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Report to Congressional Requesters

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ABRAMS TANK

Efforts to Address Engine Recuperator Problems

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National Security and
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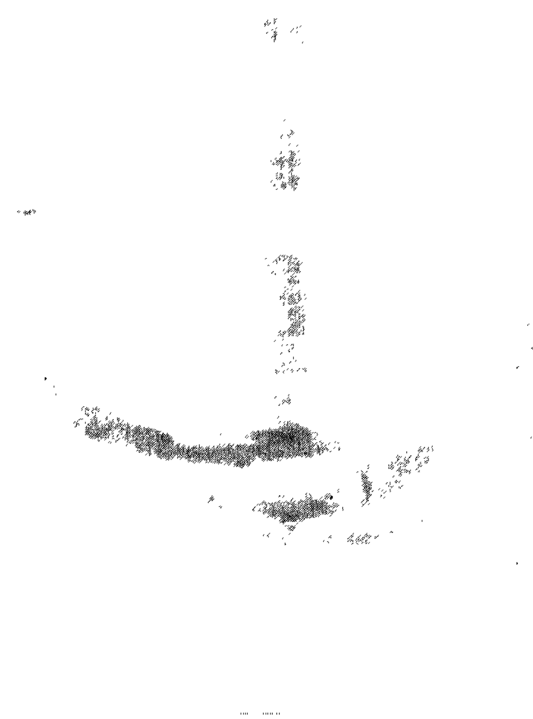
The Honorable Randy Cunningham
The Honorable Duncan Hunter
House of Representatives

In response to your request, we have reviewed the Army's efforts to improve the engine recuperator used in the M1 Abrams tank—the Army's main battle tank. Specifically, we (1) determined the Army's reasons for canceling two contracts for alternate designs of the recuperator, (2) reviewed the technical difficulties and cost overruns each contractor encountered, and (3) evaluated the Army's current plans to develop an improved recuperator.

Background

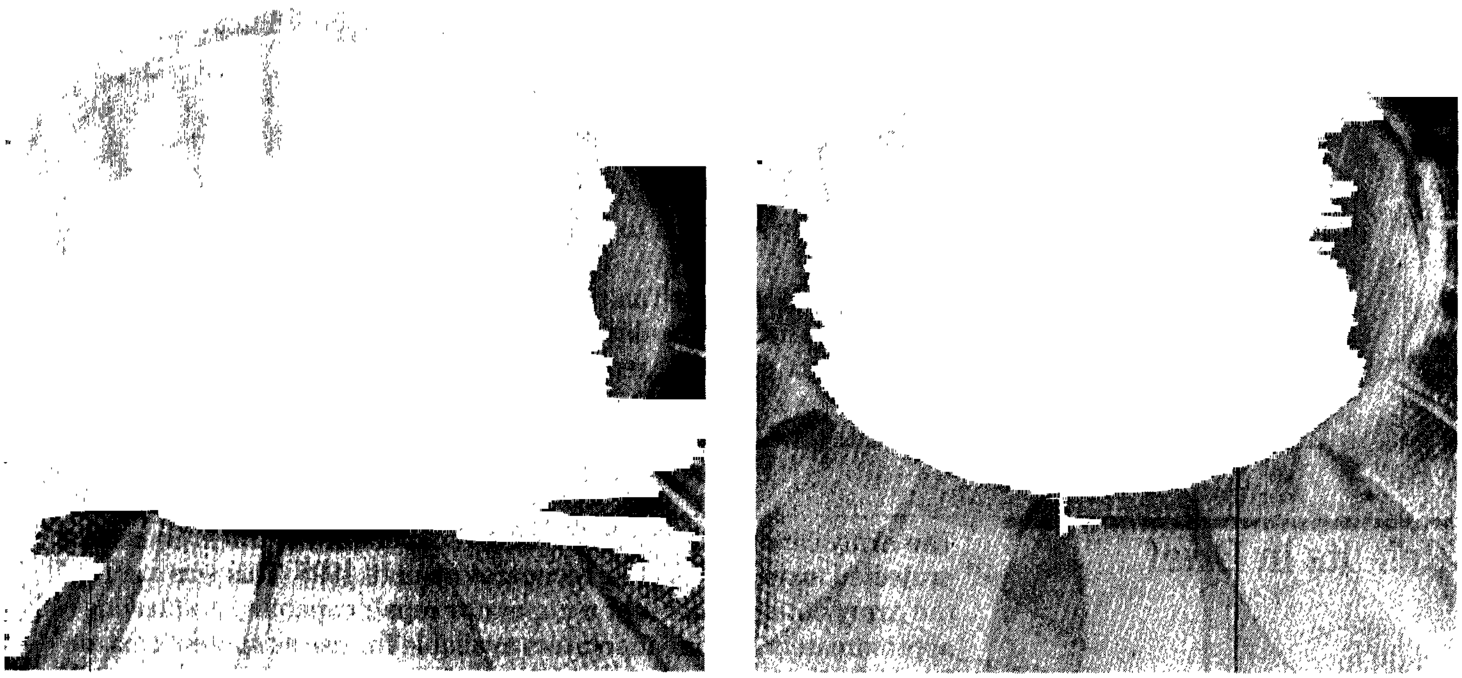
The recuperator, a component in the rear module of the M1 tank's turbine engine, transfers heat from the engine's exhaust to its incoming air, allowing the engine to operate more efficiently. Textron Lycoming manufactures both the engine and the recuperator. A current in-production recuperator is shown in figure 1.

Figure 1: Textron Lycoming's In-Production Recuperator



According to Army documentation, recuperator failures began in 1981 when the M1 tank was fielded. These failures increased when the Army began fielding the M1A1 tank in 1986. The M1A1 tank was heavier than its predecessor and included a nuclear, biological, and chemical overpressure system, which placed more strain on the engine and caused the recuperator to fail more often. The recuperator's failures involved cracking and buckling along its inner cavity and blowouts on its outside walls. Both inner cavity malfunctions cause degraded power and low fuel efficiency in the engine. An outer blowout results in an immediate significant loss of engine power. Although outer blowouts are more serious, Army officials told us that inner cracking and buckling are more frequent. (See fig. 2.)

Figure 2: Recuperators With Inner Cracking (Left) and Buckling



The Army established a panel in September 1986 to review the recuperator's failures. This panel recommended that the Army improve quality controls at its engine plant facility in Stratford, Connecticut. The Army has a contract with Textron Lycoming to run this facility. After improving quality controls, the Army tested the new recuperators and determined that the outer blowout rate had been significantly reduced, with failures occurring, on average, after 350 hours of operation. The previous rate was 150 hours. Textron Lycoming made additional efforts to resolve the problems with inner buckling by converting part of its manufacturing process from resistance-welding to laser-welding.[1]

Nevertheless, because of continuing recuperator problems, the Army decided to solicit an alternate recuperator design proposal to develop spare recuperators that were more durable and effective. In September 1988, a competitive request for proposal was issued, and in May 1989, a source selection board awarded cost-plus-incentive-fee contracts to Allied-Signal Aerospace Company, in Torrance, California,

[1]The resistance-welding technique uses high-energy electrical pulses to fuse parts of the recuperator. The laser-welding technique uses a high-energy laser beam to fuse recuperator parts.

and Solar Turbines, Incorporated, in San Diego, California, to develop alternate recuperator prototypes.[2] Secondary improvements, such as improved efficiency, reduced pressure drop, reduced fuel consumption, and intermediate support level maintainability, were also goals of the contracts.

Also in 1988, the Army certified Anniston Army Depot to perform overhauls on M1 series tank engines, including the recuperator. The Army began funding Anniston to perform these repairs in October 1989.

In 1992, the U.S. Army Tank-Automotive Command reviewed all of its programs in light of the diminished Soviet threat against U.S. forces, planned force structure reductions, and the limited resource dollars available. As a result of this review, the Abrams program office decided to terminate the alternate recuperator contracts in May 1992.

Results in Brief

The Army canceled the two alternate recuperator contracts because it projected no need for spare recuperators until 1995. This was the result of the Army obtaining a depot recuperator repair capability and having approximately 1,000 recuperators available for use as spares. Textron Lycoming's use of the laser-welding technique to resolve inner buckling problems also contributed to the decision to eliminate the requirement for spare recuperators.

According to Army contracting officials, the two contractors experienced a series of problems and increased contract costs in developing their alternate recuperator prototypes. However, these problems were not cited as a factor in the cancellation of their contracts. Allied-Signal's difficulties in manufacturing its prototypes resulted in a failure to deliver the prototypes to the Army and additional contract costs. Solar Turbines delivered its prototypes on time to the Army but failed to meet some of the design specifications and also experienced additional contract costs.

Anniston and Tank-Automotive Command officials told us that although the Army does not need to purchase spare recuperators, unresolved problems with the recuperator remain. The extent of the recuperator failures is unknown because the Army does not systematically collect field data on the performance of the recuperator. Currently, the Army has no

[2] A cost-plus-incentive-fee contract is a cost-reimbursement contract that provides for a fee, which is adjusted by formula in accordance with the relationship that total allowable costs bear to target costs. The provision for increase or decrease in the fee is designed as an incentive to the contractor for increased efficiency of performance.

plans to collect field data on recuperator failures. Textron Lycoming officials acknowledge that not all of the recuperator problems have been resolved and that, moreover, these problems may become more pronounced with the fielding of the heavier, fully equipped M1A2 tank. In an attempt to address these unresolved problems, the manufacturer has submitted engineering changes to the Army for testing.

Army's Cancellation of the Two Alternate Recuperator Contracts

According to Abrams program officials, the Army canceled the alternate recuperator contracts because it projected no need to purchase new spare recuperators until fiscal year 1995. When these contracts were awarded in May 1989, the Army had planned to buy 700 recuperators each year. However, when the Abrams program office reevaluated this requirement in May 1992, it determined that for the next 3 years the need for new spare recuperators had been eliminated, and from fiscal years 1995 through 1997, the total need was estimated to be 195.

Anniston Depot Developed In-house Repair Capability

The Army's requirement for spare recuperators was reduced, in part, because of the in-house repair capability it had developed at Anniston Army Depot. Prior to developing this capability, the depot had replaced damaged recuperators with new ones and had sent the damaged recuperators to the manufacturer for repair. The manufacturer was the only entity capable of repairing these recuperators.

According to Anniston officials, repairing recuperators at the depot is more cost-effective than purchasing new ones from the manufacturer. Information provided by the depot shows the average cost to repair a recuperator is about $17,000, compared with $34,000 to purchase a new recuperator. One Anniston official said that the costs might be cut even further if the individual recuperator components were broken out for competitive bid. Currently, he said, all recuperator components are provided by Textron Lycoming on a sole-source basis.

Army Accumulated Large Quantity of Spare Recuperators

The need to purchase spare recuperators also was eliminated because the Army had accumulated a large quantity of serviceable recuperators in its inventory. The Army decided to use these to fill its spare requirements instead of buying new recuperators. As of November 1992, the Army had more than 1,000 serviceable recuperators available.[3]

[3]These recuperators were either spares (197) or were part of serviceable spare engines (669) or rear modules (193) in inventory. Serviceable components are those components that are ready for use by maintenance personnel.

Tank-Automotive Command item managers believe that the primary reason for the high number of assets in the inventory was that the Army had overestimated the rate at which new recuperators would be needed. In 1988, when the Army last ordered spares from Textron Lycoming, the recuperator usage rate was 35 percent—35 of every 100 engines that came in for overhaul needed a new recuperator. In 1988, the lead time for delivery of spares was 22-1/2 months. By the time the recuperators began to be delivered in 1990, the usage rate had dropped to 10 percent.

Tank-Automotive Command item managers said the Army Materiel Command's decision after Operation Desert Storm to eliminate the requirement that item managers keep 2 months of reserve stock on hand as a safety margin also contributed to the high number of recuperators in the inventory. These officials also told us that for Operation Desert Storm, they had purchased more engines and engine rear modules to meet their authorized stockage levels. The extra purchases and the eliminated requirement for reserve stock created additional usable assets to fill orders for spares.

Army officials believe that the implementation of the Defense Business Operating Fund will contribute to the high stock levels. Since April 1, 1992, Army units have had to pay for repairs on the equipment sent to the depots and can no longer exchange a damaged piece of equipment for a new free one. Because of the cost to obtain a new M1 tank engine, units are starting to isolate equipment failures better, resulting in fewer recuperators being turned into the depot for repair. Consequently, fewer assets are being used to fix them.

Manufacturer Adopted New Welding Process

Another factor in the Army's decision to cancel the contracts was Textron Lycoming's upgraded manufacturing process. In October 1989, the manufacturer started using a laser-welding technique, rather than resistance-welding, to fuse the individual plates into plate pairs, a component of the recuperator. An Army engineering representative and the manufacturer stated that laser-welding creates a more precise, uniform plate pair with fewer stress points and, ultimately, a more uniform core, which is expected to reduce inner buckling. However, an Anniston official said it was too early to determine whether laser-welding had improved the recuperator's performance because most of the recuperators in the field were still resistance-welded.

Alternate Recuperator Contractors Not Successful in Producing Their Prototypes

According to Army contracting officials, the two contractors experienced a series of problems and increased contract costs in developing their alternate recuperator prototypes, although these were not factors in the cancellation of their contracts. When its contract was canceled, Allied-Signal had not yet delivered its prototypes to the Army. Solar Turbines did deliver prototypes, but they failed to meet contract specifications. Overruns on both contracts totaled approximately $7.1 million.

Allied-Signal Did Not Deliver Its Prototypes to the Army

Although the Army extended the delivery date from March to November 1991, Allied-Signal was still unable to deliver its prototypes to the Army for testing. As a result, the Army was unable to test the prototypes in a tank to determine whether they met the durability requirements. In addition, the contractor experienced increased contract costs. According to Army documentation, the Army awarded Allied-Signal a contract for approximately $8.5 million, but manufacturing problems increased the contract costs to approximately $13.5 million by April 1991. The Army notified Allied-Signal that no additional funds would be available, and the contractor began working at its own expense.

Allied-Signal representatives told us that they chose to miss the Army delivery deadlines in order to address their manufacturing problems and validate their prototype design in contractor testing before delivering it to the Army. At the time of the contract cancellation, Allied-Signal had completed 60 of the 180 hours of planned engine tests and had three prototypes ready to ship once the tests were completed.

Solar Turbines' Prototypes Did Not Meet Specifications

Solar Turbine's prototypes, delivered to the Army for testing in March 1991, did not meet contract specifications. According to Solar Turbines' documents, its prototypes were 30 pounds too heavy, and they did not achieve the required 75-percent heat transfer effectiveness stated in the contract. Solar Turbines also had cost overruns. According to Army documentation, the Army awarded Solar Turbines a contract for approximately $6.7 million, but manufacturing problems increased contract costs to approximately $8.8 million before the contract was terminated in May 1992.

An Army document also shows that at the time the contract was canceled, the Army had completed about 25 percent of the durability testing and that one prototype had experienced a failure. Army requirements stated that the alternate recuperator could have only one failure during the entire test. Army representatives expressed doubt that Solar Turbines' prototypes would have finished the remaining 75 percent of the test without another failure.

According to Solar Turbines representatives, they were unable to comply with contract specifications on engine effectiveness because the Army did not provide it with accurate engine data in a timely manner. An Abrams program official said that the contracts required the Army to provide only engines to the contractors, not engine data. He said the Army did provide the engines to Solar Turbines on time. Regarding the recuperator failure experienced during vehicle testing, Solar Turbines representatives told us that the failure was experienced immediately prior to the contract cancellation and that no evaluation was conducted to determine whether the failure was caused by a recuperator flaw or an engine problem. An Abrams program official agreed that the cause of the failure had not been determined.

Army Lacks Data to Support Need for an Improved Recuperator

Anniston and Tank-Automotive Command officials told us that although the Army currently does not need to purchase spare recuperators, unresolved performance problems with the recuperator remain. The extent of the recuperator failures is unknown because the Army does not systematically collect field data on how often recuperators fail, including data on the laser-welded recuperator's performance in the field. Textron Lycoming officials acknowledge that not all of the recuperator problems have been resolved and that they may become more apparent when the heavier, fully equipped M1A2 tank is fielded. The Army is evaluating proposed engineering changes to the recuperator design that Textron Lycoming believes will address these problems.

Army Representatives Believe Recuperator Problems Remain

Tank-Automotive Command and Anniston officials believe that there are still unresolved problems with the recuperator. For example, Anniston collected data on recuperator performance during Operation Desert Shield/Desert Storm and reported that the recuperators experienced the same types of failures and the same level of repairs as they experienced during peacetime. An Abrams program official stated that the recuperator is currently the engine component that fails most often, and an Army contracting official said it is the tank's second largest operational and support cost, behind the track that covers the tank's wheels.

According to Army officials, the decline in the Army's requirement for spare recuperators is not the result of a diminishing problem. Tank-Automotive Command item managers pointed out that, while the usage rate for spare recuperators declined from 35 to 10 percent, the order rates for plate pair assemblies, which are used by Anniston depot to repair recuperators, have increased from 47 to 100 plate pairs per overhaul.

Data on Recuperator Failure Rates Is Not Collected

Our review indicated that the Army does not keep field data on how often recuperators fail, including data on the laser-welded recuperator's performance. An Abrams program official said this data was not maintained by his office. According to an Anniston official, the Army, overall, does an inadequate job of collecting data on failure rates and has no formal system in place to do so. He said that the depot is unable to keep complete data because field units do not send in maintenance records with the components. As a result, depot personnel do not know why a part has been sent in for repair or how many hours it has been used. In addition, each of an engine's four modules could have come from four separate engines, each having a different maintenance history and each experiencing a different kind of failure.

Despite these problems, the Anniston depot collected limited data on the numbers and types of recuperator failures. Anniston's data shows that, as of November 1992, the depot had repaired, rebuilt, or replaced 1,145 recuperators since it had started doing so in October 1989. The data also shows that approximately 80 percent of the failures were caused by cracking on the inner cavity of the recuperator. We attempted to determine whether the Army had any concrete plans to collect field data from units, but the Army was unable to give us a definite answer.

Army Is Evaluating Design for a New Recuperator

Textron Lycoming acknowledges that it has not resolved all of the problems with its recuperator, particularly problems associated with outer blowouts. Under a systems technical support contract, which gives the contractor the opportunity to fix equipment problems encountered when the government imposes changes on the procured items, Textron Lycoming has proposed engineering changes for a redesigned recuperator. Textron Lycoming believes these changes will resolve the current blowout problem and eliminate problems that fielding the heavier, fully equipped M1A2 tank may pose. According to an Abrams program official, the first production line M1A2 tank, with the laser-welded recuperator, came off the production line on December 1, 1992. The Army plans on acquiring

62 M1A2 tanks and modifying an additional 1,079 M1 tanks to the M1A2 configuration.

The Army is evaluating Textron Lycoming's in-production laser-welded recuperator and its improved recuperator design by "piggybacking" them on other tests that use 70-ton M1A1 test tanks. The 70-ton M1A1 test tank approximates the weight of a fully equipped M1A2 tank, but it does not have all the systems and equipment that an M1A2 has. The Army has not tested the recuperator in a fielded M1A2 tank to determine if any of the tank's 32 additional systems and equipment will place a greater demand on the engine. However, an Abrams program official believes that the M1A2's new systems will not create additional engine stress because he believes only the electrical system will be affected. An Abrams program official said the laser-welded recuperator experienced three failures during 30,000 miles of testing. As of January 1993, the improved recuperator design had not experienced a failure.

According to an Abrams program official, the cost of the "piggyback" testing for the improved recuperator is minimal. However, the Army funded some minor administrative and oversight costs for the improved recuperator, as well as the cost of a prototype. Textron Lycoming paid for the development of the design and the manufacturing costs for two additional prototype recuperators for the test.

Recommendations

We recommend that before the Army makes a decision on whether to acquire Textron Lycoming's improved recuperator, the Secretary of the Army (1) collect and evaluate field data on the performance of the laser-welded recuperator on both the M1A1 and M1A2 tanks and (2) test the proposed improved recuperator on a fully equipped M1A2 tank to determine whether it has significantly greater durability than the current laser-welded recuperator.

Scope and Methodology

We conducted our work at the U.S. Army Tank-Automotive Command, Warren, Michigan; Anniston Army Depot, Anniston, Alabama; Textron Lycoming, Stratford, Connecticut; Solar Turbines Incorporated, San Diego, California; and Allied-Signal Aerospace Company, Torrance, California.

At the locations we visited, we interviewed personnel and obtained documentation to gain an understanding of why the two alternate recuperator contracts had been canceled, what difficulties had been experienced during the development of the alternate recuperator prototypes, and how often failures were being experienced by the present recuperator. We obtained and reviewed Army documentation relating to the Army's decreased need for spare recuperators.

We conducted our work from June 1992 through January 1993 in accordance with generally accepted government auditing standards. As requested, we did not obtain fully coordinated Department of Defense comments on this report. However, we discussed the results of our review with representatives of the Offices of the Assistant Secretary of Defense for Logistics and Maintenance; the Under Secretary of Defense for Acquisition; and the Secretary of the Army for Research, Development, and Acquisition. They generally agreed with the results of our review and provided some clarifications that were incorporated where appropriate.

We are sending copies of this report to the Chairmen of the Senate and House Committees on Armed Services and on Appropriations, the Senate Committee on Governmental Affairs, and the House Committee on Government Operations; the Director of the Office of Management and Budget; and the Secretaries of Defense and the Army. We will also make copies available to others upon request.

This report was prepared under the direction of Henry L. Hinton, Jr., who may be reached at (202) 512-6226 if you or your staff have any questions concerning this report. Other major contributors to this report are listed in appendix I.

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