Development of a Modular Combat Veh Family For TK T-72

BY

Maj Y S PARMAR

DISSERTATION

Submitted in Partial Fulfilment of the Requirement

For the Degree of Master of Technology in Mechanical Engineering

of

JAWAHAR LAL NEHRU UNIVERSITY

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CERTIFICATE

Certified that the dissertation "Development of a modular Combat Veh family for TK T-72" submitted by Maj YS Parmar in partial fulfillment of the requirement for the award of Master of Technology (Mechanical) degree of JNU, is a record of Student Own Work carried out by him under my supervision and guidance.

Col TV Sadasivan
~~Headquarters~~
~~Base Wksp Group EME~~
~~Delhi Cantt - 10~~

संयुक्त निदेशक
Jt Director
संग्राम वाहन निदेशालय
Dte. of Combat Vehicles
अनुसंधान एवं विकास संगठन
Research & Development Orgn.
रक्षा मंत्रालय, नई दिल्ली-110011
Ministry of Defence, New Delhi-110011

Dated :

COUNTER SIGN

Col
Head AE Dept
(COL. K.K. Dhingra)

SYNOPSIS

1. The T-72 is one of the great success stories of modern tank history. The concept of Modular combat vehicle family for tank T-72 offer feasible alternatives that should be of interest to Army and R & D institutes all over the world. In the modular concept the constant element consists of a 'chassis' frame, running gear of a heavily protected crew pod to which an interface panel is added alongwith one of a 'functional pods'. The functional pod may be meant for a tank role, fire support role, (Tank Destroyers) self propelled gun role or an Infantry Combat Vehicle (ICV) role.

2. Existing and under development tracked vehs based on modular concept has been studied to suggest new approaches in developing, implementing and fielding modular combat vehicle family for Tank T-72. Analysis of the basic T-72 design suggests that it is feasible to have variants such as Tank destroyers, self propelled gun or ICV based on T-72 chassis. Easy to monitor and with reduced inventory, these vehicles require little support and only a minimum of crew training. Their wide tracks and improved suspension allow them to traverse all but the boggiest of terrain.

3. It is envisaged that the practice of continued evolution of existing fielded system will considerably abridge the gap between prolonged design and development process. With the pod's available in the theatre of operation it will be possible to change the T-72 into it's variant, in situ, based on the tactical situation. Hence maximum flexibility, both tactically and technically, will be obtained from a limited inventory resulting in reduced financial and logistical cost. The modular concept will also result in improved engg sp as defective/damaged module can be easily replaced.

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FIG 1. TANK T-72

FIG 2. A T-72 CHASSIS

INTRODUCTION

1. The revised nature of Army mission all over the world, calls for a new and revolutionary way of restructuring procurement and acquisition philosphies for modernization of armoured vehicles. The everchanging global political situation is straining an invariably decreasing defence budget in almost all the countries.

2. The T-72 is one of the great success stories of modern tank history. Fast reliable yet relatively cheap to construct these tanks are presently in service with Indian army and a large No of other countries such as Iraq, Syria, Libya etc. Models of T-72 are being built not only by soviet state arsenals but also under license in Czechoslovakia, Poland, India and Yugoslavia. These tanks have always been built to a cheap, rugged design encompassing good fire-power, mobility and armoured protection. Easy to maintain, they require little support and only a minimum of crew training. It's wide tracks and improved suspension allow it to traverse all but the boggiest of terrain. Although extensive trial for 'Arjun' are being held in India , the T-72 will remain in front-line service for many years to come.

3. The Infantry fighting Vehicle/ Command and support Vehicle (IFV/CSV), the Air Defence (ADV) the tank destroyer and Advanced Field Artillery System (AFAS) are some of the other forms of Armoured vehicles. India is having soviet designed BMP (Boyevay Mashina Pekhoty) as the ICV to allow infantry to keep attacking at high speed. Although the BMP is small by western standard, it's 250-hp six cylinder engine is nevertheless powerful enough to match the main battle tanks in cross country to accommodate an eight man section of fully equipped infantryman. Catapult, based on Vijayant chassis is the in service self propelled howitzer in India. It has a 130 mm armament with maximum range of 2700 mtrs.

4. Apart from this, locally produced 130mm catapult self propelled gun and the remains of 68, 105mm Bickers Defence systems Abbot self propelled guns, the Indian Army does not have any modern self propelled artillery system in service. These howitzers generally are deficient in range, lethality & survivability and also lack the mobility to keep up with rest of the manoeuvre force. These limitations, combined with a heavy crew work load, severely impede the howitzer's ability to engage in close support manoeuvre and effectively demonstrate its full fire power potential. It is therefore paramount to consider new approaches in developing, implementing and fielding an advanced field artillery system.

Armoured Fighting Vehicles Families and the pod concept

5. In recent years there has been a trend towards the design of complete families of armoured fighting vehicles which have a wide range of components common, so enabling development time and costs to be dramatically reduced. Very often these vehicles have used proven commercial or military components that have already been used on other military vehicles. This helps to reduce life cycle costs which can be any thing upto three times the original cost of the vehicle. Separate from but utilizing the capability of the strap-on armour idea, is the module or pod concept, which requires that combat tasks be designed into separately manufactured interchangeable units.

6. In the proposed modular concept the constant elements consists of a chassis frame, running gear and a heavily protected crew/automotive pod to which an interface panel is added along with one of a 'Functional Pods'. The functional pods may be based on an external mounting (tank destroyer or fire support tanks) a

compartment with or without a slaved weapon pod (IFV,CSV) or some combination of two configuration eg on-site selection of assets for a given mission, much in the manner that ordnance is selected for air craft tactical ground support mission.

7. Three levels of modularization are needed; factory modularization for the production of short standard articulated hull units; base modularization to obtain maximum flexibility from a limited inventory and field modularization to allow the exchange of interface and functional modules on each of these types of hull unit.

AIM

8. Aim of this dissertation is to study the various aspect of development of a modular combat vehicle family for Tk T-72.

Origin of pod concept and the Armoured Family of Vehicles

9. In the tactical nuclear heydays of the late fifties and early sixties, the united states sponsored a major program using early M 60 sub systems to examine unconventional configurations. One of the goals was a crew pod offering a high level of the nuclear all around protection. Since the power train and armament were also to be lightly and separately podded and the pods carried in a frame, this was the first point of contact between the tank and aircraft protection philosophy. The project was scotched, as lack of any adequate means of slaving the armament or remoting the primary vision and sighting system made the basic geometry of the design unworkable. Later the emphasis also swung back to ballistic protection where the frontal are concept was suppose to hold good.

10. Now, at the end of this century looks to be a point at which the antiarmour threat, the state of the art, and the restorability concept would be combined to produce a design revolution. The mean are now available and these type of project could well be implemented.

11. In 1996 Royal Ordnance unvelled the RO 2000 family of full tracked vehicles but this is no longer being marketed as, shortly afterwards, the Royal Ordnance Factory at Leeds was sold to Vickers Defence Systems. Full details of the RO 2000 family of light tracked armoured vehicles were given in Jane's Armour and Artillery 1990-91 pages 526 to 528.

12. The private venture BMY Modular Support Vehicle (Jane's Armour and Artillery 1989-90 page 509) and the BMY Mobility Test-Bed (Jane's Armour and Artillery 1989-90 page 510) were never completed.

13. One of the most interesting armoured fighting vehicle families developed in recent years is the former Mechanic Creusot Lorie MARS 15 family which was launched in 1990. Despite intensive marketing and the construction of several proto type vehicles, there was no significant market response and the whole programme has been stopped by Giat Industries. Details of the MARS 15 were given in Jane's Armour and Artillery 1993-94 page 421 to 423.

14. In addition to these armoured fighting vehicle families, there are many other vehicles which share common components and some of these are listed here. Most vehicles, especially MBTs and armoured personnel carriers, have many variants of the basic chassis.

15. A typical example is the French Giat Industries AMX -30MBT whose chassis has been the basis for many vehicles including an armoured recovery vehicle, an armoured vehicle launched bridge, a twin 30mm self propelled anti aircraft gun, the EBG armoured engineer vehicle, the Roland surface-to-air missile systems driver training vehicle, the GCT 155mm self-propelled howitzer, the Pluton surface-to-surface tactical nuclear missile system and the Shahine surface-to-air missile for Saudi Arabia.

16. In the CIS, the PT-76 light amphibious tank has also formed the basis for a complete family of light armoured fighting vehicles, used for a wide range of battlefield roles. Further development of the BTR-50P armoured personnel carrier version took place in China and the former Czechoslovakia with modifications to suit local operational requirements.

17. While there are obvious cost advantages to developing a family of vehicles that share common components to reduce both procurement and life cycle costs, many of the more recents attempts to develop such families have failed.

18. This is because of lack of response from the market place, for example MARS 15, or changing operational requirements, for example the US Army's Armoured Systems Modernization plans which have so far come to nothing.

19. The next large European programme is the French VBM and German GTK programme which must over come political and Industrial, obstacles before even reaching the prototype stage.

Country		Sharing common automotive components
Argentina	:	TAM medium tank and VCTPIFV with Thyssen Henschel of Germany also offering variants. These are related to the Marder 1 IFV used by the German

Army.

Austria	:	Stay SK 105 and Steyr 4KA 7FA APC
Brazil	:	ENGESAEE-9 (6x6)armoured car and EE-11 (6x6) APC
France	:	Giat industries AMX-10RC (6x6) armoured car and AMX-10P tracked IFV Panhard ERC Sagaie (6x6) car and Panhard VRC (6x6) APCAMX-13 light tank VCI infantry fighting vehicles, 105mm SPH 155mm Mk F3 SPG DCA twin 30mm SOAAG Panhard AML (4x4) armoured car and M3 (4x4) APC Giat Industries VAB (4x4) and (6x6) APC and VBC 90 (6x6) armoured car.
Germany	:	Jagdpanzer Kanone and Rakets, and Marder 1 IFV
Italy	:	FIAT Puma 4x4 and 6x6 vehicles Infantry Armoured Fighting Vehicle and M113A1 APC
Spain	:	SANTABRABARA BMR-600 (6X6) APC and VEC (6x6) cavelry scout vehicle.
Sweden	:	Magglunds vehicle Pbv 302 APC, 1Kv-91 light tank. Brovbv941 bridgelayer and bgbv 82 ARV.
UK	:	Alvis Saladin (6x6) armoured car and Saracen (6x6) APC FV 432 APC and Abbot 105mm SPG Shortland (4x4) armoured petrol car and shortland (4x4) APC
USA	:	M41 light tank , M42 twin 40mm SPAAG, M44 155mm SPH. Lynx command and reconnaissance vehicle and M113 APC united Defence LP M2 IFV/M3 CFV and Fighting Vehicles and M113 A2 APC M110 203mm and M107 175mm self-propelled artillery weapons. M109 155mm and M108 105mm self-propelled howitzers

Former Yugoslavia : BOV APC, BOV anti-tank vehicle and BOV antiaircraft vehicles.

20. As on date no armoured veh family based on modular concept is existing. However, same chassis has been also used as different tank variants in some of the following armoured vehicles.

(a) The M60 MBT, is service with US Marines, has both M60 AVLB (Armoured veh Launched Bridge) and M728 CEV (Combat Engineer Vehicle). The AVLB consists of a std chassis with a hydraulic cylinder assembly, and a scissors bridge. The M728, is based on a modified M60 A1 tank chassis.

(b) T-72 has got Main battle tk, and ARV VT-72 versions based on same chassis. A T-72 mounted SP gun version is under development in other countries including India.

(c) In the scorpion and scimitar of UK a whole family of vehicles has been designed using the same basic automotive components. In British Army the scorpion is artificially designed CVR(T) or combat vehicle Meconnaissance (tracked). Other vehicles in the family include the spartan armoured personnel carrier which has also been adopted for many speciatised roles for example anti-tank with two Milan missiles in ready to launch position, and anti-aircraft with four Javalian surface-to-air missiles is ready to launch position; Samaritan armoured ambulance, sultan armoured Command Vehicle, Samson armoured recovery vehicle, striker anti tank vehicle; steaker high mobility load carrier, and starmer APC.

(d) The AMX-30 of French Army has been modified for several specialist roles. The AMX-30D armoured recovery vehicles, the AMX-30 combat engineer Tractor, are some of the versions of AMX-30.

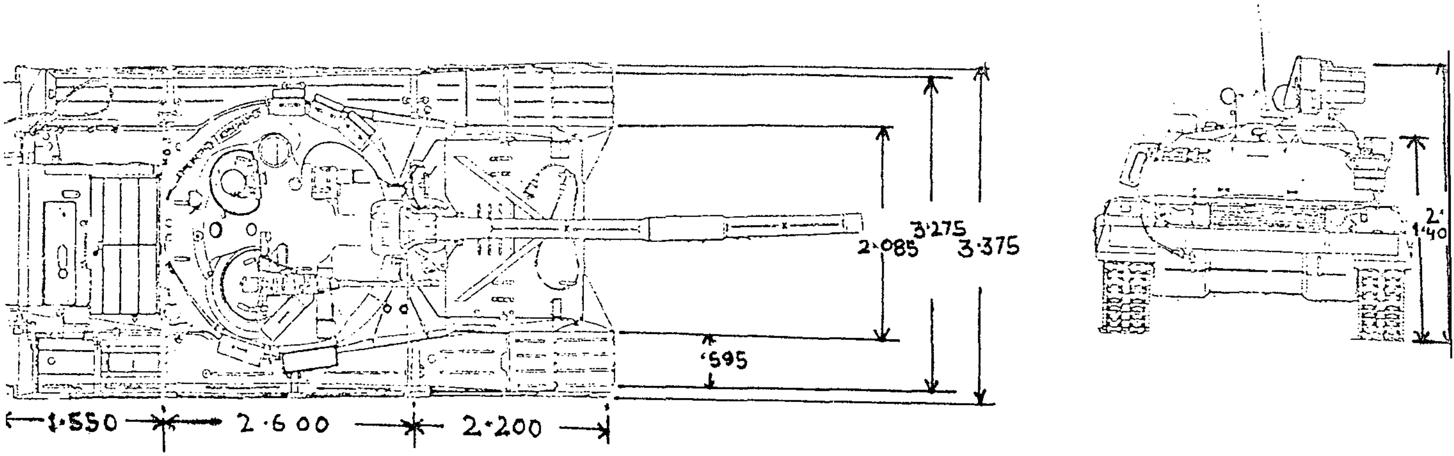
(e) Indian Vijayanta also had its ARV and Gun SP 130mm versions. In case of Gun SP 130mm length of veh ie 10.66mtrs instead of 9.788mtrs as in tank Vijayanta. Ground pressure has been reduced from 0.95 Kg/cm^2 to 0.82 Kg/cm^2 and No. of track link has been increased to 105 fron 96. In Gun SP 130mm based on Vijayanta chassis instead of turret, hood is fitted and bogie wheels are 14, instead of 12 in Vijayanta.

21. However, non of the above designs are based on modular concept and interchanging of main functional components is not possible. The same is now discussed for armoured vehicles based on T-72 chassis, its prudent to analyse the basic elements of the T-72 family which would have an overall effect on the technical and tactical performance of T-72 variants.

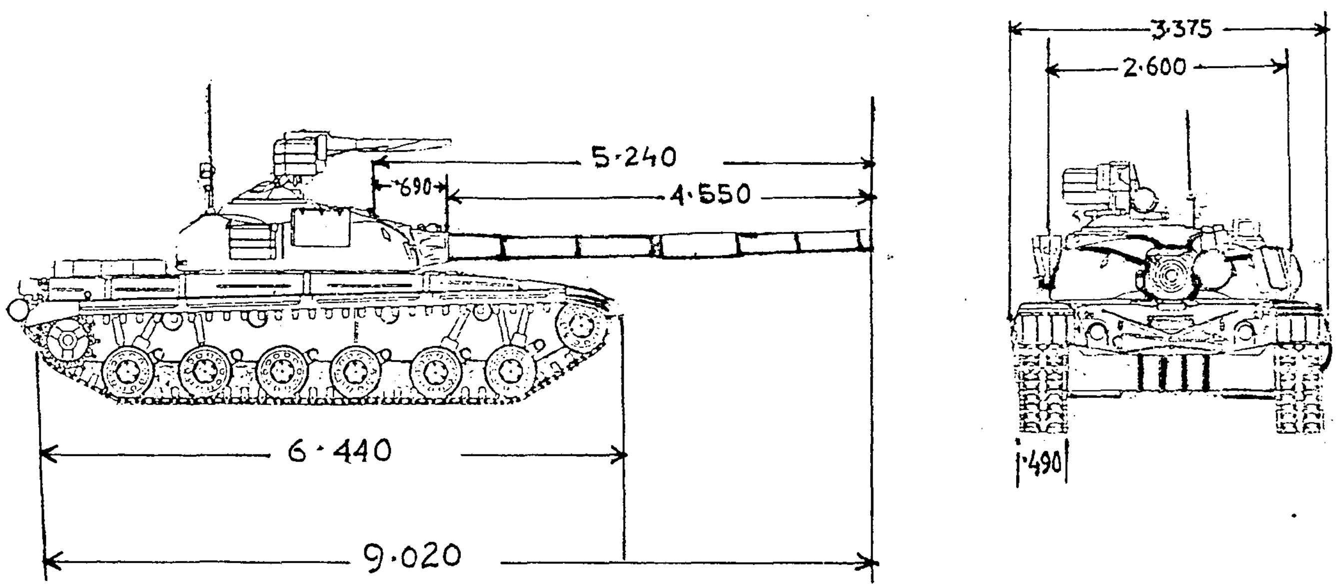
CHARACTERISTICS ATTRIBUTED TO BASIC T-72 DESIGN

22. Fire power, mobility and protection are basic characteristics of any AFV. For all design of tanks in world the fire power is given top priority. There is difference of opinion regarding mobility and protection. In Israel (Markava series tk) protection is given most importance as it has engine in front, heavy armour (62 Tons) and ammunition is kept in rear extreme. In AMX-30 of France, mobility has been given precedence over protection as its lighter in weight, ie armour material is less. Experts feels that even T-72 tank have mobility more important than protection but Russian claims that they have equal protection also.

23. Volume of fire, accuracy of fire, speed of engagement and ability to penetrate enemy armour are the factors that affects fire power. Mobility in general refers to high crushing speed



A view drawing of early T-72 with
all dimensions given in metric figures



CRITICAL DIMENSIONS OF T-72 (FIG-3)

with good acceleration. Mobility includes strategic mobility (one theatre of operation to another), Tactical mobility (within theatre of operation) and battle field mobility. Factors affecting mobility are power train factor, Running gear factor and crew factor.

Critical dimensions of TK T-72

24. Critical dimension of Tk T-72 (ref fig 3) can be analysed to discuss various characteristics which can be attributed to these parameters and the construction under which these dimensions are fixed. Critical dimension of tk T-72 are :

W = Wt of tank = 41 ton

L = Length of track in contact with ground (on one side) = 4.25mtr

Lo = Overall length of tk (depicts the length of tk) = 6.4M

Q = Approach angle = 30^{o}

θ = Departure angle = 25^{o}

C = Distance between center of tracks = 2.69 mtr

B′ = Width of tk from outer edge of the track to outer edge of another track = 3.275 mtr

B = Overall width of the tk including side clearance = 3.375 mtr

T = Track width = 0.580 mtr

Z = Inner distance between tracks = 2.5 mtr

Fixing Dimension of Tk T-72

25. A tank is designed based on national doctrine, threat and available technology. For all design of tanks in the world, fire power is given top priority. The choice of a tanks main armament is governed by many factors. Among these are the tactical doctrine of the country developing the tank, the potential enemy's armour protection, and the requirement to destroy a variety of

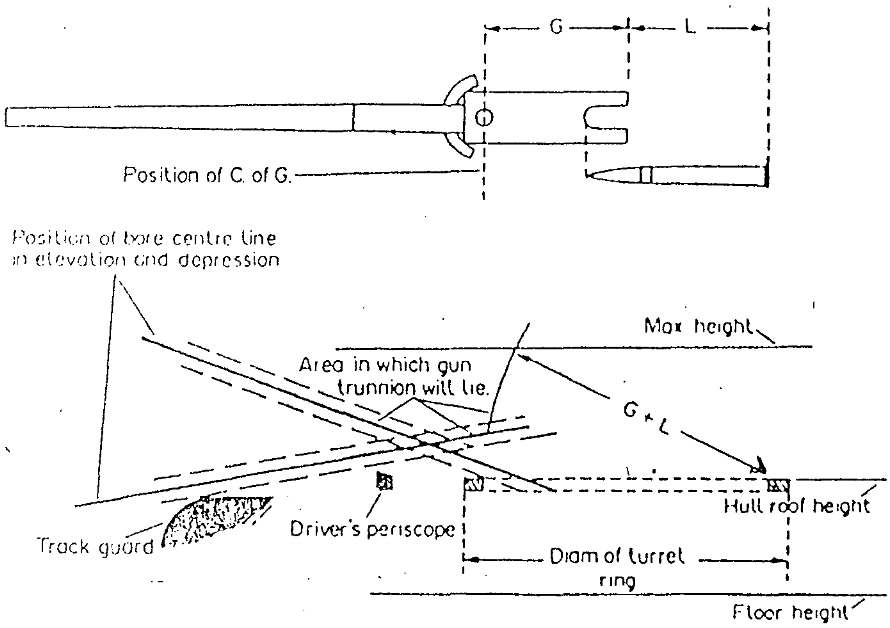


FIG. 4(a) Fitting the main armament.

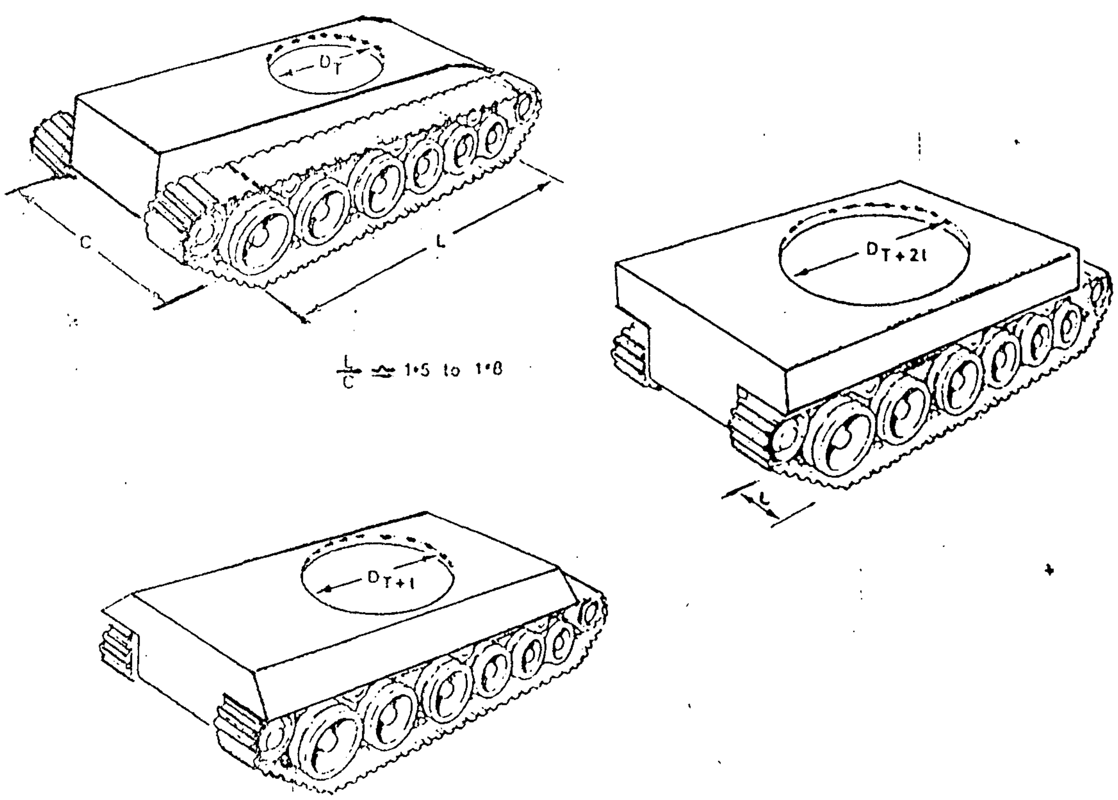


FIG. 4(b) Fitting the turret ring into the hull.

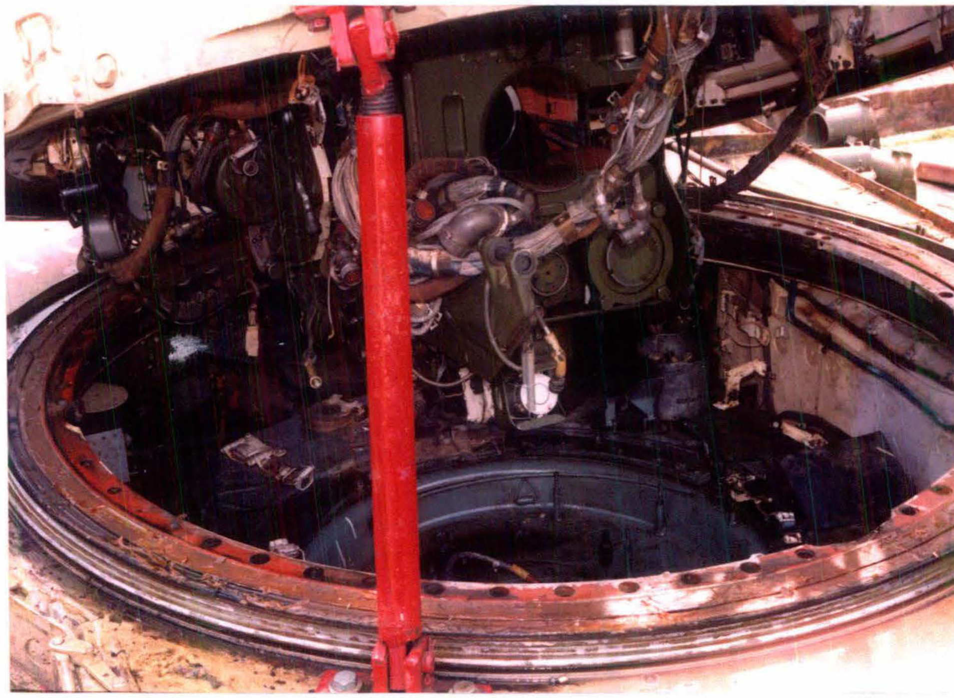


FIG 5. TURRET RING OF T-72

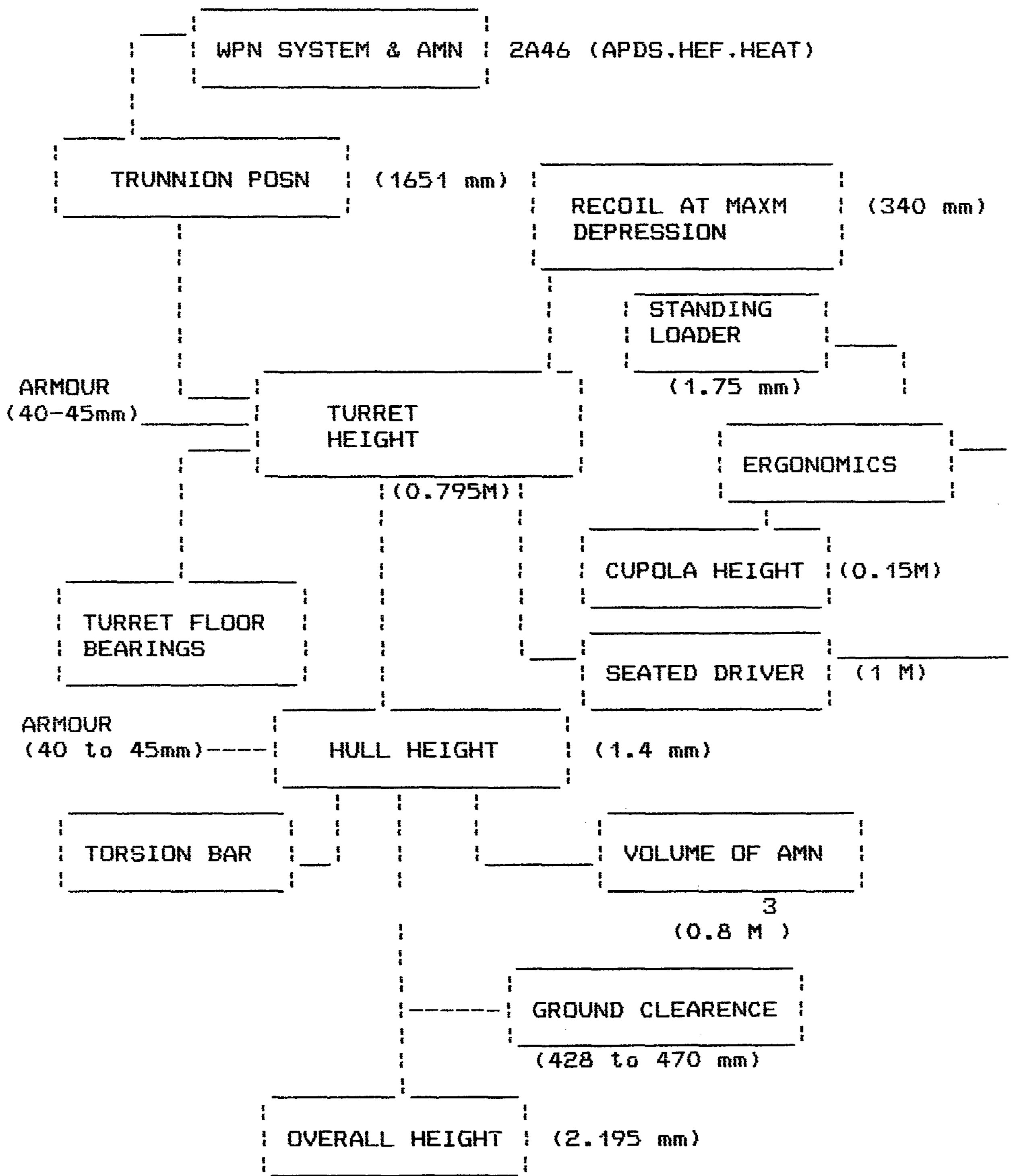


FIG 6. FIXING HEIGHT OF T-72

targets. Based on these factors 125mm smooth bore gun of the model 1A46 have been choosen as the main armament for tk T-72. This gun is capable of firing Armour- piercing discarding sabot (APDS), High explosive fragmentation (HEF), and High explosive antitank (HEAT) shells.

Height

26. Height to bore of the gun is 165mm and normal length of recoil is 270 to 320mm with maximum length of recoil being 340mm. As Warsaw pact countries don't believe in firing from reverse slope hence height of trunion and heigth of tank can be kept low. The maximum by which the gun can be depressed get constrained by driver periscope or engine compartment. Track guard level has been taken as maximum depression ie maximum depression is decided by the highest point on hull. These are the out side considerations. Inside consideration is that the gun should be able to elevate by 18" to 20" without fouling with turret floor. In loading and firing at all angles of elevation are to be possible than the diameter or turret ring is critical. It the turret rings is to be kept within the width of track (fig 4&5) than it immediately fixes the width of the tank to the maximum permitted by the appropriate railgauge. Hence with a tank ring dia of 2.04mtr and taking into account the recoil at maximum depression (340mm) and height to bore of gun 161 mm) the turret height of 0.795M is fixed for Tk T-72. Fig 6 shows that considering other factors eg ergonomics, ground clearance and armour protection overall height of 2.195mtr is fixed for Tank T-72. A critical element in this design is that by controlling the height of the tank the weight has been reduced as the frontal armour is thickest and requires more weight to maintain a given level of protection. Thus, as the height of the tank is lowered and if weight is kept at constant,

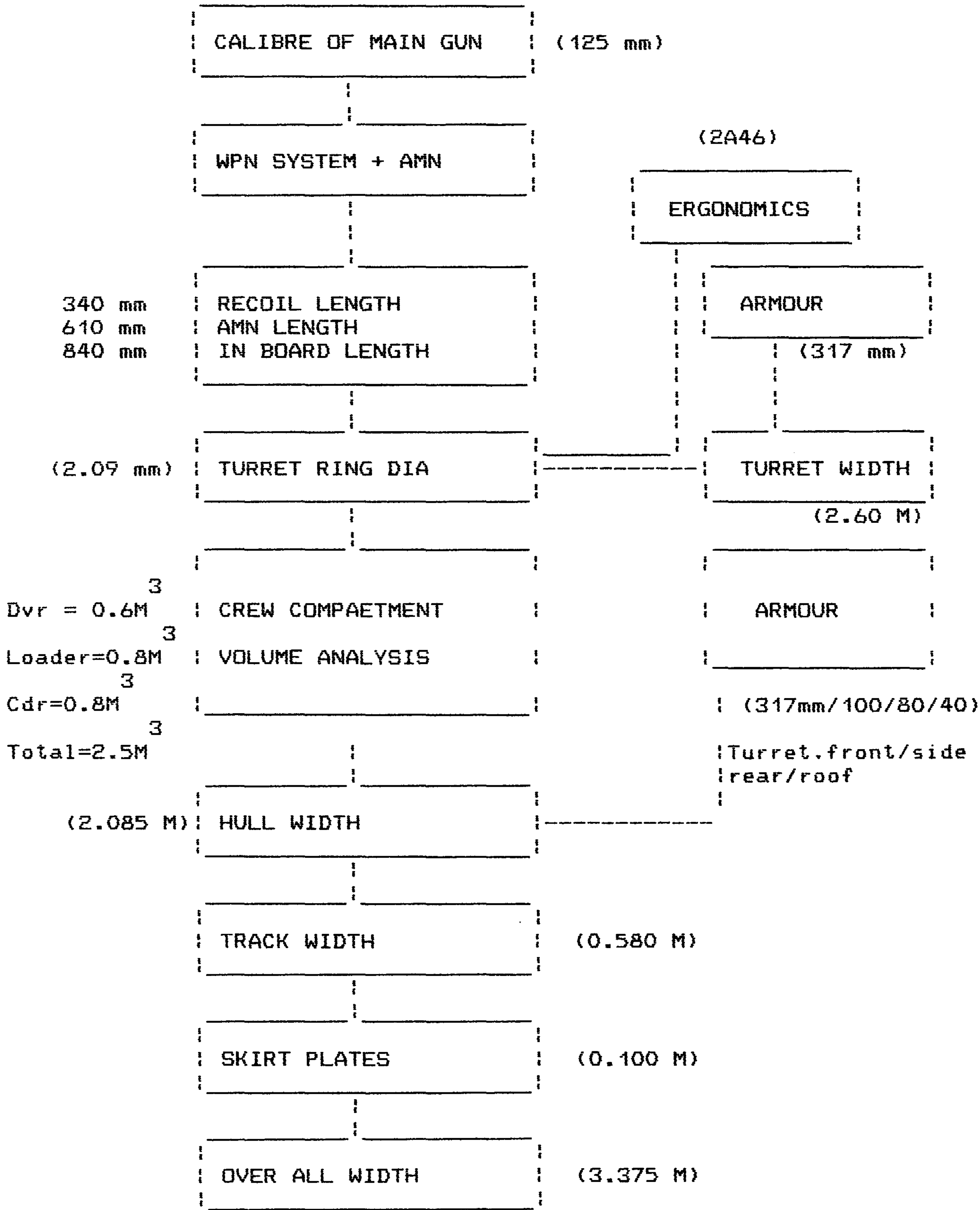


FIG 7. FIXING WIDTH OF T-72

the frontal armour can be thicker because it need not to cover as great an area. Ground clearance is normally specified by user, which in this case is 428 to 470mm.

27. The height of the hull is normally limited by the space required by the engine height (902mm) and average height of 1mtr for the seated driver. The turret roof height is also governed by the need of the loader to stand and load main gun rounds. There must be at least 1, 676mm from the hull floor to inside turret roof for the loader to stand. Hence by adding the thickness of turret roof armour (40-45mm), Thickness of the flooring, thickness of torsion bar, and thickness of belly armour and ground clearance overall height of 2.19mtr is achieved.

Width

28. Width is perhaps the most critical dimension on a armoured vehicle because it governs the tank's capability to move along highways, cross bridges, be transported and maneuver. The width of tank transporters, air craft and rail board cars also affect the design width of tanks. The erstwhile USSR limits the width of cargo transported by rail to 3, 414mm. This inturn establishes the maximum width of Soviet armoured vehicles.

29. As discussed earlier the width of a armours vehicle is also affected in part by dia of turret ring. The turret ring must allow the gun breech to swing down to aim at an elevated target and must allow enough room for the gun to be loaded with a long main gun round. Fig 7 indicates that considering all the factors as discussed above, overall width of 3.375mtr has been fixed for Tk T-72.

Length

30. Tank length is governed to some extent by tank width (3.375mtr). The ability of tank to turn is greatly influenced by the ratio of the length of the track an ground and the distance between centre of tracks. If the ratio becomes two large, turning is impossible forward thrust is offset by the power lost in the skid of the tracks. If L/C ratio is low (below 1.5) the tank will tend to be unstable in the turns and unless a side track is used, the nominal ground pressure (NGP) will be high leading to poor performance over soft ground. The determination of the optimum range of the L/C ratio as lying between 1.5 to 1.8 has been largely empirical.

31. The determination of hull length will depend on No of other factors. Starting at the front, there is the armour thickness of the glacies (100mm) and toe plate to be considered. There is also a need to accommodate the driver in a reclining position so that periscope is still forward of the turret ring. The 'Sacred Arc' (arc formed when gun rotates about its turning inside the turret length of amn) must be kept free. Hence in T-72 two piece ammunition is used so that combined length of ammunition becomes irrelvent.

32. In order to devote a greater proportion of the armoured vehicle overall weight to armour, and to reduce the hull length, the space taken by power plant ($1.3M^3$ in T-72) is kept minimum. The engine is kept transversely ie across the hull. The engine is mated to intermediate gear box (IGB) which than drives two side gear boxes. About 1 cubic metre of space has been saved in this way, allowing room for more ammunition.

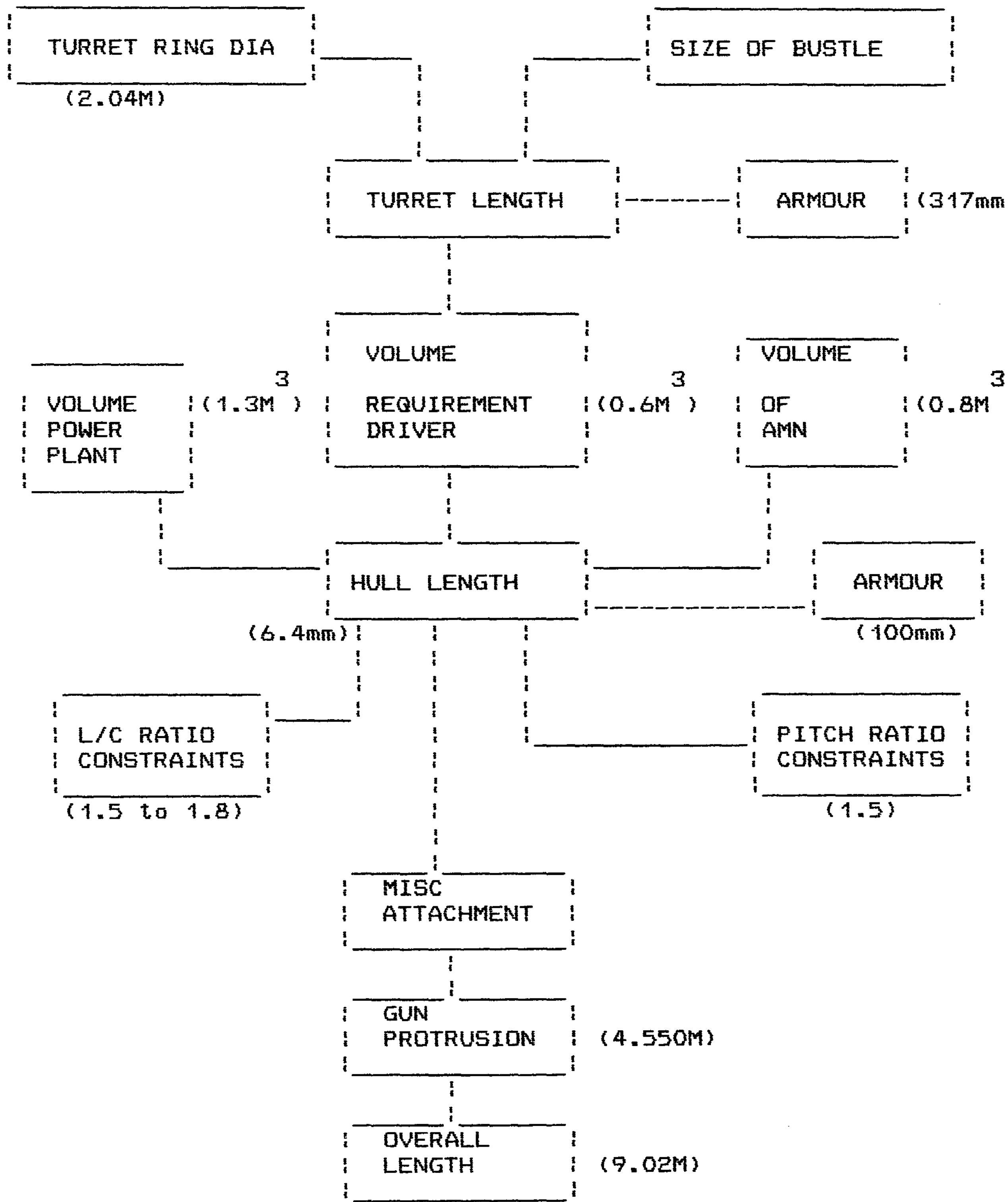


FIG 8. FIXING LENGTH OF T-72

33. Theoretically, provided the length of track in contact with ground is kept within the limits of L/C ratio (1.5 to 1.8) then the length of the tank hull could be extended to give it a larger over hang without penalty. Unfortunately, this is not so as there are severe limitations on the amount the hull can be extended for wards or rear wards over the track contact length. The first limitation is the angle of approach and departure. If the hull protrudes beyond the track envelope in front, then the tank will have difficulty climbing banks or crossing ditches. Similarly, the rear of the tank should not extend beyond the rear sprocket or idler, although is practice this is not so important as the angle of approach. The relationship between the contact length and the overall length is called the 'Pitch ratio' and designers aim for a ratio of about 1.5 to 1.8. Anything above 1.8 is likely to the major contributory factor to excessive vehicle pitching, causing motion sickness or crew fatigue and could become a limiting factor to the speed at which the vehicle is able to move cross country. A further effect of excessive overhang could be that the nominal ground pressure would increase as the overall weight of the tank would become greater without providing for a larger area of track in contact with ground.

34. Taking L/C ratio, pitch ratio constraints and other parameters as discussed above, the length of tracks in contact with ground is found to be 4.25 mtr with hull length of 6.4 mtr and overall length with gun in forward position is fixed to be 9.020 mtr. Ref fig 8.

INTERACTION OF T-72 DESIGN PARAMETERS

35. Optimization of any single parameter in isolation is impossible because it will disturb existing value of other parameter.

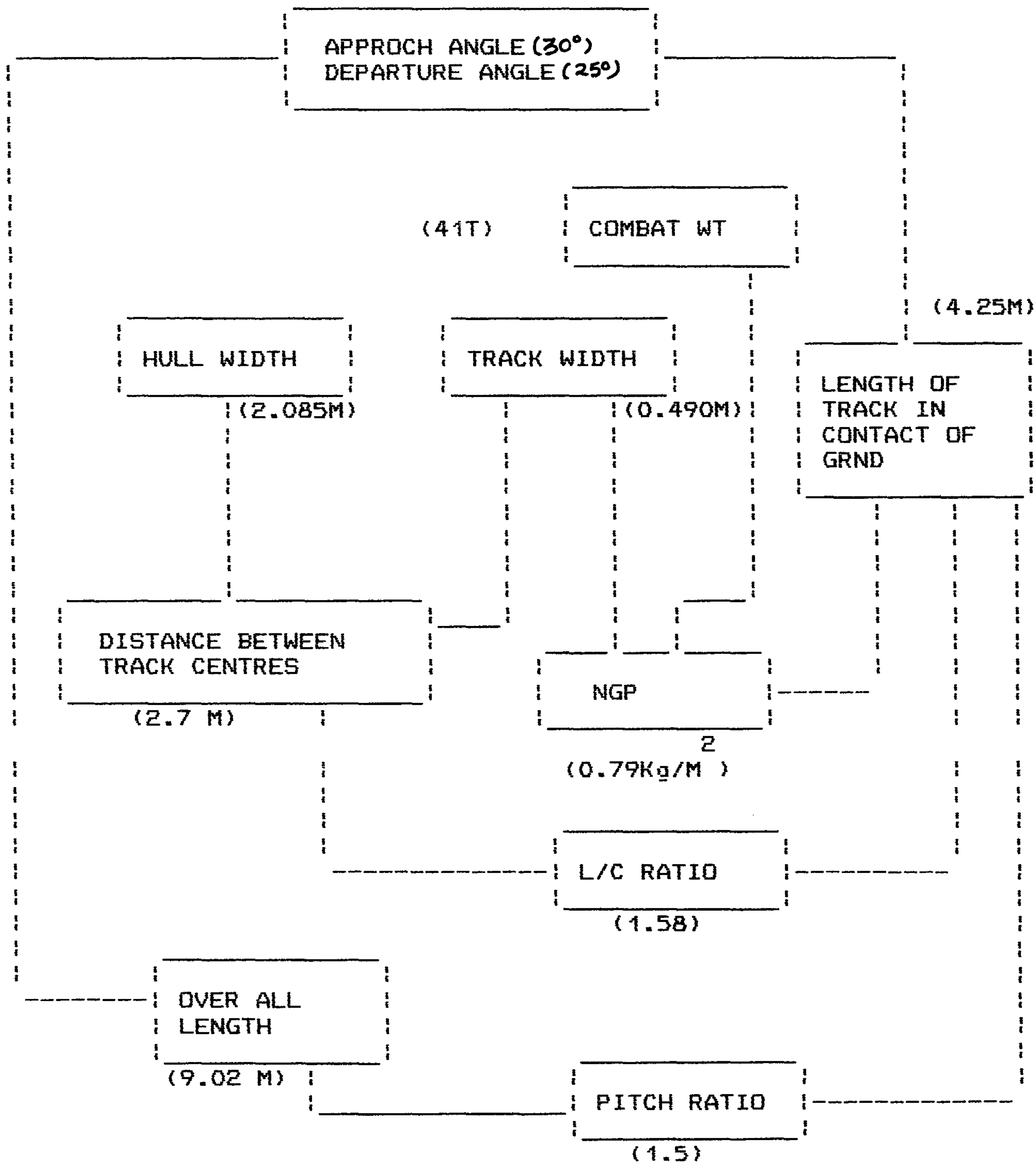


FIG 9. INTERACTION OF DESIGN PARAMETERS OF T-72

It is particularly important in case of L/C ratio and NGP etc. Nominal ground pressure (NGP) is defined as :-

$$NGP = \frac{\text{Vehicle weight}}{\text{Area of tracks in contact with ground.}}$$

It's units are KPa (SI) or kg/cm^2

The erstwhile USSR sets a limit of 0.85 kg/cm^2 for dead (non rubber bushes) track. However, the Soviet have not fielded main battle tanks with a ground pressure greater than 0.81 kg/cm^2. Generally speaking the lower the ground pressure, the easier it is for a tank to travel over poor terrain. Fig 9 indicates the interaction of design parameters of T-72. It's a block diagram giving how these ratio are inter related. Distance between track centers is decided by hull width (2.08mtrs) & track width (0.580 mtr) as C = B'-t. NGP also depends on track width (t) and combat wt (W) and the track contact length 'L'.

36. We should like to have a low value of NGP for better cross country performance. To have a low value of 'NGP' either reduce weight 'W' or increase 'L' and 't'. Their is a limit upto which weight can be reduced due to requirement of armour protection. (46% of total weight of armoured veh is due to armour). Once minimum protection level is decided, weight can not be reduced. Then you can increase 'L' or 't' to reduce 'NGP'. However with increase in L/C ratio steeriability of tank will be affected hence when L/C is fixed 'L' can't be increased. Then increase track width 't'. When 't' is increased keeping 'C' fixed the hull width is affected, but hull width can't be increased indefinitely as transportability restriction are to be borne in mind. Increasing 't' without increasing hull width is not possible. Even if we try to reduce inner distance between track (Z) without increasing 't' it will simultaneously affect the hull width also. As 'Z' reduce

$NGP = W/2Lt$; $W = 41$ Tons, $NGP = 0.79\ kg/cm^2$, $Lt = \frac{41000}{2 \times 0.79}$

$Lt = 26214.8$; As $L/C = 1.58$, $L = C \times 1.58$

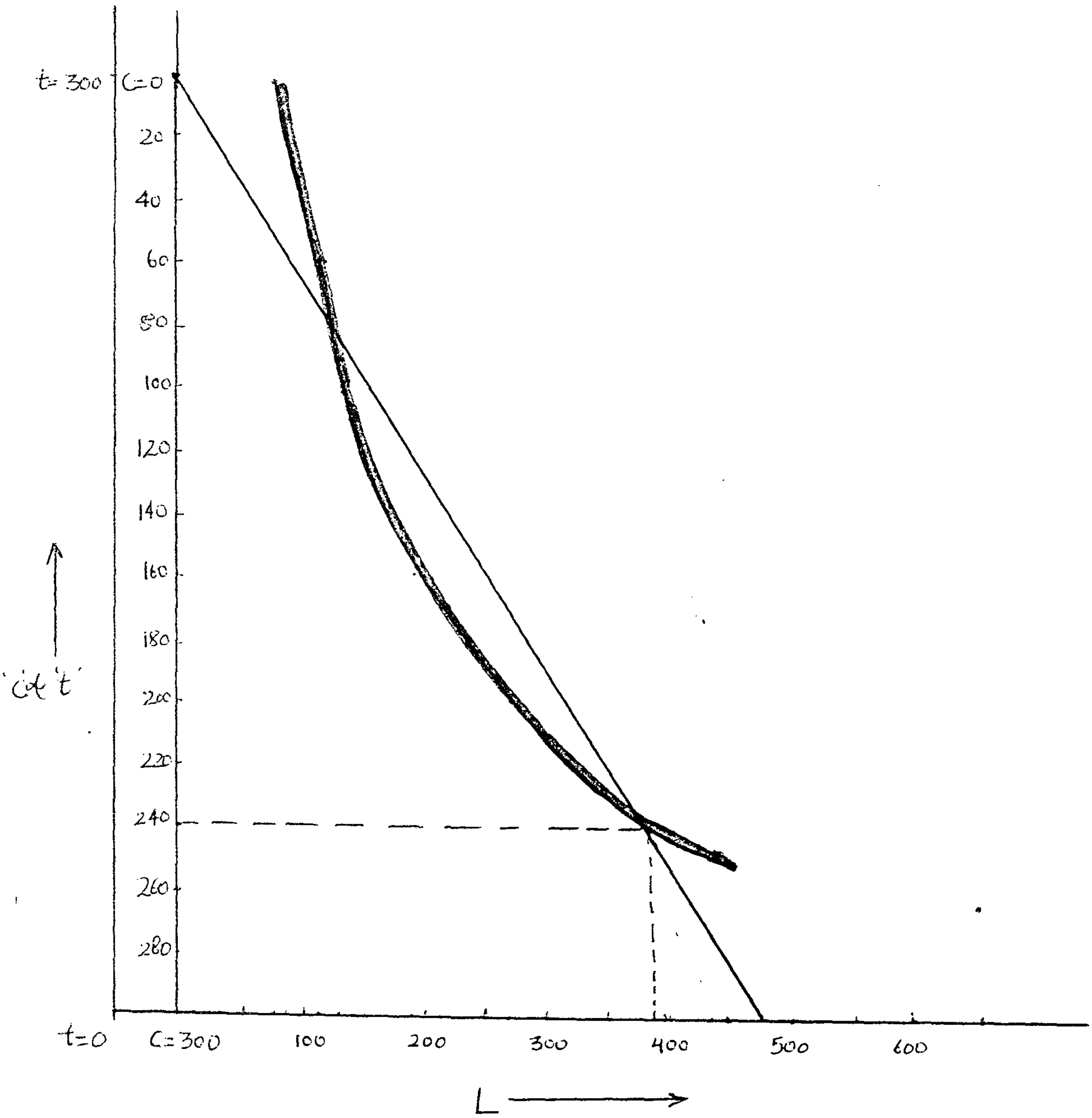


Fig 10. DESIGN BASED ON NGP

turret ring diameter will also reduce making it difficult to put gun in turret as with decrease in 'Z' internal armour volume will reduce, making it difficult to accommodate sub systems and components. Turret ring dia has already been fixed by fixing (G+L) hence 'Z' can not be reduced. Presently composite armour is being used as glacis armour protection, (23% of total weight of tank). If we can get low weight of armour protection material to give same level of protection or we use more of electronics component, it is possible to reduce the weight and hence the NGP. (0.782 kg/cm^2 for tank T-72).

Parametric design of T-72 based on NGP

37. It is under the assumption that weight is given and NGP's chosen depending on performance of vehicle desirable in desert terrain. NGP lies between 0.7 to 0.8 kg/cm^2 depending on strength of the soil. NGP for Tk T-72 is fixed at 78.2KPa or 0.782 kg/cm^2 based on national doctrine.

$$\text{as NGP} = \frac{\text{Weight per track}}{\text{track contact length x track width}} = \frac{W}{2Lt}$$

$$0.782 = \frac{41000}{2xLt}$$

$$\text{or } Lt = 26214.8 \text{ cm}^2$$

Now we plots graph (ref fig 10) in which L (in cm) is on 'X' axis and 'Y' axis have two parameters. 'C' is increasing downwards from 0 to 300 cm and 't' increasing from '0' at origin to 300 cm going upwards in 'Y' axis. A curve is plotted for which Lt = 26214.8 cm^2 for NGP of 0.782 kg/cm^2 by taking different value of 'L' & 't'. Now by approximately deciding the L/C ratio, (taking as 1.588 depending on streeability of tank) a line is drawn which touches the 'Y' axis at C=0 and 'X' axis at L = 300 x 1.58 = 474 cm. So at pt 'P' or 'Q' the tank is to be designed. By drawing perpendicular to X axis we get value of 'L' as 385 cm and 't' as 60 cm and 'C' as 240 cm. If pt 'P' is considered value of 't' will be 240 cm & 'C' is 60 cm which is unrealistic hence these points are not considered. With this procedure we have found that t = 60 cm and C = 240 cm.

hence Z = 240-60 = 180 cm

& B = 240+60 = 300 cm

These values are near to the actual dimensions of T-72. It is also evident that the ultimate value of NGP is not due to weight alone and by manipulation of L/C value desired 'NGP' can be achieved. For a desired 'NGP' with variation in value of 'L', 't' is also required to be varied.

Track and wheel design of T-72

38. As discussed graphically, 'L' and 't' is influenced by 'NGP'. Hence technique of designing the dimension of tracks is based on 'NGP', ie

$$NGP = \frac{W}{2Lt} \qquad \text{(i)}$$

and L/CxC = L

$$\text{Hence } L/C \times C = L = \frac{L}{C}(B' - t) \qquad \text{(ii)}$$

(Where B'is the distance between external extremities of the tank and Z is the distance between internal extremities ie Z+t = C and C+t = B' or C = B' - t)

Substitute eqn (ii) in eqn (i) to get value of 'L'

$$\text{ie } L = \frac{W}{2NGP \times t}$$

$$\text{or } L = \frac{L}{C}(B' - t) = \frac{W}{2 \times NGP \times t}$$

$$\text{or } t^2 = B' - t + \frac{W}{2 \times NGP \times L/C} = 0$$

This is the method which have been used for fixing the dimension of tracks. Other dimensions are already fixed as follows :

(a) Fixed 'W' because of armour material requirement =41 ton

(b) Fixed NGP for movement is traficiability requirement = 0.782 kg/cm^2

(c) Fixed L/C for steering constraints = 1.52

Hence track width 't' is fixed last. Total width

B' = 337cm is already fixed.

$$* \; t^2 = 337t + \frac{41 \times 10^3}{2(NGP)\ L/C} = 0$$

solving the quadratic equation

$$t = + \frac{337 \pm \sqrt{(337)^2 - 4(1)\ (16591.60)}}{2}$$

$$\text{or } t = \frac{337 \pm 217.26}{2}$$

t = 59.80cm or t = 277 cm

t = 277 cm been too unrealistic as width between the tracks will be come 3 37 - 277 = 60 cm which is not acceptable hence t = 59.8cm is approximate value of track width of T-72.

Fixing diameter of road wheel of T-72

39. Attempt on designing the diameter of wheel is based on deciding Mean Maximum Pressure (MMP). The MMP theory believes that maximum pressure is more important as digging of ground will be more under the wheels. Mobility of AFV in a cross country terrain like sand and clay are found to be better predicted by using empirial formula based on MMP than NGP. The ratio of NGP : MMP can be upto 1 : 4. In case of T-72 the MMP is fixed to be 237 KPa or 2.37 kg/cm^2. Using the empirial formula, and by knowing width and pitch of track and by fixing No of wheel the diameter of boggie wheel can be fixed as follows :-

$$\text{as} \quad MMP = \frac{1.26}{mt\sqrt{pd}}$$

where M = No of boggie wheeld fixed as 12 t = Width of track = 58 cm

P = Pitch of track = 13.5 cm

$$237 = \frac{1.26 \times 41 \times 10^{3}}{12 \times 0.58\sqrt{135 \times d}}$$

$$\sqrt{13.5 \times d} = 313.82$$

$$d = 72.5 \text{ cm}$$

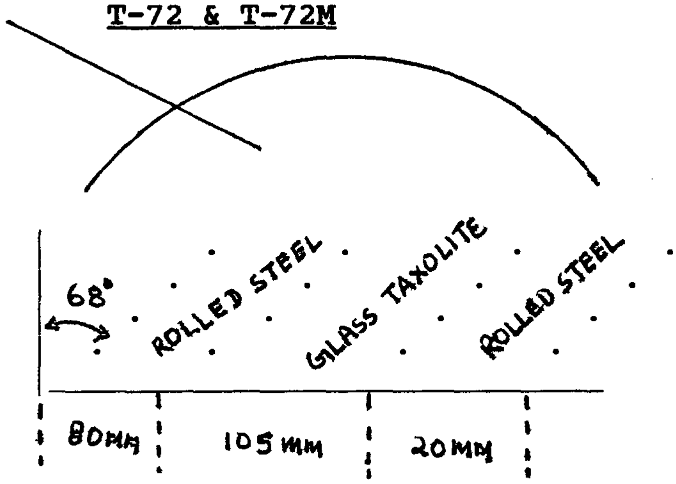
Hence based on MMP the diameter of wheel of T-72 is fixed as 72.5 cm.

Armour Protection

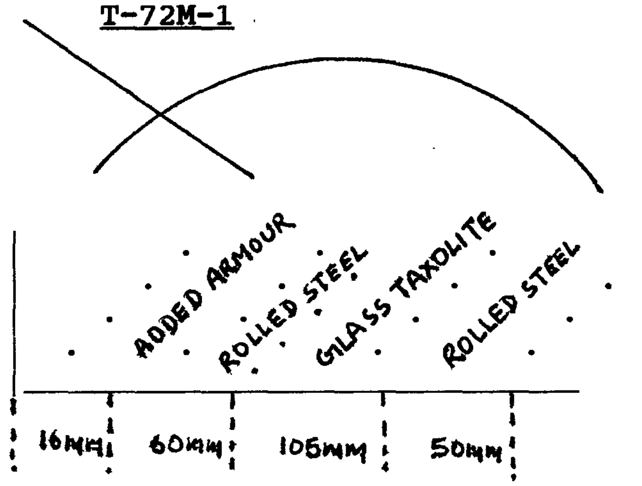
40. Armour protection governs to large extend the ability of a tank to survive under fire and to the extend that it will make them immune to a number of enemy weapons. The principle of survive ability is that the design should be such that the AFV should not be detected, if detected it should not be hit, if hit it should not be penetrated and if penetrated it should survive. All measures taken against the ballistic attack attributes to primary protection and protection against fire and explosion forms part of secondary protection. The basic T-72 design have following protection.

41. It has got sandwich armour which consists of ceramics/polymers sandwiched between metal layers. It affords high degree of protection against KE & CE attack. A composite armour have the advantage of high strength, low density, high stiffness to density ratio, toughness and improved oxidation and corrosion resistance. Kanchan armour has been developed by Kanchanbagh Hyderabad. T-72 has got well slopped glacis plate welded ribs and thick turret. In T-72 M-1 produced in India, by having added armour on glacis plate protection against Heat and AP rounds have been increased by 44% and 15% resp.

T-72 & T-72M



T-72M-1



Analysis of level of protection on T-72

42. The chance of survival of tank is the chance of fire coming from immune sector. The immune sector is the sector in which a shot with a given shot power will not be able to penetrate the Armour of given thickness. Whittakers Directional Probability Variation (DFV) can be utilised to analyse the chances of survival of T-72. The DFA theory suggests the following :

(a) Economy of armour by distribution depending upon the threat.

(b) Threat means probability of fire from a specified direction.

(c) The threat is calculated by the above theory.

(d) Calculation of probability is based on a table which gives probability of fire from all angles from 0^{0} to 360^{0}

(e) The theory is developed based on certain assumption which are :

(i) The tank drives forward at a steady speed upto and through a line of anti tank weapon.

(ii) Anti tank guns do not have any knowledge of tank armour.

43. Equivalent protection curve (ref appx 'A') are used to give the arc over which the tank is immune for the given thickness of the armour against given shot power of the shot. Shot power is the capability of the shot to penetrate the armour and is expressed in terms of thickness along with the angle of impact. The ADFSDS penetration for T-72 is 350mm at 0° and for T-72/M1 it is 150mm at 60°. The armour protection for T-72 is as under :-

(a) Turret - front /sides/rear/roof : 317/100/80/40-45mm

(b) Hull :-

(i) Nose - 60mm

(ii) Glacis = T-72/T-72M/T-72M1

205/205/231

(c) Side/bottom/rear :- 22.5-80mm/24mm/21.40mm

44. To calculate the chances of survival (COS) we assume that the curve follows the 2nd curve (ref appx A) and the shot power is 350mm at 0° with initial layer of front 205mm at 68°, side 22.5 at 30° and rear 21.40 at 0°.

<u>Case-1</u>

<u>Front</u> :- The effective thickness $= \dfrac{205}{(TQ/TN) \text{ at } Q\text{-}60^{\circ} \text{ curve 2}} = \dfrac{205}{0.25} = 820$

$\therefore \dfrac{TQ}{TN} = \dfrac{820}{350} = 2.34$ $\therefore$ Total chances of survivability at front

<u>Side</u> :- The effective thickness $= \dfrac{80}{(TQ/TN) \text{ at } 0\text{-}10^{\circ} \text{ curve 2}} = \dfrac{80}{0.82} = 97.56\text{mm}$

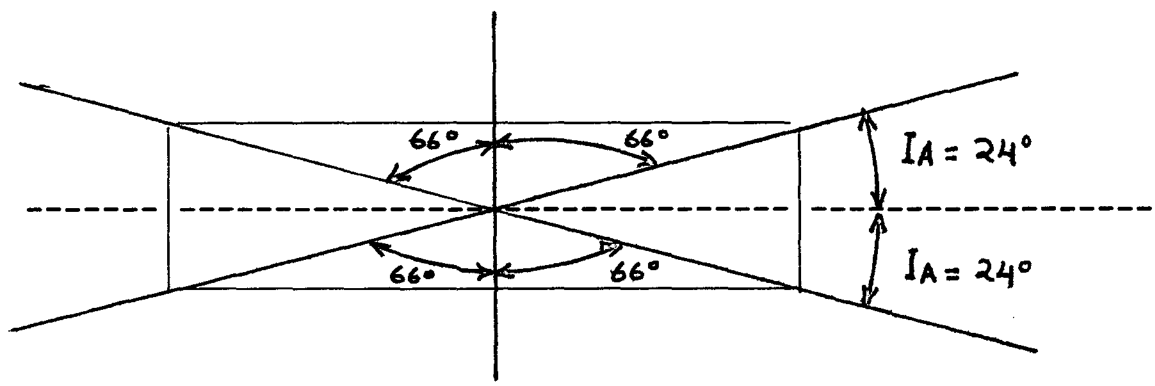
$\therefore \dfrac{TQ}{TN} = \dfrac{97.5}{350} = 0.28 = Q = 66^{\circ}$ (from curve 2)

$\therefore$ COS = $P(90^{\circ} - 66^{\circ}) = P(24^{\circ})$

$\therefore$ Immune angle = 24°

Appx 'B' gives the probability of a attack P(U) between 0° to 90° based on whittaker's direction probability variation.

therefore COS at $P(24^{\circ}) = 36.32\%$



Rear :- Effective thickness = 30mm

therefore $\frac{TQ}{TN} = \frac{30}{350} = 0.085$ therefore $Q > 70^{\circ}$

Hence the COS are 36.32% at given configuration for T-72.

These COS can be increased by giving additional armour or redistributiing the armour at front or side however with overall weight restriction the given configuration is found suitable.

TERAMECHANICS : APPLICATION OF EMPIRICAL METHOD TO DETERMINE T-72 PERFORMANCE

45. Vehicle Cone Index (VCI) is the minimum Rating Cone Index (RCI) that will permit specific No of passes by a given vehicle. It is denoted by a suffix indicting No of passes ie VCI50 or VCI1. The rating Cone Index, RCI = RI x CI. Cone Index (CI) is the pressure required to push the steel cone of an instrument called cone panetrometer and Remolding Index (RI) is the indexing accounting for loose of strength by soil, when they are distributed. If MMP of AFV is known then their are graph available (ref appx C) to determine VCI50. If RCI of get is known then by using graph between difference of RCI-VCI50 and drawbar pull (ref appx D) the draw bar pull can be obtained.

46. Hence from appx 'C, for MMP of 230 Kpa we get VCI 50 of approx 58. this value of VCI can also be calculated using mobility Index (MI) of vehicle. MI gives an index to mobility of vehicle. It is obtained by using an equation which includes all factors that will affect the mobility of the vehicle. All these factors are given empirical values.

47. To get mobility index of T-72 we have made use of following data of T-72 :

Weight = 41 ton

Length L = 4.25mtr, Track width t = 0.58mtr

Pitch track = 0.14mtr, Gd clearance = 450mm

(a) Contact pressure factors $= \dfrac{\text{Gross weight in lbs}}{\text{Area of track in contact in inches square}}$

therefore CPF $= \dfrac{41 \times 10^3 \times 2.22 \times 2.54 \times 2.54}{2 \times 4.25 \times 0.58 \times 10^4}$

$= 11.8 \text{lb/inch}^2$

(b) Weight factor (WF) = 1.4(empirical value for tanks between 70×10^3 to $(100 \times 10^3 -1)$lbs

(c) Track Factor (TF) $= \dfrac{\text{track weight in inches}}{100} = \dfrac{0.58 \times 10^2}{2.54 \times 100}$

$= 0.228$

(d) Bogie factor $= \dfrac{\text{Gross weight in lbs/10}}{\text{No of bogies in contact with gd x area of one track shoe in sq inch}}$

$= \dfrac{41000 \times 2.2 \times 2.54 \times 2.54}{10 \times 12 \times 58 \times 14} = 5.98$

(e) Grouseer factor (GP) = for less than 1.5 inches high = 1

(f) Clearance factor (CF) $= \dfrac{\text{Ground clearance in inches}}{10}$

$= \dfrac{45\text{cm}}{2.54 \times 10} = 1.77$

(g) Engine factor (EF) => as P/W $= \dfrac{780\text{HP}}{41} = 19$

as P/W ratio is > 10

therefore EF = 1

(h) Transmission factor (TF) taken as 1 for manual transmission Mobility Index for tracked vehicle ie given by empirical relation.

$$MI = \frac{(GPF \times WF + BWF - 1.77) \times 1 \times 1.05}{0.220 \times 1}$$

$$= 80.5$$

VCI50 is given by empirical relation

VCI50 = 19.27 + 0.41 MI - (125.79/MI + 7.08)

hence for T-72

$$VCI50 = 19.27 + 0.43 \times 80.5 \frac{(125.74)}{(80.5 + 7.08)}$$

$$= 52.4 \text{ PSI}$$

48. The mobility Index (MI) is important as the vehicle parameters would have been redesigned to get desired VCI 50. the VCI is important because it is important to know if the ground will be able to take particular No of passes of vehicle and also to estimate DBP & to check if the vehicle can climb on a gradient for which BCI is known. In this particular case assuming RCI of 100 PSI. from graph at appx 'D'.

L/W% = 58%

ie tan Q = L/W = 0.58 and IBP, D = 0.58 x 41 = 23.78 Tons

or $Q = 30^{o}$

49. The performance prediction of T-72 can also be made using mobility numerics in the following manner :-

(a) Assuming track on clay and with MMP = 230 MPa

let RCI = 50PSI = 50 x 6.9 = 345 Kpa

the mobility index on clay $CT = 2.8 \left(\frac{RCI}{MMP}\right)^{0.72}$

$$= 2.8 \left(\frac{345}{230}\right)^{0.72} = 3.74$$

Now to determine draw bar pull at (20% of slip)

we have empirical relation for clay as

$$D\,20/W = 0.09\;CT^{0.88} - 3.6(0.01 + CT^{-2.7})$$

$$= 0.09\,(3.74)^{0.88} - 3.6\,(0.01 + 3.74^{-2.7})$$

$$= 0.287 - 0.1382 = 0.15$$

$$\therefore D\,20 = 0.15 \times 41 \times 10^{3} \times 9.81$$

$$= 60.49 \text{ KW}$$

and maximum gradient $= \frac{D20}{W} = \frac{60.49}{41} = 0.15$

Hence $Q = 8.5^{o}$

(b) For tracks on sand : Taking CI gradient (G) = $4200 KH/M^{3}$

breadth of track (b) = 0.58 M

and contact length of track (1) = 4.25m

$$\therefore \text{Mobility index } \pi\, ST = \frac{G(bl)^{3/2}}{W}$$

$$= \frac{4200 \times 10^{3}\;(0.58 \times 4.25)^{3/2}}{\frac{41 \times 10^{3} \times 9.81}{2}}$$

$$= 80.82 \text{ per track}$$

for track on sand Drawbar pull at (20% slip) is given by empirical relation;

$$D20/W = 0.205 + 0.162\log_{10} \pi\, St$$

$$= 0.205 + 0.162\log_{10} 80.82$$

$$= 0.514$$

$$\text{and } D20 = 0.154 \times 41 \times 10^{3} \times 9.81$$

$$= 206.74 \text{ MN}$$

and gradient capability => $\tan Q = \frac{D20}{W}$

$$= \frac{206.74}{410} = 0.154$$

$$Q = 27.2^{o}$$

Hence T-72 has better DBP and better gradiability in sand than in clay.

DESIGNING GEAR BOX FOR T-72

50. The important parameters required for designing the gear box are maximum velocity at level road and maximum gradient negotiable. These requirement are fixed by the user and have been taken as 60KM/h and 30^{o} respectively. the weight (41 tons) acceleration and wheel radius rw of 0.36mtr have been fixed earlier.

(a) **To fix top gear ratio (TGR)** : Speed at maximum power (NP) max forms basis for designing TGR such that

Np max = Nw x TGR where Nw is angular speed of wheel

but $V = rw\ W = \frac{rw2\ \ Nw}{60}$

where rw is radius of wheel

hence $TGR = \frac{Np\ max \times 2\ \ rw}{60 \times V\ max}$

The data available for T-72 are

Gross Horse Power at 2000 rpm (Np max) = 780 HP x746

= 581880 Watt

Gross torque at 1300 to 1400 rpm (NT max) = 315 x 9.81 = 3090N

max speed on paved road at rated speed = 60 KM/hr

Maximum grade ascending ability = 30^{o}

Radius of road wheel = 0.363 M

Hence for T-72 $TGR = \frac{2000 \times 2 \times\ \ \times 0.363 \times 3600}{60 \times 60\ 10}$

= 4.56

(b) **To determine lowest gear ratio (LGR)** considering maximum gradient condition we have to find total resistance (Rt) offered to vehicle. When maximum gradient is specified then acceleration is zero hence total resistance becomes equal to tractive effort ie Rt = TE

at maximum gradient eng is at T max such that

T max x t x LGR = TE x rw

where TE = Rt and nt is efficiency of transmission.

therefore $LGR = \frac{Rt \times rw}{T\ max \times nt}$

Total resistance consists of following :-

(i) The rolling resistance Rr is obtained using empirical relation of tracked veh

ie sp Rr = (0.062 + 0.00048V) KN/KN

where V is in KM PH

for T-72

Rr = (0.062 + 0.00048 x 60) x 410

= 37.28 KN

(ii) Gradient resistance RG = W sin Q

therefore $RG = 410 \times \sin 30^0 = 205$ KN

(iii) Air resistance though negligible for tracked vehicle ie determined as

$$Ra = \frac{1}{2}\ Cd\ AV^2\ \&$$

where Cd = Coefficient of air drag (take as 0.8)

A = Projected front area = 7.64 M^2 for T-72

V = Velocity in mtr/sec = $\frac{60000}{3600}$ = 1.667M/sec

& = density of air = 1.25kg/cm^2

$$Ra = \frac{1}{2}\ Cd\ Av^2\ \& = \frac{1}{2} \times 0.8 \times \times 7.64 \times (1.667)^2 \times 1.25 = 1.061KN$$

total resistance Rt = Rr + RG + Ra

= 37.28 + 205 + 1.061

= 243.34 KN

Taking efficiency of transmission as 80%

$$LGR = \frac{Rt \times rW}{T\ max\ Rt} = \frac{243.34 \times 0.363}{3090 \times 0.8} = 35.73$$

r1 will be first gear ratio such that $r1 = \frac{LGR}{TGR}$

$$r1 = \frac{35.73}{4156} = 7.83$$

z is ratio between NT max and Np max

$$\text{ie } z = \frac{NT\ max}{Np\ max} = \frac{1400}{2000} = 0.7$$

as the subsequent gears are in geometric propagation hence

$$rn = z^{n-1}\ r1 \text{ where n is } 1,2,3,\ldots\ldots\ldots$$

$$\text{or } (n-1) \log z\ (0.7) = \log \frac{rn}{r1}$$

$$\text{or } (n-1) \log (0.7) = \lg \frac{1}{7.83} = (n-1)(-0.3566) = -2.058$$

$$\text{or } n-1 = \frac{-2.058}{-0.3566} = 5.77 * \quad R = 6.77 = 7$$

$$\text{Therefore } R_2 = zr_1 = 0.7 \times 7.83 = 5.4$$

$$r_3 = z^2\ r1 = (0.7)^2 \times 7.83 = 3.8$$

$$r_4 = z^3\ r_1 = (0.7)^3 \times 7.83$$

$$r_5 = z^4\ r_1 = (0.7)^4 \times 1.9$$

$$r_6 = z^5\ r_1 = (0.7)^5 \times 1.3$$

$$r_7 = z^6\ r_1 = (0.7)^6 \times 0.93$$

These values of gear ratio are close to the actual gear ratio and the deviation could be due to approximation in transmission efficiency, air resistance and value of 'a'.

Having designed the gear box of T-72 we carry out analysis of gear box of T-72.

Power Transmission T-72

52. Type - Mechanical with step up gear box unit that drives compressor, starter generator, and fan of cooling system.

Transmission ratio - 0.706

Mass - 320 Kg

Final gear boxes t-72

53. Type - Planetary, 8 range (seven fwd and one reverse) friction clutch engaged and hydraulically controlled.

Number of clutches in each final gear box :

Steering clutches - two

Brake clutches - four

Method of steering - By engaging low range in final gear box on the side of lagging track.

(a) Transmission ratios (i) and rated turning radij (R)

	I	R
1st gear range	8.173	2.79m
2nd gear range	4.4	6.04m
3rd gear range	3.485	13.42m
4th gear range	2.787	13.93m
5th gear range	2.027	10.23m
6th gear range	1.467	10.1m
7th gear range	1.000	8.76m
Reverse	14.35	2.79m

Final drive transmission ratio (i) = 5.454

(b) **Operation of various gears**

Gear	Clutch, Brake Engagement	Member Braked	Gear train taking part
Foot Brake	T_4 T_5	C_1 C_2 C_3	A_4 S_4
Neutral	T_4	S_4	
Reverse	T_5 F_3	C_1 C_2 C_3 C_4 $A3 \to S_4$	$S_3 \to A_3 \to S_4 \to C_4$ $\to C_5 \to A_5$
1.	T_4 F_3	S_4 $A_3 \to S_4$	$S_4 \to C_3 \to A_4 \to C_4$ $\to S_4 \to C_5$
2.	T_4 T_6	A_2 S_4	$S_2 \to C_2 \to A_4 \to C_4$ $\to S_5 \to C_5$
3.	T_6 F_3	A_2 $A_3 \to S_4$	$\vert\text{-->}A_4$ ------ $S_2 \to C_2 \to C_3 \to A_3 \to S_4 \to C$ S_3 <-- $S_5 \to A_5$ <-
4.	T_1 T_6	S_1 A_2	C_1 $S_2 \to C_2 \to A_4 \to C_4 \to C_5$
5.	T_1 F_3	S_1 $A_3 \to S_3$	C_1 $A_3 \to S_4$ $S_2 \to C_2 \to C_3 \to A_4 \to C_4 \to C_5$ S

6. F_2 T_4 $S_1 \rightarrow A_2$

$$
\begin{array}{c}
A_2 \\
| \\
S_2 \rightarrow C_2 \rightarrow A_4 \rightarrow C_4 \rightarrow C_5 \\
| \\
C_1
\end{array}
$$

7. F_2 F_3 $S_1 \rightarrow A_2$ 1 | S_1

$A_3 \rightarrow S_4$ 2-->3-->4

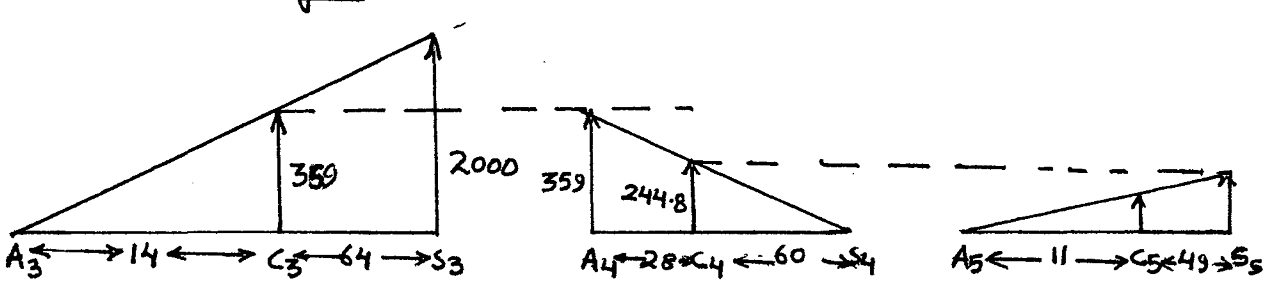
Rev T_5 F_3 $S_3 \rightarrow A_3 \rightarrow S_4 \rightarrow C_4 \rightarrow C_5 \rightarrow A_5$

(c) **No of teeth**

S_1 :- 27	C_1 :- 18	
S_2 :- 30	C_2 :- 15	A_3 :- 60
S_3 :- 14	C_3 :- 25	A_3 :- 64
S_4 :- 28	C_4 :- 16	A_4 :- 60
S_5 :- 11	C_5 :- 19	A_5 :- 49

54. **Gear ratio analysis**

(a) 1^{st} gear



As $\frac{Na-NC3}{Na3-NC3} + \frac{-Ta3}{-Ta3}$ => $\frac{C-Nc3}{2000-Nc3} = \frac{-14}{64}$

$-64Nc3 = -2000 + 14\ Nc3$ => $Nc3 = 358.97$

Similerly $\frac{Na4 - Nc4}{Na4 - Nc4} = \frac{-Ta4}{Ta4}$

$$\frac{359 - Nc4}{O - Nc4} = -28$$

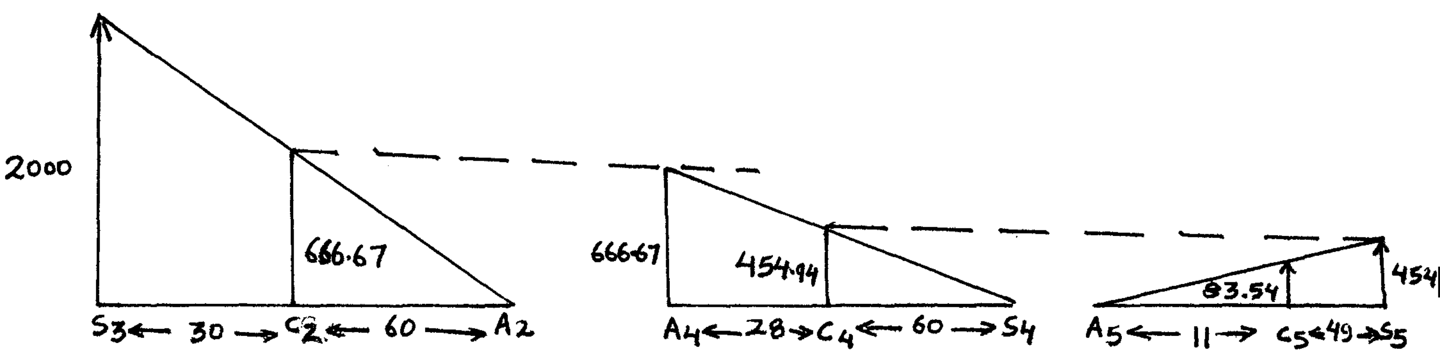
$359 \times 60 = 88\ N_{c4} \Rightarrow N_{c4} = 244.8$

Gear ratio (Nc.1) $= \frac{2000}{244.8} = 8.17 : 1$

as fdr = 5.45 : 1

$\therefore$ (OGR)1 = 8.17 x 5.45 = 44.5

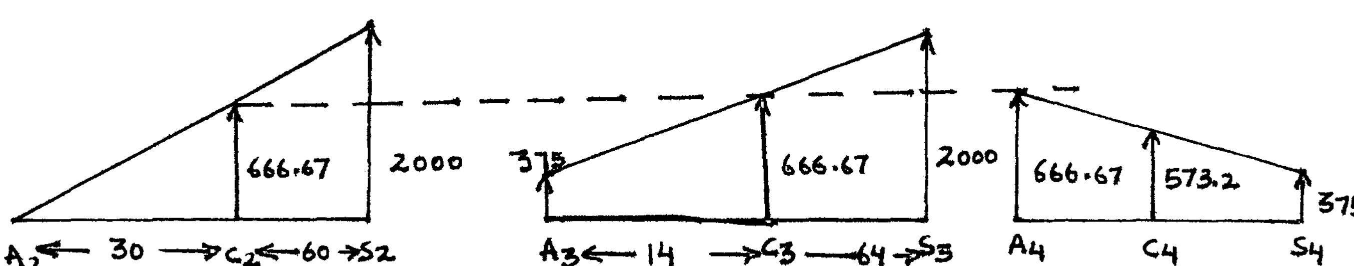
(b) **2nd gear**



Gear ratio (No2) $= \frac{2000}{454.54} = 4.39 : 1$

(OGR)2 = 4.39 x 5.45 = 23.98

(c) **3rd gear**



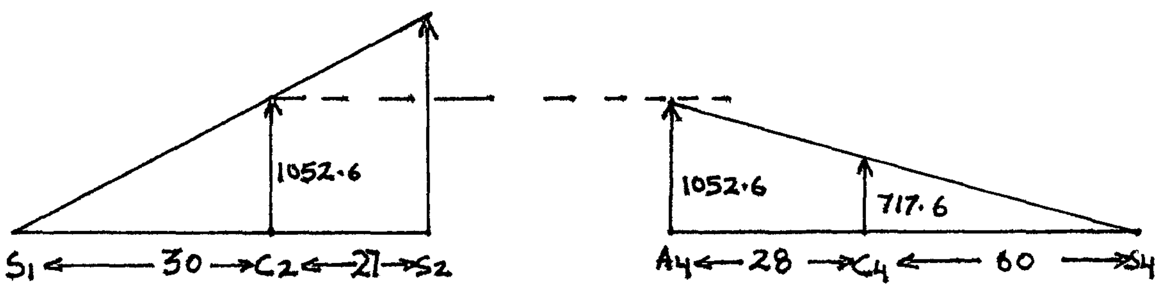
As $\frac{666.67 - Na2}{14} = \frac{2000 - 666.67}{64}$ * Na3 = 375

also $\frac{N66 - Nc4}{28} = \frac{Nc4 - 375}{60}$ = Nc4 = 573.0

(GR)3 $= \frac{2000}{573.9} = 3.485 : 1$

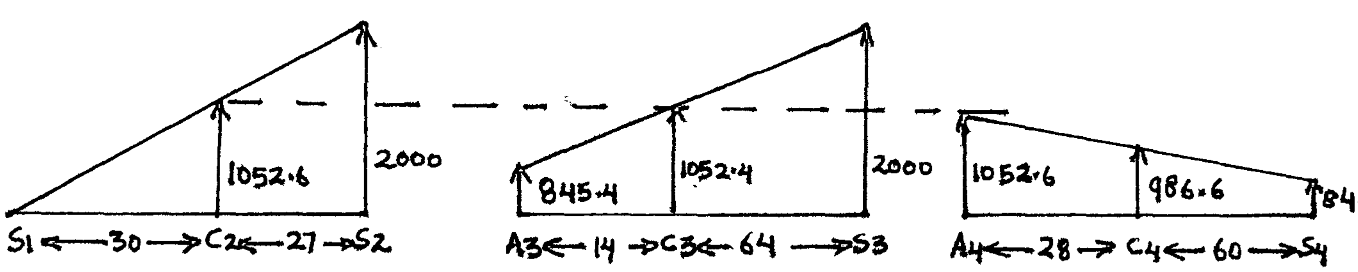
(OGR)3 = 3.485 x 5.45 = 18.99

(d) **4th gear**



(GR)4 = $\frac{2000}{717.7}$ = 2.787 and $(OGR)_4$ = 2.787 x 5.45 = 15.187

(e) **5th gear**

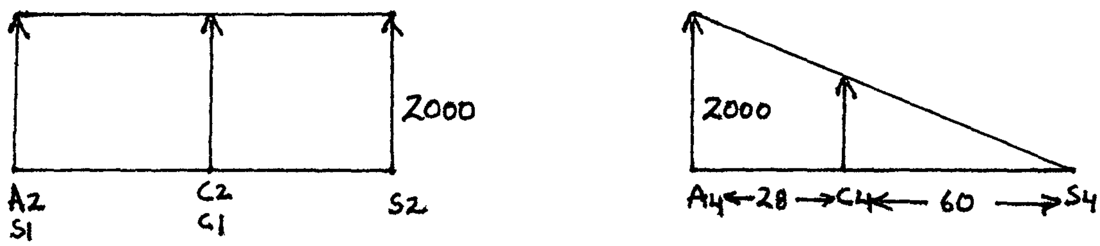


In 3rd train $\frac{1052.6 - Na3}{14} = \frac{2000 - 1052.60}{64}$ = Na3 = 845.4

(GR)5 = $\frac{2000}{986.69}$ = 2.027

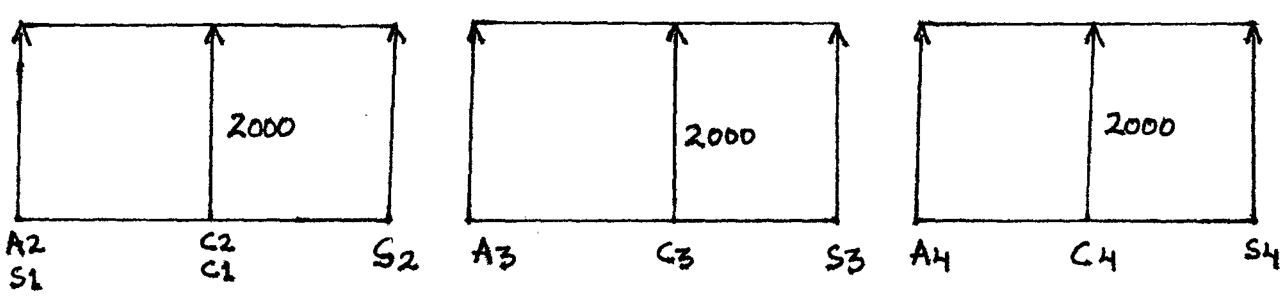
(OGR)5 = 2.027 x 5.45 = 11.05

(f) **6th gear**



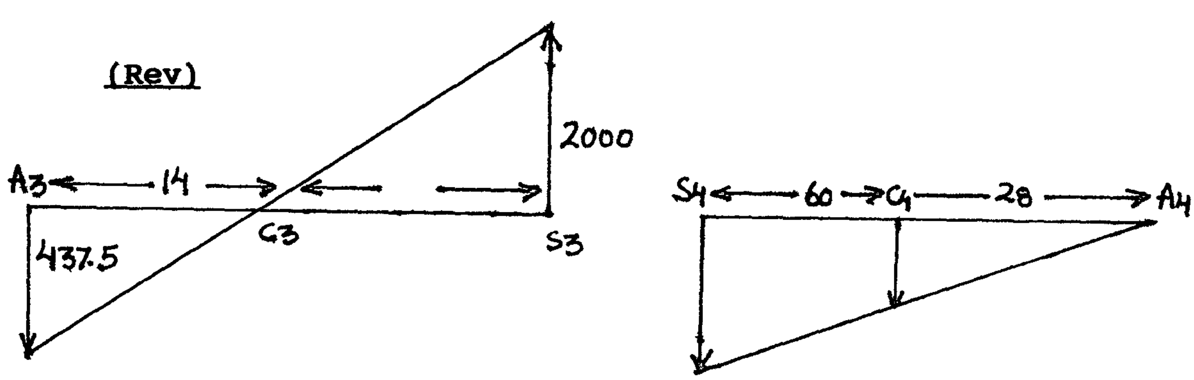
(GR)6 = $\frac{2000}{1363.6}$ = 1.467 and (OGR)6 = 1.467 x 5.45 = 7.99

(G) **7th gear**



(GR)7 = 2000/2000 = 1 and (OGR)7 = 1 x 5.45 = 5.45

(Rev)



In 3 rd train Na3 = - 20064x 14 = -437.5 In 4th train

Ns4 = $\frac{-437.5 \times 28}{88}$ = -139.20

(GR)Rev = $\frac{2000}{139.20}$ = 14.37 and (OGR)Rev = 14.37 x 5.45 = 78.30

THE MODULAR CONCEPT

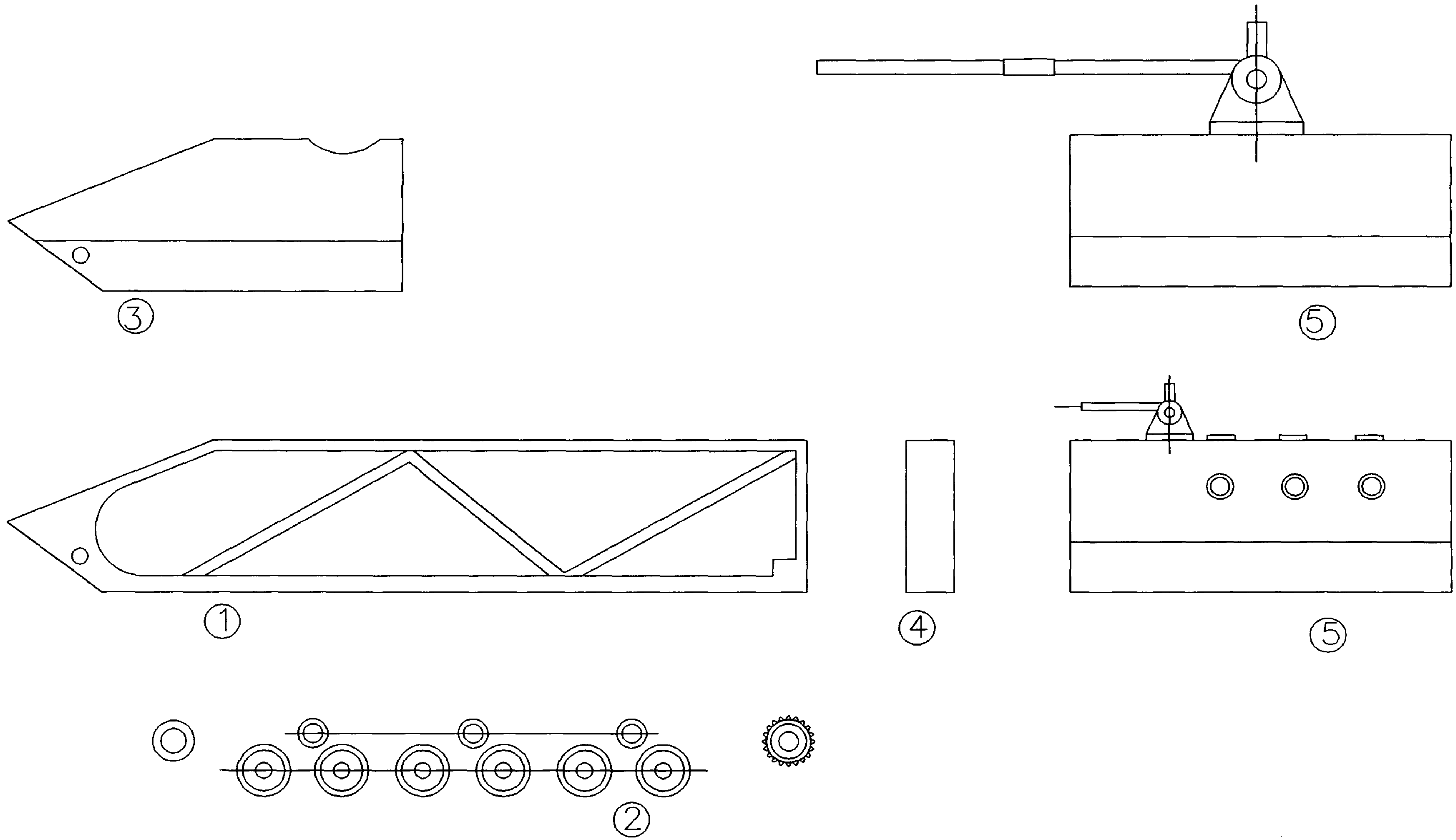


FIG 12. T-72 CHASSIS FRAME

MODULAR ARMOURED VEHICLE FAMILY FOR T-72

55. The module or pod concept requires that combat tasks be designed into separately manufactured inter changable units. Three levels of modularisation are possible; factory modularisation for the production of short, standard, articulated hull units; base modularisation to obtain maximum flexibility from a limited inventory, and field modularisation to allow the exchange of inter face and functional modules on each of these types of hull units. As this paper deals with modular armoured vehicle family based on T-72 chassis, hence only field modularisation will be considered.

56. the field modular concept (ref fig 11) has constant elements which consist of a "chassis" frame and running gear (2) based on T-72 design discussed earlier, and a heavily protected driver or front pod (3) to this are added an inter face panel (4) ref appx 'E' and one of a number of functional pods (5). the functional pods may be based on external mounting (tank destroyer or fire support tanks) a compartment with or without a slaved weapon pod (IFV), CSV) or some combination of two configurations, eg an air defence vehicle (ADV). The automotive pod (6) at the rear also forms a constant element of the vehicle family.

57. The basic structural element is a chassis frame (ref fig 12) that provides ,mounting points for the other elements and stoutness over the rear half of the vehicle. The running gear is mounted on the either side of the frame which is hydro-pneumatic, have a rear sprocket, and provide very large vertical road wheel deflections. The material and design of these two elements are chosen to make them as open as possible. They are unarmoured

apart from the suspension unit housings being hardened against the level of non dedicated attack likely to reach them.

58. The driver pod in front have the driving stick and other arrangement as in normal tank T-72. The front glacies is having additional armour protection as already discussed. The rear part is similar to standard T-72 tank in which the engine compartment is at rear and eng is placed transverselly giving drive to IGB which subsequently drive two side gear boxes connected to left and right hand side sprockets. The power train forms the inner part of an integrated compound armour system and its housing are hard-ened against the residual energy of attack.

59. The first set of role oriented module consists simply of interface panels fitted to the rear of the main pod to match it physically and electronically to the functional modules. the principal weapon platform would produce an external gun tank, complemented, if necessary, by a tank destroyer (TD) mounting a longer and/or larger gun, may be with limited usable traverse and lower rate of fire. The multisensor heads would be on the trun nions. support above the gun level, giving "turret defilade". This module would be partially or completly unarmoured, relying on minimal real presented area to reduce hit chance and on the curva-ture and inherent strength of major components to ward off or with stand minor attack.

60. The infantry fighting vehicle/ command and support vehicle (IFV/CSV) variant would have modular control compartment mounting and an appropriate slaved weapon pod. The air defence vehicle (ADV) and minor variants. could be based on either the platform or box concept.

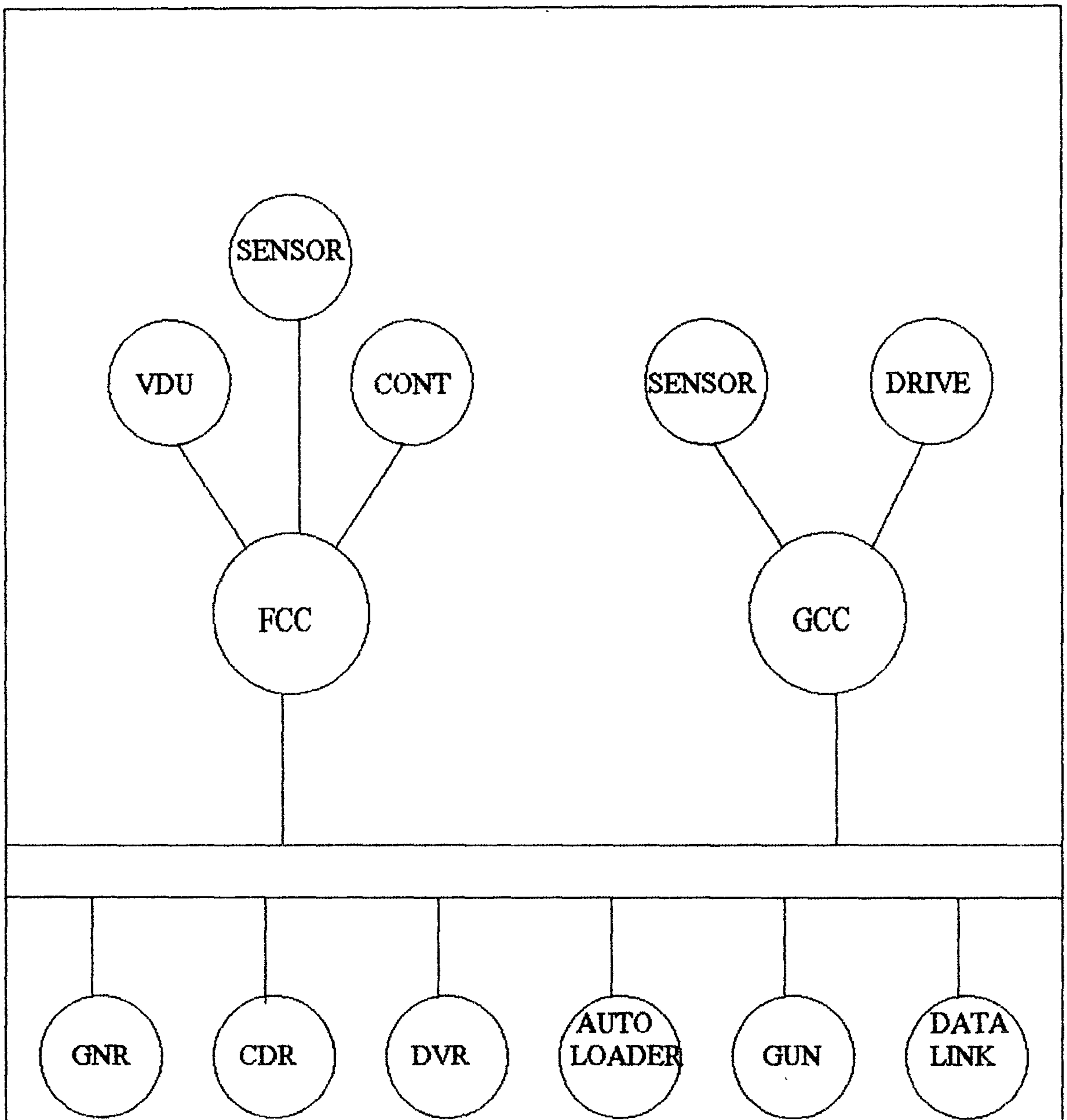


FIG 13 (VETRONICS)

61. The main functional modules would weigh 12.5 - 15 tones they could form swapable bodies for logistic vehicles and the exchange would be carried out by horizontal longitudinal body swamping techniques. In the long haul. this could become the normal method of ammunition replenishment for the major weapon platform.

Suggested Vetronics

62. An acronym derived from " vehicle electronics" vetronics is described as the method by which the modular Concept moves from paper to reality. Not only would all communication intelligence, cornsat systems and electronic warfare be developed in a uniform manner for all vehicles, but this concept would be the means to meet standardized interface specification for the future close combat vehicles (FCCV). In parallel with increased capability would go promise of increased total system reliability.

63. For the modular combat vehicle family based on T-72 chassis, it is proposed to have all electronic system combined by one digital data bus (ref fig 13). Data link is a large base of information data processing which have Navigation, Logistic data, BITE (built in test equipment). Training communication and future growth. The logistic data includes position of fuel, enemy location, No of reports to be sent etc. Software is such that a gun tank can do a commander tank job and so on. Every armoured vehicle is having communication network. Here, only one navigation system is suggested which is common to every armoured vehicle. Future growth potential have been recommended for additional subscriber on a bus bar.

64. The driver is each of the vehicle sub family is sitting in the front and gunners and commander in the turret of the functional module. (depending upon the tank) having initial stations with

control of surveillance and fire power subsystem, mutual line up and driver over ride. The primary vision and inputs to those stations come from independent multi sensor heads at the top of the various functional modules via image processors, and from the on board computer in its fire control mode. The secondary optical system (with a "direct"passive night vision aid) provides excellent unity power buttoned-up vision but no sighting facility. As much as possible of the vehicles electrical power system and electronics to be located in driver and crew pod. The driver compartment has its own collective nuclear, biological and chemical protection system a separate system being provided where required for functional modules.

TANK DESTROYERS BASED ON T-72 CHASSIS

65. The fire tanks were essentially infantry direct support (DFS) vehicles because the concept of Main Battle Tank (MBT) as we know it today had not emerged. This vehicle is not a tank as it is not designed to participate in offensive armoured operations. It is, however, employable as a tank destroyer as well as a mobile platform for a gun with which to provide intimate direct fire support to infantry who will give it protection against short - range anti tank weapon when it is moving. The main features of these vehicles when compared with tanks are reduced armoured protection and expense.

66. Conventional tank destroyers have a large caliber gun, similar to that of an MBT, in a mount that is fixed in azimuth but not in elevation, although the degree of elevation possible is generally small. It is sought to have a vehicle that can form the basis for a family of vehicles. This would lead in reduction in production costs and improve the logistics problem inherent in a

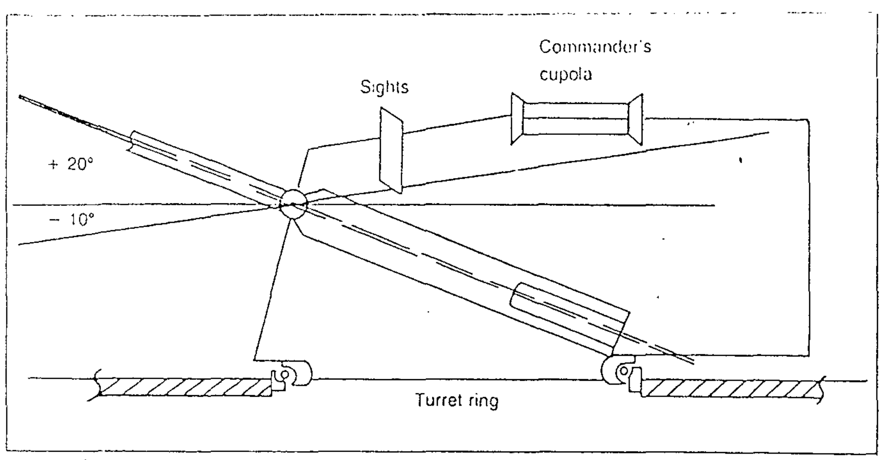


Figure 14 — Schematic of a gun-above-ring design. Because the turret ring is too small, the breech end of the gun must be above the ring at full elevation. This results either in a very restricted elevation/depression arc, or in unacceptable heights between hull roof, trunnions, and turret roof.

multi-type vehicle park. One possible solution is provided by Swedish UDESXX 20 design using an articulated chassis. Other solution is to have a pod concept based on T-72 chassis , which is discussed here.

67. As Richard simpkin has noted in studies on armour, the cost of electronics in current and near term project tanks averages between 40-60 percent the overall cost of the vehicle. If this is true, it would seem to suggest that any tank destroyer design light or heavy would most likely cost as much as a force companion tank.

68. By inference then it would seem more practical to design an armoured vehicle at lower cost produced in volume such that it could be assigned to either the tank troops or the tank destroyer troops as desired.

69. To have an all-round traverse even in the pure anti tank role "Gun above ring" design (ref fig 14) is one of the options with lightly armoured or even open turrets. Examples are FIREFLY (77mm) on M4 SHERMAN. The short coming of this design is that because the turret ring is too small, the breech end of the gun must be above the ring at full elevation. This results either in a very restricted elevation/depression arc, or in unacceptable height between hull roof, trunions, and turret roof.

MOUNTING THE TANK DESTROYER GUN

70. The external mounting system is increasingly favoured in the west, however for a T-72 chassis, the turret like weapon pod of the soviet crew-in hull configuration is appropriate for a MBT role. Preference for this solution is evidently geared to the soviet philosophy on ammunition storage-putting it at the bottom

rear of the hull and to their auto loader technology. As far the protection of weapon pod is concerned even shielding the fire power sub-system from non specialised attack contributes to system survivability. The draw back is that, as in conventional tank, the portion which must be exposed when firing offers a sight picture of a "solid" target with a visible centre of mass, thus increasing the chance both of hit and of a fair hit.

Suggested Turretless Configuration for T-72 Tank Destroyer

71. A turretless functional module is suggested to be mounted on the T-72 chassis for a tank destroyer role. The 125mm smooth bore gun can be mounted in T-72 chassis in one of the following manner :

Internal mounting or fixed gun

72. (a) The concept of fixing the gun to the chassis is very attractive because this would then immediately offer a simple method of automatic loading and would also permit a longer barrel to be used than would be possible in a turreted tank of comparative size and weight.

(b) The vehicle is essentially simpler as the complexity or a fully rotating turret is avoided and because of its compatible automatic loading a three-men crew becomes viable with the consequent advantages of reduced interior volume and hence the possibility of smaller lighter vehicle. The only armoured vehicle currently in production utilising this configuration is the Swedish Bofors 'S' tank. Because the gun is fixed in relation to the hull, the gun is aimed in azimuth by traversing the whole vehicle. Elevation is achieved by changing the relative positions of the front and rear road wheels.

(c) The fixed gun tank offers the advantage of a lower silhouette because the gun can be placed close to the turret roof. The main problem faced by this design is the difficulty of firing on the move, it is possible to design a computer based firing system that would allow the tank, whilst still on the move, to sweep through an arc and fire when the target image and the correct lay of the gun are coincidental, but the hazards of such a system are obvious and this configuration is not recommended for a T-72 tank destroyer.

External mounting

73. Three configurations are possible :

(a) Lift and turn

(b) Over head gun

(c) Raisable Tank gun

(a) **Lift and turn**. Swedish UDES 17 is having this kind of arrangement in which the gun is externally mounted and it can be lifted and traversed. Gun returns to 12 'O' clock position for reloading as ammunition is inside the hull and gun is required to be in line for loading. the top vision is possible only when gun is in depression position. When gun is in elevation then some of the target being aimed cannot be seen by the crew (when sitting), hence top vision is possible only when gun is in depression. In turretless tanks for direct observation crew has to come out and see.

(b) **Over head gun**. US Tank test bed (TTB), Armoured gun system (AGS), and UDES-19 have externally mounted gun. The gun is mounted on a pillar with reduced diameter. It has the disadvantage of gun mounting being fully exposed and protection is required for the mounting. top vision is not possible in this configuration and complex design for auto loader is required. The options available for auto loader design are :-

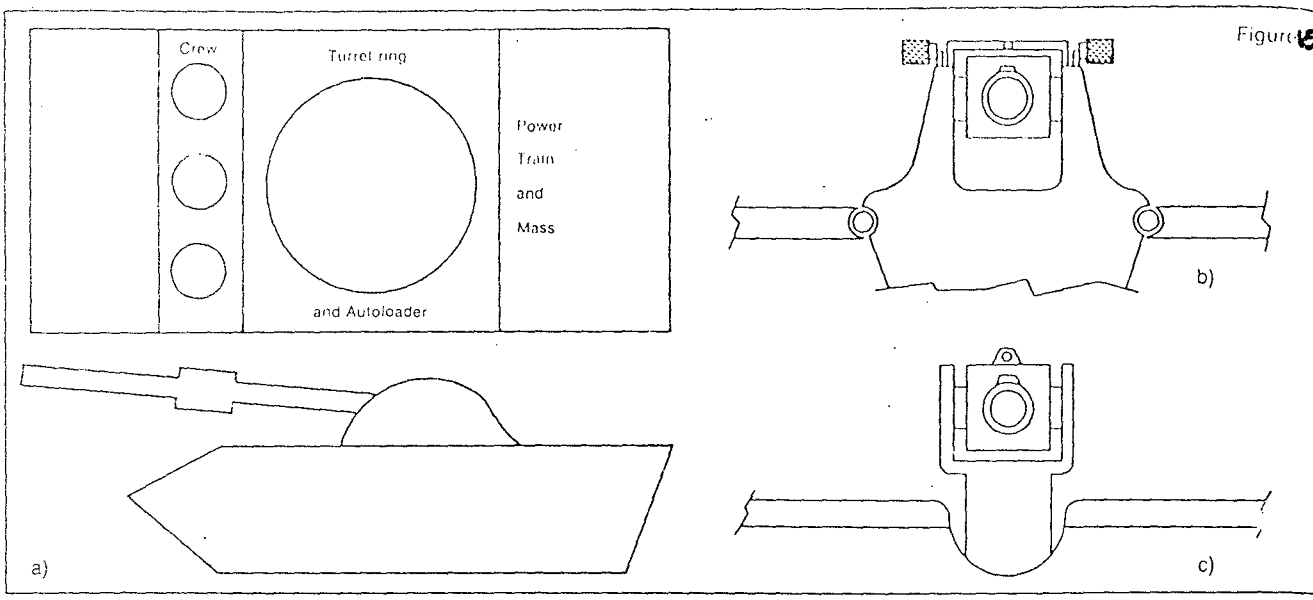
(i) A proportion of ammunition carried in gun. Replenish this from hull during break in battle.

(ii) Rounds are transferred and loaded from hull to what ever be the position of the gun. It is a difficult task as irrespective of position of gun a disc like arrangement is to rotate alongwith gun and an opening always available below position of the breech, making it a complicated design. It will also lead to problem of interface between hull and opening leading to problems during NBC environment.

(iii) Ammunition may be carried at hull back out side armoured of volume gun and loading the gun by a belt feed system. This system has been tried in UDES-19 and has been found successful. However ammunition out side the hull is vulnerable and particularly in T-72 design, the engine compartment being at the rear this arrangement may not be very suitable.

(c) **Raisable tank gun**. the difference between lift and turn and raisable tank gun is that a raisable tank gun rotate without being lifted. This configuration exists in US ELKE vehicle (elevated kinetic energy vehicle). In this arrangement the gun is externally mounted and to operate, the gun is initially traversed into line of target then the gun is raised above the crew vision. The elevation, depression and stabilisation is possible in raised position. Top vision is possible when gun is in lowered position.

Figure 15



Possible forms of mounting for a crew-in-hull tank — (a) The turret-like weapons pod (after Babadzhanyan [2]), (b) Yoke mounting, (c) Pillar mounting.

74. These three concepts have many characteristic in common. The crew arrangement is same. Driver is on front and the mini turret has the main armament. In the turret the gunner will be sitting on left and the commander on right hand side. The commander and gunner will have identical optical system and the same sets of controls available to them.

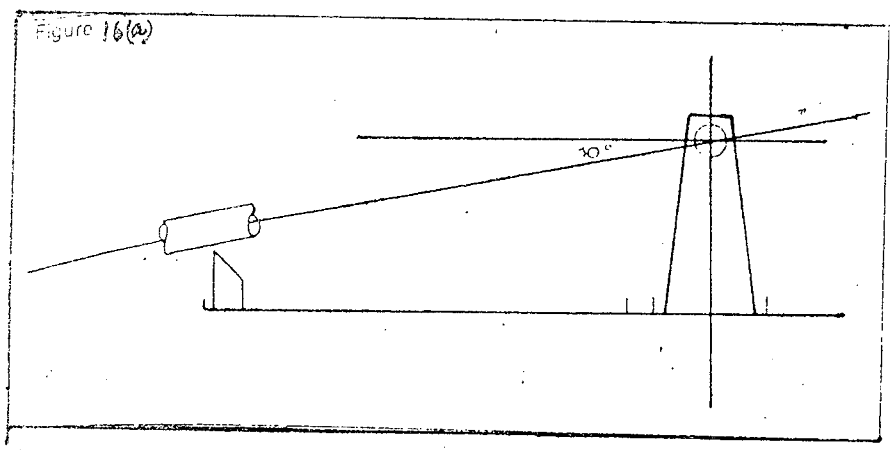
The Retractable gun concept

75. The retractable and non-retractable forms of external mounting are indicated in the UDES 40 out line concept and schematically in (fig 15 b and c). The full yoke mounting, which we have seen in the German and Swedish MARDER/ 105mm test rigs and on UDES XX 20, has a great deal going for it. both the sight picture and the real presented target area are small and broken up, lacking a visible centre of mass. The design is structurally excellant, providing maximum strength against the accelerations of both ballistic attack and cross-country travel for a minimum of weight. The diameter of the mounting ring ties in well with that of the concentric autoloader race, so that the two can be designed and fitted as a single unit. And the cylindrical volume projected downwards from this unit is large enough in diameter to accommodate two sets of slip rings (or the equivalent) as well as the in board (driving) ends of the mounting and multisensor head drives. The hollow vertical members allow mechanical drives and wiring harness to be run up to and above trunnion level with environmental and ballistic protection at no cost in weight, and their top offer platforms for multisensor heads which have to traverse and elevate independently of the gun. In sum the full yoke mounting has the makings of an out standing technical solution so much so that the swept armoured volume required for a retractable yoke mounting might well be a fair price to pay.

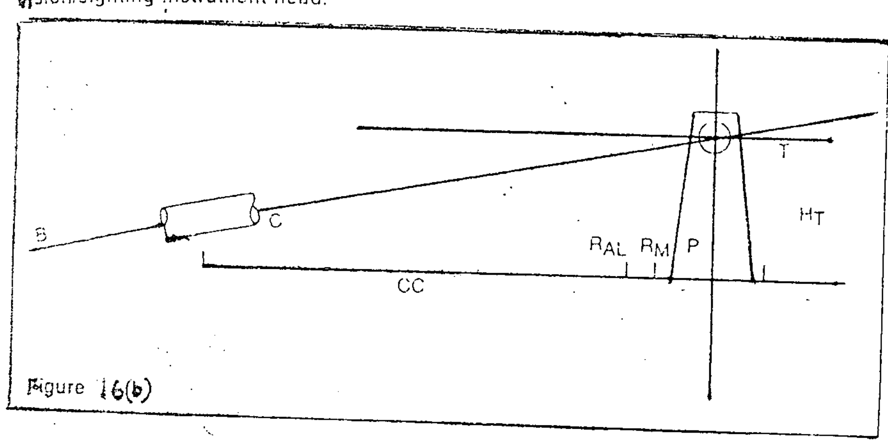
76. At first sight, the natural form for a retractable mountings is a pillar, but the drawbacks of a pillar mounting are the precise converse of the arguments deployed in favor of the yoke. The pillar looks wrong to a tank man. Its both looks and is liable to be bent and jammed by KE effects, blast or impact with trees or buildings. Even if a relatively slender pillar can be shown to be rugged enough, only wiring can easily be passed up it and out of it. thus the complete drives for gun elevation and multisensor head movement would have to be at the top. because of this, the trunnion bearing will inevitably sprout a pair of anything but angelic wings, increasing the frontal presented area right at the top and putting some relatively expensive hardware just where it is most vulnerable. So one can see the pillar starting to grow fatter. Quite apart from making the hackles of anyone familiar with tank design rise, this grow creates a "solid" target with a distinguishable centre of mass. One is on a slippery slope which leads towards the possible Soviet solution without offering any of its advantages.

77. Whilst conceding that the pillar may in the end prove to be valid solution. We should therefore like to have retractable gun argument in terms of a full yoke mounting. The first concept becomes the reintroduction of a swept armoured volume "expensively armoured air" as General von Sengerund Etterlin and others call it of the same order as the usable internal volume of a conventional turret. This is precisely what the crew-in-hull concept sets out to avoid.

78. On the other hand this volume is there anyway (because of the basically rectangular configuration or the hull), and since most of the contents of the rear third of the hull, the "Service



Trunnion height and gun depression, (a) when limited by hull roof, (b) when limited by vision/sighting instrument head.



compartment", will be electrical working units, one might well arrive at a design in which retraction of the mounting in fact wasted very little space. This question can only be answered by detailed design study.

79. The second and related argument against successors to the conventional tank, the height from hull roof to trunnions required for 10^{o} depression is 250-300mm (fig 16a). The objectives and sensor heads of the surveillance and sighting systems will per se be at the top of the mounting. The crew stations will have only hatches of vision domes and unit power vision blocks or periscopes, which are low and likely to be included within the angle made by the depressed gun barrel and the edge of the roof.

80. To give point to retracting the gun, the primary surveillance heads at least, and quite possibly the sight heads if these are separate, must be at the two "fighting crew" (erstwhile "turret crew") stations. We only need to look at the PERIR17 commanders instrument of LEOPARD 2 to appreciate that this kind of instrument would protrude well above the hull roof within the most probable arc of engagement. the need for the gun to clear this instruments head in full depression would at least double the height of the trunnions (fig 16b), with disastrous effects on stability on firing, mounting weight, silhouette height and soon not to mention doubling the armoured volume needed for retraction. Theoretically, these hull-mounted instruments could be retracted as the mounting was raised. But this leaves the crew with a very awkward vision gap which is at best going to increase the time of engagement; and the physical configuration of a crew station makes it very difficult to retract a large instrument of this kind.

81. So the primary surveillance and sighting systems would in fact have to remain on the mounting, although it would be possible to fit a single instrument such as the zeiss PERI R17 in the hull and to retract this between the fighting crew stations when the gun was raised. Quite apart from this, the primary sight head would, it is suggested, have to be on the mounting because, with a retracting gun, there is no sufficiently accurate way of establishing a constant vertical interval between hull-mounted sight (whether optical or optronic) and the axis of the bore, even the use of a muzzle reference sight does not overcome this problem, since its receiver element must evidently move with the gun. thus the greatest single apparent advantage of retracting the gun, the provision of a first rate but relatively simple surveillance system at hull roof level could well prove to be nugatory.

82. The same goes for reduction of silhouette height of the moving vehicle from, say, 1900mm (200mm above the trunnions) to 1500mm or so would significantly reduce the frequency and duration of ex-posure of a correctly handled tank moving through many types of terrain. But moving with the gun retracted facilitates to the ability to fire on the move or to come straight off the move into a fire position with the gun already laid. Since inability to fire, or at least to lay on the move is one or the strongest arguments against S Tank, and since the cost of top traverse in terms of the optics, optronics and electronics needed is enormous one then has to ask whether retraction external gun concept is cost-effective in comparison to a fixed-gun design. Admittedly, the tank could have stabilisation and move gun-up when in contact but then the advantage of reduced silhouette height is lost on precisely the occasions when matters most.

The relationship between kill times (acquisition + engagement times) with visual acquisition (t_{KV}) and automatic acquisition (T_{KA}), firing exposure times (t_{FE}) and hit chance. The same applies to movement exposure times which, in the nineties, are likely to be similar to firing exposure times if the tank is correctly handled.

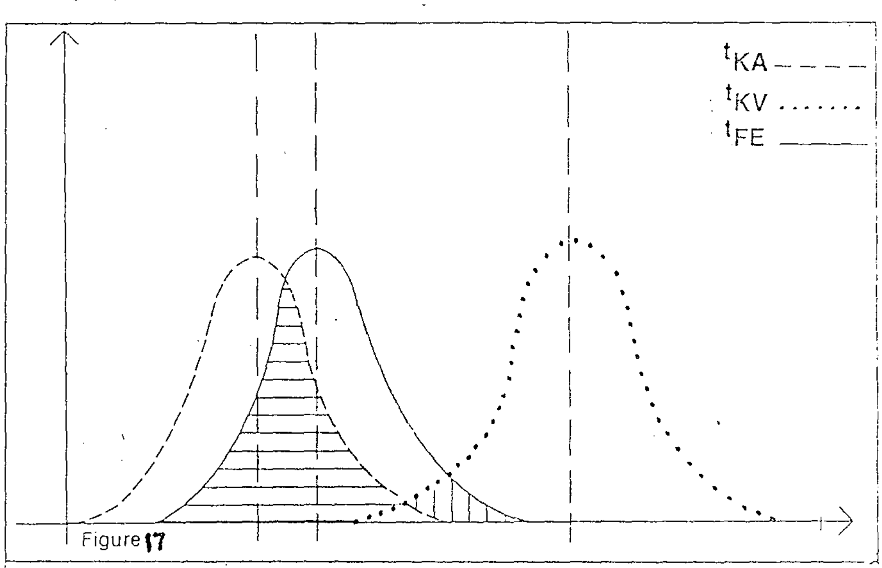
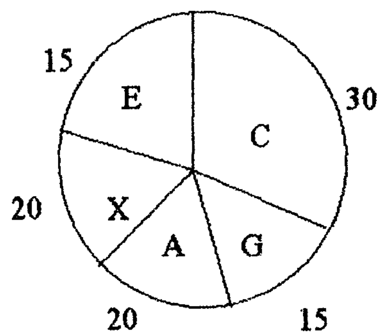


Figure 17

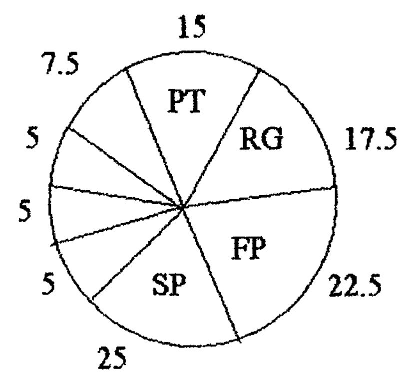
83. The third, and perhaps the strongest argument for a retractable gun is that it allows the vehicle to come from a position of observation ("Turret down") to, a fire position ("hull down") without moving. Certainly this short move forward at best produces a conspicuous visual and audio signature and may result in advertent exposure of the hull. With luck this will come too late for the target, but it makes the firing tank highly likely to be acquired by another tank covering the target or an over watching or helicopter-mounted ATGMS. The ability simply to raise the gun to fire and lower it again certainly reduces this risk. On the other hand, the muzzle effects are so conspicuous that they can hardly be missed, and even when it lowers its gun or pulls back to "turret down", the firing tank remains a direct fire target to overwatching position on higher ground, and of course to attack helicopters.

84. So a tank which fires is going to have at least to jockey within its selected area and probably to move elsewhere if it is not to invite destruction. And contemporary tanks can all range, lay and load turret down and held their lay as they come up to fire, so that stationary exposure need only be momentary. In these terms the only real advantage of a retractable gun in the engagement situation is the postponement of probable disclosure from the moment of moving from turret down to the moment or firing. This is a period of unit seconds, well below current or predictable acquisition times and at least current engagement times. In these terms, a retractable gun would only show a real pay-off if an automatic acquisition of kill times (ie acquisition time + engagement time) and firing exposure times would have a substantial overlap (fig 17) Since hit chance varies roughly as the square of the area of overlap, the elimination of pre-firing

(a)



(b)



Up :-

A = Ammunition, C = Crew, E = Electric etc., G = Gun,
X = Unusable for major items

Down :-

A = Armament, C = Crew, E = Electrics, FP = Frontal Protection, PT = Power Train, RG = Running Gear, SP = Structure/all round Protection, X = Mud and tolerances

Typical armed volume analysis excluding eng compartment (a) and weight analysis (b) for a convention turreted tank.

FIG. 18

exposure time by the use of a retractable gun might be a worthwhile response.

Suitability of basic T-72 design as a Tank destroyer

85. As already discussed in preceeding paragraphs, conventional tank destroyers have a large calibre gun similar to that of an MBT, in a mount that is fixed in azimuth. By removing the rotating turret (as a module) and replacing it with either of a 'turretless configuration module' as suggested in para 72 and 73, we should be able to obtain a T-72 variants which have the basic compact design features of a MBT with added advantage of reduced silhouette.

86. With the same chassis the hull protection is assumed to be same. However, the cast on piece turret (in case of T-72 and T-72M) or cast on piece turret with silicon filings (to increase protection for as by 20% and HEAT 22% for T-72 M1) has been replaced by Tank destroyer 125mm gun. We can try to see as to what proportion of vehicle mass, and perhaps what absolute mass, might be available for protection of an external gun tank against specialised attack. If we exclude the engine compartment (which takes up about one third of the hull armoured volume). We can start with the volume analysis of a conventional tank typified by figure 18a. If we exclude loading space and the swept volume of the gun, all now external, we can reduce the volume by about 15%. Much of the weight comes from their armour envelope (fig 18b refers) and the weight of the later depends, in turn, on the space it has to enclose as well as the thickness of armour. In well protected battle tanks of recent years the percentage of weight accounted for by armour has generally fallen within the narrower range of 45 to 51 percent and its weight per unit of internal

volume has been 1.3 and 1.7 ton/M^3. Hence with a 15% reduction is volume we should be able to fix a weight of approx 34 tons for T-72 destroyer, figure nicely born out by 'S' tank and the heavy version of UDES40.

87. At about 34 tons, within the weight limit for swimming with an on-vehicle screen, there is now to be had a vehicle which is a true successor to the turreted main battle tank in combat worth and offers an advantage of a 17% weight out into bargin.

Performance Capability of T-72 Variant as a 'Tank destroyer'

88. In modern day tactical scenario armour can be employed in 'Tank destruction task' under following conditions :-

(a) **Destruction of Laying off Tanks**. Tanks destroyer may destroy in pre-selected and if necessary, pre-prepared positions to engage the laying off tanks.

(b) **Destruction of Enemy Armour Attempting to Penetrate the Defence**. During the resistance stage of own defence, when the enemy is trying to crumble the defences and enlarge his foothold, own 'Tank destroyer' may be used to break up enemy armour attacks. They would do this by occupying, pre reconnoitered fire positions on the flanks of the enemy attack axis and shooting up enemy tanks as they attempt to penetrate the defences.

(c) **Destruction of Enemy Armour Trapped in killing Areas**. If the enemy can be successfully channelised into selected killing area, he can then be destroyed by concentrated fire of all available 'Tank destroyer'.

(d) **Infantry Tank Cooperation**. In modern day Army armour and mechanised infantry operate accordingly to common tactical doctrine. One of the more frequently used configuration is that the infantry/mechanised infantry operates in the assault role and the tanks are in fire support role, firing from a static location called fire basic. The tank destroyer design of T-72 suggested as above will be an appropriate one to ensure mission reliability where the AFV is to operate in fire support or more and less static role. (with adequate battle field mobility).

155MM SELF PROPELLED GUN BASED ON T-72 CHASSIS

90. Self propelled howitzers are key players on the modern battle field, once equipped with an effective and autonomous command and control system, they are capable of expeditious deployment and rapid relocation of concentrated fire power. To accomplish the fire support mission under all weather and combat scenario, a modern self-propelled howitzer must posses these basic characteristics :

(a) Autonomous rapid firing reaction

(b) High operational availability

(c) Optimum crew ballistic protection

(d) Significant reduction of manpower work load intensity

91. Apart from the locally produced 130mm catapult self propelled gun (consisting of a modified Vijayanta chassis with the Soviet 130mm M-40 gun fitted to the rear) and the remains of 68,105mm Vickers Defence System Abbot self-propelled guns the Indian Army does not have any modern self propelled artillery system in service.

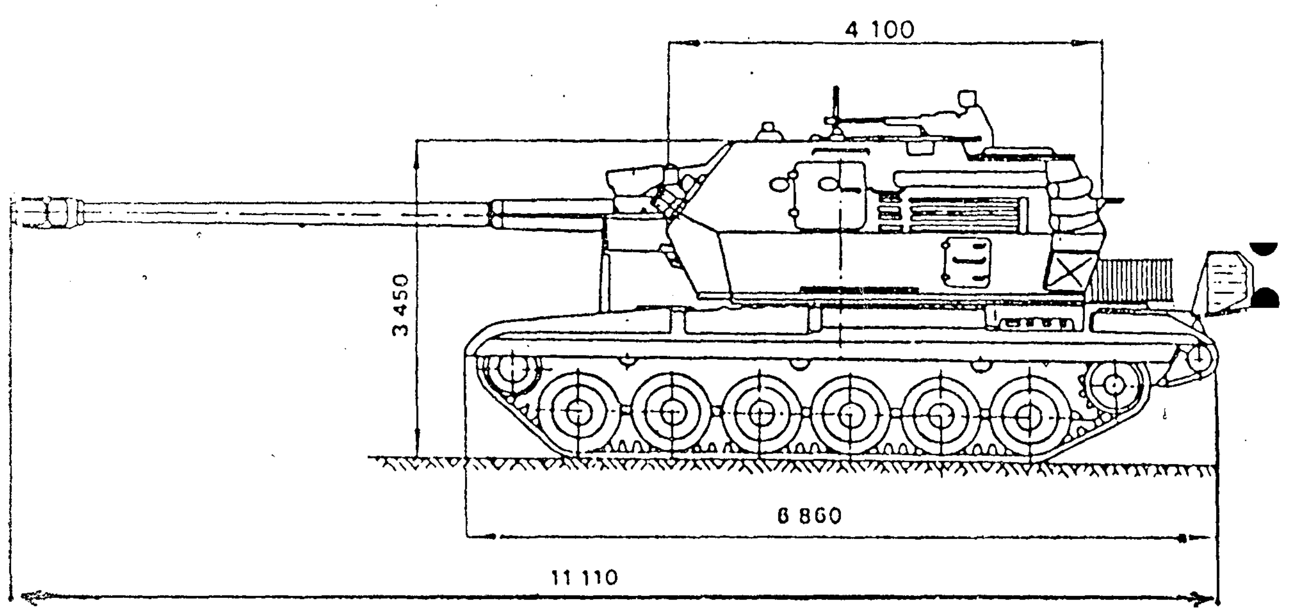


Fig 19 *Side drawing of T-72M1 chassis fitted with Zuzana 155 mm/45 calibre artillery turret*

92. Vijayanta tanks are being phased out from Indian Army, which means that 130mm Catapult SB Gun would also be out of production. The self propelled gun so far have been found to be deficient range, lethality and survivability and also lacks the mobility to keep up with rest of the manoeuvre force.

93. The Indian Army thus has a requirement of upto 600, 155mm/45 calibre self propelled artillery systems which could be based on the locally produced T-72 MBT chassis hence a functional module of 155M/45 calibre artillery turret can be fitted on T-72 common chassis to obtain a self propelled gun of T-72 family.

94. Various system available to be mounted on a locally manufactured T-72 MBT chassis are :-

(a) French GIAT industries 155/40 calibre GCT turret

(b) UK VSEL 150mm/39 calibre As-90 turret system

(c) South African LIW (a division of Denal) 155mm/52 calibre T6 turret system.

(d) Slovakians ZTS 155mm/45 calibre Zuzaan turret system

95. After fire power and mobility trials, ZVS 155mm self propelled gun-howitzer Zuzaan, normally mounted on an 8x8 wheeled chassis, has been recommended to be fitted on the locally manufactured T-72 M1 MBT chassis. (Ref fig 19).

96. The 155mm/45 calibre ordnance fires an extended Range Full Bore-Base Bleed (ER FB BB) projectile to a maximum range of 39.6 Km with a total of 40 projectiles and associated charges being carried. Due to the installation of an automatic loader a maximum rate of fire of six rounds per minute can be achieved or 30 rounds in 6 minutes. Using manual loading a maximum rate of fire of one round every two minutes can be obtained.

Suitability of basic T-72 design as a self propelled gun

97. The T-72 chassis providing improved mobility, ability and manoeuvreability can keep up with the maneuver forces and provide optimum ballistic protection. Implementation of a modified available tank chassis will substantially reduce development cost and technical risks, shorten the development cycle, greatly reduce the logistic burden and preserve the industrial base for production of T-72 tanks and other armoured vehicles. Hence a common chassis concept for a family of armoured vehicles is availed approach and worth pursuing today more than even before.

Specifications

98. Crew : 4 Max road speed- 60 KM/hr

Combat weight - 38 tons, Power to weight ratio-2052HP/ton

Ground pressure - 0.72 Kg/cm^2

Length : (overall) - 11.10M, Hull - 6.86M Width - 3.59M

Height : (with AAMG) - 3.45M, Range road - 650KM

Engine - Model W 46.6V - 12 diesel developing 780hp at 2000rpm

Transmission - Manual with 7 speeds forward and one speed reverse

Steering - Clutch and brake. Suspension - torsion bar

Armament - (Main) 1x155mm gun

(AA) 1x12.7mm MH

Ammunition - (main) 50 x 155mm

GCE - Turret power control - hydraulic/manual

Traverse - 360^o, Gun elevation/depression - $+70^o/-3.5^o$

Performance capability of T-72 Variant as a 'Self propelled gun'

99. Self propelled howitzers are key/dangers on the modern battle field while the normal field medium and heavy artillery (with the calibre in the range of 100-155mm) can engage the enemy targets upto a range of approx 30-35 KMs, they have the inherent

disadvantage of lack of mobility. Hence own gun areas become a lucrative target of enemy fire. Under such conditions, higher calibre and long range of a 155mm turret system coupled with high mobility and protection levels due to inherent T-72 design, will enable a 155mm self propelled gun based on T-72 chassis, to accomplish the fire support mission under all weather and combat scenarios.

INFANTRY COMBAT VEHICLE (ICV) BASED ON T-72 CHASSIS

100. Armoured personnel carrier (APCs) have normally been used as battle field taxis to transport an infantry section as close as possible to an objective before a six to eight strong assault element dismounts to fight on foot. Usually armed with a pintle mounted 7.62mm or 12.7mm machine gun; The APC can only provide limited fire support, compared with older APCs the latest ICVs have significant improvements in armour, mobility and firepower allowing them to operates more closely with main battle tanks. It is also of great importance that if a new MBT is fielded an ICV should have similar mobility if they are to work together. In the USA the M1 Abrams MBT and M2 Bradley were fielded together as were the British Army's Challenger - I and warrior.

101. With T-72 common chassis the ICV is likely to be more in weight than most of the in service ICVs all over the world. the point to be borne in mind is that latest trend as such is towards "adequate" protection of ICV. Hence, the ICV can boast of the same protection level as modern MBT. this doesn't seem to present too many technical problems, and adequate space for an infantry squad can certainly be provided in a vehicle having the same armour protection an on MBT. There is also no reason why an MBT armoured ICV should carry a prohibitive price tag.

FIG 20. T-72 CHASSIS

DESCRIPTION OF PROPOSED ICV

102. The T-72 chassis and running gear (ref fig 20) as discussed earlier is proposed to be used for modular ICV design with same driving and engine compartment. The functional modules will consist of a turret of all welded aluminium armour construction providing the crew with protection from small arms fire and shell splitters. The turret is in the centre of the vehicle with the commander seated on the right and the gunner on the left. The commander has a single piece hatch cover that opens forward with integral periscopes for observation purposes. Day/night sights and search light is mounted on the forward part of his cupola.

103. In the roof of the vehicle, forward of the commander's hatch is a large rectangular hatch that open to the left which may be used for ammunition/missile resupply purposes. In addition, there is a rectangular hatch in the turret roof towards the rear that opens forwards, which may be used for ejecting spent cartridge cases.

104. Over the frontal arc the turret is provided with a layer of spaced armour and mounted on either side of this is a bank of three 81mm electrically operated smoke grenade dischargers

105. the completes weapon system proposed is similar to as existing on the BMP-3, is known as the 2K23 and consists of a 100mm gun, 30mm 2A72 coaxial cannon and a 7.62mm coaxial machine gun, al in a common mount.

106. The 100mm 2A70 rifled gun will fire 3UOF17 and 3OF32 high explosive fragmentation rounds at a rate of fire of 8 to 10 rds/min, or the 3UBK-10.3 with the 9M117 laser-guided missile. The 100mm high explosive rounds are fed from an automatic loader

when the 100mm laser guided projectiles are fed upto the breech manually.

107. The 9M117 (Bastion) has US designation of AT-10 with the cartridge cases being similar to those used by other 100mm projectiles. The 9M117 can also be fired by modernised T-55 MBTs fitted with the Kiadivo fire control system and the 100mm MT-12 towed anti-tank gun. the missile itself weight 26.8 kg with a flight time to the maximum range of 4,00M of 12 seconds.

108. There are 40 rounds of high explosive fragmentation ammunition carried for the 100mm gun, 22 of which are for ready use in the automatic loader. This round has a maximum range of 4,000M and a muzzle velocity of 250M/s.

109. A total of eight 9M117 anti-tank guided missile will be carried is a semi-automatic LASER beam guided missile and all the gunner has to do to ensure a hit is keep his sight on the target.

110. The main armament is fully stabilised as is the gunner's sight which has a day channel with a magnification of x8 and a night channel with a magnification of x5.5.

111. The fire control system will include a ballistic compute, a LASER range finder which is mounted in a box over the main armament and a met sensor.

112. The gunner will have a secondary day sight with a magnification of x2.6 while the commander has a dual sight 1P3-10 with a magnification of x1.2 and x4 and a periscope TKN 3MB for observation purpose with a magnification of x5 by day and x3 by night.

113. Mounted coaxially to the right of the 100mm gun will be the 30m 2A72 cannon which is ballistically identical to the 30mm 2A42 cannon of the earlier BMP-2. The more recent 30mm 2A72 only has 349 parts whereas the older 30mm 2A42 has some 578 parted.

114. The dual feed 30mm 2A72 cannon will be able to engage armoured vehicles to ranges of 1.500 to 2,000mm and helicopters out to 4,000M. Cycle rate of fire is 330 rds/min and three types of ammunition are fired is API,HES and HEAT. The API has a muzzle velocity of 960 to 980 m/s while the HEAT has muzzle velocity of 960 to 980 m/s. The API projectile will penetrate 25mm of steel at an angle 60^{o} at a range of 1.500M. A total of 500 rds of 30mm ammunition will normally be carried. 305 of which will be HEAT and 195 API.

115. Turret traverse will be full 360^{o} with weapon elevation from -5 to $+60^{o}$. The latter enables the weapons to engage helicopters. Turret traverse and weapon elevation are powered.

<u>Suitability of Basic T-72 as an Infantry Combat Vehicle (ICV)</u>

116. The conventional characteristics of infantry armoured vehicles are :-

(a) Capacity

(b) Mobility

(c) protection

(d) Fire power

A little thought however, will indicate that there are good reason for changing two of these - Mobility and Protection. There are other additional consideration as well. These includes the reliability of the vehicle, the ease with which it is maintained and the ease with which it can be repaired. While protection is a key ingredient, what the veh must really do is survive on the battle

THE MODULAR I.C.V.DESIGN

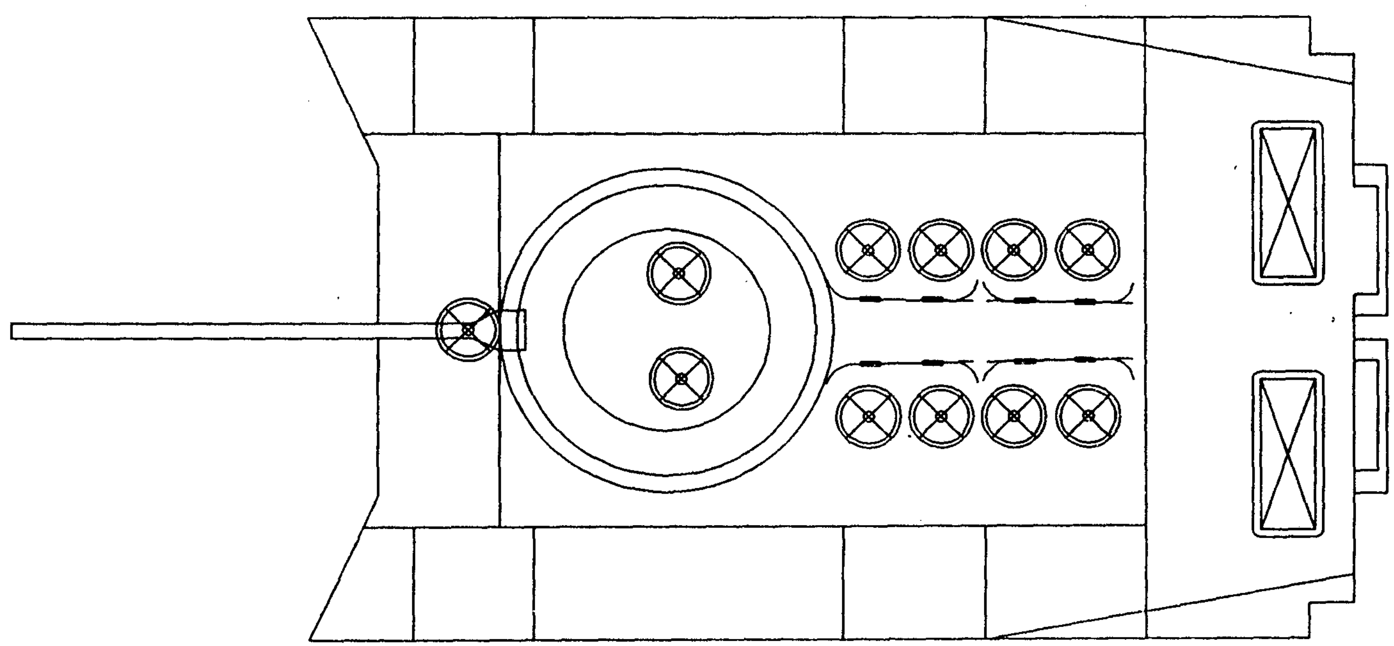
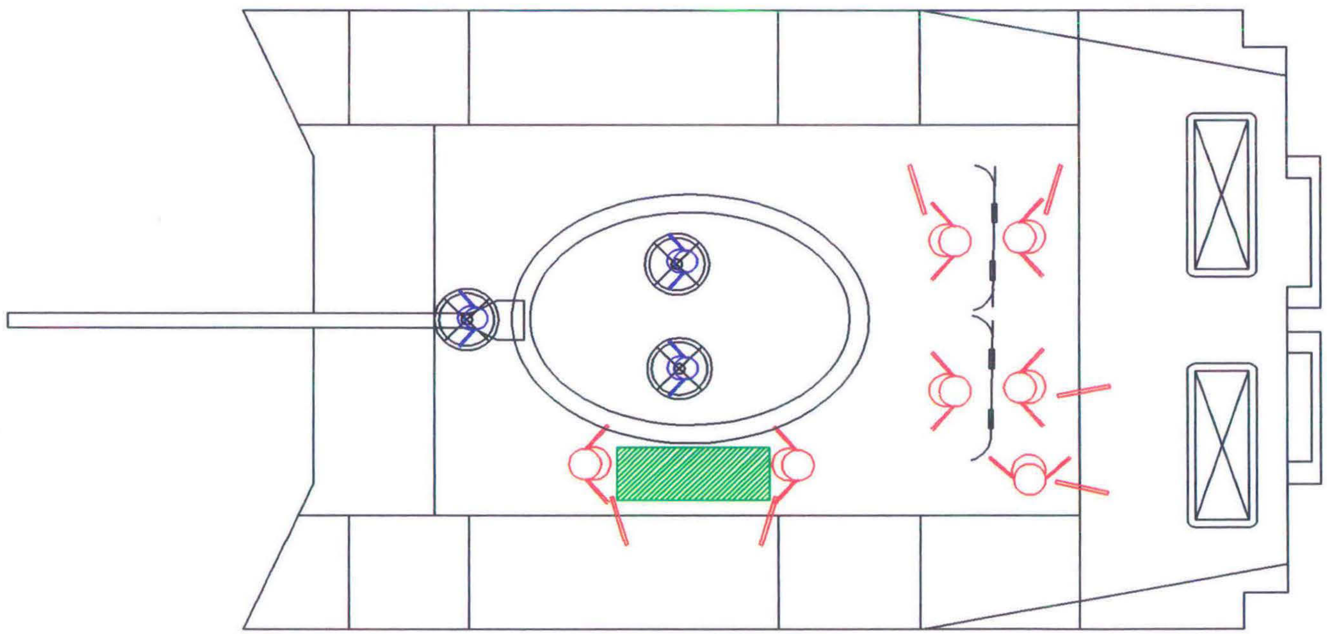


Fig 21 (a)

THE MODULAR I.C.V.DESIGN



field. Hence, two of the basic characteristics of infantry ie 'Mobility' and 'Protection' could be replaced with term such as 'Availability' and 'Survivability'.

117. Analysis of basic T-72 design in the preceeding paragraphs has revealed that with a simple design and sufficient engineering support available in the country,'Availability' and 'Survivability' of T-72 as an Infantry Combat Vehicle (ICV) could easily be maintained. Driver compartment and engine compartments are fixed. As suggested in fig 14, with loading space and swept volume of the gun excluded, volume can be reduced by 15% with reduced thickness of turret armour and weight per unit of internal volume being between 1.3 and 1.7 ton/M^3, approximate weight of 32-33 ton can be fixed for ICV based on T-72 chassis.

118. The basic crew consists of commander, gunner and driver. (ref fig 21a). A total of seven to eight infantry men can be carried. The seating arrangement can be of two type. Eight infantry men can be carried at the rear (like in BMP series ICVs) two on either side. An alternate configuration for the tps is shown in fig 21b, it is similar to Broadly M2 in which the gunner sits is the left hand side of the turret and the vehicle commander, who dismounts with the infantry, in the right hand side, six firing ports are provided so that the infantry can shoot from inside the vehicle. Over the top of the troop compartment large rectangular roof hatches are proposed along with two doors in the functional modules on the left and right hand side of vehicles. As these doors are opened steps automatically fold down. All most all the present day ICVs have doors in the hull rear. However, such as arrangement is not possible in the proposed configuration of fixed engine compartment at the rear.

Though BMP-3 has engine at the rear compartment. but the power pack is located low down at the very rear of the hull and rear doors have been provided for troops to mount and dismount. Even this arrangement of BMP-3 is said to be in-convenient for the troops. With the T-72 engine compartment at the rear, entry and exist doors cannot be provided there and this appears to be one of the major design constraints in having modular design concept based on T-72 chassis as the eng compartment is forming one of the constant elements.

119. With the increased weight of upto 33 tons the machine's amphibious quality has become a chancy thing. However, it will still have the shallow fording and deep fording capabilities like any T-72 MBT.

Performance Capability of T-72 Variant as an Infantry Combat Vehicle (ICV)

120. The requirements for three separate type of infantry can be easily identified. The three types of infantry can be called light, mechanised and armoured infantry. In present day tactical scenario the armoured infantry are gaining acceptance as a specialised form of Infantry. The German army has had 'Panzer grenadiers' for many years. The armoured infantry vehicle must have the same mobility as do the tanks with which it operates. It must provide a high level of protection, defeating all anti-APC cannon on the battle field. Ideally it should withstand the same levels of attack as the tank. British MCV80, is a modern armoured infan try vehicle.

121. **Organisation for Combat**

A 'Combat Team' is a tactical group of arms based on an armour squadron (14 tanks) or Mechanised Infantry company (15 ICVs) Headquarter. The combat team normally comprises a complete tank squadron or complete mechanised infantry company, with one or more non organic sub units placed under command. These combat team's are the fundamental units of modern mechanised warfare. Hence armour and mechanised infantry would almost be operating together. Fighting formations such as armour brigades etc have been designed on these lines. Factors for considering the size and composition of a group (ie more no of tanks or ICV) are :

(a) Mission

(b) Ground

(c) Enemy opposition

(d) Availability of own troops

(e) Time available for execution.

122. **Regrouping in the Field**

With an T-72 variant as Infantry combat vehicle capable of carrying 8 infantry men, a tactical regrouping in the field is possible, specifically changing the 'tank - infantry' balance. It is envisaged that for effective utilisation of 'Combat Vehicle family based on T-72 Chassis', an integrated combat arm, is a prerequisite to full exploitation of task configuration. Under such arrangements, 'Combat Teams' of the required balance can be formed by the company level regrouping from a balanced force of conventional tanks and infantry battalions. Based on tactical situation, a change in first line balance of the force as a whole can only be achieved by backloading tanks with their crews, or ICVs with their squads and bringing forward manned vehicle to replace them.

123. With a progressive training system within composite (armour and mechanised infantry elements) platoons, it would be feasible for the exchange of functional modules (Tank or ICV turret) and reduce the infantry strength. This is thinkable on a limited scale, since the men released might be required as individual replacements for casualties within the force. The more probable requirement for going infantry heavy would entail the converse exchange of functional modules. Again, given the progressive integrated training system, the tank crew would be capable of providing the mounted crew and squad commander of T-72 ICV. This is an acceptable war time expedient; as in a battle field more extreme disruptions, brought about simply by loses, could be expected.

Proposed Specification

124. Height : (Over turret roof) 2.30mtr

(Overall) 2.65mtr

Firing height : 2.02mtr

Ground clearance : Track width = 580mm

Length of track on ground = 4.25mtr

Maximum speed : (Onwards) 70Km/Hr, reverse = 20Km/Hr

Eng : Same as T-72 MBT

Txn, Suspension, Electric System : Same as MBT T-72

Armament : (Main) = 1x 100mm 2A70 Gun

Coaxial = 1x 7.62mm PKT MG

(Smoke grenade dischargers) =12x 381mm

Ammunition : (100mm) 40, (22 in automatic loader) ATGW-8

(7.62mm) 60

GCE : Gun stabilised in Traverse and elevation by Cdr & Gnr

Gun elevation/ depression : $+60^{o}/-6^{o}$

Turret Traverse = 360^{o}

ADVANTAGE OF MODULAR COMBAT VEHICLE FAMILY

125. The user and logistical advantages of modular combat vehicle family are as under :-

(a) Given careful design, two third or three quarters of the hardware's unit cost and at least 60% of the maximum indivisible load of short and standard variants will be contained in the hull elements, (considering factory moduleri-sation with standard, short and expended - sub family). The carriage of reserved functional modules, interface panels with role oriented electronic packs in the logistic Train becomes in itself attractive, in terms both of inventory and of sea, air and road lift.

(b) Functional modules would weigh between 8-10 tons, together with ancillaries. They could be carried in normal logistic vehicles and managed by crane or by horizontal swapping techniques. Kolos/ Tatra authorised to each armoured formation forms part of 'Immediate Replenishment Group' (IRG) and they could be utilised to carry the functional modules. Alternatively ~A' Vehicle tracked (forward repair teams) ie AVT (FRTs) or armoured recovery vehicle (ARVs) can be suitably modified to carry these functional modules. The decision to vary various type of functional modules is left to the tactical commanders.

(c) The other advantage of this kind of arrangement is the ability to keep key functional modules in service when other parts suffer battle damage or service technical failure. Similar modules can be easily cannibalised/ replaced from other equipment.

(d) Task configuration means the ability to optimize the structure and equipment or a task formation or combat team for a particular operation, campaign or mission. A modular combat vehicle family would allow an intervention force to be equipped from stock in a way that precisely matched its needs. By the same token, the need for equipment oriented retraining would be minimized. The availability of a saving arising from commonality and modular construction, combine to put a new look inter and intra theatre air mobility indeed on strategic mobility and long time intervention in general.

(e) Regrouping in the field is feasible, specifically changing the "tank infantry" balance. For example the more probable requirement for going infantry heavy would entail the converse exchange of functional modules. Again, given the progressive integrated training system the tank crew would be capable of providing the mounted crew and squad/commander of the IFV. Manned reserve functional modules could be exchanged with other functional modules for this purpose. Hence one would almost certainly be forced to adopt the principle of vehicle and personnel staying and moving together. Re-enforcements could only be used for restructuring as a very short-term expedient; in any event, they may not be available for this purpose. This slice of manpower and equipment would be far better placed in coherent, balanced, integrated combat arm unit to start with.

126. Briefly, the advantages of the pod concept in terms of restorability and survivability are these :

(a) Armoured volume to be fully protected is small, and the space within the integrated frontal protection system is fully utilised.

(b) Side protection is enhanced by the frame and running gear and skirt plate could be used.

(c) The rear is covered by the engine compartment.

(d) The external gun configuration reduces the tank height and silohutte and provides a degree of supplementary over head protection to the crew compartment.

(e) The crew compartment need not be exposed in fire position, and will be exposed to fire on well under 50 percent of movement exposure of the vehicle.

127. If, for these reasons, we allow the pod and running gear a 30 percent chance of survival by passive protection and the same of hit avoidance, we close the survivability gap for the mobile sub system crew plus pod, frame and running gear (comprising 80 percent or more of system cost), and gain an imponderable asset in the shape of improved morale, The greatest threat becomes in fact an anti-tank mine even then, the vehicle would be recoverable (in the normal sense). The price of this 'restorability' concept is evidently short-term loss of availability and carriage of replacement functional modules.

PROBLEM AREAS IN DEVELOPING MODULAR COMBAT VEHICLE FAMILY BASED ON T-72 CHASSIS

128. (a) The hull of the family of vehicle is indeed nothing more than a mobile, variable protected space which can be reconfigurated for each task role tank, infantry carrier, self-propelled artillery chassis, etc. (With limited additional design time and effort). The automotive drive train and suspension as well as many similar pieces of equipment such as hatches, periscope, air filtration system and so on

would be common 'Strap-on' or modular armour has been ruled out here to develop the combat vehicle, because in Indian context, we hardly see where a unit, victorious in combat will take precious pursuit time to, return to the rear to bolt-on or remove such armour for the next (presumed) mission. Though it has applicability for inter-theatre transport (helicopter loading) one must also question practicali ty of moving entire vehicle battalions by helicopter or air transport once in the theatre. Naturally, as long as the vehicles do not grow to a weight exceeding that of prevailing heavy, long range lift capacity, it would seem reasonable to transport the vehicle with armour attached given that both must arrive at a location at some relative point in time and though fuel consumption might be reduced when using such vehicles for police mission (IS duties etc), it is hardly to be expected that tanks, mortar carriers or self-propelled artillery would see similar service and, as such, be designed to a given level of armour protection as selected for the tank (certain to require the most armour), well below maximum load stress level for automotive and suspension component, growth in armour protection to meet requirement of future close combat would be assured.

(b) The module or pod concept is one to which analysis so far have been casting a declining vote. The reason for the same are not far to seek. Though all of the features of automotive suspension and general components commonality are met, we see little but problems arising from both the function, mechanical and tactical aspects of the proposal. As to the former, a vehicle chassis would suffer from inherent design weaknesses at critical points or chassis stress over

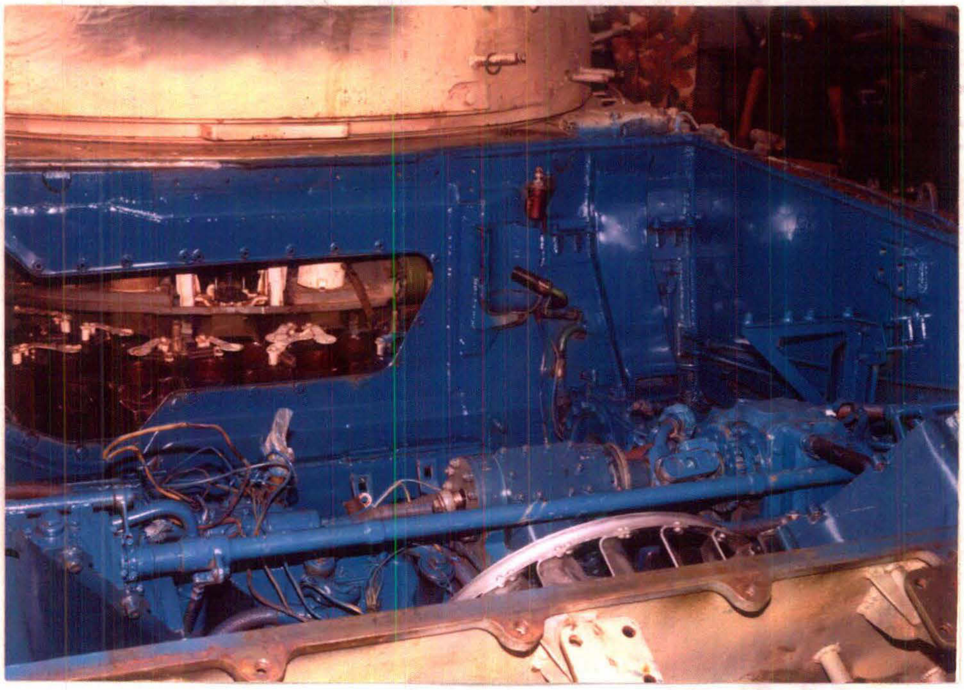


FIG. 22 T-72 ENG COMPARTMENT

design - with a weight increase yielding no practical defensive or automotive benefit. Mechanically the concept has little more to often than the 'Swing - wing' design on high performance jet aircraft, where such interface problems were encountered in strengthing the wing-roots. More over the proposal suggests that a vast array of electronic assemblies would require a 'plug-in' approach of design, which would offer no more than the problems experienced with the 'plug-in' two missiles and launcher system. It is clear, that the module concept although ostensibly offering multiple functions for T-72 chassis as the need arises (tank, personnel carrier, SP gun), indicates nothing about what could be done with temporarily discarded modules and crews to man them.

(c) Placing the engine (ref fig 22) and transmission at rear of the hull imposed serious design constraints to develop the modular combat vehicle family for T-72. The rear engine configuration have the advantage of depression possible for the gun and to keep the height of the tank to reasonable limits. Also there are less chances of optical problems in line of sight due to rising heat from the engine compartment. In rear engine less protection is required thus reducing weight of the tank. Rear engine leads to comparatively stable cross country side with less of pitching movement and better gun stabilisation.

129. The placing of engine and transmission forward of the fighting compartment will increase the protection for the crew in the MBT role. If it is intended to produce a series of vehicle based on same chassis, than the forward engine and transmission configuration has a very strong attraction. For example, recovery

vehicle (based on common chassis) would like an unencumbered rear working compartment to house a winch and allow direct rear access.

(a) If it is intended to use the chassis as a basis of a self-propelled (SP) gun, then the forward engine compartment becomes even more advantageous. No extra support is required in the form of spade or other such aid to help support the firing force (which is transmitted along line of action). When large amount of ammunition are to be carried, rear turret offer easier loading facility.

(b) It is in the range of medium and light AFVs that the forward engine location finds most favour. The advantages of unrestricted rear access for personnel carriers, ambulances and command vehicles are immediately apparent. ICV based on T-72 common chassis have the inherent design flaw of no rear door possible, forcing the troops to use top hatch or specially made side opening folding door in the functional module (along with the mini turret).

(c) Although the latest Russian ICV BMP-3 have power pack at the rear compartment however, the power pack is located low down at the very rear of the hull allowing enough space for entry of troops via two doors in the hull rear opening left and right. Moreover the engine side and capacity (500hps) are less than the 780hp engine fitted in the T-72 common chassis. The engine and its location in the rear compartment can not be tempered with, as it is forming a constant element of our modular combat vehicle family.

<u>CONCLUSION</u>

130. The effort to design a new family of close combat vehicle is a prodigious task. Research and development in employment technology can yield profits by reducing design time-line, risk

and cost. Important of course, is that the design of these vehicle meet the primary goal of enhancing a combat commander's ability to out think and out fight his opponent.

131. Adoption of a modular concept for T-72 design would be likely to entail a weight penalty, from known analogies of probably around 5 percent. Against this one must set substantial savings in inventory cost, logistic cost and logistic lift. Despite difficulties in designing the modular construction is restroability. The ability to offset attrition very quickly by replacing battle damaged functional modules on fit hull with fit crew - even more may be, the saving in crew casualties that the 'restorability' concept offers.

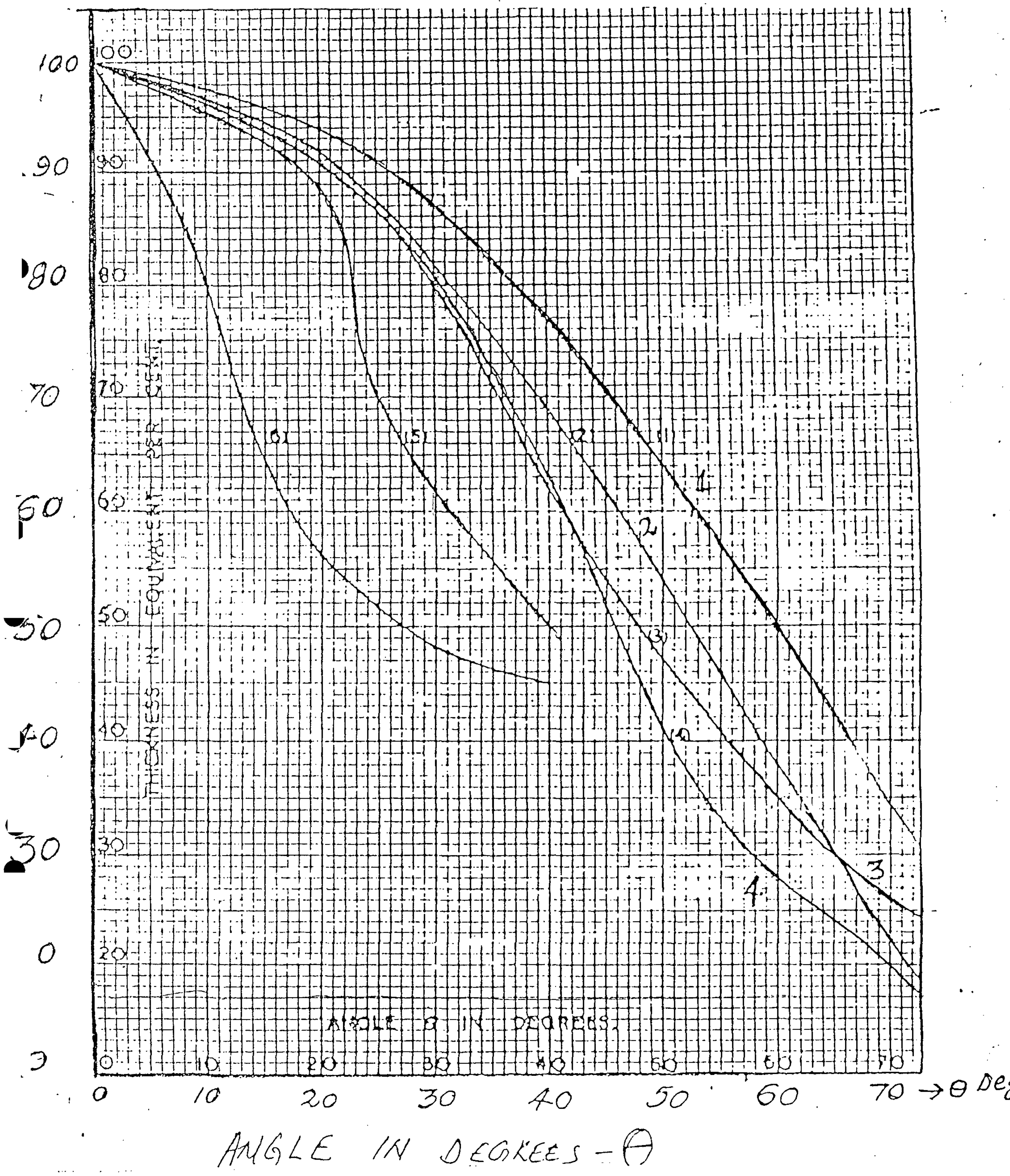
132. A comprehensive modular armoured vehicle family looks to offer a dramatic pay of in flexibility at base level. For a tolerable inventory cost, a task - configured force could be equipped within the time needed to establish and train it. Task configuration saves manpower, increases combat worth, and dramatically reduces the lift needed both for deployment and for subsequent logistic backup.

133. At factory level, the economics of modulersation would turn on production techniques, notably methods of production control, and the size of the total production run. Certainly automated control and robotized lines favour modular design. In a long war, modular design would greatly ease both innovation and the turning of production programs to changing need. Hence the concept of common chassis for T-72 has great merit, and in todays environment where most of countries are struggling to maintain some semblance of tank industrial base, we may have a perfect oppurtunity to achieve multiple kills with one Sabot.

THICKNESS / ANGLE PERCENTAGE EQUIVALENTS, WEIGHT AND PROTECTION.

APPENDIX - A

$\frac{T_\theta}{T_N}$, WHERE T_N IS VERTICAL THICKNESS ATTACKED AT 0° & T_θ IS THICKNESS OF SLOPED PLATE OR OF ANY PLATE ATTACKED OBLIQUELY AT θ°.



APPENDIX 'B'

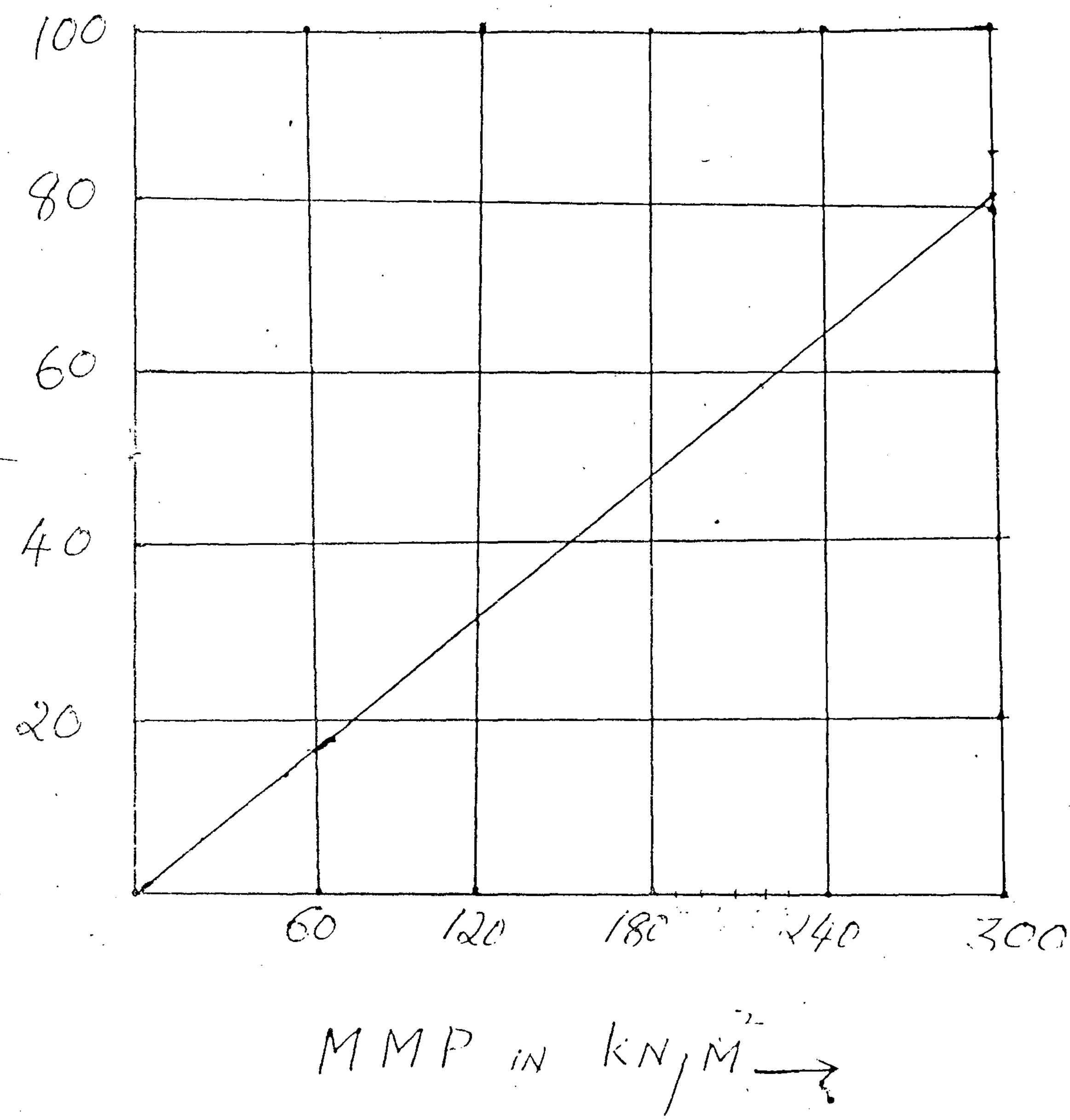
P(U): Probability of Attack between ±U

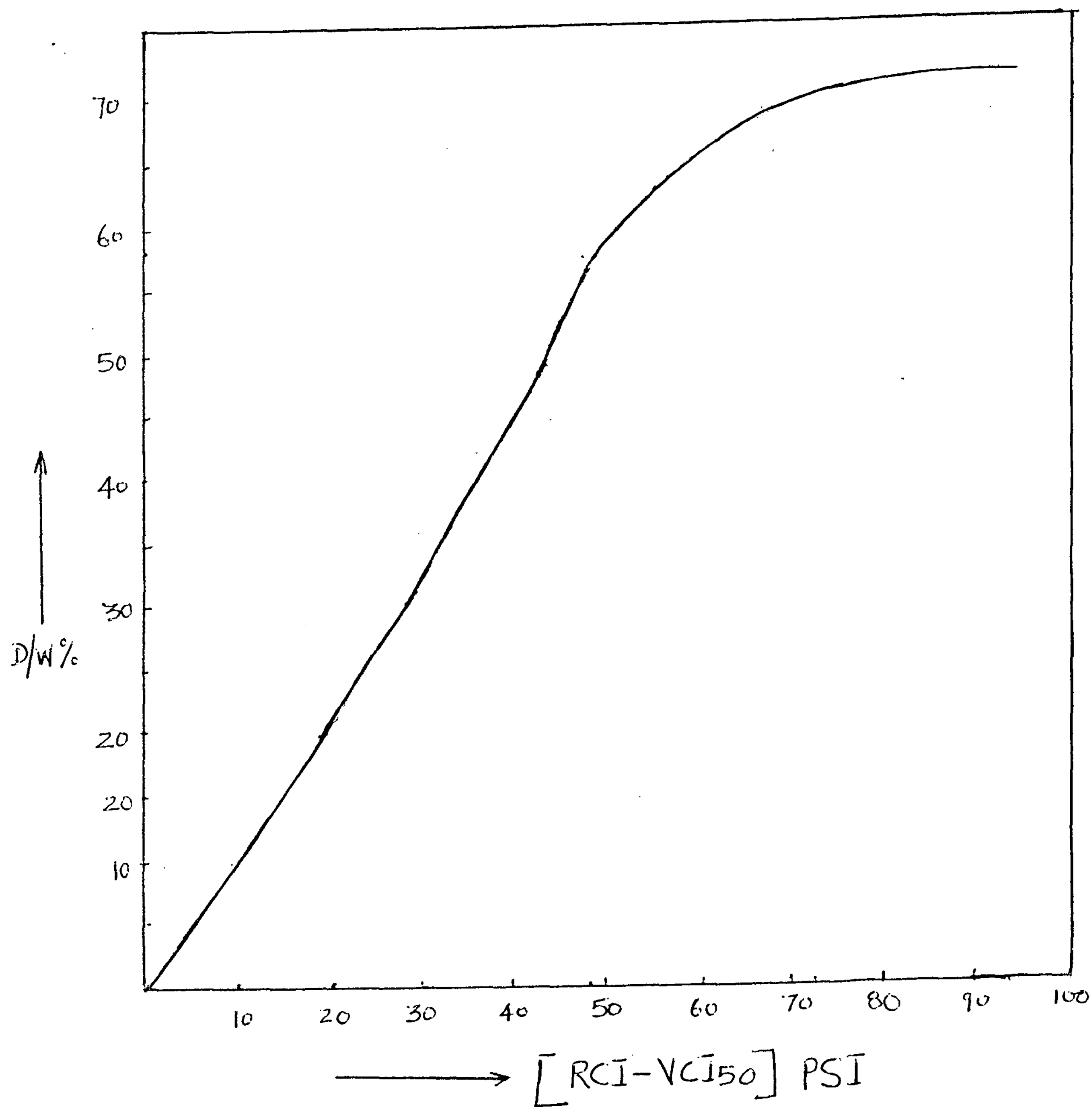
90° U 180°

U	P(U)	U	P(U)	U	P(U)
90	.8297	120	.9244	150	.9809
91	.8335	121	.9269	151	.9821
92	.8372	122	.9294	152	.9833
93	.8409	123	.9318	153	.9845
94	.8445	124	.9342	154	.9856
95	.8481	125	.9365	155	.9867
96	.8517	126	.9388	156	.9877
97	.8552	127	.9411	157	.9887
98	.8587	128	.9433	158	.9897
99	.8621	129	.9455	159	.9906
100	.8655	130	.9476	160	.9915
101	.8688	131	.9497	161	.9923
102	.8721	132	.9517	162	.9931
103	.8754	133	.9537	163	.9938
104	.8786	134	.9556	164	.9945
105	.8818	135	.9575	165	.9952
106	.8849	136	.9593	166	.9958
107	.8880	137	.9611	167	.9964
108	.8911	138	.9629	168	.9969
109	.8941	139	.9646	169	.9974
110	.8971	140	.9663	170	.9978
111	.9000	141	.9679	171	.9982
112	.9029	142	.9695	172	.9986
113	.9057	143	.9711	173	.9989
114	.9085	144	.9726	174	.9992
115	.9113	145	.9741	175	.9994
116	.9140	146	.9755	176	.9996
117	.9167	147	.9769	177	.9998
118	.9193	148	.9783	178	.9999
119	.9219	149	.9796	179	1.0000
120	.9244	150	.9809	180	1.0000

Appendix 'C'

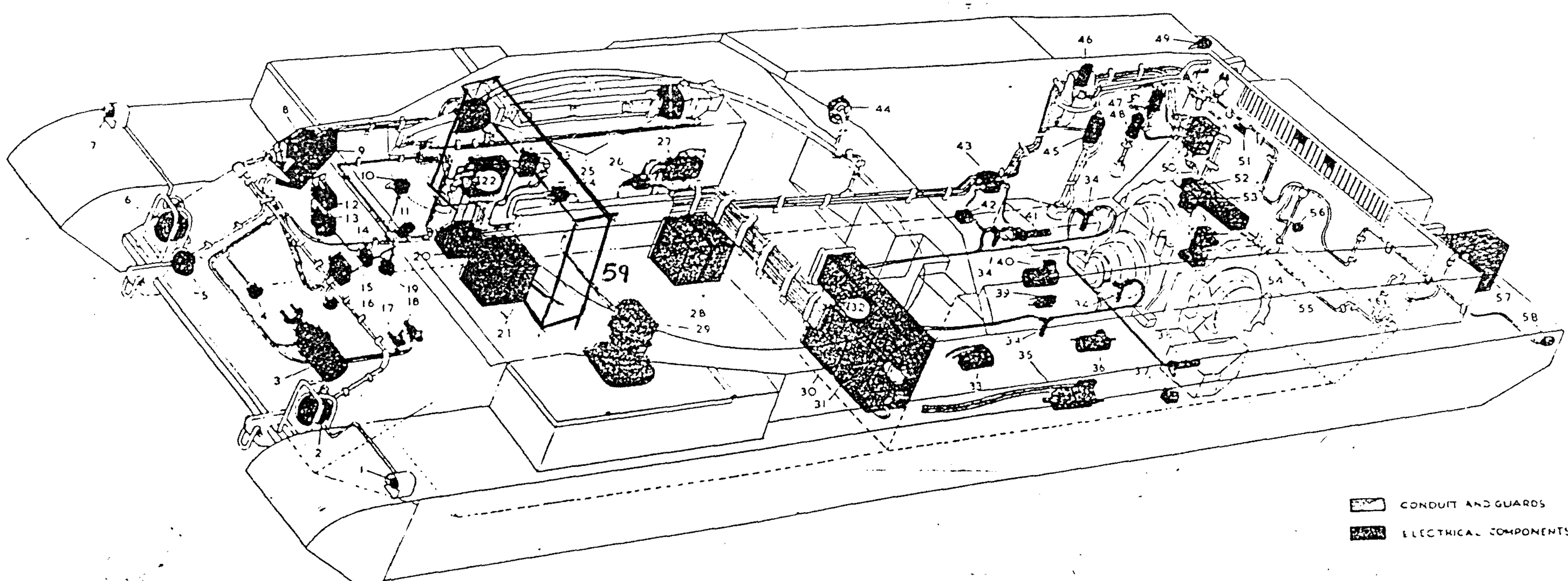
MMP Vs VC150





D/W% VS [RCI-VCI50] PSI

Appendix E



Hull electrical installation

1. SIDE LAMP (LH)
2. HEAD LAMP (LH)
3. GEARBOX CONTROLLER
4. FIRE ALARM HORN
5. TRAFFIC HORN
6. HEAD LAMP (RH)
7. SIDE LAMP (RH)
8. FAN AND WIPER SWITCH BOX
9. INSTRUMENT PANEL
10. DRIVER'S SAFETY SWITCH
11. HORN PUSH AND DIP SWITCH
12. MAIN ENGINE SWITCH BOARD
13. AUXILIARY ENGINE SWITCH BOARD
14. SUPPRESSION UNIT
15. EXTERIOR LIGHT SWITCH BOX
16. INTERIOR LAMP (DRIVER)
17. PRESSURE WARNING SWITCH
18. REVERSE PUSH
19. DRIVER'S PERISCOPE WIPER MOTOR
20. BATTERY MASTER SWITCH
21. BATTERIES
22. HULL MAIN JUNCTION BOX
23. BOILING VESSEL CONTROL BOX
24. NEGATIVE LINE JUNCTION BOX
25. VENTILATION FANS
26. POSITIVE LINE JUNCTION BOX
27. FLAME SWITCH TEST BOX
28. BATTERIES
29. ROTARY BASE JUNCTION
30. GENERATOR PANEL NO. 6 MK. 2
31. GENERATOR PANEL NO. 7. MK. 2
32. HULL DISTRIBUTION JUNCTION BOX
33. STARTER (AUX. ENGINE)
34. FLAME DETECTORS
35. GENERATOR (AUX. ENGINE)
36. GENERATOR (MAIN ENGINE)
37. SUPPRESSION UNIT (LH)
38. FUEL FEED PUMP (LH)
39. ENGINE JUNCTION BOX
40. STARTER (MAIN ENGINE)
41. FUEL FEED PUMP (RH)
42. SUPPRESSION UNIT (RH)
43. ENGINE COMPARTMENT JUNCTION BOX
44. FUEL GAUGE
45. BILGE PUMP MOTOR
46. DUST EXTRACTOR FAN
47. FILTER UNIT
48. TRANSMITTER ELECTROMAG
49. TAIL LAMP (RH)
50. HULL REAR JUNCTION BOX
51. NUMBER PLATE LAMP
52. GEAR SELECTION SOLENOID
53. GEARBOX GOVERNOR
54. TEMPERATURE SWITCH (GEARBOX)
55. OIL PRESSURE SWITCH (GEARBOX)
56. CONVOY LAMP
57. INFANTRY TELEPHONE BOX
58. TAIL LAMP (LH)

59. PROPOSED INTERFACE PANEL

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D S COMMENTS