Tankograd

2014 - 2019

Tuesday, 10 January 2017

T-54

The T-54 was reasonably advanced for its era, arguably more so than the American Patton family up til the M60, but it could never quite be described as being on the cutting edge in terms of technological sophistication. The tank is rationally constructed and technically excellent where the traditional three criteria of mobility, firepower and protection are concerned, but it was also plagued by minor drawbacks that may not be immediately obvious at first glance. Some of the drawbacks have received quite a lot of attention, like the issue of internal space. Others, like the cooling system that could throw dust from the tracks up in the air if the tank was travelling at high speed in the desert, are less well known. The usual criticism that Soviet tanks had subpar fire control systems is partially true with the T-54, as it lacked a rangefinding device. But what is less well known is that the sight was very well made, very convenient to use and had higher magnification than the ones used in contemporary Western tanks. A thorough inspection of the tank will tell you that the T-54 was very competitive for its time and remained capable of fulfilling front line roles well after newer and better designs took its place in the limelight.

More often than not, the Soviet military industry had been plagued by lackluster technological capabilities in some fields. This was especially true immediately after the end of the war, and this was not necessarily limited to the level of scientific progress but often by the manufacturing capability. Some factories were also short of qualified personnel, worsening the quality of the tanks they built. Nizhny Tagil, for instance, was almost totally devoid of experienced and qualified staff after the war ended as most of the Kharkov factory workers and engineers had decided to return to the recaptured Kharkiv factory in Soviet Ukraine near the end of the war. After the conclusion of the war, the transfer of experienced personnel from the Urals to Kharkov was completed. In Kharkov, KMDB design bureau chief designer Alexander Morozov became responsible for the T-44 project and its soon-to-be legendary successor.

However, the poor quality of the products from some tank factories quickly became the exception rather than the rule. The tenacious pursuit of mass production that practically halted the implementation of new technologies during the war fell away with the capture of Berlin, galvanizing the continuation of pre-war innovation with the benefit of an enormous database of combat records, captured documents, and free access to the latest examples of Allied tank technology such as the M26 Pershing.

Given that the T-54 is history's most enduring tank, the design team clearly succeeded in their goal. Besides the vast numbers of T-54 tanks fielded by the Soviet Army, thousands of tanks were exported and thousands more were produced by China. Dozens of variants of the basic model have been produced, most of them used by the Soviet Army.

As usual, we will only be covering the models used in the USSR but not abroad. We will be examining the most relevant variants of the T-54 except the models designed to fulfill supporting roles like firefighting and bridge laying.

There were a few prototype models, but the only one that made it to low rate production and small scale issuance was the T-54 obr. 1947, also known as the T-54-1. T-54-1 was first deployed to units in the Belorussian military district for crew familiarization and exercises, and it was there that a myriad of design flaws were discovered. As they were unfit for frontline use, most, if not all T-54-1s were relegated to reserves or storage soon after its more evolved brothers appeared. In the mid 60's, many T-54-1s and T-54-2s were taken apart and their turrets used as static pillboxes along the Chinese border and as coastal defence guns in the Far East.

Here are T-54-1 turrets installed on reinforced concrete pillboxes for coastal defence.

And here are T-54-2 turrets, one used for coastal defence and one on the border. Note the extremely small size and low height of the turret compared to the man.

The T-54 is a descendant of the legendary but obsolescent T-34, but after numerous revisions, the technical similarities between the two medium tank eroded away and the relationship between the two tanks had become purely historical by the early 1950's. Practically speaking, there was very little in common between the T-34 and the T-54 save that they both share roadwheels of the same diameter and the same track pin retention system (T-34-85 tanks stored in reserves were later modernized with T-54 roadwheels in the 1950's and 1960's). The noteworthy use of a transverse mounting scheme for the engine resulted in an enormous reduction in the volume of the engine compartment, leading to a cascading effect where the reduced volume also resulted in a reduced surface area that required armour protection, and the weight of the tank was consequently reduced. This freed up a considerably surplus of weight that could be distributed to other parts of the tank as additional armour thickness.

ERGONOMICS

Being smaller yet roomier and more thickly armoured than a T-34, the T-54 is excellent evidence that smaller tanks are not necessarily more cramped than a larger one. The main parameter is volumetric efficiency, in which the T-54 is rated highly. The total internal volume of the T-54 measured in at 11.4 cubic meters, of which 8.05 cubic meters forms the fighting compartment at the front and middle of the tank and the remainder forms the engine compartment. The share of the fighting compartment volume from the total volume is 71.25%, which is much higher than the 60.4% of the M47, 59.2% of the M48 and 60.7% of the M60A1. Of course, the volume of the T-54 fighting compartment is undoubtedly smaller than the aforementioned tanks in real terms: the M47 which is considered somewhat cramped compared to other Cold War era American tanks has a larger fighting compartment with a volume of 9.06 cubic meters. The roomy M48 has a fighting compartment volume of 10.48 cubic meters and the M60A1 is simply luxurious by comparison, having a fighting compartment volume of 11.17 cubic meters. Of course, one cannot ignore the fact that the M47 had five crew members and carried 71 rounds of 90mm ammunition as opposed to the four crew members of the T-54 and 34 rounds of 100mm ammunition, but the M48 and M60A1 have a clear and overwhelming advantage in terms of the volume allocated to each crew member. With this in mind, it can be said that the T-54 has a remarkably efficient allocation of volume and armour but with relatively little actual room due to the small overall size of the tank. Ideally, the efficient layout of the T-54 could have been scaled up, but the small silhouette of the tank was a serious advantage in terms of survivability at the time as it made the tank harder to hit, especially when it is moving.

The T-54 has a turret ring diameter of 1,825mm. In all incarnations of the turret design, the structure of the front half of the turret lies close to the turret ring but the structure rear half of the turret lies on top of a shelf. On the commander's side of the turret, this shelf space is taken up by the radio and control boxes, thus making up for the lack of a bustle. By right, the amount of room available in a T-54 turret should be at least comparable to a tank like, say, the Centurion MK. 2 and all subsequent models which shared the same cast turret, which had a 1.88 m turret ring, but as we know from actual comparison, that is not the case. This is at least partially due to the rather large breech of the D-10T gun and the lack of a turret bustle which was used to mount the radio (on the loader's side of the turret) in the Centurion, and more significantly, the commander in a Centurion is seated on top of the turret ring on the first step of the two-stepped turret bustle. This can be seen in the photo below.

With the commander seated this way, more space was created between the commander and gunner. This also allowed the gunner to have his own backrest - a luxury that the T-54 does not have. However, by placing the commander's seat in the turret bustle, the turret also had to be much taller to accommodate him; according to official drawings it is 959mm tall. This increased the overall height of the tank to 2,635mm when measured up to the turret roof, and the total height was 2,972mm. This also added weight; a combat-loaded Centurion Mk.3 weighed a whopping 50.8 tons - equal to a Soviet T-10 heavy tank and weighing 14 tons more than a T-54, yet having less armour than its Soviet medium tank counterpart, a less powerful gun, worse automotive performance, and a much worse travelling range. It was also not as roomy as an M48 Patton which still managed to weigh 5 tons less. Needless to say, there was no chance that such characteristics would have been acceptable for a Soviet medium tank.

The T-54 turret is slightly wider than the turret of an M46 which had a turret ring of only 1.75 m in diameter, and comparable with the M47, which had a turret ring that measures 1.85 m in diameter. A comparison between these tanks is fitting because they all have a similar needle-nose ballistic shaping with sloped turret sides, unlike the Centurion, which does not have significantly sloped plating on any facet of its turret. All of these tanks had rather narrow turret rings compared to the M48, as that had a 2,160mm diameter turret ring. In a comparison between the T-54 and its closest counterpart, the M48, the T-54 loses out in the amount of internal space available to the crew by a wide margin.

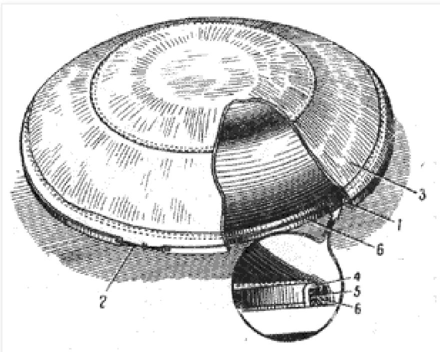
Bild 9: KPz T-54 bei der Feldinstandsetzung. Bemerkenswert ist die einfache Turmkonstruktion (ohne Turmkorb); durch die schmale Blende ist ein Waffenausbau nach vorn nicht möglich.

The low profile of the tank is advantageous when concealing the tank in prepared positions and it is also helpful if the tank is driving across open terrain as it reduces the likelihood of being hit, especially since tanks of that period had poor rangefinding capabilities, but the low profile is not so conducive for the loader. With a maximum internal height of only 1,600mm from the crew compartment floor to the turret ceiling, it was not possible for any of the crew members to stand upright in the turret unless they were particularly short. Nevertheless, the available internal height of the tank was considered enough for a loader by Soviet standards and the D-10T gun was designed with a horizontally-sliding breech as opposed to a vertically-sliding breech with this in mind. From this perspective, the T-54 is directly comparable to the M26 Pershing, M46 and M47 Pattons, but not the Centurion or the M48 Patton.

According to factory drawings, the Centurion has a total internal height of 2,057mm, but the tank stows a large quantity of ammunition on the floor of the hull underneath a rotating floor which the loader stands on. As such, the actual internal height from the rotating floor to the turret ceiling is 1,816mm - more than enough for an average man to stand up straight inside the tank. This is partly thanks to the fact that the Centurion uses an externally-mounted Horstmann suspension system which conserves the internal space of the tank, although there is no volumetric miracle as the Centurion is a very tall tank in the first place.

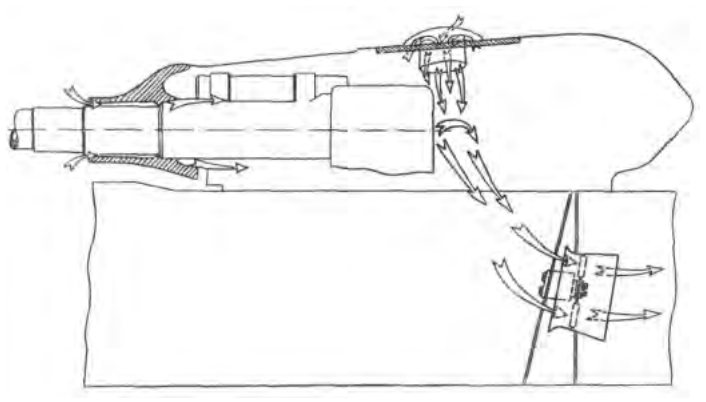
In the case of the M26, M46 and M47, the immense external height of the tanks did not translate into an equally immense internal height in the crew compartment because the turret basket was suspended far above the floor of the hull. For the M26, the floor was suspended more than halfway above the hull itself because a large quantity of ammunition was stored on the floor of the hull. It was the same for the M46 and the M47, both of which stored ammunition on the floor of the hull. Because of this, a large quantity of ammunition could be carried relatively safely in these tanks but the internal height was actually less than the T-54. Furthermore, ammunition was also stowed in vertical racks next to the loader in all of the aforementioned Western tanks, which is convenient for the loader but also takes up a large amount of space as shown in this photo of an M47. As such, the horizontal space for the loaders of these tanks is far less than the turret ring diameter suggests, and the cramped conditions for T-54 loaders are perhaps not so cramped in this context.

VENTILATION



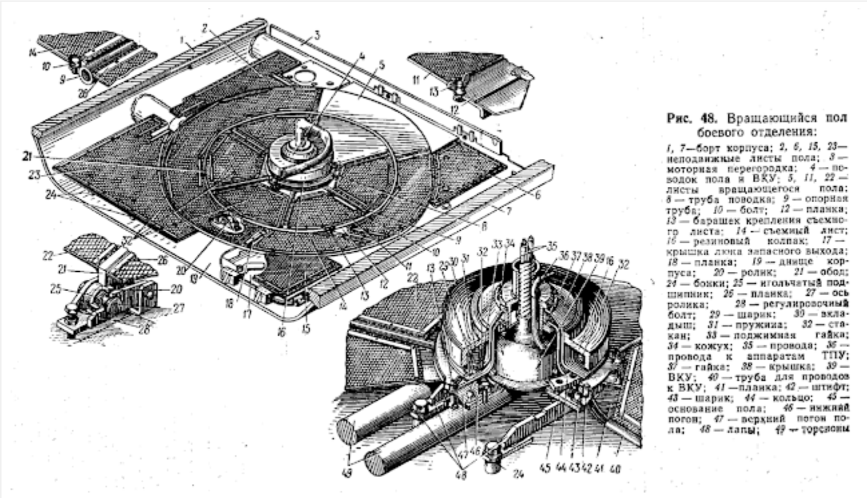
The tank does not feature any air conditioning, adjustable air blower vents or any other kind of device to direct air towards individual crew members. Ventilation in the earlier T-54 models like the T-54-1 up to the T-54B model was facilitated by a dome shaped ventilator fan installed in the roof, just in front of the loader's hatch. As you can see in the picture below (screenshot taken from this video), the dome is a thick armoured steel casting that is welded to the turret. The heavy steel walls of the dome and the good sloping enables the dome to shrug off machine gun rounds and artillery fragments.

Ordinarily, the primary purpose of this ventilation fan is to extract propellant fumes that enter the fighting compartment from the gun breech, hence its position. However, it will also act as an airway for increased ventilation as the diagram below shows. The diagram depicts a T-54-1 (T-54 obr. 1947) but it is valid for any T-54 model. Here, the airflow for the engine has been switched to the fighting compartment intake which is a fan on the firewall between the engine compartment and the fighting compartment so that the supply of air for the engine must pass through the fighting compartment first. This creates a continuous rush of air through the crew stations and serves as an excellent form of ventilation.

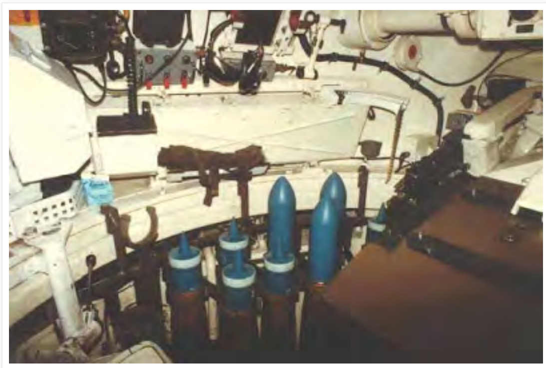


In cold weather conditions, using the fighting compartment engine air intake this way is undesirable, so it can simply be deactivated and the engine will obtain air through the intake vent on the engine compartment deck instead. There is no dedicated heater for the crew, but heat for the fighting compartment may be supplied by the nozzle-type engine and oil preheater placed in the rear left corner fighting compartment, clearly visible in the photo below (credit to Jim Chandler and the Warwickshire Armour Modellers for the photo). The exhaust of this heater is located on the belly of the hull. This heater can only be used if the tank is not in combat or conducting maneuvers as the engine would have to be running.

The heater had to be moved slightly when a rotating floor was introduced in the T-54B in order to enable a floor of maximum diameter to be installed, although the floor was still somewhat narrow as it had a diameter of only 1,370mm. This was considerably narrower than the rotating floor of the Centurion Mk.7 which had a diameter of 1,549mm. Unlike contemporary Western tanks, the T-54 lacked a turret basket and only had the rotating floor, although the turret basket floor of tanks like the M47 was also quite narrow because the turret basket tapers inward from the turret ring.



The lack of a turret basket allowed the gunner to stretch his legs into the driver's compartment when the turret was facing forward, but more importantly, it eliminated the need to store the tank's ammunition supply within the boundaries of a turret basket. In the Centurion, Leopard 1 and M48 (to list only a few), a large quantity of ammunition is stored next to the loader in vertical racks or bins which greatly reduces the available space in the loader's side of the turret. In the case of the M48A5, the loader has only half the space that the turret ring diameter alone suggests, as you can see in the photo on the left below. It is more or less the same for the Leopard 1, as shown in the photo on the right below. A T-54 loader is provided with a similar amount of headroom as its Western counterparts and he has more room in other respects.



On a side note regarding the rotating floor of the T-54, it seems rather improbable that the loader or anybody else will get his foot ripped off by the heater when the turret turns. It overhangs the rotating floor by only an inch or two and it is in the left rear corner of the fighting compartment, so the loader will only be in its vicinity in a narrow range of turret azimuths. Also, the loader will often be working with ammunition from the hull, so he should be very much aware of anything that might be dangerous.

Besides the general crampedness of the tank, a minor weakness of the T-54 is the scarcity of storage space. Besides the containers on the track fenders for storing tools and spare parts, there is no dedicated container for the personal effects of the crew. The abundance of external handrails and hooks for camouflage netting made it convenient for the crew to secure their canvas bags around the circumference of the turret (this is standard procedure taught to recruits), but it is not as convenient nor as secure as having proper stowage bins. One of the most common modifications of exported T-54s is the addition of external baskets and bins for stowage.

The handrails (two large ones on either side of the turret, and two small ones at the base of the rear of the turret. See photo above) make for great footholds to help the crew mount the turret.

COMMANDER'S STATION

The commander is seated on a padded triangular seat with a padded backrest, and there is also a cushion attached to the turret ring for him to rest his left knee upon. A fold-out footrest is provided. On earlier T-54 models, the lack of a rotating turret floor made this feature mandatory like on older tanks such as the T-34-85. The commander has access to the turret traverse lock, which is placed next to the radio transceiver on the turret shelf. Aside from that, he does not have any direct control over the turret or the weapons other than the target designation system as the T-54 does not provide duplicated controls for the commander. However, the extremely close proximity of the commander to the gunner's controls may allow him to override the gunner in a somewhat more direct way by simply leaning over and using the gunner's turret traverse controls.

In terms of space, the commander is severely restricted in his ability to move forwards and backwards as well as side to side. The small length of his station is because he is seated very close to the gunner in front of him, and the main culprit of the limited width of the commander's station is the location of the radio set. Being placed on the turret shelf just next to the commander, he can access it more easily than if it were installed behind his backrest, but this comes at the cost of restricting his working space above waist level. The narrow width of the commander's station can be seen in the two screenshots below, taken from the video "Танк Т 55 – снаружи, внутри, на ходу" from Ivan Zenkevich's channel.


The shoulder guard on the commander's right side isolates him from the recoil path of the D-10T cannon. It is possible to remove the arm guard. This gives the commander some much needed breathing space, but this can only be done in non-combat situations, for obvious reasons. This is also done to enable the commander to move to the loader's station, or vice versa, but to do that, the recoil guard behind the cannon breech assembly must be folded down as well. This is all shown in the two screenshots below, again taken from the video "Танк Т 55 - снаружи, внутри, на ходу" from Ivan Zenkevich's channel.


The commander and the loader can move over to each others' positions with relative ease once the deflector shield is folded down, although the keyword here is "relative". Furthermore, the commander's seat can be folded up for better access to equipment located below the turret ring and for maintenance and stowage purposes.

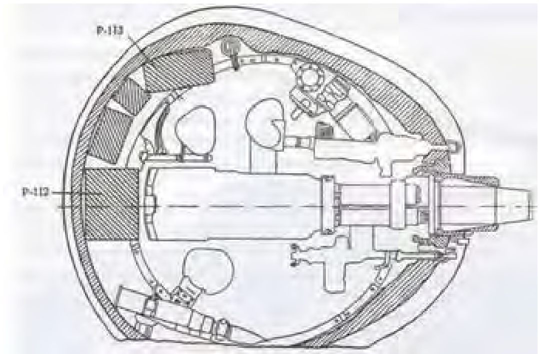
In terms of comfort, the commander gets a somewhat better deal than the gunner, who does not have a real backrest. Still, even though the commander has a footrest he has practically no legroom, forcing him to wrap his legs around the gunner. The advantage is that it is easy to nudge the gunner and give him quick orders. The disadvantage is that it quickly becomes very uncomfortable especially in hot weather, but perhaps it would be the opposite in cold weather. Nevertheless, the high level of physical intimacy between the two crew members is not particularly desirable.


COMMUNICATIONS

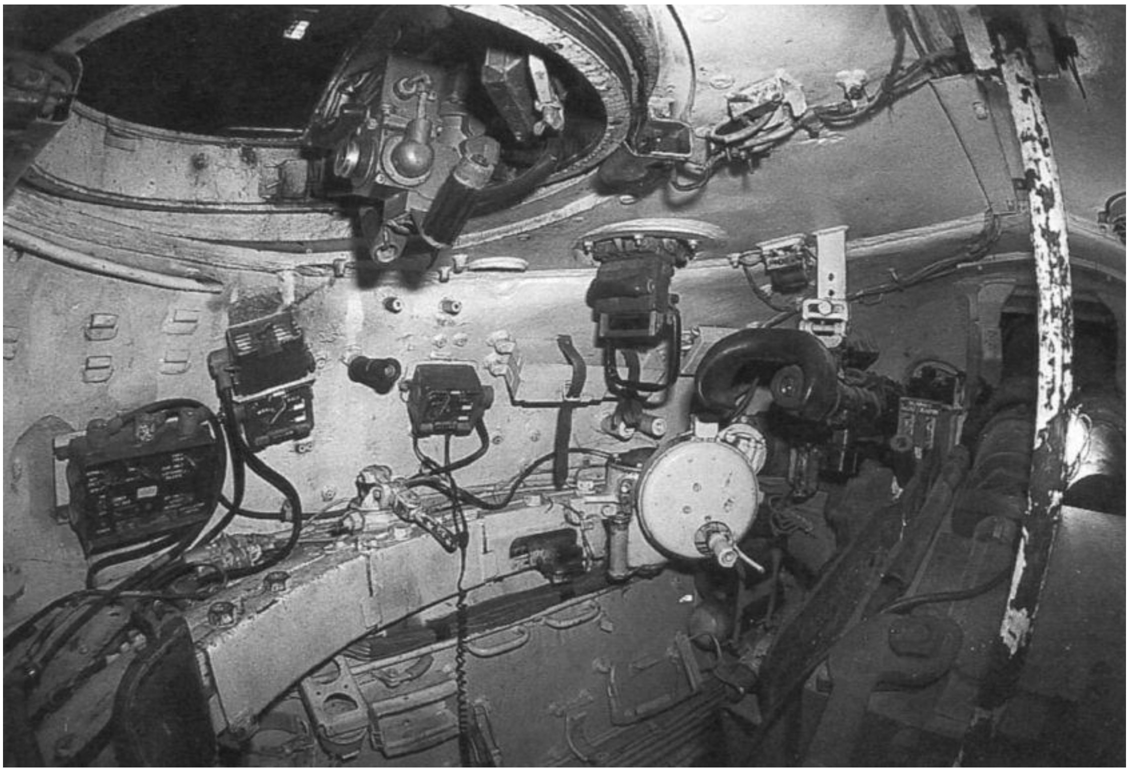
Originally, the T-54 was provided with a 10RT-26E radio transceiver mounted to the turret wall next to him. The radio is designed to operate in the 3.75-6.00 MHz frequency range. All Soviet armoured vehicles from the later half of WWII and the immediate postwar period featured a 10RT series radio, but by the early 50's, the series was rendered obsolete by a new government decree allocating the 20.0-22.4 MHz frequency range for the exclusive use of tank radios.

The production of the venerable 10RT series ceased entirely in 1956, having been replaced by the R-113 radio set in 1955. Beginning in 1955, all new production T-54s were equipped with the R-113 radio transceiver set. A video of an R-113 radio in operation can be found here (link). The R-113 belonged to the first generation of Soviet tank radios designed in the post-war era. It is a standard VHF radio operating in the 20-22.375 MHz frequency range with a maximum range of 20 km with the whip antenna extended, reduced to 8-12 km in the presence of noise and 10 km in the presence of jamming. For regular tanks in tank platoons, the radio is usually kept in the simplex receiving mode to receive orders from the platoon leader, while the platoon leader operates his radio in the half duplex mode, although he is forbidden from transmitting except in emergencies. In general, all tanks mainly operate in the receiving mode to receive orders from the company commander. The R-113 radio and the BP-2A power supply unit are shown in the photo below.

The T-54K command tank variant was created in 1959 and came with an additional R-112 radio mounted on the back of the turret. The R-112 operates in the 2.8 - 4.99 MHz frequency range, and has a range of 6 km with a whip antenna and 25 km with a mast antenna. The tank must be stationary to deploy the mast antenna. The R-112 radio allows the T-54K to communicate with the tank commanders of other tank companies as well as battalion commanders. The large size and mass (90 kg) of the radio made it impossible to install it inside the tank without removing something else. In this case, the ammunition rack holding five rounds at the back of the turret behind the deflector shield was removed and the radio is mounted there instead, as shown in the drawing on the right. The single round stored at the back of the hull was also deleted which led to a reduction in the total ammunition capacity from 34 rounds to 28 rounds in the T-54K.



Communication between crew members was facilitated by the their headsets and laryngophones which were connected to the TPU-47 intercom system. The components of the intercom system can be seen on the wall of the turret at the left side of the photo below. The tank in the photo below does not have a radio. The turret traverse lock can also be seen attached to the turret ring, and the metal loops for personal stowage can be seen on the wall of the hull at the bottom of the photo. Each crew member in the T-54 was allotted some space of personal equipment and each crew member was provided with a two-liter aluminium bottle which would be stowed in a special holder near their respective stations. Two clips for stowing two rounds of ammunition can also be seen at the bottom right corner of the photo.



CUPOLA

The commander's cupola is mounted on a separate substructure that is bolted onto the turret. On the T-54 obr. 1947 (T-54-1), the cupola protrudes very slightly from the turret roof and the roof of the cupola is flat much like the cupola design of the T-44. Three forward-facing periscopes are installed in the fixed roof of the cupola and the hatch opens forward. This limited the size of the commander's hatch somewhat, and the low number of observation devices restricted the commander's vision to a narrow forward sector. The commander's cupola on the T-54 obr. 1947 is shown in the two photos below, taken from the Net-Maquettes scale modelers' website. The central periscope is an MK-4 periscope (also known as a Gundlach periscope) which is adjustable in the vertical axis and the two supplementary periscopes on either side of the MK-4 are simple fixed periscopes. When not in use, armoured covers can be closed to protect the fixed periscopes from gunfire.

Looking at the two photos, it is evident that the commander has good forward visibility but completely lacks sideways and rearward vision. The cupola can be rotated, but the ability to rotate the cupola does not completely solve these issues as it would take much more time for the commander to scan his surroundings. Furthermore, the MK-4 was obsolete as a primary observation device as it did not provide magnified vision. This limited the commander's viewing range and restricted his ability to conduct fire correction for the gunner.

Due to the limitations of the cupola design, a new cupola was installed together with the new turret that was implemented on the T-54 obr. 1949 (T-54-2). The new cupola was slightly taller, but had an improved primary observation device with two additional fixed periscopes aimed to the sides. The two additional periscopes increased the field of view of the commander such that the only blind spot was an arc of 45 degrees directly towards the rear. For the remaining 315 degrees, the commander did not need to rotate the cupola to see them through his periscopes.

The new cupola also had a beveled external surface that provided excellent ballistic protection from machine gun fire. However, the basic layout of the cupola did not change and the commander's hatch remained limited in size. This cupola design, shown below, stayed with the T-54 and all of its derivatives throughout the production lifetime of the tank.

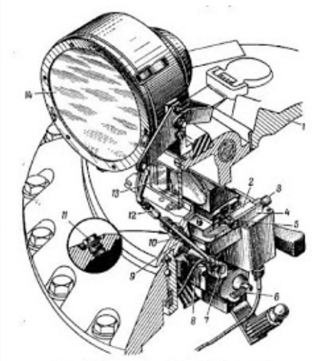


Рис. 52. Установка прибора ТКН-1 в танке:
1 — крышка люка командирской башенки; 2 — рама крепления прибора наблюдения; 3 — стопор рычага цапфы; 4 — рычаг цапфы; 5 — цапфа; 6 — рукоятка шторки; 7 — замковое устройство; 8 — прибор наблюдения ТКН-1; 9 — тяга; 10 — уплотнение тяги; 11 — пробка; 12 — стяжная муфта тяги; 13 — защитное стекло; 14 — прожектор ОУ-3

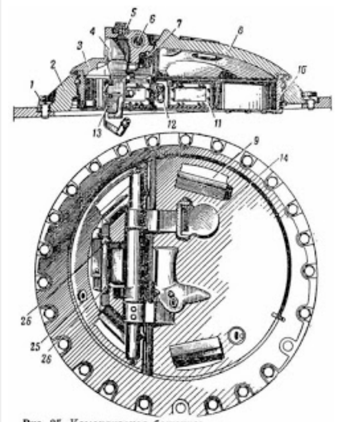
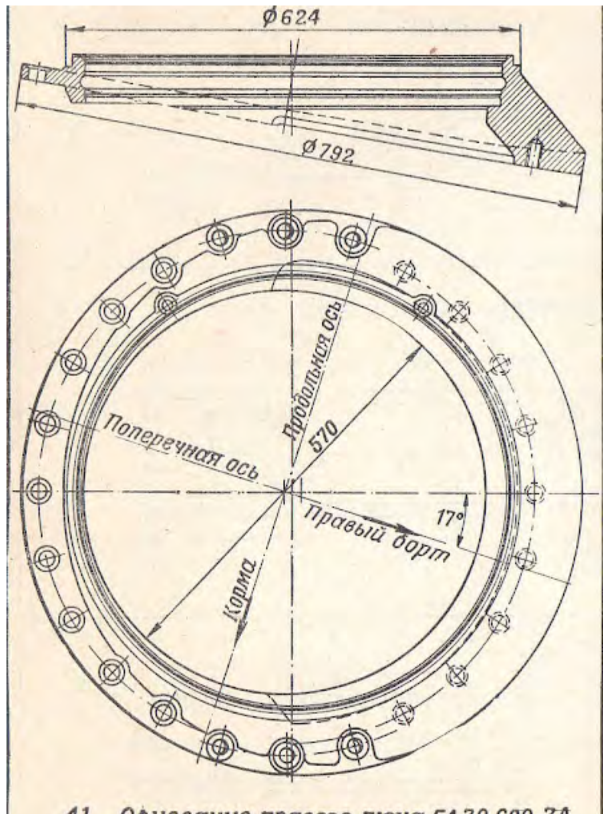


Рис. 25. Командирская башенка:

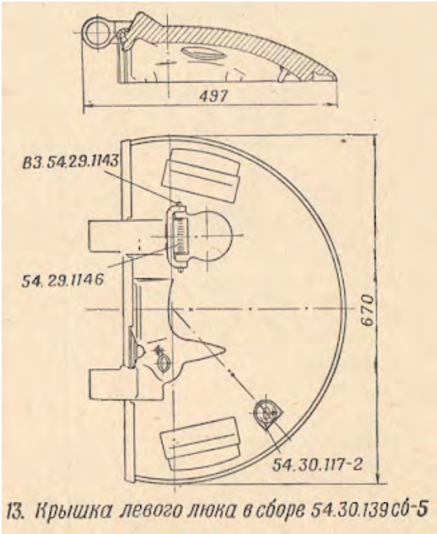
The bolt-on substructure on which the cupola is mounted has a minimum internal race ring diameter of 570mm and the substructure itself has an external diameter of 624mm. The rotating cupola itself fits inside this substructure. As shown in the drawing, the substructure is horizontally slanted by 17 degrees to offset the slope of the T-54 turret roof. This creates a level plane for the cupola to be mounted on, which is important because a tilted cupola makes it extremely difficult for the commander to use the viewing devices and the cupola itself would require more force to rotate.



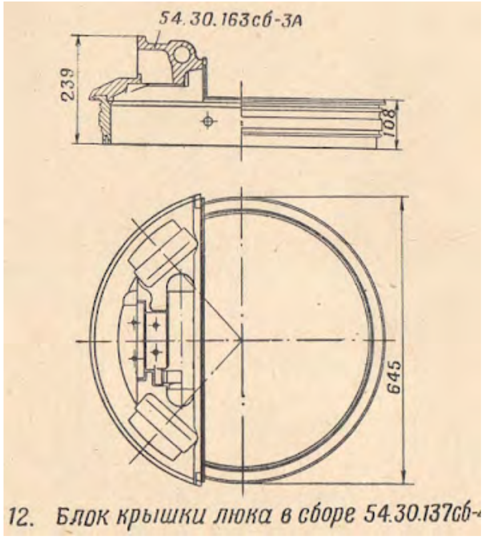
41. Основание правого люка 54.30.680-3А

The cupola and the cupola hatch are shown in the two drawings below. The hatch itself has a total length and total width of 497mm and 670mm respectively, but the actual opening in the cupola through which the commander can ingress and egress is much smaller as the length of the hatch includes the hinge where it attaches to the cupola and the edge where it overlaps with the lip of the cupola race ring. The actual size of the opening is only approximately 400mm long and the width is 570mm as indicated by the minimum internal diameter of the cupola substructure.

The height of the exposed cupola excluding the race ring which fits into the cupola substructure is 131mm and the entire cupola is thickly armoured and sloped.



13. Крышка левого люка в сборе 54.30.139сб-5



12. Блок крышки люка в сборе 54.30.137сб-

This cupola design was considered very successful at the time and was inherited by every subsequent Soviet medium tank and main battle tank.

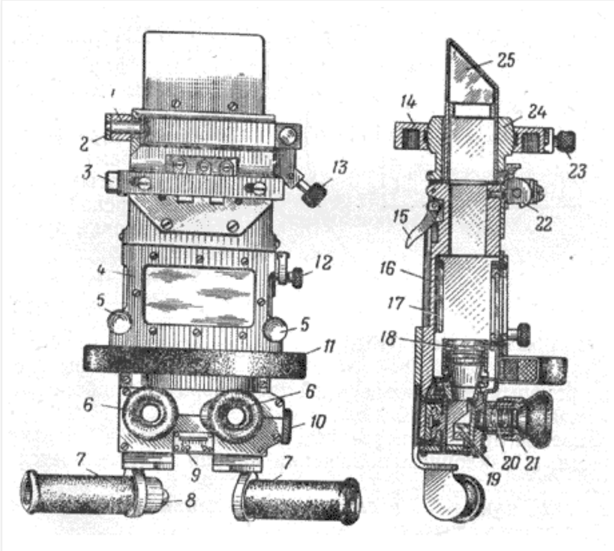
MK-4

The earliest production models of the T-54 obr. 1947 were very conspicuously descended from the WWII era-designed T-44 in many ways, including the sighting systems. Like in a T-44, the commander of a T-54 obr. 1947 was supplied with an MK-4 periscope for general observation.

As MK-4 is a direct vision periscope with no magnifying power whatsoever, the early T-54 obr. 1947 suffers from a bad case of short sightedness. According to Soviet studies (supported by foreign studies), an optical sight with no magnification would allow the gunner to see and identify a tank from a distance of 1.0-1.5 kilometers. This is the same as viewing with the naked eye. Although this seems adequate, it is too limited to permit the commander to perform fire corrections for the gunner and it does not allow the commander to differentiate between different tank models as he simply cannot discern such details.

Nevertheless, the independence of the periscope from the cupola gives the commander some extra breadth of view, and the little vertical freedom offered by the periscope is useful too, but the inadequacy of the MK-4 meant that it was only ever a stopgap solution before the TPK-1 was ready for production.

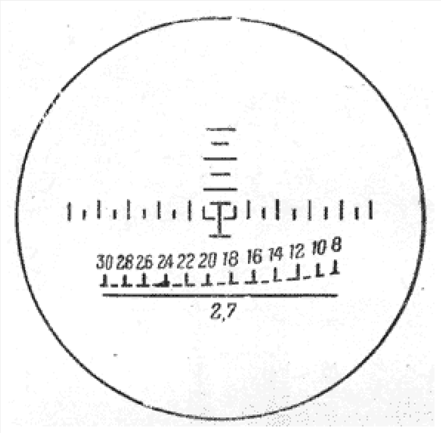
TPK-1



TPK-1 came with the T-54 obr. 1949, and remained with the T-54 family for the next 9 years. The device was implemented in parallel with the new cupola design of the T-54 obr. 1949 turret. It is an improvement over the old MK-4 for observation at longer distances as it provides a 2.5x magnification power. The requirement set by the GBTU (Directorate of Armoured Forces) was for an effective viewing range of 1,500 meters and easier fire correction than from the venerable MK-4, and the TPK-1 periscope meets these requirements. A prismatic block above the binocular eyepieces duplicates the function of the MK-4, giving the commander the luxury of both a wide-vision 1x periscope and a 2.5x magnified optic in the same device. The prismatic block can be seen in the drawing above.

Although the modest 2.5x magnification of the device is totally inadequate for long range observation in a modern context, studies and records showed that tank combat distances during WWII generally did not exceed a kilometer. In fact, combat data from the Aberdeen Proving Ground showed that 80% of all encounters between tanks and other tanks or anti-tank weapons occurred at a distance of less than 1,000 yards. There were practically no encounters beyond 2,000 yards. From this perspective, the device is quite adequate, although not entirely ideal since a higher magnification would certainly have been appreciated for easier target identification at the upper boundaries of expected combat distances. For long range observation, the commander would have to rely more on his personal 8x30 field binoculars which were usually of superb quality, as most examples of this line of binoculars made in the USSR were built using tooling plundered from the German Zeiss-Jena factory at the climax of WWII.

What a pair of 8x30 field binoculars doesn't have, though, is a stadiametric rangefinder. The stadia markings in the TPK-1 viewfinder allowed the commander to rapidly estimate the distance to a typical tank-type target with a height of 2.7 meters, and the additional markings allowed him to lead the target to a limited extent. These modest features were not insignificant, considering the fact that the MK-4 periscope lacked any mil markings whatsoever and did not permit even basic range estimations.



That, however, is not the biggest breakthrough from this new device. The most significant feature of the TPK-1 is its ability to designate targets for the gunner. This is done by simply aiming the device at the target and pressing the left thumb button. An electric signal is sent to the turret traverse motor, and by referring to a deflection sensor attached to the cupola ring, the turret is automatically rotated to meet the target. The new cupola of the T-54 obr. 1949 featured special rings to accommodate the sensor. The deflection sensor detects if the cupola is turned away from the 12 o'clock position relative to the turret but does not record the actual azimuth of the cupola. If the sensor detects that the cupola is rotated counter-clockwise relative to the turret, the turret will be rotated counter-clockwise and vice versa. Once the commander has designated a target, the turret will turn until the cupola is once again at the 12 o'clock position relative to the turret - indicating that the turret is facing the same direction as the commander - and the turret traverse motor is halted.

Turret traverse is only conducted at maximum speed in order to minimize the reaction time of the system. As the gun elevation mechanism lacked power controls, it was still up to the gunner to adjust in elevation. The commander does not need to hold the button to slew the turret all the way to the target. A single click will do. Holding the button will prompt the turret to slew to meet the target and remain slaved to the periscope, thus allowing the commander to commandeer the turret as its movement would then depend on the commander rotating his cupola. Small corrections made by rotating the cupola slightly will not cause the turret to jerk onto the new aiming point even though turret traverse is done at maximum speed by default. This is because the traverse motor will need time to accelerate the turret to its maximum speed (due to inertia), so the turret will turn quite slowly if the arc of rotation is very small. The effect is that the commander can guide the gunner onto target quite gently if he turns the cupola slowly enough.

This arrangement can be described as a hunter-killer system, making the T-54 the first tank ever to implement such a system, followed by the British Conqueror heavy tank in 1955. The commander of a T-54 is not provided with duplicated firing controls so he cannot override the gunner completely, but this has little bearing on the definition of a hunter killer system. During the early 1950's, the TPK-1 periscope and the associated fire control modifications was retrofitted to IS-2 and IS-3 tanks to modernize them to the IS-2M and IS-3M standard, thus bringing the hunter-killer feature to the Soviet Army's workhorse heavy tanks as well.

TPKUB, TPKU-2B

The commander of an early issue T-54B was equipped with the TPKUB binocular periscope. The only difference between it and the much more common TPKU-2B was that it had only one handgrip as opposed to two. This new periscope is a step forward over the TPK-1 in many ways. Many older T-54 models were retrofitted with the TPKU-2B to bring it up to the same level of technology as the T-54B.

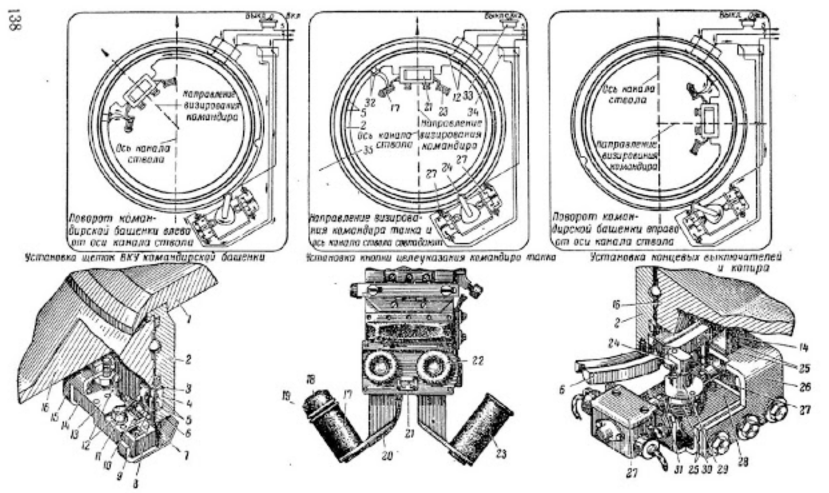
The sight has two modes of adjustable magnification of either 1x or 5x. Under 1x magnification, the field of view from the sight is 17.5 degrees. This is reduced to 7.5 degrees under 5x magnification. The general layout of the viewfinder and the reticle is the same as in previous periscopes. The viewing distance is improved by the higher magnification factor, but the rangefinding capabilities of the periscope are probably not improved at all. A report made available on tankandafvnews reveals some interesting information on the precision of rangefinding through the TPKU-2B; from the table in page 121 (page 64 of the photo album), the mean error in ranging tank-shaped screens, broadside tanks, oblique tanks (meaning: angled hull) and head-on tanks is 14.57%. The results of an analysis of the data were extremely counter-intuitive.

Page 122 of the report (page 65 of the photo album) mentions that the precision of rangefinding against hull-down tanks was surprisingly unaffected by the fact that half of the target was out of sight. The report does not say why, but we can conjecture that it is because stadia rangefinding is partly technique and partly guesswork. The full report on tankandafvnews is worth reading in its entirety as it is very enlightening.

The tests show that the commander is able to range the target in an average time of 3.3 seconds, and this section of the report concludes that the short time required to obtain a range estimate is unobtrusive to the loading and laying of the gun. This means that by the time the gunner has visually acquired the target, he will already know the range, and can open fire without delay.

Additionally, it must be noted the lack of stabilization in the rangefinders installed in the Patton series of tanks would have made it difficult to operate them while on the move, especially since they are fixed at a high magnification. The M17 rangefinder used in M60A1, for example, would have been next to useless if the tank was in motion over rough terrain since the rangefinder had a fixed 10x magnification, so the oscillations from the movement of the tank would cause too much jolting for the commander to keep the target focused. This means that the rangefinder is only useful when the tank is static, which is perfectly fine for the M60A1, as it was designed with NATO's defensive doctrine in mind. The T-54 lacks a dedicated rangefinder, but is an offensive tank designed around the Soviet Army's mobile "deep warfare" doctrine. A stadia rangefinder was probably the best choice as it was at least fast enough to be useful when firing from slow crawls or short halts. Therefore, optical rangefinders were understandably absent from Soviet medium and heavy tanks, but NOT from Soviet tank destroyers and assault guns. Case in point: the SU-122-54 and the experimental Obyekt. 268 both had stereoscopic rangefinders installed on the commander's cupola. Optical rangefinders only found their way into Soviet tanks with the advent of the T-64 main battle tank; the first tank to have an independently stabilized primary gunsight, and also the first tank to have an integrated optical coincidence rangefinder installed in said gunsight.

Like the TPK-1, the TPKU-2B has a target designation function. The target designation system is a rather simple one; A direction sensor is installed in the 5 o'clock position of the cupola. The direction sensor consists of a roller placed in permanent contact with the cupola race ring, a cam attached to the roller and two switches. The roller is recessed into a notch in the cupola race ring when the cupola is turned to the 0 o'clock position relative to the turret. When the cupola is turned to the right, the motion of the cupola race ring dislodges the roller from the notch and causes the roller to be deflected to the left by friction. The cam attached to the roller also rotates left, causing it to touch the switch on the right (see diagram on the top right, below). The right switch triggers the turret rotation motor to turn the turret to the right until the roller returns to the notch, which would mean that the gun is now facing the same direction as the commander's cupola. The same mechanism is repeated in reverse when the cupola turns to the left. Since the direction sensor is composed of two switches which can only be either on or off, the command to initiate turret rotation is binary. This means that the turret is either turning, or it is not. For that reason, the turret always rotates at maximum speed when the target designation system is activated.



The binary system also does not allow the commander to precisely lay the gun on target, because precision gun laying is done at the minimum turret rotation speed, which would be 0.07 degrees per second in the case of the T-55. Potentiometers would be needed in order to have a variable speed of turret rotation. However, as mentioned before, small corrections made by rotating the cupola slightly will not cause the turret to jerk onto the new aiming point, even though turret traverse is done at maximum speed by default. This is because the somewhat underpowered traverse motor will need time to accelerate the turret to its maximum speed. There is no vertical deflection sensor attached to the TPKU-2B periscope, so it is not possible for the commander to raise the cannon onto the target from his station.

TKN-1, TKN-1S

As the TPKU-2B lacked any provisions for nighttime use, it was necessary to swap out the periscope for the TKN-1 before commencing night operations. The TKN-1 was introduced in 1951 for the T-54 obr. 1951, and continued to be used on the T-54A, T-54B, and later on in the T-55 as the TKN-1S, for the lack of a better alternative.

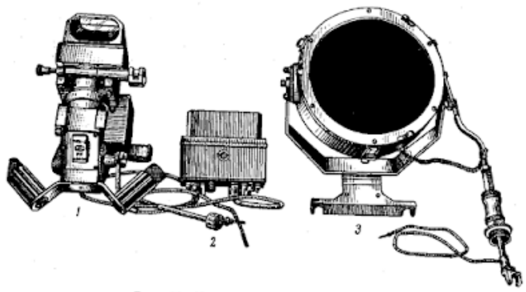
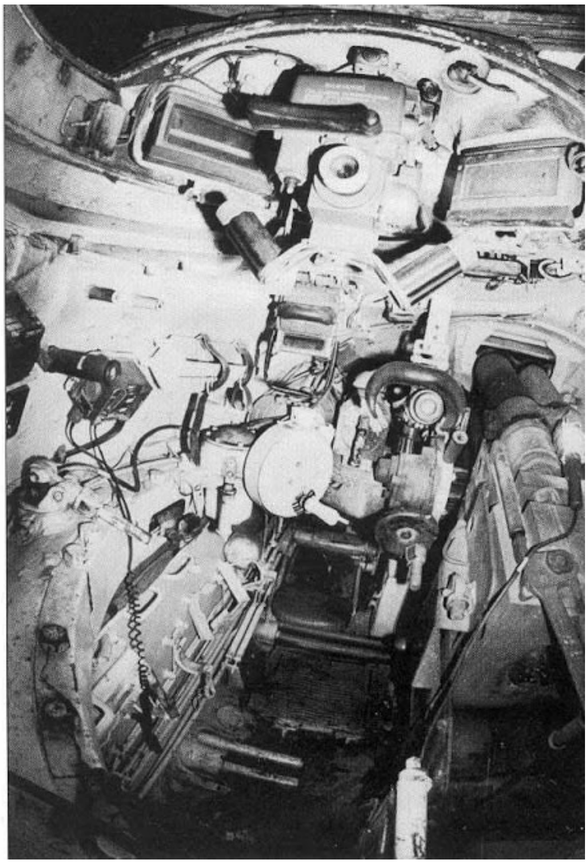


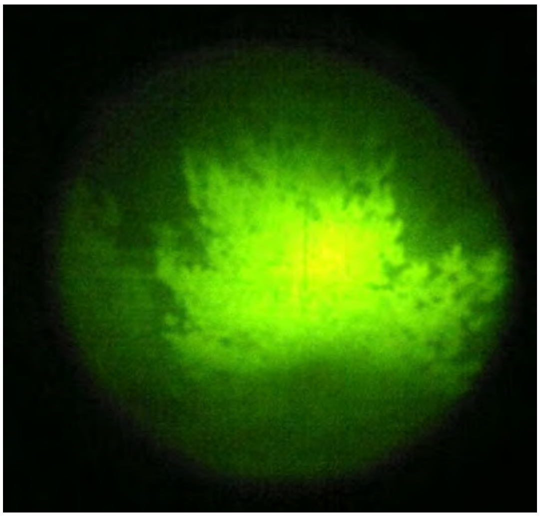
Рис. 63. Комплект прибора ТКН-1:
1 — прибор наблюдения; 2 — блок питания; 3 — прожектор инфракрасного света

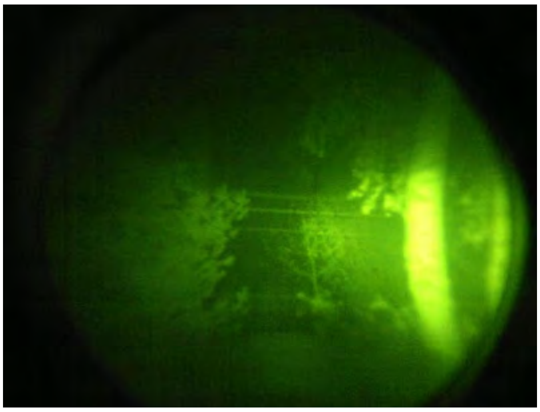
TKN-1 has a fixed 2.75x magnification, making it unsuitable for long range observation. The angular field of vision is 10 degrees. TKN-1 fits in the same slot as the TPKU-2B. Older model T-54s can also use TKN-1, but only if they have been modernized to include the BT-2-26 power supply system.



The infrared light from the spotlight illuminates the target, and the reflected light entering the objective lens of the periscope is then amplified by an image intensifier tube operating on 17 kV. The power cable connecting the periscope to the tank's electrical system can be seen on the left side of the periscope, as seen in the photos below (Photo credit to ancientpieces from ebay). The power cable supplies power to the transformer housed in the box on top of the eyepiece, and another cable runs from the transformer to the image intensifier installed inside the optic.

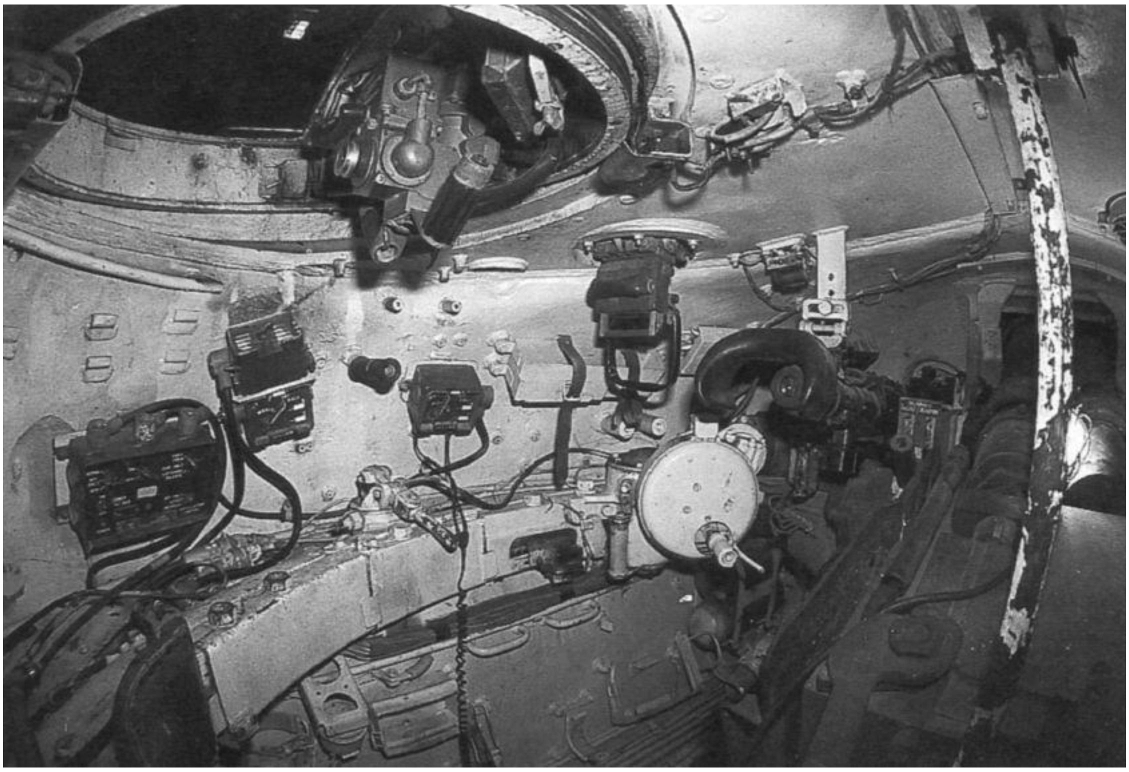
Using the TKN-1 with the illumination from the OU-3 will enable the commander to identify tank-type targets at a distance of only 250-300 meters. Due to the short viewing distance, the TKN-1 is generally only suitable for spotting enemy tanks that are also using active infrared illumination, for following the fall of tracers, for observing the impact of shots and for spotting the muzzle flash of enemy tanks. The view through the eyepiece of the TKN-1S is shown in the two photos below (image credit to kmshik from the GAZ 69 forums).





Like the TPKU-2B, the TKN-1 can be used to designate targets by pressing the left thumb button. On the right handgrip is a thumb button to activate the OU-3 infrared searchlight on the cupola. It is not only possible for the sight to be turned to the active infrared imaging mode without turning on the searchlight, it is highly recommended. If enemy tanks have infrared searchlights as well, then the commander will be able to spot them easily without needing to turn on his own, thus remaining hidden. Use of infrared illumination is usually only viable with good coordination and fire control, or when enemy tanks have absolutely no night vision equipment at all.

GUNNER'S STATION



The T-54 obr. 1947 and T-54 obr. 1949 models featured a single MK-4 periscope beside the telescopic main sight, which you can see in the photo above. The periscope gave the gunner unusually good situational awareness, considering that most tank gunners had only a single fixed forward-facing periscope, but it was considered to have few practical uses. After the numerous field exercises conducted by units equipped with the T-54, it was found out that the MK-4 could not be used for too long when the tank was driving over rough ground, as the pitching of the tank made the gunner carsick. It was far more profitable to focus on the operating the main sight instead, and leave the MK-4 be until it was needed, like when the tank is entering a turret defilade down position. The gunner would then use the periscope to observe targets without needing the turret to be exposed. On the T-54B model, the MK .4 was replaced by the TPN-1 night vision sight, so its role was taken over by a single fixed forward-facing periscope installed above the TSh2-22 primary sight.

Sometime during the 50's, possibly in 1954, the T-54 gained the ability to conduct indirect fire. Laying the gun in elevation was done using a spirit level affixed next to the gun, and laying the gun in the horizontal plane was facilitated by a turret azimuth indicator, as seen below. The indicator works like a clock with two hands. The indicator can be seen next to the manual turret traverse handwheel in T-54 models beginning from the T-54A (1954).

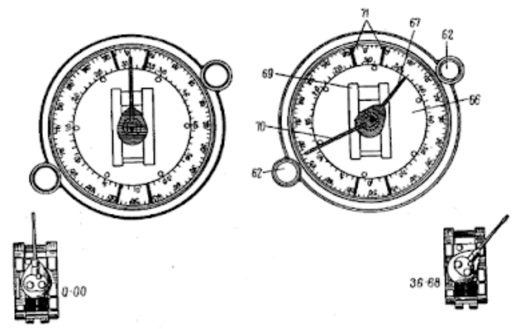


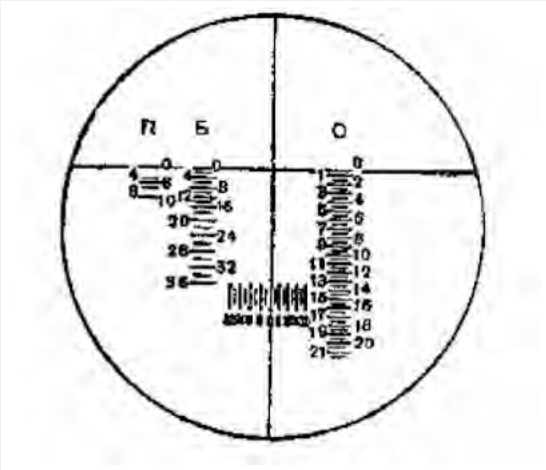
Рис. 47. Шкалы азимутального указателя:
обозначение позиций то же, что и на рис. 46; *71* — габаритные указатели

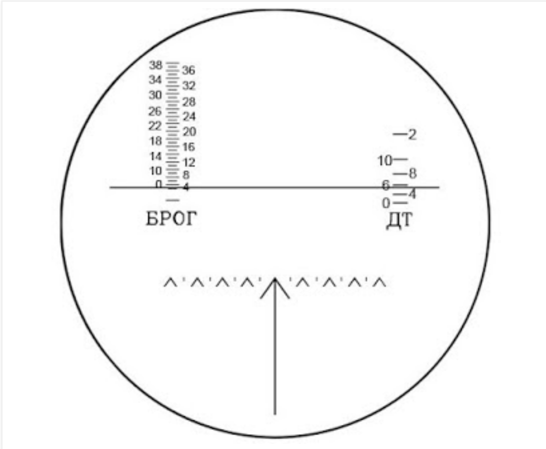
A hole in the commander's cupola allows a periscope for indirect fire to be installed.

TSh-20

The TSh-20 is an articulated telescopic sight. Most telescopic sights from the WWII era were fixed to the cannon, so that if the cannon elevated, the telescope went with it. This meant that the eyepiece would never be in the same spot as the gunner fiddled around trying to get a firing solution for his target. In the TSh-20, the telescopic aperture is joined to the telescope body with a hinge, optically connected by cleverly placed mirrors. With an articulated telescopic sight, the eyepiece and the main telescope body could stay fixed while only the aperture moved. This eliminated the problem of gunner fatigue and improved firing accuracy, as the gunner will always maintain optimum eye relief. This arrangement was first used in the Soviet weapons industry in the TSh-16, which was installed in the T-34-85.

The T-34's PT-4-7 sight (below, left) featured a similar system of range adjustment. The horizontal line can be moved while the vertical line remains static, unless lead is applied. The intersection point between the two lines forms the crosshair. As the horizontal line is moved down the range scales to the appropriate distance to the target for a given ammunition type, the crosshair is moved down by the same amount.





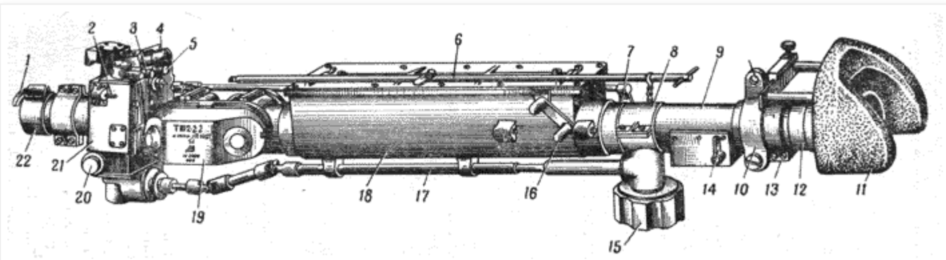
The newer TSh-16 (above, right) offered an improved viewfinder arrangement. The viewfinders on the TSh series of telescopic sights generally have a better layout as all of the "clutter" is concentrated in the top half of the sight picture where there is nothing but sky. This means that the gunner's view of everything from the ground up to the horizon is perfect, but his view of the sky is not, which is obviously not important. Insufficient magnification power of the TSh-16 aside (only 2.5x), the design of the viewfinder was considered sound, so it was carried over to the TSh-20.

One excellent feature of the TSh-20 sight is the large rubber brow pad. It is large enough to fit around the gunner's forehead and temples - even if he is wearing his helmet - and stiff enough to hold his head in place, so that even if the gunner's body is rocking about, his head will be held firm and his eyes can be glued onto the eyepiece. This is a traditional feature of almost all gun sights on Soviet and Russian tanks, including later sights present on the T-54, which we will discuss later, all the way up to the Sosna-U on the latest T-90MS.

TSh-20 offers a fixed 4x magnification with a 16° field of view. This is horrible by modern standards, but *arguably* within acceptable limits for a 1945 product. For example, the M71C for the Pershing had a fixed 5x magnification with a 13° field of view. The extra wide vision arc offered by the TSh-20 enabled the gunner to survey for targets at short to medium distances more easily, but severely handicapped the long range viability of the tank. Whether high magnification was necessary during that particular stage of global tank evolution is not too clear. U.S research showed that the average tank duel in the Korean war occurred at an average distance of only 450 yards (411 m) due to the abundance of natural obstacles and obscurants. In addition to that, Soviet experience and research during WWII showed that almost all tank duels fought by Red Army tanks occurred under 1 kilometer in distance. With heavy, hours-long artillery barrages usually preceding breakthrough assaults, smoke and dust in the air often reduced tank engagement distances to just a few hundred meters, with many tanks only meeting each other at "knife fight" distances (also making head-on collisions, accidental and non-accidental, surprisingly common).

If the T-54 obr. 1947 came early enough to fight in WWII, or if its sequel was conducted in much the same way, then perhaps TSh-20 is good enough. However, it was impossible not to recognize that tank warfare was evolving. Soviet strategists felt that fluid and mobile "meeting engagements" would be the primary mode of combat in a hypothetical European world war, as opposed to the frontal attack. Scoring a hit on the first round was essential, and the crews themselves complained that 4x magnification was just not good enough. The solution was simple: increase the magnification power.

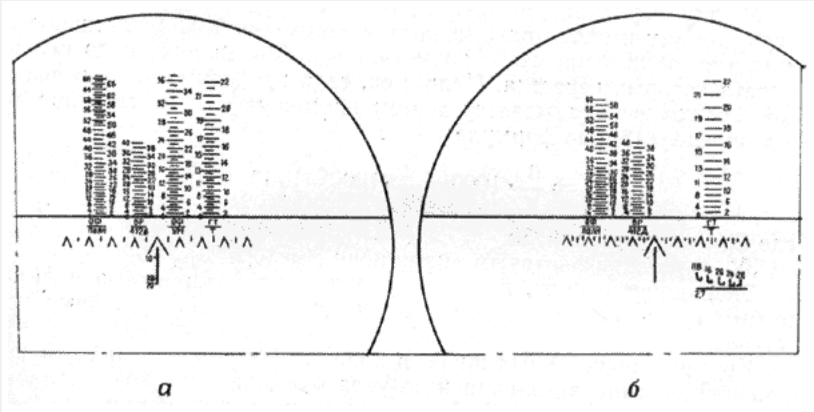
TSh2-22, TSh2B-22



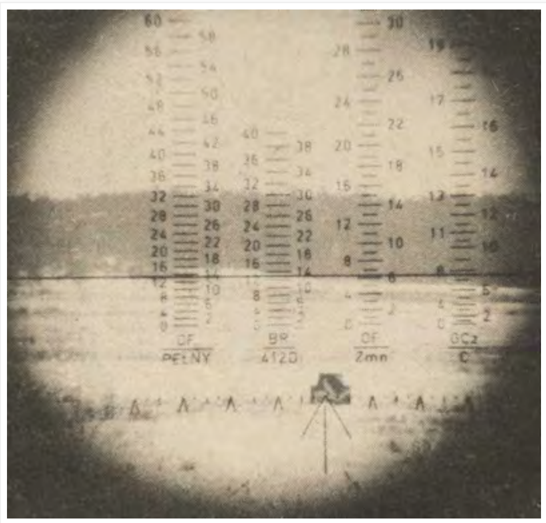
TSh2-22 was introduced with the T-54 obr. 1951. Continual field trials of previous T-54 models up til this point had shown that one of the chief complaints was the limited magnification of the TSh-20. Consequently, TSh2-22 features variable magnification settings of 3.5x and 7x. By implementing variable magnification in the gun sight, the gunner could enjoy both wide vision and high power magnification, though obviously not at the same time. For an even wider field of view, the MK-4 rotating periscope would more than suffice. The TSh2B-22 sight was a modification of the basic model with new design features that gave it compatibility with the STP-1 gun stabilizer of the T-54A respectively.

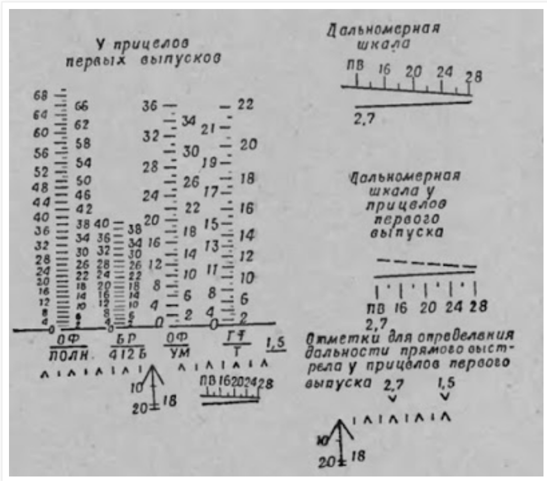
TSh2-22 is directly comparable to the Centurion's No.1 sight which had a variable magnification of 1x or 6x and the M47 Patton's M20 sight, which also had a variable magnification of 1x or 6x. The M20 sight was shared by the M48 as well.

There are multiple variations of the TSh2-22 viewfinder. An early versions (a) has four scales; three for main gun rounds and one for the coaxial machine gun. Listed from left to right, they are: HE-Frag with a full charge (53-UOF-412), APBC (53-UBR-412B), HE with a reduced charge (53-UOF-412U) and finally, the coaxial machine gun. A late version (b) has just two scales for main gun ammunition: HE with a full charge and APBC, plus one for the coaxial machine gun.

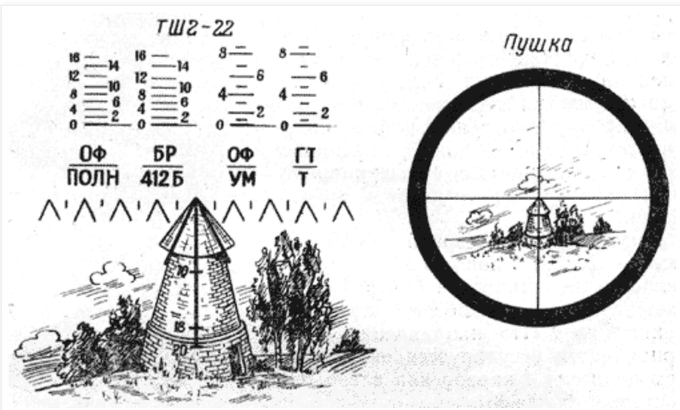


Moreover, the later version included additional horizontal lead markings and a stadia rangefinder scale to allow the gunner to quickly measure the range in case the commander is preoccupied or if the tank is running in a degraded state with a 3-man crew. Another difference is the removal of the range markings on the vertical line below the center chevron. These range markings are meant to be convenient aiming points for common combat distances using APBC shells to aid the gunner if he decides to use the bracketing gunnery technique to engage a target. It is reasonable to assume that with the addition of a stadia rangefinder scale, it became superfluous as it would be slower, less accurate, and more wasteful of ammunition compared to stadia rangefinding. At least, this was the case in other contemporary sights. Multiple viewfinder configurations with various combinations of markings existed and small changes were implemented over time, making it rather difficult to classify the TSh2-22 this way. The markings were etched on a special viewfinder glass disc that could be removed relatively easily and replaced with updated markings when new ammunition became available.



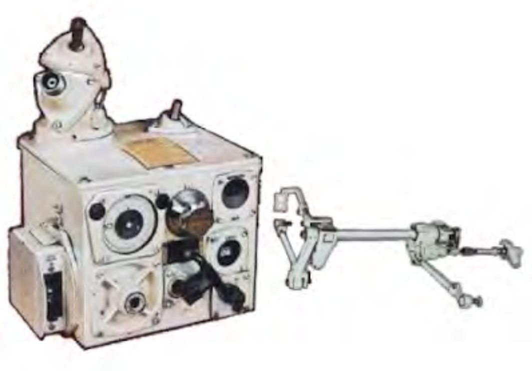


The sight is ordinarily zeroed to a distance of 1,200 meters or more. The drawing below depicts a method of zeroing the sight in field conditions by using a landmark.



Much has been said about the T-54's lack of sophistication in the fire control department, and while there may be a lack of an optical rangefinding device, there is no substantial evidence that this is true. Let us first begin by understanding what constitutes an "advanced" fire control system of that era by taking a look at the M48 Patton which comes with an analogue ballistic computer and a stereoscopic rangefinder.

The M48 is principally the same as the M47. The M48 has an M20 (T35) variable power periscopic primary sight, paired with the M12 stereoscopic rangefinder. In models produced before problems with the T30 ballistic computer were solved, the T24E1 ballistic drive connected the elevation mechanism of the cannon with the M20 sight and the T25 range drive, which was a simple mechanical device that converted rangefinder adjustments into vertical displacement of the reticle in the M20 sight. Once the M13 (T30) mechanical analogue ballistic computer was installed, a slightly modified T24E1, now the T24E2 ballistic drive, was used.


M13 ballistic computer with linkage

This system works thusly: The gunner finds the range to the target by operating the rangefinder by twisting an adjustment dial. This simultanrously causes the reticle in his M20 sight to raise or lower. By raising the reticle onto the target using the control handles (known as "Cadillacs"), the cannon elevates accordingly and the gunner obtains a ballistic solution. The fire control system of the M47 works identically. The only function of the M13 was to provide a ballistic solution given a range input. It could not account for other factors like wind, ambient temperature, etc. It had an input for barrel wear, but that had to be done manually (the computer did not automatically count the number of shots fired).

(Source: **Camp Colt to Desert Storm: The History of U.S. Armored Forces**)

(Source: Extract from publication in Forum post. Unknown publication)

If you understand the principles behind the operation of the TSh series of gun sights, then you will have noticed some similarities. The TSh2-22 sight itself performs the same basic function as the M13 ballistic computer, whose only role is to interpret range data into an appropriate superelevation angle which it does with the spinning of wheels and the twisting of cams. The TSh2-22 is simpler in that it achieves the same results by simply printing out the ballistic solution for gun elevation for a range of distances in the form of range scales into the sights. This is essentially the same as printing out the values on a dial on an external adjustment device and having the gunner refer to that instead, which is how it was done in the Centurion. On a purely technical level, the M47 and M48 are certainly more complex and arguably more sophisticated, but in practice, the advantage is minimal.

By displaying all of the range scales in the viewfinder and not on an external dial, the gunner can conduct the entire target acquisition procedure without removing himself from the sight and losing visual contact with the target. This problem was solved in the Centurion in a rather creative way; a mirror was placed in front of the gunner's left eye at such an angle that the gunner could see the range drum with his left eye as he adjusted it, and then - by just moving his eyes - return to the sight and resume targeting.

To use the rangefinder, the gunner only needs to bracket the target tank between the stadia lines and read the figure corresponding to the height of the target, and then turn the range adjustment dial until the horizontal line is on the correct range scale mark for the desired ammunition type. It is also possible for the gunner to use the multitude of chevrons and lines that form the reticle of the sight viewfinder and combine them with his own memorized information of tank widths and lengths to obtain a range estimate.

The shortcomings of the stadia rangefinder of the TSh2-22 are numerous. For one, it is not possible to range targets other than tanks to any significant degree of accuracy. If the target vehicle is a jeep, a self-propelled anti-aircraft gun, a truck or a bunker, the stadia rangefinder is totally useless. The only practicable option at that point would be to use the burst-on-target technique.

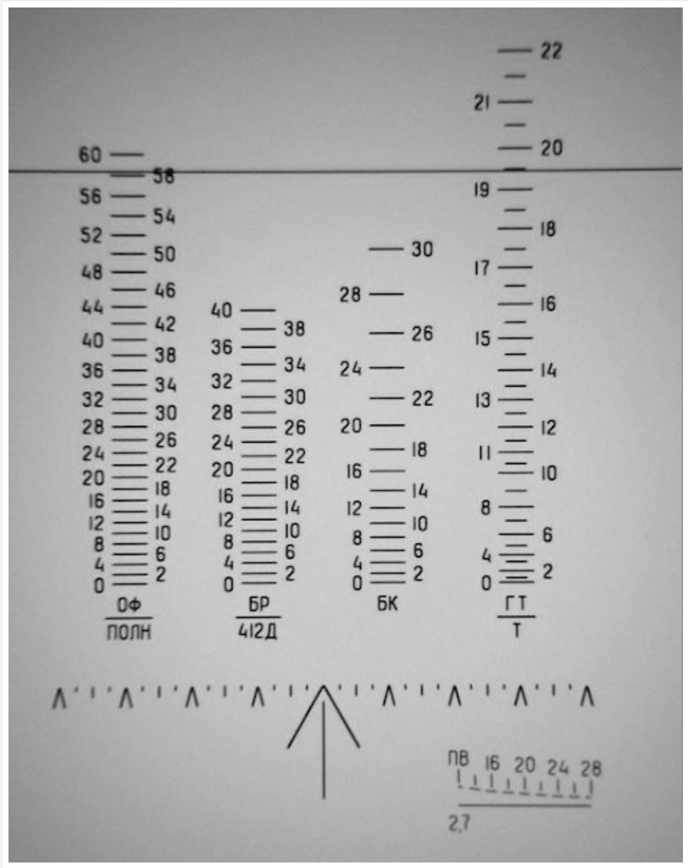
In an early 1970s test involving a stationary Belgian M47, the efficacy of three types of rangefinding was conducted by determining the probability of hit against a 2.3 sq.m target. A newly developed laser rangefinder was pitted against the original M12 stereoscopic rangefinder with 7.5x magnification found on most M47s, and a stadia reticle, which appears to have been retrofitted to the Belgian M47 as the original tank did not have one.

The results of the test are as follows:

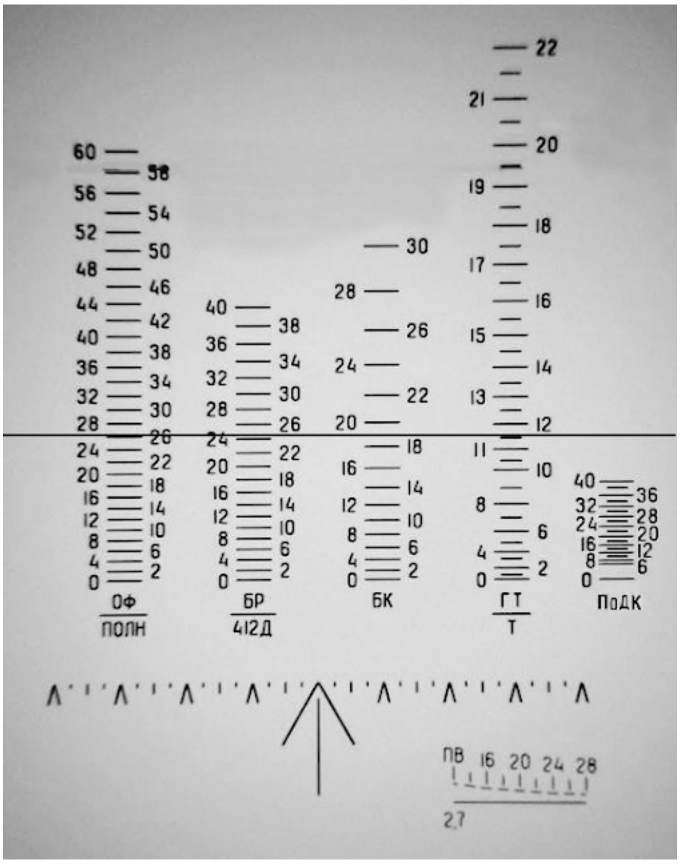
Range	Laser Rangefinder	Stereoscopic Rangefinder	Stadiametric Rangefinder
500 m	98%	97%	98%
1,000 m	86%	70%	34.5%
2,000 m	34%	14%	4%

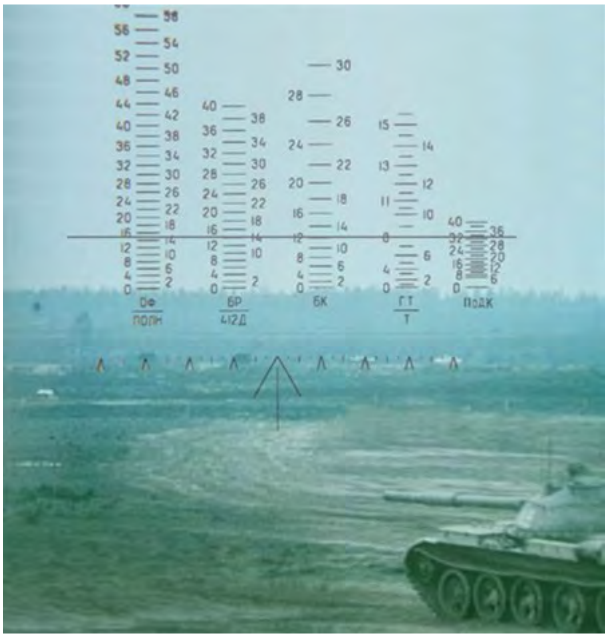
TSh2B-32, TSh2B-32P

TSh2B-32 was first implemented in the T-54B. The sight was practically identical to the previous articulated telescopic sights with the main difference being that it was designed to connect to the new STP-2 gun stabilizer. This sight continued to be used in the T-55 series as the fire control system did not change. The configuration of the viewfinder markings follows the latest variant of the TSh2B-22. As shown in the photo below, there were range scales for HE-Frag with a full charge, APCBC, HEAT and the coaxial machine gun. Additionally, the markings for HE ammunition with a reduced charge were permanently removed as this type of ammunition had become obsolete.



In January 1965, the TSh2B-32P was installed in the T-54B and T-55. The only difference between it and the TSh2B-32 is the new range scale for 3UBM8 APDS ammunition. The "P" in "TSh2B-32P" standns for "podkaliberniy", or "subcaliber", referring to APDS. Tanks that had the TSh2B-32 equipped were modified by swapping out the viewfinder glass disc with a new disc with the additional markings to transform them into the TSh2B-32P.





Besides the range scale for APDS rounds, there are no other differences.

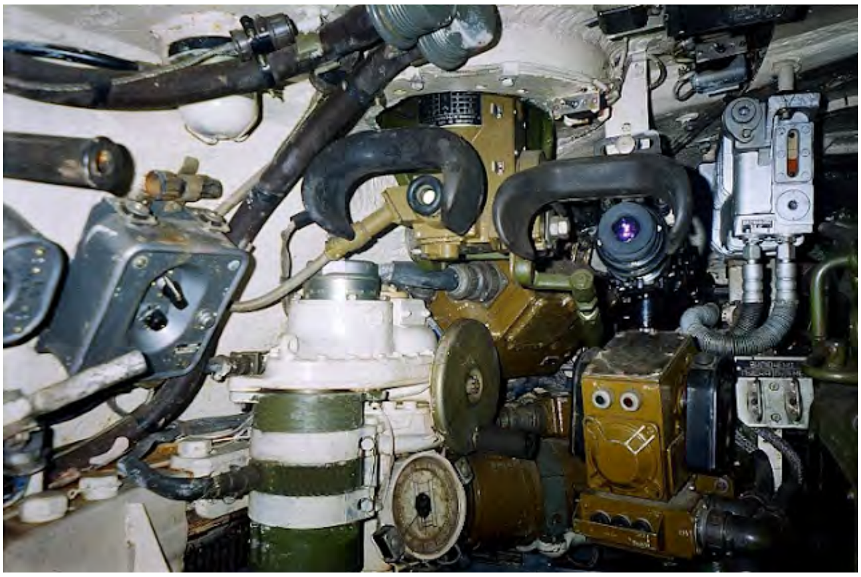
KDT-1

In 1974, many T-55A tanks still in active service were fitted with the new KDT-1 laser rangefinder. KDT-1 does not have a direct connection to the sight, nor is there a ballistic computer to interpret range data for the sight to process. The gunner is informed of the range via a digital readout installed in a corner. To apply the range data, he must utilize the range dial located on the underside of the sight.

T-55A tanks outfitted with KDT-1 retain the same designation. It is not known if the T-55 or if T-54 tanks were retrofitted with KDT-1, and if they were, the precise number of examples is not known. All T-54-style tanks equipped with KDT-1 display the T-55A loader's hatch with anti-aircraft machine gun, so it is likely that only T-55A tanks received the laser rangefinder.

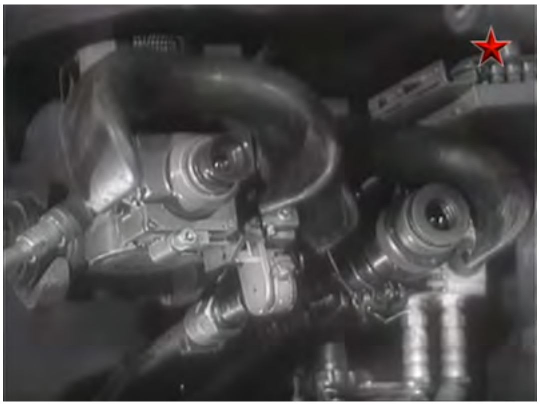
New handgrips were fitted. They are principally identical to the old KB-4 handgrips, but with a thumb trigger to fire off the laser rangefinder.

TPN-1-22-11

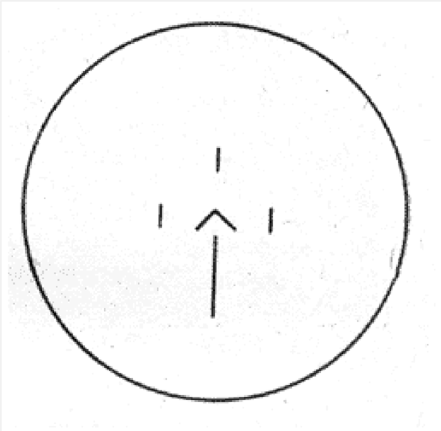


In the year 1957, the T-54 entered its tenth year of formal service in the Soviet Army and also the tenth year of its continuous evolution, becoming the T-54B. In that year, the T-54 became capable of night fighting with the installation of the TPN-1-22-11 active infrared imaging sight. Although not impressive by modern standards, the inclusion of a night vision sight on the T-54B together with a night vision TKN-1 optic for the commander gave it a distinct edge over the contemporary M48A2 which lacked any form of night vision sighting equipment whatsoever. Only the M60A1 from 1962 was equipped with a night vision sight (M32) and a night vision optic for the commander (M36).

TPN-1-22-11 can operate in either the active infrared imaging mode or the passive light intensification mode. In the active infrared imaging mode, the infrared light supplied by the L-2 "Luna" spotlight mounted co-axially to the main gun is visible through the sight, allowing the gunner to identify a tank-type target at a maximum distance of 750-800 m, which is very decent for night vision equipment from the 50's. The L-2 "Luna" spotlight uses a filament bulb and consumes only 200 W. This is very weak for a spotlight. In the passive mode, the sight employs a 1st Generation light intensifier tube to amplify ambient light, providing a nominal maximum identification distance of 400 m for a tank-type target under lighting conditions of no less than 0.005 lux.

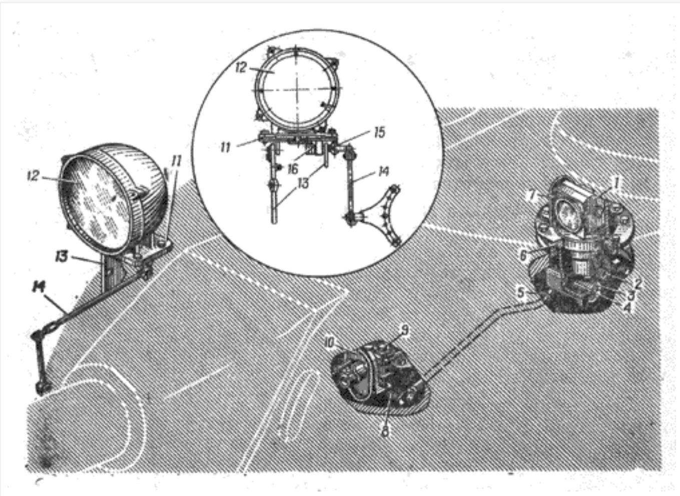


TPN-1-22-11 has fixed 5.5x magnification, and a narrow field of view of 6 degrees. The magnification is quite reasonable for a night vision device, as the IR sight for the Chieftain only had a 3x magnification. The viewfinder is extremely simple, as you can see below. The tip of the chevron is sighted for BR-412D AP rounds for a distance of 200 m, going down to 400 m at the upper tip of the vertical reticle line below the chevron. A more comprehensive adjustment system was not included as the short range of the TPN-1-22-11 night vision system limited engagement distances to 800 meters or less anyway.



The TPN-1-22-11 has an internal lightbulb to facilitate aiming at night. It is either on or off without the option of dimming, but it can be turned on in either the day mode or the night mode as the gunner wishes. It is preferable to remain in the day mode with an illuminated reticle when operating during sunset or twilight hours.

TPN-1-22-11 is similar to its telescopic counterpart in that it is not stabilized. It is only connected to the main gun by a mechanical linkage (see the drawing below). Disregarding its night vision capabilities, the sight is otherwise quite simple.



During the late 50's, nearly all T-54 obr. 1949 tanks (built and issued from 1949 to 1951) and T-54 obr. 1951 tanks (built and issued from 1952 to 1954) underwent a modernization program to improve its combat capabilities to the level of the T-54B, which was the latest iteration at the time. The technical details for the modernization of older tanks - excluding the troublesome obr. 1947 model - to the standard of the T-54B model was prepared simultaneously with the development of the T-54B itself, thus ensuring that a large part of the Soviet Army's T-54 fleet would be kept up to date at the highest available level of technology. One of the upgrades was the addition of night fighting capabilities via the installation of the TPN-1-22-11 night vision sight and the associated equipment, including the L-2 "Luna" spotlight and a new power supply system to handle the new equipment. The T-54-2 in the two photos below is an example of a tank modernized to T-54B standards. Note the counterweight at the muzzle of the cannon. This will be examined further in the article.

The addition of a night fighting capability to the vast majority of the T-54 tanks in the Soviet Army represented a significant tactical advantage, considering that the M60A1 was only being produced in relatively small numbers during the early 60's and the M48A2 modernization in 1956 did not grant the U.S Army's large fleet of M48 Patton tanks a night fighting capability. Even when the M48 gained a xenon spotlight and the M32 periscope in 1963 as part of the M48A3 upgrade, the T-54 retained an advantage because its night sight had a passive image intensifier mode that made it possible for the gunner to engage targets without turning on its infrared spotlight, whereas the enemy M48A3 and M60A1 tanks were forced to rely entirely on active IR or white light illumination.

The night vision equipment was tested in a British/Israeli assessment of the T-55, among other things. The full report is available in the Tanks and AFV News site. The relevant page of the report can be viewed here (link). According to the test, TPN-1-22-11 allowed the gunner to see:

Target	Distance (m)
Man	200
Topless Jeep	400
Chieftain (from behind)	400

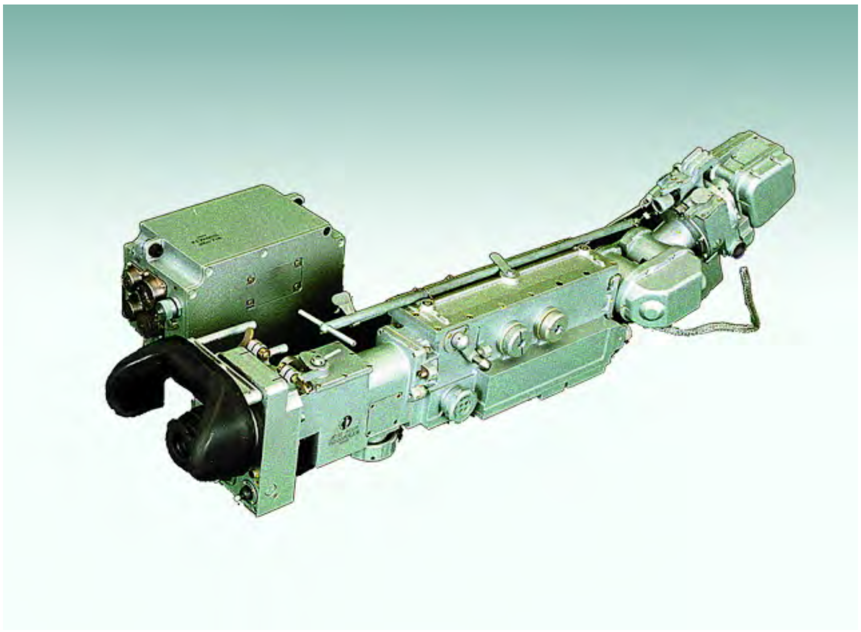
However, the report notes that the equipment was "suspect in nature" and that too much significance should not be attached to the results. This is possible evidence that the night vision equipment was downgraded for export. It is also possible that the sight was somehow damaged or defective. The problem does not lie in insufficient illumination (200 W spotlight), as the TPN-1-22-11 was also tested using the Chieftain's 2 kW infrared spotlight, but this only marginally improved the maximum identification distance to 500 meters when used to identify a Chieftain target tank.

Another explanation is that the TPN-1-22-11 has lackluster performance simply because it is older than whatever the Chieftain uses by almost a decade, but then, why did the report mention that the equipment was "suspect in nature"?

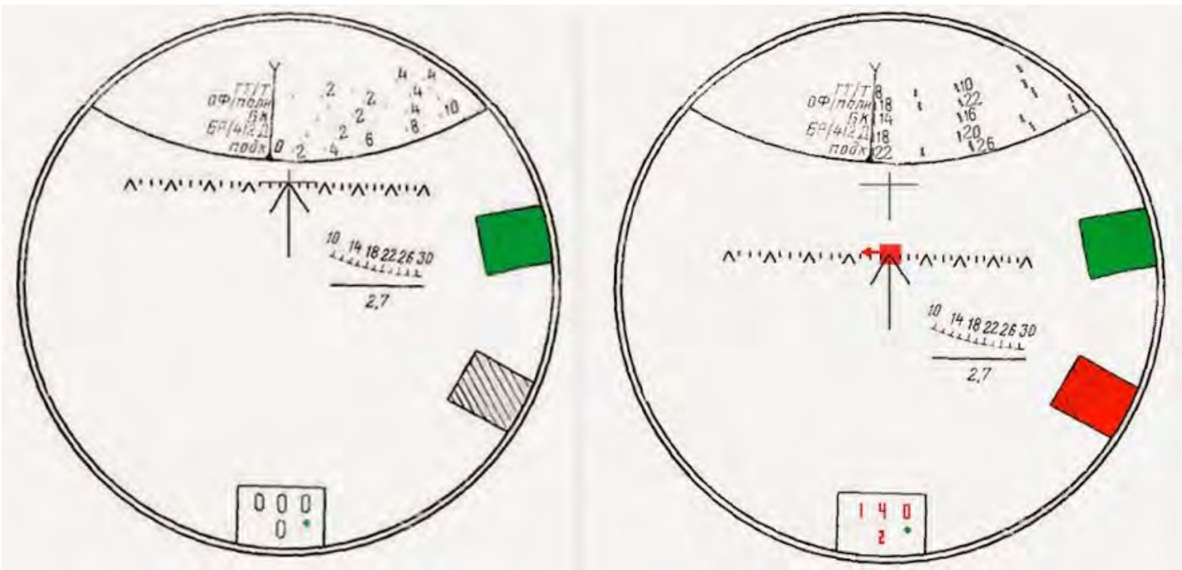
Volna Fire Control System

The T-55AM deep modernization programme of 1983 involved a total overhaul of the fire control system as well as a base overhaul of the engine and other essential components.

TShSM-32PV



Introduced as a complement to the Volna fire control system, TShSM-32PV is substantially more advanced than the previous telescopic sights used in the T-54 series. TShSM-32PV features a viewfinder that is very similar to the TPD-K1 in layout, especially with the removal of the range scales and its substitution with a more space efficient dial-type range indicator at the top.



The magnification of TShSM-32PV is practically identical to its predecessors; either 3.5x power magnification or 6.9x. The sight offers a field of view of 18 degrees in the low magnification setting and 9 degrees in the high magnification setting. The sight is independently stabilized in the vertical plane with a maximum accuracy of 0.3 mils, which is quite good. At 1000 m, the sight will have a maximum deviation of 0.3 meters from the point of aim.

Now that the sight is linked to an analogue ballistic computer, additional features had to be implemented in order to add more functionality. An LED tab at the bottom of the viewfinder displays the ammunition type and the range. The range dial at the top of the viewfinder spins (different dial rings spin at different rates via a differential mechanism) to display the range equivalent for different types of ammunition. In the right hand side drawing of the viewfinder above, you can see that the number "140" displayed in the range display tab, and the range dial for BK (HEAT ammunition) set to "14". This means that the target is 1400 meters away, and HEAT is selected. Switching the ammunition type will reset the range dial accordingly.

The same reticle design was retained in the TShSM-32PV, as was the method of gun laying. Once the range was automatically inputted into the sight via the BV-55 ballistic computer, the reticle drops a certain amount. The gunner must then manually raise the reticle and lay it on target. This is not as convenient as having the cannon raise automatically while the reticle remains static, as was the usual in digitized Western FCS appearing in the late 70's and early 80's.

1K13-2

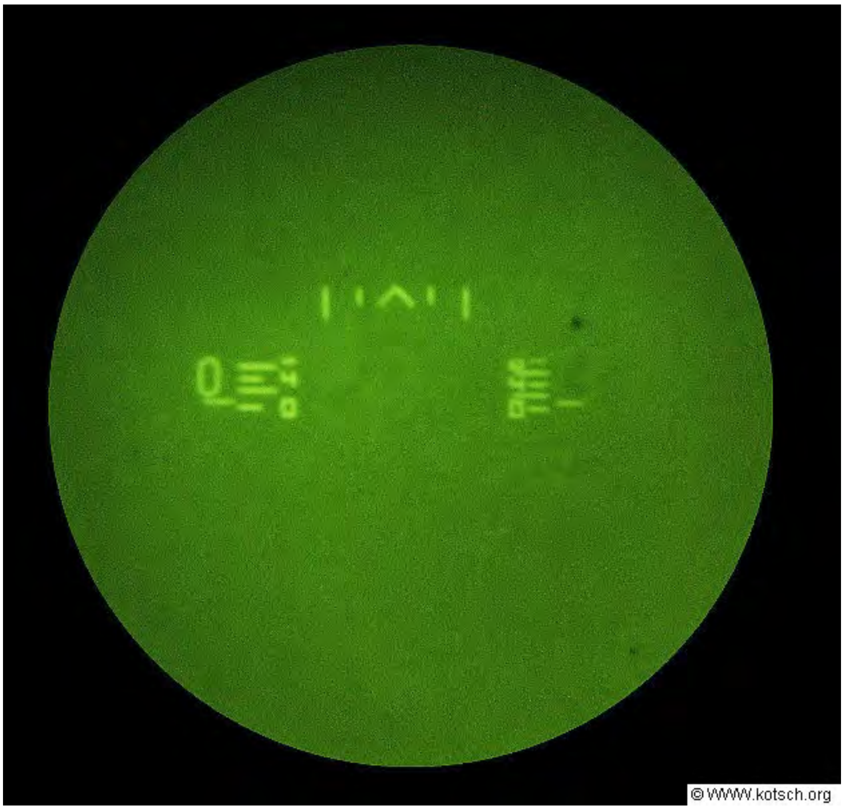
By outfitting the T-55 with the 1K13-2 sight, the tank instantly gained a missile-firing capability. 1K13-2 is significantly TPN-1-22-11 in target engagements capabilities; With a fixed 8x magnification in the daytime channel and 5.5x magnification in the nighttime channel, its effectiveness as a long range daytime observation device rose slightly above the gunner's main telescopic sight, but because 1K13-2 is not integrated with the Volna FCS, its usefulness for long range fire is limited somewhat.

The sight has a field of view of 5 degrees in the daylight setting or 6°4' in the nighttime setting. It is independently stabilized in the vertical plane, with +20° elevation -7° depression.

Daytime mode

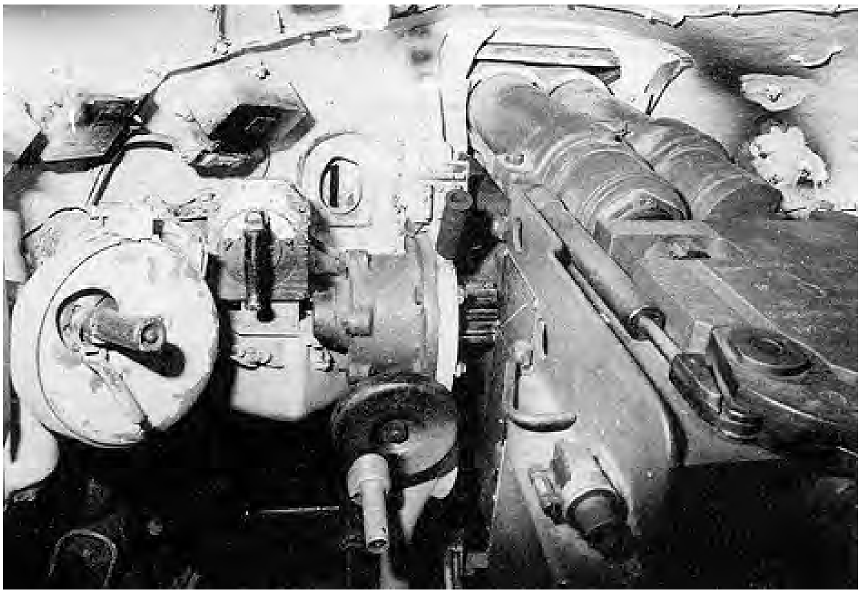
The sight's active infrared imaging system is slightly improved over the TPN-1-22-11. Now, the viewing range in the active mode is increased to 1200 m, though the light intensification unit has not been improved, meaning that the 1K13-2 sight still has a viewing distance of only 800 m under ambient lighting conditions of no less than 0.005 lux. The identification distance and image clarity improves with increasingly brighter lighting conditions, but excessive brightness can oversaturate the image, and overwhelming brightness can overload and possibly damage the sight.

In accordance with the extended viewing distance in the active infrared mode, the sight is now equipped to adjust the superelevation of the reticle, just like the telescopic sights described before. This is to enhance firing accuracy at ranges above the reasonable range of distances for battlesighting.



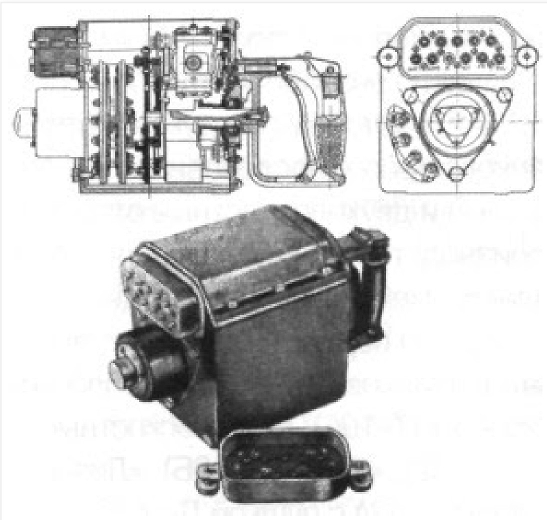
1K13-2 viewfinder in the passive light amplification mode, aimed at nothing in particular (Photo credit: Stefan Kotsch)

POWER TRAVERSE, STABILIZERS



The original production T-54 did not have gun stabilization. The T-54-1 used the EPB-1 electromechanical turret rotation drive, also used in the IS-4 heavy tank. Later on, the 1951 model used the improved EPB-4 instead. Both had the same performance, differing only in small details. Both were precise enough that it was possible to conduct final gun laying at short distances without using the manual handwheels, but it was still not very precise, and quite underpowered to boot. EPB-4 enabled the turret to turn at a minimum speed of 0.1 degrees per second, and at a maximum speed of only 10 degrees per second. Unlike the power traverse scheme on earlier tanks like the T-34-85, the turret will not continue rotating after the cessation of gunner input due to inertia, as an electric brake was installed. The electric brake will activate to reduce the speed of the turret or stop it whenever the gunner changes the degree of twist applied on the handgrips.

Control of turret rotation is done with the KB-3A control unit (for the EPB-1), and later on the KB-4 (for the EPB-4), both of which took the form of a spade grip with a bakelite paddle. The gunner squeezes the paddle and turns the grip clockwise or counter-clockwise to turn the turret to the right or left respectively. The control unit is essentially a rotary rheostat that registered the angle of deflection of the spade grip and transmitted a signal to an amplidyne amplifier. The amplidyne amplifier would then generate a high voltage proportional to the angle of deflection of the spade grip to power the turret traverse motor, which would then spin the turret at the desired speed. The KB-3A or KB-4 control unit is located at midriff level of the gunner, close to the gun elevation drive which is just next to the cannon. The gunner's left hand will be on the traverse control grip and his right hand will adjust the elevation of the cannon. A manual turret traverse handwheel is located on the turret ring next to the power traverse control. The triggers for firing the cannon and the coaxial machine gun are both on the elevation handwheel handle. Overall, the layout of the gunner's controls is quite rational and is ergonomic enough that prolonged use is not fatiguing to the gunner, which cannot be said for the layout of the gunner's controls in some other tanks. The most major drawback to the system is the lack of powered gun elevation, forcing the gunner to conduct gun elevation manually via the gun elevation handwheel. Despite the ease of using the manual gun elevation drive, this still meant that gun laying was slower than in tanks like the M47 and Centurion Mk.3, but did not mean that it was inaccurate as manual gun elevation was still the most precise method of gun laying available in any tank at the time. To switch from powered traverse to manual traverse, the powered traverse drive clutch had to be disengaged and the manual drive clutch had to be engaged.



However, this system had a multitude of deficiencies. It took some time for the motor to accelerate, so there is a slight lag when rotating the turret. Secondly, the minimum turret rotation speed of 0.1 degrees is insufficiently accurate for long range engagements. 0.1 degrees is equivalent to 1.778 mils, which means that at 1,000 meters, the maximum horizontal deviation of the gun may be as high as 1.778 meters. At ranges greater than one kilometer, final gun laying using the manual traverse drive is desirable for maximum accuracy, but the time needed to engage a target at long range is extended as a consequence. Thirdly, EPB-4 consumed a lot of power and put extra high loads on the engine and batteries. It would not be possible for a T-54 obr. 1951 to operate at full capacity on battery power with its engine off.

STP-1 "Gorizont"

Introduced on the T-54A which arrived in 1954, the STP-1 stabilizer complex for the D-10TG made the T-54 the second postwar tank to receive a gun stabilizer, albeit without full two-plane stabilization. The Centurion Mk. 3 was the first, featuring an advanced two-plane stabilization system in 1948. As mentioned before, both the primary and night sights piggyback on the cannon to benefit from the stabilization system.

The history of STP-1 dates back to research and testing efforts beginning in 1947. In accordance with a government resolution passed on the 19th of April of that year, the responsibility for the design and implementation of a stabilizer system for the then-brand new T-54 tank was assigned to Factory no.707 of the Ministry of Shipbuilding Industry, but by the end of 1948, it turned out that the factory could not fulfill this task. Renewed efforts in 1949 by TSNII of the Ministry of Armaments under the leadership of Vasiliy Grabin (designer of the ZiS-3) led to the creation of two prototypes, S-88S and S-84SA. These were single-plane (vertical plane) stabilizers. Testing on T-54 tanks was began in July 1952 and wrapped up in February 1953. Parallel work carried out by the TSNIIAG Factory no.9 in accordance with a new government resolution passed on the 29th of March, 1952, produced a single-plane (vertical) stabilizer, which was installed in three experimental T-54 tanks. These tanks underwent acceptance tests in August of that year and underwent field testing in September.

In the summer of 1954, Factory no.183 in Kharkov produced three T-54 tanks with new two-plane stabilizers from both TSNII and TSNIIAG revealed that the two-plane stabilizer improved the chance of a hit on the first shot was higher by 2 times and the overall practical rate of fire rose by 1.5 times. However, TSNII dropped out of the tank stabilizer race in 1954 due to reassignment, and TSNIIAG became the sole producer of tank stabilizers. However, issues with mass production meant that the advanced two-plane stabilizer could not be implemented on a large scale, and a stabilizer system was badly needed by the T-54 in order for it to remain competitive against the latest Western tanks like the Centurion. As a result, the less advanced but more readily available single-plane system, now developed into the STP-1, entered mass production in 1954 as a stopgap measure.

The stabilizer system is composed of multiple elements working in concert, but the focal point of our attention is the electric gun elevation control system. With a minimum elevation speed of 0.07 degrees per second, the maximum deviation is 1.24 meters at 1,000 m. The maximum elevation speed is 4.5 degrees per second.

STP-1 included the new TAEN-3 electromechanical turret rotation drive, but did not include horizontal stabilization. A new EMU-5PM amplidyne amplifier was implemented, which solved the problem of excessively high power consumption. The TAEN-3 electric drive for turret traverse is located above the manual traverse handwheel. The electric motor is mounted horizontally, as opposed to the vertical mounting of the electric motor seen in the STP-2, which we will examine later. The TAEN-3 motor is quite small.

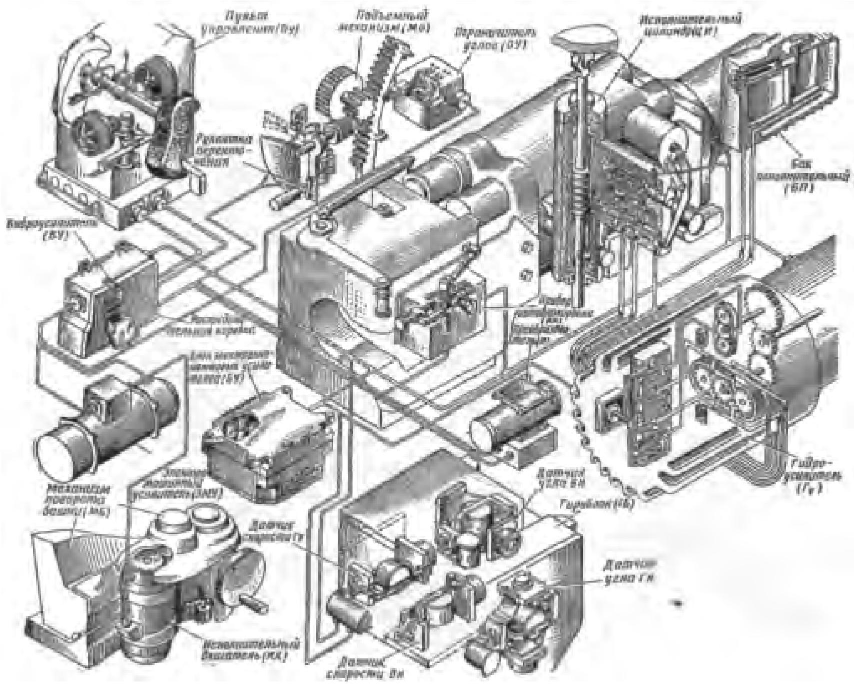
TAEN-3 was highly underpowered, as it only allowed the turret to turn at a painfully slow maximum speed of 10 degrees per second. The gun lacked horizontal stabilization, meaning that firing on the move could only be done if the tank was travelling in a straight line. The handgrip controllers were updated to the KB-4, pictured below. KB-4 is colloquially known as "Cheburashka", in reference to the large ears of the beloved Russian cartoon mouse. Having a single controller with a pair of handgrips to control the orientation of the tank turret and gun is objectively superior to a separated layout like on the Centurion Mk.5 from an ergonomic point of view.

Modernized versions of the tank like the T-54A, T-54B, T-55, the T-62 and even the BMP-1, all used the basic design of this controller in some form or another. along with the fire control systems of many other military vehicles.

STP-1 was decent enough, but partially by virtue of its presence alone. After all, stabilization is better than no stabilization. Various useful safety features were also implemented, including a safety device to keep the cannon under control as the tank hurdles over undulating terrain, so as to prevent the cannon from wildly swinging up and down and potentially damaging itself as well as anybody close by. A feedback system was also installed. By monitoring the load on the stabilizer motor, the stabilization system can detect if the cannon is being pushed up or down by an external force. The stabilization system will then depress or elevate the cannon in the opposite direction until the extraneous load is removed. This prevented the cannon from digging into hard objects like large rocks and concrete walls when the stabilizer was turned on.

STP-2 "Tsyklon"

The STP-2 stabilizer was introduced in the T-54B for the D-10T2S gun. STP-2 featured a new, more powerful electric turret drive and featured stabilization in the horizontal plane, which is an big improvement over the STP-1. Small batches of T-54B tanks were built in 1955 and 1956 for field trials and troubleshooting, and the tank officially entered service in 1956. Mass production of the T-54B with its new "Tsyklon" stabilizer began in 1957.



If you happen to be inside a T-54B or a T-55, it may be useful to know that the STP-2 can be distinguished from the STP-1 by the vertically placed electric motor on the turret ring, next to the manual turret traverse handwheel.

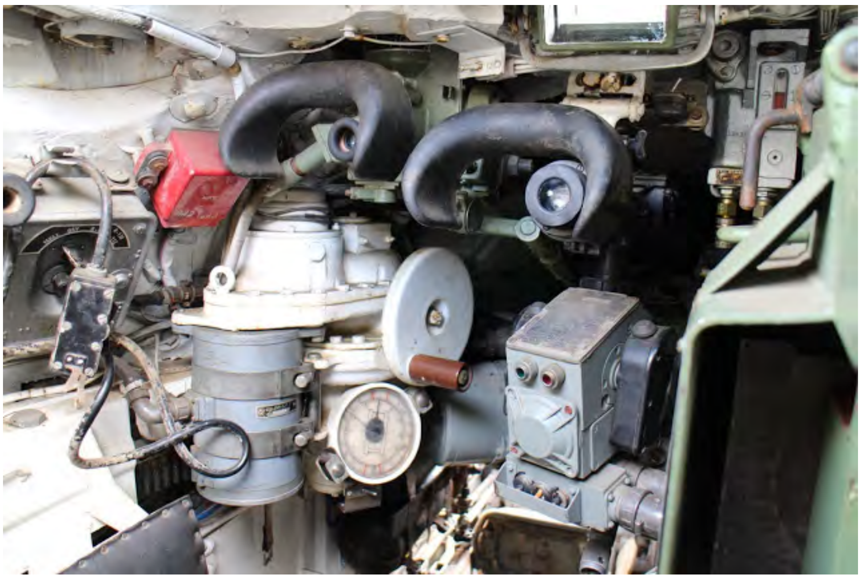
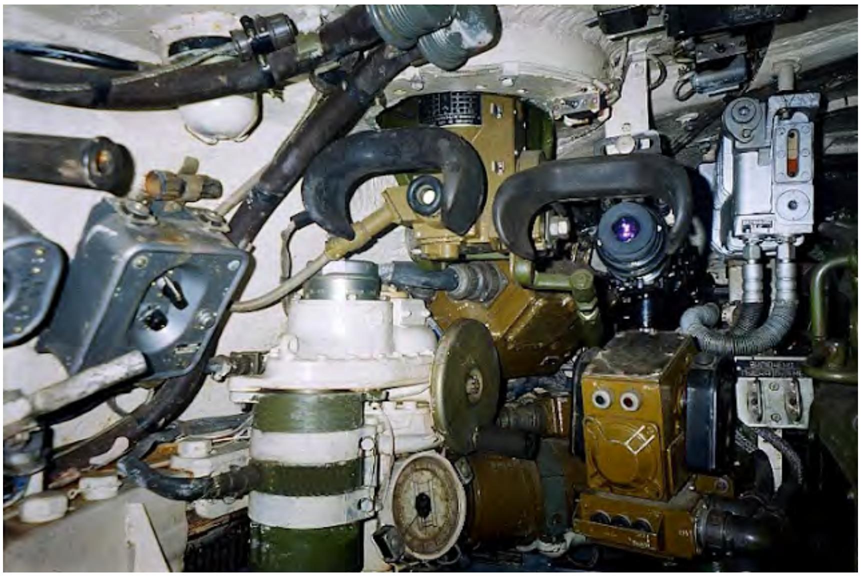


Photo credit belongs to Jim Chandler of the Warwickshire Armour Modellers

The turret traverse motor can be seen again in the photo below. It is the green cylinder in the same position as before.

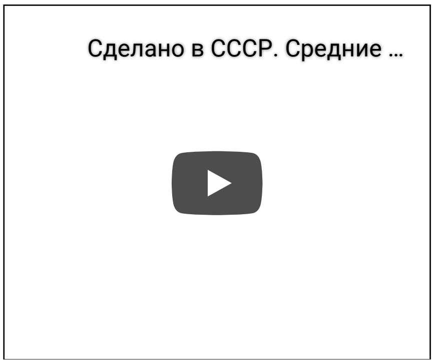


The vertical stabilization system was carried over from the STP-1, but with some differences. Components such as the gyrostabilizer box, amplidyne amplifier and the mounting system for the electronics were modified and rearranged.

Unfortunately, powered traverse was still quite slow even with the improved turret drive, which was not very powerful compared to the hydraulic systems being used in Patton tanks at that time. According to a T-55 manual, the turret could spin at 15 degrees per second, meaning that it would take 24 seconds to complete a full rotation. This is marginally faster than the Centurion Mk. 7, which took 25 seconds to complete a full 360 degrees, but the M47 tank (no stabilizer) was faster by 14 seconds. A U.S Armor School document on the T-54B claims that the turret could complete a full rotation in 21 seconds.

The slow turret traverse speed can be lethal for the tank if it is caught in an ambush, as the crew will not be able to react quickly enough. On the upside, the lack of flammable hydraulic fluid being circulated inside the turret was beneficial towards the survival of the crew and the tank as a whole if it was hit. Moreover, the slow turret traverse speed of Israeli Sh'ot tanks during its service in various conflicts (most notably the Yom Kippur war) did not seem to be a serious detriment, as it - apparently - cut down hordes of Syrian and Egyptian tanks like wheat from a field.

The slow traverse speed can also be a handicap when the tank is neutral steering (turning on the spot) or zigzagging at a low speed, because the hull can turn faster than the turret. If this happens, the turret might not be able to catch up, making it jerky, as you can see in the video below (skip to 5:42).



The minimum speed of both gun elevation and turret traverse is 0.07 degrees per second, equating to a maximum deviation of 1.24 mils at 1000 m. The maximum speed of gun elevation is 4.5 degrees per second. The vertical stabilizer is designed to suspend turret traverse and lift the cannon by about 3 degrees immediately after firing in order to improve loader access to the breech. This is part of the loader's assist function of the stabilizer designed to ensure that the loader can load the cannon quickly and safely using ammunition from the hull. The side effect is that the gunner's primary and secondary sights will follow, thus making it impossible for the gunner to observe the effect on the target. If the gunner wishes to maintain visual contact with the target, he can request the loader to turns off the loader's assist function of the stabilizer by pressing the loader's safety button. This returns full control to the gunner but disables the safety systems built into the D-10T2S that prevent it from firing electrically or mechanically, so the gunner must take more care to ensure that his finger is off the trigger while the gunner is loading.

A captured T-55 tested by the Israelis in 1969 yielded interesting results. The T-55 was tested on a flat sandy track at a steady speed of 15 km/h. Out of 35 shots, only 3 hit the target - a success rate of only 8.5%. This is better than the quoted value of "3% and below", but still extremely poor. Photos of the report are available on tankandafvnews. The relevant pages are Page 52 (photo), Page 53 (photo), Page 54 (photo).

The report mentions that STP-2 is only suitable for stabilizing the gunner's line of sight, not firing on the move. The poor performance of STP-2 is most likely due to the lack of range data, but the chassis itself definitely has an impact as well. The low energy dampening characteristics of the suspension meant that vibrations were transmitted to the chassis more readily. This translated to minute oscillations of the gun barrel, accelerated wearing of the stabilizer itself, and the oscillations were too small to be compensated by the stabilizer, thus degrading firing accuracy.

A more optimistic reviewer might suggest that the stabilizer in this case was not maintained properly, was subjected to extended periods of exposure to the extreme heat inside the tank as it baked under the hot desert sun (and cycled unhealthily between extreme heat and extreme cold). Combined with the high probability that the Arab handlers of these T-55s might not have the required specialist skills to maintain the sensitive stabilizer system, and we have a decrepit, worn-out device that cannot be expected to work at peak condition. I would not, however, go so far as to say that the stabilizer system was one of the components of the tank that was deliberately downgraded for export.

The test results can be found here (Link).

Six of the targets presented a broadside profile (side profile), two of the targets presented a head-on profile, and two of the targets presented an oblique broadside profile (angled profile). All of the targets were paper targets. The visible height of the target ranged from 1.45 meters to 2.45 meters, which would be representative of an average Soviet tank, but not a Western one; the Centurion is 3.01 meters tall, the M48 is 3.10 meters tall, and the M47 is an astonishing 3.35 meters tall.

At target distances averaging 1200 m with outlying targets at the unusually short distance of 600 m and the unusually long distance of 2140 m, the ratio of the number of hits to the number of rounds fired was obtained. The results are listed below:

Crew	Phase	Number of Targets Engaged	Number of Rounds Fired	Hits
A	1	5	12	2
A	2	5	11	4
B	1	5	12	3
B	2	5	11	3

This test was not to determined the accuracy of the gun and fire control system, unlike the test of the Centurion detailed above. This test was a simulation, with unknown and unexpected target positions, unknown distances to these targets, and so on. Another factor to consider is that these tests were held in the same extremely dusty conditions that so badly affected the crew's ability to sense the point of impact of shots. Without a doubt, this contributed to the inability of the crew to correct their fire and score hits. In fact, if we scan the details of each shot as analysed and listed in the report, we can see that literally all of the misses (including the ones involving incorrect horizontal lay) either went high or low. Therefore, the gun was almost always laid correctly on the target (credit to the horizontal stabilizer system of STP-2). The only issue was the ability of the crew to ascertain the range to the target and obtain a ballistic solution.

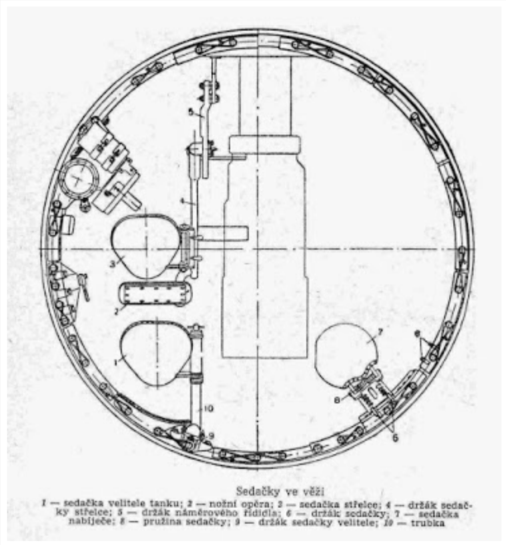
Out of 12 shots in phase A1, there was only one shot where the shell was off target in the horizontal plane. In phase A2, out of 11 shots, there was, again, only one shot where the shell was off target in the horizontal plane. In phase B1, out of 12 shots, we have two shots off target in the horizontal plane. In phase B2, out of 11 shots, we have one shot off target in the horizontal plane. All of the misses were due to the shot going high or low. It is very likely that in less dusty conditions, the T-55 could achieve much, much better accuracy. On a related note, the exclusive use of APDS ammunition for anti-tank purposes in the Centurion MK. 3 greatly contributed to good accuracy at all ranges, as the high velocity of APDS shells partially negated ranging errors.

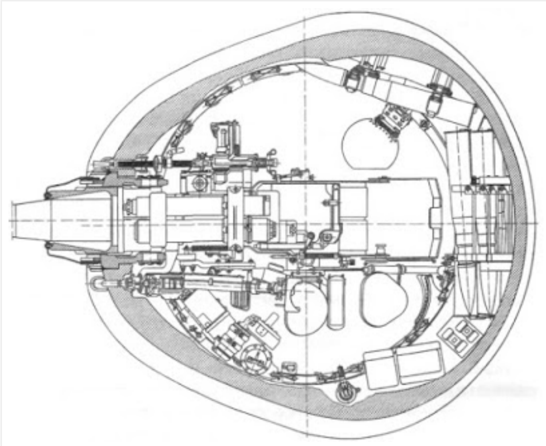
From a statistics standpoint, relying on this report to generalize the performance of all T-55 tanks in all conditions will be erroneous. Therefore, I ask the reader not to take any of this data at face value. This test cannot be used to represent the majority of T-55 tanks in real battle, and certainly not T-55 tanks in Europe, where environmental conditions are very different. Take this little analysis as supplementary knowledge.

D-10T

D-10T had a larger caliber than any other tank gun fielded on a medium tank at the time of the T-54's introduction, and it was a very modern weapon then. However, it was slow to receive advanced features that were common on Western tanks like fume extractors, and the barrel of the cannon was not of a quick-change design like the M3 90mm gun. The lack of a fume extractor was especially hard on the crew, as the stick propellant used in the ammunition was rather smoky. Efforts to design and install a fume extractor were combined with the ongoing STP-1 stabilization project in the mid 50's, resulting in the D-10TG stabilized cannon with a fume extractor located at the very end of the barrel. This cannon was used by the T-54A. Later on, the cannon was adapted to the "Tsyklon" dual-axis stabilization system, changing the designation to D-10T2S. The spring-loaded loading tray featured on the 85mm ZiS-S-53 cannon of the T-34-85 was not implemented on the D-10T.

The cannon mount is slightly offset to the right of the cannon. The large breech assembly occupies a lot of space in the turret, and the offset appears to be intended to increase the working space for the commander and gunner as a significant amount of space is occupied by the equipment installed on the turret wall.





As mentioned before in this article in the section examining the TPN-1-22-11 night vision sight, nearly all T-54 obr. 1949 tanks (built and issued from 1949 to 1951) and T-54 obr. 1951 tanks (built and issued from 1952 to 1954) underwent a modernization program during the late 1950's to improve its combat capabilities to the level of the T-54B, which was the latest iteration at the time. However, the modernized tanks were not to be fitted with a fume extractor which was standard for the D-10TG and D-10T2S. Instead, a counterweight was added to the end of the barrel to simulate the load of a fume extractor to balance the cannon properly for the stabilizer to function. These unusual guns, adapted for the STP-2 "Tsyklon" but with a counterweight in lieu of a fume extractor, were designated D-10T2. The two photos below show two different T-54 models both upgraded to the standard of the T-54B. The photo on top shows a T-54 obr. 1951 and the photo on the bottom shows a T-54 obr. 1949.

The rationale behind the decision to use a counterweight instead of simply retrofitting a fume extractor to the gun barrels of modernized tanks is unclear. There is no conceivable advantage whatsoever in omitting a fume extractor or than perhaps expediency. Nevertheless, the widespread implementation of fully stabilized guns and the addition of a night fighting capability was not a trivial matter. The increase in overall combat capabilities was a large boost for the vast tank fleet of the Soviet Army.

The production of D-10T, D-10TG and D-10T2S guns at the No.9 plant in Sverdlovsk and the No.172 plant in Perm is documented in the table below.

Производство 100-мм танковых пушек Д-10Т в 1947–1957 гг.

№ завода	Тип пушки	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957
№ 9 Свердловск	Д-10Т	20	-	-	-	814	925	900	1000	300	-	16
	Д-10ТГ	-	-	-	-	-	-	-	-	935	1754	840
	Д-10-Т2С	-	-	-	-	-	-	-	-	-	15	1190
№ 172 Пермь	Д-10Т	580	600	500	250	981	1000	1000	1300	-	10	-
	Д-10ТГ	-	-	-	-	-	-	-	-	1167	100	-

Примечание: *В армейских документах у нас всегда не было порядка, и в индексах тире ставят, кто во что горазд. Часто в служебных документах встречается не Д-10Т2С, а Д10-Т2С.*

All of the guns have a gun elevation and depression limit of +18 to -5 degrees respectively. The maximum chamber pressure of all D-10T models is 289 MPa. It is directly equivalent to the M3A1 90mm and 20. pdr (84mm) cannons in that respect, but due to the longer barrel, large ammunition (100mm D-10T cases are 88mm longer than 105mm L7 cases) and large caliber, D-10T could be considered to be in a league of its own. By the late 50's, advances in cannon technology allowed the improved M36 90mm and L7 cannons to compete directly with the D-10T by using better ammunition with hotter loads.

The D-10T weighs a total of 1,950 kg in its base form, including the gun cradle and armoured gun mask. The D-10T together with the gun cradle weighs only 1,438 kg. For comparison, the 105mm M68 weighs only 1,122 kg and the 105mm L7 weighs 1,282 kg, but these figures ignore the weight of the gun cradle. On the M60A1, the M68 together with its gun cradle weighs 1,410 kg and the combined weight of the entire cannon assembly with the gun mantlet weighs 3,260 kg. On the Leopard 1, the L7A3 with the gun cradle and gun mantlet weighs 2,900 kg. From this, it can be seen that the decision to abandon a turret design with a gun mantlet as on the T-54 obr. 1947 in favour of a much more compact gun mask led to a large reduction in the mass of the cannon assembly and thus reduced the work needed to elevate or depress the cannon.

Weight aside, however, the D-10T could be considered on par with the L7 in terms of muzzle energy. An L28 APDS projectile weighing 5.8 kg (sabot plus subcaliber projectile) coming out of the muzzle at 1470 m/s is only slightly more powerful than 3BM8 APDS, which has a projectile weighing 5.7 kg (incl. sabot) flying at 1415 m/s at the muzzle. Generally speaking, both guns were quite similar but differed in ammunition technology. Western cartridges were generally more advanced, being smaller and lighter but packed with propellant with a higher energy density.

On a related note, the Israeli Defence Forces (IDF) incorporated hundreds of captured T-54 into their arsenal as Tiran tanks, and although some Tiran tanks retained the D-10T, most were refitted with the 105mm L7, which was not a small project. The breech had to be flipped 180 degrees and the recoiling mechanism had to be rearranged in order to enable loading from the left. The decision to mount the L7 had many justifications. For one, Israel did not produce Soviet 100mm ammunition; Secondly, production of the L7 and 105mm ammunition was already established; Thirdly, the L7 was more compact than the D-10T, freeing up valuable space inside the cramped tank. All this, plus the lighter ammunition for the L7 made the loader's job noticeably easier. All of the Tiran 4 and Tiran 5 tanks operated in combat ready units by the IDF were refitted with the L7. The T-54s that were not fitted with an L7 were were sent to Lebanon as military aid.

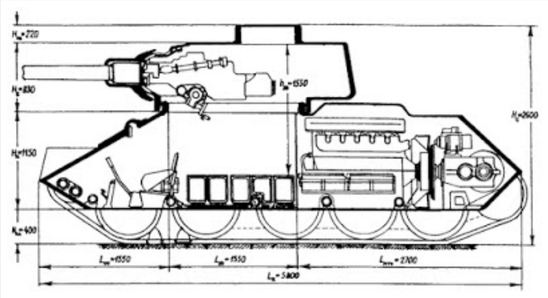
To replace the barrel, it is necessary to lift the turret off the turret ring and pull the entire cannon assembly out the back. The turret is designed to tilt forward and stay propped open to make this easier to do in the field, but it is still by no means a quick procedure.

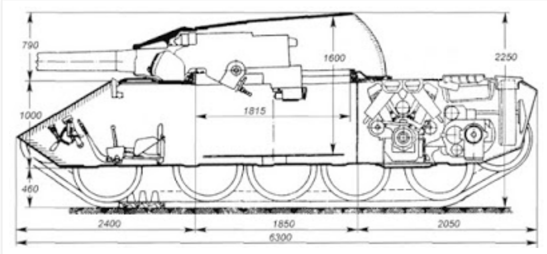
Here's a scene of this procedure being carried out in the field. The cannon is being lifted by an engineering vehicle.

The D-10T was quite well known in the West, though not necessarily as a tank gun for the T-54. Rather, it was studied as a component of the familiar SU-100 in the form of the D-10S, and it was represented indirectly by the BS-3, a towed 100mm rifled cannon that fired the same ammunition. Captured SU-100 tank destroyers and the D-10S cannons they wielded were trialed in the UK. The results are available in the ammunition section of this article. As a direct result of tests of the D-10S conducted in the UK, it was decided to upgrade the upper glacis armour of next production Centurions to a 127mm plate from the original 76mm. This modification was later formally accepted as the Centurion MK. 8/1, and the earlier MK.5 and MK. 7 were later upgraded with a 44mm weld-on applique armour plate. Imagine the seriousness of the threat, that the original 76mm upper glacis of the Centurion was so inadequate that the thickness needed to be boosted by 67%! Around the time the Centurion was upgraded with a thicker hide, HEAT ammunition arrived, making the added armour partly redundant. Suffice to say, the D-10T was an excellent multipurpose tank gun.

LOADER'S STATION

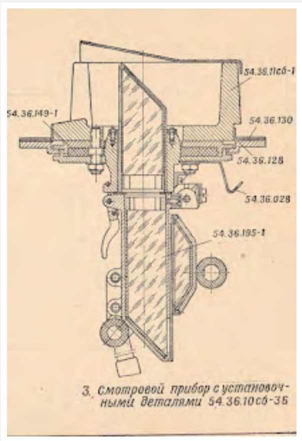
The T-54 is rather short compared to the T-34, so it is quite surprising that the actual available vertical space inside the T-54 is actually quite similar to its predecessor. Measuring from floor to turret ceiling, the fighting compartment of a T-34-85 was 1.56 meters in height, or 1.585 meters, or 1.55 m, depending on the source. The T-54, on the other hand, had a maximum internal height of 1.6 meters, even though the T-54 is 2.32 meters tall while the T-34-85 is 2.7 meters tall. This wizardry was only possible because a large part of the floor of the T-34-85 is taken up by an ammunition box which stows the majority of the tank's ammunition supply. Being tall enough to stow 85mm shells three rounds deep, the box takes up a considerable portion of the tank's available vertical space. As the floor of a T-54 only needed to accommodate the torsion bars and the false floor, it could have the same internal height as the taller T-34-85. The length and width of the loader's station in the T-54 was also improved over the T-34-85 thanks to the wider turret ring, although any improvement in loading speed were probably cancelled out by the much larger bulk and weight of the 100mm rounds.





The requirement for at least 1.6 meters of vertical space was not arbitrary. According to an article published in the April 2004 issue of the "*Tekhnika i Vooruzhenie*" magazine titled "*Основы теории и история развития компоновки танка*" (*Fundamentals of the Theory and History of the Development of Tank Layouts*) by Vasily Chobitok, the height of the loader's station should be between 1.6-1.7 m tall and 0.5 m wide with a space of 1 cubic meter to accommodate the loader.

The commander and gunner can sit down with a reasonably comfortable allotment of headroom, but 1.6 meters is not nearly enough to let a man of average height stand upright, even with the infamous practice of choosing smaller servicemen for tank crews. According to "Foundations of Design of Armament for Self Propelled Guns and Tanks", the average height of a man is stated to be 1.7 meters, so a loader of average height would have to conduct his duties from a seated or half-standing position. As the loader's protruding cupola breaks the turret's sloping profile, he has room to stand a little straighter directly when he is directly underneath the hatch, which, conveniently, is where he needs to be in order to ram rounds into it, but otherwise, the turret is far too low to allow the loader to work with a straightened back. The low ceiling at the front part of the turret is not a problem, as there is no ammunition there that is stored above waist level at the front of the turret. The loader's seat can be unhooked from the turret and relocated to a new position near the rear of the turret, so there are two possible seated positions from which the loader can perform his duties. As usual, the seat can be folded up and out of the way for the loader to stand and move around freely in his station, but the seat can also be unhooked and stowed away for extra space. There are two fire extinguishers at the rear of the turret, directly underneath one of the possible positions for the loader's seat. The loader is also furnished with an MK-4 periscope for general visibility. The periscope is installed in front of the loader's hatch and its aperture window is surrounded by an armoured collar that is a part of its rotating mount.



The loader is drilled to return to the MK.4 periscope immediately after loading and readying the cannon to help observe the fall of every shot and help search for targets until he is called to load another round by the commander. However, in practice, if the loader is not servicing the cannon, he is either getting another cartridge ready or rearranging the ammunition into the ready racks. The periscope is marginally useful when under threat of imminent contact with the enemy as it grants the tank an extra pair of eyes, but attempting to use a non-magnified periscope to help spot targets is usually a waste of time. The greatest value of the periscope is in the psychological benefit of giving the loader a sense of his surroundings. The extra lighting may be helpful as well, since the loader's station has only one dome light.

When an IR night sight was installed beginning in 1957, the addition of an IR spotlight on the starboard side of the turret above the coaxial machine gun port had the unfortunate side effect of blocking the loader's view in the 12 o'clock sector. As such, the loader's view was restricted to the right side of the turret only, which limits his ability to assist in finding targets and completely prevents him from observing the fall of shots. However, granting forward vision to the loader is often considered superfluous given that both the gunner and commander would be looking forward and observing the target anyway. As such, the loader would be more helpful if he was focused on scanning the right side of the turret instead.

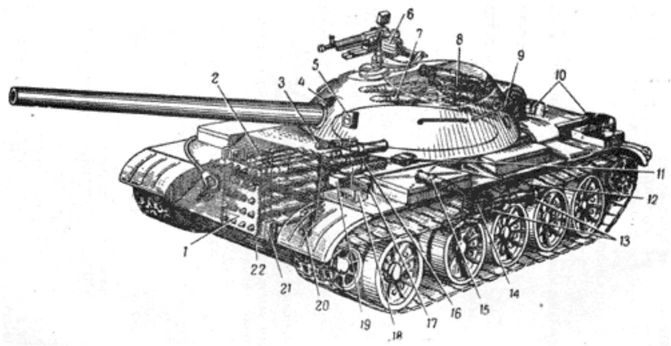
AMMUNITION STOWAGE

The T-54 generally had a relatively small ammunition capacity, but not all T-54 models carry the same load of ammunition. All T-54 variants created between 1947 and 1958 could only carry a measly 34 rounds - nearly half that of tanks like the M46 and the Centurion. To be fair, this was compensated by the significantly higher explosive and anti-armour performance of each 100mm shell compared to a 90mm or an 84mm one, but only to a certain extent. By having fewer rounds at their disposal, a T-54 crew must be more mindful of ammunition expenditure as the probability of obtaining a direct hit was low due to the simple fire control system and the lack of high velocity ammunition such as APDS or APFSDS.

Unlike American and British tanks and post-war German tanks, the loader in the T-54 is situated on the right side of the turret, to the right of the gun. Because of this, he loads with his left hand and not his right hand, which is the dominant side for 90% of the world's population. This has been criticized as an ergonomic failing point as it is thought that this would tire out loaders at a quicker rate, but contrary to this perception, it was never noted to be an issue during combat or during field exercises in the T-54, or in other tanks with left-handed loading including WWII-era German tanks. It is possible that the lack of any quantifiable difference is because neither of the two loading layouts are without flaws. For left-handed loading, the loader holds the base of the cartridge with his left hand and holds the nose of the cartridge with his right arm or cradles it in his right arm. Since unitary cartridges are invariably nose-heavy, this would be most comfortable for the loader. The downside is that the loader must ram the cartridge into the cannon with his left hand. For right-handed loading, the loader holds the heavier end of the cartridge with his left hand and rams it into the cannon with his right hand.

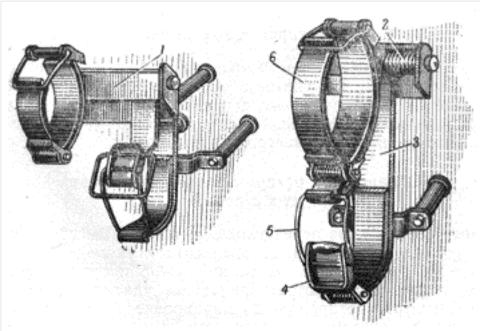
Rather than left-handed or right-handed loading, the main impediments to a T-54 loader are the length and mass of the 100mm cartridges. This was the main downside to having a more powerful gun than the American Pattons and the British Centurions during the 1950's. The base diameter of each cartridge case is 147.32mm and the length is 692mm. Naturally, the armour-piercing rounds have shorter projectiles and are therefore shorter overall compared to HE-Frag and HEAT rounds, but generally speaking, the cartridges were quite long. For comparison, the cartridges for the 105mm L7 cannon were noticeably more compact, having a base diameter of 147.3mm and a case length of 617mm. The reduced length makes them easier to handle inside the confines of a tank.

A drawing of ammunition placement in a T-54 obr. 1951 is shown below. As the arrangement of ammunition in a T-54 obr. 1949 is practically identical to that of the more historically relevant T-54 obr. 1951, we will only be discussing the latter.



The 1951 upgrade that brought the new egg-shaped turret also brought improvements in the ammunition stowage scheme. Most notably, the bevelled turret rear was filled out, and this allowed an additional five rounds to be carried. You can see these racks in the photo below.

The five rounds are stowed crosswise, tip to tail. Three rounds are stowed pointing towards the commander, and two are stowed pointing to the loader. Unfortunately, the turret bustle is too shallow for the loader to avoid the recoil stroke of the cannon when retrieving ammunition from these racks. As such, it is dangerous to extract ammunition from these racks immediately after the cannon has been loaded as the loader will not know when the gunner will decide to fire, making it impractical to lapload using these racks. These racks are deleted from the T-54K command tank variant as the space is taken up by an additional R-112 radio.

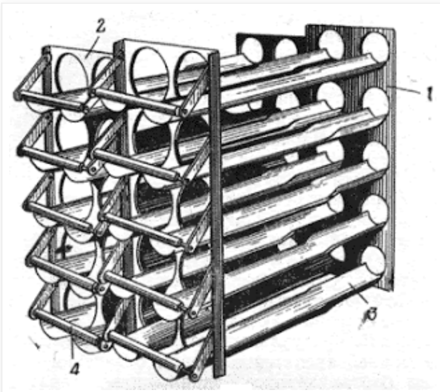


An additional two rounds are stowed on the turret wall next to the loader. The rounds are mounted facing forward. This was a rather odd design decision, since this forces the loader to hold the base of the shell with his right hand and hold the nose end with his left, even though he can only ram the round in with his left hand. This prevents the loader from extracting the round, turning around and loading the round in one fluid stroke.

Four rounds are stowed with clips at shin level on the wall of the hull, on the loader's side. These are not very convenient to use in battle if the turret is pointing forward, but they are still easier to access than the ammunition located at the very back of the fighting compartment. If the turret is pointed to the right relative to the hull, these racks will be convenient for the loader as they would then be situated directly in front of him. The presence of these four rounds decreases the available width of floor space available to the loader by 147mm (the base diameter of a 100mm cartridge case) which is somewhat inconvenient.

Twenty rounds are stowed in a metal skeleton frame rack at the front of the hull. The loader must squat down to access these racks, but the way they are placed is extremely convenient for him. These racks are placed underneath the flat part of the hull ceiling due to geometric incompatibility with the sloping front part of the hull. Underneath the 60 degree slope of the upper glacis plate, and in front of the ammo racks, is a large triangular fuel tank.

Here's a still from a video uploaded by Tanknut Dave showing these racks:

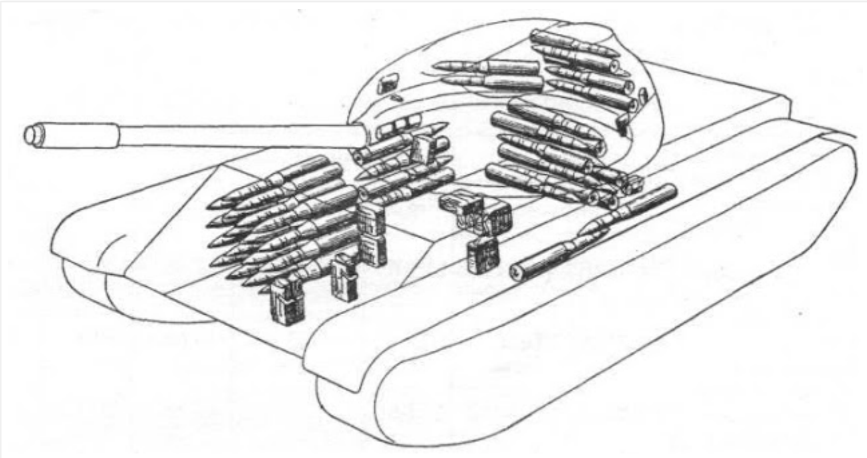


Here it is being used in an FSA-operated T-54.

Finally, there is a single cartridge stowed on the floor of the hull next to the engine compartment bulkhead. Five 250-round ammunition boxes for the coaxial machine gun are stowed on the floor of the turret, underneath the cannon, and another two boxes are placed next to the front hull ammunition racks, next to the driver's seat.

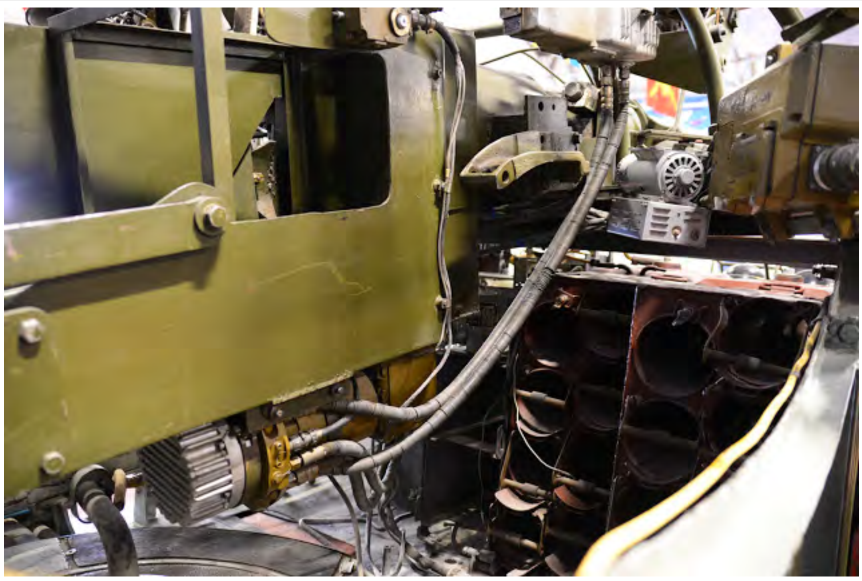
The front hull racks are the most convenient to access, behind only the ammunition stowed in the turret. According to Stefan Kotsch, a former East German T-55 and T-72 crewman, the tank crew is trained to point the hull toward an enemy tank in a tank duel. This presents the most heavily armoured zone of the tank to the enemy and naturally makes the front hull racks a convenient source of ammunition to the loader. However, there are additional nuances with the stowage scheme, one of them being that the rounds stowed at the bottom rows of the front hull racks would be harder to access than the rounds stowed at the top rows. The loader would need to take every opportunity available to rearrange the ammunition in such a way that they are convenient to access.

T-55



The T-55 introduced new front hull racks. Instead of a simple metal skeleton frame, these racks are conformal fuel tanks with slots for ammunition. Two rounds had to be sacrificed to make the arrangement work, slashing the total number of rounds stowed in the racks from 20 to 18. The rear hull fuel tank next to the engine compartment bulkhead was removed, but the new conformal fuel tank held 300 liters of diesel which offset removal of the rear hull fuel tank and increased the total fuel capacity of the tank by 100 liters, giving the tank an extended driving range. This was a considerable performance boost, especially since no additional useful internal space was used by the new special fuel tank and new stowage spaces became available by the removal of the rear hull fuel tank. Despite losing two ammunition slots in the front hull racks, the T-55 could carry 43 rounds of ammunition, which is 9 more rounds than the T-54.

The photo below shows the front hull ammunition racks in a special T-55 training demonstrator as seen from outside its imitation turret.



Contrary to the commonly held belief that the removal of the bow machine gun enabled more ammunition to be stowed (a belief repeated by The Chieftain in his video review of the T-54), the extra ammunition was not stowed anywhere near the removed bow machine gun, and it had nothing to do with it at all. Rather, the area in front of the bulkhead separating the fighting compartment from the engine compartment which previously held only one round in clips in the T-54 obr. 1947 up until the T-54B, had a new stowage rack for nine rounds installed in the T-55. The racks can be seen below (some space is being used in a non-historical manner for assorted machine gun ammunition boxes).


Photo credit to Jim Chandler of the Warwickshire Armour Modellers

It is not as easy to extricate ammunition from these racks as it is from the front hull racks or from the turret racks due to the horizontal arrangement of the ammunition and the presence of the large casing deflector extending almost to the turret ring. Therefore, these racks are considered non-ready racks for reserve ammunition. As these are not ready racks, they are usually filled with HE-Frag rounds as opposed to AP or HEAT rounds which would be stowed in the front hull racks. In the event that the loader must load the cannon when the turret is turned to the right, the rear hull racks will become much easier to access and would become his primary source of ammunition besides the rounds stowed in the turret.

It is possible for the loader to load the gun from a seated position. To do this comfortably, the seat should be placed in the rear position (facing forward) as this would allow the loader to easily access the two ammunition racks in the turret without any real difficulty. If the loader carries out his duties while seated, there would be no problems with the limited vertical height of the tank and even people of above average height would be able to load the gun with ease, but the limited amount of ammunition stowed in the turret makes it impractical for the loader to remain seated for the entire length of an engagement as he would need to access the ammunition in the hull to replenish the turret ready racks. If the situation is very dire, it would be faster to simply begin taking ammunition from the front hull racks once the turret racks are depleted. The GIF below shows a loader in a T-55A loading an APDS round while seated.

Experiences in various conflicts throughout the Cold War era have indicated that it is rare for a tank to expend more than 20 rounds of ammunition in a single engagement. Most often, the tank only needs to fire around a dozen rounds before the enemy is either destroyed or routed, keeping in mind that tanks do not operate alone - the firepower of a tank platoon or tank company is very high indeed, especially if tactical numerical superiority is achieved. This knowledge is reflected in the designs of tanks like the Pershing, M46, Centurion, and all the rest. In all of these tanks, and in the tanks that came after, ammunition stowage is divided into two types; ready and non-ready. Ready rounds are stowed in racks close to the loader, so that he can load as quickly as possible during battle. During the lulls between battles, the loader refills the ready racks with ammunition from the non-ready racks. The T-54 is no worse than any of its counterparts in this sense. The total number of rounds available in the ready racks in a T-54 is 29, whereas in the T-55, it is 27 rounds. As you may recall, another four rounds are stowed by the loader's feet at shin level, but they are not necessarily ready rounds in the strictest sense.

By comparison, a 20-pdr-armed Centurion has 28 ready rounds, according to a U.S Army report posted in abridged form by Nicholas "The Chieftain" Moran on the World of Tanks forum. There are 8 rounds in the ready racks in front of the loader and 20 more rounds in the voluminous front hull racks next to the driver. A 105mm-armed Centurion, on the other hand, has only 24 ready rounds in two racks close to the loader. The front hull racks hold 20 rounds as they did before, but now the ready racks in front of the hull only contain 4 rounds. These racks can be seen in the picture below. It can be seen that the ready racks partly obstruct the loader's access to the front hull racks, making it quite difficult to extract ammunition from those racks. The T-54 is more ergonomic in this respect.

The loader in a T-54 or T-55 is able to reach virtually all of the ammunition in the tank in both ready and non-ready racks, with the insignificant exception of the single cartridge stowed on the floor next to the gunner's seat. That single round is only useful when the turret is pointed directly behind the tank, which would prevent the loader from accessing any of the other hull ammunition racks. Obviously this is a rather inappropriate position for the tank to fight in, so the lack of any ammunition in the hull in such a scenario is not a disadvantage in any way. Furthermore, the low ammunition capacity of the T-54 is not a disadvantage where modern tank combat is concerned, such as in a meeting engagement. However, it can be an issue when meeting engagements become pursuits as the Soviet Army (hypothetically) blitzes across Europe. An adequate stream of supplies must always be maintained in order to keep up the pace of combat operations, and higher dependency on ammunition resupply may prevent some tank units from exploiting gaps in the enemy's defence in certain situations, although it is rather difficult to quantify the effects of lower ammunition capacities.

A popular myth is that the Soviet Army was ambivalent towards the T-54's relatively low ammunition capacity as it was believed that the tank would be sent to its doom in massed frontal attacks against dug-in NATO tanks and anti-tank weapons, so it only needed enough ammunition for one battle as entire tank fleets could be replaced within hours of its loss. However, this was never mentioned as official policy in any documents or in any Soviet military literature and it was certainly not part of the design requirements of the T-54, or any other Soviet tank for that matter. It must be said that huge losses were expected if the Soviet Army were ever to push into Europe, but that was simply the reality of warfare on such a large scale. The only reason why the T-54 has such a small stock of ammunition compared to NATO tanks is because of the paradox of having a large gun and a small tank at the same time.

RATE OF FIRE

Official Soviet documentation of tank crew norms (battle drills) specifies that loading an Object 137 and Object 155 (a T-54 and T-55 respectively) from the ready racks should take no more than 13 seconds. The "minimum" grade, which is the minimal passing grade, is 13 seconds, and the "good" grade is 11 seconds, while the "excellent" grade is 10 seconds. The standards for loading speed from the other ammunition stores are more lax; when loading from any ammunition rack other than the ready racks, the "minimum" grade is 15 seconds, the "good" grade is 13 seconds, and the "excellent" grade is 12 seconds. However, these numbers are contradicted by the rate of fire figures from the manuals.

The manual for the T-55A tank states that the combat rate of fire when firing from a standstill is seven rounds per minute and that the expected rate of fire when on the move is four rounds per minute. A 1969 manual for the T-54 (T-54 obr. 1951 with no stabilizer) gives the same numbers - the combat rate of fire is seven rounds per minute when firing from a standstill and four rounds per minute when firing on the move. Considering that the very first prototype of the T-54 had a rate of fire of only 5-6 rounds per minute, and that the T-44 using the ZiS-S-53 along with the T-34-85 could attain a rate of fire of 7-8 rounds per minute, it appears that the newer turret design of the T-54 provided a more conducive working environment for the loader.

Seven rounds per minute can be considered quite average for a medium tank, albeit one with a 100mm cannon. This amounts to a nominal sustained loading speed of 8.5 seconds per shot, assuming that acquiring a target and aiming at it takes less time than that. However, keep in mind that there is a technicality in the testing procedure. The Soviet measuring criteria calls for the use of all of the ammunition in the tank, not only the rounds from the ready racks. Drawing from only the most convenient ammunition racks and containers, the loader could achieve a higher burst rate of fire.

However, it should be noted that the combat rate of fire figures given in the manual definitely does not represent the loading speed of the loader. Qualitative analyses of gunnery trials at firing ranges showed that the loading speed does not exceed 7 seconds even when firing on the move, but the actual time between shots was longer due to other factors.

Reloading while the tank is on the move is more difficult in most variants of the T-54 compared to some other tanks due to the lack of a rotating turret floor, even if that was counter balanced by the rather sluggish spinning speed of the turret. Nevertheless, four aimed shots per minute is not a bad result when compared to other tanks, as you can see in the table below.

TABLE 11.
Rates of Fire by the Centurion, T41 and M24 Tanks
Rounds/Minute*

Condition	Tank: Centurion	T41	M24
Over-all Average	4.62	4.44	3.14
Straight Smooth Course			
6 mph	4.66	5.91	3.14
15 mph	6.70	5.00	3.33
Straight Rough Course			
6 mph	5.30	4.70	3.00
15 mph	3.95	4.42	
Zigzag			
6 mph	4.10	3.20	
15 mph	3.30	2.93	
Circular			
6 mph	4.51	2.56	

* In the calculations for rounds per minute the first round fired on each run was disregarded to eliminate variations in starting procedure.

[44] Subsequent to the completion of this report, Project Stalk was conducted by APG. The purpose of this project was to measure the times discussed in this section, among others, for a variety of tank and fire control combinations. The reader is referred to "An Assembly of Project Stalk Data" by F. I. Hill, et al BRL Memorandum Report No. 745 (Confidential) January 1954.

[45] "Tank, 76mm gun, T41 Integrated Fire Control System and Comparative Tests of Tank Gun Stabilizer," SECRET. (Ref. 9).

[46] Fort Knox, Ref. 2.

CONFIDENTIAL

Older models of the T-54 that lack a stabilizer may have a lower rate of aimed fire when firing on the move as the time taken to acquire the target is much longer due to the need to halt or slow to a crawl in between shots as opposed to the T-54B and T-55 where the gunner can scan for targets while on the move.

AMMUNITION

According to the September issue of the 2008 edition of the "*Техника и вооружение*" magazine, the ammunition loadout of a typical Soviet T-54 and T-54A consists of 12 HE-Frag rounds, 4 "Shrapnel" rounds, 6 HEAT rounds and 12 AP rounds. The loadout of a Soviet T-55 and T-55A consists of 18 HE-Frag rounds, 4 "Shrapnel" rounds, 6 HEAT rounds and 15 AP rounds. The "Shrapnel" rounds most likely refer to 3USh-1 rounds with the 3Sh5 Flechette shell which contains 1,800 steel flechettes packed in a special casing which is fuzed to break apart during flight to release the flechettes. Due to the rarity of this round, most tanks probably substituted them with standard HE-Frag rounds.

The standard loadout of a Yugoslavian T-54 consists of 17 HE, 11 AP and 6 HEAT.

Two types of ammunition casings are available; D-412 steel cases, and Kh-415 brass cases. D-412 weighs 8.50 kg, whereas Kh-415 weighs 6.0 kg. Brass cases are mostly used for AP, APDS, APFSDS and HEAT ammunition to improve firing consistency, while steel cases are mostly used for HE-Frag ammunition as accuracy is slightly less important.

HE-Frag

A tank's target is not necessarily another tank. Most of the time, it isn't. And to that end, the average T-54 tends to have a larger number of HE-Frag ammunition in its loadout compared to its stock of anti-armour ammunition. Out of a total load of 34 rounds, a T-54 with a standard loadout can carry 10 HE rounds and 4 Frag rounds. When the ammunition capacity was increased to 43 rounds in the T-55 upgrade, the number of HE rounds increased to 18 rounds, but the number of Frag rounds remained the same. However, the implementation of HE-Frag rounds made Frag ammunition redundant. The number of HE-Frag rounds carried is the sum of HE and Frag rounds.

53-UOF-412
53-OF-412

The UOF-412 cartridge weighs a total of 30.2 kg. The OF-412 shell itself weighs 15.6 kg while the propellant charge contained within the steel or brass casing weighs 5.5kg. The explosive charge is TNT. The use of TNT can only be described as conservative, since RDX (also known as Hexogen) is clearly a superior choice as it is much more powerful and has higher brisance, allowing it to shatter the steel casing of the warhead more effectively into smaller and speedier fragments for increased anti-personnel lethality. One plausible explanation is that perhaps TNT was much cheaper and the expenditure of HE-Frag shells in times of war was expected to be so high that the cost efficiency of using TNT outweighed the drawbacks.

A 20 pdr. HE shell, for instance, weighs 7.8 kg (according to an Unexploded Ordinance brochure) and contains an explosive charge of 0.6 to 0.75 kg of TNT or Composition B (60% RDX, 40% TNT), depending on the exact model of shell. The OF-412, on the other hand, weighs twice as much at 15.6 kg and contains twice as much explosives with a 1.46 kg TNT explosive charge. For every 100mm HE round that the T-54 carried, a Centurion Mk. 3 would need two 20 pdr. ones to match it in payload. The raw kinetic energy of OF-412 shells is also much higher, as it not only weighs twice as much but also has a higher muzzle velocity of 892 m/s compared to just 602 m/s for a 20 pdr. HE shell. This makes OF-412 very useful against hardened structures as it is capable of penetrating reinforced concrete pillboxes and heavy field fortifications when the PD fuze is set to the "HE" mode for delayed detonation. The range of the shell is also extended, making the T-54 more useful for indirect fire.

OF-412 is is topped off with an RGM-6 point detonating (PD) fuse. The fuze is armed only by centrifugal forces, thus making it inert until it has been fired through a rifled gun barrel. There are two fuze settings with three possible firing methods. The superquick setting is marked with an "O" and the delayed setting is marked with a "З" (a Cyrillic "Z").

Type of Fuse	Type of operation of shell required	Order	Setting for firing CAP	Setting for firing FUSE	Normal (Basic) Setting
RGM-RGM-6	Fragmentation	"Fragmentation"	OFF	To "O"	Cap on,
	H.E.	"H.E."	ON	To "O"	Setting at
	Ricochet or H.E. withdelay	"Delayed"	ON	To "3"	"O"
DBR-2	No setting required				

In case of failures during HE - fragmentation firing with the RGM and RGM-6 fuses set at "3", the fuse setting should be charged to "O".

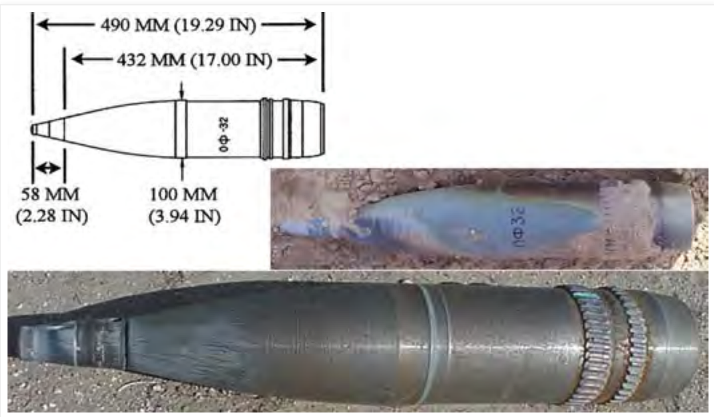
During heavy rain, HE fragmentation shells with RGM and RGM-6 fuses must not be fired without the waterproof cap, because there may be a premature explosion during flight.

The superquick setting detonates the shell 0.027 seconds after impact and the delayed setting detonates the shell 0.063 seconds after impact. Superquick action guarantees reliable detonation in snowy or swampy ground, and delayed action gives a small time allowance for the shell to penetrate its target before detonating. Keeping the (waterproof) safety cap on the fuze has a delaying effect on the fuze (refer to the table above) and switches the round from the "Frag" mode to the "HE" mode. Setting the fuze is the loader's job, but it is the commander who dictates which setting is used. The variety of fuzing possibilities gives OF-412 an added degree of flexibility against targets of all types, meaning that the T-54 has to use fewer rounds overall compared to an early Centurion equipped with the 20 pdr. gun. This offsets the difference in ammunition quantity.

The delayed fuzing feature is beneficial to overall efficiency when the T-54 is used in an indirect fire role. When RGM-6 fuze is set to the delayed mode, OF-412 can be very useful against underground or dug-in positions, as the shell assumes an arcing ballistic trajectory when shooting at long range.

The fuze slot at the tip of the shell is also compatible with the V-429 variable delay fuse designed in the 60's. The V-429 fuse is point-detonating and armed by centrifugal forces, like RGM-6. The V-429 fuse differs from the V-429E (used in the 115mm U-5TS and 125mm D-81T), which is armed by the braking effect from the unfolding of the stabilizer fins of the shell. Like the RGM-6, the V-429 has two possible settings: superquick and delayed. The main advantages of the V-429 are that it is waterproof even without a waterproofed safety cap, and it has additional safety features to prevent the detonation of the shell even if the fuze is accidentally set off.

3UOF10
3OF32



3UOF10 is a more modern cartridge, incorporating the 3OF32 shell. This round was introduced in 1975. 3OF32 is designed to produce a more optimal pattern of fragmentation for increased casualties but also remain sturdy enough that it can penetrate reinforced concrete targets without breaking up. The 3OF32 shell is furnished with the V-429 fuze as standard.

Muzzle velocity: 900m/s

Complete round mass: 30.36 kg
Propellant Charge Mass: 5.6 kg

Mass of Shell: 15.96kg
Explosive Charge Mass: 1.7kg
Explosive Type: A-IX-1 (96% RDX, 4% phlegmatizing wax)

Number of Preformed Fragments and Their Mass:
With a mass of not less than 0.5 g: 1993
With a mass of 0.5 g to 2 g: 814
With a mass of 2 g to 15 g: 928
With a mass exceeding 15 g: 251

Statistical Average Mass of Fragments: 6.2 g (mean is more important, but the statistic is not provided)

Velocity of Fragments and Ratio of Fragment Velocities:
100% - at least 1040 m/s
90% - 1060 m/s or more
80% - 1080 m/s or more

Interestingly, the 3OF32 was later used in the 2A70 low pressure cannon of the BMP-3. In that particular application, the low velocity of the shell further decreases the penetration of the shell into soil and snow, thus improving its fragmentation value, but the low velocity also reduced the energy of the shell and reduced the time allocation for it to penetrate hard obstacles, making it exceedingly unsuitable for bunker busting. It could, however, still be used to remove earth and log fortifications.

Armour Piercing (AP)

Before the dawn of the HEAT menace, full caliber steel armour-piercing rounds were the only armour-piercing round available for the T-54, but even after reliable HEAT shells became available, full-caliber and subcaliber armour-piercing rounds were the mainstream method of dealing with armour. The typical example of this type of ammunition was cheap, reliably lethal, and tended to be more accurate than other types of ammunition, excepting APDS. Out of a full standard loadout of 34 rounds, a T-54 carried 12 armour piercing rounds. The T-55 had an expanded ammunition capacity of 43 rounds and carried 15 armour piercing rounds in a standard loadout. When APDS became available in 1967, it replaced full caliber steel shells entirely so that the APDS became the exclusive KE-based armour-piercing round.

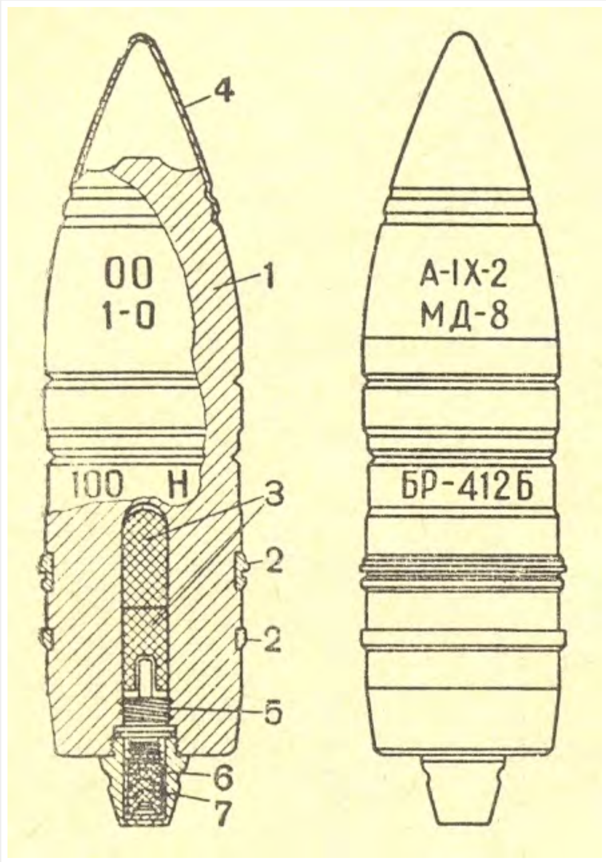
Throughout the military career of the T-54 series in the USSR and in most of its satellite states, AP shells were preferred over HEAT shells despite the obvious superiority of the latter in armour penetration power. When HEAT became available for the T-54, the ratio between AP and HEAT ammunition was 2:1, and when the T-55 tank was introduced with a larger ammunition capacity, it carried AP and HEAT ammunition in a 2.5:1 ratio. For example, according to ex-NVA tank commander Stefan Kotsch, a standard combat loadout for an NVA T-55 was comprised of 15 APDS rounds, 6 HEAT rounds and 22 HE-Frag rounds. It was the same in the Soviet Army.

The point blank range for BR-412B and BR-412D is 1,220 m for a target with a height of 2.7 meters, representing a NATO tank. This means that the gunner can set the sight at 1,220 m prior to an engagement, and when an enemy tank is spotted, the gunner simply aims for the center mass of the target. If the target is exactly 1,220 meters away, the shot will land on the turret ring. If the target is closer than 1,220 meters, the shot may land on the turret. If the target is slightly further than 1,220 meters, the shot may land on the hull. Either way, a hit is quite likely within the margin of error provided by the point blank distance. This is a faster method of engaging tank-type targets, and given the high threat posed by tanks, it is probably the preferred gunnery technique employed by most T-54 gunners. For precision gunnery, the range reading obtained by stadiametric rangefinding can be used to further enhance to probability of a hit.

53-UBR-412B
53-BR-412B

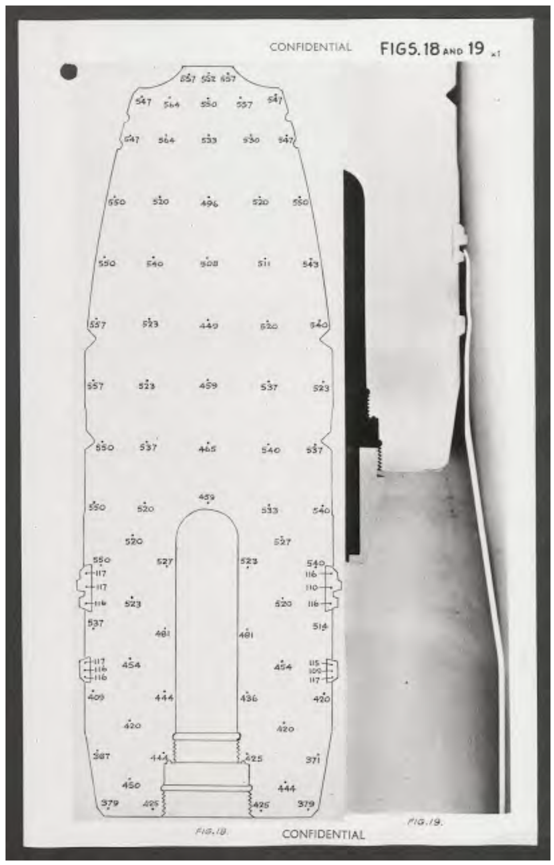
When the T-54 entered service in the Soviet Army, there were only two types of armour piercing ammunition available for it. BR-412 AP, and BR-412B APBC. BR-412B was formally introduced sometime around 1946 (apparently, it was already in production by early 1945, but not issued) as a modified version of BR-412, featuring a blunt nose and a ballistic cap to maintain an aerodynamically pointed nose. The shape of the blunt nose is similar to the older 57mm BR-271 APHE-T shot in that it has a small bump on the tip, but the bump is completely flattened and not rounded. As the ballistic properties of the two rounds were different, chiefly due to this ballistic cap, it made little sense to keep the worst of the pair, so the early incarnations of the T-54 were stocked entirely with BR-412B.

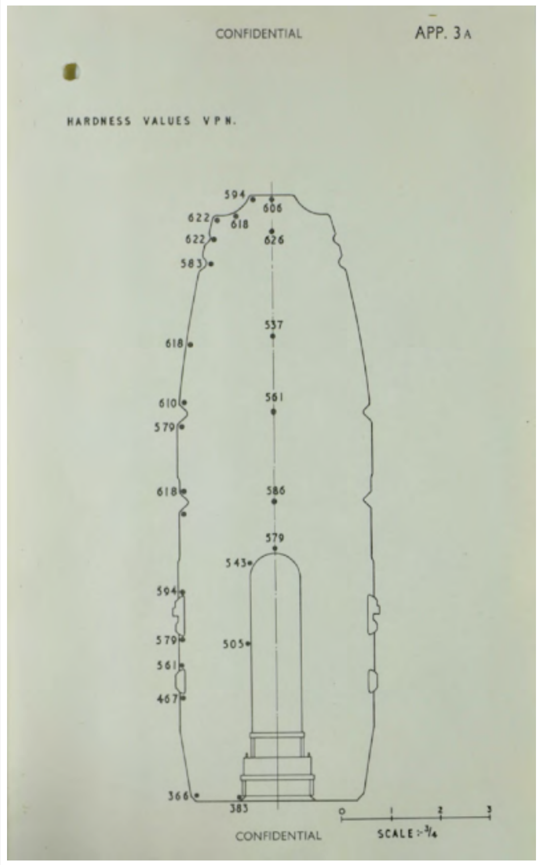
When fired from the D-10T, the probable deviation of BR-412B at a distance of 1 km is 0.3 meters in the horizontal axis and 0.3 meters in the vertical axis. At a distance of 2 km, the probable deviation is 0.5 meters in the horizontal axis and 0.6 meters in the vertical axis.



The quality of the steel is considered high, and the hardness is respectably high as well. The hardening of the shell progresses uniformly - hardest at the tip and areas close to the surfaces, and slightly softer at the center. In contrast, wartime production 76mm BR-354B for the ZiS-3 gun ranges from 47 points Rockwell C to 38 points (451 BHN to 351 BHN) at the tip alone. Such shells were prone to shattering on impact with hard armour. A hardness of at least 600 BHN at the tip - which BR-412B achieves in excess - is necessary to prevent this from happening. The BR-412B shell is fired from the D-10 series of guns at a chamber pressure of 294.2 MPa.

Below are two different analyses on different BR-412B samples. Both were done by the Ministry of Munitions in the U.K, but at different times. The one on the right was done in 1963 with ammunition from an unspecified recent conflict, and the one of the left was done in 1958 with ammunition taken from a captured Egyptian SU-100 from the Suez Crisis.





According to a U.S army document analyzing the Soviet 76mm BR-354B, it was mentioned that American armour piercing shots are generally hardened to approximately Rockwell C 60 (654 BHN) at the nose. By this metric, BR-412B can be considered on par with U.S ammunition.

The lethality of BR-412B is quite high, due in part to the 65-gram explosive charge of A-IX-2 at the base of the shell (assuming that armour perforation is achieved, of course). The British evaluation states that the detonation of the explosive charge has the effect of shattering the rearmost portion of the shell into five to six pieces as the shell exits the rear of an armour plate, supplementing the large spray of secondary projectile fragments and spall from the armour plate itself. These five to six large chunks of hard steel may also produce even more fragmentation as they impact the interior walls of the tank. In addition to that, the high energy of these chunks has a much greater chance of detonating ammunition inside the tank compared to smaller fragments. Contrary to how APHE shells are often perceived, the explosion will not send fragments in all 360 degrees like a grenade. It must be remembered that the walls surrounding the cavity containing the explosive charge are very thick - too thick to act as an effective fragmentation casing.

Nevertheless, the killing power of the shell is augmented to some extent by the percussive effect of the blast, which has greater power than that of an F-1 fragmentation grenade (which holds 60 grams of TNT), even though most of it is spent in cracking the base of the shell into several pieces. Confined inside the small spaces of a tank, the effect of the blast is magnified and the incendiary effect of A-IX-2 increases the chance of igniting fuel and ammunition, not to mention burning the crew and internal equipment. While 65 grams may not seem like much, A-IX-2 is a particularly useful explosive-incendiary compound because it contains aluminium as a fuel additive. A-IX-2 consists of 73% RDX, 23% aluminium powder, and 4% phlegmatizing wax. The aluminium powder content produces an incendiary effect, because aluminium powder is used as a fuel additive to increase the heat of combustion (Türker 2016, p. 426).

The high aluminium content in A-IX-2 means that there will be some unburnt aluminium powder dispersed into the surrounding air, where it will burn at reduced rate due to the reduced oxygen level in the air (and also in the RDX itself, as RDX is oxygen deficient) and due to the increased concentration of gaseous byproducts from the explosion. Augmenting this effect is the fact that the burning of aluminium generates an alumina (aluminium oxide) coating over the surface of the aluminium particles. The alumina acts as an insulation layer, thus delaying the burning of the aluminium itself so that the efficiency of combustion is reduced. This has the effect of extending the duration of combustion, extending the release of heat energy, increasing the explosive impulse, extending the radius of the incendiary effect, and increasing the probability of igniting other flammables in the vicinity of the explosion. The unavoidable side effect of the reduced efficiency of combustion is that the explosive velocity is slightly lower compared to pure Hexogen, but the actual explosive power of A-IX-2 is greater. Because of these factors, all APHE shells developed in the USSR after 1940 used A-IX-2 exclusively. On the other hand, medium to large caliber HE-Frag shells usually had an A-IX-1 or TNT filler, presumably for cost reasons.

Muzzle velocity: 895 m/s

Mass of Complete Round: 30.1 kg
Projectile Mass: 15.88 kg

Mass of Explosive Charge: 0.065 kg
Explosive Charge Type: A-IX-2

Chamber Pressure: 294.2 MPa

According to the Yugoslavian tests, BR-412B could only defeat the front turret armour of a T-54A at a distance of 500 meters. This means (indirectly) that BR-412B can perforate 200mm of steel at 0-30 degrees at 500 meters. This is well within the figures listed below.

Penetration at 0 Yards:

164mm at 30°
133mm at 45°
96mm at 60°
59mm at 70°

Penetration at 1000 Yards:

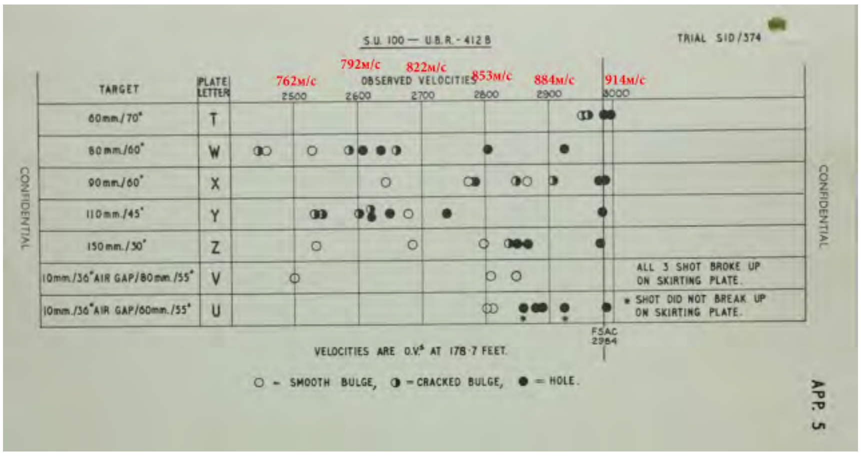
140mm at 30°
115mm at 45°
82-85mm at 60°
51mm at 70°

Source: British Army test document: DEFE 15/1107
"The Performance of Russian SU 100 APHE/T Shot UBR-412B Against Armour Plate"

All values are for a 50% chance of penetration.

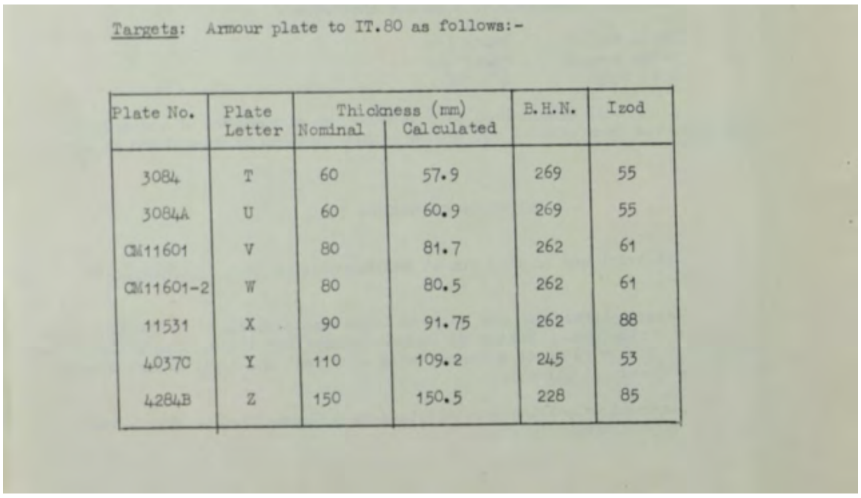
The British use the V50 standard instead of the Soviet/Russian V80 standard. If the document were Russian, the distance where the shell would be able to penetrate the armour of the tank would be listed as shorter. Besides that, the criteria for what constitutes armour penetration differs substantially from the Russian criteria. The British and American criteria dictates that at least 50% of the projectile mass must end up on the other side of the armour plate per a certain velocity, or in more practical terms, a certain distance (as the function of distance is the derivative of velocity). This forms the basis of the V50 standard. The Russian criteria as manifested in most firing tables dictates that at least 75% of projectile mass must be found on the other side of the armour plate. In actual certification testing, though, an 80% standard is used. This is responsible for the differences in penetration values of Russian ammunition in both military and civilian literature.

These figures are backed up by this page of the report:



Each vertical divider on the chart represents 250 meters.

All values are in V50 standard. The hardness of the target plates is listed below.



Targets: Armour plate to IT.80 as follows:-

Plate No.	Plate Letter	Thickness (mm) Nominal	Thickness (mm) Calculated	B.H.N.	Izod
3084	T	60	57.9	269	55
3084A	U	60	60.9	269	55
CM11601	V	80	81.7	262	61
CM11601-2	W	80	80.5	262	61
11531	X	90	91.75	262	88
40370	Y	110	109.2	245	53
4284B	Z	150	150.5	228	85

Penetration at 0°:
100 m: 235mm
250 m: 226mm
500 m: 211mm

750 m: 197mm
1000 m: 185mm
1250 m: 172mm
1500 m: 161mm
2000 m: 141mm
2500 m: 123mm
3000 m: 108mm

(*WWII Ballistics: Armour and Gunnery*, corroborated with *Janes' Ammunition Handbook*)

As usual, the ballistic arc of the shell is not significant enough to affect armour penetration on sloped targets by any significant amount. According to Soviet firing tables reproduced in the CIA report "*Technical Information on the 100-mm Gun and Other Armament on the T-54 Tank*" from 1960, the angle of descent of BR-412B and BR-412D is 0.4 degrees at a distance of 1 km and 1 degree at 2 km.

In terms of penetration power and post-penetration lethality, BR-412B is nominally superior to 90mm M318A1 APCBC. However, the T-54 did not have access to "premium" ammunition like M304 HVAP, though 100mm BR-412P HVAP ammunition was built in some small quantities and was considered for full issuance. Ultimately, regular steel rounds were considered adequate and BR-412P never saw the light of day. For situations where steel AP was inadequate, multipurpose HEAT ammunition could do the job better than tungsten cored HVAP ammunition while simultaneously offering a secondary anti-personnel function thanks to its explosive charge and thick steel casing.

Once full armour perforation is achieved, the results are utterly devastating. (The photo on the left is actually from a BR-412D penetration, but the effect is much the same).

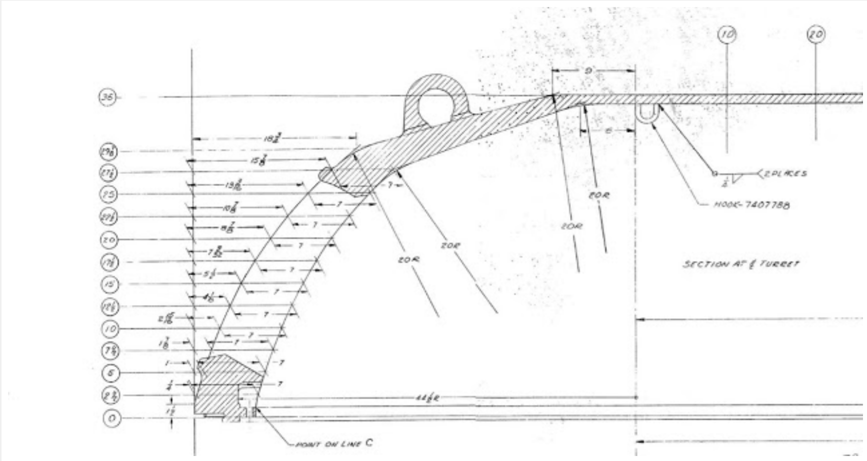
As a rule of thumb, the entry channel in a thick armour plate is always larger than the actual caliber of the shell and the exit channel is typically equally large if not more so. A blast of armour fragments is ejected at extremely high speed into the tank, followed by shards of the shell, followed by the shell itself which may or may not be intact. If intact, the explosive filling at the base of the shell detonates and fragments the steel body, creating additional fragmentation and increasing the spray cone angle of fragmentation after clearing the armour plate. The MD-8 fuse embedded in the rear of the shell has a delay to ensure that the explosive charge detonates a certain distance inside the tank past the armour, making it more deadly than if it detonated immediately after perforating the armour plate, or during the penetration phase inside the armour plate.

Although it was originally intended for defeating increasingly thick German tank armour near the end of the Second World War, the intended targets for the BR-412B shell quickly changed to American tanks. The M26 Pershing, and by extension the M46, both have a 100mm-thick cast steel upper glacis angled at 46 degrees. Factoring in the lower efficiency of cast armour compared to rolled armour and the information from the British tests, it should be vulnerable to BR-412B at a distance in excess of 1.5 km. As for the M47, Yugoslavian ballistic testing found that the 100mm cast steel upper glacis with a slope of 60 degrees can be perforated by BR-412B at a distance of 750 meters. This would not have been an acceptable result by WWII standards as average tank combat distance was between 200-800 meters, but as tank optics improved, this became rather close for comfort. Nevertheless, the T-54 still nominally outranges the M47.

According to page 25 of *WWII Ballistics: Armour and Gunnery*, a 100mm cast armour plate within the 220-300 BHN hardness range is 93% as effective as rolled armour with a hardness of 240 BHN at a 0 degree impact angle against 100mm armour piercing projectiles. The book does not list the relative efficiency of cast armour when it is sloped, but this information agrees with the results of the Yugoslavian tests, implying that the efficiency does not change significantly with the angle of the plate.

The M47 became the mainstay of many European armies including the West German Bundeswehr, but the improved M48 was the backbone of the U.S Army for most of the Cold War. The upper glacis of the M48 is cast steel, 110mm thick sloped at 60 degrees, which is more somewhat formidable than the upper glacis of the M47. 110mm of cast steel should be equivalent to around 102mm of rolled steel, making the upper glacis of the M48 approximately on par with the T-54 itself. A detailed report on the performance of BR-412B against the M48 is detailed in this Tank Archives post, courtesy of Peter Samsonov. The original 1958 report is titled "*Броневая Защита Американского Среднего Танка М-48*". Soviet testing revealed that BR-412B was not capable of penetrating the upper glacis of the M48 even at point blank range, which should not be surprising as the Yugo test report mentions that BR-412B was not capable of perforating the upper glacis of a T-54A. However, the lower glacis of the M48 could be perforated at 2,500 meters. It is interesting to note that the Soviet report concluded that BR-412B needed an impact velocity of 940 m/s to defeat the upper glacis armour of the M48, which is substantially higher than the muzzle velocity achieved by firing BR-412B out of a D-10 or a BS-3 gun. Defeating the upper and lower side hull armour of the M48 from a side angle of 30 degrees (from the longitudinal axis of the tank) is possible from a distance of 500 meters.

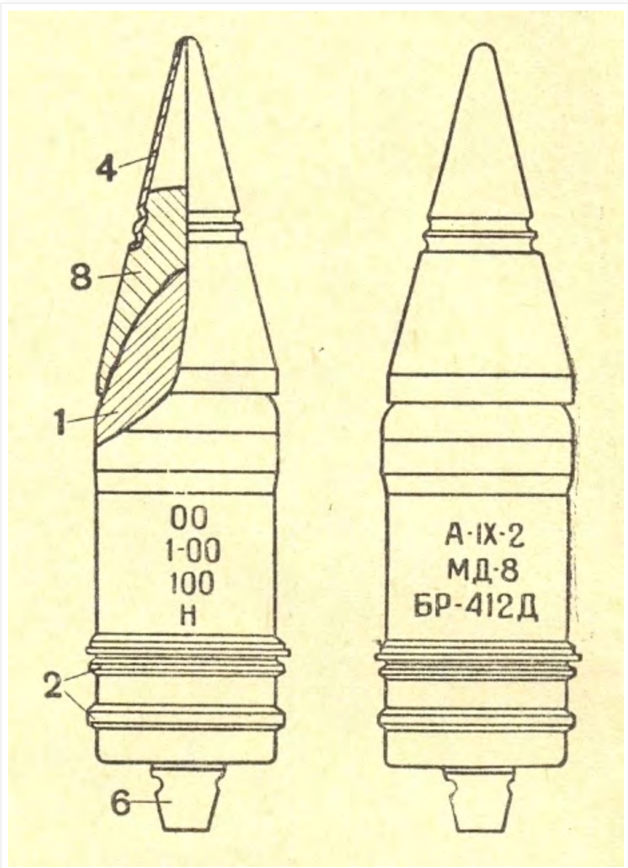
The turret of the M48 is weaker than the upper glacis - mostly because it is not nearly as sloped as the upper glacis - but it is still very well rounded and quite formidable. The thickness of the front turret face at the gun mantlet region varies from 178mm to 100mm, with sloping that ranges from 14 degrees at the very bottom edge of the turret where it is thickest to 56 degrees near the turret roof, where it is much thinner, but no matter what the thickness or slope is, the thickness on the front turret face invariably measures up to exactly 7 inches, or 178mm. The thickness reduces considerably beyond the immediate front turret face, but this is somewhat compensated by additional horizontal slope, although the final LOS thickness is still less than the front turret face. By referring to the penetration values given earlier, we can see that the front turret face cannot be considered well protected against BR-412B.



The gun shield overlaps the front turret face slightly, but the area of overlap is very small and the gun shield itself is negligibly thin. The most significant portion of the gun shield is 110mm thick, sloped at 30 degrees, which comes out to 127mm in LOS thickness. This should be vulnerable to BR-412B at a distance of more than 1,200 meters.

Overall, BR-412B should be able to perforate the area near the base of the turret at distances in excess of 1,250 meters, and the area near the roof should be highly vulnerable at a distance of at least 800 meters. This was inexcusable, since BR-412B was by no means new by the time the M48 entered service. For this reason, the Soviet report "*Броневая Защита Американского Среднего Танка М-48*" concluded that 100mm rounds are generally effective against the M48, despite the inability to defeat the upper glacis armour. However, better ammunition in the form of BR-412D became available at the same time that the M48 entered service in the U.S Army.

53-UBR-412D
53-BR-412D



Steel shell with a soft steel armour piercing cap. This shell formally replaced the BR-412B as the standard anti-armour round in 1953, but it came as early as 1951 as an component of the loadout of the T-54 obr. 1951 (the brand new TSh2-22 sight for the T-54 obr. 1951 had a range scale for BR-412D). Both BR-412B and BR-412D continued to be used side by side for some time, so in actuality, BR-412D supplanted the BR-412B rather than replaced it outright in Soviet service. Some former Soviet satellite states were still using BR-412B into the 2,000's until they eventually scrapped their T-54 tanks completely.

SCALES:
BR/412B or BR/412D
Sight TSh2-22
"Mils" = elevating gear.

ARMOUR-PIERCING - TRACER SHELL BR-412D
(with AP and ballistic caps)

Fuse DBR-2
Ranges of grazing shot : 1070 m with target height 2 m
1220 m with target height 2.7 m
1270 m with target height 3.0 m

Full charge
Muzzle velocity for BR-412D = 887 m per sec

Range	Sight according to scale		Height of trajectory	Directional corrections		One graduation of telescopic sight alters height of impact	Angle of elevation	Angle of fall	Terminal velocity	Time of flight	Probable errors		Range
	BR/412B or BR/412D	"Mils"		for drift	for Cross-wind of 10m. per sec						vertical	lateral	
m	grad.	mil.	m	mil.	mil.	m	° '	°	m.per sec	sec	m	m	m
200	2	1	0,1	0	0	0,1	0 05	0,1	868	0,2	0,05	0,05	200
400	4	3	0,3	0	1	0,3	0 09	0,2	849	0,4	0,1	0,1	400
600	6	4	0,5	0	1	0,4	0 14	0,3	830	0,7	0,2	0,2	600
800	8	5	1,1	0	1	0,5	0 18	0,3	811	0,9	0,2	0,2	800
1000	10	6	1,7	0	1	0,7	0 23	0,4	793	1,2	0,3	0,3	1000
200	12	8	2,6	0	1	0,9	0 28	0,5	775	1,4	0,3	0,3	200
400	14	9	3,7	0	2	1,1	0 33	0,6	757	1,7	0,4	0,4	400
600	16	11	5,0	0	2	1,3	0 39	0,7	739	2,0	0,4	0,4	600
800	18	12	6,4	0	2	1,5	0 44	0,8	722	2,2	0,5	0,5	800
2000	20	14	8,0	1	2	1,7	0 50	1,0	705	2,5	0,6	0,5	2000
200	22	16	10	1	[illegible]	1,9	0 56	1,1	688	2,8	0,6	0,6	200
400	24	17	12	1	2	2,2	1 02	1,2	671	3,1	0,7	0,6	400
600	26	19	15	1	3	2,4	1 09	1,4	654	3,4	0,7	0,7	600
800	28	21	17	1	3	2,7	1 15	1,5	638	3,7	0,8	0,7	800
3000	30	23	20	1	3	3,0	1 22	1,7	622	4,0	0,9	0,8	3000
200	32	25	24	1	3	3,3	1 29	1,9	606	4,4	1,0	0,8	200
400	34	27	28	1	3	3,7	1 36	2,1	590	4,7	1,1	0,9	400
600	36	29	32	1	3	4,0	1 44	2,3	575	5,0	1,2	0,9	600
800	38	31	36	1	4	4,4	1 52	2,6	560	5,4	1,3	1,0	800
4000	40	33	42	1	4	4,8	2 00	2,8	545	5,8	1,4	1,0	4000

The armour piercing cap prevents the shell from breaking up when it impacts thick steel plate at high velocities. Controlled fracturing of the nose of the shell is beneficial towards penetration on sloped targets, but shattering of the shell will neutralize it completely. This shell is superior to the BR-412B on both low and high obliquity targets, but the difference is most noticeable at low obliquity. In page 10 of "Mechanisms of Armour Penetration" by Niko Holkko, it is shown that uncapped APBC and AP shells are more effective on thin plates (0.4 calibers) at all angles compared to APC and APCBC shells, but the inverse is true when the plate thickness reaches 0.45 calibers and above. On a thick plate (1.3 calibers), APC and APCBC rounds vastly outperform APBC at 60 degrees obliquity. In practical terms, the superior penetration on thick sloped armour makes BR-412D a favourable choice when engaging modern tanks of the era such as the M47 and M48.

Muzzle Velocity: 887 m/s

Complete Mass of Round: 30.4 kg
Projectile Mass: 15.88 kg

Mass of Explosive Charge: 0.061 kg
Explosive Charge Type: A-IX-2

Chamber Pressure: 294.2 MPa

Point-blank ranges:

For a target height of 2.0 m - 1,070 m
For a target height of 2.7 m - 1,220 m
For a target height of 3.0 m - 1,270 m

For armour penetration, Zaloga gives these figures (Link):

Penetration at 0°:
100 m: 200mm
500 m: 185mm
1000 m: 170mm
1500 m: 155mm
2000 m: 125mm

Penetration at 30°:
100 m: 150mm
500 m: 140mm
1000 m: 130mm
1500 m: 120mm
2000 m: 100mm

These values are in Soviet standard. Soviet target plates had a hardness of between 250 to 350 BHN.

Penetration at 0°:
100 m: 250mm
1.0 km: 185mm
1.5 km: 170mm

(Source unknown)

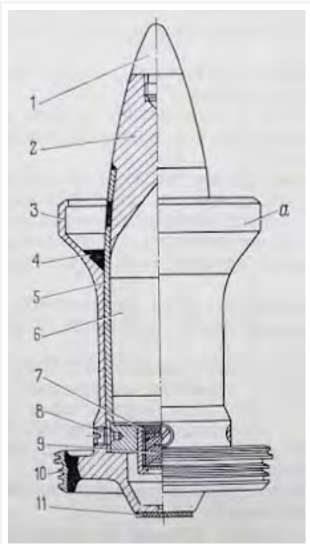
The CIA report "*Technical Information on the 100-mm Gun and Other Armament on the T-54 Tank*" has this penetration table for the BR-412D:

Range m.	Thickness of armour being pierced, mm AP-Tracer Shell BR-412D Muzzle velocity 887 m.per sec. Angles of impact	
	60°	90°
500	150	200
1000	140	185
1500	130	170
2000	120	155
3000	100	125

Comparing these figures to Zaloga's, we can see a significant discrepancy. The CIA's figures are much higher, especially when we go up to and beyond 2,000 meters. At 500 m and 1,000 m, the CIA's figures are 10mm higher for a 30-degree impact and 15mm higher for a 0 degree impact. At 2,000 meters, the CIA's figures are 20mm (!) higher for a 30-degree impact and a 30mm (!) higher for a 0-degree impact. The figures in the report are apparently taken from Soviet documents.

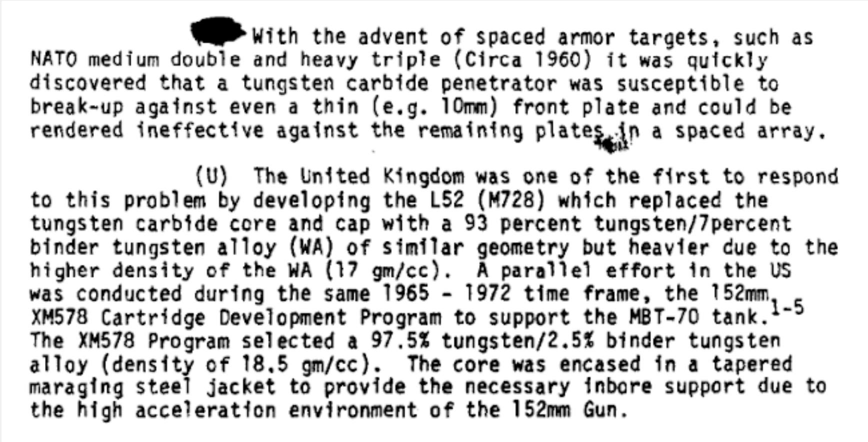
According to these figures, BR-412D should be more than capable of perforating the front hull armour of a Leopard 1 at distances in excess of 1,500 meters. The Panther's 82mm upper glacis sloped at 55 degrees was found to be penetrable at a distance of 1,500 meters. As for the M48, the BR-412D should have an effective range of several hundred meters more than the BR-412B when attacking the turret, but the most noticeable advantage is that BR-412D should be able to perforate the upper glacis of the M48 at a distance of around 500 meters, based on the difference in slope modifiers.

3UBM8
3BM8



3BM8 is an APDS shell for the D-10T that entered service in 1967. The development of Soviet anti-tank munitions is highly unusual in that APFSDS rounds entered service before APDS rounds whereas foreign nations invariably developed APDS rounds before upgrading to APFSDS ammunition later on. 3BM8 had good performance on vertical plate, possibly as good as 105mm L28 APDS, but its effectiveness on heavily sloped plate was largely unremarkable, and this is apparent when the design of the penetrator is examined closely. When comparing 3BM8 to the 20 pdr. MK.3 and the 105mm M28, it can be seen that the core of the 3BM8 and the MK.3 is an ogive whereas the L28 has a blunt tip. This is responsible for the better penetration of L28 on sloped armour plate at the expense of some penetration performance on flat armour plate. However, it is worth noting that problems with L28 were encountered during combat, prompting the development of tilting caps.

As a side note, MK. 3 and the more advanced L28 are similar in that they both have an unsecured cap. The MK.3 projectile has a small blunt steel cap (possibly non-ballistic in function, as it is referred to as a spacer) and the L28 has a conical tungsten carbide cap. For 3BM8, an extraordinarily thick section of low hardness alloy steel in front of the core acts as the armour piercing cap, and the hollow tip of the structure is partially filled with some lightweight metal (probably aluminium) to act as a windscreen. Although it appears to be less elegant than the solution used in the L28 round, the large steel cap may be highly beneficial against simple dual-layered spaced armour as the cap cannot be easily removed by a thin spaced plate: the thickness of the cap is too high to be eroded by a thin spaced plate, and the firm integration of the cap as a part of the jacket for the core makes it more difficult to dislocate the cap or deflect it away from the core after passing through a spaced plate. This is an interesting perspective to consider, as the deficiencies of L28 on thin spaced armour was well known - a thin 10mm steel plate could not only remove the tungsten armour piercing cap but also shatter the tungsten carbide core, making it ineffective on any subsequent plates. The extraordinarily thick steel cap of 3BM8 may have been designed to alleviate this issue, and this is explored later in the article.



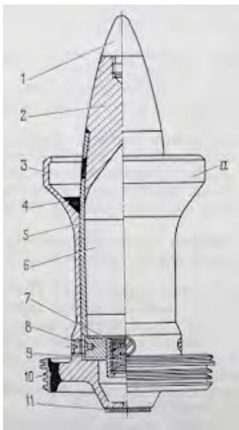
[redacted] With the advent of spaced armor targets, such as NATO medium double and heavy triple (Circa 1960) it was quickly discovered that a tungsten carbide penetrator was susceptible to break-up against even a thin (e.g. 10mm) front plate and could be rendered ineffective against the remaining plates in a spaced array.

(U) The United Kingdom was one of the first to respond to this problem by developing the L52 (M728) which replaced the tungsten carbide core and cap with a 93 percent tungsten/7percent binder tungsten alloy (WA) of similar geometry but heavier due to the higher density of the WA (17 gm/cc). A parallel effort in the US was conducted during the same 1965 - 1972 time frame, the 152mm XM578 Cartridge Development Program to support the MBT-70 tank.[1-5] The XM578 Program selected a 97.5% tungsten/2.5% binder tungsten alloy (density of 18.5 gm/cc). The core was encased in a tapered maraging steel jacket to provide the necessary inbore support due to the high acceleration environment of the 152mm Gun.

Besides that, the tungsten carbide core in 3BM8 is smaller and lighter than the one in MK. 3 and also lighter to the one in the L28, although the diameter is slightly larger. From left to right: 3BM8, MK.3, L28 with tilting cap. Earlier L28 variants had a core with a blunt tip instead of a hemispherical tip. The hemispherical tip allowed the cap to slide against the tip of the core, which would not have been possible with a blunt tip.



The same design of core contained within the 3BM8 projectile is shared by the 122mm 3BM11. The development of the 3BM8 is directly related to the 3BM11, as they were both born out of the same set of requirements. The shared heritage can be seen in their identical designs. 3BM11 appears to be larger than 3BM8, but that is mostly due to an increase in the thickness of the steel sheath over the core, leading to an increase in the overall diameter of the projectile but not in the diameter in the core itself. The sabot has a distinctly larger diameter. 3BM11 penetrates 320mm at 0 degrees and 110mm at 60 degrees, but this is purely due to the higher power of the cannon that fires it.

Muzzle Velocity: 1,415 m/s

Maximum Chamber Pressure: 3,000 kg/sq.cm

Mass of Complete Round: 20.9 kg

Projectile Length (incl. sabot): 240mm

Projectile Mass (incl. sabot): 5.7 kg

Subprojectile Diameter: 55mm
Subprojectile Length: 223mm
Subprojectile Mass: 4.13 kg

Source for dimensions: (Link)

Core Material: Tungsten carbide
Core Diameter: 50mm
Core Length: 120mm
Core Mass: 2.82 kg

Point-blank ranges:

For a target height of 2.0 m - 1,680 m
For a target height of 2.7 m - 1,930 m
For a target height of 3.0 m - 2,020 m

Penetration at 2.0 km:

290mm at 0°
80mm at 60°

All information from official instructional booklet on 3BM8 and 3BK5.

As seen in the viewfinder of the TShSM-32P sight, APDS ammunition was a huge improvement over the old full-caliber steel AP rounds. According to V.A Grigoryan in "*Защита танков*" (Download), 3BM8 has a muzzle velocity of 1,415 m/s and a velocity of 1,202 m/s at 2 km. The rate of velocity decay from this data amounts to 106.5 m/s per kilometer. In comparison, 105mm L28 APDS with a muzzle velocity of 1,478 m/s has a velocity of 1,381 m/s at 1 kilometer, implying a rate of velocity decay of 97 m/s per kilometer. Given that the rate of velocity decay increases with distance, the aerodynamic performance of 3BM8 can be considered functionally identical to L28 and also to the L36 and L52 which share the same ballistic shape as L28.

The tables below are taken from page 205 of "*Particular Questions of Terminal Ballistics*" 2006 (*Частные Вопросы Конечной Баллистики*) published by Bauman Moscow State Technical University on behalf of NII Stali. The first column from the left indicates that 3BM8 is the tested projectile and the next three columns from the left list the spaced armour configurations: b1 and b2 denote the thickness of the first and second plates in millimeters, and L denotes the size of the air gap in millimeters. The fourth column from the right lists the velocity limit of 3BM8 for the described spaced armour configuration, and the third column from the right lists the velocity limit for a monolithic plate of the same thickness in steel (b1 + b2). The difference in the velocity limit is listed in the second column from the right. The first column on the right shows the difference in the velocity limits between the spaced armour configuration and a monolithic RHA plate in percentage points, and also represents the improvement in mass efficiency. For example, in the table below for spaced armour targets at a 0 degree obliquity, 3BM8 can defeat a 150-300-90 spaced armour design angled at 0 degrees at an impact velocity of 1,215 m/s, whereas a monolithic 240mm plate (150 + 90) can be defeated at a velocity of 1,050 m/s. The difference in velocity limits amounts to 15.7%, showing that the spaced armour is 15.7% more effective than a monolithic armour plate of the same mass. In terms of distance, a velocity of 1,215 m/s corresponds to a distance of 2 km and a velocity of 1,050 m/s roughly corresponds to a distance of 3.4 km.

Фактическая стойкость стальной ДБ с различными соотношениями толщин первой и второй преград и разными МПР при $\alpha = 0°$ по сравнению со стойкостью РМБ

Калибр, индекс снаряда	Преграда			$V_{ПКП}^{ДБ}$, м/с	$V_{ПКП}^{РМБ}$, м/с	$\Delta V_{ПКП}$, м/с	$\Delta \bar{V}_{ПКП}$, %
	b_1, мм	L, мм	b_2, мм				
100 мм, 3БМ8	45	300	90	844	750	94	12,5
	150	300	90	1215	1050	165	15,7
	45	300	150	984	930	54	5,8
	90	300	150	1180	1050	130	12,4
	150	300	150	1375	1210	165	13,6
	45	1750	180	1428	1010	—	—

The table below shows the velocity limit of 3BM8 on similar spaced targets but at an angle of 30 degrees. From the table below, it can be seen that the effect of increasing the thickness of the spaced plate from 20mm to 50mm to 90mm while maintaining the same amount of spacing and the same 150mm RHA back plate causes a negligible increase in the effectiveness of the spaced armour in terms of mass efficiency: only from 21.5% to 22.5%. Of course, in real terms, the use of a 90mm front plate makes the sloped spaced armour effectively immune to 3BM8 at point blank range whereas a monolithic plate with a thickness of 240mm (90 + 150) under the same conditions could be defeated at a velocity limit of 1,160 m/s, which translates to a distance of roughly 2.5 kilometers. Overall, it can be seen that the increasing the thickness of the back plate of a spaced armour design has a much larger effect than increasing the thickness of the front plate for spaced armour sloped at 30 degrees.

Таблица 4.3

Фактическая стойкость стальной ДБ с различными соотношениями толщин первой и второй преград и разными МПР при $\alpha = 30°$ по сравнению со стойкостью РМБ

Калибр, индекс снаряда	Преграда			$V_{ПКП}^{ДБ}$, м/с	$V_{ПКП}^{РМБ}$, м/с	$\Delta V_{ПКП}$, м/с	$\Delta \overline{V}_{ПКП}$, %
	b_1, мм	L, мм	b_2, мм				
100 мм, 3БМ8	20	300	50	640	560	80	14,3
	90	300	50	900	875	25	2,9
	90	300	80	1080	975	105	10,8
	20	300	150	1185	975	210	21,5
	50	300	150	1280	1045	235	22,5
	90	300	150	1420	1160	260	22,4

This analysis is reinforced by shooting results at 30 degree targets with 122mm 3BM11, which has the same projectile design as 3BM8 and only differs in the increased muzzle velocity when fired out of a 122mm cannon. As seen in the table, the use of a 200mm back plate with a spaced 20mm front plate and a 350mm air gap results in a 42.1% increase in mass efficiency. The use of a spaced 10mm front plate with an 80mm air gap and a 140mm back plate yields practically no improvement in mass efficiency whatsoever, which is the opposite of the expected result for an L28 round. Experiments conducted with L28A1 imitators and L28A1 scale models also showed that the design was highly sensitive to spaced armour. It was shown that a 20-300-50 spaced armour design sloped at 30 degrees yielded a 62.8% increase in mass efficiency, which is quite large compared to the 14.3% increase when 3BM8 was shot at the same target. VK-12 tungsten carbide was used for the L28A1 imitators. VK-12 has a 12% cobalt binder instead of the normal 8% nickel binder of VN-8.

122 мм, 3БМ11	20	350	200	1563	1100	463	42,1
	20	675	200	1552	1100	452	41,0
	90	0	150	1170	1160	10	0
	90	80	150	1370	1160	210	28,1
	90	420	150	1440	1160	280	24,1
	90	420	140	1380	1130	250	22,1
	90	650	140	1580	1130	450	39,8
	20	85	140	1090	940	150	16
	20	750	140	1154	940	214	22,8
	10	80	140	930	920	10	0

The table below shows the velocity limits of 3BM8 for a target angled at 60 degrees in the same format. The data below is obviously quite significant in determining the capabilities of 3BM8 against simple spaced armour such as the type found on upgraded Leopard 1 tanks, but useful data on the velocity limits for monolithic plates is also given. According to the table, the velocity limit for a 100mm monolithic plate (from the table: 20 + 80) is 1,220 m/s, corresponding to a target distance of just under 2 km. Also, the velocity limit for a monolithic 85mm plate (from 40 + 45) is 1,125 m/s which corresponds to a distance of between 2.5-3.0 km, and the velocity limit for a monolithic 90mm plate (10 + 80) is 1,160 m/s, corresponding to a distance of between 2.0-2.5 km. From this data, the 80mm penetration figure for a 60 degree target at 2 km appears to be a guaranteed or a minimum penetration figure and the actual achievable penetration can be much higher at the same distances.

Regarding the optimization of the spaced armour designs, it can be seen that the most effective configuration in real terms is the 20-300-80 array, which can only be defeated from near-point blank range (velocity limit of 1,400 m/s). However, the most efficient configuration is the 20-300-45 array, which had a 21.1% mass efficiency advantage over a monolithic armour plate of the same mass. However, the 20-300-45 armour could be defeated at a velocity limit of 1,150 m/s and a 65mm plate (20 + 45) could be defeated at a velocity limit of 950 m/s, corresponding to distances of roughly 2.5 km and 4.4 km respectively.

Таблица 4.4

Фактическая стойкость стальной ДБ с различными соотношениями толщин первой и второй преград и разными МПР при $\alpha = 60°$ по сравнению со стойкостью РМБ

Калибр, индекс снаряда	Преграда			$V_{ПКП}^{ДБ}$, м/с	$V_{ПКП}^{РМБ}$, м/с	$\Delta V_{ПКП}$, м/с	$\Delta \overline{V}_{ПКП}$, %
	b_1, мм	L, мм	b_2, мм				
100 мм, 3БМ8	20	300	80	1400	1220	180	14,8
	20	300	45	1150	950	200	21,1
	40	300	45	1207	1125	82	7,3
	30	300	45	1150	1050	100	9,5
	10	1300	80	1255	1160	95	8,2
	10	1300	80	1220	1160	60	5,1
	10	1300	80	1157	1160	0	0

The graph below illustrates the change in velocity limit for changes in the thicknesses of the first and second spaced plates. The thickness of the first plate is alternatively expressed in terms of the ratio of the thickness to the diameter of the tungsten carbide core.

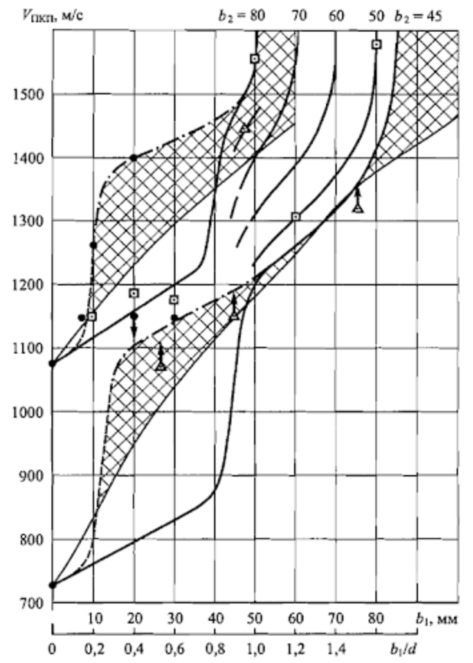


Рис. 4.27. Зависимости фактической стойкости стальной двухпреградной брони по сравнению со стойкостью равномассовой монолитной брони при воздействии штатных 3БМ8 (•) и 3БМ11 (3БМ7) (▲) и модельных 3БМ8 (▣) снарядов ($\alpha = 60°$, $L = 300$ мм). *Заштрихованная область* — прирост стойкости

Although higher than the more commonly cited figure of 80mm at 60 degrees at 2 kilometers, the penetration figures for a 60 degree plate from "*Particular Questions of Terminal Ballistics*" still fall short of the claimed performance of the 105mm L52 APDS round from the early 70's (reportedly entered service in 1973 in the U.K, 1974 in the U.S in the form of M728), which is comprised of a tungsten alloy core with a steel armour piercing cap and can reportedly perforate 120mm RHA at 60 degrees at a distance of 1,830 meters (according to a marketing brochure) and penetrate 250mm RHA at 0 degrees at 1,000 meters (according to Janes'). The use of soft but tough tungsten alloy core in the L52 instead of a tungsten carbide core with exceptionally high hardness but low toughness was aimed at improving the performance of the round on non-monolithic targets, particularly simple dual-layered spaced targets. An increase in performance on oblique targets was also obtained. This improved performance came at the cost of reduced performance on monolithic RHA targets, which is reflected in the penetration figures mentioned earlier - 250mm RHA at 0 degrees at 1 km for L52, and 290mm RHA at 0 degrees at 2 km for 3BM8.

The merits of the increased performance on sloped and non-monolithic targets are self-evident. At the time, all of the known Soviet medium and heavy threats incorporated heavily sloped armour and there was no indication that Soviet armour designs would trend towards thick and flat homogeneous steel plating in the near future. Similarly, the newest NATO tanks as of 1967 - namely the M60A1 and the Chieftain - also relied heavily on the complex oblique ballistic shaping of their cast hulls and turrets. The design of the 3BM8 penetrator was unsuited for such targets, which is indicative of a large technological gap between the USSR and the West. That said, the side armour of any NATO tank could be defeated by 3BM8 from a high angle of incidence.

Aside from that, it is clear that 3BM8 boasts greatly improved penetration power compared to the dated all-steel BR-412B and BR-412D rounds at all angles of obliquity, but it could be argued that the primary benefit of the APDS round was the enhanced probability of achieving a hit on faraway targets and especially moving targets. This advantage carries more weight than the increased penetration power, as despite the increased armour piercing performance, the challenge of defeating the frontal armour of contemporary tanks like the M60A1 and Chieftain would practically insurmountable. If the T-54/55 hoped to defeat these formidable foes from the front in the 1961-1975 time frame, it could only do so with HEAT ammunition.

3UBM7
3BM19

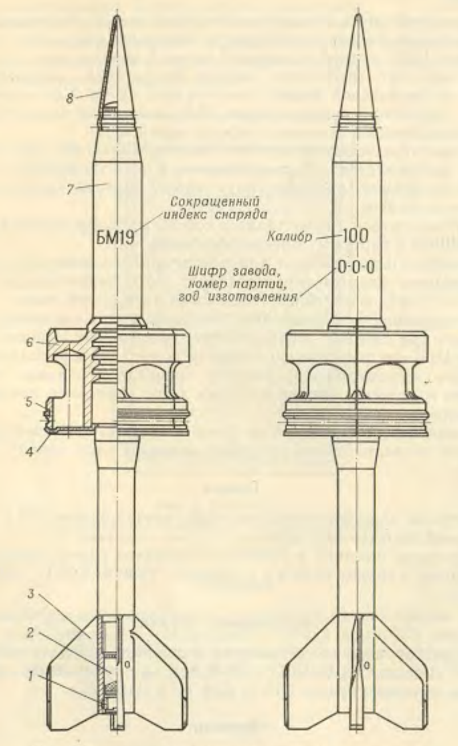


Рис. 4. Бронебойный оперенный подкалиберный снаряд. Маркирование:

1 — гайка трассера; 2 — трассер; 3 — стабилизатор; 4 — резиновая прокладка; 5 — медный поясок; 6 — ведущее кольцо; 7 — корпус; 8 — баллистический наконечник

3BM19 is a pure steel projectile. Its torpedo shape is indistinguishable from contemporary APFSDS rounds in the 115mm and 125mm calibers. The increased speed of the shell compared to even 3BM8 APDS enables the T-55 to engage targets with much greater confidence. With a battlesighting range of 1690 meters against a 2-meter high target, it is possible for the gunner to lay his gunsights on the bottom part of the silhouette of an enemy tank and expect a successful hit at any range within 1700 meters.

The three piece sabot differed significantly from the usual "ring" type sabot for the smoothbore 115mm and 125mm guns. It was purpose-built for the D-10 family of guns, and had some special features to ensure that round could operate normally with rifling.

The back end of the sabot was lined with a sheet of rubber. When the projectile assembly is being propelled through the barrel, the high energy gasses pushing on the back of the sabot causes the rubber to expand and form a gasket to seal the gap between the rifling lands and grooves. This prevents the propellant gasses from exiting the barrel before the projectile.

The single copper driving band on the sabot is loosely connected to the rest of the sabot. It is meant to engage the rifling on the barrel, but the friction between it and the sabot is not great enough to cause the sabot to spin. The driving band supplements the rubber gasket in sealing the bore to prevent the escape of propellant gasses ahead of the projectile.

There is only one copper driving band on the sabot, but make no mistake, there are two contact points with the barrel. This is proven by the lack of copper bearings on the ends of the stabilizer fins. Therefore, the two contact points must be on the sabot itself. The second contact point is the band-less segment of the sabot. It only contacts the lands of the rifling, never with the grooves. This is not optimal, as aluminium alloy is very soft but still harder than pure copper.

Weight of Complete Cartridge: 19.5 kg

Projectile Mass: 4.58 kg

Odd as it might seem, 3UBM7 APFSDS is lighter than 3UBM6 APDS. The reduction in weight further lightened the loader's burden, but conversely, the greater length of the cartridge made it harder to manipulate inside the confines of the T-54.

3UBM8
3BM20

BM20 is externally similar to the BM19, but it has a tungsten carbide core and armour piercing cap in the same configuration as the 125mm 3BM15. This is immediately obvious when the cross section of the tip of the projectile is inspected (shown below). The design of the armour piercing cap of 3BM20 gives it far superior performance on sloped targets compared to the obsolete BM8 APDS round.

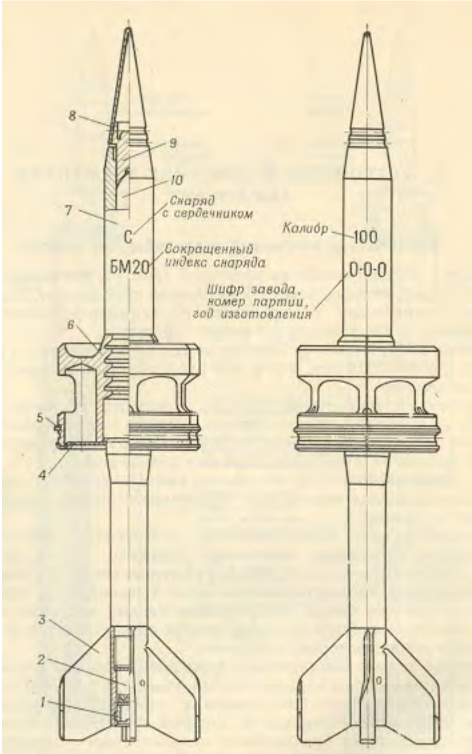


Рис. 3. Бронебойный оперенный подкалиберный снаряд. Маркирование:

1 — гайка трассера; *2* — трассер; *3* — стабилизатор; *4* — резиновая прокладка; *5* — медный поясок; *6* — ведущее кольцо; *7* — корпус; *8* — баллистический наконечник; *9* — демпфер-локализатор; *10* — сердечник

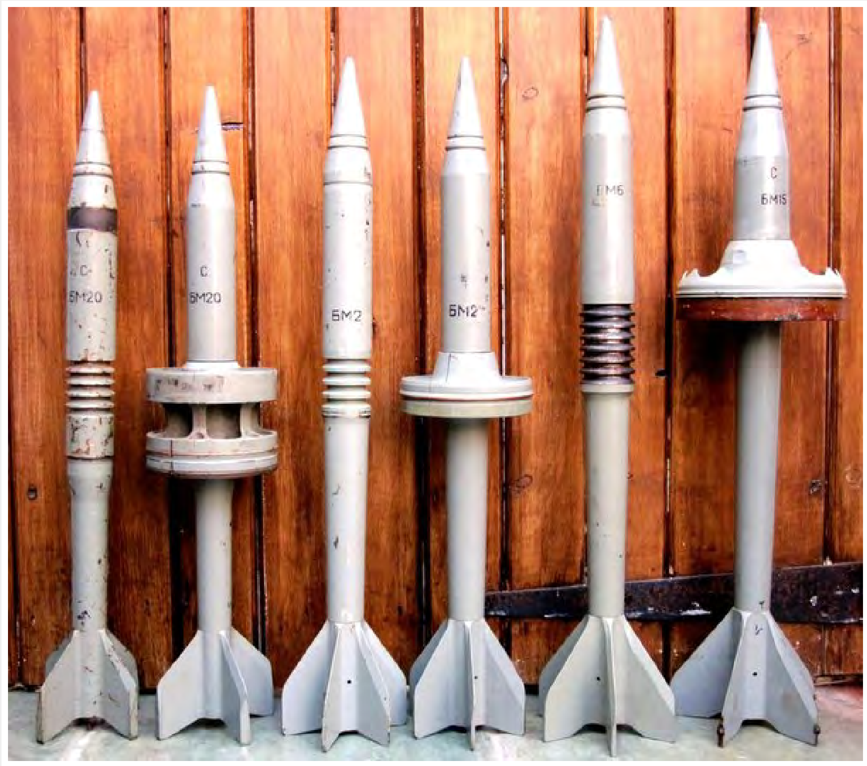
Penetrator Mass: 0.17 kg

Projectile Mass: 4.58 kg
Projectile Diameter: 38mm
Projectile Length: 496mm

Core Material: VN-8 Tungsten carbide

Penetration at 2 km:
240mm at 0°

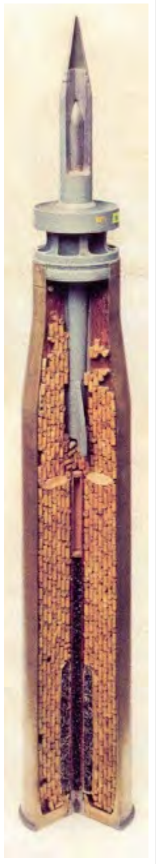
The penetration power of BM20 is practically identical to BM8 on a flat target at two kilometers, but BM20 performs much better on sloped targets at all ranges. Most importantly, BM20 uses only 170 grams of tungsten - only 5.7% the amount used in the BM8. In economic terms, BM20 is an exemplary war winning design. The length of the BM20 projectile is 496mm which is close to the 508mm length of the BM2 projectile for the MT-12 towed anti-tank gun, but it is shadowed by the larger 115mm BM6 projectile and the 125mm 3BM15 projectile, as shown in the photo below.



3UBM11
3BM25 "Izomer"

3UBM11 was formally introduced in 1978, but mass production had been underway since around 1975 or 1976. The order for the modernization of anti-tank munitions for anti-tank guns of the 100mm to 125mm calibers was issued in 1972, and led to the creation of 3BM25 "Izomer" alongside 3BM21 "Zastup for the 115mm U-5TS tank gun, 3BM24 "Kalach" for the 100mm T-12 and MT-12 towed anti-tank guns and 3BM22 "Zakolka" for the 125mm D-81T tank gun. The three-piece sabot was carried over from the 3BM-19.

The internal construction of "Izomer" is identical to the other APFSDS rounds in the 100-125mm range of calibers. A VN-8 tungsten carbide core is located at the tip of the projectile, behind a VNZh-90 tungsten alloy armour-piercing cap. The remainder of the projectile is made from 35KhZNM tool steel. The 0.27 kg VN-8 tungsten carbide core is the same as the one used in 125mm APFSDS rounds, which is larger than the 0.17 kg core used in 3BM20. The cross section of the projectile shown below shows the large tungsten alloy armour piercing cap with its blunt tip.



In terms of length and diameter, the 3BM25 projectile appears to be very close to the 3BM20 projectile if not identical. Like its predecessor, the 3BM25 projectile has four stabilizer fins.

Total Length: 978mm
Total Mass: 20.7 kg
Mass of Projectile: 5.02 kg

Core Material: VN-8 Tungsten carbide
Core Diameter: 20mm
Core Length: 71mm

Muzzle velocity: 1430 m/s

Information from "*Оружие России (2001-2002)*".

The change in muzzle velocity of the shell with temperature is tabulated here:

Muzzle Velocity	Temperature
1430 m/s	+15° C
1466 m/s	+40° C
1364 m/s	-40° C

It is interesting to note that the mass of the projectile is slightly greater than the 125mm 3BM22 projectile (5.02 kg vs 4.86 kg) and that the dimensions of both rounds are roughly comparable, but the rate of velocity loss for 3BM25 is lower than 3BM22 due to the smaller stabilizing fins. However, the velocity of 3BM25 at the muzzle is only equivalent to the velocity of 3BM22 at a distance of 2,700 meters due to the lower chamber pressure of the dated D-10T gun. Based on the expected impact velocity, the penetration of 3BM25 at the muzzle can be estimated to be around 400-450mm RHA at 0 degrees, and the penetration at 1 km can be estimated to be between 380-430mm RHA at 0 degrees. The penetration on a steel target with a 60 degree slope is harder to estimate, but based on the performance of 3BM22, it can be assumed that 3BM25 will also have a similar drop in penetration. It is estimated that the penetration of 3BM25 on a 60 degree target will be around 150mm RHA at 1 km.

HEAT

The use of shaped charge ammunition is often viewed as an equalizing factor that virtually invalidated all tank armour for a large part of the Cold War. However, this is only a half-truth. HEAT ammunition was a convenient alternative to conventional steel and subcaliber armour-piercing rounds, but was not a substitute. In fact, throughout the service life of the T-54 and 55, only 6 rounds were carried out of a total load of 34 and 43 rounds respectively. When the ammunition capacity of the tank increased with the introduction of the T-55, the number of HEAT rounds did not increase whereas the number of full caliber steel armour piercing rounds increased from 12 to 15 rounds, the ratio of HEAT rounds to other rounds actually fell. This contradicts the widespread belief that the Soviet army preferred HEAT rounds over KE rounds, and instead shows that the opposite is true.

Only the French army can be considered to have viewed HEAT ammunition as a universal replacement for all other armour-piercing ammunition types, as the unusual Obus-G HEAT round was the only anti-armour round available to AMX-30 tanks for a considerable length of time. However, it was eventually accepted that HEAT was not only a non-optimal anti-tank round, but that the Obus-G design itself was critically flawed in that it had a high cost due to the high tolerance requirements, but low penetration power and an accuracy advantage that was too minor to be worth the tradeoff.

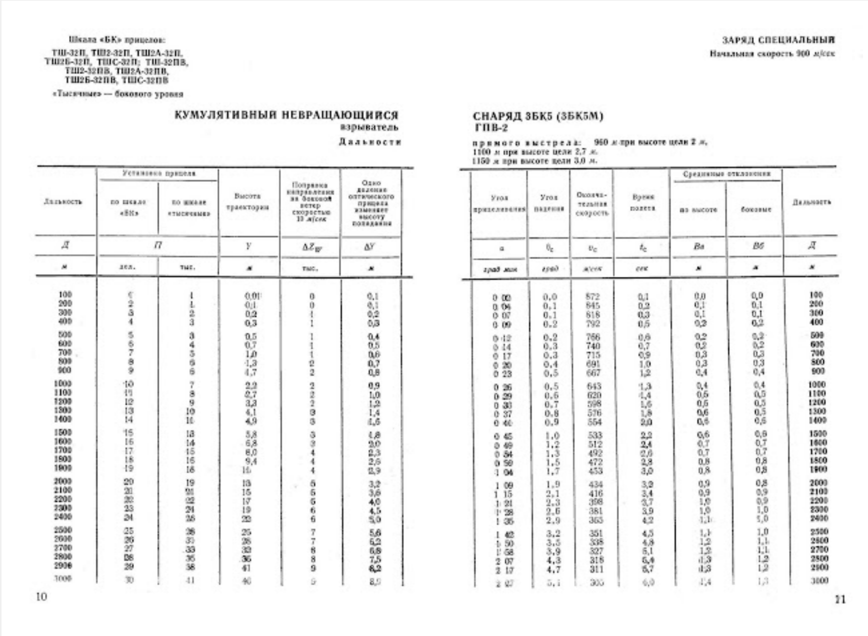
That said, HEAT ammunition was valuable for the T-54 as it allowed it to reliably defeat the frontal armour of the M60A1 and the Chieftain at any distance, assuming that it could score a hit.

3UBK4, 3UBK4M
3BK5, 3BK5M

The first HEAT round design for the D-10T, introduced in 1961. The appearance of this round coincided with the appearance of the heavily armoured M60A1 tank. 3BK5 had more than enough penetration power to defeat the strongest parts of the M60A1 and still retain enough residual penetration to be able to eliminate the crew and destroy important equipment.

Photo credit to PzGr40 of the wk2ammo site

The advantage of 3BK5 over typical armour piercing rounds is slightly offset when taking the poorer ballistic properties of the shell into consideration. Although the shell has a muzzle velocity that is slightly higher than BR-412B and BR-412D armour-piercing shells, it was significantly lighter so the shell carried less kinetic energy as well as momentum which is more important in this context. This means that it slows down more rapidly from aerodynamic drag, which is compounded by the higher drag from the stabilization fins, leading to a larger drop in velocity over distance. As the firing table below shows, the point blank range of 3BK5 is consistently shorter at all distances compared to BR-412B and BR-412B. It also becomes subsonic at a range of 2,550 meters whereas the firing table for BR-412B/D ends at 4,000 meters with the shell still maintaining a velocity of 545 m/s.



Шкала «БК» прицелов:
ТШ-32П, ТШ2-32П, ТШ2А-32П,
ТШ2Б-32П, ТШС-32П; ТШ-32ПВ,
ТШ2-32ПВ, ТШ2А-32ПВ,
ТШ2Б-32ПВ, ТШС-32ПВ
«Тысячные» — бокового уровня

ЗАРЯД СПЕЦИАЛЬНЫЙ
Начальная скорость 900 м/сек

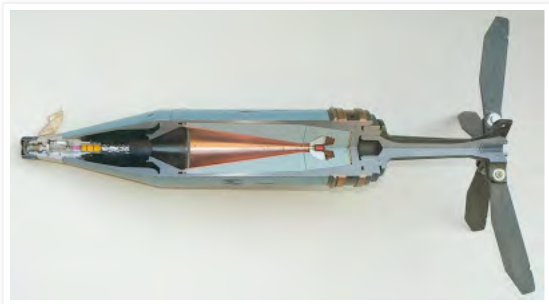
КУМУЛЯТИВНЫЙ НЕВРАЩАЮЩИЙСЯ **СНАРЯД 3БК5 (3БК5М)**
взрыватель ГПВ-2
Дальности прямого выстрела: 960 м при высоте цели 2 м,
1100 м при высоте цели 2,7 м,
1150 м при высоте цели 3,0 м.

Дальность	Установка прицела: по шкале «БК»	по шкале «тысячные»	Высота траектории	Поправка направления на боковой ветер скоростью 10 м/сек	Одно деление оптического прицела изменяет высоту попадания
Д	П		У	ΔZ_W	ΔУ
м	дел.	тыс.	м	тыс.	м
100	1	1	0,01	0	0,1
200	2	1	0,1	0	0,1
300	3	2	0,2	1	0,2
400	4	3	0,3	1	0,3
500	5	3	0,5	1	0,4
600	6	4	0,7	1	0,5
700	7	5	1,0	1	0,6
800	8	6	1,3	2	0,7
900	9	6	1,7	2	0,8
1000	10	7	2,2	2	0,9
1100	11	8	2,7	2	1,0
1200	12	9	3,3	2	1,2
1300	13	10	4,1	3	1,4
1400	14	11	4,9	3	1,6
1500	15	13	5,8	3	1,8
1600	16	14	6,8	3	2,0
1700	17	15	8,0	4	2,3
1800	18	16	9,4	4	2,6
1900	19	18	11	4	2,9
2000	20	19	13	5	3,2
2100	21	21	15	5	3,6
2200	22	22	17	6	4,0
2300	23	24	19	6	4,5
2400	24	26	22	6	5,0
2500	25	28	25	7	5,6
2600	26	31	28	7	6,2
2700	27	33	32	8	6,8
2800	28	35	36	8	7,5
2900	29	38	41	9	8,2
3000	30	41	46	9	8,9

Угол прицеливания	Угол падения	Окончательная скорость	Время полета	Срединные отклонения: по высоте	боковые	Дальность
α	θ_c	v_c	t_c	Вв	Вб	Д
град мин	град	м/сек	сек	м	м	м
0 02	0,0	872	0,1	0,0	0,0	100
0 04	0,1	845	0,2	0,1	0,1	200
0 07	0,1	818	0,3	0,1	0,1	300
0 09	0,2	792	0,5	0,2	0,2	400
0 12	0,2	766	0,6	0,2	0,2	500
0 14	0,3	740	0,7	0,2	0,2	600
0 17	0,3	715	0,9	0,3	0,3	700
0 20	0,4	691	1,0	0,3	0,3	800
0 23	0,5	667	1,2	0,4	0,4	900
0 26	0,5	643	1,3	0,4	0,4	1000
0 29	0,6	620	1,4	0,5	0,5	1100
0 33	0,7	598	1,6	0,5	0,5	1200
0 37	0,8	576	1,8	0,6	0,5	1300
0 40	0,9	554	2,0	0,6	0,6	1400
0 45	1,0	533	2,2	0,6	0,6	1500
0 49	1,2	512	2,4	0,7	0,7	1600
0 54	1,3	492	2,6	0,7	0,7	1700
0 59	1,5	472	2,8	0,8	0,8	1800
1 04	1,7	453	3,0	0,8	0,8	1900
1 09	1,9	434	3,2	0,9	0,8	2000
1 15	2,1	416	3,4	0,9	0,9	2100
1 21	2,3	398	3,7	1,0	0,9	2200
1 28	2,6	381	3,9	1,0	1,0	2300
1 35	2,9	365	4,2	1,1	1,0	2400
1 42	3,2	351	4,5	1,1	1,0	2500
1 50	3,5	338	4,8	1,2	1,1	2600
1 58	3,9	327	5,1	1,2	1,1	2700
2 07	4,3	318	5,4	1,3	1,2	2800
2 17	4,7	311	5,7	1,3	1,2	2900
2 27	5,1	305	6,0	1,4	1,3	3000

10 11

There are two variants of the 3BK5 shell. One is the basic 3BK5, which had a steel liner, and the other is the 3BK5M, which had a wave shaper and a copper liner. The wave shaper was a block of inert material that controlled the propagation of the blast wave to optimize the formation of the cumulative jet of the shaped charge. 3BK5M had improved penetration power. Both the 3BK5 and 3BK5M were introduced simultaneously in 1961.



Fuse: GPV-2 PIBD

Muzzle Velocity: 900 m/s

Total Mass of Cartridge: 25.5 kg
Mass of Projectile: 12.38 kg
Mass of Explosive Charge: 0.990 kg (3BK5), 1.038 kg (3BK5M)

Penetration (at all ranges):

180mm RHA at 60 degrees
390mm RHA at 0 degrees

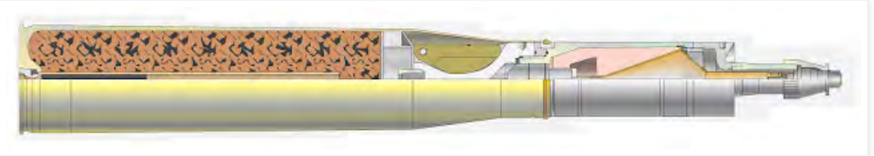
Chamber Pressure: 235.36 MPa

Point-blank ranges:

For a target height of 2.0 m - 960 m
For a target height of 2.7 m - 1,100 m
For a target height of 3.0 m - 1,150 m

With each cartridge weighing in at just 25.5 kg, 3BK5 was easier to load than either AP and HE, but not APFSDS. It is interesting to note that during the famous Yugo tests, 90mm M431 HEAT failed to fuze on the upper glacis of the target T-54 if the tank had a side angle of more than 20 degrees, but there were no such remarks to the same effect regarding the 3BK5. It can be inferred with reasonable confidence that 3BK5 with the GPV-2 fuze can handle steep slopes.

3UBK9, 3UBK9M
3BK17, 3BK17M



Newer HEAT round, entered service in 1978. The penetration power of this new round is higher thanks to the implementation of new liner manufacturing technologies, but it is quite interesting to note that the mass of the projectile was substantially reduced, allowing the round to achieve a substantially higher muzzle velocity. The increase in muzzle velocity is helpful when engaging moving targets at a distance, but the magnitude of the improvement in hit probability is not likely to be major

Total Length of Cartridge: 1,093mm
Total Mass of Cartridge: 21.9kg
Mass of Projectile: 10.0 kg

Muzzle velocity: 1,085m/s

Projectile Mass: 10 kg

It is worth noting that the short spike tip of the 3BK17/M round has a protruding ring just behind the tip of the fuse. This is to eliminate an aerodynamic phenomenon known as dual flow, which greatly increases the drag coefficient of the projectile during high velocity flight. However, it is particularly interesting that the 115mm 3BK-15 "Zmeya" round that was designed under the same developmental program as "Ikra" lacks this ring. The ballistic properties of spike tip designs is explored in Tankograd's T-62 article.

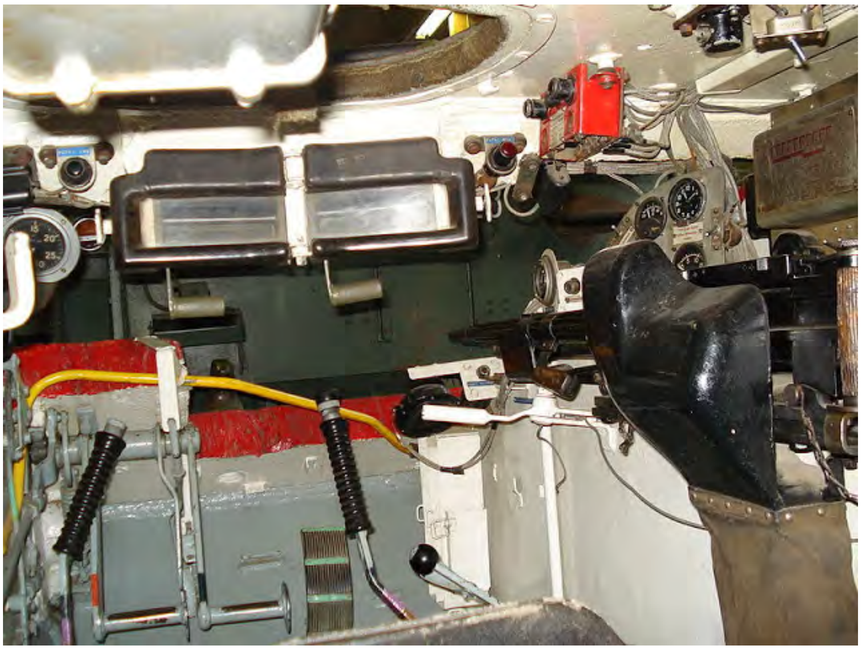
CO-AXIAL MACHINE GUN

The T-54 mounts the SGMT on the right side of the main gun as a co-axial weapon. It has a cyclic rate of fire of 600 rounds per minute, and it is fed from a 250-round box of which ten more are stowed inside the tank for a total of 2,750 rounds of ammunition. The SGMT could be fired with the trigger button on the elevation handwheel or the left trigger button on the gunner's handgrip on the T-54A and all subsequent models. Firing the machine gun is also possible with the solenoid trigger button attached to the back of a receiver in case of a total failure of the tank's electrical systems.

In 1964, the SGMT was swapped out for the PKT machine gun. The two were practically indistinguishable in ballistic performance, but the PKT fires at a higher cyclic rate of 800 rounds per minute. Ball and AP-I is linked with API-T in a 4:1 ratio.

BOW MACHINE GUN

The T-54 has a fixed SGMT machine gun mounted just to the right of the driver (pictured below). This was not unusual in any way, especially considering the roots of the design of the tank. However, what is unique to the T-54 is that there is a bow machine gun, but no dedicated bow machine gunner as the SGMT is aimed and fired by the driver. In this sense, the T-54 was a more forward-thinking design than tanks like the M46 while also being a more silly one.

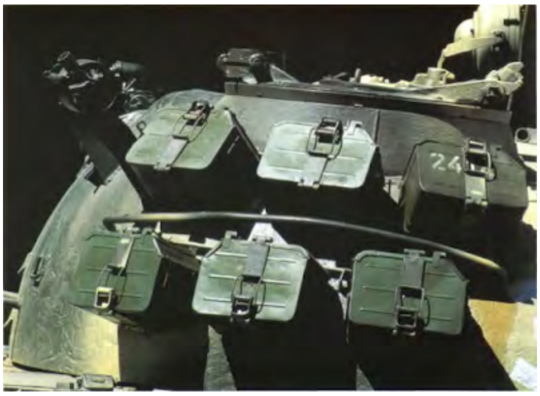


Ammunition is supplied by a 250-round box mounted to the right of the gun. Spent ammo belts and casings are ejected into a deflector and fall into a canvas collection bag placed just below the machine gun. Reloading the machine gun is the driver's duty. It is fired using a solenoid thumb trigger on the end of the right steering tiller, but there is no way to aim it at all, other than by steering the tank. It doesn't take much imagination to figure out how effective this would have been in combat. One plausible use for the bow machine gun is for the driver to suppress the area directly in front of the tank without aiming for no other reason than to induce panic in enemy forces by sheer volume of fire. In practice, the ammunition allocated to the bow machine gun probably would be used up by the coaxial machine gun instead.

ANTI-AIRCRAFT MACHINE GUN

The original T-54-1 (T-54 obr. 1947) was a departure from the WWII-era policy for medium tanks in that it had a DShKM anti-aircraft machine gun installed on its roof in a simple skate ring mount. Prior to the T-54, only IS-2 heavy tank had one, and only from November 1944 onward. Medium and light tanks in the Red Army generally did not have external machine guns of any kind unless field modifications were performed whereas American tanks infamously bristled with machine guns, often installed in impractical positions. Beginning with the T-54 obr. 1951 model, the machine gun was relocated to a new mount on the loader's cupola. This design was retained until the T-55 model omitted an anti-aircraft machine gun entirely, but when the T-55A reintroduced the DShKM due to the threat posed by attack helicopters, it was installed on a new loader's cupola with minimal changes to the operating mechanism of the gun mount.

Ammunition was provided in standard 50-round boxes which were stowed outside the turret, on the loader's side. This was so that the loader could easily reach over and retrieve an ammunition box when the machine gun is aimed forward. Although stowing ammunition outside the tank is clearly not an ideal solution as the boxes may be damaged by bullets, blast and fragmentation, there were good reasons for this decision. The most important reason is that there was simply not enough room inside the tank to fit a full load of 300 rounds of 12.7mm ammunition, and another reason is that the loader's hatch is not large enough to permit the easy transfer of the large 50-round boxes from inside the tank to outside. As such, placing the ammunition boxes on the side of the turret was in the best interests of improving the ergonomics of the crew and improving the speed of reloading the anti-aircraft machine gun.



Aiming at ground targets is accomplished with either the standard iron sights on the DShKM or the K-10T anti-aircraft collimator sight. The K-10T facilitates accurate aiming at both ground level and high altitude targets, although the basic leaf sights on the machine gun itself would be more appropriate for aiming at ground targets as it can be adjusted for various distances. The K-10T is offset to the right in order to allow the ladder-type iron sights to be raised for long-distance fire.

One of the drawbacks to the layout of the T-54 turret is that the IR spotlight partially blocks the anti-aircraft machine gun in a narrow 12 o'clock sector in depression. When aiming forward, the tank loader is able to fire straight ahead and apply superelevation for distant targets, but he cannot depress the machine gun more than a few degrees. This was arguably acceptable given that the DShKM was an anti-aircraft machine gun after all, so gun depression was not a high priority. Given that the elevated mounting of the IR spotlight was intended to reduce vertical parallax with the gunner's IR night sight, the drawback of reducing the depression angle of the anti-aircraft machine gun was an acceptable concession and the overall layout represented the best compromise.

PROTECTION

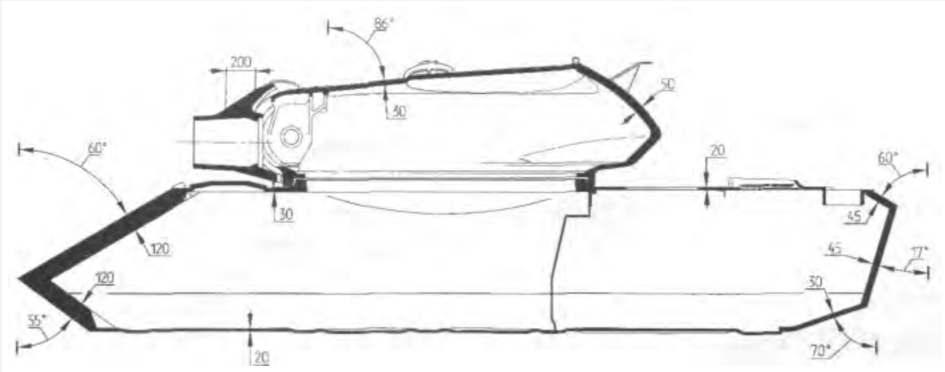
The T-54 was a product-improved version of the T-34, and would assume the same roles as its predecessor, but while the T-34 had become badly outdated by the end of WWII, the progress of technology made the T-54 as fearsome as its predecessor was at the start of Operation Barbarossa, once again returning the USSR to the forefront of tank technology. Production model T-54s had more than two times more armour than the T-34, and prototype models had even more. Original design requirements dictated that the frontal armour had to withstand shots from the 7.5cm L/43 KwK 40 and 8.8cm L/71 KwK 43 which can only be described as a remarkable demand because this was the same requirement for the IS-2, a heavy tank, and also the basic requirement of the IS-3. The specific requirements for the prototype of the T-54, as translated by Peter Samsonov from Tankarchives, are:

1. Determine the armour that will protect the hull and turret from 75 mm and 88 mm shells with the muzzle velocity of 1000 m/s.
2. Improve the shape of the hull from the point of view of robustness and shell resistance.
3. Improve the armour of the turret to the point that it resists shells as well as the front of the hull.
4. Develop armour screens for the T-54 to protect it from HEAT shells up to 105 mm in caliber inclusive and Faust type anti-tank rockets.
5. Develop a robust track and track pin (increase track life to 3000 km).
6. Investigate the optimal location for ammunition in the tank.

The original requirement of the T-54 for protection from the Pzgr. 39 round fired from the 8.8cm Pak 43 or KwK 43 at a muzzle velocity of 1,000 m/s was created because it was expected that the Pak 43 and KwK 43 or an equivalent cannon would become the standard cannon for future German medium tanks while the existing Tiger II heavy tank would eventually be replaced with a new design equipped with a 10.5cm or 12.8cm cannon. Even though the war ended before this became a reality, the requirement was not relaxed.

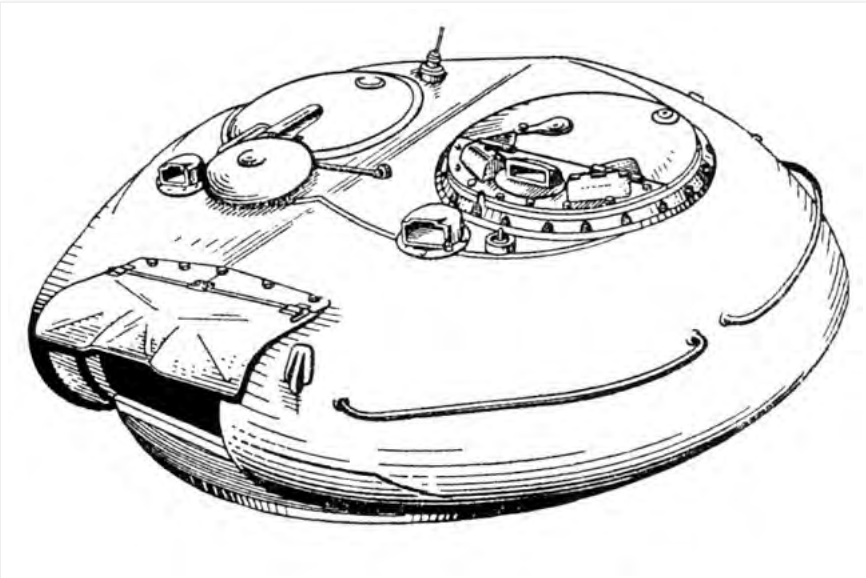
Out of the total weight of 36 tons for a standard T-54 obr. 1951, 18 tons of weight comes from the armoured plating which occupies a 50% share of the total weight of the tank.

T-54-1 (T-54 obr. 1947)

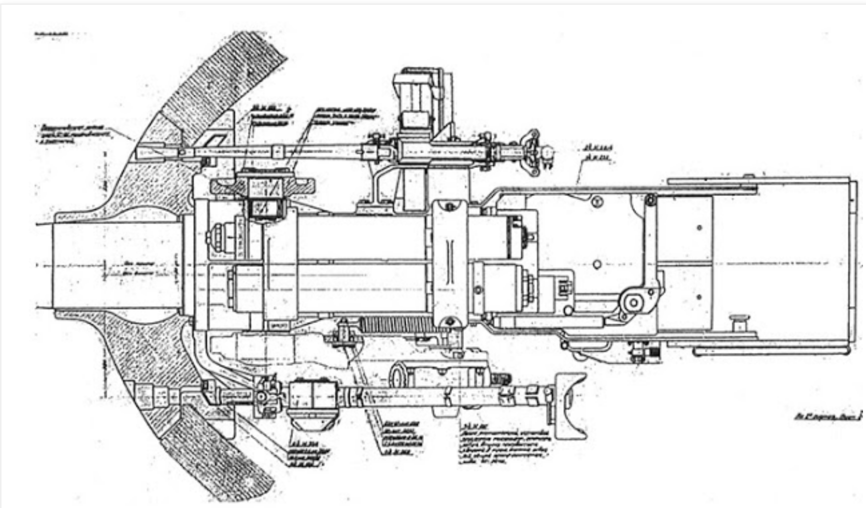


As a result of these requirements, the T-54-1 prototype tank had an upper glacis plate measuring 120mm thick, angled at 60 degrees. This was equal in thickness to the armour of the prototype of the IS-2 (cast 120mm armour sloped at 60 degrees) and thicker in total than the upper glacis of a King Tiger as well as the upper glacis of an IS-2 obr. 1944 (cast 100mm amrour sloped at 60 degrees). Even more remarkably, this also exceeded the thickness of the IS-3 upper glacis as that was only 110mm thick and sloped at a compound angle of 61 degrees for a total LOS thickness of 227mm.

The lower glacis plate was quite formidable as well since it was equally thick as the upper glacis but only slightly less well angled at 55 degrees, while the side armour was 90mm thick. An important detail in the angle of obliquity of the lower glacis armour is that its slope of 55 degrees would have caused the Pzgr. 39 shell to break up reliable upon impact. Tests showed that projectile breakup began to occur at 45 degrees, became quite consistent at 50 degrees, and occurred reliably at angles greater than 50 degrees. In the end, though, the huge mass of armour made the tank too heavy for the engine and the transmission to handle.

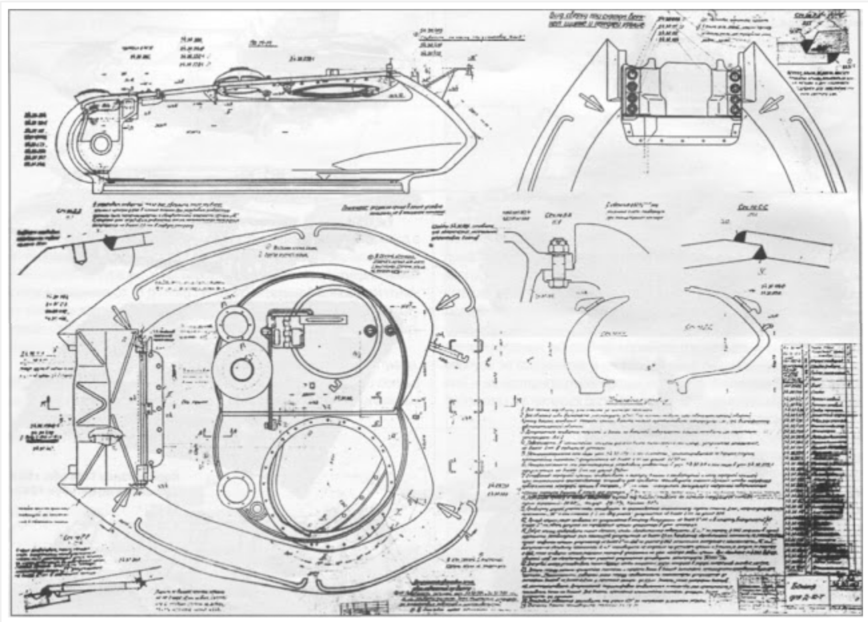


The turret has a very distinct out-of-this-world appearance, but in reality, it is merely a rounded-off reimagination of the hexagonal design of the T-34-85 and T-44 turrets. The overhead photo shown below clearly displays the six sides of the turret, analogous to the T-44 turret. Unlike the later turrets, this design retained the gunshield configuration where the gunsight and co-axial machine gun was fitted. The thickness of the gunshield can be seen in this cross sectional drawing, taken from the manual.

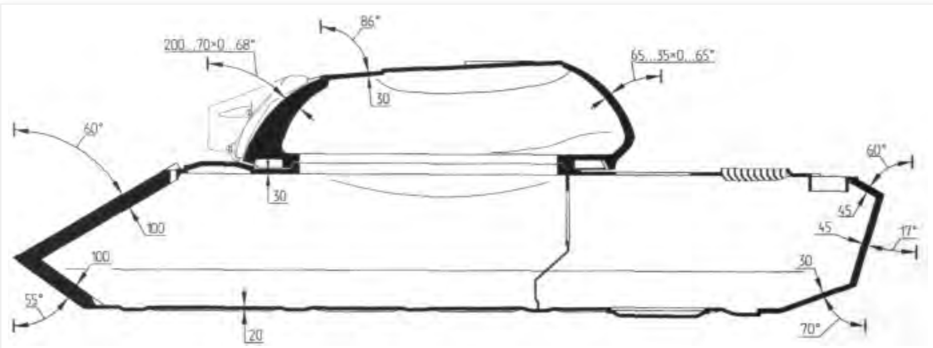


The ballistic shaping of this turret was better than the previous versions, but the large shot traps around the turret ring area was considered a huge liability. Other than that, the good angling of the side cheeks of the turret in combination with the well-rounded gunshield provided good protection. See the photo below (of an abandoned pillbox turret), kindly provided by Vladimir of Urban3p. The photo shows the gunner's station. The hole at the end is for the TSh-20 telescopic gunsight. By comparing the angle of the wall of the turret to the cannon breech, we can see that the horizontal slope of the turret is quite steep. There is not much in the way of vertical slope, but the turret is rounded.

The schematic below shows the layout of the turret.



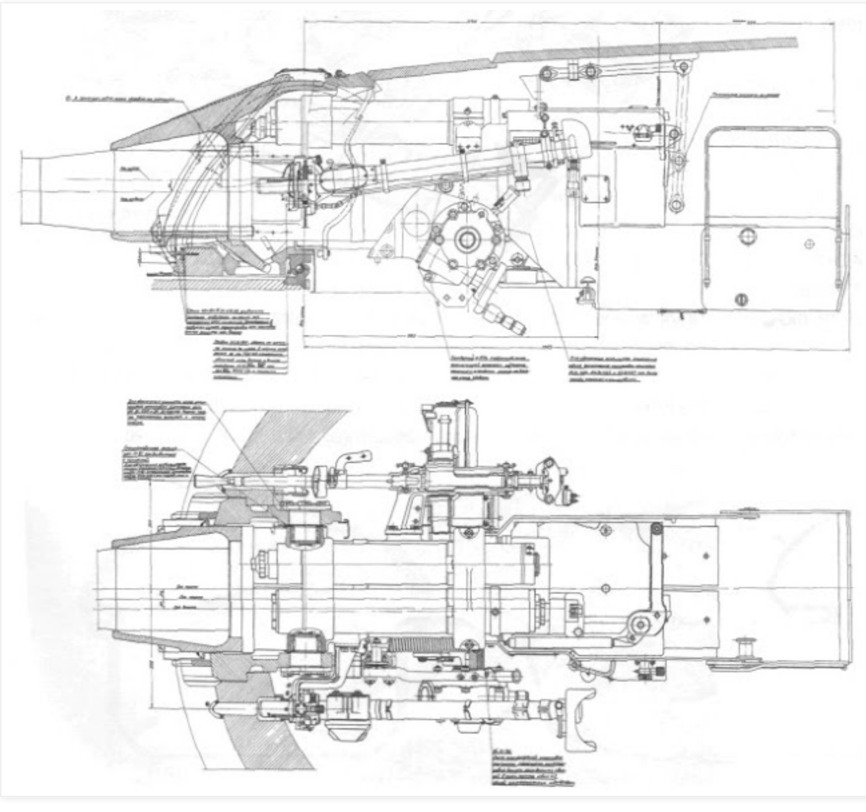
T-54-2 (T-54 obr. 1949)



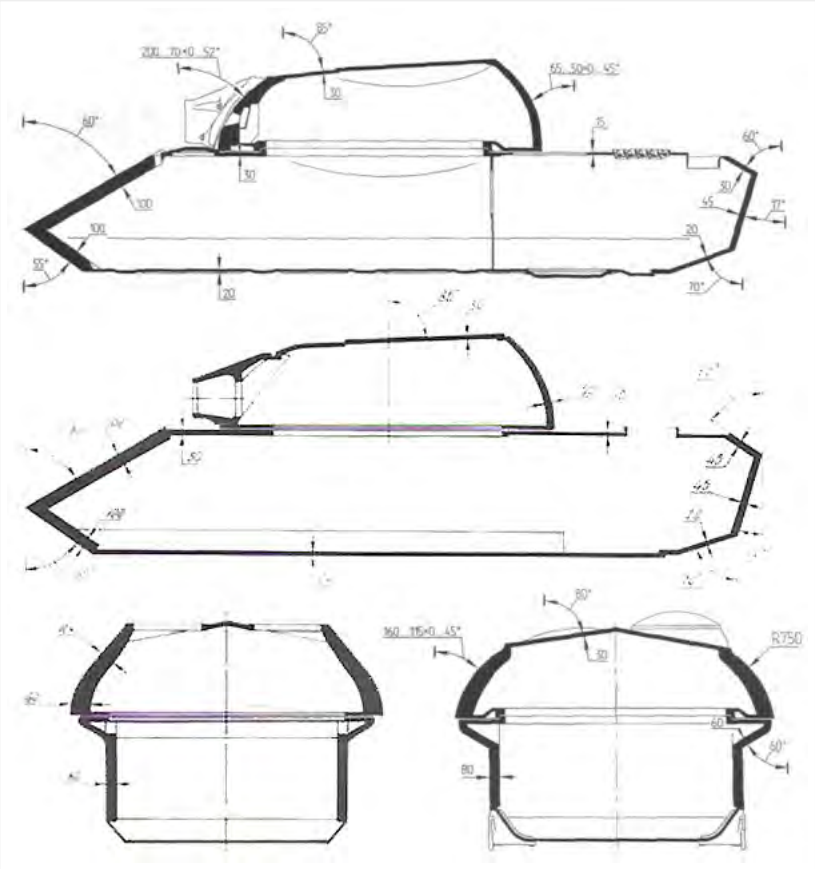
In 1949, the revised T-54-2 arrived with a new turret. Its shape had familiar curves, but it was not quite the same as the final version. The shot traps were reduced, but still extant around the rear of the turret. The thickness of the upper glacis armour was finally reduced to 100mm. The hull side armour was reduced to 80mm. Despite the decreased mass of the frontal hull armour, the level of protection still met the requirements. Having a thickness of 100mm and sloped at 60 degrees, the upper glacis was equal in thickness to the IS-2 obr. 1944 but the crucial difference was that it was made from RHA instead of a high hardness cast steel. As such, the upper glacis of the T-54 obr. 1949 could resist the 8.8cm Pzgr. 39 fired from a Pak 43 or KwK 43 at point blank range whereas the IS-2 obr. 1944 could only resist this round from a distance of more than 450 meters.

Besides the reduction in the hull armour thickness, another significant change was the shift to a mantlet-less turret design. The base of the gun barrel is protected by a simple gun mask that only offers protection against artillery shell splinters and heavy machine gun fire. The gun mask also prevents fragments or bullets from jamming the gun elevation mechanism by becoming lodged between the gun breech block and the turret.

One disadvantage to the lack of a gun mantlet is that a tall slit has to be cut into the armour to accommodate the vertical movement of the co-axial machine gun and the aperture of a telescopic gun sight. As long as a telescopic sight is used, there must be a hole in the armour, but as a gun mantlet moves with the cannon, a gun sight aperture embedded in the mantlet only needs a single, small hole. The relatively large slit in the turret of the T-54 increases the size of the weakened zone. Examples of tanks that possess this weakness besides the T-54 include the Chieftain tank, which has a tall vertical slit in the front of the turret for the co-axial machine gun. The Chieftain bypasses the need for a slit for the gun sights by using a periscopic sight. The slit for the gunner's sight in the left turret cheek is about the size of a child's forearm, while the slit for the co-axial machine gun in the right turret cheek is a bit shorter and located a bit higher on the turret face.



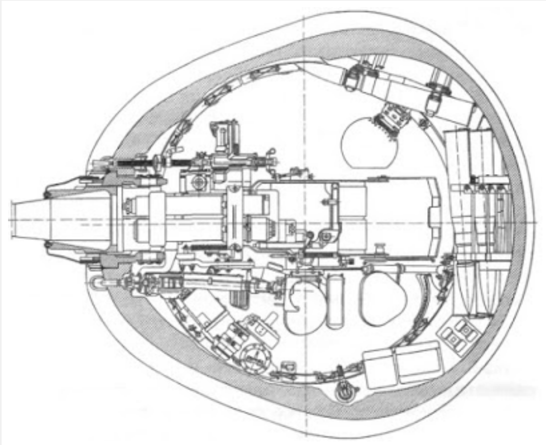
T-54-3 (T-54 obr. 1951 and onwards)



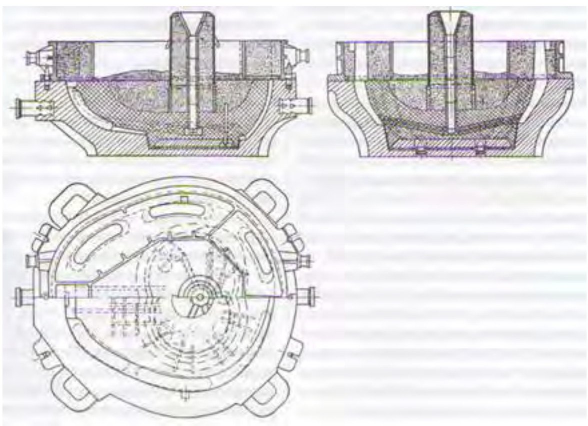
In the year 1951, the T-54 finally gained its iconic rounded turret. The turret has been described in many ways, from "overturned soup bowl" to "hemispherical". In truth, it is a unique shape with complex angles that cannot be summarized easily. From above, it is distinctly egg shaped. From the side, it is more oblong than round. Only from the front does it resemble a perfectly rounded overturned soup bowl. From a frontal perspective, the thickness of the turret is roughly uniform in the vertical axis although the actual physical thickness of the casting varies. However, the horizonal slope of the turret vastly increases the effective thickness of the turret at the edges of the turret silhouette. Roughly speaking, the thickness of the front of the turret ranges from 200mm at an angle of around 0 degrees at the base of the turret to 70mm at an angle of 52 degrees at the top edge of the turret, where the frontal armour transitions to the roof. The sides of the turret are 160mm thick at the base where the angle of the slope is none or negligible, but the side armour thins down to 115mm at the upper edge of the side where the slope is 45 degrees. However, these values are only nominal as the complex shape of the turret makes the actual thickness values difficult to describe. Overall, the high thickness of the armour increases its efficiency against contemporary armour piercing ammunition. For example, *WWII Ballistics: Armour and Gunnery* notes on page 25 that a 195mm cast armour plate with a hardness of 220-300 BHN at an angle of 0 degrees is equivalent to 195mm of rolled homogeneous armour with a hardness of 240 BHN against projectiles in the 50-152mm diameter range, meaning that it is essentially equal to an RHA plate of the same thickness. The commonly cited efficiency coefficient of 0.85-0.95 for cast armour relative to rolled armour is only true for thinner plates in the 50-100mm range.

Like the previous T-54-2 turret, there is no gun mantlet and the gun is only protected by a cast steel gun mask. The shape of the gun mask is very similar to the type used on the T-54-2, but it is unclear if the same mask design was carried over directly.

However, cutouts were made in the armour at the slits for the co-axial machine gun and the gunner's telescopic sights now. This created weakened zones where the armour thickness is substantially less than the advertised 200mm. The cutout is shown in the drawing on the right and the cutout for the co-axial machine gun can be seen clearly in the photo on the left. The photo on the left comes from flickr user solipsistnation. The combination of reduced thickness and the presence of a hole in the armour makes the co-axial machine gun port and the gunner's sight aperture especially weak to anti-tank fire.



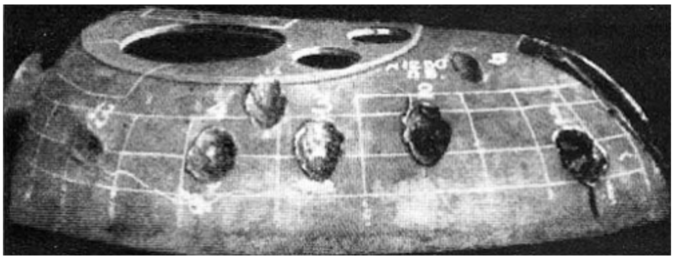
Production turrets were manufactured by chill casting, but there were issues with casting the entire roof along with the rest of the turret in one piece. To fill in the gap, the roof had to be constructed from two D-shaped rolled steel plates, which were welded onto the cast walls in an automated procedure done by a machine rig. This results in a marginally weaker turret compared to a turret made from a single casting as the roof plates might be ripped off at the weld seams or the seams may burst if the roof was struck by glancing cannon fire. However, using rolled steel plates in this location has the benefit of increasing the chance of a ricochet when struck since rolled steel plates invariably have better ballistic properties than cast steel of the same hardness. An illustration of the chill casting mold is shown below.



The welds joining the hull roof to the side hull, and the welds joining the hull roof to the glacis plates and to the floor and all the welds in between were strengthened in the T-54-3 compared to the T-54-2. The geometry of the fittings between the armour plates was changed to increase the surface area between the joints and thus improve the strength of the seams. This helped to improve the armour integrity of the hull and thus improve protection without changing the thickness of the plates. The hull roof is 30mm thick.

The hull and turret were evaluated against anti-tank guns of a myriad of calibers of both domestic and foreign make. The frontal aspect of the tank had to be proofed against common tank guns like the 90mm M3 of the M26 Pershing and the M46, but it was also tested against the tank's own D-10T and the 85mm S-53 of the T-34-85. As the post war reality showed that American 90mm guns would be the main threat to Soviet armour amd not German 88mm guns, the basic requirements for the ability to resist 88mm shells "with a muzzle velocity of 1000 m/s" (referring to PzGr. 39 shell fired from the 88mm KwK 43 L/71) became very convenient as the tank would not have to be uparmoured to deal with the new expected threat. M82 APCBC/HE-T was obtained via lend-lease, and became one of many foreign-made munitions for use in testing.

The photos below show the armour of a T-54-3 pattern model tested against anti-tank weapons of various calibers. Note that the roadwheels are of the spoked type, indicating that the test vehicle is indeed a T-54 obr. 1951, and not a T-54A or T-54B which were fitted with "star" type roadwheels.

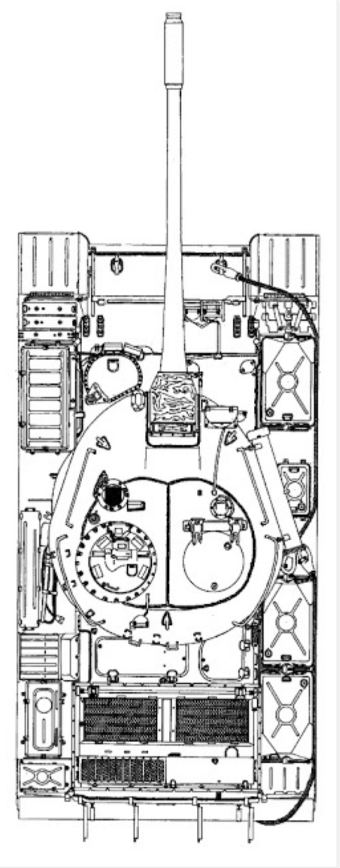


The photo above shows scallops in the turret from various shell impacts and the photos below show the setup of the testing rig for comprehensive turret and hull testing.

The sides of the tank turret and hull were tested just as thoroughly as the front, and with weapons of the same variety. Besides large caliber tank shells, the vulnerability of the sides of the tank to large caliber anti-aircraft cannons like the Soviet Army's own 57mm S-60 was also investigated. It is unknown if the widely used Bofors 40mm L/70 was also tested.

Both the upper and lower glacis plates and the side hull plates are constructed from 42 SM armour grade steel. The rear armour plate and the roof plate was made from 49 S armour grade steel, and the belly of the tank was made from 43 PSM armour grade steel. The cast steel turret was made from 74L CrNiMo armour grade steel, while the two-piece roof welded onto the cast turret was made from 43 PSM steel. The 49 S and 43 PSM steel plates installed in the roof and belly of the tank was quite thin - only 20mm, so it is quite surprising that these steels are rather soft for their thickness. This table states that 49 S and 43 PSM have a hardness of only 180-250 BHN. The rule of thumb is that thinner plates are easier to harden than thicker plates, so the plates used in the tank are definitely closer to latter than the former, but even so, that is relatively soft for such thin plates. 42 SM and 74L, on the other hand, are medium hardness steels with a hardness of 270-340 BHN and still quite thick. The hardnesses are optimal for resisting armour piercing rounds for the thicknesses of the given plates. This information comes from the "*Техника и Вооружение*" magazine.

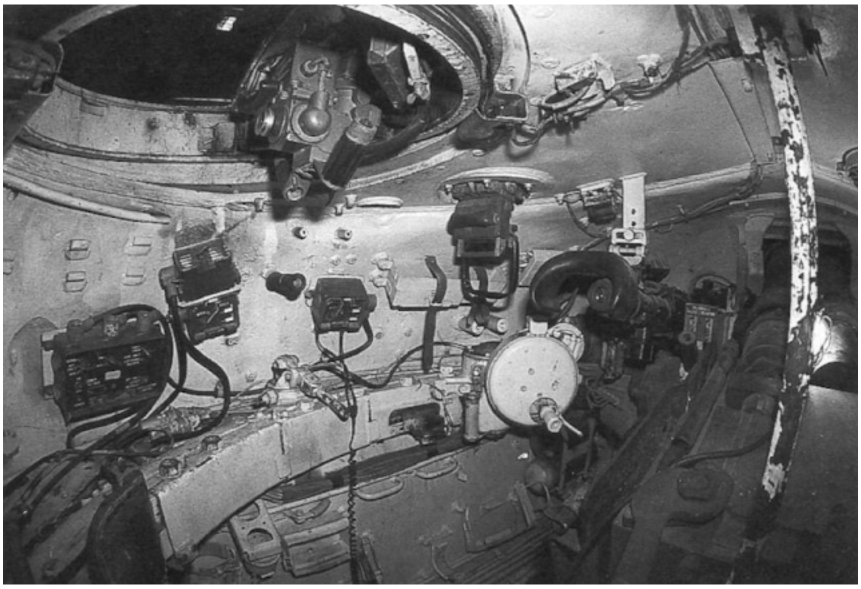
Foreign appraisals of the steel for the armour of the tank were consistently positive. In the (translated) famous Yugo tests document, for example, it was noted that "T-54A cast parts were 270 BHN (rolled plates were 290 BHN) and were judged to be of excellent quality". From this, we know that 74L cast armour steel has a hardness of 270 BHN, while 42 SM has an average hardness of 290 BHN when combining the softer glacis with the harder side armour. The hardness and thickness of the various armour plates were controlled to offer optimal efficiency against the type of armour piercing shells expected to be used by the perceived enemy.



The sides of the turret slope inwards at 60 degrees and converge at the gun mantlet, giving it a rounded needle-nose shape. This shape is excellent for an all-steel turret from a ballistic point of view, but the effect on internal space in the turret is somewhat negative, which is compounded by the fact that the turret of the T-54-3 is also dome-shaped. The sides of the turret that slope inwards to form the needle-nose shape are 150mm to 170mm thick, thickest as it transitions from the turret front and thinner as it curves round to the back. The rear part of the turret sides, at the commander's and loader's areas, are around 100mm to 120mm thick, thickest at the bottom and thinner as the steel curves towards the top.

If we take a close look at the turret wall behind the gunner's primary gunsight, we can see very plainly how the turret immediately assumes a side slope after the gunsight port.

The photo above also shows that the flat part of the front of the turret is shaped like a right angled triangle. This is the weakest part of the T-54 turret, as it is only sloped in the vertical plane. Aside from the flat triangle, the turret is sloped in three dimensions.

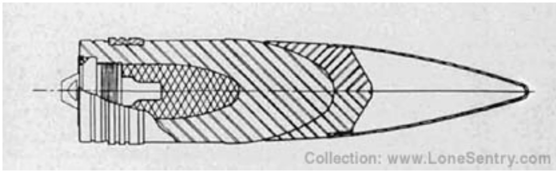


As you can see in the photo, the area behind the gunner's MK.4 periscope is distinctly more curved than the rest of the commander's station. In other words, the flat part of the turret is much narrower than it appears in exterior photos.

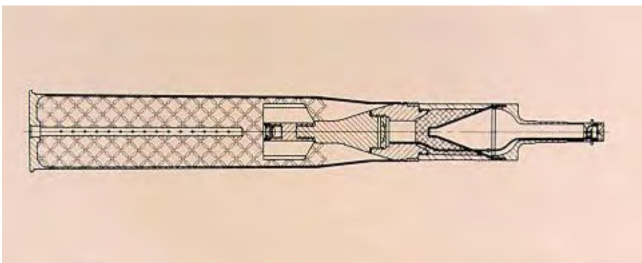
VERSUS SPECIFIC AMMUNITION

Penetrating just 147mm at 0 degrees at a thousand meters' distance, M82 was simply inadequate against the T-54. A large portion of the side of the turret has the potential to shrug off a hit from M82 at close range, and the side hull is largely immune at most angles, unless it is struck straight on.

Much later on, the M36 gun became available as well, as nearby Yugoslavia operated 319 M47 Patton tanks. According to the famous Yugoslavian tests, the front of the turret could only be perforated by PzGr. 39-1 APCBC fired from the KwK 43 at a dangerously close distance of 600 meters. The upper glacis was totally immune even from a hundred meters, but the sides of the turret can be defeated at a distance of up to 1750 m.



Fired from the 90mm M3A1, T33 APCBC rounds (shown above) totally fail to defeat the front of the T-54's turret at any range. Shot perpendicularly from the side, the front part of the turret sides can only be defeated at a suicidal range of 250 m. When hot loaded T33 rounds are fired from the higher pressure M36 cannon, the chances improve a bit. The shell is still not capable of getting through the glacis even at a hundred meters, but the front of the turret can now be perforated at 350 m. The frontal part of the side turret can be perforated at 850 m, which is a much more comfortable shooting distance. M304 APDS is mandatory when fighting the T-54, as the front turret can be perforated at 750 m. Nevertheless, the inability to defeat the armour of the T-54 except from the sides can be considered a serious drawback for opposing forces armed with 90mm guns.



M431 HEAT works well at any range on any part of the T-54, but the killing power is low and the shell has fuzing problems on angled parts of the armour. It has a high probability of failing to detonate if it strikes the upper glacis when the tank is angled 20 degrees sideways. The shell may not work properly on the well rounded shape of the turret, especially the top half. Also, M431 was not introduced until the late 50's. Details on the M431 are available here (Link). Fuzing issues with other HEAT rounds were also observed on the T-34-85 during the tests. Of special interest is the performance of the 75mm M20 and the 105mm M27 recoilless rifles. The M310 HEAT round fired from the 75mm M20 fails to defeat the upper glacis armour of the T-34-85 (45mm at 60 degrees) if the side angle was 20 degrees or more and it fails to defeat the upper side hull armour (45mm at 40 degrees) if the side angle was 30 degrees or more. The same result was obtained with the 105mm M27 which could not defeat the upper glacis armour with the M52 round if the side armour was more than 20 degrees. Since the upper glacis of the T-54 is sloped at the same angle as the T-34, the same results can be expected. The sides may be more vulnerable, however, as there are only fuel tanks and stowage bins on the track fenders and no sloped armour plating.

The M82 APCBC/HE-T round packs 200 grams of RDX, but it is largely impotent against the T-54 unless the gunner aimed for the side hull or rear hull and turret. M82 was not included in the Yugo tests, but it is not difficult to predict its performance. According to U.S Army tests detailed here (link), T33 fired from the M3 cannon is capable of defeating the upper glacis (82mm at 55 degrees) of a Panther at a range of up to 1100 yards, but M82 fired from the same cannon cannot repeat the same feat, despite having a capped penetrator. At most, it could deal with the lower glacis - which measured 60mm thick at 55 degrees - at a maximum range of something over 950 yards.

The T-54 offered the next best chance against itself, behind the long-barreled 88mm KwK 43 as the 100mm BR-412B round is capable of perforating the front of the turret at 500 m and the front part of the side turret at 1000 meters. With BR-412D, a better result may be obtained.

The M48 will find itself in a rather bad situation in comparison to the T-54 where hull armour is concerned. It is well known that cast armour is significantly weaker than rolled armour, but the extent is not often grasped by many. In the Yugo tests, testing of domestic M47s have shown that the upper glacis, a 100mm cast steel plate sloped at 60 degrees, can be defeated by BR-412B at a distance of 750 meters even though BR-412B is technically only rated to penetrate 96mm of rolled steel angled at 60 degrees at a point blank distance according to a British evaluation using the same metrics of penetration. The 100mm rolled steel upper glacis of the T-54A is unsurprisingly immune to BR-412B from all ranges. The T-54 can be considered arguably on par with the M48 or the M60 tank in terms of hull armour protection.

There is much more information that can be gleaned from the results of those tests, but only if we pay close attention to detail. The tests involved shooting at the side of the turret from a right angle, but as we know, the turret is sloped inward. If the turret is attacked at a perfectly perpendicular side angle, the front part of the sides of the turret will have a horizontal slope of 30 degrees, thus making the LOS thickness 196mm to 173mm. We know that T33 fired from the M36 cannon is capable of defeating this at 850 m.

However, a shot coming at the turret from a forward 30 degree angle would also have to face between 173mm to 196mm of LOS armour, because the 60 degree inward angle of the turret sides is reduced to just 30 degrees. This means that if the turret is attacked from its forward arc, it may only be as strong as its side in certain parts. In general, the turret becomes more vulnerable as the incident angle increases from 0 degrees to 30 degrees to 50 degrees and so on, up til a point at 90 degrees where it is as vulnerable as it is at 30 degrees. This is a peculiarity of this type of ballistic shaping, and it is not limited to the T-54. The turret of the M60A1 has the same problem, only it is even further amplified because the cheeks of the M60A1's turret are thinner - only 140mm thick. The T-54's turret can be considered to be extremely resilient to anti-tank guns of its time, but it is not without certain weaknesses.

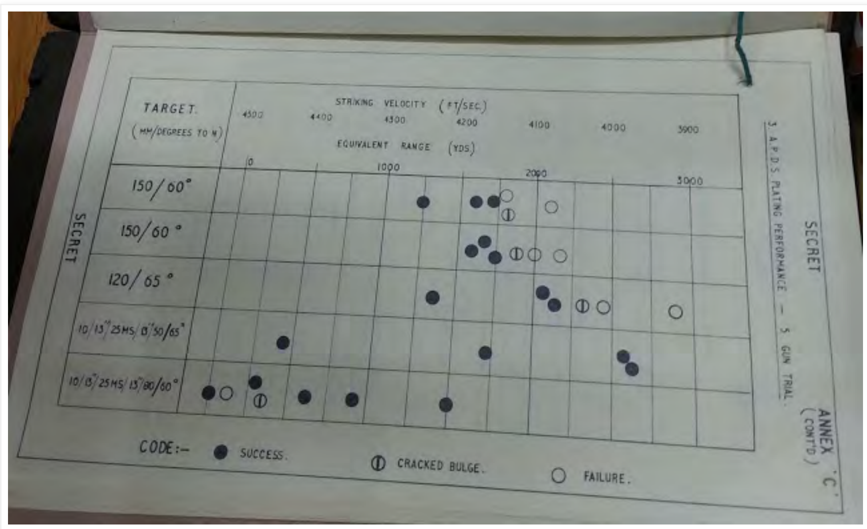
VS 20 pdr

According to British tests, Centurion's MK.3 APDS for the 20 pdr. gun would fail to defeat its own upper glacis (76mm at 57 degrees) at a minimum distance of 4400 yards, or 4023 meters. After the addition of a 44mm weld-on applique armour plate, the distance of immunity was decreased to just 850 yards, or 777 meters. This means that MK. 3 APDS can penetrate less than 120mm RHA angled at 57 degrees at 777 meters, and less than 76mm at 57 degrees at 4023 meters.

According to Swedish archive documents shared by renhanxue, owner and administrator of the Swedish Tank Archives website (tanks.mod16), 20 pdr. APDS (most likely MK. 3) can penetrate 240mm of vertical plate at 500 m, and 95mm at 60 degrees at 1000 yards (914 m), and it fails to penetrate 122mm angled at 60 degrees at 500 m. This is congruous with the aforementioned tests. The hardness of the plate used is unknown. However, the drop in penetration performance is between 4400 yards and 1000 yards is suspiciously small for an APDS round. It is possible that the Centurion's rolled steel plates are softer than the test plates used during the Swedish tests.

Taken all together, this means that using MK. 3 APDS, a Centurion Mk. 3 should have the ability to defeat the upper glacis plate of a T-54 only from below 900 meters. This makes the Centurion the best performer among all of its Western peers in a hypothetical face-off against Soviet T-54s.

Let's see how MK. 3 does against shallowly sloped plates:



So, MK. 3 can confidently defeat 150mm RHA angled at 30 degrees at about 1750 yards, and pierce 120mm RHA angled at 25 degrees at up to 2250 yards. This would allow it to perforate the base of the T-54 obr. 1951 turret in the region around the gun mantlet, but the frontal arc of the turret is still capable of resisting a hit from MK. 3.

According to Swedish test data provided by renhanxue, 105mm L28 penetrates 200mm RHA at 30 degrees at 1500 m, and 140mm RHA at 55 degrees at 900 m. On the Tank-Net forum, renhanxue states that the British give a penetration value of 120mm RHA at 60 degrees at 1000 yards for L28. Overall, this means that the turret of the T-54 is vulnerable from combat ranges of 1500 meters and beyond, so the 105mm L7 gun is an effective countermeasure against the T-54 in a frontal attack.

Additionally, any evaluation of the T-54's survivability is not complete without also reviewing the value of its relatively small silhouette. Being quite small for a tank, the T-54 is easy to conceal in vegetated areas. The small surface area of the tank also makes it less time consuming to camouflage.

Although it is an aspect of the T-54 design that is often criticized, a small silhouette was not only coveted by Soviet tank designers. It was a common goal of practically every major military power that was influenced by statistical probabilities calculated from years' worth of combat data. For example, the height of the M60A1 was recognized as excessive and the M60A2 introduced a low-profile turret design to minimize the projected area of the turret while maximizing protection.

A BRIEF AND GENERAL ANALYSIS OF T-54 COMBAT LOSSES

Compared to some other tanks, the T-54 might seem to have a rather spotty combat history, particularly in major wars like in Vietnam, but all too often, a short analysis of the circumstances can reveal why. Generally speaking, T-54s have performed well as long as they have been used well. Below is a photo of a destroyed T-54 featured in the January issue of Armor Magazine, 1973, along with an excerpt.

This T54, shown on the highway 13 along the rubber trees about one kilometer south of An Loc, was probably part of small probe on May 23. At that time, six to eight vehicles came north in column without infantry or artillery support, moving relatively slowly. About 45 minutes after the tanks were detected, they were engaged by F4 aircraft with 500-pound bomb. Two or three of the tank were caught on the road. M72 and XM202 anti-tank weapons knocked out the others. This tank was stopped, and the crew assumed to be dead. Two airborne soldiers mounted the tank. Just at that time, its engine started and the vehicle moved out! After some hand wrestling with the tankers who were tugging from inside, the hatch was pulled open and a grenade was dropped in, killing the crewmen.

So as it turns out, driving slowly down a highway in a column is not the best idea. Just like that, six or eight T-54s were destroyed. Can you blame the tank? Here's another case:

The turret of this T54 was displaced from the turret ring by the force of an explosion inside the vehicle. Fighter aircraft were responsible for the kill

A T-54 destroyed due to the air superiority enjoyed by U.S forces. Below, you can see a T-54 knocked out by two armour piercing shots to the rear, plus what appears to be a single HEP shell. It was powerful enough to rip off part of the rear plate from the floor and the side hull.

What sort of armoured unit lets themselves get shot in the rear by large caliber cannons?

The photos below shows three tanks knocked out in an ambush at the Lang Cha Ca intersection by the 81st Airborn Ranger Battalion of Vietnamese Rangers, a light infantry force trained and assisted by U.S special forces. There is no trace of doubt that they were knocked out with M72 rocket launchers.

Three communist T54's knocked down by ARVN's Airborn Ranger troops on April 30, 1975 (Lang Cha Ca intersection, seen from the rear)

You can see in the photos that the tanks were flanked by shop houses on one side. The rearmost tank is pointing its gun into one of them. Evidently, two of the tanks were put out of commission by a barrage of rocket launchers from within the shop houses, and the last tank had just enough time to slew the turret before getting knocked out as well. The last tank burned up (photo). Here is a colour photo (link).

Here's another case:

US Air destroyed these Russian tanks overturned in water: 2nd Airborne Battalion caught 5 NVA tanks and 57 soldiers crossing the river, American Advisors brought in air support and the Vietnamese used small arms to destroy the unit; 57 NVA KIAs, one paratrooper wounded.

Five tanks, one of them captured in the photo above, were eliminated by air power as they were crossing a river.

T-54s were destroyed as they drove down Saigon's streets in columns, parade-style. According to the 81st Airborne Ranger Group and Vietnamese Special Forces Association website (link), several more tanks were destroyed in the last day of the war as NVA forces roamed the streets of Saigon.

At 6:00 A.M., five T-54 tanks and a column of accompanying VC infantry advancing into Saigon were stopped in front of the gate to Tan Son Nhat Airbase by resistance from elements of the Airborne Division and the 81st Airborne Rangers. Four VC tanks were destroyed, and the last one turned around and retreated. The Airborne Ranger companies that fought to defend the front gate of the JGS were the 817th Company, commanded by First Lieutenant Le Van Loi, and the 818th Company, commanded by Captain Nguyen Anh.

At 7:00 A.M., another column of Viet Cong armor headed toward the main gate into the JGS compound. A team from the 81st Airborne Rangers fighting in a tall building destroyed the lead vehicle with an M-72 rocket. The second tank fired its main turret gun into the building, neutralizing the defensive position there, but this vehicle was then destroyed by soldiers from 1st Lt. Le Van Loi’s 817th Company in front of the gate into the JGS.

From the huge haul of information gathered during my research, of which only a fraction is presented here, it appears that the vast majority of T-54s in Vietnam were lost to rocket launcher and recoilless rifle fire, the majority of which can be attributed to the M72 LAW. The T-54 held up as well as could be expected, considering that they were often poorly handled and blundered into ambushes. A significant number of tanks were destroyed by air power or forces aided by air power, though this is often downplayed or not mentioned at all like in Wikipedia:

"The NVA and ARVN engaged each other with tanks for the first time during Operation Lam Son 719, in February 1971. During that battle, 17 M41 light tanks of the ARVN 1st Armored Brigade destroyed 22 NVA-tanks, 6 T-54 and 16 PT-76, at no loss to themselves,[21][22][*full citation needed*] but the friendly units lost 5 M41s and 25 APCs.[23]"

This summary of the battle is incomplete. The truth is that the ARVN 1st Armored Brigade was supported by gunships armed with a pair of anti-tank rocket pods on each wing which strafed the NVA tanks. This is mentioned in "Vietnam War: The New Legion, Volume 2 by Vinh Truong. The author has provided a method of reading his work for free via this forum topic here: (Link). The relevant post is post #12, copied out below:

"*Some troop elements had done conspicuously better than others. The ARVN armored units had been especially early in the operation the 1st Squadron, 11th Armored Cavalry had encountered NVA elements in a fight at southern Fire Base 31 and performed brilliantly, destroying six enemy T-54 tanks and sixteen PT-76s without any friendly losses in the first major tank-to-tank engagement of the war, but of course with our gunship air cover supported joint-strafing with the both flank-sides [of our helicopters] equipped [with] two 19-shot 2.75-inch antitank rocket pods. Today by chance we got the record shooting into the POL pipe-line at random burned all of them for a while right after NVA shut-off the pipes.*"

By "2.75-inch antitank rocket pods", the author is, of course, referring to Hydra 70 rockets. 70mm M247 HEDP rockets have a shaped charge warhead that can penetrate 145mm of steel armour. This might not seem a lot compared to the 66mm warhead of an M72 LAW which can penetrate up to 200mm of armour, but 145mm of penetration is already more than enough to punch through the sides and rear of a T-54 tank. Even if HE rockets were used instead of HEDP ones, the tanks' observation equipment can still be destroyed, rendering them blind. Either way, it is clear why the battle was so one-sided.

Besides Hydra rockets, TOW guided anti-tank missiles fired from helicopters as well as ground mounts were responsible for a sizable portion of T-54 losses during the closing stages of the war. The TOW was especially successful when it was first used in April 1972 on Huey UH-1B gunships. Here are two excerpts from "History Of The TOW Missile System", page 168.

"After two days of classes the TOW was called upon to fire against a live enemy T-54 tank. On the morning of 22 May the 369 Brigade CP was attacked by a combined tank-infantry force consisting of 9 tanks and approximately 200 troops. Sgt Tillman quickly manned his weapon and sighted in on a T-54 at a range of 900 meters. Seconds later there was the unfamiliar roar of the TOW, followed by a victorious cheer, more akin to gridiron than to the battlefield, as the T-54 was engulfed in a bright orange ball of fire. The battle ended 2 hours later with all 9 tanks destroyed and 117 enemy confirmed dead.

"I know that this was the first kill recorded by the TOW in the Vietnamese Marine Corps, possibly the first kill in actual combat. In any case it was a fine job done by Sgt Tillman with a fine new weapon—the TOW."[25]

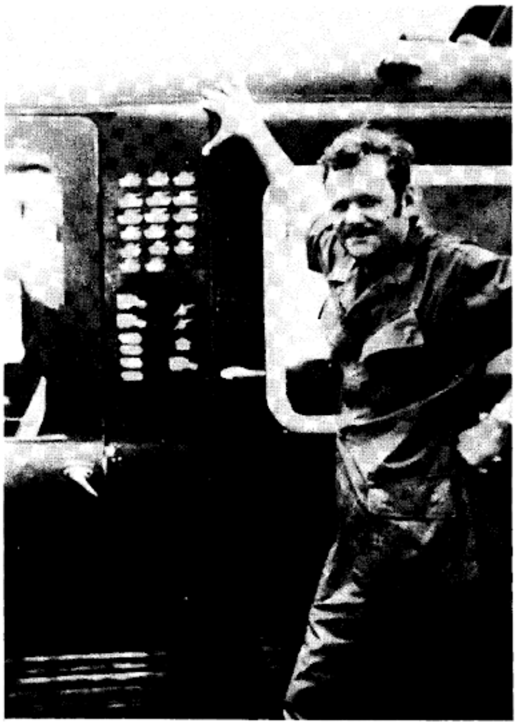
(U) The North Vietnamese launched the expected attack on the provincial capital of Kontum before dawn on 26 May 1972. Tactical air strikes pounded enemy forces within a mile of the city, but were hampered by the closeness of the enemy force to the defenders in the house-to-house battle underway inside the city. The two Huey gunships went into action at 0640 and before the morning ended flew several sorties apiece. They expended 21 missiles during several hours of continuous operation and scored nine tank kills—every one they found—as well as destroying other targets, including a machine gun on a water tank.

(U) In the ensuing days, there were other battles and other tank kills, but the opportunities for helicopter-tank engagements gradually diminished. During May and June 1972, the months spent in Vietnam by the temporary duty (TDY) team, the two helicopters fired a total of 94 TOW missiles in combat engagements, scoring 81 hits on a variety of targets, including 24 tanks, 9 trucks, 4 armored personnel carriers, 3 bunkers, 2 machine gun emplacements, 2 artillery pieces, 2 ammunition dumps, a bridge, and a rocket launcher. According to Warrant Officer Lester Whiteis, neither of the gunships was hit by enemy fire. They encountered considerable machine gun fire, but avoided most of it by staying high. Before leaving Vietnam, the TDY team trained replacements from the 1st Aviation Brigade. The XM-26 airborne TOW system remained in Vietnam until late January 1973.

(U) Between 30 April 1972 and 11 January 1973, the two Huey gunships fired a total of 199 TOW missiles—37 in training and 162 in combat engagements. The 37 training firings began on 30 April 1972 and continued through 7 August 1972. BG William J. Maddox, Jr., the Director of Army Aviation, fired one of the training rounds on 21 May 1972, during a 10-day visit to Vietnam, and scored a hit on a previously destroyed M-41 tank.

(U) Of the 162 airborne TOW missiles fired in combat engagements, 151 (93 percent) were reliable and 124 (82 percent) of the latter scored hits on a variety of targets. Among the targets destroyed were 27 tanks, 11 trucks, 5 armored personnel carriers, 3 artillery pieces, 1 antiaircraft gun, 1 122mm rocket launcher, 5 machine guns, 2 57mm guns, 5 caves, 8 bunkers, 2 bridges, 2 mortars, 2 ammunition storage dumps, 2 TOW jeeps (1 with launcher and 1 with missiles), and 1 house. Eleven of the missiles fired malfunctioned and four misses occurred when the gunner fired the missile at a range in excess of 3,000 meters and lost it when the guidance wire ran out.[20]

Here is a photo of one of the Huey gunships.



Hughie J. McInnish with one of the two TOW-armed UH-1B helicopters which scored 27 kills, including 17 tanks, during May and June 1972.

170

The TOW missile system was extremely deadly to T-54 tanks by the virtue of its accurate SACLOS guidance system and the large 5-inch warhead, which had greatly overmatching penetration against the basic steel armour of the T-54 and thus produced very powerful beyond-armour effects.

Additionally, when tanks of any technical capabilities compared, it is nearly impossible to form any accurate conclusions from their performance in battle without also taking into account the competence of the army fielding them, besides also taking into consideration the individual peculiarities of the local combats where the tank was involved. Here, I would like to use the example of the Chinese incursion into Vietnam in 1979.

North Vietnamese forces had captured Saigon just a few years prior, and their neighbour Laos was under the governance of the genocidal Khmer Rouge. To maintain law and order in the South, the Hanoi regime deployed their best tanks, which were already stationed there anyway, and others were used in the skirmishes against Khmer Rouge guerrilla forces. With almost all of their T-54 and Type 59 tanks located in the South, the only tanks available up North were T-34-85s, which had been demoted to auxiliary roles and army reserves since 1965 owing to its increasingly obvious obsolescence.

When the Chinese intervened in response to the Hanoi regime's hostility towards Pol Pot and the Khmer Rouge - both Chinese affiliates - they brought with them an initial invasion force of more than 80,000 soldiers and the best tanks available in the PLA across the border, including the Type 59 medium tank, Type 62 light tank and a number of Type 63 armoured personnel carriers, with a smattering of Type 63 amphibious tanks. Despite all this, the Chinese failed to penetrate deeply into Vietnamese territory and were repulsed after sustaining 50% more losses than the Vietnamese, in defiance of all expectations. It would be asinine to refer to this incident to claim that the T-34 is better than the Chinese Type 59, and by extension, the T-54, so what went wrong? As usual, the reason is because the Chinese invasion was atrociously deficient on all levels, from planning to execution. The battle-hardened and well motivated Vietnamese army, now evolved into a de jure conventional army, bested their totally inexperienced Chinese counterparts in every way.

Besides tanks, the Chinese invasion force were largely equipped with the same weapons and gear as their Vietnamese counterparts. Soviet-designed artillery, anti-aircraft guns, mortars, machine guns and small arms were the primary weapons on both sides, with the Vietnamese army being supplemented with captured South Vietnamese arms.

Similarly, the poor performance of the T-54 in Arab hands against the Israelis during the Yom Kippur war of 1973 has left an extremely misleading impression. Hundreds of T-54s were lost to the heavily outnumbered Israelis in that infamous war, but hundreds of American tanks fell to the Israelis in preceding conflicts as well. Using mostly M50 and M51 Shermans, also known as Super Shermans, the Israelis felled Jordanian M48, M48A1 and M47 tanks and captured (!) about 100 M48 tanks - more than half of Jordan's fleet of 170. Jordan had none of the same success with the Centurion as the Israelis did with theirs during the Six Day war, and later on, the Yom Kippur war. For us, the Yom Kippur war deserves special mention because it featured the use of the T-54 is a truly mammoth scale, and also because T-54s were lost in equally appalling numbers.

This famous photo of knocked out Syrian T-54 and T-62 tanks on the Golan Heights has sometimes been shown as "proof" of the inferiority of Soviet tanks, but in reality, it is quite meaningless.

Take a closer look. All of the vehicles in the photo have been abandoned, including the two trucks, but most importantly, all of the tanks (except one) have their guns aimed behind them. The tank that fell off the bridge in the foreground was moving from left to right (based on the assumption that no idiot driver is going to reverse a tank over a narrow scissor bridge), and that tells us that that was the direction of the advance or retreat. So why do all of the tanks have their rears pointed in the direction of advance/retreat and their turrets pointed in the opposite direction? The photo below is a close up of the scene, showing two of the knocked out tanks. They were clearly not destroyed or disabled by enemy fire, but by crew incompetence.

In all probability, this scene had nothing to do with combat. Most likely, these tanks were abandoned when the dismounted crew was ambushed by infantry or tank fire while they were restocking ammunition (this explains the presence of unarmoured trucks). This is most likely a case of insufficient reconnaissance, leading to the failure to anticipate enemy movements.

One of the most storied accounts from that war is that of Zvi Greengold, which has become something of a crowd-pleaser. Although the events undoubtedly occurred and were hugely impressive, the unfortunate reality is that the story has been exaggerated and distorted. It is not necessary for me to elaborate too much, as there are already very good publications on the subject, including this article here (Link). Zvi Greengold's story has less to do with the superiority of certain tanks, and more to do with the superhuman endurance and fighting spirit and quick thinking of Israeli ***tankers***.

Zvi Greengold's story was not the only one where Arab tanks were lost. Many tanks were knocked out while travelling in columns, unaware that they were being targeted (which we can blame on the lack of forward reconnaissance). More importantly, however, the vast majority of Egyptian and Syrian tanks were not destroyed, but captured. According to this article (link), the Israelis had 1000 captured T-54 and T-62 tanks in their arsenal, and had 444 of them in active service in the form of modified "Tiran" tanks. The number of captured tanks is especially shocking when considering the fact that most estimates place the number of tanks in the Syrian invasion force at the Golan Heights at around 1300 to 1400 tanks, while the Egyptians crossed the Suez Canal with as many as 1000 tanks. As a rule, if the tank is burned out, it is no longer usable in any capacity. Therefore, it can be reasonably inferred that a majority of Arab losses were in fact due to their crews abandoning their tanks even though their tanks were still serviceable, or at least in repairable condition. This dispels the widespread impression that Soviet-built tanks are hopeless deathtraps, and it also shows that the Egyptian and Syrian armies lacked the tactical capacity to consolidate territorial gains and lacked a mature support system to recover battlefield losses. It also shows that Egyptian and Syrian tank crews lacked discipline, as they neglected to scuttle their (functional) tanks as they fled the field of battle - a double act of cowardice and negligence.

The T-54's performance in the Middle East is intrinsically linked to Israeli competence and Arab incompetence. In those conflicts, as in any, the tool does not matter as much as how the workman wields it. One is reminded of the atrocious performance of advanced Chieftain tanks in Iranian hands when facing off against Iraqi T-54s, Type 59s, T-62s and Type 69s. And yet, there can be no reasonable doubt that the Chieftain is the superior tank in every respect. If we go even further back, the example of Char B-1 tanks is particularly appropriate. Even though the Char B1 was quite clearly a superior tank to the more numerous German ones at the time of the invasion of France, a plethora of mitigating factors completely negated whatever advantages the tank might have had to the point where these supposedly superior tanks became practically useless. The **only** logical explanation for these apparent inconsistencies is that in no way do any of these conflicts truly represent the T-54's capacity for war. In many of these cases, one of the belligerents was totally outmatched in skill and motivation by the other.

Of course, there is no excuse if the T-54 has displayed consistently poor performance throughout its life, but it does not need to be said that the T-54 does not have the monopoly on poor tactical leadership and poor crew training. The Pakistani M48 and Sherman pictured below, destroyed at Asal Uttar, illustrates that perfectly.

We have examined the T-54's armour, and we have seen that it was very well protected from common Western arms of the era. But what good is your thick frontal armour when the enemy has the opportunity to shoot at you from the flanks? In some rare cases, exposing your vulnerable sides is unavoidable, but if it becomes a habit, then there is a deep rooted problem.

Speaking of deep rooted problems, it is not wise to ignore religion as a factor. Read this Indian Defence News article for more. Here is an excerpt from the article.

"*The Pakistanis would abandon a tank soon after it was hit, fearing that it would catch fire and they would be charred in flames—not the best way to die for a Muslim." So many Patton tanks recovered were brand new. They had just done 30 to 35 miles. Pakistani Army had far superior equipment, but weren't trained to use them," says Brigadier JP Singh*."

According to Islamic teachings, cremation is strictly forbidden as it is considered a sin. It is customary for a Muslim to be buried with his body intact, wrapped in white cloth. Before learning that their Abrams tanks were mostly immune to RPGs, it is observed that Iraqi tankers had an unspoken policy of ditching the tank immediately after it was hit even once. It is not uncommon to see U.S Army soldiers, training staff and active servicemen lamenting the poor discipline of Iraqi and Afghan soldiers on social media and forums in situations other than drills and rehearsed maneuvers. Bottom line: Arab tank crews are to blame, not the T-54.

Now that we have covered the Middle East, let's take a look at a less well known example: The South African Border War.

In September of 1987, the first tank battle between the Angolan and South African forces occured at the Lomba river, involing FAPLA T-54/55s and SADF Olifants. A wide variety of factors affected the course of the battle, with the final result being that the Angolans were beaten badly into a retreat. Throughout the much of the conflict, the Angolan experience was appreciably worse than the South Africans'. Much of this can be attributed not to the superiority of South African armour, but to the superiority of South African artillery and air power. I recommend reading 'Bush War: The Road to Cuito Cuanavale: Soviet Soldiers' Accounts of the Angolan War' to better understand the situation. Angolan artillery was often outranged by SADF artillery, as the SADF had G6 (155mm) howitzers while the Angolans usually only had smaller caliber artillery pieces like the D-30 (122mm) and BM-21 "Grad" (122mm). Virtually all of the anecdotes told in the book mention constant bombardment by artillery, sometimes by rocket-assisted shells, while they (the Angolans) had their hands tied by the limitations of their own equipment. Air defence systems like the Osa and Strela-10 were often destroyed, not by SEAD ops, but by artillery fire. Furthermore, systems like the ZU-23-2 were inoperable during an artillery barrage due to the open nature of the rig. All this seriously compromised what meager air defence the Angolans were afforded, leaving them vulnerable to air strikes. Mobility was occasionally hampered as shrapnel filled the air almost every hour of the day, puncturing both the thin sheet metal skin and the tyres of the trucks that served as Angolan APCs. All this meant that even when T-54 tanks were available to spearhead assaults on SADF positions, those tanks were themselves not protected from South African rocket launchers. It's absurd to single out the T-54 as the root cause of all the failures of FAPLA forces when it is the other way around.

In the right hands, the T-54 was easily capable of success. Cuban T-54/55s and Cuban-guided Angolan T-54/55s proved themselves in Cuito Cuanavale against South African forces (SADF) in late 1987 and early 1988. On 14 February 1988, three battalions of SADF troops, reinforced by a six battalions of UNITA guerilla fighters and 100 armoured vehicles including 40 Olifant tanks, launched their second attack on Cuito Cuanavale, breaking the already severely demoralized 59th FAPLA Motorized Infantry Brigade. To plug the gap in the defence, a tank company comprising of 8 Cuban T-55s, commanded by Lt. Col. Hector Aguilar, was quickly deployed. This modest tank force successfully repelled the offensive, destroying 10 Olifants and 4 Ratel 90s in the process, effecting a South African rout. On the Cuban side, 6 of the 8 T-55 tanks were knocked out, three by RPG fire and three by Olifants. Of the 39 Cuban soldiers and tank crewmen involved, 14 died.

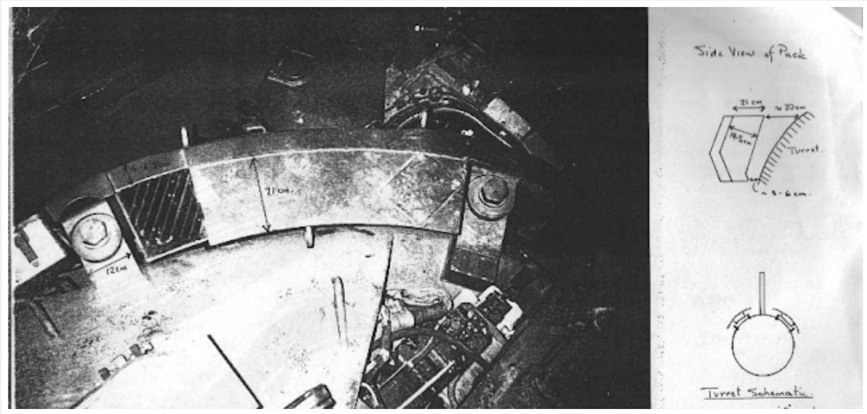
Interestingly, the generally undisciplined FAPLA forces floundered under the leadership of Soviet advisors, but Cuban commanders managed to handle them better, and needless to say, Cuban units were far superior to their Angolan counterparts. Also, 'Bush War: The Road to Cuito Cuanavale' mentions that the Cubans conducted their own reconnaissance. The result was that Cuban forces were usually equipped with good information on SADF troop movements and were better able to plan operations.

The Cuban military is not known for being particularly elite, so it might seem strange that they performed so well in the war, but this is probably due to the 13 years of prior experience with the Angolans. The Cubans had intervened in Angola in 1975 and a sizable contingent of officers had stayed there ever since. The involvement of bona fide Cuban tank crews and soldiers made quite a difference as well. The Soviets themselves were never actually involved in direct combat. The Cubans likely had a better grasp of South African tactics as well as the limitations of Angolan forces, having had extensive exposure to the local environment. Cuito Cuanavale proves that the equipment matters less than the crew when there is no clear technological advantage, and where the T-54/55 is concerned, that needs to be fully understood.

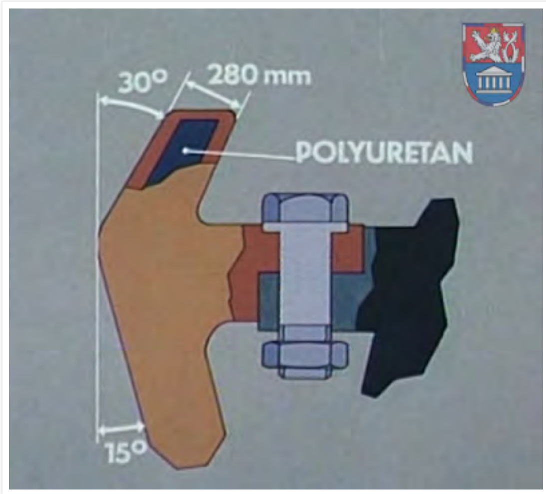
Metal-Polymer Armour

The add-on armour featured on the T-55AM and its variants is referred to as metal-polymer armour blocks. This type of armour has already been covered in Tankograd's T-62 article. It would be pointless to repeat it all here, so please head over to the T-62 article to read more. However, the unique geometry of the turret of the T-54 means that the spacing between the turret and the add-on armour blocks is not the same as on the T-62, which is a nuance worth examining.

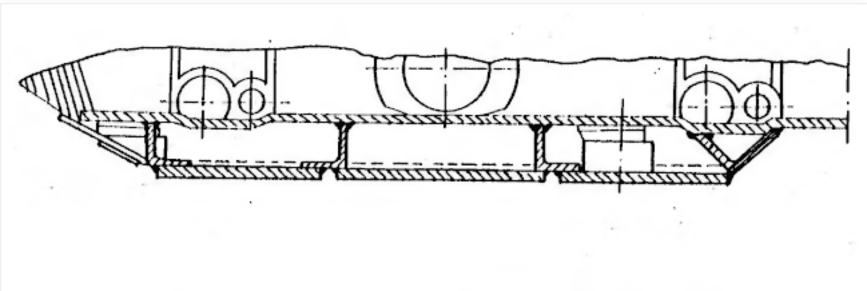
The photograph below comes from Paul Lakowski's "Modern Armour", and is apparently taken by an individual named Georg Stark. "Modern Armour" uses very old estimates and figures, but some of the information - like the photo and sketch below - is accurate as it was measured directly on the tank in question.



As you can see from the sketch, the air gap between the "Brow" armour block and the turret ranges from 50-60mm at the bottom to around 200mm at the top. The presence of an air gap behind the armour array gives room for KE projectiles to break apart as the buildup of internal stresses from the penetration of the steel front plate and the moving internal plates is suddenly released, thus magnifying the effect of the armour. For shaped charge jets, the air gap may give room for disturbed jet particles to disperse radially outward, such that they do not contribute to the total penetration depth from the residual jet tip.



The belly armour was enhanced with rudimentary spaced armour plate welded onto the hull. Six thick steel plates were welded onto the front half of the tank belly with the proper spacing ensured by spacer ribs. Unlike more modern mine and IED protection kits, there is no low-density filler between the spaced plate and the tank belly so there is little blast attenuation. The main function of the spaced armour would be to prevent the tank belly from being breached by an explosion.



Rys. 5. Dodatkowe opancerzenie dna kadłuba

The separate spaced plate sections can be seen below. There are ports built into the armour for drainage plugs, but the tank's escape hatch has been rendered unusable.

NBC PROTECTION

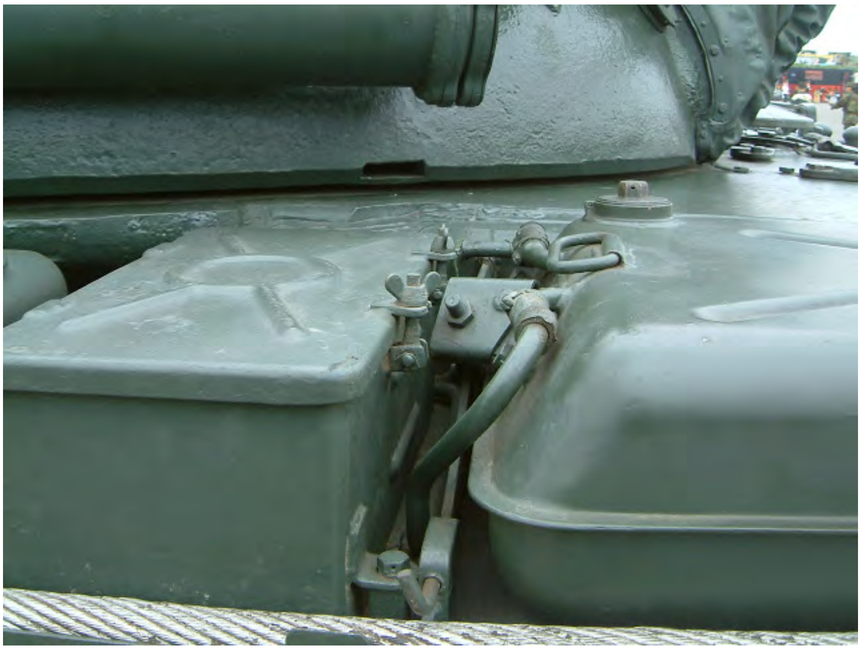
In the wake of the Hiroshima and Nagasaki atomic bombings, the first priority in the Soviet Union was to develop their own nuclear weapons and the means to deliver them, but as time went on and new battle theories were formed, the question arose; what place will the tank have in a nuclear war? As the T-54 was designed during the closing years of WWII and was finalized only after its conclusion, no considerations were made for the effects of nuclear destruction. As part of tests carried out between 1952 and 1953 to determine the effects of nuclear weapons on various ground equipment, including tanks, the T-54 tank was exposed to a nuclear explosion from various distances. As it turned out, even at large distances, the turret could be displaced by the sheer power of the nuclear winds even when the turret was locked in the travelling position, causing the gear teeth around the turret ring to break and render the tank unserviceable. As a result of these tests, the turret locking mechanism was strengthened, so that even at around 300 meters' distance from the detonation of a 2 to 15 kiloton bomb, the tank remained serviceable.

However, it was discovered in subsequent tests that at distances of up to 700 meters, animals (rabbits, dogs) standing in for the tank crew died immediately from the shock wave and overpressure of the blast. As a result of these findings, the requirements for a comprehensive anti-nuclear protection suite for the T-54 were drawn up, and in 1956, the KB-60 design bureau from Kharkov finalized the "PAZ" (Nuclear Protection System) complex and sent the technical documentation to the Uralvagonzavod tank factory for implementation.

PAZ was first implemented on the T-55. It was an advanced collective type system. A gamma radiation sensor was used to detect the detonation of a nuclear bomb and initiate countermeasures before the shockwave could reach the tank. The system could react 0.3 seconds after detecting a spike in gamma radiation. All openings in the tank would be automatically sealed by heavy steel wedges activated by explosive squibs. The engine and the cooling fan would be stopped, and the armoured louvers over the engine deck would be closed, all done automatically.

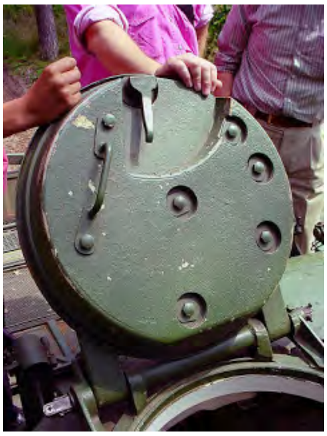
The old dome ventilator was insufficiently powerful to create an overpressure inside the tank and it only provided low level filtration of dust and smoke, so it was replaced by a new ventilator system. The ventilator drum is placed right beside the co-axial machine gun, in front of the loader. Not only was it capable of producing an overpressure inside the tank to prevent foreign particles from seeping in, the filtration system could also remove chemical and biological agents, though only when activated, either manually or automatically. In normal operation, the powerful compressor fans are not used, and the ventilation system performs the same basic function as the old dome ventilator.

A tiny slit was created at the rear of the turret at the 2 o'clock position to let air out and control the flow of air to prevent the internal pressure from building to excessively high levels.

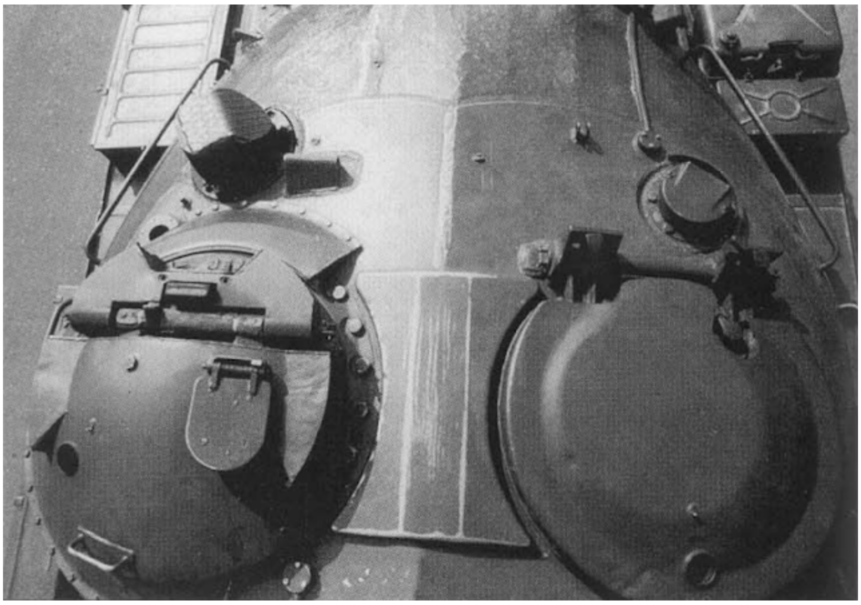


The T-55A obr. 1967 provided an additional layer of security from the harmful effects of a nuclear explosion by including a special anti-radiation lining. The anti-radiation material is a lead-impregnated polymer composite textile that is layered and cut into the desired form before it is installed on the surfaces of the tank. It is designed for absorbing gamma radiation - the most dangerous form of radiation as it can penetrate even relatively large thicknesses of steel - but it can also perform a secondary function as a spall liner when present in sufficient thickness.

The anti-radiation lining is secured onto the internal surfaces of the fighting compartment by bolts. They mainly cover the areas of the tank where the armour thickness is lower and therefore less effective at attenuating radiation. The turret ceiling is completely covered by the lining and most of the turret rear and sides are covered. Even the hatches have a layer of anti-radiation lining. The photo on the right below shows the loader's hatch and the large cutout for the hatch locking handle.



The commander's cupola and loader's cupola on the T-55A both had relatively high radiation permeability due to their relatively low thickness of armour. As such, a large thickness of anti-radiation lining was needed to ensure a sufficient level of protection, but this thickness was too large to be practical as a lining on the internal surfaces of the cupolas. Instead, the anti-radiation material was installed outside the cupolas in the form of prefabricated conformal blocks and given a sheet steel shell to protect it from the weather and from the initial blast and heat of a nuclear explosion. Anti-radiation material was also added to a small strip of the turret roof joining the two cupolas.



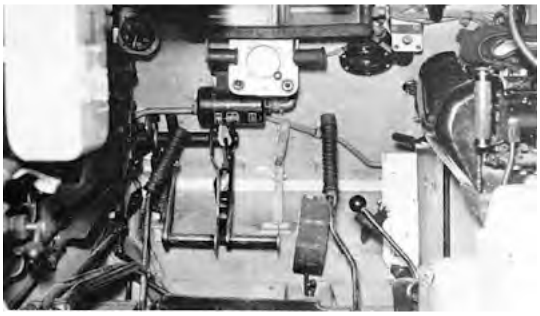
The large thickness of the anti-radiation blocks on the loader's cupola can be seen in the two photos below. If this amount of material was used as an internal lining instead, it probably be so thick that it may constrict the size of the loader's hatch and it would certainly severely restrict his headroom.

The commander's cupola received similar treatment. However, the commander's hatch and cupola roof has a noticeably larger thickness of external anti-radiation cladding compared to the loader's hatch, and this is because a lining would have intruded much more into the commander's available headroom than for the loader, who is not confined to a fixed position underneath his cupola.

ESCAPE HATCH

The T-54 has an escape hatch. It is located behind the driver's seat. It is held in place by four locks. Once all four have been disengaged, the hatch drops down, allowing the crew to crawl out. It is much easier said than done, and it will be nearly impossible to do a quick escape from a hatch of such small size, but having a hatch presents unique tactical opportunities, as the crew can exit the tank without being seen by the enemy.

DRIVER'S STATION

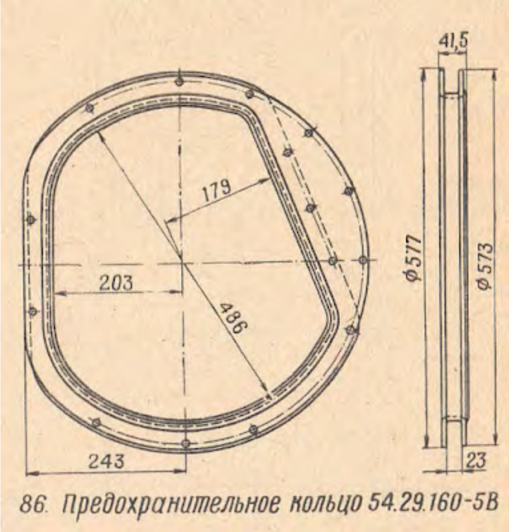


The driver's station in the T-54 was a departure from the T-34 driver's station in that it had less headroom due to the significantly shortened hull, but the driver's comfort and visibility improved because the periscopes were relocated from a hatch on the upper glacis plate to the hull roof. This meant that the driver could be seated in a far more natural posture while driving. There were also other ergonomic improvements were added for the driver's benefit, such as handlebars built into the periscopes for the driver to hold on to as he ingresses or egresses from his station. The driver's station changed very little throughout the evolution of the tank, as exemplified by the two photos above. The photo on the left shows a T-54A and the photo on the right shows a T-55. The only major difference is the absence of a bow machine gun on the latter tank.

We have already examined most of the components of the driver's station in Tankograd's T-62 article. As the driver's station in a T-62 is almost identical to one from a T-55, there is no point to repeat it here. Please head over to the T-62 article. However, there are some small historical details that uniquely belong to the T-54. One of them was the periscopes.

Originally, destroyed periscopes were almost impossible to remove if a powerful shell struck the armour in front of it as the mounting piece would usually be damaged in a most inconvenient way. This was solved in 1953 by using a heat-treated mounting piece of a higher grade of steel, increasing the strength of the welds and by thickening certain components.

The design of the driver's hatch of the T-54 was finalized on the T-54 obr. 1947 and it was retained throughout the production life of the tank series. The design is shown in the drawing below. One side of the hatch opening is slanted which was necessitated by the overhang of the turret over the turret ring. The dimensions of the hatch opening are not particularly large but it is very reasonable. It is particularly important to note that the width of the hatch is 486mm which is substantially more than the average shoulder width of an average Soviet Army conscript, so in general, the size of the hatch can be considered sufficient for a tank driver even when wearing winter clothing.



In 1951, the TVN-1 infrared night vision driving periscope was introduced along with an infrared headlight on the T-54 obr. 1951. With the help of the tank commander who was provided with the new TKN-1 night vision monocular periscope, the driver of the T-54 gained the ability to navigate at night more stealthily than if conventional white light headlights were used and tank units could march more confidently at night. When the more capable TVN-2 night vision periscope became available in the late 1950's, the TVN-1 was phased out in favour of the newer type. The two images below show TVN-2 periscopes installed in the appropriate periscope slot.

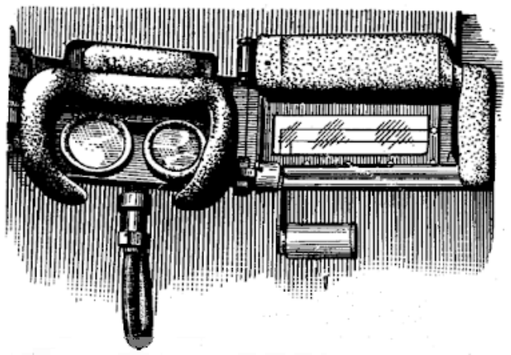


Рис. 72. Установка прибора ТВН-2 в положение по-боевому

For a more detailed examination of the night vision devices, please head over to Tankograd's T-62 article.

MOBILITY

Traditionally, most people would assume that a medium tank like the T-54 is classified as such for its greater speed and agility, which a heavy tank lacks. And where the heavy tank lacks agility, it makes up for in armour protection and firepower. The light tank, then, is on the other side of the spectrum with very high agility, but nearly no armour and little in the way of weaponry. A combination like good firepower and good mobility with poor armour protection forms the usual description of a tank destroyer. The medium tank, then, should have medium armour, medium speed, and medium firepower. As the T-54 was invented as a medium tank during the immediate postwar period, this is more or less (but not completely) true.

A superior gearbox enabled the tank to get more out of its 520 hp V-12 piston engine, designated the V-54, and the new super-compact dry plate clutch transmission made the T-54 just as quick and agile as the T-34 despite having a worse power-to-weight ratio. The top speed when travelling in a straight line was slightly worse compared to its legendary predecessor, but the new mechanical synchromesh transmission enabled the driver of a T-54 to shift gears more easily and accelerate quicker.

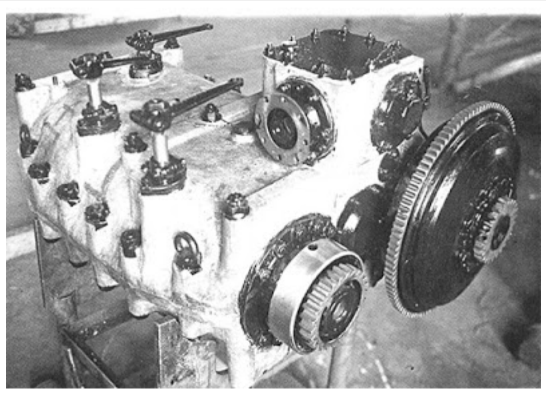
The T-34-85 had a top speed of 56 kph on paper, while the T-44 had a top speed of 51.1 kph. The T-54-1, with its heavy upper glacis armour plate and sides, chugged along at 43.5 kph. The definitive T-54 base model, the T-54 obr. 1951, had a top speed of 50 kph. The T-55 had a higher top speed of 55 kph. The rate of acceleration is not known, but it is presumed with high confidence to be superior to the T-34 and T-44 due to thr improved transmission.

The T-55 utilized an improved air filter and an improved V-55 engine. The V-55 produced 580 hp. The added power comes from a better optimized compression ratio and an improved fuel injection system. The improved air filter also helped by reducing the power loss in extremely dusty environments.

The T-54 used a dual epicyclic geared steering system. This steering system is functionally the sa achieved by having two separate final drives with separate gear boxes for each track, connected by a central transmission assembly. Steering is accomplished by stepping down the gear ratio of the inside track to a lower gear, thus reducing the speed of that track. By manipulating the gear ratio instead of applying a brake like in the clutch-and-brake system used in the T-34, the tracks can be slowed down incrementally rather than braked for smoother and more precise steering. However, geared steering does not work on first gear, because there is no gear lower than first gear except neutral, so the T-54 is fitted with an auxiliary clutch-and-brake system as well. The driving tillers (or levers) each control the track on its side. Each tiller has three positions, the first (1) for full forward, the second (2) for engaging the planetary mechanism to reduce speed to that track, and the third (3) to engage the clutch and brake system for really tight turns, for turning in first gear or for pivot turning in neutral. But what is a clutch-and-brake system? In a T-34, steering is accomplished by locking one of the tracks by disengaging the clutch and applying the brake. This can create very tight turns, but it has the effect of slowing down the tank significantly when making small course adjustments.

The geared steering system is a regenerative steering system, meaning that it supplies full power to both tracks so there is minimal energy loss when turning. This means that the T-54 is much more energy efficient than the simple clutch-and-brake type steering system present in many WWII era tanks (including the T-34 and KV-1), allowing the T-54 to preserve most of its speed while turning, and even more so in muddy or swampy ground. The energy efficiency of the geared steering system is roughly comparable to contemporary double and triple differential systems in use by Western tanks of the same era, with the caveat that the T-54 still used tillers to steer. This directly relates to the tank's speed in real world conditions. After all, there are not many paved highways on the battlefield, and zigzagging is a better tactic for survival than travelling in a straight line. In other words, the T-54 can be as fast as a T-34-85 in actual combat conditions, or maybe faster. One big selling point of the geared steering system is its hardiness and extremely reliability. It is one of the reasons why the T-54 is still used (with minimal maintenance) in third world armies to this day. The photo above shows the transmission casing, the power take-off block atop it, and the finals drives and brake drums behind it.

The power take-off block is the box at the top right of corner of the photo below. The block connects directly to the master drive shaft from the engine as a mini gear box of its own, so the amount of power supplied to the block changes only when the output of the engine itself changes. The block splits the power between three smaller drive shafts. One goes to the AK-150 air compressor (we will examine that later), seen attached to the block to the right side of the photo above. The second connects to the centrifugal radiator fan, as seen here (link). The third connects to the radiator coolant pump.



The three crane-like protrusions on the transmission casing are part of the steering system. These work the gear boxes to bring about the changes in gear ratio. They connect to control rods that are operated by the tillers. The three loops on the corners of the transmission casing are lifting eyes, to be used with a winch to lift the entire unit out of the tank's engine compartment such as shown in the photo below.

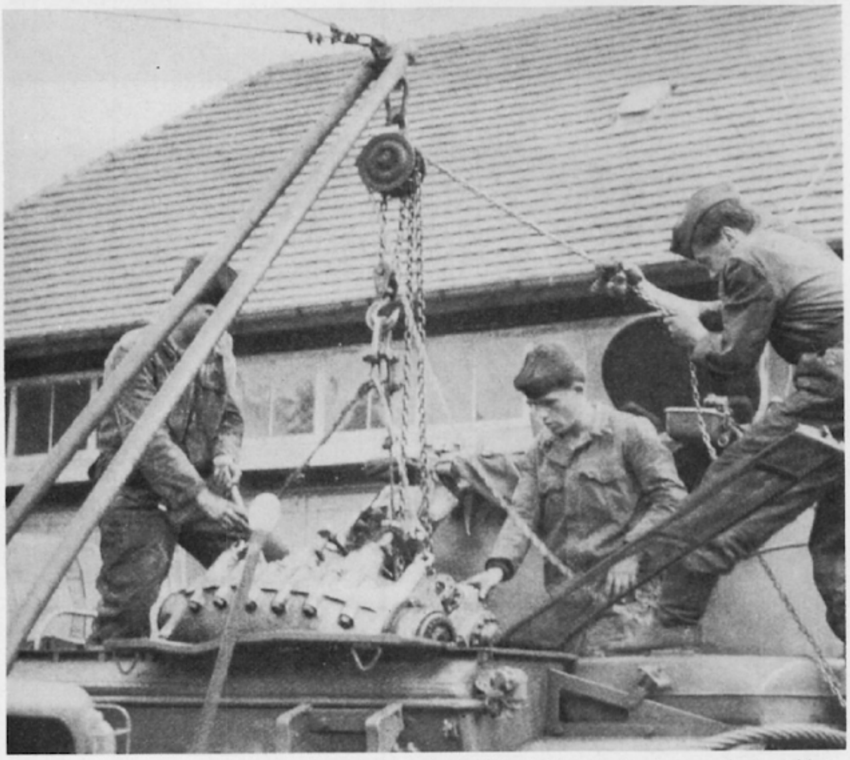


Bild 136: Demontage des Schaltgetriebes eines KPz T-54 mittels eines auf einer Lkw-Stoßstange montierten Hebegeschirrs sowie eines Flaschenzuges.

Like many tanks preceding it, the T-54 has the option of using compressed air to start its engine. Two 5-liter air tanks mounted in the driver's station inject air into the cylinders of the engine, forcing the pistons into motion. This method is harsh on the engine, but dependable. Starting the engine in the summer is usually done electrically, but in the wintertime, the electric starting system may not be reliable due to piston lockup, so using air is necessary. In the harshest weather conditions, with the most poorly maintained T-54, starting the engine will require a combination of both methods simultaneously.

However, like the T-34, the compressed air tanks in a T-54 are not refilled automatically, so the reserves of compressed air is limited. This was changed in the T-55, which was equipped with an AK-150 V-shaped air compressor, powered by the engine. AK-150 is a typical V-shaped reciprocating compressor. It runs on an input shaft from the engine and uses pistons (operating essentially like a reverse order piston engine) to compress air drawn from the engine compartment, which it then routes directly to the air tanks. The AK-150 compressor can be seen in the photo of the exposed engine compartment above, partially obscured. The photo below shows the compressor on its own. On a related note, AK-150 compressors seem to be rather popular in the civilian market as a cheap, extremely durable and extremely reliable high pressure air compressor for miscellaneous commercial uses.

It must also be said that the T-54 is extraordinarily light compared to its foreign counterparts. Weighing in at only metric 36 tons dry, it is lighter than a generic Centurion tank (52 metric tons) by an entire 16 tons, and lighter than an M48 tank (45 metric tons) by 9 tons, and despite this, it is comparable in most respects and manages to achieve superiority in others. The light weight of the tank enables it to not only exploit bridges intended for light loads, but to also use pontoon bridges and scissor bridges with impunity, as there will be a large load surplus. A large convoy of T-54 tanks may cross a pontoon bridge without needing to take turns.

The T-54 exerted a ground pressure of 0.8 kg/sq.cm, whereas the newer and heavier T-55 exerted a ground pressure of 0.81 kg/sq.cm.

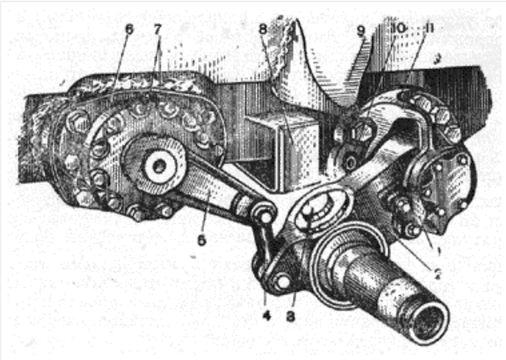
SUSPENSION

Like the T-44 before it, the T-54 used torsion bars instead of the famous Christie spring suspension of the T-34. This saved internal space, but by retaining the same unsupported Christie track concept (no return rollers), there was no space for traditional cylindrical shock absorbers. See the tanks below - the M47, M48 and M60, in descending order.

Note that all of these tanks have three large shock absorbers, two for each of the two frontmost roadwheels and one for the rearmost roadwheel. From reading the testimonies of ex crewmen, one can safely assume that these worked quite well and made these tanks easy to drive and comfortable to ride. On the T-54, there is no room for this type of shock absorber, as you can see below.

Photo from this travel blog

In order to overcome this limitation, a special compact rotary hydraulic shock absorber was invented and installed on the T-54. The shock absorber arm is joined to the roadwheel arm by a rod.



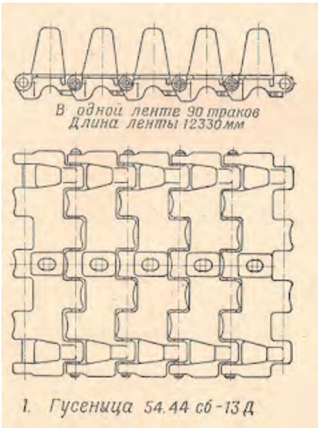
These shock absorbers were paired with the first and last roadwheels on either side of the hull. They were installed behind the roadwheels. However, two on either side was not quite as good as having three or more, resulting in more vibrations when travelling over uneven ground compared to several foreign contemporaries. This likely had an affect on the efficiency of the crew in the long run and weapon accuracy when firing on the move.

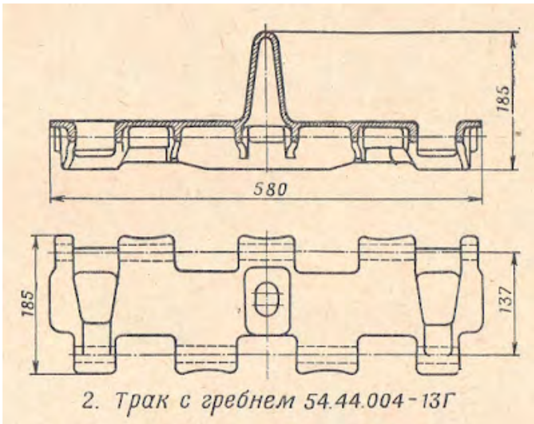
The torsion bars were swapped out for better ones in the T-55AM modernization and the variants thereof, including the T-55AM2, T-55AM2B, and others. This was mainly due to added weight of the tank from the add-on "Brow" armour, but the improved steel of the new torsion bars combined with the heavier mass of the modernized tank improved the damping of vibrations.

OMSh tracks

As with earlier Soviet medium tank tracks, the T-54 uses OMSh tracks. OMSh stands for open metal-pinned tracks. The single-pin track links are held together with bare metal pins which are only secured on the inner end of the track by an oversized head. There are no clips or fasteners to retain the pin on the other end of the track, so when the tracks move, the pins gradually come loose and eventually worm their way out of their slots, but only in the direction of the hull. A steel ramp is welded onto the side of the hull just next to the drive sprocket to knock these loose pins back into the track.

The T-54 obr. 1947 used a proprietary OMSh track design with a width of 580mm that was not carried over to later T-54 models. Beginning with the T-54 obr. 1949, a new OMSh track design was implemented and this came to be the standard design for the T-54 family and its derivatives for the next two decades. These OMSh tracks can be easily identified by the distinctive loop at the end of each track link. The track links are made from cast steel. There are 90 links on each side. The track width remained the same at 580mm and the track pitch is 137mm.





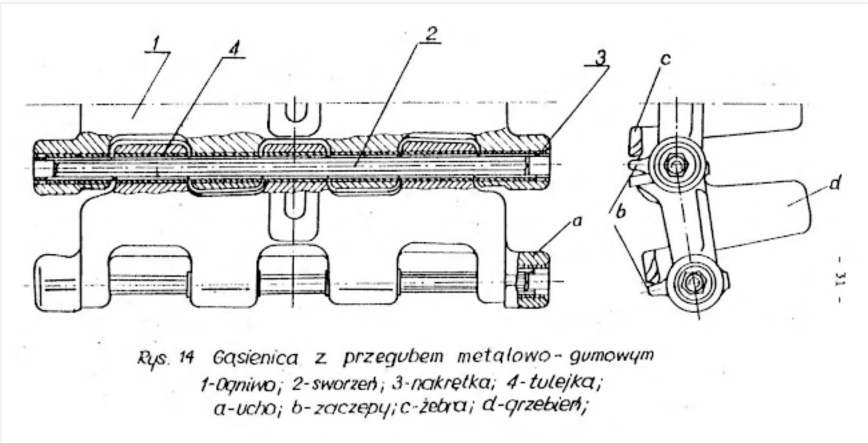
The requirement for the lifespan of the track was fulfilled by the original OMSh track design of the T-54 prototypes, four years before the new OMSh track for the T-54 obr. 1949 was developed. Recall that the T-54 was developed under a set of six requirements, the fifth being: "*Develop a robust track and track pin (increase track life to 3,000 km)*". Testing in 1946 revealed that the T-54 prototype drove 20,000 kilometers and wore out 6 pairs of tracks, equating to an average lifespan of 3,333 kilometers per track, thus exceeding the original requirements by an average of 11.1%.

There were no rubber bushings and no rubber pads on the inner surface of the track links. Furthermore, the open design of the tracks meant that sand and dust could slowly accumulate inside the gap between the track pin and the track link socket. The abrasion from these foreign objects could wear out the track pins which could make them more susceptible to breaking, thus increasing the probability of the tank throwing a track when performing a hard maneuver of some kind. The deficiencies of open-type tracks were recognized and work was done to implement new track designs with an increased lifespan.

RMSh

To improve the lifespan of the tracks, a new RMSh track design was developed by the Omsk Transport Engineering Plant with development concluding in 1962. Beginning in 1966, these new RMSh tracks were fitted to new-production T-55 tanks on a mass scale and the new tracks gradually replaced old OMSh tracks on existing T-54 and T-55 tanks as they wore out during normal use. However, the new track did not become a common sight until much later because large stockpiles of OMSh tracks had been accumulated in the Soviet Army and there was a plentiful supply of spares.

RMSh stands for rubber-lined metal tracks. The tracks have the same width of 580mm as the previous OMSh track design. The track pitch is 137mm, which is also exactly the same as the previous OMSh track design. The track pins are hexagonal and fit into the rubber-lined track pin sockets in the track links and are fastened at the ends with hexagonal nuts.



These tracks were not only designed for increased durability but also higher dynamic loads, so they were built heavier and sturdier than the OMSh design. A full set of ninety seven RMSh track links weighs 1,655 kg. Theoretically, the increased mass of the tracks increased the rolling resistance of the tank which translates to a reduction in the acceleration rate, but in actuality, the increased traction and dynamic characteristics of the tracks reduced power loss by 20%. The driving range and the speed of the T-55 also increased by 15% compared to a tank equipped with OMSh tracks. The biggest improvement offered by RMSh tracks is the increased service life, which is around twice that of the OMSh tracks. Thanks to the shock and vibration damping effect of the rubber bushing, the lifespan of the RMSh track was improved to 5,000-6,000 km and the ride quality in the tank also improved. The noise level of the RMSh tracks was also reduced.

The RMSh track design was also used on the T-62 and it was later carried over to the T-72. Since the T-54/55, T-62 and T-72 became the most numerous tanks in the Soviet Army by a large margin with the T-54/55 and the T-72 being the most and second-most produced tanks in history respectively, the use of the same tracks undoubtedly helped simplify the logistical burden of operating multiple different tank models. It was probably also quite convenient for units transferring from the T-54/55 or T-62 to the T-72.

SWAMP TRACKS

Rare type of tracks designed for operations in swampy terrain, or perhaps "duck bill" clip-on extensions for the standard OMSh tracks. Whatever they are, not much is known about them, except that they are very wide.

COOLING SYSTEM

One important drawback to the design of the powertrain of the T-54 is the barely-adequate cooling system. The system works on simple principles. The engine is water cooled, and the radiator is located on the back half of the engine deck. A large centrifugal fan at the very rear of the engine compartment draws air through the radiator and into the engine compartment from the outside, and then ejects the hot air out through a port, thus cooling the engine. The main flaw in this design is that hot air from the radiator passes into the engine compartment before it exits through the centrifugal fan, so the engine compartment is heated by the hot air and more heat energy is retained overall, making it slightly less efficient. The centrifugal fan can be seen in the photo below.

As mentioned before, the fan is driven at a very high speed by a shaft from the gearbox. Along with the compressor and generator, the fan comprises one of the parasitic elements reducing the final amount of power that is transmitted to the drive sprockets.

The radiator pack is rather large. Inside it is a maze of tubes and heat sinks to maximize the loss of heat. The radiator pack is protected from above by an armoured cover, complete with armoured louvers. The armoured louvers can be closed to protect the radiator and the gear box under it from air attack and molotov cocktails, but the consequence of closing them is that the airflow into the radiator is severely restricted, so that less heat is removed from the coolant.

The armoured cover is hinged and can be lifted up and away, as seen in the photo above. The radiator pack can be lifted up and away in the same manner, and it even has two rubber padded handles for this purpose, as seen in this photo. Both the radiator pack and armoured cover are sprung with a torsion bar so that one man can easily lift them open without assistance. Once out of the way, the gear box, transmission, brakes, radiator pump and coolant reservoir can all be accessed.

Unfortunately, the cooling system is not effective in high ambient temperatures. As a result, engine performance tends to be worse than normal when operating in hot climates, such as in the Middle East, especially when the tank has been running for long periods of time, or when it has been parked under the open sun for hours. In hot weather of 30° or more, the T-54 may have to stop every few dozen or so miles of continuous driving to prevent the radiator from boiling over.

A common remedy for this issue is to simply open up the armoured radiator access hatch, so that airflow is maximized. Unless the tank is operating in urbanized areas, nearly all T-54-type tanks seen fighting in hot climate countries like Syria and Iraq can be found with the radiator access hatch open.

In the photo of an Syrian Arab Army (SAA) T-55 below, the armoured radiator cover is seen locked in the open position as the tank fires on rebel positions from afar. Keeping the armoured cover open maximizes airflow over the radiator pack and helps keep it cool.

Chinese T-54As, or Type 59s as they are called, share the same troubles. Here is a Type 59 participating in an exercise in a desert environment with its armoured radiator cover opened up.

One other disadvantage of the cooling system is that the ejected air is blown out of the centrifugal fan at a high velocity, so that the dust kicked up by the tracks gets sucked into the air stream. The effect is that there is a "rooster tail" of dust spouting from the back of the tank. This tends to be a problem in very dry and dusty conditions like in deserts or in some European summers but not in hot and humid conditions like in South East Asia (including Vietnam). If you happen to be a scout conducting forward observation in a very dry part of the world, faint "rooster tails" in the distance would be a dead giveaway that T-54 tanks are coming your way.

Swapping out the engine was not an easy procedure. I do not know how long it would take on average, but it has to be more than an hour.

Many armour historians have observed that, among other things, one of the main factor behind the T-54's longevity is its automotive reliability and simplicity of maintenance. This is generally true. Quoting from Stefan Kotsch's website (link), which uses Russian sources including Uralvagonzavod's official works on the T-54:

"For example, in the period from October to November 1956, service station no. 20 was tasked to repair 188 tanks T-54. Of these, 18 had tanks, covered with the meantime the engine has change, a driving distance of around 8,000 km. Another 56 tanks reached an average of 6,031 km. The engines on 15 tanks achieved an average operating hours of 600 Mh, an even 696 Mh. Constructor Kartzev presented in 1956 found the tank T-54 can be used without major repair, for replacement of individual modules, certainly achieve a mileage of up to 10,000 km. Thus, the T-54 can be described as one of the most reliable tanks in the world."

According to Pat Ware and Brian Delf in "The Centurion Tank", the engine life of the Rolls-Royce Meteor was reported in service to be only around 3,000 miles (4,828 km) before a base overhaul was required. Many other tanks have been deemed "satisfactory" or "perfectly sound", but not many tanks have the same legendary reputation of toughness as the T-54.

However, this came at a cost. The T-54 is reliable and extremely sturdy, but as we have already learned, the driver's controls were not as user-friendly as contemporary Western tanks which had steering wheels and automatic gearboxes.

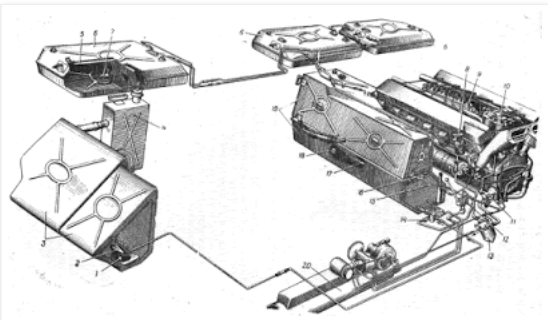
WATER OBSTACLES

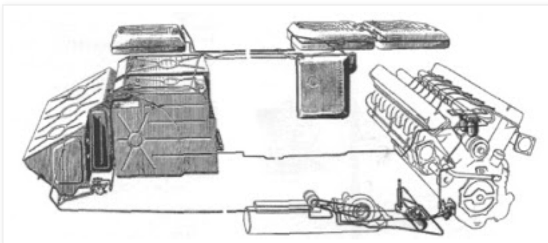
In 1958, the T-54 received the OPVT snorkeling system, thus gaining the ability to cross water obstacles as deep as 5 meters.

If the obstacle is too deep for unassisted fording but too shallow for the full snorkel tube to be used, a shorter snorkel section can be installed, as the photo below showcases.

When not in use, the OPVT snorkel is stowed away at the back of the tank, underneath the wooden log.

FUEL





The T-54 obr. 1947 featured four internal fuel tanks and three external fuel tanks on the fenders above the tracks. The four internal fuel tanks had a total capacity of 520 liters, of which 320 liters is held in the front hull fuel tanks in the nose of the glacis and 200 liters in held in the rear hull fuel tank next to the engine compartment bulkhead. The T-54 obr. 1951 featured an increased fuel capacity thanks to the addition of a 95-liter fuel tank on the right track fender. This arrangement was retained up to the T-54B model.

As shown in the diagrams above, the external fender fuel tanks are not connected with the fuel lines of the internal fuel tanks, but both the internal and external fuel tanks are can supply fuel to the engine through their separate pipes. This is designed so that the fuel supply to the engine can be switched between the internal fuel tanks, the external fuel tanks or switched off entirely, all done remotely from a rotary switch located in the driver's compartment. It was recommended to use up the internal fuel supply first, so that the only fuel left in the tank will be located in the engine compartment and the external tanks, thus eliminating a fire hazard.

The T-55 modernization introduced new conformal fuel tanks that replaced the front hull ammunition racks in the tank which held 300 liters of fuel. The rear hull fuel tank of earlier T-54 tanks was removed and replaced with new ammunition racks, so the net increase in the fuel capacity was actually only 100 liters. An additional 280 liters of fuel was carried in the external fuel tanks located on the right track fender. Thanks to the additional fuel reserve, the driving range of the T-55 was expanded to 485-500 km on paved roads and 290-320 km when driving cross-country.

The T-54 had good fuel economy and a long driving range which was an advantage that was further accentuated by the T-55. Beginning with the T-54B, the driving range of the tank could be enhanced by two removable 200-liter fuel drums mounted at the rear of the tank. These fuel drums were not connected to the fuel network so the fuel must be siphoned into the fuel system manually, as was the case with the T-34. Doing so would require the tank unit to make a short halt which would delay the pace of the march, but not as much as completely stopping the unit and waiting for refueling trucks. Even so, this was recognized as a limitation and the T-72 was designed to have quick-detachable fuel drums that were connected to the fuel system.

In the absence of tank transporter lorries or appropriate rail transport, the T-54 could cover 500 km on a paved road under its own power. If the two external 200-liter fuel drums were fitted, the driving range of the T-54 and the T-55 on paved roads increased to 600 and 650-715 km respectively. Travelling across dirt roads and rough terrain will reduce the travelling range by almost half, as a rule of thumb.

The Centurion, in comparison, consumed fuel at an eye-watering rate of just 0.27 to 0.52 miles to the gallon, giving a range of just 33 to 62 miles. When Stalin closed down all avenues of entry to West Berlin in 1948 (nearly starting WWIII in the process), it became clear that Centurions would not be able to reach the city from their bases in West Germany without needing to refuel en route and waste precious time. This problem was only solved in 1963 with the installation of a bolt-on 109-gallon fuel tank at the rear of the tank, but the T-54 still maintained a huge - only now slightly smaller - advantage in road range and more importantly, fighting endurance.

DISTRIBUTION

It is impossible to discuss the T-54/55 without mentioning that it is the most widely produced tank design in the history of tanks. About 60,000 examples have been produced in the USSR alone, and tens of thousands more have been produced in satellite states. Copies and derivatives of the design, including the Chinese Type 59 and Type 69 boost the total number of tanks even further, making the T-54 the most produced tank in human history. The absurdly high production figures for the T-54 series gave the Soviet Army a decisive numerical superiority during the Cold War and ensured the longevity of the tank in the years to come. For comparison, Simon Dunstan stated that the production of the Centurion Mk. 3/5 medium tank ran from 1946 to 1958, during which 2,833 Mk. 3 tanks (1946-56) and 221 Mk. 5 tanks (1955-58) were manufactured. Three facilities were responsible for Centurion final assembly: Vickers Armstrong and the Royal Ordnance Factories at Leeds and Dalmuir. According to Spencer Tucker, a total of 4,423 Centurions of all types were built, of which 2,500 were exported.

Currently, the T-54 is in service in Russia as hard targets on firing ranges all over the country. A few examples are were serving in the Far East as coastal defence guns as recently as 2012, but since then, virtually all existing T-54 tanks have dismantled and melted down for their steel. Almost all of the examples that actively served in the Far East were leftover T-55A tanks equipped with KDT-1 laser rangefinders, but even these are now almost never seen outside of storage facilities.

T-54 technical manual (Link)

T-55 technical manual (Link)

BIBLIOGRAPHY