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Comparing Depot Maintenance Work Requirements (DMWR) and
Commercial Overhaul Manuals for Ease of USe

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A cost reducing initiative of the Army Depot Systems Command (DESCOM), has been to try to increase the efficiency of Depot mechanics by doing away with their old overhaul manuals, Depot Maintenance Work Requirements (DMWR), in favor of overhaul manuals of the commercial sector. However, DESCOM has not explained why commercial manuals are preferrable to DMWRs. Six common tests of technical manual usability have been used in this study to try to answer this question.

A large representative sample of manuals from both repair sectors were compared together first to see if there were any significant differences between the two sets. Significant differences would then be evaluated as to their effect on Depot efficiency. However, the data collected revealed no significant differences between the two manual sets.

An obvious implication of these findings seems to be that replacement of DMWRs for very similar commercial manuals is not warrented. A better course of action seems to be to insist that DMWRs be written and updated against usability standards.

Depot Maintenance Work Requirement, 168
Technical Manual
Commercial Overhaul Maintenance Mannual N/A

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COMPARING DEPOT MAINTENANCE WORK REQUIREMENTS (DMWR) AND COMMERCIAL OVERHAUL MANUALS FOR EASE OF USE

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COMPARING DEPOT MAINTENANCE WORK REQUIREMENTS (DMWR) AND COMMERCIAL OVERHAUL MANUALS FOR EASE OF USE

ABSTRACT

The Depot Systems Command (DESCOM), a division of the Army Material Command (AMC). has sought to increase the efficiency of the Army Depot system and reduce its costs, and has targeted its overhaul manuals (the Depot Maintenance Work Requirements (DMWRs)) for termination. It is DESCOM's contention that the DMWR does not compare favorably with other forms of technical overhaul manuals, particularly not with the best forms of overhaul manuals of the commercial world, and it wants to adopt these "other" forms. However, DESCOM has not specifically stated what is desirable or undesirable in manuals, nor what is bad, with respect to DMWR usability, or what is good, with respect to commercial manual usability.

This study provided a locus of verifiable data and related research to act as a source to answer some of these questions. It employed six common manual usability tests to compare a representative sample of overhaul manuals from the commercial and the Depot sectors. The findings of the tests indicated that there are no significant differences in the two manual sets.

One implication of the findings is that, since DMWRs are not significantly different from commercial manuals, trading DMWRs for commercial manuals (technical data packages) may be simply more costly than beneficial. Another implication for DESCOM is that the practice of editing commercial manuals (technical data packages) to make them into DMWRs might not necessarily add value to DMWRs or the Depot system. Whether DMWRs are scrapped or not, however, the findings and principles outlined in this study seem to represent good standards (at low costs) for any technical manual to have.

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CHAPTER I

INTRODUCTION

The US Army is well known as an organization that has the capacity to be both a very big business as well as a natural monopoly. Who in the civilian world, for instance, has battle tanks to develop, maintain, and operate? Millions are appropriated in advance each year by Congress to operate the Army, and in many cases, the Army has the only capability to earn those dollars. Competitive bids by parties outside the military are encouraged, but competing to get a piece of the appropriation has been difficult.

Therefore, The Office of Management and Budget has set a policy for Department of Defense that commercial industry will be the repair sector of choice, if possible, to do organic (military) workload. (35:A-2)* This poses little concern for the military when it feels it is competitive with the commercial sector. However, there is evidence that the military has lost some competitiveness: the commercial sector is growing in relation to the military sector. (11:1-2)

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* A numbered bibliography is used in this study. The first number identifies the reference number in the bibliography. The second number identifies the page of the reference.

Military equipment repair Depots are prime examples of military establishments which compete for work with contractors in both peace and war. Depots have a competitive advantage still, because a set percentage split (70/30) for Depot vs contractor workload levels (31:E-9c) exists. This maximum "split" means, essentially, that a contractor may bid for work destined for the Depot only if the work is in excess of the Depot's capacity to repair. Eighty-five percent facility capacity utilization is recognized by US industry as the minimum for efficiency, while present Depot capacity is slightly more than 50%, on average. (36:3-2)

However, Depots still believe that present and/or future business is in jeopardy. They are seeking ways to cut any cost to maintain a margin of safety. One such attempt seeks to find the relative costs/benefits of Depot equipment repair manuals compared to those of the private sector, in order to use the better manual. The initiative is called "Best Commercial Practices" (BCP), and is discussed in the section of this study titled "Background".

Depot Systems Command (DESCOM), a higher headquarters over the various Army Depots, feels that its manuals, the Depot Maintenance Work Requirements (DMWR), compare badly to manuals of the commercial sector. It feels that this weakness contributes to higher costs for repair. DESCOM feels that the DMWRs' intrinsic weaknesses cause such things as

1. less responsive repair to customers
2. difficulty in being updated
3. poor ability to match competitors' cost, which

results in poor capacity utilization of depots

4. poor ability to match competitors' use of state of the art repair processes, which results in workload which only requires "old technology" repair capability. (40:1)

These "intrinsic weaknesses" hamper depot competitiveness for repair of military equipment. Military equipment developers, required to produce equipment under budget, opt to develop no Depot maintenance future for a particular piece of equipment, rather than do so and be faced with the prospect of going over budget thereby. (40:1) DESCOM requires these developers to provide either a DMWR or great quantities of technical data before Depots may perform work. Since DMWRs are very expensive, some developers opt not to develop them, in favor of providing the "technical data" instead. (40:1) Without work for the Depots, Depots stagnate, and could eventually be scrapped.

DESCOM feels that this a vicious circle, and could be short-circuited if DMWRs were intrinsically better manuals. To DESCOM, the DMWR is "a major reason for the current decline in organic Depot systems competitiveness for repair/overhaul work with respect to contract Sources of Repair." (40:1) The BCP initiative is designed to correct this decline by requiring that all repair/overhaul be done in accordance with other forms of technical data rather than with the DMWRs.

The Commander, AMC, has applauded this effort, and mandated that a pilot program to test the concept (being conducted at Anniston Army Depot) be immediately expanded. He has requested that

> each MSC identify at least one commodity, which presently requires the use of DMWR, for establishment of a pilot program to explore the effectiveness of [this initiative]. (39:1)

One potential problem that may inhibit the pilot program and future operations of the depots is that DESCOM has not published verifiable findings establishing what is specifically "wrong" with DMWRs, or what is specifically "right" with commercial manuals. For instance, no data exists comparing DMWRs with commercial manuals with respect to ease of use, or the ability to be updated, or other similar quantifiable measures for comparison. It is not possible to evaluate something until it is defined objectively.

Purpose of Study

The purpose of this study is to compare classes of equipment overhaul manuals of the US Army Depot maintenance system with corresponding classes of manuals of the US commercial equipment maintenance system to determine if Depot overhaul manuals are relatively more difficult to use.

Analysis of the Problem (subproblems)

In order tc determine the relative ease of use of Depot versus Commercial Overhaul manuals, the following subproblems must be addressed.

The first subproblem. The first subproblem is to determine the relative simplicity of the manuals, as in their ease of readability.

The second subproblem. The second subproblem is to determine the relative number of illustrations per manual between the manual sets (commercial vs DMWR).

The third subproblem. The third subproblem is to determine the frequency of use of any aids to understanding in the texts, such as cues, marginalia, and underlining.

Hypotheses

The First Hypothesis. The first hypothesis is that there is no significant difference between the commercial and Depot manuals' readability.

The Second Hypothesis. The second hypothesis is that there is no significant frequency difference between the commercial and the Depot manuals' illustrations.

The Third Hypothesis. The third hypothesis is that there is no significant difference between the commercial and Depot manuals' relative practice of using aids to understanding in the text, aids such as cues, marginalia, and underlining.

Assumptions

The first assumption. Depot and commercial mechanics and technicians are equally skilled in the use of repair standards, criteria, and procedures, from repair publications.

The second assumption. Depot and commercial mechanics and technicians are equally motivated to use repair standards, criteria, and procedures from repair publications.

The third assumption. Depot and commercial mechanics and technicians can equally apply repair standards, criteria and procedures from repair publications to produce high quality products.

The fourth assumption. The modern, generally accepted readability criterion for published matter indicate well the reading grade level of a text.

The fifth assumption. Comparing general classes of equipment repair/overhaul manuals (for instance, commercial and military diesel engine overhaul manuals), will not introduce significant bias about comparative text readability, number of illustrations, or use of textual aids to understanding.

The sixth assumption. Picking only three standard usability criteria, e.g., reading grade levels, heuristic (cue and illustration frequency), and user testing, will be sufficient so that an unbiased, reasonable difference could emerge to be evaluated.

The seventh assumption. The perception that the DMWR is hard to use exists with those workers who actually use the manual as well with those workers at the higher, DESCOM levels, who wrote the BCP initiative.

The eighth assumption. The illustrations, cues, and words counted and compared represent correct repair technology.

Scope and Limitations

This study includes manual comparisons for only three sets of items of equipment used by both the Army and the civilian sector. These three items represent the test population because they seem to typify best the Army Depot commodities that are overhauled (aviation, ground mobility, communication/electronics).

This study focuses on the depot/commercial type of maintenance best relating to "reliability centered" maintenance (replace as needed) as opposed to "strict overhaul" (replace all parts).

This study does not evaluate any other variables of equipment repair such as test and diagnostic equipment, tools, and facilities.

This study does not explore the ability of mechanics/ technicians to repair items by "experience", "feel" or "intuition", as opposed to using a manual.

This study does not attempt to validate the procedures for developing manuals, or the constraints under which manual writers write, or the qualifications of manual writers to write manuals.

Although this study is limited in its scope, it provides a body of data which AMC (the proponent for writing DMWRs) does not currently have, which could be used to improve DMWRS of all kinds. Improved DMWRs would contribute much to reducing costs, increasing readiness, and improving the working conditions of Depot employees.

Definition of Terms

The following terms are used throughout this paper. They are words and phrases not generally used outside the realms of depot or commercial repair, and are important to know to understand this study.

Depot Maintenance Activity. A Depot is an industrial type facility established to perform Depot level maintenance on weapon systems, equipment, and components of the military. The term includes DoD installations and commercial contractors.

Depot Maintenance Work Requirement (DMWR). DMWR is the name of the maintenance manual for the military Depots.

Industrial Maintenance Support. This support is Depot workload, meaning maintenance performed on materiel after its withdrawal from custody of the using military command.

Maintenance end item. An end item is a final combination of assemblies, components, and parts that performs a major operational function.

Background

The Department of Defense uses repair Depots to overhaul equipment in each of the principal sister defense services, Air Force, Navy and Army. The US Army Depot maintenance program is typical, and is directed and workloaded by the Depot Systems Command (DESCOM) of the Army Materiel Command (AMC), through individual commodity commands called Major Subordinate Commands (MSCs).

Overall Depot maintenance policy is formed by DESCOM. It designates primary and secondary repair facilities for an item, and collects management and physical data about each Depot and forwards this through AMC to Army Headquarters. Examples of this data important to this study are cost and timeliness statistics from the repair of items of equipment.

The MSCs serve as item managers for the Army's classes of weapons systems programs, identifying depot level maintenance requirements, supporting depots and field commands with their commodity's repair parts, and making the decision whether a Depot Maintenance Work Requirement (DMWR) will be required for a developing piece of equipment. Many new items do not have DMWRs because the items are too new to require overhaul, so the writing of the DMWR is postponed to a later date. In most cases, if an item has no DMWR, the item developer has decided that it does not need one. Examples of equipment without DMWRs are the 1 1/4 ton Commercial Utility Cargo Vehicle and M915 diesel engine.

Depot facilities are fixed, industrial-type buildings equipped with industrial tools and test equipment. Each Depot may be workloaded with hundreds or thousands of different line items of equipment to repair. Depots generally repair only Army items and subcontract backlog to commercial repairer only when backlog exceeds capacity.

Individual depots perform the highest levels of maintenance repairs within the Army system. Skilled Department of the Army (DA) civilian mechanics, materiel workers and handlers, technicians and engineers do the production planning, controlling, quality assurance and other processes to render unserviceable equipment to a "like new" condition. In the current three-level army maintenance system (Unit level, Direct/General support, Depot), the Depot may perform each level as necessary and allowable under its program.

Equipment repaired in the Depot comes from owning units, but that same piece of equipment generally does not return to that unit. It is turned in to the supply system for general distribution. Additionally, there are no differences in the final application of equipment repaired in the Depot and commercial scenario. The equipment repaired in either sector does not necessarily go to reserve/National Guard or active duty units. Therefore, MSCs do not communicate specific requirements differences in materials, repair parts, or processes of repair to manual writers because of the sector of equipment repair.

DESCOM believes that, when DMWRs do not exist, competitiveness of the Depot automatically decreases since

> equipment developers will not contact Depots for cost estimates on repair of their equipment when they know no DMWR has ever been developed, in the mistaken belief that all Depot work must be done by DMWR. (40:1)

Actually, Depots have done Depot level work without a

DMWR. (40:1) However, existing DMWRs must be used, regardless of better manuals which may exist. (40:1) One problem with not having a DMWR is that depots are in that case very reluctant to

> provide cost estimates to equipment developers for equipment without a DMWR, because they hesitate to provide a questionable (baseless) estimate fearing they will not be able to refine/ renegotiate after gaining enough experience to develop a more realistic unit-funded cost. (40:1)

Depots operate on a cost basis. They are programmed to repair a certain number of items based on Army need and individual Depots manhours available. Army needs essentially dictate the number of manhours available, constrained, of course, by budget ceilings. Depots must operate within that budget and produce the required number of repaired items to military specifications.

Commercial maintenance facilities, on the other hand, operate on a profit basis. They cut costs any way they can, and change as often as they must in order to stay solvent. As long as benefits outweigh liabilities, commercial concerns will spend money to make money. This is important to keep in mind in the subsequent discussions about commercial technical manuals. Commercial concerns tend to buy manuals which allow the largest profit from operations rather than follow a set format (such as the Army does).

Commercial maintenance establishments are essential to the effective conduct of war, because only the commercial sector can afford to run the number of facilities needed to repair the volume of equipment that a modern war would destroy.

Conversely, Depots are also essential to the effective conduct of war, because their advantage--their small size--allows them to more easily change operations quickly during crucial mobilization time frames. They are also known to have a relatively lower occurrence of default/nonconformance than the commercial sector. (36:3-3) Depots are therefore designed to operate under set procedures at all times so that at any time they can transform without undue cost and time to mobilize the Army.

Peacetime planners, paid to cut costs, tend to forget this wartime mission focus of Depots in favor of maximizing peacetime cost concerns. They try, for instance, to lower the high standards of the DMWR in order to cut costs. Since Depots operate on a cost basis, they place themselves at risk in times of recession (escalating costs) to become uncompetitive with respect to the commercial sector. Thus negatively compared, equipment developers opt not to include depots in maintenance plans, and Depot facilities and skills become increasingly underused. Thus, military planners of the DMWR must maintain an acceptable balance in a tradeoff between sometimes divergent goals.

To assume a fair and equitable comparison between contractor and depot bids for repair workload, The Department of Defense (DoD) has mandated that "in-house cost estimates must be based on the same scope of work [as for contractors]." (30:7-5) This is important to the research topic, because it tends to ensure that, whatever the application of Depot/commercial repair, work within the DoD will be based on similar scopes of work.

The Depots are facing a "technological revolution" (10:1-2), meaning new technologies exist for virtually every aspect of Depot life. The many new materials and better item reliability is changing the workloads of Depots, so Depots need to modernize, simplify, and become more competitive with respect to commercial sources of repair.

The Army most often contracts the development of DMWR writing to the commercial sector. Very few DMWRs are written by the military itself. This is why these publications run a risk of being developed in a potential commercial vacuum. (8:2-18) That is, coordination, data input, and verification can become cursory between a widely separated commercial and Depot world. This can increase manual cost and decrease effectiveness because of the distances over which coordination must be accomplished. DESCOM believes that "the adoption of existing technical data [BCP] will be less costly than development of the formalized DMWR" (36:3-12), ostensibly due in part to the fewer coordination difficulties.

The Army has long worked to improve the clarity of its manuals. Indeed, this has been the focus of research and development efforts for over 35 years. (45:70) Traditional maintenance manuals have had a "staid style, tedious and complex language, and a lack of illustrated procedures" (47:26) making them difficult to use.

DESCOM believes that commercial manuals are easier to use, and cheaper to write and update since they are not constrained by governmental intervention or the needs of military application. DMWRs are "rigidly structured...

[and] many original DMWRs are inadequate and must be rewritten by Depot engineers and technical writers". (37:1)

Depots have a publications writing section that updates DMWRs. This section is staffed by proven technicians, (not necessarily proven writers) who design, update, and change DMWRs. (8:2-25) One of their main functions is to take existing tech data packages developed by commercial sources, and modify them to conform with the DMWR format specification.

One DMWR manual can cost over $150,000, with each page costing between $250 and $300 to write. (8:2-14) There are over 5,300 DMWRs, averaging 100 pages per manual, and updating them therefore is expensive. It has been estimated that to update the (1984) DMWR library to the latest military specification requirements will cost $95 million. (8:2-35)

Significance of the Study

US Army DESCOM and its depots have been faced with both shrinking market share and shrinking budgets. The 1990-1991 Army budget has likewise sustained a $1.8 billion reduction below that of the previous year, with the Army being required to operate at 1989 spending levels. (50:Cover story) Additionally, Depot OMA resourcing will take a $102.7 million growth cut over the next 5 years. (36:3-1)

The proportion of contract/depot repair work appears to be shifting, with an apparent loss of market share for the Depots. A modernization move by DESCOM, to reduce that apparent market imbalance, is to improve its repair manuals. Its proposal is to use its $200 million DMWR technical library less, in favor of other technical data that it must develop, because it feels (but has not yet substantiated) that its DMWR is hard to use and update. A potential problem for DESCOM is that it may develop new technical data packages which contain the same problems that the DMWRs have, unless it finds out what the problem areas are first.

This study will seek to find specific reasons why the DMWR is purportedly harder to use than comparable commercial technical data. These data could be used by DESCOM to improve its manuals, rather than resort to throwing them out and starting fresh. Diagnostic upgrading, after all, is what each Depot normally does to each piece of equipment it overhauls--to fix it, rather than simply to throw it out and buy a new item.

Outline For The Remainder of the Study

The remainder of this study consists of four additional chapters. Chapter II provides a review of the literature and regulations that relate to this study. Chapter III describes the procedures selected for collecting and evaluating the data needed to solve the problem. Chapter IV presents the results of study, inferred from the findings and data collected. Chapter V contains a summary of the study's proceedings, recommendations for employing the data collected, and conclusions drawn as a result of the study.

CHAPTER II

RELATED LITERATURE

This chapter contains summaries of the more significant literature about "the ease of use" of the Depot Maintenance Work Requirement (DMWR). It also discusses commercial repair practices and some characteristics of commercial overhaul manuals. Subsections of this chapter are: developing military and commercial manuals, previous evaluations of maintenance manuals, comparing contract vs organic scenarios, previous evaluations of commercial manuals in the Depots, readability analysis in technical manuals, and the validity of the tests to be used. This chapter concludes with a summary.

Developing Military vs Commercial Manuals

The Department of Defense (DoD) has developed and used quite extensive specifications for producing its technical manuals. The Defense Logistics Agency (DLA) identified 480 different specifications for writing manuals. (45:75) However, research shows that these specifications have not been sufficient alone to produce usable manuals. Specifications "only address the manual as a product, not how to produce that product." (45:75) It is as important to make a technical manual readable as to make it technically accurate.

The commercial and the Depot sectors both strive to have the best manuals possible, for the lowest costs, in order to reach the ultimate goal of low cost and quality repair. The need for cost effectiveness in the competitive environment of equipment overhaul is high. However, no one has attempted to increase effectiveness of repair by comparing Depot to commercial manuals to try to grade possible usability differences.

One of the chief Army regulations stipulating manual development specifications is Army Regulation (AR) 25-30, The Army Integrated Publishing and Printing Program, dated March, 1989. It mandates very high and very comprehensive standards for all Army publications, with entire chapters devoted to central concerns such as " Writing and Revising Publications", "Preparing tables and illustrations", and "changes, revisions, reprints, and recisions." (22:index)

Information of particular relevance to this research from this regulation are the tests for readability, which establish reading grade levels (RGLs). The Army has taken great pains to require that its manuals be specific in content as well as readable.

Specifications for the content and format of Technical manuals come from MIL-M-38784B Military Spec: General Style and format Requirements. Among other things, it stipulates that technical manuals will have readability standards (32a:3.3.3), illustration standards (32a:3.5.7), and illustration scale and letter point size minimums

(32a:3.6.1).

Specifications for the content and format of DMWRs come from MIL-M-63041C Preparation of Depot Maintenance Work Requirements. (33) The Army is so serious about its desire to have usable manuals that there is even a specification for the specification, and the final draft is awaiting approval. The draft, MIL-M-63041D, clarifies ambiguous passages of MIL-M-63041C, improves its readability, amplifies its discussion of standards, and makes it more usable for writing the DMWR.

Specific standards for preparing manuals for the commercial sector exist, but vary widely as to content, depth of coverage, and style. Commercial manuals are generally written by different publishers with different standards (45:70). This is relevant because it seems to suggest the philosophical differences between commercial and military: the military is more authoritarian in its specification and values consistency in its manuals across the broad spectrum of its repair facilities.

Other regulations help ensure Army publications are both standard and contain information covering every maintenance contingency. AR 700-127 Integrated Logistics Support contains detailed plans for developing maintenance planning, test/measurement and diagnostic equipment needs, and technical data for equipment being developed. It thus has a indirect but significant impact on the DMWR. (25:3-10)

AR 70-1, Acquisition Policy, stipulates at what period in the equipment development process the decision must be made whether DMWR will be required for the piece of equipment. (23:5-1) In theory, the earlier a DMWR is planned and written in the life of a piece of equipment, the better the manual will be.

The relevance of these discussions to the research topic is that they summarize the apparent differences between the development of commercial and military manuals. These differences need to be taken into account when determining the ease of use of the DMWR, because knowing the manual development philosophies can help orient judgements about the manuals themselves.

Previous Evaluations of Maintenance Manuals

The DMWR has undergone many evaluations for the purpose of determining its acceptability as a maintenance manual. These evaluations each explore different aspects of the effects of DMWR use on Depot repair management and operations. They can be subdivided into two categories: subjective, and objective, evaluations. The "subjective evaluation" is the Best Commercial Practices initiative, already discussed in the introduction and background.

The "objective evaluations" are those from the Material Readiness Support Agency (MRSA), various Integrated Logistics Support (ILS) offices, and The General Accounting Office (GAO). Others include, a commercial engineering firm, the Naval Postgraduate School, and the Air College. These each are bodies of verifiable data from which valid conclusions can be drawn. None quantified the usability differences between Depot and commercial manuals, however.

The purpose of the MRSA study (1985), was to "assess the overall efficiency of the current policies, management structure, and operational procedures of DMWR management" (8:iii). The study was chartered to address "ongoing improvement actions... and quality and efficiency of Depot writing groups." (8:encl 1)

A product of this study was its exhaustive list of recommendations proposed to improve the DMWR, based on the research questions, "Is the current DMWR system cost effective, and does it make sense?" (8:1-1) Overall, the study determined that "both the product, ie, DMWR publication, and the management of the DMWRs , could be improved." (8:iv)

Notwithstanding this general negative comment, many specific comments were positive. The study found that Depot writers/revisors of the DMWR were not trained manual writers, but were still "producing satisfactory DMWRs...which require[d] very little substantive change at DMWR validation." (8:2-18) Some manuals were found to be out of date (8:2-35), but regulations and guidance for the preparation of DMWRs were judged to be "clear, specific and adequate, in general." (8:2-53)

The relevance of this study to the research topic is that it suggests that many faults in DMWRs may come from forces outside itself, ie, from writers and/or manual validators.

A Naval Postgraduate School study investigated an apparently excessive cost differential between electronics equipment repair done at different Depots in 1984. (19:45)

The researcher tried to determine what contributed to these differentials. A finding of the study was that repair and overhaul standards procedures differed at each Depot for the same items. (19:60)

This finding is important to this research study, because it shows graphically that depots without DMWRs can develop repair methods which are of lesser or greater cost effectiveness. It supports with evidence that when manuals are allowed to be written based on best practices rather than on standard guidance (as in specifications), cost differences in repair of similar items can result. This tends to indicate that using manuals designed on commercial practices rather than MIL-M-63041C can have negative side effects.

The General Accounting Office (GAO) prepared a study in 1979, titled "Management of Maintenance Manuals in DoD." The study reported that maintenance manuals were often difficult to use, were often out of date, and were inaccurate. (12:1) The study concluded that in many cases the value of maintenance data was questionable because descriptions in manuals were too complicated, complex procedures were not explained in sufficient detail, and necessary information was very difficult to locate. (12:5) However, the GAO also found that Army management of DMWR was "best DoD wide and good enough to be the standard for all services...in development, coordination, [and for ensuring] uniformness between operators manuals and maintenance manuals." (12:27) The GAO recommended that standardizing the use of specifications for preparing manuals would ease the burden of the contractors furnishirg specifications to the services. (12:28)

The relevance of this study to the research topic is that, though it found that maintenance manuals were hard to use in general, it found that both the Army management and its publication specifications were good and beneficial. Therefore, it is likely that Army Depot manuals are the most usable service-wide.

The US Air force, in conjunction with the TRW Corporation, did a study in 1979 to determine why many repair techniques, procedures, and allowable limits for repair in commercial aircraft manuals were so different from those of the Air force. (16:1) Of all the many thousands of procedures surveyed, in eight sets of manuals of identical pieces of equipment in and out of the Depot, only twenty-three significant differences were found overall. (16:2)

The study found that commercial aircraft engine overhaul manuals appeared to contain a larger number of repair procedures than did the Air Force Technical manuals, and that "differences in operating environment, inspection criteria, and overhaul time limits...[made] a commercial procedure unsuitable for Air Force use." (16:3) Additionally, a number of commercial repair manual procedures were considered by the TRW engineers to be not economical, not sound for engineering, or merely not needed. (16:A-6) Commercial manuals were not always better than military manuals, according to this study. Comparisons of manual usability was not undertaken by this study.

An ongoing MRSA study called "Integrated Logistics

Support (ILS) Lessons Learned" records the effects of DMWR usability on integrated logistics support. The following reports are of particular relevance to the research topic, because they have recorded the actual effects of poor DMWR usability:

> DMWRs, that do not represent the latest end item/weapon system configuration because of configuration changes not incorporated into the final DMWR, delay in-house overhaul. (13:7-7)
>
> Many [user-oriented] problems are encountered when the Depots are not involved early in the development of contractor prepared DMWRs. (7:1)
>
> When a technical data package has never been purchased for a piece of equipment, and equipment arrives in a depot for repair, Depots must employ costly reverse engineering procedures to develop technical data. (9-24)

Elements of DESCOM appeared to share these views. DESCOM circulated letters within the Army Material Command (AMC) which stated that commercial maintenance practices (as evidenced in their manuals) in general "incorporate[d] latest state-of-the-art processes," (37:1) and had merit of which the "effectiveness...[should be] explored." (39:1) DESCOM also believed "these practices would probably reduce cost and the lead time necessary to develop DMWRs." (41:1)

The relevance of these claims to the research topic is that they indicated that DMWRs were not well liked by their users. As these claims were written only two months ago, it seems also likely that the same attitudes could still exist. And, these claims must have some validity, since they came from a user. A user is generally in a good position to render a reasonable judgement about something it uses.

However, since this user (DESCOM) provided no verifiable data in defense of its opinions, these opinions must be classified as "subjective" for the time being.

The relevance of the many "objective evaluations" to the research topic is that they tend to show that DMWRS and commercial manuals can be compared, that the previous comparisons have been for aspects other than ease of use, and only insignificant differences to date have been found in the technical aspects of Depot vs commercial manuals.

Comparing Contractor vs Organic Scenarios

The following literature constitutes background on the differences between contractor and depot (organic military) scenarios, so it is indirectly related to the "ease of use of the DMWR." However, it is important to understand in order to judge the commercially developed, military used DMWR.

The policy of the US government regarding contracting is covered in the Federal Acquisition Regulation (FAR). It prescribes policies and procedures for use in acquisitions of commercial or industrial products and services based on Office of Management and Budget (OMB) Circular No. A-76. It provides guidance to DoD and the Army about all aspects of giving or receiving of goods or services, including the preparation of army manuals.

The FAR specifies that work performance standards, upon which much of government technical manuals are based, "must ensure a comparable level of performance for both Government and contractor and a common basis for evaluation." (32:7-4.1) This is relevant to this research topic because it ensures that no one will arbitrarily reduce the required steps in a repair procedure, solely to undercut a competitor's bid proposal. Any repair manual can become very easy to read if it is allowed to contain little or no substance.

The FAR, (based on OMB Circular A-76, chapters 5 and 6) specifies that the government must recognize the differences between the military and the commercial worlds. The US Government must

> (a) rely generally on commercial sources for supplies and services, if certain criteria are met, while recognizing that some functions are inherently Governmental and must be performed by Government personnel, and (b) give appropriate consideration to relative cost in deciding between government and contractor performance. (32:7-4.1)

DoD Directive 4151.1, Use of Contractor and DoD Resources for Maintenance of Material supports this, stipulating that

> prime consideration shall be given to the use of contractor support for indirect (Depot) maintenance ...[and] Depot capacity...shall be kept to the minimum required to ensure a ready, controlled source of competence and resources necessary to meet war. (35:E8, E9)

Army regulations also support this. AR 750-2 Army Maintenance Wholesale Operations, specifies that workload beyond the capability of a Depot may be contracted to commercial sources, but may not exceed 20% of the total dollar value of the authorized in-house job order. (27:5-4) Additionally, The Department of Defense has directed that

> each DoD component's organic Depot maintenance peacetime physical capacity shall be planned to accomplish no more than 70 percent of its gross mission-essential Depot maintenance workload requirements. At least 30 percent...shall be decided on the basis of economy, the timely availability of private, commercial sources, and the need to maintain a commercial industrial mobilization basis. (35:E9c)

These last four references are of particular relevance to the research topic because they require the military to fight becoming a complacent (and inefficient) monopoly, and require that military specifications be honored if possible. Also, these references caution that cost (and, by extension, manual use) comparisons must be done with care and consideration of industry differences. As reported in the TRW/Air Force study discussed above, some specifications in Technical Order manuals and Commercial manuals have been industry specific, and should have been allowed to exist. This finding is applicable to the present as well.

Both the military and commercial sectors have been found to have a similar reliance on an engineering focus for their manuals, rather than a user focus. (46:385) This could contribute to "difficulty of use." However, one researcher still feels that the military has made more progress towards producing effective texts than the commercial sector has. (46:385) The military has

> contributed to the development of specifications for effective designs... provided guidance in explicit detail... achieved consistency of design...and provided detailed rationale for their designs (ineffective as some of them [have been]) The commercial world has not! (46:385)

The private sector has made some relative strides beyond the military in manual readability technology, however. Both Caterpillar Corporation and McDonnell Douglas have developed forms of "simplified English" which they have used for some of their manuals. Their experience is that simplified English "was hard to use at first..and productivity dropped at first, but soon returned to normal." (47:25) The relevance of this information to the research topic is that it shows the relatively radical procedures the commercial World has taken to cut costs, but which still have not especially improved manual usability.

The reports by the Logistics Management Institute (LMI) compared commercial and depot modernization tactics. Though not directly related to "the usability of DMWR," these reports represent a body of data collected on management strategy differences in the two maintenance sectors. These data are important in order to know management's modernization philosophies, which could explain differences in the relative work done to make manuals usable.

The first LMI report surveyed (5:12) outlined the scope, cost and complexity of modern DoD Maintenance depots with emphasis on the ways they have modernized operations to increase cost effectiveness. The report showed that "the same things which have closed private corporations--management complacency, poor business practices, excessive redundancies--exist in Depots." (5:12)

Helicopter component repair cycle times, shown to be "much too lengthy," (5:11) were cited as a result. The report did not consider that maintenance manuals have been shown to have an effect (perhaps an even more direct effect) on repair cycle times than has management. (19:60)

Another LMI report (11) discussed modernization strategies of four Depots and from three major corporations of the private sector. It showed that when either the DoD or the private sector focused first on simplifying "processes" and later introduced automated production and inventory controls, modernization was better realized. (11:iii) Conversely, "several companies even said that they made costly mistakes by prematurely applying high technology to complex, poorly understood processes." (11:4-1) In other words, addressing the problem of high cost Depot repair at the operational process or causal level of the problem is the best approach. "Operational processes" of maintenance are, for instance, manuals that are readable, have many illustrations, and have published "aids" that promote understanding.

The process/product theory applies also for manual writing. Significant research has shown that the product oriented approach to writing (using specifications) is "an inadequate means of controlling the product." (45:76) Rather, research suggests that "the focus must be on the expertise of the writer and on the process of writing" (45:76) to get usable manuals. The manual itself should not be written unless the writer is uniquely capable.

The next LMI report surveyed the "problems and issues that are unique to contractor repair." (15:c-1) The report selected six leading firms with excellent repair management programs which also repaired items comparable to those of

DoD. It found that the commercial sector had "known shorter repair turnaround times" (15:C-2) than did the Depots. "Turnaround time" is the time needed to repair a piece of equipment, and equates roughly to customer satisfaction. The study said that one of the causes of the difference was that companies visited made a "conscious commitment to minimize repair cycle times...at the expense of repair efficiency." (15:D-11) Repair efficiency can be a product of manuals designed for easy use.

Though contractor repair turnaround time was positive, other elements of contractor repair were <u>negative</u> for producing the finest examples of usable manuals. The contractor repair facilities surveyed were characterized by

> diminished control and visibility...[and had problems in] workload forecasting and scheduling, contracting procedures, and performance measurement and visibility. (15:C-1)

These are the same difficulties that the Army has sought to overcome through the use of readability tests and detailed manual specifications. (22:1-7) However, the commercial world has not highly valued these aids to manual development. For the commercial repair facility, "the bottom line [is] profit, and usability [is] a cost burden and [is], at best, only weakly related to sales." (46:386) This study found that the appreciation of manual usability was generally lacking in the commercial world.

The relevance of the foregoing literature to the research topic is that it presents some of the basic, work-related differences between organic military Depots and commercial repair facilities. These differences should be taken into account when judging the usability of a maintenance manual in either sector.

Previous Evaluations of Commercial Manuals in the Depot

Chapter 6 of AR 25-30 specifies when and under what conditions commercial equipment repair manuals may be used in the military. It does not specify that either manual must be chosen based on ease of use or updating, however. It specifies that commercial manuals may be used when they cover the majority of Army requirements, are verified by appropriate testing conducted prior to the procurement of equipment, and are for off-the-shelf commercial items. (22:6)

The MRSA DMWR study (previously addressed) found that commercial manuals have been deficient in data needed for repair/overhaul of Army equipment and have not addressed repair/overhaul in a military environment. (8:2-69) Test information was found to be lacking, especially for electronic equipment; commercial parts lists were incompatible with Army parts list; many needed commercial design illustrations, being proprietary, were not shown for patent reasons; and commercial mechanical tolerances far exceeded those allowable for Army equipment. (8:2-70) All these commercial manual attributes added to the amount of supplementation required for military use, which, the MRSA study implied, have contributed to relative difficulty of use.

It should not be surprising to find that commercial manuals could be harder to use than military manuals. The military has been using lesser educated technicians for a long time--probably longer than "the rest of our technological society," (45:70) the Carnegie Communications Design Center pointed out. Lesser educated military technicians have needed, and have been given, manuals designed to their education levels. On the other hand, commercial mechanics are selected because they are experts, and can understand more complicated procedures. (45:70]

An Air Force Institute of Technology study determined the adequacy of commercial manuals for Air Force intermediate and Depot level maintenance, in 1989. The study conducted an opinion survey among Air Force commercial manual users in the Depots. Sixty percent of the respondents felt that commercial manuals were inadequate. (6:46)

However, the commercial manuals used in the Depots which were determined to be adequate for use by the user actually had not been thoroughly reviewed. (6:viii) Manuals found to be inadequate were reviewed by personnel most thoroughly qualified to review manuals (e.g., the technical order specialist, the equipment specialist, the maintenance technician, and the using command). The manuals found to be "adequate" were reviewed by "personnel having the least knowledge on the day-to-day functions of technical manual development." (6:47) The reason that the commercial manuals were found to be inadequate was that they generally lacked comprehensive maintenance and safety procedures, and did not display the needed information on "hardware accuracy, data rights, and part numbers." (6:47) In any event, the study found that the commercial manuals used were generally not adequate. No attempt was made to compare Depot vs commercial manuals for readability and usability, but the study recommended that a follow-on study be made to do this. (6:53)

The MRSA study (previously addressed) discovered that the Army Depots have accepted commercial manuals with apparently great shortcomings. It found that

> generally, if the commercial manual is adequate in perhaps half or 2/3 of the information needed, it may be judged acceptable by the proponent and user. (8:2-42)

The relevance of the previous two studies to the research topic was that they showed that in both of the existing, available studies where commercial manuals were compared to Depot manuals, the usability of the commercial manuals was seen as suspect. However, though neither study showed that commercial manuals were especially harder to use than Depot manuals, both showed that commercial manuals typically have less information in them. Further research is needed to determine if there are beneficial usability aspects of commercial manuals that could be incorporated into military manual specifications.

Readability Analysis in Technical Manuals

There are many types of evaluation procedures for textual material. Some are better suited to certain classes of publications. However, almost any evaluation is better than none to assess the readability of written material. (62:418)

The choice of which evaluation or combination of evaluations to use should be based on a thorough knowledge of the goal of the verification study. If the results would be used to design or redesign writing systems, many varied tests should be used. If the goal of testing would be a market survey of existing manuals, fewer or less comprehensive (and less expensive) tests might achieve the goal. (62:419) This research study, therefore, would fall into the latter category.

Research has shown that there is "no universally correct way of presenting information." (62:425) Information is communicated to different people under different circumstances, through multiple channels. (62:432) Therefore, it follows that individual evaluation techniques cannot evaluate every possible aspect of a manual. Such is the case with this study. The purpose of this research study is to determine if the DMWR is harder to use than commercial manuals, so the goal would be to find a suitable number of verifiable, comparable characteristics, and simply present the set with the larger number of characteristics.

For the purpose of this research, evaluation testing is indispensable, but otherwise, most publishers are little motivated to use such testing. One of the best established materials evaluation theories is that of Learner Verification and Revision (LVR), which has been promoted for the last decade. It is an editorial philosophy of verifying an individual text's ability to communicate effectively with individuals, based on feedback from learners. (50:397) Although LVR has been lauded by academicians, the initial enthusiasm for LVR "soon dissipated in the face of...apathy and publisher's resistance." (50:410)

Many researchers have denounced most readability formulae. A complete description of their criticisms, and why they do not apply here, follows in the next section.

AR 25-30 requires publications to be edited to make them "more usable, understandable, and readable in accordance with the Army Readability Program." (22:1-20b) However, one study of four commercial publishers of military manuals showed that none had planning goals that took the reader into account, unless the military specification required it. If there was a requirement, it was translated into a maximum sentence length requirement. (45:76)

Notwithstanding this apparent commercial apathy about manual usability testing, over 100 user-oriented design techniques have been used in the military since 1950. (45:70) Experimental evaluation of these techniques has indicated that, when properly implemented, they yield significantly improved manual user performance. (45:70) However, one study showed that the military seldom ever conducted true verifications of their manuals during or after manual development, nor did it often consider audience and task context during document development. (45:75) This was true even when developers knew that consistent coordination between the equipment developer/Depot and the manual writer could make a manual more usable. (45:75)

The point of user testing is that the best manuals are seen as clear and instructive to a broad spectrum of users. (45:74) Inexperienced (or highly experienced) mechanics should be able to use the manuals easily. This way, the manuals are more efficient, as well as easier to use for either set of mechanics.

When evaluation is used, a conventional method is some form of question-and-answer procedure, (62:427) where a skilled examiner or test questions a reader on what he has read. This method is best for text with a strong theme, or much symbology. (62:427) Maintenance manuals have neither of these traits.

For maintenance manuals, a good but expensive method of content evaluation is "task evaluation." (62:428) Through such things as field observations or laboratory tests, data are gathered on how well a task can be performed after it has been described in a text. A significant drawback of this method is that it is almost impossible to be unobtrusive enough as a tester to be able to get unbiased results. (45:75) Therefore, this approach, though good in theory, normally is not used in practice.

One of the most frequently used methods of evaluation is editorial commenting. (62:425) This method is objective, but only gives slight indication of possible textual problems. It also does not compare existing manuals well, as is the aim of this research study.

Another method of evaluation is called "Cloze testing," where random words of a written paragraph are erased, and test subjects write in the omitted words. (62:426) It is an inexpensive, objective test. This method indicates how the structure of a paragraph and its sentences contribute to overall meaning. It is most appropriate in text consisting of paragraphs. (62:426) Maintenance manuals do not generally have long, thematic paragraphs, however, which restricts much use of this test for maintenance manuals.

Wright advocates an evaluation termed "heuristic." (62:422) The heuristic asks an evaluator to judge text based on its supposed power to motivate reading. The more it motivates, the better it is. Demotivators in "Component psychological processes" (e.g., pattern recognition, memory, and comprehension) make a manual less useable. (62:423) In a maintenance manual, motivators of understanding are such things as understanding assistance cues, and illustrations.

The heuristic approach cannot be objectively validated, but its theory is rooted in logic as well as in much psychology research. (62:422) Judging a text's usability based on the heuristic is also quick and easy. As long as a list of "demotivators" is known, then their occurrence in a test can be both counted and compared to examples found in other texts.

"Demotivators" of textual material are such things as the poor placement of illustrations with respect to text, and paragraphs of monotonous text packed together tightly, without helpful cueing devices. To perform the heuristic approach, an evaluator counts the relative occurrence of interest demotivators between two manuals, and makes a comparison.

The term "heuristic" has a negative connotation, because one common definition of it is that it is an aid to problem solving, but otherwise unjustifiable. This is really an unfortunate designation, because in some applications, such as in this research project, the heuristic has ample justification. A more accurate, and equally used definition of "heuristic" is that it is a simple aid, perhaps not exactly precise, but nonetheless serviceable. Further discussion on the justification for using heuristic tests for the purposes of this research study follow in the next section.

Another method of evaluation discussed in the literature is that of readability formulae. Readability tests have existed for years. A complete discussion follows, in the next main subsection of this chapter. Readability formulae are well suited to making quick objective comparisons of two textual passages. (62:431)

The relevance of this information to the research topic is that it tends to support the fact that no verification technique is fail-safe or is sensitive to all readers' abilities or problems with reading, but that even one is far better than none. Certain tests appear to have the highest applicability to technical manual assessment, are typically objective, and lend themselves well to the development of a relatively quick, inexpensive body of data for comparing different manuals. The best tests for this research are Readability formulae, and the heuristic approach for counting illustrations and cue frequency, and the user test, as limited.

The Validity of the Tests to be Used

Readability in texts (Reading Grade Level). AR 25-30 discusses the methods approved for use in measuring the Readability of Army publications. The "approved method" (22:1-28) is the Kincaid Readability formula, which results in a usability score called a Reading Grade Level (RGL). AR 25-30 cautions that using RGLs to measure readability is only a partial indicator of readability (22:1-28), but it still is the only Army approved test with a formula which results in any score which can be validated. Therefore, it is the formula which will be used in this research study.

Studies have shown some shortcomings in readability formulae. (62:423) One study has shown that revising a test to meet readability criteria is "no guarantee of [getting the result of] successful communication. (62:423) By this the writer means that, though the text can be thus quantitatively graded, that is where its utility ends. A host of other factors internal and external to the text can still block learning after the text is evaluated. Another complaint about readability formula is that such tests are extremely simplistic, and do not taking into account the intended use of the manual. (62:423)

Redish (56:46) wrote scathing criticisms in 1985 of the use of readability formulae as the only means of text evaluation. However, the criticisms apply, in every case, to subjects outside the scope of this research study. Redish supported the use of RGL tests for "comparison, objectivity," (56:46), and correlating certain features between texts. (56:49) Redish only supported expensive, difficult user testing, "to test everything...to make the document understandable and useful." (56:51) One of her main arguments was that RGL testing was invalid because it did not test for important comprehension aids, such as "graphics and typography." (56:50) RGL tests were designed for text comparisons, and that is still the approach of this research study.

AR 25-30 stipulates that RGLs of target audiences will be the criteria by which all new manuals will be written, but that an existing publication will not be revised solely to lower its RGL. (22:2-10(1)-(3)) AR 25-30 also says that for equipment repair manuals, the RGL will be for the target audience, but not to exceed RGL 12. (22:2-10b2) And, equipment developers will determine that manufacturers' equipment publications are acceptable for use only when they meet the requirements of MIL-M-7298 (not on the basis of RGLs). (22:2-1062)

The Kincaid readability Formula measures the average words per sentence of a text, compares it to the average syllables per word, and indicates a reading Grade Level (RGL) for text tested (see figure A1). The RGL is a scale from 5 to 34, with each number roughly equal to a grade level in the American school system, until grade 17 (College level)). Numbers above level 17 equates to simple "reading difficulty levels." (22:fig 2-1).

The original Flesch Readability Formula included another, similar test, called the "human interest level," (1:frontispiece) which compared the percent of "personal words" to the percent of "personal sentences" in a text, resulting in a score on "dullness" (see figure A2). Flesch felt that the more "personal" words in a text, the more interesting the text would be. (1:251) The Army rejected this part of Flesch's formula, though current research has shown that personal words in a text increase interest paid to printed material. (60:184)

The emphasis placed on RGLs by AR 25-30 appears to be determined, yet tentative. That is, this test has been authorized, but its wholesale use has been constrained for use only under certain circumstances. This appears to lend precautionary notice, (added to the previous precaution about this method), which should be remembered during the evaluation of data gathered.

Heuristic (Illustrations in texts). Illustrations are important to DMWRs, because illustrations aid understanding in many ways. First and foremost, illustrations "can help the reader get the facts and ideas in the text." (2:182) They help the reader learn the fact or idea, because it has been found that "it is easier to tie a memory to a picture than an idea." (3:91) Illustrations are also essential to "amplify and stress a central theme or idea already expressed in the text." (52:739) Illustrations describe complex objects. In fact, a direct relationship has been found between the necessity of having illustrations in a text, and the complexity of the material to be presented. (52:730) In general, the more illustrations, the better.

Dwyer points out that in over 30 independent studies and 100 experiments conducted, color has been found to be "a viable instructional variable" (Oa:149) which can improve illustrations. Dwyer also points out research in learning theory that shows that learning is more complete and facilitated when there is more realism in the training (O:4). He shows that the simple black and white line drawing, of 8 possible illustration mediums, ranks last in realism and efficiency in facilitating learning (O:5). However, MIL-M-38784B, the military general style specification, stipulates that military illustrations will be used "in lieu of photographs." (32a:3.6.2)

Heuristic (Cuing Aids in Texts). Much has been written in psychology journals about the learning process, and specifically, about the need for "management of the reader's attention [in reading]." (44:192) Management aids such as "typographical cues" help readers understand written material. (44:192)

Understanding is a complex activity which involves the simultaneous process of recognizing, identifying, organizing, and integrating ideas, text, and meanings. (44:193) All these actions compete for a limited amount of human memory space. (44:194) Readers cope with this situation by "allocating their attention differentially to text information." (44:194)

Readers define and decode the organization of a text and internalize the information sequentially, that is, after progressing through the text and encountering the author's meaning cues. (44:195) If the author makes these cues stand out, by underlining them, pointing to them with arrows, or summarizing them by headings, it helps the reader's "understanding workload." (44:194)

Research has shown that when text has no published "cueing aids," readers provide their own. In a survey of 200 randomly selected, used college textbooks, 92% were found to contain cues written in by students. (44:195)

Cues were also found to aid readers interpreting complex tables, graphs, and illustrations (44:199) such as are found in maintenance manuals. These cues "focus the readers attention on the critical components...to break the figure into its component parts and simplify its interpretation." (44:199)

In his studies of the "Physiological Effects of Cueing," Dwyer discusses the foundation principle supporting the modern typesetting practice of double column paragraphing (Oa:153). As the human eye can only sharply focus in a "small foveal region of about 2 degrees, and the rate at which this narrow beam of sharp vision is limited to about 3-5 degrees/second" (Oa:153), the narrower the column, the quicker and more efficient reading is. MIL-M-38784B also requires that "unless otherwise specified, manuals shall be prepared double column." (32a:3.2.2) However, of the 30 technical manuals annotated in the bibliography of this study, including new and old manuals, only 19% of the DMWRs were double column, but 67% of the commercial manuals were double column. The range of dates for the DMWR manuals in double column format is from 1972-1986. The range of dates for commercial manuals in double column format is even greater, from 1973 to 1988.

User Testing and User Perceptions. Much has been written about motivators/demotivators to reading (44:192, 60:184, 0:throughout, 1:throughout). When a reader perceives that a text is easy to read and helpful, he tries hard to use it (and the opposite is also true).

A reader can spend much or little time reading a technical manual, and this attention can be measured. More attention is given to good manuals than to bad. User testing (56 and 46) tests a manual by observing the care and attention given to it by readers.

There is one aspect of user testing employed in this study, namely, gauging the interest effect of RGL, illustrations, and cues on persons who are inexperienced with the manuals. Do these things motivate or demotivate reading? This form of user testing agrees with other descriptions in Redish (56) and Duffy (46), involving an inexperienced user, making observations about a manual's technical usability. However, in this study, user testing does not test techniques, but is used as a vehicle for recording user impressions and reading motivation.

User testing is very well thought of by researchers, because it tests the overall quality of a manual. However, since user testing is so difficult, costly, and time consuming (56:51), this study uses a modified test. This test's biggest divergence from other user testing (described in the literature) is in its method chosen to record observations. The literature describes the use of an independent, trained tester, who records all apparent, important observations of many test takers, using one test, testing one manual. (46) In this study, the "user test" is a self administered test, using a one-person sample (the researcher), testing many manuals, with many tests, and is a careful record of all important observations from the reader.

Under these conditions some bias is possible, because any control elements of the test amount to the self control of the researcher. Therefore, care is taken by the researcher to make as many observations as possible, without prizing whether those recordings represent positive or negative observations. Results from this test (when administered carefully) increase the chance that true interpretations are drawn from data gathered, because its qualitative data couples with the quantitative data of other tests, and helps verify the data.

The preceding discussion of readability, cuing aids, illustrations in texts, and user perceptions is important to this research study because each aspect can help or hinder a mechanic in his job. An overhaul manual with these aids can help the average mechanic understand his work well. Such understanding can mean fewer work errors and quicker work.

Summary

This chapter contains summaries of some of the more significant literature concerning the topic, "the ease of use of the DMWR." It discusses the many differences between the commercial and Depot scenarios, with implications concerning manual formats and judgement of the usability of the DMWR. It shows previous comparisons of Depot and commercial manuals, and shows that relatively few real usability differences have been researched/discovered so far. Many simple methods to do this study exist, and were discussed, with the aim of showing their applicability to evaluating maintenance manuals. Some research findings were presented on the importance of instructional cues, illustrations, readability in texts, and user perceptions, in order to further support a testing procedure for this study. Three tests, readability testing, heuristic tests, and user tests (including text "characteristics" and point size and page layout "observations") seem to be best suited for this research and therefore are the tests used.

CHAPTER III

RESEARCH METHODS

The Data

The data of this research were of two kinds: primary data and secondary data. The nature of each of these two types of data is given below.

The Primary Data. The Depot Maintenance Work Requirements and the commercial maintenance manuals in each commodity area were the sources of primary data. The data were quantitative, such as the number of occurrences of an aspect of usability (i.e. illustrations or cues), an RGL score, or a format style, such as the use of double column paragraphs or the letter point size of the two sets. The data were also qualitative, such as the characteristic style, form, or content which could effect a reader's perceptions about readability or understanding. (56:51) Hereafter, the word "characteristics" relates to the user tests, and the word "observations" relates to the findings for point size and page layout (double column paragraphs).

The Secondary Data. The secondary data were published studies, reports, texts, and articles, and the unpublished user letters and messages dealing with specifications, contracting-out, previous attempts at manual evaluation, and usability evaluation theory. The data were qualitative, representing theories, ideas and concepts.

The Criteria for admissibility of the Data

Only published DMWRs and published commercial maintenance manuals for diesel truck engines, helicopter turbines, and radio receivers/transmitters, were used in this study.

The Research Methodology

Wright pointed out that certain tests for quantifying the usability and readability of texts could be used better by certain researchers and applied better to certain research projects. (62:427) While it was admitted that "almost any evaluation is better than none", (62:418) the choice of assessment procedure would have to take into account the "certain classes of...communication that might be crucial for that text...in order to attain the specific [research] objective". (62:418)

As the aim of this research study was to compare competitive texts, the choice of techniques for this study was based upon selecting those tests and theories that compared texts. The tests which were chosen were suited to measuring relative quantities of common attributes of manuals, e.g., short paragraphs, many illustrations, and extremely specific textual passages.

Redish and others adamantly championed user testing as a test available "to test everything [well]", (56:51) and an attempt was made in this research effort to provide some aspect of user testing, commensurate with the study's scope. The researcher, representing an "inexperienced" reader of the publications (45:74), recorded many characteristics of the manuals which seemed to be either easy or difficult to read or understand, or which could be either easy or difficult for another reader. These "characteristics" (anything that makes reading productive, tiresome, fun, or difficult, etc) have been shown in the research to positively or negatively motivate a reader to read. (62:422) The remainder of this study will use the terms "positive" and "negative" reading motivators when discussing these characteristics.

The fact that these data were collected only from one observer does not necessarily mean that the sample size was unacceptable, because the data came from a large sample of manuals. No attempt was made to unnaturally "manufacture" comments to record, nor was any attempt made to balance the record of positive or negative motivators, nor was any attempt made to record data supportive of any bias of the researcher. However, the "characteristics" were required to be logical, supported by research known at the time, and substantive. The bulk of the readability characteristics from the user tests (see Appendix J) were based on a set locus of research questions.

Leedy defined the research method most appropriate for collecting data from simple physical observations as the simple survey, and specifically, the descriptive survey. (4:88) This was the method used in this study. Primary data sources for this study were surveyed with tests of usability, e.g., the Kincaid Reading Grade Level (RGL) formula, and two heuristic counting tests, for illustrations and instructional cues. "Characteristics" (such as those that might be made in a user test by any average, inexperienced reader) and "observations" (those of either viewing of the user test, of point size data, or page layout style) were collected by the researcher as they became evident in the research data collecting effort.

Specific Treatment of the Data for Each Subproblem

Subproblem one. The first subproblem was to determine the relative simplicity of the manuals, as in their ease of readability.

The Data Needed

The data . eded for solving subproblem one were the RGLs of a cross section of selected DMWRs in each of the three equipment categories, the RGLs of a cross section of selected commercial manuals in each of the three equipment categories, and the user test observations and characteristics from each of the manuals. Five manuals each from both the Depot and commercial sector for each of the three equipment categories were compared, so that a reasonably representative sample size was studied and therefore any significant bias was reduced.

The Location of The Data

DMWRs were located in Army Material Command/Major Subordinate Command (AMC/MSC) Publications Centers at the following addresses:

1. Commander, USA Aviation Systems Command AVSCOM
   Attn: AVSAV-MCTP
   4300 Goodfellow Blvd
   St Louis, Mo 63120-1798

2. Commander, USA Tank and Automotive Cmd TACOM
   Attn: AMSTA-MBC
   Warren, MI 48397-5000

3. Commander, USA Communications/Electronics CECOM
   Attn: AMSEL-LC-ME-P
   Fort Monmouth, NJ 07703-5000

Commercial manuals were located at the following commercial business addresses:

1. Superior Diesel Service
   2106 E Main Street
   Richmond, Va
   phone (804) 643-4021

2. Commonwealth Jet Services Co
   Sandston, Va
   phone (804) 222-5474

3. Aero Services
   Richmond Airport
   Richmond, Va
   phone (804) 226-7231

4. Dominion Communications Systems
   135 Pickwick Ave
   Colonial Heights, Va
   phone (804) 526-6373

The Means of Obtaining the Data

A letter was sent to each DMWR manual owner requesting six DMWRs, by designation and number. These were sent, studied, and returned (if return was requested). For commercial manuals, the above mentioned distributors were visited, and the manual was surveyed in the distributor's office. Data relating to each of the six tests (RGLs, illustrations, cues, user test characteristics, point size observations, and page layout style preferences) were collected from the manuals.

The Treatment of the Data

Only the two manual sets in the three categories were used. Individual manuals were selected from these categories by a random choice from DA PAM 25-30, Consolidated Index of Army Publications, 30 Jun 1989. The choice was made from the subheadings: Engines, Diesel; Engines, Aviation; and Radio, Receiver. Six selections each were made, then their military designations were cross-referenced to DMWR designations from AMC PAM 310-9, Index to DMWRs in Print, 1989. However, when the requested manuals were not available, alternates (judged acceptable by the above criteria) were accepted.

How the Analysis was Made

The RGL usability test was performed separately on each manual. The scores were entered into the summary table (see Appendix E). An average of the scores was determined for each commodity, test and repair sector. These were also entered into the summary table.

The following formula was used to calculate the RGL:

> Select a 150 word passage. Begin with a paragraph or selection and continue to the end of a complete sentence, even though it may exceed 150 words

STEP 1

Figure the average sentence length. (Divide the number of words by the number of sentences.)

(150 / 10 = 15)

STEP 2

Figure the average number of syllables in each word. Count numbers as one word. Count acronyms and abbreviations as one syllable unless they spell a word of more than one syllable. Count the syllables. Divide the number of syllables by the number of words

(300 / 150 = 2.0)

STEP 3

Compute the RGL on the nomograph (see appendix C). Connect words per sentence and syllables per word using a straightedge. The point where the line crosses the RGL scale showed the reading grade level.

(RGL = 13.7) (22:fig 2-1)

The following rules were followed for the counting of RGLs:

1. Count syllables the way the word is divided in the dictionary, the way the word would correctly be spoken.

2. Count numbers as one word.

3. Count acronyms and abbreviations as one syllable, unless they spell a word of more than one syllable. For instance, TRADOC (Training and Doctrine Command) constituted 2 syllables, CINCEUR (Commander in Chief, Europe) constituted 2 syllables, and SQT (Skill Qualification Test) constituted one syllable. (22:fig 2-1)

4. Count the next closest suitable page if an illustration page was identified to be used.

5. Count each non-blank page individually.

6. A 150 word passage could be an entire page of many small paragraphs.

7. Select a starting point for counting at random on the page.

8. Count titles/headings that come within the selection body, but ignore figures.

9. Count hyphenated words as two words, and hyphenated words or numbers as one syllable either side of the hyphen.

10. Count titles as one sentence if they contained more than one word or if they headed a multi-paragraph section.

11. A "note" or "caution" heading belonged to the following sentence, and was therefore not counted as a whole sentence, even if it preceded a note or caution statement of more than one paragraph.

12. A colon or semicolon did not constitute a sentence break.

13. In DMWRS, count titles as two words (DMWR plus number), even though the title contained many hyphens. Count paragraph, figure, and title number designations (i.e., 5-46) as one word and one syllable. Count National Stock Numbers (NSNs) as two words and two syllables (NSN plus #).

14. If the DMWR was too small to have 14 sample pages, but mentioned a Technical manual (TM) which was used to amplify the DMWR, then count the TM as an integral part of the DMWR.

15. Count misspelled words as they should be, not as they were represented in the text.

16. Do not count RGLs (or pages, cues, or illustrations) of an appendix, index, or table of contents.

Sample Size

To select a manageable sample size, and to facilitate a sampling variance from the true score which would be as small as possible, the following procedure was selected. An arbitrarily chosen range of allowable percent variances between 0 and 15 was plotted on the x axis of a graph (see appendix I). An arbitrarily chosen range of sample sizes between 0 and 16 was plotted on the y axis. The sample size corresponding to the intersection of the 5th percent variance level and a derived concave frequency distribution was selected. The sample size of 14 was derived by averaging 10 random RGL samples from one manual as a standard, then plotting the percent difference from other sized samples against it on the graph. RGL samples above size 14 produced small changes in x. A variance of 5% was selected, and this is also a commonly accepted allowable variance (3a:507).

The following procedure, called "percentile page determination" was used to sample each manual for data for the RGL only. This was a modified version of the sample selection criteria from MIL-M-38784B, changed to allow for a larger sample size (32a:4.4.1). Characteristics, observations, illustrations, and cues were not collected based on the percentile page method. Their occurrences were not uniform enough, throughout the manuals.

The percentile page procedure allowed equitable sampling for RGLs from each section of the manual, and allowed a large sample size. The sampling procedure also kept sample sizes both manageable, and of equal size between each manual. This was very important, because some of the manuals varied in size by hundreds of pages.

First, the number of pages in the manual was determined.

Then, that number was multiplied by .077 (7.7%) so as to divide the manual into "percentile pages". The figure .077 was derived so as to yield 14 equal samples. If the number computed included a fraction, the score was rounded to the nearest whole integer. Pages corresponding to the 7.7th percentile page were the only pages studied. By this method, only 14 pages were sampled per manual. In every manual the first page was always treated by the tests.

Characteristics and observations were counted, based on the following rules:

1. Scan throughout each manual once for general positive or negative motivators, and record each impression, regardless of its apparent magnitude.

2. Record characteristics in Chapter IV, under findings relating to the three quantitative tests. Record observations and general characteristics in separate sections in Chapter IV.

3. Scan no more than 30% of the manuals at one sitting, so that fatigue does not influence the record.

4. Randomize the manuals, and alternate between Depot and Commercial manuals during the scan, to further reduce the opportunity for user (reader) bias.

5. Scan only two pages of each manual (one with significant verbage, and one with a significant illustration) and test each for any significant impressions relating to each of the following topics:

negative motivators	positive motivators
a. Incomprehensible sentence meanings.	aa. Excellent illustrations.
b. Light, small, or blurry lettering.	bb. Precise words.
c. Too few words for completeness.	cc. Aura of professionalism.
d. Too many words to be considered brief.	dd. Bold, crisp lettering.
e. "Busy" (confusing) illustrations.	ee. Layout motivates respect.
f. Annoying style or form of any kind.	ff. information motivates respect.

6. Record characteristics obtained from paragraph four in appendix J.

Because these characteristics were essentially subjective, weights were not assigned to them. Positive characteristics, or those which helped understanding or motivate reading, were assigned a +1 score. Negative characteristics, or those which did not help understanding or motivate reading, were assigned a -1 score. All scores were added, and a final score was given. Manual final scores (for this test) were converted into a percentage of the total of the characteristics and observations made, to yield comparable negative and positive percentages.

How the Data Were Interpreted

Any differences in RGL, illustration or cue scores were tested for significance by using the Two-Way Analysis of Variance (ANOVA) test. (3a:503-508) This test was used because it compared differences between manuals within a repair category as well as between Depot and commercial manuals.

The independent Two-Way ANOVA statistic showed the true relationship between the variables of repair sector and equipment category. In this test, the mean of each variable was taken, and the ANOVA test determined the statistical difference between the two means. If at least one significant difference was shown, its related hypothesis was rejected. This was repeated for each of three tests. Characteristics and observations user tests were not verified by the ANOVA test.

For the ANOVA tests, the scores for each of the five manuals within one equipment commodity were averaged, and placed in the ANOVA table (see appendix F). Formulas (see appendix F) were applied, and the results were placed in the ANOVA summary table (see Appendix F).

The summary table provided two calculated scores for the ANOVA test: Ft, comparing the treatment of commercial and military manuals against repair scenarios, and Fb, comparing the three commodity blocks against each other. These two statistics were compared to an F distribution table (see Appendix H) showing numerator and denominator degrees of freedom, and a .05 area in the upper tail, $F_{.05}$. A larger Ft or Fb value than the table F value would cause the hypotheses to be rejected.

Validity of the Counts

In each manual, one page was checked for counting errors by a person who did not make the original count. If that page count differed from the original count by more than 2%, another page was be counted. If that count differed by more than 2%, then all counted pages in that manual were recounted. This helped ensure correct counts. One manual's results were outside the 2% tolerance, and it was recounted.

All mathematical computations were checked by being performed a second time. This helped ensure accurate computations. Each time information was transferred from collection sheets to the draft study, the figures were double checked to ensure that there were no erroneous transferals.

Subproblem Two. The second subproblem was to determine the relative number of illustrations per manual between manual sets (commercial vs DMWR).

The Data Needed

The data for solving subproblem two were illustrations in each manual, converted to a number of illustrations per page per manual.

The Location of the Data

The locations of the manuals were the same as for the first subproblem.

The Means of Obtaining the Data

The means of obtaining the data were the same as for the first subproblem.

The Treatment of the Data

The total number of illustrations in each manual was counted and converted into a percentage. The scores were placed in the summary table (appendix E).

The definition of an illustration to be counted as a single entity was:

1. The illustration was a procedural, descriptive graphic, which took the form of a blown up picture, a figure, a table, or a list.

2. The graphic was accompanied by its own sequential number, recorded below, above, or beside it.

3. The graphic was referred to in the text.

How the Data were Interpreted

The interpretation of data was the same as for the first subproblem.

Subproblem Three. The third subproblem was to determine the frequency of use of any aids of understanding in the texts, such as cues, marginalia, and/or underlining.

The Data Needed

The data for solving subproblem three was the number of cues per page per manual.

The Location of the Data

The location of the data was the same as for subproblem one.

The Means of Obtaining the Data

The means of obtaining the data was the same as for subproblem one.

The Treatment of the Data

The item analysis was made as described in subproblem one. The following rules were followed in determining the constitution of a cue:

1. A cue was either an underline of a title or an idea, boldface type of a title or idea, or an arrow or other typographic accentuator, used for the purpose of accentuation, or a footnote.

2. A cue was a published part of the original manual.

3. A cue was reasonably obvious to see at a casual glance.

4. For pages written only in boldface or with all words underlined, only cues were counted that were significantly different in appearance from the rest.

5. Multiple, underlined column head subtitles on one sentence plane (such as a table heading) were counted as one cue.

6. A cue, highlighted to make it more visible, constituted two cues.

7. Page numbers were not cues, but page headings were cues.

8. Entire paragraphs, which were highlighted, were counted as one cue, not a paragraph of cues.

9. Only words, not acronyms, were counted as cues.

How the Data Were Interpreted

The data were interpreted as stated in subproblem one.

CHAPTER IV

RESULTS OF THE STUDY

Introduction

This research study compared classes of equipment overhaul manuals of the US Army Depot maintenance system with corresponding classes of manuals of the US commercial equipment maintenance system to determine if Depot overhaul manuals were more difficult to use. A review of the significant related literature indicated that such a comparison was both possible and needed: "possible" because other studies made general comparisons of the two manual sets but did not compare usability, and "needed" because the proponent for Depot manuals (DESCOM) has no published research data to support its belief that Depot Maintenance Work Requirements are less desirable (harder to use) than their commercial counterpart manuals.

Manual Owner Response. Because of the method used to sample the population of overhaul manuals from the Depot and commercial sectors, 100% of the samples requested for use in this research study were obtained and studied. That is, thirty manuals were requested for study, and thirty manuals were received. Furthermore, the owners of the manuals responded quickly and accurately to provide the manuals for the research. In a few cases the exact manual requested was either not available or was unsuitable for the research (i.e., it specialized in subjects only indirectly related to equipment overhaul). However, replacement manuals were randomly chosen and of the correct specifications, which fulfilled the selection objectivity requirement.

The Tests Used. The related literature described verifiable usability tests that were used for comparing the two sets of manuals: the (standard US Army) Kincaid Reading Grade Level (RGL) test, Heuristic tests to compare the frequency of use of illustrations and of instructional cues, and a modified user test. The results of all but the last of these tests were compared using the Two-Way Analysis of Variance (ANOVA), at the 1st and 4th degrees of freedom, to determine the degree of difference between the two manual sets. The last test, being essentially qualitative in nature, was not tested with the Two-Way ANOVA. Since this test required only comparisons of simple percentages made of the differences between the lists of "positive" and "negative" motivators, no statistical test was necessary.

The findings, ANOVA test summary, and treatment of the hypothesis for each of the tests appear below. After each "treatment" and "hypothesis" appears a compilation of user-test discovered characteristics related to that subject. Each test of the research methodology produced findings which, when interpreted together, provided a plausible response to the hypotheses stated in this study.

Reading Grade Level (RGL)

Findings. The first hypothesis of the study stated that there was no significant difference between the commercial and Depot manuals' readability, as measured by a comparison of their reading grade levels. Determining the validity of this hypothesis required comparison of Reading Grade Level (RGL) data collected from the sample population. The results are summarized in Table 1, which compares the average overall RGL for the commercial and Depot commodities of truck engines, aircraft engines, and radio receivers/transmitters. The individual RGL scores were averaged from 14 RGL samples in each text. (See Appendix L for complete results.) Smaller values are better than larger values.

The Table shows that the RGL average for commercial truck engines was 1.9 grades lower than the Depot average; for commercial aircraft manuals the RGL was 0.2 grades lower than the Depot average; and for commercial radio receivers/transmitters the RGL was 1.1 grades higher than the Depot average.

Table 1
RGL DATA SUMMARY

The Three Sample commodities	# of text copy	RGL for repair sectors: COMM	DEPOT
TRUCK ENGINE	1	6.0	9.0
	2	5.5	10.0
	3	8.8	8.7
	4	8.5	8.8
	5	8.0	10.1
Commodity Ave	$\bar{X}$	7.4	9.3
AIRCRAFT ENGINE	1	9.0	9.0
	2	8.8	8.7
	3	8.0	9.1
	4	8.8	9.3
	5	10.3	9.9
Commodity Ave	$\bar{X}$	9.0	9.2
RADIO TRANSMITTER /RECEIVER	1	9.8	10.1
	2	11.4	10.4
	3	9.2	6.7
	4	10.7	7.8
	5	10.4	11.0
Commodity Ave	$\bar{X}$	10.3	9.2

Anova test. To test hypothesis one, the ANOVA test was performed to measure significant differences. (3a:503-508) Table 2 summarizes the ANOVA test data. The Table shows the data collected from the Grand Means and the *F* statistic calculations. The critical value in the Table was derived from the table in Appendix H.

Table 2
Two Way ANOVA Data for RGL

Block	MILITARY MANUAL	COMMERCIAL MANUAL	ROW TOTALS	ROW MEANS $\bar{X}$
Truck Engines (TE)	9.3	7.4	16.7	8.35
Aircraft Engines (AE)	9.2	9.0	18.2	9.1
Radio Receivers (RR)	9.2	10.3	19.5	9.75
Column Totals	26.7	27.5		
Column Means $\bar{X}$	8.9	9.2		

Grand Mean $\bar{\bar{X}} = (\bar{X}_1 + \bar{X}_2) / 2$ (columns) $= 9.05$

Grand Mean $= (\bar{X}_{TE} + \bar{X}_{AE} + \bar{X}_{RR}) / 3$ (rows) $= 9.07$

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Test Statistic
Treatments Military & Commercial	0.135	1	0.135	$F_t = 0.118$
Blocks TE, AE, RR	1.962	2	0.981	$F_b = 0.855$
Error	2.293	2	1.147	
Total	4.39	5		

For formulas, see Appendix F.

The critical value from Appendix H, with 1 and 4 Degrees of Freedom, equals 7.71.

Hypothesis. With 1 and 4 degrees of freedom at the 0.05 level of significance, the critical value of 7.71 was obtained from Appendix H. If the value calculated using the Two-Way ANOVA test was less than or equal to the critical value, the hypothesis should be accepted (fail to reject) (3a:507). The calculated values of 0.118 for treatments and 0.855 for blocks were both much lower than the critical value. Therefore, the stated hypothesis was accepted. There were no significant differences between the RGL (i.e. readability) of commercial overhaul manuals and Depot overhaul manuals.

Related Characteristics. The following characteristics of commercial manuals represent the opinion of a manual user (the researcher) recording aspects of the manuals especially negative (or positive) to reader motivation (for additional characteristics, see Appendix J). All of the characteristics in this set represent the initial of two viewings, and record only observations relating to RGL. (The first three "characteristics" are negative motivators for commercial manuals.)

1. Detroit manuals had long paragraphs and much writing per page. Less writing is considered better.

2. Mack manuals had extremely complex instructions and wordy sentences.

3. Perkins and Pratt Whitney manual letter point sizes were so small, the manuals were hard to read.

The following characteristics of Depot manuals were especially negative to reader motivation:

1. CECOM DMWR 11-6625-2917-5 had many typographical errors in it.

2. Most DMWRs were laid out in 8 1/2 inch, margin to margin sentence lengths. This contributed to eye strain. Only 19% of the DMWRs studied used double column style (3 of 16), whereas 67% of the commercial manuals studied used double column style (10 of 15).

The following characteristics of commercial manuals were especially positive to reader motivation:

1. Caterpillar manuals, written in "Caterpillar Fundamental English," had very little unexplained jargon.

2. Caterpillar manuals had step by step procedures which were extremely easy to follow.

3. Perkins manuals were written usually in one sentence paragraphs. This tied one thought to one repair step.

The following observation of Depot manuals was especially positive to reader motivation:

1. The point size for the letters in DMWR words was in most cases larger than that for the letters in commercial words. Larger letters were easier to read. For instance, the average point size for DMWRs in this study was 7.4, with a size range of 7 to 8. The average point size for commercial manuals in this study was 6.53, with a size range of 4 to 7. There was an 11.8% difference between the point sizes of Depot and commercial manual letters.

Analysis for Reading Grade Level (RGL)

Use of the Two-Way ANOVA statistical test on the RGL data collected from DMWRs and comparable commercial overhaul manuals revealed that there was no statistical difference between the two manual sets. The largest difference between any set of manuals occurred between commercial and Depot truck engines (1.9 RGLs). The smallest difference was between commercial and Depot aircraft engines (0.8 RGLs). The greatest variance within this test was between a commercial truck engine manual (RGL 5.5), and a Depot truck engine manual (RGL 10.1). The highest and lowest RGLs were, respectively, a commercial truck engine manual (RGL 5.5), and a commercial radio manual (RGL 11.4).

These findings indicated that some differences existed between the manuals. However, when taken as a whole, manual sets were found to be not significantly different. Both individual manuals and manual sets exhibited positive and negative quantitative and qualitative characteristics, and their differences averaged out. The only differences that seemed appreciable were the point size and page layout comparisons. The DMWRs appeared to be more consistent and consistently better, in point size comparisons. However, as MIL-M-38784B stipulates that "[DMWRs] shall be such as to provide for a minimum final letter size, when printed, of 8 points", (32a:3.6.1.1) and this research study showed that 60% of the manuals were below that standard, DMWRs could be improved by having sizes of at least 8 points. Commercial manuals appeared to be more consistent and consistently better in page layout comparisons. This finding seemed strange, since MIL-M-38784B stipulates that "unless otherwise specified, manuals shall be prepared double-column". (32a:3.2.2) Only 3 of 15 DMWRs had a double column layout. (See page 67 for the other results.)

The RGL values ascended from trucks to aircraft to radios, and this rise in RGL value held logically over commodities, parallelling technological difficulty between commodities. It was surprising to find that the commercial overhaul repair sector's manuals generally had lower RGLs than did the Depot's, in light of Duffy's research showing that commercial manuals tend to have only a cursory interest in usability. (46:386) It would seem logical that if the commercial sector did not particularly care about having a low-RGL value manual, it would not have had one.

The overall finding, that there was no difference between the sets, lends doubt to Gringas' assertion that the "simplified Code English" of many manuals (i.e., Caterpillar manuals) is significantly different from the English of DMWRs. (47:25) In the user test portion of this research study, Caterpillar "Code English" was compared to the language in other commercial and Depot manuals, and although Caterpillar manuals seemed very easy to use, there appeared to be no differences in the language used.

Duffy claimed that the commercial world generally lacked appreciation for manual usability, but Depots have some appreciation for it. (46:386) However, three commercial manuals surveyed included usability questionnaires in their texts, whereas no DMWRs had them--but every DMWR did have some sort of short statement encouraging user comments. (see

Appendix J) No other commercial manuals made this attempt.

The overall findings seemed to support the TRW study, which also discovered few (if any) significant differences between Depot and commercial aircraft overhaul manuals. (16:2) Additionally, both sets of manuals appeared to have similar faults. The user test portion of this research study showed that commercial and Depot aircraft manuals had approximately the same style, layout, format, and even vied jointly for having the most imprecise words and ungrammatical sentences. (See Appendix J)

By strict count of this user test data only, commercial manuals exhibited more characteristics positive to reader motivation than DMWRs did, but both were equal for negative motivators. Since negative characteristics received an unweighted value of -1, and positive characteristics received an unweighted value of +1, Depots received a user test score for RGLs (in this viewing) of -1, and commercial manuals received a score of 0. These results are not appreciably different.

Illustrations.

Findings. The second hypothesis of the study stated that there was no significant difference between the commercial and Depot manuals' readability, and was measured by comparing the frequency of manual illustrations. Determining the validity of this hypothesis required comparison of Illustration Frequency data collected from the sample population. The results are summarized in Table 3, which compares the average overall illustration frequency for the commercial and Depot commodities of truck engines, aircraft engines, and radio receivers/transmitters. The individual illustration scores were recorded as a number of illustrations per page. The Table shows that the average illustration score for commercial truck engines was 1.1 higher than the Depot average; for commercial aircraft engines it was 0.2 lower than the Depot average; and for commercial radio receivers/transmitters it was 0.1 lower than the Depot average.

Table 3
ILLUSTRATION FREQUENCY DATA SUMMARY

The Three Sample commodities	# of text copy	Illustrations per page for: COMM	DEPOT
TRUCK ENGINE	1	1.8	0.5
	2	1.4	0.6
	3	1.6	0.8
	4	1.9	0.3
	5	1.3	0.4
Commodity Ave	$\bar{X}$	1.6	0.5
AIRCRAFT ENGINE	1	0.4	0.8
	2	0.4	0.5
	3	0.4	0.6
	4	0.4	0.4
	5	0.6	0.5
Commodity Ave	$\bar{X}$	0.4	0.6
RADIO RECEIVER/ TRANSMITTER	1	0.5	0.8
	2	0.2	0.6
	3	0.6	0.5
	4	0.8	0.3
	5	0.1	0.2
Commodity Ave	$\bar{X}$	0.4	0.5

<u>Anova test</u>. To test hypothesis two, the ANOVA test was performed to measure significant differences. (3a:503-508) Table 4 summarizes the ANOVA test data. The Table shows the data collected from the Grand Means and the *F* statistic calculations (see appendix F). The critical value in the Table was derived from the table in Appendix H.

Table 4
Two Way ANOVA Data for Illustrations

Block	MILITARY MANUAL	COMMERCIAL MANUAL	ROW TOTALS	ROW MEANS $\bar{X}$
Truck Engines (TE)	0.5	1.6	2.1	1.05
Aircraft Engines (AE)	0.6	0.4	1.0	0.5
Radio Receivers (RR)	0.5	0.4	0.9	0.45
Column Totals	2.4	1.6		
Column Means $\bar{X}$	0.8	0.53		

Grand Mean $\bar{\bar{X}} = (\bar{X}_1 + \bar{X}_2) / 2$ (columns) $= 0.665$

Grand Mean $= (\bar{X}_{TE} + \bar{X}_{AE} + \bar{X}_{RR}) / 3$ (rows) $= 0.67$

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Test Statistic
Treatments Military & Commercial	0.109	1	0.109	$F_t = 0.413$
Blocks TE, AE, RR	0.435	2	0.218	$F_b = .8265$
Error	0.528	2	0.264	
Total	1.072	5		

For formulas, see Appendix F.

The Critical Value from Appendix H, with 1 and 4 Degrees of Freedom, equals 7.71.

Hypothesis. With 1 and 4 degrees of freedom at the 0.05 level of significance, the critical value of 7.71 was obtained from Appendix H. If the value calculated using the Two-Way ANOVA test was less than or equal to the critical value, the hypothesis should be accepted (fail to reject) (3a:507). The calculated values of 0.413 for treatments and 0.826 for blocks were both much lower than the critical value. Therefore, the stated hypothesis was accepted. There were no significant differences in the frequency of illustrations between the commercial overhaul manuals and Depot overhaul manuals.

Related Characteristics. The following characteristics of commercial manuals represent the opinion of a manual user (the researcher) recording aspects of the manuals especially negative (or positive) to reader motivation (for additional characteristics, see Appendix J). All of the characteristics in this set represent the initial of two viewings, and record only observations relating to illustration frequency. (The following two "characteristics" of commercial manuals were especially negative to reading motivation).

1. Caterpillar manuals did not have numbered illustrations or figures.

2. Allison manuals had no illustration index, and tables, figures and illustrations were scattered throughout the text.

The following characteristics of Depot manuals were especially negative to reading motivation:

1. Illustrations, no matter how small, were placed on a page their own. This caused separations of text and illustrations.

2. DMWRs used only black and white, line drawings.

3. DMWR pages were not headed by a title which defined the work being done. Since there were no illustrations on the same page as the text, it was very hard to keep the many different operations within one manual separated, especially since illustrations separated from text caused the reader to have to turn a lot of pages.

4. Some DMWRs had no table of illustrations, though this table is required by MIL-M-38784B.

The following characteristics of commercial manuals were especially positive to reader motivation:

1. Cummins manuals had the same illustration format for each page: one repair step, one illustration. Cummins also placed a multi-language pictorial instruction symbol by each picture, making pictures and instructions not only very simple, but also more understandable in multi-lingual settings.

2. Detroit manuals had only high resolution black and white photographs for illustrations.

3. Caterpillar and GE manuals had some color in their illustrations.

The following characteristics of Depot manuals were especially positive to reader motivation:

1. AVSCOM DMWR 55-2835-209 was written in double

column paragraphs with illustrations interspersed with text.

2. No illustration was reduced in size simply to make it fit with the text.

3. CECOM DMWR 11-5805-722-34 (and the TM) had double column paragraphs and black and white photograph illustrations interspersed with text. Its TM had higher quality type and illustrations than the DMWR did.

Analysis for Illustration Frequency

Use of the Two-Way ANOVA statistical test on the illustration data collected from DMWRs and comparable commercial overhaul manuals revealed that there was no statistical difference between the two manual sets. The largest difference between any set of manuals occurred between commercial and Depot truck engines (1.1 more illustrations per page in commercial manuals). The smallest difference was between commercial and Depot radio receivers/ transmitters (0.1 more illustrations per page in Depot manuals). The greatest variance within this test was between a commercial truck engine manual (1.9) and a Depot truck engine manual (0.3). The highest and lowest illustration frequency were, respectively, a commercial truck engine manual (1.9 illustrations per page), and a commercial radio manual (0.1 illustrations per page).

These differences (although statistically insignificant) indicated that commercial and Depot truck engine manuals were the most variable and different. The qualitative test supported this finding, because it seemed to indicate that these manuals were the most positively motivating, being impressively and professionally laid out and instructive.

Apparently, commercial manual writers, not constrained by rigid manual specifications, included illustrations to clarify text (the purpose of illustrations), and not simply to fulfill a specification mandate. It appeared to be true for illustrations in DMWRs that they often appeared to be cursory, almost an afterthought. In this respect, the MRSA study contention that DMWRs could be improved, (8:iv) seemed to be supported. DMWRs could have better illustrations such as good photographs and illustrations closer to the text and interspersed with the text. Commercial manuals often had these characteristics.

It was surprising to find that commercial aircraft manuals, usually published through high technology, modern, financially stable companies and made for expensive, tightly controlled equipment, did not make better or greater use of illustrations. Illustrations can rivet and focus the attention of any mechanic, and therefore are a great means of multiplying the effectiveness of any manual. It was not surprising to find that the illustration frequency rose respectively from low to high in radios and trucks. This progression seemed to correlate well with the conceptual difficulty of the respective repair technologies.

By strict count (for this data section only), commercial manuals exhibited more characteristics positive to reader motivation than DMWRs did, and fewer negative characteristics. Since negative characteristics received an unweighted value of -1, and positive characteristics received an unweighted value of +1, Depots received a user test score for illustration frequency (in this viewing) of -1, and commercial manuals received a score of +1. The test scores did not appear to be appreciably different.

Cues.

Findings. The third hypothesis of the study stated that there was no significant difference between the commercial and Depot manuals' readability, measured by the manuals' use of aids to understanding (cues). Testing this hypothesis required comparing cue data collected from the sample population. These data are summarized in Table 5. This Table compares the average overall cue frequency for the commercial and Depot commodities of truck engines, aircraft engines, and radio receivers/transmitters. The individual cue scores represent the number of cues per page. Larger values are better than smaller values. The Table shows that the average cue score for commercial truck engines was 0.8 higher than the Depot average; for commercial aircraft engines it was 0.3 lower than the Depot average; and for commercial radio receivers/transmitters it was 0.8 higher than the Depot average.

Table 5
CUE FREQUENCY DATA SUMMARY

The Three Sample commodities	# of text copy	Cues per page for: COMM	DEPOT
TRUCK ENGINE	1	5.5	3.0
	2	6.8	5.9
	3	4.7	3.3
	4	2.2	2.7
	5	5.0	5.1
Commodity Ave	$\bar{X}$	4.8	4.0
AIRCRAFT ENGINE	1	4.0	5.0
	2	5.0	3.8
	3	3.3	3.7
	4	2.6	3.5
	5	2.5	3.2
Commodity Ave	$\bar{X}$	3.5	3.8
RADIO RECEIVER/ TRANSMITTER	1	6.4	9.2
	2	7.4	2.7
	3	6.0	4.2
	4	3.2	3.9
	5	5.1	3.8
Commodity Ave	$\bar{X}$	5.6	4.8

Anova test. To test hypothesis two, the ANOVA test was performed to measure significant differences. (3a:503-508) Table 6 summarizes the ANOVA test data. The Table shows the data collected from the Grand Means and the *F* statistic calculations (see appendix F for the formulas). The critical value in the Table was derived from the table in Appendix H.

Table 6
Two Way ANOVA Data for Cues

Block	MILITARY MANUAL	COMMERCIAL MANUAL	ROW TOTALS	ROW MEANS $\bar{X}$
Truck Engines (TE)	4.0	4.8	8.8	4.4
Aircraft Engines (AE)	3.8	3.5	7.3	3.65
Radio Receivers (RR)	4.8	5.6	10.4	5.2
Column Totals	12.6	13.9		
Column Means $\bar{X}$	4.2	4.63		

Grand Mean (columns) $\bar{\bar{X}} = (\bar{X}_1 + \bar{X}_2) / 2 = 4.415$

Grand Mean (rows) $= (\bar{X}_{TE} + \bar{X}_{AE} + \bar{X}_{RR}) / 3 = 4.417$

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Test Statistic
Treatments Military & Commercial	0.276	1	0.276	$F_t = 1.34$
Blocks TE, AE, RR	2.40	2	1.20	$F_b = 5.83$
Error	0.412	2	0.206	
Total	3.087	5		

For formulas, see Appendix F.

The Critical Value from Appendix H, with 1 and 4 Degrees of Freedom, equals 7.71.

Hypothesis. With 1 and 4 degrees of freedom at the 0.05 level of significance, the critical value of 7.71 was obtained from Appendix H. If the value calculated using the Two-Way ANOVA test was less than or equal to the critical value, the hypothesis should be accepted (fail to reject) (3a:507). The calculated values of 1.34 for treatments and 5.83 for blocks were both lower than the critical value. Therefore, the stated hypothesis was accepted. There were no significant differences in the frequency of cues between the commercial overhaul manuals and Depot overhaul manuals.

Related Characteristics. The following characteristics of commercial manuals represent the opinion of a manual user (the researcher) recording aspects of the manuals especially negative (or positive) to reader motivation (for additional characteristics, see Appendix J). All of the characteristics in this set represent the initial of two viewings, and record only observations relating to cue frequency. (The first four characteristics were especially negative for commercial manuals.)

1. Allison manuals used cues mostly on page headers and footers, leaving out cues elsewhere in the text.

2. Perkins figure numbers were hard to visually pick out from the text.

3. Perkins manuals used vertical lines in the column to highlight text, but these were so unobtrusive, they did not stand out readily.

4. Detroit manuals used few cues, except to underline the word note.

Depot manuals had no especially negative characteristics recorded from this viewing.

The following characteristics for commercial manuals were especially positive to reader motivation:

1. Note and caution references in Cummins manuals were especially easy to see, because the double column paragraphs were as wide as the note, and a reader could not gloss over it to get on to repair information.

2. Detroit manuals made use of lots of italics, which stood out well.

3. Cummins had manuals written in mainly picture/symbolic language, with symbols explained in the index in four major languages.

4. All aviation manuals used many varied-shaped cues.

The following characteristics of Depot manuals were especially positive to reader motivation:

1. AVSCOM used more varied shapes of cues than any other DMWRs.

2. CECOM DMWR 11-5805-722-34 used cues more than any other manual, and had varied-shaped cues.

Analysis for Cue Frequency

Use of the Two-Way ANOVA statistical test on the cue data collected from DMWRs and comparable commercial overhaul manuals revealed that there was no statistical difference between the two manual sets. The largest difference between any set of manuals occurred in a tie between commercial and

Depot truck engines and commercial and Depot radios (0.8 more cues per page in commercial manuals). The smallest difference was between commercial and Depot aircraft manuals (0.3 more cues per page in Depot manuals). The greatest variance between manuals was between a Depot radio manual (9.2 cues per page) and another Depot radio manual (2.7 cues per page). The largest variance between the two repair sectors was between commercial and Depot radio manuals (7.4 and 2.7 cues per page, respectively).

DMWR radio manuals apparently had the greatest variability in cue frequency, between their own manuals and with commercial manuals. The qualitative test also indicated that all radio manuals, on the average, contained the least specific repair procedures.

It was surprising to find that commercial aircraft manuals, usually published through high technology, modern, financially stable companies and made for expensive, tightly controlled equipment, did not make better or greater use of cues. Cues are inexpensive and an easy effective means to multiply the effectiveness of any manual.

The GAO study claim that DMWRs had "Complicated descriptions...poorly explained procedures...[and] hard to locate information" (12:5) was borne out by the user test findings. However, since there were no apparent differences in the manuals, commercial and Depot manuals were just as likely, therefore, to exhibit the same faults. The GAO assertion that there was a great "uniformity between DMWR manuals" (12:27) appeared to hold true.

By strict count (of this first user-test "viewing"), commercial manuals exhibited more characteristics negative to reader motivation than did DMWRs, and more positive characteristics, also. Since negative characteristics received an unweighted value of -1, and positive characteristics received an unweighted value of +1, Depots received a user test score for cue frequency (in this viewing) of +2, and commercial manuals received a score of +0. The test scores did not appear to be appreciably different.

General Characteristics.

The following set of data are general characteristics of the manuals which stood out as either especially positive or negative to reader motivation. They are separate from the lists of positive and negative characteristics in the other sections, because they did not closely relate to RGLs, illustrations or cues. These were included because they were collected in the initial viewing of the manuals. They were also included as a help to other researchers should subsequent related research be done. (See Appendix J for other characteristics). The first five characteristics are especially negative from commercial manuals:

1. Mack manuals used many "non-specific" words, such as "suitable" and "particular".

2. The Caterpillar manual had so few words, it often took more than one page to collect 150-word sections. The repair descriptions were so short, they did not explain procedures as completely as other manuals did.

3. The Mack manual was very segmented, and this made it hard to read, because a reader had to flip through to follow a repair procedure.

4. The newest aviation manuals were written in single column paragraphs, which contributed to eye fatigue.

5. General Electric and Allison manuals had a very confusing pagination system, not obviously sequential, with no easy tabs.

Depot manuals had no especially negative characteristics to be reported from this viewing.

The following positive characteristics of commercial manuals were recorded:

1. Detroit manual paper was very thin, so the manuals seemed very light to hold and manipulate.

2. Cummins manuals discussed the use, scope and orientation of an illustration with respect to the equipment being repaired. It also had a very good section on "how to use this manual", giving four general steps to follow for normal situations.

3. Detroit manuals had pages throughout for "shop notes."

4. Detroit and Caterpillar manuals provided the order numbers for special tools, to help in ordering.

5. Aviation and radio manuals had sections on mounting and installation instructions not found in other manuals.

6. Motorola and E.F. Johnson manuals each had "Service Manual Questionnaires" which asked potential manual users

specific questions, on a mail-in card, on ways to improve manual usability.

Depot manuals had no especially positive characteristics recorded from this viewing.

By allotting points to the foregoing positive and negative characteristics as previously, commercial texts accumulated (for the first "viewing) +1 points overall, and Depot manuals accumulated no points. This difference did not seem appreciable.

User Test Results.

When all of the characteristics from all sections with their simple value designations were taken together, the overall values were essentially equal, as shown in Table 7.

Table 7

User test results

Commercial		Depot		Commercial		Depot	
Positive Char.	%	Positive Char.	%	Negative Char.	%	Negative Char.	%
37	37%	38	40%	63	63%	57	60%

These data tended to indicate that the manual sets were both very similar in the power to motivate reading, and that both had essentially the same proportion of positive and negative characteristics.

It was surprising to find that the Depot manuals had less bad and more good characteristics than commercial manuals did. The DESCOM user test results (36-42), which indicated that DMWRs have been generally less usable than commercial manuals, appear to slightly contradict these findings. The fact that both sets had more negative characteristics than positive ones is understandable in light of the usual low emphasis put on usability. (46:386) But that the fact that the negative characteristics occurred twice as frequently as positive characteristics was surprising. With such a large sample population as was used in this study, equal numbers of positive and negative characteristics would seem more likely than double the occurrence of negative characteristics.

These various tests, taken together or separately, contradict the DESCOM assertion that DMWRs are more "complex" than commercial manuals and have "[more] extensive [difficult] work performance instructions" (36:3-1), and are therefore not "fully competitive with contract [commercial] Sources of Repair." (40:1) The results of these varied test showed no significant differences between the manuals.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Problem

The purpose of this study was to compare classes of equipment overhaul manuals of the US Army Depot maintenance system with corresponding classes of manuals of the US commercial equipment maintenance system to determine if Depot overhaul manuals were relatively more difficult to use. The first subproblem was to determine the relative simplicity of the manuals, as in their ease of readability. The second subproblem was to determine the relative number of illustrations per manual between the manual sets. The third and last subproblem was to determine the frequency of the use of any aids to understanding in the texts.

Procedure

The procedure used in this study was to select fifteen Depot and fifteen commercial overhaul manuals from three representative equipment categories, and test the degree of similarity in the manuals for the following: Reading Grade Levels, use of illustrations and instructional cues, and the "reading motivation" affect upon manual users. The data were collected and tabulated, and a Two-Way ANOVA statistical test was performed on the results of three of the tests to determine if they were statistically different. The remaining comparison test, a two part, modified user-test, collected general observations and characteristics of the manuals. The observer was one unbiased reader who critically observed all of the texts for any traits that motivated or demotivated reading.

The first three tests were designed to answer the three hypothesis of the study. The modified user tests were included to increase the locus of tests to include some which were qualitative in nature. Their inclusion was seen as a way to help substantiate the findings of the other tests. They would also be a significant help to the interpreting of research finding differences.

Major Findings

The major findings of this research study were as follows:

1. There were no statistically significant differences between the Reading Grade Level (RGL) of commercial overhaul manuals and Depot overhaul manuals. Individual differences existed, but these differences were not significant when all manuals were compared.

2. There were no statistically significant differences in the frequency of illustrations between commercial overhaul manuals and Depot overhaul manuals. However, two

commercial manual illustration practices stood out as superior:

a. commercial manuals had multiple, high resolution, black and white photograph illustrations interspersed with supporting text descriptions. DMWRs almost never used photographs. Consequently, DMWR illustrations were almost always separated to some degree from their supporting text.

b. Commercial manual illustrations seemed to lie much closer to their supporting texts. Though this finding was not permitted to be quantified and subjected to statistical verification (by the research study's restricted scope), it was also the opinion of other researchers of the related literature. (12:5)

Much research has been completed upholding the superiority of photographs over line drawings (52:739 and 0:5) and showing the benefits of illustrations interspersed with supporting text. (62:422 and 12:5) DMWR writers should follow these recommendations to improve reading and understanding of their manuals.

3. There were no statistically significant differences in the frequency of the use of cues between commercial overhaul manuals and Depot overhaul manuals. However, of all the tests, the calculated ANOVA statistical test values for cue frequency were the closest to the critical *F* table values. There appeared to be a greater difference between the manual sets for cue frequency than for the other tests. This difference borders significance, but still does not penetrate a true significance range.

In general, cues help readers read and understand better. DMWR writers should make better use of cues to improve reading and understanding.

4. The user tests seemed to indicate that the manual sets were both similar in their powers to motivate reading, and had essentially the same proportion of positive and negative characteristics. DMWRs had slightly less negative and more positive characteristics than commercial manuals had. In both manuals, negative characteristics occurred approximately twice as frequently as positive characteristics did.

5. The only differences that appeared to be significant (though perhaps only slightly), were in the areas of point size and page layout comparisons. DMWRs appeared to have consistently larger letter point sizes than commercial manuals had, and with a lower variance of sizes. However, the DMWRs studied also had 60% of their letter point sizes below the regulati·n standard of size 8. Larger point sizes are easier to read than smaller point sizes. The commercial manuals used (the preferable) double column page layout 67% of the time, whereas DMWRs used double column layouts only 19%of the time. This was in spite of the fact that DMWRs were required by regulation to use a double column format.

Conclusions

It appears that the Depot and commercial manuals were not inherently harder or easier to read (judged by RGL), to conceptualize, (judged by illustration frequency), or to learn from (judged by cue frequency), for mechanics assumed to have equal levels of grade level instruction and mental maturity. The sets appeared to have essentially equal user test reading motivation characteristics. The only noticeable differences seemed to have appeared in the user test observations of point size and text layout. DMWRs had generally larger letter point sizes, but generally worse double column text layout style.

The values generated by the RGL test could be larger by a factor of 7 before any significance could be seen in RGL differences. The values generated by the illustration test could also be larger by a factor of 7 before any significant difference could be seen in illustration frequency. However, cue frequency test values larger by a factor of only 1.2 points could generate a significance difference in cue frequencies. This means that the individual manuals in the RGL and Illustration tests each had very small variances, but the variances between individual manuals for the cue test were larger (but not significantly different).

These various tests, taken together or separately, appear to contradict the DESCOM assertion that DMWRs are more "complex" (36:3-1) than commercial manuals, have "[more] extensive [difficult] work performance instructions" (36:3-1), and therefore are not "fully competitive with contract [commercial] Sources Of Repair". (40:1) By these tests there were no significant differences, and the small positive and negative differences essentially cancelled each other out.

Recommendations

The following recommendations were made by the researcher, based on the overall findings:

1. DESCOM and AMC should consider the findings outlined in this study before making any final decisions to retire or modify the DMWR library, if the decision would be based heavily on the assumption that Depot and commercial manuals are significantly different with respect to ease of use.

2. More extensive tests should be designed or collected which look for potential differences between Depot and commercial overhaul manuals. Significant differences could be used in recommending changes in the manuals. It is recommended that other Logistics Management Masters Degree students make the study, because they both have six months of uninterrupted time to make the complex study, they have extensive library access at Ft Lee, VA, and this, their research project, cannot be postponed--it must be completed within a six-month period.

3. Other user tests should be performed employing both experienced graders and many manual-inexperienced test takers. The findings should be compared to the findings in this study.

4. Exact measurements comparing the actual degree of illustrations/text separations should be made.

5. The scope of the subsequent studies should be enlarged to allow inclusion of other English language maintenance manuals from other countries, such as from

Japan. The best ideas from all nations should be used if possible.

6. As a minimum, the following characteristics addressed in the user tests should be followed up with more research:

a. Compare the two sets for the relative frequency of step-by-step repair procedures, where each step is clearly set apart from adjacent steps by cueing devices.

b. Discover which DMWRs do not have illustration indexes.

c. Discover the degree of separation of illustrations from their supporting texts, in DMWRs.

d. Explore the benefits from using brief statements with each illustration which describes its scope and general orientation in the repair and on the equipment.

e. Explore the benefits of including "service questionnaires" and blank "shop notes" pages in DMWRs.

f. Explore the benefits/liabilities of the use of active/passive voice in repair procedures in DMWRs.

g. Explore the reception among Depot mechanics of the inclusion of part and/or tool order numbers in DMWRs.

7. A study of the cost benefits/liabilities of swapping DMWRS for some other form of manuals should be conducted. A study should also be made of the benefits/ liabilities of editing existing technical data packages to make them conform to DMWR format. This research should help answer the question whether trading DMWRs for commercial manuals may be more costly than benficial and whether editing commercial manuals to make them into DMWRs could be

an unneeded duplication.

8. DMWRs should make more use of the following reading "motivators", in order to have better (and possibly better utilized) manuals:

a. Use double column page style.

b. Use photograph illustrations, with at least one color other than black.

c. Use more and better reading cues which help understanding.

d. Intersperse illustrations better with supporting text.

e. Design a Depot manual to have a low RGL if its overall readability can be verified as being high, by user tests.

f. Ensure that letter point size is at least 7, but if possible, always 8.

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80. Annon. "DMWR for Gas Turbine Engine, APU, Model T-62T-40-1. DMWR 55-2835-209. St. Louis, Missouri: ASAAVSCOM, 30 May 1986.

81. Annon. "DMWR for Eng, Shaft, Turbine, Model T55-L-7". DMWR 55-2840-106-1,2,3,4, St. Louis, Missouri: USAAVSCOM, 7 Jan 1985.

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83. Annon. "DMWR for Engine, Turboprop, Model T53-L-7". DMWR 55-2840-104. St. Louis, Missouri: USAAVSCOM, 15 Apr 1984.

84. Annon. "DMWR for Engine Assembly, Model T63-A-720". DMWR 55-2840-242. St. Louis, Missouri: USAAVSCOM, 15 Sep 1980.

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APPENDIX A

LETTERS OF TRANSMITTAL

20 Mar 1990

SUBJECT: Request to study some commercial manuals

TO: Superior Diesel Service
2106 E Main Street
Richmond Virginia

1. The Army Logistics Management College in conjunction with the Florida Institute of Technology is sponsoring a study to suggest ways to improve the Army equipment overhaul manuals, called Depot Maintenance Work Requirements (DMWR). This letter requests permission to look at the form and content of copies of selected commercial manuals at your facility in the month of April or May, 1990, to make the comparisons.

2. I am the principal researcher. My name is Captain Mark Newell, SSN 550-25-9081. I am stationed at Ft Ben Harrison, Ind, with duty assignment at Ft Lee, Va, until 20 June 90. My mailing address is 363-A Coral Sea Dr, Ft Lee, Va, 23801. My phone at which I can be reached is (804) 733-7069.

3. I request to be able to study five different overhaul manuals at your location at a time and in a place agreeable to you. I will be applying readability formulae to some randomly selected pages in each of these manuals.

4. I thank you in advance for your time and cooperation to assist me in this research.

Mark Newell
Cpt OD
Project Officer

13 Mar 1990

SUBJECT: Request for assistance with commercial vs military manuals

TO: Commander, USA Communications Electronics CECOM
Attn: AMSEL-LC-ME-P (Mr. DiMarco)
Fort Monmouth, NJ 07703-5000

1. The Army Logistics Management Cocllege in conjunction with the Florida Institute of Technology is sponsoring a study to suggest ways to improve the Army equipment overhaul manuals, called Depot Maintenance Work Requirements (DMWR). This letter requests copies of selected manuals, or copies of these manuals to be loaned for use in this research.

2. I am the principal researcher. My name is Captain Mark Newell, SSN 550-25-9081. I am stationed at Ft. Ben Harrison, IN, with duty assignment at Ft. Lee, VA, until 20 June 90. My mailing address is 363-A Coral Sea Dr., Ft. Lee, VA, 23801. My phone at which I can be reached is (804) 733-7069.

3. I request use of the following manuals, to be sent to me on loan for one to two months:

1. AN/GRR-23, DMWR 11-5820-805
2. R-104/ARN, DMWR 11-5826-208
3. R-109-GRC, DMWR 11-5820-502
4. R-1420/URR, DMWR 11-5820-686
5. R-418/G, DMWR 11-5820-204
6. R-903 (XE-3)PRD, DMWR 11-5820-642

I have requested six manuals, however, I will settle for five. Since I do not have access to AMC Pam 310-9, Index to DMWRs, I do not know is the above DMWRs still exist, but I have given you the old designations to help in your search.

4. I thank you in advance for your time and cooperation to assist me in this research.

Mark Newell
CPT OD
Project Officer

APPENDIX B

THANK YOU LETTER

22 May 90

SUBJECT: Letter of appreciation for assistance with overhaul manual comparison study

TO: Cdr, USA AVSCOM
Attn: AVSAV-MCTP
4300 Goodfellow Blvd
St Louis, MO 63120-1798

1. Thank you very much for supplying the DMWR manuals for my research. Your assistance was timely and accurate, and your willingness to help much appreciated.

2. With your help, and the help of your staff, I was able to complete my research far ahead of schedule. By being able to closely inspect those DMWRs, and compare them to comparable commercial overhaul manuals, I was able to make observations about the useability of DMWRs and commercial manuals which have never before been done. This information is now available to policy makers for use in making the depot repair manuals better.

3. Please contact me if I can be of assistance to you in this matter. My new address from 1 July 90 is:

Commander, Red River Army Depot
Attn: SDSRR-MC (Cpt Newell)
Texarkana, TX 75507-5000

Mark Newell
Cpt OD
Project Officer

22 May 90

SUBJECT: Letter of appreciation for assistance with overhaul manual comparison study

TO: Superior Diesel Service
2106 E Main Street
Richmond, VA

1. Thank you very much for supplying the overhaul manuals for my research. Your assistance was timely and accurate, and your willingness to help much appreciated.

2. With your help, and the help of your staff, I was able to complete my research far ahead of schedule. By being able to closely inspect those manuals, and compare them to comparable military overhaul manuals, I was able to make observations about the useability of DMWRs and commercial manuals which have never before been done. This information is now available to policy makers for use in making the depot repair manuals better.

3. Please contact me if I can be of assistance to you in this matter. My new address from 1 July 90 is:

Commander, Red River Army Depot
Attn: SDSRR-MC (Cpt Newell)
Texarkana, TX 75507-5000

Mark Newell
Cpt OD
Project Officer

APPENDIX C

READING GRADE LEVEL NOMOGRAPH

Figure 2-1. Instructions for Using RGL Nomograph

Select a 150-word passage.[1] Begin with a paragraph or section and continue counting to the end of a complete sentence, even though it may exceed 150 words.

STEP 1

Figure the average sentence length. (Divide the number of words by the number of sentences.)

(150 ÷ 10 = 15)

STEP 2

Figure the average number of syllables in each word.[2] (Count the syllables. Divide the number of syllables by the number of words.)

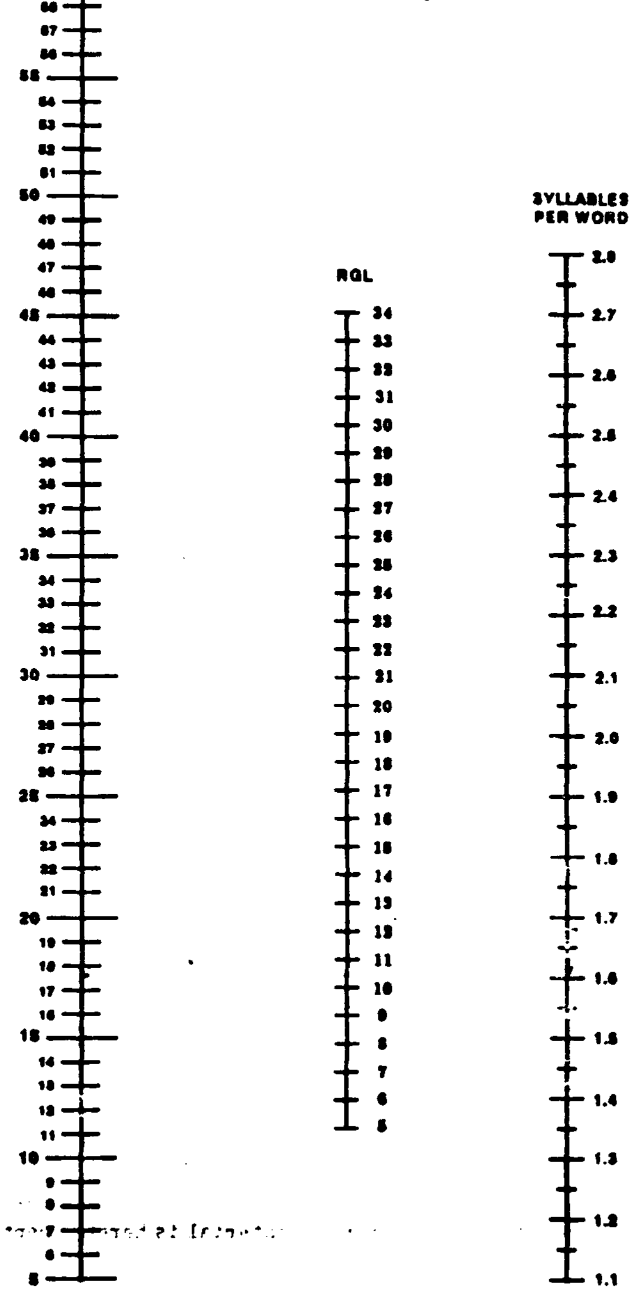
(300 ÷ 150 = 2.0)

STEP 3

Compute the RGL on the nomograph.[3] Connect WORDS PER SENTENCE and SYLLABLES PER WORD using straight edge. The point where the line crosses the RGL scale will show the reading grade level.

(RGL = 13.7)

Reading Grade Level Nomograph



NOTE:

1 Required manuscript samples

Pages	Minimum	Maximum
1 to 31	1	4
32 to 53	4	6
54 to 89	6	9
90 and above	9	30

2 Count syllables the way you would say the word. Count numbers as one word. Count acronyms and abbreviations as one syllable unless they spell a word of more than one syllable.

Word	Syllables
"row"	1
"determined"	3
"eyepieces"	3
"TRADOC"	2
"SQT"	1
"1979"	1
"10-28"	2

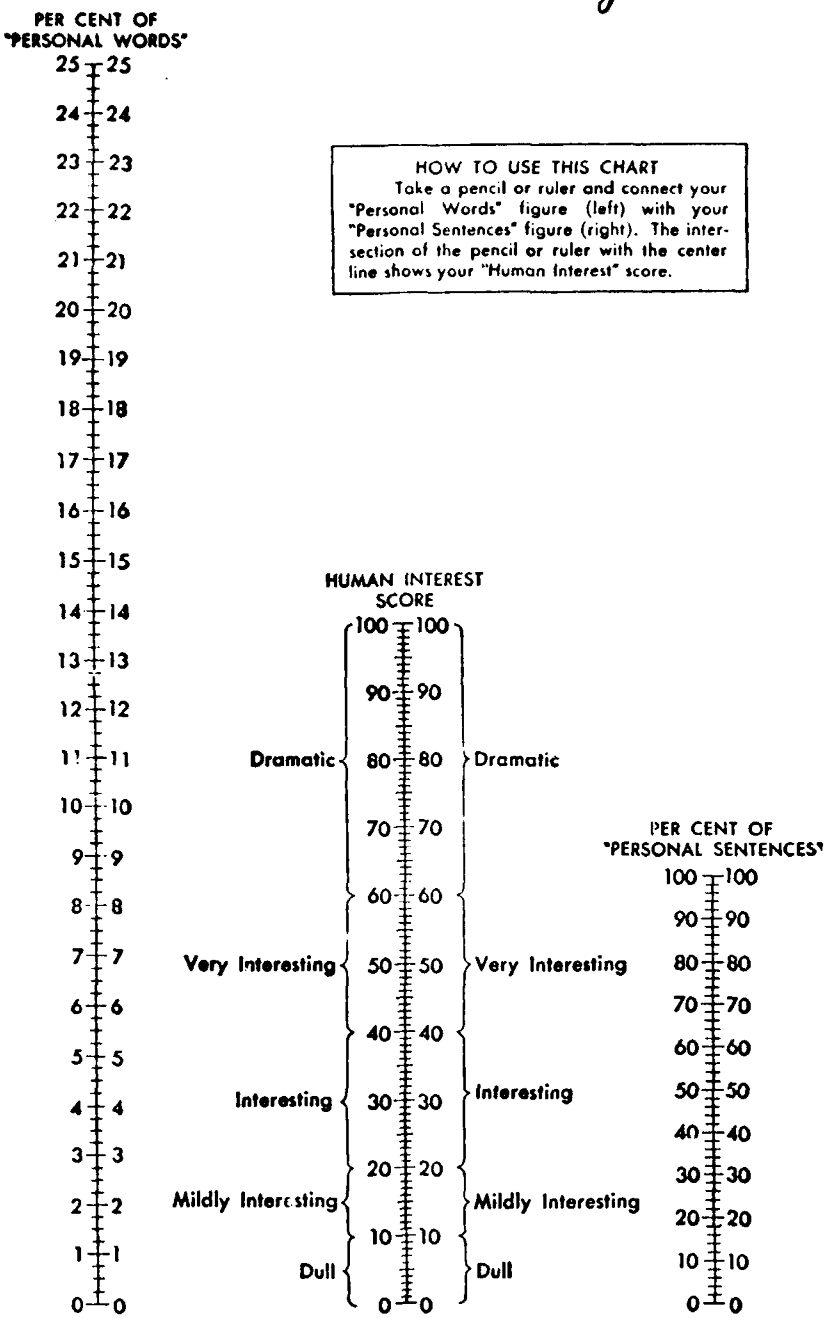
3 RGL equates to reading difficulty level when it exceeds 17 on the RGL nomograph.

Figure 2-1. Reading grade level nomograph

APPENDIX D

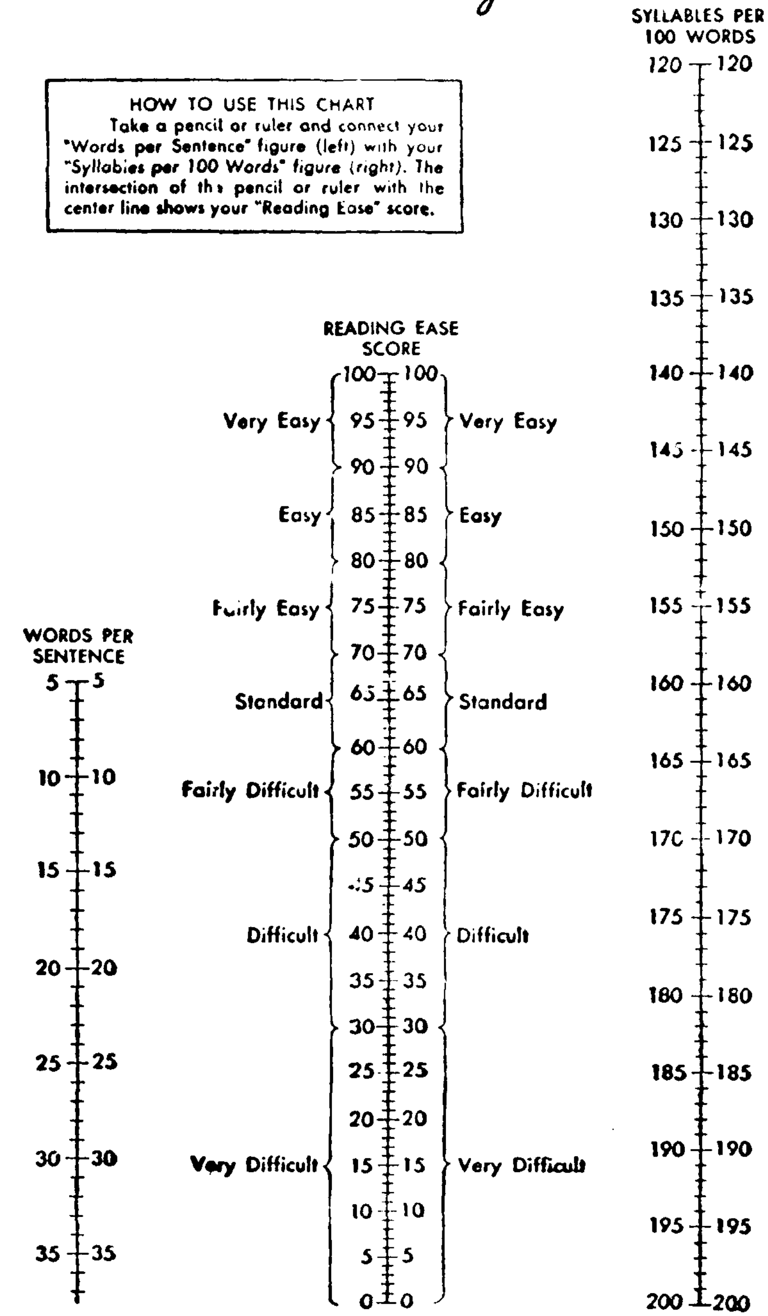
FLESCH READING GRADE LEVEL NOMOGRAPH

How Interesting?



HOW TO USE THIS CHART
Take a pencil or ruler and connect your "Personal Words" figure (left) with your "Personal Sentences" figure (right). The intersection of the pencil or ruler with the center line shows your "Human Interest" score.

How Easy?



HOW TO USE THIS CHART
Take a pencil or ruler and connect your "Words per Sentence" figure (left) with your "Syllables per 100 Words" figure (right). The intersection of the pencil or ruler with the center line shows your "Reading Ease" score.

APPENDIX E

RAW DATA SUMMARY TABLE

RAW DATA SUMMARY

TEST →	SAMPLE texts	RGL (Ave overall)		ILLUSTRATION (per page)		CUE helps (per page)	
USER*	→	COMM	DEPOT	COMM	DEPOT	COMM	DEPOT
TRUCK ENGINE	1	6.0	9.0	1.8	0.5	5.5	3.0
	2	5.5	10.0	1.4	0.6	6.8	5.9
	3	8.8	8.7	1.6	0.8	4.7	3.3
	4	8.5	8.8	1.9	0.3	2.2	2.7
	5	8.0	10.1	1.3	0.4	5.0	5.1
	$\bar{X}$	7.4	9.3	1.6	0.5	4.8	4.0
AIRCRAFT ENGINE	1	9.0	9.0	0.4	0.8	4.0	5.0
	2	8.8	8.7	0.4	0.5	5.0	3.8
	3	8.0	9.1	0.4	0.6	3.3	3.7
	4	8.8	9.3	0.4	0.4	2.6	3.5
	5	10.3	9.9	0.6	0.5	2.5	3.2
	$\bar{X}$	9.0	9.2	0.4	0.6	3.5	3.8
RADIO REC/TRAN	1	9.8	10.1	0.5	0.8	6.4	9.2
	2	11.4	10.4	0.2	0.6	7.4	2.7
	3	9.2	6.7	0.6	0.5	6.0	4.2
	4	10.7	7.8	0.8	0.3	3.2	3.9
	5	10.4	11.0	0.1	0.2	5.1	3.8
	$\bar{X}$	10.3	9.2	0.4	0.5	5.6	4.8

* LEGEND

(T=truck, A=aircraft, R=radio, C=commercial, D=DMWR)

T1D=DMWR 9-2815-205 T1C=Cummins manual
T2D=DMWR 9-2815-237 T2C=Caterpillar manual
T3D=DMWR 9-2815-213 T3C=Perkins engine manual
T4D=DMWR 9-2815-210 T4C=Mack truck manual
T5D=DMWR 9-2815-224 T5C=Detroit Diesel manual

A1D=DMWR 55-2835-209 A1C=Lycoming manual
A2D=DMWR 55-2840-106 A2C=Allison 250-C30
A3D=DMWR 55-2835-205 A3C=Allison 250-C28
A4D=DMWR 55-2840-104 A4C=Allison 250-C20
A5D=DMWR 55-2840-242 A5C=Pratt & Whitney manual

R1D=DMWR 11-5805-722 R1C=GE manual
R2D=DMWR 11-5820-667 R2C=Motorola manual
R3D=DMWR 11-5820-401 R3C=EF Johnson manual
R4D=DMWR 11-5820-529-50 R4C=RCA manual
R5D=DMWR 11-6625-2917-5 R5C=Midland Syntech manual

APPENDIX F

ANOVA TABLE FORMULAS

BLOCK 1	MILITARY MANUAL	COMMERCIAL MANUAL	ROW TOTALS	ROW MEANS $\bar{X}$
Truck Engines (TE)	$\bar{S}_{TE(MIL)}$	$\bar{S}_{TE(COM)}$	$\Sigma \bar{S}$	$\bar{X}_{TE}$
Aircraft Engines (AE)	$\bar{S}_{AE(MIL)}$	$\bar{S}_{AE(COM)}$	$\Sigma \bar{S}$	$\bar{X}_{AE}$
Radio Receivers (RR)	$\bar{S}_{RR(MIL)}$	$\bar{S}_{RR(COM)}$	$\Sigma \bar{S}$	$\bar{X}_{RR}$
Column Totals	$\Sigma \bar{S}_{(MIL)}$	$\Sigma S_{(COM)}$		
Column Means $\bar{X}$	$\bar{X}_1$	$\bar{X}_2$		

Grand Mean $\bar{\bar{X}} = (\bar{X}_1 + \bar{X}_2) / 2$ (columns)

Grand Mean $= (\bar{X}_{TE} + \bar{X}_{AE} + \bar{X}_{RR}) / 3$ (rows)

Source of variation	Sum of Squares	Degrees of Freedom (DF)	Mean Square	Test Statistic
Treatments Military and Commercial	TSS	1	TMS	$F_t = \frac{TMS}{EMS}$
Blocks TE, AE, RR	BSS	2	BMS	$F_b = \frac{BMS}{EMS}$
Error	ESS	2	EMS	
Total	Total SS	5		

$TSS = 3 \Sigma(\bar{X}_j - \bar{\bar{X}})^2$

$BSS = 2 \Sigma(\bar{X}_i - \bar{\bar{X}})^2$

$Total\ SS = \Sigma(\bar{S} - \bar{\bar{X}})^2$

$ESS = Total\ SS - TSS - BSS$

TMS = TSS/ 1 (DF)

BMS = BSS/ 2 (DF)

EMS = ESS / 2 (DF)

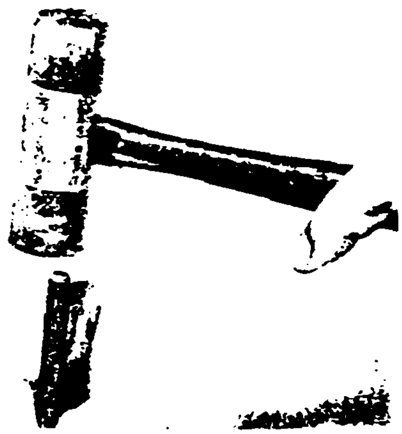
Degrees of Freedom for Critical value (1,4) (from table)

APPENDIX G

POINT SIZE SAMPLES

pulley. Use the round end of a pry bar to remove the seal. Do not damage the bore for the seal.

11. Remove the retaining ring (22).
12. Remove and discard the O-ring (24).
13. Remove the bearing assembly from the pulley.
    a. Remove the plug (29) from the pulley.
    b. Hold the pulley in a vise.
    c. Put the flat end of a punch through the plug hole. Lightly hit the punch with a



b. Connect opposite end of hose or tube to OUTLET NO. 3 STATIC BYPASS port of test stand (LTCT314).

c. Close STATIC BYPASS valve.

d. Using hand pump on test stand, bleed air from hose or tube by simultaneously applying hydraulic pressure and loosening plug installed in preceding step a. After all air has been bled, tighten plug securely.

e. Using hand pump, increase pressure until GAGE NO. 1 STATIC PRESSURE gage indicates 2900 to 3100 psi.

NOTE: When testing lubrication pressure manifold (26, figure 4-63), apply 500 to 550 psi.

Disassembly

1. Separate the water pump housing cover from the housing.

2. Remove the key from the pulley end of the shaft. See Figure 2-309.

Figure 2-309. Removing Key

5. Press the shaft out of the housing from the cylinder block end. See Figure 2-311.

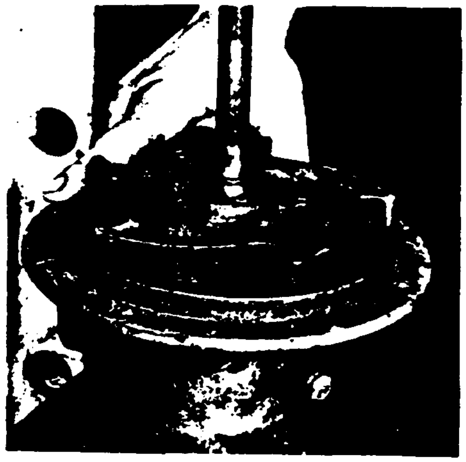


Figure 2-311. Removing Shaft

6. Remove O-ring from lower neck of housing cover.

f. The oscilloscope or counter shall indicate a 1500 Hz ±100 Hz tone or a 1750 Hz ±100 Hz tone depending upon the tone oscillator circuit used in a particular transceiver set.

3-11. Receiver Sensitivity and Signal Plus Noise-to-Noise Radio Test

a. Connect the equipment as outlined in paragraph 3-1 and as shown in figure 3-1.

b. Adjust the transceiver for 3.7 MHz operating frequency.

c. Adjust the signal generator for 3.7 MHz output at 0.5 microvolt to the rf input of the transceiver.

The 2C-ICOMs are self-compensated to 2 PPM and can not provide compensation for EC-ICOMs.

When a DFE is used with a wide spaced transmitter option, compensation voltage for the 5C-ICOMs is supplied from the +10 Volt regulator IC provided with the wide spaced transmitter option.

Oscillator Circuit

The quartz crystals used in ICOMs exhibit the traditional "S" curve characteristics of output frequency versus operating temperature.

A constant bias of 5 Volts (provided from Regulator IC U901 in parallel with the compensator) establishes the varactor capacity at a constant value over the ent mid-temperature range. With no additional compensation, all of the oscillators will provide 2 PPM frequency stability from 0°C to 55°C (+30°F to 131°F).

Compensator Circuits

Both the 5C-ICOMs and 2C-ICOMs are temperature compensated at both ends of t temperature range to provide instant frequency compensation. An equivalent ICOM circuit is shown in Figure 2.

parts should be cleaned only to the extent necessary to detect all flaws and imperfections.

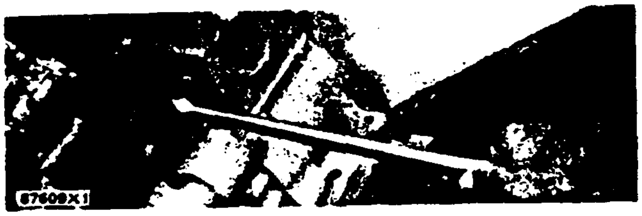
g. Because of the many variables involved in the cleaning and inspection of turbine engine parts, it is impossible to set a standard for cleaning that would apply under all conditions. Therefore, to obtain the maximum overhaul capacity while at the same time producing a quality product, both cleaning and inspection personnel must exercise good judgment and common sense to avoid unnecessary cleaning of parts.

CAUTION

b. Electrical wiring - Inspect all wiring for faulty insulation and damaged conductors. Inspect plugs and receptacles for corrosion, broken, bent, or burned pins and for distorted or cracked shells.

c. Housings - Inspect housings for cracks, dents, scratches, and corrosion. No cracks are allowed. Lesser damage such as dents, scratches, and corrosion may be repaired as instructed in the detailed procedures.

d. Spur and helical gears - Steps on tooth profile generated by



USING 9S9082 ENGINE TURNING TOOL

FUEL SYSTEM ADJUSTMENTS

Checking Fuel Injection Pump Timing: On Engine Checking with 1P540 Flow Checking Tool Group

Tools Needed: 1P540 Flow Checking Tool Group, 7S9892 Adapter, 9M9268 Dial Indicator, 3S3269 Contact Point (Engines with Precombustion Chambers) or 5P2393 Contact Point (Engines with Direct Injection), 8S2296 Rod (from

tighten the 7S9892 Adapter finger tight.

CAUTION: Do not use a wrench to tighten the adapter. There will be damage to the nozzle seat if the adapter is too tight.

5. Put the 9M9268 Dial Indicator in the adapter. Make an adjustment to the dial indicator so both pointers are on "0" (zero).
6. Turn the crankshaft a minimum of 45° in the CLOCKWISE direction (when seen from the flywheel end of the engine).
7. Turn the crankshaft in the COUNTERCLOCKWISE direction (when seen from the flywheel end of the engine) until the dial indicator gives

e. Remove lockwire and separate spark igniter (8) from rear of the engine.

f. Remove ignition exciter (10) from the gearbox by removing three nuts (1) and washers (9). Discard nuts (1, 11) and washers (9, 12).

3-51. Anti-icing and Bleed Air Systems Dismantling. Dismantle anti-icing and bleed air systems components from the engine as follows:

NOTE

The interstage bleed control valve shall hereafter be referred to as the bleed valve.

a. Detach RH anti-icing air tube (5, figure 3-63) at one clamping position by

5.2 CLOCK AND VCO ADJUSTMENT

a. Connect a frequency counter to TP1 on the audio/logic board. Adjust C9 for 400 kHz ± 10 Hz.

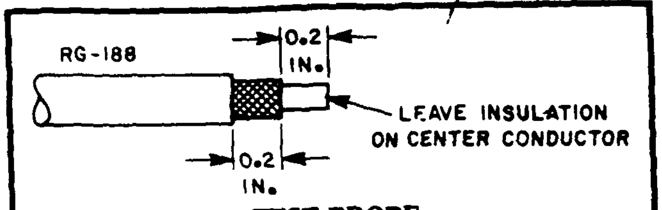
b. Connect a DC voltmeter to TP802. With a Test PROM programmed for a center channel installed, adjust C911 in the VCO for 5.0 volts ± 0.1 volt.

5.3 RECEIVER ALIGNMENT

CAUTION

When power is applied to the transceiver, temporary keying transients may be produced which could seriously damage a signal generator connected to the

the center of the band.



TEST PROBE
FIGURE 5-2

c. Connect an RF voltmeter or spectrum analyzer to the probe. Insert the probe into the hole adjacent to the L208 adjusting screw. Adjust L207 and L208 for maximum signal output.

NOTE: Do not short the helical with the probe since this will cause improper tuning. Also, do not repeak

---

DMWR 9-2815-213 2C5

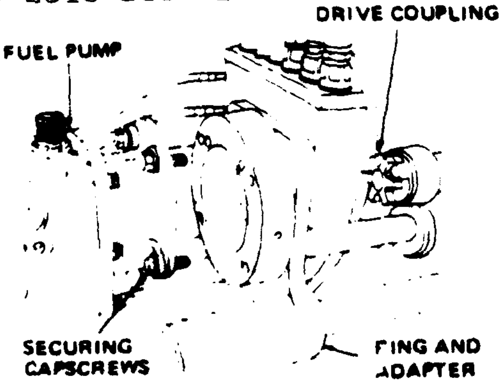


FIGURE 3-99. PUMP MOUNTED ON TEST STAND

l. Install 1/2 inch I.D. flexible hose (8 figure 3-97, 2C3) from stand "FUEL OUTLET" connector to stand "FUEL RETURN" connector (figure 3-101, 2C6).

m. Install flexible hose (6, figure 3-97 2C3) to no. 1 accumulator can (figure 3-101, 2C6) from stand "LEAK TEST" connector.

n. Turn on fuel heat switch (figure 3-98, 2C4) observe that temperature on "FUEL TEMPERATURE" gage is between 80 to 100 degrees for testing.

CAUTION: **Never operate fuel pump until check valve has been checked for restrictions.**

3-89. Fuel Pump Run-In.

a. Set stand motor switch (figure 3-98, 2C4) to

Allison Gas Turbine

250-C20 Series Operation and Maintenance

2-25. The modulated start procedure is the same as the automatic start procedure, including notes and cautions, except for the movement of the throttle to the IDLE detent. (Refer to Automatic Start Mode, para 2-23.e.). For a modulated start advance the throttle as follows:

a. When the desired N_1 cranking speed is reached, advance the throttle toward IDLE until the engine lights-off. Lightoff is evidenced by combustion noise and/or by an increase in TOT. From this point, TOT is controlled directly by the throttle; increase or decrease as required, by throttle movement.

3.8.1.1. KC Change. When the KC knob is rotated in either direction (cw or ccw) to effect frequency change, the front panel gear assembly acts as a differential gear set and indirectly drives two Oldham-type couplers. These couplers drive connecting shafts and levers to perform various tasks in several modules. Three paths of differentiation take place when the KC knob is rotated.

a. The KC knob drives spur gear F3. Spur gear F3, in turn, drives spur gear D4. Spur gear D4 is connected to the dial indicator, KC portion, which is driven when spur gear D4 is driven.

b. The KC knob drives spur gear set F3/F2/F1 which is fixed on the same shaft. The F2 portion of the spur gear set drives spur gear G1, which, in turn, drives the G-shaft. The G-shaft is connected to an Oldham-type coupler which drives a shaft in the A2000A assembly. This shaft operates S2001A (Interpolation Oscillator crystals) and S2001B (Reference Oscillator crystals).

PRATT & WHITNEY AIRCRAFT OF CANADA LTD.
OVERHAUL MANUAL
P/N 3011403

SECTION 2

SPECIFIC PARTS CLEANING

INTRODUCTION

GENERAL

1 Engine parts are illustrated in the following figures and the appropriate cleaning procedures are given by SPOP numbers in adjoining tables. Details of deviations from basic SPOPs and particulars of optional operations applicable to each specific part are given in the remarks column of the tables.

STANDARD CLEANING INSTRUCTIONS

GENERAL

CAUTION

Carefully inspect interior of each tube to ensure that no part of the swab or cloth is present to provide a possible obstruction to oil flow.

(b) Remove from compound and pull a suitable size swab (or lint free cloth) through tube.

(c) Rinse thoroughly with petroleum solvent AMS3160 at room temperature.

(d) Dry with clean, dry, compressed air.

CARBON SEALS

(continued) DMWR 9-2815-205

(5) Install connecting rod piston pin bushings.

(a) Clamp upper end of connecting rod in holder so bore for bushings is alined with hole in base of tool (fig. 3-26).

(b) Start a new bushing straight into bore of connecting rod with bushing joint towards top of rod (fig. 3-29).

(c) Insert installer J4972-2 in bushing. Then insert handle J1513-2 into installer, and drive bushing in until flange of installer meets surface of connecting rod.

(d) Turn connecting rod over in holder, and install second bushing in manner noted in (a), (b), and (c) above.

13. Trend Check Engine Analysis

A. The trend check analysis provides a method for the operator to monitor engine health. The trend check will also allow the operator to more effectively predict when preventative maintenance is required and schedule some maintenance actions that were formerly unscheduled.

B. Allison strongly encourages all operators on a voluntary basis to utilize performance trending to supplement their regular maintenance program. It should be noted that the use of performance trending does not change the requirement to operate the engine within established limits and according to applicable publications. Aircraft manufacturer engine trending procedures which are published in the applicable FAA approved flight manuals can be used in lieu of this manual's procedure if they are Allison approved. Refer to Aircraft Manufacturer Trend Check-Alternate Procedure, para 15, this section.

CHAPTER 3
TEST AND ALINEMENT OR ADJUSTMENT

Section I. TEST SETUP AND ALINEMENT OF MODULES

3-1. General

The basic tests of individual modules are referenced in Test Procedures column of table 2-2. The alinement procedures for the individual modules, using wherever practicable the test fixtures referenced in table 2-2, in conjunction with the test equipment listed in the modules functional capacity. Some modules can be tested and alined, while other modules can be tested with no alinement required.

3-2. Test Setup and Alinement of Module A11A

a. Refer to Test Procedure SC-A-401767 and connect the test equipment as shown and described in the functional block diagram, figure 1.

b. Replace the module cover with the A11A alinement cover (fig. 6-1).

DETROIT DIESEL 53 2.7.1.2

LIMITING SPEED MECHANICAL GOVERNOR

8V ENGINE

The limiting speed mechanical governor, illustrated in Fig. 1, performs the following functions:

1. Controls the engine idling speed.

2. Limits the maximum operating speed of the engine.

The double-weight governor, identified by the letters D.W.-L.S. stamped on the governor name plate, is mounted on the front end of the blower and is driven

The turbocharged engines use a starting aid screw threaded into the gap adjusting screw. The starting aid screw is threaded in the low-speed gap adjusting screw so that its head contacts the governor housing wall (Fig. 1). Both the gap adjusting screw and the starting aid screw have a nylon locking patch on the threads in place of lock nuts.

Operation

Two manual controls are provided on the governor: a stop lever and a speed control lever. In the RUN

TARCOM DMWR 9-2815-210

3-5. Temporary Preservation.

a. After Cleaning and Preshop Analysis.

(1) Assure that all openings are covered to prevent entry of water or other contaminants.

(2) Apply a light coat of preservative oil to all bare metal surfaces.

b. After Removal of Major Assemblies and Disassembly of Subassemblies.

‹MENT INSTRUCTIONS MIDLAND MANUAL 70-341/441

Remove the 8 screws securing the top and bottom covers. Install the programmed E/PROM module. Loosen the 2 screws securing the PA cover and remove the cover. Turn the volume control to a mid position and the squelch control fully counter clockwise. If the 70-E10 test set is used, the red 5 pin test socket should be connected to CM101 for transmitter alignment and the white 5 pin test socket to CM202 for receiver alignment. Both test sockets should be connected with the unused socket position toward the rear of the radio. Refer to the test pins switch position underlined in the steps below. Supply power to the radio and connect a wattmeter and dummy load with a reduced power output for a frequency counter and modulation meter.

TRANSMITTER ALIGNMENT

MAIN VCO AND TRANSMIT VCO ALIGNMENT

CHAPTER 4

QUALITY ASSURANCE/QUALITY CONTROL REQUIREMENTS

4-1. General. The responsible Quality Assurance Activity of the Contractor/Depot shall perform the quality control actions specified herein. The facilities utilized to perform these actions will meet the requirements of the procuring activity commodity manager (PA/CM). The PA/CM reserves the right to perform any of the inspections specified herein when such inspections are felt to be necessary to assure that supplies or services conform to the prescribed requirements.

4-2. Deviations and Exceptions. If the depot maintenance work requirements can-

Table 3-1 Front Panel and Chassis Mounted Components—Continued

Reference designator	Nomenclature	Figure reference
W2/P1	Cable/jack	3-1
W3/P1	Cable/jack	3-1
W4P1/J2	Cable/jack	3-1
W5/J6	Cable/jack	3-1
W6P2/J1	Cable/jack	3-1
XA1 thru XA4	Connector	3-1
XA5 thru XA7	Connector	3-1
XA8	Connector	3-1
XDS1	Lamp holder	4-3
XDS2 thru XDS7	Indicator	4-3
XDS8	Indicator light	4-3
XDS9	Indicator	4-3
Y1	Crystal OSC	3-1
Y1-P1	Connector	3-1

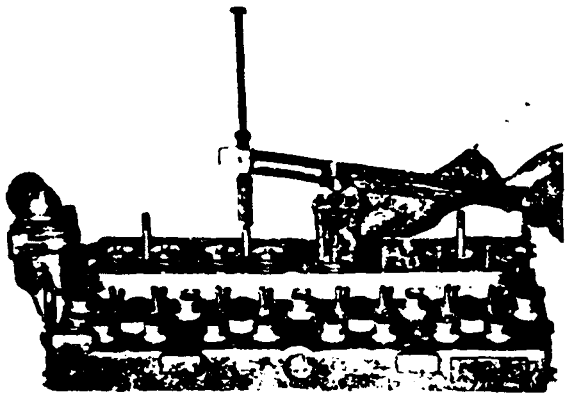
3-5. Mechanical Inspection

The mechanical inspection procedure is performed by making physical and visual/manual checks of all front panel and chassis-mounted components for loose or missing screws, bolts, and nuts and for cracks or breaks. Accessibility to these components

NOTE

It is necessary to remove the front panel to gain access to the rear panel area of circuit breaker CB1. Refer to chapter 4, section IV as required.

3-6. Continuity Checks



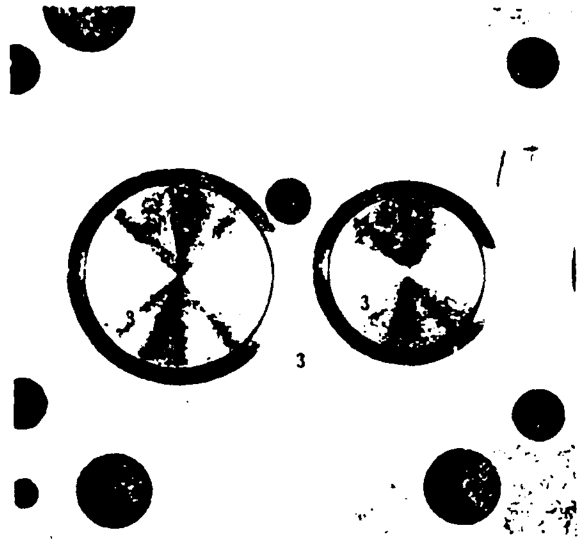
E5

Valve Guides (Early Engines)

Engines are fitted with either detachable valve guides or the valve bores are machined direct into the cylinder head.

When wear takes place in the valve bores of cylinder heads without detachable valve guides valves with oversize stems should be fitted.

Three service valves are available for both inlet and exhaust with oversize stems of 0.003 in 0.015 in and 0.030 in (0.08, 0.38 and 0.76 mm) respectively



E6

B.10 See Fig. E.7.

The maximum wear limits quoted on Page B.3 are for areas in which the smoke density regulation do not apply.

The valve seats in the cylinder head should be reconditioned by means of cutters or specialised grinding

CHAPTER 5

MAINTENANCE OVERHAUL AND REPAIR

5-1. In-Process Inspection.

a. General. The general inspection requirements are as follows:

(1) Material and parts. Material and parts that are replaced shall conform to all requirements for the material and parts listed in the applicable Department of the Army Supply Catalogs (or parts required by the applicable MWO). Whenever the material or parts are not listed in these publications, the quality of the material or parts used in the repair shall be at least equal to the quality of the original material or parts.

(2) Work Quality. Components and parts shall be required

d. Meter Readings

Connect the portable test set to the receiver metering socket and set the function selector switch to the RCVR position. Check the meter readings (with no carrier signal) and compare with the typical readings given in Figure 8.

FIGURE 8.
TYPICAL RECEIVER METER READINGS
WITH NO CARRIER SIGNAL

Selector Switch Position	Typical Meter Readings in uA	Stage
1	0 uA	455 kHz ampl. -3
3	0 uA	Extender rf and -3
4	0 uA	Disc. Sec.
5	25 uA	Disc. Primary
6	25 uA	1st Oscillator

distribution of a receiver is to apply an on-channel rf voltage to the antenna connector while monitoring a selected point in the receiver with an rf voltmeter. The amount of signal necessary to produce a specific reading on the voltmeter gives an indication of the total gain between the antenna connector and the point being monitored. The amount of signal required to produce this reading can then be compared with the values tabulated in Figure 9. Any significant deviation between measured and tabulated values indicates that some circuit between the antenna and the point being monitored is not operating correctly. The faulty circuit can usually be isolated after monitoring several points, where upon a visual inspection of soldered connectors or a dc voltage check will pinpoint the problem area.

The table below lists the rf voltage input required to obtain a reading of 100 millivolts on the

4-43. TESTING SHUTOFF PRESSURE.

Fuel Pump Testing.

(1) Install fuel pump onto tester (table 2-1) and prime pump with #2 diesel fuel, ten stokes maximum at one revolution per second.

(2) Pump displacement at one revolution per second should be 1.22 cubic inches (20 cc) per stroke minimum.

(3) Fuel flow at ten revolutions per second and 2.0 psi (13.8 kPa) should be .578 oz (16.4 g) per second at 30 revolutions per second and 2.0 psi (13.8 kPa) flow should be .889 oz (25.2 g) minimum.

(4) Shutoff pressure at 30 revolutions per second should be 7.49 psi (57.1 kPa) minimum to 8.99 psi (62.0 kPa) minimum at pump outlet. Pump must also have a lift of 12 in. HG (2.98 KPO) at 325 rpm.

4-44. PAINTING, REFINISHING, AND MARKING.

Refer to para. 4-51 for painting, refinishing, and marking instruction.

RF Circuits

RF input to the receiver is applied to the antenna jack 1J7. The Receiver casting contains the 3-TCXO Mother Module (previously discussed), the Helical Resonator Module, the Buffer Module, the Mixer/Multiplier Module, and the 14.5 MHz IF Module. The Helical Resonator Module contains five, highly selective, helical resonators (1Z1 thru 1Z5) with cast-in cavities and helically-wound coils. The RF signal is coupled electromagnetically through the cavity apertures and applied to the 1st Mixer stage in the Mixer/Multiplier Module.

1st Mixer

The Mixer/Multiplier Module contains the 1st

Module, consists of Noise Amplifier Q10, Noise Detector Q11, and Squelch Gate Q12 and Q13. When no carrier is present, the noise output of the discriminator circuit is amplified by Noise Amplifier Q10 and detected by Noise Detector Q11. The output of the Noise Detector gates the Squelch Gate which, in turn, cuts off Audio Amplifier Q7 to disable the receiver audio circuit. When a carrier quiets the discriminator the Squelch Gate turns on the Audio Amplifier and restores the receiver audio.

Receiver Disable (Muting)

When a disable (keying) voltage is applied to pins 18 or 32, transistor Q16 is biased into conduction, which triggers squelch gate Q12/Q13 into the tight

f. Scan bore to retracted probe position.

g. Remove scanner head and turbine wheel from fixture.

h. Review trace for any obvious indication of cracks. Typical indication of a crack would display a signal-to-noise ratio of 3:1.

5-9. Fluorescent Penetrant Inspection.

a. The purpose of fluorescent penetrant (black light) inspection is to detect surface defects in nonmagnetic materials. The most commonly used fluorescent penetrant (item 22, Appendix C) has a highly fluorescent oil base

(11) Allow engine to drain completely before starting. Ensure combustion chamber drain valve (refer to 73-10-01, figure 1, index 14) is not clogged.

(12) Clean or replace Pc filter or perform differential pressure check. (Refer to 73-10-06, paragraph 9.)

C. Daily water rinse compressor to remove salt deposits.

(1) Except on engines with pneumatic control system (Pc) filter, disconnect tube assembly (refer to 73-10-01, figure 1 index 3)

SECTION V. VALVES, SOLENOIDS, AND FILTERS.

5-94. FUEL DISTRIBUTION VALVE ASSEMBLY (T55-L-7C ENGINES). (See figure 5-31.) If overhaul is required, refer to paragraphs 5-95 through 5-99; otherwise clean exterior of valve and perform functional test in accordance with paragraph 5-99.

5-95. DISASSEMBLY. (See figure 5-31.)

a. Remove two bolts (1), bracket (12), and distributor dump valve cover (3).

CAUTION

Use care when removing valve cover. Cover is under spring compression.

b. Remove packing (2), and plate (4).

PARA 6. (cont)

D. If flameout has been experienced as the possible result of snow, ice, or water ingestion refer to Snow Ingestion Inspection, para 2.E, Engine-Inspection Check.

E. If the aircraft is being operated following an extended period of inactivity, refer to Special Inspections, table 603, Engine-Inspection/ Check, for recommended action.

F. Ascertain the aircraft oil tank is properly serviced.

4-29. (CONT)

r. Use growler (item 11, table 2-2) and test armature (17).

s. Apply grease (item 23, appendix C) to preformed packing (28) and install preformed packing on end plate (26).

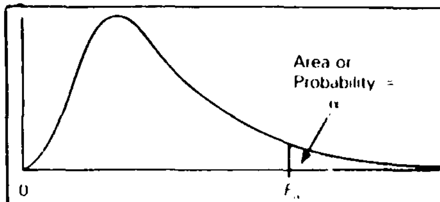
t. Apply lubricating oil (item 25, appendix C) to six capscrews (15). Align match marks and install commutator end frame assembly (16) and six capscrews on field frame (87). Torque capscrews to 15 lb ft (20 N.m).

u. Align three leads on field winding (84) with holes in three brush holders (35) and install three screws (14). Torque screws to 21 ±3 lb in. (2.4 ±0.3 N.m).

APPENDIX H

F DISTRIBUTION TABLE

Appendix Table N F Distribution



Entries in the table give F_α values, where α is the area or probability in the upper tail of the F distribution. For example, with 12 numerator degrees of freedom, 15 denominator degrees of freedom, and a .05 area in the upper tail, $F_{.05} = 2.48$.

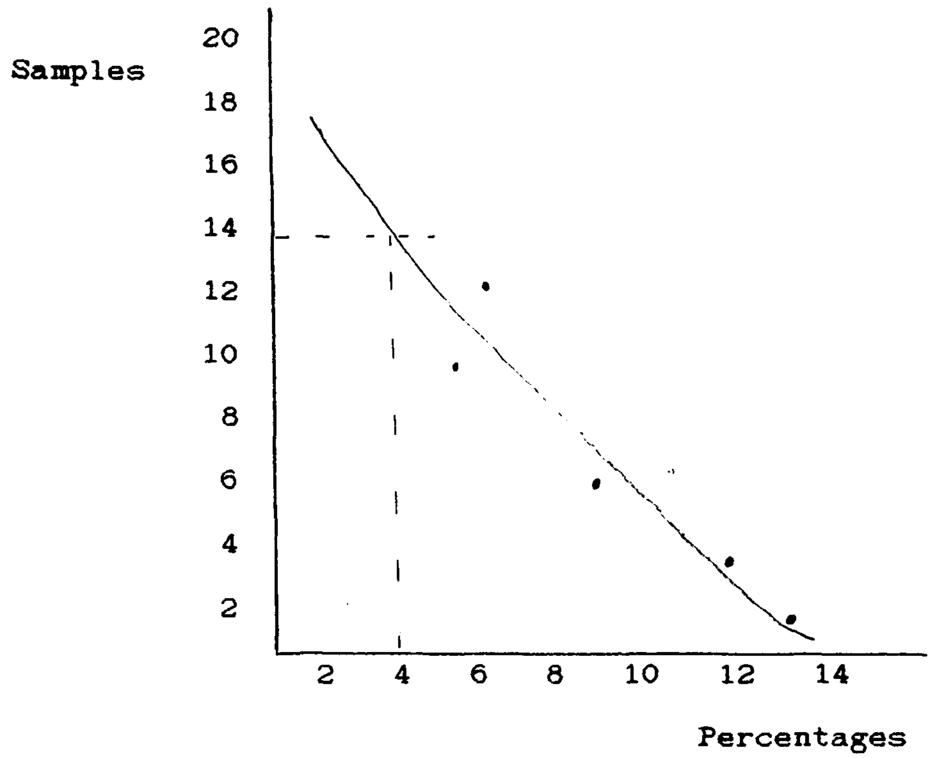
Denominator Degrees of Freedom	$F_{.05}$ Values																		
	Numerator Degrees of Freedom																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	240.5	241.9	243.9	245.9	248.0	249.1	250.1	251.1	252.2	253.3	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40	19.41	19.43	19.45	19.45	19.46	19.47	19.48	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.28	2.20	2.12	2.08	2.04	1.99	1.95	1.90	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79	1.73
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24	2.16	2.09	2.01	1.96	1.92	1.87	1.82	1.77	1.71
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.15	2.07	1.99	1.95	1.90	1.85	1.80	1.75	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20	2.13	2.06	1.97	1.93	1.88	1.84	1.79	1.73	1.67
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19	2.12	2.04	1.96	1.91	1.87	1.82	1.77	1.71	1.65
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18	2.10	2.03	1.94	1.90	1.85	1.81	1.75	1.70	1.64
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.09	2.01	1.93	1.89	1.84	1.79	1.74	1.68	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58	1.51
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	3.92	3.07	2.68	2.45	2.29	2.17	2.09	2.02	1.96	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35	1.25
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00

APPENDIX I

SAMPLE SIZE GRAPH

APPENDIX I

Sample Size Graph *



* At a greater number of samples, there was a lower percent difference between a control group of 20 pages of RGLs and any successive sample, breaking greatest at about 2%. Therefore, for any sample over about 14%, less utility was realized of samples of greater size.

APPENDIX J

USER TEST CHARACTERISTICS: SECOND VIEWING

Appendix J
Results: Second Viewing of the User Test

Introduction

The following data were collected against a 12 question user test, to be applied to the 30 manuals of this study. The questions were designed to illicit response from an average, inexperienced reader, that would expose aspects of the manual that tended to motivate or demotivate reading. Each entry below is a response to different parts of the questionnaire. The "+" or "-" sign before the entry indicates that this entry had a positive (or negative) impact on the motivation of the user to read the text. The numbers after the manual title indicate the pages from which the record comes.

Findings

Cummins Manual 8-14, 4-17.

+ one sentence, one action, with wide space between each sentence; easy to put manual down, then act, then pick back up and use.

DMWR 55-2840-104 4-1167,4-107.

- overdark illustrations were unintelligible
- many references to illustration's numbers, but the illustration is widely separated from this reference, causing need for lots of page flipping.

+ step by step repair directions, individually numbered.

+ good references to tool numbers.

- single column text, hard to quickly see.

- imprecise wording ("suitable long").

- small letters, blurry type.

Mack Truck Manual 2-307, 2-368.

+ a photo for almost every repair step.

- jargon used without explanation ("slinger").

- used very small lettering.

- had run-on sentence (poor punctuation).

DMWR 9-2815-210 2-4, 3-8.

+ step by step repair directions, individually numbered.

- nonstandard words in table heading without explanation.

GE Manual LB14984P, LB14984.

- letters too small and sentences too close together.

- long confusing sentences with lots of unexplained jargon and acronyms.

- too few illustrations.

- sentences and paragraphs not numbered; easy to get lost.

- lots of theory, but virtually no step-by step repair directions.

- annoying text: information does not pass the "so what" test.

DMWR 55-2835-209 5-2,5-85.

- imprecise words ("unnecessary, quality, maximum").

- awkward caution sentence construction.

- rambling sentences, confusing reference.

- long paragraphs with one introductory paragraph number defeat the purpose of numbering system.

- small letters, too close together.

+ double column paragraphs are good.

Caterpillar Manual 43, 61

+ many photos to go with each repair step.

+ double column, wide spaced lines.

+ step by step, one action-one sentence.

+ shows tools and their numbers prior to section.

+ layout motivates respect.

+ information motivates respect.

+ good use of precise words.

DMWR 55-2840-242 3-117, 3-161

+ well designed illustrations.

- faded illustrations, blurred letters.

+ step by step, one sentence, one action.

-paragraph heading hides in text body.

-lots of undefined jargon.

- precise wording.

- single column.

EF Johnson 5-1, 4-10

+ aura of professionalism.

+ individual sentences, step by step procedure.

+ bold, crisp lettering.

+ layout motivates respect.

+ general instruction is clearly separated from the specific instruction.

+ precise photograph illustrations.

+ double column format.

DMWR 9-2815-213. 2C5, 1G1

- faded letters/illustrations from microfiche.

- letter type for "note" information is smaller than regular type.

+ one repair step, one sentence.

+ double column style.

+ there is a highlighted word in almost every sentence.

Allison 250-C20 2-19, 3-238

- mixes direct and indirect speech.
+ crisp, sharp illustrations.
+ step by step repair instruction.
+ no nonsense aura of professionalism.
- single column style.

DMWR 11-5820-401 3-15, 3-12

- extremely busy illustrations.
- some sentences begin without pronouns.
- single column style.

Pratt & Whitney manual D-19, G-2

- unmatched tiny, very blurred type.
- multiple repair steps in one long paragraph.
- text mixes double and single column style.
- illustrations are unintelligible.

DMWR 9-2815-205 3-65, 2-14

- single column style.
+ step by step repair procedure.
+ good tool number reference.

Allison 250-C30P 72-00-00-57, 72-00-00-59

- single column style.
+ bold, crisp letters.
+ aura of professionalism.
- busy illustrations.

- many words, but not a lot of repair steps.

<u>DMWR 11-5820-667</u> 3-1, 3-12

- "run-on" in sentence construction (twice).
- figure numbered 6 in a chapter numbered 3.
- missing commas in sentences (twice).
- imprecise wording ("acceptable limits as stated).
+ step by step repair information.
- single column style.

<u>Detroit manual</u>. 2.1.1-4, 2.7.1.4-1

+ step by step directions by multiple illustrations and a very few words.
+ illustrations are precise but not busy.
+ layout motivates respect.

<u>DMWR 9-2815-210</u> 3-7, 3-207

- poor choice of word (insure not ensure).
- no reference to inspection criteria.
- portions of illustrations are hand drawn.
- use of imprecise words ("in convenient position").
- single column style.

<u>Midland manual</u> 42. 17

- single column style.
- caution statements are hidden in text.
- mixes indirect and direct language.
- unnecessarily long sentences.
- paragraphs are long and unnumbered.
- uses far too few illustrations.

<u>TM 11-5805-722-34 (and DMWR)</u> 3-2, 4-1

+ Layout motivates respect.
+ double column style.

+ step by step numbered procedures.

+ illustrations are photographs.

+ excellent illustrations.

+ precise words.

- much use of passive construction.

+ good use of notes.

- DMWR instructions are too general.

- letter point size is small.

Perkins manual E7, unnumbered

+ double column style.

- lettering is unusually small.

- no special treatment of not or caution data.

- no separation of task steps by numbers.

- imprecise wording ("suitably marked").

- excessive shadow in photo reduces illustration value.

DMWR 11-6625-2917-5 5-1, 2-2

- type is blotchy and unimpressive.

- imprecise words ("Thoroughly adequate").

- improper use of pronoun number.

- incomplete sentence.

- hand drawn table does not command respect.

- too few words to be complete.

- single column style.

Motorola manual. 24, 25

- very small letters.

+ double column style.

- long paragraphs, multi-step procedures without numbers.

+ aura of professionalism.

DMWR 9-2815-237 4-79, 4-38

- cryptic sentences, meaning is obscured.
- single column style.
+ letter font commands respect.
- small letter size.
- mixes active, passive sentence structure.
- imprecise language ("acceptable characteristics").
+ layout commands respect.

RCA manual 7, 13, 11

- manual mixes double and single paragraph style.
- extremely small letters.
- multiple repair steps in large, unnumbered paragraphs.
- far too few illustrations.
- 'keying" instructions appear outside "keying" paragraph.
- tables have information in them not explained in text.
- overall annoying style.

DMWR 55-2835-203 5-39, 5-15

+ good reference to tool numbers.
- single column style.
+ step by step directions, numbered sentences.
- imprecise language (use of "he" without antecedent, dangling modifier, non-parallel sentence construction).

Lycoming LT101 72-00-00-52, 72-00-00-2.2

- fragment sentence.

- deleted article in sentence.

- paragraph headings have unnecessary descriptors.

- single column style.

- imprecise sentence (problem with sentence object).

- too many words to be brief. Same sentence repeated three times.

- small lettering.

- extremely busy illustrations.

DMWR 55-2840-106 1 5-185, 5-873

- significant amount of undefined jargon.

- single column style.

+ step by step, numbered repair sentences.

- notes do not stand out well from other text.

- illustrations are faded and blurry.

Allison 250-C28B 72-00-00-35, 72-00-00-36

- single column style.

- incorrect word use ("ascertain the aircraft").

- imprecise notes: inverted meaning in sentence predicate.

- deletion of needed comma in sentence.

- poor pronoun reference in warning statement.

- illustrations have faded lines.

- manual does not command respect.

- awkward, poorly written sentence.

DMWR 9-2815-224 4-47, 4-91

+ good use of reference to explain jargon.

- single column style.

+ step by step, numbered repair steps.

+ very clear, professional looking graphics.

+ layout motivates respect.

APPENDIX K

SAMPLE USABILITY QUESTIONNAIRE

CUSTOMER QUESTIONNAIRE

To the Reader of This Instruction Manual:

Motorola is engaged in a continuous program of improving its instruction literature. We believe that you can aid us in this program, so that we in turn can better help you service our equipment. To foster these aims, would you please answer the following questions:

First Fold

SCHEMATIC DIAGRAMS AND CABLING DIAGRAMS

First Fold

1. ☐ Are accurate and easy to follow
2. ☐ Contain minor errors
3. ☐ Contain major errors
4. ☐ Are difficult to follow

If you have checked any box except 1, please tell us what schematic diagrams, or portions thereof, were at fault, or enter other comments.*

____

____

TEXT

1. ☐ Easy to follow – helps to service equipment
2. ☐ Would like more information on*

Second Fold ____ Second Fold

____

3. ☐ Some instruction sections are too long or superfluous such as*

____

____

4. ☐ Other comments*

____

____

____

(continued on reverse side)

PARTS LIST

1. ☐ Are complete and accurate
2. ☐ Would like more information as follows*

____

____

ILLUSTRATIONS IN GENERAL

1. ☐ Are complete and accurate
2. ☐ Want more illustrations such as*

____

____

3. ☐ Some are superfluous such as*

____

____

The name of my instruction manual is:

____

The part number of my instruction manual is:

____

(This number will be found on the cover or on the title page)

My name is ________________________

Company ________________________

Address ________________________

Date ________________________

*Whenever possible, give complete model No. of equipment, and part No. of diagram or part No. of instruction section. This information is important.

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APPENDIX L

RAW DATA FROM RGL, ILLUSTRATION FREQUENCY AND CUE FREQUENCY TESTS

CUMMINS NH/NT/NTA 855

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
157		13		232		1	2 of 6
155		13		212		20	0-3
158		14		220		40	1-6
163		12		235		60	1-28
171		9		222		80	2-10
159		13		201		100	4-6
159	158	12	12	199	200	120	7-4
165		13		223		140	8-2
153		21		210		160	8-23
156		13		212		180	14-4
167		13		240		200	14-26
170		11		251		220	14-48
152		13		290		240	18-19
159		17		229		260	20-8
2243		187		3176			
word/sen		RGL		syl/wrd			
12.0		6.0		1.42			
		#		page		#/pg	
Illust		522		292		1.8	
Cue		1735		292		5.5	

CAT MANUAL

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
155		12		254		6	6
170		8		220		12	12
158		10		241		18	18
157	157	9	9	232	232	24	27
150		7		223		30	31
157		16		211		36	36
153		18		239		42	42
157		22		247		49	49
154		16		199		54	55
159		18		210		60	60
169		12		207		66	65
159	159	22	22	230	233	72	71
152		18		205		85	86
154		17		217		85	86
2204		205		3135			
word/sen		RGL		syl/wrd			
10.8		5.5		1.42			
		#		page		#/pg	
Illust		117		85		1.4	
Cue		574		85		6.8	

PERKINS MANUAL

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
177		9		282		1	C.1
157		8		224		7	E.3
153		10		223		13	E.8
183	182	9	9	262	264	19	G.1
150		10		217		25	H.4
166		10		239		31	K.1
165		10		227		37	M.3
155		11		209		43	N.6
157		7		214		49	P.1
167		9		273		55	R.1
166		11		281		61	S.3
162		11		237		67	T.1
163		6		236		73	K.7
152		11		211		79	L.3
2273		132		3335			
word/sen		RGL		syl/wrd			
17.2		8.8		1.46			
		#		page		#/pg	
Illust		125		80		1.6	
Cue		376		80		4.7	

MACK MANUAL

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
167		7		316		1	1-1
152		11		219		65	2-43
151		10		236		130	2-100
154	154	14	14	264	267	195	2-205
154		13		242		260	2-238
160		15		221		325	2-307
152		11		212		390	2-369
152		7		228		455	2-433
158		10		238		520	2-499
160		15		230		585	2-563
170		15		255		650	2-628
162		9		253		715	3-26
165		5		244		780	4-19
173		7		258		845	4-73
2230		149		3416			
word/sen		RGL		syl/wrd			
15.0		8.5		1.53			
		#		page		#/pg	
Illust		1612		847		1.9	
Cue		1827		847		2.2	

DETROIT DIESEL

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
167		7		252		1	5
163		9		237		66	1.3.2-3
156		8		209		131	1.7.2-2
159		11		173		196	2.1.1-1
155	153	10	10	206	204	261	2.7.1.2-6
169		8		275		326	2.7.3-1
150		14		200		391	3.3-3
159		9		242		456	3.5.2-1
162		9		228		521	5.4-5
166		8		230		586	8.1-3
154		6		216		651	9.1.3-38
158		8		243		716	13.1-1
182		13		276		771	14.3.3-2
151		12		251		846	15.2-9
2251		133		3238			
word/sen		RGL		syl/wrd			
17.1		8.0		1.44			
		#		page		#/pg	
Illust		1070		853		1.3	
Cue		4275		853		5.0	

TACOM DMWR 9-2815-205

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
·163		7		284		1	1-1
168		11		341		29	2-24
162		14		288		58	3-14
151		12		215		87	3-43
165		12		247		116	3-73
163	163	13	13	273	271	145	3-102
159		11		221		174	3-131
150		18		247		203	3-156
152		14		231		232	3-187
154		14		230		261	3-217
159		10		244		290	3-247
162		10		288		319	4-11
155		8		235		348	7-1
165		8		257		377	10-6
2228		162		3601			
word/sen		RGL		syl/wrd			
13.8		9.0		1.62			
		#		page		#/pg	
Illus		188		382		.5	
Cue		1136		382		3.0	

TACOM DMWR 9-2815-237

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
152		12		271		1	1-1
150		16		258		9	2-1
162		12		281		17	3-1
164		14		292		23	3-3
150		14		222		31	4-2
153		14		273		39	4-5
155		12		257		47	4-13
152	152	12	12	229	226	55	4-28
157		9		218		63	4-45
153		16		263		71	4-48
152		6		228		79	4-78
170		6		347		87	5-1
155		7		273		95	5-6
150		11		301		103	6-1
2175		161		3713			
word/sen		RGL		syl/wrd			
13.6		10.0		1.71			
		#		page		#/pg	
Illust		69		111		.6	
Cue		656		111		5.9	

TACOM DMWR 9-2815-213

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
154		9		277		1	1A9
155		10		222		17	1B4
172		12		304		33	1C5
167		17		272		49	1D8
154		12		232		65	1E13
157		10		230		81	1G4
169		13		256		97	2A6
156	156	15	15	268	269	113	2B9
152		12		215		129	2C9
162		12		290		145	2E1
160		15		261		161	2F5
151		15		239		177	2G5
174		12		256		203	3A9
162		10		251		218	3C9
2245		174		3573			
word/sen		RGL		syl/wrd			
12.9		8.7		1.59			
		#		page		#/pg	
Illust		181		218		.8	
Cue		721		218		3.3	

TACOM DMWR 9-2815-210

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
166		11		290		1	1-1
151		12		271		40	2-2
165		12		315		79	3-1
153		11		227		118	3-32
157		10		237		157	3-65
150		18		230		196	3-112
156	157	13	13	226	226	235	3-149
160		13		248		274	3-187/188
157		10		234		313	3-227
158		11		231		352	3-266
151		15		229		391	3-305
167		8		257		430	4-23
160		6		256		469	4-60
158		9		303		508	5-2
2209		159		3554			
word/sen		RGL		syl/wrd			
13.9		8.8		1.61			
		#		page		#/pg	
Illust		137		514		.3	
Cue		1404		514		2.7	

TACOM DMWR 9-2815-224

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
156		10		270		1	1-1
152		11		276		44	3-6
164		9		318		87	3-27
161		11		309		120	4-1
151		11		236		163	4-41
163		12		294		206	4-80
153		13		225		249	4-116
157	157	9	9	256	254	292	4-158
156		14		304		335	4-197
151		13		242		378	4-232
174		11		260		411	4-273
176		11		282		454	4-319
156		9		254		497	4-361
164		7		218		540	4-416
2234		151		3744			
word/sen		RGL		syl/wrd			
14.8		10.1		1.68			
		#		page		#/pg	
Illust		217		559		.4	
Cue		2858		559		5.1	

LYCOMING LT101

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
164		11		280		1	71-00-00-5
156		9		257		28	71-00-00-29
152		10		263		56	72-00-00-11
153		31		284		84	72-00-00-38
150		9		238		112	72-00-00-66-R2
155		9		248		140	72-00-00-95
151		11		265		168	72-00-00-121-R2
165	165	11	11	278	280	196	72-30-00-7
166		12		265		224	72-40-00-14
162		20		253		252	72-60-00-7-R2
150		13		249		280	73-10-04-19
159		14		276		308	74-20-02-11
178		14		305		336	77-20-02-9
158		15		279		364	79-20-04-16
2219		189		3740			
word/sen		RGL		syl/wrd			
11.7		9.0		1.69			
		#		page		#/pg	
Illust		140		368		.4	
Cue		1484		368		4.0	

ALLISON 250-C30 P,M

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
166		11		301		1	72-00-00-1
159		11		246		34	72-00-00-36
152		6		232		68	72-00-00-68
152		21		241		102	72-00-00-102
157		11		287		136	72-00-00-315
150		18		226		170	72-00-00-612
155		11		266		204	72-30-00-206
153	152	11	11	198	197	238	72-40-00-204
167		15		265		272	72-50-00-219
152		11		198		306	72-60-00-208
153		7		248		340	72-60-00-242
151		10		216		374	73-20-02-207
163		6		278		408	74-20-03-201
166		10		285		442	77-20-01-204
2196		159		3487			
word/sen		RGL		syl/wrd			
13.8		8.8		1.59			
		#		page		#/pg	
Illust		173		443		.4	
Cue		2188		443		4.9	

ALLISON 250-C28

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
158		9		328		1	Intro 1
153		11		239		31	72-00-00-31
152		29		266		61	72-00-00-107
152		17		258		91	72-00-00-319
163		13		253		121	72-00-00-609
153		11		213		151	72-00-00-638
157	157	12	12	232	233	181	72-30-00-210
159		7		223		211	72-40-00-213
153		10		225		241	72-50-00-228
155		15		217		271	72-60-00-217
152		13		228		301	73-10-01-202
151		13		223		331	73-20-02-213
165		11		251		361	74-20-01-203&5
162		8		282		391	77-20-01-204
2185		179		3438			
word/sen		RGL		syl/wrd			
12.2		8.0		1.57			
		#		page		#/pg	
Illust		147		395		.4	
Cue		1314		395		3.3	

ALLISON 250-C20

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
155		9		305		1	ix
161		8		256		35	1-33/34
157		10		263		69	2-26
160		9		286		103	2-53
151		13		260		137	3-27
163		21		264		171	3-61
179	179	8	8	287	287	205	3-95
153		12		250		239	3-129
158		8		229		273	3-163/164
150		12		227		311	3-197
152		18		233		345	3-231
150		9		210		379	3-265
153		13		229		413	3-300
158		12		218		447	3-333
2200		162		3517			
word/sen		RGL		syl/wrd			
13.6		8.8		1.60			
		#		page		#/pg	
Illust		192		448		.4	
Cue		1174		448		2.6	

PRATT & WHITNEY PT 6A-20

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
163		9		256		1	D-19
155	155	9	9	240	240	66	F-14
157		8		272		131	B-20
151		10		220		196	B-14
165		10		258		261	G-2
182		12		293		326	G-19
159		9		220		391	F-23
160		14		234		456	I-14
151		12		268		521	A-14
160		10		268		586	D-4
175		8		322		651	F-2
155		8		269		716	H-9
180		12		317		781	C-20
150		8		260		845	A-23
2263		139		3697			
word/sen		RGL		syl/wrd			
16.3		10.3		1.63			
		#		page		#/pg	
Illust		525		845		.6	
Cue		2087		845		2.5	

AVSCOM DMWR 55-2835-209

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
157		10		275		1	1-1
150		11		268		16	2-12&3-1
157		14		242		30	4-15
152		13		265		45	5-11
156		11		281		60	5-28
152		9		262		75	5-45
160		12		237		90	5-66
168		14		236		105	5-81
159	159	15	15	259	257	120	5-98
162		15		236		135	5-120
155		14		247		150	5-130
155		19		271		165	5-144
157		10		270		180	7-1
165		9		290		195	7-15
2205		176		3639			
word/sen		RGL		syl/wrd			
12.5		9.0		1.65			
		#		page		#/pg	
Illust		169		206		.8	
Cue		1032		206		5.0	

AVSCOM DMWR 55-2840-106-1,2,3,4

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
195		8		405		1	1-1
162		17		226		118	4-35
153		20		235		240	5-69
153	153	15	15	236	236	358	5-184
165		18		253		465	5-875
164		17		251		594	5-1004
151		11		244		711	5-1121
160		14		246		835	5-1236
161		9		255		958	5-1353
154		10		234		1063	5-1441
165		11		265		1181	5-1559
152		9		236		1299	5-1667
153		8		232		1416	7-16
159		9		252		1534	10-1
2247		176		3570			
word/sen		RGL		syl/wrd			
12.8		8.7		1.59			
		#		page		#/pg	
Illust		733		1536		.5	
Cue		5774		1536		3.8	

AVSCOM DMWR 55-2835-205

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
157		10		273		1	1-1
152		11		231		22	3-5
163		11		264		43	5-8
168		12		280		64	5-29
159		10		276		85	5-41
157	158	12	12	244	243	106	5-71
163		12		257		127	5-92
170		13		277		148	5-108
152		12		253		169	5-134
159		17		276		190	5-154
175		12		295		211	2-175
157		11		231		232	5-196
163		10		267		253	6-6
157		9		273		274	8-2
2252		162		3697			
word/sen		RGL		syl/wrd			
13.9		9.1		1.64			
		#		page		#/pg	
Illust		185		285		.6	
Cue		1045		285		3.7	

AVSCOM DMWR 55-2840-104

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
156		7		315		1	1-1
151		14		266		186	4-48
170		8		268		371	4-263
170		13		265		556	4-444
155		9		248		741	4-623
173		11		276		926	4-809
153		13		243		1111	4-987
152		11		243		1296	4-1165
165		10		252		1481	4-1338
154		15		233		1666	4-1509
164		8		286		1851	4-1682
160		10		240		2036	11-54
150	150	8	8	220	221	2221	12-9
159		13		261		2406	14-1
2232		150		3616			
word/sen		RGL		syl/wrd			
14.9		9.3		1.62			
		#		page		#/pg	
Illust		987		2407		.4	
Cue		8415		2407		3.5	

AVSCOM DMWR 55-2840-242

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
_169		7		307		1	1-1
153		8		285		51	3-3
178		9		309		101	3-4.6
151	151	9	9	251	251	151	3-64
150		11		229		201	3-116
151		13		268		251	3-159
163		14		245		301	3-172
174		12		272		351	3-220
154		10		230		401	3-266
156		9		245		451	3-311
154		9		240		501	3-356
159		11		254		551	4-27
168		9		276		601	4-48
170		15		282		651	6-1
2250		146		3693			
word/sen		RGL		syl/wrd			
15.4		9.9		1.64			
		#		page		#/pg	
Illust		316		652		.5	
Cue		2108		652		3.2	

GE SERIES E MANUAL

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
170		13		273		1	1
153		13		244		4	1
159		10		260		8	7
164		11		278		12	1
167		13		289		16	2
155		9		233		20	4
201		7		294		24	1
166		13		268		28	4
163		6		253		32	1
152		8		239		36	1
150		8		239		40	1
154	153	12	12	284	283	44	2
177		7		280		48	1
160		9		219		52	3
2291		139		3653			
word/sen		RGL		syl/wrd			
16.5		9.8		1.59			
		#		page		#/pg	
Illust		24		53		.5	
Cue		341		53		6.4	

MOTOROLA MANUAL

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
174		10		314		1	1
152		10		263		4	8
172		10		242		7	16
159		10		274		10	22
152		10		261		13	29
160		11		266		16	3
153		7		267		19	11
151		7		230		22	18
159	158	9	9	265	264	25	13
167		5		283		28	25
158		10		259		31	27
151		7		266		34	96
177		9		310		37	99
155		10		276		39	93
2240		125		3776			
word/sen		RGL		syl/wrd			
17.9		11.4		1.69			
		#		page		#/pg	
Illust		25		137		.2	
Cue		1010		137		7.4	

E F JOHNSON MANUAL

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
172		10		282		1	1-1
170		14		294		3	2-1/2
151		10		247		5	3-1
174		10		281		7	3-3
167		10		250		9	3-5
150		8		231		11	3-7
160	160	7	7	253	253	13	3-11
155		12		255		15	3-13
160		15		273		17	4-1
151		11		266		19	4-3
151		8		256		23	4-7
151		11		221		24	4-8
169		11		241		27	5-1
154		13		234		29	5-3
2235		150		3584			
word/sen		RGL		syl/wrd			
14.9		9.2		1.60			
		#		page		#/pg	
Illust		16		29		.6	
Cue		173		29		6.0	

RCA MANUAL

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
152		12		284		1	5
156		14		272		5	9
151		11		259		9	15
164		13		239		13	17
158	157	15	15	258	256	17	19
168		7		276		21	5
155		8		267		25	6
158		12		256		29	11
156		12		288		33	17
163		11		337		37	5
163		9		284		41	10
151		7		252		45	12
175		10		320		49	14/15
159		7		238		53	20
2229		148		3830			
word/sen		RGL		syl/wrd			
15.1		10.7		1.72			
		#		page		#/pg	
Illust		53		69		.8	
Cue		211		69		3.2	

MIDLAND SYNTECH MANUAL

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
156		11		291		1	2
151		10		250		7	7
173		10		283		13	13
158		11		250		19	17
163		10		254		25	42
164		11		227		31	43
151	151	8	8	247	249	37	51
158		8		274		43	52
160		7		241		49	54
151		9		291		55	55/56
164		9		227		61	75
163		6		254		67	81
165		6		225		73	82
152		10		240		79	84
2229		126		3554			
word/sen		RGL		syl/wrd			
17.7		10.4		1.59			
		#		page		#/pg	
Illust		12		85		.1	
Cue		432		85		5.1	

CECOM DMWR 11-5805-722 (DMWR & TM)

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
183		13		320		1	1-1
155		11		259		10	3-1
184	181	13	13	336	336	19	4-1
160		17		333		28	4-3
150		11		255		37	1-1
156		9		247		46	2-5
155		8		234		55	2-14
168		11		287		64	3-3
170		14		285		73	3-12, 4-1
151		9		274		82	4-11
150		8		231		91	4-20
159		12		277		100	4-32
153		8		248		109	4-41
156		11		212		118	4-50
2250		155		3798			
word/sen		RGL		syl/wrd			
14.5		10.1		1.69			
		#		page		#/pg	
Illust		95		116		.8	
Cue		1063		116		9.2	

CECOM DMWR 11-5820-667

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
151		10		306		1	1-1
155		12		297		5	1-6
152		10		257		9	21-
182		10		361		13	2-6
159		10		321		17	2-10
166	166	13	13	262	265	21	3-3
163		11		238		25	3-7
166		9		245		29	3-11
151		8		205		33	3-15
150		11		216		37	3-19
161		10		280		41	3-23
166		11		300		45	4-1
157		17		218		50	5-2
160		8		275		54	7-1
2239		150		3781			
word/sen		RGL		syl/wrd			
14.9		10.4		1.69			
		#		page		#/pg	
Illust		33		54		.6	
Cue		144		54		2.7	

CECOM DMWR 11-5820-401

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
168		13		243		1	1-1
162		11		207		41	3-9
160		17		227		85	3-53
156		8		225		121	3-89
150	150	20	20	213	214	162	3-130
151		7		258		203	3-171
158	157	16	16	250	247	241	3-209
156		16		226		283	3-251
156		17		229		321	3-289
153		16		230		361	3-328
159		9		264		402	3-369
154		7		264		444	3-411
159		13		234		501	3-448
172		11		215		541	4-9
2214		181		3285			
word/sen		RGL		syl/wrd			
12.2		6.8		1.48			
		#		page		#/pg	
Illust		279		522		.5	
Cue		2184		522		4.2	

CERCOM DMWR 11-5820-529-50

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
151		7		278		1	1-1
171		10		294		2	1-2
156		20		295		4	2-1,2-4
169	169	7	7	253	253	5	3-1
157		12		215		7	3-3
150		13		222		8	3-6
151		10		243		10	3-8
167		13		282		11	3-9
160		20		238		13	3-11
161		14		233		14	3-4
162		16		219		16	3-12
166		14		236		17	3-7
156		14		250		19	3-10
164		15		241		20	3-5
2243		186		3514			
word/sen		RGL		syl/wrd			
12.1		7.8		1.57			
		#		page		#/pg	
Illust		6		20		.3	
Cue		77		20		3.9	

CERCOM DMWR 11-6625-2917-5

word/sec	chk	sen/sec	chk	syl/sec	chk	page	actual
170		13		301		1	1-1
180	179	8	8	296	297	3	1-3
154		18		282		4	2-1
156		15		267		6	3-1
158		9		279		7	5-1
153		7		298		9	5-2
155		13		255		10	5-3
162		9		322		12	7-1
152		14		277		13	7-2
174		7		314		15	7-3
153		14		285		16	7-4
157		17		277		17	7-5
150		12		271		18	7-6,8-1
163		13		289		19	2-3,4-1
2237		169		4013			
word/sen		RGL		syl/wrd			
13.2		11.0		1.79			
		#		page		#/pg	
Illust		3		19		.2	
Cue		73		19		3.8	

APPENDIX M

EXAMPLE OF AMC PAM 310-9

DMWR 55-2840-104 THRU DMWR 55-2840-106-4

ENGINE SHAFT TURBINE MDL T55-L-7,7B,7

MEDIA SIZE

CAGE NOMENCLATURE/AMDF MDL TYPE-DES END-ITEM-NIIN

91547 ENGINE,AIRCRAFT,TUR T55-L-7

91547 ENGINE,GAS TURBINE T55-L-7B

91547 ENGINE,GAS TURBINE T55-L-7

ENGINE SHAFT TURBINE MDL T55-L-7,7B,7

DATE PAGES MAN ML PUB-TYPE MEDIA SIZE

JAN 1989 548

CAGE NOMENCLATURE/AMDF MDL END-ITEM-NIIN

91547 ENGINE,AIRCRAFT,TUR T55-L-7

91547 ENGINE,GAS TURBINE T55-L-7B

91547 ENGINE,GAS TURBINE T55-L-7

ENGINE,SHAFT TURBINE T55-L-7,7B,7

DATE PAGES MAN ML PUB-TYPE MEDIA SIZE

JAN 1989

CAGE NOMENCLATURE/AMDF MDL TYPE-DES

91547 ENGINE,AIRCRAFT,TUR T55-L-7

DMWR 55-2840-106-4 THRU DMWR 55-2840-113-2

APPENDIX N

SUMMARY OF POINT SIZE FINDINGS

SUMMARY OF POINT SIZE FINDINGS

The following list represents the data collected from the manuals in respect to point size. The standard point sizes, from MIL-M-38784B, are located in Appendix O.

DEPOT MANUAL	COMMERCIAL MANUAL
8	7
8	7
7	7
7	7
7	7
7	6
7	6
7	7
7	4
8	7
7	6
8	7
7	7
8	7
8	6
109	98

Depot average point size 7.4
Commercial average point size 6.5

APPENDIX O

TYPE POINT SIZE

TYPE POINT SIZE	HEIGHT OF FONT DIMENSIONS INCHES (+.005)
4	L - .035 S - .025
6	L - .055 S - .030
7	L - .060 S - .040
8	L - .070 S - .045
9	L - .080 S - .050
10	L - .090 S - .055
11	L - .095 S - .060
12	L - .105 S - .065
14	L - .125 S - .075

L - Equals upper case letters and numerics plus b,d,f,g,h,j, k,l,p,q,t, and y.

S - Equals the following lower case letters: a,c,e,i,m,n,o, r,s,u,v,w,x, and z.

FIGURE 4. Type point sizes

VITA

Cpt Mark E. Newell was born on 23 October 1956. He graduated from the University of California, Davis, in 1981, with a degree in English (teaching), and German. Upon graduation, he was commissioned a 2nd Lieutenant in the Army, and has served in Organizational, Intermediate, and General Support Maintenance levels since then, in Germany and the United States. In Germany, he commanded a (formerly depot level) maintenance facility, the Kaiserslautern Maintenance Center, performing General Support/ Theater Retrograde maintenance on M1 Abrahms tanks and heavy wheeled vehicles. After completion of masters degree studies through the Florida Institute of Technology, Cpt Newell will work as a production controller at Red River Army Depot, overhauling M2/M3 Bradley Fighting Vehicles.

Briefing

The Depot Systems Command (DESCOM), a division of the Army Material Command (AMC), has sought to increase the efficiency of the Army Depot system and reduce its costs, and has targeted its overhaul manuals (the t Maintenance Work Requirements (DMWRs)) for termination. I is DESCOM's contention that the DMWR does not compare favorably with other forms of technical overhaul manuals, particularly not with the best forms of overhaul manuals of the commercial world, and it wants to adopt these "other" forms. However, DESCOM has not specifically stated what is desirable or undesirable in manuals, nor what is bad, with respect to DMWR usability, or what is good, with respect to commercial manual usability.

The hypothesis of this study was the standard "null hypothesis", or, "no difference between the two sets."

This study provided a locus of verifiable data and related research to act as a source to answer some of these questions. It employed six common manual usability tests to compare a representative sample of overhaul manuals from the commercial and the Depot sectors.

viewgraph 1

6 tests

These are the six tests. The user test was the only qualitative test, and the other 5 were qualntitative.

viewgraph 2

Research data

The related research showed that:

1. The two sets are similar enough to be comparable

2. No previous test showed significant differences

3. A usability comparison was seen to be needed

4. Reading Grade Level tests are not good for the designing stage of manuals, but can be good to compare exi.ting texts. A lower RGL is better, if the manual is also judged readible by a user test.

5. Cues help readers pick out of texts important meaning. More cues, (up to a point), are better.

6. Illustrations help conceptualize information, but should have as much color and realism as technically possible. More illustrations are better.

7. "Other" represents the fact that larger point sizes are better than smaller, and double column paragraph style is better than single.

8. The Army has put little investment in designing DMWR manuals to motivate reading. That is, making the text desireable for human beings to read.

viewgraph 3

Samples

The sample was a big one, of 15 commercial and 15 Depot manuals, representing more than 12,500 manual pages, in three equipment catagories (truck engines, aircraft engines, and radios).

viewgraph 4

Findings (1)

This is the first of two viewgraphs on findings. The findings of the tests indicated that there are no significant differences in the two manual sets.

The calculated TWO-Way ANOVA test for blocks and treatments for these three manual usability tests are all lower than the critical value for significance, so in every case, the null hypothesis was accepted. There are no significant usability differences between the two manual sets, as judged by these tests.

viewgraph 5

Findings (2)

1. DMWRs had a larger average point size than commercial manuals, but had a smaller point size than the regulation calls for.

2. DMWRs had much fewer manuals with double column, though the regulation stipulates that they should always

have double column, unless otherwise stated.

3. The user test was the best loved test of all tests, by the researchers. By this test, DMWRS come out a little bit ahead and not so far behind, but the difference is not greater than 2%. In both cases, there were more bad aspects of both the manuals than good aspects.

viewgraph 6

Recommendations

The general recommendations are:

1. Somebody else should try their hand at finding differences between the manuals.

2. A cost benefit study should be done to see what value is added to Depots by the usual practice of rewriting commercial manuals to make them into DMWRS (the change so far has not made the manuals significantly different).

3. The Army should pay attention to "reading motivators and demotivators", because no matter how silly they may seem, if the human beings that overhaul movers (trucks and aircraft), shooters, and communicators (radios), don't read the manuals, how good can the quality be?

4. The findings and research principles in this stuay should be used to improve DMWRs, rather than scrapping the $250 million DMWR library in favor of manuals that aren't significantly different.

SIX TESTS

*READING GRADE LEVEL
*ILLUSTRATIONS
*CUE FREQUENCIES
*USER TESTS
*LETTER POINT SIZE
*PAGE LAYOUT STYLE

RESEARCH DATA

*COMPARABLE

*NO DIFFERENCE

*USABILITY ?

*RGL, CUES, ILLUSTRATION

*OTHER

*READING MOTIVATION

REPRESENTATIVE SAMPLE

*15 DEPOT MANUALS

*15 COMM MANUALS

*3 COMMODITIES

*12,594 SAMPLE PAGES

FINDINGS (1)

	CALC	CRIT
RGL	.118, .855	7.7
ILL.	.413, .826	7.7
CUE	1.34, 5.83	7.7

FAIL TO REJECT

FINDINGS (2)

	DAWR	COMM
POINT SIZE	7.4	6.5
COLUMN STYLE	19%	67%
USER TEST	40%	37% (GOOD)
	60%	63% (BAD)

RECOMMENDATIONS

*MORE TESTS

*COST BENEFIT STUDY

*READING MOTIVATORS

*USE THESE FINDINGS !