventing the escape of the powder gases before the shell leaves the mortar barrel. This mortar can be used for firing chemical shells.

Given equal calibers, mortar shells have a stronger splinter effect than artillery shells. This is mainly due to the fact that the large angles of incidence of mortar shells increase the area of splinter damage. The high-explosive effect of mortar shells also exceeds that of artillery shells of the same or approximately the same calibers since mortar shells contain more explosive because of the thinness of the walls. However, the percussion effect of mortar shells is appreciably less than that of artillery shells.

12. Rocket Shells

Rocket shells are used in artillery collective-fire systems. They serve to annihilate enemy personnel and fire weapons, combat vehicles and other materiel in concentration areas, as well as to neutralize artillery and mortar batteries. These shells are especially effective for repelling massed attacks and for fire assaults on major concentrations of enemy troops and materiel.

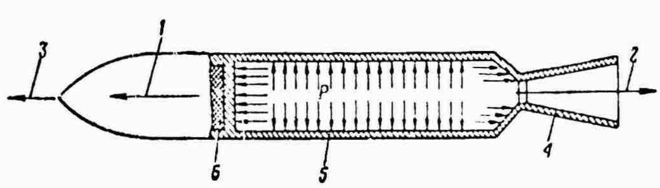


Figure 48. Schematic diagram of a reaction engine:

1) direction of reaction force; 2) direction of gas escape; 3) direction of motion of rocket shell; 4) nozzle; 5) engine chamber; 6) explosive of shell warhead; P) pressure of gases in engine chamber.

Rocket, or reaction-propelled, shells owe their name to the principle underlying their design -- the use of a reaction force. It arises in a reaction engine as a result of the escape through a special opening -- the nozzle -- of gases generated during combustion of the fuel. Figure 48 shows the schematic diagram of a reaction engine and the direction of the reaction force. It can be seen from the diagram that the forces of the gas pressure on the side walls of the engine chamber counterbalance each other, while the force acting on the front wall is greater than the force on the bottom, since the area of the front wall is greater than the area of the bottom because of the presence of the nozzle in the latter. The difference between these forces is the reaction force causing the projectile to move.

Modern unguided rocket shells were first developed in the Soviet Union. As early as 1927 there were tests of an 82-mm rocket shell, in whose engine chamber seven propellant sticks were placed. Somewhat later, pilot models of a more powerful 132-mm rocket shell were developed. The tests of these shells began in March 1928 and were reassuring on the whole. The shells were fired at a range of up to 5-6 km, but their deflection from target was very high.

The problem of providing acceptable accuracy of fire proved exceptionally complex and difficult. It took years of persistent work to find a fin shape assuring shell stability in trajectory. The answer was stabilizers with dimensions significantly exceeding shell caliber. For example, the fin span of the 82-mm shells was 200 mm and of the 132-mm shells 300 mm.

The fruitful creative work of staff members of the scientific center V. A. Artem'yev, N. I. Tikhomirov, Yu. A. Pobedonostsev, B. S. Petropavlovskiy, G. E. Langemak, I. T. Kleymenov, L. E. Shvarts, F. N. Poyda et al. was crowned with great success. By 1938 "RS's" (rocket shells) -- the main component of the future "Katyusha" -- were created.

The 82-mm fragmentation and 132-mm high-explosive fragmentation rocket shells were installed on combat aircraft. Thus eight RS-82's were put on each I-16 and I-153 fighter plane, eight RS-82's or RS-132's on the Il-2 attack plane, two RS-132's on the "SB" bomber. The test pilot G. Bakhchivandzhi, who later was to be the first in the world to fly a jet plane, was the first to fire rocket shells from a fighter plane in combat. In August 1939 in the region of the Halhin Gol River in Mongolia the new weapon showed high combat effectiveness in engagements with the Japanese invaders.

Just before the Great Patriotic War the last tests were completed in the Soviet Union of the M-8 and M-13 rocket projectiles, designed for service in the land forces.

Rocket shells began to be used in the air forces of England and the United States in 1942 and in Germany in 1943.

Unguided rocket projectiles are not only in service in the land forces at present. The air forces and navy also have them. Fighter planes, fighter-bombers, attack planes and bombers, as well as direct infantry support helicopters are armed with these projectiles. In the navy, surface vessels, naval infantry chasti and ship-based aircraft are supplied with rocket shells.

Rocket projectiles are subdivided, according to combat purpose, into fragmentation, high-explosive fragmentation, high-explosive, shaped-charge, incendiary, smoke and other projectiles. The unit of fire of the American 115-mm launcher M91 includes only chemical shells.

In respect of flight stabilization method, rocket projectiles are divided into nonrolling (fin-stabilized) and spinning (spin-stabilized) projectiles.

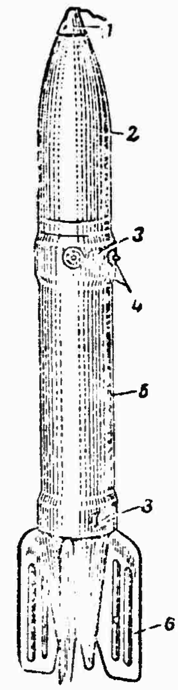


Figure 49. Fin-stabilized rocket projectile:

1) fuze; 2) warhead; 3) guide pins; 4) cartridge igniters; 5) rocket engine; 6) stabilizer.

A fin-stabilized rocket projectile (Figure 49) consists of a warhead, powder rocket engine and stabilizer.

The warhead or projectile proper has a burster with an explosive (or other filler) and a nose fuze.

The rocket engine consists of a reaction chamber, nozzle, powder charge and igniter. The reaction chamber is connected to the warhead by thread or other means.

The powder elements for the rocket charges are usually made of tubular nitroglycerin powder in the form of cylindrical sticks with an interior through duct. During combustion the outside surface of each powder stick decreases and the inside surface increases, while the total burning surface remains approximately constant. This powder-stick shape makes it possible to obtain uniform gas generation during combustion of the charge, as well as approximately constant pressure of the powder gases in the reaction chamber of the engine. In some rocket projectiles powder sticks are used which have an inside duct of cross-shaped section.

Grates or diaphragms are used to keep the powder charge from longitudinal displacement during transport of the projectile and to retain the powder sticks in the chamber during their combustion. They are placed over the nozzle.

The smoke powder igniter provides reliable and rapid ignition of the entire surface of the powder charge during firing. Together with an electric primer, it is placed in a moisture-proof jacket. The weight of the powder in the igniter depends on the size of the surface of the charge powder sticks which it is supposed to ignite. There are base and nozzle igniters, depending on their location in the reaction chamber. Base igniters are in the base of the chamber, nozzle igniters in the opposite part of the chamber in the nozzle.

The powder charge igniters are ignited by electric primers or squibs. On firing, the electric circuit is closed and the squib is actuated: its electric blasting cap element is heated to the ignition temperature of the powder lot. The flame from the squib ignites the igniter in the reaction chamber, and the igniter ignites the entire powder charge.

If the rocket projectile is fired from a rail-, frame- or other type of guide rather than from a barrel, two guide pins in the plane traversing the longitudinal axis of the projectile are attached to the outside surface of the engine chamber. The pins confine the projectile to the launcher guide before firing and serve to conduct the projectile along this guide at the time of firing.

A shortcoming of fin-stabilized rocket projectiles is the comparatively great dispersion, several times (sometimes even ten times) as large as the dispersion of rifled artillery shells. Therefore, improving accuracy of fire is one of the principal problems in the design, production and combat employment of rocket projectiles.

The trajectory of a rocket projectile consists of two sections: a powered and an unpowered section. The rocket engine operates in the powered section. The projectile reaches maximum velocity at the end of this section. The length of the powered section for field-artillery rocket projectiles ranges from several dozen to several hundred meters.

The action of the reactive force ceases when fuel combustion in the engine stops. This marks the beginning of the unpowered section of the trajectory. The velocity of the projectile gradually decreases under the influence of the force of air resistance and gravity. On the descending branch of the trajectory projectile velocity increases somewhat again as a result of the action of gravity. Thus, in the unpowered section of the trajectory the motion of a rocket projectile is practically no different from the motion of an artillery projectile or mortar shell.

Hence it follows that the causes of the significant dispersion of rocket projectiles must be sought in the powered section of the trajectory. Such causes may be eccentricity of the reactive force, aerodynamic asymmetry of the projectile (nonsymmetry of external shape, slight bending or crumpling of fin etc.), initial perturbations received by the rocket projectile on takeoff from the launcher guide, gusts of wind, especially at the very start of the trajectory when the rocket projectile has low velocity and is very unstable in flight, etc.

To improve the accuracy of fire of fin-stabilized rocket projectiles, they are, for example, given a rotary motion during flight (spin). For this purpose tangential holes are drilled in the rocket engine chamber near the center of gravity of the projectile. Some of the powder gases escape from the chamber through these, forcing the projectile to spin around the longitudinal axis, and this contributes to a certain reduction in the influence of the eccentricity of the reactive force.

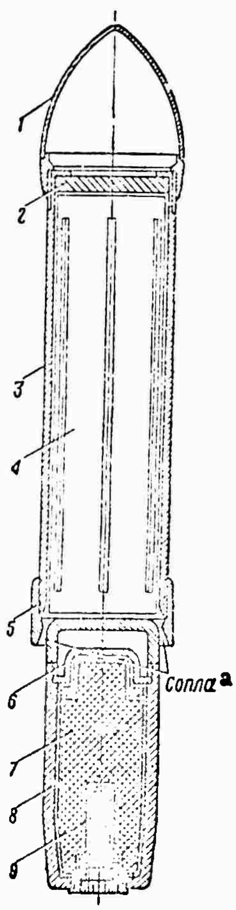


Figure 50. Spin-stabilized projectile:

1) windshield; 2) upper grate; 3) reaction chamber; 4) powder charge; 5) nozzle apparatus; 6) diaphragm; 7) explosive charge; 8) case; 9) detonator.

Key: a) Nozzles

Spin-stabilized projectiles (Figure 50) have no fins at all. They are stabilized in trajectory by rotation around the axis of symmetry by means of canted nozzles. It is known that a rapidly rotating projectile takes on the property of a gyroscope -- resisting the forces and moments seeking to overturn it.

The rotational speed of the projectile depends on the cant angle of the rocket nozzles. The following considerations serve as a guide here. A low rotational speed does not assure projectile stability in trajectory because of the weak gyroscopic effect, and the gyroscope-projectile will not be able to resist the overturning action of the force of air resistance. Too high a rotational speed is also disadvantageous. The gyroscopic effect may grow so much that the force of air resistance will prove insufficient to force the rotating projectile to move head forward all the time. In addition, an increase in the rotational speed of spin-stabilized projectiles will lead to a reduced range of flight, because the steeper the canted nozzles are, the less the powder gases escaping from them take part in increasing the velocity of the projectile.

Foreign specialists believe that from an economic standpoint rocket projectiles are less advantageous than artillery projectiles or mortar shells. Delivery of a rocket projectile to target requires considerably greater material expenditures than does the firing of artillery projectiles at the same range (with the same effectiveness of fire). For example, a single rocket projectile takes twice to three times as much powder to fire as an artillery round, and if there is an engine, several times as much metal is required.

It is also noted that the high consumption of rocket projectiles in salvo fire systems complicates the task of supplying them to troops in the course of operations.

In assessing the comparative advantages and disadvantages of artillery and rocket projectiles, foreign military specialists arrive at the conclusion that rocket projectiles, although they have indisputable advantages for inflicting sudden damage on large-sized targets, cannot replace artillery projectiles and mortar shells. In particular, field rocket artillery is a supplement to cannon-type artillery in the general fire system.

13. Rocket-assisted Projectiles and Mortar Shells

The principle of combined action and reaction as a way of improving the combat characteristics of artillery guns and mortars has become popular during the last few years in the United States, France and other countries. Foreign specialists consider the use of rocket-assisted projectiles and mortar shells to be one of the most promising ways of increasing the range of fire and decreasing the weight of guns and mortars.

A rocket-assisted projectile combines the properties of a conventional (action-propelled) and a reaction-propelled projectile. A combination projectile of this kind is fired from a gun as follows. On ignition of the conventional (active) powder charge the delay pellet of the reactive charge is ignited. The powder gases generated from the combustion of the conventional charge eject the projectile from the barrel at a certain muzzle velocity, while the reactive charge, which burns in trajectory, creates additional velocity, assuring a significant increase in the range of fire.

A rocket-assisted projectile permits either an increase in the maximum effective range with a fixed gun weight or a decrease in the gun weight with a fixed range.

However, rocket-assisted projectiles also have disadvantages. First, they have a lower effectiveness of target action due to the reduced weight of the bursting charge as compared with a conventional projectile. The explosive charge has to be squeezed in (reduced) to make room for the rocket powder charge. Second, they are more complicated to design and hence more expensive than conventional ammunition.

The development of rocket-assisted projectiles in the U.S. Army was conducted on the 115-mm XM70 gun, the "Moritzer." Maximum range of fire of about 16 km was obtained, with the gun itself weighing 1500 kg in firing position. The work on the XM70 "Moritzer" enabled the Americans to ascertain the advantages and disadvantages of rocket-assisted projectiles and to determine the direction of further research in this field.

The results obtained during the development of the XM70 "Moritzer" were used to create a 105-mm rocket-assisted howitzer projectile. The latter has an elongated head. The rocket engine assembly is made separately and is screwed onto the base of the projectile. The rocket engine assembly also includes a pyrotechnic delay element, housed separately and covered with a cap, by means of which the engine can be turned on or off. Nose percussion, mechanical time or proximity fuzes can be used in the projectile. If the rocket engine is turned off, the rocket-assisted projectile functions in the same way as a conventional high-explosive fragmentation projectile.

The unit of fire of the new French 120-mm light mortar MO-120-60 includes the PEPA rocket-assisted mortar shell. It consists of a steel body containing an explosive burster and rocket charge, a fuze and propelling charge situated on the stabilizer tube. The range of fire with the rocket-assisted mortar shell (6550 m) is almost twice as great as the range of fire from this same mortar with a conventional mortar shell (3600 m).

Since 1965 the United States has been doing research and experimental work on the use of rocket-assisted projectiles for naval artillery fire on coastal targets.

The foreign press notes that according to preliminary data these projectiles may increase the maximum effective range of guns 30 percent. For example, the range of fire of the naval 127-mm base gun with a barrel length of 4826 mm rises from 11 to 14 miles, and that of the 127-mm gun with a barrel length of 6858 mm from 14 to 19 miles. At the same time a study is under way of the possibility of developing rocket-assisted projectiles for 203-mm naval guns, whose maximum effective range can be increased from 17 to 22 miles.

In U.S. land forces rocket-assisted projectiles are under development for all 11 models of armament from 40-mm to 155-mm caliber. American studies have shown that the use of such projectiles increases the range of fire of guns by 25-100 percent. At the same time the cost of ammunition increases 10-15 percent, while target effectiveness is somewhat reduced.

A radical difference between the new American rocket-assisted projectiles and the projectiles developed at the end of the Fifties and the beginning of the Sixties is that the rocket engine in the new projectiles does not switch on immediately on leaving the bore, but in trajectory. Better accuracy is achieved this way. Specialists assert that the accuracy of fire of the new rocket-assisted projectiles is comparable to the corresponding characteristics of guided missiles and is only slightly below the firing accuracy of conventional artillery projectiles. The projectiles withstand high rotational speeds (up to 12,000 rpm), as well as high accelerations (up to 15,000-20,000 units instead of 200 as in rocket projectiles and missiles).

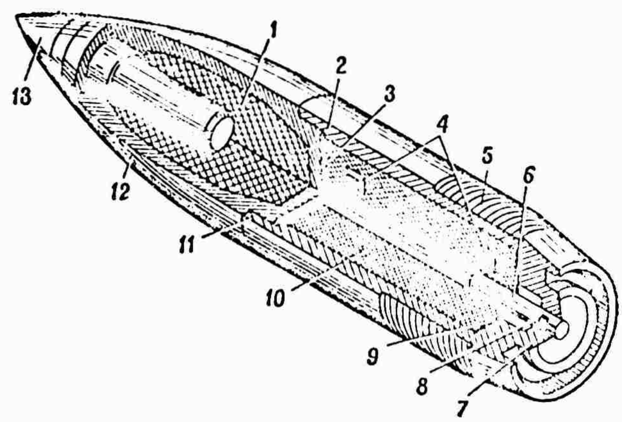


Figure 51. American 127-mm rocket-assisted projectile:

1) explosive; 2) terminal cap; 3), 9) vibration dampers; 4) propellant charge inserts; 5) rotating band of projectile; 6) launch delay element; 7) obturator pad; 8) jet nozzle; 10) powder sticks of rocket engine; 11) ring obturator; 12) warhead; 13) fuze.

A rocket-assisted projectile (Figure 51) has the appearance of a conventional projectile, but has a solid-fuel rocket engine built into its body. Attempts are under way abroad to produce rocket-engine solid fuels of greater density and strength, with higher specific impulse and minimum smoke formation. Much attention is being given to operating reliability tests of projectiles. The aim of developers is that rocket-assisted ammunition be as reliable under various conditions of employment as conventional artillery projectiles. In particular, it is required that the rocket engine ignition system be activated under any and all environmental conditions.

In the United States a rocket-assisted projectile is under study whose solid-propellant rocket engine is enclosed in a container filled with a special fluid. This fluid compensates for the destructive effect on the propellant charge of large overloads occurring at the time of firing. After the projectile leaves the bore the container with the fluid is destroyed under the influence of internal and external aerodynamic forces. When the igniter is turned on, the fluid left in the propellant charge is forced out, the duct of the charge is dried and the engine is turned on, imparting additional acceleration to the projectile.

The compensating fluid in this case is considered practically incompressible. Its function is uniform distribution of the loads which occur. Therefore, the body of the projectiles themselves can be made relatively thin-walled, which permits approximately a doubling of the range of fire.

The American army is also studying the question of creating a rocket-assisted mortar shell with a liquid-propellant rocket engine. The mortar shell is designed to be fired from a 106.7-mm mortar, whose design requires no modifications. It is reported that the range of fire of the new mortar shell may far exceed the range of flight of conventional projectiles or mortar shells. It is expected that prepackaged liquid engines will be used in these mortar shells, with dimethylhydrazine as the fuel and nitric acid as the oxidizer.

Possible ways of increasing the accuracy of fire of rocket-assisted projectiles are under study. In the United States a preliminary study was recently begun of the possibility of stabilizing such projectiles in trajectory by means of a gyroscopic control system. A rocket-assisted projectile with a liquid engine has been recognized as most suitable for the experiments. The control system incorporates a gyroscope with two axes and a pneumatic transmitter. The thrust vector is controlled by the method of secondary liquid injection. The liquid rocket engine turns on after a conventional artillery round is fired. The principal difficulty in implementing the plan is considered to be the development of relatively inexpensive gyroscopic instruments for the control system.

Foreign specialists emphasize that in comparison with a solid-propellant engine a liquid engine will, in principle, provide higher accuracy of fire by virtue of improved thrust vector control, will simplify and eliminate the hazard of thrust cutoff and, finally, will reduce the amount of smoke that forms and discloses fire positions. Control of projectile flight must be effected by gas jet deflection by means of a rotatable nozzle, and control of flight range by propellant cutoff. Holes with a burst membrane are used for thrust cutoff in solid-propellant rocket engines. This may lead to impairment of the aerodynamic quality of the projectiles or to the dangerous discarding of nozzles over the positions of friendly troops. Projectiles with a liquid rocket engine do not have these disadvantages.

Chapter VI

FIELD GROUND ARTILLERY

1. Towed Guns

Despite the well-known trend towards equipping modern armies with self-propelled artillery the most numerous and common artillery systems up till now in all armies of the world are still towed pieces.

Some foreign military specialists believe that, in addition to self-propelled artillery, all available towed guns, including models of the World War II period, can and must be used in our day until self-propelled guns are manufactured in sufficient quantity.

Other experts assert that the existence of towed pieces must not be made to depend on the saturation of armies of self-propelled artillery. Here logistic considerations come to the fore: maximum combat effectiveness of pieces with minimum production cost; high operating reliability; strength of design; simplicity in training, service and operation; feasibility of mass production.

It is noted that no special chassis are needed for towed artillery because pieces are transported in a trailer behind general-purpose prime movers and, if necessary, behind civilian vehicles and tractors. Self-propelled guns, however, are mounted on special chassis as a rule. If these are tank chassis, tank output is of course reduced.

Foreign specialists emphasize that no gun system, especially artillery, must be obsoleted for as long a time as possible. This requirement is bound up with the supply of materiel and equipment for troops and the creation of necessary stockpiles for the contingency of war. The relatively slow updating of the artillery park is also due to the existence of large ammunition stocks which can be stored for dozens of years in depots.

Towed pieces of the World War II period and of the first post-war years are in service in the American, English and other armies of capitalist states: for example, in the United States the 105-mm howitzer M101, 155-mm howitzers M114 and 203-mm howitzer M115 (previous designations M2A1, M1A2 and M2 respectively); in England the 87.6-mm howitzer-gun Mk2, 114.3-mm gun Mk2, 139.7-mm howitzer-gun Mk3, 182.9-mm howitzer Mk6, 233.7-mm howitzer Mk2 and other systems.

Modern towed artillery in the armies of the capitalist states is represented by 105-mm howitzers (United States, England, France, West Germany, Italy, Sweden etc.), 155-mm howitzers (United States, England, France, West Germany etc.), 155-mm and 175-mm guns (United States), 203-mm howitzers (United States, England etc.).

All these guns are intended to neutralize and wipe out personnel and fire weapons, destroy defensive installations, and combat enemy field artillery and mortars (depending on the caliber of pieces). The fact that they have shaped-charge shells in their unit of fire enables towed pieces successfully to repel the attacks of tanks and other armored vehicles.

The structural design of the above-enumerated pieces is classical. It has been examined in detail in Chapter IV of the present book.

105-mm howitzers have a monoblock barrel with muzzle brake and vertical or (less frequently) horizontal sliding-wedge breechblock. The recoil mechanism consists of a hydraulic recoil brake and pneumatic or spring recuperator. The elevating and traversing mechanisms are of the rack type. Gun carriage: split-trail, wheel-mounted with pneumatic tires. Some 105-mm howitzers are equipped with a carriage with three or four folding trails in order to provide all-round fire. Firing elevations of the 105-mm howitzer range from -5 to + 65°.

A distinctive feature of 155-mm and 203-mm howitzers is that they have built-up barrels, horizontal sliding-wedge or screw-type breechblocks, and equilibrators of the spring or pneumatic type. Howitzer carriage: split-trail, wheel-mounted, two-axle, pneumatic tires. On going from traveling to firing position the bottom carriage is suspended on a central tray (French 155-mm howitzer M50) or lowered to the ground (American 203-mm howitzer M115).

In recent years an appreciable revival in the development of new towed pieces has been observable abroad. The main attention has been given to increasing the power of guns and lightening their weight. The efforts of developers have concentrated chiefly on the development of light air-transportable 105-mm all-round howitzers.

Let us consider the Swedish 105-mm Bofors howitzer M/42 and the American 105-mm howitzer M102.

b

Figure 52. Swedish 105-mm Bofors howitzer M/42 in firing (a) and traveling (b) position.

The Swedish 105-mm Bofors howitzer M/42 is intended for use in division artillery. Principal characteristics: weight of projectile 15.5 kg; muzzle velocity 610 m/sec; maximum range of fire about 15,000 m; weight in firing position 2600 kg; elevations from -5 to + 65°; traverse 360°.

The howitzer (Figure 52) has a monobloc barrel with muzzle brake, horizontal wedge-type breechblock, hydraulic recoil brake and hydropneumatic recuperator. The recoil mechanism is located under the barrel. A tilting shell tray serves to facilitate loading. The semi-automatic feed mechanism makes it possible to obtain a rate of fire up to 25 rounds per minute in the first minutes of firing.

All-round fire of the howitzer is made possible by the design of the carriage with four folding trails and a mechanism for suspending the wheeled running gear in the firing position.

The American 105-mm howitzer M102 is in service in the airborne and airmobile troops and marines. It constitutes the basis of the field artillery of U.S. ground forces in South Vietnam.

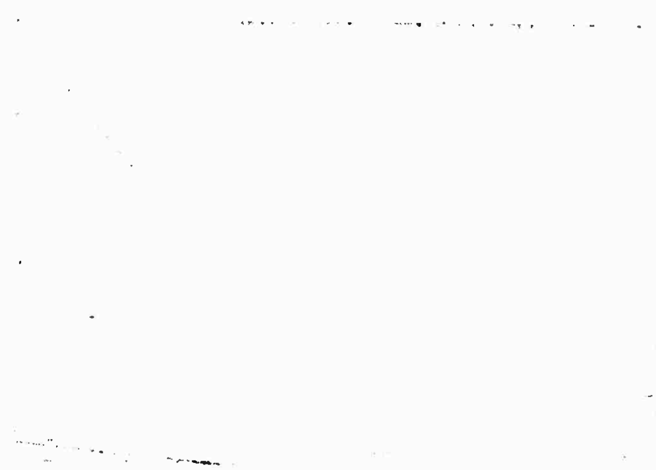


Figure 53. American 105-mm howitzer M102.

The design of the howitzer characterizes the trend in the development of American artillery for limited wars (light weight, great range of fire, low silhouette, air-transportability).

Basic performance characteristics of the M102 howitzer: weight of projectile 13 kg; muzzle velocity 610 m/sec; maximum range of fire 15,000 m; weight in firing position 1450 kg; firing elevation from -5 to + 75°; traverse 360°.

The howitzer can be transported by helicopter or aircraft, dropped by parachute, and towed by ground transport facilities. A distinctive feature of the table of organization for a battery of these howitzers in South Vietnam is the lack of ground transport facilities. To move the howitzers into the combat zone, firing platoons are given helicopters of the CH-47 type. Emplacement time after delivery to firing site: 2-4 minutes. The comparative ease of moving the howitzer by helicopter permits its use to support combat operations of small podrazdeleniya down to and including patrols.

The howitzer (Figure 53) has a barrel with a muzzle brake which absorbs 55-60 percent of recoil energy, vertical wedge-type breechblock, and hydropneumatic recoil mechanism. The carriage consists of a single trail shaped like a little bow (wishbone) and is mounted on two wheels with pneumatic automobile tires.

Under the front carriage section a light base plate is mounted on which the piece is let down in firing position. The rear trail assembly rests on a cylindrical, longitudinally arranged roller. Connected to the roller is the drive of the traversing mechanism which provides relatively high traversing speed. If the drive is disconnected, two men can easily turn the piece on the base plate. Such construction permits the delivery of all-round fire. The base plate on which the howitzer turns is fixed in the ground by means of aluminum stakes at the firing site.

American specialists consider the creation of the 105-mm howitzer M102 a representative example of the new approach to problems in modern artillery design. They note that during World War II the basic requirement in the development of artillery systems was to make them strong and reliable in operation. In the name of this objective the weight of pieces was even made excessive. The modern army has become more mobile -- an army of maneuver. Now helicopters take part in moving troops, artillery and ammunition. Therefore one of the basic requirements set for modern models of armament is weight reduction with maintenance of requisite dependability.

The Vietnam war experience has had a definite influence on the American army's technical policy in the sphere of artillery. According to foreign press reports, the transport of artillery under conditions in South Vietnam is hampered by difficult terrain and the lack of good roads and bridges. The rainy season affects artillery mobility especially adversely. Under these conditions helicopters are the main -- and sometimes even the sole -- means of artillery transport and ammunition supply.

The old American 105-mm howitzer M101, still used at present in combat operations, does not possess certain characteristics necessary for airborne operations. When this howitzer, which weighs more than 2000 kg, is transported by helicopter, it has to be disassembled. Moreover, the howitzer has limited maximum traverse (23° to the right and 22.5° to the left), range of fire 11,100 m, maximum angle of elevation $+65^{\circ}$. To emplace this piece, trail spades must be braced in the ground.

In the development of the 105-mm howitzer M102 the latest achievements of technology and materials science were used. The carriage is made of highly weldable aluminum alloys. In the design of the howitzer wide use is made of plastics -- for bushings and coatings of various kinds (for example, coating of guiding slots of the cradle) where resistance to corrosion and temperature fluctuations is important. In the recoil mechanism plastic gland packing and gaskets are used. The jacket of the cradle is equipped with vinyl-coated parts. Weight saving is also provided by wheel webs made of magnesium, light-weight clutch assemblies etc. The howitzer is so designed that loads during firing are uniformly distributed over the entire structure of the carriage. This has made possible a reduction in the weight of the gun.

Also regarded as an advantage of the new gun is the low altitude of the line of fire (760 mm at angle of elevation 0°), which reduces to a minimum overturning moment during firing and cuts down the trail length necessary to give the howitzer stability during firing. The new collimating sighting system eliminates the use of aiming posts. The rate of fire of the M102 howitzer is almost twice (180 rounds per hour) that of the old howitzer.

The 105-mm howitzer M102 can deliver fire with all the kinds of ammunition constituting the unit of fire of the old howitzer and besides with a new projectile which makes possible a maximum range of 15,000 m on the eighth charge. The old howitzer is not adapted to this shell.

On swampy terrain and in the flooded rice paddies of the Mekong (South Vietnam) River delta the M102 howitzer is mounted on a special firing platform, which is adapted for muddy ground up to 60 cm deep and covered with a 60-cm layer of water on top. In addition to the howitzer, it can accommodate a six-man crew and a stock of 110 rounds of ammunition. The howitzer can be turned 360° on the platform.

However, experience in combat employment of the M102 howitzer in Vietnam has also shown the weak points of this weapon. Cases have been noted of cracks appearing in the base plate, barrel failure at the muzzle end, unserviceability of the sight, bobbing up and down of the howitzer during firing, intense effect of muzzle wave on gun crew.

Towed cannon-type antitank guns, which earlier were the basic weapon of antitank warfare, have in the opinion of foreign specialists to a considerable extent exhausted the possibilities of any further increase in effectiveness by the methods known in practice. Under modern combat conditions the shortcomings of towed antitank guns have become more apparent. Antitank warfare of the 1960's required a sharp increase in the point-blank range of antitank guns. However, an increase in point-blank range, say to 2000 m, will result in such an increase in the weight of guns that they will become cumbersome and unsuited as infantry antitank weapons. Therefore, the course taken abroad is to supply troops with self-propelled antitank guns.

The basic performance data of some towed guns of the armies of capitalist states are presented in Table 9.

The trend in the further development of towed artillery in foreign armies is towards maximum reduction of gun weight (so that pieces can be moved by helicopter) while preserving or increasing their fire power. Two ways have been chosen to make guns lighter: wide use of high-strength light alloys and employment of the most rational design schemes.

Promising development projects give special attention to increasing the maximum rate of fire of guns. According to comments of the troops, artillery fire inflicts maximum casualties on the enemy before his personnel take cover. Hence the desire to fire as many rounds as possible in a short interval of time. This has compelled American designers to seek ways of creating effective quick-fire artillery pieces.

Table 9

BASIC PERFORMANCE DATA OF SOME TOWED GUNS OF ARMIES OF CAPITALIST STATES

Gun model	Weight of projectile, kg	Maximum range of fire, m	Weight in firing position, kg
U.S.			
105-mm howitzer M101	15	11,100	2,040
105-mm howitzer M102	13-15	15,000	1,450
155-mm howitzer M114	43	14,600	5,770
155-mm gun M2A1	43	23,400	12,600
203-mm howitzer M115	91	16,900	14,500
England			
87.6 gun-howitzer Mk2	11.3	12,200	1,800
139.7-mm gun-howitzer Mk3	45	15,700	5,440
182.9-mm howitzer Mk6	91.6	15,500	10,000
233.7-mm howitzer Mk2	131	12,700	16,000
France			
105-mm howitzer M50	16	14,000	2,700
155-mm howitzer M50	43	18,000	8,000
Italy			
105-mm mountain howitzer	15	10,100	1,300
Sweden			
105-mm Bofors howitzer M/42	15.5	15,000	2,600

Research began in this field in 1960-1961 with the development and testing of the American 115-mm combination six-chambered automatic gun, the "Moritzer" XM70. Research continues on other design schemes of five- and six-chambered guns.

Regarded as promising in the American army are designs of guns with a reverse recoil cycle. Such guns, according to foreign press reports, make it possible to cut down recoil energy, which in turn may lead to the development of a light-weight piece with a higher rate of fire than contemporary guns have.

In pieces with the conventional recoil cycle the recoiling parts on firing move to the rear at high speed, while the recoil mechanism retards their movement and stops them. Then counterrecoil takes place.

In the new developments the recoil cycle has the opposite sequence. The moving parts of the gun are locked in the extreme rear position, i.e. in the recoil position. During firing the recoiling parts are released from the locked position and rush forward. This action precisely matches the counterrecoil operation in conventional gun systems save only that the moving parts travel at a far higher velocity.

When the recoiling parts reach a certain zone and a precalculated forward speed, the firing mechanism switches on. The energy of the powder charge first overcomes the energy of the forward motion of the recoiling parts, then pushes them backwards where they are held by locks.

The duration of the forward recoil cycle of a standard American 105-mm howitzer is about 3 sec. The reverse recoil cycle takes about 1.5 sec, i.e. half as long. The potentiality of an increase in the maximum rate of fire thus emerges.

Other advantages of guns with a reverse recoil cycle are also noted: elimination of rear trails, thereby freeing a large area around the muzzle end for gun crew operations; decrease in total length of the piece and good compactization of the entire system; decrease in height of the line of fire; simplification of the recoil mechanism etc.

The operating reliability of this structural scheme presupposes the realization of three basic requirements. First, the firing mechanism must be actuated at a strictly specified time, when the recoiling parts, moving forward, reach the necessary speed and the prescribed point on their path. Second, the powder charge must ignite and burn under specified, always identical conditions. Third, the locks must be actuated without fail on every shot.

2. Auxiliary Propelled Guns

Auxiliary propelled guns are intended to escort infantry and tanks on the battlefield. In contrast to towed pieces they have self-propulsion units making possible independent travel by road and across country without a prime mover. For great distances auxiliary propelled pieces are moved in a trailer behind wheeled or tracklaying prime movers.

Self-propulsion units consist of an engine, transmission and control mechanisms.

Air-cooled, internal-combustion piston engines (of the motorcycle type) are installed on auxiliary propelled guns in order to convert the chemical energy of fuel into mechanical work, which is used for self-propulsion. The engine includes starter mechanisms, as well as instruments to power and control its operation.

The transmission is the totality of the apparatus conveying torque from the engine to the driving wheels. The transmission consists of the clutch, gear box, main drive shaft, rear axle assembly, Cardan drives and cross drive transmission.

A frame is welded onto one of the trails of the gun in order to house the engine together with clutch, gear box and brake. Armored protection is used to guard the mechanisms against the impacts of shell cases ejected during firing and against getting hit by small fragments and bullets.

Fuel for powering the engine is put inside the trails.

The actuator for self-propulsion can be power-driven or hydraulic.

The power drive is constructed and operates as follows. Along the trail from the gear box to the bottom carriage runs the main drive shaft, which connects with the driving shaft of the final drive of the rear axle assembly. The rear axle assembly is attached to the bottom carriage and by the Cardan drives is connected with the cross drive transmissions mounted on the cranks of the axletree and suspension.

Torque from the engine is transmitted via the clutch to the gear box, then to the main drive shaft, rear axle assembly, Cardan drives of cross drive transmissions, to the cross drive transmissions and driving wheels of the piece. The torque on the driving wheels varies with road conditions. For example, in negotiating difficult road sectors when torque in first gear is not sufficient to negotiate difficult sectors, the dual-high transmission switches on.

To increase cross-country ability under difficult road conditions, the design of an auxiliary propelled gun sometimes incorporates a differential blocking mechanism and a self-extricator. Differential blocking enables a piece to move using one wheel if the other is spinning due to a poor grip on the ground. The self-extricator works like a winch. By means of it a gun can be pulled out when both wheels have got stuck or are spinning. The drums of the self-extricator are located on the webs of the driving wheels, and the cable on the shield. Anti-skid chains are also used for the driving wheels.

The control mechanisms are designed to change the direction in which the piece is moving, reduce the velocity of its motion and stop the piece on upgrades and downgrades. They also make possible control of the operation of the engine and transmission assemblies.

The control mechanisms consist of the steering system, brake and driving controls. All controls are concentrated near the driver's seat, which is situated on the rear trail assembly. A spring-mounted seat for the driver is located on a bracket welded to the trail. To facilitate the driver's work, the seat has a back and a cushion. When a piece is changed from firing to traveling position, the driven wheel is raised up for towing behind a prime mover.

Auxiliary propelled guns are supplied with a system of electric equipment to illuminate the way during nighttime locomotion and to light up the sight scales during nighttime firing.

In a trailer behind a prime mover an auxiliary propelled gun is usually transported at the speed which prime movers permit. During self-propulsion (minus the prime mover) guns can move at a speed of 15-25 km per hour with "barrel backwards," and at a speed of 5-6 km per hour with "barrel forward."

It is permissible to transport the gun crew and ammunition chests on auxiliary propelled guns. If the gun is transported in a trailer behind a prime mover, the ammunition and personnel are accommodated in the body of the prime mover.

Auxiliary propelled guns were first developed in the Soviet Union after the Great Patriotic War. One of them, for example, was the 85-mm auxiliary propelled gun.

The principle of artillery self-propulsion has also been put into practice in other states too. In the United States, for example, it is thought that the creation of auxiliary propelled guns is a successful way of raising the mobility of towed artillery on the battlefield. In the opinion of the Americans, this method is advantageous and economical since it permits use of towed guns which the troops already have or are available in depots.

The American army has in service a new 155-mm auxiliary propelled howitzer M123A1 with hydraulic actuator. On a trail of the howitzer carriage is mounted a gasoline four-stroke 35-h.p. engine, connected with the actuator. The driver is situated in the middle of the trail and controls the motion by means of two levers. Total weight of the howitzer: 6400 kg, including 500 kg attributable to self-propulsion units. The howitzer's speed of self-propulsion on the road is up to 15 km per hour, and permissible towing speed is 80 km per hour. The howitzer can turn on the spot, which accelerates laying and makes possible all-round fire. In addition, the piece is adapted for air transport.

The experience in combat employment of the 155-mm auxiliary propelled howitzer M123A1 is rated favorably in the United States. At present a 105-mm auxiliary propelled howitzer M124 is under development for the American army.

In the middle of the 1950's England also made attempts to design experimental models of auxiliary propelled antitank guns. In so doing the English tried to develop special auxiliary propelled carriages with a more rational arrangement of assemblies rather than to adapt existing field carriages to self-propulsion. For example, the English 76-mm auxiliary propelled antitank gun had a special four-wheeled carriage and moved over a dirt road at speeds up to 40 km per hour. Places were provided on the gun carriage to accommodate the gun crew and ammunition chests. The power plant and driver's seat were located on the right. During firing the front wheels were locked, and the rear wheels spread at a 90° angle relative to the longitudinal axis of the machine and served as a rest during firing.

Essentially, the four-wheeled auxiliary propelled gun was found to be a poorer version of self-propelled gun mounts. Therefore, at the beginning of the 1960's the English gave up further development of such auxiliary propelled guns and went over to the creation of modern self-propelled guns.

The West German 90-mm auxiliary propelled antitank gun PAK-90 is coming into service in antitank podrazdeleniya of motorized infantry divisions of the Bundeswehr.

It has a barrel (40.4 calibers in length) with a muzzle brake. The breechblock is semiautomatic with a firing mechanism of electromagnetic or mechanical type. Loading is manual, while breechblock opening and closing as well as the extraction of spent cases is automatic. The recoil mechanism of the piece is mounted in the cradle, over the guides of which the barrel moves during firing. The mount consists of top and bottom carriages.

Gun pointing mechanisms make possible a vertical field of fire from -8 to + 25° and traverse of 50°. Optical and infrared sighting mechanisms are designed for day and night firing.

On the bottom carriage, which is made in the form of a box frame, are located the power plant for self-propulsion, steering wheel and engine controls, seats for three crew members, braking system, folding lower shield and ammunition chests.

The gun is steered over the terrain by means of the rear driving wheels. When the support frame of the rear wheels is let down, the gun is in firing position. The spade, which is actuated by a pneumatic device, is sunk into the ground.

The power plant of the gun not only provides self-propulsion but also performs the functions of a power source for the hydraulic equipment of the system. To get the gun into firing position, the rear wheels are pulled back by means of a hydraulic drive, and the piece is lowered. A short abrupt run to the rear with the help of the engine forces the spade tightly into the ground. After the suspension is disconnected and the barrel released, the gun is ready to fire.

Special attention is given to providing the piece with auxiliary self-propulsion over difficult terrain. For this purpose large-diameter driving wheels (principle of the araba) are provided, and gun carriage clearance is made equal to 380 mm. On heavily broken wooded and marshy terrain the driving wheels can operate independently of each other.

Total weight of the gun is about 5000 kg; height 1.4 m; length 7.3 m; width 2.5 m. In the position for self-propulsion the barrel of the gun is pulled backwards by means of a hydraulic drive. The total length of the gun in this case is reduced to 6 m.

The engine has tractive power of 2.4 tons, which enables the gun to negotiate the gentle banks of rivers and other terrain barriers and even to pull out a prime mover that has got stuck in muddy ground. Grade climbing ability of the gun: 27°; grade descending ability: 43°.

For long distances the gun is towed as a trailer. Trucks or army prime movers with load capacity over five tons are used as prime movers.

The Western press rates the new West German 90-mm auxiliary propelled antitank gun PAK-90 highly. Noted as its advantage is the combination of such characteristics as short emplacement time, high rate and precision of fire, and its capability of speedily changing firing site unaided by tow vehicles.

Creating auxiliary propelled guns is one method of increasing the mobility of towed artillery systems immediately in the combat zone.

The principal advantages of these guns over towed pieces are: higher maneuverability on the battlefield (by quickly assuming and changing fire positions); the short time required to go from traveling to firing position and vice versa; reduction in the number of gun crew members and lightening of their work.

Auxiliary propelled guns are considered an intermediate link between towed and self-propelled artillery. In the development of auxiliary propelled guns the endeavor has been to avoid the complexity and high cost characteristic of self-propelled guns.

3. Self-propelled Artillery

Modern self-propelled artillery is intended for escort and fire support of tanks and motorized infantry in combat and operations, as well as for antiaircraft cover of troops against attack by enemy aircraft.

The origin of self-propelled artillery was occasioned by tank forces' need of powerful and highly mobile means of artillery reinforcement on the offensive. In addition, self-propelled guns became a powerful antitank weapon and participated in escorting the infantry.

Self-propelled artillery was first employed on a mass scale by the Soviet Army on the battlefields of the Great Patriotic War. The adversaries of self-propelled artillery in the various armies used just one argument: The self-propelled gun is "a tank gone wrong." The experience of World War II and, above all, the combat experience of the Soviet Army, completely refuted the views of skeptics and opponents of the development of self-propelled artillery. Its high combat effectiveness became obvious to all. Therefore the rapid development of self-propelled artillery was a fundamentally important trend in World War II ordnance.

The Soviet experience in the development of self-propelled artillery undoubtedly influenced the appearance in the German Fascist Army of the 75, 105, 128, 150-mm assault self-propelled guns and howitzers and especially of the 88-mm self-propelled gun Ferdinand. There was even an attempt to develop an experimental model of a 600-mm self-propelled mortar with a total weight of 70 tons.

In the United States the following self-propelled guns were developed and went into service during the war: 75-mm howitzer M8 Scott, 76-mm guns M10 and M18, 90-mm gun M36, 105-mm howitzers M7 Priest and New Priest, 155-mm gun M40, 155-mm howitzer M41, 203-mm howitzer M43; in England 76-mm gun The Archer, 87.6-mm howitzer-guns The Bishop and The Sexton.

The influence of Soviet design thinking in the sphere of self-propelled artillery was not limited to World War II. It was also strongly felt in the postwar period.

In recent years in the developed capitalist states basic efforts in the sphere of artillery armament have concentrated on the development of self-propelled guns.

In this connection a distinction is drawn between self-propelled artillery in the modern sense (with bulletproof armor) and assault self-propelled artillery, which has the same armor plating as tanks.

Foreign specialists point out a number of advantages which self-propelled guns have over towed guns and explain the reasons for the preference accorded self-propelled artillery by many capitalist countries in the development of new models.

First, owing to changes of views on the fundamental principles of warfare caused by the emergence of nuclear weapons, the requirements set for the protection, mobility and fire power of troops and combat materiel have grown considerably. This applies in full measure to artillery armament too. Self-propelled guns equipped with atomic defense means are adapted to conditions of nuclear warfare and are better protected against enemy fire.

Second, it is generally recognized that tank forces best answer the character of nuclear warfare. But tanks cannot successfully perform the missions assigned them without artillery support if in their way they encounter organized enemy resistance in prepared positions. Towed field artillery is not always in a position to give continuous support to modern tanks and motorized infantry engaged in nuclear combat. Self-propelled guns, however, possess high tactical and operational mobility, sufficient fuel distance, and good cross-country ability off the roads and over broken terrain plus negotiation of obstacles.

Third, in modern fast-moving warfare cutting down the emplacement time of guns sharply increases the fire capabilities of self-propelled artillery in comparison with tractor-drawn guns and raises the general combat readiness of chasti and soyediniya. For example, it takes five minutes to bring American 155-mm towed howitzers from traveling into firing position, and from 30 minutes to six hours (depending on the ground) for tractor-drawn 155-mm guns and 203-mm howitzers. However, it takes one minute to get 155-mm and 203-mm self-propelled howitzers ready for combat.

Fourth, self-propelled guns have smaller overall dimensions than towed guns plus prime movers and therefore a shorter march column length.

Finally, a smaller number of personnel are required to attend self-propelled guns.

The shortcomings of self-propelled artillery are also noted: difficulties in camouflaging and concealing large-sized vehicles; unserviceability of entire gun in event of damage to chassis engine; impossibility of using gun to bring up ammunition when the gun is in a fire position. Self-propelled guns are considerably more expensive than towed guns, and for their mass production a country must have well-developed industry at its disposal.

The following pieces can be self-propelled: field howitzers and guns, antiaircraft guns, mortars, recoilless guns, antiaircraft artillery mounts, salvo rocket-launching field artillery. The present section takes up only field self-propelled and antitank artillery. Other types of self-propelled systems will be shown in the appropriate sections of the book.

The self-propelled gun is a single compact combat vehicle having powerful artillery armament and motorized running gear (chassis) with partial or complete armor plating.

Sometimes self-propelled guns are called self-propelled mounts or self-propelled artillery mounts. These terms arose historically because earlier self-propelled guns were created by mounting (setting, fitting) the then existing field guns on the chassis of tanks, tractors or motor vehicles. In so doing, the tipping and rotating parts of field guns plus pointing mechanisms remained almost unchanged, while the chassis replaced the bottom carriage.

The basic difference between self-propelled guns and tanks is in the principles of combat employment and in the character of the missions performed by them. For a tank three main characteristics are essential: armor, armament and speed. Only a harmonious combination of these characteristics in a combat vehicle defines the concept of "tank." Under modern conditions tanks possess not only fire power but also striking power. They are capable of operating both with infantry and by themselves.

Self-propelled guns, however, are a variety of artillery possessing high mobility and cross-country ability and providing troops with continuous accompanying fire.

Given the same weight, a self-propelled gun has a caliber that is more powerful than a tank's, and armor plating that is weaker.

In respect of construction the following types of self-propelled guns are distinguished: armored, semiarmored and open, with front or rear placement of the fighting compartment.

In armored guns the body is the supporting structure for all accessories and mechanisms. Three varieties of such guns are possible: with a nonrotating turret, with a turret that rotates in a limited sector, and with a rotating turret.

Semiarmored guns are mounted on a special cross beam or pedestal of the housing of the armored body. They are open from above and behind.

Open self-propelled guns have a top carriage, shield and special chassis-supporting frame. Depending on the power of the gun, all-round or limited fire is provided.

In respect of the construction of the motorized running gear, self-propelled guns are divided into tracklaying, half-track, wheeled and convertible self-propelled guns.

The tactical mobility of self-propelled guns is determined by how quickly they can move over broken terrain and change fire positions and in how little time they can be made ready for action and the march. Mobility is characterized by average speed of movement over the terrain under combat conditions, specific ground pressure, and the ability to negotiate various obstacles (ditches, fords, vertical walls, downgrades and upgrades), turning radius of the vehicle, good pickup of the engine, ability of engine to operate steadily in a wide range of revolutions and loads, time required to convert gun from traveling to firing position and vice versa.

Average indicators of cross-country ability of modern self-propelled guns: specific ground pressure of tracks 0.5-0.8 kg/sq cm; clearance 300-500 mm; width of negotiable ditch 1.5-3.0 m; depth of ford 0.6-1.2 m; height of vertical wall 0.7-1.0 m; ascent and descent 25-30°; careen 20-30°.

The maximum rate of travel of self-propelled guns ranges from 35 to 65 km per hour.

Any self-propelled gun consists of armament, armored hull or frame, power plant, transmission, running gear, electrical and special equipment (hydraulic drives, compressors etc.), signal communication facilities and surveillance equipment. All these parts are housed in four compartments of the hull or frame: fighting compartment, engine compartment, transmission compartment and driving compartment.

The armament includes the artillery weapon, sighting and surveillance equipment, small arms and basic load of ammunition.

The power plant consists of engine and fuel, lubricating, air-cooling and filtering system.

The transmission includes the main clutch, gearshift box, side clutches or planetary rotation gear, cross drive transmission (reduction gear).

The running gear is composed of tracks, driving wheels (sprockets), idler wheels (track idlers) with tightening device, bogie wheels, track support rollers, and suspensions (springs).

The electrical equipment includes storage batteries, generator with regulating relay, lighting system and individual electrical accessories.

Signal communication facilities are divided into intercom and communication with other units. The intercom is for communication between the commander of the self-propelled gun and crew members. It works by telephone, throat microphone and light signals. Communication with other units is effected by transceiver with a radius of action of 20-25 km.

Sighting and fire-control equipment is intended for the vehicle commander, driver and gunner. It includes mechanical, optical and television apparatus, inspection hatches, holes and slits covered with protective glass.

The fighting compartment in self-propelled guns is located in the front, middle or rear of the vehicle. In arranging the elements of a combat vehicle the starting point is most effective use of armament, better provision of invulnerability for all assemblies, and achievement of good mobility and cross-country ability of the gun.

The size of the fighting compartment is determined by the caliber and type of armament, the layout of the armament, the range of the sweep of the guard of the tipping parts of the gun, composition of the crew, and size of the basic load of ammunition.

The minimum height of the fighting compartment is approximately 1200 mm when the gunner is constantly in a seated position. To avoid his hitting his head against the hull roof plate during cross-country travel, especially when obstacles are being negotiated, the distance from the plane of the gunner's seat to the hull roof plate is set at 900-980 mm. The upper limit is for a gunner of above average height (175 cm) in a seated position.

The loader, whose position varies according to the degree of dispersion of the stowage of ammunition, requires a minimum height of about 1500 mm (average between seated and standing position) and about 1800 mm (for standing position).

The width of work area affects the ease of crew operation to an even greater extent than does height. Space requirements differ for each crew member: least space (0.6 cu m) for gun commander and radio gunner; somewhat more (0.8 cu m) for gun-layer and driver-mechanic; most of all (1.1 cu m) for the loader.

The gun is set on the chassis in different ways: on a pintle mount with bracings; in a hinged frame; by direct attachment of cradle trunnions to the armor of the rotating turret; or in an immobile frame attached to the rotating turret.

Gun mounting in a hinged frame is employed more frequently in case of installation in a fixed turret. The frame has a hole top and bottom for vertical trunnions, by means of which the frame is attached to the hull of the self-propelled gun. The frame and, together with it, the tipping parts of guns turn around the vertical trunnions in the horizontal plane to specified angles to the right and left.

Horizontal holes for inserted cradle trunnions with needle bearings are also made in the frame. The tipping parts of the gun, rotating on the bearings of the horizontal trunnions, permit firing elevations to be obtained in a prescribed range.

The artillery armament of self-propelled guns differs in design from that of towed artillery. Important characteristics of self-propelled systems: armor-plating of tipping parts; special arrangement of recoil mechanism; use of a guard, cartridge ejectors, bats for spent cartridges, ejection chutes, rammers and mechanisms for feeding a complete round into the loading line; air circulation and ventilation of fighting compartment.

To prevent the mechanisms and crew of a self-propelled gun from getting hit by shells and bullets, bubble-shaped armor plating is attached to the cradle. It covers the opening in the armor at all angles of elevation and traverse.

Armor plating makes gun design complicated. Secure attachment to the cradle must be assured; tipping parts must be balanced; and cradle, frame and elevating mechanism strengthened, since with the increase in the weight and moment of inertia of the tipping parts the inertial forces on these assemblies during motion sharply increase.

To decrease the size of the fighting compartment and of the entire self-propelled system as a whole, the gun is so designed that on firing the barrel recoils the minimum length (200-400 mm). For the same purpose high-efficiency muzzle brakes and massive breech rings are used to increase the weight of the recoiling parts.

The crowded conditions under which the recoil mechanism is housed in the fighting compartment necessitate a reduction not only in the length but also in the diameters of recoil-brake and recuperator cylinders. Compactness of recuperators is achieved by increasing initial pressure to 60-70 kg/sq cm.

Of the three known methods of accommodating the recoil mechanism relative to the barrel (on top, underneath, on the side), the bottom position is more often used since it does not limit angles of elevation or increase the weight factor of the breech end.

In the design of self-propelled guns and the grouping of their tipping parts mounted in the rotating or fixed closed turret of the vehicle, the attempt is made in every possible way to reduce the radius of sweep (distance from the axis of trunnions of the gun to the rearmost face of the tipping parts).

In modern self-propelled guns cradle trunnions are not placed in the center of gravity of tipping parts (this would result in very large dimensions for the fighting compartment), but are put back towards the breech face of the barrel. This being the case, there can no longer be natural balancing of the barrel since the muzzle end becomes overweighted. Gun pointing under these conditions not only requires great efforts but may simply prove impossible.

To compensate for overweight of the muzzle end and to facilitate laying of the gun for elevation, balancing mechanisms (equilibrators) are used. They are of the spring and pneumatic type.

A guard serves to keep crew members from being hit by the breech ring during recoil. It consists of fixed and sliding parts. On the rear wall of the sliding guard a cartridge ejector and tipping shell tray are sometimes placed to facilitate loading.

Self-propelled guns are usually supplied with two or three trigger mechanisms -- electric-fuze, electromagnetic and mechanical. The last-named is an emergency mechanism. The electric-fuze trigger mechanism differs advantageously from the others in its very short firing time lag (five or six times less than for the mechanical trigger mechanism), small size and simplicity of construction.

In the development of the self-propelled gun special attention is given to the positioning and stowage of ammunition. Above all, the basic load of ammunition must be compactly and conveniently placed in the fighting compartment. This conduces to an increase in the maximum rate of fire. To eliminate impacts of shells (especially fuzes) against the wall or other objects when the self-propelled hull vibrates during travel and firing, they must be safely secured.

Figure 54. Stowage of ammunition in fighting compartment of self-propelled gun:

1) charges; 2) shells.

Several methods are known of stowing ammunition in the fighting compartments of self-propelled guns: in metal chests with hinged lids (on the floor of the fighting compartment); on racks attached to the walls; vertically along the walls of the fighting compartment, attached by clamp-type snap fasteners (Figure 54); in honeycomb racks fastened to the floor of the fighting compartment; or in a recess of the turret. Owing to the cramped space in the fighting compartment and the desire to accommodate the maximum number of rounds, combined stowage is employed. If there are rammers, stowage of ammunition can be varied since individual groups of rounds or even an entire unit of fire will have to be accommodated on the carrier.

The basic load of ammunition depends on gun caliber and weight of the round. For example, for American 105-mm self-propelled howitzers it is 100 rounds, for 155-mm howitzers it is 50, and for 203-mm howitzers only 10 rounds.

Some self-propelled guns employ rammers and mechanisms for feeding rounds from stowage to the loading line.

Closed self-propelled guns are supplied with a ventilating system for the fighting compartment in order to remove foul air.

In the development of field self-propelled guns abroad, in particular in the American army, four stages are differentiated.

The first stage, which began during the World War II period, is characterized by mounting of field guns on tank chassis, with the fighting compartment not armor-plated.

In the second stage, which was the consequence of Korean war experience, guns with full armor plating were developed, but as previously they were mounted on tank chassis.

The third stage, which began in 1961-1962, represents complete abandonment of tank-based self-propelled guns with heavy armor. Main attention was paid to an increase in mobility, fire maneuverability, reduction in the weight of the vehicle, provision of air transportability and amphibious capability, and a rise in the rated cruising range of self-propelled guns. The new guns have rotating turrets with all-round fire, large angles of elevation, and smaller crews due to partial mechanization of the loading process. Armored carriers or specialized tracklaying chassis are used as the base.

In 1968-1969 the fourth stage began -- the stage of joint development by the United States, England, France, West Germany and other capitalist states of the new self-propelled guns of the 1970's. For example, the decision was recently made to develop a 155-mm self-propelled howitzer that can fire ammunition produced in all these countries.

It is assumed that while preserving their high mobility, the self-propelled guns being designed will have a longer range of fire and higher fire power. Extensive standardization of gun assemblies and accessories is envisaged in order to facilitate their operation, supply and repair.

Table 10 shows the course of development of the field self-propelled artillery of the American army during the postwar period.

From the table it can be seen that during the postwar years the armament system of field self-propelled artillery was renovated three time in the American army -- the replacement of artillery armament being carried out not with single models, but entire systems, including all the basic field artillery calibers. The time taken for the development of new guns was also shortened.

Table 10

DEVELOPMENT OF AMERICAN FIELD SELF-PROPELLED ARTILLERY
DURING POSTWAR PERIOD

B Калибр орудий / **A** Годы принятия на вооружение	**C** Гаубицы			**D** Пушки	
	105-мм	155-мм	203-мм	155-мм	175-мм
	E Наименование орудия				
[illegible]	M37	M41	M43	M40	—
[illegible]	M52	M44	M55	M53	T162
[illegible] 1962	M108	M109	M110	[illegible]	M107

Keys:

A. Year of adoption for service
B. Gun caliber
C. Howitzers
D. Guns
E. Designations of pieces

Let us consider several models of modern self-propelled guns of foreign armies.

The American 105-mm self-propelled howitzer M108 has a monobloc barrel with muzzle brake. The breechblock is vertical, sliding-wedge type. The recoil mechanism consists of a hydraulic recoil brake and a spring recuperator.

The ordnance is mounted in a closed rotating turret on a special chassis, based on assemblies of the M113 armored carrier. Aluminum alloys are widely used in its construction. In particular, the hull and turret are made of aluminum, which permitted a reduction in the weight of the howitzer and enabled it to be made amphibious and air-transportable.

The aluminum armor plates of the hull and turret protect the crew from the fire of infantry weapons, shell fragments and flames. The hull is airtight. All hatches are closed by covers with hermetically sealing gaskets. The fighting compartment has a reinforced double wall floor.

The gun is supplied with atomic defense means and automatic firefighting equipment (two 4.5-kg cylinders of carbon dioxide).

The power plant is a V-8 liquid-cooled turbosupercharged Diesel engine developing 425 h.p.

The running gear with rubber and metal tracks has seven bogie wheels on each side. The rocker arms of the driving (in front) and idler (in the rear) wheels are equipped with hydraulic shock absorbers. During firing the chassis suspension is disconnected. This reduces the vibrations of the entire vehicle during the delivery of fire and increases the accuracy of fire.

Combat weight of the howitzer: 20.8 tons; maximum speed of travel: 65 km/hr; rated cruising range: 400 km; crew: five men.

The 105-mm howitzer M108 fires shells weighing 13 kg for distances up to 15,000 m. Angles of elevation: from -4 to + 75°; traverse: all-round.

In order to negotiate water barriers afloat, the howitzer is equipped with a special set of floaters (six inflatable rubberized containers and three wave-repelling shields). The tracks serve as a propeller afloat.

A 12.7-mm machinegun is mounted on the rotating turret of the howitzer. To fire it, 500 cartridges are carried in the fighting compartment.

Figure 55. American 155-mm self-propelled howitzer M109.

The American 155-mm self-propelled howitzer M109 (Figure 55) in its structural design resembles the 105-mm self-propelled howitzer M108 and is set on the same M113 armored carrier chassis. These howitzers have in the main the same inside equipment in vehicles.

The 155-mm howitzer M109 differs from the 105-mm howitzer M108 in caliber, weight and certain structural peculiarities. In particular, the M109 howitzer employs a semiautomatic screw-type breechblock with sector thread, introduces a device to facilitate loading, and effects turret traverse by hydraulic drive.

Maximum range of fire of the howitzer: 18,500 m; angles of elevation: from -3 to + 75°; traverse: 360°.

Combat weight of the gun is 23.6 tons; rated cruising range 350 km; crew: five men. Buoyancy of the howitzer is provided by the same means as for the M108 howitzer. Negotiable obstacles: ascent up to 31°; ditch 1.83 m wide; ford 1.2 m deep and vertical wall 0.53 m high.

The 155-mm howitzer M109 can deliver fire with conventional and nuclear projectiles.

As is known, the development of nuclear ammunition for artillery pieces in the United States began in the 1950's. The Americans fired the first artillery shell with a 10-15 Kt nuclear charge on 25 May 1953 from a 280-mm gun specially developed as a tactical means of employing nuclear weapons. Subsequently this gun, which was of great weight (85 tons) and had little mobility (it was towed by two prime movers) was taken out of service. The United States developed a 203-mm nuclear projectile with a yield of 2 Kt.

In November 1963 the Pentagon announced the development of a nuclear projectile for the 155-mm howitzer (yield about 1 Kt, range of fire 14,000 m). According to foreign press reports, the 155-mm nuclear projectile is packed in a container, in which it can be conveyed by all kinds of transport and dropped by parachute. The firing device is stored separately in the same container.

155-mm self-propelled howitzers M109 are also in service in the armies of West Germany, Belgium, Holland, Denmark, Canada and other countries.

Recently the M109 howitzer underwent modernization in the United States. In order to reduce the effect of firing on crew and vehicle, the barrel was lengthened 2.4 m (model M109E1).

Figure 56. American 175-mm self-propelled gun M107.

The American 175-mm self-propelled gun M107 (Figure 56) was developed on the special standardized chassis which is used for the 203-mm self-propelled howitzer M110, repair and evacuation vehicle M587, infantry combat vehicle XM701 and other purposes. The hull of the chassis is welded from armor steel plate.

The gun itself is set on a pedestal. The fighting compartment does not have armor protection. The driving compartment and power compartment (turbosupercharged 450-h.p. Diesel engine and hydromechanical transmission) are located in the front end of the hull. The running gear is constructed without track supporting rollers and the conventional idler wheel, the role of which is taken by the last bogie wheel. In the estimation of foreign specialists, this design makes possible a reduction in total height and weight of the vehicle, lowering of vibrations and noise, and decrease in the loss of power in the running gear. Suspension: individual, torsion.

Combat weight of the gun: 28.2 tons. Maximum speed of travel over roads: about 60 km/hr. Rated cruising range: approximately 700 km. Crew: six men.

The 175-mm self-propelled gun M107 is considered quite a maneuverable gun. It can negotiate ascents up to 31°, ditches 2.15 m wide, fords 1.2 m deep and vertical walls up to 1 m high. The gun is air-transportable by two airplanes: the chassis on one plane, the tipping parts of the gun on the other.

To give the gun stability during firing, two spades are attached to the rear end of the hull of the vehicle. They are raised and lowered by means of a hydraulic drive.

At projectile muzzle velocity of 915 m/sec, the gun fires projectiles weighing 67 kg for a maximum range of 32,000 m. The gun mount makes possible maximum traverse of 60° and angles of elevation from -2 to + 65°. The main laying drives are hydraulic; auxiliary drives: manual. Loading is effected from the ground with a special mechanism for lifting and ramming the projectile. The powder charge is put in a bag.

The 175-mm self-propelled gun M107 has been employed by American forces in Vietnam since December 1965. These guns are ferried across the ocean by military transport planes of the C-141 type. Regular transport of the guns is due to the necessity of keeping constant the combat ability of artillery chasti of the American army.

Experience in the combat employment of the M107 175-mm guns in South Vietnam has revealed an inadequate accuracy life of the barrels for heavy-charge firing. Excessive pressure of the powder gases necessary for long-range firing of heavy shells results in premature wear of 11.7-mm barrels. Under such conditions the barrel stands up for only 200-300 rounds instead of the 700 rated rounds. This leads to frequent barrel replacement (each barrel is worth $18,000).

Figure 57. English 105-mm self-propelled gun "The Abbot."

The English 105-mm self-propelled gun "The Abbot" (Figure 57) is intended for combat operations as part of highly mobile military chasti. It is the first self-propelled artillery system of British make for use in mobile operations. It has a barrel with a muzzle brake and a mechanism for the removal of powder gases after firing, semiautomatic vertical sliding-wedge breechblock, two hydraulic recoil brakes and a hydropneumatic recuperator.

The gun is accommodated in a rotating turret with all-round fire. Angles of elevation: from -5 to + 70°. The turret and gun are rotated by means of a manual mechanical drive. Both gun-layer and commander have traversing control levers.

The self-propelled gun is armor-plated (10-12 mm armor) and possesses amphibious capability (after being provided with special devices kept constantly with the gun). It is noted that the "Abbot" gun is adapted for operations in zones of radioactive contamination. It is hermetically sealed and supplied with air conditioning apparatus. The gun is also air-transportable.

Loading of the gun: separate case. Its unit of fire includes high-explosive fragmentation, armor-piercing, illuminating and smoke shells. Number of multisection charges: eight. Forty rounds are transported with the gun, and 1200 cartridges for the 7.62-mm machine-gun mounted on the commander's cupola. Under combat conditions the piece is serviced by a five-ton carrier, from which ammunition is fed directly to the gun.

The crew of the self-propelled gun consists of four men: commander, gun-layer, loader and driver.

A multifuel six-cylinder engine with vertical cylinder arrangement and automatic transmission are mounted on the gun chassis. Engine horsepower: 240.

The running gear uses tracks with rubber and metal hinges. There are five bogie wheels on each side. The wheels are twin with rubber tire setting.

Combat weight of the gun is 17 tons. Maximum speed of movement over land: up to 50 km/hr. Speed afloat: 5.6 km/hr. Rated cruising range: 480 km. The gun can negotiate the following obstacles: grade up to 30°; ditch up to 2.1 m wide; ford up to 1.2 m deep.

Maximum range of fire of gun: 15,000 m. Weight of projectile: 15.4 kg.

The Swedish Borors 155-mm self-propelled gun AKV-155 (Figure 58) differs from all the self-propelled guns here considered in that there is an automatic loading mechanism.

To feed projectiles to the gun, there is installed in the rear part of the gun turret a lifter with a crane arm, which is an integral part of the piece. When ammunition is unloaded from a motor carrier, the lifter takes from the vehicle a cassette with fourteen shells and inserts it in the magazine, which operates on the principle of utilizing the recoil of the barrel. There are seven compartments in the magazine, each of them holding two shells. Shells are fed one at a time into the shell tray which is mounted on a tipping mechanism under the magazine. The shell tray feeds a shell to the breech end of the barrel, and the slideblock seats it in the powder chamber of the piece. These operations are performed under the actuation of the cocked springs of the loading and ramming mechanism.

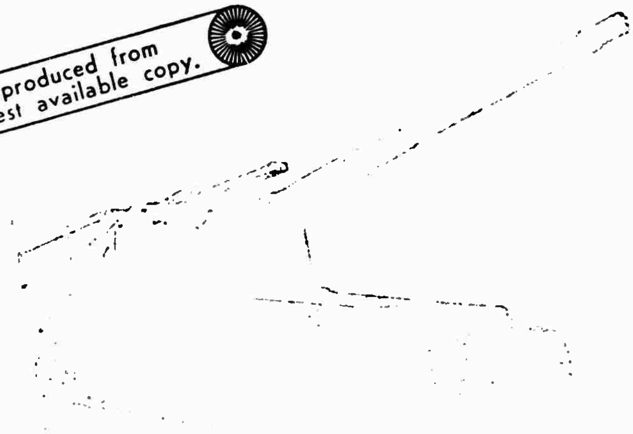


Figure 58. Swedish 155-mm self-propelled gun AKV-155.

The piece is capable of delivering not only single-shot, but also automatic fire. The entire basic load of ammunition (14 rounds) can be discharged in 45 seconds in automatic fire.

Basic performance characteristics of the 155-mm self-propelled gun: weight of projectile 47.6 kg; muzzle velocity 840 m/sec; maximum range of fire 24,700 m; angle of elevation from -5 to + 40°; maximum traverse 30°.

The gun is set on a tank chassis. Thickness of armor of the fighting compartment and magazine: 20 mm; of hull plate: 15 mm. Combat weight (with crew, fuel reserve and unit of fire): 49.2 tons.

There is a combination power plant on the chassis. It consists of a multifuel 240-h.p engine and a gas-turbine 330-h.p. engine, which can be used separately and independently of each other or together. Maximum speed of movement: 35 km/hr.

The gun is serviced by a seven-man crew. Four men are directly with the piece. They are accommodated in two compartments, which are protected against the penetration of radioactive dust.

Swedish designers encountered great technical difficulties in their attempts to automate the field self-propelled 155-mm caliber piece with a round weighing 85 kg. Therefore, over 10 years were taken to develop this gun, and it was not until 1965 that it went into service in the Swedish army.

Basic performance of some self-propelled guns of armies of capitalist countries are presented in Table 11.

Table 11

BASIC PERFORMANCE DATA FOR SOME SELF-PROPELLED GUNS OF ARMIES OF CAPITALIST COUNTRIES

A Образец орудия	B Вес снаряда, кг	C Наибольшая дальность стрельбы, м	D Боевой вес, т	E Запас хода, км	F Экипаж, человек
1 США					
2 105-мм гаубица M37	15	11 100	20,8	160	7
3 105-мм гаубица M52	15	11 100	24,5	170	5
4 105-мм гаубица M108	15	15 000	20,8	480	5
5 155-мм гаубица M41	43	14 800	19,3	[illegible]	12
6 155-мм гаубица M44	43	14 800	28,3	120	5
7 155-мм гаубица M109	43	18 500	23,6	350	5
8 155-мм пушка M40	45	22 000	36,8	170	8
9 155-мм пушка M53	43	23 100	44,4	270	6
10 175-мм пушка M107	67	32 000	28,2	760	6
11 203-мм гаубица M43	90	16 900	36,3	170	8
12 203-мм гаубица M55	90	16 900	42,6	260	6
13 203-мм гаубица M110	93	16 900	26,5	700	5
14 Англия					
15 87,6-мм гаубица-пушка «Би[illegible]»	11,3	12 200	18,0	220	4
16 87,6-мм гаубица-пушка «Сек[illegible]»	11,3	12 200	25,5	200	6
17 105-мм пушка «Аббот»	15,4	15 000	17,0	480	4
18 139,7-мм гаубица-пушка	45	15 700	50,0	200	6
19 Франция					
20 105-мм гаубица AMX-50	16	14 000	15,9	220	[illegible]
21 105-мм гаубица DE 105 CT	13–16	15 000	17,0	300	5
22 155-мм гаубица AMX-2D	43	21 000	17,0	300	7–9
23 Швеция					
24 155-мм автоматическая пушка AKV-155	17,6	24 700	49,2		4–7

Keys:

A. Gun model

1. U.S.
2. 105-mm howitzer M37
3. 105-mm howitzer M52
4. 105-mm howitzer M108
5. 155-mm howitzer M41
6. 155-mm howitzer M44
7. 155-mm howitzer M109
8. 155-mm gun M40
9. 155-mm gun M53
10. 175-mm gun M107
11. 203-mm howitzer M43
12. 203-mm howitzer M55
13. 203-mm howitzer M110
14. England
15. 87.6-mm gun-howitzer "The Bishop"
16. 87.6-mm gun-howitzer "The Sexton"
17. 105-mm gun "The Abbot"
18. 139.7-mm gun-howitzer
19. France
20. 105-mm howitzer AMX-50
21. 105-mm howitzer DE 105 CT
22. 155-mm howitzer AMX-2D
23. Sweden
24. 155-mm automatic gun AKV-155

B. Weight of projectile, kg

C. Maximum range of fire, m

D. Combat weight, tons

E. Rated cruising range, km

F. Crew, men

Let us consider the present state of self-propelled antitank artillery.

Since special antitank weapons require effectiveness in quite a wide range of fire, foreign military experts consider it unfeasible to develop a single general-purpose antitank weapon for all conditions under which combat operations are conducted. In their opinion, successful warfare against enemy tanks must be provided by well thought-out organization of a fire system of mutually complementary antitank weapons of various types. This includes antitank guided missiles, recoilless guns, and close-combat antitank weapons (rocket handguns and rocket launchers).

The tank is regarded as the best antitank weapon. However, in the opinion of foreign specialists, it is hardly a feasible task practically for even the economically most advanced countries to create the number of tanks which the troops need for this purpose.

Foreign armies follow the course of using all kinds of artillery up to 155-mm caliber inclusive for direct fire on armored targets with shaped-charge and armor-piercing shells. In addition, during the past decade definite attention has been paid to the development and adoption for service of specialized self-propelled antitank guns. The American, English, West German and other armies have such pieces.

The American 90-mm self-propelled antitank airborne assault gun M56 "Scorpion" is in service in the airborne troops.

The artillery part of the gun is set on a pedestal mount inside the hull of a special tracklaying chassis. The self-propelled gun as a whole is of the open unarmored type.

Structural peculiarities of the chassis: aluminum riveted hull; torsion suspension; bogie wheels with multiple-cord tires. The power compartment is located in the nose of the hull, and the driving and fighting compartments are in the rear. Engine horsepower: 205.

The light weight (7.5 tons), wide tracks and high specific power enable the Scorpion self-propelled gun to negotiate grades up to 31°, ditches up to 1.2 m wide, fords up to 1 m deep and vertical walls up to 0.75 m high. In addition, it is air-transportable.

The effective range of fire of this antitank gun is approximately 1500 m; maximum range of fire 18,100 m; muzzle velocity 930 m/sec; weight of projectile 10.8 kg. Angles of elevation: from -10 to + 15°; maximum traverse: 60°.

The 90-mm M56 Scorpion self-propelled antitank gun was a unique experiment, animatedly discussed by American military specialists. The opinion was expressed that the absence of armored protection for the crew and of machinegun armament raised a doubt regarding the advisability of employing the M56 self-propelled gun for the conventional infantry division. However, more detailed study of this machine and analysis of its capabilities showed that these shortcomings could be disregarded. The conclusion was reached that speed, mobility, light weight, low silhouette and other advantages make the M56 self-propelled gun an effective antitank weapon. The experience of developing this gun was taken into account in the creation of the 105-mm and 155-mm self-propelled howitzers.

The West German 90-mm self-propelled antitank gun "Jagdpanzer" was adopted for service in the Bundeswehr several years ago and is designated as a tank destroyer. It uses a special tracklaying chassis with turretless design of the hull, which is made of rolled armor plate.

In its interior ballistics and in the construction of many assemblies and parts of the piece (cradle, muzzle brake, recoil mechanism etc.), the Jagdpanzer gun resembles the American 90-mm gun, which is mounted on the M48 tank. Unified standard NATO ammunition is used for both guns.

Table 12

BASIC PERFORMANCE DATA OF SOME SELF-PROPELLED ANTITANK GUNS OF ARMIES OF CAPITALIST COUNTRIES

A Образец пушки	B Вес снаряда, кг	C Начальная скорость, м/сек	D Дальность действительного огня, м	E Наибольшая дальность стрельбы, м	F Боевой вес, т
1 Англия					
2 76-мм пушка «Арчер»	7,7	880	1000	11 200	18,0
3 США					
4 90-мм пушка М56 «Скорпион»	10,8	930	1500	18 100	7,5
5 ФРГ					
6 90-мм пушка «Ягдпанцер»	10,8	930	1500	18 100	23,0

Keys:

A. Gun model

1. England
2. 76-mm gun "The Archer"
3. U.S.
4. 90-mm gun M56 "Scorpion"
5. West Germany
6. 90-mm gun "Jagdpanzer"

B. Weight of projectile, kg

C. Muzzle velocity, m/sec

D. Effective range of fire, m

E. Maximum range of fire, m

F. Combat weight, tons

The Swiss Hispano-Suiza armored carrier HS-30, which is standard equipment in the Bundeswehr, is employed as chassis. The vehicle is supplied with an eight-cylinder 500-h.p. engine, independent torsion suspension, reversing gear which makes possible identical speeds forward and backwards, an air-conditioning system, filtering and ventilation equipment, optical instruments for observation and fire control by day and night, a radio set and interphone system, two 7.62-mm machineguns (one of them an antiaircraft machinegun), and eight smoke generators.

Foreign specialists note that the fact that there is an airtight armored hull and filtering and ventilation equipment assures protection of the crew (four men) against bullets and fragments and makes combat operations possible under conditions of radioactive terrain contamination. Favorable characteristics of the gun also include the low silhouette of the self-propelled piece. However, the weapon does not possess amphibious capability and cannot be dropped by parachute. Water obstacles are negotiable only by fording, and for this purpose it has exhaust inverted valves and a mechanism for shifting air feed to the engine.

The basic performance data of some self-propelled antitank guns of armies of capitalist countries are presented in Table 12.

The trend in the further development of field and antitank self-propelled artillery abroad is proceeding along the line of an increase in the fire power of armament and a rise in the rate of aimed fire, a lowering of crew size and maximum possible increase in the basic load of ammunition, a shortening of preparation time for firing, a rise in mobility and cross-country ability, provision of amphibious capability and air-transportability of pieces.

Foreign specialists believe that for self-propelled artillery prospects are good for a multifuel engine, capable of operating on gasoline, kerosene, diesel and other fuels. The advantages of such engines are obvious: rated cruising range increases, and fuel supply is simplified. The first series multifuel engines have been installed on the Swedish 155-mm and English 105-mm self-propelled guns.

Chapter VII

RECOILLESS GUNS, MORTARS AND ROCKET ARTILLERY

1. Recoilless Guns

Recoilless guns are classed with combined dynamic and reactive artillery systems, in which barrel recoil on firing is eliminated by the escape of powder gases through a nozzle in the breech end of a piece.

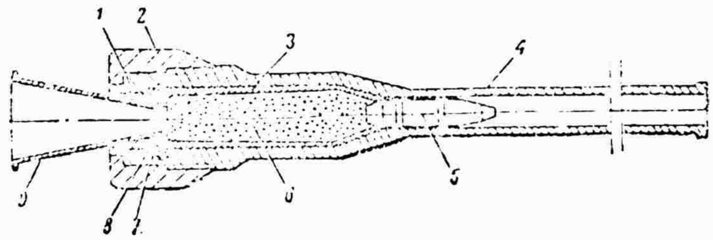


Figure 59. Diagram of construction of recoilless gun with central nozzle:

1) breechblock; 2) breech ring; 3) shell case; 4) barrel; 5) projectile; 6) powder; 7) adjusting ring; 8) sabot; 9) nozzle.

The operating principle of the recoilless gun is as follows (Figure 59). On firing, some of the powder gases rush through the nozzle in the opposite direction of the projectile's movement. A reaction force arises which is equal to the force of the powder-gas pressure on the base of the projectile. The size of the powder charge necessary to give a projectile the required muzzle velocity depends in a given case on the magnitude of the minimum area of nozzle cross section (or nozzle ports). This cross section is said to be critical.

The area of critical nozzle cross section is so selected that the impulse of the reaction force of escaping powder gases is equal to the impulse of the force of the gas pressure on the base of the projectile, whereby practical recoillessness of the barrel of the weapon is achieved. As a result, the need for recoil mechanisms (as in conventional pieces) or for base plates (as in the case of mortars) is obviated, and gun carriage weight sharply declines. In recoilless guns the carriage experiences practically no dynamic loads at the time of firing. It serves only to support the barrel and accommodate the pointing mechanisms.

Recoilless guns possess the following merits: relatively high power with light weight of system; simplicity of construction; high metal utilization factor. However, they are characterized by shortcomings too: the revealing effect of powder gases emanating from the nozzle; the existence of a danger zone behind the gun; high powder consumption; inconvenience in servicing.

Thus, it takes three to five times as much powder to fire a single round from a recoilless gun as it does from a conventional artillery weapon of approximately the same caliber and power although the pressure of the powder gases in the barrel of the recoilless gun is almost half. It is entirely impossible to eliminate these shortcomings. To eliminate the rearward escape of gases from the nozzle means abandoning the combined dynamic and reactive principle. Therefore, recoilless guns are employed when the requirements of lightness plus high power in a weapon are decisive.

It may not be amiss to discuss here the fundamental difference between reactive systems, on the one hand, and combined dynamic and reactive (recoilless) systems, on the other.

In reactive systems the propelling charge is located in the projectile itself, and its combustion takes place not only in the bore or on the launching guide, but also in trajectory.

In combined dynamic and reactive systems the propelling charge is located outside the projectile, and it burns in the bore prior to the exit of the projectile. The projectile moves along the bore as it does in the conventional rifled gun or mortar -- solely by virtue of the pressure of powder gases in the bore.

Recoilless guns are one of the new types of artillery weapons. In May 1923 Soviet Engineers L. V. Kurchevskiy and S. A. Izenbek were the first to propose the original design of the recoilless gun -- the combined dynamic and reactive gun, in which the rate of escape of powder gases was regulated by the nozzle. The nozzle had the shape of an expanding cone and was in the rear part of the barrel.

Recoilless guns underwent further development in the Soviet Union at the end of the 1920's and the middle of the 1930's. A special commission headed by Engineer V. M. Trofimov and later Professor Ye. A. Berkalov made a study of them. The design team of L. V. Kurchevskiy carried on especially intensive research in this field in 1932-1934.

By 1937 many models of recoilless guns for the ground forces, aviation and navy had been adopted for service or were in the final stage of development (37-mm antitank rifle RK, 76-mm battalion gun BPK, 76-mm high power gun, 76-mm aircraft cannon APK-4, 305-mm self-propelled field howitzer SPGK etc.). All pieces had rifled barrels, case loading, and breechblocks with a central nozzle. For the times they had fairly high performance characteristics. Thus, the 305-mm recoilless gun could fire a 250-kg projectile at muzzle velocity of 600 m/sec for a distance of 16,000 m.

Foreign armies had no recoilless guns in service at all prior to World War II. According to foreign press data, the first recoilless guns are believed to have been the German 75-mm guns M40 and 105-mm guns M40 and 42, which appeared in the German Fascist army in limited quantity during World War II for use in the airborne troops. Structurally, the German recoilless guns differed only slightly from our Soviet recoilless guns of the 1930's, but in their power and operational characteristics were somewhat inferior to them. There were no shaped-charge projectiles in the unit of fire of German recoilless guns. Therefore they did not gain acceptance.

The attitude towards recoilless guns changed radically in the middle of World War II when the use of shaped-charge projectiles in guns and howitzers began on a mass scale.

The shaped-charge projectile breathed new life into the recoilless gun. In the United States, for instance, the 57-mm and 75-mm recoilless guns M18 and M2C were adopted for service at the beginning of 1945, and the development of the 105-mm gun M27 began. In Japan the first experimental models of the 81-mm and 105-mm recoilless guns were manufactured at the end of World War II. Despite the inadequate refinements in the design of the recoilless guns of the war years the use of the combined dynamic and reactive principle and of the shaped-charge projectile made possible the development of a light and effective antitank weapon. Therefore recoilless guns underwent further development in many armies of the world in the postwar years.

Modern recoilless guns are in service in infantry, motorized-infantry and airborne podrazdeleniya. They are intended for the destruction of armored targets, the neutralization and annihilation of enemy personnel and fire weapons, and direct fire on the embrasures of earth-and-timber pillboxes. Shaped-charge projectiles (mortar shells) are fired at armored targets, and fragmentation or high-explosive fragmentation shells at personnel and fire weapons.

Calibers of modern recoilless guns are from 57 to 120 mm; weight in firing position 50-310 kg; armor-piercing ability up to 400 mm on the normal; point-blank range against tanks 400-800 m; and effective range of fire up to 1000-1500 m.

Recoilless guns are single- and multibarreled, towed, self-propelled and transportable in the body of a motor vehicle.

At present there are several versions of recoilless guns, differing from each other in design and external appearance.

The simplest type of recoilless gun is the widespread manual antitank grenade launcher. The barrel of the grenade launcher is a smooth-walled tube open at both ends. The sight and trigger-and-firing mechanism are mounted on the barrel. A shaped-charge or fragmentation mortar shell (grenade) is inserted in the barrel from the muzzle end. The weapon is fired from the shoulder or resting on a bipod, breastwork of a trench etc.

Antitank grenade launchers are considered one of the most powerful close-combat weapons. However, this still does not suffice for modern antitank defense. Grenade launchers are supplemented by antitank weapons with a greater range of action -- recoilless guns.

Figure 60 shows the general construction of the modern recoilless gun. The barrel is smoothbore or rifled. At its breech end is located the breechblock with one or more nozzle ports. A replaceable adjusting ring is inserted in the breechblock. Recoillessness of the barrel is practically completely provided by the selection of the size and shape of the nozzle adjusting ring, the size of the powder charge, weight of the projectile and strength of the sabot. The gun is loaded from the breech.

In firing from rifled recoilless guns the projectile is rotation-stabilized in flight. Nozzle ports are placed at a certain inclination, which creates a tangential component of the reaction force in the direction of the projectile's rotation, and that prevents spinning of the barrel. In some designs, in order to reduce the time and effort of engraving the rotating band of the projectile into the grooves of the barrel and in order to raise the efficiency of the charge, grooves are made on the rotating band of the projectile. However, this creates certain inconveniences in loading: it is hard to bring the projections of the band of the projectile into coincidence with the grooves of the barrel. As a result, loading time increases and the rate of fire decreases.

Figure 60. Construction of recoilless gun:

1) barrel; 2) sight; 3) protective shield; 4) nozzle; 5) breechblock; 6) wheeled running gear (in firing position); 7) mounting (tripod) with laying mechanisms.

To fire from smoothbore recoilless guns, mortar shells are used, which are fin-stabilized in flight.

A distinction is drawn between recoilless guns with case loading and those with caseless loading. A characteristic feature of the shell case is the numerous holes in its body and sabot for the escape of powder gases. Therefore, such a case is said to be perforated. Lest the powder run out, the holes in the case are closed with a thin film, and those in the sabot by a special forcing disk made of thick cardboard or plastic. The main function of the disk is to create a certain closed space during the first moment of firing. This assures ballistic stability and sounder use of the powder charge.

The perforated shell case reduces the discharge of powder particles through the nozzle and conduces to a certain rise in the charge utilization factor.

The charge is ignited by a primer cup or by means of electric igniters. In recoilless guns with a central nozzle the primer cup is not placed at the rear, as in rounds for conventional guns, but at the side.

In caseless loading the powder charge is placed on the long tube of the mortar shell stabilizer. Short nozzle ports permit the use of central instead of lateral ignition. Central and simultaneous ignition of the entire charge assures the stability of its combustion at relatively low powder-gas pressures under normal, low, and high temperature conditions.

At present, improvement of the design of recoilless guns continues abroad. Above all, designers are attempting to raise the rate of fire. There have been attempts to design semiautomatic guns and guns without breechblocks. Recoillessness is achieved in different ways with these experimental models. In the former, the energy of the powder gases was used to unlock the breechblock and eject spent shell cases; in the latter (case and caseless loading) the diameter of the critical nozzle cross section after loading was found to be somewhat less than the diameter of the barrel. For this reason the nozzle was made up of spring-mounted sectors, which traveled in diametric and longitudinal directions. During loading, as the projectile (in this case, finned) passed into the powder chamber, it shifted the sectors forward with its ogive, increasing the nozzle diameter. After loading, the sectors under the action of the springs reduced the diameter of the critical nozzle cross section to the necessary size.

It is thought that such design does not provide stable ballistic characteristics or, hence, a sufficiently close pattern of shooting since nozzle diameter can vary during firing (dirt, powder particles, scale, and grease get in between sectors and the inside nozzle surface).

In some designs of recoilless guns the shell case is immobilized during firing by means of check stoppers which, under the influence of the powder gases, enter the grooves of the base of the case, or by using a fluted shell case which, under the influence of the powder gases, presses against the fluted inside surface of the barrel. When the gas pressure drops, the shell case is released and ejected to the rear.

A fairly large variance in the muzzle velocities of recoilless guns impairs the accuracy of fire. This is due to the fact that from round to round the amount of powder burned and discharged through the nozzle varies. To prevent the discharge of unburned powder particles through the nozzle, there have been developed, for example, pre-nozzle chambers with grates or special "pockets" in the rear end of the barrel. In some gun designs, in order to improve ballistic characteristics, replaceable brasses are used during firing under varying temperature conditions. However, replacement of the brasses under combat conditions takes a great deal of time.

Recoilless guns are sometimes called (and not without reason) "powder eaters." Therefore designers strive to raise the efficiency of the powder charge, i.e. create conditions under which the greatest part of the charge will be used for imparting motion to the projectile and the least part for creating the reaction force which eliminates recoil during firing. One of the technical solutions is simultaneously to "fire" a projectile forwards and some massive (inertial) body backwards from the recoilless gun.

A body flying backwards at high speed may inflict injury on friendly troops. Therefore, in some designs this body is a pressed powderlike substance with great specific gravity. In order for it to disintegrate completely during firing, a sharp jump in the pressure of the powder gases in created in the powder chamber. At first the powder gases partially escape into the bore through special openings (in front of the projectile). As soon as the projectile begins to move forward and these openings are covered over by the shell body, the powder-gas pressure sharply increases, the inertial body disintegrates and its residues are discharged to the rear. Although such a design gives a constant muzzle velocity, it does not assure complete recoillessness of the gun since the beginning of the projectile's motion does not coincide with the beginning of the escape of the powder gases through the nozzle.

Fire positions for recoilless guns also have their specific peculiarities. At the moment of firing powder gases, individual particles of unburned powder and residues of the disintegrated forcing disk fly out from the breech end of the barrel, and a danger zone up to 25-50 m deep and up to 20 m wide is created behind the gun. Therefore, concealed routes of approach for ammunition supply are located to the right and left of the gun, rather than behind. In the danger zone there must be no ammunition or readily inflammable objects (for example, hay, straw etc.), and there must be no vertical walls within 5-7 m behind the gun. The distance between adjacent recoilless guns is so selected that, whatever the angles of deflection, within their assigned sector of fire gun crews are not caught in the danger zone of adjacent guns.

Intensive firing from recoilless guns increases the crew's fatiguability. For ear protection special helmets are employed.

Various technical solutions have been suggested and tried out in order to reduce the danger zone behind a recoilless gun. For example, in England a design of a recoilless gun was developed at the beginning of the 1960's, the basic advantage of which was believed by its authors to be the almost total absence of a danger zone. The ballast scheme of the piece envisaged two barrels, with dynamic balancing achieved here by "countershooting" from the rear barrel, which was placed at an angle to the forward (combat) barrel. A special spade absorbed the force of the recoil resulting from the oblique positioning of the forward and rear barrel. The ballast fired from the rear barrel was lead shot enclosed in a jacket. The jacket opened up behind the gun at an altitude of 15-20 m and descended to earth with the help of a miniature parachute.

At present, recoilless guns are in service in the antitank artillery of almost all the armies of the world. For example, in the United States, West Germany, Canada, Italy and other NATO countries they are the 106-mm recoilless guns of American make, in England the 120-mm, in France the 75-mm, and in Sweden the 90-mm. The 57, 75 and 105-mm recoilless guns, dropped from service in the American army, have been passed on to the armies of the many countries receiving military assistance from the United States.

Modern recoilless guns, with rare exception, are not classed among towed systems. They are self-propelled or are transportable in the body of a motor vehicle (armored carrier).

The need to have in service compact, light and mobile antitank weapons, suitable for operations in infantry battle formations, has led to the creation in the armies of the capitalist states of a whole series of self-propelled mounts equipped with recoilless guns. The changeover to self-propelled recoilless guns was also occasioned by the fact that with the increase in caliber and power, the weight of the barrel of a piece naturally rises too, which in turn causes a corresponding growth in the weight of the carriage -- the weight of the carriage appreciably increasing with the increase in the speeds of transport. If we take into consideration that it is practically impossible to limit the towing speed of guns, under modern conditions relatively great weights of gun carriages must be anticipated. As a result the weight of a recoilless gun on a wheeled carriage becomes so great that the piece can no longer be regarded as light and maneuverable for a three- or four-man crew. Thus, the basic advantage of the recoilless gun as an infantry direct-support fire system is quickly lost with an increase in caliber and power. However, when recoilless guns are mounted on vehicles, the limits of the practical power and calibers of recoilless guns expand significantly. At the same time, in most cases the possibility is provided of delivering fire both from the vehicle and from the lightest possible mounting (of the tripod type), on which the gun is mounted for ground fire.

Basic performance data of some recoilless guns of the armies of the capitalist countries are presented in Table 13.

Table 13

BASIC PERFORMANCE DATA OF S'ME RECOILLESS GUNS OF ARMIES OF CAPITALIST COUNTRIES

A Образец орудия	B Вес снаряда, кг	C Начальная скорость, м/сек	D Дальность действительного огня, м	E Вес в боевом положении, кг
1 США				
2 57-мм безоткатное орудие M18	1,2	365	До 500	42,3
3 75-мм безоткатное орудие M20	6,5	305	До 1000	72
4 105-мм безоткатное орудие M27	13,3	380	До 1200	632
5 106-мм безоткатное орудие M40A1	7,9	500	До 1500	216
6 106-мм шестиствольная самоходная установка — истребитель танков M50 «Онтос»	7,9	500	До 1500	8300
7 Англия				
8 120-мм безоткатное орудие «Бат»	12,8	470	До 1400	997
9 120-мм безоткатное орудие «Мобат»	12,8	470	До 1400	730
10 120-мм безоткатное орудие «Вомбат»	12,8	470	До 1400	295
11 Франция				
12 75-мм безоткатное орудие M50	6,35	275	До 1000	75,7

Keys:

A. Gun model

1. U.S.
2. 57-mm recoilless gun M18
3. 75-mm recoilless gun M20
4. 105-mm recoilless gun M27
5. 106-mm recoilless gun M40A1
6. 106-mm six-barreled self-propelled mounting-tank destroyer M50 "Ontos"

7. England
8. 120-mm recoilless gun "Bat"
9. 120-mm recoilless gun "Mobat"
10. 120-mm recoilless gun "Wombat"
11. France
12. 75-mm recoilless gun M50

B. Weight of projectile, kg

C. Muzzle velocity, m/sec

D. Range of effective fire, m

2-6, 8-10, 12. Up to . . .

E. Weight in firing position, kg

Let us consider a few models of modern recoilless guns.

The American 106-mm recoilless gun M40A1 has a rifled barrel with screw-type breechblock. Four nozzles are made in the breechblock for the escape of powder gases to the rear. The barrel is connected to a tripod mount by rapid-action coupling. Weight of the piece in firing position: 216 kg.

Fire is delivered from the piece at firing elevations from -17 to + 55°; maximum traverse: 360°.

The 106-mm M40A1 recoilless gun is equipped with a 12.7-mm spotting gun, which is above and parallel to the gun barrel. Before opening fire on a target from the piece, the gun is registered by tracer bullets from the spotting gun. When the spotting gun hits the target, a round is fired from the piece and simultaneously a burst of tracer-bullet fire. In the opinion of foreign specialists, this procedure of fire delivery significantly shortens the time required for laying the gun, increases the probability of hitting the target with the first round, and avoids premature disclosure of the gun. The trajectory of a bullet coincides with the trajectory of a projectile at low elevations, and rounds from the spotting gun and the piece are fired by the same lever.

For direct laying fire an elbow telescopic sight is used, and for indirect laying fire a panoramic sight. The unit of fire of the piece consists of fixed rounds with a steel perforated case and non-rotating finned shaped-charge projectile weighing 7.9 kg with muzzle velocity of 500 m/sec. The gun also fires rotating high-explosive fragmentation and smoke projectiles.

The gun crew consists of three men (gun commander, gun-layer and loader), but one gunner can service it.

The 106-mm M40A1 recoilless gun is transportable in the body of a prime mover, and there also exists a self-propelled version mounted on a quarter-ton motor vehicle or armored carrier. In the latter case the gun can deliver all-round fire directly from the motor vehicle without changing its position. If necessary, the gun is removed from the motor vehicle for ground firing.

Recently the M40A1 gun was adopted for service in the Bundeswehr.

The 106-mm self-propelled mount-tank destroyer M50 "Ontos" is in service in the U.S. Marine Corps as an antitank weapon. In the execution of landing operations the mount must come ashore with the first marine echelons and, after a base of operations is taken by the landing force, repel the attack of enemy tanks.

Six 106-mm M40A1 recoilless guns with four 12.7-mm spotting guns and one 7.62-mm machinegun are accommodated on top a tracklaying vehicle. The guns are mounted three on the right and three on the left on a special bracket attached to the turret of the vehicle. The laying mechanisms of the gun mount are equipped with manual drives. Elevations from -10 to $+20^{\circ}$; maximum traverse 80°.

Fire is delivered by one or two guns or by a volley simultaneously from all six guns. For ground firing it is permissible to remove two guns from the self-propelled mount. Reloading of the guns is accomplished under cover.

The basic load of ammunition of the Ontos M50 self-propelled mount is 18 rounds for the six guns, 80 cartridges for the four 12.7-mm spotting guns and 1000 cartridges for the 7.62-mm machinegun.

In comparing the advantages and disadvantages of recoilless guns, foreign military specialists rate highly the great mobility of self-propelled mounts, which makes it possible to provide powerful surprise and accurate fire at the most crucial moments of battle and constant readiness to open fire since the piece, combat crew and the specified amount of ammunition are always together.

In foreign armies the following basic trends have been distinguished in the further development of recoilless guns: increase in power by an increase in gun caliber (57 mm in 1945 and 106-120 mm nowadays); increase in point-blank range and of effective range of fire against tanks to 1500-2000 m; increase in armor-piercing capability through the use of nonrotating shaped-charge projectiles and the employment of copper hollow cones (from 70 mm according to 1945 norms to 300-400 mm at present); wide use of high-strength steels and light alloys for the purpose of maximum gun weight reduction; increase in the maneuverability of guns by mounting them on wheeled or tracklaying chassis of increased cross-country ability.

The relatively low pressures of the powder gases in recoilless guns creates the prerequisites for a further reduction in the weight of barrels. In the United States, for example, preparatory work recently began on the production of barrels for recoilless guns made of plastic materials in combination with fiberglass.

2. Mortar Armament

Mortars are indispensable fire weapons for infantry and tank support and escort and for the destruction of enemy personnel and combat materiel in the immediate vicinity of friendly troops.

The main combat characteristics of mortar armament are great fire power, high rate of fire, simplicity of construction and combat employment, constant readiness for immediate opening of fire without special preparation, dependability and reliability of operation under any climatic conditions in any season of the year and at any time of day. The important merits of mortars are the great curvature of the flight trajectory of mortar shells, which permits the annihilation of concealed targets that are invulnerable to rifle, machinegun and flat-trajectory artillery fire, as well as the possibility of wide employment under broken and difficult terrain conditions. Therefore, mortars have a firm place in the armament system of modern armies of all countries.

The first mortar in the world was created in September-October 1904 by the heroic Russian defenders of Port Arthur during the Russo-Japanese War. Since that time mortars have come a long way in combat and have become a formidable weapon tested in two world wars. In our day the high combat effectiveness of mortar armament has been conclusively demonstrated by the able fighting men of the South Vietnamese armed forces of national liberation in the struggle against the American aggressors.

The commonest mortar calibers in modern armies are 81 and 120 mm. The basic structural design of these mortars is the same: smooth barrel -- bipod or mounting -- base plate, muzzle loading. The American 106.7-mm mortars with rifled muzzle-loading barrels constitute an exception.

120-mm caliber is the highest caliber of mortar armament in the armies of almost all the capitalist states. Foreign military specialists believe that development of mortars of higher caliber than 120 mm will become possible only on successful solution of the problem of increasing the range of mortar fire to the level of howitzers of corresponding calibers. The sole foreign army which has heavy mortars is the Israeli army, which the Zoltam Company supplies with 160-mm mortars.

The basic principles of mortar construction were set forth in Chapter IV of this book. Let us consider the performance characteristics and distinctive features of the designs of some models of modern mortar armament in foreign armies.

The American 81-mm mortar M29 is produced in a portable version and is disassembled for transport into three pieces: barrel 12.7 kg, bipod-mount 14.1 kg, and base plate 21.8 kg. The mortar has a smooth barrel and fires finned mortar shells.

Rifling is made in the outer surface of the barrel in order to increase the cooling area during intensive firing.

The base plate consists of an inside and outside. This makes possible all-round fire without moving the plate itself.

The maximum rate of mortar fire during the first minute is not more than 27 rounds, and during continuous firing four rounds per minute.

In firing the 81-mm M29 mortars in South Vietnam the American army uses high-explosive fragmentation mortar shells of both the old and new type. The maximum range of fire with the old mortar shell is 3600 m.

The new mortar shells have special obturators, which separate after the mortar shell leaves the barrel. They have an improved fin design, which increases the grouping of shots. The wings of the stabilizer are made of aluminum alloy and are placed at an angle of 5° to the plane of symmetry of the mortar shell. As a result, the mortar shell in flight receives a certain rotatory motion.

The new high-explosive fragmentation mortar shell weighs 4.13 kg. Nine increments make it possible to vary muzzle velocity from 64 to 264 m/sec and provide a range of fire from 75 to 4700 m.

In the French army 120-mm mortars are the basic regimental fire weapon of infantry support. Constant attention is given to improvement of models of this caliber. Several modifications of the 120-mm mortars are known.

The 120-mm mortar M51 (weight of mortar shell 13 kg, range 6600 m, weight 500 kg) has nondetachable wheeled running gear which serves as mount. During firing the suspension of the running gear is disconnected and the wheels are braked.

The 120-mm mortar M60 (weight of mortar shell 13 kg, range 7100 m, weight 80 kg) is manufactured in the main of high-strength steels. Therefore, it is more than six times as light as the M51 mortar. The range of fire is increased through the employment of rocket-assisted mortar shells. The reactive charge switches on after the mortar shell leaves the bore and burns for 5 sec.

The 120-mm mortar MO-120-RT-61 (weight of shell 13 kg, range 6700 m, weight 434 kg) has detachable wheeled running gear with bullet-proof tires and can be towed by a light motor vehicle on the road at a speed up to 50 km/hr. Firing is conducted directly from the wheeled running gear or from a bipod. Firing elevation: from 40 to 80°; traverse: 360°. The mortar is serviced by a six-man crew, including the vehicle driver.

The 120-mm mortar MO-120-60 (weight of shell 13.6 kg, range when firing conventional mortar shell 3600 m, when firing rocket-assisted shell 6550 m, weight 91.5 kg) is similar in design to the 81-mm mortar MO-81-61. Therefore, it takes only a few hours to re-train crews.

When the mortar is set up in a fire position, the initial angle of elevation is taken into consideration for firing. If it is less than 60°, the base plate is braced in the ground.

For transport purposes the mortar is disassembled into three basic parts (Figure 61): barrel 34 kg, bipod 24.9 kg, and base plate 32.6 kg. The light weight of the mortar permits it to be transported in motor vehicles and on pack animals, as well as to be carried manually across country. A mortar shell is extracted from a watertight container immediately before use. Depending on the range of fire, the loader puts the required number of increments (seven in all) into the stabilizer tube containing the base charge. The fuze of the mortar shell can be set for instantaneous or delayed action.

Some mortars of the French army are set on armored carriers or armored cars and they become self-propelled. For example, two modifications of 60-mm self-propelled mortars have been created on the basis of the Panhard armored car. One of these has a 60-mm mortar and two 7.62-mm machineguns with unit of fire of 53 mortar shells and 3800 cartridges, while the other has a 60-mm mortar and a 12.7-mm machinegun with unit of fire of 41 mortar shells and 1200 cartridges.

Basic characteristics of some mortars of American, English and French armies are presented in Table 14.

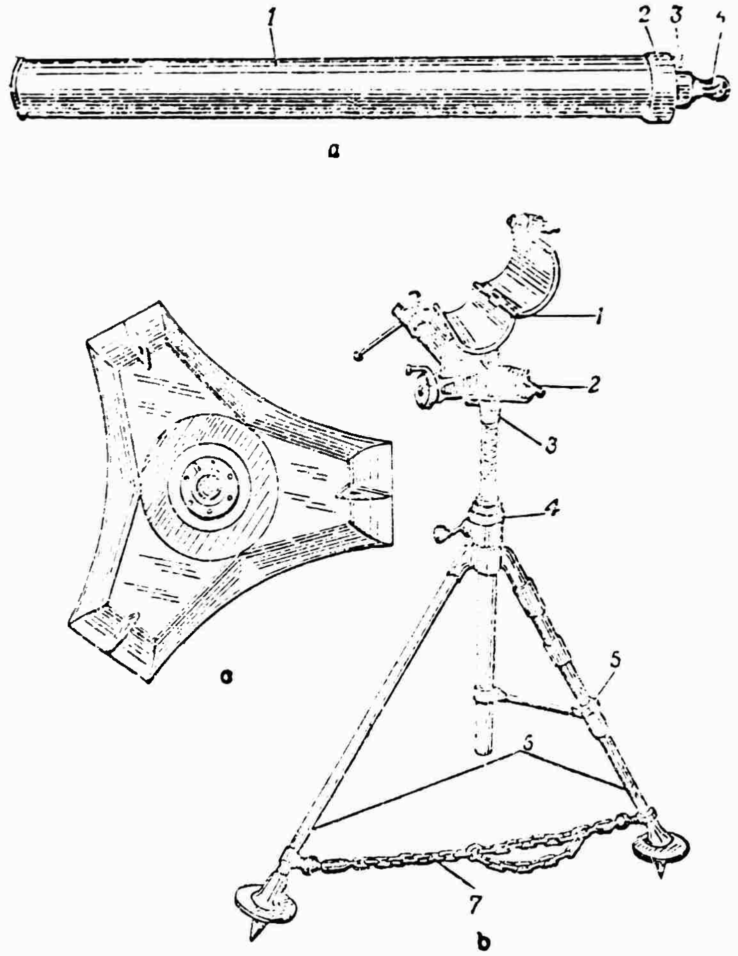


Figure 61. French 120-mm mortar MO-120-60:

a) construction of barrel: 1) tube of barrel; 2) breech ring; 3) firing mechanism; 4) lower rounded end of mortar tube; b) bipod mount: 1) yoke and shock absorber; 2) traversing mechanism; 3) site for attaching sight; 4) elevating mechanism; 5) leveling mechanism; 6) bipod; 7) chain; c) base plate.

Table 14

BASIC PERFORMANCE CHARACTERISTICS OF SOME MORTARS OF ARMIES OF CAPITALIST COUNTRIES

A Образец миномета	B Вес мины, кг	C Дальность стрельбы, м	D Вес миномета, кг
1 США			
2 81-мм миномет M29	4,13	3600–4700	48,6
3 106,7-мм миномет M30	12,0	5500	259–320
4 Англия			
5 81,5-мм миномет Mk2	4,5	2500	57
6 81-мм миномет L1A1	4,3	4100	31,5
7 106,7-мм миномет Mk2	9,0	3700	125
8 Франция			
9 60-мм миномет «Брандт»	1,35	1900	19,4
10 81-мм миномет образца 1944/61 г.	3,5	3700	41,2
11 81-мм миномет MO-81-61C	3,25–4,3	4100	38,5
12 81-мм миномет MO-81-61	3,25–4,3	5000	40,5
13 120-мм миномет M51	13	6600	500
14 120-мм миномет M60	13	4700–7100	80
15 120-мм миномет MO-120-RT-61	13	6700	434
16 120-мм миномет MO-120-60	13,6	3600–6550	91,5

Keys:

A. Mortar model

1. U.S.
2. 81-mm mortar M29
3. 106.7-mm mortar M30
4. England
5. 81.5-mm mortar Mk2
6. 81-mm mortar L1A1
7. 106.7-mm mortar Mk2
8. France
9. 60-mm m\u0063rtar "Brandt"
10. 81-mm mortar M1944/61
11. 81-mm mortar MO-81-61C
12. 81-mm mortar MC-81-61
13. 120-mm mortar M51
14. 120-mm M60
15. 120-mm mortar MO-120-RT-61
16. 120-mm mortar MO-120-60

B. Weight of mortar shell, kg

C. Ranfe of fire, m

D. Weight of mortar, kg

In the opinion of foreign specialists, the following basic trends are clearly distinguished in the development of mortar armament in recent years:

increase in the maximum effective range of mortars, specifically through the employment of rocket-assisted mortar shells;

increase in power and effectiveness of action of mortar shells at target and improvement in grouping of shots;

weight reduction of mortars by virtue of the extensive introduction of titanium, aluminum and magnesium alloys and high-strength steels;

increase in maneuverability by the development of self-propelled mortar mounts;

improvement of performance characteristics (reliability, accuracy life, simplicity and convenience of servicing, safety in handling);

provision of all-round fire without repositioning the base plate;

use of mortar barrels and ammunition in combination weapons.

3. Combination Weapons

It is known that every variety of artillery armament has its valuable characteristics and, at the same time, certain shortcomings. The question occurred to designers whether the merits of various types of guns could not be taken while avoiding the shortcomings if possible. Thus the idea of creating combination weapons sprang up.

Many instructive examples along this line are known in the experience of Soviet artillery armament design. Mention has already been made above of the Soviet 152-mm gun-howitzer M1937, in which our designers found the optimum combination of howitzer and gun characteristics.

In foreign armies work has long been under way on the development of combination arms by combining designs of guns and howitzers (for example, English weapons), mortars and howitzers, mortars and heavy mortars (mortira), howitzers and recoilless guns etc. Let us consider some models of combination weapons.

The American 115-mm combination weapon "The Moritzer" XM70 (Figure 62) combines characteristics of the howitzer and mortar. Hence the name "Moritzer" -- the first part of the word "mortar" and the latter part of the word "howitzer." In the opinion of foreign specialists, the Moritzer is a good type of U.S. Marines weapon for combat during a landing.

The weapon is rifled, automatic and a six-shooter. It is a breech-loader rather than a muzzle-loader. Automatic fire is provided by two cassette which rotate like the cylinder of a revolver. Rate of fire: six rounds in 2.5 sec. Bursts or single shots are fired.

The recoil mechanism consists of two hydraulic recoil brakes and a hydropneumatic recuperator.

Figure 62. American 115-mm combination weapon "Moritzer" XM70

The gun mount has a top and bottom carriage, trails, bottom plate and jack for lowering and lifting it, wheeled running gear with suspension system. Firing elevations: from -6 to + 75°; traverse: 40°.

Maximum range of fire (16,000 m) is provided by a rocket-assisted projectile. A conventional projectile weighing about 20 kg is fired for a distance of 9000 m.

In the opinion of American specialists, the Moritzer weapon has succeeded in preserving the basic advantages of the mortar as a powerful high-angle weapon and simultaneously in increasing the range of fire. The foreign press notes that the gun is the most significant achievement in the development of American cannon-type artillery in the last 20 years. It is superior to all existing American 105-mm howitzers in basic performance characteristics.

For ground forces the Moritzer weapon is being developed in a self-propelled version (total weight together with chassis more than 7000 kg).

The American 106.7-mm howitzer-mortar "Howtar" M98 is in service in the American marines who are interested in a light but effective direct-support weapon combining the advantages of the mountain howitzer with the accuracy of fire and mobility of the mortar. Its design is based on the barrel of the 106.7-mm mortar set on the improved carriage of the 75-mm mountain howitzer.

The name "Howtar" is compounded from the first part of the word "howitzer" and the latter part of the word "mortar."

Favorable characteristics of this combination weapon, in the opinion of foreign specialists, are: large caliber and adequate effectiveness of fire (weight of projectile 11.8 kg instead of 6.6 kg for the 75-mm howitzer, weight of explosive 3.6 kg and 0.68 kg respectively); light total weight (585 kg); transportable by air, on vehicles and pack animals, and manually for short distances. The maximum range of fire 5400 m is the same as for the 106.7-mm mortar, from which the barrel and ammunition are borrowed.

In 1969 the United States developed an experimental model 105-mm combination gun XM 193 consisting of a rifled barrel similar to the barrel of the towed 105-mm howitzer M102, a round base plate of the mortar type, and a two-wheeled carriage. This weapon can deliver high-angle fire for howitzer ranges with dispersion characteristics close to corresponding howitzer characteristics. The weight of the system is approximately one-third that of the M102 105-mm howitzer. It will be towed by a quarter-ton motor vehicle or lifted by helicopter.

It is noted that the new experimental model for the time being is utilized to test, evaluate and confirm the soundness of ideas for the design of a direct-support weapon for the troops.

The new American "Sheridan" light reconnaissance tank employs yet another variety of combination weapon. A short-barreled 152-mm gun-launcher is mounted in the rotating turret of the tank. It can fire conventional 152-mm shaped-charge projectiles at armored targets at short range. The barrel serves simultaneously as a luncher for firing the "Shillelagh" antitank guided missile.

The examples cited do not exhaust the possibilities for the creation of combination weapons.

4. Field Rocket Artillery

On 14 July 1941 at 1515 hours the first battery of field rocket artillery in the world, under Captain I. A. Frelov, struck a powerful artillery blow against the railway junction in the city of Orsha in Belorussia. In several seconds about a hundred rocket projectiles fell on the Fascist echelons with their troops, equipment, ammunition, and fuel concentrated at the station. Hundreds of Hitlerite soldiers and officers met their death in this tornado of fire.

Such was the baptism of fire of the new Soviet weapon -- the famous guards' mortars fondly called "Katyushas."

The development of rocket armament was a great achievement of Soviet scientific and design thinking. It was preceded by years of persistent work by Soviet scientists and designers. They carefully studied and fully utilized the experience accumulated by Russian scientists and practitioners of rocketry in the past.

The great Russian scientist K. E. Tsiolkovskiy made an invaluable contribution to the development of the theory of rockets and reaction propulsion. At the very dawn of the Soviet regime during the difficult years at the beginning of the reconstruction of the national economy the Communist Party and the Government gave much attention to the development of rocketry. A striking proof of this is the Soviet Government's decree of 9 November 1921 creating conditions for K. E. Tsiolkovskiy to work on rockets.

The work of K. E. Tsiolkovskiy and other scientists, as well as the success achieved by our country in the development of science and technology opened up wide possibilities for the expansion of further research on the creation of rocket armament.

Why was the question of the development of rocket artillery raised with such urgency in the very first years of Soviet power? First, the experience of conducting large-scale maneuver operations during the civil war and the ever increasing rate of troop motorization necessitated a sharp rise in the maneuverability of artillery. Second, the reaction engine in principle made it possible to eliminate the effect of recoil during firing and therefore to get rid of cumbersome carriages and barrels made of expensive and scarce steel. Finally, the simplicity of construction and the light weight of rocket-projectile launchers enabled them to be mounted on motor vehicles, tanks, aircraft and ships.

At first there were many difficulties. The young Soviet state had of course received neither industrial base nor scientific centers for rocket armament design from Tsarist Russia. Substantially all questions regarding the design, production and employment of rocket armament had to be solved by our scientists and designers anew.

Extensive theoretical and experimental investigations and intensive creative work yielded the first practical results: in 1927 the first 82-mm rocket projectile in the world was developed, and later the 132-mm projectile.

In 1938 Soviet designers put forward the fundamentally new idea of creating a multiple launcher for conducting salvo fire. Much labor was invested in the development of launching guide design and methods of igniting rocket charges.

The design of rocket projectiles changed too. They already differed significantly from their aircraft predecessors, having a considerably heavier weight of explosive and an increased maximum effective range.

The launcher for firing salvos of the new rocket projectiles was original in construction, simple and convenient. It consisted of guides of the rail type united into a single package by side members, a barbette carriage, and elevating and traversing mechanisms. Before firing, projectiles were fastened to the launching rails. The launcher was pointed at the target with the help of the sight, elevating and traversing mechanisms. The salvo was fired by closing an electric circuit by means of an instrument in the driver's cab.

In June 1939 a multiple launcher, which subsequently received the designation BM-13, successfully passed proving ground tests. By the beginning of 1941 plants had manufactured 11 combat launchers set on the chassis of three-axled motor vehicles. During tests with the troops they showed their good combat characteristics: the necessary mobility; maneuverability; capability of creating massed salvo fire for several seconds. The range of fire of projectiles was brought up to 8500 m.

In February 1941 the Soviet Government adopted a decision regarding the factory production of the BM-13 launchers, which had 24 launching rails, and later of the new launchers designated BM-8.

In June 1941 the rocket launchers received a high evaluation from party and government leaders. On 21 June 1941, the day before Fascist Germany's attack on the Soviet Union, a decision was made to develop field rocket artillery in every way possible and immediately to establish series production both of rocket projectiles and the combat vehicles for launching them.

Soviet scientists and designers were the first in the world to create multiple salvo rocket launchers possessing high maneuverability. The thunder of the bursting shells of Captain I. A. Flerov's battery at the beginning of the Great Patriotic War announced that a formidable force -- rocket artillery -- had made its appearance on battlefields.

Soviet industry quickly ironed out the production of rocket projectiles and launchers. One after another rocket artillery chasti went to the front. In November 1941 already about 45 Katyusha divisions were operating on the front. Rocket artillery chasti were awarded the title of guards' chasti. This emphasized their special significance and the exceptionally high responsibility of personnel for keeping the new weapon a military secret. For the Hitlerites made desperate attempts to capture, or at least destroy, the "hellish meat grinders," as they called the "Katyushas."

The BM-13 and BM-8 rocket systems from the very first days of the war meritedly gained the renown of a powerful weapon and played a great role in the "fire budget" of our artillery since they possessed good mobility and the capability of making surprise fire assaults on the enemy and had a strong demoralizing effect.

In their performance characteristics Soviet multiple salvo rocket launchers far excelled the rocket artillery models which appeared abroad during and after the war. For example, German launchers, mounted on field carriages, were comparatively heavy and less convenient in combat. The effectiveness of the fire of the German six-barreled mortar was half that of the Soviet BM-13 rocket launcher. The Germans themselves were compelled to recognize that trailer launchers were far inferior to Soviet self-propelled rocket launchers, especially in maneuverability and magnitude of salvo.

In the United States field rocket artillery began to develop from 1942 on. During World War II the American army had in service 114.3-mm and 182-mm rocket systems, which in their combat characteristics were inferior to Soviet models.

In the postwar period field rocket artillery became popular in many foreign armies. There are salvo rocket systems in the United States (114.3-mm, 115-mm), England (114.3-mm, 127/76-mm), France (150-mm), Italy (100-mm), Switzerland (80-mm, 80/100-mm) and other countries. They are designed for firing chemical, high-explosive fragmentation, high-explosive, shaped-charge and smoke projectiles for distances up to 8-15 km. Launching devices are set on motor vehicles, armored carriers, and two-wheeled mounts or are themselves launching carriages.

In their construction rocket artillery launchers differ essentially from the customary designs of artillery weapons or mortars although they have a number of assemblies and components in common.

Modern self-propelled rocket launchers consist of artillery parts and running gear.

The artillery parts include a cluster of a certain number of barrels, a barbette carriage, pedestal, elevating and traversing mechanisms, equilibrator, electric equipment, sighting mechanisms, and special equipment for the running gear.

The running gear is the chassis of an army cross-country vehicle. All basic components and assemblies of artillery parts are mounted on side members of the chasis.

The barrels are designed to guide the flight of a rocket projectile. They are arranged in several rows parallel to each other.

The cluster of barrels is attached to a barbette carriage and can move in the vertical plane, i.e. it is the tipping unit of the launcher.

The barbette carriage serves for movement of the cluster of barrels in the horizontal plane. On it are located the elevating and traversing mechanisms and equilibrator, as well as the sight. The barbette carriage is mounted on a pedestal and is the rotating unit of the launcher.

The pedestal is the support for the rotating unit and is attached to the underframe, which is securely connected to the side members of the chassis.

The laying mechanisms are practically no different from the corresponding mechanisms of artillery pieces.

The electric equipment is intended to ignite the powder charge of rocket projectiles. It consists of storage batteries, firing apparatus, portable coil and cables. Electric current is fed from storage batteries to the firing apparatus mounted in the cab of the vehicle, and thence via cables to the barrel contacts. The current goes hence to the shell-igniter contact. The portable coil is used during firing from cover tens of meters away from the launcher.

The sighting mechanisms include the sight, panoramic telescope and a group of sockets.

The special equipment of the running gear of the launcher consists of protection for the cab, protection for the gas tank, lifting jacks, and protection for the rubber tires of the wheels. Cab protection (easily removal metal shields) keeps the cab and crew inside it safe from the dangerous effect of the gas jet during firing. If the side windows of the cab are not covered by shields, they are raised during firing.

The lifting jacks assure stability of the launcher during firing and take the load off the springs of the rear axle assembly of the chassis. Launchers are leveled on uneven terrain by means of jacks.

Launcher designs provide for locking devices to secure rocket projectiles in the barrels during traveling and to create the necessary forcing effort which enables projectiles to leave the barrels at a specified descent velocity and decreases their scatter in trajectory.

Let us consider some models of modern launchers of foreign armies.

The Swiss 81-mm 10-barreled launcher "Leska," developed by the Hispano-Suiza Company, has a split-trail carriage and is towed (Figure 63). Maximum range of fire: 10,000 m; weight of rocket projectile: 11.2 kg.

The 20-barreled self-propelled launcher "Leonsin," designed to use the same 81-mm rocket projectiles, was developed in Switzerland using the chassis of a "Mowag" motor vehicle. There is also a twin automatic 81-mm launcher using the same chassis.

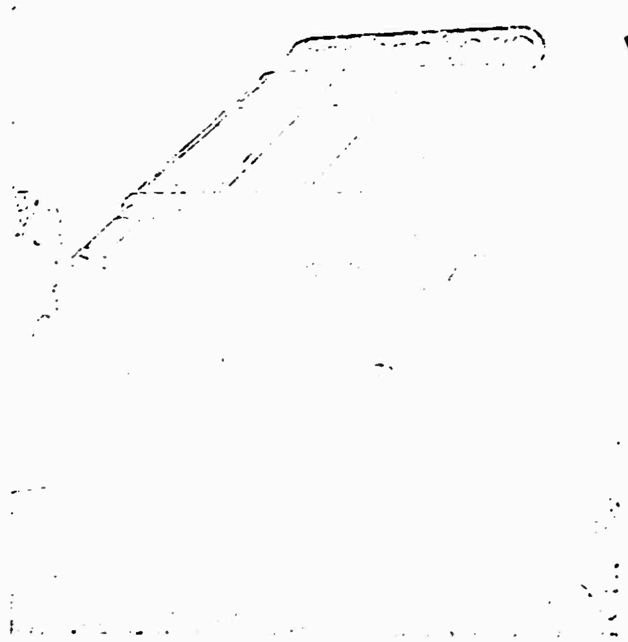


Figure 63. Swiss 81-mm 10-barreled launcher "Leska."

In the United States the 114.3-mm 25-barreled launcher M21 has been replaced by the new 115-mm 45-barreled launcher M91. Its unit of fire has only toxic projectiles. According to American data, the M91 multiple launcher is a chemical offensive weapon. Therefore a low grouping of shots is even deemed desirable when a weapon of this kind is used over large areas.

The cluster of 45 barrels is mounted on a wheeled carriage (towed version) or on a 2.5-ton motor vehicle (self-propelled version). Nine barrels form a section. The five sections are placed one on the other and secured to special clamps of the top carriage of the launcher. By means of the elevating mechanism the cluster of barrels is given angles of elevation up to 60°. The traversing mechanism makes possible laying for direction ± 10°. Range of fire of the launcher: 9600 m. The 115-mm rocket projectile has a folding stabilizer, which automatically opens up when the projectile leaves the barrel. Full loading of the launcher takes 20 minutes. All 45 projectiles can be discharged in a 20-second salvo.

Transport containers made completely of plastic have been developed for 115-mm projectiles.

Intensive development of multiple salvo launchers has been under way in West Germany in recent years.

The West German 110-mm 36-barreled self-propelled launcher has been developed in two variants, viz. with one cluster of 36 barrels, and with two clusters each of 18 barrels. The latter variant is also equipped with an antiaircraft machinegun. A seven-ton cross-country 6x6 wheeled (six wheels, all driving wheels) army vehicle is used for the chassis. The cab has light armor plating and hinged metal shields to protect the windows from the gas jets of projectiles.

The cluster of barrels is mounted on a turntable providing maximum traverse of 100°. Firing elevation: 50°. Fire can be delivered in salvos, semisalvos and single shots. A complete salvo is fired in 18 seconds.

Weight of rocket projectile: 36.7 kg. Range of fire: 15,000 m. Weight of entire system: 15 tons. Crew: three men (commander, gun-layer and driver).

Under the program for strengthening the fire power of the Bundeswehr two types of 110-mm rocket projectiles have been developed: "Lar" (light artillery rockets) and "Mar" (medium artillery rockets). They are equipped with high-explosive fragmentation, smoke or incendiary warheads.

Work is under way in West Germany to increase the maximum effective range of salvo rocket systems to 16-20 km. It is noted that the 36-barreled self-propelled launcher here described (Figure 64) significantly raises the fire power of organic artillery during zone fire. It serves to complement the existing models of tube artillery and, above all, the 155-mm self-propelled howitzer M109, which is in service in the West German army.

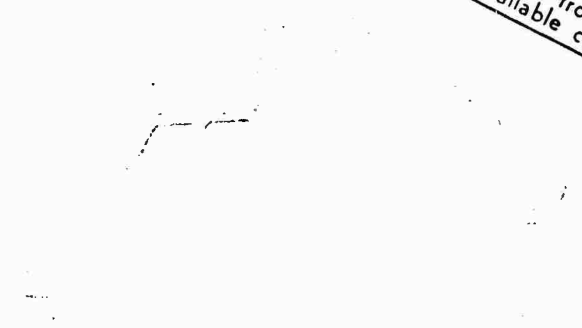


Figure 64. West German 110-mm 36-barreled self-propelled launcher.

Basic performance data of some models of the field rocket artillery of the armies of capitalist countries are presented in Table 15.

The American army is at present working on the development of a new "Mars" multiple rocket system with a 30-40 km range of fire. It is intended for shelling large concentrations of troops and tank ordnance.

Table 15

BASIC PERFORMANCE DATA OF SOME MODELS OF FIELD ROCKET ARTILLERY OF ARMIES OF CAPITALIST COUNTRIES

A Образец установки	B Вес снаряда, кг	C Наибольшая дальность стрельбы, м	D Вес в походном положении, т
1 США			
2 114,3-мм 25-ствольная буксируемая пусковая установка М21	19	8900	0,66
3 115-мм 45-ствольная буксируемая пусковая установка М91	25,8	9600	0,55
4 [illegible]			
5 110-мм 15-ствольная буксируемая пусковая установка «Ларак»	36,7	15 000	1,9
6 110-мм 36-ствольная самоходная пусковая установка	36,7	15 000	15
7 Швейцария			
8 81-мм 10-ствольная буксируемая пусковая установка «Леска»	11,2	10 000	1,25

Keys:

A. Launcher model

1. U.S.
2. 114.3-mm 25-barreled towed launcher M21
3. 115-mm 45-barreled towed launcher M91
4. West Germany
5. 110-mm 15-barreled towed launcher "Larak"
6. 110-mm 36-barreled self-propelled launcher
7. Switzerland
8. 81-mm 10-barreled towed launcher "Leska"

B. Weight of projectile, kg

C. Maximum range of fire, m

D. Weight in traveling position, tons

In the opinion of American military specialists, the anticipated advantages of the Mars rocket system over conventional artillery lie not in accuracy or range of fire, but in increased efficacy of operation against personnel targets, which is achieved by the large number of shells falling on targets in a very short period of time. Conventional artillery will require rapid-fire pieces by the tens for this. In addition, significant material outlay for the concentration of artillery is involved.

It is assumed that the Mars launching system will have a cluster of rail guides for three or six rocket projectiles. Laying the cluster for elevation and range will make it possible to give the launched projectile the necessary trajectory.

However, to hit a target accurately, projectiles need correction in the final phase of trajectory. For this purpose a stabilization and control system is envisaged which will assure projectile stability against yawing and pitching. Rotation of the projectile around the longitudinal axis (careening) is limited by fins.

The plan is to supply the Mars rocket projectiles with warheads of the cluster type equipped with "baby bombs."

Foreign specialists call attention to the following basic trends in the further development of field rocket artillery:

increase in the cluster of barrels (launching rails) in order to increase salvo effectiveness;

decrease in the size and weight of launchers through the employment of rocket projectiles with folding (prior to firing) and unfolding (during flight) fins;

extensive introduction of aluminum alloys and plastics for the manufacture of barrels;

provision of all-round fire;

increase in maneuverability through the development of launchers which can be conveyed by all kinds of transport, including air transport.

Chapter VIII

SPECIAL TYPES OF ARTILLERY

1. Field Antiaircraft Artillery

The transition of military aviation to jet engines in the post-war period led to a sharp increase in aircraft flight speeds. Antiaircraft artillery, however, remained essentially at the technical level of the World War II period. The rate of fire of antiaircraft guns was clearly inadequate, and the lack of improved radar fire control systems substantially diminished the combat effectiveness of antiaircraft artillery. Therefore, the view firmly hardened in the armies of a number of capitalist states, particularly America, that antiaircraft artillery had lost its importance as an active means of air defense. In the United States, for example, the production of antiaircraft guns was sharply curtailed and by the beginning of the 1960's was halted altogether. The mission of combating aerial targets was assigned wholly to antiaircraft guided missiles.

Such extreme views of the role of antiaircraft artillery did not find unqualified support in all foreign armies. For example, the English, West German, Swedish, Swiss and other armies continued to keep cannon-type antiaircraft weapons in service.

The experience of the war in Vietnam has shown that under present-day conditions antiaircraft artillery is a very effective means of destroying aircraft at low altitudes. Therefore foreign armies have expanded on a large scale experimental design work aiming at the creation of new models of cannon-type antiaircraft artillery.

Foreign military specialists believe that land forces equipped with modern varied-purpose armament systems can function effectively only if they, their fire weapons and movements are safely protected against enemy air attack. Simultaneously with coverage of troop formations in the front lines, an air defense system assures protection of operational and strategic targets in the rear area since even one plane breaking through the air defense system of the main line of resistance may turn out to be the carrier of a nuclear weapon.

In the organization of forward area air defense for NATO armies serious attention is given to timely detection of the air enemy and alerting of troops. Reconnaissance radar is detailed for this purpose. The airspace which is not scanned by radar is monitored by air observation posts equipped with optical facilities. Data on enemy planes and helicopters are transmitted to the command post, where the air situation is analyzed and a decision made regarding the issuance of a target assignment to active air defense means.

It is believed that small-caliber (20-40 mm) antiaircraft artillery guns should be used to protect troops and important installations from low-altitude air attacks since the combat effectiveness of medium- and large-caliber antiaircraft artillery against low-flying air targets is very slight. However, it is disadvantageous and irrational to use artillery to destroy high-altitude targets (over 3000 m) since ammunition consumption is very high.

Modern small-caliber antiaircraft guns differ from models of antiaircraft artillery at the end of the Forties in higher rate of fire and accuracy, increased aiming speed, and the transition to self-propelled chassis with a greater cruising range and better cross-country ability. The high rate of fire assures a high density of fire.

Whereas by the end of World War II the rate of fire of 20- to 40-mm antiaircraft guns had reached 80-250 and sometimes 480 rounds a minute, the rate of fire of antiaircraft guns of the same calibers is now up to 1000 rounds a minute per barrel. Foreign specialists assert that even a higher rate of fire can be attained if artificial cooling of barrels is employed so as to prevent their being overheated and becoming unserviceable.

Another way to increase the density of antiaircraft artillery fire is to create multibarreled -- twin, triple, quadruple and sextuple -- antiaircraft mounts.

Various methods are used in the attempt to increase the accuracy of antiaircraft artillery fire: selecting the optimum caliber of weapon and increasing the number of barrels per mount; using antiaircraft projectiles with effective proximity fuzes; employing special instruments for the precise determination and recording of variations in the initial velocity of projectiles; improving the antiaircraft fire control system.

The high flight velocities of modern aircraft at low altitudes require a sizeable increase in the aiming speed of antiaircraft guns. This parameter has reached 90 deg/sec in some foreign models of the last few years, i.e. it has grown significantly in comparison with the World War II period.

The general trend towards increased troop maneuverability in modern operations has extended to all antiaircraft defense weapons, particularly antiaircraft artillery. Self-propelled antiaircraft artillery mounts now move at speeds up to 50-62 km/hr for distances up to 400 km without refueling under a specific load of 0.6-0.7 kg/sq cm.

Tanks and armored carriers are additionally armed with small-caliber antiaircraft guns for protection against air attacks. This function was previously performed by large-caliber machineguns.

However, foreign military specialists note that since the appearance of armed helicopters which have guided antitank missiles and unguided rocket projectiles on board there has been a considerable increase in the direct threat to tanks, armored carriers and self-propelled field artillery. Therefore, 12.7-mm antiaircraft machineguns should be left for the present to protect armored and mechanized troops against the attack of both armed helicopters and fighter-bombers operating at low altitudes.

Radar antiaircraft fire control systems assure target detection and automatic tracking, as well as the preparation of all initial fire data. This sharply increases the effectiveness of antiaircraft fire.

Modern antiaircraft guns are automatic. All reloading and firing operations (opening the breechblock, extracting the cartridge case from the chamber, cocking the breechblock, feeding the next round to the ramming line, ejecting the cartridge case from the breech screw extractors, chambering the cartridge, closing the breechblock and releasing the firing pin) are performed automatically through recoil energy or the energy of powder gases specially drawn off from the bore for this purpose.

Automatic guns, unlike semiautomatic guns, have several additional mechanisms: rammers, feeders, automatic release mechanisms etc. We distinguish between horizontal, vertical and drum feed, depending on the direction in which the cartridges move during feeding. Feeds are divided into belt feeds (solid or link), magazine feeds (box or drum) and clip feeds according to the method whereby cartridges are united into groups which move as a single whole when the mechanisms of the automatic gun are in operation.

Antiaircraft guns can conduct automatic fire in short or long bursts, as well as in single shots. A restriction on the delivery of continuous fire at different rates of fire is the degree of barrel heating. Usually continuous fire is conducted until the heating temperature of the muzzle end of the barrel reaches 400° C. To resume fire the barrel is cooled in various ways, for example, by means of a cooling device.

An automatic antiaircraft gun generally includes the following: barrel with muzzle brake and counterrecoil mechanism, breechblock and clamping collar for the barrel with an accelerator and tightener, magazine, cradle with mechanisms, hydraulic buffer, ramming mechanism and recoil brake, carriage with a platform, pointing devices and equilibrator, electric (or hydraulic) tracker and automatic antiaircraft sight.

Antiaircraft guns can be self-propelled or towed.

The barrel is a monobloc tube to which is attached a spring counterrecoil mechanism. The assembled barrel with counterrecoil mechanism is inserted into the throat of the cradle and is joined to the barrel clamp by two sector cams on the breech.

The barrel length of antiaircraft guns is 70, 90 and even 120 calibers, i.e. more than that of any gun used for a different purpose.

Automatic antiaircraft guns most often use the screw-type breechblock. It is located in the cradle. In firing the breechblock is opened during recoil by the accelerator mounted on a bracket attached to the barrel clamp. The breechblock is rammed into the forward position and is closed by the springs of the rammer mechanism situated on the hydraulic buffer. Manual opening of the breechblock is accomplished by a manual breechblockcocking mechanism found on the cradle.

The barrel clamp with accelerator and tightener is mounted in the cradle and during firing slides with its guide keys along the cradle guide rails. The accelerator gives the breechblock accelerated motion relative to the barrel during recoil. The tightener serves to set the breechblock screw at a strictly prescribed position relative to the magazine when the breechblock is on autosafety.

The magazine receives fixed rounds and feeds them to the ramming line. It is attached to the left (right) wall of the cradle and consists of a body and a number of mechanisms (feed, automatic cocking, interlock etc.).

Continuous automatic fire is provided by a loader continuously feeding cartridge clips into the magazine. The gunner can halt fire at any time. Automatic fire ceases when cartridge clips cease to be fed into the magazine. Due to the presence of the interlock mechanism one cartridge remains in the magazine. The parts of the magazine assume the position in which automatic fire resumes when the next cartridge clip is fed in, without manual reloading. This assures constant readiness of the gun for fire if fire was interrupted because of a lag in the feeding of cartridges to the magazine.

The recoil brake is hydraulic with a liquid replenisher. The recoil brake cylinder is fastened to the throat of the cradle, while the piston rod is connected to the bracket of the accelerator and recoils during firing together with the barrel and barrel clamp.

The cradle serves to assemble all mechanisms of the automatic device thereon, to guide the barrel and barrel clamp during recoil and counterrecoil, and to direct the movement of the breechblock as it is cocked and rammed. To the side walls of the cradle are attached trunnions for support on the carriage; the cradle swings on these in a vertical plane. The elevating sector is attached to the bottom part of the cradle body.

The carriage with platform is the rotating part of the gun and consists of a top and bottom part. The bottom part of the carriage and the platform are the site of the tipping parts of the gun, the pointing mechanism, equilibrator, power drive, sight and other instruments.

An automatic antiaircraft sight of the mechanical type is mounted on the carriage bracket. The input data of the sight required for solving the problem of the impact between projectile and moving target are slant range, target speed, angle of approach, and dive or pitch angle. Slant range is determined by a range finder, angle of position is fed into the sight automatically during target sighting, and the remaining data are estimated by eye and established according to the appropriate scales.

The azimuth tracker opens up fire according to the data of the sight at the moment when it, together with the elevation tracker, brings into coincidence the vertical cross hair of the azimuth collimator and the horizontal cross hair of the elevation collimator.

The cooling device serves to cool the barrel in the intervals between fire. A cooling liquid is pumped through the bore for this purpose.

The electric (hydraulic) trackers are designed to obtain a high speed of antiaircraft gun pointing in azimuth and elevation and assure smooth high-precision target tracking. For automatic remote pointing of a battery of antiaircraft guns the trackers of each are connected by cables with the PUAZO [antiaircraft fire director] and a power supply station. The tracker for each gun has two laying channels: a channel for laying in azimuth and a channel for laying in elevation. Direct laying of the gun is performed by actuating motors kinematically coupled via toothed gears with the reduction gear of the elevating and traversing mechanisms.

In automatic antiaircraft gun fire different methods are used for pointing the gun at a target: automatic laying by PUAZO-controlled trackers; semiautomatic laying by means of semiautomatic layer-controlled trackets (target sighting is performed by an automatic antiaircraft sight); manual laying according to PUAZO or sight data.

In the classical automatic weapon the energy source for operation of the automatic device is the powder gases generated during firing and withdrawn from the barrel, or the blowback. Recently, multibarreled guns with an automatic device operating off an external electric motor have begun to be widely used in antiaircraft artillery and aviation artillery equipment. This has made it possible to obtain ultrahigh rates of fire.

To achieve an ultrahigh rate of fire there has been a return abroad to the idea of Gatling's so-called mitrailleuse, patented by him over a hundred years ago (in 1862). The mitrailleuse was a cluster of several barrels mounted on a wheeled carriage. The cluster was revolved by hand, thus assuring consecutive fire from all barrels with a total rate of fire of 350 shots per minute.

The principle of the Gatling system made it possible to combine various operations of the cycle of the automatic device to the maximum extent, while consecutive fire from several barrels did away with forced cooling of the barrels, since their life was assured even without this. At present guns and machineguns for cartridges of various calibers are used in the American army for the arming of antiaircraft artillery, aircraft and helicopters. Such weapons include, for example, the 20-mm six-barrel aircraft cannon M61 Vulcan, whose automatic device operates off an external electric motor and makes possible a rate of fire of 6000 rounds per minute.

A multibarreled antiaircraft gun consists of the following basic components: a cylindrical block with guide rails for the breechblocks; a barrel clamp rigidly connected to the cylindrical block; breechblocks; a receiver with cam slot, with which the breechblock rollers interact during rotation of the cylindrical block; cartridge feeder; a coupling mechanism which disconnects the cartridge feeder when the firing stops; electric-contact and blocking devices to make firing possible only when the bore is locked and to rule out firing when the barrel is not completely locked; an electric motor.

When the electric motor is turned on, the block with the barrels begins to rotate. As a result of the interaction of the breechblock rollers with the cam slot the breechblocks reciprocate in their guide rails, effecting the ramming of a cartridge into the cartridge chamber, locking of the bore, ignition of the primer, unlocking of the bore and extraction of the empty case. The cartridge primer is ignited by feeding it 300 v direct current which goes through the contact on the jacket, through the breechblock and striker. At the moment the bore is locked, the breechblock roller enters the area of the cam slot perpendicular to the axis of rotation of the block of barrels, and therefore as the rotation of the block of barrels continues, the breechblock makes no translatory motion, and the bore is locked until the pressure of the powder gases drops to a safe level for unlocking.

Design improvements in multibarreled automatic guns include the development and introduction of special starter-braking devices and a system of linkless cartridge feed.

The starter devices are necessary for rapidly overcoming the rest inertia of the rotating parts of the gun at the very beginning of each burst so as to achieve the prescribed rate of fire, the braking devices for quick stopping of the rotating block of barrels after firing has stopped. Usually the starter-braking devices are made in the form of a single mechanism which offerates off an internal or external energy source.

The simplest starter device is a clamp with barrels inclined somewhat relative to the axis of rotation. Such a barrel arrangement results in the appearance of a blowback component contributing to the rotation of the block of barrels. In a mechanical starter-braking device the energy accumulated in braking the block of barrels at the end of each burst is used to accelerate this block at the beginning of each subsequent burst. Pneumatic-type starter-braking devices are also used.

In view of the trend towards further increases in the rate of fire and the limitation due to the strength of the cartridge belt, a linkless feed system is used for multibarreled guns. It consists of a fixed exterior and a rotating interior drum. The cartridges are packed in rows in longitudinal slots of the exterior drum, and they go headfirst into the spaces between the flanges of the double spiral of the interior drum, which as it rotates moves them forward to the exit. Mounted on the ends of the interior drum are an inlet and outlet transmission disk. In the fixed covers of the exterior drum are separators which, together with the transmission disks, transmit the cartridges moving along the longitudinal slots to the feed belt. Rotary motion is transmitted to the interior drum and separators by a planetary gear.

An attempt is being made to raise the effectiveness of field antiaircraft artillery by improving its fire and maneuver qualities. In order to protect tanks and motorized infantry against air attack, antiaircraft artillery must stike at attacking planes at any time of day in all kinds of weather, possess high mobility, be able to change quickly from traveling position to firing position and vice versa, and have a large ammunition supply. In short, it requires a combination of antiaircraft-battery fire power plus tank mobility and cross-country ability. In order for modern antiaircraft guns to meet these requirements, they are equipped with fire directors which provide precise target location and lead computation.

Air defense includes several phases. First come target search, earliest possible identification of target's national affiliation, and continuous precise target fixing. Then rapid and precise calculation of target flight path and continuous ballistic calculation of lead, precise automatic control and continuous target tracking. The last phase is fire on target at a high rate of fire and high initial shell velocity, using highly effective ammunition. Each of these phases is decisive for success in battle. Therefore, antiaircraft guns, especially self-propelled, are equipped with all the necessary instruments for successful performance of the aforementioned operations: target search and coordinate-determining radar, computers and automatic gun layers.

Great difficulties arise in the development of an antiaircraft self-propelled gun. First of all, the entire system of equipment has to be accommodated in a very small space in such a way that each crew member can perform his functions unimpeded. Precise target tracking and fixing are usually accomplished by radar. Optical instruments are also used in an attack on low-flying aircraft under conditions of strong signal reflection by the terrain. Each of these systems has to be mounted on a separate axis which does not depend on the rotation of the turret, and visibility restrictions due to turret equipment, gun barrels and radar antenna must be minimal.

Rigid requirements are set for target detection instruments, especially radar: operating reliability under severe conditions, high ability to distinguish targets against the background of the surrounding terrain, all-around fire with maximum angle of elevation. The electronic equipment of self-propelled antiaircraft guns must be of minimum size, be resistant to shocks, impacts and high temperatures, and at the same time possess the necessary precision and operating reliability, which is provided only by the use of modern microminiature electronics and semiconductors.

An important problem for self-propelled antiaircraft artillery and one that is difficult to solve structurally is that of accommodating a large amount of ammunition and replenishing it quickly. The larger the caliber of the gun, the smaller the size of the basic ammunition load.

Foreign specialists note that an unfavorable attitude towards self-propelled antiaircraft guns is due to their complexity, high cost and low reliability. The suggestion is sometimes made that their design be simplified by dispensing with radar and computers. However, the complexity of self-propelled guns is due to the complexity of the missions to be executed by them. A complex gun system is naturally less reliable than a simple one, but its effectiveness is much higher. Therefore, the tendency is to increase reliability by improving gun systems rather than simplifying them -- something which is entirely feasible at the present level of technology. As for the high cost of self-propelled antiaircraft guns, the view of foreign specialists is that the character of functions to be performed by them should be taken into consideration. The protection of tanks and troops on the march by means of towed antiaircraft artillery requires a significantly larger number of tactical artillery units than does protection by self-propelled antiaircraft artillery. In addition, the latter are less vulnerable to the enemy than are conventional unarmored antiaircraft guns, and therefore they have a longer life under combat conditions.

Let us consider the performance characteristics and design features of some models of modern antiaircraft artillery found in foreign armies.

Figure 65. American Vulcan (M61) aircraft 20-mm six-barrel automatic cannon.

The American Vulcan 20-mm six-barrel automatic antiaircraft cannon (AAC) comes in two versions: the towed XM167 (also air-transportable) and the self-propelled XM163 based on the tracklaying armored carrier M113. The basis for these versions was the M61 Vulcan 20-mm aircraft cannon (Figure 65).

A serious difficulty in the search for a combustible case material has been the problem of the porosity of the material. It is believed that high porosity is an important condition for the production of a fully combustible material, while high porosity is a negative factor for assuring the necessary overall strength of a round.

The American press recently has pointed out the following problems facing developers of combustible artillery cases: operational strength of the case; long storageability under adverse conditions (high and low surrounding temperature, rain, moisture etc.); and, finally, total combustion of the case on firing. It is noted that it is a hardly feasible task to combine the optimal parameters for all three problems. Therefore, the efforts of researchers and designers are now directed towards achieving the proper combination of strength, moisture resistance, and fast and clean combustion. In the view of foreign military specialists, success in choosing the proper combination of parameters will produce great changes in ammunition and artillery as a whole.

It is also thought that it is economically infeasible completely to reequip combat vehicles with new pieces and pieces with redesigned breech rings. Besides, this would make large stocks of ammunition with metal cases unsuitable for use. Therefore, the American army was confronted with yet another problem -- the development of ammunition with a partially combustible case, which can be used without any changes in existing pieces.

The partially combustible case, made mainly of a combustible material, has a shortened metal base 50-60 mm high, which provides obturation of the barrel. Partially combustible cases are light in weight, cut down the penetration of harmful fumes into the fighting compartment of vehicles, and are less bulky than ordinary metal cases.

Combustible and partially combustible ammunition has also been developed for the American 105-mm howitzer and 105-mm and 120-mm guns (Figure 32).

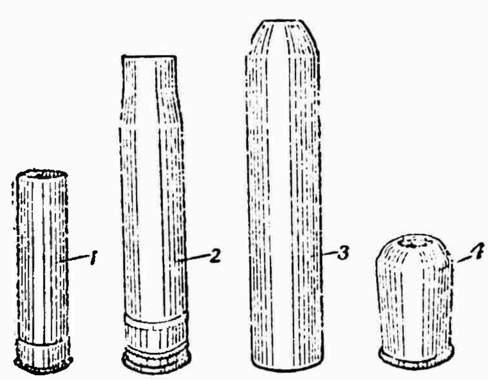


Figure 32. Combustible cases:

1), 2) partially combustible cases for American 105-mm gun; 3), 4) fully combustible cases for 120-mm gun and 152-mm gun of the Sheridan tank.

The working principle of the Vulcan AAC is as follows. During firing the six barrels are rotated around a common central breechblock by means of an electric drive. The rate of fire of the cannon is determined by the rotational speed of the barrels. All barrels are fed by one common cartridge belt. The life of the cannon is lengthened as a result of the fact that the rate of fire per barrel is considerably less than in a single-barrel gun. The design of the cannon makes it possible to conduct fire in such a way that each succeeding round is not dependent on the preceding one, whereby good system reliability is achieved. A special controlled muzzle clamp makes it possible to vary the character of the fire dispersion.

In the towed version the cannon is placed in a rotating turret which is open at the top and has a convex armor cover to protect the gunner from the direction of the rear cone. Together with the turret, the cannon forms a self-contained assembly which is mounted on a light two-wheeled carriage. The weight of the cannon is 133 kg, and that of the entire piece plus carriage in the towed version 1360 kg.

The fire control system of the Vulcan cannon consists of an improved sight with a resolver for lead calculations and angular target tracking, and light radar for target range determination.

The self-propelled 20-mm Vulcan cannon is a self-contained turret with six barrels mounted on an army armored carrier. The cannon has armor protection of aluminum alloys, and a convexo-concave armor shield serves to cover the gunner from the direction of the rear cone. The combat weight of the piece is about 12,000 kg.

The turret, actuated by electric drive, has all-around fire. The maximum angle of elevation of the piece is 80°. The turret of the mount is not stabilized, and therefore it is recommended that fire not be conducted on the move.

The horizontal rotational speed of the cannon is about 90 deg/sec, vertical 45 deg/sec. The constant rotational speed of the turret during fire is controlled by the memory unit of the tracking system in the fire control system.

The electric drive system is powered by three 24-volt nickel-cadmium batteries: two for the power drives of the cannon and one for the turret. The batteries are designed for about 45 minutes of continuous operation. They are usually charged by the vehicle's generator or, if the vehicle is damaged, by a portable auxiliary generator.

The unit of fire of the piece consists of 2000 rounds, including 1200 in a drum-type magazine and 800 in the fighting compartment of the armored carrier. After 1100 cartridges are used, a special mechanism refills the drum of the feed system. The spent cases are thrown overboard from the armored carrier.

The cannon fire is effective against aircraft flying at speeds up to 1120 km/hr at ranges of 500 m. Three rates of fire are provided: 3000 shots per minute (for fire on air targets), 400-1000 shots per minute (on ground targets) and single-shot fire. A special positioning stop permits salvos of rigidly defined duration (from one to 200 rounds).

Recently in the United States the decision was made to develop a new automatic antiaircraft gun system, the Bushmaster, designed to be used in the Seventies in a new series of army combat vehicles. This system will have a caliber of 20 mm and will replace some models of 12.7-mm machineguns and 20-mm antiaircraft guns. The feed mechanism will permit the firer to select the type of ammunition from the piece's unit of fire according to the character of the target. It is envisaged that ammunition will be developed with increased range of fire and increased damage characteristics.

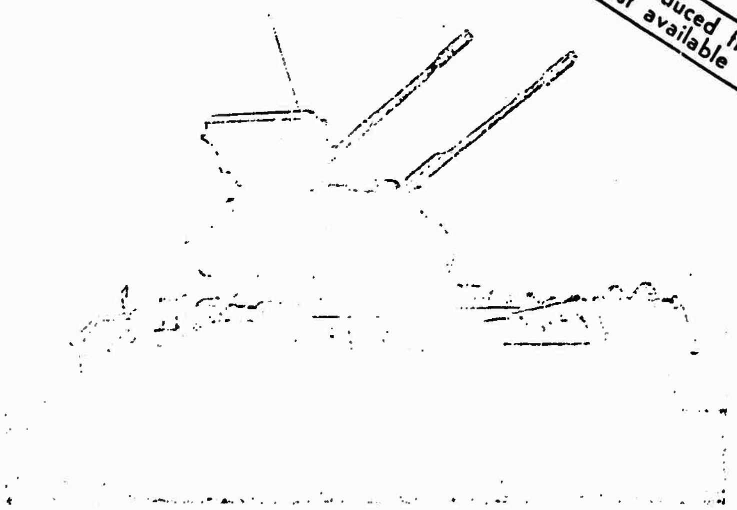


Figure 66. Swiss Oerlikon 35-mm twin self-propelled automatic antiaircraft cannon.

The Swiss Oerlikon 35-mm twin self-propelled AAC (Figure 66) consists of two guns of the ZLa/353 type arranged along the sides of the rotating turret. On the turret are mounted target detecting and tracking radar antennae. The guns are laid in azimuth and elevation with the aid of power drives. The equipment is mounted on the chassis of the West German Leopard tank.

The combat weight of the self-propelled gun is about 39,000 kg. There is a two-man crew. Maximum running speed up to 65 km/hr, rated cruising range 560 km. Surmountable obstacles: angle of ascent 31°, ditch 3 m wide, ford 2.2 m deep, wall 0.95 m high.

The Oerlikon 35-mm cannon was specially developed to combat high-speed low-flying air attack weapons. It has an automatic device based on the principle of powder gas withdrawal and rigid barrel locking. The receiver and barrel lie loose in the cradle. Short travel is assured by a counterrecoil mechanism consisting of a spring recuperator with a hydraulic buffer.

The unit of fire of the piece includes rounds with high-explosive fragmentation and armor-piercing incendiary projectiles. The muzzle velocity of the projectiles is 1175 m/sec.

The Swedish 40-mm twin self-propelled AAC VEAK-40 (Figure 67) is a short-range antiaircraft gun and is designed to protect large mobile soyedineniya against the attacks of low-flying offensive means at speeds up to 1450 km/hr.

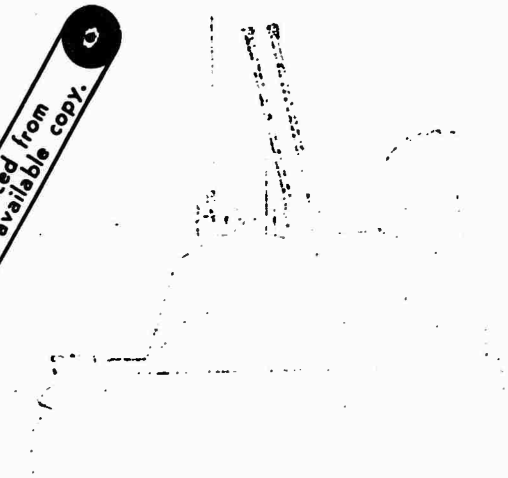


Figure 67. Swedish 40-mm twin self-propelled automatic antiaircraft gun VEAK-40.

The new self-propelled mount was developed by the Swedish firm of Bofors. Its years-long experience in the creation of antiaircraft guns goes back to the years of World War II when Bofors 40-mm antiaircraft guns were extensively used by many armies in the world, including the British army, the U.S. army and navy etc. Along with other antiaircraft guns, the Bofors 40-mm twin guns were the basis for the creation of American antiaircraft systems (the M19, M42 etc.).

In the postwar period Bofors considerably improved the design of the guns developed by the firm, replacing manual control with power systems and optical sighting devices with a radar fire control system. At the same time, barrel length was increased from 60 to 70 calibers, which raised the muzzle velocity of projectiles from 875 to 1000 m/sec. There was a two- to threefold increase in the rate of fire of the guns.

The new 40-mm guns, which were given the mark L/70 (the index indicates barrel length in calibers) were a step forward compared to the L/60 type guns. However, they failed to meet the mobility requirements set for antiaircraft weapons by tank forces and other mobile types of forces, since they were based on towed carriages. It took much time to bring the guns and radar equipment (also trailer-mounted) into firing position.

Therefore, as early as 1956 Bofors undertook to develop a self-propelled antiaircraft system consisting of two vehicles. One was intended for the gun, the other for the radar equipment. However, this plan was recognized as unsatisfactory and work was halted. In 1959, at the request of the Swedish army, Bofors began the development of a self-propelled mount using a single vehicle. This work led to the creation of the 40-mm twin antiaircraft gun VEAK-40, which is now in the stage of evaluation tests.

The equipment is mounted on the chassis of the new Swedish tank S, which has a combination power plant (Diesel engine and gas turbine). The total power of this plant (540 h.p.) permits a gun weighing 35 tons to move at speeds up to 60 km/hr, as well as to negotiate water obstacles without any outside help.

The turret houses two L/70 40-mm automatic guns, the fire control system and battle supplies. Here too is found the three-man gun crew: the commander and gunner on the right side of the turret, the driver on the left side. The driver's location in the turret makes possible delivery of fire only after the vehicle is stopped, since gun laying for direction is not feasible on the move. However, it takes altogether only 30 seconds to bring the gun into firing position after the vehicle is stopped, while it takes 1.5 hours to bring the 40-mm twin towed antiaircraft gun and its radar into firing position.

The gun barrels are of the monobloc type. The recuperator consists of a cylindrical spring which encompasses the tail end of the barrel. Breechblock: wedge type. There is an equilibrator. The barrels are laid by means of two hydraulic drives powered by a special electric motor. The hydraulic drives are connected to the fire control system computer, which puts the guns in a given position according to information received from the radar equipment of the mount. The rotational speed of the turret is 85-90 deg/sec; the speed of barrel laying in elevation 45-75 deg/sec.

The gun barrels are cooled with water from a 100-liter tank located in the turret of the mount, at intervals between salvos.

Gun feed is automatic, from a magazine. The basic ammunition load is 425 rounds with high-explosive and armor-piercing shells. The high-explosive fragmentation shells use a radio fuze which is actuated 4.8 m from the target.

The all-weather radar equipment carries on low-flying target search at ranges up to 20 km and automatic target tracking. The search may be a circular scan at an antenna rotational speed of 240 deg/sec or a sector scan within a 90° angle. The antenna is controlled in site manually or automatically. Information goes from the radar to the computer, which puts out data for pointing the piece in site and azimuth at the future position. In addition, there are optical target tracking instruments, as well as a simple periscope and a ring sight designed mainly for fire on ground targets. On the march the antenna is folded to avoid damage from tree tops and other obstacles.

The principal tactical-technical data of some automatic guns used in the field antiaircraft artillery of the armies of the capitalist states are given in Table 16.

The following basic trends are projected abroad in the further development of field antiaircraft artillery:

improvement in models of small-caliber antiaircraft guns (20, 25, 30, 35 and 40-mm caliber);

increase in the rate of fire of antiaircraft automatic weapons and in the muzzle velocities of shells;

increase in angular gun-pointing speeds;

increase in the mobility of antiaircraft guns by mounting them on light and maneuverable self-propelled chassis;

development of multibarreled automatic devices with a rotating block of barrels;

providing antiaircraft guns with fire directors equipped with target detection radar and identification equipment;

automation not only of the firing process, but also of the preparation of data for the opening and delivery of fire;

organizational integration of tube-type antiaircraft artillery with light antiaircraft missile systems.

Table 16

PRINCIPAL TACTICAL-TECHNICAL DATA OF SOME AUTOMATIC GUNS USED IN THE FIELD ANTIAIRCRAFT ARTILLERY OF ARMIES OF CAPITALIST STATES

A Образец	B Вес снаряда, *кг*	C Максимальная досягаемость по высоте, *м*	D Скорострельность, *выстр/мин*	E Вес в боевом положении, *кг*
1 США				
2 20-*мм* 6-ствольная АЗП «Вулкан»:				
3 буксируемая XM167	0,10	2800	3000	1360
4 самоходная XM163	0,10	2800	3000	~12 000
5 25-*мм* самоходная АЗП 6425	0,18—0,45	3000	570	75 (без станка)
6 40-*мм* спаренная самоходная АЗП M19	0,94	4800	240	16 800
7 40-*мм* спаренная самоходная АЗП M42	0,94	4800	240	19 400
8 Франция				
9 30-*мм* спаренная самоходная АЗП AMX-13	0,4	3000	650×2	15 000
10 [illegible]-*мм* самоходная АЗП AMX-51	0,96	4600	240	14 000
11 Швеция				
12 40-*мм* АЗП L/70	0,96	4600	240	3850
13 40-*мм* спаренная самоходная АЗП VEAK-40	0,96	4600	6[illegible]0	35 000
14 57-*мм* АЗП L/60	2,6	6300	120	8000
15 Швейцария				
16 20-*мм* АЗП HS-820	0,13	2400	1000	376
17 30-*мм* АЗП HS-831	0,42	3000	650	1100
18 30-*мм* 4-ствольная АЗП HS-667	0,36	3000	650×4	4600
19 30-*мм* спаренная самоходная АЗП HS-30	0,36	3000	650×2	11 600
20 35-*мм* спаренная АЗП ZLa/353	0,55	3500	550×2	5850
21 35-*мм* спаренная самоходная АЗП «Эрликон»	0,55	3500	550×2	39 000

[Keys on next page]

Keys to Table 16:

A. Model

1. United States
2. Vulcan 20-mm six-barrel automatic antiaircraft cannon
3. Towed XM167
4. Self-propelled XM163
5. 25-mm self-propelled antiaircraft cannon 6425
6. 40-mm twin self-propelled antiaircraft cannon M19
7. 40-mm twin self-propelled antiaircraft cannon M42
8. France
9. 30-mm twin self-propelled antiaircraft cannon AMX-13
10. 40-mm self-propelled antiaircraft cannon AMX-51
11. Sweden
12. 40-mm antiaircraft cannon L/70
13. 40-mm twin self-propelled antiaircraft cannon VEAK-40
14. 57-mm antiaircraft cannon L/60
15. Switzerland
16. 20-mm antiaircraft cannon HS-820
17. 30-mm antiaircraft cannon HS-831
18. 30-mm four-barrel antiaircraft cannon HS-667
19. 30-mm twin self-propelled antiaircraft cannon HS-30
20. 35-mm twin antiaircraft cannon ZLa/353
21. Oerlikon 35-mm twin self-propelled antiaircraft cannon

B. Weight of projectile, kg

C. Maximum vertical range, m

D. Rate of fire, rounds/min

E. Weight in firing position, kg

5. 75 (minus carriage)

2. Artillery Armament of Tanks

A tank is a tracklaying combat vehicle which combines high-power armament, reliable armor protection and high mobility.

The main armament of the modern tank is a highly effective stabilized gun which fires subcaliber armor-piercing shells at muzzle velocities up to 1300-1500 m/sec.

Foreign military specialists consider the main type of tank nowadays to be a medium tank weighing about 35 tons, equipped with a high-power stabilized gun with a caliber of 105-120 mm and a direct range of fire of 1200-1400 m. For reconnaissance there are light amphibious and air-transportable tanks. The renunciation of heavy tanks recently contemplated abroad is due to their low maneuverability, heavy weight, low rated cruising range, as well as the introduction of effective antitank weapons, primarily antitank guided missiles with high armor-piercing ability.

Since the main function of a tank is to fight enemy tanks, the selection of tank gun parameters (caliber, muzzle velocity of projectile etc.) is based on the damage to the armor of tanks of the same class.

Tank guns are usually mounted in tank turrets. To make possible laying for elevation, the tipping parts of the tank gun are connected to the tank turret by means of trunnions and an elevating mechanism. The placement of the turret on a race permits laying for direction by means of a traversing mechanism.

However, there are also tanks of the turretless type, for example the new Swedish Bofors tank S. Here a 105-mm gun is rigidly mounted in the tank hull. The piece is pointed at a target by special control handles. The entire tank is rotated by rotating the handles, and as the handles turn, the tank hull is raised or lowered by means of a hydropneumatic suspension. The absence of a turret made it possible to reduce the tank weight (to 37 tons), lower the silhouette of the tank, and increase overall invulnerability somewhat.

Let us turn to a consideration of the artillery armament of turret-type tanks. The stresses occurring during firing are transmitted to the tank hull via the trunnions, elevating mechanisms and ball race. The recoil force is very great in modern tank guns, and in high-power pieces it reaches 250-300 tons. Therefore, tank parts, mechanisms and assemblies are made to be very rugged. In addition, special measures are taken to reduce the unfavorable effect of firing on the tank structure.

The barrel of a tank gun is usually placed in a cradle clip, which is connected to it via the recoil mechanism. The body of the cradle is a steel cylindrical tube with brackets for fastening the machine gun, recoil mechanism, gun sight, elevating rack and other parts. Attached to the inside surface of the cradle are bronze guide bearings, along which the barrel slides on recoil and counterrecoil. The cradle is attached to the turret armor directly on horizontal trunnions or via a single cylindrical mask. To prevent shell fragments and bullets from damaging the mechanisms or injuring the crew, armor plating, spherical in shape, is attached to the cradle. It covers the chink in the armor at all angles of elevation and deflection.

The peculiarities of the tactical employment of tanks, and the requirements of high mobility, trafficability and accurate fire in motion gave rise to a number of specific mechanisms and devices in the artillery armament of tanks: expansion links in the aiming mechanisms, electric and hydraulic power drives, armament or line-of-aim stabilizers, bore scavenging devices etc.

Expansion links are cone or disk friction clutches and serve to protect the elevating and traversing mechanisms. The point is that when a tank moves along severely broken terrain the moving and rotational speeds of the tank vary sharply, nor is the possibility ruled out that the gun will hit some obstacle directly. In this case the large loads on the aiming mechanisms exerted by the gun and turret may break the teeth of the worm and toothed gears and their shafts. The expansion links of the aiming mechanisms absorb most of the unexpected and excessive loads.

The main type of fire delivery from a tank during an attack or counterattack is direct marching fire. It is this capability which fundamentally distinguishes the modern tank from other types of ground armament. However, as the moving speed of the tank increases, the effectiveness of marching fire is sharply reduced as compared to stationary fire, since the shaking and jolting of the gun and of the gunner himself, caused by the accidents of the terrain, irregularity of speed and the properties of the suspension, lead to significant shell dispersion. For example, at a range of 500 m and a moving speed of 15 km/hr the probability of hitting a rectange with sides equal to the length and height of the tank is lowered 10-fold, and at a moving speed of 25 km/hr almost 20-fold.

For the successful delivery of aimed fire at moving speeds of 25 km/hr or more, modern tanks are equipped with armament stabilizers.

A tank armament stabilizer is an automatic control system which assures rapid and smooth aiming of the gun at a target and retention of the prescribed direction of the bore axis during vibrations of the hull of the moving tank.

During tank gun fire the air in the fighting compartment of the tank is heavily contaminated by powder gases and the by-products of combustion. Some of the smoke and gases escape with the shell through the muzzle face, but the greater part remains in the bore so long as the breechblock is closed. The carbon monoxide in the powder gases has a harmful effect on the human respiratory organs and poisons the organism.

Removal of the powder gases from the fighting compartment presents a serious problem. It has been solved in various ways: suction of the air from the fighting compartment by the running engine of the tank, and scavenging of the bore with air feed from a compressor or from flasks. The first method has proved unacceptable for reasons of antiatomic protection, the second is too complex and expensive.

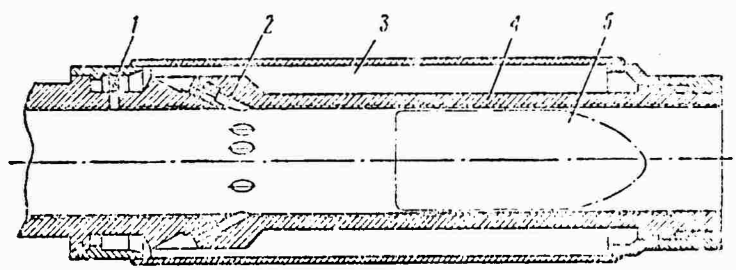


Figure 68. Ejector for scavenging of bore:

1) ball valve; 2) nozzle; 3) chamber; 4) barrel; 5) shell.

The following idea has won acceptance as best: using a small part of the powder gases generated during firing to remove the rest of the gases in the barrel. An ejector is used for this purpose. The working principle of the ejector is shown in Figure 68.

A cylindrical chamber is mounted and attached to the muzzle end of the barrel behind the muzzle brake. Nozzles are made in the wall of the barrel evenly in a circle and inclined towards the bore axis at an angle of about 25°. During firing, after the shell passes through the opening of the ball valve and nozzles, the powder gases rush through these openings into the chamber. In the process the ball of the valve rises. When the pressure of the powder gases in the bore and chamber becomes equal, no more gases enter the chamber. The gases remain there under a pressure of 35-50 kg/sq cm.

As soon as the shell leaves the barrel and the pressure of the gases in the bore drops, the ball, acted upon by the pressure in the chamber, sinks to the seat and closes the opening. The powder gases in the chamber rush through the nozzles into the bore at a high speed reaching 500 m/sec. Behind this rapid gas flow, directed to the muzzle face, a vacuum is formed which carries the powder gases away from the bore and, in part, from the shell case. They are then borne away (ejected) from the muzzle face of the barrel. Inasmuch as the ejection process itself proceeds rapidly (1-2 sec), the contaminated air is also exhausted from the fighting compartment to some extent after the breechblock is opened and the shell case extracted.

In the West German Leopard tank after firing the shell cases drop into a box with a spring cover, which automatically closes as the case drops in, preventing the escape of gases into the fighting compartment. A gas removal device consisting of a system of hoses and a ventilator removes the gases from the box containing the cases and from the twin machinegun, and expels them through the machinegun opening in the gun mask.

Figure 69. English Chieftain tank.

The English Chieftain tank (Figure 69) uses 120-mm separate bag-loading rounds. The bag, which burns up completely during firing, leaves no smoke in the fighting compartment, as usually happens with case loading.

The principal tactical-technical characteristics of the artillery armament of some modern army tanks of capitalist states are given in Table 17.

The trend in the further development of tank artillery armament abroad proceeds along the line of an increase in the fire power of the armament, an increase in the rate of aimed fire, automation of the loading process (reduction of crew size to three men), and improvement of crew living conditions in the closed hatches (provision of temperature and humidity air-conditioning systems).

Table 17

PRINCIPAL TACTICAL-TECHNICAL CHARACTERISTICS OF THE ARTILLERY ARMAMENT OF SOME MODERN ARMY TANKS OF CAPITALIST STATES

A Образец танка	B Калибр орудия, мм	C Начальная скорость подкалиберного снаряда, м/сек	D Наличие стабилизатора вооружения	E Боевой вес танка, т	F Экипаж, человек
1 США					
2 Танк M60A1	105	1470	Есть	46,3	4
3 Англия					
4 Танк «Чифтен»	120	1350	Есть	52,2	4
5 Франция					
6 Танк AMX-63	105	1000 (кумулятивного)	Нет	36	4
7 ФРГ					
8 Танк «леопард»	105	1470	Есть	39,5	4
9 Швеция					
10 Танк S	105	1470	Нет	37	3

Keys:

A. Tank model

1. U.S.
2. M60A1 tank
3. England
4. Chieftan tank
5. France
6. AMX-63 tank
7. West Germany
8. Leopard tank
9. Sweden
10. Tank S

B. Gun caliber, mm

C. Muzzle velocity of subcaliber projectile, m/sec

6. 1000 (shaped-charge)

D. Is there an armament stabilizer?

2, 4, 8. Yes
6, 10. No

E. Combat weight of tank, ton

F. Number of men in crew

Many foreign military specialists take an unfavorable view of the mixed cannon-missile armament of a tank. They believe that a tank with such armament will have important disadvantages: complex design, less operating reliability, increased personnel qualification requirements and the resultant inevitable lengthening of training periods, complications in logistical support etc.

3. Air Artillery Armament

The history of the development of aircraft artillery armament indicates that Soviet designers have achieved great success in this field of military technology. Designers had to solve complex engineering and technological problems due to the specific peculiarities of aviation artillery: high cyclic rate, light weight and small size of weapons, high automation of control.

The first 20-mm aircraft cannon, the ShVAK (Shpital'nyy, Vladimirov, aircraft, large-caliber), was created as early as 1936 and proved excellent in combat. It had a cyclic rate of 800 rounds per minute and weighed in all 42 kg.

In 1941 the 23-mm VYa (Volkov, Yartsev) aircraft cannon was developed, and later the 37-mm NS-37 (Nudel'man, Suranov, Zhirnykh, Nemenov, Lunin et al.). The NS-37 was used during the Great Patriotic War on the Yak-9T and Il-2 planes. On the Yak-9T fighter the cannon was placed in the camber of the motor blocks so that its barrel passed through the tubular shaft of the reducing gear of the engine. On the Il-2 attack plane two cannons were mounted in the wings.

Aviation artillery has not lost its importance under modern conditions, and at low altitudes it is considered the basic weapon of fighter planes, bombers and attack planes.

Air artillery armament underwent significant changes in the postwar period. The reason was the increase in the flying speeds of aviation and changes in the tactics of weapon utilization. Plane design also changed. Thus, due to change in airfoil profile (the profile became thinner) the gun armament of fighters is most often completely concentrated in the fuselage. The guns are mounted closer to the axis of the plane, whereby a high concentration of fire on the target under attack is achieved.

Since the guns are securely attached, aiming is performed by the fuselage.

With the increased flying speeds of bombers, forward-cone attacks by fighters became improbable in the view of foreign specialists. Therefore, foreign bombers use only tail gun mounts to protect the rear cone from fighter attacks. Bombers performing combat missions without fighter cover have gun armament to repel attacks from several directions.

Foreign air-defense fighters, as well as bombers and helicopters (for fire support of troops) have 20- to 30-mm aircraft cannons in service.

Modern aircraft guns are light in weight, have a high cyclic rate of fire and good sighting equipment.

Weight is considered one of the principal factors in the selection of a particular system of air artillery armament. Thus, modern aircraft guns together with auxiliary equipment weight from 70 to 200 kg.

A fixed round of 20-mm caliber weighs 0.4 kg, of 30-mm caliber 0.9 kg. A mount of four 30-mm guns with 300-350 rounds of ammunition per barrel will then weigh about two tons. Such a weight is considered substantial for a fighter.

Figure 70. Tail gun mount of American B-52 strategic bomber.

The cyclic rate of fire of modern aircraft cannons is high, reaching 1000 rounds per minute or more per barrel. Thus, the tail gun mount of the American B-52 strategic bomber (Figure 70) has four 20-mm guns, and their total cyclic rate of fire is 4000 rounds per minute.

The tail mount of the B-58 bomber has six 20-mm guns. Their rate of fire reaches 6000 rounds per minute.

Control of the tail-gun mount is fully automated.

The control system of the B-52 gun mount has two radar units to perform target scanning, lock-on and tracking. After lock-on of the detected target the tracking radar puts out continuous information regarding its position, speed and range. The fire command is given by the gunner on signal from the control system.

Multibarreled aircraft guns are ring-mounted or mounted in special detachable pods suspended under the wings or under the fuselage of aircraft.

The guns most widely used in practice have been those whose automatic device operates off an external electric motor. However, automatic guns are also under development which employ the principle of powder gas removal or the principle of barrel recoil (an external energy source is not required in this case).

The trend abroad has been towards the standardization of aircraft and field antiaircraft automatic guns. This can be seen, for example, in the American Vulcan M61 20-mm six-barreled gun.

In the United States, multibarreled systems with a cyclic rate of 600-1000 rounds per minute per barrel are used to equip attack aircraft. The fire from these systems is delivered by uranium arrows 10 cm long, primarily at tanks. Tests have shown that the uranium arrows pierce armor better than projectiles with tungsten windshields. The arrows ignite on impact with the armor and continue to burn inside the tank.

In addition to gun armament, combat planes carry launchers for firing unguided missiles at ground and air targets. For example, the American 70-mm high-explosive fragmentation rocket projectiles are designed to be fired from fighters at bombers and tanks, the 88.9-mm armor-piercing and 127-mm high-explosive fragmentation rocket projectiles to hit ground armored targets, and the 298.5-mm high-explosive rocket projectile to be launched from aircraft against large ground targets, tanks and ships.

In the last few years there has been stepped-up interest abroad in the development of conventional aircraft weapons. In this connection it is believed that fighter and attack planes will have both artillery and missile armament.

The task has been assigned of increasing the effectiveness of aviation artillery fire by creating guns which fire rocket projectiles. It is assumed that such a rotation-stabilized projectile, comparable in size with a conventional 20-mm or 30-mm projectile, will have high muzzle velocity and high accuracy of fire. In addition, the idea is to create new automated systems based on the use of computers to select the weapon on a plane according to the target under attack.

In the mid-Fifties work was begun in the United States and France on the use of helicopters as mobile platforms for fire support weapons on the battlefield.

The war in Vietnam is characterized by the Americans' use of armed helicopters on a mass scale.

Armed helicopters increase the mobility and fire power of the infantry. They are used for: the protection, escort and fire cover of landing troops during their transportation, landing and combat activity; reconnaissance by fire of flight courses and landing zones; battlefield observation and airborne fire support; the supplying of enemy-surrounded forces and the evacuation of wounded.

There are two types of armed helicopters:

conventional transport helicopters with armament installed on specially designed mounts with rapid-action bracing;

combat helicopters in which the armament and the universal bracing for it are a component part of the helicopter.

Combat helicopters are designed to execute combat missions, and therefore they are not given transport functions. In external appearance they differ from transport helicopters in having a narrower silhouette and armament. In the next few years the U.S. army intends to increase the number of combat helicopters to 18,000.

Combat helicopters are armor-plated, have flying speeds of 250-300 km/hr, and possess standby power. The crew consists of two men (pilot and gunner or copilot). The pilot controls the fixed armament, the gunner the mobile armament (directly or via a control system).

The armament of modern helicopters includes antitank guided missiles, unguided rocket projectiles, automatic guns and grenade launchers, machineguns. Antitank guided missiles are intended for the destruction of enemy tanks long before they enter the field of fire of ground antitank weapons, i.e. as tank chasti march to the combat area, as they regroup from one direction to another, during pursuit etc.

American helicopters in South Vietnam are armed with four- and six-barrel 7.62-mm machineguns (XM21 system), twin 20-mm automatic guns (XM31 system), twin 30-mm XM140 automatic guns (XM30 system), 40-mm XM129 automatic grenade launchers, seven- or 19-barrel (XM17 system) or 24-barrel (XM3 system) launchers for 70-mm unguided rocket projectiles. The last-named are used for zone fire.

The armament of helicopters is arranged symmetrically -- on both sides of the fuselage or in side hatches (windows, doors).

The 40-mm automatic grenade launcher is mounted in a ball armored mask in the nose of the helicopter. Its automatic device operates off an electric motor. 40-mm fragmentation grenades are used for firing. These are analogous to the rounds of the 40-mm M79 infantry grenade launcher, but with a higher muzzle velocity, making possible fire at ranges up to 2000 m. Belt cartridge feed. The cartridges are fed through a flexible groove from an ammunition container. Cyclic rate of fire: 350 rounds per minute. Insignificant recoil is noted during firing from the grenade launcher.

The path followed in the development of a weapons system for combat helicopters, which has passed through the stages of a fixed mount, a hatch mount, a mount with weapon control according to pointing angles, and has ended in research aimed at the creation of a rotating turret on a flying platform, duplicates to some extent the path followed in the development of models of armored tank equipment. A certain correspondence is also observable in the specialization of models according to tactical mission: just like armored tank technology which has light reconnaissance tanks and heavy tanks, aviation contemplates specialization in light reconnaissance helicopters and support helicopters with effective armament.

In the view of foreign military specialists, reconnaissance helicopters will develop mainly through the improvement of aircraft. In the creation of new support helicopters the problem of reinforcing armament is joined to this problem.

It is noted in the foreign press that more has been achieved in the creation of tactical air weapons during the last five years than during all the fifty preceding years.

4. Naval Artillery Armament

Naval artillery -- shipboard and coast -- was for a comparatively long period of time the only fire weapon of the navy of decisive importance in combat operations at sea.

The role of naval artillery and the character of the mission performed by it have changed with the appearance of new weapons -- nuclear guided weapons.

Under modern conditions naval artillery is used mainly as a close-combat weapon (its range of operation is about equal to the distance of the visible horizon). It possesses a number of good tactical properties, the role and importance of which in sea fighting must not be underestimated.

Since it has a significant cyclic rate of fire and a large unit of fire, naval artillery can provide continuous prolonged action against a target, which is of great importance in repelling the attacks of high-speed air and surface targets, when fire is opened from maximum possible ranges and ends at minimum permissible ranges. The large unit of fire makes it possible to close in on the enemy repeatedly.

Also regarded as an important factor is the operating reliability of ordnance and fire directors during their tactical employment, i. e. the capacity for prolonged trouble free operation under combat conditions.

In addition, naval artillery can rapidly concentrate fire on the most dangerous targets, which is very important in repelling high-speed air targets or light surface forces which have broken through to a naval base, ship or naval force.

Shipboard Artillery

Shipboard artillery is one of the types of warship armament.

Under modern conditions shipboard artillery is mounted on ships in conjunction with guided missile weapons (Figure 71) and is mainly used to defend ships against an air enemy at low (up to 3500 m) and medium altitudes (up to 10,000 m) and to combat torpedo carriers. In addition, it is used to shell the enemy's shore, support friendly troops in the coastal zone, and control shipping.

Unlike ground artillery, shipboard artillery operates from a moving and rolling platform, and fire is most often directed at a moving and maneuvering target.

These peculiarities require more complex fire control directors for shipboard artillery, as well as pointing systems and mechanisms which will assure precision, speed and smoothness of fire under the conditions involved in the tossing of the ship.

Modern shipboard artillery is a complex technical system. It differs in many respects from the shipboard artillery of the World War II period and provides highly effective target damage within its zone of fire.

This has been achieved by introducing a number of improvements in the design of artillery mounts, fire director systems, and ammunition.

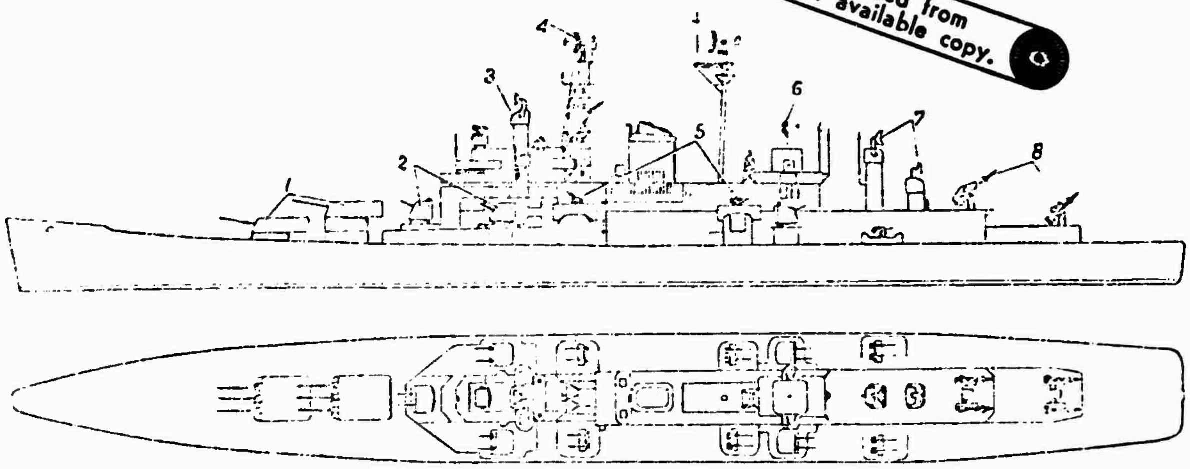


Figure 71. Diagram of arrangement of artillery on missile-carrying cruiser (Boston class):

1) 203-mm main battery turrets; 2) 127-mm multi-purpose automatic artillery mounts; 3) fire control tower; 4) surface-search radar; 5) 76-mm multi-purpose automatic artillery mounts; 6) air-search radar; 7) antiaircraft guided missile guidance station; 8) antiaircraft guided missile launchers.

Cyclic rate of fire has been increased several fold by automation of the loading and firing processes; fire director systems have been devised which operate on new principles, take less time to produce firing data, and have greater operating accuracy; pointing speed has been increased; ammunition quality has been upgraded etc.

In addition, modern shipboard artillery mounts are mainly multipurpose, i.e. they can fire on waterborne, coastal and aerial targets with approximately the same accuracy, which was not the case previously.

Multipurpose artillery mounts possess a significant cyclic rate, have large quadrant elevations (85-90°) and high elevation and deflection speeds.

Non-multipurpose artillery mounts are adapted mainly for combat with waterborne and coastal targets.

Shipboard artillery is classified according to the size of the caliber, the type of mounts, the firing, loading and guidance systems.

In respect of caliber size, it is divided into large-caliber (100 mm or more), medium-caliber (76-90 mm) and small-caliber (under 76 mm).

At present, in view of the new range of missions to be performed the maximum caliber of shipboard artillery is limited to 203 mm.

The heaviest artillery on shipboard, as before, is called the main battery.

Artillery up to 100 mm in caliber is mounted on small ships (cutters, mine sweepers, submarine chasers etc.), and 100- to 203-mm caliber on large ships (aircraft carriers, cruisers, destroyers).

Small-caliber (under 76 mm) artillery mounts as a rule are adapted for combat with low-flying air targets. Their combat capabilities against waterborne and coastal targets are limited. Such mounts are called small-caliber antiaircraft artillery. They are usually multi-barreled and are used on ships of almost all classes.

In respect of type of mount, shipboard artillery is divided into turret, deck-turret and deck mounts.

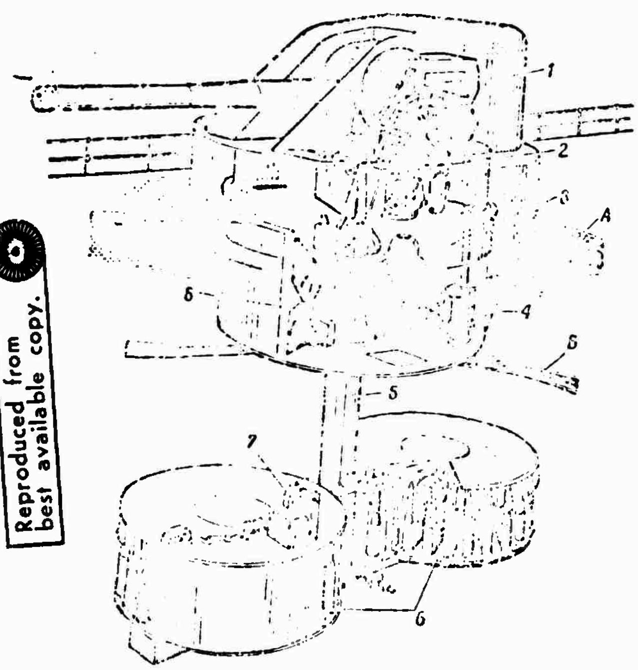


Figure 72. Layout of 120-mm single-gun turret multipurpose automatic artillery mount with drum ammunition feed:

A) upper deck; B) lower deck; 1) gun rooms; 2) elevation mechanism; 3) subturret chamber; 4) deflection mechanism; 5) trunk; 6) drums with ammunition; 7) drum actuating mechanism; 8) artillery mount control panel.

Modern shipboard artillery mounts are mainly of the turret type (Figure 72). All mechanisms and instruments, personnel stations and ammunition lines are protected by closed armor, and therefore turret artillery mounts have a long life and provide safe protection for personnel, mechanisms and instruments against fragments, bullets and nuclear exposure.

Characteristic features of modern ship turrets are their hermeticity, ovalness of the armor protection, and mounting of the front armor plate at considerable angles to the normal.

In addition, turrets have large-diameter bases, which enables personnel to take up action stations directly from the hull of the ship without going out onto the deck. The rotating part of the turret is the gun room housing the guns, guidance and loading mechanisms, turret fire directors, and the personnel operating these mechanisms and instruments. Beneath the gun room is the subturret chamber, in which are to be found certain auxiliary turret mechanisms, ammunition lines, and ready ammunition boxes.*

A characteristic feature of turret artillery mounts is that the gun room, ammunition lines and magazines constitute a unified system.

Medium- and large-caliber turret artillery mounts have one, two or three guns, and are mounted on large ships.

In deck-turret artillery mounts the gun room and ammunition lines are protected by open armor; the magazines are not part of a unified system and are isolated from the turret.

Deck-turret artillery mounts are usually large-caliber. Like turret mounts, they consist of a gun room and subturret chamber.

The gun room is the rotating part of the artillery mount, the subturret chamber the fixed part. The rear end of the turret is not protected with armor and serves for the removal of shell cases during firing. The bottom likewise is open, which assures good ventilation and prevents the turret from becoming smoke-filled.

As a rule, deck-turret artillery mounts have one or two guns and are placed on large ships.

In some mounts the gun room is stabilized, which facilitates laying during rolling and improves conditions for operation of the mechanisms and instruments by personnel.

Deck-turret artillery mounts are also used without a subturret chamber. In this case the ammunition is fed from the deck. Such mounts are classed as deck mounts.

In the case of deck artillery mounts, magazines and ammunition lines are completely isolated from them, and the ammunition lines have exits on the upper deck near the mounts.

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*Ready ammunition boxes are places for storing a small quantity of ammunition in case fire must be opened immediately on targets unexpectedly appearing, without waiting for ammunition to be delivered from the magazines.

Personnel, instruments and mechanisms are protected by bullet- and splinterproof armor in the form of individual shields or shelters with or without a roof.

Medium- and large-caliber deck artillery mounts have one or two guns; small-caliber mounts are more often multibarreled. They are simple in design, simple to operate and light in weight, and therefore can be used on merchant vessels mobilized in wartime.

Some small-caliber deck artillery mounts are stabilized.

On the basis of firing, shipboard artillery mounts are divided into automatic, semiautomatic and nonautomatic (old bag-loading mounts).

The number of automatic artillery mounts (of all calibers) on ships is constantly increasing at the present time. Loading, firing, and case extraction after firing are all performed automatically in these mounts, which significantly increases the cyclic rate of fire. In semiautomatic artillery mounts, only opening of the breechblock and case extraction are automatic. Just as in ground artillery, automatic artillery mounts have cartridge (fixed-ammunition) loading, while semiautomatics have cartridge and separate case loading.

Shipboard artillery mounts are characterized by three types of laying: automatic, semiautomatic and manual. In the automatic method guidance is effected by means of a power servodrive without the participation of gunners. This type of laying is performed by remote guidance control.

Semiautomatic laying is performed by gunners actuating the power drives.

Automatic laying is considered fundamental. It assures great accuracy and high guidance speeds in medium- and large-caliber artillery mounts (for laying for elevation and direction) exceeding the guidance speeds of World War II artillery mounts several times.

Modern shipboard artillery mounts have high initial shell-flight velocities and cyclic rates. This has been achieved by a number of innovations in the design of artillery barrels and their new mode of operation.

Monobloc barrels made of alloy steels with high mechanical characteristics are usually employed to assure the necessary strength and a sufficiently long life. Barrel length ranges from 50 to 70 calibers, and pressure in the barrels reaches 3500-4000 kg/sq cm. With such characteristics, muzzle velocities of 1000 m/sec can be obtained, which is very important when firing at high-speed air targets.

The increase in the cyclic rate necessitated changes in the operating conditions of barrels so as not to reduce their life.

Artillery mounts have been equipped with devices for cooling barrels with outside water after they have been heated up in intensive fire. The device consists of a rubber hose, one end of which is connected to the ship's fire main; the other end, which has a spout, is inserted in the gun chamber. The barrel is cooled by passing water through the bore for 1.5-2 minutes, permitting fire to be resumed at the full cyclic rate.

Other methods provide continuous cooling of barrels during firing.

Thus, one method is based on barrel cooling by water passed under pressure through the jacket on the barrel. The water is injected into the jacket around the barrel breech and removed around the muzzle end through a draw-off hose into a cooler, whence it is again fed into the jacket.

Some barrels use interlayer cooling. In this case the barrel is patterned after a barrel with a liner. Longitudinal grooves are made in the jacket on the inside (for its entire length). Water is passed under considerable pressure through these grooves from the breech to the muzzle end. Then it goes into the cooler via a draw-off hose. In both cases special desalted water is used rather than outside water.

Innovations for medium- and large-caliber turret artillery mounts include special ejector devices for removing powder gases from the bores after firing a round. This device is mounted around the muzzle end. It is simple in design and without auxiliary mechanisms in the breech ring (as was the case previously), and it quickly and reliably removes powder gases from the bore.

Ammunition lines and the loading and firing processes in modern shipboard artillery mounts are practically fully automated. Whereas it took 10-12 men to perform these services in World War II, it now takes 2-4 men, and for the most part they only monitor the operation of the machinery.

One of the variants for automated ammunition feed from magazines (it is known as drum feed) is shown in Figure 72. In this case selective ammunition feed is possible for striking at aerial, waterborne and coastal targets. No personnel are required to operate such feeds. They are needed only to replenish the drums with cartridges.

The growth of the cyclic rate of fire of shipboard artillery mounts can be judged from the data given in Table 18.

Table 18

CHANGE IN THE CYCLIC RATE OF FIRE OF SHIPBOARD ARTILLERY MOUNTS

A Калибр, мм	B Скорострельность установок, выстр/мин	
	1939–1945	C современных
20–40	250–180	Over 500–200
76–100	20–12	90–60
120–127	12–10	50–45
152	8	17
203	5	12

Keys:

A. Caliber, mm
B. Cyclic rate of fire of mounts, rounds/min
C. of present-day mounts

The artillery mounts of ships have a certain amount of ammunition per barrel. Since modern shipboard artillery is multipurpose for the most part, its unit of fire makes it possible to strike at aerial, waterborne and coastal targets. A certain type of ammunition is employed to strike at each of them.

In practice a ship's unit of fire is determined by the cyclic rate of fire of the artillery mounts, the ship's displacement, the holding capacity of the artillery magazines etc. The unit of fire of medium- and large-caliber artillery mounts is several hundred rounds per barrel, and that of small-caliber mounts several thousand.

The ammunition on shipboard is stored in special compartments -- artillery magazines.

Magazines as a rule are located in the hold below the waterline, far from the machinery and boiler compartments, and are well insulated against exposure to high temperatures. They are supplied with the necessary equipment to make possible prolonged storage of ammunition: shelving, cabinets and chests for storing ammunition; magazine ventilating, lighting, heating, flooding, sprinkling and drainage systems. Fixed ammunition, for example, is stored in honeycomb shelves with nests for each cartridge in a horizontal position, and is secured with special locks.

Ammunition is fed from magazines to artillery mounts by hoists.

Time- or proximity-fuzed high-explosive fragmentation shells are used to fire at air targets from medium- and large-caliber artillery mounts; percussion-fuzed high-explosive fragmentation and high-explosive shells at waterborne and coastal targets; armor-piercing shells at armored targets.

Point percussion-fuzed fragmentation tracers are fired from small-caliber antiaircraft artillery mounts, but for light-armored targets fire is conducted with base-fuzed armor-piercing shells.

In Vietnam combat operations the American navy is using ships armed with 127-mm guns (barrel length 38 and 54 calibers, range of fire 16.5 and 23.8 km respectively), 152-mm (47 calibers and 23.8 km) and 203-mm (55 calibers and 27.4 km) guns. The U.S. Navy is increasing the number of ships with artillery armament by demothballing them. In the shelling of the Vietnam coast there took part a battleship equipped with old 406-mm guns (weight of shell 1057 kg, range of fire 33.8 km).

For the conduct of combat operations in the coastal and inland water areas of Vietnam the American command is using a large number of different patrol boats armed with machineguns and cannon (from 7.62 to 40 mm in caliber), 40-mm automatic grenade launchers, and 81-mm mortars. The last-named has a recoil mechanism and therefore can also be mounted on small cutters. A peculiarity of the design of this mortar is its ability to fire not only at large elevations, but also at small ones (like a gun). It was recently modernized: a 12.7-mm machinegun was added to the barrel.

Rapid improvements continue to be made in shipboard artillery (of all calibers). In the opinion of foreign military specialists, it will develop as multipurpose automatic artillery with good protection against nuclear exposure, high cyclic rate of fire, precision of fire, and great destructiveness of the shell at target. Its main function will reduce to doing battle with air targets at low and medium altitudes. Medium- and large-caliber artillery mounts will also be able to strike at waterborne and coastal targets. For this purpose, work is under way to create more powerful conventional explosives, and projectiles with nuclear charges are under development.

The designs of mechanical and proximity fuzes are being improved by an increase in sensitivity and noise immunity.

In the United States experimental design work is under way on rocket-assisted projectiles for shipboard artillery, particularly for 127-mm guns used on destroyers. It is envisaged that the range of fire of these projectiles will be increased by 30 percent.

It is contemplated that the weight and size of shipboard artillery as a whole will be reduced by the use of light and high-strength alloys, as well as by efficient artillery mount designs.

This will make it possible to increase the number of fire weapons on ships or the amount of ammunition, which is of no small importance for ships operating far from their bases.

In the United States evaluation testing was begun in 1968 on a new 127-mm automatic gun for destroyers, which is three times lighter than existing guns of the same caliber. It takes only six men (instead of 16) to operate it. The shells are belt-fed to the gun. Pointing is performed automatically on instructions from a computer.

Coast Artillery

Coast artillery is charged with the mission of defending important coastal areas and islands against enemy sea attacks. In addition, it is used for the support of land forces operating along the coast.

Coast artillery is divided into fixed and mobile artillery depending on the type of mount.

Fixed artillery is of the turret type and is uncovered (patterned after deck artillery). Its armament consists of shipboard guns with a caliber of 130-180 mm or more with appropriate fire directors similar to those on ships.

Fixed coastal batteries are not being built at the present time.

Mobile coast artillery (self-propelled, tractor-drawn and railroad artillery) has found the widest use. Its caliber is in the 100- to 180-mm range.

Railroad artillery includes shipboard-type gun mounts. Tractor-drawn and self-propelled artillery consists mainly of models used by land forces.

Mobile artillery makes it possible to concentrate a large number of gun mounts at the point where there is greatest danger of landing operations or an enemy strike, thus assuring the protection of a large expanse of coastal area. In addition, it can be quickly shifted to places where no defense has previously been organized.

There have been significant changes in mobile coast artillery in recent years. The weight of vehicles has been reduced; their mobility and cross-country ability under difficult terrain conditions have been increased, as well as fire power. Preference at present is given to self-propelled artillery. Self-propelled guns have a high running speed and good cross-country ability. They can be quickly concentrated or dispersed and require less personnel to operate. Self-propelled guns are several times superior to railroad guns and tractor-drawn gun mounts in the time required for zeroing in.

Further improvements in mobile coast artillery, in the view of foreign specialists, will proceed along the line of an increase in maneuverability, maximum effective range, cyclic rate and accuracy of fire.

Chapter IX

ARTILLERY INSTRUMENTATION

1. Ground Artillery Observation Instruments

Successf·· performance of the missions with which ground artillery is charged is inconceivable under modern combat conditions without extensive employment of the most diverse artillery instruments.

The development of artillery instruments is inseparably linked with the development of artillery and the qualitative improvement of artillery weapons.

Observation instruments and topographical survey equipment have an important place in artillery instrumentation.

Ground artillery observation instruments are intended for study of the terrain and battlefield observation, the conduct of reconnaissance and determination of target coordinates, preparation of artillery fire, as well as the performance of topographical survey work.

In their design observation instruments are very diverse. The basis of their optical scheme is a telescopic system. Instruments adapted for observation with two eyes are called binocular instruments, and those adapted for observation with one eye are called monocular instruments. They have two and one telescopic systems respectively.

Every optical instrument has different characteristics, depending on its purpose. These include: magnification; field of view; diameter of entrance and exit pupils; exit pupil distance; illumination; resolving power; plasticity; and periscopism.

The magnification of an optical instrument is the name given to the number showing how many times larger the angle is at which the image of an object is visible in the instrument than the angle at which the same object is visible to the naked eye. Magnification 6, 8 and 15 times is the name given to six-, eight- and 15-fold magnification, and is designated as 6X, 8X and 15X.

The part of space visible in an instrument without moving it is called the instrument's field of view.

The entrance pupil of an instrument is the smallest aperture in the objective of an instrument through which light rays enter. The size of entrance pupils is designated on instrument cases. For example, binoculars with 8X magnification and an entrance pupil diameter of 30 mm has the designation 8X30.

The exit pupil of an instrument is the image of the entrance pupil given by the eyepiece, i.e. the circle of light which can be seen in the direction of the eyepiece of the instrument if the objective of the instrument is aimed towards the light.

Exit pupil distance is the distance from the outside surface of the last lens of the eyepiece to the eye of the observer. Lest light from the side interfere with observation, rubber eye shades are put on the eyepieces of an instrument.

The ratio of the image illumination of an object received on the retina of the eye during observation through an instrument to the image illumination of the same object when observed by the naked eye is called the illumination of the instrument. The square of exit pupil diameter is conventionally taken as the measure of an instrument's illumination. For example, the illumination of 15X binoculars with a 3.3 mm exit pupil diameter will equal ~ 10.

By resolving power is meant the ability of an instrument to give separate images of the fine detail of an object.

The capacity of a binocular instrument to give an observer the feeling of depth and relief of an observed space is called plasticity.

Periscopism of an instrument is the excess of the bundle of rays entering an instrument over the bundle leaving it. Periscopism makes it possible to conduct observations from behind cover.

The basic characteristics of observation instruments are presented in Table 19.

From among binocular observation instruments let us consider prism binoculars, the stereoscopic range finder and exploration theodolite, and from among monocular instruments, the periscopic aiming circle.

Binoculars are used for battlefield observation, terrain study and target reconnaissance, observation during firing, as well as for measurement of vertical and horizontal angles.

Binoculars (Figure 73) consist of two telescopes joined together by a hinge pin. They can be rotated around the pin and adjusted to the observer's eyes. In the right telescope a reticle with scale division 0-05 is plotted on a glass plate.

Each telescope consists of an eyepiece, case and objective. The case has right-angle prisms of the erecting system which serves to obtain an erect image, increase the instrument's plasticity and decrease its length.

The internal construction of all binoculars is the same. Binoculars with increased magnifying power have compound eyepieces.

For improvement of observation during fog, in bright sun, in winter, when objects are situated against a background of snow, as well as for long-range observation, yellow-green light filters are put on the eyepieces of binoculars in order to increase the image contrast of remote objects.

With the help of binoculars angles can be measured and the distances to objects determined. Horizontal and vertical angles are measured according to the reticle with accuracy to two or three azimuth micrometer scale units. Distances to local objects and targets can be determined if the observer knows their size. For this purpose the angle at which the height or length of the object (target) is visible is measured according to the reticle of the binoculars, and the magnitude of the distance is found according to the formula

$$D = \frac{l}{\alpha} 1000,$$

where l is linear size of the object, m;

α is angular size of the object, in azimuth micrometer scale units.

Table 19

PRINCIPAL CHARACTERISTICS OF OBSERVATION INSTRUMENTS

A Характеристики	B Бинокли			F Стереоскопический дальномер			J Разведывательный теодолит		M Перископическая артиллерийская буссоль ПАБ-2
	C Б6 (Б6×30)	D Б8 (Б8×30)	E Б15 (Б15×50)	G ДС-0,9	H ДС-1	I ДС-2	K РТ	L РГ-2	
1 Увеличение	6×	8×	15×	14×	12×	20×	10×	10×	8×
2 Поле зрения	1-42 (8°30')	1-42 (8°30')	0-67 (4°)	0-50 (3°)	0-83 (5°)	0-50 (3°)	0-83 (5°)	0-83 (5°)	0-83 (5°)
3 Диаметр входного зрачка, мм	30	30	50	34					22
4 Диаметр выходного зрачка, мм	5	3,8	3,3	2,1		2	4,5	5,4	2,8
5 Удаление выходного зрачка, мм	11	10,8	13	18,8		18,5	18,5	28	12,5
6 Светосила	25	14,4	10						Около 8
7 Разрешающая способность, сек	5	5	4	7	6	6	6	6	5
8 Перископичность, мм				220	302	369	300	300	350

Keys:

A. Characteristics

1. Magnification
2. Field of view
3. Entrance pupil diameter, mm
4. Exit pupil diameter, mm
5. Exit pupil distance, mm
6. Illumination
7. Resolving power, sec
8. Periscopism, mm

B. Binoculars
C. B6 (B6X30)
D. B8 (B8X30)
E. B15 (B15X50)
F. Stereoscopic range finder
G. DS-0.9
H. DS-1
I. DS-2
J. Exploration theodolite
K. RT
L. RT-2
M. Periscopic aiming circle PAB-2

6. around 8

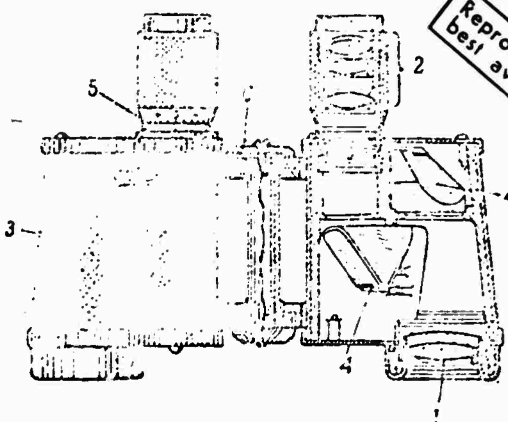

Figure 73. Binoculars:

1) objective; 2) eyepiece; 3) case; 4) erecting prisms; 5) scale of eyepiece for adjusting binoculars for image sharpness; 6) scale of interocular distances.

The stereoscopic range finder is a ground artillery general-purpose observation instrument. It is intended for target detection, determination of target distance and position (coordinates) and is also used for fire adjustment, topographical surveying and measurement of angles.

The stereoscopic effect of human vision -- the perception of the spatial arrangement of observed objects -- underlies the determination of distance by the stereoscopic range finder. Perception of the spatial position of objects is possible only with simultaneous observation by both eyes.

The stereoscopic range-finder kit (Figure 74) includes the range finder proper, support, tripod, illumination accessory, instrument for measuring the base line of the eyes, and carrying cases.

To assure accurate operation, the stereoscopic range finder is periodically adjusted for height of image and coincidence.

Height-of-image adjustment is performed every time before the start of operations. It consists in adjusting the wander marks in the right and left eyepieces to the same position for height.

Coincidence adjustment must be performed if the range finder has been subjected to violent vibration or blows, or if a new range-finder operator, who has to determine his "adjustment number," is starting to work the instrument. It consists in checking whether or not the parallelism of the optical axes of the stereoscopic range finder has been disturbed.

By means of the stereoscopic range finder target position is determined in a polar system of coordinates which are characterized by the horizontal angle between the base line of fire and target direction and distance.

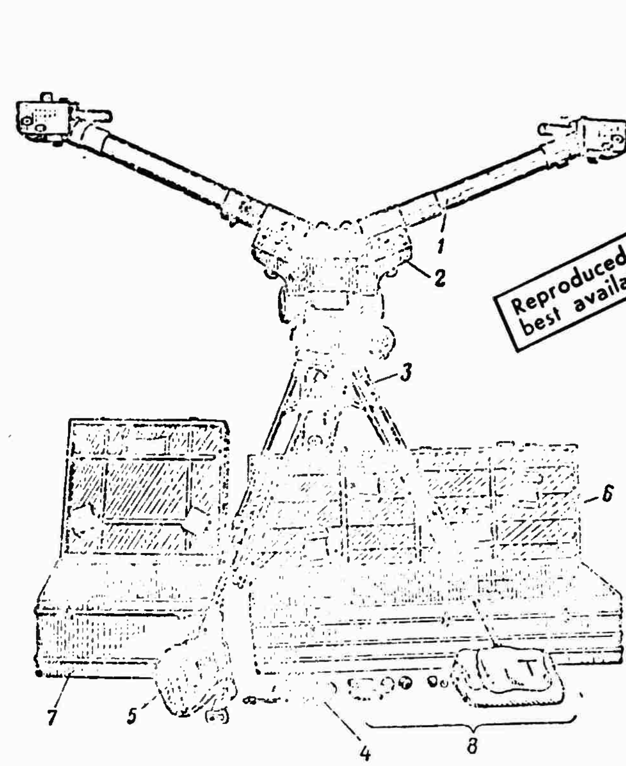

Figure 74. Stereoscopic range-finder kit:

1) range finder, 2) support; 3) tripod; 4) illumination accessory; 5) storage battery in bag; 6) range-finder carrying case; 7) support carrying case; 8) spare parts, tools and accessories.

The horizontal angle between base line of fire and target direction is found as the difference between 30-00 and target reading or calculated directly from the scale of the azimuth circle and measuring drum.

To determine range, the range finder is pointed at the target so that the central wander mark is above the target or beside it with a clearance of one-fourth the height of the mark. This is done so as not to lose the sensation of stereoscopism. Stereoscopic coincidence of the images of the central mark and of the target is then obtained by rotating the measuring roller and taking the reading according to the range scale. This reading will be the target distance. The measurement is made two or three times and the arithmetic mean of the obtained readings is taken.

When necessary, polar coordinates are transformed into rectangular coordinates by means of a special coordinate converter or by reference to the nomogram of the instrument's course, graphically on the chart (plotting board), analytically on a computer or according to special tables.

The exploration theodolite is used for detailed study of terrain and targets, observation during firing, and measurement of angles and distances (range).

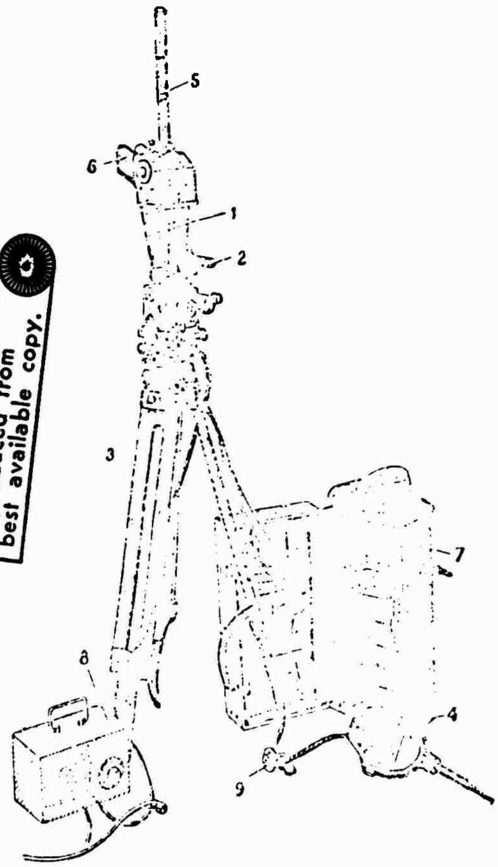

Figure 75. Exploration-theodolite kit:

1) theodolite; 2) declinator; 3) tripod; 4) pintle; 5) sighting rod; 6) blind; 7) carrying case; 8) storage-battery box; 9) illuminated reference point.

The exploration-theodolite kit (Figure 75) includes the theodolite proper, declinator, tripod and pintle, sighting rod, blind, illumination accessory, computer and carrying case.

The computer is used for computations in determining the coordinates of intersected targets and for the solution of computing problems in topographical survey work.

For the theodolite to work properly and accurately, it must be carefully checked. If in the process it is found that troubleshooting errors exceed permissible norms, the instrument must in all cases be repaired.

Accuracy in the theodolite-aided measurement of angles and distances depends on the care with which the instrument is pointed.

In measuring horizontal angles the theodolite is aimed first at an object on the right, then at an object on the left. The difference between the readings for the objects on the right and left will be the magnitude of the angle being measured.

An angle is usually measured twice. If the difference between measurements does not exceed 0-00.3, the angle has been found accurately. If it exceeds 0-00.3, the measurement is repeated.

Vertical angles are measured by reference to the reticle of the right eyepiece or by means of the elevating mechanism. The magnitude of the angle is determined as the difference between the angles of site of the features between which the angle is determined, taken with their signs.

Distances are determined with the theodolite by one of the following methods:

by reference to a known permanent base;

by reference to a range pole;

by intersection from base-end stations.

Distances can be measured by reference to a known permanent base and by reference to a range pole only in an area where friendly forces are disposed.

The measurement of distances by reference to a known permanent base rests on the employment of the theodolite as a range finder with a permanent base and a variable angle. The angle at which the base can be seen from the theodolite station is measured and the distance is found by using the formula which we know:

$$D = \frac{l}{\alpha} 1000.$$

Determination of distances by reference to a range pole is based on the use of the theodolite as a range finder with a constant angle and a variable base. Taken as the magnitude of the constant angle is the angle 0-05, for which at a given distance there is a given corresponding magnitude of a segment of the special pole. A count is made of the number of divisions of the pole found in 0-05 and if the value of these divisions is known, the distance is found.

To determine distances (range) by intersection from base-end stations, the following formulas are used:

$$D_r = \frac{B \sin(30\text{-}00 - L)}{\sin \gamma}; \quad D_l = \frac{B \sin R}{\sin \gamma},$$

where D_r and D_l are distances to the same object from the right and left observation posts;

B is intersection base;

γ is intersection angle;

L and R are theodolite readings from the left and right observation posts.

Quantities D_r and D_l are determined analytically or by means of the computer according to these formulas.

The periscopic aiming circle is an observation instrument and can be used for observation and reconnaissance, target location by intersection, measurement of horizontal and vertical angles and distances. However, its main purpose is the orientation of guns and instruments in a given direction, and determination of terrain magnetic azimuth and grid azimuths.

The periscopic aiming circle can be used at an observation post and fire position, as well as in topographic work for the tying-in of battle formations.

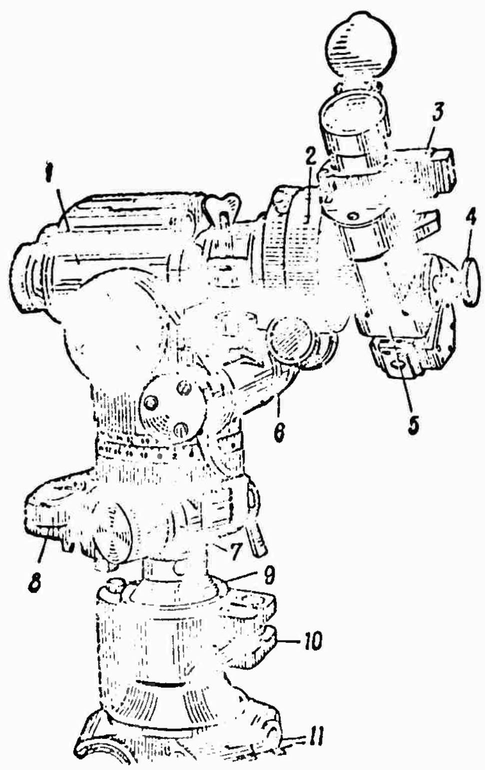

Figure 76. Periscopic aiming circle:

1) monocular; 2) azimuth cap; 3) level; 4) mechanism for turning the head of the sight; 5) sight; 6) body of reading worm; 7) body of adjusting worm with main pinion; 8) declinator; 9) vertical axis of pinion with ball pivot; 10) cup; 11) head of tripod.

The periscopic aiming circle kit (Figure 76) consists of the aiming circle with case, periscope with case, azimuth cap, illumination accessory and tripod.

The aiming circle is a compass connected with an azimuth and an optical instrument. The role of compass is played by the declinator, which serves to orient the aiming circle according to the magnetic needle.

The monocular of the aiming circle is a telescope of the same construction as the telescopes of binoculars.

The azimuth cap is an optical instrument intended for astronomical orientation of the aiming circle. It is fastened by means of a bracket with a carrier to the connecting piece of the objective of the monocular of the aiming circle.

Pieces and instruments are oriented in a prescribed direction by means of the periscopic aiming circle both before and after being placed in fire positions and observation posts.

Horizontal angles are measured by means of the aiming circle by reference to the reticle of the monocular, by reference to compass scales and by reference to azimuth scales.

Vertical angles between terrain features are measured according to the reticle of the monocular or determined as the difference between the angles of site of these features, taken with their signs.

Measurement of ground distances by means of the aiming circle is accomplished by reference to the range scale of the reticle of the monocular with the use of a two-meter pole, by reference to a known permanent base, by reference to a special range pole and by intersection from base-end stations. In the last three methods distances are measured in the same way as in operations with the exploration theodolite.

The method of measuring distances by reference to the range scale of the reticle of the monocular of the aiming circle with the use of a two-meter pole is based on the use of the aiming circle as a range finder with a permanent base and a variable angle. Distances from 50 to 400 m can be determined by this method.

2. Laser Range Finders

The greatest scientific discovery of the past decade in our century is lasers -- optical quantum generators, or simply light generators. Their operation is based on the phenomenon of the amplification of electromagnetic oscillations by means of the stimulated induced emission of atoms and molecules.

The first investigations in the sphere of laser generators and amplifiers were those of the Soviet scientists N. G. Basov and A. M. Prokhorov, who were awarded the Lenin Prize for this discovery. Later, the international Nobel Prize was also conferred upon them.

The value of lasers is that their emission possesses a number of remarkable properties. Unlike light emitted by conventional sources, it is coherent (the phase difference between oscillations is constant) in space and time, monochromatic, propagates in a very narrow beam, and is characterized by extraordinarily high concentration of energy. The energy density at the focus of the laser ray amounts to tens and and even hundreds of millions of watts per square centimeter of area. Even the sun does not radiate energy of such density. On its surface the radiation intensity is only about 10,000 w/sq cm. A low-power laser ray is capable of burning holes practically instantaneously through sheet steel and diamond, setting fire to various materials and creating temperatures on their surface up to 8000°.

The operational range of existing lasers varies from ultraviolet radiation with an 0.3-micron wavelength to infrared radiation with a 300-micron wavelength.

Prospects for the employment of lasers for various technical purposes are unusually wide and diverse (direction finding and navigation, medicine and biology, chemistry and geophysics, industrial processing of materials etc.). The use of lasers in ground communications will lead to a veritable revolution in communications engineering. For example, theoretically about a billion simultaneous telephone conversations can be carried on only one laser beam.

At present, according to a foreign press report, lasers are beginning to be adopted in artillery as range finders. They make possible the rapid and accurate determination of target range and a sharp increase in the probability of its first-round kill. By means of the laser a beam of light is obtained whose angular divergence does not exceed three angular minutes. Such a beam can be focused to a width of about one angular second, and at a distance of 1 km from source a light spot about 10 cm in diameter can be obtained.

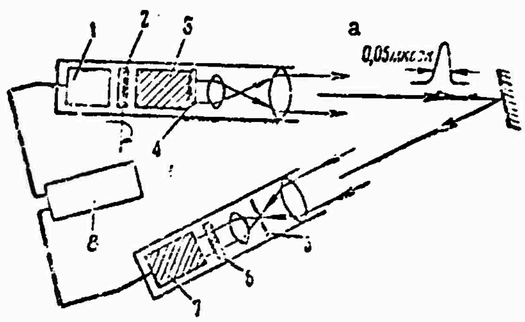

Figure 77. Schematic of laser range finder:

1) photodiode; 2) rotating prism; 3) ruby rod; 4) mirror; 5) diaphragm; 6) interference filter; 7) photomultiplier; 8) counter.

Key: a) 0.05 microsecond

The operating principle of the laser range finder is as follows (Figure 77). A laser beam is directed at an object through a transmitter telescope. Striking the surface of the object, it is reflected by it. Part of the reflected signal is trapped by a receiver telescope, at whose output a narrow-band optical filter is placed. By means of the filter the reflected signal is extracted even against a background of solar radiation and then goes to the input of a photomultiplier. The amplified signal actuates a pulse generator. Target range is determined from the number of pulses arriving at the input of the instrument during a given period of time.

Ordinarily a laser consists of three principal parts: active (working) material, for example, a ruby; resonance system, which consists of two parallel plates with reflective coatings applied to them;

and excitation (pumping) system, which can be a xenon flash lamp with a power source.

The ruby is produced synthetically from aluminum oxide, in which a small number of the aluminum atoms have been replaced by chromium atoms (0.05-0.5 percent). The color of the ruby depends on the amount of chromium, ranging from pale rose to dark cerise (as the chromium content is increased). Chromium ions are the active material.

The ruby rod is inserted in the helical xenon flash lamp, whose coils hold it on all sides. A large-capacitance capacitor, charged by a rectifier, serves as the power source. It discharges through the lamp, whose flash lasts for milliseconds. During this time the lamp consumes several thousand joules of energy. Most of the energy goes to heat the instrument, and a smaller part in the form of blue and green radiation is absorbed by the ruby. This energy makes possible the conversion of the ruby to nonequilibrium state by excitation of the chromium ions. Stimulated emission is thus obtained.

The laser range finder emits a light pulse of very short duration. To shape short pulses of great amplitude, rapidly rotating mirrors and prisms are employed. At the moment when the rotating mirrors are in a certain position, a pulse is emitted which reaches the target, is reflected by it and trapped by the optical system of the receiver part. The process of energy accumulation and emission in simple form is called Q-switching. Information about target range lights up on the lighted panel indicator beside the optical sighting device.

The principal advantages of laser-based range finders are as follows: high accuracy in the measurement of range, considerably exceeding the accuracy of conventional range finders; accuracy of measurement regardless of target range; small size of the beam-shaping system; immediate output of measurement results. In addition to range, the laser range finder permits rough measurement of azimuth and angle of sight.

Laser range finders also have shortcomings which lessen the effectiveness of their use: low efficiency ratio not exceeding 10-15 percent even in the most powerful designs; great losses occurring during the transformation of electrical energy into the light energy of the flash lamp and then during its conversion into the coherent luminous energy of the laser. But a more significant shortcoming of the laser range finder is its dependence on the composition and properties of the atmosphere, i.e. on meteorological conditions. A light pulse weakens appreciably during rain and fog.

The laser range finder can be transported and serviced by one operator. It can be mounted on tanks, artillery pieces, aircraft and helicopters. The range finder is employed to determine target range on the battlefield, during bombing, in escort systems, in navigation and in topographical measurements. In addition, the range finder can also be used for meteorological purposes.

3. Sound-Ranging Equipment

Sound-ranging in the ground artillery is conducted by sound-ranging podrazdeleniya constituting artillery observation.

Sound-ranging podrazdeleniya are supplied with special sound-ranging equipment which makes it possible to determine the coordinates of firing enemy batteries (guns, mortars, rocket artillery launchers) from their reports and, when servicing the fire of friendly artillery, to tell the sites where projectiles or mortar shells fall from the sound waves originating when the shells burst.

Visibility conditions do not affect the propagation of sound waves. Therefore, sound-ranging facilities successfully fix firing enemy batteries under poor visibility conditions (night, fog, rain etc.), as well as batteries located in concealed fire positions and not observable from ground observation posts.

A characteristic feature of sound-ranging instruments is that they are designed chiefly for receiving reports (bursts) only. Extraneous sounds occurring on the battlefield have practically no effect on the functioning of a set if their sources are several hundred meters away from sound-ranging stations.

Firing with the help of sound-ranging podrazdeleniya is conducted, as a rule, with guns (mortars) of larger caliber than 105 mm, which make it possible to obtain good recordings of the sound waves of shell bursts at an intersection range of 6-8 km or more.

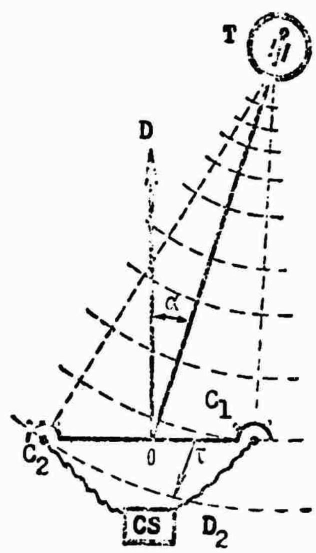

Figure 78. Principle of determining bearing of sound-producing target:

T) target; C_1) and C_2) sound collectors; $C_1 - C_2$) sound ranging base; 0) center of sound ranging base; OD) directrix of sound ranging base; CT) sound bearing ; CS) sound central station.

The principle whereby the bearing of a sound-producing target is determined is shown in Figure 78. Generally, the battle formation of a sound-ranging podrazdeleniye consists of sound-ranging stations situated at a distance of 2-4 km from the main line of resistance of friendly forces and 1-1.5 km away from each other, a central station, one or two warning stations and a meteorological station. Successful functioning depends in many respects on proper location of sound stations, warning station and central station.

Sound stations are so arranged as to assure good audibility and the possibility of performing topographical survey work etc. rapidly and accurately. The warning station is usually sited at a point in the reconnaissance zone where sound waves arrive at least one second earlier than they do at the sound station closest to the target.

The site for the central station is selected in the middle of the line of sound-ranging stations, far from roads with heavy traffic. It must be concealed from enemy ground and air observation. The meteorological station is situated near the central station.

Each sound-ranging station has sound collectors. They receive enemy gun reports and convert them into electric current oscillations for transmission to the recorder at the central station. At this same place are located a data-processing station and a communications center.

The recorder receives and records on paper tape the electric current oscillations coming from the sound collectors.

The processing station processes tape with recordings of gun reports and determines the coordinates of the sound sources. The communications center is in communication with the batteries whose fire is adjusted by the sound-ranging podrazdeleniye. In addition, it controls the operation of the sound-ranging stations and the warning station, which conducts visual observation of enemy artillery and mortar activity and starts up the recorder.

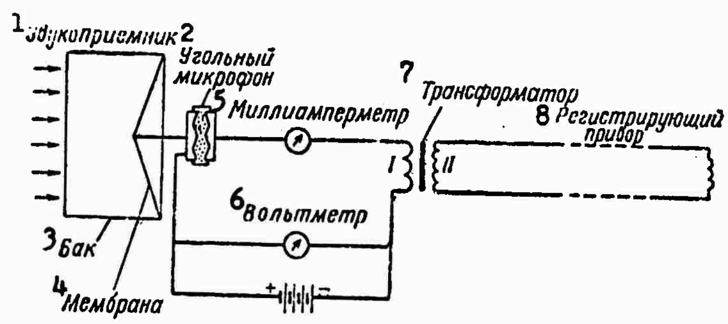

Figure 79. Basic circuit of sound-ranging set.

Keys:

1. Sound collector
2. Carbon microphone
3. Tank
4. Membrane
5. Milliammeter
6. Voltmeter
7. Transformer
8. Recorder

The meteorological station measures the ground temperature of the air, wind direction and velocity, and transmits measurement results to the processing station to be taken into consideration in determining the coordinates of reconnoitered targets or the sites of shell bursts.

In speaking of the operating principle of sound-ranging, it must be borne in mind that first sound bearings are determined from the centers of sound-ranging bases, and then these bearings are graphically constructed on the plotting board, and the position of the sound source is obtained at the site of their intersection.

To determine a sound bearing, the principle used is the time difference between the arrival of a sound at the stations on the sound-ranging base. To locate sound sources by intersection when servicing the fire of friendly artillery, the sound-ranging podrazdeleniye employs sound ranging apparatus (Figure 79), which consists of the sets of instruments of the sound-ranging station and the warning station, the instruments of the sound central station, and the instruments for processing sound-ranging tapes and readings and for determining target coordinates.

In addition to the sound collector, the instruments of a sound-ranging station include a transformer, storage battery and telephone. The sound collector consists of a tank, membrane and microphone. The membrane picks up low-frequency sound waves generated during the firing of a gun or during a shell burst and oscillates in response to them. The microphone transforms the sound oscillations into electric oscillations.

The transformer serves to transform the ripple current, which appears when sound is received in the primary circuit of the sound collector, into alternating current in the secondary circuit with an increase in its voltage.

The secondary winding of the transformer cuts in the circuit of the corresponding writing coil of the recorder which records the electric current oscillations on paper tape. The recorder consists of a writing mechanism, tape drive and tuning-fork mechanism, start and stop mechanism and control panel. The writing mechanism has several writing systems (according to the number of sound-ranging stations) and one writing system for time-scale recording. The writing system is an electromagnet, in whose magnetic field is placed a writing coil having on one side a plate with a glass pen and on the other an elastic plate fastened at one end in a clamp.

As the current from the secondary transformer winding enters the writing coil, it forms a magnetic field around the latter. This field interacts with the magnetic field of the electromagnet producing oscillations of the writing coil and, consequently, of the pen as well, which records on the moving paper tape the oscillations resulting from the action of the sound wave on the membrane of the sound collector. The tape drive pulls the tape at a constant speed. It consists of an electric drive and tape winder.

The tuning-fork mechanism produces oscillations of electric current of constant frequency in order to maintain constant the number of revolutions of the electric motor of the electric drive of the tape transport and in order to record time scale on the paper tape. The start and stop mechanism serves to start up the recorder from the warning station and stop it after the tape recording of the gun report has been obtained.

The control panel is equipped with instruments to monitor the operation of the recorder.

The set of instruments of the warning station includes a warning device and a telephone.

The warning device starts up the recorder only at those times when sound sources must be recorded. The chief of the warning station starts the recorder by pushing a button on the warning device which breaks the circuit of a special relay installed in the recorder. The relay usually actuates and starts up the recorder before the sound of a shot (**burst**) arrives at the sound-ranging stations.

Sound-ranging stations and the warning station are connected with the recorder by communication lines.

In determining the coordinates of sound-producing targets and in servicing the fire of friendly artillery the processing station first processes tapes (decodes them and takes readings) and then readings, i.e. computes the sound bearing from the center of each sound-ranging base. The decoding problem is to find the necessary recordings among the large number received on tape. If fire activity is weak, this presents no special difficulty.

Regarded as the basic method of tape decoding is the geometric method, which is based on the fact that for every target there is one corresponding rigidly-defined recording system on the tape, given a particular reciprocal arrangement of sound-ranging stations and targets on the terrain.

After the recording system is found, the starts of recordings are noted. If there are sharp rises in the recordings, it is rather simple to determine the starts. After this, readings are taken and the time difference found between the arrival time of a sound at sound-ranging stations on the sound-ranging base. Readings are taken directly by measuring segments between recording starts on the tape in tenths of a millimeter. The number of resultant tenths of a millimeter equates to a reading in thousandths of a second.

The target bearing from each sound-ranging base is then computed. Knowing the target bearing from the centers of sound-ranging bases, the central station determines target coordinates by graphic constructions on the target plotting board, or analytically.

The graphic method is employed only in cases where the tying-in of sound-ranging stations has been performed by reference to map (photograph) by eye-sketching methods.

The analytic method takes considerable time for computations and therefore is rarely used except when the coordinates of especially important targets must be determined more precisely.

There is another combination method of determining target coordinates. It is employed in tying-in sound-ranging stations on a complete topographic basis. In this case some of the work is performed graphically, and some analytically. It is believed that the combination method is simple and sufficiently accurate. Therefore it is the basic method.

The accuracy of sound-ranging work depends on the quality of survey training and the method of allowing for meteorological factors.

This is the essence of the operation of the sound-ranging equipment which is employed to support artillery and mortar fire. There may be differences in instrumentation (use of magnetic recording, oscilloscopes, computers etc.) in specific models of sound-ranging sets, but the operating principle of these sets remains unchanged.

The first sound-ranging set was designed back in 1909 by an officer in the Russian Army, N. A. Benua. Later such sets appeared in Germany, France, England and the United States.

During the years of the Great Patriotic War sound-ranging sets of the SChZM-36 (ink-recording set M1936) type were in service in our artillery. They were handy and stable in operation on any terrain and in any weather.

A sound-ranging set AN/TNS-5, consisting of four autonomous azimuth-determination sets transmitting obtained data to a central computer station, has been developed for the American Army. Target position is determined by triangulation.

Each azimuth-determination set consists of a condenser microphone, magnetic tape recorder, oscilloscope and computer. The recorder makes possible measurement of the relative time required to receive a signal by visual comparison of the signals appearing on the oscilloscope screen.

The time difference between the signals coming from the two microphones is fed into the computer, which calculates the azimuth of the arriving signal.

The autonomous azimuth-determination sets are placed in the corners of a square with a diagonal from 50 to 600 m (usually 300 m). The received sound signals are continuously recorded on individual tracks of magnetic tape, which is a closed loop 90 m long moving at a speed of 10 m/sec. A photosensitive track with timing marks is entered on the tape by a photo process. When the track is illuminated, pulses appear which are compared with a frequency standard for regulating tape speed. Thus, timing marks on the reverse of the tape make possible exact determination of absolute signal arrival time, and this is used to distinguish azimuth data received from the different sets during protracted listening.

In the compilation of a triangulation map all recorded targets have the same sound source. In addition to the four recording tracks for signals from the microphones, a correcting track runs along each tape edge in order to eliminate tape skew while listening to the recording.

The recorded signals are reproduced by means of a special head rotating at a speed of 20 rpm. The frequency of the recorded signals is converted in a range from 160 to 16,000 cps.

Under ordinary operating conditions the operator listens to signal recordings with earphones. When target signals appear, the operator halts the tape and analyzes the signals, using the oscilloscope. On the oscilloscope screen signals from the four microphones appear on individual tracks, and the operator superposes them on one another by means of two knobs. In the event of complete coincidence of tracks the computer calculates the azimuth of the received signal with correction for wind velocity. Signal arrival time is calculated from the reverse of the tape.

Tape recording of signals continues during analysis of the signals on the oscilloscope screen. A tape with a new recording constitutes a loop, which is stored in a special compartment. After analysis of the data the loop automatically moves out of the compartment, and after readout of the signals returns again to the compartment. Duration of storage of recording: four hours.

Accuracy of azimuth determination by the AN/TNS-5 sound-ranging set: $\pm 0.06^{\circ}$; absolute time accuracy during protracted listening: 0.1 sec; during brief listening: 0.01 sec.

Evaluation tests of this set conducted several years ago showed that it is too cumbersome and requires more operating personnel than the sound-ranging set employed by the Americans during World War II.

In 1968 the United States developed a sound-ranging system for determining the position of artillery pieces. The system is composed of ten transmitters, nine receivers, seven microphones, three power sources, two control blocks, switches, antennas, as well as the necessary tools, packing bags and monitoring apparatus.

Structurally the system is executed in the form of individual blocks, the weight of each of these not exceeding 11.3 kg. The system is set up on the terrain not only by means of ground equipment but also by means of air equipment.

When the system is deployed under field conditions, sixteen lines of radio communications are formed, over which signals are transmitted in three basic directions: from two forward observation posts to command post; from command post to each microphone; from microphones to command post. The use of coding, synchronization and time-division multiplex makes it possible to conduct 16-channel communication on two frequencies.

Broadband end-fed antennas in the form of half-wave dipoles connected to the antenna switch block are common for receiver and transmitter. The microphones, which are of exceedingly rigid construction, permit signal reception on frequencies from 1 to 300 cps. A special circuit is provided in these for automatic adjustment of sensitivity in relation to wind force and external-noise level.

Recently the United States developed the "X-Sonad" sound-ranging system for determining the position of enemy mortars. It consists of a number of remote pickups, joined by cables with electronic equipment (acoustic signal processing apparatus and indicators) which is mounted in a motor vehicle. Each pickup includes two moving coils and two gradient microphones placed in mutually perpendicular planes in a windproof case, which permits operation of the pickup at wind velocity up to 32 km/hr.

The gradient microphone is an acoustic converter with two diaphragms situated on both sides of the symmetrical case. The microphone output signal is proportional to the sine or cosine of the angle of incidence of the sound wave originating during mortar firing. The use of two microphones per pickup assures its omnidirectionality in determining the direction of the arrival of sound waves.

The accuracy of the X-Sonad system is 1°, which at a range of 300 m does not exceed 50 m. The operating frequency range of pickups is 10-125 cps.

The acoustic signals of pickups (up to four) are reproduced on the oscilloscope screen. The operator feeds the signal of one of the pickups into the processing apparatus, producing an output signal which is then reproduced on the screen of the second oscilloscope. The system also provides a device for separating the rapidly changing noises and fast acoustic signals created during mortar firing.

Weight of the electronic equipment in the system: 227 kg. Volume: 0.28 cu m.

4. Topogeodetic Tying-in Equipment

This equipment is intended for the topogeodetic preparation of artillery, which consists in creating the initial basis for topogeodetic tying-in and in the topogeodetic tying-in proper of positions, stations and posts.

Depending on purpose, topogeodetic tying-in equipment is divided into the following groups:

azimuth instruments (theodolites, artillery gyrocompass, periscopic aiming circle);

instruments and devices for the measurement of terrain distances (survey tapes, optical range finders, range poles);

calculating instruments (arithmometers and other calculators, slide rules and computers, nomograms of instrument behavior);

instruments and accessories for graphic work (artillery protractors, milrules, dividers, rules, triangles).

By means of these instruments and devices the artillery control survey net is created; the coordinates of fire positions, observation points, and the posts and positions of podrazdeleniya of ground artillery reconnaissance are determined; guns and observation instruments are oriented in the principal direction; targets and reference points are located by intersection; and grid bearing angles of terrain features are determined.

Topogeodetic tying-in equipment also includes the topographic survey vehicle and mobile artillery observation point, by means of which position data can be automatically determined.

The theodolite is a basic azimuth instrument of average accuracy. It is intended for the measurement of vertical and horizontal angles, and distances, as well as for the determination of true azimuths from astronomical observations of celestial bodies.

The theodolite kit (Figure 80) consists of the theodolite with trivet, tripod, declinator, periscope with case, eyepiece cap, illuminating accessories, packing case for the apparatus, and shockproof chest for transporting the theodolite.

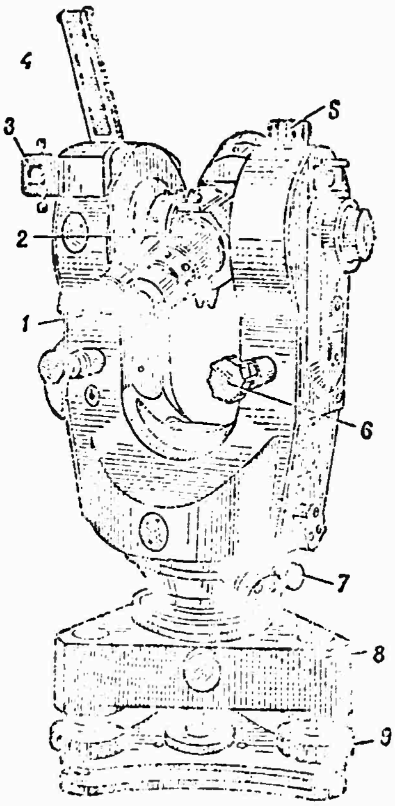

Figure 80. Theodolite:

1) telescope eyepiece; 2) telescope focusing ring; 3) level of vertical circle; 4) mirror; 5) telescope clamp screw; 6) slow-motion screw of telescope; 7) slow-motion screw of horizontal circle; 8) tripod; 9) tripod elevating screw.

The declinator is intended for magnetic orientation of the theodolite.

The periscope is put on the objective of the telescope when working with the theodolite from behind covered positions.

The eyepiece cap on the telescope is used for convenience in pointing the telescope at large angles of inclination, as well as in astronomical fixation.

Horizontal angles are measured by a theodolite in two ways: the individual-angle measurement method and the method of rounds. The second method is employed in cases where two or more angles must be measured from a single point.

Both methods consist of two rounds: first, the angle is measured with the vertical circle placed to the right of the telescope ("face right"), then with the vertical circle placed to the left of the telescope ("face left"). The divergence between the values of the measured angle in the rounds must not exceed 20".

Measurement of vertical angles (angles of inclination) is also accomplished by two rounds.

Distances are determined by means of a theodolite by reference to a special range pole according to the principle of distance measurement by a fixed-angle range finder. In the process two short lines of the reticle of the telescope of the theodolite are used.

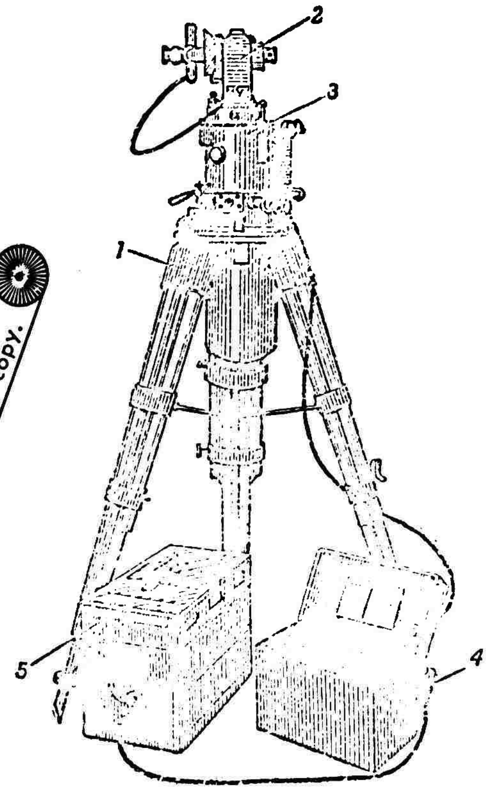

Figure 81. Artillery gyrocompass:

1) tripod; 2) azimuth scale part (special theodolite); 3) gyro unit; 4) storage battery; 5) current converter.

The artillery gyrocompass (Figure 81) is designed to determine the grid and true bearing of orienting lines of the terrain in any season of the year and at any time of day regardless of meteorological conditions. In practice the operation of the gyrocompass is independent of the earth's magnetic field. Therefore, it can be employed under any conditions, including regions of magnetic anomalies.

The gyrocompass is comparatively simple in construction, and its operating principle can be mastered on the basis of an elementary knowledge of physics.

The gyrocompass package includes a gyro unit, special theodolite, tripod, power source, current transformer, azimuth cap, and electric aiming stake, as well as spare parts, tools and accessories for preventive maintenance and correction of very simple defects.

The gyro unit is the basic part of the gyrocompass. It serves to determine the true north heading of the gyrocompass station and consists of a sensitive element and a reservoir of supporting fluid.

The sensitive element is a hollow, hermetically sealed cylinder, inside which is the gyroscope (a rapidly rotating flywheel). The element floats freely in the reservoir of supporting fluid, and is centered relative to the reservoir. The geometric axis of the sensitive element strives to maintain a vertical position. However, the shifting of the center of gravity relative to the point of support gives the element the appearance of a pendulum.

In pendulum-type gyrocompasses the main axis of the rapidly rotating gyroscope is capable of executing a slow oscillating motion relative to the true north heading. This property of the sensitive element is the consequence of two fundamental properties of the gyroscope itself, which underlie the operating principle of the pendulum-type gyroscope:

the main axis of the rapidly rotating gyroscope tends to maintain its position unchanged relative to space;

if a couple is applied to the main axis of the rapidly rotating gyroscope, the axis under the action of the moment of this couple will turn in a plane perpendicular to the direction of the action of the applied forces; at the same time, the direction of turning coincides with the direction of the force turned 90° in the direction of the rotation of the gyroscope rotor.

The special theodolite with autocollimating telescope serves to determine the reading which corresponds to the true north heading according to the autocollimating mirror and the terrain feature reading. In addition, by means of the special theodolite it is possible to measure horizontal and vertical angles and magnetic azimuths, as well as perform astronomical fixation.

Work with the gyrocompass at a point for determination of the grid bearing of an orienting line consists in: preparation of the instrument for operation; observation of the reference point and reversing points; and in calculation of the grid bearing.

During observation of the reference point the telescope in "microscope to the right" position is aimed at the reference point, and a horizontal circle reading taken. Reversing points are observed in the oscillation range of the sensitive element from 5 to 25°. Reversing point readings are taken with a notation of the time of day of the observation of each point. Reading results are recorded in an observation log.

For greater accuracy the grid reference of an orienting line is determined by observation of four reversing points with allowance for gyrocompass correction, which is found as the difference between the true azimuth of some direction and the azimuth of the same direction obtained by means of the gyrocompass.

Accuracy in the determination of the true azimuth (grid bearing) of an orienting line by means of the artillery gyrocompass equals 1'-3'.6.

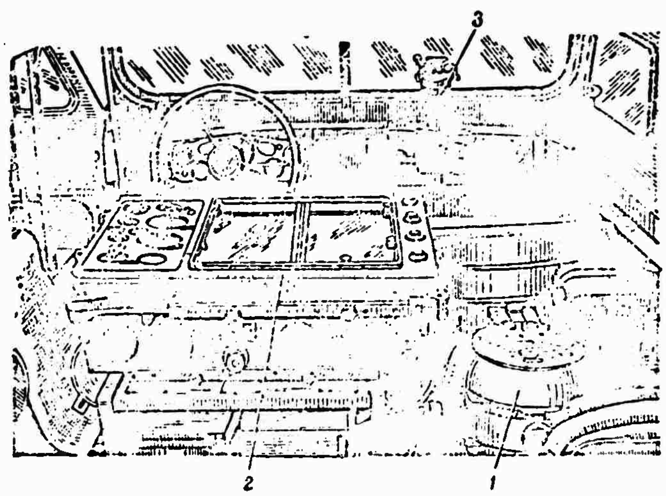

Figure 82. Topographic survey vehicle:

1) gyroscopic course indicator; 2) course plotter; 3) sighting device.

The topographic survey vehicle is used for the topogeodetic tying-in of elements of artillery in position during fast preparation and during combat. It can be employed to supply initial points in the areas of deployment of artillery observation points and ground artillery reconnaissance equipment in the absence of maps or aerial photographs with a grid, as well as in work on terrain poor in contour points.

The topographic survey vehicle is a motor vehicle, on which is mounted a set of special ground navigation instruments intended for the automatic determination of the coordinates of ground points to be tied-in.

The operating principle of the survey vehicle is based on continuous solution of the direct geodetic problem by feeding a computer data regarding the route taken by the vehicle and the grid bearing of the vehicle's motion.

The problem is solved automatically by the basic instruments of the topographic survey vehicle: gyroscopic course indicator, route data unit, course plotter, power unit, and sighting device.

The kit of the topographic survey vehicle also includes an aiming circle for determination of the grid bearings of orienting lines during the initial-point orientation of the topographic survey vehicle and during monitoring of orientation while plotting the survey route, and a range finder for measuring distances from 50 to 1000 m by observation of ground features.

The gyroscopic course indicator is intended for working out the angle of turn of the motor vehicle and transmitting them to the course plotter. The main part of it is the gyroscope, which serves to maintain in space the direction first given to its axis of rotation. By means of the gyroscope the grid bearing of the longitudinal axis of the motor vehicle's motion relative to the axis of the gyroscope is continuously and automatically determined, and the results transmitted to the computer in the form of electric pulses.

The distance traversed by the motor vehicle is determined by the route data unit from the nondriving wheels and transmitted to the computer.

The computer (course plotter), from the coordinates of the initial point of the topographic survey vehicle's operation and from the data continuously received from the gyroscopic course indicator and route data unit, works out the coordinates of the topographic survey vehicle's position for each moment it is in motion, as well as tracing on a map, by means of a special plotter, the route of the vehicle's movement.

The sighting device is intended for initial-point orientation of the topographic survey vehicle, for monitoring of orientation during operation, and for taking grid bearings from a point where the topographic survey vehicle is halted to ground features.

In order for the topographic survey vehicle to operate successfully in the tying-in of elements of artillery *in position*, the following are necessary: to save tie-in time, the navigation apparatus is switched on in advance; initial points are selected as close as possible to the area of the points being tied-in; itineraries are plotted over the shortest possible distance.

If several points are to be tied-in simultaneously, the topographic survey vehicle goes by all points in turn and closes the run at the contour point.

If the points to be tied-in are visible to each other, the topographic survey vehicle is oriented by means of the gyrocompass at a point situated approximately in the middle of the area of the tie-in points, and then by mutual referencing the orienting line is transmitted to all tie-in points. Simultaneously by means of the sighting device the grid bearings of the points are taken, and the distances to them measured by the range finder. The grid bearing values and ranges are fed into the course plotter in turn and the coordinates of the tie-in points are obtained.

In the absence of mutual visibility of the tie-in points, the coordinates of the points are determined and a bearing is taken for each one in turn by driving from one point to the other.

Accuracy in determining the coordinates of the tie-in points depends on the character of the terrain and the length of the itinerary. With itinerary length under 5 km, mean error can be 30-50 m, depending on map scale.

The mobile artillery observation point (MAOP) is an armor-plated tracklaying vehicle for use as a command post or forward observation post of artillery chasti and podrazdeleniya and for the conduct of reconnaissance and artillery fire control.

In isolated cases the MAOP is used for the topogeodetic tying-in of artillery in position. For this purpose it is fitted out with special instruments, whose operating principle is the same as in the topographic survey vehicle.

For the solution of topogeodetic tying-in problems the MAOP has a gyroscopic course indicator complete with current transformer and motor-generator, route data unit, and course plotter. The purpose of these instruments is the same as in the topographic survey vehicle.

5. Meteorological Support of Artillery Fire

Meteorological conditions are one of the most important elements affecting performance of the missions confronting all kinds of artillery. Meteorology deals with the study of these conditions. From the viewpoint of practical application, meteorology is divided into a number of applied disciplines, among which artillery meteorology is included.

It studies questions of the effect of meteorological conditions on artillery combat activity and especially on firing. It develops methods and practical procedures for determining these conditions and taking them into account during preparation for firing, and seeks the most efficient forms of meteorological support of all types of artillery.

At present, as a rule, not a single round of medium- or heavy-caliber artillery is fired without taking meteorological conditions into consideration.

As is known, a projectile moving in the air, apart from the force of gravity, is also acted upon by the force of air resistance and by the wind. The resistance of the air is directly proportional to its density. Therefore, the flying range of a projectile declines with an increase in air density, and vice versa. However, air density in turn depends on atmospheric pressure, air temperature and atmospheric humidity. The wind alters the flying range of a projectile and deflects a projectile away from its original direction of flight.

Hence it can be seen that in artillery fire it is necessary to take into account the state of the atmosphere, which is characterized by the values of such meteorological elements as air temperature, atmospheric pressure, wind velocity and direction, as a function of altitude in the various strata of the atmosphere. It has been established that if accurate data regarding the altitude distribution of meteorological elements are available, artillery can employ the full preparation of initial firing data without fire adjustment.

It is especially important to take meteorological conditions into account in antiaircraft artillery fire. Whereas in ground artillery fire adjustment is possible, permitting the elimination of errors in the preparation of initial firing data, no adjustment is performed in antiaircraft artillery fire on aerial targets -- fire is delivered straightway for effect. Therefore, antiaircraft artillery fire must be carefully prepared, taking into account the meteorological factors that affect the position of bursts.

Meteorological support of artillery is performed by meteorological podrazdeleniya. They conduct ground meteorological observations and temperature and wind-velocity sounding of the atmosphere.

Ground values of meteorological elements are usually determined at an altitude of 2-5 m above the earth's surface. In artillery meteorology the values of meteorological elements at some specified altitude are called actual values in contrast to mean values, by which are understood the average values of meteorological elements from the earth's surface to the prescribed altitude.

Meteorological stations are considered the basic units of the meteorological service. In some artillery podrazdeleniya there can be meteorological posts.

Meteorological stations perform the entire complex of necessary ground meteorological observations and temperature and wind-velocity sounding of the atmosphere.

Meteorological stations compile weather bulletins and storm warnings from the results of ground observations and atmospheric soundings.

Depending on their affiliation, meteorological posts conduct ground observations of the wind, air temperature, atmospheric pressure and wind-velocity sounding of the lower atmospheric strata.

The meteorological data published in bulletins must be accurate, complete, timely and obtained as close as possible to the place where they will be used. For this purpose meteorological stations travel in the course of combat operations and are deployed at short distances from artillery fire positions.

Ground observations in podrazdeleniya of the artillery meteorological service are conducted with instruments and without -- visually.

Air temperature, wind direction and velocity, and atmospheric pressure are determined with instruments. The accuracy of meteorological data depends on the accuracy with which the instruments operate. Therefore, the instruments must be checked in advance. All observations and computations are conducted in strict conformity with established regulations.

Visual observations are made of dangerous natural phenomena (thunderstorms, cloudbursts, snowstorms, dust storms, fogs).

Observations of atmospheric phenomena and cloud cover, as well as the recording of pressure change make it possible to judge the state and character of the change of the weather.

Podrazdeleniya of the meteorological service measure the ground temperature of the air by liquid (mercury and alcohol) thermometers. Meteorological stations determine the direction and velocity of surface wind by means of an anemorhumbometer, while meteorological posts make the determination by means of a field anemometer.

An anemorhumbometer is an electrical instrument with remote transmission of wind data from a wind velocity and direction sensor. It is constructed according to the principle of converting wind data into electrical quantities. An eight-blade vane serves as wind-velocity receiver in the instrument, and a wind vane as wind-direction receiver.

The field anemometer is an instrument of mechanical type. It determines wind velocity and direction at the site where it is set up.

The principle of wind-direction measurement is the same as for the anemorhumbometer. Wind-velocity measurement is based on the fact that the deflection angle of the plate (wind receiver) is a function of the value of the pressure on the air flow plate, i.e. of wind velocity.

The surface pressure of the atmosphere is determined by various types of metal aneroid barometers and mercury barometers. The principle of pressure measurement by means of an aneroid barometer is based on the relationship between the measured pressure and the elastic deformations of the membranes of the aneroid cases.

Surface humidity under field conditions is found by means of psychrometers and special psychrometric tables. A distinction is drawn between absolute and relative air humidity. By absolute humidity is understood the pressure of the water vapor present in the air. It is expressed in millimeters of mercury. The more water vapor in the air, the greater the vapor pressure.

Relative humidity is the ratio between absolute humidity (vapor pressure at the time of observation) and maximum vapor pressure at the same temperature. It characterizes the degree of water vapor saturation of the air and is expressed as a percentage.

The variation in relative humidity is the opposite of temperature variation. Therefore, minimum relative humidity is observed by day and in the summer, and maximum relative humidity by night and in the winter.

Only relative humidity is determined in the layers of the atmosphere.

Temperature and wind-velocity sounding of the atmosphere is performed by means of radiosondes operating together with a radar set.

A radiosonde consists of a radio transmitter, baroswitch, temperature sensor (thermistor) and power unit. The radiosonde automatically transmits air-temperature and pressure data in the form of coded radio signals.

The radiation of the radiosonde transmitter is used by the radar set for the radiosonde bearing and its automatic angular tracking by angular coordinates.

In the U.S. Army, for example, radiosondes are mounted on large balloons which are capable of ascending to an altitude of 35-40 km at a speed of 450 m/min. During ascent and at a specified altitude the radiosonde transmits data about atmospheric pressure, temperature and humidity.

In addition to balloons, meteorological rockets are used in foreign armies as carriers of meteorological apparatus. They are usually two-stage rockets. An instrument compartment is placed in the second stage. When the rocket attains maximum altitude, the instrument compartment is ejected by means of a pyrotechnic device. It then descends by parachute, measurement data being transmitted the while to the ground station. A sonde-tracking radar set determines wind velocity and direction.

The measurements received at meteorological stations are processed and distributed to artillery podrazdeleniya in the form of a "meteo-mean" bulletin, on the basis of which ballistic mean values (deviations) of meteorological elements are calculated.

Ballistic mean values are used to determine the corrections to be taken into consideration during firing under given meteorological conditions.

The employment of radar equipment in military meteorology has become part of everyday practice in many armies. This is due to a number of advantages which radar methods of meteorological observations have over other methods, for example, theodolite optical observations of pilot balloons. First, radar sets have a greater range of vision, and greater volumes of space can be covered, with measurement results independent of the time of day or state of the weather. Second, it takes little time to obtain the meteorological data in a station's operating range.

The U.S. Army command attaches great significance to matters concerning the development of military meteorology. As one of the most important areas of scientific research work in the near future, the U.S. Department of Defense is proposing investigations in the field of medium-altitude (tropospheric) meteorology and development of new means of atmospheric sounding.

Requirements to be met by the meteorological systems under development are high-speed receipt, processing and transmission of meteorological data to the troops. To raise the reliability of weather reports, especially under conditions of mobile combat operations, the functions of data processing and transmission have been automated by wide-scale use of electronic computers.

6. Sighting Mechanisms

Calculated firing data are used in sighting mechanisms.

Despite differences in details the essence of the construction of all gun sighting mechanisms is the same. To point a piece, first its barrel must be turned in the direction of the target, or if a target has not yet been designated, the piece must be given the principal direction. This is called laying for direction. Second, the muzzle end of the piece must be elevated or lowered to such an extent that the barrel forms a certain angle with the horizon, given which the projectile will fly for just the prescribed distance to target, no farther and no less. Giving the barrel of the piece the angle of elevation is called laying for elevation.

Laying for direction is performed with the azimuth mechanism and traversing mechanism of the piece; laying for elevation with the sight proper and the elevating mechanism of the piece. Thus, every sighting mechanism must have an azimuth mechanism and a sight.

There are dozens of varieties of sighting mechanisms employed in antitank, tank, antiaircraft, aircraft, coastal and shipboard artillery, in mortars and field rocket launchers. Sights are mechanical and optical (panoramic, collimating, telescopic), nonautomatic and automatic. Special sights for conducting fire by night have become popular in antitank and tank artillery.

Ground artillery employs two types of sighting mechanisms, viz. for direct and indirect laying. Guns which combat fast-moving and readily visible targets (tanks, armored carriers etc.) have direct-fire sights. Most modern pieces are supplied with two sights -- for direct and indirect laying.

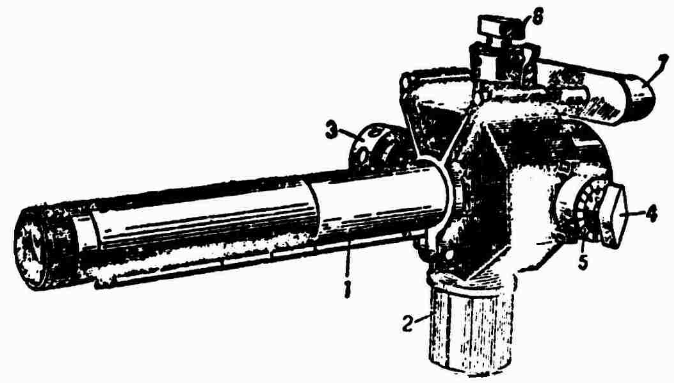

Figure 83. Direct-fire optical sight:

1) telescope; 2) knob of elevation mechanism; 3) drum of lead mechanism; 4) thumbscrew of deflection-correction mechanism; 5) deflection scale; 6) thumbscrew of height-correction mechanism; 7) forehead piece.

A direct-fire optical sight (Figure 83), which is a telescope with an elevation mechanism, is rigidly attached to the tipping parts of the piece. The optical axis of the sight is parallel to the axis of the bore. The optical system of the sight has a glass plate on which are plotted the scales in hundreds of meters for various projectiles, the lateral lead scale in azimuth micrometer scale units, and indicators (marks) for pointing at target.

Laying is very simply accomplished. The gunner, by turning the handwheels of the elevating and traversing gear of the piece, brings the scale division corresponding to required range into coincidence with the target. Depending on the direction and velocity of motion of the target. lead is introduced according to the lateral pointing correction scale or by bringing one of the lateral marks into coinciden-- with the target.

Indirect-fire sighting mechanisms (Figure 84) consist of panoramic sight and sight proper. They are beside the barrel, on the left side.

A panoramic sight is an optical instrument for angle measurement. It is fixed securely in a special telescope socket. The panoramic sight is made to be periscopic lest the gunner's headgear obstruct aiming points situated to the rear. The head of the panoramic sight can rotate in the horizontal plane. Therefore the gunner behind the gun shield is able to see objects in front, at the side and to the rear without taking his eyes away from the eyepiece.

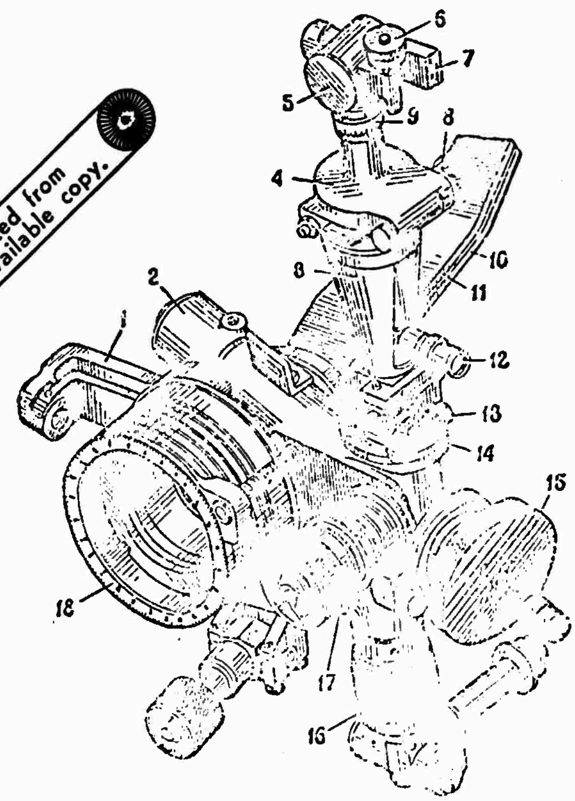

Figure 84. Sighting mechanism with independent line of sighting:

1) trunnion of telescope mount; 2) telescope mount; 3) telescope socket; 4) panoramic sight; 5) head; 6) elevation micrometer; 7) sight; 8) azimuth micrometer; 9) azimuth circle; 10) gun pointer; 11) sight pointer; 12) eyepiece; 13) cross level; 14) angle-of-site level; 15) handwheel; 16) nut of sight elevating mechanism; 17) angle-of-site scale; 18) range drum.

The panoramic sight gives a magnified and erect image. On looking through the panoramic sight the gunner sees cross hairs, through the center of which the optical axis of the instrument runs. In night firing these cross hairs are illuminated by a lamp through a special window of the panoramic sight.

The azimuth mechanism of the panoramic sight consists of a rotating circle divided into 60 parts, and a drum divided into 100 parts. In one rotation of the drum the optical axis of the panoramic sight turns one circle-scale unit (1-00) in the horizontal plane or 1/60 of the circumference of the azimuth circle. As the drum turns one scale-unit, the head moves 1/6000 of the circumference of the azimuth circle (0-01).

In the panoramic sight there is a mechanism (a rotating head) which moves the optical axis in the vertical plane. Readings of the angles of the rotating head are made according to the scale and the drum.

Since the optical axis of the panoramic sight moves not only in the horizontal but also in the vertical plane, the aiming point can be selected in various directions, and above or below the gun's horizon.

The sight proper is intended to give the gun barrel the necessary angle of elevation.

All sights are divided into gun-dependent and gun-independent sights according to the character of their attachment to the gun.

If during the operation of the gun elevating mechanism the sighting mechanism (for example the panoramic sight) moves together with the tipping parts. the sight is said to be gun-dependent. Such sights are used mainly in mortars, antitank and tank artillery. They are very convenient for direct laying performed by one gunner.

If the panoramic sight remains immobile during operation of the gun elevating mechanism, the sight is said to be gun-independent. Such a sight is readily distinguishable from any other by its external appearance. It has two pointers -- a sight pointer and a gun pointer. The sight pointer registers the prescribed angle of elevation. To give the barrel the angle of elevation specified on the sight, one has only, by means of the gun elevating mechanism, to bring the gun pointer attached to the cradle into coincidence with the sight pointer.

Gun-independent sights are good for indirect laying (the gun can be loaded during laying, and the laying itself can be performed by two gunners).

All gun-dependent sights have the dependent line of sighting, while gun-independent sights have the independent (or semi-independent) line of sighting. In a sight with dependent line of sighting, with a change of sighting angles the optical axis of the panoramic sight moves in the vertical plane, i.e. the cross hairs of the panoramic sight shift relative to the aiming point by the corresponding angle. In a sight with independent line of sighting the optical axis of the panoramic sight does not move in the vertical plane with a change of sighting angles, i.e. the cross hairs of the panoramic sight will always coincide with the aiming point. This is the idea of the independent line of sighting.

Two gun crew members point the piece at the target in conformity with a command issued to them. The first gunner performs laying for direction and establishes sighting angle and angle of site. As is known, the angle of elevation equals the algebraic sum of sighting angle and angle of sight. In the process the sight pointer deflects from the gun pointer by a certain angle. Now to point the gun at the target in the vertical plane the second gunner, turning the elevation handwheel, brings the gun pointer into coincidence with the sight pointer.

A sight with semi-independent line of sighting is the name given a sight if the optical axis of its panoramic sight does not change its position in space with a change in sighting angle, but does change position with a change in angles of site. In this sight there is no angle-of-site mechanism. It is replaced by a longitudinal-level mechanism. Due to the simplicity of their construction, sights with semi-independent line of sighting have become popular in modern ground artillery.

On sighting-angle scales divisions are plotted in range-scale units or in angular units (thousandths).

In direct-fire sights one graduation mark of the range scale corresponds to 100 m, in other sights to 50 m. Every projectile and charge of a given gun must have its own scale on the range drum. The merit of range scales is that the necessary sight setting for a specified range can be computed without firing tables.

The advantage of a scale in thousandths is that it can be used in firing any projectiles and charges, as well as in adding up all corrections made in the total field of fire for deviation of given firing conditions from the normal. However, in setting a sight it is necessary to use firing tables or know by heart the values of angles for the most probable ranges of fire, for example, in delivering fire on tanks.

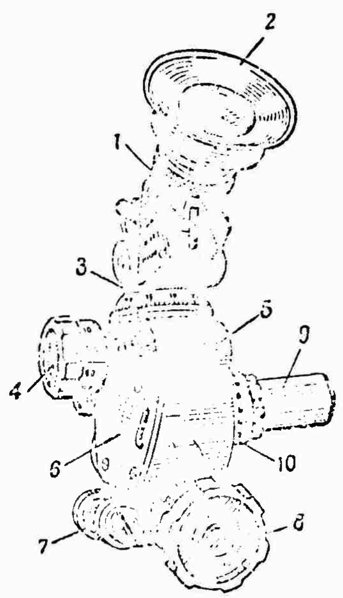

Figure 85. Mortar sight

1) optical telescope; 2) corrugated eye shade; 3) head of azimuth mechanism; 4) azimuth micrometer; 5) cross level; 6) sight casing; 7) angle-of-site level; 8) sight drum; 9) axis of sight; 10) scale of large graduations of sight.

Mortar sights first were mechanical, nontipping, and made in the form of the simplest azimuth mechanism -- the quadrant. The mortar sights in use at present have mechanisms making possible exact setting of angles, optical sights, and a rotating sight head, by means of which a mortar can be laid while situated in an indirect laying position.

The optical sight of the 120-mm mortar (Figure 85) is an example of the modern artillery sight. The sight consists of a sight hinged to the head of the azimuth mechanism and a casing with the axis. In the casing are mounted the azimuth mechanism, elevating mechanism, angle-of-site level, and two cross levels.

7. Night Vision Equipment in Combat

The history of warfare clearly shows that night is the best time for combat operations which have to be conducted stealthily. It is easier to conduct reconnaissance, penetrate enemy lines and get necessary on-the-spot information by night. Surprise attacks against the enemy are usually delivered under cover of night.

That is why night observation not only does not come to a halt during combat operations, but even increases. However, the night-vision capabilities of the naked eye are very limited since in the darkness human vision cannot perceive surrounding objects with sufficient clearness.

For this reason many armies are giving a great deal of attention to the development of night-combat support devices tailored to the specific circumstances of their employment in different areas.

The design and technical characteristics of the devices under development are determined by their purpose and modes of combat employment.

The primary functions performed by night vision devices include the following: carrying out of reconnaissance for the purpose of determining the composition and disposition of enemy troops; increase of the effectiveness of the employment of individual and group weapons; organization of all-round protection on the perimeter of friendly troop dispositions and installations, etc.

Characteristic of the present time is the trend towards the development of complex systems of reconnaissance and fire support, including various technical devices: radar, optical, acoustic, seismographic etc.

Devices based on the use of infrared (IR) radiation and amplification of the luminous intensity of the visible spectrum have an important place in the aggregate of these devices.

Heated bodies are good sources of IR radiation, which is often called thermal radiation.

That portion of the spectrum lying approximately in the wavelength interval from $7.5 \cdot 10^{-4}$ to 1 mm is regarded as the region of IR radiation.

IR devices are divided into two classes: active and passive.

Active IR devices require the use of powerful IR searchlights for the illumination of targets. This is a significant shortcoming since the position of the device is revealed and the possibility arises of its destruction by the enemy or its neutralization by interference.

Passive IR devices operate on the principle of the amplification of visible light. They amplify an image several thousand times and permit observation to be conducted under conditions of very poor illumination afforded by the stars or the moon. These devices do not have the shortcomings characteristic of active IR instruments, are smaller in size, simpler to handle and require less power. For this reason preference is now given to passive night-vision devices.

An image converter tube constitutes the basis of both active and passive IR devices.

The energy received from an object illuminated by the IR rays of a searchlight or under natural conditions of night illumination is focused by an objective lens system on a photocathode sensitive to the radiation of the IR spectrum (Figure 86).

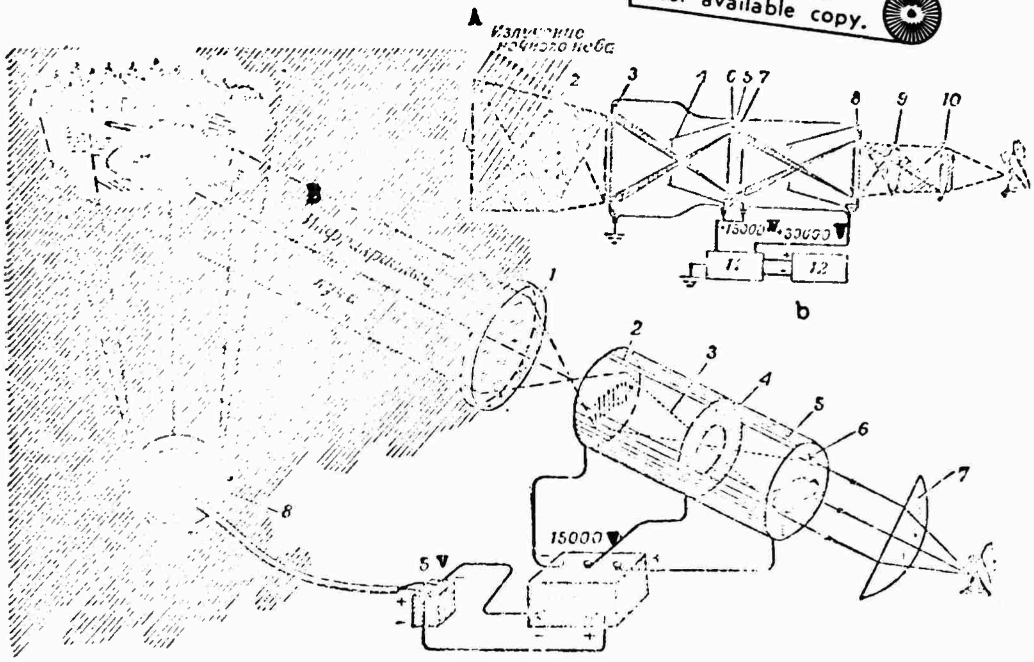

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Figure 86. Schematic diagrams of night-vision devices:

a) diagram of night-vision device using searchlight: 1) objective; 2) inverted invisible image on photocathode; 3) electron flux; 4) diaphragm focusing electron flux; 5) image converter; 6) screen on which visible image of object appears; 7) eyepiece; 8) searchlight covered with IR filter. b) diagram of night-vision device operating with natural night illumination: 1) observed object; 2) objective; 3) first cathode; 4) focusing system; 5) transparent partition; 6) intermediate screen; 7) second photocathode; 8) output screen; 9) erecting system; 10) magnifier; 11) high-voltage power block; 12) primary power source.

Keys:

A. Radiation of night sky B. Infrared rays

The electron beam emitted by the photocathode is amplified by an electrostatic field and focused on a screen which fluoresces in the region of the visible spectrum.

The operator observes the resultant image directly, or it is transmitted to a remote power source for subsequent amplification and display on the screen.

IR binoculars are employed for night observation of the battlefield and for motor-vehicle driving.

For convenience in use the binoculars are attached to a headpiece. They consist of an objective, directing lens, image converter and eyepiece. Illumination is provided by the headlights of a motor vehicle or a searchlight on which IR filters have been placed.

The system is powered by dry-cell batteries.

American IR binoculars for tank commanders weigh 500 g. Their range of action depends on the power of the IR radiation source employed for illumination. It amounts to about 50 m if tank headlights with IR filters are used, and to about 800 m if a powerful searchlight is used.

In addition, several modifications of night-vision devices operating in the region of the visible spectrum have been developed in the United States for the army. These include a rifle sight which can be used as a vision device (its range of action is 180 m), and a collective weapon sight (weight 9 kg) mounted on a machinegun or 106-mm recoilless gun and providing a range of fire of 450-900 m.

In the development stage are helmet-attached binoculars, hand binoculars and night-driving aids.

IR sights have found wide-scale employment in the antitank artillery. The kit of such a sight includes elements adapted for conditions of direct aimed night fire from open fire positions.

The IR sight is mounted on the same bracket with the daylight sight. The searchlight is more often placed behind the gun shield in order to reduce the effect of the firing shock wave on it. Power sources are mounted on the gun trails.

Constructed appropriately, such sights can be employed on tanks and self-propelled guns.

The range of action of artillery night sights for tanks and armored vehicles does not exceed 1500 m.

In recent years wide-scale introduction of IR night-vision devices has been noted in the armies of many countries. The principles of their combat employment as night fighting aids have been intensely studied. Maximum use of passive devices is recommended, and camouflage methods have been developed for active devices. For example, the following method of camouflage for podrazdeleniya equipped with active devices is provided: IR searchlights are so mounted as to assure illumination of important observation targets, while observers with receiving devices are disposed at a considerable distance from the radiation source. It is thought sufficient to have one IR searchlight per platoon of combat vehicles.

Especially great significance is attached to the use of IR equipment for supporting the combat operations of squads, platoons, companies and battalions.

To increase fire effectiveness under night conditions, the use of night-vision devices by forward observers is envisaged for target reconnaissance and adjustment of artillery and mortar fire.

Perfection of the design of night-vision devices is proceeding along the line of weight and size reduction and improvement of operating characteristics.

8. Ground, Air and Sea Target-acquisition Radar

Among all the miscellaneous target detection and reconnaissance equipment an important role falls to radar. Its merits are that it is practically independent of meteorological conditions and time of day, it possesses high accuracy in the determination of target coordinates and makes possible observation of the enemy over wide ranges.

The shortcomings of radar include its sensitivity to interference and the difficulties of surreptitious operation.

The employment of electronic vision aids has vastly increased the combat effectiveness of weapons and war materiel and has led to significant changes in the tactics of land, air and sea warfare.

Ground Target Reconnaissance Radar

Under modern conditions ground target reconnaissance radar is regarded in many armies as one of the most effective means for target reconnaissance on the battlefield and for warning of an enemy surprise attack.

Tactically, ground target acquisition radar abroad is subdivided into short-range (under 2 km), medium-range (up to 8 km), and long-range (up to 20 km).

The primary functions performed by these sets are to detect and determine the coordinates of ground targets, observe changes in the combat situation, issue the necessary data for target destruction by fire, and assure the combat security of troops.

Structurally, radar for ground target reconnaissance and battlefield observation can be divided into two basic groups: devices for moving-target reconnaissance and devices for field artillery fire support.

The operating principle of moving-target reconnaissance radar is based on the utilization of the Doppler effect, which is that radar signals reflected by moving targets are frequency-modulated, while signals reflected by stationary objects are not modulated.

Modulation frequency discrimination by means of appropriate detecting devices makes it possible to distinguish moving targets against a background of noise created by terrain feature reflections, and in a number of cases determine the character of the targets and measure their traveling speed as well.

Several such sets are now in service in the American army.

One of them (the AN/PPS-4) is portable, weighs 63 kg, has a range of action of about 4 km for a single moving person and 6-8 km for a moving vehicle. Its first modification has tube construction and is powered by a gasoline unit. In recently produced sets a transition has been made to semiconductor circuits with dry-cell battery power. The operator conducts target search manually by rotating the antenna.

The width of the beam is 6.6°. Presentation of the located target is aural by means of earphones.

Only one target can be observed at a given moment of time, and this lowers the set's tactical capabilities.

Recently the United States has developed a number of new radar sets with improved performance characteristics for the reconnaissance of moving ground targets.

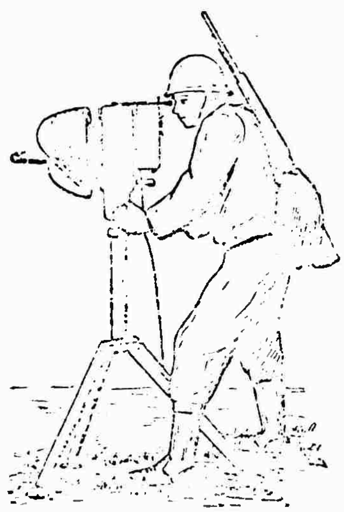

Figure 87. Transceiver and antenna system of American AN/PPS-5 radar set

The apparatus of one such set (AN/PPS-5) consists of a transceiver (Figure 87) with antenna system (weight 25.3 kg, required power 24 w), remote control and display unit (weight 16 kg, required power 12 w), and coupling cable. All the apparatus is stowed in three packages portable by three soldiers, and is adapted for dropping by parachute.

The apparatus is powered by a silver-zinc dry-cell battery with a service life of nine hours.

The set can be remotely controlled by means of a special extension mechanism. The operators can be up to 15 m away under cover, which contributes to improvement of camouflage and increased stealth of operations.

The combat crew consists of two men: one services the apparatus, the other plots detected targets on the map and transmits the information to the command post of the podrazdeleniye served.

The detected targets are represented on two cathode-ray indicators, one of which serves to determine range only, the other simultaneously determines range and azimuth.

In addition to visual display, aural presentation is also provided. From the tone of the noises originating in the earphones an experienced operator can tell the character of a target (a walking or crawling person, a moving vehicle).

The range within which a set can detect moving people is 6-8 km; the range for motor vehicles is 10 km.

It is thought that the accuracies of target-coordinate determination obtained under conditions of aural presentation make possible mortar fire control.

Similar ground target reconnaissance sets are being developed in France, England and other countries.

The function of field artillery fire-support radar aids is the determination of the coordinates of the positions of firing mortar and artillery batteries (gun mounts), as well as the adjustment of the fire of friendly artillery in order to neutralize these positions and other targets.

Radar set AN/MPQ-4 is in service, for example, in direct-support artillery battalions of the American army. It fixes the positions of mortars and guns delivering high-angle fire by extrapolating the trajectories of mortar shells and projectiles of caliber not less than 60 mm. The set's range of action: 10 km. Accuracy of target-coordinate determination for range: 50 km; for azimuth: 0.1°.

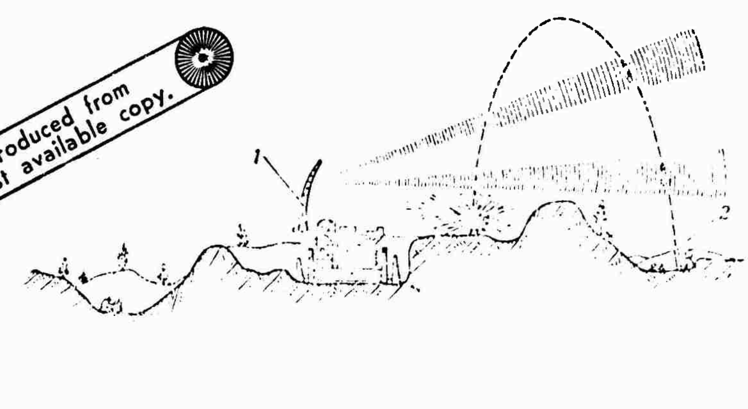

Figure 88. Diagram of operation of English "Green Archer" mortar-position fixing radar:

1) radar set; 2) firing enemy mortar.

The "Green Archer" mortar-position fixing radar, which is in service in the English and Swedish armies, has an analogous operating principle (Figure 88).

Two modifications of the set have been developed, viz. on a wheeled and a tracklaying chassis. The equipment is also transportable by aircraft and helicopters.

The equipment includes the radar set, computer, remote control panel, power generator, trainer set for operator instruction, and monitoring and testing equipment.

The set on a tracklaying chassis is automatically leveled by a hydraulic drive.

Water obstacles are negotiated afloat, for which purpose extension-type floats are provided.

A direct-support artillery regiment is assigned a radar section consisting of two stations and a control post mounted on a command car. Section personnel number 32 men.

A station operates as follows. Beforehand two angles of site -- an upper and a lower -- in the direction of the radar beam are selected. First of all, the antenna is set at the lower angle of site. At the time a mortar shell passes through the radar beam the operator takes the first fix by pressing a button and thus starting a timing register. Then the antenna is set at the upper angle of site. On the appearance of the second signal reflected by the mortar shell the operator again takes a fix, after which the antenna returns to its initial position.

The necessary data are fed into a computer which extrapolates the trajectory of the mortar shell's flight and determines the coordinates of the mortar's position according to the flight time of the mortar shell between the times of the two fixes, as well as according to the azimuths and ranges of the mortar shell's consecutive positions as determined by the station.

The time required to solve a position-fixing problem from the moment a shot is fired is about 30 sec, which makes it possible immediately to open fire on a spotted target.

In order to assure stealth in the operation of a station, an attempt is made to shorten the time it is in the radiation mode by using target data from forward sound-ranging stations.

In addition to its direct purpose, a station is used for artillery fire adjustment by determination of the position of air bursts of projectiles, for moving target reconnaissance, and aircraft and helicopter control.

Much attention is being paid abroad to improvement of the old, and development of new reconnaissance radar devices. It is thought that reconnaissance radar equipment will retain its great importance in the overall reconnaissance system of ground forces in the future as well.

One of the basic problems is to assure the noiseproofing of electronic equipment as a whole and radar equipment in particular. Serious research is under way to guarantee the ability of equipment to operate under conditions of interstation interference.

The approach to solution of this problem consists in studying a particular radiating device in conjunction with other devices rather than in isolation.

Great importance is attached to increasing the range of action, assuring automatic operation and an all-round field of view , and reducing the size and weight of equipment.

In addition, in the design of new models much attention is paid to increasing equipment reliability and the simplicity and ease of its use so as to reduce operator qualifications to the minimum.

Air Search Radar

Modern air defense is inconceivable without technical equipment for long-range and high-altitude air search.

Such equipment includes, primarily, radar, which makes it possible to use active means of air defense with great effect.

Radar equipment in the air defense system is used to perform a great number of functions: location of the air enemy and determination of his coordinates, guidance of fighter aircraft to the enemy, search for the air enemy by fighters, control of antiaircraft artillery fire and surface-to-air missiles.

In respect of its principle of operation radar is divided into pulsed radar and continuous-wave (frequency) radar; in respect of its wave band into meter-wave, decimetric-wave, microwave and ultrashort-wave; in respect of purpose into long-range and short-range radar; and in respect of site of installation into ground (mobile and stationary), shipborne and airborne radar.

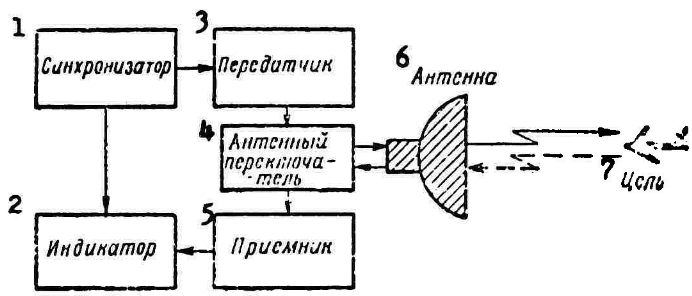

Figure 89. Block diagram of radar.

Keys:

1. Synchronizer
2. Indicator
3. Transmitter
4. Antenna switch
5. Receiver
6. Antenna
7. Target

The operation of any radar set reduces to the following. Electromagnetic energy is produced; it is radiated in the direction of a target; a signal reflected by the target is received and recorded. During this cycle the radar set determines the spatial coordinates of the target (slant range, azimuth, angle of site or altitude) relative to its position of observation.

Pulsed radar emits a brief signal lasting several microseconds, which on being reflected by the target is picked up by the radar operating on reception. The radar is then switched again onto emission and the cycle is repeated. The greater the target range, the greater the time interval between sending and reception of the signal. Target range is determined by knowing this time and the rate of radiowave propagation.

Frequency radar emits a signal continuously, the frequency of emission varying according to a certain linear law. The difference between the frequencies of the emitted and received signals is the quantity by reference to which target range is determined.

The pulsed method has gained wide use in various types of antiaircraft defense radar. The frequency method is used mainly in airborne electronic observation equipment and early-warning radar.

A radar set consists of the following basic elements (Figure 89): transmitter, receiver, antenna, indicator (measuring instrument), synchronizer (generates short electric pulses) and antenna switch.

The design of each of the above-enumerated elements is decided according to the purpose of the radar set.

The basic radar performance characteristics are considered to be: maximum and minimum range of action; the number of target coordinates that can be determined, and the accuracy with which each of them is determined; resolution; scanning time and the frequency with which target data are issued; immunity to jamming.

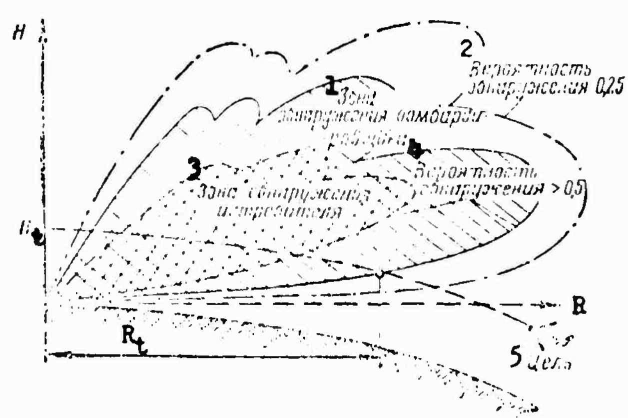

Figure 90. Radar warning zones in vertical plane.

Keys:

1. Bomber detection zone
2. Probability of detection 0.25
3. Fighter detection zone
4. Probability of detection > 0.5
5. Target

Radar is capable of detecting a target only in a certain zone, the so-called detection zone (Figure 90). This zone is not a strictly defined quantity, but varies in a fairly wide range depending on the character of the target. The larger the target, the larger the reflecting surface and the farther away a target is detectible.

Radar's range of action depends on the power radiated by the transmitter, the sensitivity of the receiver, and the directionality of the antenna.

In modern foreign long-range (500 km or more) warning radar pulsed power goes as high as 2000 kw or more, and accuracy of measurement is as follows: accuracy of range 500-300 m, azimuth 0.5-0.3°, height of target 500-300 m.

The accuracy of measurement of firing radar is considerably greater than the accuracy of search radar.

Resolving power, i.e. the capability of separately recording signals from targets situated at a certain distance from each other, is regarded as an important radar characteristic. The higher the resolving power, the clearer the picture of the air situation that is obtained on the screens of the radar indicators.

Much attention is given in radar design to making it jamproof against electronic countermeasures.

Modern U.S. stationary search radar in the antiaircraft defense system has a range of action up to 500 km for bombers. The motor vehicle version has a range of action up to 400 km.

The upper limit of the detection zone is not less than the possible altitudes of aircraft flight. For low-flying targets the range of radar action is limited to line of sight.

Air search radar continues to be improved in many directions: jamproofing of sets, increase in their range of action (especially against low-flying targets), improvement of selectivity, size and weight reduction, simplification of operation.

Shipborne Electronic Observation Equipment

Shipborne electronic observation equipment performs the most diverse functions in the support of sea warfare. With its help a search is made for air, surface and underwater targets, and spotted targets are identified; target coordinates are determined; data are worked out for the control of artillery and torpedo fire and for the guidance of guided missiles; navigational problems are solved; the joint navigation of ships is made possibile; operating sets of the enemy are jammed.

Structurally, shipborne radar differs from ground radar and has a number of distinctive features due to the necessity of allowing for the motion and roll of your own ship, eliminating the interference of neighboring sets, protecting the equipment against jolts, vibration and increased humidity, accommodating the antenna equipment and set instruments under conditions of insufficient space etc.

Shipborne radar to support artillery requirements includes air and surface search radar as well as rocket-artillery fire control radar. Many set antennas are stabilized so that the target will not be lost due to the rolling of the ship.

Air search radar is mounted on large and medium surface ships, on radar-patrol submarines and at shore installations. It conducts all-round scanning of the air space and issues a target designation to firing radar. The operating range of such sets against high-flying targets is as much as 500 km.

Surface search radar is mounted on all classes of ships. It serves for surface observation and for determination of the coordinates of detected targets.

The range within which sets detect large surface vessels is 25-30 km or more. In many respects the operating range of these sets depends on the height of the antenna mounting above sea level, the character of the target and the conditions of radio wave propagation above the surface of the sea.

Air and surface search radar is usually equipped with VIKO [remote plan position indicators], which are installed at command posts and battle stations. The indicators permit the fire controller to observe the picture of the air and surface situation obtained from search radar.

Since an increase in the operating range of shipborne search radar involves great technical difficulties, efforts are proceeding along the line of developing radar patrol vessels and aircraft with powerful radar equipment in order to obtain the necessary detection ranges.

Firing radar is installed on ships with artillery armament. It continuously tracks selected air or surface targets according to search radar data and accurately determines their present position for firing. The most advanced foreign radar of this type determines target range correct to 15-20 m, and angular coordinates correct to within fractions of a degree.

Firing radar has a greater operating range than the weapons it services. This is done so that by the time a target arrives in the weapon's zone of action, the firing data will already be prepared.

As a rule, firing radar has automatic target trackers, which assure smoothness and accuracy in the output of target coordinates to fire control instruments.

Fire-adjustment functions are usually entrusted to surface-target fire-control sets. For this purpose they have devices making it possible to observe the sites of shell impact, measure the deviations of shellings from target and make the necessary adjustment for range and direction in fire directors. Therefore, the sets possess high resolving power for range and direction. Fire is not adjusted during the delivery of fire on aerial targets (in view of the fluidity of the firing process), but the fire director observes the effectiveness of fire. Criteria of fire effectiveness are destruction of the target or sharp evolutions of it as shells burst in its vicinity.

In the opinion of foreign naval specialists, shipborne radar is now and will continue in the near future to be the main means of air and surface search, as well as the means of backing up the use of artillery, rocket and torpedo weapons. Therefore, scientific research and design work is under way on a large scale abroad for new, more advanced shipborne radar that will be small in size and simple to service.

Special attention is being given to the development of radar for the detection of submarine periscopes and low-flying targets.

9. Artillery Fire Control Equipment

As regards the degree of accuracy and completeness in the solution of firing problems, artillery fire control equipment can be divided into simplified and complete equipment. Here we must bear in mind that every type of artillery (antiaircraft, ground, shipboard etc.) has its own fire control instruments for solution of the firing problems characteristic of that given type of artillery alone.

Fire control equipment includes the complex of electromechanical, optical and radar instruments installed in a battery, on aircraft and shipboard, which make it possible to conduct target search, transmit a target designation to control stations and guns, determine the coordinates of a target (moving and stationary), produce firing data continuously and in a centralized manner with allowance for the character of target motion, lay guns and aiming posts automatically, and perform other functions.

Simplified systems of fire control instruments solve firing problems with allowance for only a few corrections and according to data which are partially estimated by eye.

Complete systems of fire control instruments solve firing problems automatically according to data determined by the instruments and with allowance for all meteorological and ballistic corrections.

Artillery fire control is a whole system of various measures. It includes determination of target position and character, fire planning, topographic, ballistic, meteorological and technical preparation, determination of the ways and means of performing missions, calculation of fire adjustments, monitoring of firing results etc. Each of these procedures involves the performance of tedious calculations, and in the shortest possible time owing to the fluidity of modern combat operations.

Artillery tries in every possible way to shorten the time required for mathematical computations. This is achieved by the introduction of mechanical and graphic mechanical instruments, nomograms, tables, graphs of calculated adjustments. However, it is increasingly more difficult on the basis of the old instrumentation to obtain a further sharp cut in the time required for the performance of computations while maintaining their high accuracy.

New technical equipment based on the use of the latest achievements of scientific and technology is required. Such equipment includes primarily electronic computers.

Electronic computers, which make it possible to perform the necessary computations accurately and in minimum time, increase even more the advantages of artillery as a highly maneuverable and effective weapon of destruction. With the aid of electronic computers the following basic problems in artillery fire control can be successfully solved: processing of data from reconnaissance, topographic tying-in of artillery in position, and meteorological sounding of the atmosphere; performance of calculations involved in fire planning; computation of settings for firing and calculation of adjustments during verification fire.

Field Artillery Fire Control Instruments and Systems

Field cannon-type artillery and mortar podrazdeleniya employ several simplified models of fire directors which make possible preparation of data for firing at ranges up to 30 km. These are wooden or metallic plotting boards, to which are attached a coordinator, deflection sector and range slide. At the top of the plotting board is pasted a thick paper with a grid. A map can be attached to the plotting board by two hinged strips. With the help of these fire control instruments the rectangular and polar coordinates of points plotted on the board can be determined; points are plotted on the board according to the above-indicated coordinates; fixes are geographically processed; graphs are constructed of calculated or adjustment corrections; and ultimately calculated target data are determined. However, it takes a great deal of time to perform these operations with no assurance of the necessary accuracy in the solution of firing problems.

Research is under way at present abroad to develop complete systems of fire control instruments in order to speed up significantly the preparation of firing data and increase the accuracy thereof. One version of a system developed in the United States is presented in Figure 91. The system is intended for the automatic transmission of fire control commands from a remote command post to gun fire positions. It permits automatic transmission to the command post of confirmation of accuracy in the execution of commands, as well as the transmission of field-of-fire commands to any piece in the battery. Visual indicators of the system show whether the crew of each gun has executed commands correctly.

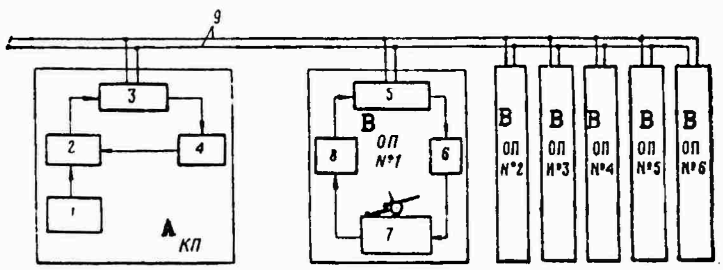

Figure 91. Block diagram of fire control system of ground battery:

1) control panel; 2) coding control block; 3) transceiver; 4) decoding control block; 5) gun transceiver; 6) gun (address) decoder; 7) comparator; 8) gun coding control block; 9) double-wire communication line.

Keys:

A. Command post
B. Fire position No. 1, 2, 3, 4, 5, 6

A command to fire from a certain piece includes the address (number of the piece), azimuth, angle of elevation and, if necessary, muzzle velocity of the projectile.

For each piece in the system there is a coordinate converter issuing the true azimuth and angle of elevation of the piece (with allowance for the tilt of the axis of trunnions of the piece) and making possible a comparison in a special comparator of the true fields of fire ordered for the piece with the actual ones.

The fire control system consists of the apparatus installed at the command post and the apparatus of the pieces, which is the same for each piece of the battery.

Two-way communication between the command post and fire positions is effected over a two-wire line. A command to fire a specific piece, issued from the command post, consists of 13 binary-coded decimal places. The first place specifies the number of the piece. Commands for angle of elevation, azimuth and muzzle velocity of the projectile each consist of four places. To transmit commands from the command post to fire positions, a switch is turned on, with coding control block 2 determining the sequence in which each command is transmitted. The command to be transmitted is formed at control panel 1 by feeding data from the computer into it manually or automatically. In both cases the necessary firing data come from the fire control center.

The coding block 2 has units which issue coded binary digits and synchronizing signals in a definite sequence. These signals go to the generators controlling the output signals of transceiver 3.

When a command is transmitted, the coding control block 2 transmits the digits of the first value in the binary system (for example, zeros) to one generator, and the digits of the second value (for example, ones) to the other.

Each binary digit coming to the generators actuates the generator in question, causing transmission of the signal of the first (f_1) or second (f_2) frequency selected for the generators. Consequently, each transmitted digit consists of a short pulse of a given frequency of specific length.

Synchronizing signals can be longer pulses of frequency f_1 or f_2. As soon as the crew lays the piece in keeping with the commands received, a signal will be received at the command post by wire confirming that the piece to which the command was sent has been laid correctly.

An answering signal arrives at transceiver 3 and then at the filters separating the binary digits, and at decoding control block 4, which switches on the visual indicator corresponding to the number of the piece. The switching on of the indicator signifies that the piece has been laid correctly and gives the officer at the command post the right to issue an order over the wire line to open fire. At every fire position the command sent from the command post is received on transceiver 5, which is identical with transceiver 3.

The filters after the transceiver separate the binary digits of the coded command. The first part of the command containing the number of the piece goes to address decoder 6. If this unit establishes that the command actually refers to this piece, it transmits the remainder of the command to comparator 7. The comparator has three visual indicators, which compare the commanded azimuth, angle of elevation and projectile muzzle velocity with actual values for the piece. The gun crew changes the pointing parameters of the piece in conformity with the indicator readings.

A command is repeated at intervals of less than 1 sec until the piece is correctly laid, after which coding control block 8 via transceiver 5 transmits an answering signal to the command post confirming proper execution of the command.

On receipt of the answering signal, decoding control block 4 transmits a special signal for a halt to transmission of the command by coding control block 2. If the same commands are transmitted to all the pieces of the battery, transmission ceases after confirmation of execution is received from the last piece. If there are errors in the transmission of commands, the error detector connected with comparator 7 and the decoder transmits a signal to coding control block 8, in accordance with which the block transmits the erroneous command to the command post. The erroneous command received by transceiver 3 is decoded, after which a signal for repetition of this command is transmitted by coding control block 2. It takes about 0.12 sec to transmit a command to one piece and receive a reply.

Antiaircraft Fire Directors

Complete fire control systems are most widely represented in antiaircraft artillery. This is due to the specific peculiarities of antiaircraft artillery fire.

Fire on aerial targets differs significantly from fire on ground targets both in respect of the organization of fire and in respect of the theoretical prerequisites. Aerial targets move in space at high speeds, are small in size, and are in the zone of fire for a short time. This results in the rapid change of firing data and necessitates delivery of fire for effect at once without fire for adjustment.

At present antiaircraft artillery is supplied with fire control instruments which make possible the destruction of aerial targets under any conditions by day or night.

Modern systems of antiaircraft fire direction (Figure 92) include antiaircraft directors (AAD), radar, stereoscopic range finders, power servo and synchrotransmission systems connecting all these instruments, as well as power units providing the mechanisms and instruments of the system with electric power.

The basic fire control instrument is the antiaircraft director, which has the function of target prediction, i.e. determining, from present position data obtained by means of range finders or radar, the anticipated future position and piece and fuze settings in order to assure bursts at the predicted point. These data pass continuously from the AAD to the guns by means of self-synchronous transmission systems.

Existing AADs use various computers. Analytic target prediction is performed by the method of successive approximations automatically, continuously and practically instantaneously.

At present, mechanical, electrical and electronic computers are in use, which permit the solution of complex dependences according to one or more programs, for which the particular computer is designed.

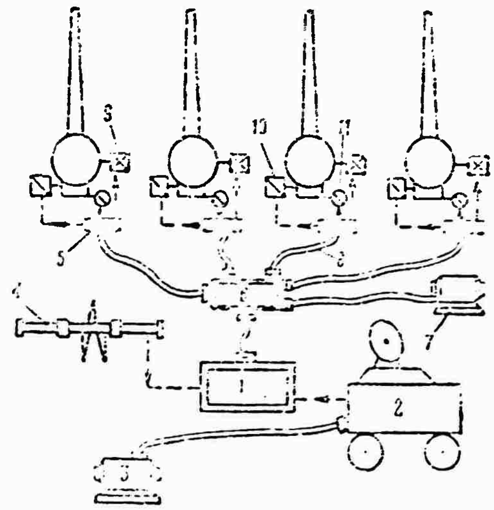

Figure 92. Diagram of antiaircraft artillery battery:

1) AAD; 2) radar; 3) power unit; 4) range finder; 5) gun junction box; 6) main junction box; 7) power unit; 8) cable of self-synchronous data transmission system; 9) azimuth receiver; 10) elevation receiver; 11) fuze-setting receiver.

Computers and data processors are automatically interconnected. They constitute the control system which selects the most advantageous solution, stores the obtained results and uses them later on during the solution of the primal problem. It is believed, for example, that the development of analytic methods for the solution of the control problem raised here must provide for the use of electronic computers.

To assure the operation of the instruments both as a system and autonomously in the solution of fire problems and in the transmission of various quantities and signals coming from search radar and command posts into the computers, as well as to assure centralized control of all the instruments, self-synchronous (selsyn) data-transmission and servo systems are used.

Selsyn systems assure the simultaneous turning of two or more shafts of electrical instruments, not mechanically linked, by equal or proportional amounts.

Servo systems permit the automatic tracking of quantities transmitted by data transmitters and their output into actuating mechanisms (aiming mechanisms).

A selsyn data transmission system in the simplest case consists of two or more electrically connected electromagnetic instruments (synchronous electric motors), which are a-c or d-c electrical machines. Some of these electrical instruments are called data transmitters, the others receivers. The turning angle of the shaft of the data transmitter represents the transmitted quantity on the adopted scale. The receiving instrument turns its axis synchronously (simultaneously) with the shaft of the transmitter and reproduces the transmitted quantity on the same scale.

Selsyn data-transmission systems are of the indicator and power type. In indicator selsyn data-transmission systems the only load on the receiving element is the needle of the instrument. Power selsyn data-transmission systems have large loads on the shaft of the receiving instrument corresponding to the exertions necessary for laying a piece.

Selsyn data-transmission systems make possible rapid and accurate transmission of quantities between transmitters and receivers. Accuracy of transmission is determined according to the greatest possible displacement angle between transmitter and receiver under certain operating conditions and is measured in angular quantities.

Servo systems are sometimes called remote gun control.

Aiming takes place by virtue of the fact that the remote control via power drives converts electric pulses coming from control instruments into the mechanical work of rotating the shafts of the laying mechanisms.

Electric pulses corresponding to certain fields of fire arrive at the receivers, but these pulses are very weak and cannot produce useful work. For amplification the pulses are sent to amplifiers whence, amplified thousands of times, they go to the control units. These units control the power drives which make possible the operation of the laying mechanisms.

The power drives may be electric or electrohydraulic.

With electric power drives the signal voltage goes from the amplifier to a dynamoelectric amplifier (amplidyne), which secondarily amplifies the signal and produces the working voltage for the actuating (power) motor connected with the appropriate laying mechanism.

At present, electrohydraulic drives have gained the widest use. Their electric motor has a hydraulic universal speed regulator -- hydraulic drive -- making possible a smooth change in laying speed. A signal goes from the amplifier to the control device (servo drive), where it is converted into mechanical force, which is transmitted by way of a mechanical connection to a hydraulic drive regulator (hydraulic pump cylinder block).

Electrohydraulic drives have high efficiency and make possible great laying speed and accuracy.

Electrohydraulic drives make possible automatic and semiautomatic aiming. Automatic aiming is effected without the participation of gunners. In semiautomatic aiming the gunner, using power drives, performs the aiming according to the data of the receiving instruments or sighting devices of the piece.

The sighting devices of antiaircraft guns are usually classed as simplified fire control systems since they solve firing problems taking only certain corrections into consideration and according to data which are partially estimated by eye. Such systems are most characteristic of small-caliber antiaircraft artillery.

Fire Control Instruments of Tank Armament

Modern tanks are equipped with sighting devices (Figure 93) which make possible control of the fire of basic and auxiliary tank armament.

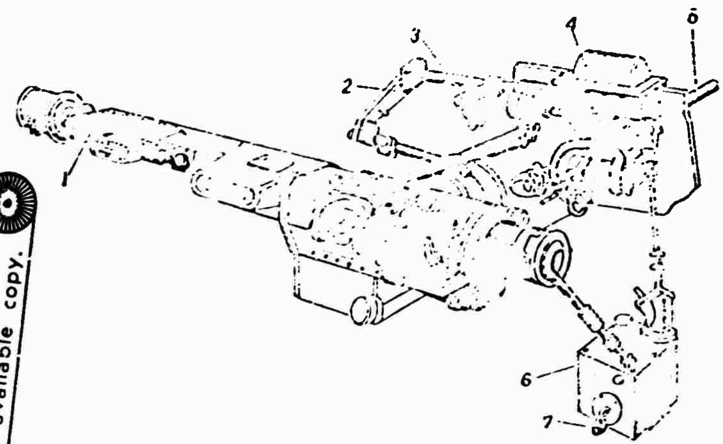

Figure 93. Tank sighting mechanism:

1) range finder; 2) target-angle transmission gear; 3) quadrant; 4) periscopic sight; 5) auxiliary optical sight; 6) computer; 7) manual adjustment.

For fire control foreign tanks have combination sights and range finders, periscopic sights, auxiliary optical sights and computers with transmitting mechanisms for setting target angles.

Combination sight and range finders of various systems are used, including stereoscopic, combined and laser-type, connected with a computer mechanically or hydraulically.

The combination sight and range finder is ordinarily used by a tank commander, and periscopic and telescopic sights by a gunner in delivering direct fire. The periscopic sight is the basic sighting mechanism, the telescopic sight is the auxiliary mechanism. Two optical systems are mounted in the periscopic sight. One is intended for surveying the terrain lying in the field of vision; the other, with strong magnification, for pointing the piece at a target by means of the reticle of the sight.

The computer serves to calculate the target angle. It processes range data obtained by means of the combination sight and range finder, and takes into account ballistic and meteorological firing conditions.

Adjustment for ballistic and meteorological conditions is made in range readings by means of the crank on the panel of the computer. When the crank of the combination sight and range finder is turned, the indicator shows the size of the target angle.

The computer can be switched from mechanical to electrical control.

The target angle indicator shows the target angle matching the type of projectile with allowance for ballistic and meteorological firing conditions and target range. The target angle is then transferred to the sight.

Aiming takes place as follows. The tank commander carries on battlefield observation by means of the combination sight and range finder and actuates the aiming crank with the tank turret rotating. After the gunner finds the target, the tank commander releases the control crank and the gunner takes over control of the turret and piece. The tank commander measures the range and switches on the computer, which automatically determines the target angle and transmits it to the sighting mechanism. After this the gunner executes accurate aiming according to the readings of the sighting devices: the periscopic sight and combination sight and range finder.

The tank commander or gunner delivers fire with the help of electromechanical instruments or manually.

The basic type of tank fire is marching fire. But during motion, especially over broken terrain, a tank experiences various vibrations, and this significantly hampers the delivery of fire. Therefore, in order to improve aiming conditions on the move and achieve high accuracy of the shoot and effectiveness of fire, tanks are equipped with stabilizers.

A distinction is drawn between stabilization of the piece and stabilization of the line of sight.

Stabilization was first achieved in tanks by Soviet designers in the 1930's. TOS /stabilized optical tank/ sights with stabilized line of sight for 45-mm guns were installed on T-26 and BT tanks.

During tank motion several kinds of vibrations arise which, acting simultaneously, produce a complex oscillatory motion of the tank hull, turret and gun. The vibrations experienced by the tank are regarded as the sum of the vertical longitudinal angular (in the vertical plane), horizontal angular (in the horizontal plane) and transverse angular (around the longitudinal axis of the tank) vibrations. The greatest influence lowering the effectiveness of marching fire is exerted by longitudinal angular vibrations when fire is delivered from the gun in the direction in which the tank is moving. To get a general idea of the intensity of the vibration characteristics of a tank moving over medium-broken terrain at speeds of 10-20 km/hr, it suffices to point out that the amplitude of vibrations is from 0.5 to 4°, angular velocity of vibrations from 0.5 to 8 deg/sec, and vibration frequency from 30 to 60 per minute.

To keep tank armament in the aimed position, first stabilizers were developed which react to angular vibrations in only one plane, and then stabilizers which react to angular vibrations in two planes -- in the vertical and horizontal planes simultaneously.

The operating principle of the tank armament stabilizer is shown in Figure 94. When a tank is in motion over broken terrain, owing to the vibrations of the hull disturbing moment of constantly varying intensity and direction acts upon the gun. Therefore, the controlled quantity -- angle of elevation of the barrel φ_o -- varies too. If the gun, rotating in trunnions, is connected with the tank turret by means of an actuating electric drive, then by controlling the operation of this drive, moment compensating for the disturbing moment M_d can be created, i.e. the piece can be stabilized.

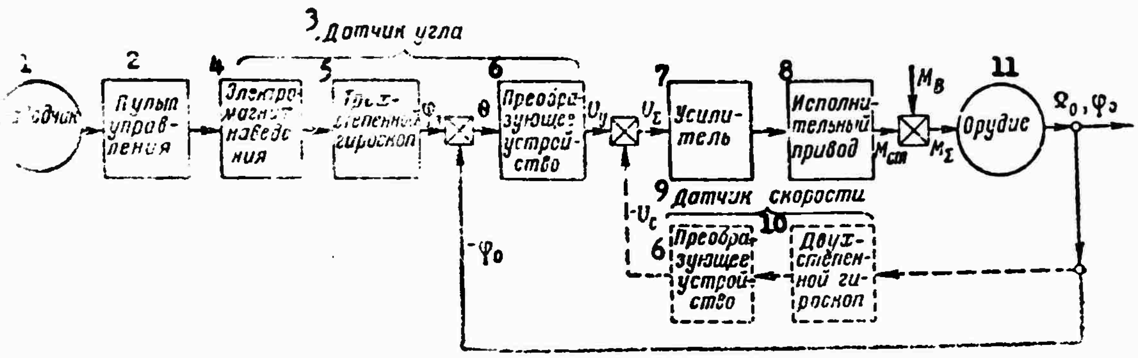

Figure 94. Functional diagram of tank armament stabilizer.

Keys:

1. Gun-layer
2. Control panel
3. Angle transmitter
4. Aiming electromagnet
5. Two-axis gyroscope
6. Converter
7. Amplifier
8. Actuating drive
9. Velocity transmitter
10. Single-axis gyroscope
11. Gun

M_B = disturbing moment M_d

M_{cm} = stabilizing moment M_{st}

U_c = U_{sig}

φ_3 = prescribed angle of elevation φ_{pr}

A special direction transmitter accurately assures stabilization of the prescribed direction. This transmitter is a two-axis gyroscope. The main axis of a free gyroscope, as is known, maintains unchanged in space the direction given it when started up, and resists the external forces tending to deflect it from the assumed position. The stability properties of the gyroscope are utilized in tank armament stabilizers.

The gyroscope base is attached to the gun in such a way that the axis of its external frame is parallel to the axis of trunnions. As the gun vibrates there is formed between the plane of the external frame and the axis of the bore displacement angle θ, which is equal to the difference between prescribed angle of elevation φ_{pr} and actual angle of elevation φ_o. Special sensors create an electric signal proportional to the displacement angle.

Output voltage U_y of the converter will be the greater, the greater the displacement angle, and the direction of deflection of the piece determines the phase or polarity of the output signal. This signal is too small for direct control of the actuating drive. The control signal is amplified by means of electronic, semiconductor, magnetic or other amplifiers. The actuating drive creates stabilizing moment M_{st} which is directed towards disturbing moment M_d. Total moment $M_\varepsilon = M_d - M_{st}$, acting upon the gun, decreases, and this results in a decrease in displacement angles. Thus, the prescribed direction of the piece remains constant with a specified degree of accuracy.

In order to increase pointing accuracy, another gyroscope -- the velocity transmitter -- is used. It is a single-axis gyroscope with a frame whose angle of rotation is proportional to the angular velocity of the gun. Angular velocity is converted into electric signal U_{sig}, which is proportional to the velocity of the gun. Total control signal U_ε creates stabilizing moment M_{st}, whose phase leads the angular position of the gun, thus contributing to a decrease in the amplitude of vibrations relative to the prescribed position.

Shipboard Artillery Fire Control Instruments

In shipboard artillery, fire control instruments are called PUS /pribory upravleniya strel'boy; fire (strel'ba) control instruments/ in contrast to the fire control instruments of ground artillery, which are called PUO /pribory upravleniya ognem; fire (ogon') control instruments/. They can be complete or simplified.

Modern complete control systems make possible multipurpose artillery fire on sea, coastal and air targets with the same accuracy under any meteorological conditions and at any time of day. Fire control instruments are placed at various stations of a ship according to their purpose and the character of the functions performed.

A complete system of fire control instruments includes the following basic instruments (Figure 95): instruments for target detection and designation, observation and determination of present position of a target, and production of firing data, gun-laying instruments, various signal and firing circuit devices.

Target detection and designation instruments are used to find a target and determine its coordinates approximately. They include radar sets and various optical instruments (range finders, sights, direction finders etc.), which are classified as auxiliary equipment.

Observation instruments and present position locators are intended for target observation, continuous determination of target coordinates and transmission thereof to computers in the battery plotting room, for solution of the target interception problem and production of firing data. This group of instruments includes radar sets, optical sights, range finders and other instruments located in fire control towers or stabilized directors.

Firing data development instruments are used for the continuous development of full elevations and deflections. This group of instruments includes a fire director, coordinate converter, instruments for the transmission of commands to artillery gun mounts, firing circuit control devices etc.

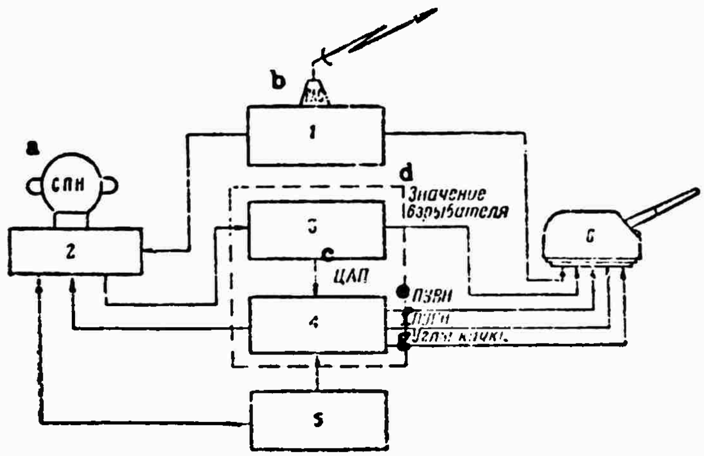

Figure 95. Diagram of interrelationship between fire control instruments of complete shipboard system:

1) target detection and designation; 2) instruments for producing present position data for a target; 3) fire director; 4) coordinate converters; 5) instruments for working out angles of roll; 6) turret control instruments.

Keys:

a. Stabilized director
b. Relay-controlled automatic system
c. Battery plotting room
d. Fuze length
e. Full elevation
f. Full deflection
g. Angles of roll

The fire director is the basic computer which solves problems of firing on waterborne, coastal and aerial targets with identical accuracy and produces gun-laying data for artillery mounts disregarding angles of roll. In addition, the fire director works out fuze lengths for firing at aerial targets.

The coordinate converter, on receiving field-of-fire data from the fire director disregarding angles of roll, works out full elevations and deflections taking into consideration angles of roll, which come to the coordinate converter from special instruments producing angles of roll.

Fields of fire are worked out continuously and automatically in the fire director and coordinate converter.

Gun-laying instruments (turret fire-control instruments) are accommodated in the fighting compartments of artillery mounts. They include full elevation and deflection receivers, and in the case of stabilized artillery mounts a roll angle receiver.

All instruments are connected with the battery plotting room by a selsyn data-transmission system.

Signal and firing circuit instruments serve to monitor the readiness of artillery mounts for firing, close the firing circuit and fire the round.

In addition to the instruments considered here there are instruments placed on artillery mounts which are a simplification of the PUS [fire control instruments] system -- sights which make possible independent fire on visible waterborne, coastal and aerial targets without involvement of the battery plotting room.

Remote gun control (servo system) is a component part of the PUS [fire control instrument] system and, in accordance with data produced in the battery plotting room, automatically lays artillery mounts and stations with great speed and accuracy.

Laying is effected by means of power drives, which in the case of modern shipboard artillery mounts are electric or electrohydraulic.

From foreign press reports it can be seen that the development of fire control instruments is proceeding along the line of the creation of automated systems. Such systems will be able to produce firing data without human participation and will have a short operating time. The use of the latest achievements in the field of electronics and computer technology is contemplated in the new fire-control instrument systems, which will permit a significant reduction in the size and weight of instruments as well as an increase in the precision of fire.

For small-caliber gun mounts the creation of portable sighting stations set directly on the gun mounts is contemplated. These stations will have their own present position finders and computers.

CONCLUSION

We have become familiar with modern artillery weapons and the basic trends in their further development and improvement.

V. I. Lenin taught that the defensive capability of the socialist Fatherland should be treasured as the apple of one's eye, and appealed for the utmost vigilance and constant readiness to repel imperialist aggression. This precept of Lenin's has taken on special timeliness in our day. The wars unleashed by the imperialists in Vietnam and the Near East and the whipping up of tension in other regions of the globe are evidence of the growing aggressiveness of imperialism.

Under these complex conditions Soviet fighting men understand the extreme responsibility for the defense of the sacred boundaries of our country and other countries of the socialist community. Lenin's precept of vigilance and constant readiness to defend the gains of the October Revolution from imperialist aggression means first and foremost that they must tirelessly increase their combat expertise and persistently master their weapons and combat materiel.

Soviet artillerymen with honor do their important duty to the Fatherland.

It is not just first-class combat materiel that constitutes the might of our artillery, but above all people, strong of spirit, educated, perfect masters of their weapons, who know how to make full use of the combat capabilities of their arms. The ranks of the artillerymen are replenished every year with well-trained young people who are worthy successors to the combat traditions of their senior comrades in arms.

In artillery chasti a persistent effort is under way to increase the number of experts in combat and political training, as well as outstanding gun crews, otdeleniya and podrazdeleniya, class-room specialists. Personnel master allied specialties since in modern battle interchangeability of piece crew members is of paramount importance for all artillery combat activity.

The results of exercises, field firing and all-army artillery contests of recent years show the growing tactical, technical and fire training of the troops.

Our artillerymen, as well as the combat soldiers of the other arms of the service, safely stand guard over the peaceful creative work of our people -- the builders of communism.

SOME NOTEWORTHY DATES IN THE DEVELOPMENT OF SOVIET ARTILLERY WEAPONS

25 October (7 November) 1917 2145 hours	Round of artillery from the legendary cruiser "Aurora" anounces to the world the beginning of a new era in the history of mankind.
17 December 1918	Commission for Special Artillery Experiments created in Petrograd -- first Soviet scientific center for solution of special-research problems in the development of artillery weapons.
18 June 1920	V. I. Lenin visits Artillery Committee of Main Artillery Administration.
1923	Work begins on creation of self-propelled artillery.
1927	76-mm regimental gun M1927 -- first piece created by Soviet designers -- adopted for service.
1927-1928	First experimental models of 82-mm and 132-mm rocket shells tested.
1928	Modernization of 76-mm antiaircraft gun M1915/28 -- first model of antiaircraft gun produced by Soviet industry -- completed.
18 July 1929	Revolutionary Military Council of the USSR adopts decree "On System of Artillery Weapons for the First Five-year Plan."
13 February 1931	37-mm antitank gun M1930 -- first special antitank cannon in Soviet artillery -- adopted for service.
1931	Following modernized models of artillery weapons adopted for service: 76-mm gun M1902/30 with barrel length 30 and 40 calibers; 107-mm gun M1910/30; 122-mm howitzer M1910/30; 152-mm howitzer M1909/30; 152-mm gun M1910/30.
1931	First Soviet 82-mm mortar developed.
1931	Development of 76-mm antiaircraft gun M1931 completed.
1931	203-mm howitzer M1931 developed (adopted for service 10 June 1934).
1931	122-mm gun M1931 developed (adopted for service 13 March 1936).
1932	45-mm antitank gun M1932 adopted for service.
5 August 1933	Revolutionary Military Council of the USSR approves proposals regarding system of artillery weapons for second five-year plan.

21 September 1933	Scientific Research Institute of Jet Propulsion created.
22 March 1934	Council of Labor and Defense adopts decree "On System of Artillery Weapons of Workers' and Peasants' Red Army for Second Five-year Plan."
1934	107-mm mortar M1934 developed.
1934	Modernization of 152-mm gun-howitzer M1910/34 completed.
11 May 1936	76-mm gun M1936 adopted for service.
1936	82-mm mortar M1936 adopted for service.
1936	20-mm ShVAK [Shpital'nyy Volkov aircraft heavy cannon] developed.
1937-1938	Four models of mortar adopted for service: 50-mm company mortar M1938; 82-mm battalion mortar M1937; 107-mm mountain pack mortar M1938; and 120-mm regimental mortar M1938.
1937-1938	82-mm and 132-mm rocket shells adopted for aircraft armament.
13 May 1937	152-mm gun M1935 and 280-mm mortar M1939 adopted for service.
8 May 1938	305-mm howitzer M1939 adopted for service.
22 June 1938	45-mm antitank gun M1937 adopted for service.
1938	76-mm antiaircraft gun M1938 adopted for service.
22 September 1938	76-mm mountain gun M1938, 76-mm division gun M1939, 122-mm howitzer M1938, 122-mm gun M1931/37, 152-mm howitzer M1938, and 152-mm gun-howitzer M1937 adopted for service.
1938	First air search radar RUS-1, RUS-2 and "Pegmatite" adopted for service.
December 1939	Main Artillery Administration adopts decision to make an experimental lot of BM-13 launchers and rocket shells for them.
1939-1940	Automatic antiaircraft guns 25-mm M1940 and 37-mm M1939 adopted for service, as well as 85-mm semiautomatic gun M1939.
1940	76-mm casemate gun M1940 developed.
1940	107-mm gun M1940 developed.
30 April 1941	76-mm tank gun M1940 adopted for service.

21 June 1941	Soviet government adopts decision regarding series production of field rocket artillery.
14 July 1941	First field rocket artillery battery in the world under Captain I. A. Frelov delivers fire assault on railway junction at city of Orsha in Belorussia.
1941	23-mm VYa aircraft cannon developed.
1941	37-mm NS-37 [Nudel'man-Suranov aircraft wing gun] developed.
1941	82-mm and 120-mm mortars M1941 developed.
12 February 1942	76-mm gun M1942 adopted for service.
15 June 1943	57-mm antitank gun M1943 adopted for service.
8 August 1943	152-mm howitzer M1943 adopted for service.
4 September 1943	76-mm regimental gun M1943 adopted for service.
31 October 1943	122-mm tank gun M1943 adopted for service.
15 December 1943	85-mm tank gun adopted for service.
1943	82-mm and 120-mm mortars M1943 developed.
1943-1944	Self-propelled guns SU-85, SU-100, ISU-122, SU-152 and ISU-152 developed.
17 January 1944	160-mm mortar M1943 adopted for service.
7 May 1944	100-mm field gun M1944 adopted for service.
21 October 1944	Presidium of Supreme Soviet USSR issues ukase establishing Artillery Day as annual holiday. Since 1964 the Nineteenth of November has been marked as Rocket Forces and Artillery Day.
2 July 1945	85-mm antiaircraft gun M1944 adopted for service.

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