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SWEDISH 'S' TANK

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RAC EQUIPMENT TRIALS WING

REPORT

SWEDISH 'S' TANK

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RAC EQUIPMENT TRIALS WING, RAC CENTRE

REPORT ON

SWEDISH 'S' TANK

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WAREHAM, Dorset.

Date 13 February 1969

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ABSTRACT

1. This report covers a trial on two Swedish 'S' Tanks between Apr-Sep 68. The aim was to evaluate the concept of a turretless tank as embodied in the 'S' Tank. Parts of the trial were carried out by the Tactical School RAC Centre, Army Personnel Research Establishment, HQ Technical Group REME and FVRDE, as well as branches of ETW, each of whom has contributed to this report in separate annexures.

2. It has been difficult in many instances to separate the detailed test results from a concept evaluation and this is reflected in some portions of the report.

3. The trial showed the concept is viable, but its realisation may give rise to lower reliability than its competitors. The major advantages of the concept are:

a. A reduction in the crew to three men, and even one or two for short periods in emergency.

b. Having all main armament rounds ready. To maintain simplicity a restriction to two main natures and a small number of a third nature, which may require some positive mechanical action by a crewman, will be necessary.

c. A lower silhouette leading to a better use of ground and easier selection of fire positions.

d. A much easier design problem to meet the requirement for protecting the crew.

e. It facilitates the combination and duplication of controls.

4. The major disadvantages are:

a. Its inability to fire effectively on the move, which is fundamental to the concept.

b. Its inability to engage targets without the main engine running and hence the loss of surprise especially at night.

c. Although not experienced on the ground used for the trial there will be limitations in its ability to traverse in e.g. bocage country and in certain circumstances in built up areas.

5. In determining the advantages and disadvantages of the concept the aim was achieved. A definite statement for or against the concept is not given as it was beyond the scope of the trial. The fundamental question arising from the trial concerns firing on the move, a capability now provided in good measure in CHIEFTAIN. The recommendation, therefore, is for further study:

a. To determine to what extent will firing on the move be required in the future, and whether the disadvantages of not delivering accurate main armament fire on the move outweigh the undoubted advantages of the concept.

b. A cost analysis of the design, development and production of a turretless tank should be carried out.

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ACKNOWLEDGEMENTS

The Equipment Trials Wing wishes to acknowledge the great help received from AB BOFORS and their senior representative, Kapt K. JONELL, during the trial. In particular their resident engineers, Mr. G. NYGREN and Mr. H. WESTERDAHL, who worked all hours of the clock and always remained cheerful throughout the six months. The crews appreciated the excellent training provided by the team of instructors, and the spares service impressed everyone with its efficiency and speed. Almost all items requested were at London Airport in the early hours of the following morning. Larger spares by sea were no less speedily despatched.

The success of this trial also depended greatly on the Tactical School RAC Centre for the Tactical Phase, the Army Personnel Research Establishment (APRE) for the human factors assessment, HQ Technical Group REME for the maintenance assessment, and FVRDE for certain performance tests and assessment of design features. RAC Equipment Trials Wing is indebted to all these for their assistance and cooperation.

THE TRIAL REPORT ON THE SWEDISH 'S' TANK

INTRODUCTION

The 'S' Tank concept is unique in that the gun recoils in the normal manner is otherwise fixed in relation to the hull and the hull is used to traverse and elevate/depress the gun. The tank is therefore turretless. The Swedish philosophy behind this concept was based on the following factors:

a. Topography. Sweden is 2000 kms long. A line from the southern tip of Sweden 2000 kms long would reach as far south as Rome in Italy. It contains a very varied terrain with temperatures down to -40°C (-40°F). The country is crossed by many rivers, some of considerably size, as well as over 60,000 lakes, many too deep to ford or snorkel. The tank had, therefore, to swim and be rail transportable. This set an upper weight limit of 37 metric tons.

b. Tactics. The population is small and any war would be defensive. The main task of the limited number of Armoured Brigades would be to contain an enemy attack and then counter attack to force the enemy back over the frontier. There are fewer tanks in the armoured brigades in comparison to other armies and this dictated a tank with a very high chance of survival on the battlefield with no sacrifice in the demand for the highest level of fire power, mobility and protection despite the weight limit.

c. Financial. The in-service life of the tank will be long as cost rules out early replacement. Hence a new vehicle must be technically advanced.

d. Training. The Swedish Army is a conscript one with a nine months period of service followed by 15 days training every third year thereafter. Experience of turreted vehicles showed that considerable time was needed for crew training at the expense of tactical training. The 'S' Tank had to be simple to operate by the crew, preferably one man should be able to fight it alone in emergency. This emphasized the need for a well designed fighting compartment.

2. These factors led to the following technical characteristics:

a. Very low silhouette thus presenting a small target area.

b. Target acquisition ability both stationary and on the move to be high.

c. Capable of withstanding at least two direct hits on the front from APDS without putting the tank out of action.

d. The greatest possible chance of withstanding hollow charge attack over the front arc.

e. A minimum reaction time between target acquisition and a "kill".

f. A 105mm to be used to maintain compatibility with CENTURION but with greater penetration and rate of fire.

g. A weight limit of 37 metric tons.

/3. ....

3. The major saving in weight is achieved by eliminating the turret and installing an automatic loader, hence saving one crew member. The gun is then put in the hull and this was the starting point in 1956 of basic design study for the 'S' Tank. After system trials on adapted vehicles showed the feasibility of the 'S' Tank concept the development contract was placed with BOFORS in 1958. When the prototypes began trials reports appeared which created great UK interest in the concept and officers who visited Sweden recommended that the 'S' Tank should be more closely examined. This was requested by DAWS and a contract was negotiated with the BOFORS Company for the loan of two 'S' Tanks for a period of six months. This report covers the complete trial of the two tanks.

AIM

4. To evaluate the concept of a turretless tank as embodied in the 'S' Tank.

AUTHORITY

5. The authority for the trial was MOD(AD) AEP 17. Application for RAC Equipment Trial A/58/A Vehs/383 AEP 17 dated 18 Mar 68.

DESCRIPTION OF THE EQUIPMENT

6. The 'S' Tank is a low (under 10ft) turretless tank with a battle weight of 83,200 lbs. The vehicle can swim and is powered by a two engine installation consisting of a Rolls Royce K60 Engine which drives a torque convertor. The output of this engine is coupled to the fixed ratio gearbox as is a Boeing gas turbine engine. This automotive power train is placed on the front of the vehicle and drives the front sprockets through a clutch brake system and a final drive epicyclic gear train. The fighting compartment, situated in the middle of the vehicle, is L shaped to accommodate a three man crew, the driver/gunner and rear driver on the left-hand side and a commander on the right-hand side. Duplicate driving/gunnery controls are provided for the commander and driver/gunner and the former in addition has a cupola which has power traverse and a stabilised sight.

7. The armament consists of a 62 calibre length QF 105mm gun held in a mounting fixed in relation to the hull. In the rear of the hull are two magazines between which is the automatic loader and the breech of the gun, the gun itself passing through the centre of the crew compartment in a jacket. In addition there are two fixed coaxial MGs mounted in an external armoured box above the left-hand wing and a commander's MG mounted on the cupola.

8. The K60 engine powers the vehicle hydraulics which give elevation and depression by moving the suspension. Centre point traverse is provided by an additional variable hydraulic drive to the sprockets through the final drive epicyclic gear train. This also provides regenerative steering and prevents reverse drive during clutch/brake steering.

9. A detailed description of the 'S' Tank is given in Annex A.

CONDUCT OF THE TRIAL

10. Two series 'A' 'S' Tanks were provided for the trial. These were numbered 2132 and 2133. These tanks landed at HULL docks on 27 Mar 68 and arrived at ETW on 3 Apr 68. The tanks were returned to Sweden from ETW on 24 Sep 68. The main outline phases of the trial were:

/a. ....

a. Crew training carried out by instructors provided by BOFORS for six weeks. A total of three crews were trained.

b. The Weapon Assessment by Weapons Branch, Equipment Trials Wing.

c. The Tactical Field Trials carried out by the Tactical School. These took place on the SALISBURY PLAIN Training Area.

d. A Human Factors Assessment conducted by the Army Personnel Research Establishment.

e. A Maintenance and Servicing Assessment carried out by HQ Technical Group REME.

f. An Automotive and follow-up trial phase.

g. An FVRDE Assessment on vehicle 2132 at CHOBHAM. This covered certain automotive performance tests and an assessment of certain design features.

RESULTS

11. The 'S' Tank system of elevation/depression and traverse is viable. It can perform all the functions of a tank except the important one of firing effectively on the move and an inability under certain circumstances of terrain to traverse at all.

12. The results have been presented below as advantages or disadvantages under main trial headings. Certain aspects such as swimming cannot be assessed as the vehicles were not equipped for this. Detailed results are given in Annexures as follows:

Annex B	-	Dimensions Analysis.
C	-	Weapons Trials.
D	-	Tactical Assessment.
E	-	Evaluation of Human Factors.
F	-	Automotive Trials Results.
G	-	FVRDE Answers to User Questions.
H	-	Troop Leader's Comments.
J	-	Technical Group REME Results.
K	-	Photographs.

13. Weapon Aspects. The main advantages of the turretless concept are:

a. Allows the use of an automatic or semi automatic loader and magazine. Hence all rounds are "ready" rounds.

b. The loader can be dispensed with and a sustained rate of fire with no fatigue can be maintained.

c. The combination and duplication of controls allows the duties of commander, gunner and driver to be carried out by two men or even one in an emergency.

d. It gives a lower silhouette and allows an easier selection of fire positions as driver and commander are on the same level.

/14. ....

14. The disadvantages are:

a. It cannot fire the main armament on the move effectively as the chances of the gun being brought to coincidence in both azimuth and elevation, even for an instant, are remote.

b. The main engine must be run to use the main armament, coaxial machine gun and the commander's machine gun on power. This prevents the achievement of surprise in a night engagement.

c. The non provision of a traverse indicator handicaps switches for line at night. It is also a necessity for long range HE engagements and semi indirect fire.

15. Tactical Aspects. The main advantage is that the reduction of vehicle size and the mounting of the main armament close to the roof line gives greater freedom in the selection of fire positions, covered approaches and generally aids concealment.

16. The disadvantages are:

a. That an 'M' kill is a 'K' kill. This is fully defined in Annex D para 2 but briefly any failure or damage to the automotive components renders the main armament unusable.

b. Concealed fire positions are liable to disclosure as the main engine must be run if the armament is to be used.

c. The inability to fire the main armament on the move, which is compensated to a limited degree in the 'S' Tank by the commander's machine gun being stabilized in line. This, however, distracts the commander, if he is firing, from other essential duties.

17. Human Factors Aspects. The major advantage is the removal of large recoiling masses from the crew compartment with the attendant problem of fumes from the weapons. It is also much simpler to seal the crew compartment from NBC hazards and approach the pod idea.

18. Automotive Aspects. The advantages are:

a. The ability to provide duplicated controls and simple provision for reverse driving.

b. The traversing requirement provides excellent manoeuvreability in confined spaces from the separate variable steering imput. Despite its sometimes frightening sharpness on roads the ability to turn in any direction rapidly without selecting the appropriate gear as in the Meritt system outweighs any disadvantages.

19. The drawback is that the requirement for a low silhouette, elevation/depression and rapid traverse means a short length of track on the ground (L) and an L/C ratio in the order of 1.1 to 1.25. This leads to a rough pitching ride cross country. The crews compensate for this by reducing speed and hence increasing exposure time. Any desired increase in elevation could mean an even shorter length of track on the ground.

/20. ....

20. The disadvantages of a gas turbine, as installed in 'S' Tank, are:

a. Noise. This is of a relatively high frequency and allows reasonably accurate location of its position. Cf., low frequency track rattle which appears to come from all points of the compass at night.

b. Heat Shimmer. The heat from the exhaust often gave away its position. The thermal signature is a real problem to overcome.

c. Signature. As the only gas turbine vehicle on the battlefield at present, it is easily identified by ear.

DISCUSSION

21. The discussion will concentrate on the relative merits of two concepts of mounting a gun as main armament in vehicles. In one concept the mount is fixed in relation to the hull, and in the other it is independent of the hull in elevation/depression and traverse. The concepts actually tried were as embodied in the 'S' Tank and CENTURION respectively and inevitably the report becomes a critique to some extent of the 'S' Tank itself compared with CENTURION. Nevertheless, it must be borne in mind that the conventional turreted tank, e.g. CENTURION, is not the only alternative.

22. The main disadvantage of the fixed mount concept is that it does not allow effective firing of the main armament on the move, a capability now provided in good measure in CHIEFTAIN as a result of 20 years development. Its system is simple to operate, reliable and effective, giving a high chance of a hit. Any future major war will be one involving the use of large mobile armoured forces and the protection/fire power balance can only be kept by increasing protection or the use of mobility. To exploit the latter fully there must be no necessity to halt to fire. Therefore, the question is not "is firing on the move necessary?" but rather "can we afford to give up our present capability of firing accurately on the move?".

23. To attempt to answer this question goes beyond the scope of this report but it is relevant to the argument that Sweden has not at present given up turreted vehicles. Her armed forces will continue to include CENTURION as well as 'S' Tank. The main advantages of the 'S' Tank are in defence. This leads to the idea that turreted AFVs should be in predominately armoured formations for offensive roles and turretless AFVs in predominately infantry formations to hold ground and replace existing anti tank guns in infantry battalions. This has been the ideology in several armies in introducing the limited traverse SP gun, usually a common tank chassis with a heavier armament. The idea behind this must assume lower cost for the turretless SP gun. Where 'S' Tank differs from SPs so far experienced is on providing an integral fine lay in the traverse, but the cost of doing this is unknown. Before any definite statement for or against the concept can be made there is a need for a costing exercise to determine:

a. The development and production costs of a turretless tank using its hull for all round traverse and elevation/depression of its weapon system. It must incorporate:

(1) A higher level of reliability for the automotive components than past and existing vehicles possess, because an "M" failure could mean failure to use the weapon systems.

/(2) ....

(2) Retention of a short length of track on ground and a L/C ratio of 1.1 to 1.3 to retain a low silhouette but leading to the unlikelihood that the vehicle could be the basis of a family.

(3) The incorporation of limited silent traverse and elevation/depress with a traverse indicator and crest clearance indication provided.

b. The equivalent cost of a similar weapon system giving stabilised all r traverse and elevation independent of the hull.

24. The tactical trials were limited in scope and the absence of the expected Solartron Direct Fire Weapons Effects Simulator was a handicap to establishing the tactical viability of the concept. Nevertheless they indicate the desirability of its further examination as embodied in the 'S' Tank on a tactically larger scale, e.g. a squadron combat team where problems of command and control can also be st

CONCLUSIONS

25. The major advantages of the concept are:

a. A reduction in the crew to three men, and even one or two for short per in emergency.

b. Having all main armament rounds ready. To maintain simplicity a restri tion to two main natures and a small number of a third nature, which may req some positive mechanical action by a crewman, will be necessary.

c. A lower silhouette leading to a better use of ground and easier selecti of fire positions.

d. A much easier design problem to meet the requirement for protecting the crew.

e. It facilitates the combination and duplication of controls.

26. The major disadvantages are:

a. Its inability to fire effectively on the move, which is fundamental to the concept.

b. Its inability to engage targets without the main engine running and henc the loss of surprise especially at night.

c. Although not experienced on the ground used for the trial, there will be limitations in its ability to traverse in e.g. bocage country and in certain circumstances in built up areas.

d. The non provision on the 'S' Tank of additional gunnery aids including crest clearance indication, traverse indicator and a means of checking the bore is clear of mud etc. These items are not fundamental to the concept.

27. The trial has been successful in that the evaluation of the concept has high lighted its advantages and disadvantages. It has not been possible in the scope of the trial to analyse in depth the RAC doctrine of being able to fire on the mo and the many other benefits obtained from a stabilised gun system. Nor did the trial cover a proper cost study of the two basic designs. Without this backgrou study a definite statement for or against a turretless concept cannot be made.

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28. The conclusion is that the turretless concept as embodied in the 'S' Tank is viable but not yet reliable. The next step should be a detailed evaluation of its cost and theoretical and practical studies of its advantages and disadvantages in a tactical setting.

RECOMMENDATIONS

29. The fundamental question arising from the trial concerns firing on the move. The questions posed are: to what extent will firing on the move be required in the future; and are the disadvantages of not delivering accurate main armament fire on the move outweighed by the undoubted advantages of this concept? An analytical study of the tactics used with our present turreted tanks against those required for a turretless concept is therefore recommended, leading to a carefully planned series of field trials at up to squadron strength with supporting arms. These field trials should be based on obtaining data from Solartron Direct Fire Weapon Effects Simulator.

30. It is also recommended that a cost analysis of the design, development and production of a turretless tank is carried out. This design is to incorporate the requirements of this report and is to be compared against a stabilised all round traversing design. This comparison should be based initially on the same armament gun. Any relevant factors, i.e. one design allowing greater calibre to be mounted should also be subsequently considered.

Annex 'A' to AT/1123/GT 428
dated 13 February 1969

DESCRIPTION OF THE EQUIPMENT

GENERAL DESCRIPTION

1. This Swedish tank, called the 'S' Tank Series A by BOFORS or STRIDSVAGN 103 (STRV 103) by the Swedish Army, is a turretless three man tank. It mounts a 105 mm gun of 62 calibres length and three 7.62 mm machine guns, one being mounted on the cupola and the others being fixed to the hull. These weapons are laid in traverse by turning the whole tank hull and elevated or depressed by altering the pitch of the hull through movement of the suspension. Magazines holding 50 rounds and a semi automatic loader for the 105 mm are situated behind the gun. They can cater for two natures of ammunition automatically and a third with manual assistance. The vehicle carries a three man crew, a commander on the right hand, a driver/gunner on the left hand side, and facing the rear behind the driver/gunner on the left hand side is a third man whose main task is to drive the vehicle in reverse. The commander has a cupola which is provided with powered traverse, and powered elevation for the gyro stabilised sight. A line up facility with the main armament is provided. An external 7.62 mm machine gun is mounted on the cupola and aligned with it in azimuth. It is hand elevated and controlled from inside the vehicle. Local smoke is provided by two four barrelled grenade dischargers mounted on the cupola.

AUTOMOTIVE DESCRIPTION

Automotive Components (Fig. 1)

2. Main Engine.(1) This is a Rolls Royce K60, vertically opposed piston, 2 stroke compression ignition engine developing 240 HP (SAE) at 3650 r.p.m.

3. Gas Turbine. (5) This is a Boeing 502-10 MM developing 300 HP (SAE). The maximum gasifier speed is 38000 r.p.m. It is a simple in line two shaft type. The gasifier consists of a single stage radial compressor and axial type compressor turbine. The secondary shaft has the power turbine and reduction gears. This engine is to be replaced by a Boeing 553 in later Series B tanks.

4. Torque Converter. (2) The output from the K60 is directly connected to the Volvo DRH-1M torque converter. It acts as a clutch and is controlled hydraulically to give three ratios (1st Gear, 2nd Gear and direct drive).

5. Transfer Box. (3) The outputs of the torque converter and gas turbine are connected to the gear box (4) through the Volvo SV-2 transfer box.

6. The Gear Box. (4) The Volvo FBTV-2B gearbox provides two speeds, one for roads and one for cross-country in either direction for forward or reverse driving. The gears are operated hydraulically through discs and selection for the type of drive and direction are controlled by two levers mounted in parallel, one for the driver/gunner and one for the commander. The reverse driver can reach the commander's lever. Gear Ratios are:

Forward Direct Gear	1:1
Forward Cross Country	2.94:1
Reverse Direct Gear	0.89:1
Reverse Cross Country	2.61:1

7. Transmission. The gearbox output is into a Volvo VV-11 drive bevel gearbox (6). The output shafts are connected to the Final Drive (9) via dry disc 3 plate clutches (7) and steering brakes (8). The Final Drive consists of an epicyclic Train, and shaft carrying the sprocket.

/FIG. 1 - AUTOMOTIVE LAYOUT

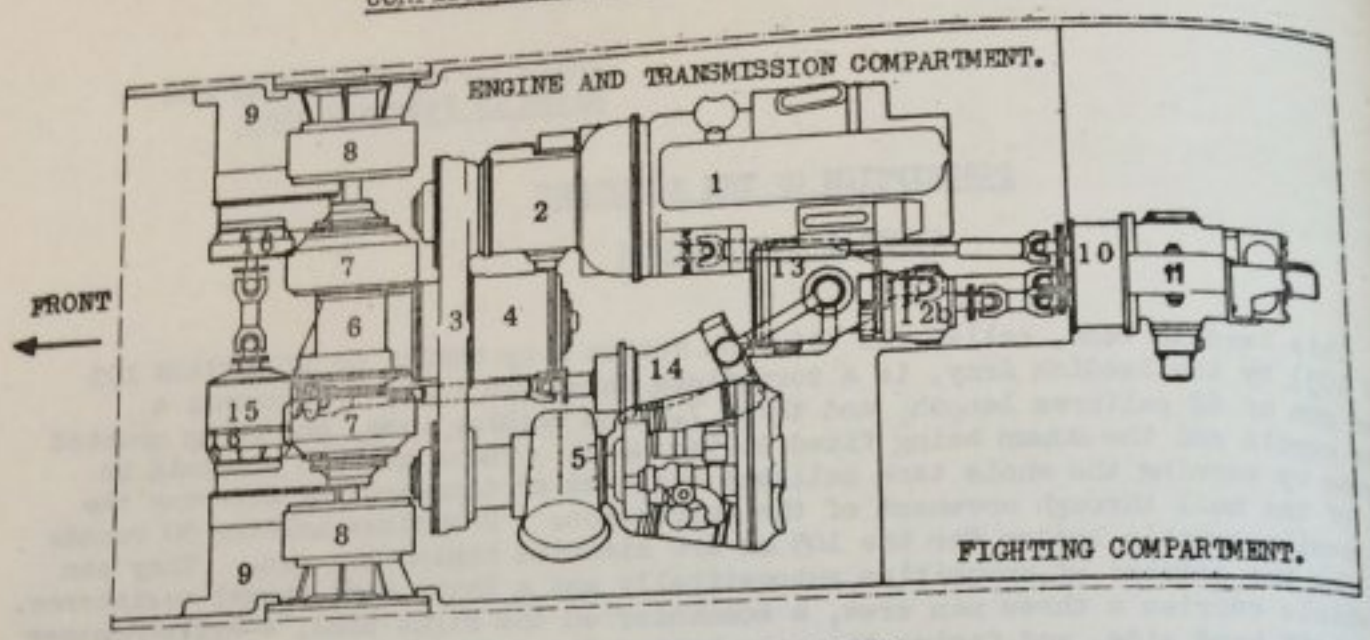


FIG. 1 - AUTOMOTIVE LAYOUT

1. MAIN ENGINE - ROLLS ROYCE K60.
2. TORQUE CONVERTER - VOLVO DRH-1M.
3. TRANSFER BOX - VOLVO SV-2.
4. GEARBOX - VOLVO FBTV 2B.
5. GAS TURBINE - BOEING 502-10MM.
6. DRIVE BEVEL GEARBOX - VOLVO VV-11.
7. STEERING CLUTCHES.
8. STEERING BRAKES.
9. FINAL DRIVES.
10. HYDRAULIC TRANSMISSION.
11. ELEVATION HYDRAULIC DISPLACEMENT PUMP.
12a. SERVO OIL PUMP (215 lbs/in²).
12b. SERVO OIL PUMP (930 lbs/in²).
12c. LUBRICATION PUMP FOR TRANSMISSION GEARBOX.
12d. PUMP FOR ENGINE COMPARTMENT VENTILATION FAN (1290 lbs/in²).
13. STEERING HYDRAULIC DISPLACEMENT PUMP.
14. STEERING HYDRAULIC MOTOR.
15. STEERING BEVEL GEARBOX.
16. STEERING SHAFT BRAKES.

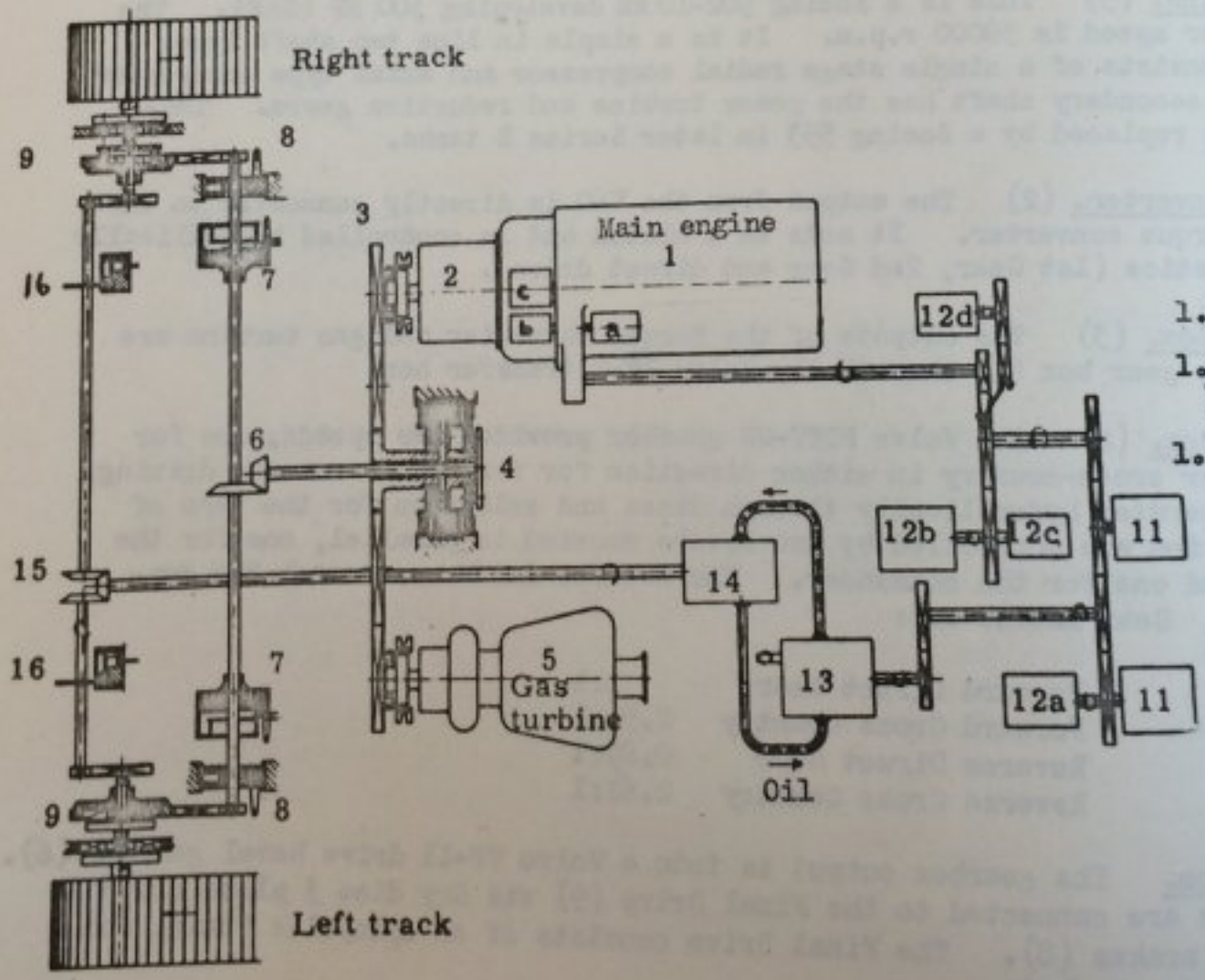


FIG. 2 - AUTOMOTIVE AND STEERING DRIVES

8. Cooling/Lubricating System:

a. The cooling system consists of a header tank above the K60 engine. Two radiators and their fans are located at the rear of the hull on each side. Coolant is used in heat exchangers to cool the separate main engine, gas turbine and certain servo oil systems.

b. A fan is provided at the front right hand side of the hull to draw air through an air inlet into a duct to the steering brakes. This air passes through the engine compartment and is expelled through a louvre to the right of the commander's cupola.

c. The hydraulic servo systems for the cooling and lubrication systems consist of:

(1) A pump (Fig 2 Item 12d) to drive the motor for the cooling air in the engine compartment.

(2) A pump (Fig 2 Item '1b') on the K60 drives the motor for a pressure pump and three drain pumps grouped together under the gearbox. The pressure pump draws lubrication oil from the gearbox sump to lubricate the gearbox, transfer box, drive bevel box and for gear changing. The three drain pumps draw lubricating oil from the bevel gearbox and two points on the transfer box back to the gearbox sump.

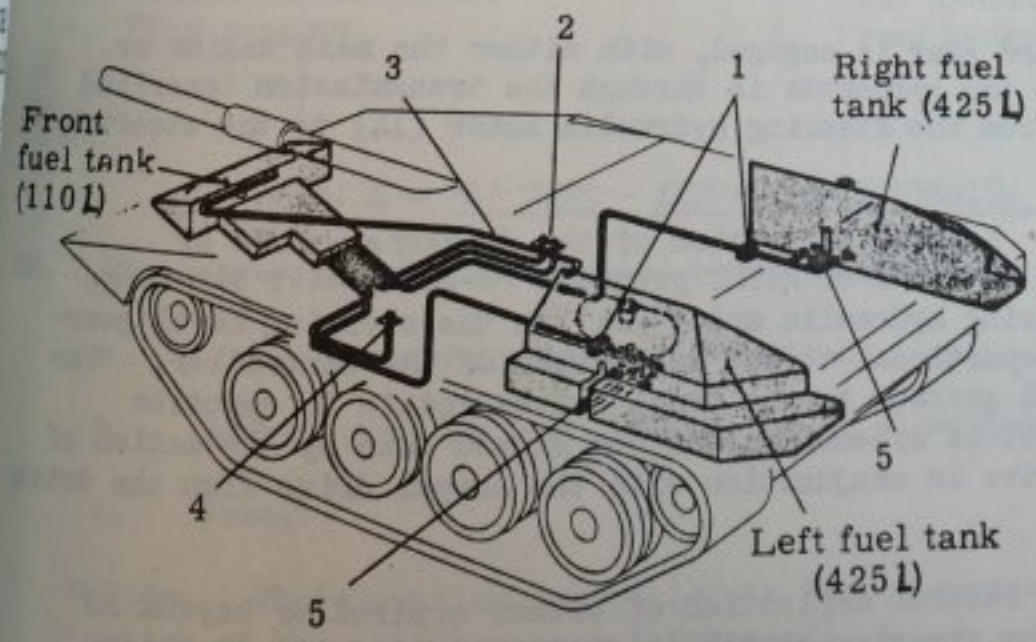
(3) When the main engine is not running a hydraulic pump on the gas turbine drives the pressure pump and three drain pumps described in (2) above.

(4) A pump (Fig 2 Item '1c') for the radiator fan motors. This hydraulic oil is air cooled.

..

(5) There is a single hydraulic oil tank for these systems situated above the torque converter.

9. Fuel System. Both engines use diesel fuel which is contained in three tanks. The nose tank at the front containing 110 litres (24.2 galls) and one at each side in the rear half of the vehicle sponsons containing 425 litres (93.5 galls) each. This gives a total of 960 litres (211.2 galls). A warning light shows when the remaining quantity of fuel is less than 90 litres (19.8 galls).



Fuel tanks

1. Fuel taps
2. Rapid connections for main motor fuel system
3. Air out-let pipe line
4. Rapid connection for gas turbine fuel system
5. Tuel tank drain taps

FIG. 3 - 'S' TANK FUEL SYSTEM

/10. ....

10. Suspension. The vehicle has a front sprocket with two rings similar to CENTURION. The rear idler bracket contains a worm screw for adjusting the track tension. There are four road wheels on each side on axle arms connected to hydro-pneumatic cylinders. The top rollers on each side support the track. Bump stops for each wheel are provided by oil filled buffers.

11. Tracks. Two types of track were provided for each tank, one with bonded rubber pads and one steel. Each is a dry pin centre horn track with four/five lugs.

12. Electrical. Two 12V, 114 AH batteries in the fighting compartment are provided for the primary 24 volt DC system. The main engine charging system is an AC generator and rectifier made by Rotax rated at 2.85 KW. If the gas turbine is in use, without the K60 running, charge is provided by the DC Starter/Generator (A Boeing 10-40051-1) with a Bosch regulator. It is rated at 0.18 KW. A static converter supplies a secondary AC voltage at 115 volts 400 Hz automatically when the main engine runs and the servo oil pressure is correct. This AC voltage is used for the servo circuits of the hull elevation/depression system and for traversing the cupola and stabilising or elevating the commander's sight.

Automotive Operation (Fig 2)

13. The normal working of the vehicle on cross country or when the weapon system is to be used requires both the main engine (K60) and gas turbine to be used. As there is a delay in obtaining full power the technique for the driver is to keep the accelerator depressed and use the brakes to control the vehicle speed. A control in the driver's/gunner's compartment operates the free wheel on the torque converter output. In the normal locked position at 2500 rpm on the K60 the torque converter is in third gear (Direct Drive). Additional deflection of the accelerator brings the gas turbine to full power, hence for neutral turns and running power from the gas turbine can boost the K60 power to drive the hydraulics. It would also be possible to start the K60 by the gas turbine but as it would rotate at 2500 rpm it is not normally allowed.

14. On level roads the vehicles can be driven on the main engine only. This engine powers the hydraulic system through a propshaft. If the gas turbine has become defective it must be disconnected by a free wheel device within the power pack.

15. It is possible to use the gas turbine only as an emergency get-you-home system. As there is no power to the hydraulic system mechanical steering levers are provided for the driver/gunner. He must also alter the free wheel lever to 'Unlock' (see para 13).

16. Steering. When a forward gear is engaged, with either the main engine or both engines running, drive to the sprockets is through the transmission described in para 7 above. The drive from the steering hydraulic motor (14) to the steering bevel gearbox (15) is locked.

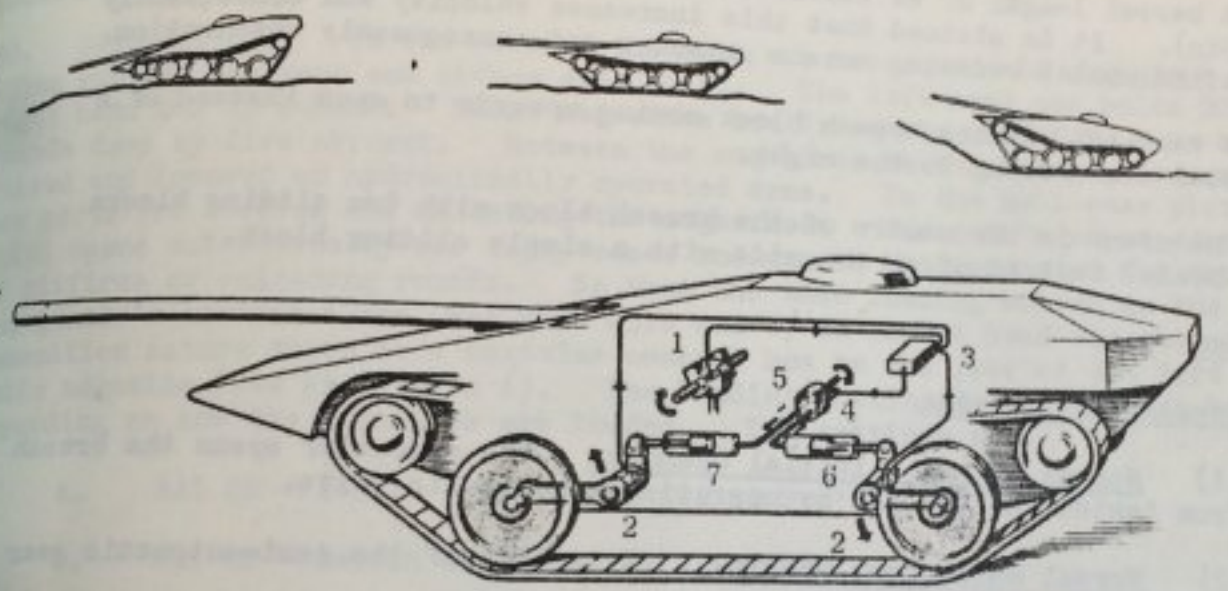
17. Re-generative Steering. Lateral deflection of the driver/gunner's or commander's control unit up to 20° LEFT or RIGHT provides re-generative steering. The output shaft from the steering hydraulic motor (14) to the steering bevel gear-box (15) rotates at a speed proportional to the deflection of the controller. The outputs from the steering bevel gearbox to the final drives rotate in opposite directions. Hence one sprocket is speeded up and one slowed down by the action of the epicyclics in the final drive in conjunction with the normal drive from the drive bevel gearbox (6).

18. Clutch Brake Steering. Lateral deflection of either controller beyond 20° operates a steering valve. One steering clutch is disengaged and the steering brake on the same side is engaged. The drive is therefore taken to one track only. A smaller turning radius than that which corresponds to the distance between the tracks is obtained as the re-generative steering system is working in parallel to the clutch brake system.

19. Neutral Steering. With the gear level in neutral and the brakes engaged (by use of the brake pedal or hand brake) a neutral turn is obtained around the vehicle centre line.

20. Mechanical Steering. This is only used when there is a hydraulic failure or the main engine cannot be used. Without any hydraulic pressure the two steering shaft brakes (16) on either side of the steering bevel gear box are locked on. Operation of a mechanical lever then operates the clutch brake steering by a mechanical linkage to the appropriate clutch and brake.

21. Elevation/Depression. The pitch of the hull is varied by the transfer of hydraulic fluid between the front and rear road wheel hydraulic cylinders which are connected to elevation displacement pumps, hence altering the deflection of these wheels and the hull. This is electrically controlled by position servos mounted on the commander's and driver/gunner's control units, front and rear axle arm pivots and hydraulic pumps.



Left elev. servo system

1. Control unit with synchro
2. Pendulum arm synchros
3. Transistor amplifier
4. Pilot magnet
5. Hydr. displacement pump (driven by main motor)
6. Rear hydraulic cylinder
7. Front hydraulic cylinder

FIG. 4 - 'S' TANK - ELEVATION/DEPRESSION SYSTEMS

22. The suspension can be operated in three modes:

a. Fully lowered by a separate switch.

b. Locked with the gun level or at 4° elevation.

c. Free.

(Note: The elevation controller is locked automatically when the firing switch of the main armament is pressed).

/23. ....

23. In the FREE position an upward deflection of the control unit twist handles sets up a misalignment between the pump and axle arms. The pump, therefore, pumps oil from the rear wheel hydraulic cylinders to the front ones until the servos are realigned, hence elevating the hull. Similarly an opposite deflection gives depression. In addition, an average height servo comprising an injection valve controlled by all four axle arm servos signals and the control unit signal maintains the track tension during elevation or depression by slightly lowering the hull. There is no facility to level the suspension laterally.

MAIN ARMAMENT

Gun

24. Description. A high-velocity, long-barrelled, semi-automatic QF 105 mm gun fitted with a fume extractor, its design is based on the British Gun 105 mm Tank L7A1 but differs in that the Swedish gun has:

a. A barrel length of 62 calibres (21ft 4in) compared to 51 calibres (17ft 9in). It is claimed that this increases velocity and consequently penetration whilst reducing muzzle pressure and consequently obscuration.

b. A vertical sliding breech block moving upwards to open instead of a horizontal one opening to the right.

c. The crank in the centre of the breech block with two sliding blocks (cross-heads) instead of at the side with a single sliding block.

25. Operation:

a. Opening the Breech:

(1) Normal Method - Initial Opening. The commander opens the breech from inside the vehicle by operating a hydraulic valve.

(2) Normal Subsequent Opening. By action of the semi-automatic gear on firing.

b. Closing the Breech. Normally automatic on the loading of a round when the extractors are tripped and disengage from the shoulders of the breech block. On the cessation of firing the only method of closing the breech is to trip the extractors with the tool provided. This can only be done from outside the tank and through the hull roof port.

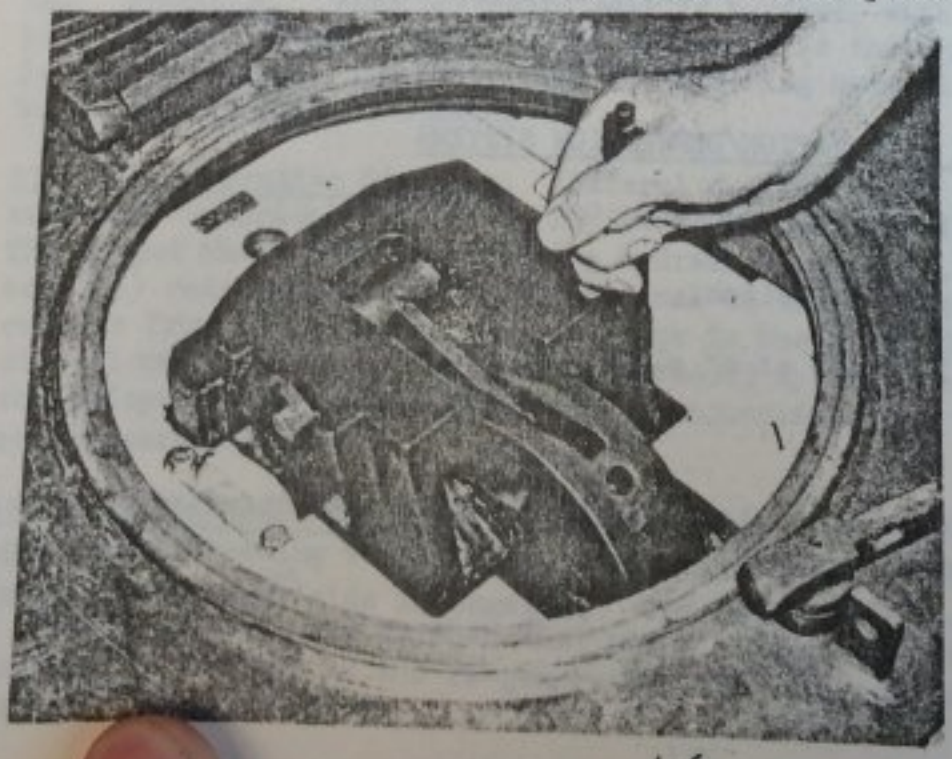


FIG. 5 - 'S' TANK - MANUAL CLOSING OF BREECH

Mounting and Recoil Systems

27. Mounting. The ring type cradle is fixed in relation to the hull, and the barrel which recoils inside it is supported in bushes 22in apart, as it is in the cradle of the CENTURION mounting. There is also a barrel stay on the glacis plate at the front, 5ft from the muzzle when the gun is at forward battery. There is considerable clearance between the barrel and this stay which merely acts as a support during vehicle movement.

28. Buffer Recuperators. The recoil system consists of two hydro-pneumatic buffer recuperators mounted either side of and behind the breech ring. They are serviced through ports in the hull roof. The normal recoil length is 11in (280mm) as with the UK gun and a recoil indicator is fitted so that it can be read by the reverse driver.

29. Semi-Automatic Gear. This consists of a rack and pinion which causes the breech to be opened on run-out.

The Loading System

30. Description. In the rear of the hull are two automatic magazines for the 105mm gun, to the rear and either side of it. The left hand one holds 20 and the right hand one 25 rounds. These magazines are in square rack form four or five rounds deep by five abreast. Between the magazines is the loading tray which is raised and lowered on hydraulically operated arms. In the hull rear plate there are ports for loading and unloading the magazines. There is also an ejection port which opens automatically for empty cases and can be hand operated for the ejection of misfires or unloading rounds. So that the same loading button on the commander's and gunner's control boxes, see para 43.b and c, is always used for the same ammunition nature there is a magazine control box on the rear of the left hand auto-matic magazine (see Fig 6 Item 6). The Loading Setting Switch on this box is set depending on how the magazines are loaded. The settings are:

a. All HE - switch fully clockwise at 2 o'clock.

b. All AP - switch clockwise at 1 o'clock.

c. Left magazine HE and right magazine AP - switch anti-clockwise at 11 o'clock.

d. Right magazine AP and left magazine HE - switch fully anti-clockwise at 10 o'clock.

/FIG. 6 ....

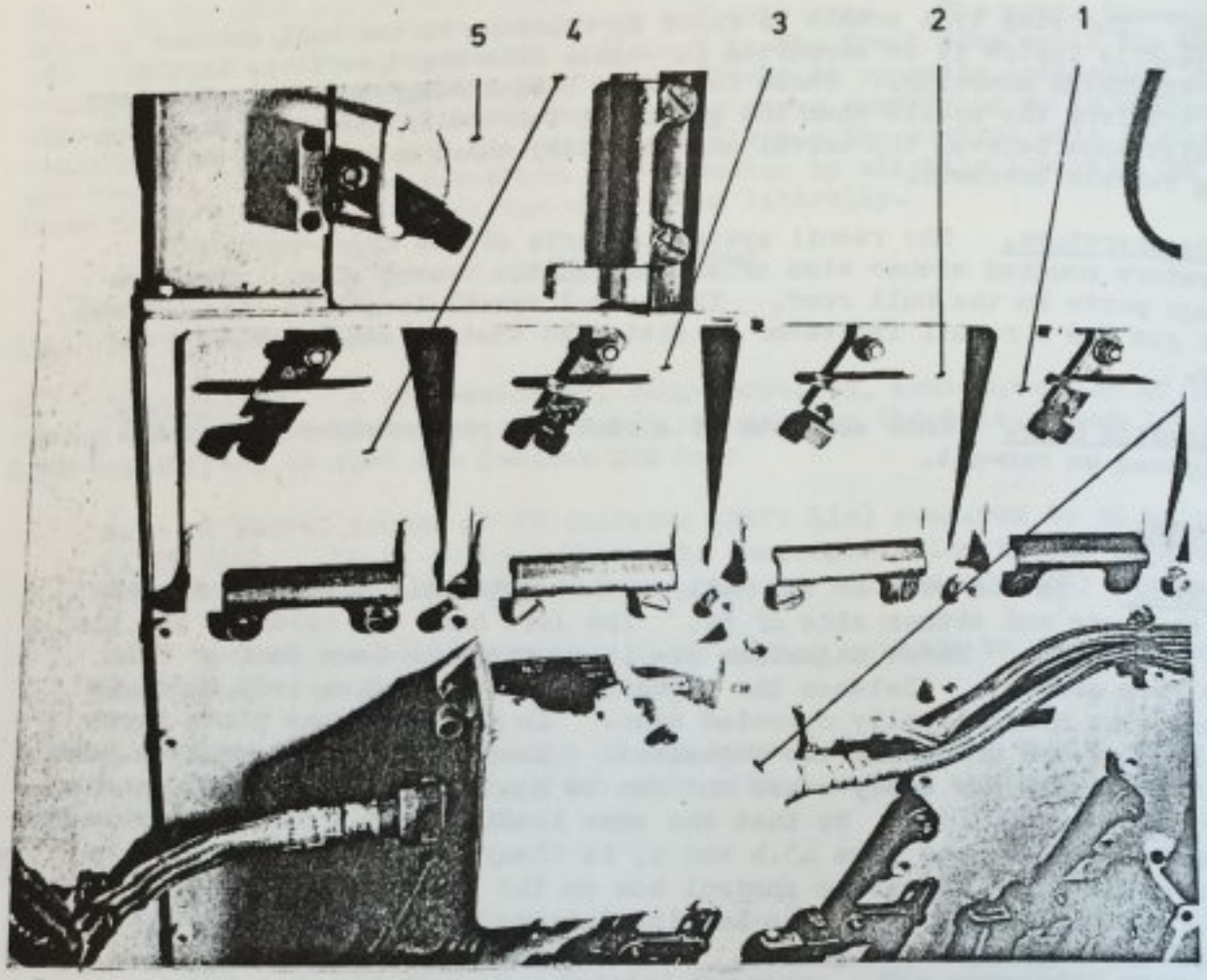


FIG. 6 - 'S' TANK - LEFT HAND MAGAZINES AND CONTROL BOX

KEY

1 - 4. Automatic Magazine Compartment Doors.
5. Hand Loaded Magazine Compartment Door.
6. Control Box with Magazine Loading Setting Switch on top.

31. Operation. The loading system is electrically controlled and hydraulically operated. The commander and driver/gunner both have controls enabling them to load a round from whichever automatic magazine they select. The system has a cut-out so that a round will not be fed into the gun if the breech is closed. The round to be loaded is fed from the bottom of the selected magazine onto the loading tray which then rises to the breech height where the round is automatically rammed into the chamber. The breech closes as the rim of the round trips the extractors and the loading tray lowers itself. During these actions the other rounds in the bottom row are indexed inwards towards the loading tray. The complete cycle takes about 2.5 secs. As the bottom row is emptied rounds from the outermost filled stack drop into position under control and stacks are thus emptied in succession. On firing the empty case is ejected through the automatically opened ejection port. A further round cannot be loaded until the empty case is out, the ejection port closed and a crewman operates his loading switch. To enable rounds to be unloaded without subjecting them to the ramming into and ejection from the breech an unloading control box with buttons for the left and right automatic magazines is located at the bottom of the left magazine.

/32. ....

CONTROL BOX

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/32. ....

32. Loading the Third Nature. By loading one of the automatic magazines with APDS and the other with HE the commander or driver/gunner can select either nature by pressing the appropriate loading button. To enable a third nature to be carried and fired there is a five round magazine above the left hand automatic magazine (see Fig. 6). It is operated by the reverse driver who can set the fuzes on these rounds as required and hand load them onto the loading tray which he operates with a separate hydraulic control to that of the automatic system. There is provision for manual operation of the breech and ejection port if natures with insufficient recoil energy to operate the semi-automatic gear are used.

33. Quantities of Rounds by Natures. The arrangements of the magazines gives the commander the choices of:

a. APDS Predominant:

(1) Right Magazine 25 rds APDS.

(2) Left Magazines:

(a) 20 rds HE.

(b) 5 rds of a third nature.

b. HE Predominant:

(1) Right Magazine 25 rds HE.

(2) Left Magazines:

(a) 20 rds APDS.

(b) 5 rds of a third nature.

Drills

34. Circuit Testing. The novel mounting of the gun within the hull necessitates a change from the normal circuit tester. The instrument provided with the 'S' Tank is in the form of a flat spade with a centre contact inserted between the front face of the breech block and the breech ring from inside the tank by the reverse driver. The commander or driver/gunner then presses a firing button to check that the bulb illuminates.

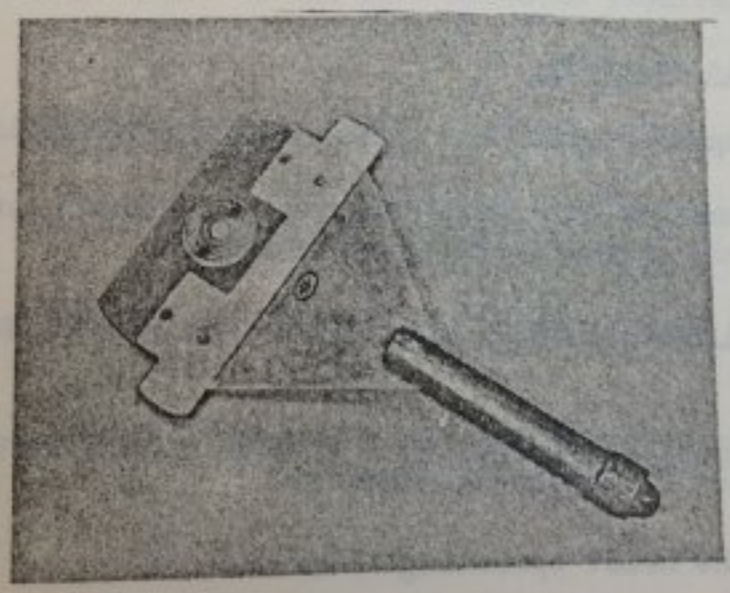


FIG. 7 - 'S' TANK - CIRCUIT TESTER

/35. ....

35. Loading the Magazines:

a. Decide on the allocation of ammunition natures to magazines.

b. Open the loading ports.

c. Open the door of the compartment nearest the hoist and insert a round, projectile first, of the appropriate nature for the magazine. Push the round fully home and close the compartment door. This action allows the round to drop in the magazine to make room for the next one.

d. Repeat c. until four (left magazines) or five rounds (right magazine) have been loaded. Then repeat with the other compartments working outwards until all the rounds have been loaded in the automatic magazines.

e. Set the Loading Setting Switch to the appropriate position (see para 30).

f. The last five rounds for the hand loading magazine are loaded through a separate compartment door on the upper left (see Fig. 6 Item 5). These rounds have to be wound across individually using a handle situated in the reverse driver's position.

36. Unloading the Magazines. With the K60 engine running:

a. Open the unloading port at the centre bottom of the rear hull plate.

b. Ensure the hoist is in the lower position.

c. Press one of the unloading switches situated at the bottom right of the left hand magazine. This feeds a round out of its magazine on to the hoist tray. Remove this round.

d. Repeat c. until all rounds are unloaded from the two automatic magazines.

e. The last five rounds in the hand loading magazine have to be taken out through its compartment door. The first one is removed and subsequently the feeder has to be wound back and the remaining rounds rolled back by hand. This is done by inserting the hand into the magazine while seated in the reverse driver's position.

37. Loading the Gun:

a. From Automatic Magazines:

(1) The commander opens the breech with the hydraulic control.

(2) The commander or gunner/driver presses the appropriate loading button on their laying/steering control unit.

b. From the Hand Loading Magazines. With the breech open as in a. the reverse driver:

(1) Pushes a lever to release the round whilst turning the feeder handle one revolution anti-clockwise.

(2) Pulls the hoist operating lever.

/38. ....

38. Unloading the Gun:

a. The commander or reverse driver opens the ejection port.

b. The driver/gunner elevates the hull.

c. The commander opens the breech.

d. The commander dismounts and removes the round from the hull if it has not fallen out and checks the chamber and bore are clear.

e. The ejection port and breech are closed.

39. Misfire Drill. The basic procedure is similar to CENTURION with the checking of switches and the correct closure of the breech. Should there be a genuine misfire the breech is opened hydraulically and the round ejected as described in para 38 above. If the round does not fall out the tank can be reversed and suddenly braked, which should remove the misfire by its inertia. The loading of another round can then take place.

GUN CONTROL EQUIPMENT

Methods of Gun Control

40. The Normal Method. The K60 main engine drives the hydraulic pump for the normal traverse and elevation systems and has to be run at 1,500 to 2,000 rpm for effective control. Both commander and driver/gunner are able to use these systems, the commander having the power to override the driver/gunner by pressing down on his accelerator. Control reverts to the driver/gunner when the commander releases his accelerator and puts it in the vertical position.

41. Emergency Method. Should the K60 engine fail there is a hand hydraulic pump for elevation but there is no effective traverse system.

Gun Controls

42. General. The commander and driver/gunner have similar control units which are used for both gun laying and steering. The laying/steering controls are handles on either side of a control box mounted on a bracket. Steering/traverse is obtained by moving the handles in the direction desired - as with bicycle handles. For elevation control the same handles are rotated about their longitudinal axes in the same sense as the hull movement required.

/FIG. 8 - 'S' TANK - STEERING AND GUN CONTROL UNIT

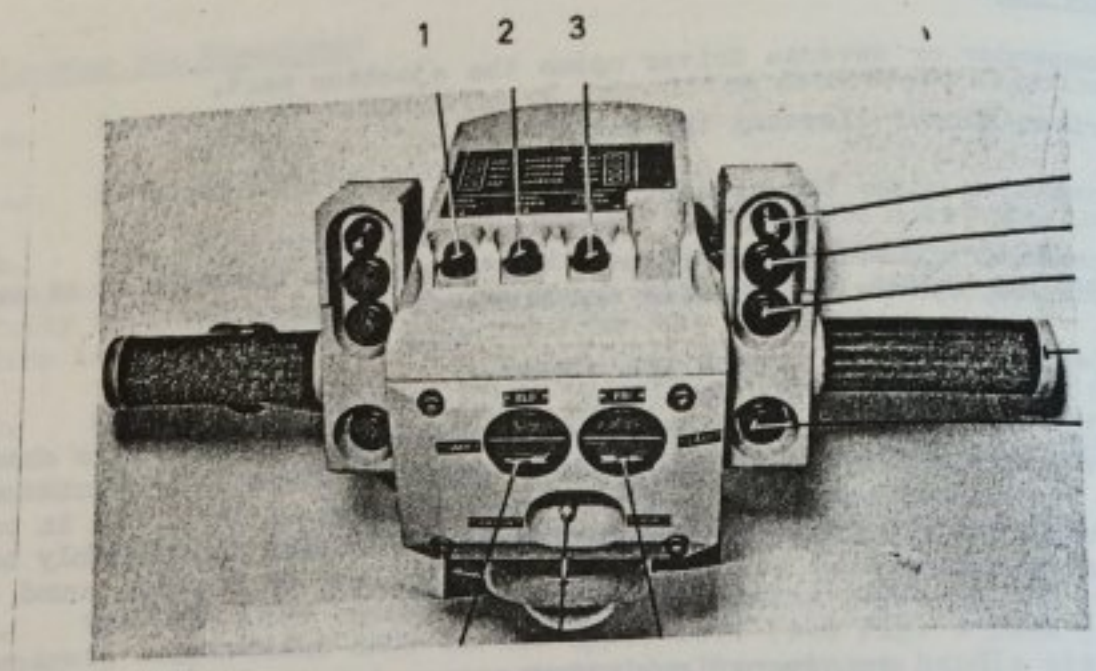


Fig 8

FIG. 8 - 'S' TANK - STEERING AND GUN CONTROL UNIT

KEY

1. Warning Lamp - K60 Engine.
2. Warning Lamp - Gas Turbine.
3. Warning Lamp - Transmission.
4. AP Loaded Ready Light.
5. AP Loading Switch.
6. Firing Switch.
7. Elevation Controller.
8. HE Loading Switch.
9. Elevation Safety Switch.
10. Armament Selector Switch.
11. Firing Safety Switch.

43. Control Box Facilities. The following switches and indicators are mounted on the control box in three panels facing the operator:

a. Centre Panel:

(1) The Armament Selector Switch. (Fig. 8 Item 10). A toggle switch at the bottom centre panel with two positions:

(a) KANON - to the left for the main armament.

(b) KSP - to the right for hull MGs.

(2) The Firing Safety Switch. (Fig. 8 Item 11). A quadrant switch on the upper left of the panel with two positions:

(a) SAKR - arrow horizontal : 'Safe'

(b) ELD - arrow vertical : 'Fire'

/(3) ....

(3) The Elevation Safety Switch. (Fig. 8 Item 9). Similar to (2) but on the upper right of the panel. Its positions are:

(a) LOK - arrow horizontal : elevation controller locked, hull pitch fixed at 0 or +4°.

(b) FREI - arrow vertical : elevation controller can be rotated to alter hull pitch.

b. Right-hand Panel. Starting from the top the lamp and push button switches are:

(1) AP Loaded Ready Light (Fig. 8 Item 4).

(2) AP Loading Switch (Fig. 8 Item 5).

(3) Firing Switch (Fig. 8 Item 6).

(4) HE Loading Switch (Fig. 8 Item 8).

c. Left-hand Panel. This is the same as the right-hand panel at present but b.(1) is the HE loaded ready light. When the new fire control system is installed this panel will be modified on the commander's controller to operate the laser and other equipment.

44. Other Controls:

a. Main Gun Safety Switch. As well as the commander's and the gunner/driver firing safety switches on their panels there is a further main gun safety switch mounted on the left of the commander above the internal barrel sleeve. When the lever is locked in the 'safe' position the firing needle assembly is physically withdrawn back into the breech block if this is closed. If the breech block is open a linkage is operated so that even if the breech block is closed the firing needle assembly will still be retracted.

b. Weapons Switch. As an additional safety there is a weapons switch on the main switch panel under the gun. No weapon firing circuits are energised until this switch is made.

c. Emergency Firing. For the hull MG's only there is an emergency mechanical firing gear for the gunner/driver situated to the left of his steering/laying control unit. When operated it fires both hull MG's together.

Traverse

45. Normal Operation. Normally with the K60 engine running traverse is obtained from the hydraulically controlled differential steering system. This gives an increasing traverse rate up to 90°/s at 20° deflection. (The traverse rate is to be increased to 170°/s in later tanks). Beyond 20° deflection the clutch and brake system is engaged and by acceleration of the engine 180° traverse can be obtained in about 2 seconds when on the move. The clutch/brake system only operates at this speed when moving. When stationary 180° traverse takes about 12 seconds.

46. Emergency Operation. The gun may be roughly aligned by the clutch and brake system if the gas turbine but not the K60 is running. The control by this method is not fine enough for effective laying. Should neither engine be running there is no system of traverse whatsoever.

/Elevation

Elevation

47. Description. The pitch of the hull on level ground can be varied between -10° and +12° elevation by the transfer of hydraulic fluid between the working cylinder of the front and rear suspension units which in turn varies the static deflection of the road-wheels. It is electrically controlled by synchro units mounted at the elevation controllers, the hydraulic pumps and the front and rear axle arm pivots. The effective elevation range may be curtailed but control is still available if one or two of the corner suspension units become inoperative as they can be individually isolated.

48. Operation. At the halt with the K60 engine running no movement of the hull will take place in pitch if all the synchro rotors are aligned. If the elevation controller is rotated a set amount of corresponding deflection of its synchro rotor will occur which will be instantly followed by the synchro rotor of the hydraulic pump. The synchro rotors at the axle arm pivots will now be realigned by the resultant movement of the axle arms.

FIRE CONTROL AND OBSERVATION EQUIPMENT

General

50. Both the commander and driver/gunner can lay the hull armament with their sights, which are similar. The commander's sight is mounted in a cupola to enable it to be used to search for targets without moving the tank hull and for aiming the commander's MG. Also, it is stabilised so that it can remain on a target area despite changes in hull attitude when on the move.

51. There is a clinometer graduated in mils but otherwise no sight or range gear for:

a. Direct HE engagements over 4000m.

b. Semi-indirect fire.

c. Indirect fire.

Driver/Gunner's Sight

52. Description. This is a periscope in a fixed mounting on the hull roof with two optical systems sharing the same object prism. The unity system for general observation has an eye prism and 100° horizontal field of view. For target identification and gun laying there is the binocular system with a fixed ballistic graticule in the right eye-piece and a quick change selection of x6, x10 or x18 power with decreasing fields of view. Two novel features of this sight are:

a. A Flash Shutter. When the firing button is pressed a shutter is operated in the sight for an instant to prevent the gunner being blinded by muzzle flash.

b. A Camera Recorder Facility. A robot 35 mm camera can be attached to the underside of the sight, without any interference to normal operation, which will record the gunner's lay at the instant of firing.

53. Operation. The sight is set up for use as follows:

a. Interocular Setting. The scale is below the left eye-piece with the normal range of 54 to 76mm. Set the required interocular distance by turning the adjustment knob to the right of the right eye piece.

/b. ....

b. Selection of Magnification. With the lever to the left of and above the left eyepiece select x18 magnification. (Fig. 10 Item 1).

c. Focus. Achieved in the normal manner by rotating the eyepieces which have a range of ±6 dioptres. Focussing is best done at the highest magnification, which is the most critical. After focussing a lower magnification can be selected without re-focussing.

d. Filter. To reduce glare in strong sunlight three filters operated by a lever to the right of the right eyepiece, are provided. (Fig. 10 Item 4).

e. Graticule Adjustment. To align the sight to the main armament, horizontal and vertical graticule adjusters with 0.2‰ graduations are situated above and to the right of the unity eye prism and on the right hand side of the sight respectively.

f. Graticule Illumination. This can be varied by a control lever.

54. The Graticule. A sketch and detailed description of the fixed ballistic graticule visible in the right eyepiece of the binocular system is given in Fig. 9. The full range of HE markings can only be used with x6 magnification. The x10 and x18 magnifications with their reduced fields of view exclude the HE markings below 3800m and 2500m respectively. Briefly it has:

a. HE markings every 100m from 600 to 4000m.

b. APDS markings every 200m from 600 to 2200m.

c. A MG scale marked for 200, 400, 600, 800 and 1000m.

d. A vertical scale above the zero point from 0 to 40‰.

e. Line scales from 0 to 50‰ either side of the zero point.

f. APDS aim off marks for targets moving between 10 and 60 km/hr.

g. HE aim off marks for targets moving between 10 and 60 km/hr up to 2000m range and for 5 and 10‰ crosswind between 2000 and 4000m.

/FIG. 9 - 'S' TANK - GRATICULE PATTERN

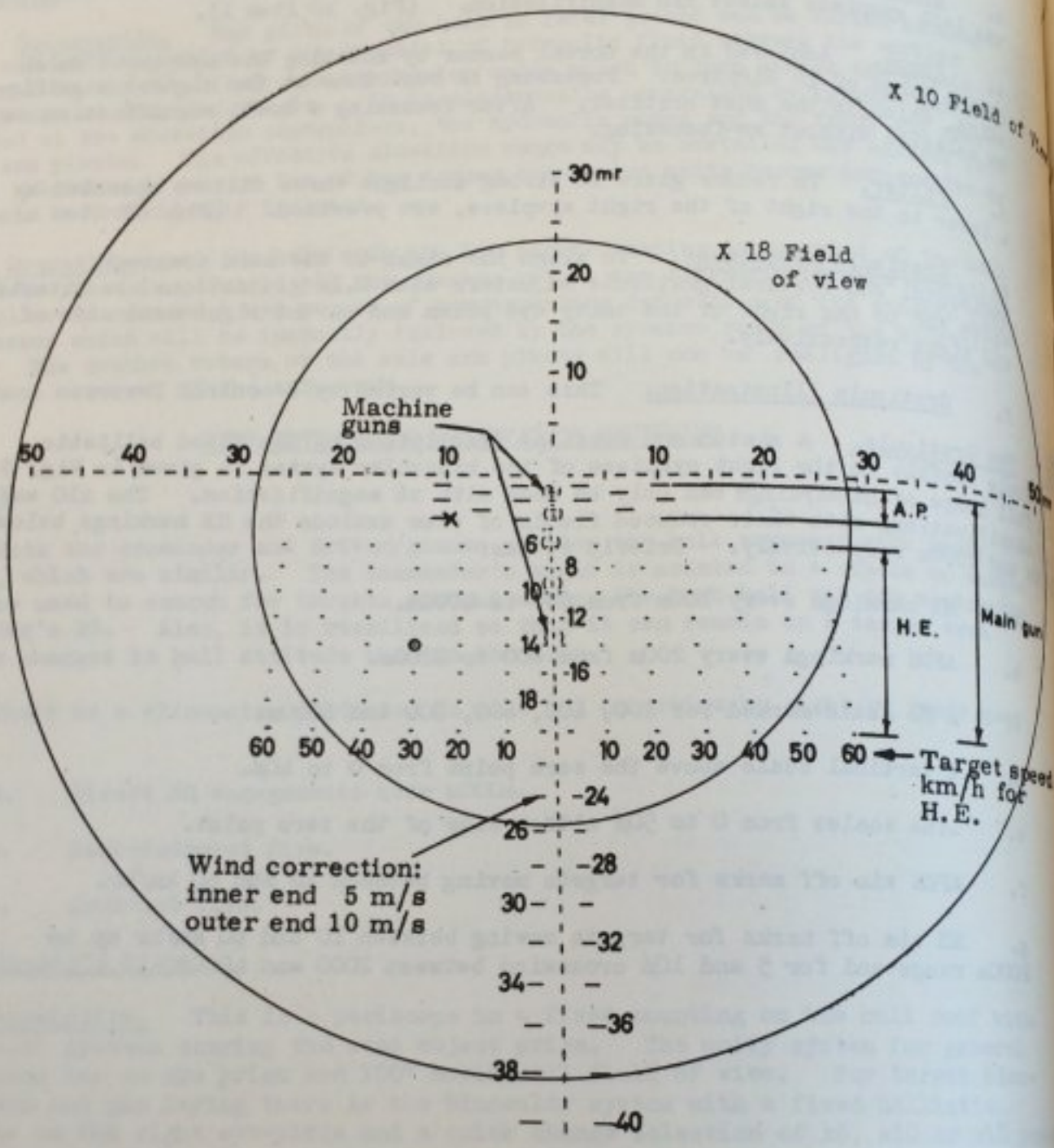


Fig 9. S TANK - GRATICULE PATTERN

Machine guns: Ranges 2, 4, 6, 8 and 10 x 100 m (within parenthesis)

A.P. am: Ranges 6, 8, 10, 12, 14, 16, 18 and 22 x 100 m (speed lines only for underlined figures)

Aim-off lines: Inner ends for 10, 30 and 50 km/h target speed
Outer ends for 20, 40 and 60 km/h target speed

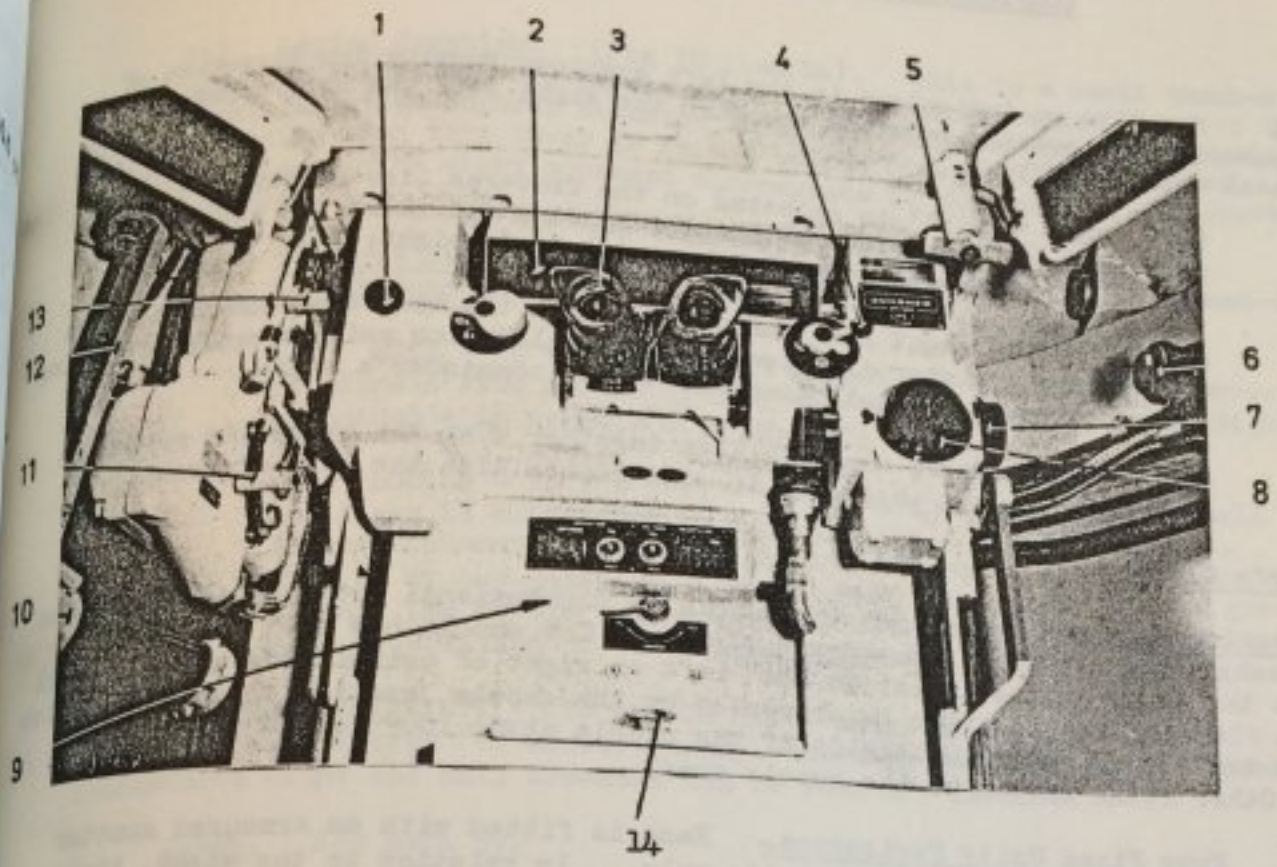


FIG. 10 - 'S' TANK - COMMANDER'S SIGHT AND CONTROLS

KEY

1. Magnification Selector Lever.
2. Unity Eye Prism.
3. Left-hand Eyepiece.
4. Filter Selector Lever.
5. Sight Cover Operating Handle.
6. Cupola Grip Handle.
7. Elevation Graticule Adjuster.
8. Line Graticule Adjuster.
9. Sight Control Unit with Traverse Line-up Switch.
10. Commander's MG Elevating Handle.
11. Sight Elevation Control Selector Lever.
12. Commander's MG Elevating Arm.
13. Sight Tilting Prism Hand Operating Lever.
14. Cupola Laying Joystick.

Commander's Sight

55. Description. This is the same instrument as the driver/gunner sight but has more facilities:

a. It is mounted in a rotatable cupola giving it a traverse facility independent of the hull.

b. Has a tilting prism which can be:

(1) Locked in a vertical coincidence with the hull armament for laying or target indication.

(2) Stabilised in elevation when on the move or used to search for target in elevation when stationary or mobile, independent of hull attitude in elevation.

(3) Linked with the commander's MG to aim it.

/c. ....

c. Has line up indicators in the left eyepiece showing the direction of traverse or elevation required to align the sight with the hull armament. These work as follows:

(1) When 'LOCKED' is selected on the Traverse Line-up Switch (see para 56.d.(2)) the traverse pointer appears and shows the position of the hull armament relative to the commander's sight.

(2) When the sight has been aligned with the hull armament in azimuth the traverse pointer disappears and the elevation pointer appears showing the position of the hull armament to the commander's sight.

(3) Both pointers are only seen together when the hydraulic system is off and the sight is locked in coincidence with the hull armament.

Commander's Cupola

56. Description. In appearance the cupola is conventional but is unusual in that it has stabilisation of the commander's sight. The cupola has 360° traverse in effect as the sight may be traversed 200° left or right of coincidence with the hull armament. Continuous rotation is prevented by the cupola junction and master switch box which is mounted on the underside of the cupola about 100° to the right of the sight. Other items fitted to the cupola are:

a. Four Fixed Unity Periscopes. Each is fitted with an armoured shutter which can be opened from the outside only. In relation to the sight, these face:

(1) Left front.

(2) Left rear - this one is at present obscured by a spent case bin for the commander's MG.

(3) Right rear.

(4) Right front.

b. Commander's MG Mounting. This is situated above the two left-hand periscopes. There is also an alternative pintle mounting between the right-hand periscopes. Details of these are given in paras 65 and 66.

c. Sight Elevation Control Selector Lever. (Fig. 10 Item 11). On the underside of the cupola to the left of the sight is a selector lever with three positions:

(1) Top - Links the tilting prism to the commander's MG elevating arm so that the sight can be used to aim this MG.

(2) Centre - Enables the prism to be tilted by hand when the K60 engine is off.

(3) Bottom - Connects the tilting prism with a rate gyro for stabilisation and also a servo allowing power elevation control by means of the laying joystick. See d. below.

d. Sight Laying Control Unit. This is suspended under the sight. Its two controls are:

/(1) ....

(1) Laying Joystick. (Fig 10 Item 14). This is a small thumb-sized joystick which controls cupola traverse for all three positions of the sight elevation control selector lever and controls the tilting prism in elevation when this lever is in the bottom (see c.(3)) stabilised position. The sight movement corresponds to the sense of the joystick movement.

(2) Traverse Line-up Switch. (Fig.10 Item 9). This is a semi-rotary lever switch just above the joystick. It has two positions:

(a) FREE - to the right - it allows the cupola to be traversed by signals from a rate gyro or the joystick even through sight coincidence in azimuth with the hull armament.

(b) LOCKED - to the left - it locks the cupola to the hull when the sight is coincident in azimuth with the hull armament. Until the coincidence is obtained the cupola may be traversed by its rate gyro or by the joystick. When under the control of the gyro signals the cupola will contra-rotate enabling the commander to keep observation of the target whilst bringing the gun to bear.

e. Traverse Indicator. The cupola has a small aperture to the left of the sight elevation switch (c. above) through which the azimuth angle between the commander's sight and hull armament can be read off in mils.

f. Hatch. See para 59.

57. Operation. The commander can use his cupola and sight to:

a. Search for and locate targets independently and regardless of the hull attitude whilst stationary and mobile. The stabiliser and gun laying controls enable him to lay on to an acquired target without losing observation of it through his sight.

b. Lay the hull armament or indicate targets to the driver/gunner.

c. Aim his cupola MG independently, regardless of the hull attitude.

Range-finding Equipment.

58. Originally it was intended to mount a ranging gun in a pod on the front of the tank opposite the hull MGs and above the right track. This system has been discarded in favour of a computer/laser system which has not yet been fully engineered. It is to be operated by the commander.

Other Observation Equipment

59. Hatches. The commander has his own hatch in the cupola and the other two crewmen share a large one which is big enough for both to have their heads out. The view forward from the commander's and driver/gunner's positions is excellent because of the sloping glacis-plate. The reverse driver has quite a good view to the rear except that the square end of the tank gives him a blind zone to about 25m from the tank. He can drive opened up, however, because of the position of his controls. Both hatches have three positions:

/a. ....

a. Fully open.

b. Umbrella.

c. Fully closed.

60. Periscope. In addition to the periscopes in the cupola (see para 56.a.):

a. The Driver/Gunner has one on the left of his sight, facing half left, so giving him a good wide unity vision even at ground level close to the tank.

b. The Reverse Driver has one facing directly astern which has a blind zone up to about 25m from the tank with the hull level. He has another one facing to the left rear of the vehicle.

SECONDARY ARMAMENT

Machine Guns

61. There are three machine guns mounted on the tank. They are Swedish models of the FN gas-operated GPMG and almost identical to the UK 7.62mm Infantry L7A1 MG. The main differences are the removal of the bipod and replacement of the butt by a buffer assembly for ease of mounting on the tank. There is no toxicity problem as all the guns are mounted outside the fighting compartment and the normal pattern infantry flash hider and foresight are used. The foresights are lighter than the UK pattern and can be folded flat. Butts, bipods, slings and spare barrels are carried so that all three guns may be used in the dismounted role.

Hull MGs

62. Description (Fig. 11). Two MGs, which are the equivalent of co-axial MGs, are mounted in an armoured pod on the left front of the vehicle above the track. Inside the pod the guns are side by side with the right hand one slightly forward of the left hand one to ease the belt exits. Each gun is fed from a 500 round box on its left. Belt exit guides are provided for both guns which pass the empty belts out of the pod on to the glacis plate, that for the left hand gun bridging the right hand gun. Empty cases fall into the bottom of the pod. Both mountings allow for adjustment so that the guns can be zeroed to the sight after bore-sighting the main armament. The guns are fired by solenoids and cocked manually by a handle in the driver/gunner's compartment which operates the remote wire-connected cocking gear. The driver/gunner also has an emergency manual firing lever. The clearing rod, spare barrels and the dismounted role equipment are all stowed in the pod bin.

63. Operation. The guns are laid by the normal main armament laying controls. They fire alternately when the electrical firing switch is pressed but together when mechanical firing is used. Should one gun run out of ammunition or suffer a stoppage which immediate action fails to clear then firing will only take place from the working gun on alternate pressures of the firing switch. For servicing and ammunition replenishment the pod lid has to be unlocked and raised to the vertical position to allow access to the guns and ammunition boxes. As the lid is hinged at the bottom front the normal muzzle apertures are in contact with the track guard when the lid is raised. To avoid accidents happening when clearing the gun in these circumstances there are two plastic capped holes aligned with the gun muzzles in the lid.

/FIG. 11 ....

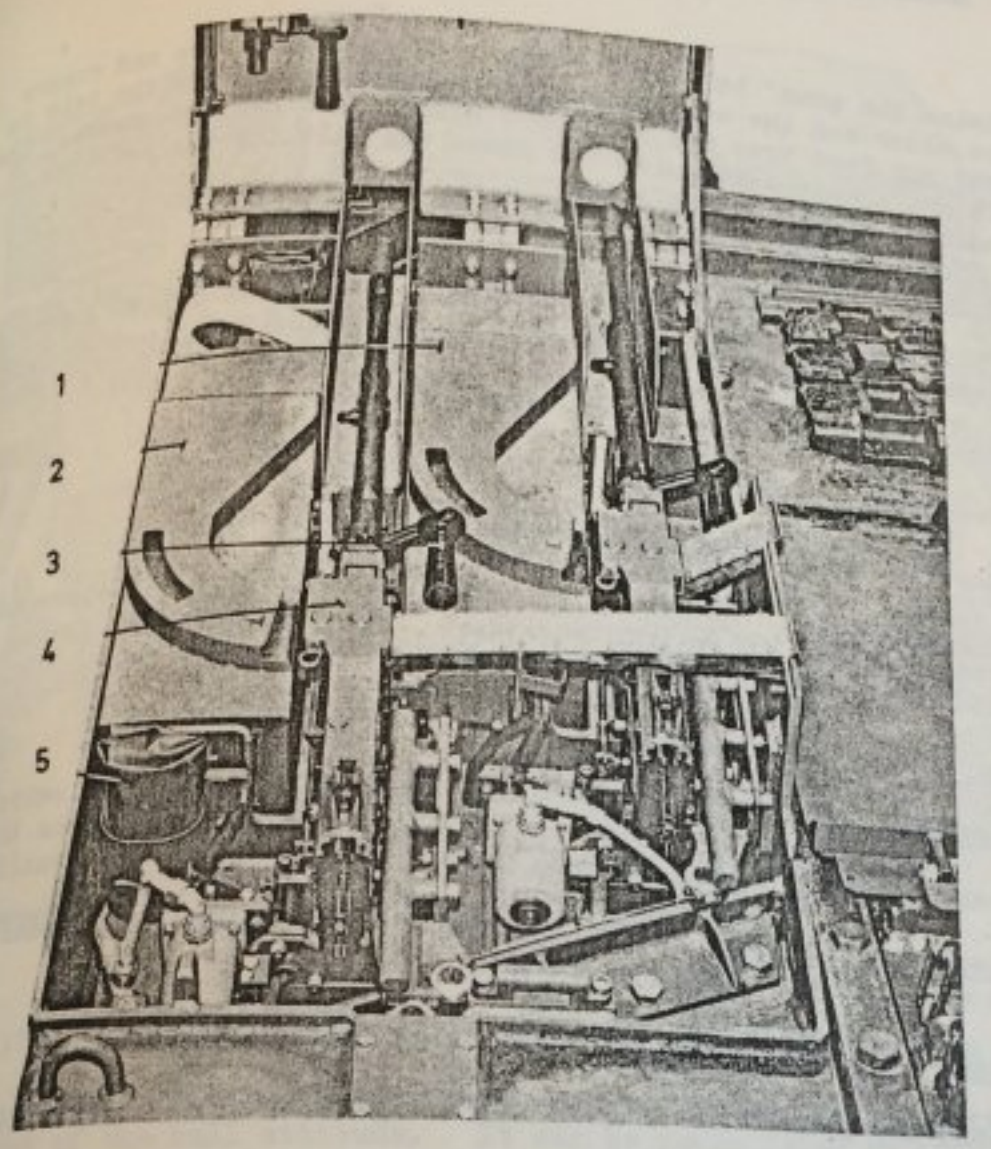


Fig. 11

FIG. 11 - 'S' TANK - HULL MG POD

KEY

1 and 2. 500 Round MG Ammunition Boxes.
3. Carrying Handle of Left-hand MG.
4. Left-hand MG.
5. Spare Parts Wallet.

64. Drills:

a. Half-Loading:

(1) Ensure that the safety switches on the driver/gunner's and commander's controllers are at SAKR (Safe).

(2) Unlock and raise the pod lid.

(3) Press down the catches and remove the empty ammunition boxes.

(4) Remove any empty cases from the bottom of the pod.

(5) Replace and secure full ammunition boxes with the belt exits facing the guns.

(6) Raise the guns' belt exit guides. Open both covers and ensure guns are clear and the working parts are forward. Place the belt in the right gun feed tray and belt exit guide and close the cover. Lower the left gun's belt exit guide and place the belt for the left gun in its feed tray and belt exit guide.

b. Loading and Firing:

(1) Pull the cocking lever on the upper left of the driver/gunner's compartment fully forward with a rotary movement.

(2) Select KSP(MG) with the armament selector switch.

(3) Switch the safety switch to ELD (Fire).

(4) Lay and press the firing button.

c. To Make Safe. Pull the cocking lever forward as in b.(1) above and engage the handle to hold it in this position. To fire the guns again, pull the handle out of engagement and return the lever to the rear.

d. Stoppage Drill:

(1) Immediate Action. Cock the guns and press the firing switch twice. If firing takes place on only one of the two pressures then the other gun has a secondary stoppage or has used all its ammunition.

(2) Secondary Action. Raise the pod lid and follow the normal pattern of secondary action for GPMG.

e. Unloading:

(1) Cock the guns.

(2) As for a.(1) and (2).

(3) Raise the left gun's belt exit guide. Open both gun covers, remove the belt and ensure the guns are clear. Close the covers and ease springs.

(4) Clear the empty belts from the exit guides.

(5) Press down on the ammunition box catches and remove the boxes.

(6) Remove the empty cases from the bottom of the pod and lower the left gun's belt exit guide.

(7) Close and lock the pod lid.

Commander's MG

65. Description. (Fig. 12). The commander's MG is mounted on the cupola to the left of the commander's sight with which it is aligned in azimuth. It can be linked with it in elevation so that the sight can be used to aim the MG and observe and correct fire. The elevating arm which extends vertically downwards from the gun into the commander's compartment has at its lower end a horizontal handgrip incorporating a lever trigger. In the underside of the cupola roof behind the elevating arm is the remote wire cocking gear. On the left of the mounting a holder for a 250-round ammunition box which feeds directly into the gun. The empty cases and belts fall freely from the gun.

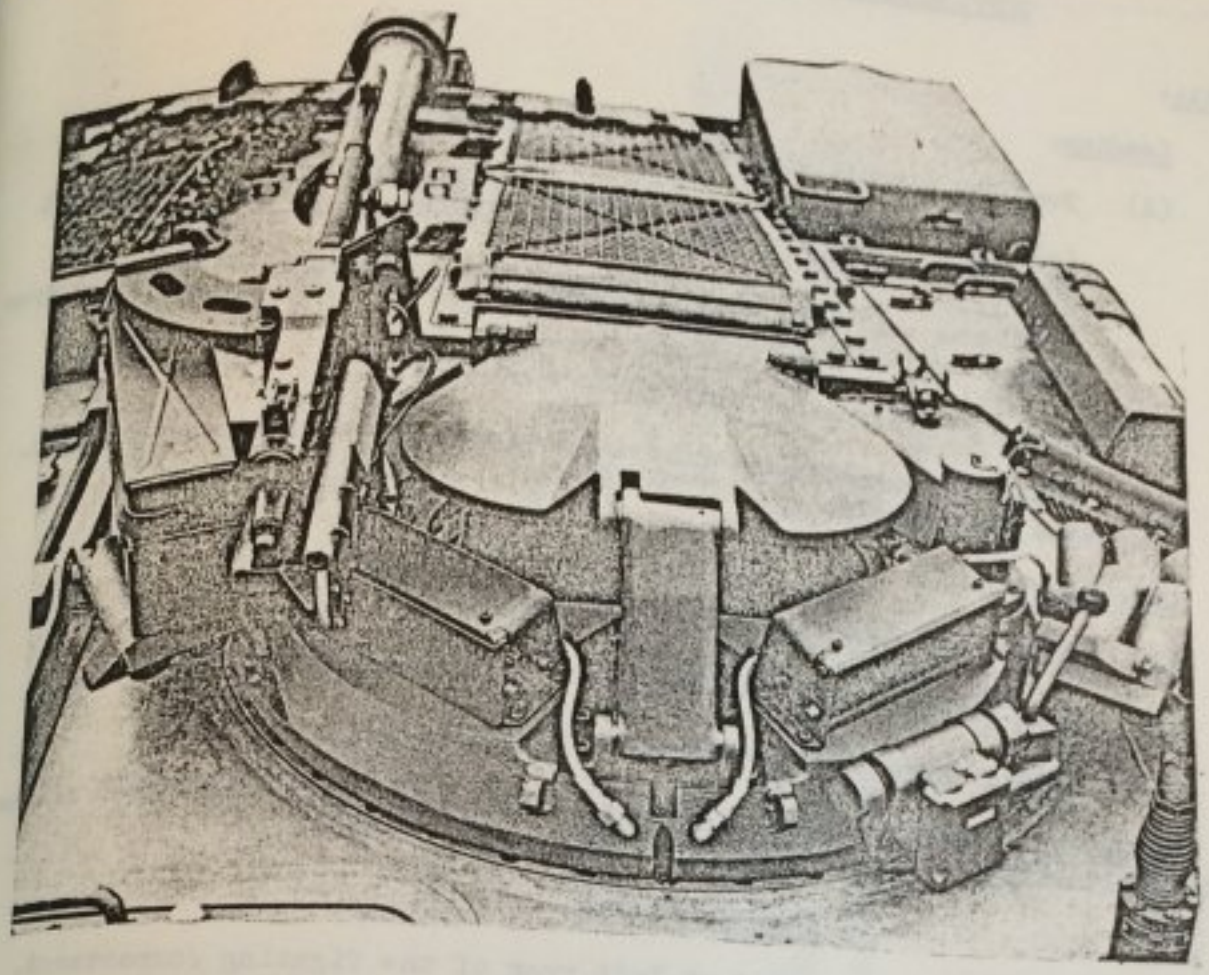


FIG. 12 - 'S' TANK - COMMANDER'S CUPOLA AND MG (SPENT CASE BIN NOT FITTED)

66. Operation. Being mounted on the cupola the gun has traverse and elevation independent of the hull attitude. It can be power layed or stabilised in traverse but elevation control is by hand with the elevating arm. A spare box of 250 rounds is carried in the commander's compartment.

67. Drills. The drills are similar to those for the commander's MG on CHIEFTAIN.

Local Smoke

68. Description. Local smoke protection is provided by eight White Phosphorus Grenades in two four barrelled dischargers mounted on the left and right of the cupola. The grenades are issued with two sets of detonators. One set is for use when the grenade is thrown by hand. The others have a propelling charge which blows the grenade out of the discharger for a distance of about 20m. The detonator, for use in this mode, is timed for 2 secs and initiates the grenade when it is about 2m from the ground, assuming this to be level in the vicinity of the tank. The firing controls are on the commander's Sight Laying Control Unit and consist of a 'safe'/'fire' toggle switch and a firing button which is pressed to fire the grenades. Only four grenades, two from each discharger, are fired when the button is pressed, to fire all eight grenades it has to be pressed twice. To avoid accidents there is a safety interlock which isolates the firing circuit whenever the hatch for the driver/gunner or reverse driver is open. The circuit is tested with a lamp circuit tester.

/69. Drills.

69. Drills:

a. Loading:

(1) Test the circuit with the circuit tester to ensure:

(a) The test lamp lights when the firing button is pressed with the safety switch at 'fire' and the crewmen's hatch closed.

(b) The test lamp does not light when the crewman's hatch is open and/or the safety switch is at 'safe'.

(2) Screw the detonators into the grenades.

(3) Place the grenades in their dischargers, propelling charge first. Push them home firmly.

b. Unloading:

(1) Ensure the safety switch is at 'safe'.

(2) Open the crewman's hatch to isolate the firing circuit.

(3) Remove the grenades from their dischargers.

c. Misfires. As for unloading but the circuit should be re-tested at the first opportunity.

COMMUNICATIONS

70. Two Radios RT 246 VRC are located at left rear of the fighting compartment. Frequency coverage is 30-75 MHz in two bands 30-52 MHz and 53-75 MHz, range approximately 20 miles.

71. A pre-selected remote frequency change system is provided, ten channels being manually set up.

72. Facilities provided by the sets and harness are:

a. Automatic squelch circuit.

b. Automatic aerial tuning.

c. Tank I/C.

d. Facilities which enable all crew members to speak over the air except when the commander selects 'AUTO' on either set.

e. Remote control over twin cable up to ¼ mile.

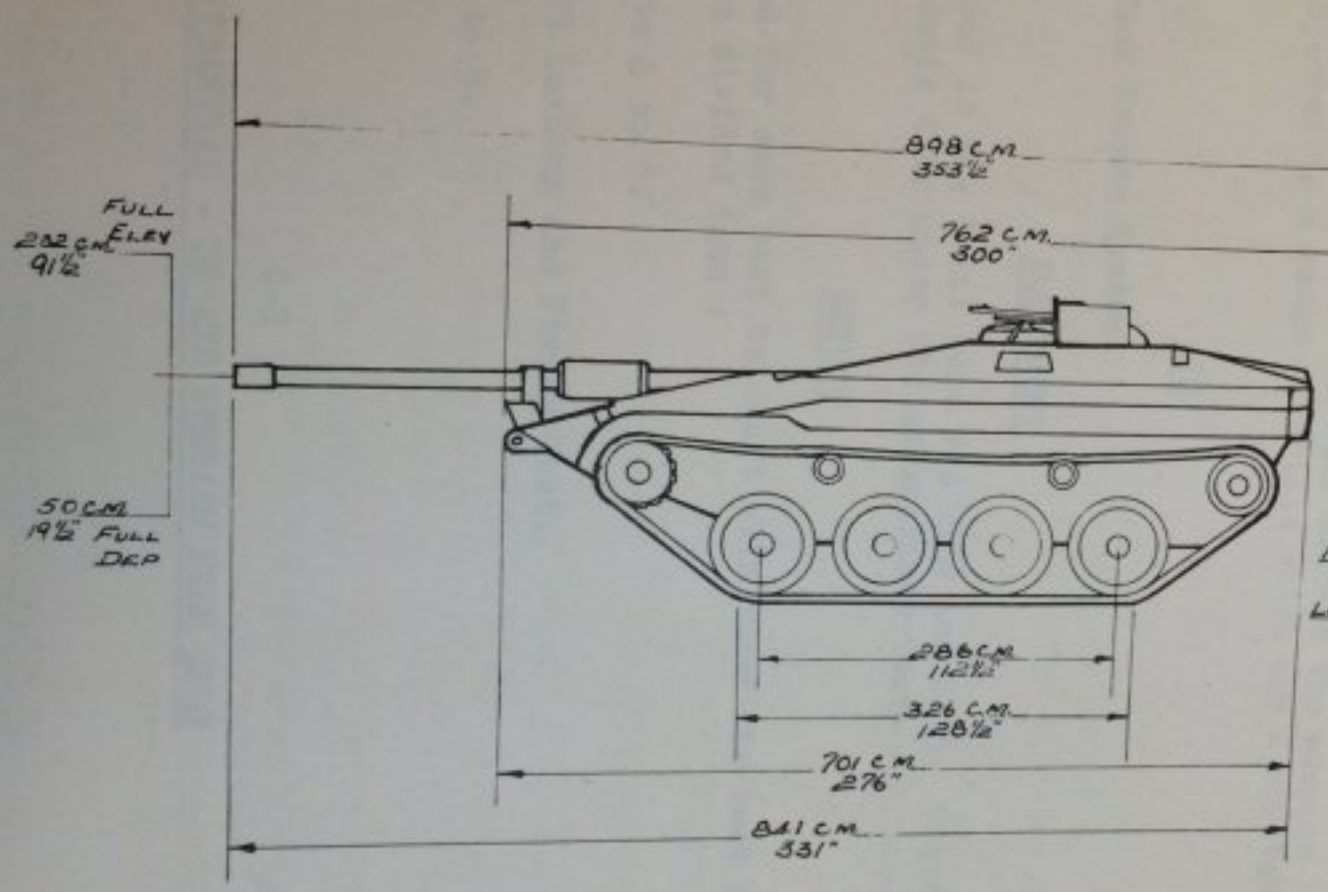
f. A call light on receiving an incoming signal.

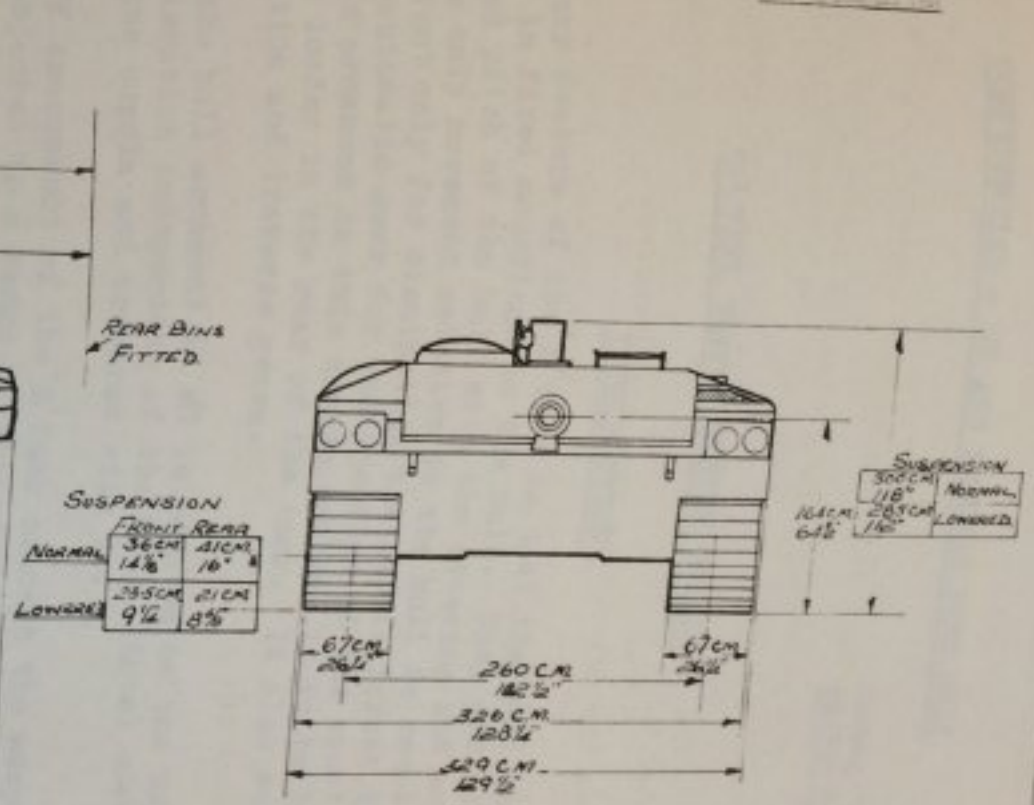
g. An infantry tank telephone with approximately 40ft of cable which is rewound under power when the vehicle master switch is switched ON .

h. Speakers may be fitted.

j. Live I/C on selection.

73. Headset is built into the crewman's helmet. A clip-on throat microphone is provided. The cable from the headset to the vehicle junction box is of the self coiling type.


898 C.M.
353½
762 C.M.
300"
FULL ELEV
232 C.M.
91½
50 CM.
19½" FULL DEP
288 C.M.
112½
326 C.M.
128½"
701 C.M.
276"
841 C.M.
331"


REAR BINS FITTED
SUSPENSION
FRONT REAR
NORMAL 36CM 14⅛" 41CM 16"
LOWERED 28.5CM 9½ 21CM 8⅜"
67CM 26½"
260 CM 102½"
326 C.M. 128½"
329 C.M. 129½"
SUSPENSION
NORMAL
LOWERED

Annex 'C' to AT 1123/GT 428
dated 13 February 1969

'S' TANK WEAPON SYSTEM TRIALS

INTRODUCTION

1. The revolutionary feature of the 'S' Tank is that the main armament and hull (co-axial) MGs are in fixed mountings in the hull. They are layed entirely by altering the yaw and pitch of the hull with the steering and suspension systems. The main armament's only movement relative to the hull is recoil and run-out which is convenient not only for dissipating the recoil forces but also for actuating the semi-automatic gear for the ejection of the spent case. The mounting of the main armament in this manner enables it to be loaded by a compact semi-automatic loader in the rear of the tank. It also saves the space and weight in elevation and traverse gears.

2. In addition to the hull armament an MG is mounted on the commander's cupola with traverse and elevation independent of the hull. Local smoke dischargers are also fitted to the cupola and traverse with it.

3. As part of the UK assessment of the 'S' Tank concept the weapons system of this tank were subjected to a range of trials which are described in this Annex.

AIM

4. To assess the 'S' Tank Weapon System.

EQUIPMENT

5. The two 'S' Tanks used in the trial were Nos 2132 and 2133. Other equipment used is listed in Appendix 1 or under the appropriate test.

METHOD

6. The detailed method for each test is dealt with under the test heading. Generally the trial was divided into :

a. Non Firing Tests A to C.

b. Preliminary APDS Loading and Firing Test.

c. Firing Tests 1 to 9.

/Background

TEST A - AMMUNITION STOWAGE

Background

7. The Main Armament Ammunition for the 'S' Tank is carried in the rear of the vehicle in three magazines. On the right of and below the breech ring is a 25 round electro-hydraulically operated magazine. Opposite it on the left is a similar 20 round magazine with a manually operated 5 round magazine above it. This arrangement restricts the main armament to only three natures in set proportions of 25, 20 and 5 in any one stow but it does simplify ammunition stowage and replenishment.

8. MG Ammunition. In the Swedish Army MG ammunition is delivered in wooden boxes and packed into the steel boxes used on the tank by the crew. The MG ammunition carried on the tank comprises:

a. 2 x 500 Round Boxes. One for each hull MG and carried in their spon...

b. 6 x 250 Round Boxes. These are all for the commander's MG. One is the ready box with the gun on the cupola. The remaining five boxes are carried in the stowage bin just forward of the hull MGs.

9. Grenades:

a. Local Smoke Grenades. Eight white phosphorus smoke grenades of Swedish design are carried loaded in the dischargers on the commander's cupola. A further 16 are carried in a bin on the vehicle roof just to the rear of the cupola. The grenade has a small propellant charge attached to its base and plugs into the discharger barrel in the same manner as the UK Jack Grenade. These grenades are standard infantry pattern, the crew replacing the striker mechanism by the propellant charge before stowage.

b. Anti-Personnel Grenades. Six anti-personnel grenades are carried inside the tank for use in the same manner as the No. 36 grenades carried in UK tanks. They are stowed in the fighting compartment.

Aim

10. To determine the time required to stow the 'S' Tank with a full load of ammunition.

Equipment

.... 11. See Appendix 1 paras 1 to 3.

Method

12. The ammunition was placed in a three ton truck with the main armament ammunition laid on the floor unboxed. This was the nearest simulation to racking that could be achieved. Two three man crews were timed for the whole operation from dismounting to re-mounting having completed the stow.

13. Practice runs were not held beforehand. It was thought that to do so would be unrealistic, as crews are not generally rehearsed when stowage is initially carried out on operations.

/14. ....

14. The packing time for a 500 round MG ammunition box was noted for six separate fillings. This was not included in the stowage time. The MG boxes were merely placed in the tank as it was considered that in the British Army the MG boxes would all be factory filled in accordance with current UK practice.

Results

15. Neither crew were unduly fatigued or experienced any difficulty in the stowing of the ammunition. Times for the operation were:

a. Crew A - 14 min 52 secs.

b. Crew B - 14 min 25 secs.

16. The times to pack a 500 round MG ammunition box were:

a.	Fastest	-	56 secs
b.	Slowest	-	95 secs
c.	Mean of 6 packs	-	72 secs

Discussion

17. The time for carrying out the full ammunition stowage of CENTURION with an experienced crew of four is 30 to 45 mins depending on the Mark of tank. This does not include the loading of the local smoke dischargers which would add a further 10 minutes. To achieve these times is fairly exhausting. With the S Tank it was noticeable that the crew were not fatigued and the effort involved was far less. Despite the simplicity and ease of the ammunition stowage it is unlikely that work study and practice could reduce the stowage time below 10 mins but it would be much easier to achieve a consistent time for the operation than with other tanks. The general simplicity of the system would make replenishment, when only a partial load is required, much easier and also ease night replenishment or stowage.

Conclusion

18. It takes only 15 mins to fully stow the 'S' Tank with ammunition with a relatively inexperienced crew. With a fully experienced crew this time would probably be reduced to 10 mins. In either case it is unlikely that carrying out the operation in the dark would add significantly to the time required.

TEST B - POLAR DIAGRAMS OF THE OPTICAL INSTRUMENTS

Aim

19. To determine the dead zones of vision to the closed down crew of the 'S' Tank.

Equipment

20. See Appendix 1, paras 4 and 5.

Method

21. The tank was placed on level ground with the commander's sight co-incident with the main armanent. The near point of visibility was checked throughout the field of view of each optical instrument. The angles were measured by artillery director and the distances by tape measure.

22. The same procedure was repeated with the tank at maximum elevation + 21‰ (+12°) and at maximum depression -178‰ (-10°).

Results

23. The results are shown diagramatically in Appendix 2. Briefly it was found that with the tank:

a. Level. There were no blind approaches as the optics gave 6400‰ coverage. Using bearings from the main armament the complete dead zone ie. that which is so close to the tank so as to be blind to all instruments is :

(1) From 5650‰ to 1500‰ a radius of 9 to 10 m (30 to 33ft).

(2) From 1600‰ to 3600‰ a radius of 23 to 25 m (70 to 76ft).

(3) From 3600‰ to 4950‰ a radius of 13.5 m (44ft).

(4) From 4950‰ to 5650‰ a radius of 17 m (56ft).

b. Fully Elevated. The tank is blind from a frontal ground approach from 4550‰ to 650‰ and from 1400‰ up to 1850‰. (Angles measured as in a.). The dead zones were :

(1) 650‰ to 1400‰ a radius of 12 m (40ft).

(2) 1850‰ to 4550‰ a radius of 9 to 8 m (30 to 26ft).

c. Fully Depressed. The tank is blind from a rear ground approach from 1400‰ to 4600‰. Angles as measured in a.). The blind zones are :

(1) From 4600‰ to 4750‰ a radius of 25 m (76ft).

(2) From 4750‰ to 5700‰ a radius of 15 m (49ft).

(3) From 5700‰ to 550‰ a radius of 6 m (20ft).

(4) From 550‰ to 1400‰ a radius of 8 m (26ft).

Conclusion

24. The optics give good all round coverage when the tank is level and the ability to alter the hull pitch enables the dead zones to be decreased to meet a particular threat but at the expense of all round vision.

TEST C - TARGET ACQUISITION TIMES

Introduction

25. The novel method of gun control and dual sighting facilities of the 'S' Tank were points of great interest. The rapidity and choice of methods of target acquisition were therefore investigated and tested.

Aim

26. To assess the target acquisition capabilities of the 'S' Tank.

Equipment

27. See Appendix 1, paras 6 and 7.

Method

28. Traverse Times. The traverse times for 1600‰ (90°) and 3200‰ (180°) with the tank stationary were recorded under various conditions. Although not part of target acquisition the traverse rate has to a certain extent a direct bearing on the speed of target acquisition if long switches are involved.

29. Target Acquisition - Tank Static. The target acquisition times with the tank stationary and between 400 and 600‰ off target were noted for:

a. Commander Laying Against Conspicuous Targets:

(1) Target located through the commander's sight and gun layed using contra-rotation.

(2) Target located as in (1) but gun layed after bringing sight to co-incidence with the gun by traversing the cupola.

(3) Target located through a X1 periscope, the commanders sight being already co-incident with the gun.

b. Commander Laying Against Inconspicuous Targets.

(1) Repeat of method a.(1) above.

(2) Repeat of method a.(3) above.

c. Commander Transferring Gun Control to Gunner. Target identified by commander through a X1 periscope whilst his sight is locked in co-incidence with the gun. Commander lays on target area or target until gunner identifies it and takes over to make the fine lay.

d. Gunner Identifying Target but Commander Authorising Firing. Target identified through a X1 periscope by the gunner who then informed the commander as he layed the gun and fired when the commander authorised him to do so.

30. Target Acquisition - Tank Moving. The times for the commander to traverse the tank to meet a flank target at 1600‰ to the gun, halt and lay were noted for 10 occasions. In five cases the target was on the left of the tank and on the other five cases on its right. The commander's sight was locked in co-incidence with the gun and the commander located the target through his periscopes.

31. Other Details.

a. Targets.

(1) The Conspicuous Target was a Landrover at 1100 m.

(2) The Inconspicuous Targets were small turrets approximately 0.6 m long by 0.4 m high with a headlamp in their centre.

b. Timings. The engagement and timing were started by the target flashing its light to simulate gun flash. The barrel lamp was mounted in the gun as a check of the lay being on target. As the lamp can only be set up for one lay it was matched to the 800 m APDS graticule mark in the sight. The engagement ceased when the lamp flashed and the time was noted to this occurrence.

c. Crews. Four crews carried out each of the methods in Paras 29, a, 29b. and 30, ten times, traversing on from left or right of the line gun target alternatively. Only three crews were exercised in the methods in Para 29, c. and d. but in other details the methods were the same.

/Results

Results

32. Static Traverse Tinings. The tinings for 1600⁄ and 3200⁄ on hard or soft ground with the engine(s) at maximun revolutions are given below :

Table 1 'S' Tank Traverse Tinings on Hard and Soft Ground.

Serial	Engines	Times (secs)			
		1600⁄ (90°)		3200⁄ (180°)	
		Hard	Soft	Hard	Soft
(a)	(b)	(c)	(d)	(e)	(f)
1	K 60	8	10	18	20
2	K 60 and Turbine	9	11	17	20

33. Target Acquisition Times - Tank Static. The mean times for each crew and method tested are given in Table 2.

Table 2 Mean Target Acquisition Times - Tank Static

Serial	Method	Mean Acquisition Times (secs)				
		Crew A	Crew B	Crew C	Crew D	Average
(a)	(b)	(c)	(d)	(e)	(f)	(g)
1	Conspicuous Targets Commander Laying					
a.	Method A1 Tgt identified through Comd's sight. Gun brought to tgt with contra -rotation of cupola.	12.3	11.5	14.8	8.6	11.8
b.	Method A2 Tgt identified through comd's sight which was then locked to gun which was then layed onto the tgt.	11.6	9.2	12.5	6.3	9.9
c.	Method A3 Tgt identified through X1 periscope when sight locked to gun.	7.9	6.8	7.8	4.4	6.5
2	Inconspicuous Targets Commander Laying					
a.	Method A1	11.6	10.4	14.6	7.3	11.0
b.	Method A3	6.1	7.7	6.0	4.7	6.1
3	Conspicuous Targets Gunner Laying					
a.	Method B Commander identifies tgts and hands over control to the gunner when he identifies the tgt.	14.3		8.6	6.1	9.7

/Table 2 .....

Table 2 Mean Target Acquisition Times - Tank Static (Continued)

(a)	(b)	(c)	(d)	(e)	(f)	(g)
b.	Method C Gunner identifies tgt and lays on requesting permission to fire	8.6		6.5	4.6	6.6

34. Target Acquisition Times - Tank Moving. The mean times for this part of the test were :

a. Crew A - 9.6 secs
b. Crew B - 11.1 secs
c. Crew C - 13.3 secs
d. Crew D - 10.7 secs
e. Average - 11.2 secs

Discussion

35. Static Traverse Times. When the tank is moving it can be spun rapidly through a 3200‰ (180°) turn in 2 to 3 secs. When stationary traversing takes longer and as can be seen from the results in para 32 it is slower than CENTURION power traverse speeds which are:

a. 1600‰ (90°) - 7 secs.
b. 3200‰ (180°) - 12 secs.

36. Acquisition Times - Tank Static.

a. Comparison of Methods A1 to 3. With the commander laying, method A3 was obviously the quickest. If however the commander is searching for and locates a target with his sight whilst moving it independently from the main armament it is obvious that A2 is the better method for use against a conspicuous or easily marked inconspicuous target. If the target is an inconspicuous one with no definite point near it to make it easy to relocate then the contra-rotation method - A1 - is probably the best to use. Crews were however universal in their condemnation of the contra-rotation system as it exists on the 'S' Tank. Their reason is that a lot of the benefit of being able to keep the target pin-pointed whilst traversing is lost as the cupola jumps about 40‰ on locking into co-incidence with the gun.

b. Comparison Methods A3, B and C. There was no significant difference in the times by Methods A3 and C which shows that the acquisition is speediest when the gun controls are operated by one man. The reason for Method B taking longer than Method A3 is that when the commander hands control to gunner the hull does not remain at the elevation at which the commander layed it but alters to conform to the elevation at which the gunner's controller happens to be. Despite Method A3 being 35% faster Method B was adopted as it conformed more to UK practice. The philosophy behind this choice is more fully discussed in para 79.

c. Comparison with CENTURION. In similar tests carried out with CENTURION where only Method B is available the mean times for acquisition with a 530‰ line switch were 9.1 and 10.3 secs against conspicuous and inconspicuous targets respectively. This shows no significant difference to the time for 'S' Tank with Method B. The crews all considered the sights of the 'S' Tank gave a definite advantage in target location, especially as the commander's sight is a much better instrument than the CENTURION Reflector - Gun - Periscope (RCP) sight. Over larger areas the superior speed of the CENTURION Traverse would probably give it an advantage against conspicuous targets.

37. Acquisition Times - Tank Moving. These show the remarkable ability of the 'S' Tank to turn against a target when on the move. It was not possible to time the times down accurately but it is estimated that turning through the 1600‰ took about 3 secs and the rest of the time was taken with the fine laying. A comparison with the CENTURION is not directly available and the techniques for the condition differ. With CENTURION the tendency would be to engage whilst moving to cover. The 'S' Tank could not do this but in this case there is considerable argument for turning, thus presenting the best armour to the target, halting and firing.

Conclusion

38. a. Static Traverse Timings. From Table 1 it is deduced that the traverse rate is:

(1) Not significantly altered by the running of the gas turbine in addition to the K60.

(2) Marginally reduced when the tank is on soft ground.

b. Tank Static. For targets within an arc of 600‰ on either side of the main armament the 'S' Tank is quicker than CENTURION in target acquisition when the commander carries out the shoot. When the gunner carries out the shoot the 'S' Tank is as rapid. Over larger areas the CENTURION will probably be marginally quicker against conspicuous targets because of its faster traverse but against inconspicuous targets there is not likely to be any great difference because of the superior sights of the 'S' Tank.

c. Tank Moving. The speed of turning and coming into action against a surprise flank target whilst on the move is only slightly greater than that required for acquiring a target over a 600‰ line switch when static. In both cases the times make the operation a realistic one in comparison with other tanks but the 'S' Tank would be stationary.

PRELIMINARY APDS LOADING AND FIRING TEST

Background

39. BOFORS considered that the UK 105mm APDS L52 round might not be able to withstand the stresses imposed by the 'S' Tank loading system. Their main concern was that the sub-projectile would become partially separated from its sabot through the dropping of the round onto the loading tray and its subsequent ramming at 3 m/s into the chamber.

40. The UK Trials Officer considered that the round would satisfactorily stand the strain as the similarly constructed 120mm APDS projectile was able to withstand the 4 m/s ramming speed on the original CHIEFTAIN.

41. In order to resolve these arguments a preliminary trial was held with UK ammunition.

Aim

42. To determine if the UK 105mm APDS L52 round could satisfactorily withstand the stresses imposed by the Swedish 'S' Tank's loading system.

Equipment

43. See Appendix 1, paras 8 to 10.

Method

44. Inspection and loading

a. 21 APDS L52 rounds were inspected, numbered and divided into three groups of seven rounds.

b. The primers of rounds 1 to 14 were removed and re-placed by fired primers because of the alleged hazard of using UK primers in the S Tank.

c. Rounds 1 to 7 were loaded once each through both the left and right magazines of S Tank No 2133.

d. Rounds 8 to 14 were loaded twice each through both the right and left magazines of S Tank No 2132.

e. The following measurements were taken on rounds 1 to 14 after each loading :

(1) The protrusion of the sub-calibre projectile above the petals.

(2) The distance from the top of the sabot to the sub-calibre projectile nose.

(3) The distance from the neck of the cartridge case to the sub-calibre projectile nose.

f. The original primers were replaced in rounds 1 to 14.

g. Rounds 15 to 21 were set aside as control rounds.

45. Firing

a. Two 105mm APDS L28 cleaner rounds were fired from CENTURION No 44BA72. These were followed by the 21 trial rounds fired in numerical sequence, seven each at three screens 3 m square at 1370 m range.

b. All rounds were layed by muzzle boresight to reduce fire control equipment errors.

Results

46. Magazine Loading - Rounds 1 to 7:

a. 1st Run - Left Hand Magazine:

(1) Unloading. All rounds showed a tendency to stick in the chamber and had to be removed by use of the extracting tool which fits over the rim of the cartridge case. In some cases the breech had to be opened two or three times to unseat the round sufficiently to allow the tool to engage over the rim.

(2) Sub-Calibre Projectile Protrusion. Except for round 2 all rounds showed an increase in protrusion of 0.15cm above the petals as measured along the ogive.

b. 2nd Run - Right Hand Magazine. No further changes in sub-calibre projectile protrusion were noted. Unloading was no more difficult than on the 1st run.

c. Serviceability. All rounds were passed as serviceable and fit to fire by the Gunnery School RAOC Ammunition Technician.

/47. ....

47. Magazine Loading - Rounds 8 to 14:

a. 1st Run - Right Hand Magazine:

(1) Magazine Operation. The magazine on Tank 2132 used for rounds 8 to 14 was noisier and not so smooth in operation as that of Tank 2133, used for rounds 1 to 7.

(2) Unloading was even more difficult than with rounds 1 to 7 and for all rounds the breech had to be opened three or more times to unseat the round sufficiently to allow the extracting tool to engage over the cartridge rim.

(3) Sub-Calibre Projectile Protrusion. Increases of 0.15 cm and 0.05 cm were noted on Rounds 8 and 10 respectively. Other rounds were unchanged.

(4) Marks on the Ammunition. All rounds had a series of chafing marks on the cartridge case which appeared to come from the rammer chain. Other scratches were noted on both cases and projectiles but none of the marks were sufficient to render the rounds unfit to fire.

b. Subsequent Runs. The original test intention had been to load Rounds 8 to 14 through each magazine five times. This test was terminated after the 4th run however because all rounds jammed in the chamber and had to be unloaded by pushing them out with the cleaning rods. A block of wood was interposed between the rods and the projectile in each case to minimise the risk of damage. This jamming had occurred with some rounds in the 2nd and 3rd Runs as can be seen from the results of these runs in Table 3 below.

Table 3. Effects of Repeated Loading Runs on UK 105mm APDS L52 Ammunition

Serial	Detail	2nd Run Left Hand Mag.	3rd Run Right Hand Mag.	4th Run Left Hand Mag
(a)	(b)	(c)	(d)	(e)
1	Jamming in the chamber	Rounds 8, 10 and 13.	Rounds 11 and 14.	All Rounds
2	Alteration in Sub-Calibre Projectile Protrusion	No change from 1st run	Rounds 9 & 13 increased by 0.05cm. Round 14 reduced by 0.05cm. Otherwise no change.	No change from 3rd Run.
3.	Sub-Calibre Projectile Movement.	Rotary movement possible on Rounds 11 and 13	Rotary movement lost on Round 11 but present on Rounds 13 and 14. Lateral movement possible also on Round 13	Movement lost on Rounds 13 and 14. Lateral movements noted on Round 11.
4	Marks on the ammunition.	Rounds 8 and 10 badly marked. Cartridge case of Round 9 dented on shoulder.	Increase in markings on all Rounds compared to 2nd Run.	Further increase of markings on all Rounds

/c. ....

c. Serviceability. Rounds 8 to 14 were in relatively poor condition at the conclusion of the test and only just passed the Ammunition Technician's inspection as fit to fire.

48. Firings. The firing results are given in tabular form below :

Table 4. Preliminary Test of UK 105mm APDS L52 Ammunition - Firing Results

Serial	Rounds Nos	MPI (cm)		Standard Deviation (σ)		Remarks
		H	V	H	V	
(a)	(b)	(c)	(d)	(e)	(f)	(g)
1	1 to 7	L41	-112	0.23	0.22	
2	8 to 14	L81	-126	0.25	0.31	Round 13 missed the target left.
3	15 to 21 (Control)	L61	-115	0.15	0.28	Round 18 missed the target plus.

Discussion

49. Rounds 1 to 7 withstood the stresses of the loading system quite well and the small setting forward of the sub-calibre projectile did not appear to impair accuracy. The automatic loader used for Rounds 8 to 14 seems to have imposed greater stresses on the rounds. The effect on the ammunition however was not observed until after the second run. To a certain extent the results based on these rounds were prejudiced by having to force them out rearwards, although in only one case, round 14, did this treatment apparently set back the sub-calibre projectile. In all other cases it did not alter the set forward of the sub-calibre projectile induced by ramming. It was a pity that a similar sample of Swedish APDS rounds were not available for comparison under the same conditions.

50. a. Rounds 13 and 18 missed the target. In relating the direction of miss to target size and MPI it would appear that both these rounds were outside the rejection criteria of thrice the mean deviation (Reference A para 9.14.).

b. Whether Round 13 missed the target through being passed through the loading system four times or whether it was just a wild round cannot be truly established. Wild rounds do occur from time to time with APDS ammunition and there seems to be no other explanation for Round 18 missing. To have two wild rounds in a small sample of 21 is fortunately improbable and it is therefore highly probable that Round 13 did in fact miss because of the adverse effect of the loading system on it.

51. The dispersions did not differ significantly as can be shown from the Application of Fisher's F Test for Variance Ratio (See Reference B Chapter XIV and Table 15) below :

a. Comparison of Horizontal Dispersions. The highest and lowest values from Table 4 are Serial 2 with 0.25‰ and Serial 3 with 0.15‰ respectively. Both have five degrees of freedom.

$$F = \frac{0.25^2}{0.15^2} = 2.77$$

F must exceed 3.82 for even 5% significance.

b. Comparison of Vertical Dispersions. The highest and lowest values from Table 4 are Serial 2 with 0.31‰ and Serial 1 with 0.22‰ with 5 and 6 degrees of freedom respectively.

$$F = \frac{0.31^2}{0.22^2} = 1.94$$

F must exceed 4.39 for even 5% significance.

Conclusions

52. a. The double passage of Rounds 1 to 7 through the 'S' Tank loading system had no adverse effects on their accuracy.

b. The accuracy of Round 13 probably was affected by its being passed through the 'S' Tank loading system four times. The accuracy of Rounds 8 to 12 and 14 was not adversely affected by the same treatment.

53. The UK 105mm APDS L52 ammunition is capable of withstanding the stresses of the 'S' Tank loading system for one loading cycle and probably two, but further loadings using the system should be avoided.

TEST 1 ACCURACY FIRINGS

Aim

54. To determine the accuracy of the 'S' Tank Weapon System under range conditions.

Equipment

55. See Appendix 1 paras 11 to 13.

Method

56. Main Armament.

a. Series of eight or more rounds were fired from the 105mm guns of both 'S' Tanks as follows :

(1) APDS at 1000m.

(2) HE at 1000m.

(3) HE at 2000m.

b. The technique employed for laying each series was to :

(1) Lay the gun by muzzle-boresight (MBS) and adjust both commander's and gunner's sights to coincidence and then remove the MBS.

(2) Load, re-lay and fire the gun. This was done by the gunner using his sight and applying the necessary target elevation with it. A Camera affixed to the sight photographed the gunner's lay at the instant of firing so that its accuracy could be checked.

(3) Re-check the gunner's and commander's sights against the MBS after firing each round, noting any alterations in the settings of their graticule adjusters.

c. It had been intended to keep a check on barrel bend by using the FVRDE Reference Telescope but this proved impractical as the feet on the instruments held by ETW were too broad for the smaller barrel thickness presented by the 'S' Tank (the normal chase position for the telescope being under armour).

d. Target ranges were surveyed by tellurometer operated by the School of Artillery, LARKHILL who also measured HE velocities with EVA whenever possible.

e. The bore diameter at 1in (2.54cm) from the commencement of rifling was measured before firing took place and at suitable intervals between series.

57. Other Main Armament Firings. Because of the wide dispersion of APDS at 1000m the original intention of firing it at 2400m was abandoned. Instead an APDS series was fired at 1100m using a CENTURION to give a cross check on the dispersion. In addition a further APDS series at 1000m was fired from S Tank No 2133 and would have been fired from No 2132 but for mechanical troubles. The same technique as in para 55.b. was used for these series except that it was not possible to use the camera on the CENTURION.

58. MGs. One of the Hull MGs on each tank was tested by firing a 25 round burst at a screen at 500m. In both cases bursts of 10 to 20 rounds were fired before the accuracy bursts to check the operation of the guns, warm them up and ensure that the fall of shot was central on target.

Results

59. APDS. The results are given in Table 5 below :

Table 5 Test 1 - Accuracy Firing APDS Results.

Serial		Detail		S Tk No 2132	S Tk No 2133	S Tk No 2133	CENTURION No 01ZR81
(a)		(b)		(c)	(d)	(e)	(f)
1	a	MPI (m)	H	LO.12	RO.34	RO.47	LO.21
	b		V	-0.17	+0.07	+0.06	-0.58
2	a	Dispersion sd (ø)	H	0.30	0.36	0.49	0.53
	b		V	0.65	0.67	0.26	0.40
3	a	Gunners Sight	H	0.2	0.4	0.4	0.4
	b	Alterations (ø)	V	0.4	0.6	0.8	0.6

/Table 5 ....

Table 5 Test 1 - Accuracy Firing APDS Results. (Continued).

(a)	(b)		(c)	(d)	(e)	(f)
4 a	Commanders Sight	H	0.4	0.6	0.4	-
b	Alterations (⌀)	V	0.6	0.8	1.0	-
5.	Rounds Fired		9	8	12	13
6	Misses		2	2	1	1

Notes:

1. Serials 3 and 4 are the overall movements recorded on the sight graticule adjusters to retain co-incidence with the muzzle-boresight.

2. The CENTURION was not fitted with a thermal sleeve.

3. Abbreviations:

a. MPI is the Mean Point of Impact ie. $\bar{x} = \frac{1}{n} \sum (x)$ where n = number of rounds fired and x the strikes measured from the point of aim.

b. Sd is the standard deviation and includes in all cases Bessel's correction to give the unbiased estimate ie. $Sd = \frac{1}{n-1} \sum (x - \bar{x})^2$

where n and x have the same values as in a..

60. HE. The results are given in tabular form below :

Table 6 Test 1 - Accuracy Firings HE Results

Serial	Detail		Tk No 2132	Tk No 2133
(a)	(b)		(c)	(d)
1	1000m			
a(1)	MPI (m)	H	R0.20 (0.25)	R0.26 (0.28)
(2)		V	-0.48 (0.45	-0.59 (0.55)
b(1)	Dispersion sd (⌀)	H	0.30 (0.25)	0.23 (0.24)
(2)		V	0.36 (0.31)	0.25 (0.31)
c(1)	Muzzle Velocity (m/s)	Mean	674 (2210ft/s)	674 (2210Ft/s)
(2)		sd	1.85 (6.1ft/s)	2.98 (9.8ft/s)
d(1)	Movement on Gunner's Sight	H	0.4	0.2
(2)	Adjusters (⌀)	V	0.2	0.6
e(1)	Movement on Commander's	H	0	0.2
(2)	Sight (⌀)	V	0	0.6
2	2000m			
a(1)		H	R0.46 (0.78)	R1.02 (R1.02)
(2)		V	+1.62 (1.75)	-0.44 (-0.44)
b(1)		H	0.19 (0.26)	0.28 (0.28)
(2)		V	0.26 (0.30)	0.31 (0.31)
c(1)		Mean	670 (2196ft/s)	673 (2206ft/s)
(2)		sd	3.35 (11.0ft/s)	2.80 (9.2ft/s)
d(1)		H	0.2	0.2
(2)		V	0.2	0.4
e(1)		H	0.2	0.4
(2)		V	0.2	0.4

Notes:

1. The figures in parenthesis in serials 1 and 2.a. and b. are the MPIs and dispersions after correcting for laying errors as determined by the camera.

2. In serial 2.a.(2) the MPIs are relative to the lay with the 2000m mark in the case of tank No. 2132 and the 1900m with tank No. 2133. Correcting the lay of tank No. 2133 would have caused its vertical MPI to be +2.36m as the target elevation interval is 1.4‰ between 1900 and 2000m. This places the MPI from tank No. 2133 below that of tank No. 2132 at 1000m by 0.1‰ and above it by 0.74‰ at 2000m.

3. The gunner of tank No. 2133 layed using the 1700m ballistic mark in error for one round, which predictably fell minus.

4. The figures in serials 1 and 2.d. and e. represent the overall movement recorded on the sight graticule adjusters to maintain co-incidence with the muzzle boresight.

61. Sight Stability. A graph showing the alterations of the graticule adjusters settings during the test is given in Appendix 3.

62. Barrel Wear. The barrel measurements remained constant during the test.

63. MG. The MPI and Sds of the two MGs tested are given in Table 7.

Table 7 - MG MPIs and Sds

Serial	Tank No.	MPIs (‰)		Sds (‰)	
		H	V	H	V
1	2132	R0.02	-0.07	0.50	0.45
2	2133	R0.04	+0.12	0.23	0.48

Discussion

64. APDS. The Preliminary Test showed that the basic UK APDS ammunition retained its accuracy after being passed through the 'S' Tank loading system. The series of UK rounds with Swedish additive fired from the CENTURION showed that the excessive dispersion was not caused by the 'S' Tank gun, gun control equipment or fire control equipment, the last two also being cleared by the successful completion of the HE series. On the other hand, Swedish APDS containing additive performs accurately as was amply demonstrated at RAVLUNDA in August 1968 (see Appendix 4). It can therefore only be concluded that the additive caused the excessive dispersion in the UK rounds because it was not applied correctly.

65. HE:

a. The HE dispersion for all four series was remarkably constant when corrected for laying errors. Velocities were also extremely consistent. The vertical dispersion is about 0.1‰ higher than that normally obtained for UK 105mm HESH but the figure of 0.3‰ is quite good enough for HE which is not used against small AFV targets.

b. The difference in MPIs at 2000m is remarkable and is not explained by the 3m/s higher Muzzle velocity of the series from 2133. This can be shown from the HE range table which gives an increase in range at 2000m of 5.2m for a 1m/s increase in muzzle velocity, hence for 3m/s the increase

/would be ....

would be 15.6 say 16m. Converting this to a height increase by multiplying it by the tangent of the angle of descent 28⁄ gives an answer of only 0.44⁄, ie. approximately only 60% of the actual distance of 0.74⁄.

66. Sight Stability and Barrel Bend. Although the reference telescope could not be operated satisfactorily a certain amout of information can be deduced about sight stability and barrel bend by consideration of the mechanical design of the tank and the results in Appendix 3. Analysing these factors seperately :

a. Mechanical Design. Although both commander's and gunner's sights are identical instuments the gunner's is more inherently stable when mounted. This is because its housing is in the hull whereas the commander's is in a cupola which can be unlocked from co-incidence with the hull armament and rotated. Furthermore the tilting prism in the gunner's sight is locked at one set elevation with respect to the hull armament at all times. The commander's sight tilting prism can be disconnected from co-incidence with the hull armament for use in the stabilised mode or linked to the commander's MG.

b. Horizontal Variation in Graticule Adjuster Settings. For both sights on both tanks the movement of the graticule adjusters correspond in sense and amount on nearly every occasion. This shows that the sights are both following barrel bend and are not themselves unstable otherwise their adjuster movements would be random. Where variations of movement do not actually correspond they are all within 0.2⁄ of the original difference in adjuster settings and this can be explained by the fact that the adjusters are not continuous but stepped in discrete 0.2⁄ settings.

c. Elevation Variation in Graticule Adjuster Settings. The gunner's sights show less movement than they did in the horizontal plane. This movement is again almost certain to be barrel bend although in the case of Tank No 2132 the movement is so small it may be largely caused from the discrete 0.2⁄ settings of the sight. The commander's sights whilst confirming the gunner's sight adjuster movements on the whole do show some signs of instability in that on:

(1) Tank No 2132, there is a movement of 0.4⁄ after the first APDS round of each series which is not reflected by the gunner's sight.

(2) Tank No 2133, the sight appears to have started off in a different relationship to the normal one to the gunner's sight in the second APDS series and then taken up an attitude more akin to its normal one after three rounds had been fired. It can only be assumed that there was some error in the connection to the tilting prism as the graticule readings were double checked because of their variation from the expected pattern.

67. MG. The MPIs and Sds are most satisfactory considering the length of burst.

Conclusions

68. Ammunition:

a. APDS. The presence of the Swedish additive would appear to be the cause of the excessive dispersion in the UK rounds. In all probability the fault lies in the application rather than in the additive itself as the Swedish results in Appendix 4 show that accurate rounds containing the additive can be made.

b. HE. The Swedish 105mm HE is a very consistent round. Its round to round dispersion is slightly larger than that normally experienced with UK HESH but it is not required for small AFV targets and is quite accurate enough for the pure HE role. Gun to gun variations occur in range beyond 1000m.

c. MG. The dispersion is of the order of 0.4 to 0.5% sd when the gun is fired in long bursts.

69. Barrel Bend. The accuracy of the weapon system is likely to be adversely affected by barrel bend.

70. Sight Stability. The gunner's sight is extremely stable but the commander's sight appears to have an intermittent tendency to wander in elevation.

71. Barrel Wear. The Swedish additive practically eliminates barrel wear.

72. The Weapon System. The results of this test show that the S Tank weapon system can be used with accuracy by the normal crewman. The degree of consistency of the fire control equipment will be better than that of a CENTURION without a thermal sleeve because of superior sight stability of the 'S' Tank gunner's sight and mounting.

TEST 2 STATIC OFFENSIVE ENGAGEMENTS

Introduction

73. In the attack most engagements will be short range ones of a sudden nature over ground which will be relatively unknown to the crew. Unless a rapid ranging device is available to the commander he will have to judge the range on these occassions. As the 'S' Tank is not currently fitted with such a device it was decided to include firings of this type in the assessment.

Aim

74. To determine the effectiveness and rapidity of the 'S' Tank in engaging opportunity targets below 2000m.

Equipment

75. See Appendix 1 paras 14 to 16.

Method

76. The intention had been to exercise each tank crew through three AP, three HE and three MG engagements from each of two firing points. Unfortunately because of the unsatisfactory performance of the APDS ammunition in Test 1 this test was curtailed to HE and MG only.

77. For each engagement the target was indicated to the commander who then gave his fire order whilst indicating the target to the gunner who carried out the laying for the shoot. This method was adopted as it is the closest to UK practice.

Results

78. All engagements were successfully concluded and the detailed results are given in Appendix 5. The timings and average rounds/bursts fired per engagement are given in Table 8 below.

/Table 8 ....

Table 8 - Summary of Results of the Static Offensive Engagements

Serial	Crew and Ammunition	Mean Time (sec) to 1st Round/Burst	Mean Time (sec) between rounds	Mean number of Rounds/ Bursts per engagement
(a)	(b)	(c)	(d)	(e)
1	A - HE	19.4	14.1	2.5
2	B - HE	14.4	19.9	3.0
3	Mean HE	16.4	17.6	2.75
4	A - MG	12.1	-	2.0
5	B - MG	10.3	-	2.2
6	Mean MG	10.8	-	2.1

Notes

1. Serial 1 Column (c) excludes two timings of 51.5 and 32.6 secs where the crew left certain safety devices at safe.

2. Serial 4 and 5 Column (c) excludes four times above 20secs where stoppages occurred or crews left safety devices at safe.

Discussion

79. Method of Engagement. The reasons for using the normal UK method of the commander indicating the target to the gunner who did all the laying and firing are :

a. During an engagement one member of the crew should maintain general observation. The commander is the best man to do this as :

(1) He is the only one who can decide whether a fresh target or threat is more important than the current engagement.

(2) If a more important or threatening target appears the commander can take control from the gunner and lay onto it with the minimum delay. The converse is not possible ie. the gunner cannot take control from the commander.

b. In HE and MG engagements where usually more than one round/burst have to be fired the laying and observation of fire takes up too much of the commander's concentration for too long a period. He cannot receive or transmit orders nor prepare and send his contact report. The mean timings between rounds of 14.1 and 19.9secs show that there will be many cases where the commander can actually send his contact report during the shoot. On the other hand for AP engagements at short range stationary targets there is every advantage in the commander firing. Against long range AP and moving targets however the same criticisms of the commander firing apply as for HE and MG engagements.

c. MG engagements should usually be carried out with the gunner laying and firing as the commander has no means of cocking the guns to clear stoppages.

80. Timings. The timings were most disappointing. The acquisition times for the HE engagements were long and two of these results for Crew A were omitted as they included delays arising from one of the many safety switches in the tank not being made. The increase in target acquisition time when firing is not unknown and it is interesting that the mean time for the CENTURION is 16 secs on the range which is 6secs higher than that achieved in dry runs (see para 36c.). The timing between rounds was also similar to the CENTURION, of 17.8secs.

81. HE Shooting. Most of the shooting was good. Both commanders gave a very bad estimate of range on one of their targets and four rounds were needed on both these occasions to secure a hit. The commander and gunner of Crew A although slower in acquisition hit the target with their second round on four out of six of their engagements whereas Crew B had only one two round engagement.

82. MG Shooting. This was good, due in the main to the guns being zeroed to the sight. In five out of the twelve engagements the first burst was effective and second bursts were fired to give greater lateral coverage. Where the first burst was not effective the commander had incorrectly assessed the range. The Swedish ammunition has only one tracer every four rounds and without the aid of definite marks in the sight MG shooting would have been very difficult.

Conclusion

83. The 'S' Tanks performance in normal HE and MG engagements against static targets is similar to that of the CENTURION without a ranging gun.

TEST 3 OFFENSIVE SUPPORT ENGAGEMENTS

Background

84. In the offeneive support role tanks may be required to provide smoke and long range HE fire. It had been intended to test the 'S' Tank in both these types of engagement but unfortunately the Swedish smoke round was not available for use. The UK 105mm smoke round could not be used because of Swedish objection to UK primers. In addition the No 390 fuze could not be set as there was insufficient room to manipulate the fuze key in the five round manually operated magazine. This restricted the trial to longe range HE engagements. These were further restricted, as indeed smoke shooting would have been, to direct lay engagements. The reasons for this are that although the 'S' Tank has a clinometer it is only marked in mils and there is no suitable reference for line corrections such as a traverse indicator in the vehicle. Attempts were made to use the graduated markings on the cupola ring for this purpose. These were defeated as the cupola could only be properly initially centralised by locking it. When it was unlocked to lay off the required amount it moved off line by varying quantities before any traverse signal had been passed to it or the hull.

Aim

85. To assess the ability of the 'S' Tank to engage HE targets between 2000 and 4000m.

Equipment

86. 'S' Tanks Nos 2132 and 2133 and 13 rounds of Swedish HE M61A, 105mm ammunition.

Method

87. The troop leader's tank carried out the initial ranging on the target and passed the final elevation to the second tank which carried out its ranging. On the completion of the ranging both tanks fired three rounds gunfire.

Results

88. a. The troop leader opened fire 21secs after being given the target. The opening range was 3400m and the final elevation was 3575m determined in four rounds and a silent correction of 25m in 82secs from the start.

b. The second tank fired three ranging rounds. The first two straddled the target as a result of a +50m correction. A third ranging round fired on a -25m correction was just minus of the target and the gunfire was fired at this elevation of 3600m. The timings were 20, 43.5 and 59secs to the three rounds respectively after receiving the final elevation.

c. Gunfire was accurate but ragged and delivered over 30secs.

d. The whole engagement was completed in 2 min 55 secs.

Discussion

89. The timing was quite reasonable for a troop shoot. It would have been better if the second tank commander had kept to the drills and not fired the third ranging round. This wasted 15.5secs and was totally unecessary as he had straddled the target with a 50m bracket.

90. Another slow timing was the time to the first ranging round of the second tank. This was partly caused by the gunner overshooting the 3575m mark on laying and then having difficulty in re-locating this mark in the gratioule.

91. Line corrections are not easy to make in the S Tank as no proper graticule marks are provided for this at the longer ranges and there is no adequate traverse indicator. All that the gunner can do is aim off what he assesses to be the correct amount. In this shoot no line correction was needed. This was almost certainly due to the wind being only 2.8m/s (9ft/s) and almost directly down range.

92. It was of interest to note the variation in performance of the guns, that of Tank No 2133 requiring 25m more elevation (0.6m) than that of Tank 2132. This was the reverse sense of the elevations required for the 2000m HE shoot in Test 1.

93. The erratic gunfire was attributable to three causes :

a. The failure of the tanks to return to within 0.2m in elevation of their original lay after firing. This should occur if the firer keeps the firing button pressed after firing until suspension movement has ceased. It did not on the two trial tanks.

b. Obscuration at the target which was considerable as the first gunfire rounds completely obscured the target area for as much as 10secs.

c. Obscuration at the firing point which lasted up to 4 secs.

94. In comparison the CENTURION can deliver more rapid gunfire providing the loader is well trained. The tank hardly moves and the gunner can set his indirect fire instruments so that neither muzzle nor target obscuration prevent his laying and firing. Long range HE shooting and the delivery of gunfire are not the main role of the tank on the battlefield and too much should not be made of the 'S' Tank's shortcomings in this respect.

95. The semi-automatic magazine avails the crew of the 'S' Tank nothing in time during the engagement but it does give them two great advantages over the CENTURION.

a. The loader does not have to prepare for the shoot by ensuring he has at least eight HE rounds in the ready bins.

b. After completing the shoot the ready ammunition bins do not have to be replenished. This can take 5mins or even longer.

Conclusion

96. The 'S' Tank can deliver direct long range HE fire accurately up to 4000m but its gunfire is difficult to concentrate in time compared with the CENTURION. The 'S' Tank's magazine however does mean that the tank is readily available after a long range HE shoot whereas the CENTURION requires about 5mins for internal replenishment.

TEST 4 DEFENSIVE ENGAGEMENT OF MOVING TARGETS

Introduction

97. It had been hoped to test the 'S' Tank firing against moving targets. Unfortunately BINDON range was being rebuilt during the period of the trial and the moving target gear on HEATH range was out of action. Fortunately the accuracy of laying by the crew against moving targets could be assessed without firing by using a moving target and the sight camera to record the gunners lay at the instant of firing. Results by this method are given in this test.

Aim

98. To determine the accuracy with which the 'S' Tank weapon system enables the gunner to lay on a moving target.

Equipment

99. a. 'S' Tanks Nos 2132 and 2133.

b. A Landrover with a white aiming point on it.

c. Robot 35mm Camera.

Method

100. Nine crewmen each carried out three series of 10 lays on a Landrover whilst it ran laterally across their front at a speed of 20km/hr at 500m range. A white aiming point on the Landrover and a short range were used to enable good photographic results to be obtained and ensure accuracy in the analysis of the results. All crewmen used the gunner's controls.

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101. For each lay the crewman was timed from start to the pressing of the firing button.

Results

102. The results and their analysis are given in detail in Appendix 6 and the means for each of three series is given in Table 9 below.

Table 9 - Series Mean Results of Lays Against a Moving Target

Serial	Series	Time (secs)	MPI (mils) H	MPI (mils) V	Sd (mils) H	Sd (mils) V	Score (secs mils²)
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
1	1	11.6	LO.11	+0.01	0.55	0.27	1.75
2	2	9.8	LR 0	+0.06	0.50	0.29	1.49
3	3	10.2	RO.02	±0	0.37	0.22	0.70
4	Overall Mean	10.6	LO.03	+0.02	0.47	0.26	1.32

Note

The score is the product of the time in column (c) and the sds in columns (f) and (g). It gives an easy comparison in merit between series of lays by taking into account speed and consistency. The lower the score the better the lays.

Discussion

103. Unfortunately ETW have no figures for the accuracy of lay against moving targets other than the results of this test. This confines the drawing of conclusions to the individuals and occasions of this test alone. The results are not re-assuring and show the general laying error to be greater than the round to round dispersion of the ammunition. There is no proof that this size of laying error is confined to 'S' Tank as the moving targets used on ranges are always large and could therefore mask many laying inaccuracies. In future wars however the size of targets may be less and investigation into the laying errors of other equipments should be made.

Conclusion

104. As yet there is no proof that the fire and gun control equipment of the 'S' Tank is more or less inherently accurate than that of other AFVs when used to lay onto moving targets. The results of this test on the 'S' Tank show :

a. Layers generally improve with practice and that some require more practice than others.

b. The average time for a lay is of the order of 11 secs and is unlikely to be less than 5.0 secs.

c. The order of consistency after practice is about 0.37mils sd in line and 0.22mils sd in elevation.

TEST 5 MASS ATTACK

Aim

105. To test the ability of the S Tank to produce the sustained fire necessary to meet a massed AFV attack.

Equipment

106. 'S' Tanks Nos 2132 and 2133, 39 rounds of UK 105mm APDS L52 with Swedish additive, two loadings of local smoke grenades.

Method

107. The tanks advanced 20m to simulate moving from a 'turret down' to a 'hull down' position, opened fire at 14 'head on' tank target screens at between 1000 and 1400m and then withdrew to turret down under cover of their local smoke.

108. The tanks had to move forward off a slope to simulate the movement to a hull down position because of range safety considerations. The gunnery lays were recorded by a camera fitted to the sight as in previous tests.

Results

109. Faults. Two false starts were made with 'S' Tank No 2133. On the first occasion the 6th round was not ejected and the breech block re-closed on the empty case. The test was restarted but the same faults occurred on the very first round. The breech was stripped but the only point noted was a slight burr on one of the extractors. The breech was re-assembled and two test rounds fired. They were ejected satisfactorily and the test was then carried out. The fault re-occurred with the last round of the test.

110. Timings and Hits. The timings and strikes on targets are shown in tabular form below. No target was hit twice by any one crew apart from five strikes which occurred in the abortive runs of tank No 2133.

TABLE 10 Mass Attack Test Results

Serial	Detail	Results	
		Tk No 2132	Tk No 2133
(a)	(b)	(c)	(d)
1	Rounds Fired	14	16
2	Time to move to hull down position	28secs	10secs
3	Time to first round fired	51secs	27secs
4	Time to last round fired	3min 35secs	2min 30secs
5	Time to turret down position	3min 46secs	2min 52secs
6	Time between first and last rounds	2min 42secs	2min 3secs
7	Hits	11	12

111. Gunners' Lays. Analysis of the photographs of the gunners' lays showed :

/a. ....

a. 2132. The lays for rounds 1, 4, 5, 12 and 13 were central whilst those for rounds 10 and 14 were 0.3mils left and 0.2mils left 0.3mils high of centre respectively. The photographs for rounds 2, 3, 6, 7, 8, 9 and 11 could not be analysed as mud on the sight object prism had obscured the target. This mud did not interfere sufficiently with the gunner's view through the sight to prevent him laying.

b. 2133. The lays for rounds 4, 5, 7, 12, 13 and 14 were central. For rounds 2, 3, 6 and 9 they were from 0.2 to 0.4mils left of centre whilst for rounds 8 and 11 they were 0.2mils right of centre. Rounds 15 and 16 were 0.4mils high and 0.2mils left and high respectively. The photographs for rounds 1 and 8 were not clear enough to analyse.

112. Local Smoke Screening. The local smoke screen built up in 3 secs and lasted effectively for about 15 secs. The withdrawal of Tank No 2132 was completely covered by the screen but that of Tank No 2133 would have required another 6 secs screening for complete concealment.

113. Barrel Bend and Sight Adjustment. The difference in Tank No 2133 sight graticule adjuster readings before and after this test were Horizontal 0.4mils, Vertical 0.6mils. This was reflected by the commander's sight which had the same horizontal alteration and 0.8mils in elevation. Unfortunately comparative readings for Tank No 2132 were not recorded.

Discussion

114. The main points arising from this test were :

a. The Delay in Opening Fire After Halting. Both tanks took a long time after halting before firing the first round. The oscillation causing the delay was largely compounded by crew inexperience, artificial movement over a concrete firing point and range safety requirements, as was proven later on. In tank No. 2132 the first round was further delayed as the gunner had left his safety switch at safe.

b. The Relatively Slow Rate of Fire. This is accounted for by the obscuration which prevented the gunner laying with more rapidity. Unfortunately the only firing point avaiable had been fired over frequently and the ground was very dry and dusty.

c. The Relative Lack of Fatigue of the Crew. In a CENTURION such a rate of fire is only possible in the later marks with their improved stowage. Even so the loader would have needed five or ten minutes recuperation from his efforts before being a fully sensible member of the crew again. In addition he will have to replenish his ready ammunition at the first opportunity and the tank will not be ready for further prolonged engagements until this has been done.

Conclusion

115. The 'S' Tank is capable of delivering rapid sustained fire against a mass attack. In dusty conditions its rate of fire is unlikely to exceed that of a CENTURION because of obscuration preventing the gun being re-layed. In other conditions the automatic loader would probably allow the CENTURION rate of fire to be exceeded. In either case the 'S' Tank's operation has not imposed anything like the degree of fatigue imposed on the CENTURION loader and it is ready to fire the remainder of its ammunition whilst the CENTURION requires time for re-stowage within the tank.

TEST 6 FIRE WITH MOVEMENT

Aim

116. To determine any difficulties in handling the 'S' Tank in a fire with movement exercise.

Equipment

117. 'S' Tanks Nos 2132 and 2133 each loaded with 20 Swedish 105mm HE M61A, 1250 rounds of Swedish 7.62mm MG and eight local smoke grenades.

Method

118. The tanks loaded with HE and MG ammunition only carried out a fire with movement exercise over approximately 3000m and consisting of three bounds.

119. No quantitive results were acquired but the exercise was used to practice the crews in fire and movement and to deal with the problems entailed in controlling fire, sending contact reports and noting the position of flank tanks.

Results

120. Crews experienced no difficulty in carrying out the exercise. Range estimation and corrections were poor on three of the eleven targets engaged with HE fire. MG fire was well controlled and the majority of targets were hit with the first burst. Tank 2133 lost the use of one of its hull MG through a stoppage after it had fired 180 rounds. This meant that 32% of its serviceable MG on the last bound because one hull gun had used up all its ammunition, the other had a stoppage as did the commander's MG which had only fired 75 rounds.

Conclusion

121. The tank is a viable fighting system and is no more difficult to handle in a fire and movement exercise than a turretted tank. The limited MG ammunition supply and the inability to remedy stoppages without crew exposure is the weak point of the tank, as can be seen by No. 2133 ending the exercise with 40% of its ready ammunition unfired because of stoppages.

TEST 7 DEFENSIVE NIGHT FIRING

Introduction

122. The 'S' Tank has no night fighting equipment other than infa-red headlamp filters and a driver's viewer. The Swedish Army policy is not to use IR and other such devices for night firing but to illuminate targets by flares so that they can be engaged with the normal sights. To this end they have developed some excellent illuminating ammunition such as the CARL GUSTAV 84mm and the LYRAN 71mm flare which range out to 2200m and 1000m respectively and have burning times of about 25 secs. Both provide good intense illumination of over 400,000 candela which can be used with poor light gathering optical instruments such as gunner's sights.

123. British Army experience of engaging targets with AFVs firing by flare illumination is relatively slight and so it was decided to test the S Tank in these conditions.

Aim

124. To test the effectiveness of the 'S' Tank Weapon System for night firing using the 84mm CARL GUSTAV flare for illumination.

Equipment

125. 'S' Tanks Nos 2132 and 2133 together with :

a. 14 rounds of Swedish 105mm HE M61A

b. 1000 rounds 7.62mm MG

c. 84mm CARL GUSTAV Gun and 19 rounds of illuminating ammunition.

d. Head on screens and Fig 11 targets for HE and MG engagements respectively.

Method

126. The crews were practised in the recognition of targets by flare light on the night before firing took place.

127. Approximate target ranges and bearings were fed into the CARL GUSTAV gunner who fired from a position 50m to the right flank of the tanks who also received the target information by radio. On the flare illuminating the target the crew engaged it with HE fire if it was a vehicle or MG if men.

128. It had been intended to fire both tanks together but range safety restrictions forces them to be only 20m apart. At this distance firing HE caused mutual obscuration and so alternative engagements were fired for HE. MG engagements were fired together using the same flare but separate groups of targets in the same area.

129. A flank observer recorded the observation of the fall of shot and these were confirmed by checking the targets the following morning. The flank observer's assessments were not made known to the crew until after the engagement.

Results

130. CARL GUSTAV Ammunition.

a. The ammunition functioned well but there was one parachute canopy failure out of the 19 rounds fired. Flare burning times were taken for the 15 rounds fired on the second night and discounting the parachute failure these averaged 27.0 secs with an sd of 0.9 secs. This excellect performance was probably aided by the low wind speed of 0.8m/s (2.5ft/s).

b. On the training night preceding that of the test targets were successfully sighted and layed onto up to 1700m by both S Tank crews. A Gunnery School Course on CHIEFTAIN sharing the firing point achieved hits on two targets at this range with the aid of the flares. The students had no previous flare light shooting experience. Unfortunately on the night of the test mist reduced visibility to about 1000m and even below this there were opaque local pockets of it.

131. HE Shooting. Each crew fired three engagements. In both cases two first round hits and one second round hit were obtained. Ranges were target No 1 - 600m, No 2 - 900m and No 3 - 800m. The results are tabulated below.

Table 11 Results of Night HE Shooting

Serial	Tk No	Target No	Time (secs) to 1st Round	Time (secs) to 2nd Round	Flares Fired	Hits
(a)	(b)	(c)	(d)	(e)	(f)	(g)
1	2132	1	27	Not fired	1	1st Round
2	2132	2	23	Not recorded	2	2nd Round
3	2132	3	35	Not fired	2	1st Round
4	2133	1	8.5	12	1	Both Rounds
5	2133	2	25	38	2	2nd Round
6	2133	3	12.5	Not fired	1	1st Round

132. MG Shooting. Five of the six engagements were fired and all first bursts were on target. Times to first bursts and flares required are given in Table 12 below :

Table 12 Results of Night MG Shooting - All First Bursts Effective.

Tgt	Tank No 2132	Tank No 2133
(a)	(b)	(c)
1	One flare required. Fire opened after 10 secs.	One flare required. Fire opened after 12 secs.
2	Two flares required. Fire opened after 30 secs.	One flare required. Fire opened after 10 secs.
3	Two flares fired but target obscured by mist.	One flare required. Fire opened after 25 secs.

Discussion

133. General. The results were good and in all probability the timings would have been better but for the mist which made some of the targets very difficult to locate. Corrections to fire are more difficult to assess and apply by flare than by daylight but easier than with some night viewing devices.

134. HE Shooting. The lack of wind which benefitted the flares was a definite disadvantage when firing HE as the consequences of firing were not rapidly cleared from the tank and caused obscuration. True observation was difficult for the crews and only achieved at the 900m target. At the other targets assessment of effectiveness was made on the HE burst. As in previous tests the obscuration was almost certainly aggravated by the dry weather and the large amount of firing which had previously taken place from the firing point.

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135. MG Shooting. This was most effective. The ability of the crews to hit the groups of figure targets with the first burst is largely due to the fact that the MGs are zeroed to the sight. This gives the gunner a definite aiming point in the graticule unlike the CENTURION where the MG is in an unadjustable mounting and rarely approaches a match with the graticule.

Conclusion

136. Providing the general area of the target is known and the ambient conditions are reasonably calm and mist free strong flare light is a very effective method for firing in darkness.

137. The 'S' Tank can be used very effectively with flare illumination up to 1000m. The lack of a ranging device probably curtails longer range shooting.

TEST 8 LOCAL SMOKE PROTECTION

Aim

138. To test the local smoke protection system of the 'S' Tank.

Equipment

139. a. 'S' Tank No 2133.

b. 80 Swedish WP Grenades with propellant charges.

c. Stop Watches.

Method

140. a. The tank was situated on level ground between two black and white contrast screens 20m apart. Observers were positioned on the centre line facing the tank and screens, and 500m left and 900m right of it, at about 1000m range.

b. Three full salvoes of eight grenades and seven half salvoes of four grenades were fired.

c. The observers were warned by radio and timed from the firing of the grenades to:

(1) The screen being effective.

(2) The tank re-appearing.

141. Eight grenades were fired at with 7.62mm ammunition to test their reaction to small arms fire.

142. The time taken to load the grenades was noted.

Results

143. Ambient Conditions. The test was carried out on an overcast day with visibility over 2 miles. The dry temperatures were between 59 and 57°F and the humidity was between 81 and 71%. The wind was 4.4 to 6.5m/s (14 to 21ft/s) and blowing obliquely from the left front towards the tank.

144. Screening.

a. Times to Screen Effective. The mean time for all salvoes from all three observers was 4.0 secs with a spread from -1.0 sec to +1.5 secs.

b. Screening Duration Times. The results are summarised below :

Table 13 - Screening times of Swedish Local Smoke Grenades

Serial		Observers Mean Times (secs) Left	Centre	Right	Mean time (secs) all Observers
(a)	(b)	(c)	(d)	(e)	(f)
1	Three full salvoes	34.9	23.3	23.7	27.3
2	Seven half salvoes	19.8	17.4	17.5	18.2

c. Range. The grenades burst in the air about 24m from the tank.

145. Faults

a. Firing Circuits. The lower inside barrel of the right hand discharger had a faulty lead which resulted in only seven grenades being fired in the full salvoes and only three in three of the half salvoes.

b. Propelling Charges. Two grenades did not leave their barrels and as no faults were found in the firing circuits it is assumed the propelling charge was not making contact or defective.

146. Reaction to Small Arms Fire. When fired on by single shot GPMG fire the grenades, when struck, behaved in the following ways:

a. The WP contents burnt, but without running like that of the No 80 grenade.

b. The WP content was ejected burning, from the grenade. Whether this was caused by the ejector or burster charge is uncertain.

147. Loading Time. The grenades can be loaded fron their box in rear of the cupola in 1½ to 2 minutes. They are a little hard to push home and each one has to be rammed home fairly hard. After the loading test it was found that the grenades fitted so tightly into the discharger barrels of Tank No 2133 a stilson wrench had to be used to remove them.

Discussion

148. For the 2nd part of this test (para 141) the Swedish grenades were mounted on posts and not in their discharger cups. Had they been mounted in the cups with the metal caps fitted it is considered that their reaction to the small arms fire, in paragraph 146, would be for the grenades and or contents to be ejected due to the ejector and a burster charge being ignited. This would cause little or no crew hazard unless the drivers hatch was open which is highly unlikely in action.

149. These results show that although their screening times are comparable the S Tank local smoke protection has the following advantages over that of the CENTURION :

/a. ....

a. The grenades are not nearly so dangerous when hit by small arms fire.

b. The screen builds up more rapidly taking only 3 to 5 secs as opposed to 6 to 8 secs.

c. The loading is easier and can be carried out in a tenth of the time.

Conclusion

150. The local smoke protection system on the 'S' Tank is rapidly effective and screens for about 27 secs if the cupola is in the correct attitude when the grenades are fired. It can be rapidly reloaded and the grenades themselves are not as great a hazard to the crew if struck by small arms fire as those of the CENTURION.

TEST 9 COMMANDER'S MG

Introduction

151. The commander's MG on the 'S' Tank assumes greater importance than it does on other vehicles as it is the only weapon which can be fired with any chance of effectiveness whilst on the move. It is also the only weapon that could be used, albeit manually, if the vehicle were surprised when the main engine is not running.

Aim

152. To test the effectiveness of the 'S' Tank commander's MG in the various roles in which it may be required.

Method

153. The commander's MG was fired in the following roles :

a. High Elevation Fire. At maximum elevation to investigate the feasibility of use in the anti-aircraft and street fighting role.

b. All Round Defensive Fire. Over the rear of the tank to test its effectiveness as a means of giving all round defensive fire without rotating the tank.

c. Firing on the Move.

d. Hand Traverse Control. The cupola being controlled by hand when the K60 engine was not running.

e. Pintle Mounting. The alternative to the normal cupola mounting.

Results

154. General.

a. Sighting. The rapid delivery of effective fire from the commander's MG is prejudiced by the fact that there is no graticule in the sight for this MG. Further it is not capable of being zeroed to the main graticule as are the hull MGs. In these circumstances a higher ratio than that of one trace in four is required to enable the fire to be corrected onto the target quickly.

b. Elevation Control. The elevation of the MG is controlled by a long link arm with a control handle on its lower end. There is a variable damper on the arm which requires the use of a second hand to alter its setting. It was found to be impossible to get an ideal setting on this damper. It was either too stiff and prevented small corrections being made or too loose in which case the vibrations of the MG caused excessive dispersion and judder on the sight prism. The overall result is to make the engagements of cross-ing or oblique moving targets extremely difficult as both hands frequently have to be used for elevation control leaving no hand free for controlling traverse.

155. High Elevation Fire. The lack of a proper gun-sight relation as described in the previous para makes the use of the gun against even low performance aircraft impractical. It can be used against the upper storey windows in street fighting but will require two or three bursts to correct fire before it is effective.

156. All Round Defensive Fire. The commander's seat does not rotate. Hence to engage targets over the rear arc of 2000 to 4400m is impractical because of the body contortions to which the commander is subjected.

157. Firing on the Move. Effective fire can be delivered on the move because of the stabilisation of the MG in traverse. This enables the commander to concentrate on overcoming the problems of controlling the fire in elevation described in para 154 b. Only the frontal arc from 5400 to 1000m can be used practically when firing on the move because of the limitations imposed by the commander's seat as described in para 156.

158. Hand Traverse Control Firings. A grip handle is provided to traverse the cupola when the locked/free hand control is at free. This enables the cupola to be traversed by hand on a push and pull basis. The degree of control available by use of this means of traverse was not sufficient to counter-act the twisting moment of the off-set MG and prevented accurate fire being delivered.

159. Pintle Mounting. No merit could be discerned for this mounting whatsoever. It :

a. Requires two men to operate the gun as one has to feed the belt to the gun.

b. Exposes the firer and loader when used.

c. Does not have sufficient rigidity for accurate fire unless the butt is fitted to the MG.

Conclusions

160. The commanders MG is only capable of effective fire at stationary targets when :

a. Over a frontal arc of between :

(1). 5400 and 1000m when the tank is moving.

(2). 4400 and 2000m when the tank is stationary.

b. The K60 engine is running.

/COMMENTS

COMMENTS

Introduction

161. In the various test reports in the previous paragraphs comments have been omitted as far as possible. This section of the weapons report contains the comments of the Weapons Trials Officer, Troop Leader and Crews on the vehicle's design as it affects the weapon system. Some of the points raised may be debatable and the result of national or personal prejudice but the intention has been to comment on the vehicle as if it had been of UK design. Where good points have been noted these are mentioned. It may seem though that these are heavily outweighed by adverse criticisms. Unfortunately it is easier to criticise than create and the makers must be assured that a profusion of minor quibbles does not detract from the overall soundness or originality of the concept.

Main Armament

162. The Gun. The points noted for comment were:

a. Insulation. There is no thermal sleeve on the barrel. This will make the fire control system inaccurate because of barrel bend in weather conditions such as cold winds and rain or snow.

b. Extractor Operation. The design of the extractors and their mode of operation differs from the UK 105mm gun. In view of the failure of the extractors on Tank No 2133 in Test 5 (see para 109) it is possible that a redesign is required to ensure a more positive unseating of the cartridge. In all fairness however it must be pointed out that this defect only occurred with UK APDS ammunition. On the other hand it did not occur with Tank No 2132 and it is considered that the chafing of case by the loading system as noted in the preliminary test with Tank No 2133 was probably a contributory factor to this fault.

163. Recoil System. The recoil system is a hydro-pneumatic system of quite complicated design. It proved most reliable and no maintenance other than crew servicing was necessary on either tank during the trial.

164. Ammunition. The Swedes claim that higher velocity and reduced muzzle pressure from their longer barrelled 105mm gun reduces obscuration. In the opinion of the UK Trials Team there was no noticeable reduction in obscuration when firing either APDS or HE. Observation with APDS, as with CENTURION, remains impossible below about 2000m in normal conditions and the comparative minimum range for HE observation is about 600 to 800m.

165. Loading System. The loading system is complicated and not entirely reliable as yet. Jams occurred at various times on both tanks. As mentioned in the tests the semi-automatic loading system does not increase the rate of fire in a single engagement but its advantages when reliable are:

a. The elimination of loader fatigue and the freeing of a crewman to add to the observation capability of the crew.

b. The improved availability of the ammunition ie. all 50 rounds are ready rounds whereas with CENTURION there are only 14 or 15 rounds in this category even on the later marks.

166. Drills. The drills for the main armament are effective, simple and easy to apply except for :

a. Hand Loading Magazine. This requires three operations, two carried out simultaneously with separate hands, on controls which are in different areas on the reverse driver's rear bulk head. It is thought that the controls for this magazine could be simplified and concentrated at the one point.

b. Misfires and Jammed Rounds. The proposed drill of ejecting misfires is not always successful and it was found in practice when using drill rounds that these had to be removed by hand. With jammed rounds a member of the crew invariably has to dismount and remove the round with the long lipped bar provided in the tool kit.

Gun Control Equipment

167. Gun Controls - Safety.

a. There are far too many safety switches and mechanisms. The presence of all these interlocks and the omission by the crew to make them all caused serious delays in opening fire in Tests 2 and 5. In CENTURION there are only two applied safety switches to be made. These are firstly the gunner's selector lever must be positioned for the desired armament and secondly, on the main armament only, the loader's safety switch must be made. With its automatic loader the S Tank applied safety could be cut to a single three position armament selector switch with main armament, MG and safe positions. Instead there are four :

(1). The Main Armament Mechanical Safety Lever which withdraws the firing needle assembly and is situated to the left rear of the commander.

(2). The Weapons System Switch which energises the firing circuits and is situated on the main switch panel under the gun barrel.

(3). The Firing Safety Switch on the commander's and driver/gunner's control boxes. NB. Only one has to be made by whichever of these crewmen is firing but there is another switch which has to be made before any of the commander's controls become operative.

(4). The Armament Selector Switch which like (3) is on the control boxes. This must be set to either main armament or MG.

b. Despite the pre-occupation with safety interlocks the positioning and operation of the actual firing switch leaves much to be desired. This switch is far too similar in appearance, feel and operation to the loading switches. It should require operation by a different digit to the other switches, preferably the forefinger to reduce personal intervals to a minimum, and be an entirely different action ie. a pull instead of a push.

168. Gun Controls - Loading Switches. Duplication of the switches seems unnecessary and it would be more distinctive to have only one each side for a particular nature of ammunition.

169. Traverse System. The normal traverse available when the K60 engine is running is similar in response to UK powered traverse systems. Fire and rapid laying is quite simple. The worrying point about the vehicle is that without this auxiliary engine running there is no capability for traverse. This will raise training difficulties but more important is the severe tactical limitation in defensive positions at night.

/170. ....

170. Elevation System:

a. The elevation control is mainly positional and only partly rate, i.e. the elevation position is determined by the amount of deflection of the controller and the engine speed determines the rate of movement to the new position. This system is not as easy to use rapidly for fine laying as a rate system and generally results in the layer overshooting and having to reverse his direction of lay to get on to the target. The system has the advantage of being relatively simple to engineer which a rate elevation would not be on the 'S' Tank configuration. It can be used to lay accurately but layers do need considerable practice before becoming skilled in its use, especially with moving targets.

b. It was claimed that providing the firer kept the firing switch pressed until after the tank had settled from the shock of main armament discharge the elevation system would return the lay to within 0.2m of the firing lay. This did not prove to be the case and movements of up to 3m were recorded. This is considerably more than experienced with CENTURION.

171. Commander's Over-ride. Compared with the CENTURION the commander's over-ride is relatively slow in both application and release. A far greater drawback, however, is the fact that when control is handed over by the commander to the gunner the tank assumes an elevation attitude to conform with the gunner's elevation controller. Similarly, when the commander assumes control the hull elevation alters to that set by his elevation controller. This does not facilitate rapid interchange once a target has been indicated and virtually commits the commander to laying the gun for all engagements in which he acquires the target to avoid time delays. This deficiency could be overcome by ganging the driver/gunner's controller to the commander's whenever the commander assumes control.

Fire Control Equipment

172. Sights - Advantages. The commander's and driver/gunner's sights are extremely good instruments which appear to be better than UK sights in the following details:

a. Easy selection of varying magnifications to suit variations in conditions.

b. Easy selection of one of three filters to reduce glare when laying against strong sunlight.

c. Binocular vision which improves observation and performance at low light levels.

d. Automatic shutter to cut out muzzle flash.

173. Sights - Disadvantages. It is doubtful that the sights would meet the UK specifications for sealing against adverse atmospheric conditions. Other practical penalties are:

a. The large and hence vulnerable object prism.

b. The weight - 85 lbs, although they only require removing to change a damaged object prism.

/174. ....

174. Graticule.

a. The graticule pattern was not liked by the UK Crews for the following reasons:

(1). The pattern is too repetitious making it very easy for the layer to place the wrong range mark on the target. This was clearly shown when during one of the 2000m HE accuracy series the gunner used the 1700m in mistake for the 1900m mark.

(2). There are far too many aim off marks for moving targets which also confuse the eye.

b. Other criticisms are:

(1). The 600m AP mark is superflous because of the flat trajectory of APDS.

(2). The provision of windage marks appropriate for 5 and 10m/s cross winds is questionable. There is no means of measuring the wind to the target other than empirically by firing. A round on the ground allows the correction of all the line errors arising from windage and tilt but when only varying windage marks are given it is very difficult to correct for a line error at the same time. A much better system would be to have the lateral mil scale on a moving cursor where it could be used to mark:

(a) The range being used.

(b) Line corrections.

175. Cupola. The observation facilities provided by the cupola would be excellent if the commander's MG spent case bag could be dispensed with. Even with the fourth periscope blanked off the cupola gives good observation. The sight as mentioned para 172 is excellent as is the fire laying control provided by the joystick. The adverse cricisms of the cupola are:

a. There is no provision for a geared hand traverse. This is essential on a tank with no turret and no hull armament laying capability when the engine is not running. It would enable effective fire from the commander's MG to be used to defend the vehicle in leaguer and silent defensive positions.

b. The contra-rotation facility is not satisfactory. The cupola jumps about 40% on coming into or being unlocked from 'line-up' with the hull armament. Until this is rectified the facility is worthless as it defeats the object. Just as the commander gets the hull armament laid on an indistinct target the whole system moves and he has to re-locate the target and relay. This fault also nullifies the value of the traverse indicator ring which shows the angular location of the commander's sight relative to the hull armament.

c. A more positive line-up lock or automatic slowing device is required as it is possible to overshoot line-up at maximum traverse rate.

/d. ...

d. On several occassions during the trial the K60 engine was switched off without the cupola being switched off and locked in co-incidence with the hull armament. In these circumstances the cupola rotates until it comes up against the stops protecting the electrical imput leads. If left in this state damage will occur to the mechanism. To overcome the situation the engine must be restarted and power control reassumed to centralise and lock the cupola in co-incidence with the main armament.

176. Semi - Indirect and Indirect Fire. Although these are tertiary roles for tank the normal instruments for effecting semi-indirect and indirect fire are also valuable for laying on fixed lines at night. The use of a clinometer-range drum poses no problem in the 'S' Tank but the use of a traverse indicator does. On uneven ground the tank does not pivot about its centre but over arcs of up to 400m it is probable that the attendant errors would be insignificant. If the cupola were modified to overcome the instability described in b. of the previous para the present traverse indicator ring would suffice to enable line switching for fixed line firing to be recorded but it has the disadvantage of only being visible to the commander.

177. Crest Clearance. To enable full advantage to be taken of the low silhouette of the S Tank and its capability of adopting very good fire positions some mechanical method of checking crest clearance must be incorporated in the vehicle. At present in the 'S' Tank the only method of checking crest clearance is to open the breech block and ejector door dismount, remove tampion (if fitted) and look up the bore. Under certain conditions these actions may not be possible. It is therefore suggested that a simple optical device, eg. a telescope, be fitted onto the vehicle with its axis parallel to that of the main armament, this could have either its own eyepiece or its image projected into one of the main sights.

178. Observation. The 'S' Tank has probably the best coverage of all round observation by the crew of any tank because of the reverse driver. It could be even further improved by giving him a periscope covering the right rear of the vehicle.

MGs

179. General. The engineering of the MG installations is one of the weakest points of the design. In many respects they appear to have been added as an afterthought. For both the hull and the commander's MG the crews have to pack the ready boxes from separately supplied belts. With all three MGs the belt is turned through 90° in coming from its box to the gun. This tends to cause feed stoppages and not one of the guns can be cleared of a secondary stoppage without considerable exposure of a crewman. The only good point about the installations is the avoidance of toxic fumes in the crew compartments by placing the MGs outside.

180. Hull MGs. The best point about the Hull MG installations are the ability to zero the guns to the sight and the absence of toxic fumes in the fighting compartment. The first of these two is a point of general design which could be applied to other tank MG whereas the second can only occur where the MGs are mounted outside the crew compartments. The disadvantages to set against these two advantages are:

a. To release the catch holding the lid OPEN the crewman must put his head inside the pod and take the weight of the lid. This is dangerous as should he slip he would be trapped under the heavy lid and probably suffer serious if not fatal injury.

b. The inability to clear all but the simplest stoppages without exposing a crewman.

c. The restriction of the ammunition to 1000 rounds.

d. The alternate firings of the guns. It would be much better if the guns were selected and fired one at a time until their ammunition was used up or they had a stoppage.

e. The ready boxes that have to be packed by the crew require extremely careful packing to avoid frequent feed stoppages which cannot be remedied by re-cocking.

181. Commander's MG. The following adverse criticisms are made :

a. The MG mounting is too high and has a distinctive signature which frequently discloses the presence of the tank when it is 'turret down'.

b. The elevation control is awkward. The damper has to be clamped rigidly to get accurate fire in elevation and is too slow to undo to allow for rapid changes for corrections. In addition the damper makes accurate fire on the move difficult despite the stabilisation in line provided by the cupola. The elevation control could be improved by having either :

(1) A geared hand elevation system with an electric motor and stabilisation for firing on the move,

or,

(2) A quick release on/off lock operated by a lever on the hand control allowing rapid change of elevation and rapid locking once the desired lay is achieved.

c. The firing control is a lever and is awkwardly positioned in relation to the elevation controller on which it is fitted. A switch operated by a thumb would be preferred. This would leave the remaining fingers free to operate a lock/free device such as recommended in sub-para b. above.

Local Smoke

182. The system seems most satisfactory except for the tightness of the grenades in the discharger barrels which virtually prevents their being unloaded other than by firing.

Crew Duties

183. Commander. The commander has additional facilities to those provided on any other tank and can operate the vehicle single handed. Normally he will not use the driving and firing capabilities but leave these in the hands of the driver/gunner. The big advantage in the commander having these facilities is that he can save time by merely taking control for moving rapidly into a difficult fire position or the engagement of a suprise target. The one feature which may overload the commander is his MG. This is the only effective means of delivering prophylactic fire on the move and if the commander has to fire a lot it will detract from his proper function.

184. Gunner/Driver. Using one man to do two jobs is extremely desirable from a manpower view as long as efficiency is not impaired. In the case of the 'S' Tank this is so for the Gunner/Drivers were perfectly able to carry out both tasks and appeared no more fatigued at the end of the day than a normal CENTURION driver.

185. Reverse/Driver. From a work study and cost effective view the reverse driver in the 'S' Tank is an unnecessary luxury as the vehicle can be effectively fought by the two forward facing crew-members. However the advantages of having him far outweigh any of the above reasons, these are :

a. He can replace one of the other two crew members for casualty or fatigue reasons.

b. He can answer the radio if the other two crewmen are engaging a target.

c. He can maintain observation to the rear and drive the tank backwards when changing fire positions or withdrawing.

d. He is of immense value for vehicle maintenance which two men would find arduous.

e. Physchologically a two man crew is inferior to a three man.

f. A three man crew in the 'S' Tank will enable the vehicle to operate for significantly longer periods on the battlefield.

Exposure in Fire Positions

186. Frontal Aspect. As the gun does not move relative to the hull it can be mounted next to the roof as no internal swept volume is required above the gun to obtain depression. This results in the height of the sights and hull roof being reduced from 2ft 6ins above the gun on CENTURION to a mere 1ft 3ins on 'S' Tank. With its present commander's MG this good point is somewhat nullified as the mounting is so high and distinctive it helps to identify and locate the tank despite the small amount of its hull which is exposed (see para 181a).

187. Side Aspect. The comparison of the side aspect exposed by the 'S' Tank with CENTURION in any one fire position is difficult to assess truly. The two vehicles will give completely different targets in different positions because of their peculiarities. Generally speaking the 'S' Tank is smaller and will display a lower target even if it is slightly longer than the CENTURION. This would give it an advantage as the lower a target the more critical becomes the estimate of range and this makes targets of small height the most difficult to hit.

/Firing on the Move

Firing on the Move

188. Suggestions have been made that the problem of firing the main armament on the move could be overcome by having a stabilised sight. This would not really overcome the problem as even with a stabilised sight the gun still has to be brought to coincidence in both azimuth and elevation. The possibility of effecting this, even for an instant, with a vehicle embodying the 'S' Tank concept, is considered to be remote.

CONCLUSIONS

'S' Tank in Relation to CENTURION

189. The 'S' Tank has shown in its weapons trials that its traverse rate is inferior to the CENTURION but the system can be used to lay with similar accuracy. To compensate for the inferiority its optical devices are better so that in combination its target acquisition ability, overall, is equal to that of the CENTURION.

190. At present the 'S' Tank's gunnery performance when stationary firing against stationary targets corresponds to that of the CENTURION 105mm gun tank without a ranging gun. The addition of a thermal sleeve would improve the 'S' Tank's performance beyond this point because of its superior sight stability. If the intention of fitting a laser range finder is realised the 'S' Tank will then surpass the performance of the ranging gun CENTURION.

191. Against moving targets the 'S' Tank did not seem to be very accurate from an analysis of the layer's point of aim. However, no comparative data is available as yet for CENTURION. In the delivery of accurate fire whilst it is on the move, the 'S' Tank cannot compete with the latter.

192. The semi-automatic loader does not increase the rate of fire of the tank in a single engagement. It will do so, however, for prolonged firing as the first and last rounds in the magazine are equally available. Not only is replenishment within the tank avoided but replenishment from echelon is greatly simplified and speeded up by the concentration of the ammunition stowage into the loading system.

'S' Tank Design

193. The weak points of the 'S' Tank design as the vehicle exists at present are:

a. Loading System. The principle is excellent but as yet the system is not fully reliable, nor is the method of removing misfired or jammed rounds completely sound. These problems will almost certainly be solved with development.

b. Gun Control Equipment. The two main points are:

(1) The loss of lay in elevation when laying control is passed from the commander to the driver/gunner.

(2) The excessive number of applied safety devices in the firing circuits.

/c. ....

c. Fire Control Equipment:

(1) The Sight Graticule is too cluttered, confusing and repetitious for a fixed ballistic pattern.

(2) Laying Instruments. There is no real provision for fixed line, semi-indirect or indirect fire instruments. The clinometer is only graduated in mils. The traverse indicator scale showing the relative offset of the cupola cannot be used because of the way the cupola jumps when unlocked from its 'line-up' position.

d. Commander's Cupola:

(1) The advantage of a contra-rotating cupola is almost completely lost by the way in which the cupola jumps when 'line-up' is achieved or when unlocked from 'line-up'. This same fault prevents the cupola being used to measure bearings for correction of fixed line, semi-indirect and direct fire. (See c.(2) above).

(2) A hand traverse gear to enable the cupola to be rotated easily and accurately when the K60 engine is switched off would be of great assistance both in silent surveillance and for accurate emergency defensive MG fire.

e. MGs:

(1) General. The inability to clear all but the simplest stoppages and replenish ammunition without exposure of a crewman is a definite disadvantage. The presentation of the belts to the guns by turning them through 90° aggravates feed problems and frequently causes stoppages.

(2) Hull MGs. The lid of the pod containing these guns should be redesigned to make its opening and closing safer.

(3) Commander's MG. The commander's MG is the only weapon available to the crew if the tank is ambushed without its engines running. To enable it to be more effective it needs a graticule in the commander's sight and a better elevating gear. In addition its traverse in these conditions would be improved if the cupola had a geared hand traverse (see d.(2) above).

'S' Tank Concept

194. Advantages. The abolition of a turret and gun movement, other than recoil, within the hull has achieved the following advantages over a conventional turretted tank:

a. The reduction of size of the vehicle which considerably lessen the chances of it being hit. In this respect it should be noted that it is less of a target when viewed from any aspect than any other AFV.

b. The reduction of height exposed when in a fire position. This is achieved for the reasons explained in para 186.

/c. ....

c. The easy combination and interchange of the duties of commander, gunner and driver enabling these tasks normally employing three men to be carried out by two.

d. The replacement of the loader by a semi-automatic loader and the vast improvement in the ready ammunition (rounds readily available at all times).

e. The ability to mount a longer than normal gun because of the housing of a large proportion of the barrel in the hull.

f. An improved stability between gun and sight by the abolition of moving linkage.

95. Disadvantages.

a. Major Disadvantages. The two main drawbacks of the S Tank concept are :

(1) Silent Traverse. It is very difficult to engineer a silent traverse ability for use at night in defensive positions into the tank.

(2) Firing on the Move. The problem of delivering accurate main armament fire on the move would seem insuperable.

b. Minor Disadvantages.

(1) A possible reduction in the total number of rounds carried. This is largely compensated for by the improved availability of the rounds carried.

(2) The reduction of the normal 30° elevation range of -10° to +20° to the order of ie. -10° to +12° as on the S Tank. Depression is the vital factor however and providing this is not sacrificed this is not too serious a disadvantage.

APPENDIX 1 TO
ANNEX C TO
AT/1123/GT/428
DATED 13 FEB 69

EQUIPMENT

Test A

1. Vehicles

   a. 'S' Tank No 2132.

   b. One 3 Ton Truck.

2. Ammunition

   a. 105mm

      (1) 20 rounds APDS.

      (2) 25 rounds Swedish HE M61A.

      (3) 5 rounds Swedish HE representing smoke.

   b. 7.62mm

      (1) 2 x 500 round containers.

      (2) 7 x 250 round boxes.

   c. Grenades

      (1) 24 Swedish Local Smoke Grenades.

      (2) 6 x No 83 Coloured Smoke Grenades (in lieu of No 36 Grenades).

3. Other Items. Stop watches and vehicle tools.

Test B

4. Vehicles. S Tank No 2133 with all vision devices fitted.

5. Other Items

   a. Chalk.

   b. Tape Measure.

   c. Artillery Director L1A1 for angular measurement.

Test C

6. Vehicles. 'S' Tanks Nos 2132 and 2133.

7. Other Items

   a. Stop watches.

   b. Compass.

   c. Landrover.

   d. Three 0.6m wide by 0.4m high plywood replicas of a small turret such as on FERRET. Each target had a headlamp mounted in its centre which was flashed when required to simulate the muzzle flash of a gun firing.

/Preliminary APDS ....

Preliminary APDS Loading and Firing Test

8. Vehicles

a. 'S' Tanks Nos 2132 and 2133.

b. CENTURION Mk 13 No 44 BA 72 with 105mm barrel No L3580 measuring H 4.157in V 4.160in at 1in from the commencement of rifling before the test and H 4.168in and V 4.170in afterwards.

9. Ammunition

a. Two rounds of UK 105mm APDS L28.

b. 21 rounds of UK 105mm APDS L52A1 supplied on Arty 2 Requisition No A2/4/406A and without Swedish Additive.

10. Instruments

a. 105mm Service Muzzle Boresight No 362.

b. Reference Telescope No 7.

c. CENTURION Gunner's Sight Periscope AFV No 30 No 2135/63.

d. Gauges and Calipers for measurements of the shot.

e. Meteorological Instruments.

Test 1

11. Vehicles

a. 'S' Tanks Nos 2132 and 2133.

b. CENTURION Mk 6/2 No 01 ZR 81.

12. Ammunition

a. APDS. 52 rounds of UK 105mm L52 with Swedish Additive as supplied on Arty 2 Requisition No A2/473.

b. HE. 28 rounds of Swedish 105mm HE M61A.

c. MG. 200 rounds of Swedish 7.62mm MG linked one trace three ball.

13. Instrumentation

a. Range Survey. Tellurometer supplied and operated by Locating Wing, School of Artillery, Larkhill.

b. Velocity Measurement. EVA (Electronic Velocity Analyser) radar supplied and operated by the School of Artillery, Larkhill.

c. FVRDE Reference Muzzle Boresight No 12.

d. Swedish Service 105mm Muzzle Boresight.

e. Barrel Measuring Gauge for 105mm Gun L7A1.

f. Meteorological Instruments.

g. 35mm Robot Camera for recording gunners' lays. Fitted to the 'S' Tanks only.

Test 2

14. Vehicles. 'S' Tanks Nos. 2132 and 2133.

15. Ammunition:

a. 105mm. 33 rounds 105mm Swedish HE M61A.

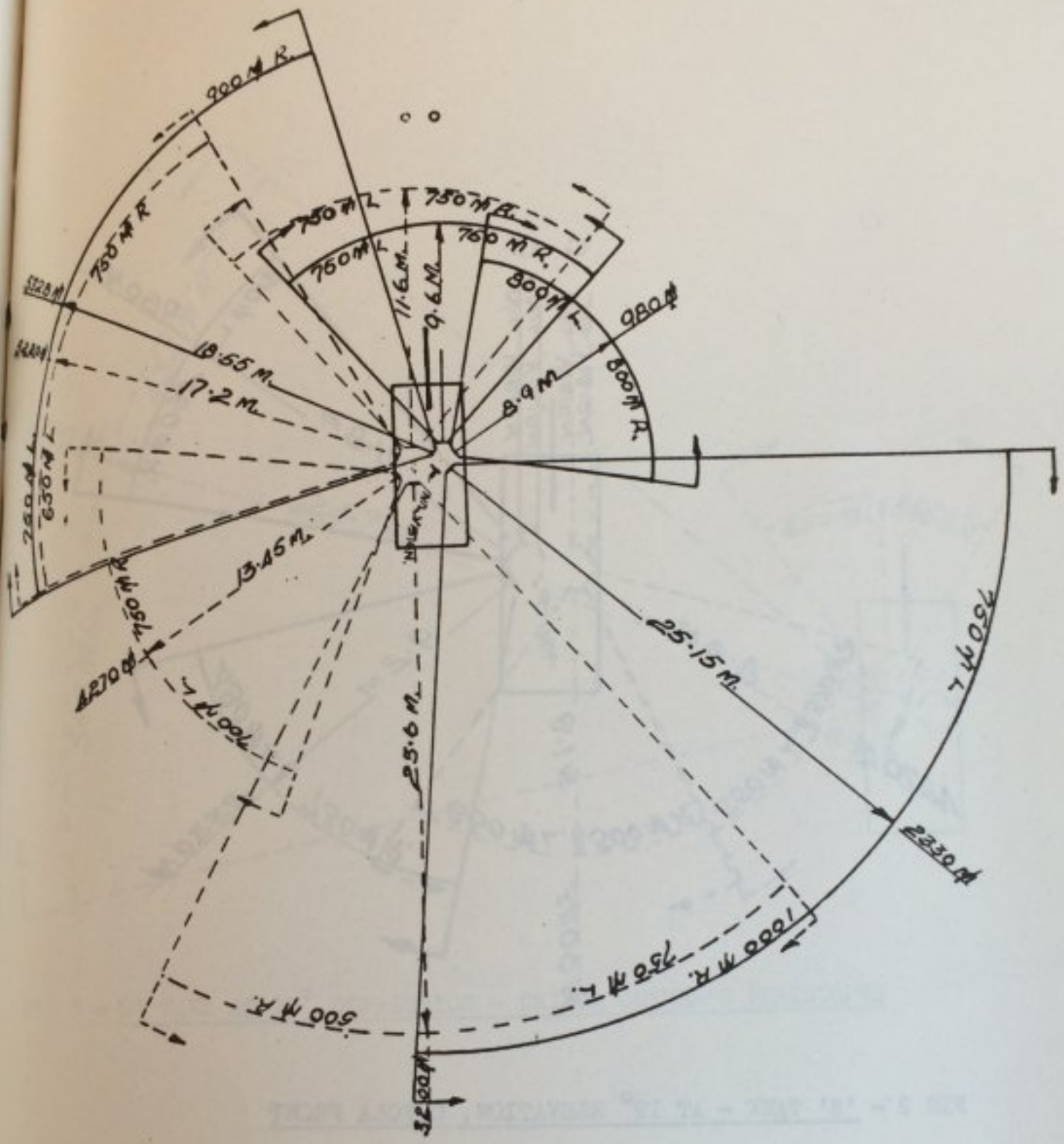
b. 7.62mm. 1000 rounds Swedish 7.62mm MG linked one trace three ball.

16. Targets:

a. HE - Head on screens.

b. MG - Fig 11.

APPENDIX 2 TO
ANNEX C TO
AT1123/GT 428
DATED 13 FEB 1969



Legend:

——— From Commander's cupola

- - - - From Gunner/Driver's hatch

FIG 1 - 'S' TANK LEVEL - CUPOLA FRONT

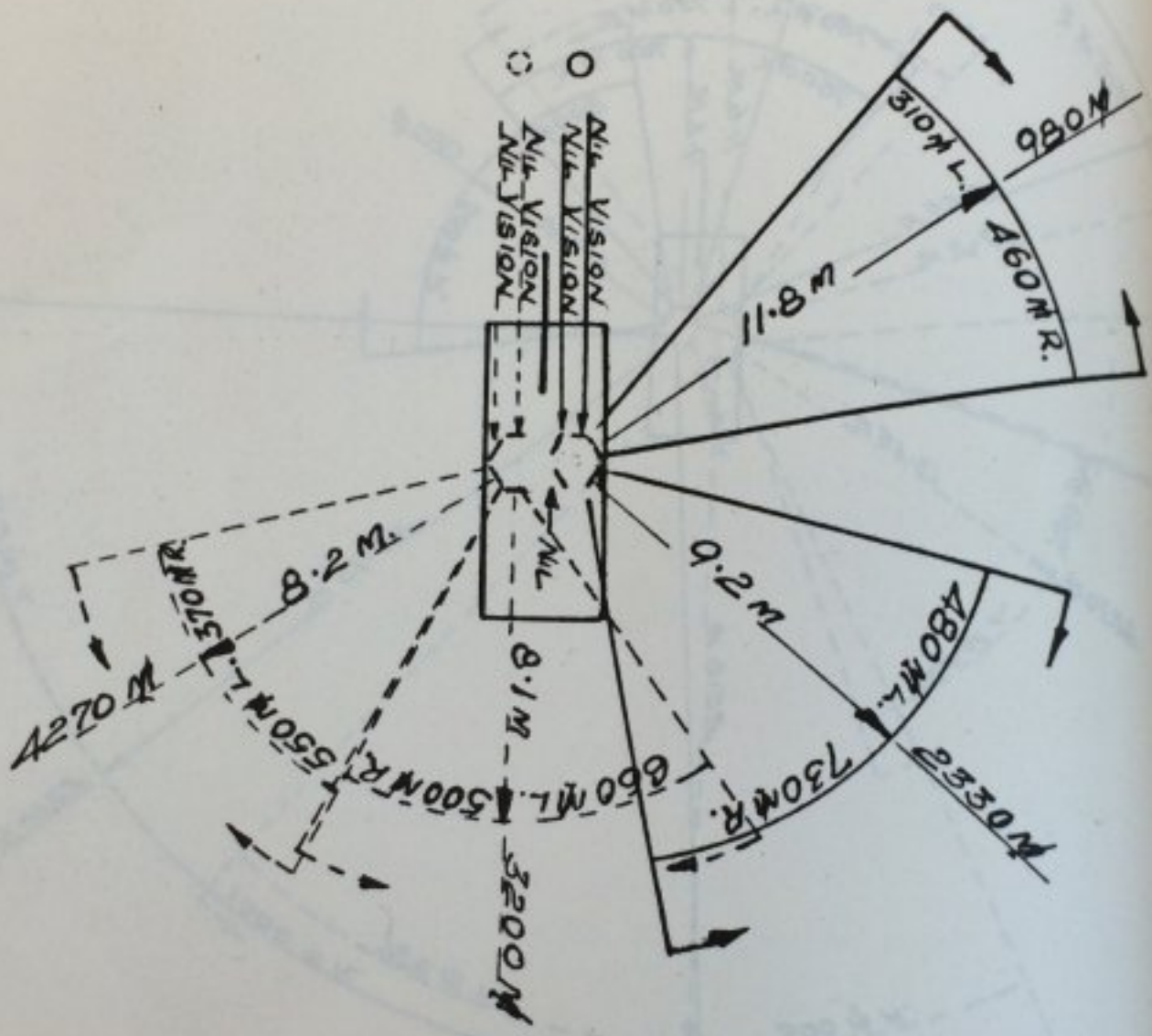


FIG 2 - 'S' TANK - AT 12° ELEVATION, CUPOLA FRONT

Legend:

——— From Commander's cupola

– – – – From Gunner/Driver's ha

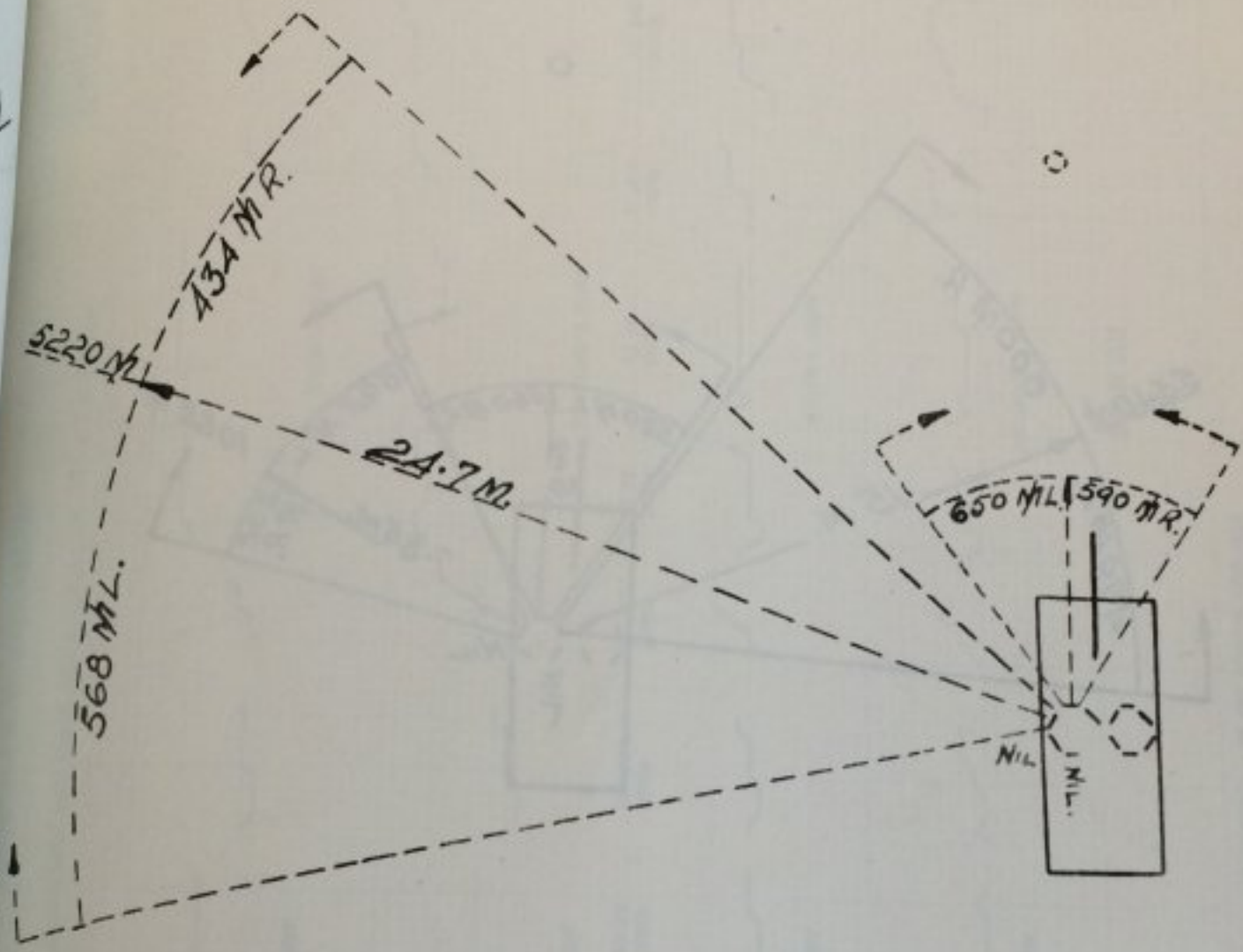


FIG 3 - 'S' TANK AT 10° DEPRESSION - DRIVER GUNNER'S PERISCOPES

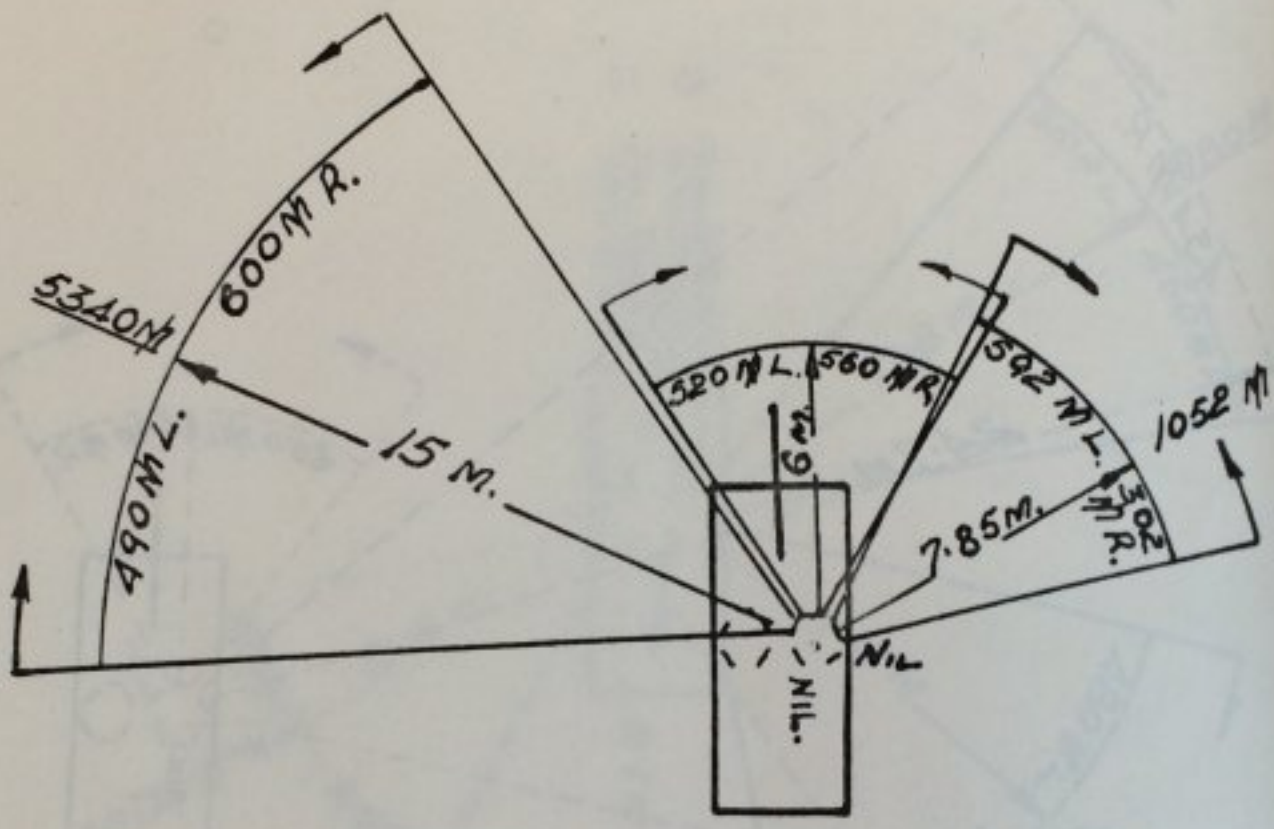
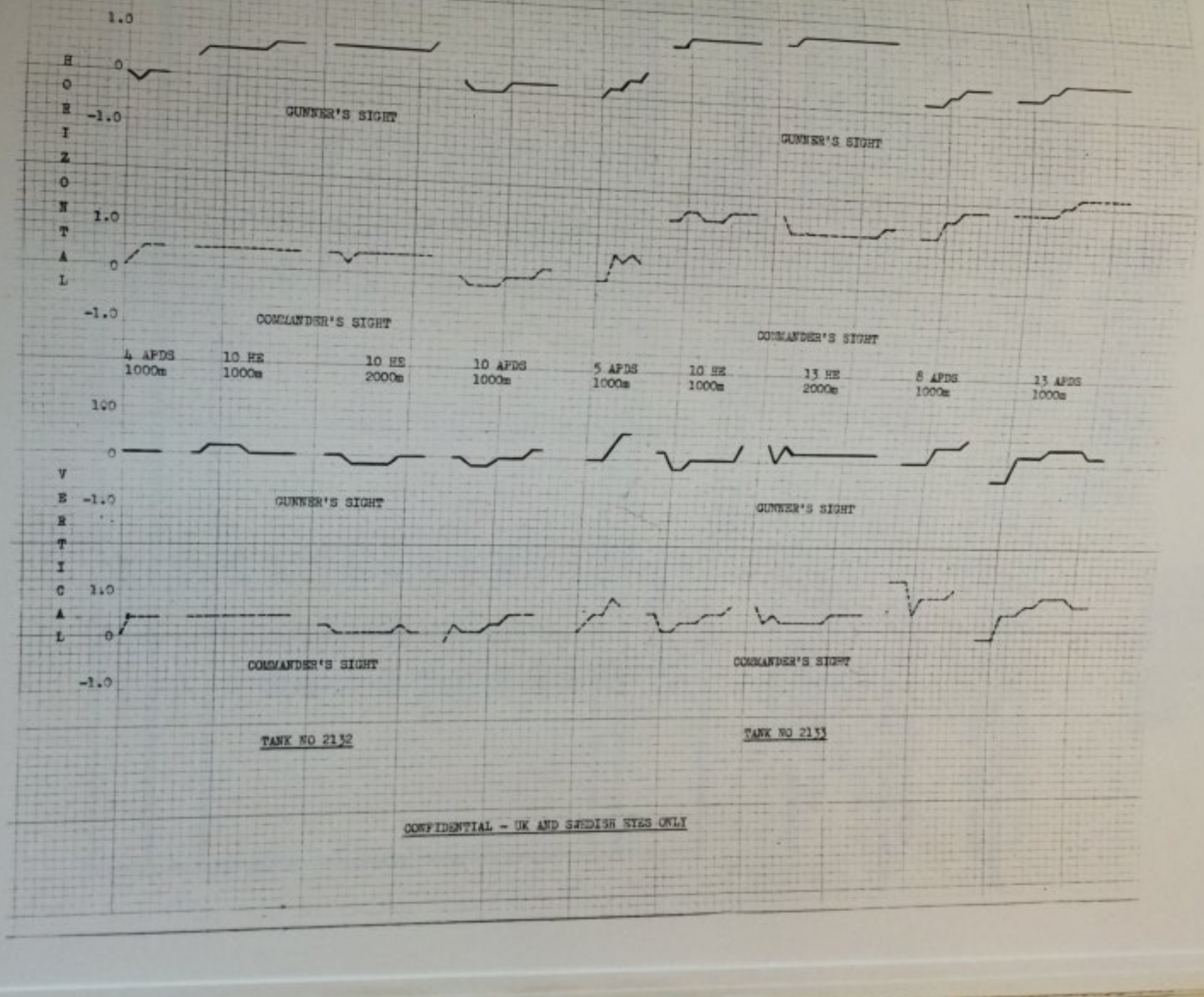


FIG 4 - 'S' TANK AT 10° DEPRESSION CUPOLA FRONT - COMMANDER'S PERISCOPES

GRAPH OF GRATICULE ADJUSTMENTS DURING TEST 1 - 'S' TANK ACCURACY TRIALS

APPENDIX 3 TO
ANNEX G TO
AT/1123/GT/4.28
DATED 15 FEB 1962



APPENDIX 4 TO
ANNEX C TO
AT/1123/GT/428
DATED 13 FEB 69

RESULTS OF SWEDISH APDS FIRINGS AT RAVLUNDA ON 7th AND 8th AUGUST 1968

1. Majors S.A.B. EDWARDS 3DG and D.D.A. LINAKER RTR attended the firing of two accuracy series of Swedish 105mm APDS (with additive). These firings were arranged because of the poor consistency noted during the UK trial with UK 105mm L52 APDS ammunition containing the Swedish additive. (See Test 1 in Annex C).

2. Both series consisted of 10 rounds and were fired at targets at 2000m using different tanks. Laying was by gunner's sight throughout and although FVRDE reference muzzle-boresight and telescope readings were taken to check barrel bend it was not compensated for by adjusting the gunner's sight. Velocities were measured and shot separation was photographed. A photographic record of the gunner's lay at the instant of firing was also made with the 35mm Robot camera. The strikes, MPIs and sds of the two series is given in Table 1 below.

Table 1 Details of 2000m Swedish APDS Accuracy Series.

Serial & Round	Tank No 2110 Strike (cm) H	V	Tank No 2114 Strike (cm) H	V
(a)	(b)	(c)	(d)	(e)
1	L74	-27	L 5	-82
2	L38	+17	R 6	-96
3	L31	-80	R17	-90
4	L64	-34	L10	-143
5	L16	-17	L66	-130
6	R 5	- 7	L58	-90
7	R 3	-20	L97	-76
8	L49	-60	L27	-43
9	L32	+52	L38	-55
10	L 9	+23	R18	-60
MPI	L30.5	-15.3	L25.9	-86.5
Sd (⌀)	0.13	0.20	0.19	0.16

APPENDIX 5 TO
ANNEX C TO
AT/1123/GT/428
DATED 13 FEB 69

TEST 2 - DETAILED RESULTS

1. HE Shoots. All engagements were successfully concluded with a hit on target. The timings and numbers of rounds fired in each HE engagement are given in Table 1 below.

Table 1 HE Shoots - Times and Rounds Fired

Serial	Target Range (m)	Time to 1st Round (secs)	Total Time (secs)	Time from first to last round	Rounds Fired	Remarks
(a)	(b)	(c)	(d)	(e)	(f)	(g)
1	950	51.5	65.0	13.5	3	Safety switches left at safe
2	1700	24.0	68.0	44.0	4	
3	1400	21.2	49.0	27.8	2	
4	1600	32.6	84.0	51.4	2	As for Serial 1
5	1050	15.1	30.0	14.9	2	
6	1300	17.1	30.0	12.9	2	
7	950	13.5	59.0	45.5	3	
8	1700	18.8	65.0	46.6	3	
9	1400	5.0	45.0	40.0	3	
10	1600	21.8	71.2	49.4	3	
11	1050	11.7	24.0	12.3	2	
12	1300	15.3	60.0	44.7	4	
13	-	19.4	59.0	-	2.5	Mean per Engagement Crew A Serials 1 to 6.
14	-	14.4	54.0	-	3.0	Mean per Engagement Crew B Serials 7 to 12.
15	-	16.4	56.0	-	2.75	Mean per Engagement both Crews.

/Note ....

Note The timings in Serials 1 and 4 are omitted from the mean times in Serials 13 and 15.

2. MG Shoots. As with the HE all engagements were successfully concluded with hits on target. The times are given in Table 2 below.

Table 2 MG Shoots - Times and Bursts Fired

Serial	Target Range (m)	Time to 1st Burst (secs)	Total Time (secs)	Bursts Fired	Remarks
(a)	(b)	(c)	(d)	(e)	(f)
1	750	44.0	70.0	2	
2	600	34.1	59.0	2	Safety lever left at safe. First burst effective.
3	700	32.5	53.5	3	As for Serial 2.
4	800	10.0	18.0	2	
5	200	12.4	18.0	2	
6	400	13.9	18.0	1	
7	750	12.2	93.0	3	Stoppage on one gun after first burst.
8	600	9.8	29.0	3	
9	700	5.9	15.5	2	
10	800	27.0	31.0	1	Safety lever left at safe.
11	200	15,2	23.0	2	
12	400	7.2	17.0	2	
13	-	12.1	18.0		Mean Crew A Serials 4 to 6.
14	-	10.3	21.0		Mean Crew B Serials 7 to 12.
15	-	10.8	20.0		Mean Both Crews.

Note. Timings from Serials 1 to 3 omitted from mean times in Serials 13 and 15 and timings from Serial 10 omitted from mean times in Serials 14 and 15. The total time in Serial 7 is also omitted from the mean total times in Serials 14 and 15.

APPENDIX 6 TO
ANNEX C TO
AT/1123/GT/428
DATED 13 FEB 69

TEST 4 - DETAILED RESULTS AND ANALYSIS

Results

1. The detailed results of this test are given in Table 1 of this Appendix. This table includes not only the average time, MPI and sds for each series of 10 lays by each layer but also a score figure. The score is simply the product of the layer's average time and his sds in line and elevation. It enables comparison to be made more easily between individuals and occasions and by using both dispersions, rather than a mean or combined one, it is weighted in favour of the more important factor of consistency. The lower the score figure the more creditable it is and to ease the task of comparison the scores have been put together in Table 2 of this Appendix.

Analysis

2. Times. In Table 1 only layers No 2, 4 and 8 show a continued reduction in average time with practice. In the case of layer No 8 this reduction of time is accompanied by a fall off in accuracy and is therefore more likely to have been achieved through sacrificing accuracy for speed than by improvement with practice.

3. MPI.

a. Horizontal. There is slight evidence of layers No 6 and 9 being biased to the left and right respectively however their MPI errors from zero are about half that of layer No 7 who has the only bad bias of L0.28m. The other six layers have random MPIs with an overall mean of left and right zero.

b. Vertical. As the main movement of the target was in the horizontal plane it is only to be expected that the MPI displacements from zero would be less in the vertical than the horizontal plane. This is clearly shown as the largest vertical error of 0.13m (layer No 6 series 2) is nearly a third of the largest horizontal error of 0.35m (layer No 7 series 3). There is some evidence of a tendency to lay high amongst the layers there being only 9 negative results out of the 27 and only one completely negatively biased layer (No 4). This tendency to a positive bias would appear to be of very little importance as all the results were within ±0.10m of centre.

4. Dispersion.

a. Horizontal. Only layers No 1, 2 and 6 achieve dispersions of less than 0.20m and No 2 and 6 did this on their first series. The worst values in excess of 0.60m are obtained by layers Nos 3, 4, 5 and 7 in either or both their first and second series. In the third series all dispersions are less than 0.60m. but layer No 3 approaches it with 0.57m.

b. Vertical. Again as with MPI displacement from zero the vertical dispersion is less than that of the horizontal. 0.50m of layer No 7 in the second series is the worst overall and in the third series layer No 1 is the worst with 0.31m sd.

/Table 1 ....

Table 1 Results For Three Series Each of 10 Lays Against a Moving Target.

Serial & Layer (a)	Series & Individual Means (b)	Time (secs) (c)	MPI (ϕ) H (d)	MPI (ϕ) V (e)	Sd (ϕ) H (f)	Sd (ϕ) V (g)	Score (sec ϕ²) Time x sdh x sdv (h)
1	1	13.5	LO.23	-0.09	0.23	0.26	0.81
	2	8.3	LO.24	+0.10	0.38	0.32	1.01
	3	13.5	RO.04	+0.02	0.18	0.31	0.75
	Mean	11.8	LO.14	+0.01	-	-	0.86
2	1	12.2	RO.12	+0.01	0.18	0.26	0.57
	2	11.7	RO.02	+0.09	0.18	0.18	0.38
	3	9.6	LO.04	-0.01	0.24	0.23	0.53
	Mean	11.2	RO.03	+0.03	-	-	0.49
3	1	8.6	LO.09	-0.03	0.93	0.45	3.60
	2	9.2	RO.11	+0.11	0.73	0.31	2.08
	3	8.8	RO.15	+0.02	0.57	0.14	0.70
	Mean	8.9	RO.06	+0.03	-	-	2.13
4	1	14.2	LO.26	-0.04	0.65	0.19	1.75
	2	12.3	RO.06	-0.12	0.25	0.17	0.52
	3	9.3	RO.12	-0.10	0.28	0.23	0.60
	Mean	11.9	LO.03	-0.09	-	-	0.96
5	1	12.6	LO.23	+0.01	1.53	0.31	6.00
	2	10.3	RO.30	+0.07	1.16	0.39	4.67
	3	11.0	RO.10	-0.06	0.27	0.21	0.62
	Mean	11.3	RO.06	+0.01	-	-	3.76
6	1	14.3	LO.15	+0.07	0.18	0.23	0.59
	2	10.2	LO.21	+0.13	0.42	0.17	0.73
	3	10.2	LO.04	+0.05	0.38	0.27	1.05
	Mean	11.6	LO.13	+0.08	-	-	0.79
7	1	9.0	LO.29	+0.10	0.49	0.20	0.88
	2	7.9	LO.19	+0.10	0.62	0.50	2.45
	3	10.0	LO.35	+0.02	0.45	0.14	0.63
	Mean	9.0	LO.28	+0.07	-	-	1.32
8	1	14.9	RO.04	-0.01	0.25	0.08	0.30
	2	13.3	RO.03	-0.01	0.31	0.16	0.66
	3	11.0	LO.04	+0.02	0.26	0.29	0.83
	Mean	13.1	RO.01	±0	-	-	0.60
9	1	5.5	RO.12	+0.06	0.55	0.43	1.30
	2	5.1	RO.10	+0.11	0.43	0.44	0.96
	3	8.0	RO.24	+0.01	0.48	0.15	0.58
	Mean	6.2	RO.15	+0.06	-	-	0.95

/Table 2 ....

Table 2 Scores (Ti

Serial (a)	Layer (b)	S
1	1	
2	2	
3	3	
4	4	
5	5	
6	6	
7	7	
8	8	
9	9	
10	Total	
11	Mean	

5. Effects of
consistency in
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From Table 2 it

a. Layers

b. Layers
practice.

c. Layer

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Table 2 Scores (Time x sdH x sdV x 100) of Individual Crewmen.

Serial	Layer	Series 1 Score	Series 1 Order	Series 2 Score	Series 2 Order	Series 3 Score	Series 3 Order	Total Score	Total Order
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)
1	1	81	4	101	6	75	7	257	4
2	2	57	2	38	1	53	1	148	1
3	3	360	8	208	7	70	6	638	8
4	4	175	7	52	2	60	3	287	6
5	5	600	9	467	9	62	4	1129	9
6	6	59	3	73	4	105	9	237	3
7	7	88	5	245	8	63	5	396	7
8	8	30	1	66	3	83	8	179	2
9	9	130	6	96	5	58	2	284	5
10	Total	1580	-	1346	-	629	-	3555	-
11	Mean	175		149		70		-	

5. Effects of Practice. The combination of the three factors of speed and consistency in line and elevation enables a check to be more readily made on the improvements in performance or otherwise between layers over the three series. From Table 2 it can be readily seen that :

a. Layers Nos 3, 4, 5 and 9 improved with practice.

b. Layers No 1 and 2 showed no positive improvement or deterioration with practice.

c. Layer No 7 had a very bad second practice.

d. Layers No 6 and 8 deteriorated with practice.

6. Performance of Layers.

a. Table 2 shows that in the third series the differences in scores between the layers had fallen off sharply and the previously poor layers were much better In contrast Layers Nos 6 and 8 who overall were third and second were last and next to last respectively in the third series.

b. Layer No 2 who was first overall was a Schools Gunnery Instructor. Layers 8 and 6 who were the next best were a driver and a gunner respectively. The four layers who showed improvement with practice were all drivers with little or no previous laying experience.

Annex 'D' to AT 1123/GT 428
dated 13 February 1969

'S' TANK TACTICAL ASSESSMENT BY THE TACTICAL SCHOOL RAC CENTRE

INTRODUCTION

Aim

1. To evaluate the concept of a turretless, three-man tank, as embodied in the 'S' Tank, under simulated battle conditions.

Duration

2. The assessment was carried out between 11 and 23 June 1968.

Terrain and Weather

3. The SALISBURY PLAIN practical training area was used. This area measures some 25 miles from west to east and varies between 6 and 8 miles from north to south.

4. The greater part of the training area consists of undulating chalk downs with some steep-sided valleys. Most of the area is grassland, although there are a number of isolated woods and copses. Fields of observation and fire are generally good. However, dips and valleys lend themselves to concealed tactical movement. The choice of concealed fire positions is often difficult because of the tendency to be drawn forward in order to cover otherwise "dead" ground in the dips and valleys.

5. The weather varied from very dry and dusty to very wet.

6. The cross-country going was generally very good, except when heavy rain made the shallow surface soil slippery.

Participation

7. Troops Taking Part:

Serial	Incl Dates	Item	Remarks
1	11-23 Jun 68	Two 'S' Tanks	
2	12-16 Jun 68	One armoured squadron	a. On 12 Jun 68, one company of APC-borne infantry also took part. b. On 15/16 Jun 68, two companies of dismounted airborne infantry also took part.
3	20-21 Jun 68	One armoured half squadron	
4	21-23 Jun 68	One armoured regiment	

/8. Observers....

8. Observers. The nucleus of the observer staff was provided by RAC Tactical School. Other observers were provided by staff officers from HQ DRAC and RAC Equipment Trials Wing. One of the 'S' tanks was commanded throughout by the Trial Project Officer, a Major on the staff of RAC Equipment Trials Wing.

9. Advice and Technical Assistance. Two members of the staff of AB BOFORS, Captain JONELL and Mr. NYGREN, were present throughout. Their co-operation and assistance were invaluable.

10. Visitors. On 20 June 1968, a Swedish party, including DRAC, Brigadier G. A. H. S. CEDERSCHIOLD and DGFVE, Brigadier C. H. B. HAGBERG, visited the trial. They were accompanied by ADAWS.

Method

11. The performance, in all phases of war, of a turretless, three-man tank ('S' Tank) was compared with that of a conventional turreted tank (CENTURION).

12. It was not the intention to conduct a measured, instrumented trial as time and resources were not available. The performance of the 'S' Tank was examined in all phases of war and in the environments in which a main battle tank may be expected to operate in BAOR, with the following exceptions:

a. Fighting in Built-Up and Densely Wooded Areas. The training area was not suitable.

b. Water-Crossing Operations. There was no suitable water and "dry" tests could not be carried out as the 'S' Tanks were not fitted with wading screens.

c. Night Surveillance, Target Acquisition, and Engagement. The 'S' Tanks were not equipped with night-fighting devices. Comments on their night-fighting capabilities are given in the Weapon System Trial Report at Annex 'C' paras 122-137. A considerable amount of night movement was, however, carried out.

d. Winter Conditions.

e. Armoured/Infantry Combat Team Tactics. Training with APC-borne infantry was limited to one day and was carried out at troop/platoon level.

13. The two 'S' Tanks were deployed in mixed CENTURION/'S' Tank troops, which consisted of two CENTURIONS and two 'S' Tanks, or one CENTURION and two 'S' Tanks. These troops took part in a series of exercises at troop, squadron and regimental level.

14. Our assessment is based on the observer's comments. These were supplemented by frequent de-briefings of both the crews of the 'S' Tanks and the troops taking part in the exercises. It is fully appreciated that the assessment is subjective.

15. Appendix 1 gives answers to questions which have been framed to cover the principal differences between a turretless, three-man tank, as embodied in the 'S' Tank, and a conventional tank. It has been difficult to distinguish between comments on the concept of a turretless, three-man tank and comments on a particular vehicle i.e. 'S' Tank.

16. The main conclusions are summarised at paragraphs 23-28 below.

/DISCUSSION

DISCUSSION

Self-Propelled Anti-Tank Gun or Main Battle Tank?

17. Turretless self-propelled anti-tank guns have been employed in many armies. This concept has traditionally been used to reduce expense or to enable a vehicle to mount a heavier gun than could be mounted in a turreted vehicle of comparable size and weight. The cost of 'S' Tank, however, is possibly rather more than that of the LEOPARD, which has a similar main armament. It follows that, for reasons of cost and weight, 'S' Tank should be compared with a conventional turreted tank and not with a self-propelled anti-tank gun.

18. It will be apparent from the detailed comments at Appendix 1, which are summarised in paragraphs 23-28 below, that the 'S' Tank must be regarded as a main battle tank. In comparing the 'S' Tank with the CENTURION the two vehicles were regarded as being required to carry out similar tasks.

Firing on the Move

19. Much of the literature on the 'S' Tank dismisses its inability to fire accurately when on the move as unimportant since no other tank is capable of doing this. The contention is no longer valid in view of the performance of CHIEFTAIN. The question relates largely to main armament, since the 'S' Tank's commander's machine gun can be used for many of the tasks normally carried out by the co-axially mounted machine gun. However, the 'S' Tank commander's machine gun is not fully stabilised and the commander will be fully occupied when firing it, to the exclusion of other tasks.

20. It is desirable that a tank should be able to deliver accurate main armament fire when on the move, and it is current British policy that our tanks should have this facility. However, the importance which should be attached to this requirement may be arguable. The main circumstances in which the facility may be used are in the assault with or without infantry or when caught in the open. Two questions emerge from this which are beyond the scope of this assessment.

a. To what extent will the ability to fire main armament effectively on the move be required in future battles?

b. Are the disadvantages of not being able to fire the main armament effectively on the move outweighed by the undoubted advantages of this concept?

The Value of a Low Silhouette

21. The value of the 'S' Tank's low silhouette as a means of both avoiding detection and reducing the size of the target presented to the enemy was very obvious. This, coupled with the excellence of the tank's vision devices, gave very good results on the ground used for the trials. However, a point could be reached when the increased concealment gained by reducing a vehicle's height will be outweighed by the crew's loss of observation as their fighting positions come nearer to ground level. 'S' Tank commanders also reported that their closeness to the ground made night navigation more difficult than on CENTURION; although this may have been due, in part, to lack of experience on 'S' Tank, the comment is valid. It is also possible to envisage terrain, a lane between high hedgerows is an extreme example, when observation could be seriously reduced and traverse impossible.

/"M-Kill" and "F-Kill" (1)

"M-Kill" and "F-Kill"

22. Because the engine, suspension and tracks are required to lay the main armament an "M-Kill" on 'S' Tank amounts to an "F-Kill". It can be argued that the crew of immobilised tank will not remain in it to fire the armament. Although history provides countless examples to the contrary, it is probably fair to say that the crew will normally leave a tank which has been immobilised by an armour-defeating weapon. On the other hand, the crew of a tank which is immobilised by, for example, mines or mechanical failure, may continue to fight it. This characteristic of 'S' Tank is undoubtedly a disadvantage - but the extent of the disadvantage is a matter of opinion.

NOTE: "M-Kill". Vehicle incapable of controlled movement. Irreparable by its crew on the battlefield.

"F-Kill". Vehicle incapable of fighting due to crew casualties or damage to the main armament or its associated equipment. Irreparable by its crew on the battlefield.

CONCLUSIONS

Summary of Detailed Comments

23. Concealment:

a. The high position of the main armament in relation to the top of the vehicle makes the 'S' Tank a very small target when in a hull-down position.

b. The shape of the vehicle facilitates camouflage.

c. The vehicle's position may be compromised by noise and heat shimmer from the gas turbine.

d. The low silhouette makes the vehicle very elusive when moving.

24. Fire Positions:

a. Viewing devices and control arrangements enable the vehicle to be rapidly moved into fire positions.

b. The low silhouette of the vehicle enables it to occupy positions in which the CENTURION would be very exposed.

c. The absence of a satisfactory method of checking "crest-clearance" prevents full use being made of the above characteristics.

25. Weapons:

a. Excellent observation is provided by first class viewing devices and sights. The rear driver is a great advantage in this respect. These facilities, combined with a traverse speed similar to that of the CENTURION turret, enable the 'S' Tank readily to acquire and engage targets over a wide arc.

b. The hull-mounted machine guns are of limited value when the vehicle is moving and they cannot be serviced or loaded from within the vehicle.

/c. ....

c. A major failure in the automotive system prevents the hull-mounted armament being laid.

d. All 50 main armament rounds are "ready". The stowage of these rounds in an accessible magazine greatly facilitates replenishment.

26. Automotive:

a. The cross-country speed of the vehicles tested was inferior to that of the CENTURION, although their road speed was higher.

b. The 'S' Tank is capable of making sudden sharp changes of direction throughout the speed range.

c. The K60 must be kept running if there is a possibility that the hull mounted armament may have to be laid without warning.

27. Versatility. The main armament cannot be fired effectively when the 'S' Tank is moving.

28. Crew Factors:

a. The commander's possession of full gunnery and driving facilities is a great asset. On the occasions he will employ them, they will simplify, rather than complicate, his task.

b. The auto-loader reduces crew tasks and fatigue.

c. Although it is technically possible to fight the 'S' Tank with a two-man crew, such a tank would be at a severe disadvantage in view of the value of the reverse driving facility and the number of tasks which will normally be given to the rear driver.

General Comments

29. It is emphasized that the assessment is based on subjective judgments formed over a short period. Subject to these limitations, it is possible to highlight the most significant tactical advantages and disadvantages of the concept of a turretless, three-man tank, as opposed to the way in which that concept has been embodied in a particular vehicle:

a. Advantages:

(1) The mounting of the main armament close to the top of the hull reduces the target exposed to the enemy when in a hull-down position.

(2) The low silhouette allows greater freedom in tactical handling and makes the vehicles very elusive when moving.

(3) Given an auto-loader and duplicated controls, the AFV crew may be reduced to three men, one of whom can be available to watch the rear and flanks.

/b. Disadvantages ....

b. Disadvantages:

(1) The main armament cannot effectively be fired when the vehicle is moving.

(2) The main armament cannot be laid unless hydraulic power is available and the automotive system is functioning.

30. Two questions were identified as possible subjects for operational research. They are:

a. To what extent will the ability to fire main armament effectively on the move be required in future battles?

b. Are the disadvantages of not being able to fire the main armament effectively on the move outweighed by the undoubted advantages of this concept?

31. The 'S' Tank has been evaluated as a main battle tank carrying out the tasks given to the CENTURION. From a tactical viewpoint there is no doubt that the vehicle carried out all the roles of a main battle tank except that it cannot deliver aimed main armament fire on the move. It is current British policy that tanks shall deliver accurate main armament fire on the move.

Appendix 1 to Annex 'D' to AT 1123/GT 428
dated 13 February 1969

SWEDISH 'S' TANK - TACTICAL ASSESSMENT
DETAILED COMMENTS

Introduction

1. The following comments consist of answers to questions which have been framed to cover the principal tactical differences between a turretless, three-man tank, as embodied in the 'S' Tank, and a conventional tank.

2. The comments are grouped under six headings:

a. Concealment.

b. Fire Positions.

c. Weapons.

d. Automotive.

e. Versatility.

f. Crew Factors.

3. It is important to bear in mind the conditions in which the assessment took place (see Annex 'D', paras 11-14).

4. Terminology. The terms "hull-down", "periscope-up" and "turret-down" are used in the same sense as when applied to a conventional tank.

Concealment

5. What kind of target does the 'S' Tank, when in a fire position, present to the enemy?

a. Excluding the commander's machine gun, the height of the sights and turret roof above the gun is 1ft 3ins on the 'S' Tank, compared with 2ft 6ins on the CENTURION.

b. The smallness of the target presented head on when in a hull-down position was very noticeable. Despite some doubt on occasions as to whether the tank was "crest clear" both observers and commanders and gunners of opposing tanks commented most forcibly upon this point.

c. No very significant increase was observed in the area exposed to a flank by the 'S' Tank as compared with CENTURION. Because of the low and flat side elevation, any such flank target is likely to be long and low rather than short and high, i.e. a more difficult target from the enemy gunner's point of view.

6. How easy is the 'S' Tank to conceal with camouflage?

a. The shape of the vehicle greatly assists concealment:

(1) The barred engine covers are ideal for covering with turf.

/(2) ....

(2) The shape of the vehicle is difficult to distinguish. It is basically one mass, not two masses - hull and turret. It has no long gun. It was on occasion noticed that the two rear-mounted bins assist in identifying what otherwise appeared as an indistinct mass as an 'S' tank. Furthermore, its position was often compromised by the commander's machine gun.

b. Whilst it is true that the 'S' Tank may disturb local cover (e.g. bushes whilst it is traversing in a way that a conventional tank would not, it must be appreciated that, while traversing, the radius swept by the main armament about the vehicle centre is less than the radius swept by the turret and main armament of the CENTURION. (17ft 6ins (534cms) compared with the 'S' Tank 15ft 10½ins (484cms)).

7. To what extent does the 'S' Tank's low silhouette make it difficult to observe and engage whilst it is moving tactically?

a. The vehicle is extremely elusive.

b. The comment at para 5.c. above is equally valid when the tank is moving.

8. To what extent is the 'S' Tank's position compromised by dust, noise, engine smoke and heat shimmer?

a. Dust. No significant difference was observed between the 'S' Tank and CENTURION.

b. Noise. The gas turbine produces a high-pitched whine which carries further than the sound of a reciprocating engine. The whine reveals the direction of the vehicle more accurately than does the low-pitched noise of CENTURION.

c. Engine Smoke. The K60s of the trials vehicles gave off considerable smoke, particularly when starting. This may have been accentuated by the inexperience of the drivers. It is understood that a fuel additive is being developed to help overcome this problem.

d. Heat Shimmer. The efflux of high temperature gases from the gas turbine is on the top of the vehicle. Heat shimmer often gave away the position of a vehicle at ranges up to 1000 metres. The thermal signature must be very distinctive.

Fire Positions

9. Is the 'S' Tank able to take up fire positions quickly in all types of country

a. Apart from difficulty in checking "crest clearance" (see para 11 below) no problems were encountered. Indeed, because the driver/gunner's optics are at the same height as the commander's, 'S' Tank is quicker than CENTURION in the final stages of moving into position.

b. It is, however, possible to envisage terrain in which a conventional tank could take up fire positions whereas the turretless tank could not: for instance "bocage" country, sunken lanes, or narrow tracks on the side of mountains. Although such conditions may be met but rarely, this could be a significant limitation of the turretless tank concept. It should, however, be borne in mind that the hull of the 'S' Tank is short and that the vehicle is able to traverse to a flank in a very narrow space (see para 6.b. above).

c. It was very noticeable on a number of occasions that the 'S' Tank was able to take up "hull-down", "periscope-up" and "turret-down" positions when this would have been impossible with CENTURION. This was due to the low silhouette of the vehicle which enabled it to make good use of small changes in the slope of the ground. It was also noticeable that the 'S' Tanks when being employed as the leading tanks in a troop advance could often be moved very much further forward (i.e. closer to the enemy) than CENTURION without becoming visible from the front or flanks.

d. The limited maximum elevation of the 'S' Tank (12^{o} as compared with the CENTURION's maximum practical elevation of 18^{o}) could limit its employment in mountainous country.

Do transverse slopes present a problem?

No difficulties were experienced in laying.

Are there any difficulties in moving between "hull-down", "periscope-up" and "turret-down" positions?

The commander's viewing devices and driving facility make this easier than on CENTURION. There is, however, no satisfactory means of checking "crest-clearance". Full use cannot be made of the vehicle's low silhouette. See Weapons System Trial Report at Annex 'C', para 177.

Is the 'S' Tank capable of moving rapidly from one fire or observation position to another?

Yes. The rear-driving facility enabled switches to be carried out rapidly and, in withdrawal, enabled the front armour to be kept facing the enemy.

Is 'S' Tank capable of covering a wide arc, both with observation and fire, particularly when closed down?

Yes.

Is there any tendency for the 'S' Tank to dig itself in whilst traversing from side to side if it is in a fire position in soft ground for any length of time?

a. Yes, but this causes no problem.

b. An 'S' Tank might be traversed from side to side in one position in two sets of circumstances:

(1) To check an arc. This will not have to be done more than once or twice.

(2) Once battle has been joined and then only when the tank is sited in defilade. If any tank is not sited in defilade it will require to move after firing in view of the fact that its position will have been compromised.

c. Traversing will not be necessary for surveillance purposes, because of the gunner's wide field of view and the commander's rotatable cupola.

/Weapons

Weapons

15. How does the 'S' Tank compare with the CENTURION in quick target acquisition and engagement and in switching rapidly between targets over a wide arc?

a. The 'S' Tank's viewing devices and sights are better than those of CENTURION although:

(1) The commander's vision is blocked by the spent case box of his machine gun and is restricted when viewing through the gas turbine efflux.

(2) The rear driver's viewing devices give the 'S' Tank a great advantage over the CENTURION but they could be further improved to give him a wider field of view (see Weapons System Trial Report at Annex 'C', para 178).

b. The engineering of the commander's cupola contra-rotation and line-up facilities is unsatisfactory (see Weapons System Trial Report at Annex 'C', para 175 b.).

c. When static the 'S' Tank speed of traverse is slower than that of CENTURION.

d. Overall, the 'S' Tank's performance appeared approximately equal to that of the CENTURION.

16. What are the tactical implications of not being able to deliver aimed main armament fire when on the move?

See under "Versatility" at para 24 below.

17. What are the tactical implications of the method of mounting the hull machine guns?

When on the move, the weapons cannot be used to deliver aimed fire or readily be used to deliver speculative fire. They cannot be serviced or reloaded unless a crewman is dismounted.

18. Is it possible for control of the hull-mounted armament to be switched rapidly from commander to gunner and vice versa?

No, owing to the fact that the commander's and gunner's elevation controls do not override each other (see Weapons System Trial Report at Annex 'C', para 17[illegible]

19. Are there any tactical problems in the use of adjustable suspension and the vehicle's tracks to lay the hull-mounted armament?

a. A noisy engine must be run continuously if these weapons are to be instantly laid without warning.

b. A major failure in the automotive system prevents this armament being laid. The significance of an "M-Kill" amounting to an "F-Kill" is considered in the Discussion at Annex 'D', para 22).

c. It appears that the accurate recording and application of quadrant elevations and line switches for indirect and semi-indirect fire would be difficult in any vehicle of the 'S' Tank type.

/20. ....

20. What are the tactical implications of the method of loading and stowing main armament ammunition?

a. The auto-loader does not increase the rate of fire in a single engagement. However, all of the 'S' Tank's 50 rounds are "ready" compared with 11 of CENTURION Mk 13's 64. There is thus no requirement, as exists in CENTURION, for "ready" rounds to be replaced by rounds stowed in less accessible positions - during which process the tank is temporarily out of action.

b. The fact that the auto-loader is fed from a magazine readily accessible from the rear of the vehicle greatly facilitates rapid replenishment.

Automotive

21. How does the manoeuvrability and speed of the 'S' Tank compare with that of the CENTURION?

a. The 'S' Tanks which were tested were not fitted with the high power turbine, nor had they been modified to enable the transmission to be switched from "road" to "cross-country" and vice versa without stopping the vehicle.

b. The 'S' Tanks were superior to CENTURION in the following respects:

(1) Road speed.

(2) The reverse driving facility.

(3) The ability to make sudden sharp changes of direction throughout the speed range.

c. The 'S' Tanks were inferior to CENTURION in the following respects:

(1) Cross-country speed.

(2) The limitations imposed by the risk of the muzzle of the main armament striking the ground when crossing deep gullies. As a result certain obstacles had to be approached and traversed obliquely. There is also the problem that if mud etcetera is suspected to have entered the barrel a crew member must dismount and check.

22. Are there any tactical advantages in the use of an adjustable suspension apart from its use in laying the gun?

a. There are two advantages:

(1) Mobility. It can be used to help the vehicle to climb steps, to cross obstacles smoothly and, in conjunction with the traverse facility, to extract itself from obstacles and sticky going.

(2) Dozer Blade. It facilitates the simple fitting of a dozer blade, which will incidentally give increased frontal protection. Dozer blades were not fitted to the test vehicles, but the advantages of the facility are obvious.

b. The fact that the vehicle can lower itself without fore and aft tilting by 4¾ ins does not appear significant.

/23. ...

23. What are the disadvantages in a main engine being used to lay the hull-mounted armament?

Although the engine can be started easily, there is a time-lag of some two minutes between starting an engine and the tank being ready for action. During this period only the commander's machine gun can be re-laid. If, therefore, there is a requirement to be prepared for immediate action, one engine must be kept running. This has two main disadvantages:

a. The vehicle's position may be compromised by noise, engine smoke, or heat shimmer.

b. Fuel consumption.

Versatility

24. What are the disadvantages, if any, of not being able to fire the main armament accurately when on the move?

This is clearly the key question of the trial. See Discussion at Annex D, paras 19-20.

25. How does the 'S' Tank perform in the infantry support role?

The 'S' Tank lacks two characteristics of CENTURION:

a. Because of its shape and the position of the gas turbine exhaust, infantry cannot easily be carried on the vehicle. In the light of current tactical doctrine, this is not seen as a serious disadvantage.

b. Aimed main armament fire cannot be delivered when moving in on the assault.

26. How does the 'S' Tank perform in built-up and densely wooded areas?

a. It was impossible to test this on the ground used for the trial.

b. The presence of obstacles such as trees and boulders within the radius swept by the hull is thought to be relatively unimportant in that on striking them the tank will pivot against them. It is, of course, possible to envisage circumstances in which obstacles are so placed that the tank lacks any capability to traverse.

c. The clutch/brake steering will give much greater agility in areas containing closely spaced obstacles, such as beech wood, than is available from CENTURION.

27. How does the 'S' Tank perform in the "Shock Action" role?

The 'S' Tank satisfies the requirement for mobile, protected firepower. The requirement for a tank to be capable of delivering aimed main armament fire when on the move is considered at Annex D, paras 19-20.

/Crew Factors

Crew Factors

28. What are the advantages and disadvantages of the system whereby two men are each able to carry out the functions of commander, gunner, driver and loader?

a. The commander's possession of full gunnery and driving facilities is of great advantage. It enables him - when rapid action is required - to move and shoot the tank himself thus avoiding the inevitable time delay and risk of confusion if orders have to be passed over an intercom system.

b. It can be argued that the possession of these facilities by the commander is merely overloading an already busy man. However, in the circumstances that he is likely to use them, they are in fact reducing the load upon him, i.e. they are making his task very much simpler.

c. It can also be argued that the commander may be diverted from other more important tasks (e.g. being immediately available on the radio). This argument is not valid in view of the circumstances in which the commander will act as driver or gunner. On these occasions the correct and rapid movement or shooting of the tank will be of far greater importance than other possible tasks of the commander, such as being instantly available on the radio net.

d. The auto-loader reduces both crew tasks and crew fatigue.

e. It is difficult to see any disadvantages in the duplication of controls other than increased complexity and cost.

29. What are the problems of the rear facing crew member?

He has no particular problems, except that his closed-down vision to the rear is somewhat limited and his position is cramped. He does not appear to suffer any ill-effects from facing rearwards when the tank is travelling forwards.

30. Is a three-man crew capable of fighting the 'S' Tank for prolonged periods without undue strain?

a. No major problems are foreseen.

b. Although working and living space is limited, the 'S' Tank has a number of distinct advantages over a conventional tank:

(1) The commander does not have to contend with the fact that he, together with his main armament, may be facing in a different direction from the hull of the vehicle.

(2) The crew have full use of all the space in the fighting compartment. They are not faced with the problem of the rear end of an oscillating gun, nor does the recoil of the gun take place within the fighting compartment.

(3) There are no machine gun fumes in the fighting compartment.

/31. ....

31. Is a two-man crew capable of fighting the 'S' Tank for prolonged periods without collapsing?

a. Tasks for the rear driver will include:

(1) Rear driving.

(2) Radio operating, including answering the radio if the other two crew members are involved in an engagement.

(3) Reduction of fatigue of commander and gunner/driver by:

(a) Carrying out radio watch and guard duties.

(b) Assisting with replenishment, servicing and camouflage.

(c) Acting as relief.

(4) Acting as reserve crewman if either of the forward-facing crew members should be incapacitated.

(5) Observing to the rear and, if given improved viewing devices, also to the flanks.

b. In view of the value of the rear-driving facility and the importance of the other tasks of the rear driver, an 'S' Tank with a two-man crew would be at a severe disadvantage.

32. Does the low height above the ground of the crew positions present any problems?

a. The only problem encountered was the difficulty of night navigation - this may have been due, in part, to lack of experience on the vehicle.

b. It is possible to envisage terrain, a lane between high hedgerows is an extreme example, when this lack of height could seriously prejudice observation.

33. What is the effect on the crew of a high speed cross-country?

Despite pitching, which appeared excessive to observers, the crews claimed that they suffered no ill-effects.

Annex 'E' to AT 1123/GT 428
dated 13 February 1969

THE EVALUATION OF HUMAN FACTORS

Prepared by

THE ARMY PERSONNEL RESEARCH ESTABLISHMENT

INTRODUCTION

1. The Army Personnel Research Establishment (APRE) had the opportunity of examining the Swedish 'S' Tank in July 1968 at the RAC Equipment Trials Wing, Bovington. APRE interest lay in the Human Factors aspects of the concept of a turretless tank designed for a full crew of three men, which appeared to be able to take an active part in combat with only two men, and which might still be able to play some limited part with only one crewman. There were thus two issues involved: the concept of a turretless tank as embodied in 'S' Tank, and the possibility of reducing the number of men making up the crew.

AIM

2. The aim of APRE work was to examine the Human Factors aspects of the turretless tank concept as embodied in 'S' Tank, and to examine some of the possible effects of reducing the number of crewmen in an operational tank to two, using the Swedish 'S' tank.

METHOD

3. The APRE investigation was conducted in three parts:

a. Measurement of the internal dimensions of the crew space in the vehicle and examination of its components.

b. Examination of some points of habitability and ergonomics of the vehicle on the Bovington Training Area.

c. A small trial using four crews in the two 'S' tanks in simulated battle conditions for 24 hours.

These three parts will be described separately below:

PART 1 - PHYSICAL DIMENSIONS OF CREW SPACE

4. The dimensions of the crew compartment were measured. All dimensions would accommodate the 95 percentile man wearing Combat Dress and Helmet. The only comments we have to make on this subject are on increased comfort and stowage. If an additional 1½ inches were added to the range of upward adjustment of the driver/gunner's and commander's seats, this would enable men at the shorter end of the 95 percentile height range to have a better field of vision forwards over the sights with the vehicle opened-up. If a further one inch were added to the same seats' downward adjustment, this would enable the taller men to have to stoop less when using the sights.

/5. ....

5. The position of the pedals enables the vehicle to be driven opened up or closed down by both tall and short men. However, a short man is in an uncomfortable position when opened up. It would be an improvement if the pedals and their mountings and foot platform and also the steering levers were attached to the seat assembly so that raising the seat also raised the pedals to come extent. As all the controls are remote - cable, hydraulic or electric - this would not be impossible. Two inches of upward movement would greatly increase driver comfort and control.

6. Crew comfort would be greatly improved by an additional 2 inches of seat back-rest height. This additional seat height would not appear to foul any other equipment or structure in the crew compartment.

7. The parking brake with its handle behind and below the driver's seat was in a far from ideal position and was most awkward to apply. However, it is understood that this has been modified on later vehicles.

8. There was very little stowage space for crews' personal kit, rations, respirators etc. Much of what other space existed could be used for this purpose had a means of retaining stowed items in position been provided. Nets with elastic supports would perhaps partially solve this problem.

PART 2 - HABITABILITY AND ERGONOMICS

9. This section deals with some of those aspects which affect the efficiency and performance of crew living in and fighting from their vehicle.

Driving

10. The ability to share this task between crew members is considered an advantage for three main reasons:

a. It enables the crews to share jobs in a way otherwise impossible, permitting rest or the doing of some other task.

b. It can save the potential difficulties of communication in that the commander can place his vehicle exactly where he wants it.

c. The vehicle can be driven off by either the driver or commander in the absence of the other. However, the act of change-over of control from the commander to the driver/gunner can create problems. The elevation controls of the driver/gunner, if not coincidental with those of the commander at the point of hand-over, will cause the vehicle to elevate or depress itself, and there are occasions when this could be embarrassing or dangerous. It is understood that this matter is receiving attention.

11. The provision of a rearward-facing driver for rapid movement in reverse is good as he has a direct view to the rear, especially if the gun is elevated (and thus the rear of the vehicle depressed).

12. Apart from the comments on dimensions and layout, the positioning of controls and instrumentation is good. The provision of only the essential instruments for driving, with warning lamps to indicate malfunction, is very good; all other secondary instrumentation is grouped together in front of the rear-facing driver/loader where he can monitor the functioning of all systems. Should he not be present, the driver has merely to turn round to check his secondary instruments either when he has time or when a warning lamp is lit.

/13. ....

13. The only adverse comment on the instrumentation is that it would be further improved if each instrument had a colour zone/state of function marking, i.e. green zone for normal function, amber for approaching trouble and red for danger. This would greatly reduce the task of identifying the particular system at fault, and the extent of any fault, among the many dials with different scales and normal function limits. It would also reduce the amount of training necessary to memorise the limits of each instrument.

14. The system of steering by handlebar rather than steering brake levers is good. American work has shown that such a system gives more precise control and also allows one-handed operation leaving either hand free for other tasks. The continuous control is preferred to the discrete brake applications and steering effect of conventional vehicles (see also APRE Report No. 12/66).

15. The ability to elevate or depress the vehicle when on the move is a useful bonus. It enables the crew to depress the vehicle on roads to give a better view forwards and to elevate to give a better view to the rear. Perhaps more important, it enables the driver to maintain his vehicle in as nearly a horizontal attitude as possible over bumpy terrain and also assists in obstacle crossing.

16. Travelling cross country using both the turbine and diesel engines forces the driver to use full throttle for full engine power all the time. He tends to use his brake for controlling speed, and this changed allocation of control tasks for his feet needs learning. This is especially so when crossing obstacles as the vehicle can no longer be eased over the summit on the throttle. However, in the latter case, the driver is helped by his ability to control vehicle attitude with the elevation control. This again requires learning but once learned can give the crew a perhaps more comfortable ride than conventional vehicles.

17. The three-position hatches for the crew are liked, especially the provision of the intermediate "umbrella position". This allows for ventilation and "head out" vision while giving some overhead ballistic and weather protection.

18. Suggestions have been made that the rear driver/loader may be made uncomfortable or sick by being driven cross country and perhaps into action facing sideways or to the rear. APRE has no specific answer to this point, but the same situation applies to some extent in other vehicles. Some of these other vehicles are held to induce travel sickness in some men while others do not seem to. It is thought that "travel sickness" is more probably a function of vehicle suspension characteristics than of orientation of personnel, and also of not being able to see the ground to be traversed. Questions to the crews at RAC Equipment Trials Wing received no answers indicating "travel sickness".

Gunnery

19. The combination of gun and driving controls into a joint system, reducing the number of separate controls, is good. The sharing of these between driver/gunner and commander is even better. Either man can line up the vehicle as necessary in anticipation of or during an engagement. The commander is thus saved in some circumstances from having to instruct his gunner, and can also, if he chooses, fire himself. This saving of communication could be useful in some situations, and this duplication means that with reduced crew the tank is still operative.

20. The only adverse criticism of the gun controls is the number of safety switches which must be operated in sequence. While the need for safety is obvious, could the procedure not be simplified? In urgent situations under stress a mistake might be possible and an opportunity lost.

/21. ....

21. The vision devices are extremely good: the large unity window gave a wide field of view; the variable magnification sights were much liked by the crews.

22. The commander's cupola and its line-up facilities are commented upon elsewhere. When the driver makes a clutch-brake turn without warning, the speed of rotation of the cupola with reference to the hull could be potentially dangerous to the commander. It is thought essential that a drill is developed so that this does not happen.

Loading

23. The provision of an automatic loader saves a fourth crewman and a great deal of heavy work. Only occasionally is the rear driver/loader required to set fuzes and load 3rd or 4th nature ammunition in the event of failure of the automatic loader or load 1st or 2nd nature ammunition in the event of failure of the automatic loader. Even in these circumstances he is saved the majority of the heavy work of the loader in a conventional tank. With a crew of only two, the commander could drive and fire while the gunner driver carried out the loading task.

Radio

24. The radios installed in the vehicle were liked from the ergonomic viewpoint in that they are pre-set to 14 frequencies during a time when the crew are likely to be not highly stressed. In the event of a need to change frequencies nothing more is required than a simple selection of the frequency concerned.

Ventilation - Air Conditioning

25. The vehicle is ventilated with the hatches open by convection and natural draught alone. When firing, an extractor fan comes into operation drawing air in through the crew compartment and out through the automatic loader. With the vehicle closed and this fan not in operation there is virtually no ventilation beyond slight leakage of air round the hatches. It is suggested that the provision of a ventilating fan forcing air through the crew compartment would be an improvement

26. With the rear of the vehicle facing into the wind when firing and the engines running, there might possibly be a toxicity problem. The only measurements APRE staff made were in a condition of light head wind. After firing 7 rounds HE, 130 parts per million of Carbon Monoxide were present, after a further 3 rounds this had risen to 400 parts per million. Firing ten rounds APDS with all hatches open gave no measurable Carbon Monoxide.

27. There are many sources of radiant heat alongside and within the crew compartment, and some shielding of these items would reduce the heat load present even during a mild English summer. These sources were sufficient to raise the dry-bulb temperature within the crew compartment by 7°C above the ambient dry-bulb temperature. While obviously for North European environments this raising of temperature is an advantage, for less Northerly areas some reduction is required.

28. During firing, the temperature of the gun barrel shield beside the gunner's shoulder exceeded a temperature of 65°C (150°F). Direct contact of bare skin against metal at such temperatures for longer than one second would cause tissue damage. Under normal conditions the driver or commander would not make such contact, but even so some further shielding would be an advantage against the risk of involuntarily/accidentally striking the shield.

/29. ....

31. The two engines' exhausts allow considerable heat to pass into the vehicle when opened up, particularly the turbine discharging just in front and to the side of the driver. This heat did not pose any great problem, but was commented upon favourably by crews. No obvious means of overcoming this are seen.

Noise and Internal Communication

32. The noise levels within the vehicle were measured, with hatches open and closed, on roads and cross country. A table showing these levels is shown at Appendix 1. The noise levels were such that some form of ear protection, better than that provided by a conventional rubber-cupped headset, was necessary if the crew were not to be exposed to severe risk of temporary theshold shift (i.e. temporary partial deafness) or after repeated prolonged exposure, to permanent threshold shift. Further, communication even through headsets against such background noise would be difficult even if a conventional microphone did not transmit some of the noise as well as speech. The helmet/headset assembly used by the Swedish Army and their own crews on this vehicle protected the ears, it is understood, by about 35 dB, and the permanently live throat microphone is noise cancelling in that it is shielded from ambient noise.

33. There is some resistance to the use of a throat microphone on the grounds of acute discomfort in hot climates (not applicable to Sweden where a boom microphone would be liable to freeze up with condensed breath), pressure on the throat (not now really necessary) and speech distortion (overcome by familiarity). For our own use a noise-cancelling boom microphone would probably be better. Either system is permanently live for intercom purposes and allows full use of both hands for other purposes after a preliminary switch setting.

Housekeeping

34. The 'S' tank has not been designed specifically to be able to remain closed down in a hostile environment for 24 hours or more. The crew are not necessarily expected to live comfortably within it for such periods, and the 'S' tank is therefore not so fully equipped as might be expected for a NBC-proof vehicle.

35. The cooker provided could with improvement be replaced by a type similar to that in CHIEFTAIN. This has thermal lagging so that not only will it keep its contents hot for some hours but is less likely to cause burns when handling it. It has a tap to draw off hot water without having to pour it out. It can be filled and will retain its contents without spillage on the move. This last point means that a crew can decide what they want for their next meal and switch the cooker on. They can then have an immediate hot meal whenever an opportunity is presented. In a long drawn out action this could have considerable morale as well as physiological value.

36. None of the seats fitted could be made to recline, nor was there space to improvise "beds" with locally acquired materials. Crews either slept in their seats or on the hull top. Neither position was very comfortable compared to what can be arranged in other more conventional vehicles.

37. In common with other present, more conventional, vehicles there was no provision for defaecation or urination within the vehicle. If modifications are envisaged to make the vehicle habitable closed down for 24 hours or more under NBC threat, the incorporation of aircraft type urinals and the polythene bag/removable seat squab systems used in APRE "Capsule Trials" would save crew being forced to foul their clothing, their vehicle or both.

/PART 3 - ....

PART 3 - REDUCED CREWS, 24 HOUR SIMULATED COMBAT

36. APRE in conjunction with RAC Equipment Trials Wing carried out a short trial. The aim of the trial was to evaluate the effect on the military operational performance of a two-man crew for periods of 24 hours of simulated combat with the facilities provided by 'S' Tank.

37. Two tanks, each with a crew of two men (commander, gunner/driver) were to act as Troop Commander's tank and Troop Sergeant's tank during 24 hours of simulated battlefield activity. Squadron HQ was located in the FV 432 Directing Staff observation vehicle. The Breakdown of Activities during the 24 hours period is attached at Appendix 2, and an extract from the radio script and a signal diagram of the radio communications used to control the 'S' tank troop and the other imaginary troops is attached at Appendix 3. This trial was to be repeated using a further 2 crews of 2 men.

38. Very briefly the 24 hour battlefield day can be broken down thus:

Moves	: about 25 to 30 miles	:	$3\frac{1}{2}$ hours total time actually involved.
Engagements	: 10 periods	:	$1\frac{1}{2}$ hours total time actually involved.
Observation	:	:	7 hours total time actually involved.
Hides/Leaguer:		:	5 hours total time actually involved.
"Waiting for something to happen"		:	7 hours total time actually involved.

39. The Directing Staff (DS), who were also Squadron HQ, followed the two 'S' tanks and observed the following:

Observation/Reconnaissance (Vehicle counts) - accuracy.
Gunnery (Indicated Targets) - accuracy of fire orders etc., response times.
Gunnery (Opportunity Targets) - response time of each crewman, accuracy of fire orders etc.
Use of Radio Codes - accuracy, security, response time.
Use of Ground/Map Reading - accuracy, choice of route.
Crew Maintenance at Base - how much, how efficiently.
Crew Maintenance in Field - how much, how efficiently.
General Crew Efficiency.
General Crew Alertness.
Observed Crew Morale.
Control of Troop (Troop Leader only).
Observed Cooking and Eating - what, when.
Observed Defaecation/Urination - when.
Observed sleep - who, when, how much.

The external meteorological conditions were measured hourly, and the wet and dry bulb temperatures within the tanks at less regular intervals. The proformas for these DS tasks are at Appendix 4.

40. As was done in APRE "Capsule" Trial, the Troop Leader's tank was fitted with an extra radio set. This set was connected to the permanently live intercom system and transmitted everything that was said within the tank to a receiver in the DS vehicle. The crews were all aware that they could be overheard, and also that there would be no action taken over anything that was said. The purpose of this radio link was to enable DS to hear details of, for instance, fire orders so that a check could be made on accuracy. It also gave the DS the opportunity to assess the degree of difficulty in encoding or decoding tasks, finding a route and so on. An assessment of morale could be made, and an opportunity to know that some incident had occurred - e.g. the gunner had bumped his head - which might have some bearing on subsequent performance.

/41. ....

41. It was appreciated that the use of only four crews could not give a valid statistically acceptable answer to the question implied in the Aim, and that a 24 hour period of only simulated battle was too short to obtain any accurate assessment of performance in operational conditions for long periods. However, it was hoped to obtain some useful qualitative information and indications.

RESULTS

42. Due to various engine/transmission system breakdowns, only one crew completed a full 24 hour run. The other three completed approximately 18, 14 and 6 hours respectively. Thus any validity implied in para 41 above is further reduced. If the very considerable quantity of maintenance and repair work had been less enthusiastically undertaken by Equipment Trials Wing, even the limited completion of the Trials would not have been achieved. Due to these factors, detailed results would be meaningless and will not be given. Comment and discussion of the performance of the tasks follow.

43. Observation/Recce. The first point to note is that the 'S' Tank had two sights capable of x18 magnification and the observers two pairs of x6 hand held binoculars. The crews could see detail at long ranges completely invisible to the DS. When given instructions to count, say, all vehicles moving East on a certain road at 2000 yards, they claimed to see the radio aerials mounted on low sports cars otherwise hidden behind a hedge, which the DS could not see! Thus on long range counts it was impossible to check accuracy of reporting. On all shorter range counts these were accurate so long as there had been no misunderstanding of orders or the interpretation of a map reference to a point on the ground was accurate. There were some examples of this, but they occurred equally during the earlier and later hours of the trial. It can probably be assumed that the performance of this task did not deteriorate to any material extent during occupation of the vehicle.

44. Gunnery - Indicated Targets. This task was carried out at a high level of performance throughout. Assessments ranged from 'Good' to a quite frequent 'Very Good' on a 5 point scale, the 'Very Goods' being scattered from the earlier to the later hours of the Trial. There was no apparent falling-off in performance.

45. Gunnery - Opportunity Targets. There was quite a variation in the response times (total for the tank and individual crewman's) both within a period of "Action" and between "Actions". There seemed to be slower responses after gaps in the traffic stream ("Enemy Vehicles") on the roads used and slower responses for engagements against slower vehicles (e.g. lorries) due to their taking longer to enter the chosen point of fixed aim. It is impossible to say on the limited data whether these differences are apparent or real, although these seem to be what might be expected. There was also an apparent trend for the responses to be slower in the later hours, but again with the limited data this is impossible to state firmly. The important point, however, is that for the full 24 hour period for the one tank which achieved this all the response times were considered to be militarily acceptable. Individual total engagement time to 1st round fired varied from 1.3 seconds to 8.4 seconds, the large majority ranging between 3.5 and 5.5 seconds.

46. Use of Radio and Codes. The use of radio was considered good or acceptable throughout except for two cases of very slow response from one tank. The use of codes varied - Griddle was well known to all crews and presented few difficulties, but Slidex was less well known by some and some difficulties arose. These difficulties occurred for the most part early in the Trial and practice reduced their occurrence with increasing time. The intercom/radio link system employed enabled the DS to overhear any conversation or comments about this task.

/47. ....

47. Use of Ground/Map Reading. The assessment of this task varied from 'Acceptable' to 'Good', the 'Good' ratings tending to be given more often in the later part of the trial. This could be partly explained by increasing familiarity with the area used for much of the trial.

48. Crew Maintenance. All crews carried out their basic maintenance tasks on the vehicles before moving off, and again at varying intervals during the trial. The crews carried out all the necessary checks and did anything necessary which was within their competence. There was no apparent deterioration in this task.

49. General Crew Efficiency, Alertness and Morale. These were purely subjective assessments by the DS of their observation of crews, and involved for the troop leader's tank and particularly for the later stages of the trial. It is thought that crews took a little time to settle down but once they had they became more efficient, more closely-knit teams.

50. Control of Troop. The competence with which the troop leader tactically controlled his 'troop' of one other tank was assessed by the DS. There were a few 'Acceptable' ratings during the earlier stages but all the rest were 'Good'. If the troop leader had any difficulties in controlling his troop from within an 'S' tank (there were comments on lack of space to spread out maps, place Slidex packs and note-books) they were apparently successfully overcome, particularly after the initial settling-down process.

51. Observed Cooking and Eating. A 24 hour period (or less) is insufficient to assess crew's operational feeding habits. All were issued with Compo rations, but most, if not all, took their own personal supplies as well. A much longer time is probably necessary for their own stocks to be used up and for their appetite and habits to become settled to the routine of operations. Some limited cooking-heating of tinned food - was done, particularly during the evening and early morning 'Hide' periods, and many "brews" were made throughout the trial. No apparent difficulty was experienced.

52. Observed Defaecation/Urination and Sleep. As noted earlier in paragraph 35, there are no built-in defaecation or urination facilities. As the crews could leave their vehicles at will, there were no problems. Had they been made to remain closed-down for 24 hours this, and the non-reclining seats which made sleep uncomfortable, would have raised considerable problems. There were many opportunities to climb out of the vehicle, particularly during the 'Hide' and 'Leaguer' periods, and crews made the most of them. There was, in the 24 hours, quite a period available for crews to sleep in turn, but many of these periods of 'Hide' did not give crews any idea of how long they would remain quiet and they tended to stay awake. During the night the vehicles were in 'Leaguer' for about $4\frac{1}{2}$ hours only, allowing each man say 2 hours sleep if they took it in turns. In fact, most commanders tended to stay on radio watch all this time, letting their gunner/drivers sleep for the whole period. In more extended trials over much larger periods when the men would become much more tired, this observed pattern would doubtless be changed. Some men slept on the warm engine deck on top of the vehicle, some men in their seats. All complained of discomfort but especially those who had slept inside the vehicle. Again, on extended operations it is more likely that bivouacs would be set up and men sleep on the ground, except in NBC risk conditions.

53. Meteorological Conditions and Crew Compartment Temperatures. These were measured solely to provide background information. If, for instance, the weather had been very hot and humid, it would be necessary to know the conditions to which the crews were exposed in case there were any obvious changes in performance of some task. In fact, the weather was pleasantly warm day and night.

/Discussion...

DISCUSSION

54. The aim of this short trial was to evaluate the military operational performance of a crew of only two men when operated for periods of 24 hours of simulated combat using 'S' Tank. As a result of breakdowns, no meaningful evaluation is possible but indications are that such operation by a crew of two men is possible. None of the factors observed by the DS showed any strong trend towards reduction of performance except perhaps for the times taken to engage 'Opportunity Targets', which indicated a slight decrement. Very few of the factors received any 'poor' gradings, and several showed indications of an upward trend with the passage of time.

55. The men used in this trial were all relatively fresh on starting. If they had already had some days of action as a full crew immediately prior to starting this trial with reduced crew, the whole picture might have been entirely different - and probably more valid. Unfortunately this was not possible.

56. In this trial crews could have their hatches open or closed at will, giving them the chance to change the position of their limbs, get out, sleep on top of the vehicle or on the ground and so on. Again, the results might have been very different if they had been made to have their hatches closed the whole time. In APRE "Capsule" Trial crews found sleeping and elimination of biological waste easy, as provision had been made, but in 'S' Tank both would have presented problems.

57. On several occasions tanks were bogged down in wet mud, mostly in the dark but sometimes by day. On one occasions one tank fell into a gully and nearly capsized. Vision, especially when closed down, is really excellent, but the relatively rearward position of the driver may be a disadvantage in that the ground close under the front of the tank is hidden. A third crew member would not have improved matters in this instance, but if the driver were located further forward these incidents might not have occurred. However, with one crew member forward, it would not really be possible to have the facility of shared controls and tasks unless another crew member was also moved forward. In other words, unless the entire crew compartment were moved forward, it is doubtful if a three man tank could be designed with the ability of being operated by two men, and still retain the normally excellent forward close-up view of the driver of a more conventional tank.

58. It is not thought that driver fatigue played any part in the incidents above, but it is probable that in prolonged operations men would become much more fatigued than in our 24 hour trial and the likelihood of the tank becoming bogged or hitting an obstacle would doubtless be increased.

59. The observed levels of 'Morale', 'Alertness' and 'General Efficiency' were all very high throughout the trial. It was quite apparent that the men were not being tested to any extent approaching their limits of performance or endurance. The two men in each tank were doing between them the work normally done in 'S' Tank by three men, or in turreted tanks by four men. It is thought that the ability to share tasks, the removal of most of the physical work, the good design of controls and vision devices, the good riding characteristics of the vehicle and the bump and noise protection afforded by the helmet, all contributed to make each aspect of the crew's tasks easier to perform. The attention paid to Human Factors aspects in the design of the tank was noticeable, with apparently successful results.

/60. ....

60. So far virtually no mention has been made of the turretless tank concept from the Human Factors viewpoint. The most important difference between the two concepts appears to be that with a turretless tank of suitable design the controls can be duplicated, allowing sharing of tasks. Sharing of tasks means that in emergencies the tank can still function operationally with a reduced crew, in this case two men for some quite long period and in even worse emergency can be still used as a tank in limited fashion by a further reduction, in this case one man. As demonstrated by the 'S' Tank, the most important tasks to be shared (and controls duplicated) seem, for several reasons, to be driving and gunnery.

61. The other aspects of the turretless tank concept which greatly affects design for Human Factors aspects is the removal of the limitation of having a driver forward on his own (except in US/FRG 70 which is, to say the least, complex) and the rest of the crew accommodated within a rotating turret and its basket. The turret ring and basket can only, for engineering reasons, be a certain percentage of hull width whereas in a turretless tank virtually the whole width is available to the designer. By the time that all the equipment which must rotate within the turret is installed there is not normally much room left for the occupants (and normally it is awkwardly shaped). For long term habitability lack of space and awkward seating positions are liable to lead to performance degradation.

63. It is not impossible but would be difficult to install an automatic loading system within a turret. Without such a system there must be a loader and he and the depression angle of the gun tend to dictate the overall height of the turret. Without a turret, the overall height of the vehicle is no longer dictated by a man's height but by other engineering factors. A floor to roof height of perhaps 48 inches is adequate if the men are sitting upright, less if reclining or partly reclining. If the other equipment could be built down to this level the result would be a very low tank.

CONCLUSIONS

64. The first conclusion is that the turretless tank concept, as embodied in the 'S' Tank, has considerable advantages over more conventional current turreted tanks. The most important of these is the duplication of controls allowing sharing of tasks which in turn reduces the mental work load on the crew. This duplication [illegible] the added advantage in that it permits in emergency a reduction in crew number.

65. The turretless tank makes installation of an automatic loading system easier, which eliminates the need for a man to load the gun as his prime task. This reduction in task eliminating a man is balanced by the bulk and weight of the loading system. It may make little difference to engagement time when a loader [illegible] fresh but after several days of action or in prolonged heavy fighting an automatic system is likely to be faster.

66. The turretless tank affords the designer greater freedom in the location of crew within the tank and imposes fewer restrictions on the shape and volume of [illegible] space allotted to the men.

NOISE LEVELS MEASURED IN 'S' TANK

LOCATION / CONDITION	GNR/DVR ENGINE IDLING	GNR/DVR 20-25 km/h ROAD	GNR/DVR 30 km/h ROAD	GNR/DVR 40 km/h ROAD	GNR/DVR 45-47 km/h ROAD	GNR/DVR 30 km/h ROAD/ CLOSED DOWN	COMDR 30 km/h ROAD	COMDR 40 km/h ROAD	GNR/DVR 10 km/h CROSS COUNTRY	GNR/DVR 15-17 km/h CROSS COUNTRY	COMDR 10 km/h CROSS COUNTRY	COMDR 15-17 km/h CROSS COUNTRY
OVERALL	102 dB	128 dB	125 dB	127 dB	126 dB	125 dB	121 dB	125 dB	108 dB	114 dB	111 dB	114 dB
31.5 Hz	77	111	105	109	113	112	103	103	102	100	99	101
63 Hz	91	116	124	118	116	124	116	121	102	111	105	108
125 Hz	98	118	112	119	118	120	113	122	102	106	104	105
250 Hz	91	109	118	121	122	119	116	120	100	105	101	103
500 Hz	87	107	109	116	115	115	113	116	102	102	99	101
1000 Hz	87	101	100	105	107	106	102	108	94	100	95	99
2000 Hz	80	94	94	100	98	98	94	101	85	92	86	92
4000 Hz	73	81	83	89	90	84	84	91	73	82	75	81
8000 Hz	65	72	69	79	79	70	72	80	64	70	64	70
16000 Hz	52	62	59	65	65	63	60	69	57	61	58	61
31500 Hz	34	47	46	54	54	50	49	57	42	47	43	57

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Appendix 2 to Annex 'E' to AT 1123/GT 428
dated 13 February 1969

24 HOUR BATTLEFIELD DAY

ACTIVITY BREAKDOWN

Total Times

MOVES	3 hours 35 mins
OBSERVATION/RECCE	4 hours 10 mins
ENGAGEMENTS	1 hour 10 mins
* HIDES/LEAGUER	7 hours 15 mins
"WAITING FOR SOMETHING TO HAPPEN"	7 hours 50 mins
ENGINE RUNNING TIME (approx)	7 hours 6 mins

* NOTE: During these periods one man was permanently on Guard/Radio Watch.

"WAITING FOR SOMETHING TO HAPPEN" refers to those periods when the DS kept the crews in a continuous state of alert. The crews were kept entirely in the dark about what their next activity would be or when it would happen.

24 HOUR BATTLEFIELD DAY

ENGAGEMENTS

DAY	1110	2 Targets (Indicated)	2 mins
	1113	1 Target (Indicated)	1 min
	1120	Opportunity Targets (approx 10 cars)..	20 mins
	1316	1 Target (Indicated)	1 min
	1650	4 Targets (Indicated with Very Light and Thunderflash)..	10 mins
	1705	1 Opportunity Target	1 min
NIGHT	2122	1 Target (Indicated)	1 min
	2207	1 Target (Indicated)	1 min
	0030	CAPSULE ATTACKED	1 min
DAY	0800	1 Target (Indicated)	1 min
	0810	1 Target (Indicated)	1 min
	0815	1 Target (Indicated)	1 min
	0900	Opportunity Targets (approx 15 cars)..	30 mins

Engagements by day .... 10 (including 2 Opportunity Target engagements of approx 10 & 15 cars) taking approx 63 mins.

Engagements by night .. 3 taking approx 3 mins.

MOVES

1005	.....	Road & Cross Country	10 mins
1100	.....	X Country	15 mins
1230	.....	X Country	10 mins
1325	.....	X Country	15 mins
1645	.....	X Country	5 mins
1655	.....	X Country	5 mins
1735	.....	X Country	5 mins
1800	.....	Road March	45 mins
1950	.....	Road March	10 mins
2030	.....	Road March	30 mins
2130	.....	X Country	5 mins
2320	.....	X Country	15 mins
0030	.....	X Country	10 mins
0430	.....	X Country	10 mins
0715	.....	X Country	5 mins
0830	.....	X Country	10 mins
0920	.....	X Country	10 mins

Day Moves ..... 11. Total time 2 hours 15 minutes
(including 45 minutes Road March)

Night Moves ..... 6. Total time 1 hour 20 minutes
(including 40 minutes Road March)

Total time of moves ..... 3 hours 35 minutes

(Total engine running time ..... 7 hours 6 mins approx)

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24 HOUR BATTLEFIELD DAY

HIDES, LEAGUER ETC.

1340 to 1645 hours	.....	Hide (1 hour Radio Silence)..	3 hours 5 mins
0040 to 0330 hours	.....	Leaguer	2 hours 50 mins
0530 yo 0650 hours	.....	Hide	1 hour 20 mins

24 HOUR BATTLEFIELD DAY

OBSERVATION

DAY	1015 ...	Vehicle Count, 1 direction, 4000 metres	30 mins
	1140 ...	"Observe ... North", no count	5 mins
	1150 ...	Vehicle Count, 4 directions at X roads, 400 metres..	30 mins
	1255 ...	Vehicle Count, 2 directions, 600 metres	15 mins
	1725 ...	Vehicle Count, 1 direction, 100 metres	10 mins
* NIGHT	2000 ...	Vehicle Count, 1 direction, 3000 metres	30 mins
	2100 ...	Vehicle Count, 4 directions, 400 metres	20 mins
	2145 ...	"Observe & Report Movement" 20° Arc out to 4000 metres..	35 mins
	(2330 to 0340 One man on Guard/Radio Watch; NO task)		
	0400 ...	Vehicle Count, 2 directions at X road, 400 metres...	20 mins
	0450 ...	Vehicle Count, 2 directions, 4000 metres	20 mins
DAY **	0730 ...	Vehicle Count, 2 directions, 2000 metres	20 mins
	0845 ...	"Observe ... North", no count	15 mins

Observation by day	2 hours 5 minutes
Observation by night	2 hours 5 minutes
Total observation	4 hours 10 minutes

NOTE: * All roads had to be located in the dark. For long ranges, this was not easy.

** This task was frequently made more difficult by mist.

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24 HOUR BATTLEFIELD DAY

USE OF RADIO, CODES

1. Radio in constant use to all Stations on Squadron Net, requiring constant monitoring by Subjects.

2. Radio Silence for 2 one-hour periods.

3. Little radio traffic between 0040 hours and 0330 hours, except for last night of each Trial.

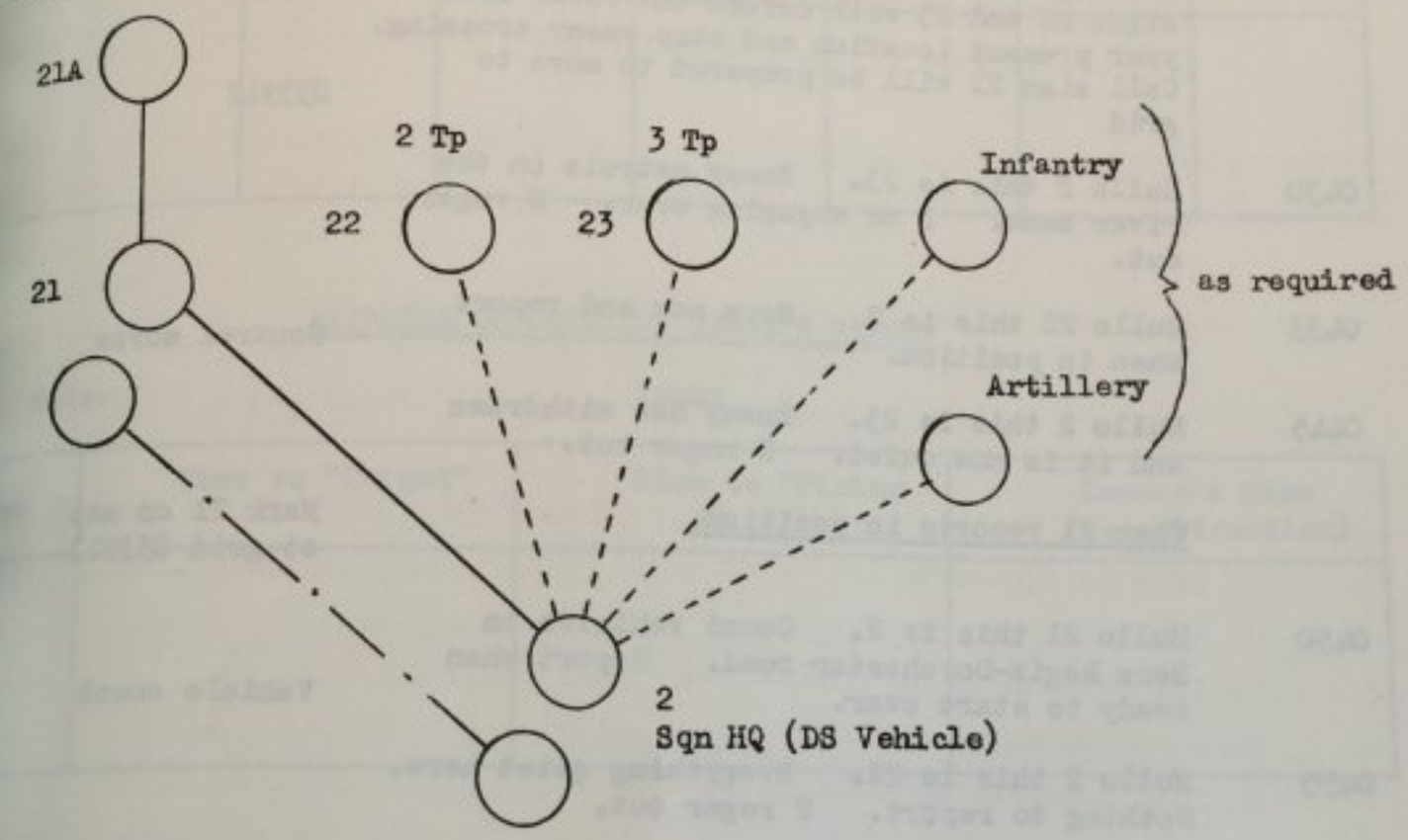
4. All Grid References of positions of "Friendly" forces were sent in "Grid" code.

5. Six messages in "Slidex" code sent to Subjects, one message in "Slidex" demanded from Subjects.

Appendix 3 to Annex 'E' to AT 1123/GT 428
dated 13 February 1969

SIGNAL NET DIAGRAM AND AN EXTRACT FROM THE SIGNAL SCRIPT

Signal Diagram:



- - - - - - - - - stations represented by the DS.

—— · —— · Monitoring net on Troop Leader's Tank.

. Extract from the radio script:

TIME (a)	MESSAGE (b)	DS ACTIVITY (c)
0425	Hullo all stations 2. This is 2. Orders, over.	Wait for 21 to reply.
	22 send over.	
	23 send over.	

(a)	(b)	(c)
	2. Aerial recce reports that the enemy is concentrating for another push across the river. It is possible that they have been reinforced by another armoured regiment although this has not been confirmed. Call signs 22 and 23 will defend the river from your present location and stop enemy crossing. Call sign 21 will be prepared to move to grid	833912
0430	Hullo 2 this is 23. Enemy patrols on the river bank. I am engaging over. 2 roger out.	
0433	Hullo 21 this is 2. Move now and report when in position.	Control moves
0445	Hullo 2 this is 23. Enemy has withdrawn and it is now quiet. 2 roger out.	
	<u>When 21 reports in position.</u>	Mark 21 on map at grid 833912
0450	Hullo 21 this is 2. Count vehicles on Bere Regis-Dorchester road. Report when ready to start over.	Vehicle count
0455	Hullo 2 this is 22. Everything quiet here. Nothing to report. 2 roger out.	
0457	Hullo 2 this is 23. Nothing to report over. 2 roger out.	
0510	Hullo 21 this is 2. Stop counting now and report over.	Stop counting
0515	Hullo 21 this is 2. Slidex message over.	Pause
	21. Report to guide at 829899. Hide.	Send coded in Slidex
0520	Hullo 22 and 23 this is 2. Things seem to be quiet at the moment. There is a chance to have something to eat. Leave one vehicle each on watch over.	
	22 wilco out.	
	23 wilco out.	

Appendix 4 to Annex 'E' to AT 1123/GT 428
dated 13 February 1969

EXERCISE OBSERVATION/RECCE REPORT

Date: Tank:

Time Start & Finish	DS Observed			Tank Reported		
	Vehicles	Men	Time	Vehicles	Men	Time

EXERCISE OPPORTUNITY TARGETS REPORT

Date: Tank:

Time	Time to "Target"	Time to "Firing	Gunner's Time (by subtraction)

EXERCISE FIRING REPORT

Date: Tank:

Quality of Fire Orders:

Overall Quality of Shot:

Errors

Time	Identification of Targets	Fire Orders Commander	Fire Orders Gunner	Range Estimation

EXERCISE METEOROLOGICAL DATA SHEET REPORT
(at 4 hour intervals)

DATE	TIME	DRY BULB °F	WET BULB °F (UNVENTILATED)	GLOBE °F	WIND SPEED MPH	WIND DIRECTION	WBGT °F	[illegible] CONDITIONS

EXERCISE DS ASSESSMENT REPORT
(at 4 hour intervals)

Date: Tank: Time:

	Good	Acceptable	Poor
1. Use of radio and codes			
2. Use of ground, Map reading			
3. Vehicle maintenance by crew at base			
4. Vehicle maintenance in field			
5. Weapon maintenance at base			
6. Weapon maintenance in field			
7. Observed crew efficiency			
8. Observed crew alertness			
9. Observed crew morale			
10. Control of Troop (Tp Ldr only)			

Note: Please comment as fully as possible, but ALWAYS for POOR grading. Please also comment on any observed:

a. Cooking/eating
b. Defaecation/urination
c. Rest/sleep

Comments:

Annex 'F' to AT 1123/GT 428
dated 13 February 1969

AUTOMOTIVE TRIALS RESULTS

INTRODUCTION

1. A full automotive assessment and reliability trial was precluded by the terms of the loan and the aim of the trial. Automotive tests were, therefore, carried out to provide information in support of tactical and weapon tests or to form an assessment of unusual features which included the use of a gas turbine. These tests were carried out by:

a. Automotive Branch of Equipment Trials Wing, who provided the crews and monitored the complete trial. The specific tests included fuel consumptions and a dimensional analysis.

b. FVRDE for limited performance tests using a fifth wheel and Kelvin Hughes Recorder and certain measurements to ascertain weights, gap crossing and vertical step ability.

c. APRE for external noise measurements.

2. The results obtained by each of these units and establishments have been combined into one Annex for convenience.

Vehicle Weight

3. The weight of the vehicle with full fuel, oil and coolant but less ammunition and crew was 79,800 lbs (36,210 kgs).

4. The battle weight with full fuel was 83,200 lbs (37,745 kgs).

Maximum Speed

5. Maximum speed in forward and reverse, top gear, road range over ¼ mile road with flying start:

a.	Dual power plant:	25.7 mile/h forward (41.2 km/h) 18.7 mile/h reverse (30 km/h)
b.	K60 engine only:	6.4 mile/h forward (10.3 km/h) 4.7 mile/h reverse (7.6 km/h)

6. Maximum speeds in all other forward and reverse gear ranges on suitable level road:

a. Dual power plant: Not possible due to automatic gear-box (Torque Convertor).

b. K60 engine only: Forward and reverse - cross country range only.

Torque Convertor Gear	Mile/h forward	Mile/h reverse
1st	1.4 (2.2 km/h)	3.5 (5.6 km/h)
2nd	5.9 (9.6 km/h)	5.3 (8.5 km/h)
Direct Drive	9.4 (15 km/h)	5.9 (9.6 km/h)

/7. ....

7. Average speed over one lap of Test Track at maximum safe speed:

a. With dual power plant: 26.7 mile/h (43 km/h).

b. With K60 engine only: 9.2 mile/h (14.8 km/h).

8. Average speed over Long Valley cross country course at maximum safe speed:

a. With dual power plant: 5.9 mile/h (9.6 km/h)

b. With K60 engine only: because of insufficient power, the vehicle was only capable of moving itself along the valley bottom. It would baulk at the least gradient.

Accelerations

.... 9. These are shown graphically at Appendix 1.

Obstacle Crossing

10. Maximum Vertical Step. The vehicle could surmount 16 inches but could not surmount 30 inches due to lack of power. No interim step heights were tested due to limited facilities. This also applied when tried in reverse.

11. Gap Crossing. The maximum width of a firm sided trench crossed was 9ft 6in. It failed at 10ft when Numbers 1 and 2 road wheels jack-knifed and fouled the far lip of the trench.

Fuel Consumption

12. Fuel consumption during a 25 mile run on the FVRDE Test Track at maximum safe speed. Because the vehicle went so slowly on its K60 engine alone, only 12 miles were run in that mode.

Power Plant	Distance	Fuel Used	Consumption			
			mile/gal	gal/mile	km/litre	litre/km
Dual	24.5 miles (39.5 kms)	41 gals (186.4 litres)	0.6	1.67	0.212	4.72
K60 only	12 miles (19.3 kms)	9.8 gals (44.5 litres)	1.22	0.815	0.432	2.3

13. Fuel consumption at Long Valley cross country under dry conditions:

Power Plant	Distance	Fuel Used	Consumption			
			mile/gal	gal/mile	km/litre	litre/km
Dual	10.4 miles (16.8 kms)	48.3 gals (221 litres)	0.216	4.65	0.076	13.15

/14. ....

14. Fuel consumption on the public road section at Bovington:

Power Pack	Distance	Fuel Used	Consumption				Average Speed
			miles/gal	gal/mile	km/litre	litre/km	
Dual	40.7 miles (65.5 kms)	62 gals (281.9 litres)	0.66	1.52	0.23	4.4	20.3 miles/h (32.2 kms/h)
K60 only	19.2 miles (30.9 kms)	17.5 gals (79.5 litres)	1.09	0.91	0.388	2.58	9.5 miles/h (15.2 kms/h)

15. Fuel consumption on the Bovington cross country course:

Power Pack	Distance	Fuel Used	Consumption				Average Speed
			miles/gal	gal/mile	km/litre	litre/km	
Dual	21.75 miles (35 kms)	69 gals (313.9 litres)	.315	3.18	0.112	8.05	8.1 miles/h (12.9 kms/h)

Neutral Turn Rate

16. The mean time of four consistent revolutions through 360° on the FVRDE Skid Pan on dry tarmac was 29.6 seconds per revolution.

17. The diameter of the circle swept by the gun in a neutral turn was 31ft 9ins (968.1 cms). For the corner of the hull the diameter was 24ft (732.1 cms).

Comparative Cross Country Performance

18. While the 'S' tank was being evaluated for cross country performance at Long Valley, the opportunity was taken to compare it with FV 4201 and FV 432. The course was 1.5 miles long of even going with one hill of 150ft.

a. Performance Table:

Vehicle	Power Plant	Distance	Time	Miles/h
'S' Tank	Dual power	1.5	15 min 58 sec	5.9
FV 432	K60	1.5	14 min 44 sec	6.11
FV 4201	L60(650 BHP)	1.5	13 min 19 sec	6.75

/b. ....

b. Odometer Readings. It is interesting to note that the odometer readings for the course for the three vehicles were:

Vehicle	Actual Distance	Odometer Readings
'S' Tank	1.5	4 km - 2.5 miles
FV 432	1.5	1.5 miles
FV 4201	1.5	1.4 miles

Crew Comfort

19. The hydro-pneumatic suspension was disappointing in that the ride across country was akin to that offered by a camel due to the relatively short length of track on the ground and the high polar moment of inertia of the hull plan. The vehicle pitched excessively even though the suspension appeared adequately damped did not bottom often. The extremely high rate of turn of the steering was necessary in order to avoid obstacles which, if hit, could well have injured the crew. For it is mandatory that the crew wear crash helmets. The extremely high rate of turn is assisted by a L/C ratio of 1.25:1 approximately (at full suspension).

20. External Noise Levels Measured by APRE. These measurements were taken with both engines running:

a. On road at approximately 22.5 miles/h (36 kms/h):
at 50ft lateral - 101 dB

b. On cross country at approximately 10 miles/h (16 kms/h):
at 50ft lateral - run 1 - 102 dB
run 2 - 97 dB
at 100ft lateral - run 1 - 94 dB
run 2 - 90 dB

c. Idling at maximum revolutions of the engines:
at 50ft lateral - 95 dB
at 100ft lateral - 91 dB

21. An octave band analysis was not taken as the correct microphone receiver was not available. (This test having been requested by Equipment Trials Wing after the arrival of APRE.).

ETW Automotive Branch Comments

22. K60 only. Only practical on fairly level roads. It is not feasible cross country.

23. Gas Turbine only. This is a "get you home" mode of operation only. Again it is only possible on fairly level going. The effort required to operate the steering levers in the mechanical mode is in excess of 60 lbs/in^2. (Note: These levers are only provided in the driver/gunner position.). The gas turbine can be for a maximum only of 15 minutes at any one time. No test on cold starting was possible but there was no failure to start the gas turbine throughout the trial.

24. Dual Power. The engine revolutions are programmed by the accelerator linkage. When top revs/min are reached on the K60 further depression brings in the gas turbine. There is a time lag for the gas turbine to build up power of about seven seconds. This necessitates controlling the vehicle over obstacles by use of the brakes and maintaining full revolutions on both engines by keeping the accelerator depressed. The general consensus was that the vehicle was under-powered.

/25. ...

25. Cross Country Mobility. The speed on cross country, particularly on Salisbury Plain, from bound to bound was slower than CENTURION. This was mainly because the vehicle had to halt to change the ratio from road to cross-country on the PBTV gearbox. Hence, if the crew selected road ratio, which was often suitable on the open plain, they had to halt at obstacles and change to cross country ratio, or if they remained in cross country ratio they did not make the best speed bound to bound. Certain obstacles had to be traversed at an angle to prevent driving the muzzle into the ground.

26. Noise. The internal noise level demanded an attenuation of 35 dB in the earpiece of the helmet to prevent temporary threshold shift in the crews' hearing.

27. Steering. This feature of the vehicle was impressive. It allowed a high degree of manoeuvring in confined spaces, such as between trees in woods, but also gave fierce and crude control on roads with the clutch brake system. The control of the regenerative steering was a combination of the amount of turn of the controller and K60 rev/min as opposed to a fixed radius dependent on the gear selected as in the MERRIT system. The clutch brake system gave large changes in direction very rapidly. Experience showed that it was advisable to warn the crew if making a sharp turn. The steering also allowed a great deal of flexibility in extracting the vehicle from bad going. It was also very noticeable that throughout the whole trial the track was never in danger of being shed despite almost deliberate misuse on certain occasions where the loss of a track would have been expected. The only comment on steering in reverse was the inadequate vision when closed down.

28. Vehicle Ride. To the onlooker the vehicle appeared to pitch alarmingly. This was aggravated by the crew using the elevation control to keep the muzzle of the gun from hitting the ground. Inside the crew compartment this pitching was not so noticeable until one used the sights and was then grateful for the helmet.

29. Fire System. Once a small fire occurred when fuel leaked from the K60 engine onto the exhaust pipes. This was effectively dealt with by the CO_2 system. However, the absence of any warning system could mean a fire getting a strong hold before the crew became aware of it.

Conclusion

30. The aim of the trial precluded a full automotive assessment except to provide specific answers for the tactical and weapon assessments phases. The human factors aspects of the vehicle automotive system are included in the APRE report at Annex E and the Troop Leader's comments on certain automotive aspects in Annex H. The overall automotive impressions were:

a. The two-engined layout does not seem to give any worthwhile advantages over a single engine providing sufficient power.

b. The use of a gas turbine does have certain tactical disadvantages in a high frequency noise, which locates the vehicle and provides a characteristic signature as well as heat shimmer. Automotively the necessity to run under full load conditions for relative fuel economy and to have full power means an unnatural driving technique in comparison with British AFVs.

c. The second variable steering input does provide a high degree of manoeuvrability. However, the clutch brake steering is very fierce and hurls the crew around if they are not warned.

d. The rubber track was insufficiently aggressive.

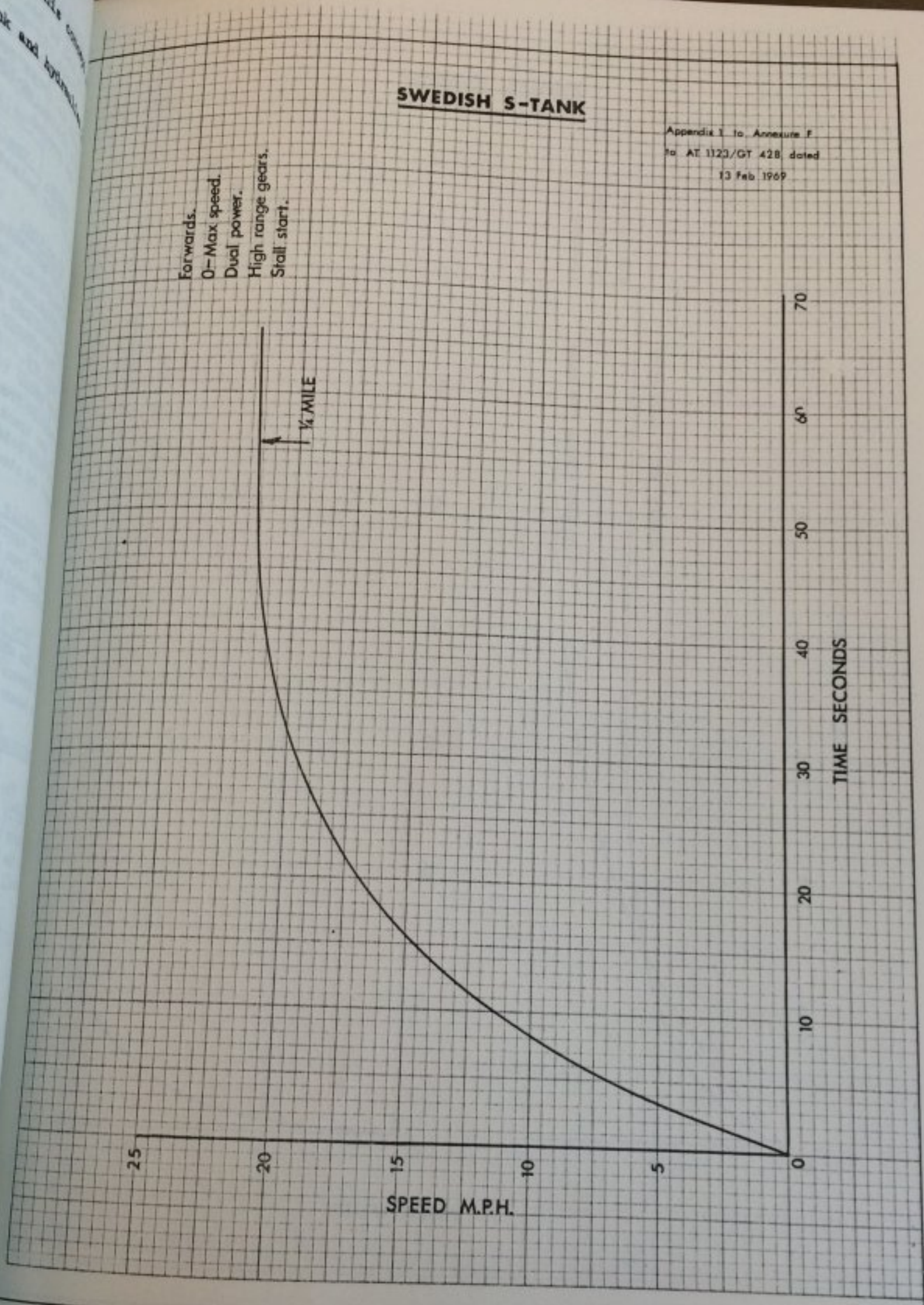
/e. ....

e. The inability to shed the track is an essential to this concept and has been adequately achieved.

f. The reliability and durability of the power pack and hydraulics in the hands of soldiers is suspect.

SWEDISH S-TANK

Appendix 1 to Annexure F
to AT 1123/GT 428 dated
13 Feb 1969



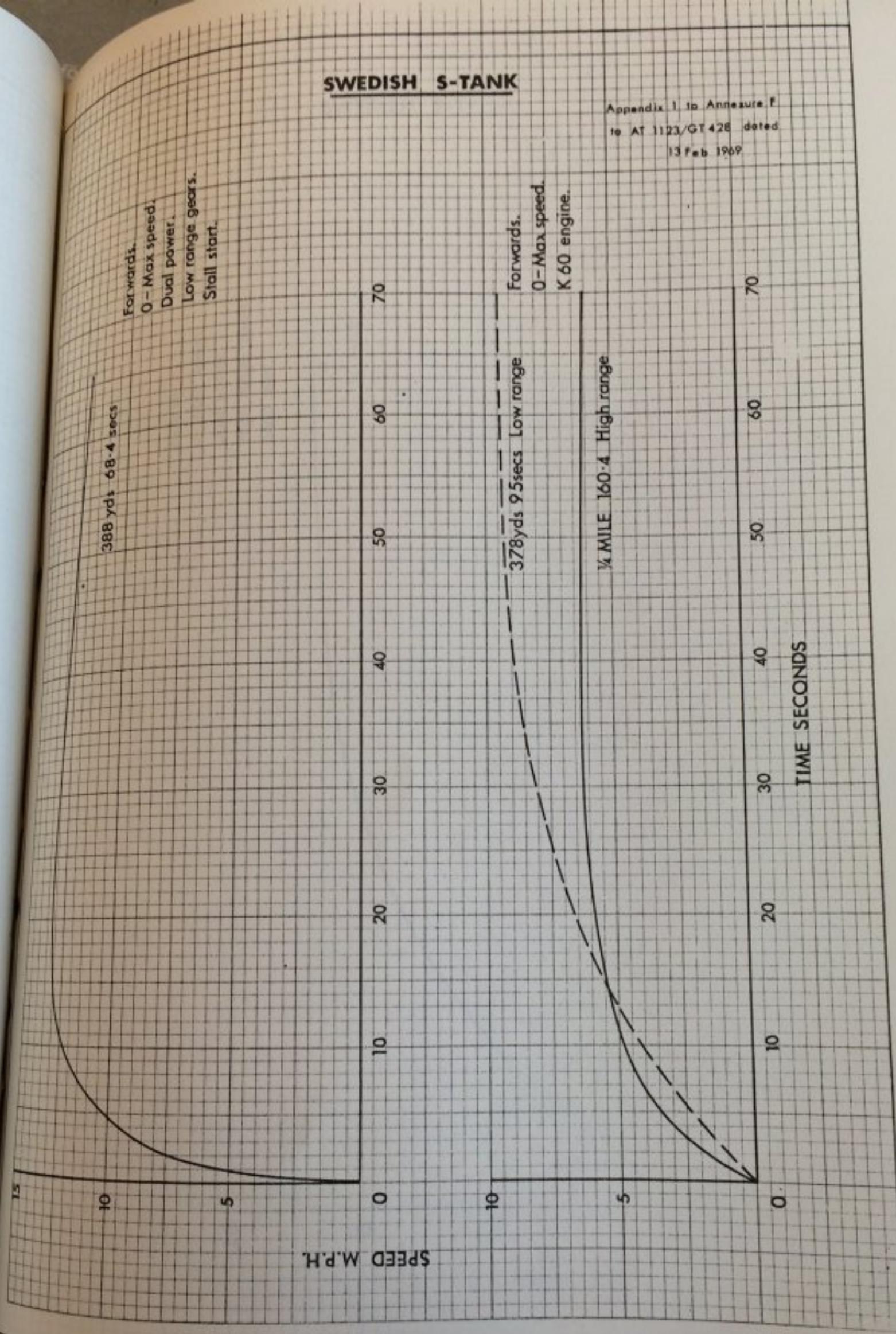
	REPORT No.
FIGHTING VEHICLES RESEARCH & DEVELOPMENT ESTABLISHMENT	TDR No. 140/68
	FIG. No.1.

F.V.R.D.E. FORM 11 1962

Dd 106463 1/66

SWEDISH S-TANK

Appendix 1 to Annexure F
to AT 1123/GT 428 dated
13 Feb 1969



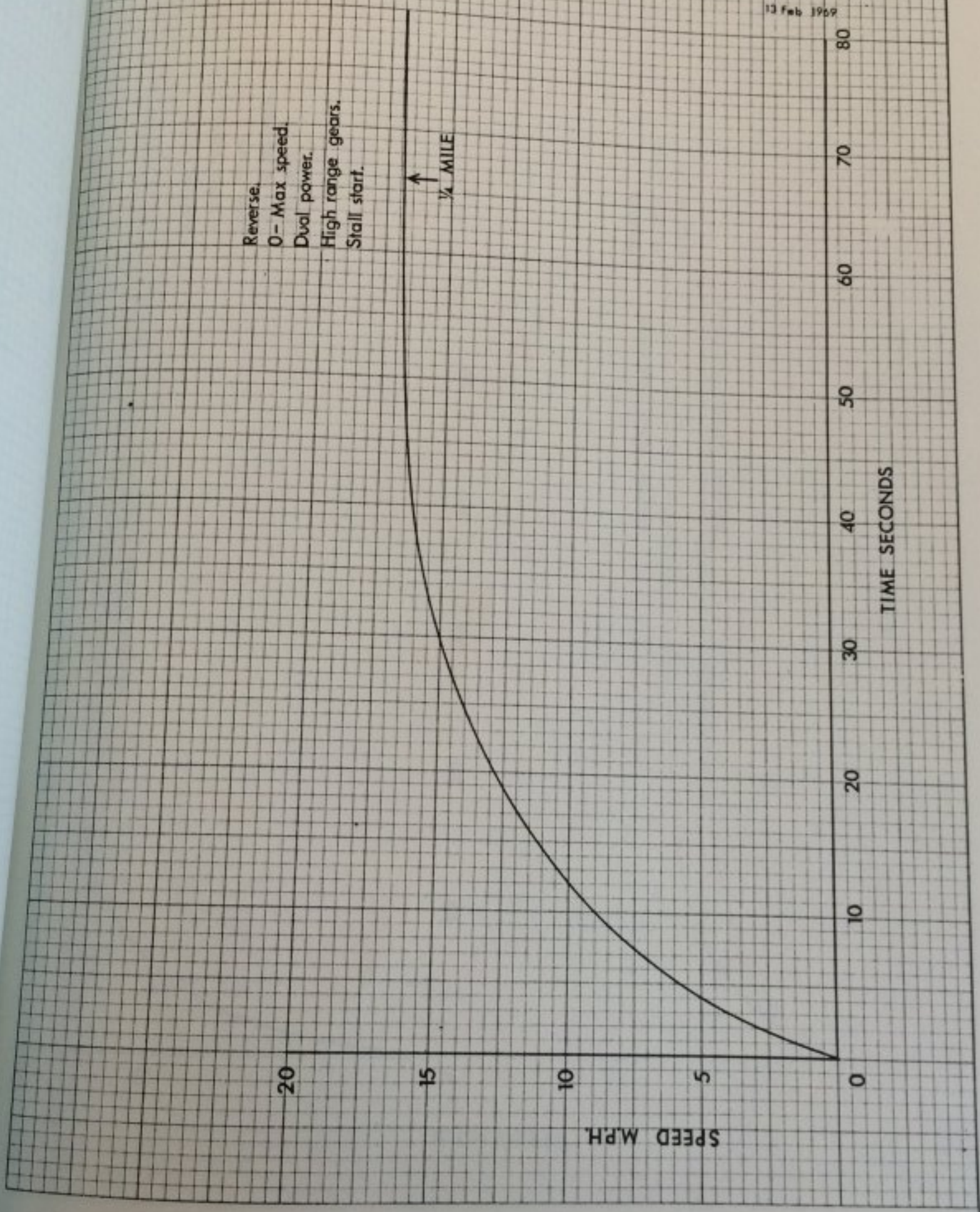
	REPORT No. TDR No.140/68
FIGHTING VEHICLES RESEARCH & DEVELOPMENT ESTABLISHMENT	FIG. No. 2.

F.V.R.D.E FORM 11 1962

Dd 106460 1/66

SWEDISH S-TANK

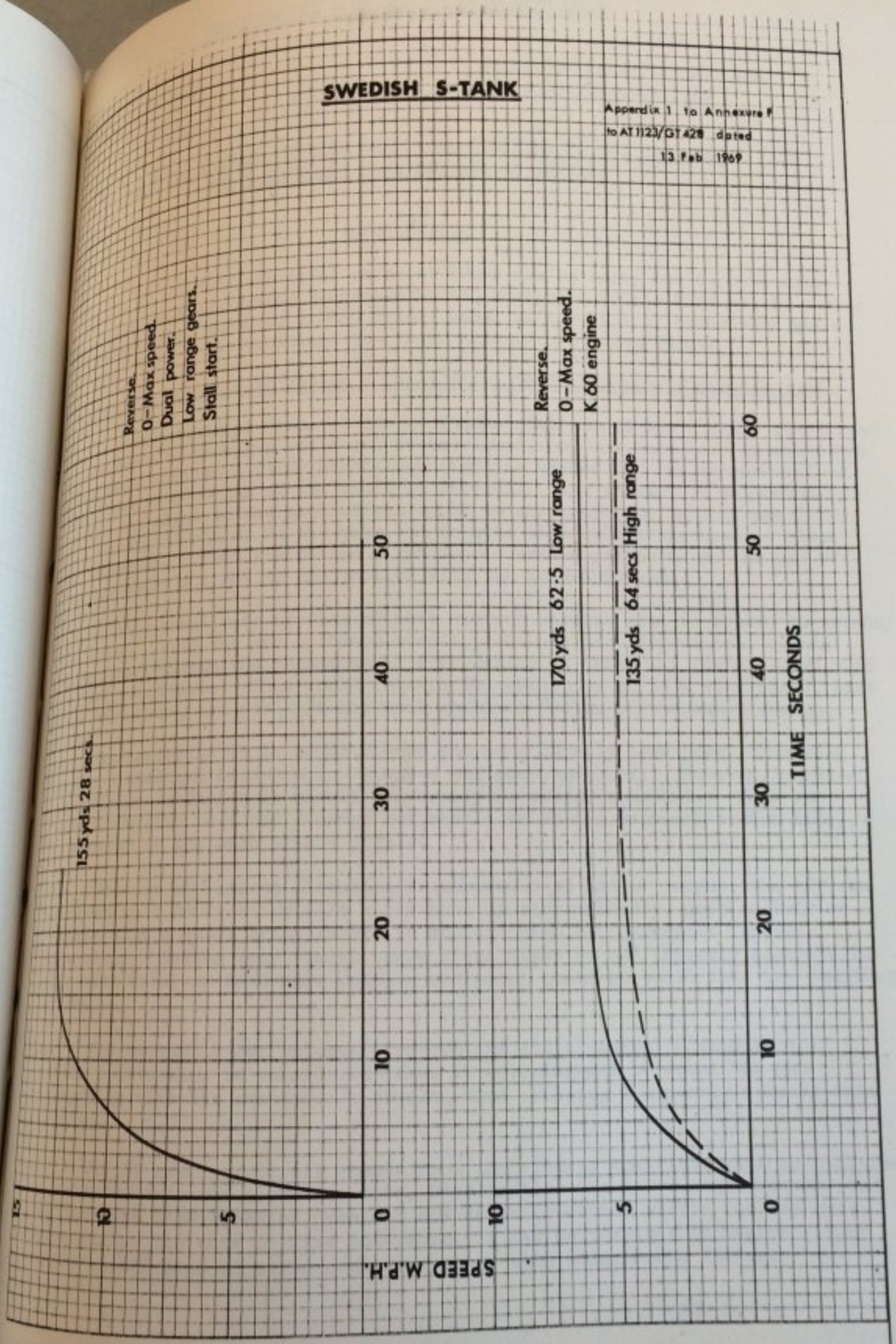
Appendix 1 to Annexure F
to AT 1123/GT 428 dated
13 Feb 1969



	REPORT No. TDR No.140/68
FIGHTING VEHICLES RESEARCH & DEVELOPMENT ESTABLISHMENT	FIG. No.3.

SWEDISH S-TANK

Appendix 1 to Annexure F
to AT 1123/GT 428 dated
13 Feb 1969



	REPORT No. TDR No. 140/68
FIGHTING VEHICLES RESEARCH & DEVELOPMENT ESTABLISHMENT	FIG. No. 4.

M.O.D. FORM 11 1962

Dd 186460 1/66

Annex 'G' to AT 1123/GT 428
dated 13 February 1969

THE FVRDE ANSWERS TO USER QUESTIONS RELATING TO THE 'S' TANK AND TURRETLESS TANK DESIGNS IN GENERAL

INTRODUCTION

The aim of the 'S' tank trial phase at FVRDE was to carry out certain auto-motive performance measurements requested by RAC Equipment Trials Wing and to answer a series of questions posed by a DRAC trials panel as a result of experience gained on 'S' tank trials. The questions and their answers are given below.

Would it be possible to design a fully stabilised commander's machine gun?

a. With certain provisos we see no fundamental reason why a fully stabilised commander's machine gun could not be developed, but one must bear in mind that this would require a fully stabilised sighting system for the commander from which the machine gun system could be servoed. Any attempt to mechanically couple the sight to the machine gun could so downgrade the laying capability and clarity of vision on the move, as to make it a relatively useless piece of equipment. This limitation might impose severe penalties on the use of the commander's sight in conjunction with the main armament.

b. The natural rate of fire of most current machine guns is around 10 rounds/sec which, using the gas operated recoil principle, could produce a cyclic disturbance within the mechanics at a frequency to which the laying servo will be very sensitive. This would require the mechanics to be a very rigid, lash free structure, and could be the most critical factor in the whole design.

c. Mechanically it is advantageous and considerably less power consuming if the stabilised hardware is balanced and non-pendulous. However, whatever the balance condition it should preferably be nearly constant. Thus the ammunition feed belt and stowage box should be on the trunnion centre line, or mounted on the main cradle pintle.

d. Because of Tangent Elevation requirements at longer ranges, the effects of cross roll or trunnion tilt might show up very markedly, particularly on a vehicle with a short track length to achieve high main armament Tangent Elevation. Beaten zone visual corrections might be sufficiently accurate to cope with this, or some more complex corrector could be built into the sighting system.

e. The necessity for automatic re-cocking and clearing of stoppages if remote positioning is considered makes it advantageous to mount the gun integrally with the commander's cupola, thus avoiding a separate azimuth axis freedom.

f. If the gun is entirely remote from the viewing position, that is isolated in both traverse and elevation axes, this doubles the servo requirements, and may increase stabilisation problems due to inter-action within the two axis. Depending on the cone of fire tolerable, it may be possible to employ a very simple on-off type of servo control system, with coincidence firing.

/g. ....

g. The design of a high performance, compact stabilised line-of-sight already exists, but a lot of mechanical data and design criteria would be required if a soundly engineered stabilised gun mounting were to be made capable of withstanding the forces resulting from firing and vehicle action.

3. Could a less complicated automatic loader be provided for the main armament which would also allow the automatic selection of up to four different ammunition natures? The automatic loader in the 'S' tank requires very careful setting up.

The automatic selection of up to four different ammunition natures will essentially complicate the automatic loader. Our experience is of automatic loaders with different functions and we can only comment that the need for careful setting up is a function of design and might be improved upon in an alternative design.

4. Could a Silent Emergency Traverse (limited) be provided to meet the following situations:- a. When no power is available from the main engine, and b. when the suspension is damaged and/or the track is broken on one side?

a. If it is possible to connect a hydraulic pump into the hydrostatic steering motor it may be possible to slew the vehicle without engine power. This depends on the details of the hydrostatic pump, motor and circuit. The slewing torque required is very high and the pumping would probably need to be done by hand. Similarly, a pump might be used to elevate the vehicle and gun, and an electric pump might possibly be feasible here.

b. If a track is broken, there is no certain method of slewing the vehicle unless the road wheels can be blocked against an obstacle. If the suspension is damaged, gun control may be possible, depending on the nature of the damage.

5. Would it be possible to design a better suspension that would reduce pitching and at the same time provide elevation of the major armament comparable to CHIEFTAIN?

a. Pitching could probably be reduced by throttling the oil in the hydro-gas system; this hydro-gas system is essential to the method of gun control.

b. The elevation of the main armament depends on the ratio between wheel lift and wheel base; to increase this elevation the wheel base would have to be even shorter, which would increase pitching.

6. Does the hull shape, which is dictated by the overall concept, allow the use of a single main engine instead of the double engine system used on the 'S' tank?

a. Only limited engine compartment dimensions could be obtained whilst the 'S' tank was at FVRDE; more detailed dimensions were requested from BOVINGTON but were not supplied, so our comments below are fairly general although we believe adequate to answer the query.

/b. ....

b. We have assumed that three constraints that dictated the choice of engines for this vehicle would still apply, namely:

(1) The single engine should not increase the minimum height already determined by the size of the automatic loader and the gun position.

(2) The engine should have inherently good cold starting capabilities, economic fuel consumption and be multi-fuel, as well as having small volume and weight.

(3) The power available would have to equal or exceed the power available from the two engines.

c. The only current engine that comes near to meeting these requirements is the L60 with a height of 45¾", but the engine compartment was measured as 50" decreasing to 38¼". It might be possible to install this engine by tilting it, but the angles would be rather excessive and would necessitate a development programme to provide a new sump and oil pick-ups; many ancillary items on the engine would have to be repositioned.

d. Therefore, with the basic layout and crew arrangement of the 'S' tank, the space allocated to engines is such that it would be difficult to install a single engine to perform the functions of the two engines.

Does the removable glacis plate weaken the frontal armour protection and could this be avoided?

a. The Swedish Authorities have stated that after early troubles when firing at the two hatches which give access to the engine, modifications were made, the frontal armour is not weakened and the following advantages apply:

(1) Easily replaced if damaged.

(2) The steel need not be weldable (although it appears to be so).

(3) If improved armour becomes available, it can easily be substituted.

b. It is difficult to give an exact answer to the query but we have the following observations:

It may be felt that welding would be stronger than bolting, but the severe bending stresses when under attack might crack the welds. Also a considerable number of bolts were used and protected by being countersunk into reinforced bars on top of the covers; the assembly would therefore not be prone to complete failure due to a few bolts shearing under attack.

Is there any conceptual reason for not placing all the fuel under armour?

Protecting all the fuel would involve the weight of extra armour; apart from this there is no reason why all the fuel could not have been under armour. If given some priority in design this fuel between armour might have been placed on the vehicle where it could serve as extra protection but finding space for such fuel tanks in the front or alongside the crew compartment would be quite a problem.

/10. ....

9. What are the problems and penalties of providing CBR protection?

a. There is no reason to suppose that this vehicle could not be fitted with CBR protection if required. The deciding factor is the air leakage rate of the vehicle when closed down. As this vehicle does not have a turret ring, which is one of the main sources of leakage, it is reasonable to assume that the vehicle could be fitted with a filtration pack.

b. The penalties are a space requirement of about 6 cu ft., a current consumption of approximately 20A and the unit cost of about £600.

10. What is the silent watch capacity of the batteries?

a. The capacity of the batteries on silent watch was obtained by calculation. The figures given below assume that only one of the two radio sets would be in use - the times will be about halved if both are used; a sight wiper is assumed to be in use in both cases. Figures assume normal temperatures: the silent watch time will be reduced at lower temperatures.

b. The battery capacity is 114 amp hrs, and it is assumed 40 amp hrs can be utilised without prejudicing engine restart. The current consumed is 0.8 amp on receive, 10 amp on high power send, 3 amp on low power send and 3 amps for the sight wiper. Assuming a send-receive ratio of 10:1 the times are calculated as:

(1) Silent watch on high power transmission: 21 hrs approximately.

(2) Silent watch on low power transmission: 31 hrs approximately.

Annex 'H' to AT 1123/GT 428
dated 13 Feb 1969

TROOP LEADER'S COMMENTS BY MAJOR R. C. BAGNELL, QOH

eral

These comments, comparing 'S' Tank with CENTURION, are made by the writer Vehicle/Troop Commander. Any tactical points are given specifically from at aspect and inevitably tend to form a critique of the tank itself as distinct om a mere concept assessment.

This section of the report should be read in conjunction with Annex 'A' - scription of the Equipment.

ctical Handling

General. The handling of 'S' Tank is generally similar to other tanks except hat in the attack it cannot deliver main armament supporting fire on the move.

Advance. In the advance I found it was better than conventional tanks due to s low silhouette allowing greater use of available cover. This led to the 'S' nk being able to get closer to the enemy before having to take up a fire position.

Withdrawal. I particularly liked the ability to reverse at the same speed as orward drive, thereby keeping the frontal armour towards the enemy.

Defence. In my opinion, due to the low silhouette, superb optics and semi- utomatic loading system, the 'S' Tank is probably the best defensive tank in service oday.

Fire Positions. Taking up fire positions in the 'S' Tank was exceptionally imple due entirely to the two factors below, but care must be taken over crest learance as it cannot be checked from inside the vehicle:

a. The driver and commander being on the same level. (In cases of difficulty the commander can take over to put the vehicle exactly where he wants.).

b. The low silhouette and the fact that observation and fire positions are almost identical allowed the use of cover that a commander would never consider possible in a conventional tank.

Vehicle/Troop Control. As a vehicle or troop commander I found no difficulties ith the 'S' Tank except for the absence of stowage for map case, code packs etc., nd map reading was relatively more difficult due to the commander being nearer the round. The 'S' Tank was not tried as a command/control vehicle. It would be ifficult, if not impossible, to command a squadron from an 'S' Tank for any length f time, due to the lack of space for a signals NCO to work in the rear driving osition.

Camouflage. The 'S' Tank was found to be simple to camouflage due to the ightweight plastic nets provided, and the absence of turret traverse.

/Automotive

Automotive

10. Driving. I found the 'S' Tank easy to drive badly and reasonably difficult to drive well. This was mainly due to the strangeness of the twin steering system and the unnatural requirement of keeping the accelerator fully down, to avoid the time lag in turbine build up, and of also using the foot brake to control cross-country speed.

11. Performance. Road performance of the 'S' Tank is good. Maximum speed was found to be approximately 50/60 kph (31/40 mph) on the vehicle speedometer. Braking proved in all cases to be brutal and the steering good, though clutch braking to steer at speed on a road sufrace is, to say the least, hair-raising. Cross-country performance was disappointing due to the current restriction of no gear changing on the move and the fact that the maximum speed of the cross-country gear is too low (17 kph/10 mph).

12. Ride/Comfort. To the outside observer the 'S' Tank appears to pitch excessively due to the variable attitude of the hull and the short track length on the ground. This is not borne out inside the vehicle mainly due to the fact that the crew compartment is at the centre of the vehicle, and that crews inevitably adjust speed and pitch to suit the terrain. (This apparent observation might have been aggravated by the fact that at no time did the 'S' Tanks travel with a full load of ammunition.).

13. Servicing. Generally the servicing of the 'S' Tank is simple and equivalent tasks take marginally less time than on other tanks. I particularly like the Swedish ruling of only topping up when levels reach the low mark, and the fact that greasing is done by a given number of strokes at given intervals. Throughout the trials the only complaints made by the crews were:

a. The inaccessibility and awkwardness of the track adjusting nut.

b. The filler for the K60 engine oil was far too small.

c. Lack of fuel gauges which forces the use of a triple reading dipstick. This could seriously slow the gathering of a Squadron replenishment requirement.

Commander's Cupola

14. General. The 'S' Tank cupola is without doubt the best I have come across due to the superb optics, speed and accuracy of traverse, line up facility and stabilization of sight. No degradation of observation arose from the non-continuous 360° traverse capability.

15. Specific Likes:

a. Range and ease of selection of the variable magnification in the sight.

b. Large clear unity window.

c. Binocular sight principle.

d. Cupola hatch is excellent due to its ease of operation and umbrella position.

/16. ....

Points for Improvement:

a. Accessibility of line up locking switch.

b. Lack of rheostat in eye piece heater circuit (eye piece could get painfully hot).

c. Adjustment of seat to cater for tall members.

d. Provision of stowage for commander's necessary small items, map case, code packs etc.

e. Provision of a device to slow the rate of traverse as the cupola approaches line-up to prevent overrun.

f. Simplify graticule pattern which was too complicated and unvaried. (Difficulty with this may have been due to lack of continual practice and different techniques).

g. Provision of commander's spotlight.

h. Provision of armoured shutter on sight head.

17. Commander's MG. This mounting I found to be superior in all ways to that of CENTURION, and superior to CHIEFTAIN for accuracy during static shooting. Whilst shooting on the move the mounting suffers from the usual problems of elevation damping. If an elevation stabiliser could be fitted this would become a really accurate weapon as it is already stabilised for traverse within the cupola. The duplex firing lever was excellent though for preference I would like it shorter. It is almost impossible to grip the elevating handle firmly without firing the gun. The cocking safety lever was adequate but could be made more robust.

18. Smoke Grenade Dischargers. These are adequate and the performance of the grenades particularly impressive, but I would like to see more of them perhaps even mounted on the corners of the vehicle (vide the British ARV).

19. Control Column. This is simple to use for both driving and laying. The only problem encountered was occasional errors in selecting the firing button and right-hand magazine loading button. This was probably due to lack of experience.

20. Driver/Gunner's Position. The main two criticisms of the controls are:

a. Inability to see instruments when in the up position.

b. Handbrake requires both hands to release if tightly applied.

21. Reverse Driver's Position. This position and the controls are adequate, though a small man is almost a necessity. Improvement could be made to the vision by the addition of another vision block to cover his vision to the right rear of the vehicle. All instruments on the control panel should be on the safe/unsafe principle to alleviate the problem of memorising a multitude of safety temperatures.

/Weapons Systems

Weapons Systems

22. Sponson Guns. The main disadvantage of these is that a crewman must dismount

a. For stoppages which cannot be cured by cocking.

b. To replenish magazine boxes. Few stoppages occurred and these were mainly bad feed due to carelessly packed magazine boxes. The wire connecting the cocking lever to the gun was not strong enough and frequently broke. It was a great advantage to be able to adjust the guns accurately to coincide with the sight marking.

23. Main Armament. The only real complaint on this system was the large number of selector/safety switches. It was found to be all too easy to forget one or more of these and thus cause an apparent misfire. Stripping and re-assembly of the breech mechanism was simple and easily accomplished after practice. Misfire drill could cause problems, especially if the round was a hard extraction, as it had to be extracted through the ejection port.

Miscellaneous

24. Tool Kit. This was very comprehensive and of good quality. The major changes we would like are:

a. Cleaning staves instead of pull through wires.

b. A more robust track tensioning tool on the ratchet principle.

25. Radio Installation/Harness. The two American sets and vehicle harness were simple to operate and the present 20 Channel Dialling System would be an asset in a British AFV. The vehicle antennae and bases were robust and not one "top section" was lost throughout the trial.

26. Crew Helmet/Harness. Everyone who travelled in the 'S' Tank was impressed by the crew radio harness; it was light, simple and easy to use. No problems were encountered with the throat microphone and its "live" capabilities were especially liked. The earphones were incorporated in the helmet, the wearing of which was compulsory. Throughout the RAC there has always been a distinct dislike and apathy towards the wearing of an AFV helmet and it was therefore surprising that everyone who wore the Swedish helmet thought it an excellent item. Admittedly crews were able to remove it from time to time, but its comfort over long periods of continuous wear was good.

27. Infantry/Tank Telephone. This was similar to the British equivalent but was fitted with a much longer powered cable. It was necessary for boresighting, but would be useful for a vehicle O.P.

28. Training Aids. The vehicles arrived with a very comprehensive range of aids as follows:

a. Barrel fitting lamp for teaching the laying on and tracking of moving targets.

b. .22in bracket for field miniature range work.

c. 6.5mm bracket for open range firing up to 300m.

/d. ....

d. Automatic sight cameras which recorded the gunners' individual lays to an accuracy of $\pm \frac{1}{4}$ mil.

e. Firing lamps which simulated main armament fire within the barrel, accurate to within approximately 4 mil of the line of sight.

Crew Comments. These were taken at a "wash up" meeting at the end of the training phase and are recorded in Appendix 1.

Appendix 1 to Annex 'H' to AT 1123/GT 428
dated 13 Feb 1969

CREW COMPLAINTS

Commander's Cupola:

a. ?3 requires stabilising in elevation.

b. Accelerator pedal to be better positioned as continued use can cause cramp.

c. More and smaller vision blocks would improve all round vision.

d. Both rate and position control to be combined into the elevation controller.

e. Cupola locking switch should be more accessible, and the cupola should slow on approaching line-up to prevent overrun.

f. Graticule adjusters need a more positive locking device.

g. Seat needs more positions to cater for all sizes of man.

h. Periscope washers not fitted.

j. Rheostat needed for eyepiece heaters; these get painfully hot.

k. An improved demister would improve the sight head.

l. An MBS mark is definitely needed in both sights.

m. Dots for the APDS markings would be better than lines.

n. Could the cupola's "umbilical" cord be replaced by slip rings to ease the danger of strangulation.

o. MG cocking gear could be more robust.

p. Lock to be fitted to stop seat rotating.

q. Tachometer, speedometer and odometer would be an asset to commander.

r. 6 x No.36 grenades to be replaced by 250 rounds for MG.

s. MG firing lever to be replaced with a thumb button on the extremity of the grip.

Gunner's Position:

a. Clino is unnecessary if semi indirect fire is not envisaged.

b. Accelerator as for 1.b.

c. Rest required for the left foot.

d. Hand brake requires great strength to operate. Wind-on ratchet type would be preferred.

/e. ....

e. Emergency steering tillers impossible to use due to the excessive force needed to operate them.

f. Gunner's sight cover too high for comfort when driving in the 'up' position, except for men of 6ft and over.

g. Some form of traverse indicator needed for long range HE and semi-direct fire if envisaged (see 2.a. above).

h. The tachometer, speedometer and warning lights cannot be read in the 'up' position.

3. Rear Driver's Position:

a. Accessibility of radios is bad.

b. Can a foot accelerator be provided?

c. Vision needs improving, especially to the right, even at full elevation.

d. Dials to be on the three colour go/no go principle.

4. General:

a. Engine decks require time and effort to lift, especially when bolted dow

b. Engine oil filler cap too small.

c. Track tensioner nut is very inaccessible, and should be hexagonal not square.

d. Tensioning spanner to be of ratchet type.

e. One spare aerial should be provided.

f. Pick axe would be useful addition to tool kit.

g. Cleaning rods should replace the existing wires.

h. Fuel gauges are a necessity.

ANNEX 'J' TO
AT 1123/GT 428
DATED 13 FEB 1969

TECHNICAL GROUP REME

MECHANICAL WING

'A' VEHICLES AND WEAPONS BRANCH

SWEDISH 'S' TANK

PROJECT No. EME 7a/10095

HQ. DEME (A) REFERENCE 58/Tech/617 dated 27 March 1968

SECTION I Object of Report

1. To compare the Swedish 'S' tank and Chieftain in respect of:-

   a. Servicing and maintenance loads.

   b. Servicing and maintenance problems arising from unconventional features.

   c. Recovery.

   d. Special tools.

   e. Suitability of available technical literature.

SECTION II Equipment

2. Equipments:

   a. Tank combat 120 mm gun Chieftain Mk 2 as described in EMER TKD. VEH. I 200.

   b. Tank 'S' Type A Swedish described in the Vehicle User Handbook.

SECTION III General

3. Background

Sponsored by AEP 17, and under contract Bofors Sweden 5739-0156/66 dated 21 February 1966, two 'S' tanks were loaned to UK for six months to enable a complete assessment to be carried out. This report (Annex 'J' of the main report) assesses the maintenance and servicing loads by making comparisons with Chieftain.

4. Method

   a. An 'S' tank was made available to Technical Group REME at Equipment Trial Wing RAC Centre Bovington during the period 19 - 30 August 1968.

/b. ....

b. Working to a pre-arranged programme, Branch technical authors (fully conversant in their respective spheres with Chieftain) examined the equipment.

c. To obtain the detailed information of the Appendices of this report, the authors cross-examined the two Swedish representatives and those REME personnel who had maintained the two 'S' tanks during trials at Bovington.

d. The few available drawings and the User Handbook were studied.

e. The only maintenance work witnessed by the authors were the removal and replacement of the power pack (which includes the gun barrel removal and replacement) and one front suspension unit.

f. Servicing was demonstrated by and discussed with RAC personnel engaged with the running trials.

g. The recovery appreciation was obtained by actual trials carried out by Technical Group REME Recovery Section.

SECTION IV - Observations

5. Comparative maintenance load

a. Automotive including gun control equipment

(1) Four days of the two week availability period were allotted to the automotive authors and during this time, 54 aspects were studied - these are detailed in Appendix 1. Each aspect was given a grading compared with Chieftain and shows that of the 54 studies, the loading was about equal i.e. 28 : 26 with Chieftain the greater.

(2) The outstanding feature against the 'S' tank is the complicated hydraulic systems with their electrical interlocks. Without comprehensive training and detailed technical information it is doubtful if REME could maintain the vehicle in the field in acceptable repair times.

b. Armament

(1) The armament authors were allotted two days, but apart from gun barrel removal and replacement, no dismantling or assembling operations were witnessed.

(2) The information obtained by the studies is given in Appendix 2.

/(3) ....

6. Servicing Aspects

a. The comparative times for automotive servicing are:-

TASKS	CHIEFTAIN	'S' TANK
First Parade	15 mins.	10 mins.
Daily	30 mins.	20 mins.
Weekly	45 mins.	2½ to 3½ hrs.
Monthly	10 mins.	3 to 4 hrs.
Quarterly	6 to 8 hrs.	None
Annually	8 to 10 hrs.	1 hr.
Bi-Annually	None	10 to 12 hrs.

NOTES:

a. At 1,000 km ar. additional 2½ to 3 hrs. is required for oil changes.

b. Apart from the 'S' Tank Bi-annual servicing time, the above times are not accumulative.

b. Comparative Servicing Loads

These are detailed in Appendix 3.

c. Comments on Servicing the 'S' Tank

(1) Apart from one hydraulic fluid filter being situated low in the engine compartment, the oil, fuel and hydraulic fluid elements are not difficult to replace.

(2) Access for making the periodical checks and adjustments is generally good.

(3) The tasks of making certain checks and adjustments should not be the responsibility of the crew members, although the tasks are relatively simple, the consequence of maladjustment could be serious.

(4) As the hydraulic systems are completely interconnected, leaks at one of many points could result in the complete immobilisation of the vehicle.

(5) Certain flexible tubes used for filling gearcases etc., are not 'on vehicle kit'. (Some tubes were brought from Sweden by the Technical Rep).

/(6) ...

(6) Hexagon type grease nipples are fitted. British vehicles currently have hydraulic type grease nipples - SSM(L) 7 - 24/4 refers.

7. Servicing And Maintenance Problems Arising From Unconventional Features

This is detailed in Appendix 4. Accepting the fact that all workshop special tools would be available together with metric spanners, the only problems are:

a. The hydraulic systems referred to in Paras 5a.(2) and 5b.(4).

b. The overhang of the gun barrel when towing from the front - see Para 8b.

8. Recovery Aspects

a. Recovery

Using a Centurion ARV and standard recovery equipment and techniques, the 'S' tank was recovered from a crater - first with its suspension jammed in the elevated position, then in the depressed position and finally laying on its side.

b. Towing

Towing trials, using a Centurion ARV and an ETW improvised towbar, were carried out successfully. The improvised towbar had been manufactured because the longest towbar issued (Drawbar Heavy LV1/ARV (FV 34136) is unsuitable. It will not span the 'S' tank towing eyes and is not long enough to provide clearance between the gun barrel and the towing vehicle when towed from the front.

c. Transportation By 50 Ton Semi-Trailer

Except for minor fouls between gun muzzle/ground/trailer/rear of hull, there was no difficulty - see Appendices 5 and 6.

9. Special Tools

Because of the small amount of repair work witnessed, a complete study was impossible.

The one feature highlighted was the slave drive used to run up the hydraulic systems with the power pack removed. This and other features are described in Appendix 7.

10. Technical Literature

The equivalent of the British Army Technical Handbook (EMERs) was not available - EME 7 letter 58/Tech/617 dated 30 July 1968 advised this. Again referring to the hydraulic systems, it is estimated that the writing of EMERs for the hydraulic and interconnecting electrical systems would, with the assistance of BOFORS resources, engage two authors for six months.

SECTION V Conclusions

11. a. Comparative Maintenance Load

There is little difference between the two total loads, but there is a difference in the loadings of the various REME tradesmen i.e. greater for the Artificer vehicle but less for the Artificer CE.

b. Comparative Servicing Load

There is little differnce between them - both vehicles have good and not so good features. The time for servicing the 'S' tank is shorter for First Parade and Daily, but longer for Weekly and Monthly.

c. Servicing and Maintenance Problems Arising From Unconventional Features

(1) Servicing - None

(2) Maintenance - One; the very complicated and interconnected hydraulic systems in which a leak at any one of the many points could immobilise the vehicle.

Recovery

Existing recovery equipment can recover the vehicle, but a new pattern drawbar is required for towing. With minor rubbing fouls whilst loading, the 50 ton transporter can transport the vehicle.

Workshop Tools

Complete sets of Swedish workshop tools and test equipment would be required.

Technical Literature

Only the User Handbook was available. There was no EMER equivalent to view. REME tradesmen could probably maintain the vehicle at Unit and Field Workshop level from basic principles except for the hydraulic systems. Systems circuits and test schedules for the hydraulic, interconnected electrical systems and autoloader would be essential.

SER. No.	ASSEMBLY/ SYSTEM	COMPARATIVE FEATURES		GREATER LOAD	
		CHIEFTAIN	S TANK	CHIEFTAIN	S TANK
(a)	(b)	(c)	(d)	(e)	(f)
1	Power pack	WEIGHT: 2 Tons OVERALL DIMENSIONS: 6' x 5'6" x 4' TIME: REMOVAL AND REPLACEMENT: 18 man hrs 6x3 Major items: L60 Engine with radiators and cooling fans, engine lubrication and TN 12 gearbox heat exchangers Lifting arrangements: FV 434 with assembly always in horizontal plane 4 - leg lifting sling Number of connecting/spannering points: 30	WEIGHT: 3¼ Tons OVERALL DIMENSIONS: 7'8" x 5'8" x 4'6" TIME: REMOVAL AND REPLACEMENT: 32 man hrs 8x4 Major items: K60 engine, gas turbine, torque converter, gear change gearbox, transverse gearbox, bevel drive gearbox and steering clutches Lifting arrangements: Leyland Recovery Vehicle (FV 434 cannot cope with weight nor the necessary manceuvring) Spreader for two point lift with ratchet chain block for longtitudinal inclinations. Number of connecting/spannering points: 50		X
2	Engines	Major items: Main engine: L60 No.4 MK 4A - 6 cylinder, opposed pistons, 2 stroke, compression ignition, developing 650 bhp at 2670 Auxiliary engine: H30 No.4 MK 7A - 3 cylinder opposed pistons, 2 stroke compression ignition (Generating set), developing 30 bhp at 2000 rev/min. Lifting arrangements: Adjustable sling, and crane Removal and replacement times:- Main engine, K60: Remove power pack, dismantle cooling system components (radiators, header tanks and fan assemblies) and air cleaner - 24 man hours 8 x 3. Auxiliary engine, H30: 6½ man hours 6½ x 1 A booster or second engine is not fitted.	Major items: Main engine: K60 MK 40K - 6 cylinder, opposed pistons, 2 stroke, compression ignition, developing 240 bhp at 3650 rev/min. Booster engine: Boeing 502 - 10 MA, gas turbine - 1 stage radial compressor, axial type turbine, developing 300 bhp at 3800 rev/min. Lifting arrangements: Rope slings and crane. Removal and replacement times:- Main engine, K60: Remove power pack, remove engine and automatic transmission from frame, disconnect transmission from engine - 32 (8x4) + 14 (7 x 2) - 46 man hours. An auxiliary generating set is not fitted Boeing engine: Engine is removed in situ - 4 man hours 2 x 2	X	X X

/Serial 3.....

(a)	(b)	(c)	(d)	(e)	(f)
3	Cooling system	Major items: Radiators Cowling and fans (includes header tanks) Pulley drive gear Lifting arrangements: Rope slings and crane Removal and replacement: Remove Power pack for complete accessibility of all items	Major items: Radiators Cowlings Hydraulic motors and fans Header tanks Lifting arrangements: NIL Removal and replacement: Removal and replacement of all items can be done in situ.	X	
4	Fuel system	Major items: LH and RH fuel tank bags. Base tanks and fuel pumps Pipes and connectors Exhaust system (Silencers and pipes) Removal and replacement: Bag tanks can be removed without special aids. Base tanks and pumps can be removed in situ. Majority of fuel connections can be reached in situ.	Major items: LH and RH fuel tank bags. Front fuel tank Fuel pumps Pipes and connections Silencers pipes and ducts Removal and replacement: Bag tanks can be removed without special aids. Front tank cannot be removed without first removing Power Pack. 13 fuel pipe connections are only accessible after removal of pack.	X X	X X X
5	Transmission	Major items: Gearbox complete with differential and steering brakes. Engine to gearbox flexible coupling. Final drives. Lifting arrangements: Three leg sling for gearbox. Lifting sling and outrigger brackets. Removal and replacement: Withdraw quill shafts and disconnect main brakes, exhaust pipes and fan drive to remove gearbox in event of failure within box, or coupling.	Major items: Torque convertor. Three speed gearbox. Transverse gearbox. Steering clutches. Bevel gearbox - steering drive. Steering brakes. Bevel gearbox - drive gear. Final drive. Lifting arrangements: Rope slings for all assemblies except final drive. Frame type sling for final drive. Lifting frame for sprocket hub. Removal and replacement: Remove Power pack. With pack on servicing stands remove K60 to gain access to Torque converter Transverse gearbox. Remove Power pack. With pack on servicing stands remove three speed box		X

/Serial 5 (Cont).....

(a)	(b)	(c)	(d)	(e)	(f)
5 Ctd	Transmissions	Withdraw quill shafts and casing to hull bolts to remove final drive assy in event of gear failure. In event of hub drive shaft failure, remove shaft in situ without removal of track. Sprocket rings can be rotated for wear.	Remove Power pack. With pack on stands remove steering clutches to gain access to drive bevel box or steering brakes.		X
			Remove Power pack. With pack on stands remove Torque convertor, Three speed box, Bevel box, Gas Turbine and upper Power Pack frame to remove transverse gearbox.		X
			Withdraw quill shafts and sponsor bin access plates. Drive can be removed if necessary complete with steering brakes.		X
			Sprocket rings cannot be rotated, they are rivetted to hub. Hub can be fitted any way round.		X
			Remove Power pack to gain access to Bevel gear - steering drive, including prop shafts.		X
		Alignment of transmission: GO- NO GO" fixture provided for Final Drive - Gear-box alignment.	Alignment of transmission: Alignment checks not necessary as manufacturing tolerances are small.		X
6	Hydraulics	Major items: a. Braking system. b. Hydraulic starting and cooling system. c. Steering brake system. Lifting arrangements: No special equipment other than a rope sling for main brake caliper frame. Removal and replacement: Access to power brake items for repair or replacement can be effected by removal of cover plate (in driver's compartment) or transmission/engine compartment hull louvres. O/H of pump, power valve and accumulator restricted to base workshops.	Major items: a. Hydraulic cooling fan drive. b. Steering brake and drive system. c. Elevation and suspension system. d. Autoloader system for main armament. e. Cupola drive system. Lifting arrangements: Special frame for removal of hydraulic gearbox and Autoloader. Removal and replacement: No equivalent single system. Automotive brakes are part of steering system.		

/Serial 6 (Contd).....

(a)	(b)	(c)	(d)	(e)	(f)
6 Ctd	Hydraulics	Access to main pump controls and fan motor for repair or replacement can be effected by raising engine/transmission compartment hull louvres.	Access to coolant system fan motors and pumps can be made without extensive stripping.		
		O/H of pump units at base level only.	Access to heat exchanger fan motor and coolant motor circuit pressure/temperature valve can only be effected by removal of Power Pack and/RH steering brake.		
			Pumps,motors and temperature/pressure valve should be O/H only at base.		X
		Access to slave master cylinder and caliper components, including disc brake pads can be effected in driver's compartment or transmission compartment after raising louvres. Removal replacing and testing of hydraulic components can be carried out at 2nd line or if high pressure equipment is available at LAD level.	Steering brakes and clutches can be removed repaired and replaced after raising front armour. All other parts of this high pressure system which includes hydraulic pressure pump and brake cylinders can only be reached after removal of Power Pack.		X
			Elevation and suspension system comprising hydraulic pumps, main accumulator, 8 pendulum arm hydraulic cylinder accumulators, valve gear and reservoir.		
			Delivery pressure can be observed on two gauges mounted on Hydraulic unit. Overall performance can be checked using a stop watch and pendulum.		
			Any faults found on any part of this system requires removal of Power Pack, or Auto loader and/or Hydraulic unit (80 man hours).		X
			Removal and replacement of the drive motor present no special problems. Repair of the motor would normally be carried out at base.		X
		Complete hydraulic system can only be tested with Power Pack and H30 installed and running.	Complete system can be tested by using a slave motor before installation of Power Pack in vehicle.		
			There are 27 connecting points or joints which are inaccessible with power pack in situ.		

(a)	(b)	(c)	(d)	(e)	(f)
7	Suspension	a. 6 independent suspension units per vehicle, two track adjusters mounted at front and 6 track supporting guide rollers. b. Major items:- (1) Each Suspension unit:- Suspension bracket. Spring pack (3 springs) Axle arms (2) Road wheels and hubs (2) Shock absorbers (2) - front units only. (2) Track adjusters:- Idler wheel and hub Cranked axle arm Tensioner screw Adjuster bracket (3) Guide rollers:- Roller wheels (2) Spindle Bracket c. Lifting arrangements:- Hydraulic jack. Rope sling d. Removal and replacement:- (1) Suspension unit:- To remove assembly it will be necessary to remove skirting plates, road wheels, spring pack, secure axle arms, and remove bolts securing bracket to hull.	a. 2 pairs of 4 hydraulically interconnected wheel link assemblies, two track adjusters mounted at rear and 4 track supporting guide rollers. (1) Each link assembly:- Link (pendulum) arm Hydraulic ram cylinder Stop/rebound cylinder Road wheel and hub (2) Track adjuster:- Idler wheel and hub Axle arm Tensioner worm screw and housing (3) Guide rollers:- Single roller Spindle Bracket c. Lifting arrangements:- Stub axle support wire Rope sling Lifting frame d. Removal and replacement:- (1) Wheel link assembly:- No. 1 and 2 wheel stations remove power pack for access to ram cylinders and connecting pins of link arm to cylinder piston rod. No. 3 and 4 wheel stations remove main gun automatic loading magazines to gain access to cylinder and connecting pins. After removal of above items, link arm can be removed by first removing road wheel and hub, stop rebound cylinder and then applying porta power pump to link arm.		X

(a)	(b)	(c)	(d)	(e)	(f)
7 Ctd	Suspension	(2) Track adjuster:- In the event of hub bearing failure, remove skirting plate, idler wheel and hub. In the event of ball ring failure, remove above items and cranked axle arm. In the event of seizure, remove skirting plate and idler wheel and tensioner assembly from hull. (3) Guide rollers:- In the event of bearing failure, remove skirting plate, roller wheels and bracket assembly. e. Filling and charging suspension system:- (1) Applicable to filling shock absorbers only. To fill shock absorbers, remove skirt plate, road wheels and disconnect shock absorber link arm. Fill shock absorber with oil and work lever arm.	(2) Track adjuster:- In the event of hub bearing failure, remove idler wheel and hub. - In the event of tensioner screw seizure, remove bolts securing housing to hull and lift off complete assembly with final drive lifting frame. (3) Guide rollers:- In the event of bearing failure, remove bracket and roller assembly. e. Filling and charging suspension system:- (1) This is a complete hydro-pneumatic system having oil and gas filled cylinders which permits control over rate of traverse and change in attitude of hull in relation to elevation, depression and ground clearance. (2) Equipment required to check pressure and charge system:- Nitrogen gas cylinder Gas connector (3) Charging and checking pressures on system refers to pressure of nitrogen gas after oil has been drained from gas cylinders. The number of operations involved to charge system or check pressures is considerable.	X X X X	X
8	Driver's controls	Major items:- Accelerator controls Auxiliary engine controls Gear change controls Hydraulic starter controls Steering controls Main power brakes Parking brakes	Major items:- Accelerator controls Gear change controls Steering controls Main power brakes Parking brakes		

/Serial 8 (Cont).....

(a)	(b)	(c)	(d)	(e)	(f)
8 Ctd	Driver's controls	Lifting arrangements:- For access to parking brakes and gearbox emergency controls adjustable slings and crane is required for removal of power pack and gearbox. Removal and replacement:- Accelerator, auxiliary engine, gearbox emergency and pump clutch for hydraulic starter are all cable operated controls, running along floor of hull between drivers and automotive compartments. For access to these controls, remove access plate in turret turntable which involves positioning turret and removing certain charge bins. For access to gearbox emergency control, remove power pack in addition to turret floor plate. Main power brakes:- Pedal control connected to hydraulic system. For details, see under Hydraulics. Parking brakes:- Lever is of the ratchet quick release type connecting by roller chain to operating cables. For accessibility, remove power pack and turret floor plate. Steering controls:- Mechanical levers, rods and interlock cross-shaft connected to hydraulic system. Accessible from driver's compartment.	Lifting arrangements:- For access to emergency steering controls, lifting beam and crane is required for removal of power pack. Removal and replacement:- All controls are duplicated for commander and driver with exception of parking control which is controlled by the driver. The third crew member has a simple mechanical steering control, brake pedal and hand throttle control. Accelerator controls:- Cable and rods, easily accessible within engine compartment. Gear change: Mechanical linkage/cable operated controls, easily accessible. Main power brakes: Pedal control connected to hydraulic system. For details, see under Hydraulics. Parking brakes:- Mechanical linkage/cable operated. For accessibility, remove power pack. Steering controls:- Hydraulic and clutch-brake operated with mechanical linkage for emergency steering. Control is an integrated driving and gun control unit, controlling lateral steering elevation and depression, loading and firing of main and secondary weapons. Control units and third crew members steering control are accessible within combat compartment and easily removable. For accessibility of emergency steering controls, remove power pack. For details of hydraulic system, see under Hydraulics.		X X X X

/Serial 9.....

(a)	(b)	(c)	(d)	(e)	(f)
9	Vehicle body	Major items: Turret and cupola Lifting arrangements: No special equipment except 3 leg sling for removal of cupola. Removal and replacement: Hull manufactured from rolled and cast steel armour, weldable by electric arc, low hydrogen rods or CO_2 processes. Vehicle tools stowed in eight stowage bins fitted between track guards and hull. Ammunition, rations and crew personal stowage contained in fibre glass containers,racks, and bins in drivers and fighting compartment. Larger containers if damaged can only be removed and repaired after lifting off cupola. Drivers hatch required spring compressor for removal and replacement. Drivers seat mechanical linkage system providing elevated and lowered seat positions for head and back rest. Can be removed from vehicle for repair. The turret body comprises turret race, cupola assembly, gunners and commanders seat assemblies stowage containers and racks.	Major items: Lifting arrangements: Chain ratchet block rope and pulley stand to raise front armour, for servicing etc. Removal and replacement: Hull manufactured from rolled steel armour plate, weldable by electric arc, low hydrogen rods or CO_2 processes. Vehicle tools stowed in either two detachable 'pods' on hull rear and three bins mounted on hull upper armour. Ammunition stowed only in Autoloader. Rations are not carried in this vehicle. Cupola and loader/driver hatch assemblies can be removed,repaired and replaced using simple hand tools. Simple vertical motion spring assisted pillar system for all seats. All can be removed from vehicles with a minimum of effort. This vehicle has no equivalent assembly.	X X X	
10 a. b. c.	Electrical and Gun Control Equipment. Charging system Battery maintenance Battery protection - extreme climatic conditions.	Main engine - D.C. generator. Auxiliary engine - generator/alternator set. Load sharing facilities. Six 12 V batteries are employed. Heating of battery electrolyte in cold climatic conditions and limiting charging rate from generators in tropical climates.	Main engine - Alternator No.1 MK 2. The three phase output is converted to d.c. in a diode box. Gas turbine engine. This has a combined generator/starter. No load sharing facilities are incorporated,the gas turbine generator being automatically open 'circuited when main engine' generator is ON LINE. Two 12 V batteries only. No comparative system.	X X X	

/Serial 10 d. .....

(a)	(b)	(c)	(d)	(e)	(f)	
10 Ctd	Electrical and Gun Control Equipment					
d.	Starting system	Main engine - Starter No. 3 MK 1 Auxiliary engine - Starter No. 4 MK 1	Similar to Chieftain Gas turbine - Starter/generator Boeing 10 - 40051 - 1 This circuit includes time relays for heater plugs, oil pressure delay to transfer box, start counter and hour meter.			X
e.	Gear change system	Electrically controlled gear changing system. This controls the changing of the six forward and two reverse gears. Inhibiting circuits are also incorporated.	No comparative system.		X	
f.	NBC System	Protection against radiation from NBC attacks The system also provides ventilation in normal closed down conditions.	No comparative system.		X	
g.	Fire warning system	Firewire fire warning system. This system will give both audible and visual warning of fire conditions in the engine compartment.	No comparative system		X	
h.	Fuel Gauge Indicating System	This system indicates the amount of usable fuel in either lh or rh fuel tanks. The gauge is graduated to indicate the tank full conditions irrespective of whether diesel or petrol is used.	Only indication to driver is a warning lamp which becomes energised when the amount of consumable fuel drops to 90 litres or less.		X	
j.	Fuel Pump Solenoid	CAV type.	CAV type.			
k.	Bilge pumps-2 off	No comparative system.	Electrically operated. Type 32 - 17 - 19 Bilge.			X
l.	Dust Extractor Fan Motor	Electrically extracts dust from main engine filters.	Mechanically extracted.		X	
m.	Main Engine Fuel Pump	Pressurizing Pump No. 3 MK 1 2 off on Chieftain	Pressurizing pump 1 off on S Tank		X	
n.	Auxiliary Engine Fuel Pump. (Chieftain)	Pressurizing Pump No. 2 MK 1.				
o.	Gas Turbine, Fuel Pump (S Tank)		Boeing 494 988 - 1			
p.	Vehicle Lighting System	Of no significant difference. The Swedish	tank has IR headlamps fitted.			
q.	Light Projector No.2 MK 3	Projection of white and IR light in elevation and bearing.	No comparative system.		X	

/Serial 10 r.....

(a)	(b)	(c)	(d)	(e)	(f)
10 Ctd	Electrical and Gun Control Equipment				
r.	Main Armament Firing Circuit	Normal, auxiliary and emergency firing mode.	No emergency facility.	X	
s.	RMG Firing Circuit	For firing 3 controlled shots in 1 second	No comparative system	X	
t.	Co-ax machine gun circuit	Electrically controlled single gun system	Electrically controlled dual gun system, each gun firing alternately.		X
u.	Commander's Cupola and Machine Gun	No comparative system	The machine gun, mounted on the cupola, is stabilized in traverse by means of an amplified gyro signal being fed to a control valve solenoid.		X
v.	Commander's Cupola Sight	No comparative system	The sight is stabilized in elevation by means of an amplified gyro signal fed to a servo motor. Under non-stab conditions the commander's machine gun can be linked to the sight.		X
w.	Main Armament Loading	Manual	The system is operated by hydraulics, the loading and unloading sequences being initiated by electrically controlled solenoid valves.		X
x.	Gun Control Equipment	The control of main armament in non-stab and stab conditions is completely electrical. The AC supplies required for the equipment are derived from a rotary inverter. Monitoring test equipment is built into the system.	The hydraulic system, operating the elevation of the main armament (and hull) is controlled and stabilized through synchro-links units which transmit error signals, until nulled, through amplifiers to solenoid controlled oil valves. The synchro-link transmitters are located in the positions listed:- (1) Front and rear wheel stations. (2) Driver's control pillar. (3) Commander's control pillar. (4) Elevation pumps. In addition to stabilization the average height of the vehicle is also maintained. The required AC supplies are derived from a static inverter. Test equipment is not built into the system but supplied as an accessory or special tool. This can be connected to a conveniently situated test adaptor socket.		X

COMPARATIVE MAINTENANCE LOAD - ARMOUR

SER. No.	ASSEMBLY	COMPARATIVE FEATURES		GREATER LOAD	
		CHIEFTAIN	'S' TANK	CHIEFTAIN	S TANK
1	Barrel	Weight 2360 lbs Length 260 in. Time, removal and replacement 18 man hrs (3x6) Lifting arrangements: F 434 or Leyland recovery vehicle Number of connecting/spannering points 59	Weight 2094 lbs Length 246 in. Time, removal and replacement 2 man hrs (2x1) Lifting arrangements: a. Leyland recovery vehicle. b. Special wire sling: than enough to pass between the barrel and half round housing in the hull Number of connecting/spannering points 8	X	
2	Breech Mechanism	Weight of breech block 140 lbs Time for dismantling and assembly 1 man hr (1x1) Lifting arrangements for breech block Adaptor fitted to breech block Number of spannering/connecting points 6	Weight of breech block 121 lbs Time for dismantling and assembly 1 man hr ($\frac{1}{2}$ x 2) Lifting arrangements for breech block Adaptor fitted to breech block to enable the block to be lifted manually. Number of connecting/spannering points 11	-	-
3	Breech Ring	Weight 1332 lbs Time for removal/replacement 14 man hrs (7x2) Lifting arrangements F 434 or Leyland Recovery Vehicle.	Weight 1168 lbs Time for removal/replacement 9 man hrs (4½x2) Lifting arrangements a. Leyland Recovery Vehicle b. Lifting adaptor secured by two bolts to top of breech ring.	X	
4	Elevation Gear Box	Weight 353 lbs Time for removal/replacement 22 man hrs (11x2) Lifting arrangements Haltrac hoist and recovery vehicle Connecting/spannering points 116	NOT FITTED	X	

/Serial 5.....

(a)	(b)	(c)	(d)	(e)	(f)
5	Traversing	Weight 286 lbs Time for removal/replacement 22 man hrs (11 x 2) Lifting arrangements: Recovery vehicle Connecting/spannering points 115	NOT FITTED	X	
6	Recuperator	Weight 145 lbs Time for removal/replacement 12 man hrs (6 x 2) Lifting arrangements: F 434 or Leyland Recovery Vehicle Connecting/Spannering points 38	Weight 102 lbs Time for removal/replacement 26 man hrs (13 x 2) Lifting arrangements: Recovery vehicle to take the weight of the recoil cylinder when being lowered at an angle through the rear of the hull. Connecting/Spannering points 68		X
7	Buffer	Weight 136 lbs Time for removal/replacement 14 man hrs (7 x 2) Lifting arrangements: F 434 or Leyland Recovery Vehicle Connecting/Spannering points 36	The buffer and recuperator are incorporated in one cylinder and there are 2 of these assemblies fitted.		X
8	Rammer	NOT FITTED	Weight 30 lbs Time for removal/replacement 14 man hrs (7 x 2) Connecting/Spannering points 56		X
9	Auto-Loader Magazine	NOT FITTED	Weight 80 lbs Time for removal/replacement 22 man hrs (11 x 2) Connecting/Spannering points 64		

SER No.	ASSEMBLY/ SYSTEM	COMPARATIVE FEATURES		GREATER LOAD	
		CHIEFTAIN (c)	'S' TANK (d)	CHIEFTAIN (e)	S TANK (f)
1	Fill and check points	Only 'fuel' and 'coolant filling points are indicated (cast with covers and on caps). Important that hydraulic fluid filling points should be marked to indicate type of fluid. Engine and transmission covers have to be lifted to carry out checks.	All access plugs/covers etc. are identifiable by letters and words stamped by metal punch beside the plug etc. The type of lubricant to be used is indicated by stamped words or colour code. Two dipsticks are a little difficult to replace.	-	-
2	Fuel check	Gauges on some vehicles not reliable (tend to 'stick'). No indication of reserve, there is in fact 20 gallon reserve when zero is indicated on both tanks. (No means of controlling flow when draining the base tank. (Fuel pumped out of main tanks due to size of container required - not servicing.	No fuel gauge fitted. Warning light indicates 90 litres reserve left from 960 litre capacity. (Large amount of fuel is trapped in main tanks by a baffle which was not drilled with by-pass holes when made) Dipstick with vehicle kit.	-	-
3	Main Engine Coolant	One filling point	Both radiator caps must be removed, when topping-up or checking, to relieve possible air lock in one radiator. Three filling points available. (Also see Serial No.6)	-	X
4	Battery filling (Distilled water)	Batteries inaccessible but new filling device will overcome this problem.	Good access, each cell can be visually checked. Batteries easily removed.	X	
5.	Draining Assemblies From Under the Hull 'Draining Tool/Device'.	Plugs are used, flow control is difficult. Several bolts on each access plate, add time to task of draining.	The draining tool supplied with vehicle kit is very effective although caution is required when holding the tool and draining hot oil. An improvement could be made by fitting tap/valve at bottom end of tool. One plug to each drain point speeds up task of draining.	X	

/Serial 6.....

(a)	(b)	(c)	(d)	(e)	(f)
6	Draining Coolant	Hose required (not in vehicle kit).	Emergency hatch must be removed. Pipes required, not in vehicle kit. Drain taps too close to the hull which does not allow clip to be used to secure pipes onto the taps. Suggest thicker washer between tap and hull.		X
7a 7b	Steering Clutch and Brake Check/ Adjustment Steering Bevel Gearbox	Simple visual check of disc pads only required. TIME: Minutes	Both assemblies check by measuring gaps. Clutch adjustment simple - crew task. Brake adjustment is REME task. (WEEKLY check). TIME: 1½ hours. (Decks must be raised for all tasks)		X
8	Final Drive Magnetic Plug	Single magnetic rod on the plug.	Easily broken - (Rod consists of laminated iron and brass (2) discs).	-	-
9	Hull access plugs	Access plates are retained by sets of bolts, therefore plates take longer to remove.	Access plugs are extensively used. They are removed easily and quickly. The combination tool, when used through an access plug hole, can damage the lead-in thread if it is not used correctly.	X	

SERVICING LOAD ARISING FROM UNCONVENTIONAL FEATURES

SER. No.	ASSEMBLY/ SYSTEM	OBSERVATIONS/COMMENTS		
		FAVOURABLE	UNFAVOURABLE	SUGGESTIONS
(a)	(b)	(c)	(d)	(e)
1	Suspension pre-load check (WEEKLY)	Check is carried out from the Commander's seat, it is not physically tiring, all valves, gauges etc are clearly visible.	This task should be carried out by an experienced crew man; (preferably REME though). The task is too complex for committing to memory.	Vehicle is lowered fully on suspension. Simple warning/reminder notice should be attached to the 'Gas and Oil tap casing'.
		TIME:- 1 Hour (One Man) If the pressure accumulator requires charging, the vehicle's traversing and elevating ability is affected which is very noticeable to the driver, so an hour's weekly check could be reduced to minutes by checking the response to controls. Over a period of several weeks at ETW no Nitrogen has been added.		Make this a monthly check.
2	Replacing the transmission (ANNUAL)		When connecting the drive shafts, the track must be broken to remove an end cap.	There is sufficient slack available in the track to enable an adjustable strut to lift the track clear of the cap. The track could be raised with the strut by lowering the vehicle on its suspension or by jacking the strut up.
3	Engine decks	The decks are only raised weekly for servicing.	Each deck (2 off) weigh 1,000 lbs. Pillar, block and tackle is used to raise each in turn which is 'on vehicle' equipment.	
4	Prop-shaft lubrication		The power pack must be removed to bi-annually lubricate some of the universal joints.	As this is stated to be a bi-annual task, this should be indicated in the approved section of engine removal/ replacement instructions.
5	Barrel support	Lubrication of the support bracket does not appear necessary as there is a ¼ inch gap between the collar and the barrel.		

LOADING ON TO TRANSPORTER BY TOW BEHIND

(a)	TASK (b)	POSSIBLE (c)	GENERAL REMARKS (d)
1	Driving on forward, suspension raised.	Yes.	A single gun plank was placed under each of the trailer loading ramps extending to the rear (to reduce the ramp angle). Without the planks the tank could not drive up the ramps due to track slip. The Swedish engineer stated that the all steel tracks fitted to the tank were non standard.
2	Driving on backwards, suspension raised.	Yes, but with muzzle fouling ground.	With 2 gun planks one on top of the other, placed with their ends butted against the lower edge of each loading ramp to form a platform, despite this the gun muzzle fouled the ground before the tank tracks were fully clear of the gun planks.
3	Winch on forward, suspension lowered.	Yes, but with fouls between muzzle and snatch block and hull and loading ramps.	(1) 2 gun planks one on top of the other placed under each of the loading ramps extending to the rear (to reduce the ramp angle and to form a run up to the ramp). The tank was connected to the snatch block with the towing hawsers; as the tank moved up the ramps the gun muzzle fouled the snatch block when adjacent to the trailer deck rollers. (2) 2 gun planks one on top of the other were placed with their ends butted against the lower edge of each loading ramp (to form a platform). The gun muzzle clears the snatch block, but the underside projections of the tank hull, final drive housing, and towing lugs foul the loading ramps. Clearance between rear of hull and ground is negligible.
4	Winch on forward, suspension raised.	Yes.	2 gun planks one on top of the other placed with their ends butted against the lower edge of each loading ramp. Rear of hull clears the ground by approximately 1".
5	Winch on backwards, suspension lowered.	Yes, but with fouls between hull and ramp/decking.	2 gun planks one on top of the other placed under or against the loading ramps, the rear of the tank hull fouls the ramps and trailer decking.
6	Winch on backwards, suspension raised.	Yes.	Adequate clearance between tank hull and trailer decking is afforded by removing rear lashing assemblies from trailer.

a. All loading was carried out using up to a total of (4) four gun planks.

b. All winch pulls were 3 to 1, the snatch block and towing hawsers are trailer equipment.

	TASK	POSSIBLE	GENERAL REMARKS
1	Gun forward, suspension raised.	Yes.	No difficulties.
2	Gun forward, suspension lowered.	Yes.	This is only possible if the front end of the tracks are packed up by single gun planks to raise the gun barrel clear of the trailer swanneck. Should the tank be moved back on the trailer platform to enable the gun to clear the swanneck without these gun planks, the trailer front lashing gear cannot be attached. The trailer track guides must be removed before loading as they foul the belly of the tank.
3	Gun backwards, suspension raised or lowered.	Yes.	Trailer track guides must be removed before loading the tank if it is to be lashed with the suspension in the lowered position.

This appendix outlines the unusual tools that would be required in first and second line Workshops. Tools for armament, wireless and electrics are NOT included.

In general, the hydraulic pump, the driving and idler sprockets, and the main body of the tank embodies the use of hexagon socket head screws, metric thread. The K60 engine, the Boeing 502 Gas Turbine and the road wheels use hexagonal headed bolts with UN thread. Use is also made of the crosshead type of screw in metric and UN threads.

The BOFORS team were in possession of a large number of tools stored in metal containers. The containers (6'x6'x7' high) are suitable for use as stores and offices, and can be locked up and transported.

While actually working on the equipment the fitter has a canvas roll containing:-

OE/Ring Spanners 8 mm to 32 mm, 15 to the set.
Double ended knuckle spanners 8 mm to 19 mm, 6 to the set.
Hide hammer 2 lb - 1
Circlip pliers 6 inch - 1
Pinch bar 18 inch - 1
Adjustable Spanners 4 in. to 8 in. 3 per set.
" " 15 in.- 1
Key set hexagonal, 5 per set.

It was apparent that the metric spanners were also used on the UN bolts with the consequent burring of the heads.

In addition, there are a number of special tools and lifting devices:

REMOVAL OF THE POWER PACK

A lifting beam, a block chain ratchet and lever, and a special three piece tool is required in addition to the tools in the canvas roll. The lifting beam is attached to the power pack frame, and the block chain and ratchet are required to tilt the power pack into position. The special three piece tool comprises a hand brace, an extension rod and a 30 mm socket; this tool is required to remove and replace the Power Pack holding down bolts. In addition, there are three special stands which are attached to the Power Pack frame before it is lowered to the ground. They are removed before the Power Pack is replaced in the hull.

SLAVE DRIVE

This piece of equipment is used for testing the hydraulic system when the Power Pack has been removed from the hull. It consists of an electric motor attached to an L shaped metal frame; weighing approximately five hundred weights. Particulars are:-

380 V; 50 cycles; 2 speeds 750/1500 rpm; rating 15/23 KW.

AMPLIFIERS

A meter for testing the amplifiers of the traverse, elevation and cupola systems is used. Particulars are:-

Styrstanslade KKH70, 37 connections, 6V, 0-100 mA 1106241, MS 3106B28-21P USA.

ENGINE COVERS

These are raised and lowered with the block chain ratchet and lever, plus a stand which also holds the covers in the open position while work is in progress.

ROAD WHEEL STATIONS

When the road wheel station is re-assembled the pendulum arm has to be set in direct relation to the synchro that controls it. A jig and tool are necessary for this operation; the jig to hold a clinometer, the tool to set the synchro in the correct position.

SPLITTING THE TRACK

This is a simple process and accomplished with a long bar and a heavy hammer. The pins are held in position by an expendable welch plug.

Plate 1 'S' TANK - FRONT VIEW
Note: Left hand headlamp cluster on vehicle missing, see Plate 13

Plate 2 'S' TANK - RIGHT HAND VIEW WITH REAR BIN FITTED

Plate 3 'S' TANK - LEFT HAND VIEW WITH REAR BIN REMOVED

Plate 4 'S' TANK - RIGHT HAND FRONTAL ¾ VIEW

Plate 5 'S' TANK - LEFT HAND FRONTAL ¾ VIEW

Plate 6 'S' TANK - RIGHT HAND REAR ¾ VIEW WITH RIGHT HAND REAR BIN ONLY FITTED

Plate 7 'S' TANK - LEFT HAND REAR $\frac{3}{4}$ VIEW WITH RIGHT HAND REAR BIN ONLY FITTED

Plate 8 'S' TANK - RIGHT HAND FRONT $\frac{3}{4}$ VIEW, SUSPENSION IN THE LOWERED POSITION

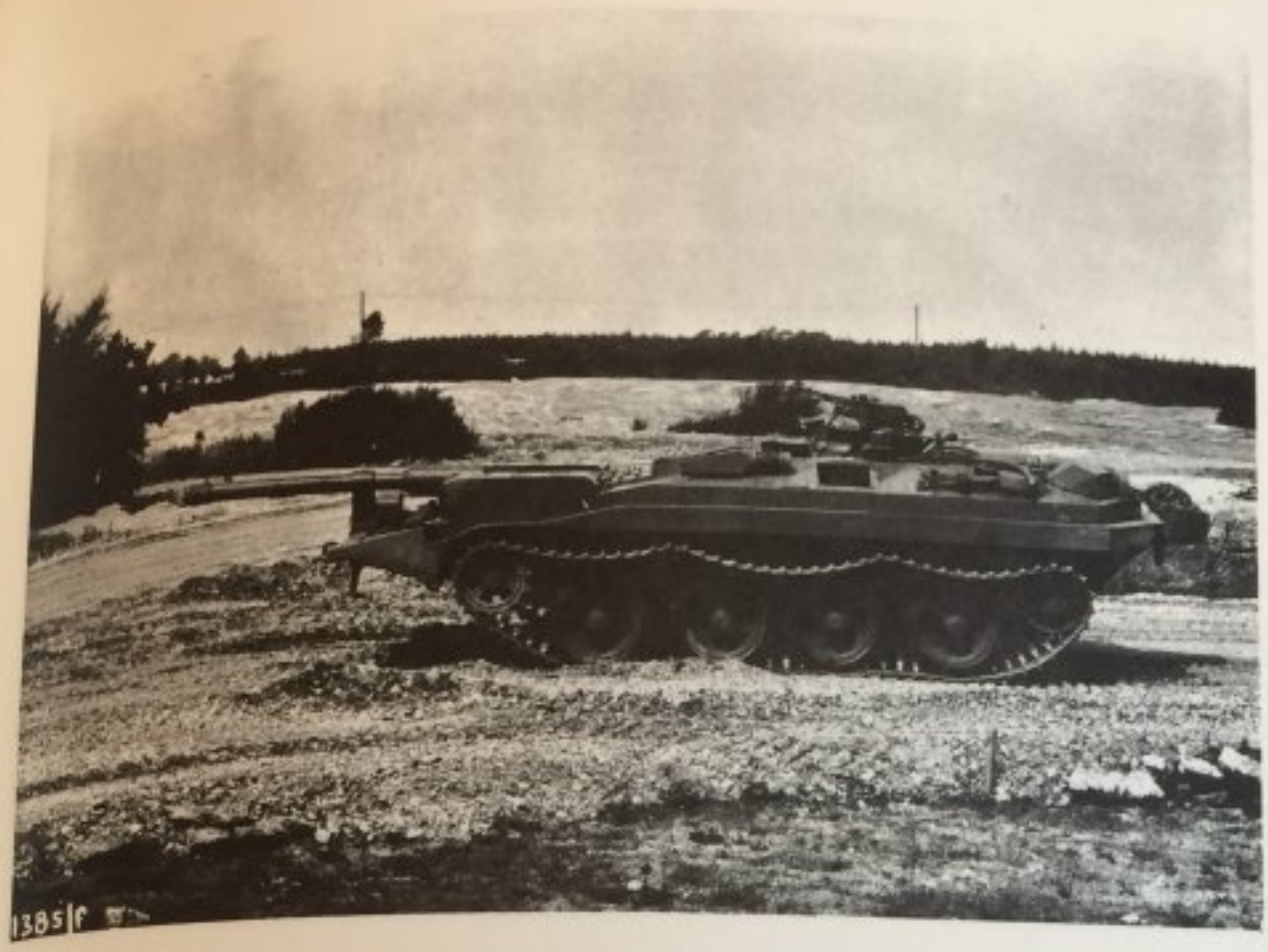


Plate 9 'S' TANK - LEFT HAND VIEW WITH SUSPENSION IN THE LOWERED POSITION

Plate 10 'S' TANK - LEFT HAND VIEW SHOWING FULL DEPRESSION

Plate 11 'S' TANK - LEFT HAND VIEW SHOWING FULL ELEVATION

Plate 12 'S' TANK - REAR VIEW WITH BOTH REAR BINS FITTED

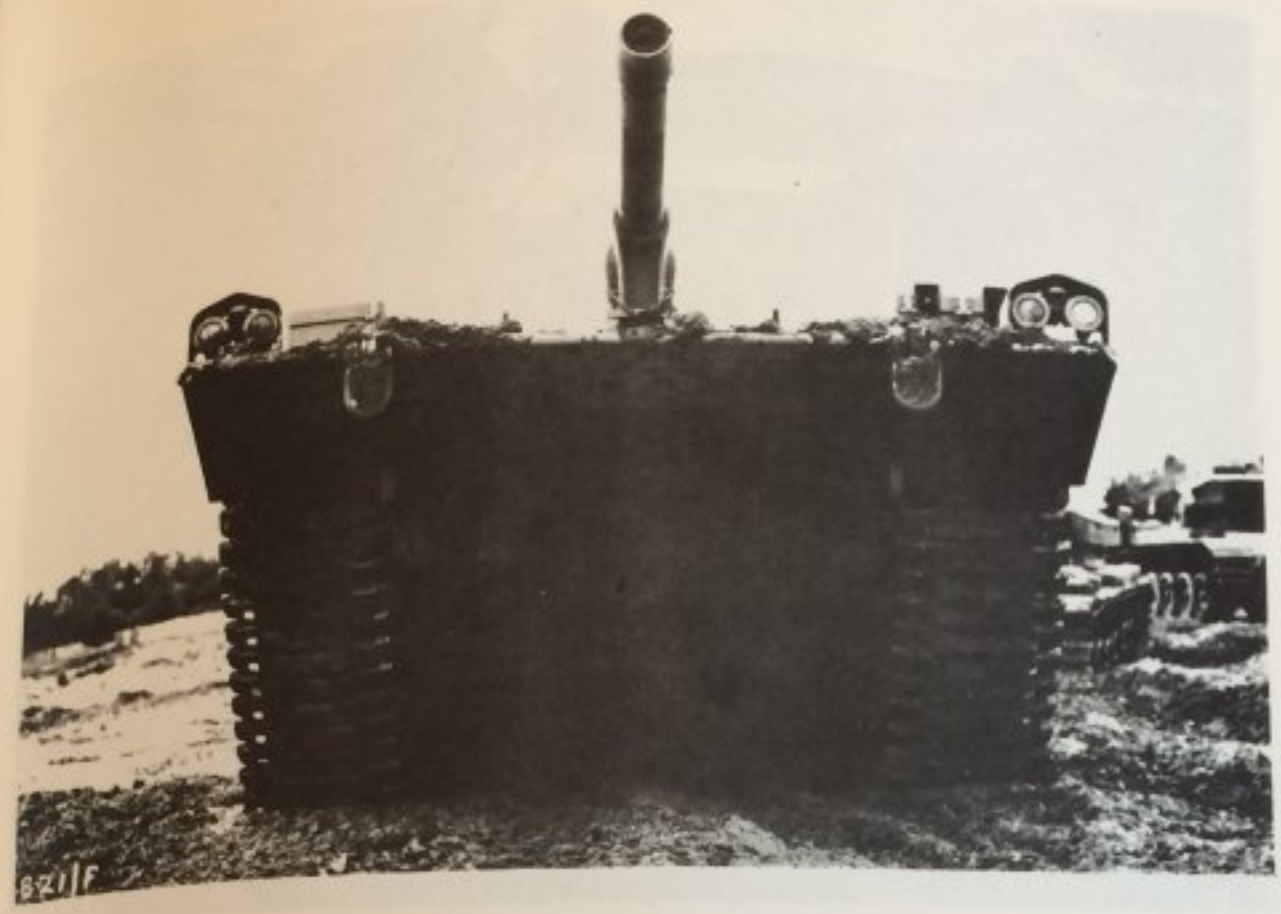


Plate 13 'S' TANK - FRONT VIEW IN FULL ELEVATION

Plate 14 'S' TANK - LEFT HAND REAR $\frac{3}{4}$ VIEW SHOWING FULL DEPRESSION

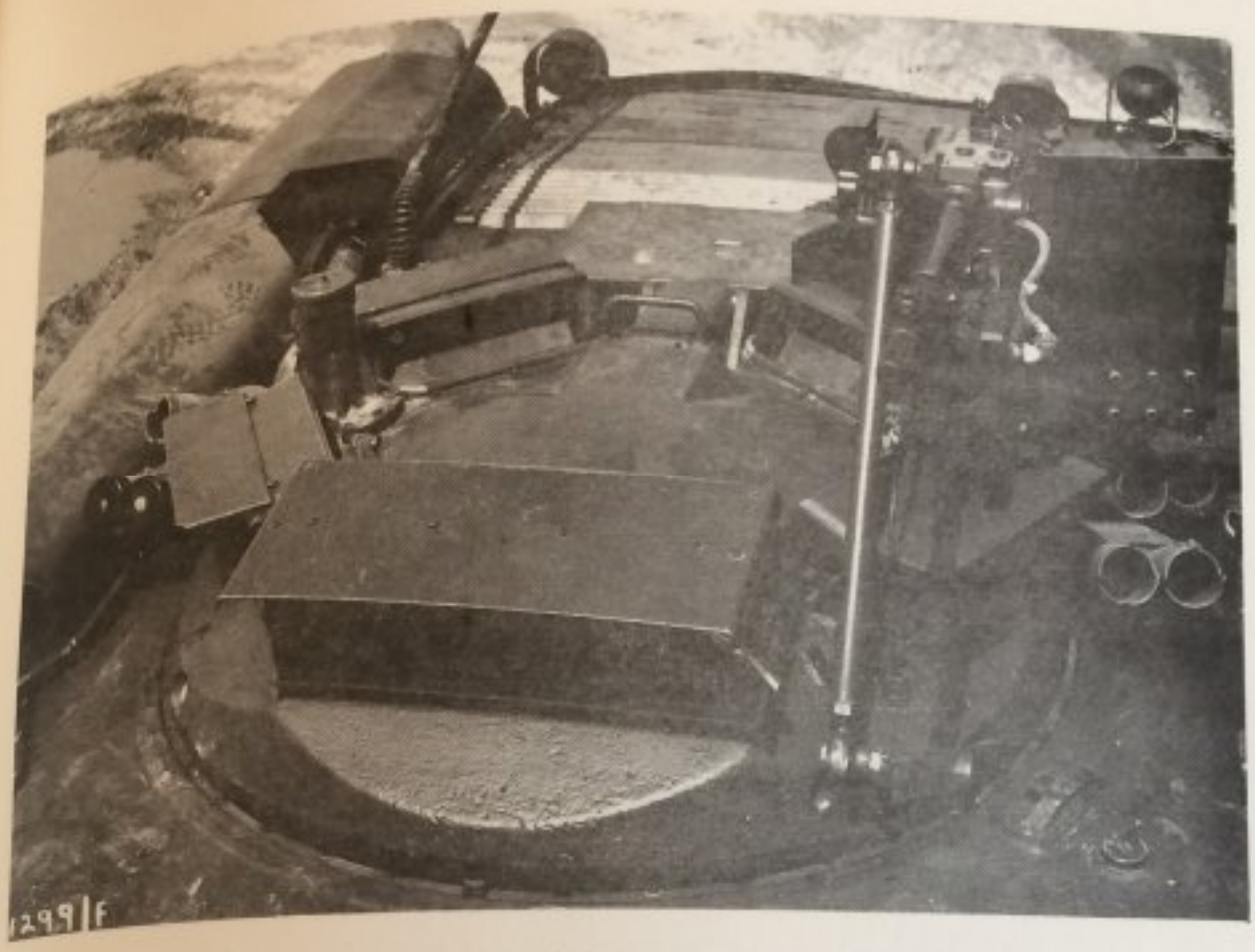


Plate 15 'S' TANK - CLOSE UP OF COMMANDER'S CUPOLA

Plate 16 'S' TANK - REAR VIEW FROM ABOVE

Plate 17 'S' TANK - FRONT VIEW FROM ABOVE

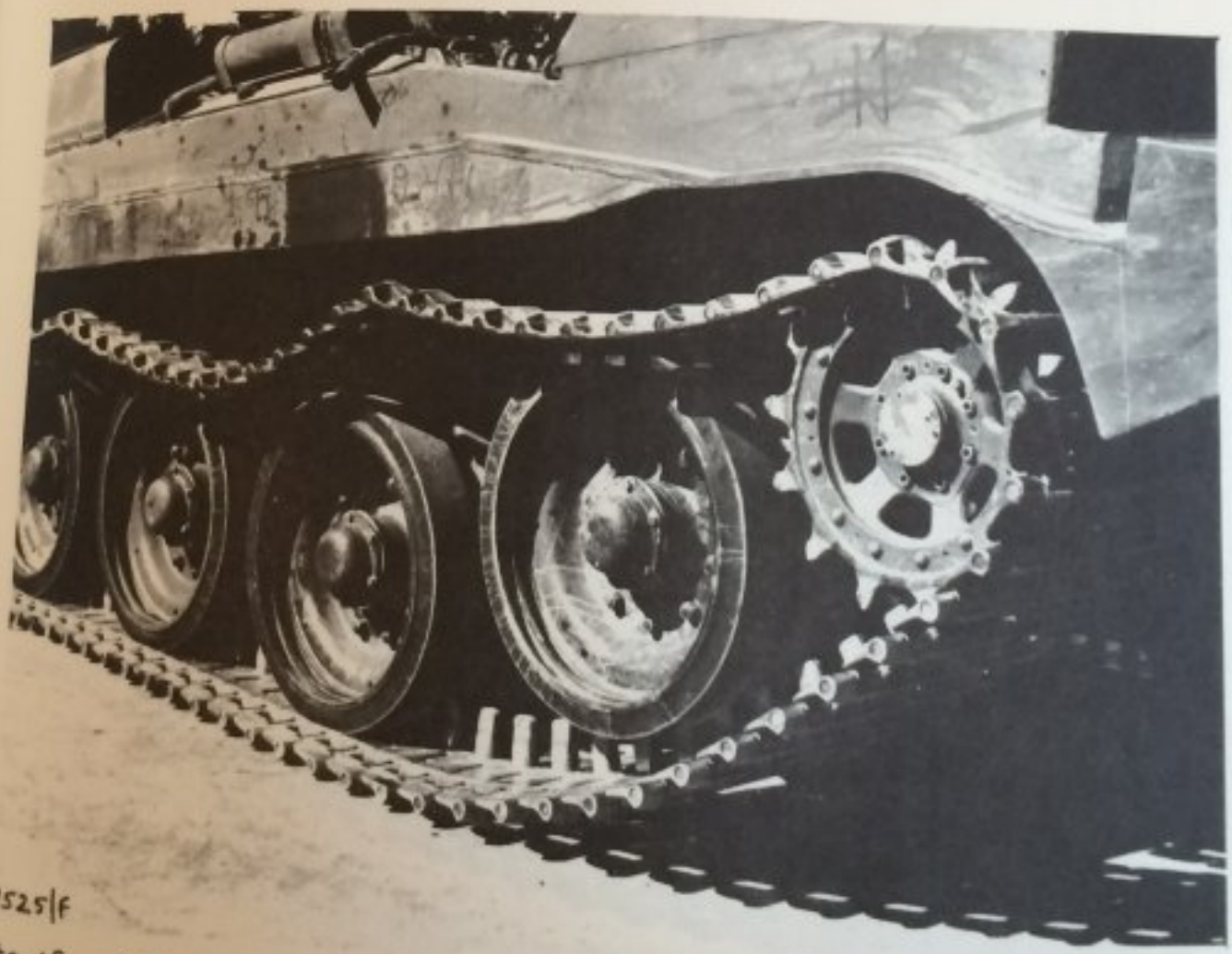


Plate 18 'S' TANK - SUSPENSION - SHOWING RIGHT HAND FRONT ROADWHEEL IN THE 'CARRIED' POSITION

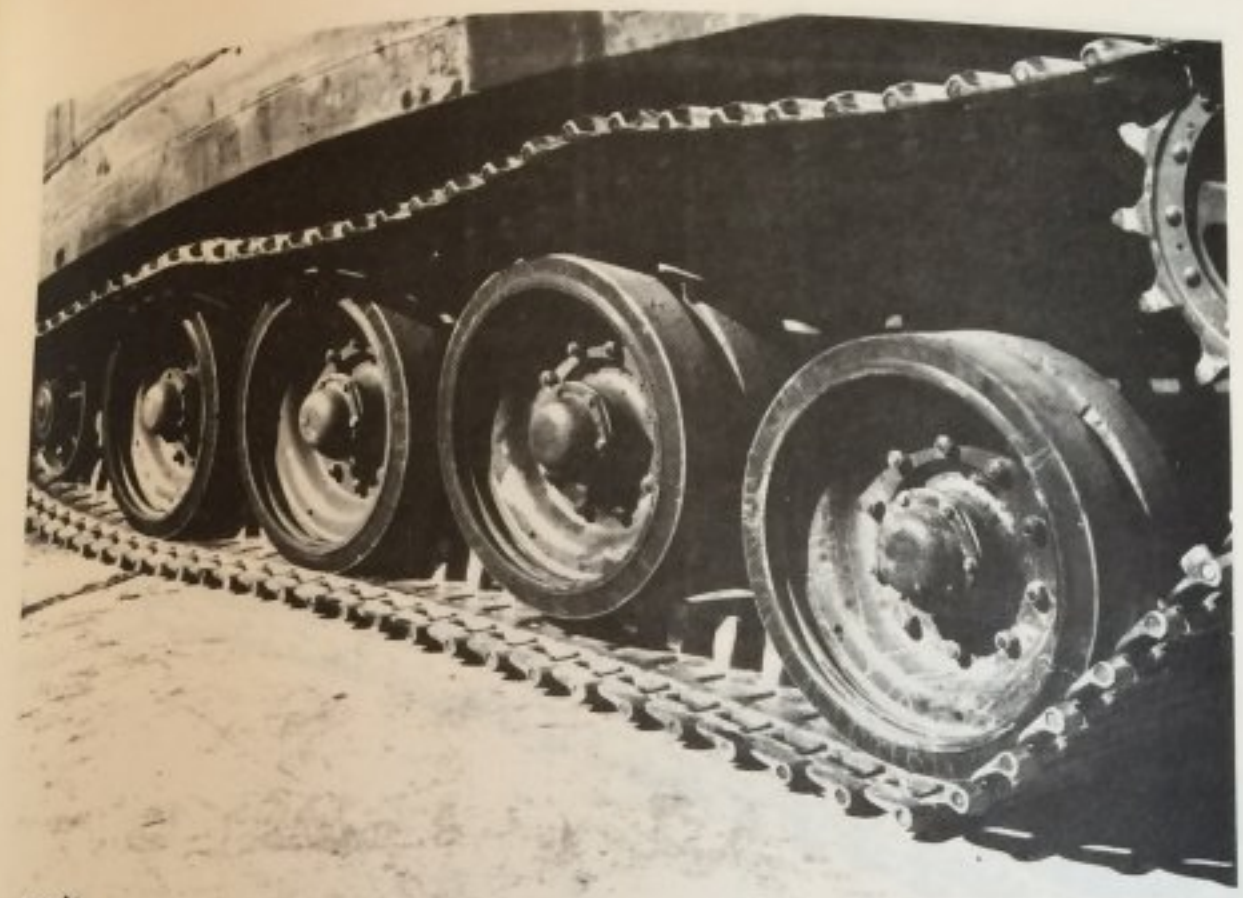


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Plate 19 'S' TANK - SUSPENSION - SHOWING RIGHT HAND 2nd ROADWHEEL IN THE 'CARRIED' POSITION

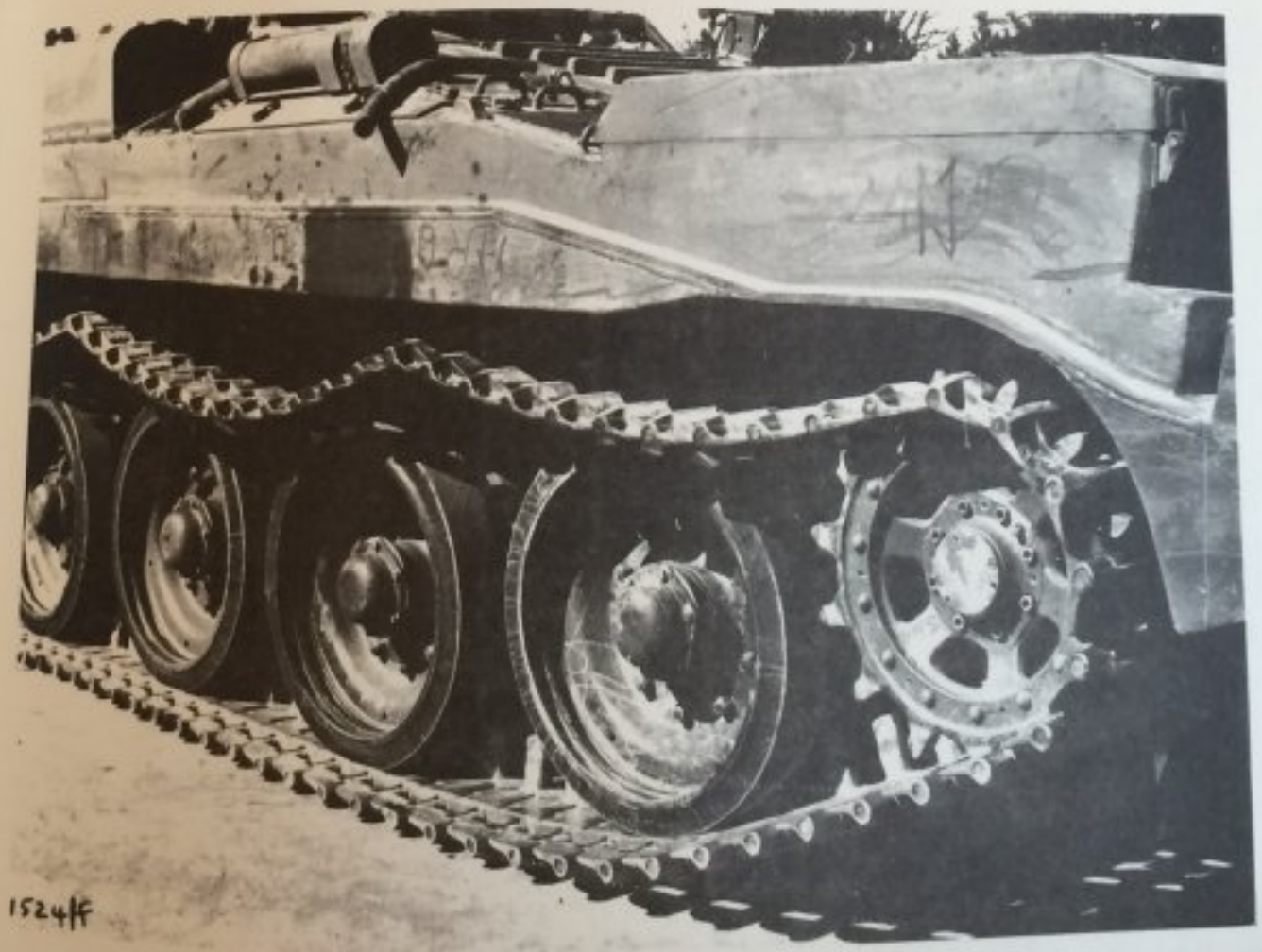

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Plate 20 'S' TANK - SUSPENSION LEVEL WITH THE RIGHT HAND FRONT ROADWHEEL CARRIED

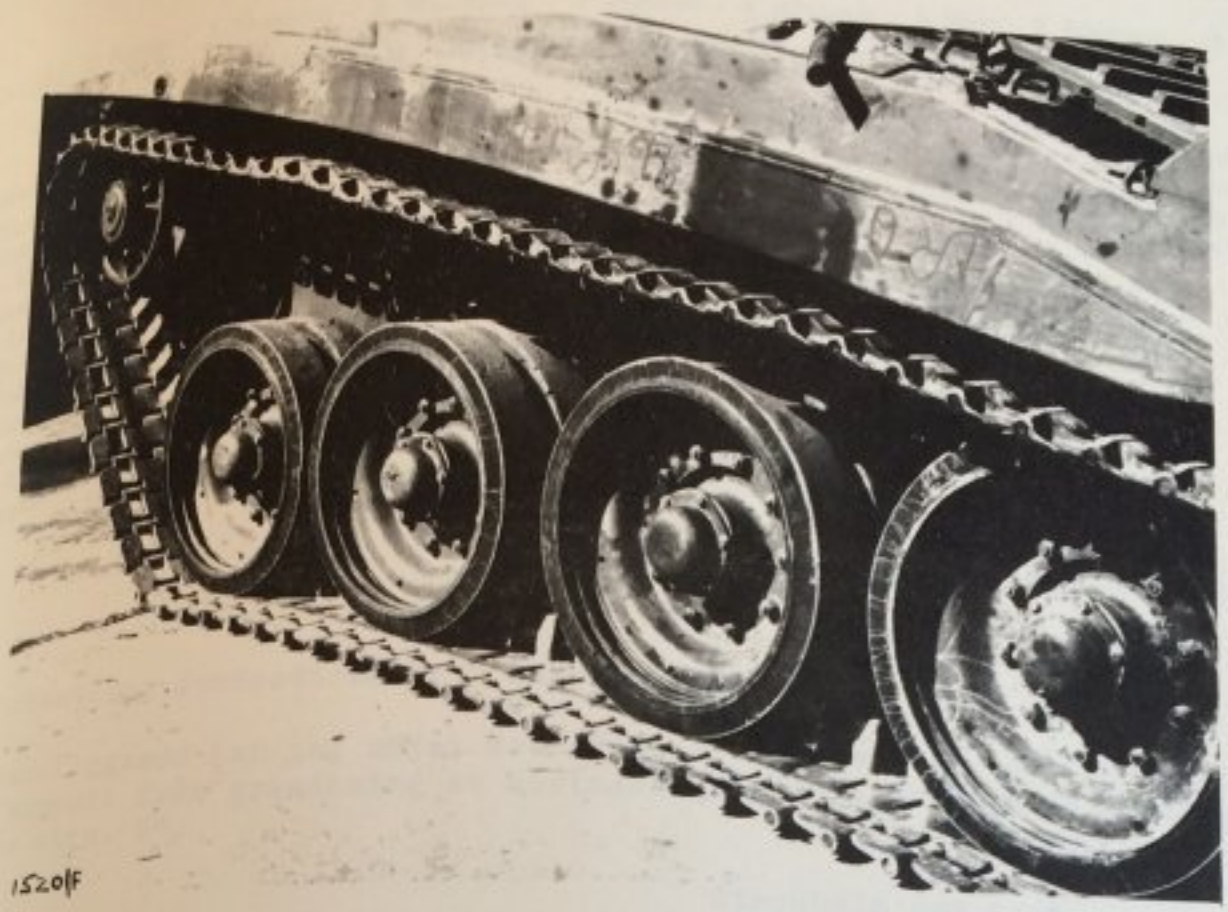

Plate 21 'S' TANK - SUSPENSION IN FULL DEPRESSION WITH THE RIGHT HAND FRONT ROADWHEEL CARRIED