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BY THE COMPTROLLER GENERAL

Report To The Congress

OF THE UNITED STATES

Large-Scale Production Of The M1 Tank Should Be Delayed Until Its Power Train Is Made More Durable

The Army has requested funds to procure 720 M1 tanks in fiscal year 1982. Although the tank has met virtually all of its major combat requirements, the tank's power train durability must be improved so that the tank's performance can measure up to its full potential.

Until this is done, it would be unwise to produce the M1 in large numbers. To do so would merely increase the inventory of tanks hampered by engines requiring frequent replacement and costly maintenance.

Other tank components also required frequent maintenance during testing. Whether this was generally a correctable problem of poor quality control at contractor plants, as the Army contends, or whether it will become a chronic problem remains to be seen.

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON D.C. 20548

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To the President of the Senate and the
Speaker of the House of Representatives

This report expresses our concern over the M1 tank prematurely entering high-rate production before its power train is able to meet the Army's durability requirement.

We undertook this review because the future course of the M1 program, the Army's most costly new weapon system, will have a significant effect on the Army's budget.

We are sending copies of this report to the Director, Office of Management and Budget, and to the Secretary of Defense.

Charles A. Bowsher
Comptroller General
of the United States

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

LARGE-SCALE PRODUCTION OF M1 TANK SHOULD BE DELAYED UNTIL ITS POWER TRAIN IS MADE MORE DURABLE

D I G E S T

Production of the M1 tank started in May 1979, but reliability and durability problems led the Secretary of Defense to limit the initial production rate to 30-a-month pending their resolution.

In September 1981, the Secretary lifted the 30-a-month production res riction, based largely on optimistic projections by a blue ribbon panel of experts convened by the Department of Defense. The panel believed the M1's power train, which presently fails to meet the Army's durability requirement, would show substantial improvement provided certain modifications to the engine and transmission are incorporated.

The Army requested $1.624 billion to buy 720 tanks in fiscal year 1982.

WHY THE REVIEW WAS DONE

GAO undertook this review because the M1 acquisition program, which represents the Army's most costly new weapon system, has reached the acquisition phase requiring the commitment of large financial resources. The course it takes will have a significant effect on the Army's budget.

ISSUES BEARING ON LARGE-SCALE PRODUCTION

There are advantages to proceeding cautiously with large-scale production of the M1 tank. This would allow time to overcome problems, such as the power train's durability. In testing, the power train's turbine engine frequently lost power or totally ceased functioning. These problems and production difficulties have slowed M1 deliveries up to now. Until October 1981 when it delivered 32 tanks, production by the prime contractor, Chrysler Corporation, had been well below the 30-a-month required by the current limited production contract.

A modest production rate would also allow time to accumulate more information on the capabilities of a diesel engine currently in development while attempts continue to improve the power train's durability. The diesel engine may offer an alternative to the M1's turbine engine.

With these uncertainties and the time still needed to ready a second tank plant for production, there seems to be no urgency to committing funds at this time for the M1's full production. The Government-owned second production plant will not be ready to begin low-rate M1 production before March 1982, at the earliest. (See p. 15.)

POWER TRAIN HAS NOT MET ARMY'S DURABILITY REQUIREMENTS

The latest series of tests has again confirmed that the M1 has met virtually all of its major combat requirements in the areas of firepower, armor protection, and mobility. The M1 has been impressive in demonstrating its shoot-on-the-move capability, its speed, its ability to rapidly traverse rugged terrain, and the protection afforded by its armor. In these respects, the M1 seems destined to live up to the Army's expectations.

Despite this fine showing, a problem of great concern was disclosed in the testing. The M1's power train failed to meet the Army's durability goal. The power train components are the engine, transmission, and final drive. In July 1981, when testing was nearly completed, the Army reported that the power train had demonstrated a 37-percent probability of meeting the requirement to achieve 4,000 miles without a need to replace a major component compared to the 50-percent probability required.

Actually, even this disappointing showing benefited from the performance of the transmission and final drive. Each improved substantially in durability after successful modifications were applied to correct earlier problems. The turbine engine failed to show similar progress. In the latest operational tests at Fort Knox, Kentucky, the replacement rate of failing engines was even higher than it was in tests held there in 1979. (See pp. 5 to 7.)

ALTERNATIVE DIESEL ENGINE WARRANTS FURTHER CONSIDERATION

Because of congressional concerns over the turbine engine's durability, the Army began developing a backup diesel engine. This engine is currently undergoing tests scheduled for completion in December 1982.

The Army plans to conduct M1 production testing from May to October 1982 in hopes of demonstrating that a quality assurance program instituted by AVCO Corporation, the turbine engine contractor, will have helped produce a power train that meets the Army's durability requirement. It would seem that the Army should also give serious thought to the potential offered by the diesel engine and have the engine demonstrate its capability in testing similar to what the turbine has undergone. Differing opinions exist on how long it would take to get a diesel engine into production, but it would be at least 2 years. (See pp. 6 and 7.)

OPERATIONAL AND DEVELOPMENT TEST RESULTS INDICATE FREQUENT MAINTENANCE IS STILL REQUIRED

In accordance with prescribed Army scoring criteria, which have been in use for several years, the M1 rolled up impressive reliability and maintainability scores. The M1, for example, averaged 126 miles between system failures, surpassing the Army's goal of 101 average miles between such failures.

However, the scores mask the fact that components failed much more frequently than shown by the official results. Actually, the M1 averaged only about 30 miles in development testing at Aberdeen, Maryland, and 32 miles in operational testing at Fort Knox, Kentucky, before a need for some type of maintenance was indicated. The Army does not attach any significance to these statistics since these maintenance actions also included minor incidents, such as tightening a clamp or operating with a missing bolt, whose correction was deferred until the next scheduled maintenance. However, statistics showed the average miles traveled between what the Army terms "essential maintenance" were not much better. They showed the tanks averaging 48 miles at Fort Knox and 43 miles at Aberdeen between essential maintenance demands. (See pp. 8 to 13.)

CONCLUSIONS

The M1 tank should perform well in combat. To take full advantage of its excellent inherent capability demands an improvement in the tank's power train durability. Until the durability requirement is met, it appears unwise to produce large numbers of tanks. To do so before an improvement is effected will create a large inventory of tanks hampered by engines requiring frequent replacing and that are expensive to maintain.

The Army plans to continue improving the turbine engine. It is also testing the alternative diesel engine. Therefore, the Army has the opportunity to compare the performance of both engines so that one of the two can be selected based on their showing in testing and their respective life-cycle costs. Prudence dictates that this opportunity not be overlooked.

RECOMMENDATIONS

GAO recommends that the Secretary of Defense should:

--Direct the Army, if the durability requirement has still not been met after the 1982 production testing, to compare the performance and durability of the turbine and diesel engines as demonstrated in testing and to prepare an analysis of the two engines that addresses their cost and performance.

--Evaluate the Army's analysis and select one of the two engines for incorporation into the balance of the production run.

--Provide the key congressional committees with an estimate of funds that may still be needed for improvements to elicit, from whichever engine is selected, the type of performance that would enable the power train to meet the durability requirements. (See pp. 16 to 17.)

MATTERS FOR CONSIDERATION BY THE CONGRESS

Although the M1 is to start large-scale production, its power train's acceptability has not been demonstrated. Therefore, the Congress should consider conditioning future appropriations for large production of the M1 on the power train meeting the Army's durability requirement.

AGENCY COMMENTS

Basically, it is the Department of Defense position that full production is warranted based on the blue ribbon panel's projections of the power train's durability potential. The panel projected that the application of certain modifications could raise the power train's durability to where it would exceed the Army's requirement The Army is aware that the engine's frequent failures would result in high maintenance and support costs.

The blue ribbon panel's report, in addition to the improvement it forecast, was concerned about vital modifications for which it saw an immediate need, including some that would correct problems that have not yet surfaced but which are to be anticipated. It urged more testing and more aggressiveness in dealing with the power train's recurring problems.

The Department of Defense officials said they will test the diesel engine but could not consider it a serious contender, principally, because they believe it will take 4 years to produce.

Granted that improving the readiness of the armed forces demands early fielding of modernized equipment, much of the advantage of early deployment could be lost if the tanks were to experience frequent durability failures and require frequent maintenance. (See pp. 17 and 18.)

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CHAPTER 1

INTRODUCTION

The Army's M1 tank acquisition program is at a critical stage. The tank started production at Lima, Ohio, in May 1979. Reliability and durability problems led the Secretary of Defense to limit the initial production rate to 30-a-month pending their resolution. The Congress has also expressed concern about the risks of proceeding with full production until an improvement is made.

The Army requested $1.624 billion to buy 720 tanks in fiscal year 1982. In September 1981, the Secretary lifted the 30-a-month production restriction, based largely on optimistic projections by a blue ribbon panel of experts convened by the Department of Defense. The panel believes the M1's power train, which presently fails to meet the Army's durability requirement, would show substantial improvement if certain modifications to the engine and transmission are incorporated.

The results of the third and final phase of operational and development testing have not been completely evaluated. Operational tests at Fort Knox, Kentucky, and Fort Hood, Texas, ended in June 1981. Development testing was conducted at several locations. The last of these tests, at the Aberdeen Proving Ground, Maryland, will be completed in January 1982.

Operational testing assessed the weapon's effectiveness in the hands of soldiers operating and maintaining it in a simulated combat environment. Development testing was done by technicians to assess the weapon's performance as compared with its design requirements.

WHY THE REVIEW WAS MADE

We undertook this review because the M1 acquisition program, which represents the Army's most costly new weapon system, has reached the acquisition phase requiring the commitment of large financial resources. The course it takes will have a significant effect on the Army's budget.

M1'S PRODUCTION

The first production contract with the developer, Chrysler Corporation, covered the fiscal year 1979 procurement of 110 tanks. The second contract covered the procurement of 352 tanks in fiscal year 1980. Rising costs necessitated amending both contracts to stay within available funds. A December 1980 amendment to the first contract reduced the tank quantities to be procured from 110 to 90. A March 1981 amendment to the second contract reduced the quantities from 352 to 309. Production problems at Chrysler, and at several subcontractors and suppliers, have prevented adhering to the delivery schedule. Through October 1981, Chrysler was to have delivered 363 tanks but had delivered only 205.

DURABILITY PROBLEMS

The most critical remaining problems concern the durability of the M1's power train. The power train consists of the engine, transmission, and final drive. These components are the key to the M1's achieving the parameters to which it has been designed in terms of speed, agility, acceleration, and endurance.

The M1 represents the Army's first attempt to incorporate a turbine engine into a ground vehicle. Because of congressional concerns about the turbine engine's test results, the Army initiated a backup 1,500 horsepower diesel engine development program in the event the turbine proved unsatisfactory. A contract to begin developing a diesel engine was awarded to Teledyne Continental Motors in March 1979. A follow-on development contract will continue through April 1982.

M1'S CAPABILITIES

The M1 has demonstrated greater combat capabilities than the currently deployed M60 series of tanks. The M1 will have much improved crew survivability. This was accomplished by using a new type of armor, compartmentalizing the storage of fuel and ammunition, and protecting crew and engine compartments with an automatic fire extinguishing system. A new stabilization system will provide a shoot-on-the-move capability. A laser rangefinder and thermal imaging system will enable the M1 to acquire and fire at targets in darkness as well as in daylight. Its 1,500 horsepower turbine engine and advanced torsion bar suspension enable the tank to attain high speeds and agility which, combined with its lower silhouette, add to the M1's survivability. A planned change would incorporate a more lethal 120-mm. gun to replace the 105-mm. gun about 1984.

COMPARING THE M60 TANK

In the last few years, the M60 series of tanks has been improved with the addition of a laser rangefinder, thermal imaging sight, and stabilization. The latest version, the M60A3, which also has the 105-mm. gun, can rival the M1 in stationary firepower. The M1, however, outclasses the M60A3 in armor protection, speed, agility, and firing on the move.

M1'S COST

In June 1981, the M1's program cost estimate was $18.6 billion. The cost has increased significantly since the tank's development began. The latest procurement cost for the 7,058 tanks in the program, as reported by the Army, was about $2.6 million per tank. At the time of the development estimates in 1972, the comparable unit cost of the quantity of 3,312, contemplated at that time, was $1.4 million.

The program has undergone several changes since it was started which have influenced the cost. Inflation rates used to estimate costs for the duration of the program have been changed several times. The original quantities have increased from 3,312 to 7,058. The planned monthly production rates have gone from the original 30-a-month to a buildup of 90-a-month with a surge capacity of 150 tanks a month.

OBJECTIVE, SCOPE, AND METHODOLOGY

Our principal objective was to determine if the M1 tank's performance, in the most recent operational and development testing, has met the Army's requirements and warrants its entering full production.

Our review commenced in December 1980. To obtain an updated overview of the program's status, we examined records and interviewed officials at the M1 Project Manager's Office in Sterling Heights, Michigan, and the Operational Test and Evaluation Agency in Falls Church, Virginia. We also observed operational testing, examined test data, and interviewed officials of the Training and Doctrine Command's Combined Arms Test Activity at Fort Hood, Texas. At Fort Knox we discussed the progress of operational testing with officials of the Operational Test and Evaluation Agency and the U.S. Army Armor and Engineer Board responsible for the testing. Similarly, we observed onsite development testing and the recording of test data and interviewed officials from Headquarters, Test and Evaluation Command, and the Army Materiel Systems Analysis Activity at the Aberdeen Proving Ground, Maryland. At Fort Knox and Aberdeen, we made our analyses based on the official reliability, availability, maintainability, and durability test results accumulated and evaluated by the Army. Since some test results were not evaluated at Fort Hood, we randomly selected 6 of 41 tanks being tested there and made our own analyses of the Army's recorded test data.

To obtain information on the outlook for meeting contractual M1 delivery requirements and production goals, we interviewed Chrysler Corporation officials at the Army Tank Plant, Lima, Ohio, where Chrysler is producing the first increments, and officials of AVCO Lycoming Division of AVCO Corporation, producer of the tank's turbine engine.

We also examined records and interviewed officials at Teledyne Continental Motors, Muskegon, Michigan, the contractor for an alternative M1 diesel engine, to determine the program status and the engine's availability, if needed. We also interviewed officials of the Tank-Automotive Command's Research and Development Center to determine their perspective on the program.

Our review of cost concentrated on the tank's estimated procurement cost rather than its development cost, which is essentially complete. We examined cost estimates made by the Army to learn what they included and to determine how planned program changes might effect future cost. We discussed cost estimates with personnel at the M1 Project Manager's Office, the Office of the Army Comptroller, and others in the Department of Defense who participated in developing the cost estimates.

A companion review on the logistics planning and supportability of the M1 tank was the subject of our July 1, 1981, report, "Logistics Planning for the M1 Tank: Implications for Reduced Readiness and Increased Support Costs" (PLRD-81-33). That report pointed out that planning for the M1 tank's integrated logistics support has been inadequate and that life-cycle costs were apt to be high because they had not received sufficient attention in deference to the emphasis on meeting initial production cost objectives. It concluded that opportunities still existed for reducing life-cycle costs by reexamining the M1's design and selecting some alternative components.

The following are other reports we have issued on the M1 tank.

--"Critical Considerations in the Acquisition of a New Main Battle Tank" (PSAD-76-113A, July 22, 1976).

--"Department of Defense Consideration of West Germany's Leopard as the Army's New Main Battle Tank" (PSAD-78-1, Nov. 28, 1977).

--"Major Deficiencies Disclosed in Testing of the M1 Tank Warrant Slower Production" (PSAD-79-67, Apr. 16, 1979).

--"XM1 Tank's Reliability is Still Uncertain" (PSAD-80-20, Jan. 29, 1980).

CHAPTER 2

TURBINE ENGINE'S LOW DURABILITY AND HIGH COST REQUIRE CONTINUED DEVELOPMENT OF AN ALTERNATIVE ENGINE

TEST RESULTS

Results of the operational and development testing indicate that as in all previous tests, the power train has still not met its durability requirement. Durability refers to the ability of certain components to operate a specific number of hours or miles without replacement. The requirement is for the power train to have a 50-percent probability of operating 4,000 miles without having to replace any of its three major components--the engine, transmission, or final drive. Emerging test results indicate this goal will not be met. After a July 1981 aggregation conference, where the Army evaluated the test scores, the power train's durability was reported to be 37 percent.

The power train's durability was measured at two test locations--Fort Knox and Aberdeen. The principal problems obviously remain with the turbine engine. In testing, it frequently lost power or totally ceased functioning. Diagnosis showed serious problems with bearings, worn seals, and failing couplings causing excessive oil leakage. If not for the better performance of the transmission and final drive, the durability achieved by the power train in testing would be even lower than the 37 percent demonstrated. To reach the power train's required durability necessitates each of its major components individually achieving a certain measure of durability. The turbine engine, for example, would have to log about 1,660 hours between durability failures. In the latest operational tests at Fort Knox, the turbine, after adjustments made in the aggregation conference, demonstrated a capability of logging an average of only 423 hours before the need to replace it arose. By contrast the transmission showed it could average 3,430 hours between durability failures against a goal of 1,098 hours. The final drive was not charged with any failures at all by the aggregation conference.

With all planned basic tests on the turbine engine nearly completed and the Army planning to enter full-scale tank production, the status of the engine's performance is crucial. It is also appropriate to reconsider an alternative to the turbine engine should it fail to show improvement in the next year. Further tests of the turbine engine are scheduled in 1982.

Operational testing

The four tanks at Fort Knox were tested 17,143 miles for durability. There were eight power train failures--five engine failures, two transmission failures, and one final drive failure.

The durability test results at Fort Knox have been particularly disappointing. Not only did the tanks fail to meet the 50-percent probability goal, but the results were lower than in the previous round of testing at that location. At the previous tests, completed in December 1979, the power train exhibited a 47-percent probability of achieving 4,000 miles without requiring a component replacement. The expected durability growth since those tests did not materialize. Instead, the tanks only achieved a probability of 15 percent in the latest test.

Development testing

The power train durability requirement will also not be met at Aberdeen. The probability calculation has been decreasing as more miles have been put on the three tanks tested there, as shown by the results of the five scoring conferences.

1st	2d	3d	4th	5th
		(percent)		
100	100	51	41	34

There were three component failures (two on transmissions and one on an engine). As of the fifth conference, 10,984 miles had been accumulated on the three tanks.

Engine replacements

In testing at all test locations up to July 27, 1981, 23 turbine engines or engine modules had to be replaced. These include engines in tanks tested for other than reliability and durability. Three failures were attributed wholly to design problems and 10 wholly to quality assurance. One failure was attributed to both. Nine failures were still under investigation at that date by the engine manufacturer, AVCO Lycoming.

The power train was still failing even after modifications were installed. At Fort Knox, for example, the latest modification was installed in February 1981. This was modification E. Following this, one engine had to be replaced in April and three others in May.

BACKUP DIESEL ENGINE PROGRAM SHOULD CONTINUE

Following expressions of support in the Congress for the Army to develop a backup diesel engine for the M1 tank, the Tank-Automotive Command in May 1980 awarded Teledyne Continental Motors an $11.6 million contract to resume developing its 1,500-horsepower AVCR-1360 diesel engine. This is the same engine that General Motors had in its version of the M1 tank used in the competition with Chrysler.

As of June 1981, Teledyne virtually completed the engine design changes as well as the vehicle design changes needed to accommodate the diesel in the M1. Two engines are to be tested. One began a 1,000-hour durability test in July 1981. The second is to be tested for its performance capabilities. Two additional engines are to be installed in M1 tanks for automotive and durability testing during the period July to December 1982.

Different opinions exist on how long it would take to get a diesel engine into production. Teledyne officials believe 24 months would be needed if development and operational testing were conducted concurrently with tooling and equipping the plant for production. The Army believes this would take about 40 months.

The Army recognized the lower acquisition and fuel costs of the diesel when it opted for the turbine, but anticipated recouping these costs through the turbine's projected greater durability and maintainability. However, the turbine has not achieved the durability and maintainability levels predicted for it. Further, its acquisition cost has risen significantly.

For the fiscal year 1981 contract still to be finalized, AVCO has proposed a unit price of $395,000 for 506 engines. In a September 1981 response to an Army inquiry, Teledyne estimated the price of its AVCR-1360 diesel engine at $110,000. However, installation of the diesel would require configuration changes to the tank whose costs are unknown.

From all of the above, it would seem appropriate to reevaluate the relative merits of the turbine and diesel engines from the standpoints of affordability, performance, reliability, and durability.

CHAPTER 3

M1'S POSITIVE ACHIEVEMENTS IN TESTING

ARE SUBSTANTIALLY OFFSET BY FREQUENT

FAILURES AND TIME-CONSUMING MAINTENANCE

The latest series of operational and development tests has confirmed that the M1, as in previous testing, has met most of its major combat requirements in the areas of firepower, armor protection, and mobility. Although some development testing is still in progress and evaluations of test results are not complete, the M1 has been impressive in demonstrating its shoot-on-the-move capability, its speed, its ability to rapidly traverse rugged terrain, and the protection afforded by its armor. In these respects, the M1 seems destined to live up to the Army's expectations.

The test scores calculated by the Army also showed the tank surpassing its reliability goals and virtually meeting its maintainability goals. They show the M1 traveling 350 mean miles between combat mission failures (failures restricting its ability to continue its mission further) and 126 mean miles before sustaining a system failure, one that did not necessarily prevent continuing its mission. The goals were 320 for combat mission reliability and 101 for system reliability. The Army's scores also showed that the tank required 1.34 labor-hours of maintenance for each operating hour, compared to the goal of 1.25 to 1.0.

However, the Army's statistics mask the fact that the M1 sustained many component and part failures that did not figure in the Army's scoring. Our analysis of the data showed that the M1 actually averaged only about 30 miles at Aberdeen, 32 miles at Fort Knox, and 36 miles at Fort Hood before the need for some type of maintenance was indicated. For our calculation at Fort Hood, we randomly selected 6 tanks of 41 tested there since the Army did not measure reliability at that location.

The Army does not attach any significance to these statistics since these maintenance actions also included minor incidents, such as a loose clamp or operating with a missing bolt, for which correction was often deferred until the next scheduled maintenance. However, statistics developed by the Army which measured mean miles traveled between what the Army terms "essential maintenance" were not much better. They showed the tanks traveling 48 mean miles at Fort Knox and 43 mean miles at Aberdeen between essential maintenance demands.

The Army's evaluation of test results was based on a scoring methodology designed to measure the inherent hardware characteristics of the tank. Therefore, failures caused by crew errors, maintenance errors, accidents, or other factors not directly attributable to the hardware components were excluded in the Army's scoring of the results. This scoring methodology may be appropriate for measuring whether or not the contractor has met hardware design requirements. In our opinion, it does not realistically assess the tank's reliability or maintainability in the hands of soldiers.

Given the expectation that the operating and maintenance crews' performance will improve as they acquire more experience with the tank, the M1's true reliability and maintainability, when it is fielded, will probably be somewhere between the statistics developed by the Army and the so-called "raw scores" of the tests.

RELIABILITY ACHIEVED IN TESTING

Against the system reliability goal of 101 mean miles between failures and the combat mission reliability goal of 320 mean miles between failures, the M1 achieved the following results according to the Army's calculations.

	Operational testing at Fort Knox (100% complete)	Development testing at Aberdeen (60% complete)
	(mean miles between failures)	
System reliability	160	99
Combat mission reliability	362	336
The combined scores would be:		
System reliability	126	
Combat mission reliability	350	

Development test results

The scores at Aberdeen were calculated, based on test results as of May 1981, after the three tanks tested there had accumulated a combined total of 10,984 miles. The tanks achieved 75 mean miles between system failures and 251 mean miles between combat mission failures. These results, shown in the table on the following page, were calculated in accordance with the Army's prescribed scoring criteria.

Scoring		System		Combat mission	
Conference	Miles	Failures (note a)	Reliability	Failures (note b)	Reliability
1	3,275	35	93	7.3	448
2	4,588	56	81	10.7	428
3	5,977	78	76	17.4	344
4	8,917	118	76	32.2	277
5	10,984	147	75	43.8	251

a/The scoring conference assigned a score of 1.0 to system failures.

b/Mission failures were scored from 0.2 to a maximum of 1.0 depending on the severity.

Following the fifth scoring conference, all failures were reviewed at the aggregation conference held July 21 to 23, 1981. Failures for which modifications had been made after their occurrence were then eliminated based on further testing which showed that the modifications had corrected the problems. The effect was to raise the reliability scores to the final scores of 99 for system reliability and 336 for combat mission reliability.

The scoring method whereby earlier failures were eliminated because of subsequent modifications appears to be a valid one, since the failures which had resulted in the earlier lower scores did not recur in the tests performed after the modifications were installed.

Although some of the problems were corrected by modifications, the continued progressive decline in reliability would indicate that other problems were surfacing which still required correction. The Army attributes many of the failures to poor quality control at contractor plants.

Operational test results

The scores at Fort Knox were calculated based on the accumulation of 14,026 miles by the four tanks tested there. The tanks achieved 130 mean miles between system failures and 304 mean miles between combat mission failures. The aggregation conference, by adjusting these results for successful modifications incorporated since the beginning of the operational tests, developed higher scores of 160 for system reliability and 362 for combat mission reliability.

At Fort Knox, there was first a decline in reliability following incorporation of the modifications, and then, a sharp upsurge. In explaining the significant improvement at Fort Knox in the last 4,700 miles of testing, project office personnel said it might have been due to increased crew experience combined with the milder weather that prevailed in the last stages of testing.

MEAN MILES BETWEEN ESSENTIAL MAINTENANCE DEMAND

Some subjective judgment necessarily comes into play in any assessment of test results and the Army's scoring methodology is sometimes misunderstood. In response to these concerns, the Army formulated a new measurement for the latest round of testing. It provided for computing the mean miles a tank was able to achieve before essential maintenance was required.

Generally, problems which required servicing by maintenance personnel were considered essential. Thus, the criteria for the new measurement provided for counting all mobility failures other than those which could be corrected by the crew in less than 30 minutes and all nonmobility failures which the crew could correct within 3 minutes. These omissions eliminated a fairly significant portion of the maintenance done on the tank. Nevertheless, this new measurement furnishes a perspective of the tank's reliability different from that provided by the Army's inherent hardware assessments. These scores, however, did not figure in the official calculations. The Army's statistics show the following achievements.

Scoring conference	Mean miles between essential maintenance demand: Fort Knox	Aberdeen
1	52	58.5
2	47	60
3	45	47
4	44.7	44
5	48	43

MAINTAINABILITY ACHIEVED IN TESTING

Although the M1 tank was designed to ensure its presence on the battlefield without excessive maintenance requirements, test results indicate more maintenance labor-hours than expected will be required to assure the tank is available for combat.

The measurement of maintainability is the maintenance ratio derived by dividing the number of maintenance labor-hours by the number of operating hours. In contrast to the goal of 1.25 maintenance labor-hours to 1 operating hour, the tank achieved a ratio of 1.34 to 1 as determined in the aggregation conference. The members at the conference only considered the results of development testing in computing this ratio in accordance with the M1's materiel need document.

Scoring conferences had first calculated the maintenance ratio at Aberdeen to be 1.71 to 1. At the aggregation conference whenever a failure was removed from the reliability scores because of subsequent modifications, all or part of the attendant maintenance labor-hours expended on the repair were also eliminated. Further, if labor-hours expended were judged to be atypical, a downward adjustment was made. These had the effect of reducing the maintenance ratio to 1.34 to 1, reasonably close to the goal.

In our analysis of the operational tests at Fort Knox, we found that the maintenance labor-hours to each hour of operation on the four tanks tested were far higher than at Aberdeen--2.67 to 1. However, the experience at Aberdeen before the aggregation conference suggests that the maintenance ratio at Fort Knox--2.67 to 1--may not be too far out-of-line. At Aberdeen two of the three tanks were maintained by civilian technicians. They achieved low ratios of 1.28 to 1 and 1.61 to 1. The third tank, maintained by soldiers, achieved a ratio of 2.17 to 1. At Fort Hood, the mileage accumulated individually by the 41 tanks tested was too low to provide a meaningful statistic.

Because significant amounts of maintenance are not considered in the official scoring, we do not believe the Army's 1.34 to 1 ratio reflects the true maintenance burden the tank may pose in combat.

The high maintenance ratios on tanks maintained by soldiers is due in large part to three factors: (1) the lack of experience in maintaining a new tank, (2) the inadequacy of the test sets which frequently failed to properly diagnose a problem, and (3) the use of incomplete or incorrect maintenance manuals.

The inadequate test sets and maintenance manuals were also problems at all test locations visited and have plagued the M1's maintenance since the tanks were first delivered. The test sets frequently diagnosed problems incorrectly. As a result maintenance was performed which did not correct the problem and, in some cases, was not even necessary. The manuals were frequently incomplete or incorrect resulting in abnormal amounts of time spent to correct a problem. In fact, these were the principal reasons cited by Army test evaluators for the high-maintenance ratio at Fort Knox. Fort Hood personnel experienced the same problems. At the Aberdeen Proving Ground, the test sets were judged only 65-percent accurate. Fort Hood personnel judged the accuracy to be much lower. Maintenance personnel at all test sites often relied on their own technical knowledge and instincts in preference to relying on the test sets. It is to be expected that improvements in the manuals and test sets, along with more experience in maintaining the M1, will eventually reduce the disappointing maintenance burden to more acceptable levels.

In summary, the Army's scoring methodology for determining reliability gives no recognition to hundreds of incidents requiring some degree of maintenance. In the category of incidents requiring less than 30 minutes of maintenance by the crew, for example, the methodology eliminated from consideration 284 of 1,164 incidents at Fort Knox and 550 of 1,126 incidents at Aberdeen. Even if many of the incidents excluded were inconsequential, we believe that because of their sheer number, the Army's calculations of the M1's reliability have to be accepted with some reservation about their relevance to the tank's ability to continue an action for as long as necessary. This is substantiated by the Army's statistics of mean miles traveled between essential maintenance demands which is so much lower than the officially reported results.

CHAPTER 4

PROGRAM UNCERTAINTIES WILL LIKELY MEAN

FURTHER INCREASES IN M1 COSTS

FURTHER FLUCTUATIONS IN COST CAN BE ANTICIPATED

The M1's program cost has increased dramatically since its inception. In 1972 the program cost estimate for a quantity of 3,312 tanks was $4.8 billion or $1.4 million per tank. By June 1981, the cost for 7,058 tanks was reported to be $18.6 billion or $2.6 million each. These include the tank's development cost.

A large share of the increase is due to underestimating inflation experienced over the 9-year period of the M1's development and projected for the balance of production through fiscal year 1988. Also contributing to the rise was the decision to increase the procurement quantity from 3,312 to 7,058 tanks. As a result of this decision, additional costs were incurred to activate a second production facility to meet planned increases in the monthly production rates.

Further significant cost fluctuations can be anticipated, most of them likely to increase the program cost.

Product improvement program

The Army is planning to upgrade the tank's capabilities by product improvement programs.

As of July 1981, the Army had identified and assigned priority rankings to 24 tank improvements it may eventually incorporate in the M1. The highest priority was given to a group of four that pertained primarily to upgrading the tank's fighting capabilities. These were

--two improvements in nuclear, biological, and chemical protection;

--an improvement in armor protection; and

--a weight reduction program.

This block of improvements is scheduled to be incorporated in August 1985. So far the program cost estimate only includes $112 million for the development of the four improvements. Their procurement cost is estimated at $427 million to $500 million in 1982 dollars.

Changes in production schedule

The current production contract calls for production at the rate of 30-a-month. The Army plans to increase production to 60-a-month in fiscal year 1982 and to 90-a-month 2 years later.

Several factors can affect adhering to this schedule and, in turn, affect program cost. Increasing costs may outstrip the availability of funds. Higher than anticipated costs, for example, forced the Army to reduce its planned 1st year buy from 110 to 90 and its 2d year buy from 352 to 309.

Another factor affecting production and cost is the inability of contractors to deliver on schedule. Through October 1981, Chrysler was to have delivered 363 tanks but had delivered only 205. AVCO was to have delivered 497 engines but had delivered only 270. Until the contractors increase their pace, the production of greater numbers of tanks may be deferred to later years when the effects of inflation in those years could have a bearing on prices.

Based on the M1's short production history, the decision to increase production may be difficult to carry out. Until October 1981, when it delivered 32 tanks, Chrysler's production had been well below the 30-a-month required even by the current limited production contract. Unless tank production picks up quickly, the question of whether to accelerate production appears moot.

The engine contractor, AVCO Lycoming, also lagged in its initial engine deliveries, but began delivering an average of about 30 engines a month since June 1981. AVCO indicated that its earlier difficulties stemmed from problems in making the transition from development to production. A spraying operation to permit engines to withstand high temperatures had to be contracted out when AVCO's own equipment was not operational. Also, some of AVCO's automated operations had to be done manually due to computer problems. Nonetheless, AVCO believed it can reach a 60-a-month level by February 1982. However, problems not previously experienced with a porous gear box cover developed in October 1981, cutting deliveries to almost half of what the company had been projecting for that month.

A second Government-owned M1 tank production line in Warren, Michigan, is scheduled to be fully operational by March 1982 to begin low-rate production. The Army expects to reach the 30-a-month level at this plant about November 1982.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The M1 should perform very well in combat when it is available for duty. There are, however, enough disturbing elements about some of the test results to raise concerns about the tank's ability to sustain an action for as long as necessary and about the cost to keep it in operating condition.

To take full advantage of the M1's excellent inherent capability demands an improvement in its power train durability. Test results show that the turbine engine's frequent failures are the primary cause of the power train not meeting the Army's durability requirement.

Until this requirement is met, it seems unwise to produce the M1 in large numbers. To do so before an improvement is effected will create a large inventory of tanks hampered by engines requiring frequent replacing and that are expensive to maintain.

A need for frequent maintenance also arose with respect to other tank components. Whether this was generally due to poor quality control over initial units produced, as the Army contends, or whether it will be a chronic problem remains to be seen.

The Army plans to continue improving the turbine engine. It also has an opportunity to test the alternative diesel engine so that the performance of both engines can be compared and the more cost effective one selected. Prudence dictates that this opportunity not be overlooked.

RECOMMENDATIONS

We recommend that the Secretary of Defense should:

--Evaluate the results of the turbine engine's testing in production model tanks, scheduled for 1982, to determine whether the engine has improved sufficiently to raise the power train's durability to a level that meets or exceeds the Army's requirements.

--Direct the Army, if the requirement has not been met, to compare the performance and durability of the turbine and diesel engines as demonstrated in testing and to prepare an analysis of the two engines that addresses factors such as

--the comparative test results,

--the engines' respective estimated life-cycle costs,

--the funding that may still be required to bring either engine up to a level that would enable the power train to meet the Army's durability requirement,

--the time needed to ready the diesel engine for production, and

--the cost to modify the M1 tank to accommodate the diesel engine.

--Evaluate the Army's analysis and select one of the two engines for incorporation into the balance of the production run.

--Provide the key congressional committees with an assessment of the power train's capability and with an estimate of funds that may still be needed for improvements to elicit, from whichever engine is selected, the type of performance that would enable the power train to meet the durability requirement.

MATTERS FOR CONSIDERATION BY THE CONGRESS

Although the M1 is to start large-scale production, its power train's acceptability has not been demonstrated. Therefore, the Congress should consider conditioning future appropriations for large production of the M1 on the power train meeting the Army's durability requirement.

AGENCY COMMENTS AND OUR EVALUATION

A draft of this report was discussed with the Department of Defense officials. Their suggestions to ensure the accuracy and completeness of the information were considered in preparing the report.

Basically, it is the Department of Defense position that full production is warranted based on the blue ribbon panel's projections of the power train's potential. The panel projected that the application of certain modifications could raise the power train's durability to where it would exceed the Army's requirement. Defense officials stressed that the panel also had some reservations about the transmission and implied that these were more serious than the engine's problems. The Army is aware that the engine's frequent failures would result in high maintenance and support costs.

The blue ribbon panel's report, in addition to the improvement it forecast, was concerned about certain vital modifications for which it saw an immediate need. Some would correct problems that have not yet surfaced but which are to be anticipated. It urged more testing and more aggressiveness in dealing with the power train's recurring problems. Although the panel cited some problems with the transmission, its emphasis was clearly on corrections that should be made to the turbine engine.

This was the third assessment of the power train by the panel. The Army said that this time it plans to carry out all of the panel's recommendations.

As to the diesel engine, according to Defense officials, they will test that engine but cited several reasons why they could not consider it a serious contender at this time, principally that in their view, it would take 4 years to ready it for production. They found this incompatible with the urgency to field the M1 now. Also, the diesel engine has experienced numerous setbacks in the 1,000-hour test, begun in July 1981, that the contractor is conducting.

Granted that improving the readiness of the armed forces demands early fielding of modernized equipment, it is our opinion that much of the advantage of early deployment could be lost if the tanks were to experience frequent durability failures and require frequent maintenance.

The Tank-Automotive Command is monitoring the diesel engine's tests. An official there said the number of incidents occurring in the first 200 hours of the test was surprising but that the types of mishaps were not atypical in early testing. According to the official, most were minor and only a few required modifications. These will be evaluated when the engine resumes testing in February 1982.

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