AD_____

Award Number: MIPR 1GCDYYM1092

TITLE: Task Analysis for MOS 63B; preliminary assessment for protocol development

PRINCIPAL INVESTIGATOR: LTC Mary S. Lopez

CONTRACTING ORGANIZATION: United States Army Center for Health Promotion and Preventive Medicine
Aberdeen Proving Ground, Maryland
21010-5403

REPORT DATE: October 2001

TYPE OF REPORT: Final

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for Public Release;
Distribution Unlimited

The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision unless so designated by other documentation.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 2001	Final (1 May 01 - 30 Sep 01)

4. TITLE AND SUBTITLE
Task Analysis for MOS 63B; preliminary assessment for protocol development

5. FUNDING NUMBERS
MIPR 1GCDYYM1092

6. AUTHOR(S)
LTC Mary S. Lopez

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
United States Army Center for Health Promotion and Preventive Medicine
Aberdeen Proving Ground, Maryland 21010-5403

E-Mail: mary.lopez@amedd.army.mil

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 Words)***

The overall purpose of this project was to identify and describe the 10 most physically demanding critical tasks and task elements performed by soldiers in 63B MOS, Light Wheeled Vehicle Mechanic, so they could be simulated in the United States Army Research Institute of Environmental Medicine (USARIEM) study, 'Job Performance and Injury Rates of MOS 63B, Light Wheel Vehicle Mechanic as a Function of Physical Fitness'. In order to accomplish this, the project focused on four main goals:

1. To identify all applicable performance standards, criteria and requirements for the 63B critical tasks.

2. To identify the tasks entailing the highest injury risk based on instructor subject matter expert (SME) opinion and ratings and published critical task documents.

3. To perform detailed task analyses of the high-risk tasks and task elements identified by the subject matter experts.

4. To develop accurate simulations of high-risk task elements based on the task analyses and expert ergonomists' evaluations.

14. SUBJECT TERMS
Ergonomic task analysis, Light wheeled vehicle mechanic, Focus groups, Expert survey, Injury prevention, High risk task simulation

15. NUMBER OF PAGES
74

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

TABLE OF CONTENTS

INTRODUCTION

Injury rates among military occupational specialties (MOS) is an increasing concern for the Department of Defense as the national defense strategy calls for restructuring the military into a smaller, more versatile force. In order to successfully implement this strategy the military needs to keep as many troops as possible in a deployable status. This means that injuries and duty restrictions must be controlled. One method of control is to prevent injury occurrence by minimizing exposure to those workplace factors that cause them such as highly repetitious motions, overly forceful muscle contractions and awkward postures.

The 63B military occupational specialty (MOS), Light Wheeled Vehicle Mechanic, has one of the highest injury rates for the Army. This MOS is classified as 'very heavy' in AR 611-201, Military Occupational Classification and Structure. The specific physical requirements for this MOS include:

1. Occasionally lifts 230 pounds as part of a 2 soldiers team (prorated at 115 pounds).
2. Occasionally lifts 150 pounds 6 feet, carries 50 feet and climbs 5 feet as part of a 2-soldier team (prorated at 75 pound per soldier).
3. Frequently lifts 75 pounds and carries 50 feet.

There is a clear need to systematically examine the soldiers' tasks and daily activities to identify controllable or preventable sources of injury. However, MOS task descriptions are general, do not encompass the breadth of duties actually performed, and do not accurately characterize the physical demands of the tasks they describe.

The overall purpose of this project was to identify and describe the 10 most physically demanding critical tasks and task elements performed by soldiers in 63B MOS, Light Wheeled Vehicle Mechanic, so they could be simulated in the United States Army Research Institute of Environmental Medicine (USARIEM) study, 'Job Performance and Injury Rates of MOS 63B, Light Wheel Vehicle Mechanic as a Function of Physical Fitness'. In order to accomplish this, the project focused on four main goals:

1. To identify all applicable performance standards, criteria and requirements for the 63B critical tasks.

2. To identify the tasks entailing the highest injury risk based on instructor subject matter expert (SME) opinion and ratings and published critical task documents.

3. To perform detailed task analyses of the high-risk tasks and task elements identified by the subject matter experts.

4. To develop accurate simulations of high-risk task elements based on the task analyses and expert ergonomists' evaluations.

This investigation involved subject matter expert focus groups and surveys at Fort Jackson, South Carolina and task analyses at Fort Meade, Maryland.

DEFINITION OF TERMS

The following definitions are provided to clarify terminology and improve understanding of this report (Fleishman & Reilly, 1995; Knapik, et al., 1997).

1. **Injury Risk.** The risk of musculoskeletal injury resulting from repeated exposure to the risk factors of awkward static postures, forceful exertions, repeated motions, vibration and contact stress. Musculoskeletal injuries resulting from repeated exposure typically affect the back, knee, ankle, shoulder and elbow, muscles, tendons, or nerves (such as with nerve compression syndromes). Musculoskeletal injuries resulting from trauma, such as a slip, trip or fall, are not included in this definition.

2. **Physically Demanding.** The subjective sensation of physical exertion, which can be related to muscular strength, endurance and power; aerobic capacity; posture; and force requirements.

3. **Frequency.** The number of occurrences of a periodic event or task within a given time period.

4. **Duration.** The length of time required to complete a specific task or activity.

5. **Task.** A set pattern of operations, which alone, or together with other tasks, may be used to achieve a goal.

6. **Subtask.** A part of a task that when performed with one or more additional subtasks will result in successful task completion.

7. **Dynamic Strength.** The ability of muscles to exert force repeatedly or continuously over a long time period. This ability is involved in supporting, holding up, or moving the body's own weight, or objects, repeatedly over time. It represents muscular endurance and emphasizes the resistance of muscles to fatigue. It does not involve cardiovascular fitness.

8. **Element**. The smallest step into which it is practical to subdivide any work activity without analyzing separate motions, movements, and mental processes involved.

9. **Static Strength**. The ability to use continuous muscle force in order to lift, push, pull, or carry objects. It is the maximum force that one can exert for a brief period of time using the hand, arm, back, shoulder or leg.

10. **Explosive Strength.** The ability to use short bursts of muscle force to propel oneself or an object. It requires gathering energy for bursts of muscle effort over a very short period. It involves short bursts of power, rather than continuous use of muscle force.

11. **Flexibility**. The ability to bend, stretch, twist, or reach out with the body, arms or legs, both quickly and repeatedly. It involves both speed and repeated bending or stretching as well as the degree to which muscles 'bounce back' during these activities.

12. **Coordination.** The ability to coordinate the movements of two or more limbs (e.g., two arms, two legs, or one leg and one arm) while the individual is sitting, standing, or lying down.

13. **Balance.** The ability to keep or regain one's balance or to stay upright when in an unstable position. This ability includes maintaining one's balance when changing direction, either while moving or standing motionless. It does not include balancing objects.

14. **Criticality of task feature.** Critical factor in determining the success of the operation.

LITERATURE REVIEW

Workplace injuries cause functional deficits that hamper performance. And, high injury rates impede an organization's ability to accomplish its mission. The Department of Defense, like any other large industrial employer, must contend with the injuries that occur within all of its diverse work environments by mustering resources to treat, rehabilitate, and compensate affected workers. To understand the entire fiscal impact of this problem the costs associated with lost time and personnel replacement must be added. Hospitalizations not only cost a great deal of money but also have the greatest impact on troop readiness (Smith, et al. 2000). Disabilities are an expensive consequence of injury since payments typically are made over the lifespan of the worker. It is estimated that 30% - 50% of all disability cases are due to injuries (Songer, et al. 2000). Musculoskeletal disorders comprise a large portion of DoD occupational injuries during periods of peace and armed conflict. During the Persian Gulf War, for example, 769 patients (34% of the total) were diagnosed with musculoskeletal injuries. Replacement cost of these personnel was estimated at $836,885 (Truax, et al. 1997).

Tasks and Injury

A significant portion of work-related musculoskeletal injuries can be attributed to exposures to mechanical stressors in the workplace. These overuse injuries occur when workers assume awkward postures, perform forceful muscle contractions, or engage in repetitious motions that exceed the tissues' capacities to recover. Keyserling, 2000, stated that musculoskeletal overuse disorders are the leading causes of compensable lost-time cases in the United States. This statement is consistent with the 1994 Bureau of Labor Statistics' (BLS) report that approximately 705,800 cases of overexertion or repetitive motion injuries occurred in one year. Responding to these prevalence reports, the National Institute for Occupational Safety and Health (NIOSH) performed a comprehensive review of over 600 studies of occupational musculoskeletal disorders and concluded that the evidence suggested a causal relationship between work-related musculoskeletal disorders (WMDs) and exposure to mechanical stressors. Jones, et al. 1994 and Koplan, et al. 1982 also found that overexertion or repetitive motion injuries could be directly linked to the amount of exposure to heavy physical demands. In a US Military population, Feuerstein, et al., 1997, & Garland, et al., 1993 found that many musculoskeletal injuries among active duty soldiers were directly related to the soldier's tasks and physical training activities.

Task Analysis Overview and Techniques

Task analysis is a well-established industrial engineering technique that concerns breaking down the motions used to perform a task into smaller components. It may involve measuring how long it takes to complete individual elements, documenting product flow, or recording how tools and equipment are used. Ultimately, task analysis strives to improve how human operators interact with the systems they use to accomplish work. Task analysis can also be used to: identify hazards workers are exposed to, provide proper allocation of resources to both humans and machines, and define the characteristics and capability requirements of personnel to enable them to carry out the task effectively (Kiwan & Ainsworth, 1992).

There are numerous task analysis techniques that can be selected to meet the demands of a situation (Kiwan & Ainsworth, 1992). Activity sampling provides information on how long it takes to perform individual elements. Task analysis may use techniques to visually depict key aspects of work processes such as timelines, fault trees, charts or diagrams. When it is

impractical to observe workers interacting in their actual workstations, computer models or simulators can created to represent the important features for analysis.

Role of Task Analysis in Reducing Injury Risk

Ergonomists use task analysis to compare task demands with the physical capabilities of a worker to help identify motions that may overtax the musculoskeletal tissue and produce injury (Drury, 1983). Task analysis helps reduce injury risk by providing a structured method for observing how work is performed. Once a task is broken down into its components it is easier to identify the potentially risky subtasks or task elements. In a sense, ergonomists use task analysis as their microscope to help find problems by focusing on one portion of the work at a time.

Several studies have shown that with proper task analysis and ergonomic intervention, the rates of injuries for specific workers have decreased. Green-McKenzie, et al. 1998, showed that a dramatic decrease in injury rates and costs were seen when a large medical facility instituted a safety-engineering program that included job analysis. Aaras, 1995, found that sick leave due to musculoskeletal illness was reduced from 5.3% to 3.1% and the reduction in turnover from 30.1% to 7.6% due to task analysis and ergonomic intervention for female workers exposed to various loads.

METHODS

STUDY DESIGN

This project consisted of three phases:

1. Descriptive. This phase involved collection and review of the critical task documents for the 63B MOS. Complete task documentation, including task descriptions, maintenance guidance, training packages and lesson plans, performance standards and criteria, and any required abilities for the critical tasks were collected and assessed.

2. Expert Rating. This phase involved focus group discussions conducted with 63B instructors and NCOs from the 63B10 Light Wheel Vehicle Mechanic Course, Fort Jackson, SC. These ratings and discussions identified and described the top 10 physically demanding tasks for the 63B MOS. This phase resulted in a consensus list of the top 10 highest injury risk critical tasks and problematic task elements, subtasks and tools.

3. Task Analysis and Simulation. The first part of this phase involved detailed task analyses of the identified high-risk tasks. The task analyses and expert evaluations resulted in the identification of specific high risk, frequently occurring subtasks which served as the basis for the simulation. The second part of this phase involved the design of task simulations of the top four high-risk subtasks based on the detailed task analysis and other input.

PHASE 1. DESCRIPTIVE PHASE

1. Phase Objectives.

    a. To identify all relevant critical task documents for the 63B MOS.

    b. To review all relevant documents to identify:

        1. General 63B MOS description and physical requirements
        2. Critical tasks for the 63B MOS
        3. Specific task processes, tools and equipment
        4. Task performance standards and criteria
        5. Required soldier ability requirements to accomplish the task

2. Data Collection. Relevant documents were identified through investigation of Army Regulations, 63B training documents, TRADOC publications, MOS reports and discussions with 63B instructors and senior NCOs.

3. Analysis. Information gathered from the document reviews was used to structure the focus group discussions and guide the task analyses and simulation.

PHASE 2. EXPERT RATING PHASE

1. Phase Objectives.

    a. To identify the top 10 most physically demanding tasks for the 63B MOS.

b. To describe the specific type of physical demands, task characteristics, tools, and subtasks which make each of the top 10 tasks physically demanding.

c. To identify the single frequently occurring subtasks which are the most physically demanding, have the highest injury risk and require the most muscular strength, endurance and coordination.

d. To assess the amount of agreement between the subject matter experts (Fort Jackson instructors) on the top 10 most physically demanding tasks and subtasks.

2. Subjects

63B10 Light Wheel Vehicle Mechanic Course, Fort Jackson, SC.
Nine selected enlisted instructors and senior NCOs were nominated by the 63B Course Director to participate in the expert rating focus group discussions as 63B subject matter experts. The instructors and senior NCOs had at least five years of experience as 63Bs. The subject matter experts included male enlisted soldiers from various racial backgrounds.

3. Data Collection

Data was collected using a structured survey interview approach (Meister, 1985) and included a modified nominal group technique (Gustafson et al., 1973) and a modified critical incident technique (Fitts and Jones,1947; Flanagan, 1954; Karwowski and Marras, 1999; Kiwan & Ainsworth, 1992).

The interview was approximately two hours in length and was held in a special room to ensure that the participants were at ease and relaxed in a non-threatening situation and to ensure privacy, lack of distractions and interruptions. The special room was located near the participants' work unit to minimize the impact on unit activities. The interview session was conducted at Fort Jackson, SC.

A trained facilitator who was experienced with teams and able to anticipate, identify and counteract biases or compensate for bias effects conducted the interview. Specifically, the facilitator monitored the group interaction and discussion for the following potential problems (Kiwan & Ainsworth, 1993):

a. Disagreements, communication failures or personality conflicts.

b. Group dynamic bias or dominating member.

c. Individual bias, memory failures, conservatism or conceptualization of scenarios.

The facilitator ensured that individuals did not dominate the group and that the discussion kept to the points of interest. The facilitator recorded key points on a flip chart and gave a verbal summary of the facilitator's understanding of particular points in order to ensure that these were accurate summaries of the experts' comments and perceptions. The facilitator did not try to change opinions or insist on reaching a consensus for each point. If there was no consensus, this was recorded. The facilitator also guided the discussion and ensured that other points could be made and that particularly interesting lines of discussion were followed up.

The interview was videotaped to record the discussion and relevant points and to capture any demonstration (e.g., of the task or use of equipment) or any diagrams or drawings. Data was collected in 2 steps.

Step 1. The course director at the 63B10 Light Wheel Vehicle Mechanic course in Fort Jackson, South Carolina determined a list of the 27 most physically demanding tasks (Appendix A). This list was extracted from the Total Army Training System Courseware Critical Task List 63B10/20 (Department of the Army, 1999). This list was narrowed down to a list of the 10 most physically demanding tasks according to the following.

Step 1 Agenda.

a. Introduction and overview.
    1. Specific purpose of the interview.
    2. Data collection objectives.
    3. Definitions of 'physically demanding', 'injury risk', 'task' and 'subtask', and 'frequently occurring'.
    4. Ground rules.
    5. Agenda.

b. Brief discussion of the description of the general responsibilities and physical demands for the 63B MOS from AR 611-201 (Department of the Army, 1995). The instructors were asked to identify and discuss the most relevant work schedule and location based variations for 63B MOS.

c. Critical task identification. The 63B instructors were asked to rank the top 27 most physically demanding critical tasks performed by the 63Bs in terms of physical demands and frequency using a critical task written survey (Appendix B).

d. Initial survey scoring and presentation of results. The surveys were scored by analyzing the initial rankings for each task according to the following scoring scheme:

    1. The scores were weighted to reflect the ranking with the highest ranking tasks (most physically demanding tasks) receiving the lowest scores, i.e., a rank of '1' (most difficult task) would be scored as 1, a rank of '2' would be scored as 2, with the scoring pattern continued to the rank of '27' which would be scored as a 27.

    2. Each task was then assigned a letter code to indicate frequency. 'A' represented a frequency of daily. 'B' represented 3-4 times a week. 'C' represented 1-2 times a week. 'D' represented 2-3 times a week. 'E' represented 1time a month. 'F' represented 1-2 times a quarter. 'G' represented less than 1 time a quarter.

e. Each of the SME's task ratings for physical demand and frequency was compared and discussed to determine the 10 most physically demanding tasks. All of the tasks, which received a ranking score, were included in the initial presentation of the ranking results. The final list of the 10 most physically demanding tasks was determined by and voted on by the expert raters.

Step 2. SME evaluation of tasks. Each of the 10 most physically demanding tasks was graded for frequency, duration, physical effort required (Borg scale) and specific task features. This step involved the use of the Focus Group Questionnaire (Appendix C). The rating questions on the written survey on specific task features -- muscular strength, explosive strength, muscular endurance, flexibility, coordination, balance, safety concerns, mission criticality and overall difficulty -- the criticality of the task features and tools for the top 10 tasks. The survey questions were based on Fleishman's Job Analysis Survey (Fleishman, et. al., 1995). The Borg Rating of Perceived Exertion Scale (1970) was included as a measure of overall physical exertion for each of the top 10 tasks.

Step 2 Agenda.

a. Focus group questionnaire. The 63B SMEs filled out a survey developed by the CHPPM Ergonomics Program. This survey asked the SMEs to rate each of the top 10 tasks in terms of:

    a. frequency
    b. duration
    c. physical effort – using the Borg scale
    d. specific task features – muscular strength, explosive strength, muscular endurance, flexibility, coordination, balance, safety concerns, mission criticality and overall difficulty)

    The SMEs were also asked:

    a. to identify tools used in the task
    b. to identify the most difficult part of the task
    c. for additional comments

b. Each 63B SME rated all 10 tasks and the findings were discussed to identify any inconsistencies and/or discrepancies between the head instructor ratings and the rest of the SME group.

c. Reassement of final scoring. The experts were asked to reassess their judgments and provide the final ranking of the top 10 tasks.

d. Survey scoring and presentation of results. The scores were summed and averaged. Only the top 10 ranked tasks were included in the final presentation of results.

e. Brief discussion on the specific task features and tools for each of the top 10 tasks.

f. Closing remarks and summary.

4. Data Analysis. Content analysis techniques were used to analyze the discussion for recurrent themes and consensus on the general task description from AR 611-201 and specific organizational and process information.

PHASE 3. TASK ANALYSIS AND SIMULATION PHASE

1. Phase Objectives.

    a. To describe and record the elements, operations, subtasks, tools and equipment for each of the top 10 physically demanding tasks identified in Phase 2 in sufficient detail to accurately reconstruct the task and physical components of the task simulation. Include temporal, distance and weight dimensions and thresholds in the task descriptions.

    b. To develop simulation of the most physically demanding tasks performed by 63Bs based on the data collected in phase 2 and task analyses to:

        1. Evaluate the ability of a representative sample of soldiers with the 63B MOS to meet simulated physically demanding 63B task requirements.

        2. Evaluate the relationship between soldiers' physical capabilities and performance on simulated physically demanding 63B tasks.

2. Subjects.

A senior mechanic assigned to Fort Meade, MD was interviewed and observed simulating the identified most physically demanding tasks as part of a normal daily assigned routine. The task processes were described and demonstrated. During this observation, tools and components were described and examined.

3. Data collection.

    a. Task Analysis.

    The top 10 tasks were reviewed and discussed in detail by the expert ergonomists and senior mechanics. There were four common elements to these tasks: reaching inside the engine compartment; overhead work under the vehicle; work requiring removal of the tire; and work requiring removal of the battery. These four elements were repeatedly cited as the most physically demanding and difficult.

    One senior mechanic was observed simulating and performing the top four physically demanding tasks and task elements as part of the normal daily assigned tasks. The senior mechanic was not asked to perform special tasks outside of normal task activities. Every effort was made to not interfere in the daily work or the shop activities. Each task was video recorded in its entirety for more in-depth analysis.

    b. Development of Simulations. Task simulations were developed by expert ergonomists based on the information gathered in Phase 1 and 2 and the results of the Phase 3 task analyses.

KEY RESEARCH ACCOMPLISHMENTS

- Critical task documents for the MOS 63B were collected and analyzed.
- The top 10 physically demanding tasks for the MOS 63B were identified and described.
- Specific high-risk frequently occurring subtasks were identified.
- A task simulation of the top four high-risk subtasks based on the detailed tasks analyses was designed.

REPORTABLE OUTCOMES

PHASE 1. DESCRIPTIVE PHASE

The following relevant critical task documents for the MOS 63B were reviewed.

1. AR 611-201 (Department of the Army, 1995)
2. MIL STD 1472F (Department of Defense, 1998)
3. Total Army Training System Courseware (TATSC) Critical Task List 63B10/20 Light Wheeled Vehicle Mechanic (Department of the Army, 1999)
4. SC 5180-90-N26, Section II. Component List/Hand Receipt and Illustrations, General Mechanics Tool Kit
5. TRAINING SUPPORT PACKAGES for the top 10 most physically demanding tasks performed by 63Bs as indicated in this paper
6. TECHNICAL MANUALS for light wheeled vehicles – lists the actual physical steps required to perform each of the tasks identified in this paper

Findings.

1. The general 63B MOS description and physical requirements (AR 611-201).
   Major Duties. The light-wheel mechanic supervises and performs unit maintenance and recovery operation on gasoline and diesel fueled light-wheel vehicles (prime movers designated as 5 ton or less and their associated trailers), and associated items; supervises unit maintenance and recovery operations on track and heavy-wheel vehicles, and on material handling equipment (MHE). Duties for MOS 63B at the MOSC 63B10 skill level are to maintain power assisted brake systems, wheel vehicle suspension systems, wheel vehicle wheel/hub assemblies, wheel vehicle mechanical (manual) steering systems, wheel vehicle hydraulic (power) steering systems, and wheel vehicle crane/hose/winch assemblies.
   Physical demands rating and qualifications for initial award of MOS. Light-wheel vehicle mechanics must possess the following qualifications:

   a. A physical demands rating of very heavy.
   b. A physical profile of 222222.
   c. Normal color vision.
   d. A minimum score of 90 in aptitude area Motor Maintenance (MM).
   e. Current equipment qualification record for all types of equipment maintained.
   f. Formal training (completion of MOS 63B course conducted under the auspices of the USA Ordnance Center and School) mandatory; or meet the civilian acquired skills criteria listed in AR 601-210.

AR 611-201 indicates the physical requirements of the MOS 63B Light-Wheel Vehicle Mechanic as follows:

a. Occasionally lifts 230 pounds as part of a 2-soldier team (prorated 115 pounds).
b. Occasionally lifts 15 pounds 6 feet, carries 50 feet and climbs 5 feet as part of a 2 soldier team (prorated 75 pounds).
c. Frequently lifts 75 pounds and carries 50 feet.

2. The Total Army Training System Courseware (TATSC) Critical Task List 63B10/20 Light Wheeled Vehicle Mechanic identified the 77 critical tasks performed by 63Bs (Appendix D).

3. Specific task processes, tools and equipment were identified in SC 5180-90-N26, Section II. Component List/Hand Receipt and Illustrations, General Mechanics Tool Kit (Appendix E).

4. Gaps between task requirements and 63B abilities were identified using AR 611-201 and MIL-STD-1472F.

Gap analysis.

AR 611-201 assigns the MOS 63B a physical demands rating of 'very heavy' requiring a soldier to occasionally lift 230 pounds as part of a 2-soldier team (prorated at 115 pounds). MIL-STD-1472F identifies the maximum design object weight limit for lifting and carrying. Table 1, 2 and 3 identifies the physical requirements of the MOS 63B, as stated in AR 611-201 and compares them to the MIL-STD-1472F. Table 1 presents and compares the physical demands rating of the MOS 63B for lifting to the maximum design object weight limit for a 2-soldier team to lift. Table 2 and 3 presents and compares the physical demands rating of the MOS 63B for lifting and carrying to the maximum permissible object weight for a 2-soldier and a 1-soldier lift and carry.

Table 1. Lifting. The values presented for MIL-STD-1472F are calculated for the maximum design object weight limit for a 2-soldier team to lift.

AR 611-201	MIL-STD-1472F	MIL-STD-1472F
	Male and Female Soldiers	Male Soldiers Only
Occasionally lift 230 pounds as part of a 2-soldier team (prorated at 115 pounds).	84 pounds	174 pounds

MIL-STD-1472F allows 84 pounds for a mixed gender 2-soldier lift and 174 pounds for a male only 2-sodier lift as a maximum design object weight limit to lift. AR 611-201 identifies the MOS 63B as 'very heavy' having occasional lifts of 230 pounds as part of a 2-soldier team. This presents a mismatch between the physical demands rating and the maximum design object weight limit to lift. The physical demands rating of the MOS 63B exceeds the MIL-STD-1472F for mixed gender and male only teams.

Table 2. Carrying an object 33 feet or less as part of a 2 soldier team.

AR 611-201	MIL-STD-1472F	MIL-STD-1472F
	Male and Female Soldiers	Male Soldiers Only
Occasionally lift 150 pounds 6 feet, carrying 50 feet and climbing 5 feet as part of a 2-soldier team (prorated 75 pounds).	82 pounds	164 pounds

MIL-STD-1472F allows a maximum design object weight limit of 82 pounds for a mixed gender 2-soldier lift and carry and 174 pounds for a male only 2-soldier lift and carry. AR 611-201 identifies the MOS 63B as 'very heavy' having occasional lifts of 150 pounds 6 feet, carrying 50 feet and climbing 5 feet as part of a 2-soldier team. This presents a mismatch between the physical demands rating and the maximum design object weight limit to lift and carry for a 2-soldier team of mixed genders. The physical demands rating of the MOS 63B exceeds the MIL-STD-1472F for mixed gender teams.

Table 3. Single soldier carrying an object 33 feet or less.

AR 611-201	MIL-STD-1472F	MIL-STD-1472F
	Male and Female Soldiers	Male Soldiers Only
Frequently lift 75 pounds and carrying 50 feet.	42 pounds	82 pounds

MIL-STD-1472F allows a maximum design object weight limit of 82 pounds for a mixed gender 2-soldier lift and carry and 174 pounds for a male only 2-sodier lift and carry. AR 611-201 identifies the MOS 63B as 'very heavy' having occasional lifts of 150 pounds 6 feet, carrying 50 feet and climbing 5 feet as part of a 2-soldier team. This presents a mismatch between the physical demands rating and the maximum design object weight limit to lift and carry for a 2-soldier team of mixed genders. The physical demands rating of the MOS 63B exceeds the MIL-STD-1472F for mixed gender teams.

PHASE 2. EXPERT RATING PHASE

Table 4. The Top 10 Most Physically Demanding Tasks Performed by MOS 63Bs indicated by 63B SMEs in ranking order.

1. Replace radiator of a light wheel vehicle
2. Replace starter
3. Correct malfunction: knuckle/gear hub
4. Replace half shaft
5. Replace front and rear brake pads
6. Replace universal joint
7. Correct malfunction: alternator
8. Replace propeller shaft
9. Correct malfunction: batteries
10. Maintain assigned toolkit

Each expert 63B was asked to rate the 10 tasks on a variety of elements that make up physical demand. The Borg Scale and the Overall scale were used to rate the task for overall physical demand while the task features, Muscular Strength, Explosive Strength, Endurance, Muscular Endurance, Flexibility, Coordination, Balance, Safety Concerns, Mission Criticality, and Overall Difficulty were used to rate individual components that determine the definition of physically demand. Note: The Borg Scale was scored on a 1 –15 scale (15 highest demand) while the other nine categories were scored on a 1 – 7 scale (7 highest demand).

Table 5. Expert Ratings of Tasks.

Expert Ratings of Tasks											
Test	Stat	Radiator	Alternator	Starter	Battery	Shaft	U - Joint	½ - Shaft	Hub	Brakes	Tool Kit
Borg	Mean	10.222	9.556	10.556	8.778	8.778	8.889	9.000	9.889	9.667	6.667
	Std Dev	2.048	2.242	2.297	1.564	2.108	2.028	2.000	1.833	2.062	1.118
Overall	Mean	5.000	5.667	6.222	5.778	5.222	5.333	4.889	5.556	5.444	4.222
	Std Dev	0.866	0.866	0.833	1.093	1.093	1.118	1.054	0.527	0.882	1.642
Explosive	Mean	4.333	5.222	5.556	5.556	4.444	4.667	4.333	4.889	4.778	4.444
	Std Dev	1.118	1.202	1.509	1.333	1.333	1.500	1.118	1.453	1.302	1.944
Endurance	Mean	5.111	5.667	6.333	5.444	4.667	4.778	4.556	5.222	4.778	4.444
	Std Dev	1.167	1.118	0.866	1.130	0.866	1.481	1.236	1.093	1.093	1.811
Strength	Mean	5.111	5.889	6.444	5.889	5.000	4.778	4.778	5.778	5.111	5.111
	Std Dev	1.054	1.054	0.882	1.054	0.866	1.093	0.667	1.093	0.928	1.453
Duration	Mean	2.444	1.333	1.556	1.111	1.556	1.222	1.444	2.333	1.778	1.000
	Std Dev	0.527	0.500	0.527	0.333	0.527	0.441	0.527	0.500	0.667	0.000

The highlighted cells represent the 5 highest scores within the categories. As can be seen by the above table there was agreement between the different elements of the definition of physically demanding as well as agreement with the Overall and Borg Scale. The Alternator, Starter, Battery, Hub and Brakes task were consistently rated as the most physically demanding tasks performed by the 63Bs.

It was theorized that the most physically demanding, frequently performed, tasks are the tasks that account for the greatest difficulty and largest MOS mismatch. To identify which physically demanding tasks are going to be simulated, the frequency in which the tasks are performed must be ascertained. The experts rated each of the 10 tasks as to the frequency they were perform within a year. The categories were weekly, monthly, and quarterly. The table below shows the percentage of occurrence for each of the tasks.

Table 6. Frequency of Tasks as Rated by Experts.

% within TASK

		Frequency			
		weekly	monthly	quarterly	Total
TASK	Replace Rad LWV		11.1%	88.9%	100.0%
	Alternator		88.9%	11.1%	100.0%
	Replace Starter		55.6%	44.4%	100.0%
	Battery	100.0%			100.0%
	Propeller Shaft			100.0%	100.0%
	Replace Universal Joint	11.1%	11.1%	77.8%	100.0%
	Replace Half Shaft	11.1%	33.3%	55.6%	100.0%
	Knuckle & Gear Hub		22.2%	77.8%	100.0%
	Replace Brake Pads F/R		11.1%	88.9%	100.0%
	Maintain Tool Kit	55.6%	33.3%	11.1%	100.0%
Total		17.8%	26.7%	55.6%	100.0%

With the exception of replacing the battery and maintaining the tool kit, most tasks were done on a monthly or quarterly basis. Focus group discussions, review of the Critical Task List Sheets and discussion of the step-by-step process used to complete each of the tasks, it was found that several of the tasks shared similar physically demanding elements. For example, replacing brake pads, and correcting malfunctions of the knuckle & gear hub requires removing the tire. A task that the experts agreed was physically demanding.

Furthermore, upon discussion with the focus group and examination of task elements it was found that many of the tasks could be grouped into two general categories that each had similar, specific, risk factor exposures. The categories were Under Chassis and Engine Compartment. The under chassis category which includes replacing the starter, propeller shaft, universal joint and half shaft requires extensive overhead reach postures while holding heavy parts and minute manipulation of nuts, bolts etc. The engine compartment category required extreme awkward postures of the trunk and arms while holding heavy parts and again, manipulating nuts, bolts, etc.

Therefore, using tasks that are representative of these two categories as well as tasks that require removing the wheels and battery, will best represent frequent postures and embody the physically demanding tasks that the 63B's have to frequently encounter.

The specific type of physical demands, task characteristics and subtasks which make each of the top 10 tasks physically demanding were described in discussion and in the open ended responses given by the expert raters on the Focus Group Questionnaires. The most frequently occurring subtasks, which are the most physically demanding as reported by the SMEs, are summarized in Table 7.

Table 7. Most difficult part of task.

Task	Most Difficult Part of Task	# of Raters
1026- Replace radiator of a LWV	Lifting out radiator / removing radiator/ removing oil cooler	4
	Removing hood	2
	Removing connecting accessories/ transmission cooler bolts / all components before major component	3
1039- Replace Starter	Remove rear nut on back of starter / hardware prior to major component	2
	Lining starter up / Alignment / holding starter in place/remove starter	7
1083- Correct Malfunctions: Knuckle/Gear Hub	Remove all primary components / Removing wheel and hub assembly prior to reaching gear hub	4
	Support gear hub during removal and installation/ Lifting and aligning geared hub	2
	Left Blank	3
1082- Replace Half Shaft	Remove 15mm bolts that hold half shaft in place / Installing/aligning bolts during installation	2
	Remove shaft from hub / dropping/replacing shaft	2
	Removing wheel/hub assembly / Removing tire and other components, then the half shaft	2
	Initial set-up	1
	Left Blank	2
1107- Replace front and rear brake pads	Bending underneath vehicle/propping head in upright position w/ no support	1
	Break testing	1
	Removing tires and other components	5
	Left Blank	2
1076-Replace Universal Joint	Replace U-joints into shaft / Holding prop shaft while unbolting u-joint	2
	Remove propeller shaft (in order to get to u-joint) / initial set-up/ Remove components before major component is removed	6
	Bending/stooping to get beneath vehicle	1
	Left Blank	2
1037- Correct Malfunction: Alternator	Remove alternator/Install alternator/ Align alternator / Leaning over vehicle to unbolt alternator / Lifting alternator	6
	Initial set-up	1
	Left Blank	2
1075-Replace propeller shaft	Remove Shaft / Holding arms up while unbolting propeller shaft / disconnecting shaft/ Holding shaft in place while remounting it	6
	Initial set-up	1
	Left Blank	2

1050- Correct Malfunction: Batteries	Remove/ install J-bolts / holding down clamps	1
	Removing batteries/ Lifting batteries	5
	Initial set-up	1
	Left Blank	2
1230- Maintain Assigned Toolkit	Not difficult at all	1
	Getting tools laid out	1
	Getting toolkit from point A to point B / Carrying/ lifting toolbox	3
	Left Blank	4

The specific type of tools and task characteristics of the top 10 physically demanding tasks were described in structured discussion during the focus group. Through this focus group the instructors identified a toolbox, which is frequently used by 63B's, as having a weight of 60 – 70 pounds and is carried 50 feet frequently (AR 611-201).

The instructors identified the relevant work variations as being: routine garrison, field, pre and post deployment. There was discussion here identifying setting, location and installation as a major determining factor as to where most of the time is spent. A general consensus was agreed upon that 60-70% of the time was spent in the field; approximately 40% of the time was spent in garrison. Pre and post deployment were both 50/50%.

SME Agreement. Kendall's Coefficient of Concordance was used to ascertain the magnitude of agreement among the SMEs on the top 10 most physically demanding tasks. To accomplish this analysis the SME responsible for teaching the lesson that involved one of the top ten most physically demanding tasks was designated as the "task subject matter expert" (task SME) for that task. The task SME's responses were compared against the other eight SMEs.

Table 8. The percent of agreement and the amount of standard deviation for each task.

Task Number	Task	Average Agreement between expert and 63B instructors (%)	Standard Deviation (%)
1026	Replacing radiator	57.1	27.2
1039	Replace starter	76.8	19.6
1083	Correct malfunction: knuckle/gear hub	75.5	16.0
1082	Replace half shaft	66.0	25.2
1107	Replace front and rear brake pads	67.2	19.0
1076	Replace universal joint	62.0	27.2
1037	Correct malfunction: alternator	76.4	14.4
1075	Replace propeller shaft	54.0	29.6
1050	Correct malfunction: Batteries	70.0	17.1
1230	Maintain assigned toolkit	57.0	20.4

The task SME/SME comparison was accomplished by recording how many SMEs scored the same as the task SME, below the task SME, or higher than the task SME. Even though the SMEs and the task SMEs did not often award tasks the same score, they were close. To

account for slight differences, a margin of error of +/- 1 for scales one through seven, and a margin of error of +/– 2 (out of a possible 15) for the Borg scale was tolerated. Figure 1 shows the percentage of agreement for each task between the task SME and the other 8 SMEs.

Figure 1. Task Agreement

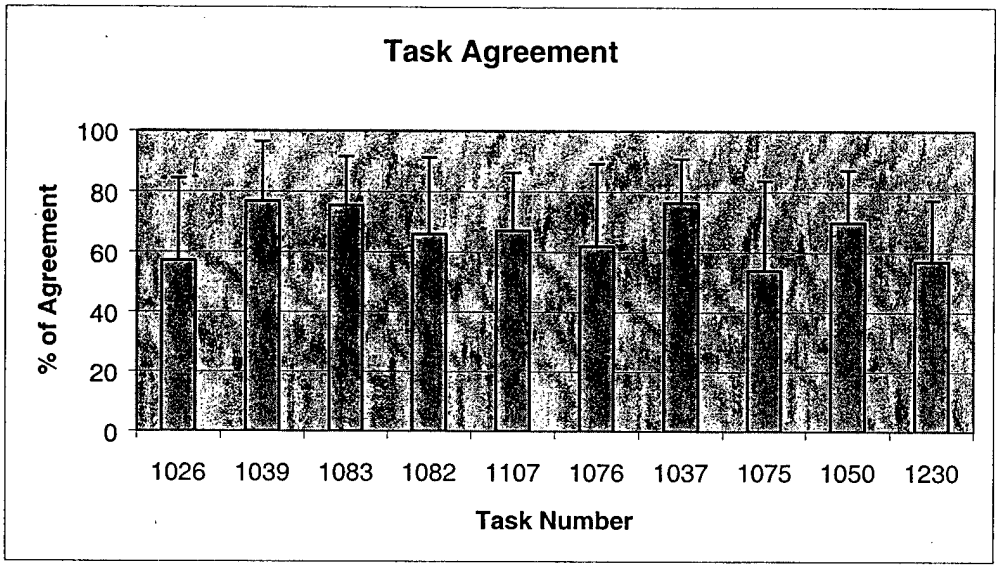


Figure 1 shows the percent of agreement and standard deviations between the task SME and the other SMEs for each task.

Agreement significance was assessed by t-test. The SMEs were in statistically significant agreement for each of the 10 tasks.

Table 9 through 18 present general comparisons of task SMEs to the other SMEs.

Table 9. Task 1026 – Replace Radiator of a Light Wheel Vehicle

Task SME = Rater 6	<	= (+/- 1 (2 for Borg))	>
	%	%	%
Frequency	0.0	100.0	0.0
Duration	0.0	50.0	50.0
Borg	37.5	62.5	0.0
Muscular Strength	37.5	62.5	0.0
Explosive Strength	0.0	85.5	12.5
Muscular Endurance	25.0	75.0	0.0
Flexibility	62.5	37.5	0.0
Coordination	75.0	25.0	0.0

Balance	100.0	0.0	0.0
Safety Concerns	50.0	50.0	0.0
Mission Criticality	25.0	75.0	0.0
Overall Difficulty	37.5	62.5	0.0
Task Average	37.5	57.1	5.2

This table shows how the eight SMEs compared to the task SME. As shown, 57.1 % of the time there was agreement between the raters. 37.5 % of the time the raters scored the task lower than the task SME, and 5.2 % of the time the raters were higher than the task SME.

Table 10. Task 1039 – Replace Starter

Task SME = Rater 1	<	= (+/- 1 (2 for Borg))	>
	%	%	%
Frequency	62.5	37.5	0.0
Duration	12.5	85.5	0.0
Borg	37.5	62.5	0.0
Muscular Strength	0.0	100.0	0.0
Explosive Strength	50.0	50.0	0.0
Muscular Endurance	0.0	100.0	0.0
Flexibility	25.0	75.0	0.0
Coordination	12.5	85.5	0.0
Balance	25.0	75.0	0.0
Safety Concerns	25.0	75.0	0.0
Mission Criticality	0.0	75.0	0.0
Overall Difficulty	0.0	100.0	0.0
Task Average	20.8	76.8	0.0

76.8 % of the time all the raters were in agreement. The other 20.8 % of the time the SME raters scored the task lower than the task SME. The task was never scored higher than what the task SME rated the task.

Table 11. Task 1083 - Correct Malfunction: Knuckle/Gear Hub

Task SME = Rater 3	<	= (+/- 1 (2 for Borg))	>
	%	%	%
Frequency	25.0	75.0	0.0
Duration	37.5	62.5	0.0
Borg	37.5	62.5	0.0
Muscular Strength	12.5	85.5	0.0
Explosive Strength	12.5	62.5	25.0
Muscular Endurance	0.0	50.0	50.0
Flexibility	0.0	62.5	37.5
Coordination	12.5	75.0	12.5
Balance	0.0	100.0	0.0
Safety Concerns	12.5	85.5	0.0
Mission Criticality	0.0	85.5	0.0

Overall Difficulty	0.0	100.0	0.0
Task Average	12.5	75.5	10.4

75.5 % of the time there was agreement among all of the raters. 12.5 % of the scores were rated below the task SME, and 10.4 % were scored higher than the task SME.

Table 12. Task 1082 – Replace Half Shaft

Task SME = Rater 3	<	= (+/- 1 (2 for Borg))	>
	%	%	%
Frequency	12.5	85.5	0.0
Duration	0.0	85.5	12.5
Borg	0.0	75.0	25.0
Muscular Strength	0.0	85.5	12.5
Explosive Strength	0.0	62.5	37.5
Muscular Endurance	0.0	62.5	37.5
Flexibility	0.0	85.5	12.5
Coordination	0.0	100.0	0.0
Balance	0.0	62.5	37.5
Safety Concerns	0.0	25.0	75.0
Mission Criticality	0.0	37.5	62.5
Overall Difficulty	0.0	25.0	75.0
Task Average	1.0	66.0	32.3

66 % of the time there was agreement among all of the raters. Only 1 % of the scores were below that of the task SME, and 32.3 % were above the task SME's score.

Table 13. Task 1107 – Replace Front and Rear Brake Pads

Task SME = Rater 4	<	= (+/- 1 (2 for Borg))	>
	%	%	%
Frequency	12.5	85.5	0.0
Duration	0.0	62.5	37.5
Borg	0.00	50.0	50.0
Muscular Strength	37.5	62.5	0.0
Explosive Strength	50.0	50.0	0.0
Muscular Endurance	50.0	50.0	0.0
Flexibility	62.5	37.5	0.0
Coordination	0.0	62.5	37.5
Balance	0.0	75.0	25.0
Safety Concerns	12.5	85.5	0.0
Mission Criticality	12.5	85.5	0.0
Overall Difficulty	0.0	100.0	0.0
Task Average	19.8	67.2	12.5

67.2 % of the time the raters were in agreement. 19.8 % of the scores were rated below the task SME, while 12.5 % of the scores were above the task SME's ratings.

Table 14. Task 1076 Replace Universal Joint

Expert = Rater 3	<	= (+/- 1 (2 for Borg))	>
	%	%	%
Frequency	25.0	75.0	0.0
Duration	12.5	85.5	0.0
Borg	0.0	62.5	0.0
Muscular Strength	0.0	75.0	25.0
Explosive Strength	0.0	75.0	25.0
Muscular Endurance	0.0	62.5	37.5
Flexibility	0.0	85.5	12.5
Coordination	0.0	85.5	12.5
Balance	12.5	75.0	12.5
Safety Concerns	0.0	0.0	100.0
Mission Criticality	0.0	25.0	75.0
Overall Difficulty	0.0	37.5	62.5
Task Average	4.2	62.0	30.2

62 % of the scores were in agreement among the raters. Only 4.2 percent of the scores were rated below the task SME, and 30.2 % were rated higher than the task SME.

Table 15. Task 1037 – Correct Malfunction: Alternator

Task SME = Rater 1	<	= (+/- 1 (2 for Borg))	>
	%	%	%
Frequency	0.0	100.0	0.0
Duration	12.5	85.5	0.0
Borg	50.0	50.0	0.0
Muscular Strength	12.5	85.5	0.0
Explosive Strength	50.0	50.0	0.0
Muscular Endurance	25.0	75.0	0.0
Flexibility	12.5	75.0	12.5
Coordination	12.5	75.0	12.5
Balance	0.0	75.0	25.0
Safety Concerns	12.5	85.5	0.0
Mission Criticality	25.0	75.0	0.0
Overall Difficulty	12.5	85.5	0.0
Task Average	18.8	76.4	4.2

The raters agreed with the expert's scorings 76.4 % of the time. 18.8 % of the time the raters scored below that of the task SME, and above the task SME only 4.2 % of the time.

Table 16. Task 1075 – Replace Propeller Shaft

Task SME = Rater 3	<	= (+/- 1 (2 for Borg))	>
	%	%	%
Frequency	0.0	100.0	0.0
Duration	0.0	85.5	12.5
Borg	0.0	62.5	37.5
Muscular Strength	0.0	62.5	37.5
Explosive Strength	0.0	62.5	37.5
Muscular Endurance	0.0	75.0	25.0
Flexibility	0.0	62.5	37.5
Coordination	0.0	62.5	37.5
Balance	0.0	25.0	75.0
Safety Concerns	0.0	12.5	85.5
Mission Criticality	0.0	0.0	100.0
Overall Difficulty	0.0	37.5	62.5
Task Average	0.0	54.0	45.7

The raters agreed with the expert 54 % of the time. For the remaining 45.7 % the raters scored the task higher than the task SME.

Table 17. Task 1050 – Correct Malfunction: Batteries

Expert = Rater 1	<	= (+/- 1 (2 for Borg))	>
	%	%	%
Frequency	0.0	37.5	62.5
Duration	0.0	85.5	12.5
Borg	0.0	85.5	12.5
Muscular Strength	0.0	62.5	37.5
Explosive Strength	12.5	50.0	37.5
Muscular Endurance	0.0	75.0	25.0
Flexibility	12.5	50.0	37.5
Coordination	12.5	85.5	0.0
Balance	0.0	62.5	37.5
Safety Concerns	12.5	85.5	0.0
Mission Criticality	12.5	85.5	0.0
Overall Difficulty	12.5	75.0	0.0
Task Average	6.3	70.0	21.9

There was agreement with the task SME 70 % of the time. 6.3 % of the time the raters scored below the task SME, and above the task SME a total of 21.9 % of the time.

Table 18. Task 1230 – Maintain Assigned Toolkit.

Task SME = Rater 5	<	= (+/- 1 (2 for Borg))	>
	%	%	%
Frequency	0.0	50.0	50.0
Duration	0.0	25.0	75.0
Borg	0.0	62.5	37.5
Muscular Strength	12.5	37.5	50.0
Explosive Strength	25.0	37.5	37.5
Muscular Endurance	12.5	50.0	37.5
Flexibility	12.5	85.5	0.0
Coordination	12.5	85.5	0.0
Balance	12.5	75.0	12.5
Safety Concerns	25.0	62.5	12.5
Mission Criticality	0.0	37.5	62.5
Overall Difficulty	12.5	75.0	12.5
Task Average	10.4	57.0	32.3

The raters agreed with the task SME 57 % of the time. Raters scored below the task SME 10.4 % of the time, and above thesTask SME a total of 32.3 % of the time.

PHASE 3. TASK ANALYSIS AND SIMULATION

1. Task analysis.

The task analysis portion of this phase involved detailed analyses of the identified high-risk tasks. Subject matter experts identified four high-risk, frequently demanding tasks that were earmarked for simulation.

Table 19. The four identified tasks to simulate

TASK
Removing and Installing an Alternator
Removing and Installing a Starter Motor
Removing and Replacing a Tire
Removing and Replacing a Battery

a. Removing and installing an alternator. This subtask involves reaching into the engine compartment and holding and positioning the alternator with one hand while positioning the bolts, washers and nuts with the other hand to hold the alternator in place. This subtask requires a forward reach of 16" into the engine compartment. The alternator is located 45" from the ground. The unmodified 60 amp alternator weighs 35 lbs. The subtask requires static strength, upper limb coordination, and manual and finger dexterity.

Table 20. Major muscle groups used to remove and install an alternator as identified by expert ergonomists (NOTE: Trunk stabilizers are utilized during all steps.)

Alternator Removal – Task Steps	**Major Muscle Groups**
1. Loosen capscrew on alternator adjusting bracket and two capscrews on alternator mounting bracket and supporting bracket.	Finger flexors, wrist flexors and extensors, elbow flexors and extensors, shoulder flexors, trunk stabilizers (15 degrees into flexion)
2. Loosen capscrew on alternator adjusting bracket and nut on alternator mounting bracket and support bracket.	Finger flexors, wrist flexors and extensors, elbow flexors and extensors, shoulder flexors, trunk stabilizers (15 degrees into flexion)
3. Remove two drivebelts from alternator pulley	Finger flexors, primary arm elbow extensors, secondary arm elbow flexors shoulder forward flexors
4. Remove two screws, lockwashers, and wire-retaining strap from alternator. Discard lockwashers.	Finger flexors, wrist flexors, elbow flexors, shoulder forward flexors
5. Remove two screws and lockwashers from terminal cover. Discard lockwashers.	Finger flexors, wrist flexors, elbow flexors, shoulder forward flexors
6. Pry cover away from waterproofing adhesive and remove cover.	Finger flexors, wrist flexors, forearm supinators/pronators, elbow flexors, shoulder forward flexors
7. Remove waterproofing adhesive around terminals.	Finger flexors, wrist flexors, elbow flexors, shoulder forward flexors
8. Disconnect lead at engine wiring harness.	Finger flexors, elbow flexors of primary arm, elbow extensors of assisting arm, shoulder forward flexors
9. Remove capscrew and lockwasher securing ground to alternator and disconnect ground from alternator. Discard lockwasher	Finger flexors, wrist flexors, elbow flexors, shoulder forward flexors
10. Remove nut, lockwasher, washer, and lead, from alternator. Discard lockwasher.	Finger flexors, wrist flexors, elbow flexors, shoulder forward flexors
11. Remove nut, lockwasher, washer, and lead, from alternator. Discard lockwasher.	Finger flexors, wrist flexors, elbow flexors, shoulder forward flexors
12. Remove capscrew, lockwasher, and washer from adjusting bracket and alternator. Discard lockwasher.	*Stabilizing hand* – [NOTE: weight of alternator is now held by subjects stabilizing hand] finger flexors, wrist extensors, elbow flexors, shoulder forward flexors *Assisting hand* – shoulder flexors elbow flexors, finger flexion ulnar

	deviation and elbow extension
13. Remove two capscrews, lockwashers, and washers, from alternator, support bracket, and mounting bracket. Discard lockwashers.	*Stabilizing hand* – [NOTE: weight of alternator is now held by subjects stabilizing hand] finger flexors, wrist extensors, elbow flexors, shoulder forward flexors *Assisting hand* – elbow flexors and extensors
14. Remove two capscrews, lockwashers, washers, spacer, power steering lines bracket, and support bracket from mounting bracket. Discard lockwashers.	*Stabilizing hand* – [NOTE: weight of alternator is now held by subjects stabilizing hand] finger flexors, wrist extensors, elbow flexors, shoulder forward flexors *Assisting hand* – elbow flexors and extensors
15. Remove nut, lockwasher, washer, long capscrew, washer, power steering lines bracket, and support bracket from mounting bracket and alternator. Discard lockwasher.	*Stabilizing hand* – [NOTE: weight of alternator is now held by subjects stabilizing hand] finger flexors, wrist extensors, elbow flexors, shoulder forward flexors *Assisting hand* – elbow flexors and extensors
16. Remove alternator.	Shoulder forward flexors elbow flexors wrist and finger flexors
17. Remove alternator pulley.	Shoulder forward flexors elbow flexors and extensors wrist and finger flexors

Alternator Installation – Task Steps	**Major Muscle Groups**
1. Install alternator pulley.	Shoulder forward flexors elbow flexors wrist and finger flexors
2. Position alternator on mounting bracket with support bracket between mounting flange and alternator and install two washers, lockwashers, and capscrews.	*Stabilizing hand* – [NOTE: weight of alternator is now held by subjects stabilizing hand] finger flexors, wrist extensors, elbow flexors, shoulder forward flexors *Assisting hand* – elbow flexors and extensors
3. Position alternator on mounting bracket with support bracket and power steering lines bracket on the outside of alternator mounting flange and install spacer between mounting bracket and alternator mounting flange with two lockwashers, washers, and capscrews.	*Stabilizing hand* – [NOTE: weight of alternator is now held by subjects stabilizing hand] finger flexors, wrist extensors, elbow flexors, shoulder forward flexors *Assisting hand* – elbow flexors and extensors
4. Position alternator on mounting	*Stabilizing hand* – [NOTE: weight of

bracket with support bracket and power steering lines bracket on the outside of alternator mounting flange and install washer, long capscrew, lockwasher, washer, and nut.	alternator is now held by subjects stabilizing hand] finger flexors, wrist extensors, elbow flexors, shoulder forward flexors *Assisting hand* – elbow flexors and extensors
5. Align alternator with adjusting bracket and install washer, lockwasher, and capscrew.	*Stabilizing hand* – [NOTE: weight of alternator is now held by subjects stabilizing hand] finger flexors, wrist extensors, elbow flexors, shoulder forward flexors *Assisting hand* – elbow flexors and extensors
6. Connect lead on alternator with washer, lockwasher, and nut. Tighten nut to 20-25 lb-in.	Shoulder forward flexors, elbow flexors wrist and finger flexors
7. Connect lead on alternator with washer, lockwasher, and nut. Tighten nut to 45-55 lb-in.	Shoulder forward flexors, elbow flexors wrist and finger flexors

b. Removing and installing a starter motor. This subtask involves the soldier working under the vehicle in a supine position on a creeper with his/her arms extended. The soldier is required to hold and positioning the starter with one hand while positioning the bolts, washers and nuts with the other hand to hold the starter in place. This subtask requires a forward/overhead reach of 23" from the ground. The unmodified starter motor weighs 55 lbs. The subtask requires static strength, upper limb coordination, and manual and finger dexterity

Table 21. Major muscle groups used to remove and install a starter motor as identified by expert ergonomists. (NOTE: Trunk stabilizers are utilized during all steps.)

Starter Removal – Task Steps	**Major Muscle Groups**
1. Remove nut, lockwasher, lead and negative cable from starter. Discard lockwasher.	Finger flexors and extensors, elbow flexors, extensors and supinators, shoulder flexors, extensors, internal rotators, and external rotators.
2. Remove adhesive sealant from positive terminal on starter.	Finger flexors, wrist flexors and extensors, elbow extensors, shoulder flexors and extensors.
3. Remove nut, lockwasher, tie down strap, leads and positive cable from starter. Discard lockwasher and tie down strap.	Finger flexors and extensors, elbow flexors, extensors and pronators, shoulder flexors, extensors, internal rotators, and external rotators.
4. Remove nut, lockwasher and lead from starter. Discard lockwasher.	Finger flexors and extensors, elbow flexors, extensors and pronators, shoulder flexors, extensors, internal rotators, and external rotators.
5. Remove screw, clip and lead from starter. Discard lockwasher.	Finger flexors and extensors, elbow flexors, extensors and pronators,

	shoulder flexors, extensors, internal rotators, and external rotators.
6. Remove screw, two clamps, negative cable and positive cable from starter.	Finger flexors and extensors, elbow flexors, extensors and pronators, shoulder flexors, extensors, internal rotators, and external rotators.
7. Loosen locknut and washer on stud connecting starter to bracket. Discard locknut.	Finger flexors and extensors, elbow flexors, extensors and pronators, shoulder flexors, extensors, internal rotators, and external rotators.
8. While supporting starter from under vehicle, remove two capscrews and washers from starter and engine. [NOTE: The subject supports the starter from step 8 to step 5 of starter installation.	Stabilizing Hand – Finger flexors, wrist flexors and extensors, elbow extensors, shoulder flexors Assisting Hand – Finger flexors and extensors, elbow flexors, extensors and pronators, shoulder flexors, extensors, internal rotators, and external rotators.
9. Remove starter and shim from engine.	Finger flexors, wrist flexors and extensors, elbow extensors, shoulder flexors.

Starter – Installation – Task Steps	**Major Muscle Groups**
1. Install a .08 in. shim on starter	Finger flexors, wrist flexors and extensors, elbow flexors and extensors, shoulder flexors and extensors.
2. Position shim and starter to flywheel housing with solenoid facing outward.	Finger flexors, wrist flexors and extensors, elbow flexors and extensors, shoulder flexors and extensors.
3. Slide front stud on starter in bracket.	Finger flexors, wrist flexors and extensors, elbow flexors and extensors, shoulder flexors and extensors.
4. Apply sealing compound to capscrews. Install two washers and capscrews on starter and engine. Tighten capscrews.	Finger flexors, wrist flexors and extensors, elbow flexors, extensors, and supinators, shoulder flexors, extensors, and internal rotators.
5. Secure starter on bracket with locknut. Using crowfoot, tighten locknut.	Finger flexors, wrist flexors and extensors, elbow flexors, extensors, and supinators, shoulder flexors, extensors, and internal rotators.
6. Install two clamps and negative cable and positive cable on starter with screw.	Finger flexors, wrist flexors and extensors, elbow flexors, extensors, and pronators, shoulder flexors, extensors, and internal rotators.
7. Connect leads to solenoid with clip and screw. Tighten screw to 20 lb-in.	Finger flexors, wrist flexors and extensors, elbow flexors, extensors, and supinators, shoulder flexors,

	extensors, and internal rotators.
8. Connect positive cable and leads to starter with lockwasher and nut. Using torque adapter, tighten nut to 25 – 30 lb-ft.	Finger flexors, wrist flexors and extensors, elbow flexors, extensors, and supinators, shoulder flexors, extensors, and internal rotators.
9. Secure leads with tie down strap.	
10. Connect lead to starter with lockwasher and nut. Tighten nut to 25 – 30 lb-ft.	Finger flexors, wrist flexors and extensors, elbow flexors, extensors, and supinators, shoulder flexors, extensors, and internal rotators.
11. Seal positive terminal leads and positive cable with adhesive sealant. Apply sealant at least 1.8 in. thick, covering all exposed metal attached to the positive terminal.	Finger flexors, wrist flexors, elbow flexors and extensors, shoulder flexors and extensors.
12. Connect negative cable and lead to starter with lockwasher and nut. Using torque adapter, tighten nut to 15 – 20 lb-ft.	Finger flexors, wrist flexors and extensors, elbow flexors, extensors, and supinators, shoulder flexors, extensors, and internal rotators.

c. Removing and replacing a tire. This subtask involves the soldier working in a standing or squatting position on the side of the vehicle. The soldier is required to remove eight lug nuts pull the wheel off of the wheel assembly, lifting and positioning the tire back on the wheel assembly and replacing the lug nuts. The subtask requires a forward reach of 15"to pull the tire. The lug nuts require a torque force of 415-475 ft-lbs. The unmodified tire weighs 120 lbs. The subtask requires dynamic and explosive strength and arm, leg and torso coordination.

Table 22. Major muscle groups used to remove and replace a tire as identified by expert ergonomists (NOTE: Trunk stabilizers are utilized during all steps.)

Tire/Wheel Removal – Task Steps	**Major Muscle Groups**
1. Place jack under lower control arm next to wheel being replaced. Center jack squarely under point of contact.	Elbow flexors/extensors, shoulder flexors, trunk extensors (trunk is flexed passed 45degrees)
2. Loosen eight lug nuts, but do not remove.	Finger flexors, elbow flexors/extensors, shoulder forward flexors and extensors, (squatting position), trunk extensors (trunk is flexed passed 45degrees)
3. Raise vehicle high enough to allow removal of wheel assembly.	Finger flexors, elbow flexors/extensors, shoulder forward flexors, trunk extensors for stabilization during trunk flexion (trunk is flexed passed 45degrees)

4. Remove eight lug nuts and wheel assembly from geared hub.	a. (Removing nuts) finger flexors, forearm pronators/supinators, shoulder forward flexors b. (Removing wheel) finger flexors, wrist flexors, elbow flexors, shoulder is positioned in forward flexion using shoulder extensors to pull the wheel off

Tire/Wheel Installation – Task Steps	**Major Muscle Groups**
1. Install wheel assembly on geared hub and secure with eight lug nuts. Tighten lug nuts to full engagement of wheel assembly to geared hub.	a. (Installing wheel onto hub) finger flexors, wrist flexors, elbow flexors, shoulder forward flexors, trunk extensors, knee extensors hip extensors, hip is in flexion and moving toward hip extension, hip extensors b. Finger flexors, forearm pronators/supinators, shoulder forward flexors
2. Slowly lower vehicle and remove jack.	Wrist flexors and supinators, elbow extensors, shoulder extensors
3. Tighten eight lug nuts in sequence indicated.	Finger flexors, elbow flexors/extensors, shoulder forward flexors and extensors, (squatting position), trunk extensors (trunk is flexed passed 45degrees)

d. Removing and replacing a battery. This subtask involves the soldier working in a standing, forward leaning position at the side of the vehicle. The soldier is required to grasp the battery handles and lift, pull and lower the battery from and into the battery compartment. The subtask requires a forward reach of 15". The batteries are located 35" from the ground. The unmodified battery weighs 74 lbs. The subtask requires dynamic and explosive strength and arm, leg and torso coordination.

Table 23. Major muscle groups to remove and replace a battery as identified by expert ergonomists. (NOTE: Trunk stabilizers are utilized during all steps.)

Battery Replacement – Task Steps	**Major Muscle Groups**
1. Unhook latches and remove companion seat from battery box.	Wrist and finger flexors, elbow flexors/extensors, shoulder forward flexors using shoulder extensors to pull seat and battery, trunk forward flexion (potentially past 45 degrees – depending on height of subject) using trunk extensors
2. Check electrolyte level.	Wrist and finger flexors, elbow

	flexors/extensors, shoulder forward flexors
3. Inspect all battery compartment components.	Wrist and finger flexors, elbow flexors/extensors, shoulder forward flexors
4. Ensure that battery terminal clamps have a light coat of lubricating oil for corrosion protection.	Wrist and finger flexors, elbow flexors/extensors, shoulder forward flexors
5. Install companion seat and secure to battery box with latches.	Wrist and finger flexors, elbow flexors/extensors, shoulder forward flexors using shoulder extensors to pull seat and battery, trunk forward flexion (potentially past 45 degrees – depending on height of subject) using trunk extensors

2. Task Simulation Design.

Review

After reviewing all of the findings of this study and the results of the task analysis, the USACHPPM expert ergonomists designed the task simulation protocol for the USARIEM study. The protocol uses a psychophysical method of limits approach (Karwowski and Marras, 1999, Salvendy, 1997, Snook and Ciriello, 1991) and a timed performance of actual subtasks. This psychophysical methodology permits soldiers to adjust the weight of the primary task component to the maximum weight at which he/she can successfully handle to complete the task. The timed subtask performance involves repeated trials with the actual primary task component to identify a 'typical' performance time for the individual soldier. Each of the simulation methodologies is described in detail below for each of the simulation subtasks.

The simulation hosts four stations--one for each of four tasks selected by the CHPPM expert ergonomists. Each station includes mock-ups of the portions of the High Mobility Multi-Purpose Wheeled Vehicle (HMMWV) appropriate to perform the targeted task. To increase the fidelity and simulation realism, mock-ups duplicate the dimensions and layout of the actual HMMWV that they are designed to represent and, whenever possible, incorporate actual HMMWV components. The design of the subtask simulations include the most critical task features, which determine the successful completion of the task.

Simulation requires up to 2 hours of the soldier's time and are scheduled to minimize the impact on the unit's activities. Soldiers perform all four of the subtasks in a manner that duplicates the postural requirements, force / torque requirements, environmental conditions and tools used in the subtask. Soldier's performances are videotaped to serve as a record from which common task-related problems and concerns can be identified.

Four light wheeled vehicle maintenance subtasks are simulated: removing and installing the alternator, removing and installing the starter motor, removing and replacing the tire, and removing and replacing the batteries.

a. Removing and installing an alternator.

1. Psychophysical methodology.

a) Apparatus. The internal components of an AMA-5102UT (60 amp) alternator are removed and a smaller cylindrical tube is inserted, leaving a gap of approximately 2 inches between the internal wall of the alternator and the tube. Lead weight is placed in the gap and the gap is covered to minimize visual clues. The mock-up contains the actual components / brackets that hold the alternator in place as well as any other connections or other proximal objects and obstacles.

b) Procedure. The subjects are aware of the hidden compartment in the simulation alternator, but do not know how much weight is placed in the compartment. The amount of weight in the hidden compartment is randomized. The soldiers are asked to adjust the weight of the simulation alternator by adding or subtracting lead shot with a small scoop to the maximum acceptable weight possible while still being able to successfully complete the subtask simulation. In order to encourage adjustments, the starting simulation alternator weight is either very light or very heavy. The subtask of removing and installing the alternator (Appendix F) is performed twice, once with an initial starting heavy weight and once with an initial light weight. If the soldier-adjusted simulated alternator weights of these two trials are within 15% of each other, the average weight between the two trials is recorded. If the simulated alternator weights are not within 15% of each other, the results are discarded and another two trials performed. This process is repeated until the two trial weights are within 15% of each other. This maximum acceptable weight is compared to the actual weights of the various alternators for the HMMWV (Appendix F) and any differences in the maximum acceptable weight and the actual weight are recorded. The time required to complete each performance of the subtask is also recorded. The soldier is given a 5-minute rest period before continuing with the subtask simulation using the actual alternator.

2. Actual subtask simulation.

a) Apparatus. An actual, unmodified AMA-5102UT (60 amp) alternator is used in these trials and the same mock-up simulation station is used.

b) Procedures. The soldier is instructed to remove and install the actual alternator (Appendix F), working at a typical pace and completing the task to the performance standard specifications. The time to complete the subtask is recorded and the subtask is repeated multiple times until the performance times reach a plateau with two performance times within 5% of each other. This time is recorded as the 'optimal' time for the individual. The soldier is given a 5 minute rest period before continuing with the next subtask simulation.

b. Removing and installing a starter motor.

1. Psychophysical methodology.

a) Apparatus. The internal components of the starter motor are removed and a smaller cylindrical tube is inserted, leaving a gap of approximately 2 inches between the internal wall of the starter and the tube. Lead weight is placed in the gap and the gap is covered to minimize visual clues. The mock-up contains the actual components / brackets that hold the starter in place as well as any other connections or other proximal objects and obstacles (e.g., propeller shaft and exhaust system).

b) Procedure. The subjects are aware of the hidden compartment in the simulation starter motor, but do not know how much weight is placed in the compartment. The amount of weight in the hidden compartment is randomized. The soldier is asked to adjust the weight of the simulation starter by adding or subtracting lead shot with a small scoop to the maximum acceptable weight possible while still being able to successfully complete the subtask simulation. In order to encourage adjustments, the starting simulation starter motor weight is either very light or very heavy. The subtask of removing and installing the starter motor (Appendix G) is performed twice, once with an initial starting heavy weight and once with an initial light weight. If the soldier-adjusted simulated starter weights of these two trials are within 15% of each other, the average weight between the two trials is recorded. If the simulated starter weights are not within 15% of each other, the results are discarded and another two trials performed. This process is repeated until the two trial weights are within 15% of each other. This maximum acceptable weight is compared to the actual weight of the starter motor for the HMMWV (Appendix G) and any differences in the maximum acceptable weight and the actual weight are recorded. The time required to complete each performance of the subtask is also recorded. The soldier is given a 5 minute rest period before continuing with the subtask simulation using the actual starter motor.

2. Actual subtask simulation.

a) Apparatus. An actual, unmodified starter motor is used in these trials and the same mock-up simulation station is used.

b) Procedures. The soldier is instructed to remove and install the actual starter motor (Appendix G), working at a typical pace and completing the task to the performance standard specifications. The time to complete the subtask is recorded and the subtask is repeated multiple times until the performance times reach a plateau with two performance times within 5% of each other. This time is recorded as the 'optimal' time for the individual. The soldier is given a 5 minute rest period before continuing with the next subtask simulation.

c. Removing and replacing a tire.

1. Psychophysical methodology.

a) Apparatus. A light-weight radial tire with a hub is modified to allow a weight to be attached to the inner surface of the tire. The weight is not visible with the hub in place. A hole is cut into the wall of the tire to allow the addition and subtraction of weight by the soldier. The hole has a removable cover to prevent any loss of lead shot during the task performance. The mock-up contains the actual geared hub and other components that hold the tire in place.

b) Procedure. The subjects are aware of the hidden weight in the simulation tire, but do not know how much weight is placed in the tire. The amount of weight in the tire is randomized. The soldier is asked to adjust the weight of the simulation tire by adding or subtracting lead shot with a small scoop to the maximum acceptable weight possible while still being able to successfully complete the subtask simulation. In order to encourage adjustments, the starting simulation tire weight is either very light or very heavy. The subtask of removing and replacing the tire (Appendix H) is performed twice, once with an initial starting heavy weight and once with an initial light-weight. If the soldier-adjusted simulated tire weights of these two trials are within 15% of each other, the average weight between the two trials is recorded. If the simulated tire weights are not within 15% of each other, the results are discarded and another two trials performed. This process is repeated until the two trial weights are within 15% of each other. This maximum acceptable weight is compared to the actual weights of the radial and bias tires for the HMMWV (Appendix H) and any differences in the maximum acceptable weight and the actual weight are recorded. The time required to complete each performance of the subtask is also recorded. The soldier is given a 5 minute rest period before continuing with the subtask simulation using the actual bias tire.

2. Actual subtask simulation.

a) Apparatus. An actual, unmodified bias tire is used in these trials and the same mock-up simulation station is used.

b) Procedures. The soldier is instructed to remove and replace the bias tire (Appendix H), working at a typical pace and completing the task to the performance standard specifications. The time to complete the subtask is recorded and the subtask is repeated multiple times until the performance times reach a plateau with two performance times within 5% of each other. This time is recorded as the 'optimal' time for the individual. The soldier is given a 5 minute rest period before continuing with the next subtask simulation.

d. Removing and replacing battery.

1. Psychophysical methodology.

a) Apparatus. A battery shell with the internal materials removed is modified to contain a false bottom compartment. Lead weight is placed in the compartment, and the compartment is covered to minimize visual clues. The mock-up contains a simulation of the battery compartment and any other proximal objects and obstacles to the battery.

b) Procedure. The subjects are aware of the hidden weight in the simulation battery, but do not know how much weight is placed in the battery. The amount of weight in the battery is randomized. The soldier is asked to adjust the weight of the simulation battery by adding or subtracting lead shot with a small scoop to the maximum acceptable weight possible while still being able to successfully complete the subtask simulation. In order to encourage adjustments, the starting simulation battery weight is either very light or very heavy. The subtask of removing and replacing the battery (Appendix I) is performed twice, once with an initial starting heavy weight and once with an initial light weight. If the soldier-adjusted simulated battery weights of these two trials are within 15% of each other, the average weight between the two trials is recorded. If the simulated battery weights are not within 15% of each other, the results are discarded and another two trials performed. This process is repeated until the two trial weights are within 15% of each other. This maximum acceptable weight is compared to the actual weight of the battery for the HMMWV (Appendix I) and any differences in the maximum acceptable weight and the actual weight are recorded. The time required to complete each performance of the subtask is also recorded. The soldier is given a 5-minute rest period before continuing with the subtask simulation using the actual battery.

2. Actual subtask simulation.

a) Apparatus. An actual, unmodified battery is used in these trials and the same mock-up simulation station is used.

b) Procedures. The soldier is instructed to remove and replace the battery (Appendix I), working at a typical pace and completing the task to the performance standard specifications. The time to complete the subtask is recorded and the subtask is repeated multiple times until the performance times reach a plateau with two performance times within 5% of each other. This time is recorded as the 'optimal' time for the individual.

3. Analysis.

a. Psychophysical methodology. Descriptive statistics are generated for the differences between the psychophysical maximum acceptable weight (MAW) and the actual subtask object weight. Significant differences between the MAW and the actual weight for each of the four tasks are evaluated by Analysis of Variance (ANOVA).

b. Correlates of physical performance. The 'optimal' subtask performance time for the individual is correlated with each of the various physical measures as surrogate indicators of physical conditioning.

CONCLUSIONS

The overall purpose of this project was to identify and describe the 10 most physically demanding critical tasks and task elements performed by soldiers in MOS 63B, Light Wheeled Vehicle Mechanic, for simulation in the United States Army Research Institute of Environmental Medicine (USARIEM) study, 'Job Performance and Injury Rates of MOS 63B, Light Wheel Vehicle Mechanic as a Function of Physical Fitness'. This was accomplished by:

1. Identifying all applicable performance standards, criteria and requirements for the 63B critical tasks.

2. Identifying the highest injury risk tasks based on instructor subject matter expert (SME) opinion and ratings and published critical task documents.

3. Performing a detailed task analysis of the high-risk tasks and task elements identified by the subject matter experts.

REFERENCES

1. American Society of Mechanical Engineers (1972). ASME Standard – Operation and Process Flow Charts. ANSI Y15.3-1974. New York, NY: ASME.

2. Burdorf A, Govaert G, and Elders L (1991). Postural load and back pain of workers in the manufacturing of prefabricated concrete elements, Ergonomics, 34(7): 909-918.

3. Christensen JM (1950). The Sampling Technique for use in Activity Analysis. Personnel Psychol, 3, 361-368.

4. Department of the Army (1995). Military Occupational Classification and Structure, AR 611-201.

5. Department of the Army, US Army Combined Arms Support Command, Fort Lee, VA. (1999). Total Army Training System Courseware (TATSC) Critical Task List – 63B10/20 Light Wheeled Vehicle Mechanic".

6. Department of the Army, U.S. Army Publishing Agency (2001). EM 0030 – High Mobility Multi-Purpose Wheeled Vehicle. St. Louis, MO: U.S. Army Publishing Agency.

7. Department of Defense (1998). MIL-STD-1472F, Human Engineering Design Criteria for Military Systems, Equipment and Facilities.

8. Drury CG (1983). Task Analysis Methods in Industry. Applied Ergonomics, 14, 19-28.

9. Fitts PM and Jones RE (1947). Analysis of Factors Contributing to 460 'Pilot Error' Experiences in Operating Aircraft Controls. Reprinted in Selected Papers on Human Factors in the Design and Use of Control Systems, Sinaiko, H.W. (ed.), 1961, pp. 332-258. New York: Dover Books.

10. Flanagan JC (1954). The Critical Incident Technique. Psychological Bulletin, 51, 327-358.

11. Fleishman EA (1984). 'Systems for Linking Job Tasks to Personnel Requirements', Public Personnel Management Journal. 13(40): 395-408.

12. Fleishman EA (1995b). Fleishman Job Analysis Survey. Potomac, MD: Management Research Institute.

13. Fleishman EA, Gebhardt DL, and Hogan JC (1986). 'The Perception of Physical Effort in Job Tasks', in G. Borg (ed), Perception of Exertion in Physical Exercise. 225-242. London: Macmillan Press Ltd.

14. Fleishman EA and Reilly ME (1995). Handbook of Human Abilities. Potomac, MD: Management Research Institute.

15. Gufstafson D, Shulka R, Delbecq A and Walister G (1975) "A Comparative Study of the Differences in Subjective Likelihood Estimates Made by Individuals, Interacting Groups, Delphi Groups, and Nominal Groups", Organizational Behavior and Human Performance, 9: 280-291.

16. Jonson BG, Persson J, and Kilbom A (1988). Disorders of the cervicobrachial region among female workers in the electronics industry: a two year follow-up, Int J Ind ergo, 3(1): 1-12.

17. Karwowski W and Marras WS (1999). The Occupational Ergonomics Handbook. New York: CRC Press.

18. Keyserling WM (2000). Workplace Risk Factors and Occupational Musculoskeletal Disorders, Part 1: A Review of Biomechanical and Psychophysical Research on Risk Factors Associated with Lower-Back Pain, AIHAJ, 61:39-50.

19. Kilbom A and Persson J (1987). Work technique and its consequences for musculoskeletal disorders, Ergonomics 30(2): 273-79.

20. Kiwan B and Ainsworth LK (1993). A Guide to Task Analysis. London, England: Tayor & Francis Ltd.

21. Knapik JJ, de Pontbriand RJ, Harper WH, Tauson RA, Swoboda JC, and Doss NW (1997). Feasibility of MOS Task Analysis and Redesign to Reduce Physical Demands in the U.S. Army. Army Research Laboratory – ARL-TR-1594.

22. Lopez MS, (2001) Tele-ergonomics report

23. Meister D (1985). Behavioral Analysis and Measurement Models. New York: Wiley and Sons.

24. Milerad E, and Ekenvall L (1990). Symptoms of the neck and upper extremities in dentists, Scand J Work Environ Health, 16(1): 129-134.

25. Myers DC, Gebhardt DL, Crump CE, and Fleishman EA (1993). 'The Dimensions of Human Physical Performance: Factor Analyses of Strength, Stamina, Flexibility, and Body Composition Measures' Human Performance, 6(4): 309-344.

26. Ohlsson K, Attewell R, Paisson B, Karlsson B, Balogh I, Johnsson B, et al (1995). Repetitive industrial work and neck and upper limb disorders in females, Am J Ind Med, 37(5): 731-41.

27. Punnett L, Fine LJ, Keyserling WM, Herrin GD, and Chaffin DB (1991). "Back Disorders and non neutral trunk postures of automobile assembly workers," Scand J Work Environ Health, 17(5): 337-346.

28. Sakakibara H, Miyao M, Kondo T, and Yamada S (1995). Overhead work and shoulder neck pain in orchard farmers harvesting pears and apples, Ergonomics, 38(4): 700-706.

29. Salvendy G (ed) (1997). Handbook of Human Factors and Ergonomics. New York: John Wiley & Sons, Inc.

30. Smith GS, Dannenberg AL, and Amoroso PJ (2000). Hospitalization Due to Injuries in the Military. Evaluation of Current Data and Recommendations on their Use of Injury Prevention, Am J Prev Med, 18(3Suppl): 41-53.

31. Snook SH and Ciriello VM (1991). The Design of Manual Handling Tasks: Revised Tables of Maximum Acceptable Weights and Forces, Ergonomics, 34(9), 1197-1213.

32. Songer TJ and La Porte RE (2000). Disabilities Due to Injury in the Military. Am J Prev Med, 18(3 Suppl): 33-40.

33. Stramler JH (1993), The Dictionary for Human Factors / Ergonomics, Boca Raton, FL: CRC Press, Inc.

34. Truax AL, Chandnani VP, Chacko AK, and Gonzalez DM. Incidence and Methods of Diagnosis of Musculoskeletal Injuries Incurred in Operations Desert Shield and Desert Storm. Invest Radiol, 32(3): 169-73.

APPENDIX A

27 Most Physically Demanding Critical Tasks

Task Number	TASK SUMMARY
	COOLING SYSTEM
091-63B-1026	Replace Radiator on a Light Wheeled Vehicle
	ELECTRICAL SYSTEM
091-63B-1037	Correct Malfunction of Alternator on a Light Wheeled Vehicle
091-63B-1039	Replace Starter on a Light Wheeled Vehicle
091-63B-1050	Correct Malfunction of Batteries on a Light Wheeled Vehicle
	PROPELLER SHAFTS
091-63B-1075	Replace Propeller Shafts on a Light Wheeled Vehicle
091-63B-1076	Replace Universal Joints on a Light Wheeled Vehicle
	AXLES
091-63B-1082	Replace Half-shaft on a Light Wheeled Vehicle
091-63B-1083	Correct Malfunction of Knuckle and Geared Hub on a Light Wheeled Vehicle
091-63B-1084	Adjust Geared Hub Spindle Bearing on a Light Wheeled Vehicle
	BRAKES
091-63B-1097	Troubleshoot Brake System Malfunctions
091-63B-1098	Replace Brake Lines and Fittings on a Light Wheeled Vehicle
091-63B-1100	Replace Handbrake Shoes on a Light Wheeled Vehicle
091-63B-1105	Replace Service Brake Shoes on a Light Wheeled Vehicle
091-63B-1106	Replace Front and Rear Brake Calipers on a Light Wheeled Vehicle
091-63B-1107	Replace Front and Rear Brake Pads on a Light Wheeled Vehicle
091-63B-1108	Replace Front and Rear Brake Rotor on a Light Wheeled Vehicle
091-63B-1109	Replace Master Cylinder on a Light Wheeled Vehicle
091-63B-1114	Replace Hydro-Boost on a Light Wheeled Vehicle
	STEERING
091-63B-1139	Troubleshoot Steering System Malfunction
091-63B-1141	Correct Malfunction of Tie Rod Assembly on a Light Wheeled Vehicle
091-63B-1143	Correct Malfunction of Power Assist Cylinder on a Light Wheeled Vehicle
091-63B-1154	Replace Power Steering Lines and Fittings on a Light Wheeled Vehicle
	SPRINGS AND SHOCKS
	Central Tire Inflation System (CTIS)
091-63B-1218	Troubleshoot Central Tire Inflation System
091-63B-1219	Replace Air Lines and Fitting on a Light Wheeled Vehicle
091-63B-1220	Correct Malfunction of air Dryer with Filter on a Light Wheeled Vehicle
091-63B-1226	Correct Malfunction of CTIS Front and Rear Air Seals on a Light Wheeled Vehicle
	GENERAL MAINTENANCE TASKS
091-63B-1230	Maintain Assigned Tool Kit

APPENDIX B

Critical Task Ranking Survey

Physical Demand	Frequency
A	Daily
B	3-4x / wk
C	1-2x / wk
D	2-3x / mo
E	1x / mo
F	1-2x /qtr
G	< qtr

Physical Demand	Task Number	TASK SUMMARY	ROUTINE GARRISON
		COOLING SYSTEM	
	091-63B-1026	Replace Radiator on a Light Wheeled Vehicle	
		ELECTRICAL SYSTEM	
	091-63B-1037	Correct Malfunction of Alternator on a Light Wheeled Vehicle	
	091-63B-1039	Replace Starter on a Light Wheeled Vehicle	
	091-63B-1050	Correct Malfunction of Batteries on a Light Wheeled Vehicle	
		PROPELLER SHAFTS	
	091-63B-1075	Replace Propeller Shafts on a Light Wheeled Vehicle	
	091-63B-1076	Replace Universal Joints on a Light Wheeled Vehicle	
		AXLES	
	091-63B-1082	Replace Half-shaft on a Light Wheeled Vehicle	
	091-63B-1083	Correct Malfunction of Knuckle and Geared Hub on a Light Wheeled Vehicle	
	091-63B-1084	Adjust Geared Hub Spindle Bearing on a Light Wheeled Vehicle	
		BRAKES	
	091-63B-1097	Troubleshoot Brake System Malfunctions	
	091-63B-1098	Replace Brake Lines and Fittings on a Light Wheeled Vehicle	
	091-63B-1100	Replace Handbrake Shoes on a Light Wheeled Vehicle	
	091-63B-1105	Replace Service Brake Shoes on a Light Wheeled Vehicle	
	091-63B-1106	Replace Front and Rear Brake Calipers on a Light Wheeled Vehicle	
	091-63B-1107	Replace Front and Rear Brake Pads on a Light Wheeled Vehicle	
	091-63B-1108	Replace Front and Rear Brake Rotor on a Light Wheeled Vehicle	
	091-63B-1109	Replace Master Cylinder on a Light Wheeled Vehicle	
	091-63B-1114	Replace Hydro-Boost on a Light Wheeled Vehicle	
		STEERING	
	091-63B-1139	Troubleshoot Steering System Malfunction	

Physical Demand	Task Number	TASK SUMMARY	ROUTINE GARRISON
	091-63B-1141	Correct Malfunction of Tie Rod Assembly on a Light Wheeled Vehicle	
	091-63B-1143	Correct Malfunction of Power Assist Cylinder on a Light Wheeled Vehicle	
	091-63B-1154	Replace Power Steering Lines and Fittings on a Light Wheeled Vehicle	
		SPRINGS AND SHOCKS	
		Central Tire Inflation System (CTIS)	
	091-63B-1218	Troubleshoot Central Tire Inflation System	
	091-63B-1219	Replace Air Lines and Fitting on a Light Wheeled Vehicle	
	091-63B-1220	Correct Malfunction of air Dryer with Filter on a Light Wheeled Vehicle	
	091-63B-1226	Correct Malfunction of CTIS Front and Rear Air Seals on a Light Wheeled Vehicle	
		GENERAL MAINTENANCE TASKS	
	091-63B-1230	Maintain Assigned Tool Kit	

APPENDIX C

FOCUS GROUP QUESTIONNAIRE

Task:_____ **Task Code: 091-63B-**___ ___ ___ ___

Is this task typically done (check one): ____in garrison ____in the field ____both

How often is this task performed? **(CHECK ONE)**:

Daily	3-4 times/week	1-2 times/week	2-3 times/month	**MONTHLY**	1-2 times/quarterly	Less than quarterly
o	o	o	o	o	o	o

How long does it normally take to perform this task? **(CHECK ONE)**:

Less than 30 min.	31min - 1 hour	>1 - 2 hours	>2 - 3 hours	>3 - 4 hours	>4 - 5 hours	> 5 hours
o	o	o	o	o	o	o

How would you describe the physical effort required for this task? **(CHECK ONE)**:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
No exertion at all	Extremely light		Very light		Light		Somewhat hard		Hard		Very hard		Extremely hard	Maximal exertion
o	o	o	o	o	o	o	o	o	o	o	o	o	o	o

Rate the task on all of these factors using this 1 - 7 scale.

extremely low	**low**	**somewhat low**	**moderate**	**somewhat high**	**high**	**extremely high**
1	**2**	**3**	**4**	**5**	**6**	**7**

Muscular strength	Explosive strength	Muscular endurance	Flexibility	Coordination	Balance	Safety concerns	Mission criticality	Overall difficulty

List the tools used in this task:

_____

_____

What part of this task is the most difficult?

_____

_____

Comments:_____

_____

_____

APPENDIX D

Total Army Training System Courseware (TATSC) Critical Task List
63B10/20 Light Wheeled Vehicle Mechanic

Task Number	TASK SUMMARY
	Engine
091-63B-1001	Service Engine Assembly on a Light Wheeled Vehicle
	ENGINE LUBRICATION SYSTEM
091-63B-1003	Replace Engine Oil Filter on a Light Wheeled Vehicle
091-63B-1005	Correct Malfunction of Engine Oil Cooler and Lines on a Light Wheeled Vehicle
	FUEL SYSTEM
091-63B-1007	Troubleshoot Fuel System Malfunctions on a Light Wheeled Vehicle
091-63B-1009	Correct Malfunction of Fuel Pump on a Light Wheeled Vehicle
091-63B-1012	Replace Fuel Fittings and Lines on a light Wheeled Vehicle
091-63B-1013	Replace Fuel Tank on a Light Wheeled Vehicle
091-63B-1014	Replace Fuel Filter Assembly on a Light Wheeled Vehicle
091-63B-1015	Troubleshoot Glow plug System on a Light Wheeled Vehicle
091-63B-1016	Correct Malfunction of Glow Plug System on a Light Wheeled Vehicle
	EXHAUST SYSTEM
091-63B-1021	Troubleshoot Exhaust System Malfunctions on a Light Wheeled Vehicle
091-63B-1022	Replace Muffler on a Light Wheeled Vehicle
091-63B-1023	Replace Crossover Pipe on a Light Wheeled Vehicle
	COOLING SYSTEM
091-63B-1025	Troubleshoot Cooling System Malfunctions
091-63B-1026	Replace Radiator on a Light Wheeled Vehicle
091-63B-1029	Replace Radiator Hoses, Lines and Clamps on a Light Wheeled Vehicle
091-63B-1031	Correct Malfunction of Fan and Fan Drive on a Light Wheeled Vehicle
091-63B-1033	Correct Malfunction of Drive Belts on a Light Wheeled Vehicle
	ELECTRICAL SYSTEM
091-63B-1036	Troubleshoot Charging System Malfunctions on a Light Wheeled Vehicle
091-63B-1037	Correct Malfunction of Alternator on a Light Wheeled Vehicle
091-63B-1038	Troubleshoot Starting System Malfunction on a Light Wheeled Vehicle
091-63B-1039	Replace Starter on a Light Wheeled Vehicle
091-63B-1041	Troubleshoot Electrical System Malfunctions on a Light Wheeled Vehicle
091-63B-1044	Replace Protective Control Box on a Light Wheeled Vehicle
091-63B-1047	Correct Malfunction of Sending Units and Warning Switches on a Light Wheeled Vehicle
091-63B-1050	Correct Malfunction of Batteries on a Light Wheeled Vehicle
	INSTRUMENT PANEL
091-63B-1053	Troubleshoot Electrical Gages on a Light Wheeled Vehicle

Task Number	TASK SUMMARY
	WIRING HARNESS
091-63B-1055	Repair Engine Wiring Harness on a Light Wheeled Vehicle
091-63B-1057	Repair Chassis Wiring Harness on a Light Wheeled Vehicle
	TRANSMISSION
091-63B-1058	Troubleshoot Transmission Malfunction
091-63B-1059	Service Transmission Assembly on a Light Wheeled Vehicle
091-63B-1061	Replace Neutral Safety Switch on a Light Wheeled Vehicle
	TRANSFER
091-63B-1066	Troubleshoot Transfer Malfunctions on a Wheeled Vehicle
	PROPELLER SHAFTS
091-63B-1075	Replace Propeller Shafts on a Light Wheeled Vehicle
091-63B-1076	Replace Universal Joints on a Light Wheeled Vehicle
091-63B-1077	Replace Center Bearing on a Light Wheeled Vehicle
	AXLES
091-63B-1078	Troubleshoot Axle Malfunctions on a Wheeled Vehicle
091-63B-1081	Replace Front Axle Spindle on a Light Wheeled Vehicle
091-63B-1082	Replace Half-shaft on a Light Wheeled Vehicle
091-63B-1083	Correct Malfunction of Knuckle and Geared Hub on a Light Wheeled Vehicle
091-63B-1084	Adjust Geared Hub Spindle Bearing on a Light Wheeled Vehicle
091-63B-1088	Replace Upper and Lower Ball Joints on a Light Wheeled Vehicle
091-63B-1091	Replace Dust Boot (CV) on a Light Wheeled Vehicle
	BRAKES
091-63B-1097	Troubleshoot Brake System Malfunctions
091-63B-1098	Replace Brake Lines and Fittings on a Light Wheeled Vehicle
091-63B-1100	Replace Handbrake Shoes on a Light Wheeled Vehicle
091-63B-1105	Replace Service Brake Shoes on a Light Wheeled Vehicle
091-63B-1106	Replace Front and Rear Brake Calipers on a Light Wheeled Vehicle
091-63B-1107	Replace Front and Rear Brake Pads on a Light Wheeled Vehicle
091-63B-1108	Replace Front and Rear Brake Rotor on a Light Wheeled Vehicle
091-63B-1109	Replace Master Cylinder on a Light Wheeled Vehicle
091-63B-1110	Replace Air Hydraulic Cylinder on a Light Wheeled Vehicle
091-63B-1112	Replace Treadle Valve on a Light Wheeled Vehicle
091-63B-1114	Replace Hydro-Boost on a Light Wheeled Vehicle
091-63B-1117	Replace Air Compressor and Belts on a Light Wheeled Vehicle
091-63B-1124	Inspect Air Brake Control Valves on a Light Wheeled Vehicle
	WHEELS AND HUBS
091-63B-1129	Correct Malfunction of Wheel and Tire Assembly on a Light Wheeled Vehicle

Task Number	TASK SUMMARY
	STEERING
091-63B-1139	Troubleshoot Steering System Malfunction
091-63B-1141	Correct Malfunction of Tie Rod Assembly on a Light Wheeled Vehicle
091-63B-1142	Correct Malfunction of Drag Link Assembly on a Light Wheeled Vehicle
091-63B-1143	Correct Malfunction of Power Assist Cylinder on a Light Wheeled Vehicle
091-63B-1154	Replace Power Steering Lines and Fittings on a Light Wheeled Vehicle
	SPRINGS AND SHOCKS
091-63B-1161	Replace Shock Absorber on a Light Wheeled Vehicle
	BODY, HOOD, AND CAB
091-63B1172	Replace Seat Belts on a Light Wheeled Vehicle
	Hoist, Winch, and Power Take Off
091-63B-1191	Troubleshoot Winch Malfunction on a Light Wheeled Vehicle
	SPECIAL PURPOSE KITS
091-63B-1213	Correct Malfunction of 100 Amp Alternator Kit on a Light Wheeled Vehicle
	Central Tire Inflation System (CTIS)
091-63B-1218	Troubleshoot Central Tire Inflation System
091-63B-1219	Replace Air Lines and Fitting on a Light Wheeled Vehicle
091-63B-1220	Correct Malfunction of air Dryer with Filter on a Light Wheeled Vehicle
091-63B-1224	Replace CTIS Pressure Switch on a Light Wheeled Vehicle
091-63B-1226	Correct Malfunction of CTIS Front and Rear Air Seals on a Light Wheeled Vehicle
	GENERAL MAINTENANCE TASKS
091-63B-1228	Maintain Test, Measurement, and Diagnostic Equipment
091-63B-1229	Maintain Assigned Vehicle
091-63B-1230	Maintain Assigned Tool Kit
091-63B-1231	Prepare Equipment Inspection and Maintenance Worksheet (DA Form 2404 or ULLS Equivalent)
091-63b-1234	Perform Scheduled Preventive Maintenance Checks and Services on a Light Wheeled Vehicle

APPENDIX E

MOS TASK ANALYSIS STUDY 63B TOOL KIT	
ITEM DESCRIPTION	**STOCK NUMBER**
Ball-joint tie rod separator	
Bar, Pry 15-1/2 IN. LG	5120-00-224-1389
Battery clamp pliers	
Battery terminal cleaner	
Belt Tension Gauge	
Bracket, Mounting rail socket, 7-3/8 In. Lg one used w/ 7 of NSN 5340-00-124-5273. The other 1 used with 10 of NSN 5340-00-124-5273 and w/ NSN 5120-00-243-7325.	5340-00-124-5270
Bracket, Mounting socket rail, 16-3/4 in. lg	5340-00-124-5272
Brake spring pliers	
Brake test machine	
Breaker bar; 14-1/2"	
Brush, Cleaning, Tool and Parts rd shape; lacquered hardwood handle; 9.5 in. O/A LG	7920-00-062-5468
Chisel, Cold, Hand: ¾" W Cut: 6 ½" O/A LG	5110-00-236-3272
Clip, spring tension ½ in. DR socket holders	5340-00-124-5275
Clip, spring tension 7 of these are used with NSN 5340-00-124-5270. The other 10 are used with NSN 5340-00-124-5270 and NSN 5120-00-243-7325	5340-00-124-5273
C-Clamp	
Drip Pan	
Extension, socket wrench ¼ DR, 6" LG	5120-00-243-7325
Extension, socket wrench 10" LG	5120-00-227-8074
Extension, socket wrench 2" LG	5120-00-243-1697
Extension, socket wrench 5" LG	5120-00-243-7326
File, Hand, Flat, type 7, 10" LG, smooth double cut face, smooth single cut edges, American pattern	5110-00-249-2850
File, Hand, RD, type 16, 8" LG heel to pt, 5/16" dia, American pattern, double cut bastard faces	5110-00-234-6551
File, Hand three SQ Type, 6" LG, No. 4 face cut, No. 4 single cut, edge cut, Swiss pattern	5110-00-884-0140
Flashlight, straight; tubular plastic case: 8" lg, 2 ½" dia; olive drab; fixed focus; colorless plastic lens; accommodates 2 D size batteries and a single contact miniature flanged bulb; watertight, use current item until unserviceable, then order.	6230-00-269-3034
Flashlight, straight shape, 2-1/4" MAX O/A dia, 9-3/4"	6230-00-269-3034
Gage, thickness English, 26 tapered blades, ¼" w. tip, 3" lg, 0.0015 to 0.025" thk, w/ blade lock	5210-00-221-1999
Hammer hand machinist's, ball peen 1 lb. Head weight	5120-01-070-4542

ITEM DESCRIPTION	STOCK NUMBER
Handle, file; adjustable; 1" dia; 4-1/8" nom lg	5110-00-595-8325
Handle, socket wrench brace w/ single revolving grip; 1/2 " sq drive; 18"lg O/A optional item	5120-00-249-1071
Handle, socket wrench ratchet, reversible; 9 in. lg	5120-01-323-0969
Handle, socket wrench, hinged speeder bar, 14 to 20" O/A lg	5120-00-236-7590
Key set, socket head screw 1/16 – 3/8", 10 pcs	5120-00-595-9244
Key, socket head screw 1/16" w	5120-00-198-5398
Key, socket head screw ½" w, optional item	5120-00-198-5391
Key, socket head screw ¼" w	5120-00-224-4569
Key, socket head screw 1/8" w	5120-00-240-5292
Key, socket head screw 3/16" w	5120-0-240-5300
Key, socket head screw 3/32" w	5120-00-242-7410
Key, socket head screw ¾" w, optional item	5120-00-222-1489
Key, socket head screw 3/8" w	5120-00-198-5390
Key, socket head screw 5/16" w	5120-00-240-5274
Key, socket head screw 5/32" w	5120-00-198-5392
Key, socket head screw 5/64" w	5120-00-224-2504
Key, socket head screw 5/8" w, optional item	5120-00-224-2510
Key, socket head screw 7/16" w, optional item	5120-00-240-5277
Key, socket head screw 7/32" w	5120-00-242-7411
Key, socket head screw 9/16" w, optional item	5120-00-240-5268
Key set, hd scw 2-10 mm, 9 pcs	5120-01-1331
Key, socket head screw 10 mm, this item is not initially issued as a component of the sko. The item may be requisitioned "as required" when authorized by the commanding officer	5120-01-045-4895
Key, socket head screw 2.0 mm, this item is not initially issued as a component of the sko.	5120-01-045-4886
Key, socket head screw 2.5 mm, this item is not initially issued as a component of the sko	5120-01-045-4887
Key, socket head screw 3.0 mm, this item is not initially issued as a component of the sko	5120-01-045-4888
Key, socket head screw 4.0 mm, this item is not initially issued as a component of the sko.	5120-01-045-4889
Key, socket head screw 5.0 mm	5120-00-900-9344
Key, socket head screw 6.0 mm	5120-00-900-9345
Key, socket head screw 7.0 mm, this item is not initially issued as a component of the sko.	5120-01-045-4892
Key, socket head screw 8.0 mm, this item is not initially issued as a component of the sko.	5120-01-045-4893
Key, socket head screw 0.050" w, optional item	5120-00-198-5401
Key, socket head screw 12.0 mm, optional item and not initially issued as a component of the sko.	5120-01-045-4896
Key, socket head screw 14.0 mm, optional item and not initially issued as a component of the sko.	5120-01-045-4897

ITEM DESCRIPTION	STOCK NUMBER
Key, socket head screw 17.0 mm, optional item and not initially issued as a component of the sko.	5120-01-045-4898
Key, socket head screw 19.0 mm, optional item and not initially issued as a component of the sko.	5120-01-045-4899
Key, socket head screw 9.0 mm, this item not initially issued as a component of the sko.	5120-01-045-4894
Knife, pocket utility	5110-00-240-5943
Knife, putty; flexible: 1-1/4" w blade	5120-00-221-1536
Padlock, 1-1/2" w, 1-1/4" h, 9/32" dia shackle, ¾ in clearance, removable case core, 9 in. lg chain, w/ clevis, w/ 2 keys, the quantity authorized may be increased if authorized by the commanding officer	5340-00-682-1508
Pliers, diagonal cutting; 7-1/2" lg	5110-00-222-2708
Pliers, slip joint; straight nose; w/ cutter; 8" nom lg	5120-00-223-7397
Pliers; 7" lg; lg rd nose	5120-00-293-0032
Punch, aligning 3/16" point, 3/8" shank, 8" lg	5120-00-293-0448
Punch, center, solid 5/32" point dia, 3/8" stock dia, 4" min lg	5120-00-293-3509
Punch, drive pin ¼" dia	5120-00-240-6083
Punch, drive pin 1/8" dia	5120-00-242-5966
Punch, drive pin 3/8" dia	5120-00-273-0001
Punch, drive pin brass, ¾" pt dia, 10" lg	5120-00-239-0038
Punch, drive pin tapered, 1/8" pt dia, 2-1.8" taper lg	5120-00-242-3433
Ratchet	
Retrieving tool, magnetic; telescoping type; 15-1/4" to 18" max closed lg; 26" to 27-1/2' max lg O/A	5120-00-545-4268
Roll, tools and accessories 13 pocket capacity, 4000 denzer strength, nylon pack cloth material, 24" ch O/A lg, 15-1/8" O/A w	5140-01-354-3516
Rule, Steel, Machinists; 6-1/4" lg; 1/32 and mm grad w/ pocket clip	5120-00-362-5100
Screwdriver, cross tip; size 1, 3" lg blade; plastic handle	5120-00-240-8716
Screwdriver, cross tip; size 2, 4" lg blade; plastic handle	5120-00-234-8913
Screwdriver, cross tip; size 3, 6" lg blade, plastic handle	5120-00-234-8912
Screwdriver, flat tip; ¼" tip w; 4" lg blade; plastic handle	5120-00-222-8852
Screwdriver, flat tip; 3/8" w tip; 8" lg blade; plastic handle	5120-00-237-6985
Screwdriver, flat tip; 5/16" w tip; 1-3/4" lg blade; plastic handle	5120-00-278-1273
Shears, metal cutting, hand; 7" lg;	5110-00-221-1085
Socket extensions	
Socket, socket wrench 1", wrenching size	5120-00-189-7927
Socket, socket wrench 1-1/16" wrenching size, optional item 62B	5120-00-189-7913
Socket, socket wrench 1-1/4" wrenching size, optional item 62B	5120-00-189-7917
Socket, socket wrench 1-1/9" wrenching size, optional item 62B	5120-00-189-7914
Socket, socket wrench ½" wrenching size	5120-00-237-0984
Socket, socket wrench 10mm, ¼" sq drive, 22mm lg, this item not issued initially as a component of the sko	5120-01-014-1833
Socket, socket wrench 10.0mm, this item not initially issued as a component of the sko	5120-00-287-4150

ITEM DESCRIPTION	STOCK NUMBER
Socket, socket wrench 11mm, in sq drive, 22 mm lg, this item not initially issued	5120-01-026-4688
Socket, socket wrench 11.0 mm, this item not initially issued as a component of the sko	5120-00-263-4138
Socket, socket wrench 11/16" wrenching size	5120-00-235-5870
Socket, socket wrench 12.0mm, optional item, not initially issued as component of the sko	5120-00-287-4151
Socket, socket wrench 13.0mm, this item not initially issued as component of the sko	5120-00-263-4137
Socket, socket wrench 13/16" wrench opening, 0.6pt, optional item	5120-00-945-4704
Socket, socket wrench 13/16" wrenching size	5120-00-189-7933
Socket, socket wrench 13mm in. sq drive, 22 mm lg, this item not initially issued	5120-01-028-8539
Socket, socket wrench 14.0mm, optional item, not initially issued as component of the sko	5120-00-263-4136
Socket, socket wrench 15.0 mm, optional item, not initially issued as component of the sko	5120-00-263-4149
Socket, socket wrench 15/16" wrenching size	5120-00-1897935
Socket, socket wrench 16.0mm, this item not initially issued as component of the sko	5120-00-263-4148
Socket, socket wrench 17.0mm, this item not initially issued as component of the sko	5120-00-263-4143
Socket, socket wrench 18.0 mm, this item not initially issued as component of the sko	5120-00-263-4142
Socket, socket wrench 19.0mm, this item not initially issued as component of the sko	5120-00-240-1428
Socket, socket wrench 21.0mm, this item not initially issued as component of the sko	5120-00-263-4140
Socket, socket wrench 22.0mm, this item not initially issued as component of the sko	5120-00-263-4139
Socket, socket wrench 24.0mm, this item not initially issued as component of the sko	5120-00-287-4153
Socket, socket wrench ¾" wrenching size	5120-00-189-7985
Socket, socket wrench 3/8" wrenching size	5120-00-237-0982
Socket, socket wrench 5mm, ¼" sq drive, 22 mm lg, this item not initially issued	5120-01-045-4884
Socket, socket wrench 5.5 mm, ¼" sq drive, 22.4 mm lg, item not initially issued	5120-01-11-0564
Socket, socket wrench 5/8" wrenching size	5120-00-189-7946
Socket, socket wrench 7mm, ¼" sq drive, 22 mm lg, this item not initially issued	5120-01-046-4938
Socket, socket wrench 7/16" wrenching size	5120-00-189-7924
Socket, socket wrench 7/8" wrench opening, 6 pt, optional item	5120-00-199-6996
Socket, socket wrench 7/8" wrenching size	5120-00-189-7934

ITEM DESCRIPTION	STOCK NUMBER
Socket, socket wrench 8mm, ¼" sq drive, 22mm lg, this item not initially issued	5120-01-031-0702
Socket, socket wrench 9/16" wrenching size	5120-00-189-7932
Test, light voltage rating 36.0 volts, AC max 36.0 DC max	6625-01-260-2387
Tire rod	
Tool box, portable 9-1/2" h, 8-1/2" w, O/A lg. 22"	5140-00-315-2758
Universal joint, socket wrench ½" dr, 2-3/4" lg	51020-00-269-7971
Vise	
Wrench set, comb box and open end 15 deg offset box opening, contains of each of the following 12 items:	5120-00-148-7917
Wrench, box and open end 1" opening, 12-1/2" O/A lg	5120-00-228-9514
Wrench, box and open end ½" opening, 5-1/4" O/A lg	5120-00-228-9506
Wrench, box and open end 11/16" opening, 7" O/A lg	5120-00-228-9509
Wrench, box and open end 13/16" opening, 10-1/4" O/A Lg	5120-00-228-9511
Wrench, box and open end 15/16" opening, 12" O/A lg	5120-00-228-9513
Wrench, box and open end ¾" opening, 8" O/A lg	5120-00-228-9510
Wrench, box and open end 3/8" opening, 4-3/16" O/A lg	5120-00-228-9504
Wrench, box and open end 5/16" opening, 3-1/4" O/A lg	5120-00-228-9503
Wrench, box and open end 5/8" opening, 6-1/8" O/A lg	5120-00-228-9508
Wrench, box and open end 7/16" opening, 5" O/A lg	5120-00-228-9505
Wrench, box and open end 7/8" opening, 10-1/4" O/A lg	5120-00-228-9512
Wrench, box and open end 9/16" opening, 5-3/4" O/A lg	5120-00-228-9507
Wrench set, socket ¼" sq drive w/ case, consists of one each of the following:	5120-00-228-9507
Extension, socket wrench 2" lg	5120-00-227-8105
Handle, socket wrench 3-1/4" driver	5120-00-242-3256
Handle, socket wrench 4" ratchet	5120-00-221-7957
Socket, socket wrench ½" 12 pt opening	5120-00-189-8610
Socket, socket wrench ½" 12 pt opening	5120-00-189-8610
Socket, socket wrench ¼" hex opening	5120-00-236-2264
Socket, socket wrench 11/32" 12 pt opening	5120-00-242-3351
Socket, socket wrench 3/16" hex opening	5120-00-236-2262
Socket, socket wrench 3/8" 12 pt opening	5120-00-242-3352
Socket, socket wrench 5/16" 12 pt opening	5120-00-235-5878
Socket, socket wrench 7/16" 12 pt opening	5120-00-235-5869
Socket, socket wrench 7/32" hex opening	5120-00-236-2263
Socket, socket wrench 9/32" hex opening	5120-00-242-3345
Universal joint, skt wrench 1-5/16" lg	5120-00-243-1686
Wrench, adjustable 0 to 1.322" jaw opening, 12" lg, ¾" thk hd, chrome plated steel	5120-00-264-3796
Wrench, adjustable steel, 6" lg, 13/32" hd thk, wrenching surface size 0.760" max single end	5120-00-264-3795
Wrench, box half-moon dbl hd, 12 pt, 9/16 and 5/8" openings, 6-1/2" lg O/A, chrome plated steel	5120-00-222-1596

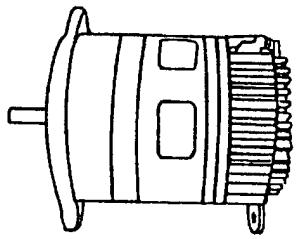
ITEM DESCRIPTION	STOCK NUMBER
Wrench, box and open end 10.0mm, this item not initially issued	5120-01-113-7134
Wrench, box and open end 11.0mm, this item not initially issued	5120-01-054-7129
Wrench, box and open end 12.0mm, optional item	5120-01-045-4906
Wrench, box and open end 13.0mm, this item not initially issued	5120-01-054-7131
Wrench, box and open end 14.0mm, optional item, not initially issued	5120-01-054-7133
Wrench, box and open end 15.0mm, optional item, not initially issued	5120-01-054-7133
Wrench, box and open end 16.0mm, this item not initially issued	5120-01-054-7134
Wrench, box and open end 18.0mm, this item not initially issued	5120-01-054-7136
Wrench, box and open end 19.0mm, this item is not initially issued	5120-01-054-7137
Wrench, box and open end 21.0mm, this item is not initially issued	5120-01-054-7138
Wrench, box and open end, combination 24.0mm, this item not initially issued	5120-01-054-7141
Wrench, comb B&OE 17.0mm	5120-01-269-9355
Wrench, open end dbl hd, 4-1/8" lg, 3/8 and 7/16" openings, 15 dg hd angle both ends	5120-00-277-2342
Wrench, open end dbl hd, 15 deg hd angle both ends, ½ and 9/16" openings, 5-3/8" lg	5120-00-187-7124
Wrench, open end dbl hd, 15 deg hd angle both ends, 5/8 and 11/16" opening, 7" lg	5120-00-277-8301
Wrench, open end box flare nut, dbl end, 7-1/2" lg, size ½ and 9/16" wrenching ends, steel w/ chromium treatment	5120-00-892-4947
Wrench, open end box flare nut, double end, 7-1/2" lg, size 3/8 nd 7/16" wrenching ends, steel w/ chromium treatment	5120-00-892-4946
Wrench, open end box flare nut, dbl end, 8-1/2" lg, size 5/8 and ¾" wrenching ends, steel w/ chromium treatment	520-01-122-9392
Wrench, plier curved jaw w/ wire cutter, 8-1/2" lg, (vise grip)	5120-00-494-1911
Wrench, spanner 11/32" hook thk, ¾" to 2" circle dia range, 6-3/8" lg, adjustable hook, steel	5120-00-288-6468
Vise	
Wrench, Allen	
Wrench, Torque	

Note: Tools listed in *italics* are not included in the 63B's toolkit, but are those that were listed as necessary for completing one or more of the top ten most physically demanding tasks of the 63B's

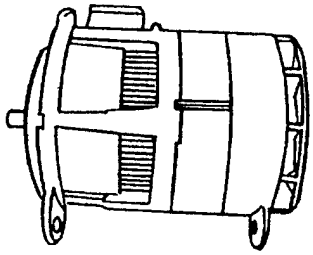
APPENDIX F

Removing and Installing an Alternator.

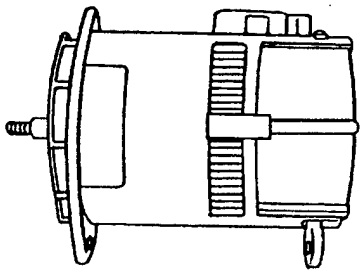
TM 9-2920-225-34



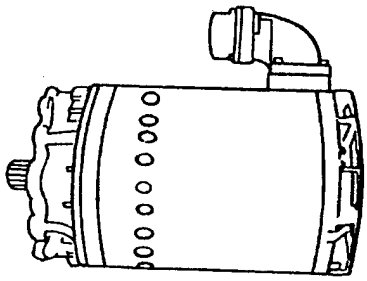
MODEL AMA-5102UT



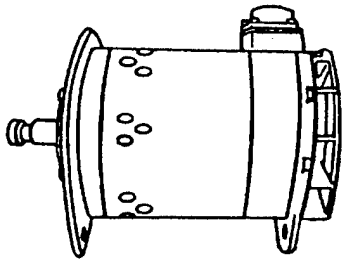
MODEL 3002AC



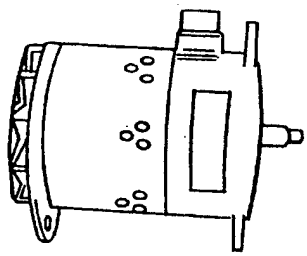
MODE L 3002AD AND 3002AE



MODELS 5504AA AND 5504AB



MODEL 5300GP



MODEL 2184AC

TA 118949

Figure 1-1. Alternating Current Engine Generator Identification

1-2

4-2. 60 AMPERE ALTERNATOR MAINTENANCE

This task covers:

a. Removal
b. Installation
c. Adjustment

INITIAL SETUP:

Tools
General mechanic's tool kit: automotive (Appendix B, Item 1)

Special Tools
Hex-head driver, 3/16 in. (Appendix B, Item 163)

Materials/Parts
Ten lockwashers (Appendix G, Item 116)
Sealing compound (Appendix C, Item 44)
Adhesive sealant (Appendix C, Item 3)

Personnel Required
One mechanic
One assistant

Manual References
TM 9-2320-280-10
TM 9-2320-280-24P

Equipment Condition
- Battery ground cable disconnected (para. 4-73).
- Hood raised and secured (TM 9-2320-280-10).

General Safety Instructions
Alternator must be supported during removal and installation.

NOTE
Prior to removal, tag leads for installation.

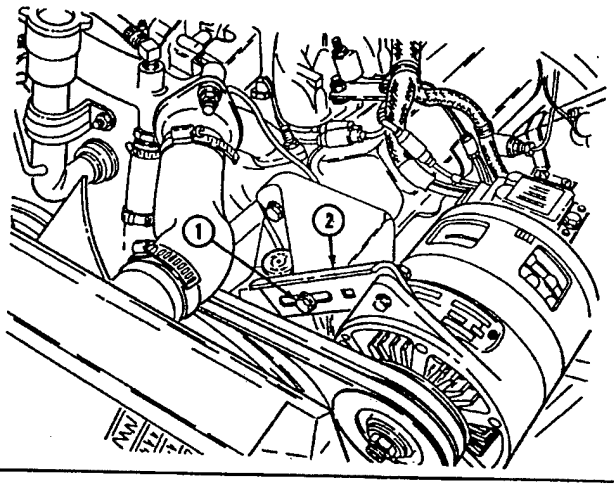
a. Removal

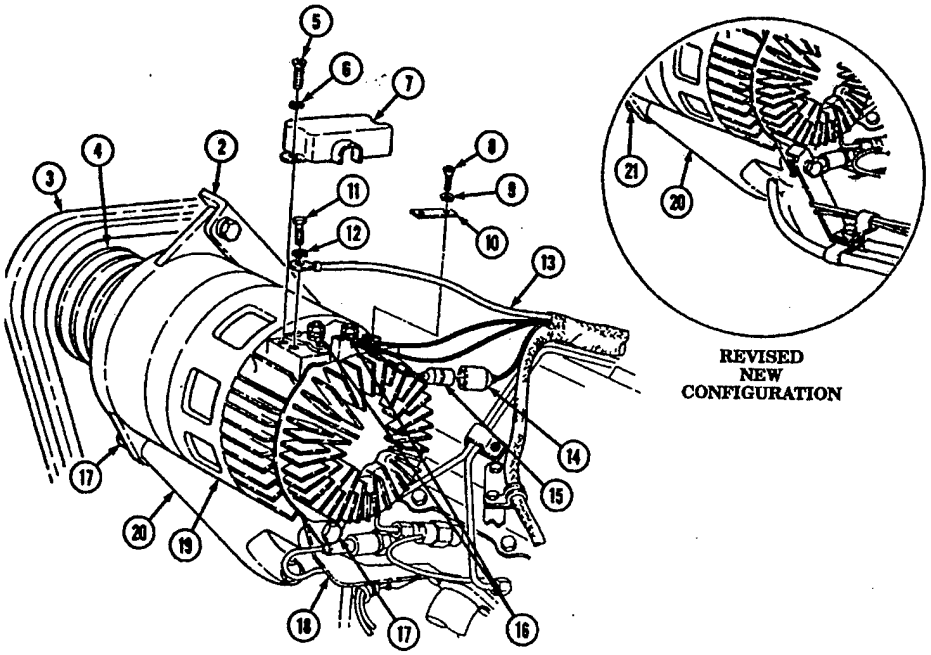
1. Loosen capscrew (1) on alternator adjusting bracket (2) and two capscrews (17) on alternator mounting bracket (20) and support bracket (18).

NOTE
Perform step 2 for vehicles with revised new configurations.

2. Loosen capscrew (1) on alternator adjusting bracket (2) and nut (21) on alternator mounting bracket (20) and support bracket (18).
3. Remove two drivebelts (3) from alternator pulley (4).
4. Remove two screws (8), lockwashers (9), and wire retaining strap (10) from alternator (19). Discard lockwashers (9).
5. Remove two screws (5) and lockwashers (6) from terminal cover (7). Discard lockwashers (6).
6. Pry cover (7) away from waterproofing adhesive and remove cover (7).
7. Remove waterproofing adhesive around terminals (16).
8. Disconnect lead 568A (15) at engine wiring harness (14).
9. Remove capscrew (11) and lockwasher (12) securing ground 3B (13) to alternator (19) and disconnect ground 3B (13) from alternator (19). Discard lockwasher (12).

4-2. 60 AMPERE ALTERNATOR MAINTENANCE (Cont'd)





REVISED
NEW
CONFIGURATION

4-2. 60 AMPERE ALTERNATOR MAINTENANCE (Cont'd)

10. Remove nut (4), lockwasher (3), washer (2), and lead 5A (1) from alternator (9). Discard lockwasher (3).
11. Remove nut (5), lockwasher (6), washer (7), and lead 2A (8) from alternator (9). Discard lockwasher (6).

WARNING

Alternator must be supported during removal and installation. Failure to support alternator may cause injury to personnel or damage to equipment.

12. Remove capscrew (13), lockwasher (12), and washer (11) from adjusting bracket (10) and alternator (9). Discard lockwasher (12).

NOTE

- Perform step 14 for vehicles with new alternator support bracket configuration.
- Perform step 15 for vehicles with revised new configuration

13. Remove two capscrews (14), lockwashers (15), and washers (16) from alternator (9), support bracket (17), and mounting bracket (18). Discard lockwashers (15).
14. Remove two capscrews (14), lockwashers (15), washers (16), spacer (21), power steering lines bracket (20), and support bracket (17) from mounting bracket (18). Discard lockwashers (15).
15. Remove nut (22), lockwasher (15), washer (16), long capscrew (23), washer (16), power steering lines bracket (20), and support bracket (17) from mounting bracket (18) and alternator (9). Discard lockwasher (15).
16. Remove alternator (9).
17. Remove alternator pulley (19) (para. 4-3).

b. Installation

1. Install alternator pulley (19) (para. 4-3).

NOTE

- Perform step 3 for vehicles with new alternator support bracket configuration.
- Perform step 4 for vehicles with revised new configuration.

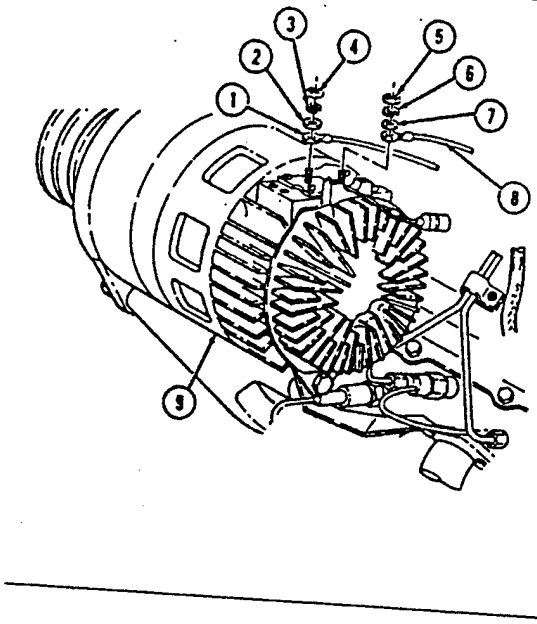
2. Position alternator (9) on mounting bracket (18) with support bracket (17) between mounting flange (18.1) and alternator (9) and install two washers (16), lockwashers (15), and capscrews (14).
3. Position alternator (9) on mounting bracket (18) with support bracket (17) and power steering lines bracket (20) on the outside of alternator mounting flange (17.1) and install spacer (21) between mounting bracket (18) and alternator mounting flange (17.1) with two lockwashers (15), washers (16), and capscrews (14).
4. Position alternator (9) on mounting bracket (18) with support bracket (17) and power steering lines bracket (20) on the outside of alternator mounting flange (17.1) and install washer (16), long capscrew (23), lockwasher (15), washer (16), and nut (22).
5. Align alternator (9) with adjusting bracket (10) and install washer (11), lockwasher (12), and capscrew (13).

NOTE

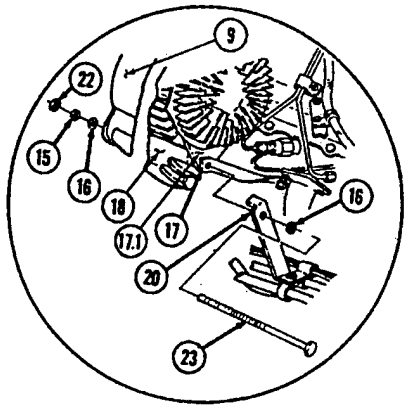
Ensure terminals are clean before connections are made.

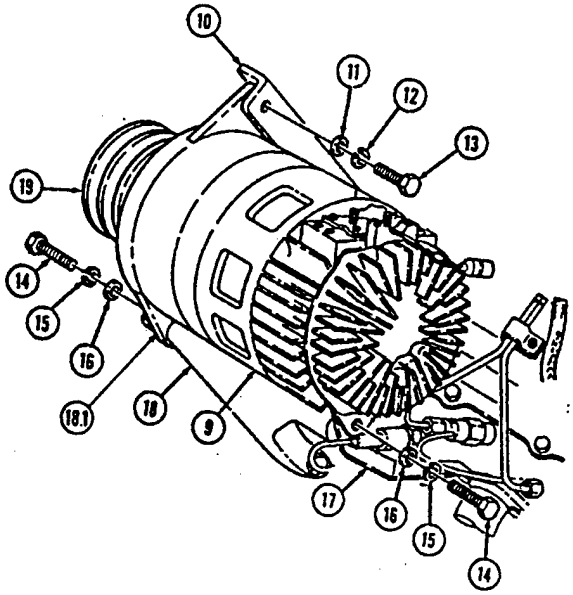
6. Connect lead 2A (8) on alternator (9) with washer (7), lockwasher (6), and nut (5). Tighten nut (5) to 20-25 lb-in. (2-3 N·m).
7. Connect lead 5A (1) on alternator (9) with washer (2), lockwasher (3), and nut (4). Tighten nut (4) to 45-55 lb-in. (5-6 N·m).

4-2. 60 AMPERE ALTERNATOR MAINTENANCE (Cont'd)



REVISED
NEW
CONFIGURATION

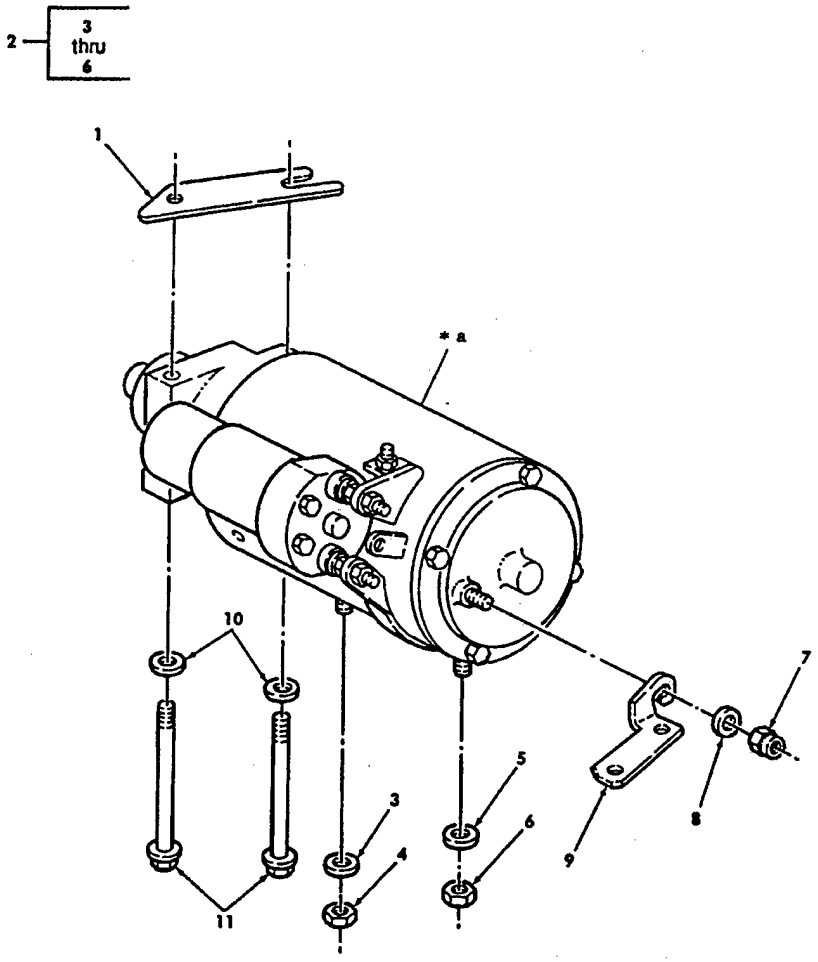




NEW
CONFIGURATION

APPENDIX G

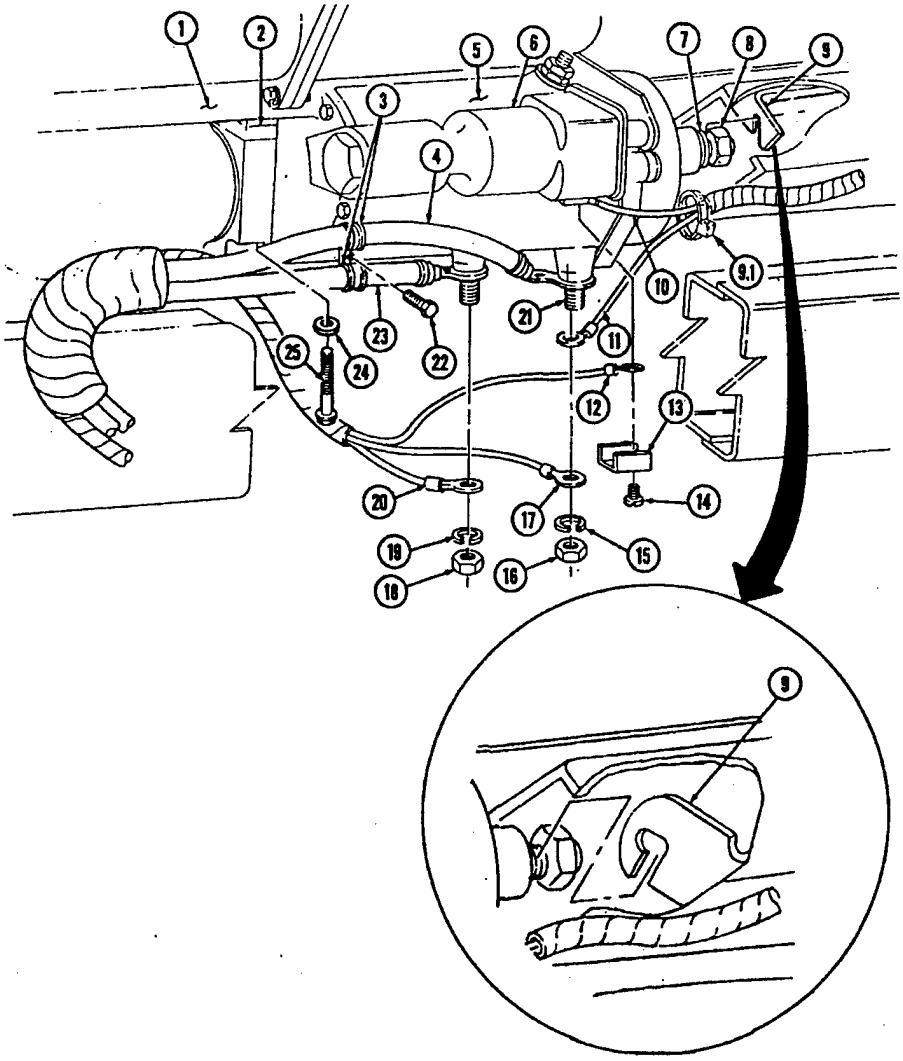
Removing and Installing a Starter Motor.



* a PART OF ITEM 2

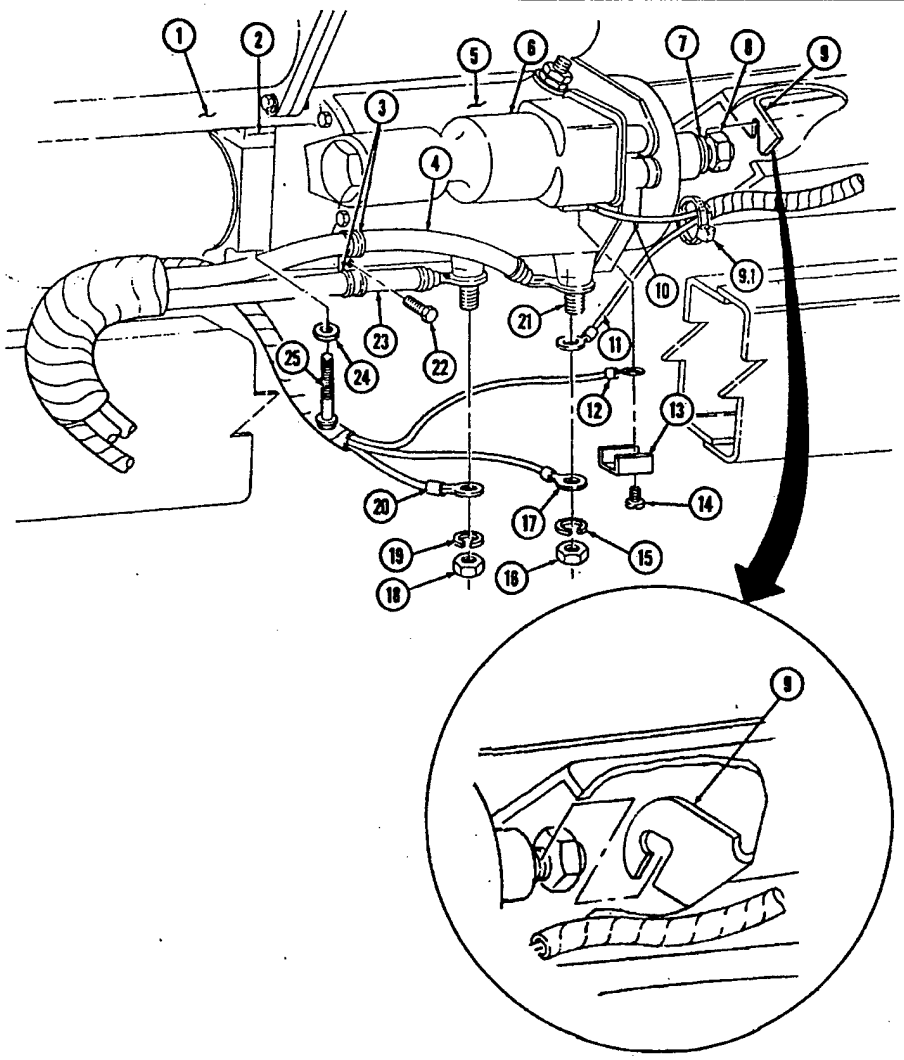
Figure 48. Starter motor.

4-8. STARTER REPLACEMENT (Cont'd)



NEW CONFIGURATION

4-8. STARTER REPLACEMENT (Cont'd)



NEW CONFIGURATION

FOLLOW-ON TASKS:
- Install converter housing cover (para. 5-19).
- Install sealed upper converter housing cover (para. 5-18).
- Connect battery ground cable (para. 4-73).
- Install arctic heater oil pan shroud (para. 12-48.2).
- Start engine (TM 9-2320-280-10) and check for smooth starter engagement.

4-8. STARTER REPLACEMENT

This task covers:

a. Removal **b. Installation**

INITIAL SETUP:

Tools
General mechanic's tool kit:
automotive (Appendix B, Item 1)

Special Tools
Crowfoot, 9/16 in. (Appendix B, Item 150)
Torque adapter, 3/4 in. (Appendix B, Item 145)
Socket adapter, 3/8 - 1/2 in. drive
(Appendix B, Item 146)

Materials/Parts
Lockwasher (Appendix G, Item 108)
Lockwasher (Appendix G, Item 112)
Locknut (Appendix G, Item 105)
Adhesive sealant (Appendix C, Item 10)
Sealing compound (Appendix C, Item 45)
Tiedown strap (Appendix G, Item 243.1)

Personnel Required
One mechanic
One assistant

Manual References
TM 9-2320-280-10
TM 9-2320-280-24P

Equipment Condition
- Battery ground cable disconnected (para. 4-73).
- Arctic heater oil pan shroud removed (para. 12-48.2).
- Converter housing cover removed (para. 5-19).
- Sealed upper converter housing cover removed (para. 5-18).

General Safety Instructions
Starter must be supported during removal and installation.

WARNING

Starter must be supported during removal and installation. Failure to support starter may cause injury to personnel or damage to equipment.

NOTE

- Illustration shown is a cutaway of the right side of vehicle.
- Prior to removal, tag leads for installation.

a. Removal

1. Remove nut (18), lockwasher (19), lead 3D (20), and negative cable 7A (23) from starter (5). Discard lockwasher (19).
2. Remove adhesive sealant from positive terminal (21) on starter (5).

NOTE

- Perform step 3 for all vehicles except M1123 and "A2" series vehicles.
- Perform step 4 for M1123 and "A2" series vehicles only.

3. Remove nut (16), lockwasher (15), tiedown strap (9.1), leads 81A (11) and 81B (17), and positive cable 6A (4) from starter (5). Discard lockwasher (15) and tiedown strap (9.1).
4. Remove nut (16), lockwasher (15), and lead 81B (17) from starter (5). Discard lockwasher (15).
5. Remove screw (14), clip (13), and leads 74B (12) and 74A (10) from solenoid (6).
6. Remove screw (22), two clamps (3), negative cable 7A (23), and positive cable 6A (4) from starter (5).
7. Loosen locknut (8) and washer (7) (if installed) on stud connecting starter (5) to bracket (9). Discard locknut (8).
8. While supporting starter (5) from under vehicle, remove two capscrews (25) and washers (24) from starter (5) and engine (1).
9. Remove starter (5) and shim (2) from engine (1).

4-8. STARTER REPLACEMENT (Cont'd)

b. Installation

1. Install an 0.08 in. (2 mm) shim (2) on starter (5).
2. Position shim (2) and starter (5) to flywheel housing with solenoid (6) facing outward.
3. Slide front stud on starter (5) in bracket (9).

NOTE

Some capscrews have sealing compound pre-applied. Additional sealing compound is not required.

4. Apply sealing compound to capscrews (25). Install two washers (24) and capscrews (25) on starter (5) and engine (1). Tighten capscrews (25) to 30-40 lb-ft (41-54 N•m).
5. Secure starter (5) on bracket (9) with locknut (8). Using crowfoot, tighten locknut (8) to 15-19 lb-ft (20-26 N•m).
6. Install two clamps (3), and negative cable 7A (23) and positive cable 6A (4), on starter (5) with screw (22).
7. Connect leads 74A (10) and 74B (12) to solenoid (6) with clip (13) and screw (14). Tighten screw (14) to 20 lb-in. (2 N•m).

NOTE

Perform step 8 for all vehicles except M1123 and "A2" series vehicles. Perform step 9 for M1123 and "A2" series vehicles only.

8. Connect positive cable 6A (4) and leads 81A (11) and 81B (17) to starter (5) with lockwasher (15) and nut (16). Using torque adapter, tighten nut (16) to 25-30 lb-ft (34-41 N•m).

8.1. Secure leads 74A (10) and 81A (11) with tiedown strap (9.1).

9. Connect lead 81B (17) to starter (5) with lockwasher (15) and nut (16). Tighten nut (16) to 25-30 lb-ft (34-41 N•m).
10. Seal positive terminal (21), leads 81B (17) and 81A (11), and positive cable 6A (4) with adhesive sealant. Apply sealant at least 1.8 in. (3.175 mm) thick, covering all exposed metal attached to the positive terminal (21).
11. Connect negative cable 7A (23) and lead 3D (20) to starter (5) with lockwasher (19) and nut (18). Using torque adapter, tighten nut (18) to 15-20 lb-ft (20-27 N•m).

APPENDIX H

Removing and Replacing a Tire

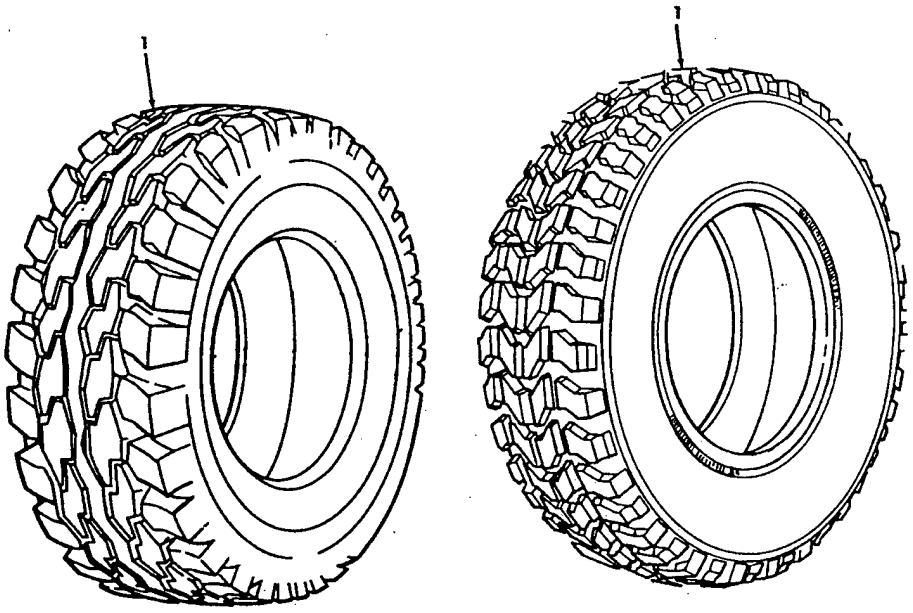


Figure 168. Tires.

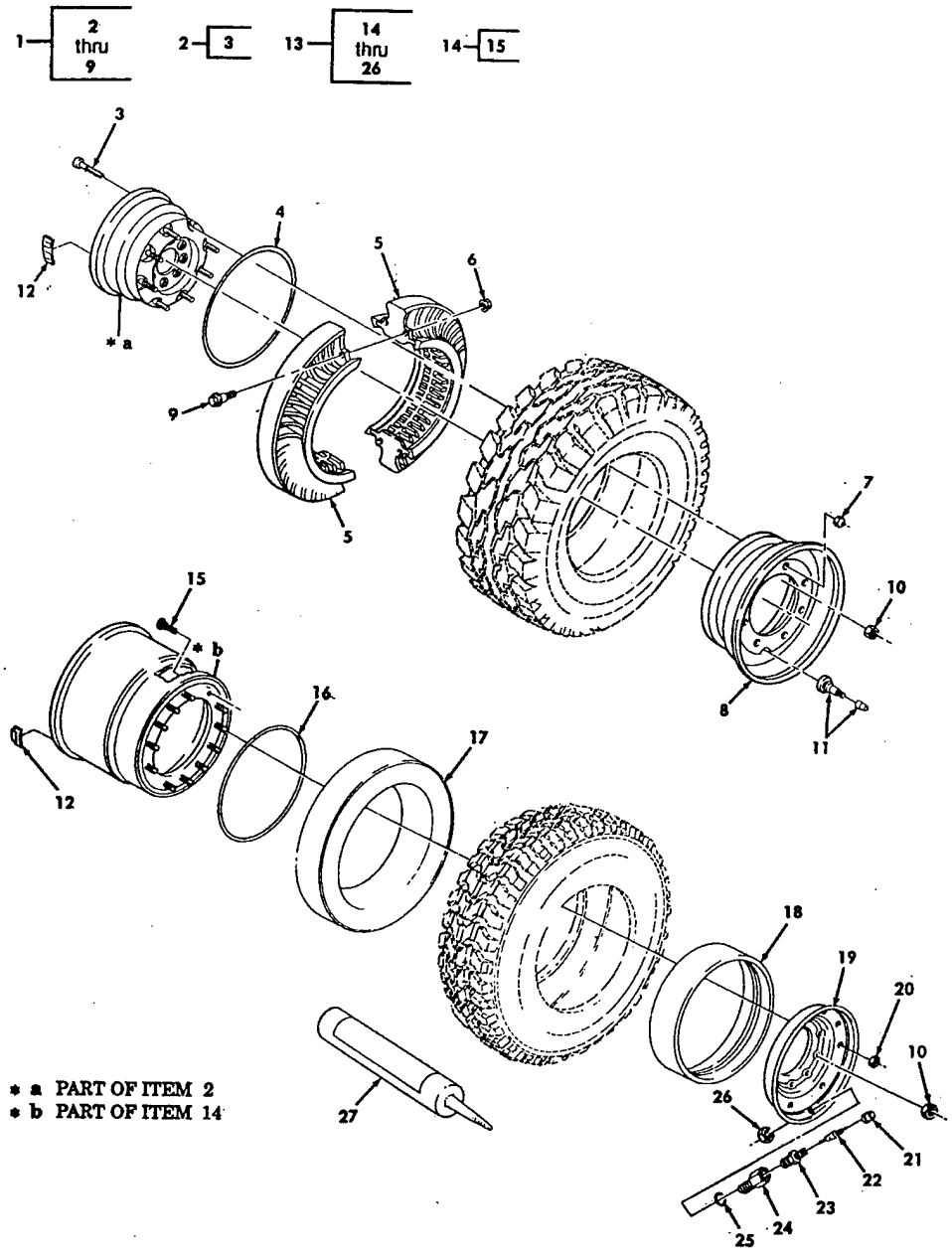
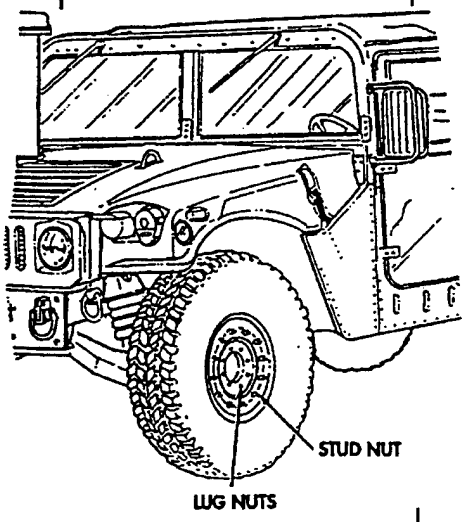


Figure 167. Wheel and Runflat Assembly.

Table 2-2. Preventive Maintenance Checks and Services (Cont'd).

Item No.	Interval	Location Item to Check/ Service	Crewmember Procedure	Not Fully Mission Capable If:
39	Weekly	Tires (Cont'd)	**b.** Measure tread thickness. Tread depth should not be less than 1/16 in. (1.59 mm) thick. **c.** Check for missing or loose wheel stud nuts and lug nuts. Tighten loose lug nuts and have unit maintenance tighten stud nuts and lug nuts to proper torque.	**b.** Tread depth less than 1/16 in. (1.59 mm). **c.** Any wheel stud nut or lug nut is broken or missing.



3-25. WHEEL ASSEMBLY REPLACEMENT

a. Wheel Assembly Removal.

WARNING

- Always apply parking brake and block opposite wheel before removing wheel assembly. Avoid removing wheel assembly when vehicle is on sloping terrain. Injury to personnel or damage to equipment may result.
- Remove only the inner group of nuts when removing a wheel from the vehicle. Removing the outer nuts which hold the rim together while the wheel assembly is inflated could result in serious injury or death.
- Ensure scissors jack is positioned directly under lower control arm next to wheel being replaced. Do not place at any other location such as frame rails. Injury to personnel or damage to equipment may result.

(1) Place jack (4) under lower control arm (5) next to wheel being replaced. Center jack (4) squarely under point of contact.

(2) Loosen eight lug nuts (2), but do not remove.

(3) Raise vehicle high enough to allow removal of wheel assembly (1).

(4) Remove eight lug nuts (2) and wheel assembly (1) from geared hub (3).

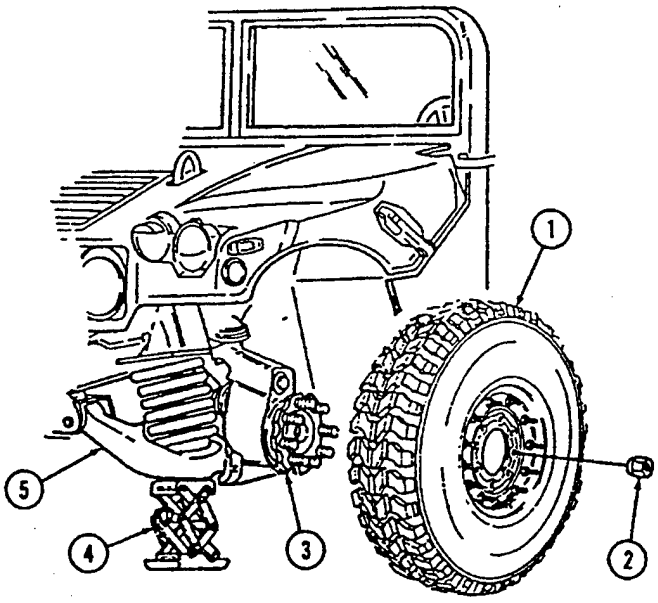
b. Wheel Assembly Installation.

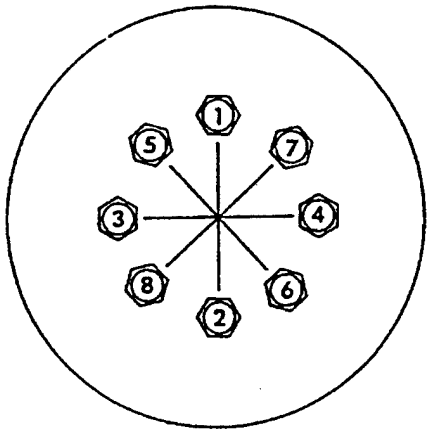
(1) Install wheel assembly (1) on geared hub (3) and secure with eight lug nuts (2). Tighten lug nuts (2) to full engagement of wheel assembly (1) to geared hub (3).

(2) Slowly lower vehicle and remove jack (4).

(3) Tighten eight lug nuts (2) in sequence indicated.

(4) Notify unit maintenance to tighten lug nuts (2) to proper torque.



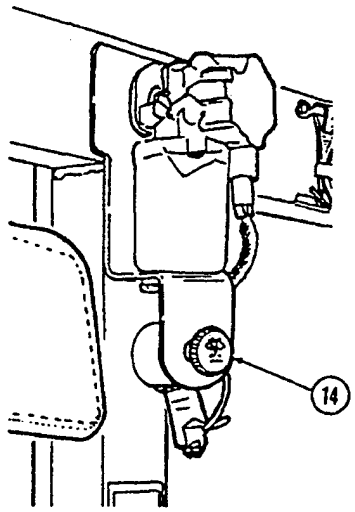


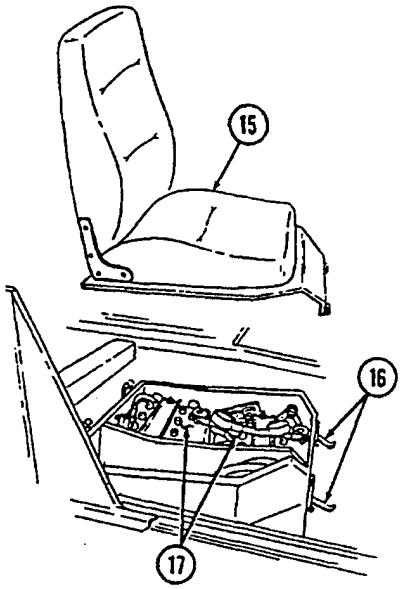
TIGHTENING SEQUENCE

APPENDIX I

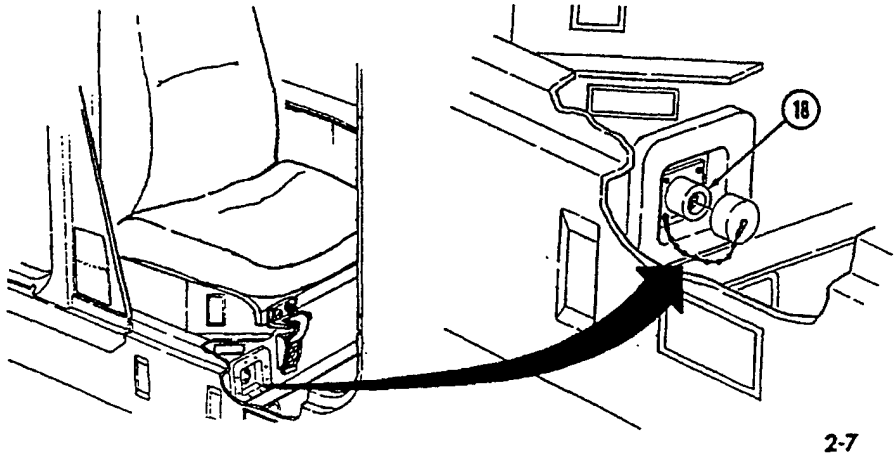
Removing and Replacing a Battery

KEY	ITEM AND FUNCTION
14	*Windshield washer/wiper control knob* operates a two-speed electric wiper motor; when depressed, operates windshield washer.





15	*Companion seat* is removed to provide access to batteries.
16	*Battery box latches* release to permit removal of companion seat for access to batteries.
17	*Batteries* provide 24-volt power to vehicle electrical system.
18	*Slave receptacle* is located at outside front of battery box. It is the connecting point for the slave cable for slave-starting the vehicle.



2-7

3-12. SERVICING BATTERIES

a. Unhook latches (6) and remove companion seat (1) from battery box (9).

WARNING

Do not perform battery system checks or inspections while smoking or near fire, flames, or sparks, especially if the caps are off. Batteries may explode, causing damage to vehicle and injury or death to personnel.

b. Check electrolyte level.

(1) Remove all battery filler caps (2) and check electrolyte level. If electrolyte level is below ledge in battery filler opening, add distilled water (appendix D, item 7).

(2) A battery that is continually in need of electrolyte may indicate an improperly adjusted charging system. Notify unit maintenance if problem continues.

(3) Inspect vented battery filler caps (2) to ensure that vents are clear, unobstructed, and permit escape of battery gases. Clean vents if obstructed; replace caps (2) if damaged.

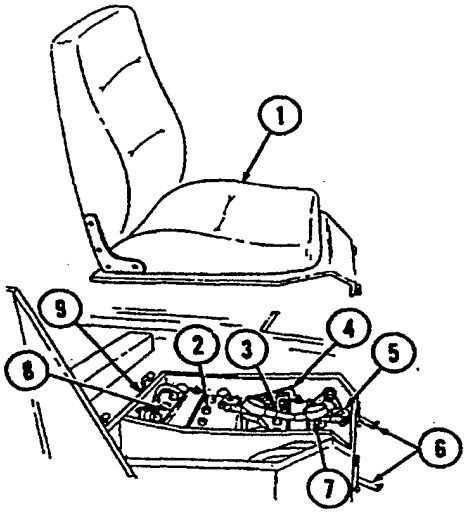
(4) Install filler caps (2).

c. Inspect all battery compartment components, including terminal clamps (5), battery cables (3), battery holddowns (8), and shunt (4) for corrosion, damage, or looseness. Inspect terminal boots (7), if installed. Notify unit maintenance if any of these problems exist.

d. Ensure that battery terminal clamps (5) have a light coat of lubricating oil for corrosion protection (appendix D, item 23).

e. Install companion seat (1) and secure to battery box (9) with latches (6).

f. Refer to TM 9-6140-200-14 for additional information.



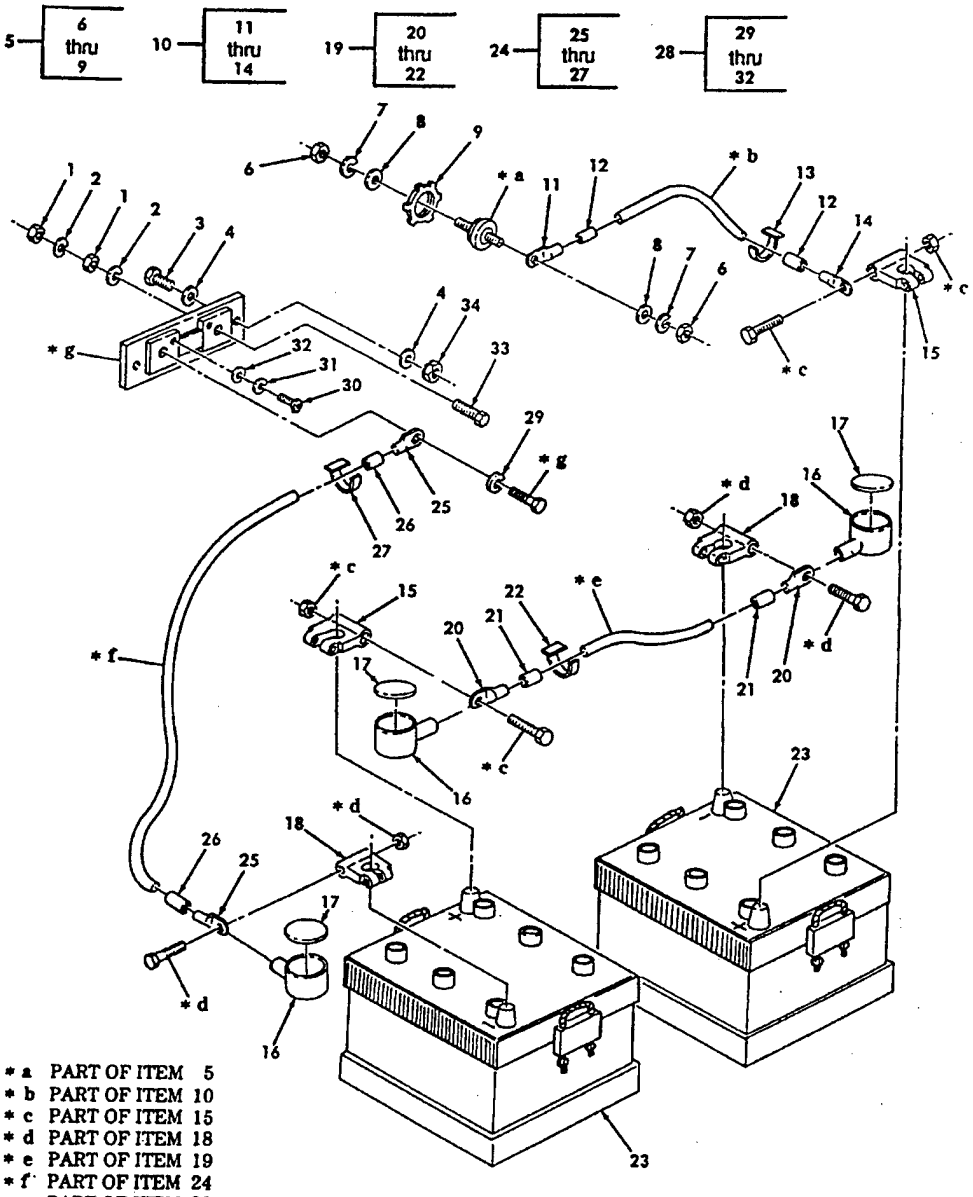


Figure 66. Batteries, Cables, and Related Parts.