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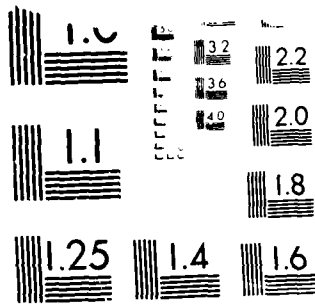
A REVIEW OF THE IMPROVEMENTS TO ARMoured-VEHICLE TRACKS 1/1
FOR THE AUSTRALIAN ARMY (U) MATERIALS RESEARCH LAB
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GENERAL DOCUMENT

MRL-GD-0004

**A REVIEW OF THE IMPROVEMENTS TO ARMOURED-VEHICLE TRACKS
FOR THE AUSTRALIAN ARMY**

T.W. Rea

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A REVIEW OF THE IMPROVEMENTS TO ARMOURED-VEHICLE TRACKS
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ABSTRACT

This paper describes some of the material improvements which have been made to the tracks of the Leopard Mk I Main Battle Tank and the M113 Armoured Personnel Carrier. These improvements were part of a program aiming for local production of replacement Leopard track in line with the existing Australian production of replacement M113 track. It gives a technical description of the operation of these live tracks, describes problems in steels and rubbers which have been exacerbated by harsh operating conditions in Australia, and describes in-service failures and the need for very strict maintenance procedures. Particular attention is given to the widespread problem of fatigue fractures of Leopard track pins, overcoming the problems with improvements that culminated in local production of pins with markedly better fatigue resistance. The role of the Leopard/M113 Track and Suspension Steering Group in the implementation of component improvements and the monitoring of their in-service performance is also described.

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1. INTRODUCTION

The introduction into the Australian Army of a high performance tracked vehicle, in the form of the Leopard Mk I Main Battle Tank, posed many problems with the track and suspension. In order to overcome some of these problems, collaborative work has been undertaken by MRL and Maintenance Engineering Agency (MEA) to support the through-life operation of the Leopard Tank tracks.

The prime cause of the problems was two-fold:

1. There was the requirement for higher technology based maintenance than was normal for the existing Army vehicular equipment.
2. The tanks were to operate in the harsh Australian environment which was so unlike that of the country of origin. Consequently a new operational and maintenance data base was required, as there was no background experience of these types of conditions available from other users of the vehicle.

The aim of this report is to provide the background description to the problems, and to describe how they were overcome.

2. DESCRIPTION OF LIVE TRACK

A tracked vehicle runs on road wheels along a track which is carried, laid on the ground and then picked up by the vehicle. The track is continuous and is assembled from a series of links so it is flexible enough to

wrap around and engage a sprocket wheel which transmits the power from the engine transmission to pull the vehicle along the track. The links are joined by through pins and the tensile load on these pins is proportional to the weight of the vehicle, the applied power and the particular manoeuvre being carried out at the time.

A heavy vehicle such as a tank can use this system to advantage as the maximum power from the motor can be applied by the sprocket wheel to the track, which is held firmly on the ground by the weight of the vehicle. Furthermore the track also distributes this heavy weight evenly over a large area and both of these factors enables the heavy tank to move freely and quickly over difficult terrain.

There are obvious differences in the appearance of tracked vehicles used for commercial purposes and those used for military purposes, however a less obvious but major difference is in the track. The commercial type vehicle uses the track to obtain a high level of traction over all surfaces while generally moving in a straight line at low speeds, whereas the military vehicle has the track that will enable it to move freely over all surfaces and manoeuvre under arduous conditions, often at high speeds. This performance cannot be achieved with metal to metal contact of the track links with the connecting pins and road wheels. Lubricated surfaces are needed to reduce wear, vibration and noise, and the simplest method is to use a 'solid lubricant' in the form of rubber inserts under compression.

The two basic types of track using the steel/rubber system are described in the following sections.

2.1 Single-Pin Track

This type of track is used in the M113 Family of Vehicles and is shown in Fig. 1. It is based on a single forged or cast "shoe" with integral lugs on the leading and trailing edge, slots to engage the sprocket wheel, a projecting horn to guide the track along the centre of the road wheels. The shoe is shaped on the upper face to accommodate a rubber road wheel pad and, on the lower face, a replaceable track pad. The track is assembled with the lugs on the front edge of one link interlocking with the lugs on the rear edge of the adjacent link and they are connected by a single pin passing through rubber bushes pressed into the lugs (Fig. 1). The bushes comprise a steel tube with octagonal-shaped bore and a smaller pin of matching cross-section; the space contains rubber of suitable formulation, bonded to both surfaces. This ensures that relative hinge movement between the links has to be accommodated by shearing of the rubber, and resistance to shear failure is the specified property of the rubber being used. In operation the greatest shear stress on the rubber bushes is minimised as the links are assembled to form a *live track*: the bushes are positioned so that the assembly is preset to an angle equal to half that required to wrap around the sprocket and idler wheels. The road wheel pad is a rubber formulation to resist abrasive wear and is chemically bonded to the track shoe. The track pad is a replaceable item, the rubber being bonded to a metal plate and this is bolted to the track shoe. The rubber here is formulated to resist chunking and abrasive wear.

Single-pin track of the steel/rubber system is restricted to light vehicles because the rubber/pin bushes limit the loading that can be placed on a track. Steel components can be increased in size and thickness as the operating forces are increased, but there is a limiting thickness that rubber can be used in the shearing mode. Alternating loads on the rubber generate heat that ultimately destroys the chemical bonding of the material. The rate of heat generation increases rapidly with increases in rubber thickness. When a greater load-carrying capacity is required, it is necessary to increase the surface area and length of the rubber bushes and reduce the angle of bush rotation; and this leads to the concept of the double-pin track.

2.2 Double-Pin Track

This type of track is used on the Leopard Mk 1 Main Battle Tank (MBT). Each element is called a link, which comprises an assembly of two link bodies (which are similar to the 'shoes' above) and two circular pins held in these link bodies. The track is assembled by joining pins from adjacent links using three separate connectors, one at each end and one at the centre of the pins (Fig. 2). The connectors have a dual purpose as the "end connectors" also act as the contact surface that engage the sprocket wheel and the "centre guide" connector incorporates a horn to guide the track along the centre of the road wheels. The rubber bushes in this track are moulded on to the pins which are then pressed into the link bodies; flats on the ends of the pin are angled relative to the end connector geometry, so that as before the assembled links have a torsional preloading equivalent to half the wrap-around angle and form the live track. This type of assembly now makes it possible to use the steel/rubber system for the track of the heavier vehicle while maintaining the same optimum thickness of rubber bushes as used in the single pin track. The use of two pins not only doubles the length of the rubber bushes available to carry load, it also halves the shearing angle on the bushes. The different properties required for the rubber bushes, the road wheel tyre and pad and the track pad are very similar in each of the two types of track described here, so that the optimum rubber formulation used in each component is found to be virtually the same in both track systems.

Despite the cushioning effect of the rubber bushings, the steel components in the track are subjected to heavy shock loading even on smooth paved surfaces. This loading is intensified when surface roughness or obstacles result in point loading of the individual link assemblies. Consider the action on a track link in a Leopard Tank travelling at speed, when seen by a bystander. The link, moving down from the idler wheel is first slammed on to the ground, seven road wheels then lumber across, it is then snatched from the ground by the action of the sprocket and accelerated to twice the road speed as it passes over the sprocket. It is subjected to its maximum tension at this last stage. It then continues to speed along the guide rollers in a whipping motion, passes around the front idler pulley and decelerates over approximately one metre to meet the ground again. In reality, these inertial changes are damped to some extent by the circular motion which occurs around the sprockets and road wheels. Under the action of steering the differential mechanism will apply high lateral forces to the individual track link assemblies.

3. REDUCTION OF THE INCIDENCE OF TRACK PIN FAILURES

The complexity of the track assembly and the inter-dependence of components is such that failure of an individual component will damage the integrity of the track system. The track will then lose efficiency, and rapid breakdown of the system will follow. Assuming that there is no design weakness, a component will fail when the material used to make the item is not to specification, when the material processing during manufacture is incorrect, or if service conditions are more severe than the design criteria allowed. In the last case modifications, will be necessary to suit the new conditions. Deferred and/or incorrect maintenance procedures can induce damage to a component so that it subsequently fails or in turn will induce damage and failure to an adjacent component. Even when the system is undamaged, an occasional failure can occur from an excessive overload on the track, especially when it is a point loading, and this can cause failure to an otherwise sound component.

It must be remembered that to obtain the maximum speed and manoeuvrability from the vehicle, the track must be kept as light as possible. If safety margins for material faults, poor production techniques, bad maintenance and excessive overload were all introduced, the track would be disproportionately heavy and a poor vehicle performance would result. Thus, in a highly-tuned fighting vehicle, with the track system working close to its design stress in normal usage, occasional failures are to be expected.

3.1 Track Pin Failures

In the M113 single pin track the connecting pin is supported along its full length by the steel tubes moulded into the rubber bushes and protected by the interlocking lugs of the track shoe. While the bushes remain intact no direct loading occurs on the metal pin, the drive load from the sprocket being applied to the body of the track shoe (Fig. 1).

In the Leopard MBT double pin track track pins are supported by rubber bushes pressed into the two link bodies, however there are unsupported areas where the 'end connectors' and 'centre guide' are attached (Fig. 2). In addition the drive loading is applied by the sprocket to the end connectors fixed to the unsupported ends of the pins, and the centre guide transmits both the drive load and lateral forces directly to the unsupported centre of the pin.

In service severe bending loads are imposed on track pins at the unsupported area between the link bodies and connecting links, and fatigue cracking of the pins initiate at sites where the abrasive action of the entrapped soils and debris erode the soft surface of the pin. The fatigue crack in the centre area of the pin had four possible locations, on the upper and lower surface of the pin each side of the centre guide; these are locations where the maximum bending stress would be applied by the passage of the road wheels across the track link. The cracks at the ends of the pins were confined to one area, on the inside surface of the pin, adjacent to the flats and level with the end connector where the maximum bending stress would be applied by the action of the sprocket wheel (Fig. 2). The cracks in the

centre area were from a single initiation point [1], however multicracking would occur in the area at the ends of the pin when the end connector moved position during service.

Responding to an Army request to simplify the existing inspection of track pins for fatigue cracking, MRL replaced the maker's inaccurate dye penetrant method of NDI with the present ultrasonic method developed at MRL in collaboration with MEA and the Armoured Training Centre (AC), Puckapunyal [2]. The MRL ultrasonic inspection of the track pins was found to take fourteen man hours (two men during 1 day), performed on the fully assembled track either on or off the vehicle. The dye penetrant method was taking sixty four man hours (a large effort spread over 3 days), and necessitated laborious stripping and cleaning of the whole track assembly [3].

As a result of investigating the fatigue cracking of the track pin, MRL recommended [1] that orders placed on Germany for replacement link assemblies should specify induction surface hardening of the original pins, as this treatment would enhance the static and fatigue strength, and increase the resistance to erosion of the track pin. (These original pins, without hardened surfaces, are referred to as "soft pins" in this report). The MEA/MRL trials [3] on track fitted with the surface hardened pins were carried out at the Armoured Training Centre, using the Leopard high-usage training vehicles. A track life of approximately 9000 km was achieved before the track was sufficiently worn and deteriorated to require removal from the tank. On examination of the track pin only slight erosion on the surface was noted and no cracking initiating from these sites was detected [3].

Static bend tests at MRL [3] on the surface-treated pin showed that the proof stress had been increased to the extent that no apparent plastic deformation occurred at fracture, whereas the original untreated pin was deformed during the bend test (23° permanent bend at fracture). The increase in proof stress of the pin also increased the resistance to fatigue crack initiation by virtue of the fatigue limit being raised above the normal level of alternating service stresses. Furthermore the resistance to erosion of the surface slows down the formation of pits which are potential stress raisers for the initiation of fatigue cracks.

The target track life of 9000 km with no pin failures, while obtained on trials at the Armoured Training Centre, was subsequently found not to be achieved at the 1st Armoured Regiment, where the incidence of failed induction hardened pins continued to be a common occurrence. On-site investigations during 1981-83 by MRL staff led to the conclusion that this difference was greater than attributable to the difference in driving skill between the instructor/trainee and the average tank crew, combined with the rougher terrain encountered by the Regiment (the Centre tended to use defined areas for training); a large measure of the higher failure rate was attributable to the lack of maintenance attention to the vehicles by the regular tank crews. It was found that inadequate and deferred maintenance procedures were being adopted, and needless rough handling of the vehicles was common-place. New inspection and maintenance procedures were established by MEA in consultation with MRL, and these, combined with an appreciation of the cause of track failure by the tank crews, has resulted in a significant lowering of the failure rate of track pins of the Regiment. A preliminary

survey by MEA has shown the effectiveness of these maintenance procedures [3], as follows:

YEAR	VEHICLES TESTED NDI OF PINS	VEHICLES WITH CRACKED PINS	%
1983	12	9	75
1984	19	7	36
1985	30	4	13

In an earlier investigation for a suitable method of Non-Destructive Inspection (NDI) of the original soft pin track [3], MRL had recommended an ultrasonic inspection at 4000-5000 km travel, with replacement of any links having cracked pins by either new or used links. Thereafter, the tracks would continue in service with inspections every 1000 km and replacement of links as required. It was estimated that an annual saving of \$300,000 in track costs would result. However, in the event, the high usage of the vehicles at this time dictated Army policy and it was decided (by Army) to follow the German practice of discarding the track after an arbitrary life of 4000 to 5000 km.

MRL proposed to the Army that refurbishment of these "soft pin" tracks could be achieved in Australia by Small Arms Factory (SAF), Lithgow, who refurbish all the M113 track used in this country using Australian-made replacement components [4]. At a meeting with representatives from SAF and MEA [3], MRL demonstrated the feasibility of the project, initially with overseas replacement components and changing over to Australian components as they become available, with the ultimate aim of a new all-Australian track. This project proceeded initially with a low priority and involved the refurbished track being trialled and modified. In 1984, when MRL reported that the quality of the new overseas track being supplied to Australia was deteriorating [1], and as costs and replacement lead times of the track were markedly increasing, the refurbishment programme was given a higher priority, especially in the development of the Australian made components.

Occasional pin failures still occur on the induction hardened pin, mostly originating at the run-out radius of the flat at the ends of the pin. Microscopic examination of failed pins has revealed that the induction hardening treatment had failed to cover a localized area across the run-out radius. Fatigue testing in the laboratory [5] confirmed this cracking behaviour, attributed to the coincidence of a geometric stress concentration with a softer surface which had inadequate fatigue resistance. Using a mechanical surface treatment by peening to induce residual compressive stresses, it was found possible to "heal" this weakness to an extent so that on further fatigue testing the cracks would initiate at other sites on the pin. It was also observed during this fatigue testing that propagation of the crack to failure was faster in these pins than in the original soft pins.

The feasibility of a joint project with the Army, to assess the degree of hammer peening required to mechanically treat the imported track pins, and the logistics of carrying out such a repair technique were under

consideration when it became evident that the manufacture of Australian-made pins was imminent. Effort at MRL was therefore redirected to correcting the problem at the production stage by collaboration with SAF in modifying the induction hardening process.

It has been demonstrated that proper care must be taken in both the tensioning and retensioning of the bolts securing the end connector and centre guide connector to the track pins. Unless the threads are thoroughly cleaned and well lubricated the correct tension required to secure the connectors to the links cannot be achieved. If this care is not applied it can lead to accelerated failure of the rubber bushes, pin failure, link body migration and in extreme cases loss of track from the vehicle. The Army has accepted these findings [5] and MRL has collaborated with MEA in advising on these procedures for inclusion in the appropriate EME Instructions.

3.2 M113 Track Pin Failures

The breakdown of the M113 track has been associated with the premature failure of the rubber bushes. Although isolated cases of broken and thrown track have been reported, it has commonly been rubber bush failures which led to metal-to-metal contact of the pin and track shoe and eventual failure of the metal shoe material and breaking of the connection. Part of the problem has been traced back to the quality control of the rubber bushes during manufacture, and these procedures have been revised by the Army Quality Assurance authorities in collaboration with MRL, in work outside the scope of this report.

4. INTRODUCTION OF LOCALLY MADE COMPONENTS

The nature of the MRL contribution to the Leopard track and suspension has changed during the life of the committee as Australian-made components are being trialled on vehicles, and dedicated testing procedures are being established. As more local components are introduced into the track system, any problems arising should be remedied in the production stage either by modifying or completely changing a production procedure. Several examples of this correction through modified production have already occurred, as listed below.

- (a) The problem of the "soft" areas found in the imported Leopard track induction hardened pins has been addressed in the SAF Australian made pins. One such modification which achieved some degree of hardening on the radius has been fatigue tested and evaluated at MRL [12]. This modification consisted of slowing down the rate of induction traverse across the critical radius, to achieve greater penetration into the radius region.

- (b) The problem of the short life of the rubber pin bushes in the M113 track has been investigated at MRL (Organic Chemistry Division) and a new rubber formulation for bushings has been developed. This formulation is currently under trial on both the M113 track and on Leopard track. Laboratory tests at MRL have indicated that bushings in the new formulation are superior to the present bushes being supplied to SAF for M113 track.
- (c) The use of a cast M113 track shoe to replace the present forged item, with a cost saving estimated at 60%, has been developed at SAF with the collaboration of MRL [4]. Two types of casting have been investigated, investment casting by SAF and sand casting by private industry.

5. PRESENT PROGRESS

It has been recognized that the tracks of both of these "A" vehicles have many similarities: the principle of operation and the action of their components is the same, the differences are in their construction. Furthermore although the track is basically constructed of hardened and tempered alloy steel to transmit the propulsion forces, there is a high degree of inter-dependence with the rubber elements of the track, thus, the steel is dependent on the rubber:

- (a) To act as a "lubricant" between the steel track pin and the steel shoe or body.
- (b) To cushion the impact of the track on the ground.
- (c) To lower the vibration and noise to an acceptable level.
- (d) To distribute the load evenly over the steel components and reduce the effect of point loading that often leads to fatigue failures.

The rubber is dependent on the steel:

- (a) To support the rubber item.
- (b) To contain and hold the rubber components in compression and so increase the shear modulus of the rubber to the required level.
- (c) To act as a heat sink to distribute the heat generated in the rubber evenly throughout the item, and transmit heat away.

In both vehicles the steel used in the various components is similar, and there is a task at MRL to rationalize the various rubber specifications used in both tracks since they are performing the same function in the same environment.

The formation of the "Leopard/M113 Track and Suspension Steering Group" [6] in 1984/85 has activated progress in both the solving of problems in the M113 track and suspension production and supply, and in the manufacture of Leopard track and suspension items in Australia. The group has a wide representation from all the areas within Defence who are concerned with the operation, maintenance and supply of "A Vehicles" and their components, and executive actions are able to be taken by the Group. The group supports a technical sub-committee to pursue defined tasks such as the writing of a new draft specification, so that improvements and modifications that arise as a result of laboratory testing or trials in the Australian environment can be written into the documentation used in the procurement of track and suspension components for the M113 A1 APC or Leopard MBT.

6. SUMMARY AND CONCLUSIONS

The support to the Army on tank track and suspension problems has been satisfactorily implemented through MRL participation in the track and Suspension Steering Group. With several years of successful activity, input to problems with the Leopard MBT has now diminished to a low level, in common with that of the M113 APC. Overcoming the problems that have occurred in the Leopard vehicle has taken a long period, but this has been dictated to a large extent by the time taken to reach the present track life of 7000 to 8000 km at the allowed travel of 1500 km per year. The developments during this period have been such that the track life is now being determined on "worn out" rather than "failed" components, a far more satisfactory state of affairs. Improved inspection and maintenance procedures have been mainly responsible for this favourable trend. The improvement to these procedures has been frustrated in part by the diminishing quality of the imported replacement track from Germany, and the changeover to an Australian-made track, in which local production is supported by Army Quality Assurance, is seen as a highly beneficial step.

Work on tank track and suspension has highlighted an important advantage in the local manufacture of equipment for the ADF other than the consideration of supply and economic advantage: modifications which stem from MRL investigations of component failure can be injected directly at the appropriate production stage and then monitored during routine operation of the equipment. This is far more cost-effective and technically satisfactory than palliative measures on the imported item. In-service monitoring of modified components and procedures has proven highly satisfactory, with enormous savings effected in cost and lead-time.

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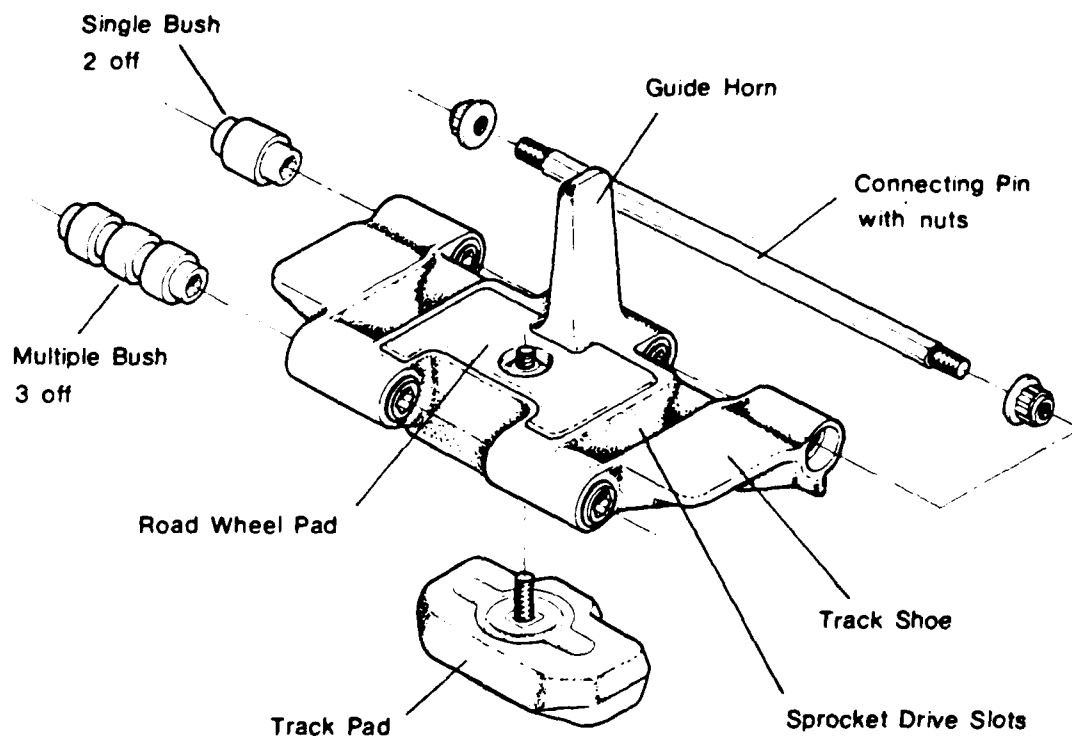
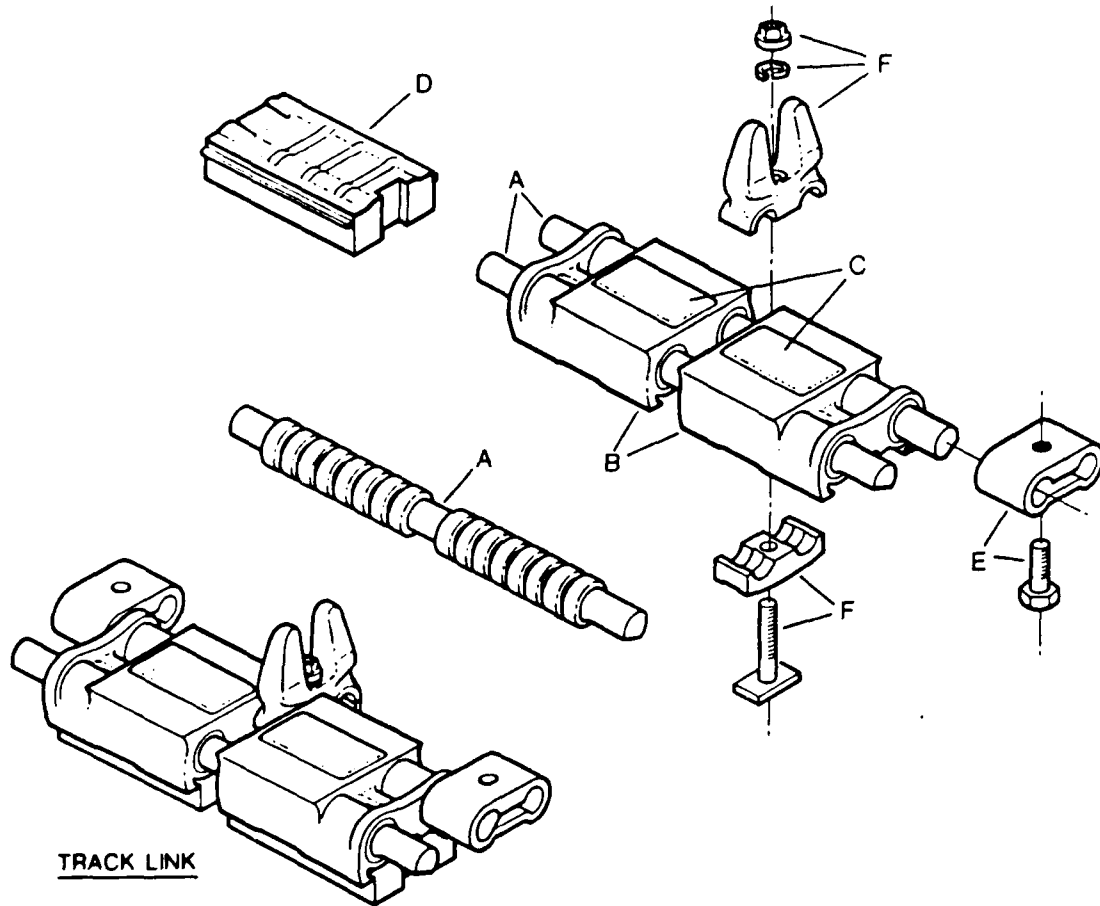


FIG. 1 M113 A1 APC - Track Shoe



TRACK LINK

The Track Link is an assembly of the following components ...

A	Track Pins	2 off	Rubber Bushed
B	Link Bodies	2 off	Each body fitted with
C	Road Wheel Pad	2 off	Rubber
D	Track Pad	2 off	Rubber bonded to steel plates
E	End Connector	2 off	Fitted with
	Set Screw	2 off	
F	Centre Guide	1 off	An assembly of
			one upper guide
			" lower guide
			" bolt
			" spring washer
			" nut

FIG. 2 Leopard Tank - Track Link Assembly

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for the Australian Army

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M113	Shoes	Pads	Rubber	Fracture	

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