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Research Report 1345

Field-Expedient Maintenance Experiences of M60-Series Tank Crewmen

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U. S. Army
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During combat, tank crewmen may need to employ field-expedient maintenance techniques to repair a malfunctioning tank. Reports of field-expedient maintenance being performed are numerous, but no data have been available on the types of techniques used nor the effectiveness of these techniques. This study collected 76 incidents of field-expedient maintenance from 33 NCOs using the critical incident technique. Fifty of the incidents were used to derive eight categories of field-expedient maintenance. The categories suggest generalizable strategies for making field-expedient repairs. In addition, (Continued)

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the specific incidents of field-expedient maintenance on M60-series tanks identified during the study provides information that may be used in designing a program to train tank crewmen to make specific field-expedient repairs.

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FOREWORD

The ARI Fort Knox Field Unit as well as other elements in ARI have an ongoing interest in improving maintenance training in the Army. Field-expedient maintenance techniques offer an added dimension to the total maintenance concept, and once identified, they may be incorporated in training programs so as to expand and enhance the Army's maintenance capabilities.

The present report describes specific field-expedient maintenance techniques used by noncommissioned officers to repair M60-series tanks. The techniques described were generally effective in returning a malfunctioning tank to its fully operational state in a relatively short period of time without the use of special tools or test equipment. Categories derived by comparing incidents of field-expedient maintenance have suggested generalized strategies for performing field-expedient maintenance that may be applicable across different situations and weapon systems.

EDGAR M. JOHNSON
Technical Director

EXECUTIVE SUMMARY

Requirement:

Armor experts have suggested that field-expedient maintenance techniques performed by tank crewmen can serve as an inexpensive combat effectiveness multiplier by keeping more tanks operational during combat. They envision training senior NCOs to apply such field-expedient techniques; however, little can be done to train soldiers in field-expedient techniques until a sufficient number of these techniques have been identified.

Procedure:

Seventy-six incidents of field-expedient maintenance on M60-series tanks were collected during interviews with armor NCOs using the critical incident technique. In addition to the reported incident itself, a standard set of questions was asked about each incident to ensure that the important information about each incident was obtained. Fifty of the incidents were used to derive eight general categories of field-expedient maintenance. The reliability of the categories was tested by having three classifiers independently sort all of the incidents into the eight categories.

Findings:

Most senior armor NCOs have used field-expedient maintenance techniques at least once in their careers. In making field-expedient repairs, these NCOs often use tools or any other available materials in unique and occasionally ingenious ways. Most of the techniques described took 30 minutes or less to complete and generally were effective in restoring malfunctioning tanks to operation. Although specific incidents of tank maintenance were collected, commonalities among incidents allowed them to be reliably classified into eight distinct categories of field-expedient maintenance. These categories suggest strategies for performing field-expedient maintenance that may be applied to other situations and weapon systems.

Utilization of Findings:

The incidents of field-expedient maintenance included in this report may provide the basis for a training program that teaches field-expedient techniques to M60A1 and M60A3 operators. Knowledge of these techniques may be crucial in combat situations. The generalizable strategies suggested by the eight categories may be taught to a broad spectrum of soldiers who might need to repair their vehicles or weapons quickly during combat.

FIELD-EXPEDIENT MAINTENANCE EXPERIENCES OF M60-SERIES TANK CREWMEN

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FIELD-EXPEDIENT MAINTENANCE EXPERIENCES OF M60-SERIES TANK CREWMEN

INTRODUCTION

A tank is a complex weapon system consisting of a number of mechanical and electrical subsystems. When it is in the hands of a well-trained crew and is operating properly, it is a force to be reckoned with. But when one or more tank subsystems are damaged or malfunctioning, the effectiveness of the tank as a fighting system may be seriously impaired.

Standard Maintenance and Troubleshooting Procedures

Under normal circumstances, most troubleshooting and repair of complex military hardware such as tanks is performed by qualified mechanics and technicians. These mechanics and technicians, trained in approved troubleshooting and repair techniques, accomplish the repairs using procedures prescribed in detail in voluminous technical manuals. In theory at least, these mechanics and technicians make repairs by the book, using authorized parts and procedures to effect repairs in the required manner.

In reality, however, technical manuals cannot possibly cover every problem that might occur with a complex weapon system; thus mechanics and technicians must depend to some extent on their troubleshooting skills in order to be effective in diagnosing system faults. A logical analysis of troubleshooting (Siegel & Jensen, 1955) identified at least four steps necessary for effective troubleshooting: (1) hypothesize the cause of the malfunction on the basis of the symptoms observed; (2) perform diagnostic equipment performance checks in order to support or disconfirm the hypothesis; (3) ascertain the cause of the malfunction from a synthesis of the information obtained from the equipment checks with the precheck hypothesis; and (4) perform the work necessary to eliminate the cause of the malfunction.

Performance of the four steps described above does not always eliminate the malfunction. Nor does the failure to perform all of these steps guarantee that the attempt to repair the equipment will be unsuccessful. Experience in evaluating and repairing malfunctioning equipment on the job often allows the troubleshooter to go directly from the symptom to the repair without making any additional checks. Such short cuts may be effective, especially when an observed symptom is almost always associated with a particular fault.

On the other hand, short cuts gained through field experience do not always work (Chalmers, 1957). Chalmers lists some common mistakes underlying poor troubleshooting performance. Among these is the tendency to jump to conclusions about the cause of a given malfunction without making the equipment checks necessary to verify that the diagnosis is correct. A related mistake is the failure to recognize that more than one malfunction source could cause the observed symptom to appear. These mistakes may be accompanied by a lack of knowledge by the troubleshooter regarding the operations and functions of the malfunctioning equipment and ignorance of the location of specific assemblies of the equipment. Thus, while short cuts gained through experience may be effective in some instances, they may lead the troubleshooter to faulty diagnosis of the problem in others. Troubleshooting and repair of complex equipment are clearly difficult and sometimes tricky processes, even for well-train i technicians with considerable troubleshooting and repair experience.

Field-Expedient Maintenance

Unlike the technicians and mechanics whose job it is to repair the tanks, tank crewmen are given almost no formal training in troubleshooting and repairing damaged or malfunctioning tanks. Their maintenance instruction consists of training in performing certain routine checks and services and in procedures for reporting malfunctions to organizational maintenance. Having the crew refer maintenance problems to skilled maintenance personnel offers obvious vantages during peacetime. Tank crewmen, free of the chore of repairing their tanks, can devote more of their energies to developing combat ski . And the repairs performed by skilled maintenance personnel are likely to be more efficient and effective than those performed by tank crewmen. On the other hand, identifying and repairing malfunctions occurring during combat may be an entirely different matter. When a tank sustains damage or malfunctions during combat and trained maintenance personnel are not immediately available, crewmen may have to rely on their own troubleshooting and repair skills to extricate themselves from life-threatening situations. Because of the immediacy with which the repairs must be accomplished and the lack of approved repair parts, crewmen in these situations must often resort to the use of unauthorized materials and techniques for effecting the repairs.

Some Armor experts have suggested that such unauthorized field-expedient maintenance techniques performed by tank crewmen can serve as a cheap combat effectiveness multiplier, keeping more tanks operational and firing during combat. Proponents of the use of field-expedient techniques at the U.S. Army Armor Center and at the U.S. Army Material System Analysis Activity have suggested that senior NCOs and other Armor leaders might profitably be trained to perform field-expedient maintenance techniques. However, these proponents find themselves in the peculiar position of advocating training programs in field-expedient maintenance techniques and yet not really knowing how many and what kinds of techniques might be trained. While proponents can usually relate an experience or two in which a "good soldier" was observed performing depot level repairs on equipment in the field to complete the mission at hand, such bits and pieces of information are not sufficient for developing a program for training field-expedient maintenance.

Critical Incident Technique

In order to develop a program to train field-expedient maintenance, a number of field-expedient techniques must be identified. Each technique must be specified in sufficient detail so that it can be evaluated for effectiveness and, if effective, explained and demonstrated to trainees. Because performance of field-expedient maintenance occurs relatively infrequently and does not occur with any predictable regularity, direct observation of field-expedient maintenance is not feasible. However, through a method known as the "critical incident technique," indirect observations of examples of field expedience can be gathered.

Flanagan and his associates first developed the critical incident technique in the 1940s for determining what behaviors were critical to effective and ineffective performance of job activities by Army Air Force avaiators (Flanagan, 1954). Since that time, the critical incident technique has been used to determine the critical requirements for effective performance in a variety of different jobs (Fivars, 1973). The technique involves asking competent observers to describe incidents in which the behavior of an individual was particularly effective (or ineffective) in performing a prescribed activity or job. An advantage of the technique is that it produces a record of task-specific behaviors that are critical to the performance of the activity, but does not require that the activity be directly observed by the researcher. Another advantage of the technique is that it obtains the record from those who are in the best position to make the necessary observations and evaluations.

Study Objectives

The present study is concerned with incidents in which tank crews used unauthorized maintenance techniques to repair malfunctions and damage of the kind that crews might find it necessary to repair during combat. The primary purpose of the study is to describe the kinds of unauthorized troubleshooting and repair techniques used by tank crewmen to repair their vehicles, techniques that might be used as the basis for the development of a training program in field-expedient maintenance. Other objectives of the study are to determine the circumstances under which field-expedient maintenance is typically performed; the manner in which it is performed--checks made, tools used, etc.; who makes the repair; and how long the typical repair takes.

METHOD

Population and Sample

The sample consisted of 37 male NCOs enrolled in ANCOC and Master Gunner Courses at the Fort Knox NCO Academy in the fall of 1982. Of these, 32 were E6s, 3 were E7s, and 2 simply gave platoon sergeant as their rank. One or more incidents of field-expedient maintenance were contributed by each of the 33 NCOs. The four remaining NCOs could not think of an incident of field-expedient maintenance--two of them had not been on a tank in the past two years, and a third was a senior instructor with no recent field experience.

Procedure

Seventy-eight incidents of field-expedient maintenance were collected from 33 senior NCOs. The incidents were gathered over a 3-day period by three interviewers from the Army Research Institute. The interviews were conducted using a structured interview form (Appendix A) on which the incident and information relating to the incident were recorded. As an additional check on the technical accuracy of the data recorded on the interview form, interviews were recorded on tape using a small cassette recorder.

NCOs were interviewed individually by one of the three interviewers. The length of the interview varied between 15 and 30 minutes, depending on the number of incidents recalled and ease with which they were recalled. Each NCO, seated at a table across from the interviewer, was read instructions that explained the purpose of the study and the kind of information being sought. The interviewee was then asked to think of the last time that he as a member of a tank crew used, or directly observed others use, unauthorized maintenance techniques that were clearly effective in restoring a disabled or malfunctioning tank to operation. To ensure that all the pertinent details of the incident were included, interviewees were asked to answer a series of questions about each incident that they contributed. The questions asked for the following information: (1) the circumstances under which the maintenance occurred; (2) initial symptoms suggesting that the tank was malfunctioning; (3) the checks made by the crew in searching for the source of the trouble; (4) the symptoms that led to the diagnosis of the fault; (5) the faulty system or component; (6) how the repair was made; (7) the rank of the soldier making the repair; (8) tools used in making the repair; (9) how much time the repair took; (10) when the incident occurred; and (11) the degree of operability of the tank following the repair. It was unnecessary in some cases to ask specifically every question because answers to some of the questions were voluntarily provided during interviewee's description of the incident.

Each NCO was asked to think of as many incidents as he could within the 30 minutes allotted per subject. Following the description of the first incident subjects were asked to try to recall a second incident, and so on, until either 30 minutes had elapsed or until the interviewee could recall no further incidents. Because of the nature of the information that they were being asked to reveal (i.e., information on the performance of unauthorized activities) names of the interviewees were not recorded. The only way the soldiers were identified was by class (ANCOC or Master Gunner), rank, and present duty position. In the instructions to the NCOs, the interviewees were specifically told that their names would not be recorded and that all information that they provided would remain anonymous.

Following the interviews, completed interview forms were reviewed for completeness and clarity. Where information recorded on the form was incomplete or required clarification, tape recordings of the incident were used to fill in the missing information. One of the interviewers failed to tape all of the incidents collected, so tape recordings were not available for every incident. Based on the review, incidents that were uninterpretable or did not qualify as field-expedient maintenance were discarded. In only two cases were incidents discarded for these reasons, leaving 76 incidents for analysis purposes.

Analyses

Descriptive analyses were used to evaluate the incidents of field-expedient maintenance on several dimensions. Among the dimensions were: (1) the circumstances under which the maintenance occurred; (2) the presence or absence of troubleshooting checks; (3) the vehicle subsystem repaired; (4) tools and supplies used in making the repair; (5) how much time the repair took; (6) the rank of the soldier making the repair; (7) the degree of operability of the tank following the repair; and (8) when the incident occurred. Incidents were characterized on each of these dimensions by calculating the proportion of incidents falling into predetermined categories comprising the dimension. For example, the dimension, time to repair the tank, consists of four categories -- 0 to 10 minutes, 10 to 30 minutes, 30 to 60 minutes, and 60 minutes plus. The proportion of incidents in each of these time categories was calculated, giving an indication of the time required to perform field-expedient maintenance of the type discussed in this report. Complete information was not collected on every incident; therefore descriptive analyses are based on less than 76 incidents in some cases.

Following these analyses, 50 of the 76 incidents were used to derive categories of field-expedient maintenance. The author carefully reviewed the incidents, searching for commonalities and differences among incidents. Incidents were sorted into stacks with those that resembled each other placed in the same stack. These stacks would later become separate categories of field-expedient maintenance. Some categories were self-evident from the start, while others had to be teased out by carefully contrasting and comparing the incidents sorted into the various stacks. The categories thus derived were then used to classify the remaining 26 incidents. On the basis of the successes obtained and difficulties encountered in categorizing these remaining incidents, the categories were refined and modified.

As an additional check on the suitability of the categories for describing field-expedient tank maintenance and as a measure of how reliably incidents could be classified into the appropriate categories, two persons not associated with the study independently classified the 76 incidents, using the categories derived by the author. The percentage of incidents on which the two classifiers agreed and the agreement between each classifier and the author were computed.

Classifiers were given the names of the resulting field-expedient maintenance categories and a short description of each. They were told to classify each incident of field-expedient maintenance, using the categories provided. They were also told that a few incidents involved two maintenance actions, and that these incidents should be classified under both categories that applied. The category descriptions and the complete set of instructions given to classifiers may be found in Appendix B.

RESULTS AND DISCUSSION

Circumstances

Approximately two-thirds of the incidents discussed in this study took place during various collective training exercises. The remaining one-third either occurred in the motor pool/assembly area or the circumstances under which the incident occurred were not specified. Roughly 27% of the incidents recalled occurred during an ARTEP. Another 14% occurred during gunnery, and 21% took place during field problems, maneuvers, marches, and other assorted training exercises. Four percent of the incidents were reported as having occurred during Reforger. Although roughly one-third of the incidents did not occur in the field, the techniques employed were such that they could have been performed in the field. All except two of the incidents--one for an M1 tank and one for an M48A5 tank--involved M60-series tanks.

Troubleshooting Checks

Soldiers reported making troubleshooting checks for only 24% of the 76 incidents. These checks usually involved looking and listening while manipulating controls, inspecting several components for damage, and checking connections for tightness. For the remaining incidents no checks were made other than a visual inspection of the suspected component. These results imply that standard troubleshooting techniques are typically not an integral part of field-expedient maintenance. This finding is not surprising given the fact that most tank crewmen have had very little training or experience in using troubleshooting techniques.

Subsystem Repaired

With one exception, the incidents were fairly evenly distributed across the following 10 tank subsystems: (1) suspension system; (2) air cleaning system; (3) braking system; (4) cooling system; (5) steering system; (6) fire control system; (7) sighting system; (8) transmission; (9) ignition system; and (10) fuel system. The exception is the suspension system; 25% of the 76 incidents involved repairs on the suspension system. Many of the incidents involved one or another variation of replacing a thrown track. "Walking on track" was frequently mentioned and might have been mentioned even more often had not some attempt been made to avoid excessive duplication of incidents. "Walking on track" is apparently something that occurs frequently in the field and is thus readily recalled.

Tools Used

For the most part field-expedient maintenance is performed with whatever tools and supplies happen to be readily convenient. These include issued items such as screwdrivers, wrenches and sockets, tanker's bar, track jacks, flashlight batteries (BA30), weapon-cleaning solvent and lubricant, track blocks, hammers, pliers, and ratchets, as well as nonissue items such as sticks, electrical tape, a spring from ball-point pin, and a bicycle pump.

Some soldiers, however, come prepared to make the field-expedient repairs that may be required. For example one soldier explained that he carries his own personal vise grips, and then proceeded to describe how he used them to repair a broken gearshift lever. Several soldiers mentioned carrying 90-mile-an-hour tape, a green sticky tape used for repairing air hoses and other parts of the air-cleaning system. Canned ether is sometimes carried for starting a cold tank engine. One soldier even carries his own field-expedient tool and supply kit consisting of the following: an accelerator belt that goes on the front of the engine; a final drive collar bolt; lug washers; wrenches (7/16 and smaller); and assorted sockets.

Some of the field-expedient repairs did not involve the use of any tools or supplies whatsoever. About 12% of the incidents reported fell into this category. Some of these incidents involved direct human intervention. For example, the soldier might manually operate a broken steering linkage or spit on the back of the round to increase electrical conductivity and cause it to fire.

Repair Time

To determine how quickly crews can make field-expedient repairs, interviewees were asked how long it took to identify a malfunction and make the repair. Repair times were reported for 70 of the 76 incidents. For these, repair times of 10 minutes or less were reported for 26 (37%) of the incidents, and another 24 (34%) incidents took between 10 and 30 minutes. Five additional incidents (7%) took between 30 and 60 minutes, and the remaining incidents (22%) required 60 minutes or more. It appears that most field-expedient maintenance performed by tank crewmen requires a relatively short period of time to accomplish and usually saves time in that crewmen are not required to wait on maintenance personnel who may be occupied elsewhere.

Repairer Rank

It is important to identify those soldiers who typically perform field-expedient repairs. In the present study soldiers having the rank of E6 were most frequently reported as having performed field-expedient maintenance. Slightly over one-third of the incidents reported were performed by E6s. For roughly another third of the incidents, interviewee could not identify a particular soldier as having performed the maintenance. In these cases, the crew was mentioned when asked for the rank of the soldier making the repair. Of the remaining incidents about 10% were made by E5s, and the rest were scattered across ranks ranging from E3 to company commander. Repairer rank was not obtained for 4 of the 76 incidents. Although these results suggest that E6s are more likely than soldiers of other ranks to make field-expedient repairs, it is important to note that most of the interviewees were E6s and many of these were reporting maintenance that they personally had performed. Thus while it may be concluded that E6s are likely to use field-expedient techniques, the data cannot be used to support the contention that E6s are more likely than tank crewmen of other ranks to use these techniques.

Tank Operability Following the Repair

Soldiers were asked to describe unauthorized maintenance techniques that were clearly effective in restoring a disabled or malfunctioning tank to operation. Following their description of each incident, they indicated the extent to which the repair allowed the crew to continue its mission. In over two-thirds of the cases, the crew was able to continue the mission in the normal mode. That is, all tank subsystems required for completion of the mission were fully operational. For most of the remaining third, the crew continued the mission in the degraded mode (i.e., one or more tank subsystems was not functioning normally). In one instance, however, the repair did not allow the crew to continue their mission, but the mobility of the disabled tank was restored, so that it could return to the maintenance area for further repairs.

Interval Between Occurrence and Reporting of Incidents

One indication of how frequently field-expedient maintenance occurs is the time elapsed between the occurrence of and reporting of the incidents. If field-expedient maintenance is very frequent and breakdowns occur often, one might expect that many of the incidents reported would have occurred within the last 6 months to a year. On the other hand, if most of the incidents recalled occurred more than a year ago, then either breakdowns in the field are relatively infrequent or field-expedient maintenance is not performed with any regularity. For the 69 incidents on which data were available 38 (or 55%) of the incidents reported had occurred more than a year before. Twenty (or 29%) had occurred less than 6 months before and 11 (or 16%) had occurred from 6 months to a year before. That the majority of incidents reported occurred more than a year before suggests that field-expedient maintenance is not an everyday occurrence. However, the frequency with which opportunities arise for field-expedient maintenance to occur is an unknown, and therefore no firm conclusions about the frequency of field-expedient maintenance can be drawn from these data.

Categories of Field-Expedient Maintenance

The initial classification system derived by sorting 50 incidents into stacks of similar incidents consisted of eight categories. Classification of the remaining 26 incidents using these categories demonstrated the need to refine the category descriptions to delineate more clearly the categories. The resulting categories of field-expedient maintenance and descriptions of each are presented in Table 1.

Each category listed in Table 1 represents unauthorized maintenance activities performed by tank crewmen. Three of the categories--"Manual Assist," "Bypass/Remove without Replacement," and "Substitute Component or Part"--are unauthorized because of the nature of the activities performed. For example, to remove a part and operate the tank without it is unauthorized regardless of who removes the part or how it is removed. Similarly, to substitute an unauthorized part is also an unacceptable procedure regardless of how well it works or who makes the substitution. The activities covered by

Table 1

Field-Expedient Maintenance Categories

Category	Description
Preventive maintenance	Maintenance performed to avoid anticipated problems. For the purpose of this report, only unauthorized preventive maintenance is considered.
Manual assist	The soldier physically inserts himself as a part of a malfunctioning system and manually assists the system <u>as it operates</u>.
Bypass/remove without replacement	A faulty component is taken out of the system and the system is operated without it, or the component is bypassed so that it is no longer a functional part of the system.
Reposition or adjust	A component that has become displaced, bent, jammed, locked, loose, or out of adjustment is returned to its normal operating position. (Nothing is removed from the system or bypassed.)
Substitute component or part	A part or component that is missing or malfunctioning is replaced with an unauthorized substitute part.
Remove and replace with authorized part	Either a component that the crew is not authorized to remove or replace is removed and replaced or the manner of the removal/replacement (e.g., tools used, method used) does not follow accepted procedures. (Does <u>not</u> involve substituting parts.)
Clean or mend	A component is cleaned, patched, or mended sometimes using typical cleaning or mending materials (e.g., water, tape) and other times using materials for cleaning or mending which would not normally be used for that purpose. (Does <u>not</u> involve substitution for or removal/replacement of a component.)
Mechanical/electrical/chemical assist	A vehicle system is induced to operate or assisted in operation by applying an external mechanical, electrical, or chemical stimulus or boost.

the remaining categories become unauthorized because of the manner in which they are performed or who performs them. For example the crew is authorized to reposition a thrown track, but not by using a large rock to walk it on. In other cases, replacing a faulty part with its exact replacement part is authorized when performed by maintenance personnel, but not when performed by tank crewmen. Thus field expedience in the present study depends on one or more of the following factors: (1) the nature of the maintenance activity being performed; (2) the manner in which the activity is performed (i.e., method, or tools used); and (3) who performs the activity. The categories of field-expedient maintenance described in Table 1 are built around these factors.

Based on the author's initial classification of the field-expedient maintenance incidents, incidents are not equally distributed across the eight categories. Table 2 lists each category and the proportion of the 76 incidents that were assigned to that category. Note that four categories--substitute component or part, clean or mend, bypass or remove without replacement, and reposition or adjust--account for more than 70% of the incidents. The largest proportion of the incidents (24%) consisted of substituting an unauthorized component or part. The smallest proportion of incidents (5%) was done for preventive maintenance purposes.

Table 2

Distribution of Field-Expedient Incidents Across Categories

Category	Proportion x 100
Preventive maintenance	5
Manual assist	6
Bypass or remove without replacement	14
Reposition or adjust	14
Substitute component or part	24
Remove and replace with authorized part	11
Clean or mend	20
Mechanical/electrical/chemical assist	6

While the numbers in Table 2 represent the distribution of incidents across categories for the present study, they may not accurately portray the relative number of different types of field-expedient maintenance performed in the field. The reason that the study results may not be representative of the true proportion is that the study attempted to avoid excessive repetition of incidents in order to obtain better coverage of the domain of field-expedient maintenance. Had the researchers not done this, the relative number of incidents in the "reposition or adjust" category, which includes repositioning thrown track, would have undoubtedly have been higher. There was also some indication that the interviewees themselves were hesitant to report incidents that they felt were commonplace and might have already been reported by someone else.

Appendix C lists the incidents reported by the interviewees. The incidents are listed by category as determined by the author. Incidents are listed for illustrative purposes only, and their inclusion does not constitute a recommendation for their use. In the interest of brevity and clarity, the examples in Appendix C are paraphrased versions of the actual incidents. Except as noted, incidents describe field-expedient maintenance by tank crews on M60-series tanks.

Category Adequacy and Reliability

The adequacy and reliability of the categories of field-expedient maintenance were determined by comparing the author's classification of the 76 incidents with that of each of two independent classifiers. The first classifier placed 72% of the incidents in the same category as the author, while the second classifier categorized 82% of the incidents the same as the author. Working independently, the two classifiers agreed on 72% of the incidents. For 62% of the incidents, there was complete agreement among all three classifiers about which category applied. Complete disagreement across classifiers was obtained for only four incidents (5%).

Closer examination of instances in which classifiers did not agree revealed that certain categories were involved more often than others. The category resulting in the most disagreement was the category labeled Mechanical/Electrical/Chemical Assist. One classifier in particular placed far more incidents in this category than did the author of the study. The author included this category to cover instances in which an external mechanical, electrical, or chemical stimulus is applied to an inoperative component or system in order to make it operate or assist in its operation. Examples include injecting ether into the air intake to start a cold tank or creating a heat tent with other tanks and tarps to warm a tank that won't start. Another example involved wiping water on the back of a main gun round in order to increase electrical conductivity so that it would fire. Because this category produced some confusion, an attempt was made to relabel and redefine the category. The new label and definition for Mechanical/Electrical/Chemical Assist is given below:

Category	Description
Apply External Stimulus	A stimulus or agent external to an inoperative system is applied to a failing system component to make it operate or assist in its operation. The stimulus may exert its effect through electrical, chemical, thermal, or mechanical means. The effect of the stimulus, however, must rest with the stimulus itself and not with the force provided by the system being maintained or the soldier performing the maintenance.

Other categories producing more disagreement than the average include "Clean or Mend," "Reposition or Adjust," and "Remove and Replace with Authorized Part." Review of these categories and the incidents that were assigned to them, however, suggests that the category definitions are probably adequate and that the problem likely stems from difference in interpreting the incidents themselves.

Despite some disagreement among classifiers, the reliability of the categories seems to be well within an acceptable range (72 to 82%) given the number of categories and the exploratory nature of the study. The reliability might have been better had the classifiers had previous maintenance experience or training. As it was, the classifiers had no maintenance background and still agreed in over 70% of the cases.

The categories derived in this study may not exhaustively describe the domain of field-expedient maintenance. Likely other categories of field-expedient maintenance could be derived. Had more incidents on the M60-series tank been collected, additional categories may have been discovered. As examples of field-expedient maintenance on other weapons systems are collected, new categories may appear. At the same time, it is expected that many of the incidents collected will fall into the eight categories described in Table 1.

GENERAL DISCUSSION

By the time they are E6s, most armor crewmen have performed field-expedient maintenance on at least one occasion in their careers. Such maintenance is most often performed during major collective training exercises such as during ARTEP's. Almost any subsystem on M60 series tanks might be the subject of field-expedient repairs. However, such repairs are most often performed on the suspension system. Soldiers making the repairs use tools and supplies that were issued to them as well as anything else that is close at hand at the time. Sometimes they even make do without using any tools or supplies at all. Other times tankers carry additional tools and supplies for the express purpose of making repairs in the field. Using their wits, imagination, and anything else available, tank crewmen typically perform these repairs in

30 minutes or less. When the repair is complete, the tank is usually able to complete its mission in a normal rather than in a degraded mode.

Field-expedient maintenance techniques differ from standard maintenance techniques in several ways and are to some extent unique. In three out of four cases, field-expedient maintenance does not employ troubleshooting checks, other than a visual inspection of the suspected component. When checks are made, they are made without the benefit of test equipment. The checks typically consist of looking and listening while manipulating controls, inspecting components for damage, or checking to see that connections are tight. The lack of test equipment is accompanied by a lack of proper tools and replacement parts to perform the maintenance. Thus crewmen make do with the tools and parts available to them, often using their tools in unorthodox ways and making substitutions for parts that they don't have. Other times they simply remove or bypass a faulty component and operate the tank without it. In a few cases crewmen assist a malfunctioning system by temporarily becoming an integral part of that system and manually operating it. For example, when steering or shifting linkages break, a crewman will sometimes operate the system from the point where the break occurs. Ingenuity seems to play a much more important role in performing field-expedient maintenance than it does in performing authorized maintenance techniques.

The field-expedient maintenance techniques identified in this study may be useful when and if the Army decides to train their senior NCOs and armor officers in field-expedient techniques. The feasibility and desirability of incorporating any given technique into the training given to these NCOs and officers will have to be based on expert judgment and further study, however. The categorization of field-expedient maintenance has identified approaches that may be used to make field-expedient repairs in a wide variety of situations. For example, soldiers might be taught that when a faulty part or component is known to be interfering with carrying out their mission and cannot be mended, then they should consider using a substitute part, bypassing the part, or removing the part completely and operating without it. Similarly soldiers could be made aware of other approaches (e.g., manual assist) that might be useful in certain kinds of situations.

The present study has identified a number of specific incidents of field-expedient maintenance on M60-series tanks. The critical incident technique coupled with specific probe questions has proven useful in gathering these kinds of information. An interview format similar to the one included in Appendix A could be used to gather additional examples of field-expedient maintenance for M60 tanks as well as for other weapon systems. The format in Appendix A ensures that questions pertinent to the incident are covered in the interview, giving the soldier ample opportunity to recall as much detail as possible about the incident. The method used in this study provides a structured way of identifying field-expedient maintenance techniques, where heretofore none existed.

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APPENDIX A

INTERVIEW DATA FORM

Date________________________________ Interviewer____________________________

Rank________________________________ Class________________________________

Present Duty Position______________________________________

During ARTEPs, FTX's, REFORGER, and other large scale collective exercises, tanks often develop mechanical and electrical malfunctions that prevent the tank crew from completing the exercise and fulfilling its mission unless the crew fixes the tank on the spot. In these situations tank crewmen have been known to use some very imaginative techniques to keep their tanks operating. The repair techniques that they use may not be authorized and do not always restore the tank to its full operational capability, but the fixes usually enable the crew to continue its mission, or at the very least enable the tank to move under its own power.

In wartime, the crew's ability to make such repairs may mean the difference between losing the tank and its crew and the successful completion of the unit's mission. Therefore we are asking experienced NCO's such as yourself to share their knowledge of the techniques used by tank crews to repair tanks in the field. The information you provide will be recorded on tape and used to train other tank crewmen to assess and repair tank malfunctions occurring during combat. Your name will not be recorded, unless of course you wish to be recognized for your contribution.

Think of the last time that you as a member of a tank crew used, or directly observed others use, unauthorized maintenance techniques that were clearly effective in restoring a disabled or malfunctioning tank to operation.

Under what circumstances did this maintenance occur? (Type of exercise, etc.)

What were the initial indications or symptoms suggesting that the tank was malfunctioning?

What checks, if any, did the crew make in searching for the source of the trouble?

What symptoms or checks led to the diagnosis of the fault?

What component or system on the tank was faulty?

How did the crew repair the tank?

What tools or materials were used for the repair?

About how long did it take the crew to identify the malfunction and make the repair?

____ 0 to 10 minutes ____30 to 60 minutes

____10 to 30 minutes ____more than 60 minutes

What was the rank of the soldier (or soldiers) who isolated the malfunction and made the repair?

To what extent did performing this maintenance allow the crew to continue its mission?

____ Continued in normal mode

____ Continued in degraded mode

____ Could not continue mission, but the tank could move under its own power

When did this incident occur?

____ Less than 6 mos ago

____ 6 mos to 1 year ago

____ More than 1 year ago

APPENDIX B

INSTRUCTIONS FOR CLASSIFYING INCIDENTS

Instructions

Listed below are eight categories representing different types of field-expedient maintenance performed on tank in the field. Seventy-six incidents of field-expedient maintenance were gathered in interviews with senior NCO's. Your task is to classify each incident of field-expedient maintenance in the appropriate category. Some of the incidents involve more than one maintenance action. In such cases the incident classification should be based on the field-expedient part or aspect of the maintenance. For a few incidents two field-expedient maintenance actions representing two different categories will be found. For these few incidents, you will list both categories that apply to the incident.

Please read the description for each category carefully prior to classifying any incidents. If any of the descriptions are unclear, you should make sure you understand them before beginning the classification task. As you classify the incidents, you should refer back to the category descriptions frequently.

Read all of the information about the incident included on the interview form. Some interviewees gave a more complete account of their incident than did others; and therefore complete information is not available for every incident. Although some incidents will be difficult to classify, given the information available, you must give it your best shot based on the information provided and by reading between the lines.

In classifying the incidents, do not write on the interview forms. Rather you should list the number for each incident, and beside it the category (or in few instances two categories) that best describes it.

Field-Expedient Maintenance Categories

Preventive Maintenance	Maintenance performed to avoid anticipated problems. For the purpose of this report, only unauthorized preventive maintenance is considered.
Manual Assist -	The soldier physically inserts himself as a part of a malfunctioning system and manually assists the system as it operates.
Bypass/Remove w/o Replacement -	A faulty component is taken out of the system and the system is operated without it, or it is bypassed so that it is no longer a functional part of the system.
Reposition or Adjust -	A component that has become displaced, bent, jammed, locked, loose or out of adjustment is returned to its normal operating position. (Nothing is removed from the system or bypassed.)
Substitute Component or Part -	A part of component that is missing or malfunctioning is replaced with an unauthorized substitute part.
Remove and Replace with Authorized Part -	Either a component is removed and replaced that the crew is not authorized to remove or replace, or the manner in which the removal/replacement is accomplished (e.g., tools used, method used) does not follow accepted procedures. (Does not involve substituting parts.)
Clean or Mend -	A component is cleaned, patched, or mended sometimes using typical cleaning or mending materials (e.g., water, tape) and other times using materials for cleaning or mending which would not normally be used for that purpose. (Does not involve substitution for or removal/replacement of a component.)
Mechanical/Electrical/Chemical Assist -	A vehicle system is induced to operate or assisted in operation by applying an external mechanical, electrical, or chemical stimulus or boost.

APPENDIX C

EXAMPLES OF FIELD-EXPEDIENT REPAIRS

Preventive Maintenance

Example 1: Due to vibration, the wedge bolt worked itself loose during an ARTEP. To prevent the wedge bolt from working loose again and eventually falling off, a hammer and chisel were used to notch the wedge bolt.

Example 2: A platoon sergeant stationed in Korea experienced heater problems with his M60A1 tanks during cold weather. The heaters would flood and take a long time to start up. To prevent this problem, at the end of each day, instead of just shutting the heaters off, the sergeant disconnected the feedlines from the heaters. No tools were needed to disconnect the lines; the lines were simply pulled and twisted off. This procedure also kept the tank from smoking a lot when it was first started up.

Example 3: A TC on an M60A2 tank always checked the track pads for broken pins in the field at the completion of the day's activities. He checked for broken pins by poking an 18-inch screwdriver in the holes in the end connectors. He considered this method of checking the pins more thorough than the method of using hammer taps.

Example 4: During an ARTEP, an M60A3 tank threw a track and it completely tore off the rear quarter of the sponson box, and bent the rear fender badly. The air cleaner box is positioned in front of the damaged parts, so that if the tank were moved with the fender bent like it was, the air cleaner box would be damaged. To prevent this from occurring, the crew hooked a tow hook and cable between the hull and the rear stowage box, and used another tank to rip off the bent fender. (Note: Also classified as Bypass/Remove.)

Manual Assist

Example 1: Moving along a tank trail during a battalion field problem the driver lost the steering. The driver stopped the tank and the crew started looking for the problem. First they opened the engine compartment and checked the linkage on the engine itself; the linkage was intact. Next they took the panel off of the fire wall inside the tank and discovered the linkage was broken into at that point. Keeping the turret stationary, the gunner manually operated the steering by pushing the linkage to the rear to turn right and pulling it forward to turn to the left. The tank commander told the gunner when to push and when to pull to turn and the driver shifted gears and controlled acceleration.

Example 2: In a convoy during REFORGER, the driver noticed that pushing the accelerator pedal was not causing the speed of the tank to increase. Inspection of the throttle linkage identified a bolt missing from the linkage. Keeping the gun over the front deck and the turret stationary, the gunner layed on the floor and manually operated the throttle as instructed by the driver.

Example 3: A tank crew was taking a tank to have it inspected. As they were backing the tank out, the driver attempted to turn using the t-bar and nothing happened. In checking for the problem, the crew first opened the top deck grill doors and watched the linkage as the driver turned the t-bar. The linkage wasn't moving, so a second observation was made inside the tank along the hull. The rod was not moving at this location either. A third check revealed that the part of the linkage behind the fixed fire extinguishers had broken. To get the tank moving again, one crewman operated the steering rod from the hull. Other crew members told the operator when to pull or push to turn the tank to the left or right.

Example 4: During a field exercise at Fort Irwin (National Training Center), a tank was making a hasty attack across an open field laced with gulleys. The tank, moving at a fairly rapid clip, hit a deep gulley, causing the shifting linkage at the back of the engine to snap. The crew had to move the tank to avoid artillery shells that were being dropped behind them as they moved across the field. To move the tank, the TC got out on the back deck and, directing the driver's actions through the external phone system, manually operated the shifting linkage.

Example 5: On a field exercise, the driver attempted to steer the tank to the right. In making the turn the steering linkage stuck and the tank continued going to the right, despite the driver's attempts to complete the turn. Positioned on the back deck of the tank with the top grill doors opened, the TC kicked the steering linkage back in place each time it locked up. This allowed the tank to move along the tank trials in a somewhat normal manner.

Bypass/Remove w/o Replacement

Example 1: During a gunnery exercise, a tank would not move forward from a stationary position after having previously locked the parking brakes. The tank commander and gunner opened the grill doors, removed the heat shield, and used a screwdriver to pry down on the rod, popping it loose thereby releasing the brakes. The screwdriver and a pair of pliers were then used to remove the cotter pin, and lacing wire was used to wire the brakes back to prevent them from locking again. (Note: Reported by three soldiers.)

Example 2: The tank crew noticed that their tank was sitting lower on one side and that one road wheel seemed to be sitting up higher than the rest. Inspection showed that a torsion bar was broken. The crew took the roadwheel off and used a heavy chain to chain the roadwheel arm in the "up" position. The chain was threaded through the eye of the hull and the chain and roadwheel arm were locked in place.

Example 3: An M60A1 tank was on line preparing for an inspection at Fort Sill, Oklahoma. The start button was pushed, and nothing happened. Under the direction of a turret mechanic, one crewman used a wire to short across the starter relay, and the tank started.

Example 4: While engaging in gunnery in Germany, a tank downrange lost its number three roadwheel and hub when it hit a large rock. The hub, roadwheel, and roadwheel arm were all damaged. Under the direction of an E6 assistant instructor and with the help of five other soldiers, the torsion bar was removed from that roadwheel arm. Using a combat tow chain of an 88 recovery vehicle, the soldiers held up the roadwheel arm and chained it through a lifting eye. The whole assembly was chained up to keep the roadwheel arm from dragging on the track. The tank was operated with the assembly chained up for about 18 hours, including going downrange to fire again. (Note: The soldier who reported this incident reported that a turnbuckle out of the tie-down equipment has been used in lieu of the chain in other instances. According to the soldier, the crew cables around both ends of the assembly, and then tightens the turnbuckle to bring it into place.)

Example 5: The tank main gun failed to operate when a Master Gunner attempted to fire it. Checks indicated that the firing squib was good and the firing pin was intact. The gun could not be fired in any of the usual ways (i.e., with the gunner's cadillacs, TC's override, blast machine, or elevation hand pump). This suggested that there was a break in the main wiring harness. In order to fire the gun, the sergeant spliced a piece of commo wire into the hot plate of the firing circuit. The splice was made to the final piece of wire that goes into the center of the wedge on the right side of the breech. This wire was run from firing circuit to the positive side of the dome light. In this manner the main gun was fired by turning on the dome light.

Example 6: During an ARTEP the wear plates on the roadwheels wore down causing the tank to make a "clanging" noise sounding something like a cow bell. Since new wear plates with bolts were not available, the faulty wear plates were removed so that the hub would not be damaged by the faulty plates.

Example 7: In the field, the brake slave cylinder on one side of the tank went bad. To keep the tank operational, the bad brake cylinder was blocked off and the tank was operated with brakes on one side only.

Example 8: During a road march, a tank bogged down and stalled. The crew checked and discovered that the fuel filter was dirty. The dirty filter was discarded and the tank was operated without a fuel filter for the rest of the road march. (Note: The soldier reported that this has happened frequently during field exercises and gunnery.)

Reposition or Adjust

Example 1: On a field problem, dirt got caught in the track forcing it off to one side. The crew took an extra track block and used it to lift the track as it was going around inside the sprocket. The driver turned the tank so that the track block lifted the track up and dropped it back down on the teeth of the sprockets. This procedure ruins the track block, but gets the track back on the sprockets. (Note: Reported by two soldiers.)

Example 2: The gunner was unable to adjust the brightness on the passive sight during a gunnery exercise. In examining the problem, the tank commander (TC) noticed that the whole reticle switch rotated when any attempt was made to adjust it. He knew immediately what was wrong with it. He took the plate off of the back of the switch and tightened a small nut that keeps the switch steady.

Example 3: The driver put the tank in gear and attempted to move forward, but the tank would not move. The parking brakes had not released properly. To release the brakes, the soldier opened the grill doors on the back of the tank, removed the heat shield, and pried the linkage loose with a tankers bar. (Note: Reported by two soldiers.)

Example 4: In moving from one range to the next during a gunnery exercise, an M60A1 tank did not respond to attempts to steer it. The steering felt loose. One crewman opened the top grill door and observed that the steering linkage was loose. Further inspection determined that a 7/16 inch bolt in the linkage had vibrated loose. The bolt was tightened and lacing wire was used to keep it from vibrating up again. (Note: Also classified as Preventive Maintenance.)

Example 5: Driving down the road in Germany, the steering was not responding as it should to the driver's attempts to turn the tank. An E6 opened the top grill doors and visually checked the steering linkages. Inspection revealed that a screw on the steering linkage had vibrated loose. A screwdriver was used to tighten the screw.

Example 6: During a live fire exercise, the loader left his asbestos mittens laying on top of the gun. When the gun fired, the mittens got jammed in the gun system as the gun recoiled. This prevented the gun from firing since the gun would no longer go all the way forward. The crew was unable to push the gun forward or pull the gloves out, so they used a tree to extract the gloves. The crew placed the muzzle end of the gun against the tree and drove the tank forward, forcing the gun back so that the mittens could be removed. (Note 1: Also classified as Mechanical/Electrical/Chemical Assist.) (Note 2: There is an authorized PM check similar to this example called exercising the gun.)

Example 7: Inspection of the track on an M60 tank revealed that the track tension was not sufficient. To adjust the tension, a platoon sergeant slid a small jack (little joe) on the hexagon-shaped part of the track adjuster. Then he removed the pin from the tow pintle and slid the pintle down the tankers bar. The hook that hangs from the pintle was hooked underneath the jack. This provided an extra three or four feet of leverage on the end for turning the nut to increase track tension.

Example 8: On an ARTEP an M60A3 tank threw a track. The crew "walked" the track back on by placing chock blocks under the roadwheels and moving the tank forward slowly until the track returned to its normal operating position.

Example 9: During a company maneuver, badly worn track on an M60A3 tank was thrown. The right track was thrown to the inside on a steep downgrade in a narrow ravine. The tank was jammed on both sides of the ravine, such that the track would move neither forward or backward and the sergeant was unable to get to the track to break it. Using a ground guide, the tank was moved forward and the track popped back on. In the process, a lot of center guides and a few end connectors were busted. Some roadwheels were also damaged. Once back on level ground the crew replaced all busted end connectors, checked for broken pins, and replaced cracked or busted end connectors. (Note: Also classified as Remove and Replace with Authorized Part.)

Example 10: During a company ARTEP, the tank hit something bending the fender and brace badly. After removing the fender, a platoon sergeant put a new kind of track jack with a 3/4-inch drive on top of the track between the two end connectors and let it ride forward just a little bit past the normal position of the brace. This caused the brace to spring back to its correct position. (Note: Also classified as Bypass/Remove w/o Replacement.)

Example 11: On a platoon training mission in Korea, a tank ran over a rice paddy wall while running tactics, throwing the left track. Working at an angle, the crew first broke track between the compensator idling arm and the #1 roadwheel after taking off as much tension as they could. Because of the angle, the track would not line up. They did <u>not</u> attach the track jacks to the side on which the track pins exit the track block. Instead they attached one track jack to the center where both pins are secured by the center guide. By pulling the track from the center and using a tankers bar wedged under the low side of the track coming off of the support of the compensating idler wheel, the crew pushed up and hooked the track in. Placing a second track jack on the inside of the track pins, the crew tightened the track back up. They then put on the outside end connector, disconnected the inside track jack, tightened up the track jack positioned in the center, and used the end connector on the inside to hook it back up. Finally the crew put the tank in neutral, rolling the tank down the hill where they were able to further tighten the track.

Substitute Component or Part

Example 1: When the driver's seat does not move properly, the tank is normally deadlined. During an ARTEP a pin broke in the mount of the driver's seat where the handles are so that the seat would move neither up, down, forward, or backward. The tank commander substituted an Allen wrench for the broken pin and the seat worked perfectly.

Example 2: During gunnery the driver told the TC that the blower motors were out on the left side. To check the blower motors the TC first stuck his hand underneath to check if the motors were blowing air out. Since no air was coming out and a burnt smell was present, the TC removed and disassembled the blower motors. When the blower motors were disassembled, a smutty residue was found around the blower motors. This suggested that the bushing in the motors was bad. A small carbon core of the blower motor brushes had worn out. To repair the motors the TC took the carbon post from two flashlight batteries, filed them down to the right size for the blower motors and replaced the blower motor filaments with the battery posts. (Note: Reported by four soldiers.)

Example 3: During gunnery exercises one of the sights on the tank had burnt out. To repair the sight, the sight was disassembled, a small defective spring was removed from the sight, and the spring from a US Army ball-point pen was substituted in its place. The sight was then reassembled.

Example 4: During qualification runs of Table VIII, the light in the passive sight went out just as the tank was pulling up to the line. The M36 periscope could not be used because a broken linkage arm prevented it from being properly boresighted. To enable them to use the passive sight, the crew unscrewed the defective bulb from the passive sight and taped the M36 bulb in the passive sight where the passive sight bulb had been removed. This lit up the reticle in the passive sight and enabled the crew to engage the target.

Example 5: Moving cross-country in a river bed during a company training mission in Korea, the driver broke the gearshift lever in shifting from low to high gear. The upper part of the gear shift lever broke off leaving about an inch of lever above where the lever went into the gear housing. To enable the driver to change gears, vise grips were clamped to the stub of the gearshift lever, providing a temporary lever for changing gears.

Example 6: During an ARTEP in Korea, a tank stopped briefly for maintenance. Following maintenance the tank wouldn't shift, so a crewmember pulled the grill doors back and inspected the shifting linkage. The crewman found that a pin had fallen out of the steering linkage, so he took a long screwdriver, and picking the loose piece up so that it overlapped the other piece, put a stick in to hold the two together. The stick held long enough to reach the maintenance trains. The maintenance trains did not have the correct pin either, so the crew got a bunch of long cotter pins and substituted them for the lost pin.

Example 7: Sitting in a defensive position during an ARTEP, a tank wouldn't start. When the driver hit the starter button, nothing happened; the solenoid did not even click. The crew immediately started checking the shifting linkages. They opened the grill doors, removed the heat shield, and checked to see if the neutral safety switch had engaged. The switch was engaged, so they shorted across the switch to determine if the switch was faulty. The neutral safety switch was found to be defective, so they removed it and substituted the back deck clearance switch in its place. (Note: The back deck clearance switch is identical to the neutral safety switch. The soldier reporting this incident felt that not having a neutral safety switch was the greater danger because without it the tank would start in any gear.)

Example 8: On a maintenance halt in the field, a check of the roadwheels discovered an enormous amount of grease on the inside of a roadwheel. Closer inspection determined that the roadwheel seal (a gasket between the big metal seal and the roadwheel itself) was worn out. A crewmember made a gasket out of paper to act as a seal and substituted this for the defective gasket.

Example 9: While training in Berlin, the tank would not shift gears properly. The tank commander visually inspected the shifting linkage and found that the linkage rods had come apart. The bolts that hold the rods together were missing. To replace the missing bolts, a soldier removed the bolts from the external phone box and used them as replacement bolts in the transmission linkage.

Example 10: During an ARTEP at Fort Carson, a tank had lost a lot of oil from the transmission. A crewman not having the recommended 10 weight oil replenished the transmission oil with 30 weight oil.

Example 11: During an ARTEP an engine (alpha pack) was blown. To get the tank back into operation, a delta pack was removed from another tank and substituted for the blown alpha pack. This substitution required switching the wires in the line for the blower motors.

Example 12: During a REFORGER exercise, the accelerator control went out. Nothing happened when the driver stepped on the accelerator. Inspection of the accelerator linkage revealed that the mechanism underneath the accelerator control was broken. A 7/16-inch bolt from the gun shield cover was used to repair the linkage.

Example 13: During an ARTEP attempts to steer an M60 tank failed to turn the tank. Checks of the steering linkage determined that a bolt was missing from the linkage. The bolt of the same size was removed from the Mantlet cover and substituted for the missing bolt.

Example 14: During a REFORGER exercise, the shift lever on an M60A2 tank fell off in the driver's hand. The driver put an 18-inch screwdriver into the shortened shift lever and used it as a shifting mechanism.

Example 15: A soldier was checking the .50 caliber machinegun to determine if it was operating properly. A serviceable circuit tester was not available so the tank dome light was used to verify that the firing circuit was working. To do this, the soldier ran a wire from the inside of the .50 caliber electrical plug to the dome light. When the soldier hit the trigger the dome light came on indicating that the machinegun was operating.

Remove and Replace with Authorized Part

Example 1: During an ARTEP in Germany, the blower motors went out causing the tank to catch on fire. The fire destroyed some of the wiring from the panel box to the blower motor relays and to the motor. The fire was extinguished and the tank allowed to cool. When the tank was cool, the tank commander and crew used a wiring schematic, wire, wire cutters and crimpers, wiring tape, and pins for making connections to replace the wiring that had been destroyed.

Example 2: A visual inspection of the tank during scheduled maintenance identified a bent center guide. The center guide was bent over so that the nut that must be removed to remove the center guide was not accessible. In order to remove the center guide, the TC took an old center guide, laying it up over the sprocket next to the one to be removed. As the tank moved forward slowly, the old center guide caused the other guide to crack so that it could be knocked off. A small hammer was used to knock the cracked center guide off. The nut was then removed and a new center guide was installed.

Example 3: On a road march in Germany, during operations preventive maintenance checks and services suggested that the blower motors were defective. In checking for the trouble, the crew listened to the blower motor circuit relay to see if it was clicking. Although the relay seemed to be clicking at that time, the crew later discovered that it wasn't working correctly. To return the tank to operation, the malfunctioning blower motors were removed and replaced with good blower motors from a deadlined tank.

Example 4: On two separate occurrences, during an ARTEP and during a Field Training Exercise, a crew used an unauthorized technique to remove the track to repair it. The technique consisted of using a sledge hammer, a tanker's bar and a ratchet to pop the track off. This technique requires the entire crew, but is faster than the recommended method of removing the track.

Example 5: During a company ARTEP a bolt needed for adjusting track tension froze up so that track tension could not be adjusted. After breaking track, the crew unscrewed the track adjusting link and replaced only the back part of the link. This procedure required less time and effort than the conventional method of removing the entire track adjusting link assembly.

Example 6: On an ARTEP in Germany a tank hit an old World War II cellar block. This caused the studs to break and the roadwheel and track to come off. The torsion bar and roadwheel were not damaged. The crew replaced the missing studs with new ones from the Prescribed Load List (PLL) package and put the roadwheel and track back on.

Example 7: A technique for replacing final drives on an M60A1 tank that could be employed in the field was used during a Q-service. In replacing power packs, it is very difficult to line up the final drives. To line up the drives the crew used large cargo straps around the drives to hold the drives. When the power pack was dropped in, the crew used the cargo straps to lift the drives and a tankers bar to position them so that they slid right in.

Example 8: In the motor pool, a tank crew was assigned the task of helping to change a sprocket. The crew tried to remove the bad sprocket using the standard method, but was unsuccessful. Following the advice of the battalion motor sergeant, they tried an unauthorized method and succeeded in removing the sprocket. First they disconnected the track and removed the inside where the universal joint is located. Then they disconnected the final drive, took off the sprocket bolts on the inside of the sprocket hub, and used a screwdriver to remove the dowels. Finally they used two center guides as wedges to cause the sprocket to push itself off. One center guide was placed in the rear portion between the sprocket and the final drive and pounded in with a sledge hammer at about the 2 o'clock position. The other center guide was pounded in at the 4 o'clock position. (Note: Although this incident occurred in the motor pool under the supervision of a mechanic, a knowledgeable crew could employ this technique in the field if the need arose.)

Clean or Mend

Example 1: During a maneuver in the desert at Fort Irwin, the tank at the end of the column was getting much of the dust and sand kicked up by the tanks preceding it. This caused the tank to lose power badly, blowing out clouds of black smoke. A check of the air cleaners found them to be full of dirt and sand. The collector box (behind the blower motor) was also full of dirt and sand. The crew needed to clean their air cleaners but didn't want to use their water to clean them. Upon arriving at the mess hall (a large tent), the crew obtained a bicycle pump and puffed their way through the air cleaners. The same pump was used to clean out the collector box. This did not completely clean the filters, but reduced the amount of black smoke and restored much of the lost power.

Example 2: During REFORGER, it was noticed that the air cleaner intake hoses were showing excessive wear in the form of holes and cracks. The TC repaired the hoses by wrapping them with 90 mile-an-hour tape (a green, sticky cloth fiber tape).

Example 3: During a training exercise at Fort Carson an M60A1 began blowing black smoke from the engine. The crew removed and cleaned the air filter, which was very dirty. Then they wrapped the air induction hose with green tape.

Example 4: During tank gunnery exercises at Fort Polk a crewman on an M60A1 tank smelled a wire burning. The crewman visually checked for a burnt or broken wire. When the wire was located the soldier used WD1 (commo) wire to splice the broken ends back together. The exposed wire where the splice was made was then wrapped with tape.

Example 5: Preparing for an ARTEP, the crew could not get their M60A1 tank to start. The crew checked the battery and the starter cables. In making the checks, the crew discovered that the starter cables had burnt through at the connecting end. The two ends were disconnected from the starter, and the cables were repaired using a propane torch kit and a roll of solder.

Example 6: The early M60A1 tanks have a thick gasket around the top of the lid of the air cleaner box, while the M60A1 rise model uses a thinner gasket. The older -20P technical manuals list only the thick gasket for the early M60A1 model. A soldier using an outdated -20P manual mistakenly ordered the wrong gasket for the rise model tank. The soldier installed the thick gasket in the lid, but found that the lid to the air cleaner box would not seal properly. To ensure that the air cleaner box was sealed, the soldier ran 90-mile-an-hour tape around the lid of the air cleaner box.

Example 7: During an ARTEP an M60A1 tank had lost most of its power so that its maximum speed was about two miles per hour. To correct the problem, the crew took the back access panel off of the turret, and removed the primary fuel filter. They cleaned the filter with diesel fuel, flushed it out, and put it back on. They also drained the water separator on the other side. These procedures restored power to the tank.

Example 8: During a field exercise, the air filter became so dirty that the engine lost most of its power. A Tank Commander on one tank had installed extra long wires on the blower motors so that the blower motors could be used to clean the filters. When the tank lost power, the TC removed the air filter and set it on top of the turret. He then took out one of the blower motors and used it to blow the dirt out of the filter.

Example 9: On an ARTEP, a tank would not start. The crew first checked the linkages and then checked the cables connecting to the engine for tightness. The crew also checked the manual fuel shut-off to make sure it wasn't keeping the tank from starting. Next a crewman shorted the neutral safety switch, but the tank didn't start indicating that the neutral safety switch was okay. In making additional checks, the tank commander found that on the turret wall where the starter cable comes into the bulkhead, the cable was tight but had pushed out and wasn't making contact with the prongs on the other end. This condition had resulted in arcing across the connection, causing the connector to melt in places. To correct this problem, the platoon sergeant made a sleeve out of a piece of tinfoil from the candy provided in a C-ration pack. The sergeant folded and formed the tinfoil until it fit snugly over the prong and then pushed the prong back in. This made the electrical connection and the tank was started.

Example 10: At Fort Hood during a 90 kilometer road march, an M1 tank seemed to be losing power. Shortly thereafter the "air filter clogged" light came on. The crew removed the air filters and lay them on top of the back deck of the tank. Then they rolled them back and forth to knock the sand out of them. The crew put the air filters back in and power was restored to the tank, although the air filter clogged light remained on. (Note: The crew was careful not to damage the seals in removing and installing the air filters.)

Example 11: During tank gunnery, the ruby rod in the laser rangefinder of an M60A3 tank had overheated and melted down a little due to constant use of the range button. The laser rangefinder was returning readings which were obviously in error. This may or may not be accompanied by illumination of the laser rangefinder light. To repair the laser rangefinder the ruby rods were removed, filed down, and reinstalled. (Note: Sometimes it is necessary to resolder the rod or build it back up.)

Example 12: A tank crew was running tactics in Korea as part of a platoon training mission. In trying to leave a riverbed, the tank slid sideways down a hill throwing the track. In tightening the track after putting it on, the driver put too much tension on the left track. When the crew began to back the tank up and move to the right, the screws that connect the adjusting arm to the adjusting link stripped, causing the adjusting arm to fall out of the link. This released the tension on the left track. Without tension on the left track, the tank would not steer correctly and the track made a loud banging noise. To correct these problems, the crew rethreaded the screws inside the adjusting arm using chisels and a ball-peen hammer.

Example 13: Driving down the road on a field training exercise in Germany, the T-bar used for steering the tank fell off in the driver's hand. The weld broke on the bottom of it, and it just dropped out. A sergeant put the broken T-bar back on and clamped it in place with vise grips. This held the T-bar together until the driver could reach the assembly area where mechanics repaired the broken T-bar by welding it.

Example 14: On an ARTEP in Germany, the tank went dead just as the crew had reached the outskirts of a town. The tank had no power to the turret, engine, or anything else. The crew called for maintenance, but the mechanic, who was unable to locate the problem, told them that they would be picked up on the way back. After the mechanic left, a crewman checked the battery for overheating and the battery cables. These checked out okay, so he worked his way back from the battery to the voltage regulator. The crewman unscrewed the plugs on the voltage regulator and tipped them over and water spilled out. Closer inspection of the voltage regulator revealed that the connections to the regulator were green and not making good electrical contact due to the moisture. To remedy this problem, the crewman squirted some solvent (normally used for cleaning and lubricating weapons) in the holes of the cannon plug of the voltage regulator and put the plugs back in. The driver was told to start the tank and it cranked.

Example 15: On a field problem in Korea an M48A5 tank was running with little power and dying frequently. Finally the tank just stopped running. The crew removed the cloth fuel filters and inspected them. The filters were very dirty so the crew cleaned them the best they could with "Break Free" and poked holes in the filter with latch pins.

Mechanical/Electrical/Chemical Assist

Example 1: During cold weather in Germany, a tank that had not been started in 48 hours would not start. To warm the tank so it would start a heat room was created by backing two or three running tanks up to the one that won't start and covering them with tarps to trap the heat. This procedure warmed the cold tank and enabled it to start.

Example 2: During cold weather in Germany, a tank would not start even when the crew tried to jump start it. To get it started, the TC injected "Start Pilot" (canned ether) into the air intakes. By using ether the TC was able to start the engine.

CAUTION: If the driver uses the preheat button on the purge pump when attempting to start engine using ether, a backfire could occur, causing personnel injury or damage to the engine.

Example 3: The main gun of a tank misfired. The crew checked the firing pin and the bullet contact. Both appeared to be okay, so they opened up the breech and wiped a little water on the back of the bullet. They closed the breech and when they fired the gun, it fired properly.

Example 4: During gunnery the sights of an M60A3 tank were obscured because of a very hard rain. To enable them to see out of the sights, the crew put an ammo crate over the sights on the outside of the tank.