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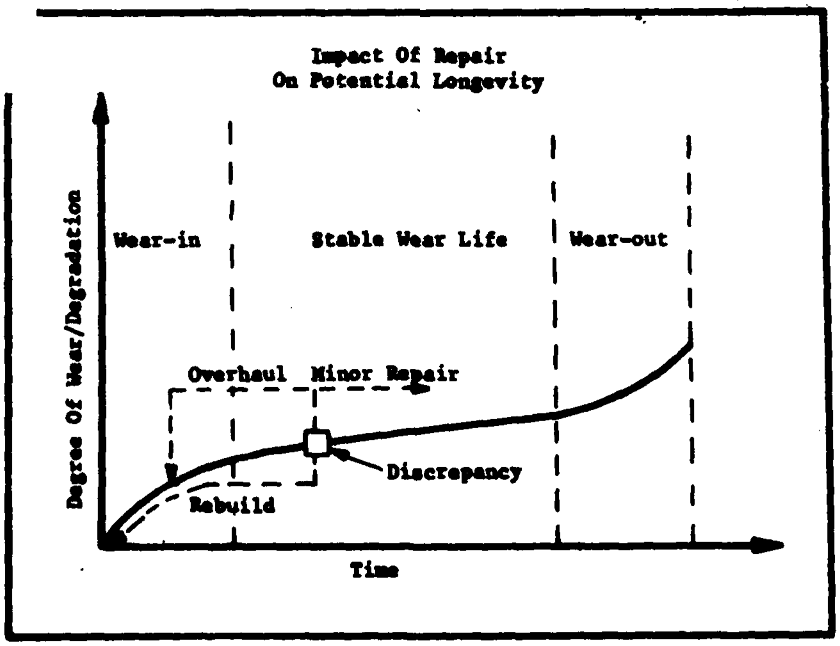
DEPOT MAINTENANCE HANDBOOK



U.S. ARMY AVIATION SYSTEMS COMMAND

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The Depot Maintenance Handbook was developed to help ensure the continued efficient and effective manner in which maintenance is performed at the Corpus Christi Army Depot. This handbook is directed to engineers, on-line maintenance personnel, and others who are involved in the planning and performance of maintenance at the depot level. It provides reference information for engineers so that they may effectively address AVSCOM Engineering Directives (AEDs) and AVSCOM Engineering Calls (AECs). It provides general information on the overall depot repair process and guidelines for repair action of the major failure modes encountered at the depot.

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DEPOT MAINTENANCE HANDBOOK

U.S. ARMY AVIATION SYSTEMS COMMAND

DEPOT ENGINEERING AND RCM SUPPORT OFFICE

CORPUS CHRISTI, TX.

Prepared as a Special Task under the auspices of the Nondestructive Testing Information Analysis Center for

U.S. ARMY AVIATION SYSTEMS COMMAND

APRIL 1985

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1988

FOREWORD

This handbook was developed to help ensure the continued efficient and effective manner in which maintenance is performed at the Corpus Christi Army Depot (CCAD). It is specifically designed for the U.S. Army Aviation Systems Command (AVSCOM) for reference purposes only and does not in any way supercede or supplement any official Army document.

The handbook is directed to engineers, on-line maintenance personnel, and others who are involved in the planning and performance of maintenance at the depot level. It provides reference information for engineers so that they may effectively address AVSCOM Engineering Directives (AEDs) and AVSCOM Engineering Calls (AECs). It provides general information on the overall depot repair process and guidelines for repair action of the major failure modes encountered at the depot.

This handbook was prepared by Reliability Technology Associates (RTA) as a Special Task under the auspices of the Nondestructive Testing Information Analysis Center (NTIAC) at Southwest Research Institute (SwRI) under Contract No. DLA900-84-C-0910, CLIN 0001A. At RTA, Mr. Douglas C. Brauer compiled and organized the technical material and developed the handbook under the overall technical direction of Dr. Daniel Henry. Final editorial preparation and publication was performed by NTIAC under the direction of Dr. George A. Matzkanin and Technical Publication Specialist, Mr. Don Moore.

On the part of the AVSCOM, the project was under the technical management of Mr. Lewis Neri, Chief, Depot Engineering and RCM Support Office. Mr. Robert Ladner, Chief of Power Train/Power Plant Branch, guided the development of the handbook and provided the necessary Army documents and other information used as input.

The proponent of this publication is HQ, AVSCOM. Users are invited to send comments to the Depot Engineering and RCM Support Office, Attn: AMSAV-MR, Corpus Christi, TX 78419-6195. Revision and updating of the handbook are envisioned at appropriate intervals.

TABLE OF CONTENTS

1.0 INTRODUCTION

This handbook is designed to serve as a reference guide in accomplishing depot maintenance repair tasks. It describes the depot repair process and the major failure modes encountered at the depot. It provides general guidelines for the repair of the major failure modes in order to effectively address AVSCOM Engineering Directives (AEDs) and AVSCOM Engineering Calls (AECs).

Army aircraft are maintained within a three-level maintenance concept in which depot maintenance is the final level (see Figure 1-1). The *first level* is aviation unit maintenance (AVUM), consisting primarily of preventive maintenance and minor repair/replacement functions. The *second level* is aviation intermediate maintenance (AVIM), consisting primarily of maintenance tasks exceeding AVUM capabilities (for example, special aircraft inspections and repair of specified components). The *third level* is depot maintenance, consisting of maintenance tasks exceeding AVIM and AVUM capabilities.

Depot maintenance is carried out in accordance with the Depot Maintenance Work Requirement (DMWR). The DMWR is a document which establishes requirements for disassembly, cleaning, inspection, repair, reconditioning, rehabilitation, modification, reassembly, servicing, testing, and packaging/preservation of aircraft, engines, aircraft components, and related ground support equipment.

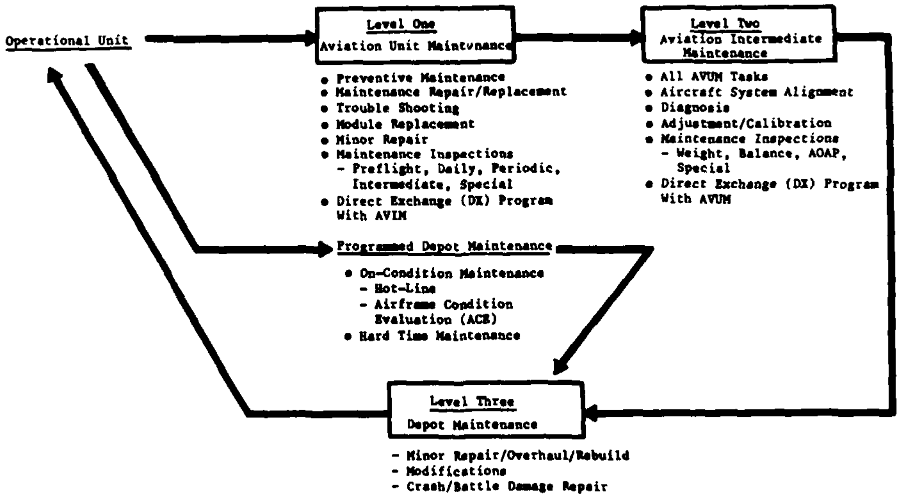

Figure 1-1 Army Maintenance Levels

To determine the specific maintenance tasks to be performed, AVSCOM applies Reliability-Centered Maintenance (RCM) concepts to aircraft and their dynamic components. RCM is a relatively new concept for developing optimum maintenance requirements and ultimately Integrated Logistic Support (ILS) data.

RCM is based on the premise that more efficient and cost-effective life-time maintenance and logistic support programs can be developed using a well disciplined decision logic which focuses on the consequences of failure. A computer-aided decision logic question sequence is applied to those parts that are maintenance and structurally significant in a particular end item, i.e., engine, transmission, rotor system, control system, airframe, etc. Each significant component failure mode is evaluated to identify maintenance tasks, specifically those that can be performed at the depot in accordance with the general guidelines given in this handbook. The logic process forces maintenance tasks to be classified into three areas: (1) *Hard Time Maintenance* for those failure modes that require scheduled maintenance at predetermined fixed intervals of age or usage; (2) *On-Condition Maintenance* (OCM) for those failure modes that require scheduled inspections or tests designed to measure deterioration of an item so that, based on the deterioration of the item, either corrective maintenance can be performed or the item can remain in service; and (3) *Condition Monitoring* for those failure modes that require unscheduled tests or inspection on components where *failure can* be tolerated during operation of the system or where impending failure can be detected through routine monitoring during normal operations.

The decision logic works within an eight-step overall RCM process. Table 1-1 identifies the steps involved in the RCM process.

Table 1-1 RCM Process

Step 1:	Determine Maintenance Significant Items
Step 2:	Acquire Failure/Repair Data
Step 3:	Develop FMECA/Fault Tree Analysis (FTA) Data
Step 4:	Apply Decision Logic to Catastrophic and Critical Failure Modes
Step 5:	Use FMECA/FTA Data to Help Answer Decision Logic Questions
Step 6:	Compile/Record Maintenance Classification - Hard Time - On-Condition - Condition Monitoring
Step 7:	Implement RCM Decisions - Depot Maintenance Work Requirements (DMWRs) - Phase Maintenance - Programmed Depot Maintenance (PDM) - Preshop Analysis (PSA) - Army Oil Analysis Program (AOAP)
Step 8:	Apply sustaining engineering based on actual experience data, eliminate default decisions, provide audit trail and assessment.

AVSCOM is using the "Automated Army Aircraft RCM," (A^3RCM) computer software package. A^3RCM provides the capability to rapidly develop a uniform and complete RCM-based maintenance program from standard, readily available input sources. It provides a maintenance history for each aircraft where requirements can be correlated to specific parts and their failure modes. It assures that *all* maintenance significant parts and failure modes are considered in the development of the maintenance requirements for an aircraft.[1]

With the use of RCM, aircraft and/or associated components can be inducted into depot level maintenance via Programmed Depot Maintenance (PDM) as illustrated in Figure 1-1. PDM includes both OCM and Hard Time Maintenance programs. Hard Time Maintenance is based on subjecting equipment to depot overhaul once the equipment operational period surpasses a specified time-between-overhaul period. OCM is based on subjecting equipment to a thorough noninvasive engineering analysis. Two OCM methods utilized are Hot-Line and Airframe Condition Evaluation (ACE).

Hot-Line is a telecon consultation between depot technicians and field maintenance personnel. It is primarily used to trouble-shoot engine problems so that repair can occur in the field. For engine problems other than crash damage, explosions, positive oil analysis, etc., the field unit must utilize the Hot-Line system before an engine can be turned into supply as a repairable. Hot-Line is a 24 hour available service.

ACE is an aircraft profiling technique utilized to improve fleet availability by identifying aircraft, using visual inspection techniques, that need repair or reconditioning to prevent degradation of inherent reliability and safety levels. The ACE program involves an annual structural evaluation of each aircraft in the operational fleet to identify those that are in the greatest need of depot maintenance; it is performed in accordance with the requirements of AVSCOM Pamphlet series 750-1. Aircraft Analytical Corrosion Evaluation (AACE) is a special corrosion evaluation program established as a companion to ACE and is performed in accordance with AVSCOM Pamphlet series 750-2. Further information on ACE and AACE is given in a three-part handbook[2] developed to provide AVSCOM managers and ACE/AACE engineers and profilers with a practical reference document of criteria, guidelines, and other information applicable to the ACE/AACE program. The ACE/AACE handbook, along with this handbook, emphasizes the application of standard, proven engineering methods and maintenance practice to ensure design integrity and quality of aircraft.

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[1]Further information on RCM is given in a report prepared by Reliability Technology Associates for AVSCOM: "Automated Army Aircraft RCM Analysis," September 1984.

[2]ACE/AACE Inspection and Analysis Handbook, AVSCOM, April 1985.

Not all aircraft sent to the depot go through the entire overhaul process. Depot maintenance involves only those tasks required to correct the aircraft defect(s) cited. Performing only those maintenance tasks that are required or need to be done, whether minor repair or overhaul, allows the depot maintenance organization to be operated in an efficient and cost effective manner.

2.0 DEPOT MAINTENANCE PROCESS

This section outlines the basic concepts and practices utilized in the depot maintenance process. Figure 2-1 illustrates the depot maintenance process as performed at the Corpus Christi Army Depot (CCAD). As shown in the figure, all equipment items are grouped into three main categories upon induction into the depot:

(1) *Category I: Aircraft*— This category encompasses the total aircraft; for example, the airframe, electrical wiring, seats, transparencies, push-pull systems and doors.

(2) *Category II: Large Components*—This category encompasses large components and major assemblies; for example, engines and transmissions.

(3) *Category III: Small Components*—This category encompasses small components and accessories; for example, generators, hydraulic pumps and oil coolers.

Scope of Work

Although overhaul is the major part of the repair performed at the depot, not all of the items processed at the depot receive a complete overhaul. An aircraft sent to the depot for a paint job, a transmission sent to the depot to replace an unreliable bearing or gear, and an engine sent to the depot to correct a seal leak are examples of cases where the Project Work Directive, or contract, stipulates the scope of work and identifies the appropriate Depot Maintenance Work Requirement (DMWR) as the technical data source to perform the repair task(s). The Project Work Directive is issued by the AVSCOM Directorate of Maintenance. Table 2-1 identifies the levels of repair applicable during the depot maintenance process.

Table 2-1 Levels of Repair

Minor Repair—restores serviceability to an item by correcting specific damage, fault, malfunctions or failure in a part, subassembly, module (component or assembly), end item, or system.
Overhaul—restores an item to a completely serviceable/operational condition as prescribed by the maintenance standard (for example, DMWR). Overhaul is normally the highest degree of maintenance performed. Overhaul does not normally return an item to like-new condition.
Rebuild—restores unserviceable equipment to a like-new condition in accordance with original manufacturing standards. Rebuild is the highest degree of material maintenance applied to equipment. The rebuild operation includes the act of returning to zero those age measurements (i.e., hours) considered in classifying hardware systems and components.

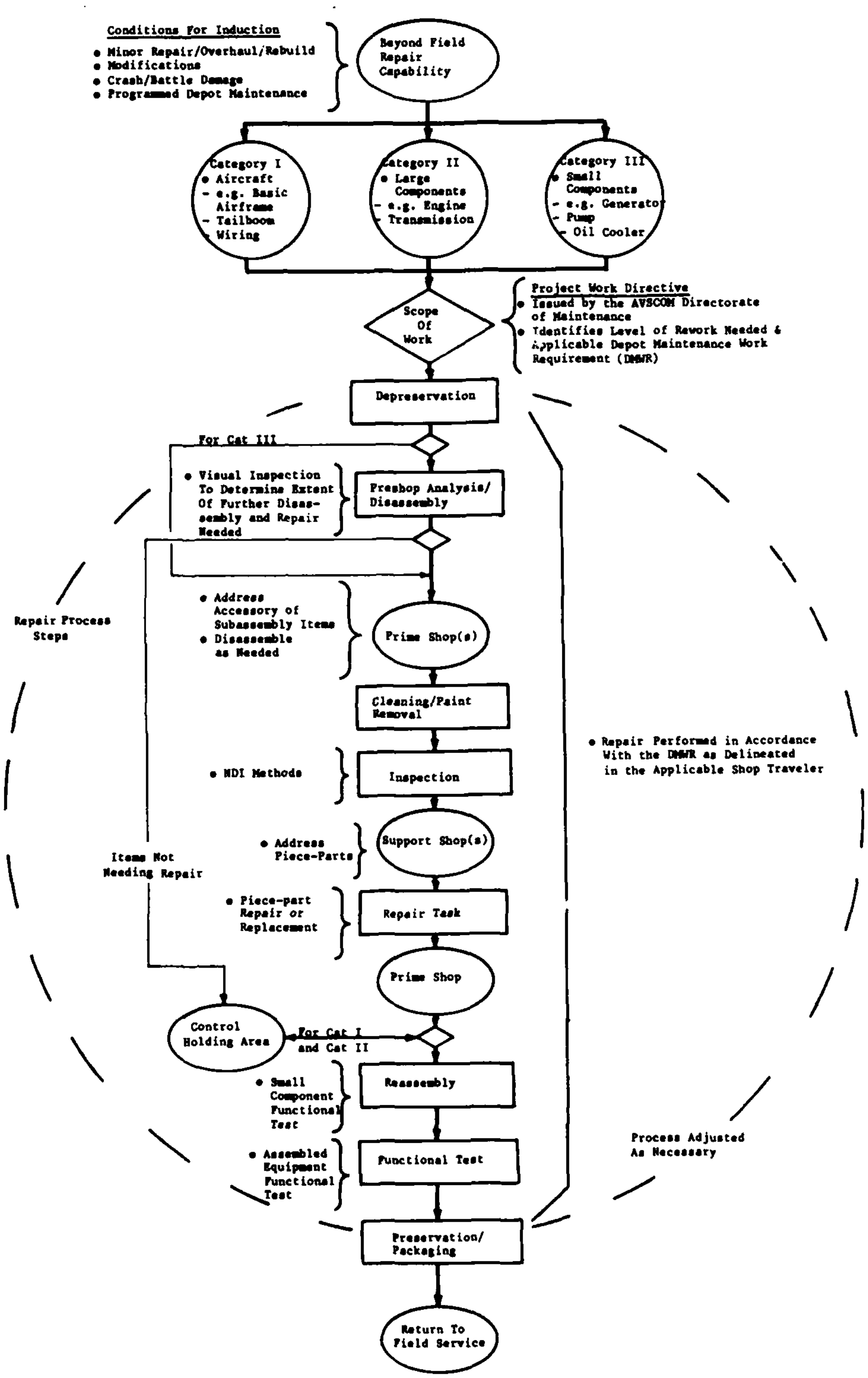


Figure 2-1 The Depot Maintenance Process

An aircraft sent to the depot for repair normally contains serviceable components (for example, engine, transmission, and gearbox) which are removed only to allow access for repair of the basic airframe and are subsequently reinstalled. If a discrepant component is discovered during assembly or functional testing and the discrepancy cannot be corrected with field level repairs, the component is turned into supply and a serviceable component issued.

Engines returned to depot for overhaul normally contain serviceable accessories (for example, fuel control, overspeed governor, and igniter unit) which are functionally tested (bench tested) and are subsequently reinstalled on the engines. Accessories which do not meet the functional test requirements and cannot be corrected by minor repairs are either turned into supply as "repairables" or inducted into a component repair/overhaul program. Some components require upgrading to a later configuration and are automatically inducted for repair. The engine DMWR normally provides the functional test criteria along with adjustment or trim criteria (where applicable). For minor repair, overhaul, or modification, the component DMWR is consulted.

When a complex unit becomes defective in the field, and is beyond field repair capability, it is often more cost effective to perform minor repair rather than overhaul the item when received in the depot. A minor repair consists of the minimum maintenance necessary to correct the specific discrepancy that caused the item to be returned to the depot along with other applicable tasks associated with reassembly, testing, and preservation. The minor repair changes the status of the unit from a repairable item to a serviceable item retaining reliability and safety design level requirements, but it does not, in general, increase its potential longevity. The determination to perform minor repair or overhaul is made after the item is inducted into the maintenance shops and undergoes a Preshop Analysis (PSA). The decision logic for making such a determination is based on fleet readiness and cost effectiveness.

Figure 2-2 illustrates a longevity curve which depicts wear/degradation behavior with respect to time. The slope of the curve during wear-in and wear-out varies from item to item as does the length and slope of the stable wear life part of the curve. A discrepancy changes an item's status from serviceable to repairable and acts as a roadblock in preventing the item from progressing down its longevity curve. When the discrepancy arises, usually either overhaul or minor repair is performed. Overhaul is performed to recover used-up wear life; in items with time-between-overhaul (TBO) limits; the longevity of an overhauled item approximates that of a new item. A minor repair removes the roadblock and allows the unit to progress; it does not recoup any of the used up wear life and therefore does not change the item's position on the longevity curve. If rebuild is performed, the item is new and is returned to the starting point of the longevity curve.

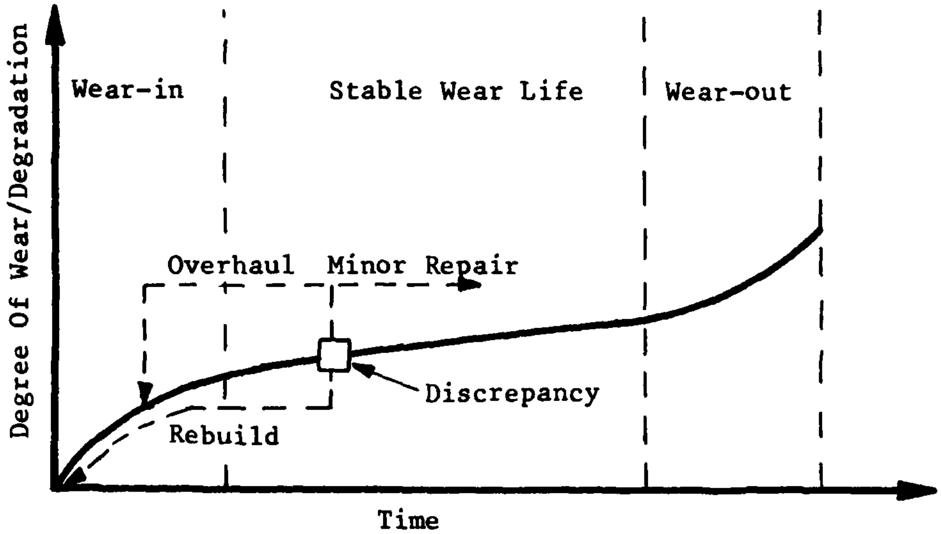


Figure 2-2 Impact Of Repair On Potential Longevity

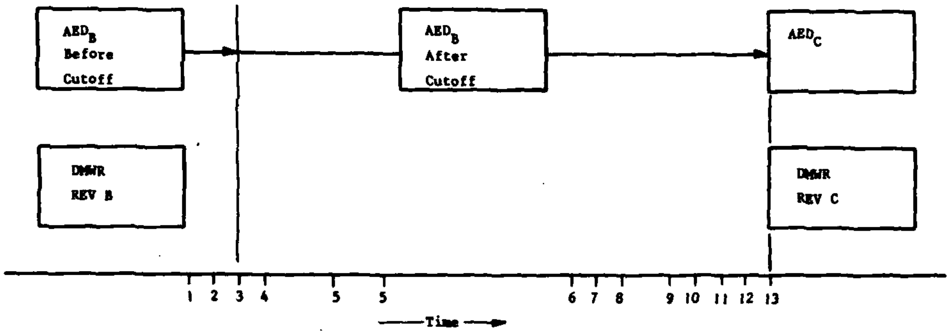
Depot Maintenance Work Requirement (DMWR)

A DMWR is a comprehensive document which contains complete overhaul criteria, identifies minimum acceptable standards and (where applicable) provides preshop analysis guidelines for determining the extent of repair required. It is normally provided as the "Statement of Work" for each item contracted or programmed for depot level maintenance. It is a "how to do" type of document which provides the necessary instructions for the complete overhaul of the item, including modification of parts, subassemblies, and assemblies and/or parts, subassemblies, and assemblies required to convert to latest item configuration as specified in depot program notices.

DMWRs are supplemented in the depot by AVSCOM Engineering Directives (AEDs). AEDs address specific problems in a DMWR and serve as an aid in updating the DMWR. AEDs are also used to formulate technical data packages for piece part repair contracts and provide alternate procedures to the depot because of unique capabilities or restrictions. AEDs of this latter type are referred to as "program" AEDs since they will not be picked up in a DMWR.

Updating DMWRs involves several groups within AVSCOM: the Maintenance Directorate's Provisioning and Technical Data Division, Technical Publications Branch, and the Depot Engineering and RCM Support Office; and the Product Assurance Directorate as well as the applicable depot (for example, Corpus Christi Army Depot). Figure 2-3 provides a chronological illustration of the DMWR revision and change processes. DMWRs are continually updated to reflect lessons learned and innovative methods utilized at the depot.

DMWR Revision Process

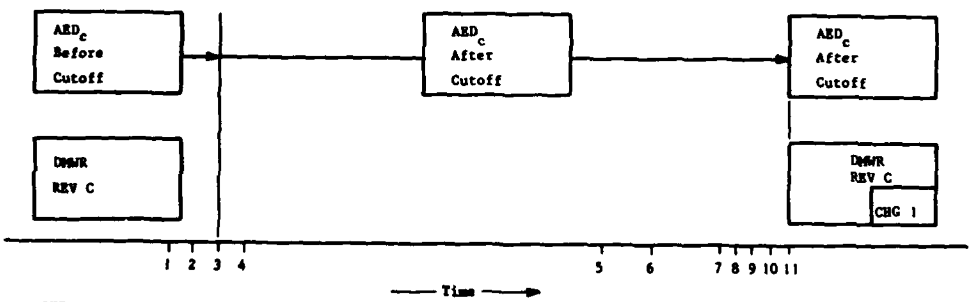


NOTE: Acronyms: AED_B/AED_C - AVSCOM Engineering Directive Which Is Applicable To REV. B/C (Respectively) Of The DMWR.

Chronological Steps:

1. Technical Publications Branch Decides To Update DMWR And Requests Engineering Review In Preparation For Update.
2. Engineering Completes Review And Provides Comments.
3. Publication Cutoff Date - No More "Changes" Can Be Accepted Against DMWR REV. B.
4. The Publication Contract Is Awarded.
5. In-Process Review(s).
6. Draft DMWR REV. C Is Provided To Technical Publications Branch.
7. DMWR Validation.
8. DMWR Verification.
9. Camera Ready Copy Of DMWR REV. C Provided To Technical Publications Branch.
10. $DMWR_C$ Goes To Print.
11. $DMWR_C$ Released To The Depot.
12. Engineering Re-Issues AED_B (After Cutoff) As AED_C.
13. DMWR REV. C And AED_C Complete Implementation In The Depot.

DMWR Change Process



NOTE: Acronyms: AED_C - AVSCOM Engineering Directive Which Is Applicable To REV. C Of The DMWR.

Chronological Steps:

1. Technical Publications Branch Decides To Update DMWR And Asks For An Engineering Review In Preparation For Update.
2. Engineering Completes Review And Provides Comments.
3. Publication Cutoff Date (Changes Can Continue To Be Accepted Against DMWR REV. C But They Will Not Be Included In The Current Update Effort).
4. Publication Contract Is Awarded.
5. Draft Change 1 Is Provided To Technical Publications Branch.
6. Tabletop Verification Of Change 1.
7. Camera Ready Copy Of Change 1 Provided To Technical Publications Branch.
8. Change 1 Goes To Print.
9. Change 1 Released To The Depot.
10. Engineering Cancels AED_C (Before Cutoff), Which Were All Picked Up In Change 1.
11. Depot Implementation - Change 1 Pages Inserted In DMWR REV. C And Cancelled AED_C (Before Cutoff).

Figure 2-3 DMWR Updating Processes

Shop Traveler

To make use of a DMWR in a practical manner, a specific item repair task to be performed during the depot process is converted into a "shop traveler." The shop traveler is attached to the item and delineates the steps taken to perform the repair action (as stated per the applicable DMWR).

Depreservation

Depreservation is the initial task to be performed in the depot process. Basically, the task is to remove the item from its incoming packaged state. Performing the depreservation task may require installing the item on a maintenance holding stand.

- *Category I*—Aircraft that are flown in do not require any depreservation. Aircraft within the continental United States (CONUS) are usually transported to the depot by truck and only Category II items may require decanning or deboxing. Items such as a tail boom or the basic airframe (i.e. the aircraft without any Category II or III items) require deboxing. Aircraft transported to the depot via ship may require removal of preservation compounds, such as Spraylatt.

- *Category II*—Requires decanning and/or other unpackaging. Any preservation fluids/compounds also need to be removed (for example, oil and grease). Techniques used to remove fluids/compounds include: vapor degreasing, emulsion degreasing, and steam/detergent.

- *Category III*—Requires deboxing and/or other unpackaging. Any preservation fluids/compounds also need to be removed (for example, oil and grease). Techniques used to remove fluids/compounds include: vapor degreasing, emulsion degreasing, and steam/detergent.

Preshop Analysis/Disassembly

Preshop analysis (PSA) is a logical inspection process that is done in conjunction with equipment disassembly. Components are disassembled to the subassembly level with the PSA team focusing on the reason(s) why the item was sent to the depot and component operating times. PSA specifies the extent of further disassembly and repair needed to be performed at the appropriate prime shop(s) and determines if component "short routing" can occur, i.e. if components can be sent directly to the control holding area or assembly lines. Defined weak spots within a component must be accessed to inspect for specified historically common deficiencies.

- *Category I*—PSA is conducted to determine the degree of disassembly required. This includes removal of all Category II and III items, tailboom, appropriate panels, and doors. After the aircraft is disassembled and PSA is completed, the airframe and airframe components (for example, tailboom, skids, panels, and doors) are routed to their appropriate prime shop. The Category II and III items are not repaired; these items are routed into a holding area or subjected to preservation and storage. If Category II and/or III items are found to be unserviceable during aircraft reassembly, they are turned into supply as repairables. These Category II and III items identified as repairables are then scheduled by AVSCOM for maintenance.

- *Category II*—PSA is conducted while removing all accessory items and disassembling the basic component into subassemblies/modules. PSA identifies the high confidence subassemblies/modules that can complete processing without further disassembly or with only partial disassembly. The accessory items are forwarded to their respective prime shop for check and test. Only minor repairs are allowed to address deficiencies; otherwise the assemblies are turned into supply as repairables and scheduled for maintenance. The subassemblies/modules of the basic component are forwarded to their respective prime shops for disassembly and processing. The high confidence subassemblies/modules receive a more thorough examination in the assembled or partially disassembled state in the prime shop. Based on findings, the prime shop can override the PSA judgment and completely disassemble the subassembly/module for further inspection and/or repair.

- *Category III*—There is no advantage to a PSA since, in any case, complete disassembly is required. These components are normally inducted into their respective prime shops where they are completely repaired/overhauled. Only those piece-parts requiring further repair (for example, machining, plating, or welding) are routed from the prime shop to a specialty shop.

Cleaning/Paint Removal

Cleaning and paint removal tasks are performed only if necessary to facilitate inspection and/or repair. When performing these tasks, caution must be taken to avoid skin contact and prolonged inhalation of vapors and dust. Also, cleaning/paint removal method effects on ceramic-coated, aluminum-coated, carbonized, painted, nitrided, magnesium, steel, and low-alloy steel type parts should be noted in order to avoid process induced damage.

- *Category I*—Normally the most needful of paint removal. This is performed using paint remover (Federal *Specification* TT-R0248), vapor blasting (for example, glass bead, light abrasive, or plastic media), or hot-alkali soak.

- *Category II*—Requires the removal of sludge and/or slurry. This is performed by masking all component openings to prevent clogging by deposits and then utilizing one of the following processes: solvent immersion, dry-cleaning solvent, vapor blasting (care must be taken to prevent wearing away of metal), hot-alkali soak, or periodic-reverse cleaning.

- *Category III*—Addressed the same as Category II components.

Inspection

Detailed inspection of components is performed at the prime shop. Inspection is directed at piece parts and utilizes nondestructive inspection (NDI) techniques, as appropriate. Appendix D presents the various NDI techniques utilized at the depot. (Components cleaned by dry-cleaning solvent have an oil film left by the process; this oil film must be removed before NDI can be accomplished.) Also, Appendix A presents a detailed list of defects and their probable causes for reference in performing inspection.

- *Category I*—Inspect for cracks, corrosion, holes, bends, delamination, distortion, wiring defects, linkage wear, hydraulic leaks, missing fasteners, etc.

- *Category II*—Inspect for cracks, bends, excessive wear, heat damage, fatigue, etc. An engine, for example, requires turbine blade inspection for deterioration and balancing flaws.

- *Category III*—Inspect for defects similar to Category II items. A fuel control, for example, requires control linkage inspection for excessive wear and damage.

Repair Task

The basic repair task for Category I, II, and III items is performed at the applicable prime shop. Items received at the prime shop are usually in the form of accessory or module/subassembly items. The Project Work Directive identifies the repair needed and identifies the applicable DMWR to be used. Normally, the specific repair action needed is identified in the form of a "shop traveler" and attached to the item.

The prime shop functionally tests the item and then performs disassembly, as needed, to the piece-part level. At this point a piece-part may be sent to a support shop for a specific specialized repair action. (Components cleaned by dry-cleaning solvent have an oily film left by the process which must be removed before painting, metal spraying, metal plating, welding, etc., can be performed.)

The Index to Depot Maintenance Work Requirements, DARCOM-P310-9 or AMC-P310-9, identifies all of the DMWRs and Technical Maintenance Manuals (TMs), including other Army documents, utilized at the depot. DMWRs and TMs are readily available for consultation by all AVSCOM personnel and any applicable practices or requirements contained within the DMWR or TM content should be adhered to.

Repair and replacement parts are identified in the appropriate repair parts and special tools list ("parts") manual pertaining to the system in question. These manuals generally have a repair parts list, a special tools list, and a National Stock Number and part number index. These lists identify the latest part number only.

The repair parts list identifies those parts authorized for use in the performance of maintenance. The list also includes parts which must be removed for replacement of the authorized parts. Illustrations corresponding to the list appear immediately preceding the list. Items appearing for information purposes only, which are not assigned source, maintenance, and recoverability (SMR) codes, are not to be requisitioned.

The special tools list identifies those special tools and support equipment authorized for the performance of maintenance. Illustrations corresponding to the list appear immediately preceding the list.

The National Stock Number (NSN) and part number index identifies, in ascending National Item Identification Number (NIIN) sequence, all of the NSNs appearing in the repair parts list and the special tools list. This list is followed by another list, in alphameric sequence, of all part numbers appearing in the repair parts list and the special tools list. NSNs and part numbers are cross-referenced to figure and item number appearance.

To obtain information on older configuration parts, the Data Master File and/or the appropriate DMWR parts listing should be addressed. The Data Master File is updated monthly and available in microfiche form. It is keyed to NSN and part number and also identifies interchangeable parts and the part which will be sent (i.e. older or latest part number) upon a part request. The DMWR listing provides the most complete listing of older part numbers.

When an item has been replaced, issue will continue to be made until existing stocks become exhausted, except in the case when replacement is limited to one-way use. To insure complete exhaustion of stock on hand, if it is acceptable to use a replaced item, the replaced item should be requisitioned. To denote one-way or two-way replacement, mnemonic codes are used in the description. The replaced item(s) always contains the mnemonic code RPL-BY. The replacing item, if it is a two-way replacement, contains the mnemonic code RPLS. If it is a one-way replacement, no code is used. Additional mnemonic codes are used to reflect the status and relationship of items similar or related items used in the end article (for example, OBS-BY, ASSYFR, OBS-AFT-CMPL-W). Table 2-2 lists common Department of Defense (DoD) maintenance manual abbreviations.

When a Source Control Number is requisitioned, several vendor items can be under this number, allowing the most economical item on hand to be shipped. If an item has limited effectivity within a model, the limitation is indicated by an entry following the item description.

The following identifies the process by which material stock and part numbers are located in a parts manual.

When NSN or part number is unknown, proceed as follows:

(1) Using the table of contents, determine the assembly group in which the repair part belongs. This is necessary since illustrations are prepared for assembly groups, and listings are divided into the same groups.

(2) Find the illustration covering the assembly group to which the repair part belongs.

(3) Identify the repair part on the illustration and note the figure and item number of the repair part.

(4) Using the repair parts listing, find the figure and item number noted on the illustration.

When NSN or part number is known, proceed as follows:

(1) Using the Index of National Stock Numbers and Part Numbers, find the pertinent NSN or part number. The index is in ascending NIIN sequence followed by a list of part numbers, in ascending alphameric sequence, cross-referenced to the figure number and item number.

(2) After finding the figure and item number, locate the figure and item number in the repair parts list.

Table 2-2 DoD Abbreviations

AN	Air Force-Navy
ANPT	Aeronautical National paper pipe thread
APLTO	Applicable to
ASSYFR	Assemble from
AV	Twenty-five
AWG	American wire gage
AX	Twenty
BE	Bale
BKDN	Breakdown
BRKDWN	Breakdown into
BT	Bottle
BTU	British thermal unit(s)
BX	Box
CC	Cubic centimeter(s)
CFM	Cubic feet per minute
CFS	Cubic feet per second
CI	Cubic inch
CK	Cake
CN	Can
CNSWTH	Consolidated with
C/O	Consists of (component of)
CP	Candle power
CRES	Corrosion resistant steel
CW	Continuous wave(s)
DEG	Degree(s)
DR	Drum
EA	Each
FIG	Figure
FT	Foot
GL	Gallon
GPH	Gallons per hour
GR	Gross
HD	Hundred
IN	Inch
INTRCH	Interchangeable with
KC	Kilocycle(s)
KT	Kit
KW	Kilowatt(s)
LB	Pound
LH	Left-hand
MASTER	Master item
MIN	Minimum
MWO	Modification work order
MX	Thousand
NAS	National aircraft standard
NC	American National coarse thread
NEF	American National fine thread
NF	American National fine thread
NHA	Next higher assembly
NS	American National special thread
O/A	Over-all
OBS-AFT-CMPL-W	Obsolete after compliance with
OBS-BY	Obsoleted by
OBSLTS	Obsoletes
PC	Piece
PG	Package
PK	Pack
PORM	Plus or minus
PSI	Pounds per square inch
PT	Pint
REWKTO	Rework to
RH	Right-hand
RMKS	Remarks
RO	Roll
RPL-BY	Replaced by
RPLS	Replaces
SE	Set
SF	Square foot
SH	Sheet
SI	Square inch
SL	Spool
SPEC	Specification(s)
SX	Stick
TRNSTO	Transfer to
TU	Tube
U/O	Used on
USBLEFF	Usable effectivity
USE-AFT- COMPL-W	Use after compliance with
USE-UNTIL- CMPL-W	Use until compliance with
U/W	Used with
W	Watt(s)
W/	With
WHEN EXHTD RQTN NHA	When exhausted requisition next higher assembly
W/O	Without

Reassembly

Reassembly of components is performed relative to instructions provided within the applicable DMWR. At this point, smaller components are functionally tested.

- *Category I*—The airframe is riveted together and painted. All Category II and III components, including transparencies, seats, doors, and wiring, are installed.

- *Category II*—Final assembly is normally performed in stages with each subassembly/module being assembled in its respective prime shop and then installed in the basic component. Subassemblies/modules often require bench testing, load testing, balancing, gear patterning, gear backlash check, measurement of fit/clearance/alignment, etc., upon assembly and/or during installation into basic component final assembly.

- *Category III*—Final assembly is normally accomplished on a given bench, starting with piece-parts.

Functional Test

A functional test is applicable to not only the aircraft's systems, but to almost all aircraft components and component accessories. This consists of subjecting the item in question to a series of tests to verify conformity to required operational specifications.

- *Category I*—Upon complete assembly, the aircraft is subjected to ground testing and any needed adjustments are made. The aircraft is then flight tested.

- *Category II*—Engines, transmissions, gearboxes, etc., are functionally tested in a test cell. Aside from the various parameters that are measured during instrumentation testing, the test operator is sensitive to noticeable oil leaks, air leaks, abnormal sounds, etc. Some transmissions and gear boxes require partial disassembly to check pinion gear tooth patterns before completing the functional test. Some accessory items, such as engine fuel controls, are adjusted to achieve compatibility with the engine during engine testing.

- *Category III*—Components are bench tested and adjusted to achieve performance requirements.

Preservation/Packaging

Preservation and packaging tasks complete the depot repair process. Preservation prepares the item to withstand effects of decomposition caused primarily by moisture and is especially applicable to items remaining at the depot under storage conditions. Decomposition does not occur in a clean atmosphere when moisture is not permitted to reach the item's surface. Packaging prepares the item for travel as well as to inhibit decomposition effects. The selection of packaging techniques depends on such factors as: susceptibility of the item to damage, normal hazards to which the item will be exposed, the length of time the item must remain in the package, and the promotional role of the package.

- *Category I*—Aircraft that are to be flown from the depot to the using unit require no preservation. Aircraft that are to be airlifted outside the continental United States (OCONUS) via the C-141 or C-5A are palletized. For example, transporting the UH-1 and AH-1 via the C-141 involves removal of the main rotor blades, the rotor head and mast, and the tailboom. The main rotor blades, along with the AH-1 rotor head and mast, are installed in a holding fixture and attached to a pallet beneath the aircraft. The rotor head and mast for the UH-1 are fixtured to a pallet and placed inside the UH-1. Each tailboom is installed in a fixture (vertical fin down) and attached to the side of its aircraft.

- *Category II*—Some components and component accessories require special preservation that can be accomplished immediately after functional test. For example, after checking pinion gear tooth pattern on a gear box, MIL-L-8188 corrosion resistant oil is used in the gearbox for the remainder (i.e., a short time period) of the functional testing. Also, the T-53 engine fuel control is drained of fuel at the end of functional testing and is filled with 10 weight oil.

  Basic components, such as an engine or gearbox, are installed in reusable metal transport/storage containers. Most of these containers are sealed air tight and contain bags of desiccant which absorb moisture from enclosed air. For example, the T-53 engine is enclosed in an air tight ziplock bag, with desiccant located inside the bag, and then placed in vented metal transport/storage containers.

- *Category III*—Components are preserved with an oil film and/or other compounds, possibly bagged, and boxed for transport.

3.0 DEPOT LEVEL REPAIR GUIDELINES

This section describes the major failure modes which are encountered during the depot repair process. It provides general reference material to assist in the preparation and processing of AVSCOM Engineering Calls (AECs) and AVSCOM Engineering Directives (AEDs) as well as in providing engineering support to the depot, as needed.

In conjunction with this section several appendices are available for use. Appendix A provides a comprehensive list of failure or oncoming failure indicators with definition and probable cause(s). Appendix B provides various gear and spline damage information and Appendix C provides various ball bearing damage information. These two appendices serve as examples of part inspection and relative action, i.e., repair, discard, or reuse, based upon inspection. Appendix D describes the various nondestructive (NDI) methods used for evaluation of parts to detect the presence of failure modes. Appendix E and Appendix F provide general unit conversion and torque information.

There are seven common failure modes:

(1) Corrosion

(2) Wear

(3) Skin Damage

(4) Fastener Damage

(5) Erosion

(6) Cracking

(7) Wiring Damage

Each of these failure modes is described in the following subsections in terms of probable causes, applicable NDI methods, indicators of failure or oncoming failure, and applicable repair actions. The matrix presented in Table 3-1 provides a quick overview of applicable inspection and repair methods for these failure modes.

Table 3-1 Applicable NDI Methods and Repair Tasks For Depot Failure Modes

	Failure Mode →	Corrosion	Wear	Skin Damage	Fastener Damage	Erosion	Cracking	Wiring Damage	Sample Components: Gear & Spline Damage Append. B	Sample Components: Bearing Damage Append. C
NDI Methods	Liquid Penetrant				●		▲		▲	▲
	Magnetic-particle				●		▲		▲	▲
	Electromagnetic						▲		▲	▲
	Ultrasonic			▲			●			
	Penetrating Radiation	●		●			●			
	Visual	▲	▲	▲	▲	▲	●	▲	▲	▲
	Dimensional	▲	▲			▲			●	▲
	Hardness		●						▲	▲
Repair Tasks	Vapor Degrease					■			■	■
	Emulsion Degrease					■			■	■
	Solvent Immersion					■				
	Dry-Cleaning Solvent					■				
	Vapor-Blast					■				
	Hot-Alkali Soak	■								
	Periodic-Reverse Clean	■				■				
	Paint Remover					■				
	Chrome Plate		■						■	
	Nickle Plate		■						■	
	Cadmium Plate		■						■	
	Silver Plate		■						■	
	Helical Coil Insert				■					
	Chase/Tap				■					
	Electro-plating Tape						■			
	Doubler & Filler						■			
	Repair Gusset						■			
	Oversized Fastener						■			
	Glass Cloth			■			■			
	Weld			■			■			
	Metal Patch			■			■			
	Abrasive-Blast	■								
	Wire Brush	■								
	Grind	■								
	Polish	■				■				■
	Lubricate		■					■	■	■
	Sanding	■				■				
	Flame Descale	■								
	Phosphoric Acid Treatment	■								
	Chromic Acid Treatment	■								
	Replacement	■	■	■	■	■	■	■	■	■

▲ - Primary NDI
● - Secondary NDI
■ - Applicable Task

Corrosion

Corrosion is caused by the presence of salt in moist air, certain chemicals in water, elements in metal, treatment of parts, and contact of dissimilar metals. High temperature and moisture are drivers of fungus and bacterial growth which produce acids and other products which expedite corrosion etching of surfaces and oxidation. Corrosion is normally not as prevalent on painted, clad, or plated surfaces. The following types of corrosion are encountered at the depot:

- *Superficial Corrosion*—This type is the least serious on aluminum clad parts. After deposits are removed, an etching is noticeable which results in the clad surface having a series of hills and valleys. Provided the etching has not reached the core, the effect on the strength of the metal is negligible. Corrosion of this same type on non-clad alloy parts is serious.

- *Intergranular Corrosion*—This type of corrosion is not easily detected. It is caused by imperfect heat treatment and occurs mostly in unclad structural aluminum alloy parts. It is the most dangerous form of corrosion for sheet stock because the strength of the metal is lowered without visible structural indicators.

- *Stress Corrosion*—This type occurs in a part along the line of grain flow if the part is stressed too high without proper heat treatment.

- *Galvanic Corrosion*—This type of corrosion occurs when dissimilar metals are in contact and an electrolyte is present at the joint between the metals. For example, aluminum and magnesium skins riveted together form a galvanic couple if moisture and contamination are present. When aluminum pieces are attached with steel bolts or screws, galvanic corrosion occurs between the aluminum and the steel. Table 3-2 presents a galvanic series chart. Metals close together, as illustrated in the table, have no strong tendency to produce galvanic corrosion and are relatively safe to use in contact with each other. The coupling of metals and the distance from each other in the table dictate the galvanic or accelerated corrosion of the metal higher on the table. The farther apart the metals are in the table, the greater is the galvanic tendency, as determined by measurement of the electrical potential difference between them.

- *Hydroscopic Material Corrosion*—This type of corrosion is caused by such materials as sponge rubber, felt, and cork absorbing water and holding it in contact with the part.

Table 3-2 Galvanic Series

MAGNESIUM			
MAGNESIUM ALLOYS			
ZINC			
CADMIUM			
ALUMINUM ALLOYS			
STEEL			
CAST IRON			
TIN	In general, two metal in contact with one another will corrode more actively the farther they are from one another in this table and............	Less actively when nearer one another in this table.	Of the pair, the metal nearer the top of the table will experience the greater amount of corrosion.
COPPER			
BRONZE			
COPPER-NICKEL ALLOYS			
TITANIUM			
MONEL			
NICKEL			
INCONEL			
STAINLESS STEEL			
SILVER			
PLATINUM			
GOLD			

NDI Methods

The extent and form of corrosion is determined primarily through Visual and Dimensional NDI. A secondary NDI method is Penetrating Radiation (radiography), but this method is not commonly used. When examining corrosion, a fine pointed instrument is used to test the area but caution must be taken to not further damage the area. It may be necessary to remove scales and powdery deposits before examination can occur.

Indicators

Indicators of corrosion include brinelling, fretting, scuffing, slatting, galling, etching, and abrading. For example, electrolytic action causes the formation of slats and deep etching of surfaces. This occurs at riveted and bolted joints, bearings, slides and screw threads.

Repair Actions

The initial action to be taken in corrosion removal is determining if its state is beyond repair. Table 3-3 delineates general guidelines for this decision as applicable to various parts. This table is not all inclusive of aircraft parts; it only provides a sampling.

Table 3-3 Corrosion Maintenance

STRUCTURAL MEMBERS	CORROSION CRITERIA	DEPOT REPLACE	DEPOT REPAIR
SKINS, WEBS, COVERS, COWLINGS, AND FAIRINGS	CORROSION DEPTH, EXPRESSED AS A PERCENTAGE OF METAL THICKNESS CORROSION COVERAGE, EXPRESSED AS A PERCENTAGE OF COMPONENT SURFACE AREA	10-100% AND 50-100%	1-10% AND 25-50%
LONGERONS, CAPS, STRINGERS	CORROSION DEPTH, EXPRESSED AS A PERCENTAGE OF METAL THICKNESS CORROSION COVERAGE, EXPRESSED AS A PERCENTAGE OF COMPONENT LENGTH	25-100% AND 30-50% OR 1-25% AND 50-100%	1-25% AND 30-50%
BULKHEADS, FORMERS, DECKS, AND SHELVES	CORROSION DEPTH, EXPRESSED AS A PERCENTAGE OF METAL THICKNESS CORROSION COVERAGE, EXPRESSED AS A PERCENTAGE OF COMPONENT SURFACE.AREA	10-100% AND 30-50% OR 1-10% AND 50-100%	1-10% AND 30-50%
COMPOSITE PANELS (SOLID AND HONEYCOMB)	CORE CORROSION, IN SQUARE INCHES OF SURFACE AREA SURFACE CORROSION, EXPRESSED AS A PERCENTAGE OF SURFACE AREA	GREATER THAN 12 SQ. IN. OR 60-100%	NONE 25-60%
HOUSINGS, CASES, FITTINGS, AND SUPPORTS (CASTINGS AND FORGINGS)	CORROSION DEPTH, EXPRESSED AS A PERCENTAGE OF METAL THICKNESS CORROSION COVERAGE, EXPRESSED AS A PERCENTAGE OF COMPONENT SURFACE AREA	10-100% AND 25-40% OR 1-10% AND 40-100%	1-10% AND 25-40%
FASTENERS - BOLTS, INSERTS, NUTS, AND RIVETS	AREA OF CORROSION PITTING, EXPRESSED AS A PERCENTAGE OF VISIBLE SURFACE AREA AMOUNT OF AFFECTED FASTENERS, EXPRESSED AS A PERCENTAGE OF THE TOTAL NUMBER OF FASTENERS IN THE INDICATOR	10-100% AND 20-100%	1-10% AND 20-30%
SHAFTS AND TUBES	CORROSION DEPTH, EXPRESSED AS A PERCENTAGE OF METAL, THICKNESS CORROSION COVERAGE, EXPRESSED AS A PERCENTAGE OF COMPONENT SURFACE AREA	5-100% AND 30-100%	1-5% AND 20-30%
STIFFENERS, ANGLES, DOUBLERS, AND GUSSETS	CORROSION DEPTH, EXPRESSED AS A PERCENTAGE OF METAL THICKNESS CORROSION COVERAGE, EXPRESSED AS A PERCENTAGE OF COMPONENT SURFACE AREA	10-100% AND 30-50% OR 1-10% AND 50-100%	1-10% AND 30-50%
HYDRAULIC COMPONENTS, SKIDS, AND LANDING GEAR	CORROSION DEPTH, EXPRESSED AS A PERCENTAGE OF METAL THICKNESS CORROSION COVERAGE, EXPRESSED AS A PERCENTAGE OF COMPONENT SURFACE AREA	5-100% AND 20-100%	1-5% AND 20-100%
ELECTRICAL CONNECTORS, COMPONENTS, AND WIRING	CORROSION ON WIRING? AREA OF CORROSION PITTING, EXPRESSED AS A PERCENTAGE OF VISIBLE SURFACE AREA OF ITEM AMOUNT OF AFFECTED HARDWARE, EXPRESSED AS A PERCENTAGE OF TOTAL NUMBER OF ELECTRICAL ITEMS IN THE INDICATOR	OVER 7 WIRES OR 5-100% AND 50-100%	NO OR 1-5% AND 50-100%

To remove corrosion from steel alloys, the following methods are applicable: hot-alkali soak, abrasive-blast, wire brush, polish, sand, grind, phosphoric acid treatment, and flame descale. Caution is needed when removing corrosion to prevent possible dust explosions. Goggles or a face shield should be worn when utilizing wire brush, grinder, or abrasive-blast removal methods.

To remove corrosion from aluminum-base alloy materials, chromic acid treatment is applicable. Anodic treatment by the chromic acid process increases corrosion resistance and provides a surface that ensures proper adherence of finishes (for example, paint).

The following are general steps in the corrosion removal process:

(1) Mask all fittings and decals

(2) Perform cleaning method

After the part is clean of corrosion, the following actions are applicable, if appropriate:

(1) Coat clean parts, except oil system components that are to be stored, with Rust Nox or Rust Foil.

(2) Coat oil system components with lubricating oil.

(3) Cover all unprotected openings with caps, plugs, or other suitable covers.

(4) Package all oil system components in plastic bags.

Wear

Wear is indicative of two contacting surfaces abrading one another. The result is a loss of material from contacting surfaces. This loss of material may occur as microscopic particles or as large particles. Wear is an expected occurrence as no surface is free from friction or foreign matter. The following factors contributing to wear are encountered at the depot:

- *Gear RPM*—Rapid, continual contact between moving parts accelerates the wearing process. Gears are made of hardened material, for example, hardened steel, to resist this action.

- *Load*—The weight of one item upon another creates a frictional force. The end result of friction is a continual wearing process when any movement is present.

- *Lack of Lubrication*—The lack of a lubricant allows for excessive frictional heat build up. The end result of friction is a continual wearing process.

- *Misalignment*—Improper positioning or adjustment of parts in relation to each other causes unexpected contact and eventual wear.

- *Vibration/Flexing*—Unnecessary and unexpected random movement between two surfaces enacts frictional forces between the surfaces and initiates wear.

- *Environmental Condition*—Conditions promoting the contamination of surfaces with particles increase the abrading process. The particles act as cutting stones, etching the contaminated surfaces.

NDI Methods

The presence and extent of wear is determined through Dimensional, Hardness, and Visual NDI. When examining parts for wear, the part surfaces under question should be free of dirt and other substances. If dimensional inspection is utilized, measuring tool sensitivity to temperature should be accounted for (see Appendix D—Dimensional NDI).

Indicators

Two major actions associated with wear are: (1) fretting - discoloration of contacting parts resulting from the removal of original surface materials and (2) frosting - minute indentations between two contacting surfaces. Other results of wear are grooving, gouging, and burning.

As an example of wear, rivets and bolts may wear the skin, spar, and frame holes so that there is not a correct fit in the holes for adequate strength in joints or attachments of a wing section. This can occur due to continued flexing of components from use or because of severe stress due to unusual operating conditions in turbulent weather or an adverse landing. This condition may also result in radial cracks from bolt holes.

Repair Actions

To correct the effects of wear, action is taken to build up the area(s) lacking material. Several actions are applicable: metal spraying; use of bushings, sleeves, and shims; welding; and metal plating. Of these corrective methods, metal plating is the most common.

The major metal plating processes utilized at the depot are chrome plating, nickel plating, cadmium plating, and silver plating. Each process includes three steps:

(1) Plate to desired thickness.

(2) Bake per specifications.

(3) Machine to dimension.

Unless otherwise specified, parts harder than Rockwell C-40 which have been ground after heat treatment are to be suitably stress-relieved before plating. Plating of carbonized areas is not to be attempted due to potential hydrogen embrittlement. A part suspected of being carbonized is to be tested for hardness. Noncarbonized areas have a Rockwell 15-N range of 75 to 82; carbonized parts are usually above 90.

Applicable documents delineating the plating processes include: Federal Specification QQ-C-320B for chrome plating, QQ-N-290A for nickel plating, QQ-P-416C for cadmium plating, and QQ-S-365B for silver plating.

Skin Damage

Skin damage affects the overall aircraft structural strength and aerodynamic stability. Excessive skin damage is capable of leading to a safety of flight incident. The following factors contributing to skin damage are encountered at the depot:

- *Environmental Conditions*—Conditions leading to skin damage include extreme values of cold and heat. Varying temperature ranges causes the skin to expand and contract eventually breaking down the original skin strength.

- *Flexing*—Continual flexing breaks down skin structural strength and permits an acceleration of defects.

- *Cyclic Changes from Tension to Compression*—Continual action of tension to compression breaks down skin structural strength and permits an acceleration of defects.

NDI Methods

Skin damage is easily detected through both Visual and Ultrasonic NDI. Utilizing Ultrasonic NDI requires trained interpretation of results (see Appendix D - Ultrasonic NDI).

Indicators

Common indicators of skin damage include the following defects: nonuniformity, gaps, cracking, holes, blistering, and delamination. Delaminated areas have a whitish appearance through translucent piles; if the piles are not translucent, delamination may be detected by lightly tapping the radome surface area with a small metal object (coin tap test), such as a 25 cent piece, taking care that the tapping is not vigorous enough to damage the part. The sound of such tapping is a clear metallic ring over well bonded areas and a dull thudding sound over delaminated areas. A relatively large delaminated area results in a soft, flexible, or ballooned characteristic of the debonded laminate and is detected visually or by exerting thumb or hand pressure to the area.

Repair Actions

Repair of skin damage is done in accordance with TM 55-1500-204-25/1. This TM identifies skin damage as requiring a Class II repair. Class II repair is specifically designed for skin punctures, delaminations, contaminations, and fractures.

To perform repair, the damaged area is removed and replaced with approved materials in such a manner that normal stress can be carried over the area. The preferred method of removing and replacing damaged face plies in accomplishing a Class II repair is by the stepped joint method. For very small damages the scarf method is used.

Fastener Damage

Victims of fastener damage include screws, threaded inserts, internal threads, and studs. Often, it is more cost effective to replace a fastener rather than repair it. The following factors contributing to fastener damage are encountered at the depot:

- *Over Torquing*—Excessive torque puts unexpected strain on fastener threads and can lead to the stripping of threads.

- *Over Loading*—Excessive load is capable of exceeding component safety factor. The safety factor is the fastener's minimum strength versus maximum stress.

- *Environmental Conditions*—Conditions to which fasteners are exposed promote decomposition and eventual loss of strength leading to breakage.

- *Vibration/Flexing*—Erratic action and stress imposed upon fasteners promotes wearing characteristics and cracking.

NDI Methods

The existence of fastener damage is usually evident through the performance of Visual NDI. If damage undetected through Visual NDI is suspected, then further inspection should be performed (if cost effective) such as Liquid Penetrant or Magnetic Particle NDI.

Indicators

Fastener damage is indicated through the presence of crossed threads, looseness, breakage, and stretching. For example, a fastener hole may become oversized due to vibration and flexing; this dictates that the fit of the fastener be corrected to provide a tight immobile bonding of parts.

Repair Actions

Often, it is more cost effective to replace a fastener rather than repair it. This determination is based on fastener acquisition cost, manhours needed to perform repair, type of repair needed, etc.

To repair a damaged thread, a suitable chasing tool, tap, or die is used. If damage is too great, a screw thread insert (helical coil) is used. Broken or loose studs in a tapped hole are repaired by using an oversized stud or screw thread insert (helical coil).

Appendix F provides guidelines for applying torque and applicable torque values for fasteners. These values correspond to type of fastener, size, and applicable material compositions.

Erosion

Erosion is indicative of an abrasive substance wearing away a part. This action is most evident on the airframe and within the engine. The following factors contributing to erosion are encountered at the depot:

- *Foreign Object Damage (FOD)*—Foreign objects hitting the aircraft create both denting and chipping of airframe surface.

- *Environmental Conditions*—Conditions promoting erosion include rain, sand storms, etc. These conditions abrade away surface coatings.

- *Contaminants*—The injection of contaminants into the engine air intake, for example, sand and dust, promotes the wearing away of components such as the turbine rotor blades, compressor rotor blades, or compressor stator blades.

NDI Methods

The detection of erosion is achieved through Visual NDI. A secondary method for erosion detection is Dimensional NDI.

Indicators

Discrepancies due to erosion consist mainly of scars, scratches, surface abrasions, and excessive wear. For example, continued effects of rain erode away airframe protective coating, i.e. paint, exposing the airframe to the corrosion effects and removing aircraft camouflage characteristics.

Repair Actions

For airframe erosion, TM 55-1500-204-25/1 identifies erosion damage as requiring a Class I repair and provides detailed guidelines to perform this repair. Erosion resistant thermal reflective coatings are applied according to TB 746-93-2. There should be no application of unauthorized paints, lacquers, varnishes, or waxes. Presence of these materials seriously degrades radar system operation.

For engine component erosion, components are replaced, if cost effective, or undergo a material build-up process. The subsection on wear, presented previously, provides a sampling of applicable techniques to perform the material build-up task.

Cracking

The formation of cracks is due to excessive stress versus material strength. Cracking results in loss of component stability and is capable of leading to a safety of flight incident if not detected and corrected. Both dynamic and static components (for example, gears, stringer cutouts, and tubing) are susceptible to cracking. The following factors contributing to cracking are encountered at the depot:

- *Overloading*—Excessive load is capable of exceeding component safety factor. The safety factor corresponds to component minimum strength versus maximum stress.
- *Vibration/Flexing*—Erratic action and stress cause material strength breakdown.
- *Thermal Cycling*—Varying temperature extremes cause expansion/contracting actions leading to material strength breakdown.
- *Over Torquing*—Excessive torque puts unexpected strain on components leading to material separation.
- *Over Pressure*—Excessive/unexpected pressure causes material deformation inducing material separation.

NDI Methods

The detection of cracking is achieved through Visual, Magnetic-Particle, Liquid Penetrant, Ultrasonic, Electromagnetic, or Radiographic NDI. When material is stressed at a maximum limit at a high temperature or is repeatedly flexed, fracture of material occurs in the form of thin hairline cracks. This is the most difficult service type failure to detect by radiographic NDI. Normally cracks which are easily detectable by radiographic NDI are visible to the naked eye.

Indications

Materials treated at high temperatures often develop interg anular or transgranular cracks. Other indications of cracking are fracturing, crazing, and breaking.

Repair Actions

Welding techniques are commonly used to repair cracked parts. Methods include fusion welding, spot and seam resistance welding, and electron-beam welding.

For cracking in cowling or airframe skin, the cracked area is cut out and replaced with a welded-in patch made from the same type of material. Upon completion of any crack repair that involves welding, a Hardness NDI is performed on the weld to ensure resistance to expected stresses.

Wiring Damage

Aircraft wiring is vital to total electrical system operation. It is imperative that damaged wiring be corrected to help ensure mission capabilities and safety. The following factors contributing to wiring damage are encountered at the depot:

- *Excessive Heat*—Heat build-up in wiring causes insulation materials to melt.
- *Aging*—Long periods of time eventually cause wiring insulation to dry out, become brittle, and develop cracks.
- *Environmental Conditions*—Conditions of changing environments, i.e., from hot to cold, create a breakdown in insulation characteristics allowing the insulation to become brittle and fall apart.

NDI Methods

Wiring is inspected through Visual NDI. In the event that wiring damage is not readily visual, other action is taken to isolate the malfunctioning component in the system. Troubleshooting actions should be supported by printed procedures, diagnostic circuits, test points, and diagnostic routines.

Indicators

Typical problems that arise in electrical systems are positive lead shorted to ground, open circuit, shorted relay contacts, and low power. The following are general criteria for wiring replacement:

(1) Wiring damaged to the extent that the primary insulation has been broken.

(2) Wiring having weather-cracked outer insulation.

(3) Wiring exposed to battery acid or on which the insulation appears to be, or is suspected of being, in an initial stage of deterioration due to the effects of battery acid.

(4) Wiring showing evidence of overheating.

(5) Wiring insulation saturated with engine oil, landing gear lubricant, or hydraulic fluid.

(6) Wiring bearing evidence of having been crushed or severely kinked.

(7) Shielded wiring where the metallic shield is frayed or corroded. Cleaning agents or preservatives are not to be used to minimize the effects of corrosion or deterioration of wire shields.

(8) Wiring bearing evidence of breaks, cracks, dirt, or moisture in the plastic sleeves placed over wire splices or terminal lugs.

(9) Sections of wire where splices occur at less than 10-foot intervals.

Repair Actions

Any wiring that is suspected of not having high quality is to be replaced. Replacement wiring is to be of similar quality as original wiring. A wiring diagram should be addressed to ensure that all proper connections are achieved and system operations have not been altered.

APPENDIX A

DEFINITIONS

ABRASION - Roughened surface, varying from light to severe.
Probable Cause (P/C): Abrasive material between moving surfaces.

BANDING - Typified by parallel bands of discoloration. Occurs on bearing component part rolling contact surfaces. Original surface is not broken.
P/C: Result of oil varnish or oxide film formation on bearing surfaces. Generally caused by high temperature bearing operation.

BEND - Distortion in a part (differs from local change in conformation).
P/C: Exposure to heat or excessive force.

BLISTER - Raised portion of a surface separated from the base. Generally found on surface-treated parts, such as plated or painted surfaces.
P/C: Poor original bond, excessive heat, or pressure.

BREAK - Separation of a part.
P/C: Severe force, pressure, or overload.

BRINELLING, FALSE - Occurs only at rolling contact surfaces of bearing rings. It is a specialized form of fretting. Recognized by presence of a series of surface blemishes in loaded side of ring at each ball or roller position. Indentations are usually polished or satin finished in appearance. Due to very slight rotational movement, indentation will frequently be flatter than the roller or ball curvature.
P/C: Result of continuous *nonrotational shaft* oscillation. Vibration caused by engine transportation may cause false brinelling.

BRINELLING, TRUE - Occurs at rolling contact surfaces of bearing rings. Recognized by presence of shallow, smooth indentations in ring at each ball or roller position on loaded side of bearing. Since original surface material has not been removed, indentations have the same surface appearance as surrounding surface area. Indentation contour is the same as the roller or ball curvature.
P/C: Result of high shock loads, leaving a permanent impression of roller or ball in the ring contact surface.

BUCKLING - Large-scale deformation of part contour.
P/C: Pressure or impact with a foreign object, unusual structural pressures, excessive localized heating, or any combination of these causes.

BURNING - Melting or loss of material.
P/C: Excessive heat.

BURNISHING - The smoothing of a metal surface by mechanical action, but without loss of material. Surface discoloration is sometimes present around the outer edges of the burnished area. NOTE: Normal burnishing from operational service is not detrimental if coverage approximates the carrying load and if there is no evidence of burns.
P/C: Rubbing.

BURR - A rough edge or sharp projection.
P/C: Excessive wear or poor machining.

CHIPPING - Breaking away of small metallic particles.
P/C: Heavy impact of foreign object.

CORROSION - Surface chemical action that results in surface discoloration, a layer oxide, or, in the advanced stages, removal of surface metal.
P/C: Improper corrosion-preventive procedures and excessive moisture.

CORROSION DISCOLORATION - Chemical discoloration of bearing surfaces without removal of surface metal; recognized by red or black colored clusters (not to be confused with corrosion pitting which is actual metal removal). If not arrested, corrosion discoloration will advance to corrosion pitting.
P/C: Result of any adverse chemical action due to water, acid, lubricant, or a corrosive atmosphere, and generally caused by improper preservation procedures or lack of precaution during installation, removal, inspection, or storage.

CORROSION FRETTING - Discoloration where surfaces are pressed or bolted together under pressure. Color of residue on steel parts is usually reddish brown while aluminum or magnesium parts are black.
P/C: Incomplete adhesion of metal or excessive loads.

CORROSION PITTING - Irregular surface depressions having ragged edges due to metal removal.
P/C: Corrosion substance adhering to exposed surfaces.

CRACK - A break in material.
P/C: Severe stress from overloading or shock.

CRAZING - Minute cracking which tends to run in all directions. It is often noticed on coated surfaces.
P/C: Uneven cooling or thermal shock.

DENT - A small, smooth depression.
P/C: A sharp blow or excessive pressure.

DISTORTION - A change from original shape.
P/C: Exposure to severe heat.

EROSION - Wearing away of metal and/or surface coating.
P/C: Hot gases, corrosive liquids, or grit.

END LOADING - Defect on face of gear tooth near end of tooth.
P/C: Axial misalignment with mating gear.

FATIQUE PITTING - Relatively deep irregular surface cavities resulting from the breaking away of portions of the surface.
P/C: Advanced corrosion condition or fatique generated by high-stress conditions.

FLAKING - Loose particles of surface metal or surface covering.
P/C: Imperfect bond or severe load.

FRACTURE - Separation of a part.
P/C: Severe force, pressure, or overload.

FRETTING - Discoloration of contacting parts resulting from the removal of original surface material.
P/C: Movement between two contacting surfaces.

FROSTING - Minute identations within a localized area.
P/C: Generally a wear-in process.

GALLING - Recognized by presence of metal from one part remaining attached to another. Occurs at poorly lubricated surfaces that are in sliding contact.
P/C: Results of localized breakdown of lubrication, causing friction, intense heat, and part fusion.

GOUGING - Removal of surface metal typified by rough and deep depressions.
P/C: Protruding object, misalignment.

GROOVING - Found on rolling contract surface of ball or roller bearings. Recognized by presence of depressions in elements of rolling contact surfaces.
P/C: Results from overload lubrication breakdown and skidding.

HEAT DISCOLORING - Characterized by a discoloring film. Color varies from straw, tan, and light brown to red-purple, purple, and blue.

P/C: High-temperature operation.

INCLUSION - Foreign matter enclosed in metal.

P/C: Occurs during manufacture of the metal.

INDENTING - Smooth surface depressions. Evidenced by metal displacement, not metal removal.

P/C: Loose material flattened by rolling action will create smooth, shallow indents.

LACK of BRAZE - Interruption (air pocket) in joint or filled cross-section braze material.

P/C: Improper braze-repair.

METALIZATION - Molten metal coating of a part.

P/C: Molten particles sprayed through the engine.

NICK - A sharp-bottomed depression that may have rough outer edges.

P/C: Impingement of foreign object on surface.

PEENING - Flattening or displacement of metal.

P/C: Repeated blows. A surface may be peened by continuous impact of foreign objects or loose parts.

PICKUP - Transfer of one material into another.

P/C: Insufficient lubrication, unbroken edges of press-fitted parts, and seizure of rotating parts during operation.

PITTING - Small indentations in a surface; usually smooth-bottomed.

P/C: (1) Chemical pitting. Oxidation of surface or electrolytic action. (2) Mechanical pitting. Chipping of surfaces caused by improper clearances and overloading, and by pressure of foreign material.

SCORING - Deep scratches following parts path of travel.

P/C: Breakdown of localized lubrication between sliding surfaces of foreign material.

SCRATCH - A very shallow furrow or irregularity; usually longer than wide.

P/C: Movement of a sharp object across the surface.

SCUFFING - Surface damage of pieces of a plated or finished surface.
P/C: Rubbing off of fine particles of metal by slight movement.

SEIZING - Advanced stages of galling. Recognized by welding of one bearing component to another, preventing rotation.
P/C: Result of localized breakdown of lubrication, causing friction, intense heat, and part fusion.

SPALLING END LOADING WEAR - Large particles or chips that break out of tooth surfaces, usually along the flank area and near the ends.
P/C: Excessive internal stresses due to heat-treatment or overloads.

STRESS FAILURE - Metal failure.
P/C: (1) Movement of a sharp object across the surface. (2) Compression. Action of two opposed forces that tend to squeeze a part. (3) Tension. Action of two directly opposed forces that tend to stretch a part. (4) Shear. Action of two parallel forces action in opposite directions. (5) Torsion. Action of two opposed forces around a common axis. (6) Shock. Instantaneous application of stress.

STRIPPED THREAD - Nut, stud, bolt, or screw damaged by tearing away part of thread form.
P/C: Improper installation or mismatching thread size.

TEAR - Parting of parent material.
P/C: Excess tension, created by an external force.

UNBALANCE - A condition that usually results in vibration.
P/C: Unequal distribution of mass about a rotating axis.

VOID - A continuous lack of braze material through a braze joint cross-section.
P/C: Improper repair.

WEAR - A loss of material from contacting surfaces. The degree of wear is dependent on such factors as gear rpm, load, lubrication, and alignment.
P/C: Contacting surfaces abrading one another.

APPENDIX B

DESCRIPTIONS FOR VARIOUS GEAR AND SPLINE DAMAGE

Gear and splined parts are inspected per applicable nondestructive inspection (NDI) methods, as delineated in Appendix D (i.e. Visual, Hardness, etc.), for conditions that signify failure or the onset of failure. Common discrepancies that occur in gear and spline units are cracks, damaged threads, excessive wear, nicks, dents, scores, burrs and scratches. Table B-1 provides examples of gear discrepancies and sample acceptable/unacceptable criteria. The following guidelines are used to detect gear discrepancies.

(1) Use 4x magnification to visually inspect gears for discrepancies such as, nicks, scratches, burrs, and chipped edges. Gears that are light straw colored are usually acceptable. Check case hardness of the applicable gear, (for example, sun, planet, or output gear), if blue or purple colored. Utilize the hardness test values given in the applicable Depot Maintenance Work Requirement. Gears that pass the hardness test are acceptable for further use, gears that do not are discarded.

(2) Use 4x magnification to visually inspect each internal and external spline area for wear, fretting, and corrosion. Light wear or fretting is acceptable provided it does not exceed inspection limits.

(3) If inner surface discrepancies are suspected, then perform Magnetic-Particle or Fluorescent-Penetrant NDI, as delineated in Appendix D.

All discrepancies found to inhibit a gear or spline are noted using the appropriate part inspection report. The report is used as criteria for the acceptance or rejection of parts.

Examples of repair action for gear and spline deficiencies include the following:

- Utilize blending techniques to repair minor nicks, burrs, and scratches on other than working surfaces of gears or splined components.
- Utilize chrome plating techniques to restore worn bearing or seal journals on gearshafts (i.e., noncarbonized or nonnitrided gearshafts).
- Machine splined ends of shafts off and replaced by electron beam welding techniques.

Table B-1 Gear Discrepancies - Visual 4x Magnification
(Sample Inspection Criteria - Engine)

Condition	Applicable Gear
Corrosion	
Any rust corrosion noted after cleaning is unacceptable.	All gears
Cracking (unacceptable)	All gears
End Loading	
Normal and moderate end wear is unacceptable.	Primary and secondary gears
Pitting end spalling due to end loading is unacceptable.	Output gear and sun gearshaft
Light end wear is acceptable. All pitting or spalling due to end loading is unacceptable.	Accessory gears
Frosting	
Light uniform frosting is acceptable. Any other condition of frosting is unacceptable.	Primary planet gear and sun gearshaft
Light frosting is acceptable. Any other condition of frosting is unacceptable.	Accessory gears
Light to medium frosting is acceptable. Any other condition of frosting is unacceptable.	Secondary planet gear and output gear

Table B-1 Gear Discrepancies - Visual 4x Magnification
(Sample Inspection Criteria - Engine) (Cont'd)

Condition	Applicable Gear
Pitting	
Light and initial pitting is acceptable at pitchline. Any other condition of pitting is not acceptable.	Primary and secondary planet gears and output gear
Initial and light pitting is acceptable. Any other condition of pitting is unacceptable.	Accessory gears
Pitting is unacceptable	Sun gearshaft
Scoring	
Light scoring is acceptable. Any other condition of scoring is unacceptable.	All gears
Spalling (unacceptable)	All gears
Wear	
All light wear of a uniform pattern around the circumference is acceptable. Any other wear condition is unacceptable.	Primary planet gear Sun gearshaft
Light to moderate wear of a uniform pattern around the circumference is acceptable. Any other wear condition is unacceptable.	Output gear
All normal and moderate wear of a uniform pattern around the circumference is acceptable. Any other condition is unacceptable.	Secondary planet gear
All normal and moderate wear is acceptable. Heavy and irregular wear is unacceptable.	Accessory gears

APPENDIX C

DESCRIPTIONS FOR VARIOUS BEARING DAMAGE

Common discrepancies that occur in bearings are pitting, scoring, wear, corrosion, and brinelling. Magnetic-Particle and/or Fluorescent-Penetrant nondestructive inspection methods (see Appendix D) are most effective in detecting these discrepancies. When performing inspections, blade oxide finishes should not be confused with overheating. Also, bearings which are subject to heavy load or high speeds are not to be used when condition is questionable. Table C-1 provides sample inspection acceptable/unacceptable criteria for bearings. Bearing inspection should be performed in a well lighted room with the room and workbench being vibration-free and maintained at a maximum practicable level of cleanliness. The following are general guidelines for detecting bearing discrepancies.

(1) Clean bearings thoroughly.

(2) Allow all bearings to stand for a minimum of three hours before inspection. This permits dimensional stabilization.

(3) Use 0x magnification to visually inspect all bearings and retainers. If necessary, bearing rings may be inspected using aid retainers.

(4) Utilize a radius probe to determine the severity of various surface defects.

(5) Inspect the thickness of bearing plating using a nondestructive thickness tester.

(6) Perform hardness inspection, particularily if heat discoloration is evident.

All bearing discrepanies are noted on the appropriate part inspection report. The report is used as criteria for the acceptance or rejection of parts.

Table C-1 Bearing Discrepancies - Visual 0x Magnification
(Sample Inspection Criteria)

Condition or Damage	Limit
Banding	Acceptable.
Brinelling, False	Acceptable.
Brinelling, True	Noticeable depressions unacceptable. Minor ring brinelling, so slight that it only can be detected in reflected light, will not be cause for rejection.
Corrosion Discoloration	Corrosion effectively removed by standard cleaning methods is acceptable. Remaining isolated pitting on active surfaces is acceptable provided: a. It cannot be felt with a 0.020 inch radius probe. b. No more than three visually evident individual pits exist in any 0.25 inch diameter area.
Fretting	Acceptable, provided rings do not have fretting on more than 20 percent of their inactive areas. Fretting on ring faces may be removed by minor lapping rework, provided rings meet dimensions' requirements.
Frosting	Acceptable, provided it cannot be felt with a 0.040 inch radius bearing probe.
Galling	Not acceptable.
Greasing	Not acceptable.
Heat Discoloration	Varnishing is acceptable, provided any heavy varnish films can be removed by standard cleaning. Staining is acceptable, provided stain is not caused by acid etch as observed after standard cleaning. Heat discoloration: Bearings discolored straw or brown color are acceptable. Bearings discolored red-purple, purple, or blue are acceptable, provided hardness inspection at three locations on both inner and outer ring faces is within limits. (When there is any doubt as to a tempered discoloration condition, hardness inspections should be performed.)

Table C-1 Bearing Discrepancies - Visual 0x Magnification
(Sample Inspection Criteria) (Cont'd)

Condition or Damage	Limit
Indenting	Isolated indenting acceptable, provided it cannot be felt with a 0.040 inch radius bearing probe.
Nicking	Small isolated nicks with no projections are acceptable on active surfaces if they cannot be felt with a 0.040 inch radius bearing probe. Minor nicks on inactive surfaces are acceptable.
Pitting, Fatigue	Not acceptable.
Retainer Damage	a. Any cracking is unacceptable. b. Overheating, as evidenced by melting or flowing of silver plate, is unacceptable. c. Wear of ball pocket and/or land-riding surfaces exposing any base metal up to 0.063 inch measured in any direction (not depth) is acceptable. Wear beyond this limit is unacceptable.
Roller End Wear	Not applicable.
Scoring	Isolated axial scoring acceptable, provided it cannot be felt with a 0.040 inch radius bearing probe.
Scuffs and Scratches	Acceptable, provided they cannot be felt with a 0.040 inch radius bearing probe. A maximum of two scratches per square inch of active surface is allowed.
Seizing	Not acceptable.
Wear	Determined by inspection of radial internal clearance, axial end play contact angle, and other dimensional inspection requirements.

NOTE

Minor scoring, fretting, or wear of the outer ring outer diameter may result from spinning or movement of the bearing in its housing. This ring outer diameter wear is acceptable, provided outer diameter measurements taken at various locations (in the wear area) are within limits.

APPENDIX D

NONDESTRUCTIVE INSPECTION PRACTICES

Nondestructive inspection (NDI) methods are techniques which are applied to a structure, component, or part to determine its integrity; composition; physical, electrical, or thermal properties; or dimensions without causing a change in any of these characteristics. The NDI methods utilized during the depot repair process include the following:

- Liquid Penetrant
  - Dye-Penetrant
  - Fluorescent-Dye Penetrant

- Magnetic-Particle
  - Direct current, wet (Continuous - Wet)

- Electromagnetic
  - Eddy current

- Ultrasonic
  - Pulse echo (immersion or contact)

- Penetrating Radiation
  - Radiographic (X-Ray)

- Visual

- Dimensional

- Hardness
  - Rockwell
  - Brinell

NDI methods in the hands of trained and experienced technicians are capable of detecting flaws or defects with a high degree of accuracy and reliability. It is important for maintenance engineers to be fully knowledgeable of the capabilities of the NDI methods and it is equally important to recognize the limitations of the NDI methods. No NDI method is ever considered conclusive. To be reliable, a defect indication detected by one method must be confirmed by another method.

NDI equipment is highly sensitive and is capable of detecting discontinuities and anomalies which are of no consequence in the service for which a component is used. Limits for acceptance and rejection are therefore as much a part of an inspection as the method itself. For example, ultrasonic inspection equipment is fully capable of detecting normal grain boundaries in some cast alloys. Therefore, inspection criteria are designed to overlook these "normal" returns and to discriminate in favor of those discontinuities which will affect the component in service.

The NDI methods commonly utilized during the depot rework process are given in a generalized form on the following pages. TM 43-0103 provides a detailed description of the NDI practices.

LIQUID PENETRANT NDI

Dye - Penetrant Inspection

This inspection method detects surface discontinuities, such as cracks, in ferrous and nonferrous materials.

(1) Clean part utilizing the vapor degreasing method.

(2) Wipe part clean and display.

(3) Apply penetrant by immersion, spraying, or brushing to completely cover all surfaces to be inspected.

(4) Allow penetrant to remain on surface for approximately 8 minutes, then wipe with clean, lint-free cloth. (Repeat step 3 if needed.)

(5) Apply developer by brushing or spraying thin, even coating over surfaces involved.

(6) Allow approximately 4 minutes for developer to dry to a thin layer before inspecting.

(7) Inspect parts under ordinary white light.

(8) Interpret results through visual inspection.

I. No distinct pattern
- *No faults apparent*

II. A continuous line indication
  - Cracks

III. An intermittent line indication
  - A partially closed defect at the surface

IV. Rounded area indication
  - Deep crater cracks in welds or porosity caused by gas or pin holes

V. Small dot indication
  - A porous condition due to pinholes or coarse grains in casting

(9) Clean part utilizing vapor degreasing method

Fluorescent - Penetrant Inspection

Wear rubber gloves when performing this inspection; oil remaining on the skin may cause skin inflamation. Presence of penetrating oil on the skin is detected under ultraviolet (black) light. Developing powder is harmless if inhaled, but heavy concentrations can be annoying.

(1) Clean all surfaces thoroughly.

(2) Immerse, spray, or brush all surfaces of the part being inspected with fluorescent-penetrant.

(3) Allow 15 to 30 minutes for fluorescent-penetrant to enter defect.

(4) Immerse, spray, or brush all surfaces of part with fluorescent-penetrant emulsifier.

(5) Allow sufficient time (3 minutes minimum) for emulsification of excess fluorescent-penetrant.

(6) Remove all pentetrant from surface of part with warm water.

(7) Dry part in hot air dryer at 140°F to 180°F.

(8) Apply fluorescent-penetrant dry developer powder to part by dusting or powder box immersion.

(9) Allow approximately 15 minutes for indications to develop.

(10) Examine part in a darkened enclosure under ultraviolet (black) light.

(11) Interpret results through visual inspection.

I. No distinct pattern
- No faults apparent

II. A continuous line indication
- Cracks

III. An intermittant line indication
- A partially closed defect at the surface.

IV. Rounded area indication
- Deep crater cracks in welds or porosity caused by gas or pin holes

V. Small dot indication
- A porous condition due to pinholes or coarse grains in casting.

MAGNETIC-PARTICLE NDI

Magnetic - Particle Inspection (continuous - wet method)

This inspection method is *only* applicable to ferromagnetic steel and is not effective on nonferrous materials.

(1) Clean all parts free of grease and foreign material.

(2) Plug all passages that are too difficult to clean.

(3) The conductor outer diameter should approximate the part bore inner diameter.

(4) Immerse part into the wet bath solution.

(5) Remove part from the wet bath solution and apply magnetizing current shot.

(6) Inspect at low-current application first and then at high-current application second.

(7) Accomplish circular and longitudinal magnetization by using three current applications each ranging from 0.4 and 0.5 second duration. (Apply the wet bath during the first two current applications only.)

(8) Magnetize parts longitudinally into the magnetizing oil so that the major part axis, centers of long shafts, and the axis of rotating parts are parallel with the coil axis. (Inspect nuts by circular magnetization.)

(9) Interpret results through visual inspection.

I. No distinct pattern or gathering of particles
- No surface or subsurface cracks.

II. A distinct sharp and well defined build up of particles
- A surface crack.

III. A broad fuzzy looking accumulation of particles
- A subsurface crack.

(10) Demagnetize part with a demagnetizing coil.

(11) Clean parts by rinsing in pure bath solution without magnetic particles.

ELECTROMAGNETIC NDI

Eddy Current Inspection

Crack detection standards are necessary to assure that an eddy current test set-up is sufficiently sensitive to detect small cracks. Proper adjustment of an instrument for material type, lift-off adjustment, etc. does not necessarily indicate that the instrument is sufficiently sensitive to detect small cracks. A suitable crack standard to check instrument calibration is mandatory.

(1) Consult test equipment manual for operating and adjustment instructions.

(2) Check probe sensitivity using a crack standard.

(3) Inspect the surface in question by rotating the probe so that the pick-up coil passes over all the surfaces.

(4) If a crack exists, the instrument will show a sharp deflection as the probe passes over it. Do not confuse this sharp deflection with the slow minor changes in the conductivity of the base material.

(5) Adjust the test equipment balance control as required to bring the meter in scale as the coil approaches the damaged surface or edge of a hole.

(6) Repeat process, as needed to verify meter readings.

ULTRASONIC NDI

Pulse Echo Inspection

This technique is used for inspecting materials and parts to detect discontinuities detrimental to the serviceability of a part.

(1) Examine material or part for any surface irregularities (for example, burns and gouges) and remove with a sander capable of producing a surface finish equal to that required for a good response. Clean part of any loose scale, dirt, or foreign material which will interfere with the transmission of the ultrasonic vibrations.

(2) Select the proper test frequency and search unit. The transducer must be capable of efficient operation at the same rated frequency as that to be used in the test. In general, a high frequency is used in the detection of internal defects of small magnitude; however, this gives minimum penetrating power. A low frequency will give the greatest penetrating power but is less sensitive to small defects.

(3) Calibrate the device according to manufacturer specifications for accurate use the required inspection data.

(4) Use the required ultrasonic quality level stated in the applicable repair procedure as the material acceptance criteria.

(a) Class AA Area:
- Discontinuity indications in excess of the response from an 0.047 inch diameter flat-bottomed hole at the estimated discontinuity depth are not acceptable.

- Discontinuity indications greater than 10 percent of the response from an 0.047 inch diameter flat-bottomed hole at the discontinuity depth are not to be closer than 1 inch or exhibit a length greater than 0.125 inch.
- Harsh or sonic noise is not to exceed 10 percent of the response height received from an 0.047 inch diameter flat-bottomed hole at the estimated discontinuity depth.
- With the instrument set so that the first back reflection from the correct test block is at 80 percent of the screen saturation adjusted for nonlinearity, the material is inspected for loss of back reflection. Any loss in back reflection in excess of 50 percent of full saturation of the screen is considered not acceptable.

(b) Class A Areas:

- Discontinuity indication in excess of the response from an 0.078 inch diameter flat-bottomed hole at the estimated discontinuity depth is acceptable.
- Multiple indications in excess of the response from an 0.047 inch diameter flat-bottomed hole are not closer than 1 inch.
- Elongated (stringer) type defects in excess of 1 inch in length are not acceptable, if, at any point along the length, the discontinuity indication is equal to or greater than 50 percent of the response from an 0.047 inch diameter flat-bottomed hole.
- Multiple discontinuities giving an indication less than the response from an 0.078 inch diameter flat-bottomed hole are acceptable only if the back reflection pattern in 50 percent or more of the back reflection pattern of sound material of the same geometry. The sound beam must be normal to the front and back surfaces to ensure that loss of back reflection is not caused by surface roughness, surface waviness or part geometry variation.

(c) Class B Areas:

- Discontinuity indications in excess of the response from an 0.125 inch diameter flat-bottomed hole at the estimated discontinuity depth are not acceptable.
- Discontinuity indications in excess of the response from an 0.078 inch diameter flat-bottom hole at the estimated discontinuity depth are not to be closer than 1 inch.

- Elongated (stringer) type defects in excess of 1 inch in length are not acceptable, if, at any point along the length, the discontinuity indication is equal to or greater than the response from an 0.078 inch diameter flat-bottomed hole.
- Multiple discontinuities giving an indication less than the response from an 0.078 inch diameter flat-bottomed hole are acceptable only if the back reflection pattern is 50 percent or more of the back reflection pattern of sound material of the same geometry. The sound beam must be normal to the front and back surfaces to ensure that the loss of back reflection is not caused by surface roughness, surface waviness or part geometery variation.

(d) Class C Areas:
- Discontinuity indications in excess of the response from an inch diameter flat-bottomed hole at the estimated discontinuity depth are not acceptable.

(e) Material or parts failing to meet the above requirements shall be subject to rejection.

(f) Inspection of Machined Parts:
- Discontinuity indications in excess of the specified ultrasonic quality level are permitted if it is established that such discontinuities are removed by subsequent machining operations. In such cases, a record of the ultrasonic test results is provided showing the location and size of indications by discontinu''y class with respect to a bench mark on one corner of the surface from which the material is scanned.

PENETRATING RADIATION NDI

Radiographic (X-Ray) Inspection

To guard operating personnel from possible danger of X-ray absorption, cover rear side of film holder with a sheet of lead thick enough to absorb fully any secondary reflected radiographic rays. As a further precaution, all personnel should wear a radiation detector-type badge or cylinder.

(1) Operate radiographic device according to manufacturer's instructions.

(2) Determine the degree of sensitivity of inspection desired and the required film density using a color densitometer. (Film density after exposure should be 1.8 to 3.0.)

(3) Use fine grain, high contrast, safety-type industrial radiographic film to ensure that all radiographs are clean and sharply define the existing discrepancy.

(4) Make measurements of the object and note differences in shape and size. This will allow determination of correct placement of the X-ray generator for an exposure or series of exposures. When a series of exposures is to be made, make up a position chart to map out the areas to be radiographed.

(5) Determine access to the object with regard to the X-ray generator.

(6) In areas of high stress, take a sufficient number of views to establish the nature and extent of the discrepancy.

(7) Visually inspect radiographs for the following:
- Evidence of material change, cracking, etc.

VISUAL NDI

This inspection should be used in conjunction with all inspection methods. To perform this inspection effectively, self-discipline is needed to correctly analyze and note defects and irregularities.

(1) Perform inspection in a well lighted room which is free of dust and dirt, if possible.

(2) Cover work benches with clean dry paper.

(3) Use naked-eye observance to detect faults.

(4) Look for:
- Loose or missing parts
- Cracks
- Distortion
- Wear
- Erosion
- Corrosion
- Damage to surface coating
- Nicks
- Dents
- Burned areas
- etc.

(5) Use micrometers and special gages where applicable.

(6) If subsurface flaws are suspected, perform a Magnetic Particle, Fluorescent-Penetrant, or Radiographic NDI.

DIMENSIONAL NDI

This inspection is specifically designed for analyzing areas of material wear, warpage, erosion, corrosion, etc. Performing this inspection involves the utilization of measuring devices, such as vernier or micrometer calipers.

Measuring devices, such as vernier or micrometer calipers, are calibrated at 68°F to 69°F and provide relative measurements at all other temperatures because of thermal expansion/contraction. This normally doesn't cause much of a problem since most such dimensional measurements are taken to assure fits and clearances. The difference between two relative dimensions provides a true fit or clearance dimension. There is always some degree of error due to the difference in the coefficients of thermal expansion (CTE) between the measuring device and the part. "Steel on steel" usually produces a negligible error unless the size of the dimension and the temperature are at extremes and the dimensional tolerance is very small. Magnesium and aluminum alloys have a high strength of weight ratio making them popular materials in the design of aircraft systems. These alloys have relatively high CTE and when large dimensional measurements are made with a steel measuring device, the mechanic should either take action to stabilize parts and measuring device as close as possible to the 68°F to 69°F calibration temperature or develop a correction table, based on temperature, for each individual dimension.

(1) Clean part of any dirt, scale, etc.

(2) Identify indentations, gouges, and deformations visually.

(3) Use measuring devices as applicable.

HARDNESS NDI

This inspection method is a test used to determine material hardness and provides information to evaluate accept/reject criteria. It is primarily used to evaluate part hardness characteristics for suspected metallurgical wear.

Rockwell Hardness Test

There are two types of Rockwell hardness testers, standard and superficial. The standard tester has a load range from 60 to 150 kilograms and is used for general aircraft parts. The superficial tester has a load range from 15 to 45 kilograms and is used mostly for surface-hardened and thin materials.

(1) Prepare sample by filing, grinding, and polishing to remove all scratches and variations that may affect reading.

(2) Select proper penetrator and place corresponding weight on weight plan.

(3) Place sample on anvil and, by turning hand wheel, raise it slowly until contact is made with penetrator. Continue turning until pointer of indicator has made three revolutions and is within five divisions (plus or minus) of upright position. This applies the 10-kilogram or minor load on sample.

(4) Apply major load by means of handle.

(5) Release major load by returning handle to its original position and read hardness number directly on indicator scale.

Brinell Hardness Test

The Brinell hardness test consists of pressing a hardened steel ball into a flat surface of the metal being tested by application of a known pressure. The impression made by the ball is measured by means of a microscope with a micrometer eyepiece, and the Brinell number is obtained by dividing the load in kilograms by the area of the spherical impression made by the ball (LOAD/AREA).

(1) Prepare sample by filing, grinding, and polishing to remove all scatches and variations that may affect reading.

(2) Place sample on anvil and elevate until hardened ball contacts surface to be tested.

(3) Apply load by pumping handle. A load of 3000 kilograms is required for steel, while 500 kilograms is used when testing softer metals. Apply load for 30 seconds. This time may be increased to one minute for hardened steels.

(4) Release pressure and measure area of impression with calibrated microscope.

(5) Calculate Brinell number (LOAD/AREA).

APPENDIX E

STANDARD UNIT CONVERSION TABLES

Table E-1 U.S. English Units to SI Units

TO CONVERT FROM	TO	MULTIPLY BY
(Acceleration)		
foot/second² (ft/s²)	meter/second² (m/s²)	3.048×10^{-1} *
inch/second² (in./s²)	meter/second² (m/s²)	2.54×10^{-2} *
(Area)		
foot² (ft²)	meter² (m²)	9.2903×10^{-2}
inch² (in.²)	meter² (m²)	6.4516×10^{-4} *
yard² (yd²)	meter² (m²)	8.3613×10^{-1}
(Density)		
pound mass/inch³ (lbm/in.³)	kilogram/meter³ (kg/m³)	2.7680×10^{4}
pound mass/foot³ (lbm/ft³)	kilogram/meter³ (kg/m³)	1.6018×10
(Energy, Work)		
British thermal unit (Btu)	joule (J)	1.0544×10^{3}
foot-pound force (ft · lbf)	joule (J)	1.3558
kilowatt-hour (kw · h)	joule (J)	3.60×10^{6} *
(Force)		
kip (1000 lbf)	newton (N)	4.4482×10^{3}
pound force (lbf)	newton (N)	4.4482
ounce force	newton (N)	2.7801×10^{-1}
(Length)		
foot (ft)	meter (m)	3.048×10^{-1} *
inch (in.)	meter (m)	2.54×10^{-2} *
mile (mi), (U.S. statute)	meter (m)	1.6093×10^{3}
mile (mi), (international nautical)	meter (m)	1.852×10^{3} *
yard (yd)	meter (m)	9.144×10^{-1} *
(Mass)		
pound mass (lbm)	kilogram (kg)	4.5359×10^{-1}
slug (lbf · s²/ft)	kilogram (kg)	1.4594×10
ton (2000 lbm)	kilogram (kg)	9.0718×10^{2}
(Power)		
foot-pound/minute (ft · lbf/min)	watt (W)	2.2597×10^{-2}
horsepower (550 ft · lbf/s)	watt (W)	7.4570×10^{2}
(Pressure, stress)		
atmosphere (std) (14.7 lbf/in.²)	newton/meter² (N/m² or Pa)	1.0133×10^{5}
pound/foot² (lbf/ft²)	newton/meter² (N/m² or Pa)	4.7880×10
pound/inch² (lbf/in.² or psi)	newton/meter² (N/m² or Pa)	6.8948×10^{3}
(Velocity)		
foot/minute (ft/min)	meter/second (m/s)	5.08×10^{-3} *
foot/second (ft/s)	meter/second (m/s)	3.048×10^{-1} *
knot (nautical mi/h)	meter/second (m/s)	5.1444×10^{-1}
mile/hour (mi/h)	meter/second (m/s)	4.4704×10^{-1} *
mile/hour (mi/h)	kilometer/hour (km/h)	1.6093
mile/second (mi/s)	kilometer/second (km/s)	1.6093
(Viscosity)		
foot²/second (ft²/s)	meter²/second (m²/s)	9.2903×10^{-2}
pound-mass/foot-second (lb_m/ft · s)	pascal-second (Pa · s)	1.4882
pound-force-second/foot² (lb_f · s/ft²)	pascal-second (Pa · s)	4.788×10

* Exact value

Table E-2 Temperature, Torque, and Fraction Conversion

UNITS OF TEMPERATURE

TO CONVERT FROM	TO	MULTIPLY BY
(Fahrenheit)	$^{o}F = (9/5)\ ^{o}C + 32$	
(Celcius)	$^{o}C = (5/9)\ (^{o}F - 32)$	
(Kelvin)	$^{o}K = ^{o}C + 273.16$	
(Rankine)	$^{o}R = ^{o}F + 459.69$	

UNITS OF TORQUE

lb. in.	gram cm.	1152.128
lb. ft.	gram cm.	13.826
lb. ft.	kp meter	0.1383
oz. in.	gram cm.	72.008
oz. in.	lb. ft.	0.005208

FRACTION AND DECIMAL EQUIVALENTS

1/64	.015625	17/64	.265625	33/64	.515625	49/64	.765625
1/32	.03125	9/32	.28125	17/32	.53125	25/32	.78125
3/64	.046875	19/64	.296875	35/64	.546875	51/64	.796875
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
5/64	.078125	21/64	.328125	37/64	.578125	53/64	.828125
3/32	.09375	11/32	.34375	19/32	.59375	27/32	.84375
7/64	.109375	23/64	.359375	39/64	.609375	55/64	.859375
1/8	.125	3/8	.375	5/8	.625	7/8	.875
9/64	.140625	25/64	.390625	41/64	.640625	57/64	.890625
5/32	.15625	13/32	.40625	21/32	.65625	29/32	.90625
11/64	.171875	27/64	.421875	43/64	.671875	59/64	.921875
3/16	.1875	7/16	.4375	11/16	.6875	15/16	.9375
13/64	.203125	29/64	.453125	45/64	.703125	61/64	.953125
7/32	.21875	15/32	.46875	23/32	.71875	31/32	.96875
15/64	.234375	31/64	.484375	47/64	.734375	63/64	.984375
1/4	.25	1/2	.5	3/4	.75	1	1.

Table E-3 SI Units and Symbols

BASE UNITS

QUANTITY	UNIT	SI SYMBOL	FORMULA
length	meter	m	...
mass	kilogram	kg	...
time	second	s	...
electric current	ampere	A	...
thermodynamic temperature	kelvin	K	...
amount of substance	mole	mol	...
luminous intensity	candela	cd	...

SUPPLEMENTARY UNITS:

QUANTITY	UNIT	SI SYMBOL	FORMULA
plane angle	radian	rad	...
solid angle	steradian	sr	...

DERIVED UNITS:

QUANTITY	UNIT	SI SYMBOL	FORMULA
acceleration	meter per second squared	...	m/s^2
angular acceleration	radian per second squared	...	rad/s^2
angular velocity	radian per second	...	rad/s
area	square meter	...	m^2
density	kilogram per cubic meter	...	kg/m^3
electric potential difference	volt	V	W/A
electric resistance	ohm	Ω	V/A
energy	joule	J	N · m
entropy	joule per kelvin	...	J/K
force	newton	N	$kg \cdot m/s^2$
frequency	hertz	Hz	l/s
magnetomotive force	ampere	A	...
power	watt	W	J/s
pressure	pascal	Pa	N/m^2
quantity of electricity	coulomb	C	A · s
quantity of heat	joule	J	N · m
radiant intensity	watt per steradian	...	W/sr
specific heat	joule per kilogram-kelvin	...	J/kg · K
stress	pascal	Pa	N/m^2
thermal conductivity	watt per meter-kelvin	...	W/m · K
velocity	meter per second	...	m/s
viscosity, dynamic	pascal-second	...	Pa · s
viscosity, kinematic	square meter per second	...	m^2/s
volume	cubic meter	...	m^3
work	joule	J	N · m

SI PREFIXES

MULTIPLICATION FACTORS	PREFIX	SI SYMBOL
$1\ 000\ 000\ 000\ 000 = 10^{12}$	tera	T
$1\ 000\ 000\ 000 = 10^{9}$	giga	G
$1\ 000\ 000 = 10^{6}$	mega	M
$1\ 000 = 10^{3}$	kilo	k
$100 = 10^{2}$	hecto	h
$10 = 10^{1}$	deka	da
$0.1 = 10^{-1}$	deci	d
$0.01 = 10^{-2}$	centi	c
$0.001 = 10^{-3}$	milli	m
$0.000\ 001 = 10^{-6}$	micro	μ
$0.000\ 000\ 001 = 10^{-9}$	nano	n
$0.000\ 000\ 000\ 001 = 10^{-12}$	pico	p
$0.000\ 000\ 000\ 000\ 001 = 10^{-15}$	femto	f
$0.000\ 000\ 000\ 000\ 000\ 001 = 10^{-18}$	atto	a

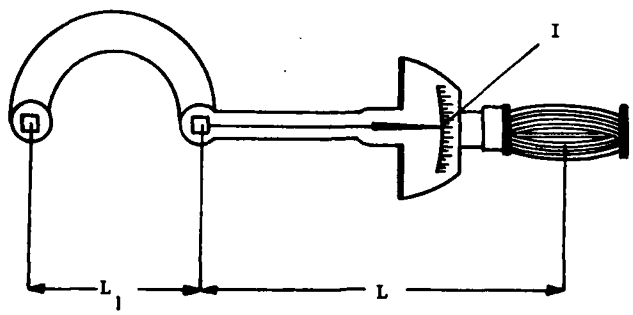
APPENDIX F

TORQUE VALUES AND PRACTICES

(1) Torque wrenches must be calibrated frequently by using weights and a measured lever arm. *Do not* check one wrench against another.

(2) Use the appropriate torque wrench size for torquing.

(3) When using torque wrench extensions or adapters, use the following formula to calculate the adjusted torquing value which should be indicated on the torque wrench scale.



$$I = \frac{RL}{L + L_1}$$

where:

I = Adjusted torque required.
R = Required torque of bolt or nut.
L = Length of torque wrench (head to mid point of handle) in inches.
L_1 = Length of extension or adapter (center to center distance) in inches.

(4) Applying torque:
- Clean parts to be tightened with dry cleaning solvent.
- Unless otherwise specified, do not lubricate parts.
- Torque slowly and evenly.
- Tighten bolts, nuts, screws in a staggered sequence until part is firmly seated; then complete tightening.

(5) If no special torque values are required, use standard torque values (see following tables).

(6) In applications where close tolerance torque is required for a locknut, determine the amount of torque required to overcome the drag of the locknut and add to the target torque.

Table F-1 Recommended Torque Wrench Sizes

Required Torque	Torque Wrench
0 to 25 Pound-Inches	30 Pound-Inches
25 to 140 Pound-Inches	150 Pound-Inches
140 to 550 Pound-Inches	600 Pound-Inches
30 to 140 Pound-Feet	150 Pound-Feet
140 to 240 Pound-Feet	250 Pound-Feet
240 to 1000 Pound-Feet	1000 Pound-Feet

Table F-2 Jamb Nuts, Bolts, and Fittings Used With Gaskets (Pound-Inches)

Tubing Outside Diameter	Thread Size	Nuts (MS9099, MS9100, MS9200, MS9201) Plug (MS9015) Union (AN815) Bolt - Universal (Banjo) Fitting (AN774 & AN775)
1/8	5/16-24	45-50
3/16	3/8-24	60-70
1/4	7/16-20	90-100
5/16	1/2-10	120-130
3/8	9/16-18	150-160
1/2	3/4-16	275-300
5/8	7/8-14	375-400
3/4	1-1/16-12	550-600
1	1-5/16-12	800-900
1-1/8	1-5/8-12	900-1000
1-1/2	1-7/8-12	900-1000

Table F-3 Standard Steel Screws, Bolts, and Nuts (Pound-Inches)

Thread Size	Slotbed-Head Screws	Hexagon-Head Bolts and Nuts
2-56	2-3	—
3-48	3-4	—
4-40	5-6	—
5-40	6-7	—
6-32	7-9	—
8-32	10-12	—
10-32	18-20	40-45
7/32-24	22-25	65-70
1/4-28	30-35	70-95
5/16-24	40-45	120-165
3/8-24	55-60	250-325
7/16-20	80-90	400-475
1/2-20 or -13	100-110	500-700
9/16-18	—	750-1000
5/8-18	—	1000-1400

Table F-4 Steel Taper Pipe-Thread Fittings and Plugs (Pound-Inches)

Size	In Steel Case	In Magnesium or Aluminum Case
1/16-27	35-40	10-15
1/8-27	75-125	30-40
1/4-18	200-250	70-85
3/8-18	300-375	95/110
1/2-14	400-500	140/160
3/4-14	500-600	175-200
1-11-1/2	600-700	230-260

Table F-5 Tube and Hose End Fittings ('B' Nuts)

Dash No. Ref	Turbine OD Inches	Flared Tubing Nuts: Aluminum-Alloy Tubing Min.	Aluminum-Alloy Tubing Max.	Steel Tubing Min.	Steel Tubing Max.	Hose End Fittings Steel Min.	Hose End Fittings Steel Max.
-3	3/16	—	—	90	100	70	100
-4	1/4	40	65	135	150	70	120
-5	5/16	60	80	180	200	85	
-6	3/8	75	125	270	300	100	
-8	1/2	150	250	450	500	210	
-10	5/8	200	350	650	700	300	
-12	3/4	300	500	900	1000	500	
-16	1	500	700	1200	1400	700	
-20	1-1/4	600	900	—	—	—	—
-24	1-1/2	600	900	—	—	—	—

Table F-6 Jamb Nuts For Bulkhead Fittings

Tubing Outside Diameter	Thread Size	Torque (Pound-Inches)
1/8	5/16-24	35-50
3/16	3/8-24	
1/4	7/16-20	85-105
5/16	1/2-20	105-125
3/8	9/16-18	120-150
1/2	3/4-16	240-280
5/8	7/8-14	320-380
3/4	1-1/16-12	500-600
1	1-5/16-12	780-880
1-1/8	1-5/8-12	960-1200
1-1/2	1-7/8-12	1200-1440

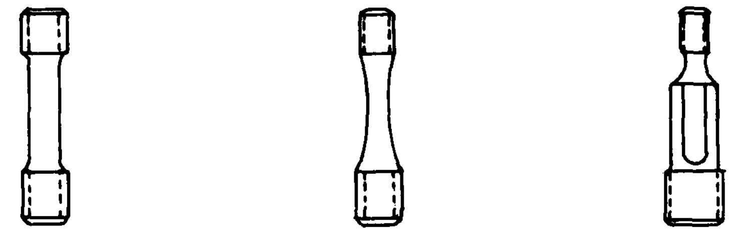


Table F-7 Stepped Stud Torque Values (Pound-Inches)

THREAD SIZE				
NUT END	STUD END	TYPE X	TYPE Y	TYPE Z
10-32	1/4-20	20 to 50		
1/4-28	5/16-18	50 to 110	50 to 75	50 to 165
5/16-24	3/8-16	100 to 240	100 to 160	100 to 350
3/8-24	7/16-14	175 to 475	175 to 325	175 to 600
7/16-20	1/2-13	250 to 725	250 to 525	250 to 1000
1/2-20	9/16-12	400 to 1150	400 to 850	400 to 1500
9/16-18	5/8-11	600 to 1650	600 to 1150	600 to 2100
5/8-18	11/16-11	900 to 2400	900 to 1700	900 to 3100

Table F-8 Straight Stud Torque Values (Pound-Inches)

THREAD SIZE				
NUT END	STUD END	TYPE X	TYPE Y	TYPE Z
4-48	4-40	3 to 7		
6-40	6-32	8 to 14		
8-36	8-32	18 to 25		
10-32	10-24	25 to 35		
1/4-28	1/4-20	50 to 95	50 to 95	50 to 105
5/16-24	5/16-18	100 to 225	100 to 225	100 to 250
3/8-24	3/8-16	175 to 375	175 to 375	175 to 400
7/16-20	7/16-14	250 to 650	250 to 400	250 to 700
1/2-20	1/2-13	400 to 1000	400 to 700	400 to 1100
9/16-18	9/16-12	600 to 1450	500 to 1050	600 to 1600
5/8-18	5/8-11	900 to 2000	700 to 1400	900 to 2200