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USAAMRDL TECHNICAL REPORT 72-11C

IDENTIFICATION AND ANALYSIS OF ARMY HELICOPTER RELIABILITY AND MAINTAINABILITY PROBLEMS AND DEFICIENCIES

VOLUME III

CARGO HELICOPTERS (CH-47, CH-54)

By

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William K. Krauss

James M. Ciccotti

April 1972

EUSTIS DIRECTORATE

U. S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY

FORT EUSTIS, VIRGINIA

CONTRACT DAAJ02-71-C-0051

AMERICAN POWER JET COMPANY

RIDGEFIELD, NEW JERSEY

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USAAMRDL Technical Report 72-11C
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IDENTIFICATION AND ANALYSIS OF ARMY HELICOPTER RELIABILITY AND MAINTAINABILITY PROBLEMS AND DEFICIENCIES

Volume III
Cargo Helicopters
(CH-47, CH-54)

American Power Jet Company Report 670-4

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ABSTRACT

This volume presents discussions of a series of reliability and maintainability problems related to Army Cargo Helicopters (CH-47, CH-54). A detailed discussion of the standard format used for problem presentation and of the various analysis elements within the standard format is provided in Volume I.

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HELICOPTER TMS: CH-47

Helicopter TMS: CH-47A,B,C
Problem No.: 01-1

Problem Title: Fastener and Rivet Failures

Problem Description:

A. Component Identification -
Most fasteners and rivets used on the CH-47.

B. Description of Failure -
Fasteners damaged, broken, lost.
Rivets loose, pulled through, lost.

Some specific areas of failure have been:

	P/N	
Shell Assy	114P5003-84	- Fasteners broken and missing, rivets loose and missing
Access Cover Assy	114P8058-2	- Rivets loose, missing
Cover Assy	114P8047-1	- Fasteners missing, rivets loose, missing
Engine Air Inlet Screen	114P8015	- Fasteners loose, missing. This was particularly troublesome, as fasteners falling off in flight were subject to engine ingestion, causing FOD.
Tunnel Access Covers	All P/Ns	- Fasteners broken, missing

Failures have occurred to varying degrees in most areas of the aircraft where rivets and fasteners are used.

C. Cause of Failure -
Inability of material and design to withstand vibration, tension and other stresses resulting from aircraft operation. Fastener failures are also induced by improper closure and damage during installation.

D. Period and Duration of Problem -
Early deployment to present

Problem No.: 01-1 (Continued)

E. Failure Rate Data -
There is no known source of data for failure rates for these items. They are common to most Army helicopters and are requisitioned and often issued in bulk quantities. However, the high frequency of failure of these items is acknowledged by all maintenance activities supporting CH-47s.

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -
Failures of rivets and fasteners do not normally present serious safety problems. Ingestion has been reported as causing engine malfunctions, and failures which permit airframe components to leave the aircraft in flight can be serious. During the period 1 January 1967 - 31 March 1971, only three mishaps recorded by USABAAR (all precautionary landings) could be definitely attributed to rivet or fastener failure. A number of cases of engine failure were attributed to foreign object damage, but the identification of the foreign object was not given.

B. Maintenance Workload Factors -
A single rivet or fastener normally can be replaced quickly. However, large-scale replacements and replacements in areas where accessibility is difficult can produce high manhour requirements. Most repairs require sheet metal skills found at DS or higher levels of maintenance.

C. Aircraft Availability Factors -
No specific downtime factors can be given. Fastener and rivet replacements can extend inspection downtime and produce unscheduled maintenance downtime, with the period of downtime depending on the extent of replacements required.

Remedial Actions:

1. ECP 555, approved in February 1968, replaced fasteners on fuel pump access panel, P/N 114S5913, with screws. The ECP provided parts for retrofit only and was implemented by MWO 55-1520-227-30/12, March 1969.

Problem No.: 01-1 (Continued)

2. ECP 615 described in Problem 01-3, improved tunnel covers to reduce the effects of vibration and the resulting frequency of rivet and fastener failures.

Data Sources:

1, 2, 3, 5, 6, 7, 13, 20, 21, 25, 26.

Cross References:

TMS	Problem Number
UH-1	01-5
AH-1	01-4, 01-8
CH-47	01-3
CH-54	-
OH-6	01-1, 01-4, 01-5
OH-58	01-3

Helicopter TMS: CH-47A,B,C
Problem No.: 01-2

Problem Title: Windshield Abrasion, Delamination

Problem Description:

A. Component Identification -

	P/N
Windshield Assembly, LH	114SS601-1
Windshield Assembly, RH	114SS601-2

B. Description of Failure -
1. Windshield crazing
2. Delamination of Plexiglas layers

C. Cause of Failure -
1. Abrasion caused primarily by windshield wipers scraping dust and other abrasives across the surface of the windshield.
2. Delamination caused by heat generated by heating elements in windshield.

D. Period and Duration of Problem -
Early deployment to present, although remedial actions discussed below have reduced the problem.

E. Failure Rate Data -
Demand data from Ft. Rucker for the one-year period ending 30 April 1971 showed windshield replacements (either right or left hand) were made at an average rate of one every 550 hours. The Boeing-Vertol engineering field evaluation program showed 65 windshield failures in 83,600 hours on CH-47B and C helicopters over a 26-month period (June 1967 - August 1969) or an average of 1286 hours between failures on one of the two windshields. These were the P/Ns 114SS601-7 and -8 glass laminated windshields.

F. Mission and Deployment Factors -
Common to all missions and deployments, but probably more prevalent in sandy and dusty environments of Vietnam and Ft. Rucker.

Problem No.: 01-2 (Continued)

Problem Impact:

A. Safety Factors -

No mishaps resulting from windshield failure have been recorded by USABAAR during the period 1 January 1967 - 31 March 1971. However, distortion from abrasion and delamination presents potential flight safety hazards.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace	4-5	Organizational

C. Aircraft Availability Factors -

Downtime for replacement - approximately one day.

Remedial Actions:

ECP 352 was approved in October 1968 to provide windshields with a glass outer layer, effective with production aircraft 69-17112, with retrofit by attrition. Subsequently, these windshields (P/Ns 114SS601-7 and 601-8) were replaced by P/Ns 114SS604-1 and 604-2, and a different windshield wiper blade was provided.

Data Sources:

1,2,3,5,6,7,10,13,18,19,20,21,23,25,27,28.

Cross References:

TMS	Problem Numbers
UH-1	01-2
AH-1	01-3
CH-47	-
CH-54	-
OH-6	01-2
OH-58	-

Helicopter TMS: CH-47A,B,C
Problem No.: 01-3

Problem Title: Tunnel Cover and Other Fiberglass Structure Failures

Problem Description:

A. Component Identification -

	P/N
Tunnel Access Covers	114S2905
Pylon Leading-Edge Hinged Lower Fairing Installation	114S3910
Lower Pylon Fixed Fairing Installation	114S3906

B. Description of Failure -
Cracking and looseness of fiberglass structures; cracking and breaking of tunnel cover reinforcement ribs; rivets loosening and pulling through; latch failure, permitting tunnel covers to loosen in flight; failure of tunnel cover struts, falling against and scoring synchronized shafting; matching edges of fiberglass structures chafing and being damaged.

C. Cause of Failure -
Vibration, buffeting airloads from rotor downwash, flexure of fuselage, some cases of improper fit of matching parts in production, damage by maintenance personnel (stepping and walking on areas not designated as steps or walkways, allowing tunnel covers to rest on cabin crown skins), and frequent removal of lower pylon fairing for access to the engine-to-combining transmission cross shafting and of tunnel covers for access to synchronized shafting. Material and design unable to withstand these stresses.

D. Period and Duration of Problem -
Early deployment to present

E. Failure Rate Data -
In September 1968, Aviation Test Board data showed a mean time between failure of slightly more than 20 hours for tunnel covers.

In January 1969, Boeing-Vertol reported a mean time between failure of about 110 hours for the lower hinged fairing.

Problem No.: 01-3 (Continued)

No data are available for the lower fixed fairing, but it is probable that the mean time between failures was approximately the same as for the hinged fairing.

F. Mission and Deployment Factors -
Common to all missions and deployments.

Problem Impact:

A. Safety Factors -
Two mishaps (classified as incidents) resulting from loss of tunnel covers in flight were recorded by USABAAR during the period 1 January 1967 - 31 March 1971. In both cases, the cover struck the rotor blades. Although neither mishap resulted in a major accident, it is apparent that such occurrences present a serious safety hazard.

Lower pylon fairing failures (hinged and fixed) do not ordinarily affect flying safety.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace tunnel cover	1.5 - 2.0	Organizational
Repair tunnel cover	6.0 -10.0	Mostly Organizational; some Direct Support
Replace hinged fairing	1.0 - 1.5	Organizational
Repair hinged fairing	5.0 -10.0	Mostly Direct Support; some Organizational
Replace fixed fairing	.5 - 1.0	Direct Support
Repair fixed fairing	5.0 -10.0	Direct Support

C. Aircraft Availability Factors -
Downtime for replacement of any one of the above components - 2 - 4 hours.
Downtime for repair of any one of the above components - 1 - 2 days, if a replacement fairing is not available and the aircraft must be grounded until repair is completed.

Remedial Actions:

1. MWO 55-1520-209-20/61, September 1967, removed tunnel cover struts from the No. 1 and No. 5 covers on aircraft prior to 66-19098.

Problem No.: 01-3 (Continued)

2. ECP 395R, approved in May 1967, revised tunnel cover latching, added stiffeners to the covers and added new struts to the No. 1 and No. 5 cover effective with production aircraft 66-19098. Retrofit was provided by MWO 55-1520-209-40/12, December 1970.

3. ECP 615, approved in April 1969, replaced the existing tunnel covers with honeycomb construction units with greater load-bearing capacity. Hinged hold-open struts were added to prevent larger covers from opening too far. The ECP was effective with production aircraft 69-17123 and subsequent.

4. ECP 614, approved in April 1969, replaced the existing lower hinged fairing with a honeycomb construction. An aluminum strip covered with anti-chafing tape was added to all edges. Access doors were installed in the fixed fairing to permit access to the shafting without removal and replacement of the fairing. The ECP was effective with production aircraft 69-17133 and subsequent.

Data Sources:

1,2,3,4,5,6,7,8,9,13,14,17,19,21,23,24,25,26,27,28.

Cross References:

TMS	Problem Numbers
UH-1	-
AH-1	01-4, 01-5, 01-8, 02-2, 12-1
CH-47	01-1, 01-4, 01-5
OH-54	-
OH-6	01-3, 02-3
OH-58	-

Helicopter TMS: CH-47A,B,C
Problem No.: 01-4

Problem Title: Doors, Work Platforms, and Related Hardware Failures

Problem Description:

A. Component Identification -

	P/N
Lower Cabin Door Installation	114S1620-1
Pilot Jettisonable Door Installation	114S1647-2
Copilot Jettisonable Door Installation	114S1647-1
Aft Pylon Work Platform Assy, LH	114S4604-1
Aft Pylon Work Platform Assy, RH	114S4604-2
Work Platform Installation, Forward Pylon, LH	114S5551-1
Work Platform Installation, Forward Pylon, RH	114S5551-2

B. Description of Failure -

1. Separation of platforms and doors from aircraft in flight.

2. Cracking and failure of platforms, doors and related hardware (hinges, latches, struts, gussets). Latch failures were a frequent and major source of loss of platforms and doors in flight.

C. Cause of Failure -

Inability of attaching fittings (hinges, latches, gussets) to withstand operating stresses, primarily vibration and flexing.

D. Period and Duration of Problem -

Early deployment to present, although corrective actions have reduced the magnitude of the problem.

E. Failure Rate Data -

Following are replacement factors at Ft. Rucker for the year ending 30 April 1971. They represent issues from stock and do not include failures corrected by repair.

Problem No.: 01-4 (Continued)

	MTBR (hours)
Lower Cabin Door	5000
Pilot and Copilot Jettisonable Doors	2500
Aft Pylon Work Platforms	1100
Forward Pylon Work Platforms	14000

A review of issues of some of the components and parts of the above installations and assemblies used for repairs provides some indication of the MTBF, including failures corrected both by replacement and repair. These rates are as follows:

	Estimated MTBF (hours)
Lower Cabin Door	1000
Pilot and Copilot Jettisonable Doors	500
Aft Pylon Work Platforms	850
Forward Pylon Work Platforms	200

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -

Loss or malfunctions of doors and work platforms in flight accounted for 8 of the 20 mishaps classified as incidents recorded by USABAAR during the period 1 January 1967 - 31 March 1971. Three precautionary landings resulted from these conditions during the same period.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace lower cabin door	2 - 3	Organizational
Repair lower cabin door	3 - 10	Mostly Organizational; some Direct Support
Replace jettisonable doors	1 - 2	Organizational
Repair jettisonable doors	12 - 18	Mostly Organizational; some Direct Support

Problem No.: 01-4 (Continued

Action	M/H	Level of Maint.
Replace forward pylon work platform	1 - 2	Organizational
Repair forward pylon work platform	2 - 6	Mostly Organizational; some Direct Support
Replace aft pylon work platform	1 - 2	Organizational
Repair aft pylon work platform	3 - 10	Mostly Direct Support; some Organizational

C. Aircraft Availability Factors -

Downtime for replacement of any one of the above components is approximately 2 - 4 hours.

Downtime for repair ranges from 1/2 to 5 days if aircraft must be down while repairs are made.

Remedial Action:

1. ECP 54, approved in March 1964, modified the forward work platforms effective with production aircraft 64-13136 and subsequent.

2. ECP 485R2, approved in April 1969, replaced the existing latch assembly and the aft pylon work platform with heavier duty latches. The ECP was implemented for retrofit by MWO 55-1500-210-40/2, August 1970.

3. ECP 519R2, approved in September 1969, reinforced the forward pylon work platform and added another latch to the upper edge of the platform.

Data Sources:

1,2,3,5,7,8,13,15,17,18,20,21,23,24,25,26,27,28.

Problem No.: 01-4 (Continued)

Cross References:

TMS	Problem Numbers
UH-1	01-3
AH-1	01-6
CH-47	01-3, 01-5
CH-54	-
OH-6	01-4
OH-58	01-1, 01-2

Helicopter TMS: CH-47A, B, C
Problem No.: 01-5

Problem Title: Cargo Door and Ramp Hinge Failures and Malfunctions

Problem Description:

A. Component Identification -

	P/N
Door Assembly	114S6002
Ramp Hinge Fittings	114S3812

B. Description of Failure -

1. Door assembly damaged when door is opened and strikes obstruction above ground level (rock, stump, etc.). Honeycomb structure is dented, gouged, crushed.

2. Hinge fittings corrode, crack.

C. Cause of Failure -

1. Cargo door: Primarily pilot error in not assuring adequate clearance before lowering door.

2. Hinge fittings: Corrosion results from proximity of dissimilar metals (magnesium and aluminum) and exposure to water and other corrosive agents. Cracks from fatigue result from high usage (primarily at the Aviation Center) and from dirt and debris accumulating in the hinge area exerting pressure against the skin at the base of the ramp when it is closed.

D. Period and Duration of Problem -
Early deployment to present

E. Failure Rate Data

MTBF cannot be obtained from data available. However, inspection is required at the periodic nearest each six-month period, and corrosion is treated if found. New Cumberland Army Depot replaces hinges and fittings on about 95% of aircraft received for depot cyclic overhaul, and cargo doors require repair or replacement on about 90% of the same aircraft. Helicopters returned to the depot for cyclic overhaul are normally high-time aircraft. Boeing-Vertol reported in June 1969 that about 25% of the aircraft received for overhaul from Vietnam required sheet metal repair in the hinge area of the ramp.

Problem No.: 01-5 (Continued)

F. Mission and Deployment Factors -

Door assembly damage - common to all missions and deployments.

Hinge fitting corrosion - primarily related to Vietnam operations.

Hinge and hinge fitting fatigue - primarily at the Army Aviation Center.

Problem Impact:

A. Safety Factors -

Door and hinge damage corrosion and malfunctions do not ordinarily present safety hazards.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Repair ramp and door	125 - 135	Direct Support and higher
Replace door	3 - 5	Organizational
Replace hinge and hinge fittings	4 - 5	Direct Support

C. Aircraft Availability Factors -

Ramp and door repair is frequently done in conjunction with depot cyclic overhaul. If done by itself, downtime will run from 8 - 12 working days, or 2 - 3 weeks. If done at depot level, time for movement to the depot, depot processing, induction into work and acceptance after work completion must be added.

Door, hinge and hinge fitting replacements produce one-half to one day of downtime.

Remedial Actions:

1. ECP 484, approved in October 1967, provided drain holes to preclude corrosion from water accumulation. The ECP was effective with production aircraft 68-15832 and subsequent. MWO 55-1500-210-50/1, April 1969, provided for retrofit at depot level in conjunction with depot cyclic overhaul.

2. TM 55-1520-209-20 and TM 55-1520-227-20 PMP inspection checklists were revised to include requirements and instructions for cleaning of ramp hinge area during periodic inspections.

Problem No.: 01-5 (Continued)

Data Sources:

1,2,3,5,6,7,8,9, 10,11,12.

Cross References:

TMS	Problem Numbers
UH-1	01-3
AH-1	01-6
CH-47	01-3, 01-4, 01-8
CH-54	-
OH-6	01-4
OH-58	01-2

Helicopter TMS: CH-47A,B,C
Problem No.: 01-6

Problem Title: Structures and Bulkhead Failures at Stations 120, 482, 502, and 534

Problem Description:

A. Component Identification -
Skin, stringers, bulkheads, and formers at stations listed in problem title.

B. Description of Failure -
Cracking and breaking of structural elements.

C. Cause of Failure -
Exact causes unknown. Station 120 is at the cargo hoist location, and stresses resulting from hoist operations are suspected as the cause. Other stations are aft in engine mount areas, and it is suspected that vibration and stresses from engine operation are primary causes of failure.

D. Period and Duration of Problem -
Early deployment to present

E. Failure Rate Data -
Data on failure rates are not available. However, it is believed that the time between failures is probably quite high (1000 hours or more).

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -
No mishaps resulting from structural cracks were recorded by USABAAR during the 1 January 1967 - 31 March 1971 period. Structural failures, if undetected, however, could have major safety implications.

B. Maintenance Workload Factors -
Manhour requirements to repair structural cracks and damage vary widely, depending on the location, nature and extent of damage. At New Cumberland Army Depot, it was stated

Problem No.: 01-6 (Continued)

that a minimum of 20 manhours was required for such repairs and a maximum could not be stated. Manhours for the various MWOs discussed below for correction of structural problems range from 16 to 225. Repairs can be accomplished at direct support and higher levels.

C. Aircraft Availability Factors -

As with maintenance manhour requirements, downtime for repairs ranges widely, depending on the extent of damage and level of maintenance at which repairs are performed. Downtime minimum is approximately 2 - 3 days, with maximum unknown but much higher.

Remedial Action:

1. ECP A0004 (class II) was approved in May 1967 to strengthen the hub flanges at the Station 502.437 former, effective with production aircraft 67-18542 and subsequent (less aircraft 67-18548).

2. ECP 452, approved in March 1967, improved the engine mount support and frame at Station 482, effective with production aircraft 66-19098 and subsequent.

3. ECP 456, approved in September 1966, modified the side frame at Station 482, effective with production aircraft 66-19042 and subsequent. Retrofit was provided by MWO 55-1520-209-30/55, October 1967.

4. ECP 459, approved in April 1967, modified the aft pylon former at Station 502, effective with production aircraft 66-19042 and subsequent. Retrofit was provided by MWO 55-1520-209-30/70, June 1968.

5. MWO 55-1500-210-30/28, April 1970, provided for strengthening of the stringer and skin at Station 120.

Data Sources:

1,2,3,5,6,7,9,13,14,17,21,26.

Problem No.: 01-6 (Continued)

Cross References:

TMS	Problem Numbers
UH-1	01-6
AH-1	-
CH-47	01-7
CH-54	-
OH-6	-
OH-58	-

Helicopter TMS: CH-47A,B,C
Problem No.: 01-7

Problem Title: Engine Mount Fitting Failures

Problem Description:

A. Component Identification -

The engine mount fitting assemblies provide the structure in which engines are mounted. There are forward and aft engine mounts for both right-hand and left-hand engines. The fittings are an integral part of the fuselage.

	P/N
Forward Assembly	114S3817
Aft Assembly	114S3819

B. Description of Failure -

1. Bolt holes in lugs of fittings become elongated.
2. Cracks and gouges occur in fittings.

Elongated holes can be repaired by removing bushings, enlarging hole slightly, and using an oversize bushing in the enlarged hole. However, limitations on the size of the enlarged hole restrict the extent to which these repairs can be made.

C. Cause of Failure -

Vibration, tension and compression stresses from engine operation cause fatigue. Maintenance activities during engine removal and installation also cause some damage, primarily nicks and gouges. Twisting action of aft engine mount link assembly also produces gouges.

D. Period and Duration of Problem -

Conditions creating problems have existed from early deployment to present, but problems have become apparent only in the past 2 - 3 years.

E. Failure Rate Data -

Data providing precise MTBF are not available. However, at Ft. Rucker, failures have been observed from 2600 to 3400 hours. At New Cumberland Army Depot, failures are found on aircraft returned for depot cyclic overhaul, and these are also high-time aircraft. The rate of failure on these aircraft is high. At New Cumberland Army Depot, it was found in September 1971 that 27 of the last 68 aircraft received required

Problem No.: 01-7 (Continued)

changing at least one engine mount, six of the 27 required changing of two mounts (right and left hand), and one required changing of all four mounts. Failure data are as follows:

TMS	No. Overhauled	No. Requiring Mount Replacement	Mount Replacements Forward LH	Mount Replacements Forward RH	Mount Replacements Aft LH	Mount Replacements Aft RH
CH-47A	41	19	12	8	3	2
CH-47B	27	8	2	2	5	2

As shown, for the CH-47A, the major problem area has been the forward mounts. With the CH-47B, more changes of the aft mounts have occurred, but the sample size is too small to permit inferences from these data.

Forward engine mount replacements resulted from cracks and bolt hole elongation. Aft mount replacements resulted from gouges, cracks and elongation.

Ft. Rucker has also had eight of their CH-47 fleet sent to depot maintenance for engine mount fitting replacement, with aft mounts representing the majority of failures.

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -
No mishaps resulting from engine mount fitting failures were recorded by USABAAR during the 1 January 1967 - 31 March 1971 period.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Repair (rebush) elongated bolt holes	16 - 20*	Direct Support
Replace fitting	125 - 135**	Depot

* With engine removed.
** With all components removed from fuselage.

Problem No.: 01-7 (Continued)

C. Aircraft Availability Factors -

Downtime for rebushing - 3 - 5 days.

Downtime for replacement - Replacement frequently is done in conjunction with other airframe overhaul, and it is difficult to assign a specific value. Replacement alone will require 8 - 12 working days. To this must be added time to ship the aircraft to New Cumberland Army Depot or Boeing-Vertol, depot inspection and induction time, and any other time spent in the depot awaiting entry into maintenance or awaiting acceptance after work completion. Downtime, at a minimum, will be 30 - 45 days, and probably more on the average.

Remedial Actions:

ECP 638 was approved in [illegible]y 1970. The ECP provided a spacer at the upper link assembly attachment point of the aft engine mount to prevent the twisting action which caused gouges. Additionally, a steel sleeve was added to the structural fittings in the lugs that support the engine, and a new bushing for the lug holes was provided. The ECP was incorporated on current production aircraft, and retrofit of field aircraft was authorized.

Data Sources:

1,2,3,4,5,6,7,9,13,21,24,25.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	01-6
CH-54	-
OH-6	-
OH-58	-

Helicopter TMS: CH-47A,B,C
Problem No.: 01-8

Problem Title: Floor Beam Assembly Corrosion

Problem Description:

A. Component Identification -

	P/N
Beam Assemblies	114S2558-5
	114S2560-11
	114S2560-12
	114S2557-5
	114S2559-1
	114S2559-42

B. Description of Failure -
Beams corrode excessively.

C. Cause of Failure -
Proximity of dissimilar metals (magnesium and aluminum) and water, animal urine, and other contaminants in contact with magnesium surfaces.

D. Period and Duration of Problem -
Early deployment to present

E. Failure Rate Data -
Little failure rate data are available. At Ft. Rucker, replacement of a floor beam has been required at about every 2000 hours. At New Cumberland Army Depot, replacement of one or more floor beams is required on essentially every aircraft returned for depot overhaul. These are normally high-time aircraft.

Inspection of the beams is required every six months, and treatment is applied to beams suffering corrosion not severe enough to require beam assembly removal and replacement.

F. Mission and Deployment Factors -
Common to all missions and deployments, but appears to be more severe in Vietnam, where the natural environment, field support conditions, and mission requirements (some transport of livestock) lead to rapid corrosion.

Problem No.: 01-8 (Continued)

Problem Impact:

A. Safety Factors -
Floor beam corrosion is not a sfaety hazard.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Inspect & treat corrosion (all areas)	45 - 50*	Organizational
Replace one beam (including disassembly to gain access to beam)	32 - 35*	Direct Support
Build up one beam from stock	36	Depot

C. Aircraft Availability Factors -
Downtime ranges from 3 - 8 days for actions requiring grounding of the aircraft, assuming a two-man crew.

Remedial Actions:

ECP 472, approved in January 1968, incorporated aluminum rails in lieu of magnesium rails, effective with aircraft 69-17100 and subsequent. Aluminum rails are also issued through supply channels as the replacement item. However, floor panels are still magensium, and the problem of dissimilar metals has not been completely resolved.

Data Sources:

1,2,3,5,6,7,8,9,17,21,25.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	01-5
CH-54	-
OH-6	-
OH-58	-

* These manhours include removal of floor paneling (approximately 30 manhours).

Helicopter TMS: CH-47A, B, C
Problem No.: 04-1

Problem Title: Main Rotor Blade Malfunctions and Failures

Problem Description:

A. Component Identification -

	TMS	P/N
Forward Rotary-Wing Blade Assy	CH-47A	114R1002-29 & all succeeding dash numbers
Aft Rotary-Wing Blade Assy	CH-47A	114R1002-30 & all succeeding dash numbers
Forward Rotary-Wing Blade Assy	CH-47B, C	114R1502-1 & all succeeding dash numbers
Aft Rotary-Blade Assy	CH-47B, C	114R1502-2 & all succeeding dash numbers

B. Description of Failure -

Failures are categorized as inherent, where failure results from material and design inadequacies to meet environmental conditions in which blades should be expected to survive, and external, where failure results from conditions in which blade survival is not expected. A Boeing-Vertol study of CH-47 rotor blade failures analyzed failures in which blades were repaired and those resulting in scrapping of the blades. Results of the study showed principal modes of failure, as follows:

Failure Category	Blade Description	Failure Cause	Percent of Failure Category - Total	
			CH-47A	B, C
Inherent	Repaired	Cracking	29	8
		Corrosion	20	25
		Unbonding	19	42
		Delamination	7	11
Inherent	Scrapped	Corrosion	80	*
External	Repaired	Foreign Object Damage	76	65
		Combat Damage	13	21

* No Pattern

Problem No.: 04-1 (Continued)

Failure Category	Blade Description	Failure Cause	Percent of Failure Category - Total	
			CH-47A	B,C
External	Scrapped	Foreign Object Damage	35	33
		Combat Damage	27	60
		Overstress	26	33
Inherent	Repaired	Cracking	50	4
		Unbonding	19	64
		Corrosion	14	15
Inherent	Scrapped	Corrosion	44	*
		Unbonding	38	*
External	Repaired	Foreign Object Damage	69	65
		Combat Damage	14	21
		Overstress	10	13
External	Scrapped	Foreign Object Damage	30	49
		Combat Damage	12	30
		Overstress	53	2

As shown, cracking was a much more severe problem with CH-47A blades than with CH-47B and C blades, while bonding problems were greater with the CH-47B and C blades. Foreign object damage and combat damage were major causes of external failures for all blades, and overstress was the reason for scrapping a considerably higher percentage of CH-47A blades than CH-47B and C blades.

C. Cause of Failure -

Inherent failures resulted from material and design inadequacies. External failures were caused primarily by combat action, blade strikes, and overspeed.

D. Period and Duration of Problem -

Early deployment to present.

E. Failure Rate Data -

The Boeing-Vertol study noted above showed the following mean time to removal data, including only removals for failures:

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* Sample too small to be meaningful.

Problem No.: 04-1 (Continued)

CH-47 Rotor Blades

Failure Category	Sample Size (No. of Blades)		Mean Time to Removal (hours)	
FORWARD:	CH-47A	B, C	CH-47A	B, C
Inherent	692	156	471	420
External	942	295	433	381
Combined	1634	451	456	395
AFT:				
Inherent	741	128	604	415
External	1064	302	359	342
Combined	1805	430	460	362

The AVSCOM Major Item Removal Frequency Report, covering the period 1 January 1964 - 30 June 1970, showed a mean time to removal (failure causes only) for CH-47A rotor blades as follows:

CH-47A Blades

Failure Category	Sample Size (No. of Blades)	Mean Time to Removal (hours)
FORWARD:		
Inherent	271	516
External	279	460
Combined	550	495
AFT:		
Inherent	332	450
External	307	378
Combined	639	415

F. Mission and Deployment Factors -

Common to all missions and deployments; however, externally caused failures are more prevalent in Vietnam.

Problem No.: 04-1 (Continued)

Problem Impact:

A. Safety Factors -

During the period 1 January 1967 - 31 March 1971, USABAAR recorded two total losses, three forced landings, and six precautionary landings from rotor blade failures. Additionally, two major mishaps resulted from blade cuff and root socket failures.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace forward or aft blade	4 - 5	Direct Support

C. Aircraft Availability Factors -

Downtime for blade replacement - 3 - 4 hours (two-man crew).

Remedial Actions:

1. ECP 161R1, approved in 1964, provided for improvements to the main rotor blade, including delamination repair. Implementation in the field was through MWO 55-1520-209-34/80.

2. ECP 179, approved in January 1964, added drain holes to the blades effective with production aircraft 63-7906 to 66-19097. MWO 55-1520-209-34/81 provided field retrofit.

3. ECP 206, approved in March 1964, reinforced the end ribs of the tip fairing effective with production aircraft 63-7906 and subsequent. MWO 55-1520-209-34/94 provided field retrofit.

4. ECP 466, approved in November 1966, modified the blade tiedown hole to provide improved erosion protection. MWO 55-1520-209-30/66, February 1969, provided field retrofit.

5. ECP 562R, approved in December 1967, improved water sealing of the CH-47B and C blades.

Data Sources:

1,2,3,5,6,7,9,13,14,16,17,20,21,22,23,25,28.

Problem No.: 04-1 (Continued)

Cross References:

TMS	Problem Number
UH-1	04-2
AH-1	04-3
CH-47	-
CH-54	04-1
OH-6	04-4
OH-58	-

Helicopter TMS: CH-47A,B,C
Problem No.: 04-2

Problem Title: Rotor Hub Lubricating Oil Tank Failures

Problem Description:

A. Component Identification -
Aft Rotor Hub Lubricating Oil Tank, P/N 114R2053-1, -6.

B. Description of Failure -
Wearing of the lugs to which helical extension spring, P/N 114R2079-1, attaches.

C. Cause of Failure -
Chafing and wearing from action of the spring in the lugs.

D. Period and Duration of Problem -
Early deployment to present

E. Failure Rate Data -
Specific MTBF data are not available, but it was stated at Ft. Rucker that the tanks were experiencing a 100% rejection rate at 600 hours.

F. Mission and Deployment Factors -
Probably common to all missions and deployments, although the only identification of the problem occurred at Ft. Rucker. However, as noted below, an ECP and MWO to remedy the situation were issued, indicating a relatively widespread problem.

Problem Impact:

A. Safety Factors -
No mishaps resulting from the lubricating oil tank were recorded by USABAAR during the period 1 January 1967 - 31 March 1971.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace	2.0 - 3.0	Organizational

C. Aircraft Availability Factors -
Downtime for replacement: 3.0 - 5.0 hours.

Problem No.: 04-2 (Continued)

Remedial Actions:

ECP 590 was approved in September 1968 effective with production aircraft S/N 66-19098 and subsequent. The ECP provided a nonmetallic washer to protect lug ears from spring chafing. MWO 55-1520-227-30/22, March 1970, for field retrofit.

Data Sources:

1,2,3,5,6,7,8,13,14,17,25,26,27.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	-
CH-54	-
OH-6	-
OH-58	-

Helicopter TMS: CH-47A, B, C
Problem No.: 04-3

Problem Title: Synchronized Drive Shaft Malfunctions

Problem Description:

A. Component Identification -

	P/N
Shaft Assemblies	114D3048-7
	114D3046-1
	114D3070-6
	114D3072-1
Annular Ball Bearing	114DS340-1
Shock Mount	J9104-5

B. Description of Failure -

Shock mounts suffer spring breakage, become spongy; bearings wear, fail. Failure of either or both the shock mount and bearing increases the normally high level of vibration from rotation of the drive shaft.

C. Cause of Failure -

Shock mounts: material unable to withstand operating stress to which it is exposed, particularly vibration and flexing of the shaft and the resulting loadings placed on the mounts.

Bearings primarily fail from result of bearing cage rubbing, which in turn frequently results from shaft misalignment.

D. Period and Duration of Problem -

Early deployment to present. Shock mount and bearing failures occurred during the CH-47A service test in 1963 and have continued.

E. Failure Rate Data -

The various shaft assemblies had a mean time to removal reflected in the AVSCOM "MIRF" report ranging from 613 to 710 hours. Demand data at the Aviation School, Ft. Rucker, showed an MTBR ranging from about 600 to 1800 hours. However, Ft. Rucker data reflects only replacements from the supply system, excluding failures corrected by repair. It should be noted that there are six shaft assemblies 114D3048-7 on the aircraft,

Problem No.: 04-3 (Continued)

and thus failure of one of the six can be expected at about one-sixth of the hours shown for the individual component. Comparative data are:

	P/N	MIRF MTR	Ft. Rucker MTBR
Shaft Assy	114D3048-7	688	1002
	114D3046-1	613	1790
	114D3070-6	672	591
	114D3072-1	710	852

Ft. Rucker demand data for bearings and mounts show a mean time between replacements as follows:

	P/N	Hours
Bearing	114DS340-1	770
Mount	J9104-5	706

As there are seven bearings and fourteen mounts along the drive shaft, a bearing failure can be expected about every 110 hours and a mount failure about every 50 hours. Bearing failures account for about 10% of the 114D3070-6 and 114D3048-7 shaft assembly removals reported in MIRF.

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -
Failures of the shaft, bearings and mounts have not had serious safety implications. A total of two incidents (of a total of 22) and five precautionary landings (of a total of 319) are recorded by USABAAR for the period 1 January 1967 - 31 March 1971. Both incidents and two of the precautionary landings resulted from maintenance error.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace shaft assy	1.0 - 2.0	Organizational
Repair shaft assy	2.0 - 4.0	Organizational
Replace bearing	3.0 - 4.0	Organizational
Replace shock mount	.8 - 1.2	Organizational

Problem No.: 04-3 (Continued)

C. Aircraft Availability Factors -

Aircraft downtime for	Hours
Shaft assy replacement	2 - 3
Shaft assy repair	3 - 6
Bearing replacement	4 - 6
Shock mount replacement	1 - 2

Remedial Actions:

1. Shaft assemblies 114D3048-7 and 114D3070-6 are the latest in a series of assemblies used on the aircraft. At least four different assemblies preceded each of the above two currently listed as the prime assembly.

2. ECP 520R2, approved in May 1969, stiffened cabin crown frames effective with CH-47C aircraft 69-17126 and subsequent. The shock mount problem was more severe on the CH-47C than on the A and B series, and the ECP reduced the mount loading.

3. Bearing failures were discussed in the EIR Digest for the 2nd Quarter, FY 1970 (TB 750-992-1, 1970), in which it was noted that bearing ball packet clearances would be increased to reduce bearing cage rubbing. Bearing deliveries starting in January 1970 had the additional clearance.

4. Excessive shaft vibration causes were discussed in the same digest issue, identifying as the usual causes:

a. Dry and/or worn adapter splines
b. Missing or incorrect hardware
c. Missing balance weights
d. Entrapped water or foreign objects
e. Broken shock mounts and hangers
f. Damage to shafts or adapters
g. Broken/cracked coupling plates
h. Improper installation

It was recommended that if none of these discrepancies were found, the shaft be installed in another location or on another aircraft, and if this did not resolve the problem, the shaft be replaced and an EIR submitted. The identical instructions were included in the EIR Digest for the 2nd Quarter, FY 1971 (TB 750-992-2, January 1971).

Problem No.: 04-3 (Continued)

5. ECP 207, approved in April 1964, provided a redesign of the synchronized shaft adapter effective with aircraft 63-7909 and subsequent. However, most problems discussed have occurred or continued since this early ECP. Retrofit provisions for earlier aircraft were included and implemented by MWO 55-1520-209-20/30, 16 July 1964.

6. ECP 423 increased the strength of the forward shaft adapter lugs, and ECP 448 improved the shaft adapters. ECP 423 was approved in December 1966, effective with aircraft 67-18470 and subsequent, with provisions for fleet retrofit. ECP 448 was approved in March 1967, effective with aircraft 67-18494 and subsequent, without retrofit provisions. ECP 423 retrofit was implemented by MWO 55-1520-209-20/57, 28 February 1968.

Data Sources:

1, 2, 3, 4, 5, 6, 7, 8, 13, 16, 17, 20, 21, 23, 24, 25, 26, 27, 28.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	-
CH-54	-
OH-6	04-1
OH-58	04-1

Helicopter TMS: CH-47A,B,C
Problem No.: C4-4

Problem Title: Transmission Oil Pressure Transducer Failures

Problem Description:

A. Component Identification -
Oil Pressure Transducer, P/N 114ES232

B. Description of Failure -
Transducer becomes inoperative, gives erroneous indications.

C. Cause of Failure -
Design inadequate to meet operating environmental conditions.

D. Period and Duration of Problem -
Early deployment to present

E. Failure Rate Data -
The Boeing-Vertol Engineering Field Evaluation Program showed a mean time between failures of 3240 hours for the transducer installed on the CH-47B and C helicopters. However, as there are five transducers per helicopter, the helicopter experienced a transducer failure at an average of 648 hours.

Ft. Rucker demand data for the year ending 30 April 1970 shows that a transducer replacement on the helicopter was required at an average of one each 906 hours.

F. Mission and Deployment Factors -
Common to all missions and deployments.

Problem Impact:

A. Safety Factors -
Failure of a transducer does not produce a safety-of-flight condition. However, it often produces a false indication that oil pressure is low, and this results in a high frequency of precautionary landings. Of 319 precautionary landings recorded by USABAAR during the period 1 January 1967 - 31 March 1971, 25 resulted from transducer failures.

Problem No.: 04-4 (Continued)

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace	2.5 - 3.0	Organizational

C. Aircraft Availability Factors -
Downtime for transducer replacement - 3.5 - 5.0 hours.

Remedial Action:

The P/N 114ES232 transducer has been replaced by a new transducer, P/N 114E237. The change was based on ECP 462R approved in May 1968. MWO 55-1500-210-30/9, August 1969, provided for fleet retrofit.

Data Sources:

1,2,3,5,6,7,8,13,17,21,23,25,26,27,28.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	11-2
CH-47	19-1
CH-54	-
OH-6	-
OH-58	-

Helicopter TMS: CH-47A,B,C
Problem No.: 04-5

Problem Title: Pitch Varying Housing Seal Failures

Problem Description:

A. Component Identification -

Seal, P/N 114R2141

B. Description of Failure -

Seal wears and permits excessive oil leakage.

C. Cause of Failure -

Entry of dirt and other abrasive materials under sealing surface.

D. Period and Duration of Problem -

Early deployment to present

E. Failure Rate Data -

The Boeing-Vertol Engineering Field Evaluation Program, using TAERS data for the period June 1967 - August 1969, showed a mean time between failures of about 3500 hours. However, as there are six seals on the CH-47, this indicates a failure of one of the seals every 580 hours, on the average. Seal failures ranked fifth in the Vertol top twenty component failure list.

Ft. Rucker demand data for the year ending 30 April 1971 showed a seal replacement required every 220 hours.

F. Mission and Deployment Factors -

Common to all missions and deployments, but more serious in dusty, sandy environments, such as Vietnam and Ft. Rucker.

Problem Impact:

A. Safety Factors -

Failure of this seal does not normally present a safety problem. No mishaps attributed to the seal were recorded by USABAAR during the period January 1967 - March 1971.

Problem No.: 04-5 (Continued)

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace	5 - 7	Direct Support

C. Aircraft Availability Factors -

Downtime for seal replacement averages 4 - 8 hours, based on use of a two-man crew.

Remedial Action:

ECP 596, approved in January 1969, provided an improved seal with an outer debris lip and a wear sleeve.

Data Sources:

1,2,3,5,6,7,9,13,21,23,25,26,28.

Cross References:

TMS	Problem Number
UH-1	04-3
AH-1	04-5
CH-47	-
CH-54	04-3, 04-8, 04-11
OH-6	04-3
OH-58	04-1, 04-3

Helicopter TMS: CH-47A, B, C
Problem No.: 04-6

Problem Title: Bearing Failures

Problem Description:

A. Component Identification -

Many bearings in the rotor and transmission functional group present failure problems. Some P/Ns with highest failure rates are:

P/N	A/C
114DS340-1*	CH-47A, B, C
114RS221-2	CH-47A, B
114RS224-1	CH-47A, B
A02R4051-1	CH-47A, B, C
114RS317-3	CH-47A
114RS317-5	CH-47A
107R3559-4	CH-47A, B, C
114RS318-2	CH-47B, C

The following hydraulic system bearings have also had a high failure rate:

P/N	A/C
114HS662-1	CH-47A, B, C
114HS662-2	CH-47A, B, C

Flight control bearings with high failure rates are:

P/N	A/C
114CS112-2	CH-47A
01-012-0437	CH-47A

B. Description of Failure -

Bearing and bearing liners worn; bearings rough, out of tolerance, binding, loose.

C. Cause of Failure -

Dirt, dust and other contaminants; material and design inadequacy.

D. Period and Duration of Problem -

Early deployment to present

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* See Problem 04-3

E. Failure Rate Data -

In a number of cases, several bearings of a particular part number are applied to a single aircraft (up to 16 for some of those listed above). Thus, while the mean time between failure for such a bearing may be reasonably high, the number of times the aircraft is down for bearing replacement may also be high. Following are data reflecting the average times at which a bearing replacement is required at Ft. Rucker. These were obtained by relating replacements to flying hours during the period 1 April 1970 - 31 March 1971. These times show the mean time between aircraft maintenance requirements for bearing replacement, not the MTBR for the bearing:

P/N	Hours
107R3559-4	130
114RS318-2	90
114DS340-1	110
114RS221-2	210
114RS224-1	560
AO2R4051-1	165
114RS317-3	400
114RS317-5	230
114HS401-1	120
114HS662-2	250
114CS112-2	215
01-012-0437	440

F. Mission and Deployment Factors -

Common to all missions and deployments

Problem Impact:

A. Safety Factors -

It is difficult to assess the actual effect of bearing failures on safety. Only three mishaps attributed to the above bearings were recorded by USABAAR during the 1 January 1967 - 31 March 1971 period, of which one was a forced landing and two were precautionary landings. However, a number of mishaps were attributed to metal particles found on magnetic plugs, and in some cases, failure of an assembly or component such as shock absorbers or drive shaft was cited as the cause for a mishap. Bearing failure could have been the basic source of the problem in such instances. Additionally, two of fourteen major mishaps resulted from failure of bearings other than those listed in this problem.

Problem No.: 04-6 (Continued)

B. Maintenance Workload Factors -

Most bearings can be replaced with minimum manhour requirements. Following are manhour requirements for the bearings listed above:

Action	P/N	M/H	Level of Maint.
Replace	107R3559-4	2.0 - 3.0	Direct Support
Replace	114RS318-2	1.0 - 2.0	Direct Support
Replace	114DS340-1	3.0 - 4.0	Direct Support
Replace	114RS221-2	.8 - 1.2	Direct Support
Replace	114RS224-1	.8 - 1.2	Direct Support
Replace	A02R4051-1	.8 - 1.2	Direct Support
Replace	114RS317-3	1.0 - 2.0	Direct Support
Replace	114RS317-5	1.0 - 2.0	Direct Support
Replace	114HS662-1	.8 - 1.2	Direct Support
Replace	114HS662-2	.8 - 1.2	Direct Support
Replace	114CS112-2	1.5 - 2.5	Direct Support
Replace	01-012-0437	2.5 - 3.5	Direct Support

C. Aircraft Availability Factors -

Aircraft downtime to replace any one of the above bearings normally ranges from 2 to 6 hours.

Remedial Actions:

1. ECP 198, approved in July 1965, provided for redesign of the lower pitch link rod end bearing, with retrofit at overhaul. The ECP was effective on production aircraft 66-086 and subsequent.

2. ECP 588, approved in October 1968, replaced bearing fabroid material with a new bearing material (fiberglide). The new material was applied to all bearings in control rods and bell cranks between the first-stage mixer and the upper boost actuator.

Other ECPs have been approved to increase performance of bearings not discussed in this problem, including vertical and horizontal hinge pin bearings and swashplate slider guide bearings.

Data Sources:

1,2,3,6,7,9,21,23,24,25,28.

Problem No.: 04-6 (Continued)

Cross References:

TMS	Problem Number
UH-1	04-4, 04-8, 04-9, 04-10
AH-1	04-1, 04-4
CH-47	-
CH-54	04-7, 04-10, 04-11, 18-1
OH-6	04-2, 04-3, 04-5
OH-58	04-1, 04-3

Helicopter TMS: CH-47A,B,C
Problem No.: 06-1

Problem Title: Hydraulic Servo, Actuator, Pump, Line, and Seal Failures and Malfunctions

Problem Description:

A. Component Identification -

The hydraulic components that fail frequently are too numerous to identify each by part number. They include servos, cylinders, pumps, filters, valves, motors, lines and tubes, seals and other elements of the hydraulic system. Some examples are valves (P/Ns 5A020, 114HS123-5, 114HS132-3), motors (P/Ns 68-119, 114HS129-3), pumps (P/Ns 114HS127-3, 114HS128-3), servos and servo cylinders (P/Ns 114H4000-B6, 114H5600-16), and filters ((P/Ns 114HS120-15, -16).

B. Description of Failure -

Lines, tubes and connections crack, break and leak; servos, servo cylinders, and valves leak and suffer internal failures; pumps suffer internal failures, leak, and incur housing cracks and breaks; seals and O-rings leak; filters malfunction and fail.

C. Cause of Failure -

Inability of material and design to withstand natural and operating environmental stresses. A particular cause of a number of problems is the inability of materials to withstand pressure surges above the rated PSI for the system. Many failures of the auxiliary motor pump, P/N 114HS128-3, result from such surges.

D. Period and Duration of Problem -

Early deployment to present

E. Failure Rate Data -

Unknown for most hydraulic components. Some examples, based on Ft. Rucker demand data, which includes failures corrected by replacements from supply but not from corrective repair, are:

Problem No.: 06-1 (Continued)

	P/N	MTBR
Pivoting Actuator	114H4000-35	800
	114H4000-36	800
Rotor Brake Cylinder	114HS105-6	1000
Filter	114HS120-16	500
Filter*	114HS120-5	1500
Valve	5A020	600
Valve	114HS123-5	400
Motor **	68-119	650
Pump **	114HS130-9	600
Servo Cylinder	1145600-16	400
Auxiliary Motor Pump	114HS128-3	800

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -

As with the UH-1 and AH-1 helicopters, hydraulic problems were responsible for more precautionary landings than any other system. Of 216 CH-47A precautionary landings, 66 or about 30% resulted from hydraulic system failures. The CH-47B rate was 17 of 53, slightly over 30%, and the CH-47C rate was 10 of 40, or 25%. The hydraulic system accounted for approximately 30% of all precautionary landings recorded by USABAAR during the period 1 January 1967 - 31 March 1971. Additionally, four total losses (of a total of 14) resulted from hydraulic system failures, with three of the four recorded as resulting from maintenance errors.

B. Maintenance Workload Factors -

Manhours required for replacement of any one item are normally not high. Most components and parts can be replaced in 4 manhours or less, with a considerable amount of work authorized at organizational level. However, in total,

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* 45 repair kits for this filter were also issued, implying that there were a number of failures corrected by repairs.

** 70 seals were used by motor P/N 68-119 and 40 by pump P/N 114HS130-9, indicating a rate of failure considerably higher than the MTBR would indicate.

Problem No.: 06-1 (Continued)

maintenance of the hydraulic system imposes a sizable workload. The Ft. Rucker maintenance activity estimated that hydraulic system replacement and repairs accounted for 12% of all maintenance performed on the CH-47A, for 10% on the CH-47B, and for 8% on the CH-47C.

C. Aircraft Availability Factors -

It can be assumed that the effect of hydraulic failures on aircraft downtime is approximately equivalent to their effect on maintenance workload. Thus, hydraulic problems account for approximately 8 - 12% of total downtime for maintenance.

Remedial Action:

Actions to correct deficiencies and improve performance of the hydraulic system have been taken since the aircraft first entered the Army inventory. The following table lists the various approved ECPs and MWOs related to hydraulic components:

ECP No.	Date Appvd. Mo.	Date Appvd. Yr.	Related MWO No.	Date Mo.	Date Yr.	Description
60R1	8	64	34/114	4	66	Modify hydraulic pump handle
67	-	64	34/68	1	65	Reroute lines
84	-	64	None	-	-	Reduce leakage at low temperatures
87	-	63	20/17	3	64	Add valve
87	-	63	20/29	2	66	Replace pump
87	-	63	20/27	8	64	Replace control valve
87	-	63	34/47	5	65	Reroute lines
101	10	63	34/56	1	65	Filter modification
107	-	63	20/26	5	64	Replace valve
119	11	63	34/76	5	68	Reroute lines
121	5	64	34/101	5	68	Improve APU starting to 60°F (minus)
145	8	64	20/32	4	65	Replace valve
154	9	64	34/118	6	66	Add check valve
176	11	64	34/120	7	68	Install filter
177	7	65	30/25	2	68	Install test connections
238	-	65	34/137	7	66	Eliminate filter bypass
245R2	12	66	30/62	7	68	Install shock mount

Problem No.: 06-1 (Continued)

ECP No.	Date Appvd. Mo.	Yr.	Related MWO No.*	Date Mo.	Yr.	Description
259R	8	65	34/124	6	67	Replace and reroute lines
274	10	64	20/35	11	64	Replace lines
315	7	65	30/56	3	67	Eliminate seal leakage - cargo winch
368	10	66	None	-	-	Modify pressure tank, utility system
370	5	66	30/41	5	67	Remove rotor brake system
392E	6	66	30/45	10	68	Reduce relief valve pressure
416R2	1	69	None	-	-	Pressurize flight control reservoirs
475	1	67	None	-	-	Provide modular filter contamination indicators
529VE	8	67	None	-	-	Replace rotor brake and swivel lock manifold
534	6	67	20/62	11	67	Install check valve in utility hyd. system
544	9	67	55-1500-210-30/24	9	69	Improve accumulator bleed-off utility system
591	4	69	55-1500-210-30/33	1	70	Add check valve to upper boost actuator drain lines

The following MWOs have been issued not related to an ECP.

MWO No. 55-1520-209	Date Mo.	Yr.	Description
34/7	2	64	Brake master cylinders
34/8	2	64	Reroute lines
34/64	9	64	SAS surge accumulators & drain installation
34/89	4	65	Reservoir pressure accumulator
34/91	2	65	Utility systems bleed valves
40/10	7	68	Contamination protection - upper boost actuators

* MWO is prefixed by #55-1520-209- except where indicated.

Problem No.: 06-1 (Continued)

Field personnel interviewed felt that hydraulic system reliability had improved with each new series. The relative workload requirements among the three series cited above support this claim. However, the CH-47 hydraulic system still presents many problems.

Data Sources:

1,2,3,5,6,7,8,9,10,11,12,13,15,17,18,19,20,21,23,25,26, 27,28.

Cross References:

TMS	Problem Number
UH-1	06-1
AH-1	06-1, 06-2, 06-3
CH-47	19-1
CH-54	06-1, 06-2, 06-3, 06-4
OH-6	19-1
OH-58	11-1

Helicopter TMS: CH-47A,B,C
Problem No.: 09-1

Problem Title: Voltage Regulator, Protection Panel, and Power Distribution Panel (Combined Voltage Regulator and Protection Panel) Malfunctions and Failures

Problem Description:

A. Component Identification -

	P/N	A/C
Voltage Regulator	51250-003,-010	CH-47A,B,C
Protection Panel	50185-010	CH-47A,B,C
Power Distribution Panel	114ES249	CH-47C

B. Description of Failure -

1. Voltage regulators became inoperative; would not come on line; came off line as the result of relay, transistor, and diode failures.

2. Protection panels became inoperative and erratic; would not come on line.

3. Power distribution panel - generators dropped off line; diodes, relays, and transistors failed.

C. Cause of Failure -

In all cases, inadequate design has been a primary cause. Inadequate quality control contributed to power distribution panel problems.

D. Period and Duration of Problem -

Early deployment to present

E. Failure Rate Data -

Voltage regulator MTBF was reported by Boeing-Vertol (based on 84,000 flying hours from June 1967 - August 1969) as 1000 hours. Protection panel MTBF from the same source was 1250 hours. No data are available on the power distribution panel. In December 1969, Boeing-Vertol reported that of the first 62 power distribution panels installed in production aircraft, 45 (73%) were removed or rejected during functional test.

F. Mission and Deployment Factors -

Common to all missions and deployments

Problem No.: 09-1 (Continued)

Problem Impact:

A. Safety Factors -

Voltage regulator and protection panel failures have not presented safety problems. USABAAR recorded only one precautionary landing during the period 1 January 1967 - 31 March 1971 (voltage regulator malfunction).

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace protection panel	.5 - 1.0	Organizational
" " voltage regulator	.5 - 1.0	Organizational
" " power distribution panel	.5 - 1.0	Organizational

C. Aircraft Availability Factors -

Downtime for replacement of any one of the above components: 1 - 2 hours.

Remedial Actions:

1. MWO 55-1500-210-30/27, published in February 1969, changed a resistor in the voltage regulator from 300 to 150 ohms to reduce generator off-line problems.

2. ECP 345VER1, approved in January 1970, provided a combined voltage regulator and protection panel installation (power distribution panel) effective with production aircraft 68-15814. MWO 55-1500-210-30/17, February 1970, provided for fleet retrofit.

3. ECP A00048 (class II) approved in June 1969, provided some improvements to the power distribution panel, including added diodes and capacitors and an improved connector crimping process.

4. ECP 543R, approved in May 1968, provided a brushless generator system which Vertol personnel believe will greatly reduce problems with these components. However, as of early October 1971, the brushless generator system had not been installed.

Problem No.: 09-1 (Continued)

5. Improved power distribution panels have been produced and applied to production aircraft as they became available. Part numbers and their effectivity are:

P/N		Effectivity
114ES249-1	CH-47C	68-15184 thru 68-15999, 68-16001
114ES249-7		68-16000, 68-16002 thru 69-17112
114ES249-10		69-17113 thru 69-17125
114ES249-11		69-17126 and subsequent

Data Sources:

1,2,3,5,6,8,10,13,17,21,22,24,25,26,27.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	-
CH-54	-
OH-6	-
OH-58	-

Helicopter TMS: CH-47A,B,C
Problem No.: 19-1

Problem Title: SAS and SAS component Failures and Malfunctions

Problem Description:

A. Component Identification -

	P/N
Variable Resistor	114HS440-1, Component of 3
Electrohydraulic Valve	114HS580-1, Component of 2
Extensible Link Actuating Cylinder	114H-6500
Linear Directional Valve	114HS114-1

B. Description of Failure -

The SAS component which fails most frequently is the variable resitor, which wears, becomes inoperative, and causes erratic operation of extensible link actuators. Valves and cylinders leak and become inoperative.

C. Cause of Failure -

A major cause of variable resistor failure has been potentiometer track wear. Improper hook-up of electrical connectors (switching) has caused some SAS failures. Inadequate design and materials to meet operating stresses accounts for most failures.

D. Period and Duration of Problem -

Early deployment to present

E. Failure Rate Data -

Ft. Rucker demand data for the year ending 30 April 1971 show the mean aircraft time between replacement of the SAS system components listed above. For components with multiple application, the mean component time between replacement is higher than the value shown by a factor equal to the number of components per aircraft. These mean time values reflect only failures corrected by issue from stocks and exclude failures corrected by repair and are thus higher than the mean time between failures.

Problem No.: 19-1 (Continued)

	Mean A/C Time Between Component Replacement (hours)
Variable Resistor	210
Electrohydraulic Valve	2000
Extensible Link Actuating Cylinder	2500
Linear Directional Valve	2000

Failure of any one item can make the SAS system malfunction. A summation of all replacements of major SAS components (those listed above plus bearing, plates, etc.) shows that for the system as a whole, an SAS component was replaced an average of once every 150 hours.

Boeing-Vertol, in their Engineering Field Evaluation Program for DA, listed both the extensible link actuator and the variable resistor among the top twenty component failures and malfunctions (Nos. 9 and 12 respectively). Mean time between failures for the actuator was 835 hours; for the variable resistor, 900 hours.

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -
As the SAS system can be overriden by the pilot, failures do not ordinarily represent a major safety problem. During the period 1 January 1967 - 31 March 1971, 11 mishaps were recorded by USABAAR, all precautionary landings.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Variable Resistor	2.5 - 3.5	Direct Support
Electrohydraulic valve	2.0 - 3.0	Direct Support
Extensible Link Actuating Cylinder	1.5 - 2.5	Direct Support
Linear Directional valve	2.0 - 3.0	Organizational

C. Aircraft Availability Factors -
Downtime for replacement of any one of the SAS components listed above ranges from 3 to 6 hours.

Problem No.: 19-1 (Continued)

Remedial Actions:

1. MWO 55-1520-209-20/15, January 1964, provided for color coding of SAS lines.

2. ECP 105, approved early in 1964, improved the electrohydraulic servo valve effective with production aircraft 63-7900 and subsequent. MWO 55-1520-209-34/84 provided field retrofit.

3. MWO 55-1520-209-34/64, September 1964, modified SAS system surge accumulators and drains installation.

4. ECP 191, approved in April 1964, provided a redesigned SAS extensible link, effective with production aircraft 64-13106 and subsequent. MWO 55-1520-209-34/107, November 1966, provided field retrofit.

5. ECP 504R, approved in July 1968, provided an improved feedback transducer to replace the variable resistor, effective with production aircraft 69-17110 and subsequent. MWO 55-1500-210-30/21, September 1970, provided field retrofit.

6. MWO 55-1500-210-30/26, July 1969, provided color coding for SAS electrical connectors.

Data Sources:

1,2,3,5,6,7,8,9,10,11,12,13,15.17,18,20,21,22,25,26,27, 28.

Cross References:

TMS	Problem Number
UH-1	06-1
AH-1	11-2
CH-47	04-4, 06-1
CH-54	19-1
OH-6	-
OH-58	-

Helicopter TMS: CH-47A,B,C
Problem No.: 19-2

Problem Title: Radio Set AN/ARC-54, Receiver-Transmitter Failures and Malfunctions.

Problem Description:

A. Component Identification -
Receiver-transmitter RT-348/ARC-54

B. Description of Failure -
Receiver-transmitter becomes inoperative; signals weak.

C. Cause of Failure -
Vibration may contribute to failures. Specific causes are unknown, but design and materials are not adequate to meet operating and natural environmental stresses to which it is subjected.

D. Period and Duration of Problem -
Early deployment to present.

E. Failure Rate Data -
The Boeing-Vertol Field Engineering Evaluation Program report shows a mean time between failures for the receiver-transmitter of 638 hours, the lowest for any avionics item.

F. Mission and Deployment Factors -
Common to all missions and deployments.

Problem Impact:

A. Safety Factors -
Failures of the receiver-transmitter have not presented safety problems.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace and test	.5 - 1.0	Organizational

C. Aircraft Availability Factors -
Aircraft downtime for replacement and test . 1.0 - 2.0 hours.

Problem No.: 19-2 (Continued)

Remedial Actions:

It is understood that the AN/ARC-54 radio will be replaced by the AN-131.

Data Sources:

1,2,3,10,12,13,23,26,27.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	19-1
CH-47	-
CH-54	-
OH-6	-
OH-58	-

Helicopter TMS: CH-54A
Problem No.: 04-1

Problem Title: Main Rotor Blade Failures and Malfunctions

Problem Description:

A. Component Identification -

	P/N
Main Rotor Blade Assembly	6415-20101-041, 6415-20201-041,-042
Tip Cap	S1515-20637-1, 6415-20209-041
BIM Indicator	S6115-20520-1

B. Description of Failure -

1. Tip caps cracked near and around the outer edge weld. In some cases, cracks propagated from the forward or aft drain holes, traveling parallel to the internal weld. In cases where the cracking propagated sufficiently to cause major weakening of the upper surface, the metal was subject to lifting and upward bending due to tip spillage. Protrusion of the metal into the blade airstream resulted in vibration and audio output.
2. Trailing-edge pockets bend and crack.
3. Separation of tip pocket bond.
4. High-frequency vibration with blades out of track.
5. Failure of studs holding balance plate P/N 6415-20240-041, allowing plate to move into or through the tip cap.
6. Leakage of blade pressurized spar seals.
7. BIM indicator malfunctions, gives false indications, test lever sticks.
8. Abrasion strips wear and peel away in spots, leaving the spar exposed.

C. Cause of Failure -

1. Tip cap failures.
   a. Lack of internal support or stiffening structure in the tip cap to reduce tip cap flexing.
   b. Outboard side welded seams unable to withstand stresses.
   c. Lack of adequate chordwise tip cap balancing.
   d. Erosion of tip cap leading edge by abrasive particles.

Problem No.: 04-1 (Continued)

2. The general cause of spar leakage, pocket bond failures, and pocket bending and cracking has not been identified. In at least some cases, however, faulty manufacturing procedures were the cause of this type of failure; i.e., rubber gasket P/N 6415-20006-102 was stretched during assembly, resulting in an enlarged gasket center hole.

3. Failure of balance plate studs resulted from initial fracture of the short stud P/N S7F111-11SA-13A, due to material fatigue. This stud, utilized for the same application on Marine CH-53A helicopters, was inadvertently used on the assembly of CH-54A aircraft in place of the designated S7F111-11SN-13A stud, which has a 25% greater strength value than the -11SA-13A stud.

4. BIM indicator malfunctions are caused by dirt and oil contamination of the lever, and unidentified internal BIM failures.

Major causes of failure cited in the USAAVSCOM MIRF report for removal of P/N 6415-20201-041 blades are:

Code	Failure	% of Total Removals	MTR
713	Battle Damage	25.0	323.2
020	Worn Excessively	17.7	732.7
190	Cracked	8.5	272.0
200	Dented	6.7	296.7
301	Foreign Object Damage	6.1	322.2
070	Broken	4.9	652.2
381	Leaking	4.9	279.6
263	Poor Bonding	3.0	289.0
540	Punctured	3.0	137.2
117	Deteriorated	2.4	610.0
780	Bent	2.4	345.0

D. Period and Duration of Problem -

1. Tip cap assembly - early deployment to present.
2. Balance weight - 1968 - 1970.
3. Blade erosion, bending, cracking, etc. - early deployment to present.
4. BIM indicator - 1968 to present.

Problem No.: 04-1 (Continued)

E. Failure Rate Data -

1. Based on MIRF failure data for the period 1 January 1964 through 30 June 1970, mean time to removal of new 6415-20201-041 blades is 427 hours. This figure was based on 164 removals, of which 41 or 25% were for battle damage. MTR of the -041 blade exclusive of battle damage is 448 hours.

2. Data in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report show component MTBF as follows (as there are 6 of each component per helicopter, the helicopter mean time between failures is one-sixth of the values shown).

		Hours
a.	6415-20201-041 Blade Assembly	1,358
b.	6415-20209-041 Tip Cap	935
c.	S6115-20520-1 BIM Indicator	15,998

3. Based on issues at Ft. Rucker during the year ending 30 April 1971, observed MTBRs for failures requiring replacement are:

		Hours
a.	6415-20201-042 Blade Assembly	752
b.	6415-20209-041 Tip Cap	718
c.	S6115-20520-1 BIM Indicator	1,436

Again, the average time between helicopter downtime for replacement component is one-sixth that shown.

F. Mission and Deployment Factors -

Common to all missions and deployments; erosion problems are aggravated by environments in which abrasive elements (sand, dust, etc.) are common.

Problem Impact:

A. Safety Factors -

Main rotor blade component failures do not ordinarily constitute safety hazards, since these types of failures tend to be characterized by gradual deterioration rather than instant failure of the blade assembly and can be corrected

Problem No.: 04-1 (Continued)

before flight mishaps occur. During the period 1 January 1967 to 31 March 1971, two precautionary landings were caused by blade failure and damage.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace main rotor blade	12.0 - 14.0	Organizational
Replace tip cap	1.5 - 2.5	Organizational
Replace BIM indicator	2.0 - 2.5	Organizational
Replace abrasion strip	2.0 - 2.5	Organizational

C. Aircraft Availability Factors -

Average downtime for main rotor blade maintenance are:

a. Blade replacement - 5 hours (assuming 4-man crew)

b. Tip cap replacement - 1.5 hours (assuming 2-man crew)

c. BIM indicator - 1.5 hours (assuming 2-man crew)

d. Abrasion strip - 1.5 hours (assuming 2- to 3- man crew)

Remedial Action:

1. ECP F8061R, February 1969, main rotor blade tip cap with nickel-plated leading edge approved for retrofit only, implemented by MWO 55-1520-217-30/36. This ECP provided a new tip cap P/N 6415-20209-041 made of two shell parts: an inner and an outer fairing riveted to a common stiffening rib. The -041 tip cap incorporates balance weights for chordwise tip cap balancing, and a hard nickel abrasion strip for protection against erosion and abrasion.

2. Remedial action for balance plate stud fractures consisted of the contractor's using S7F111-11SN-13A studs on both the CH-53A and CH-54A applications to avoid the possibility of incorrect installation.

Data Sources:

1,2,3,4,5,7,9,10,14,16,17,18,19,20,22,23.

Problem No.: 04-1 (Continued)

Cross References:

TMS	Problem Number
UH-1	04-2
AH-1	04-3
CH-47	04-1
CH-54	-
OH-6	04-4
OH-58	-

Helicopter TMS: CH-54A
Problem No.: 04-2

Problem Title: Tail Rotor Blade Failures

Problem Description:

A. Component Identification -

	P/N
Tail Rotor Blade Assembly	65160-00001-042, -045, 65161-00001-041
Tip Cap Assembly	65160-00009-081, -083

B. Description of Failure -

Tail rotor blades crack in pocket trailing edge and in root fairing.

Erosion of the stainless steel bonded leading edge of the cap assembly was causing the bonded abrasion strip, P/N 65160-00008-101, to split and peel.

C. Cause of Failure -

Blade cracking - structural design of blade inadequate to withstand stresses placed upon blade.

Failure of the bonded abrasive strip resulted from susceptibility of the stainless steel leading edge of the cap assembly to erosive forces.

D. Period and Duration of Problem -

Early deployment to present.

E. Failure Rate Data -

1. Based on CH-54A MIRF failure data for the period 1 January 1964 through 30 June 1970, mean times to removal for new tail rotor blades were:

   a. P/N 65160-00001-042: 250 hours, based on 11 removals. Approximately 82% of these removals were necessitated by cracking (Code 190).
   b. P/N 65160-00001-045: 302 hours, based on 165 removals. Major causes of failure were cracking (Code 190) 81.2%, broken (Code 070) 4.2%, foreign object damage (Code 301) 4.2%, Battle damage (Code 713) accounted for only 1.2% of removals.

Problem No.: 04-2 (Continued)

c. P/N 65161-00001-041: 483 hours, based on six removals, all of which were for cracking (Code 190).

2. Failure data presented in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report show an MTBF of 371 hours (all tail rotor blades).

Failure data on the P/N 65160-00001-045 blade show an MTBF of 402 hours; approximately 14% of the 477 failures on which this figure is based were caused by -041 fairing assembly failures.

3. Based on issues at Ft. Rucker during the year ending 30 April 1971, tail rotor blades had an observed MTBR of 964 hours and tip cap assemblies an observed MTBR of 1504 hours. As there are four blades per aircraft, the mean time between helicopter downtime for blade replacement is one-fourth of the blade MTBR.

F. Mission and Deployment Factors -

Common to all missions and deployments; however, almost 97% of reported incidents in the Sikorsky study occurred in Vietnam.

Problem Impact:

A. Safety Factors -

Aviation mishap data for the period 1 January 1967 - 31 March 1971 show one CH-54A precautionary landing due to structural bending of tail rotor blades.

B. Maintenance Workload Factors -

Replacement of tail rotor blades and tip cap assemblies is authorized at the organizational level of maintenance. Repair of blades and replacement of blade components are coded for depot level maintenance.

Action	M/H	Level of Maint.
Replace:		
Blade	1.8 - 2.2	Organizational
Tip Cap	1.0 - 1.5	Organizational

C. Aircraft Availability Factors -

Downtime for replacements ranges from 1.5 to 3.0 hours.

Problem No.: 04-2 (Continued)

Remedial Action:

1. ECP F8038, Retrofit Incorporation of an Improved Tail Rotor Blade Root Fairing, Oct 1967, provided a new fairing assembly, P/N 65161-00011-041, on production aircraft 66-18408 and subsequent and retrofit at overhaul. The new fairing incorporated two additional ribs and a new cap (longer at the chord) with added rivet attachment points.

2. ECP F8047, Incorporation of an Improved Tail Rotor Blade Pocket Design, Nov 1967, provides for delivered blades to be modified at Sikorsky, and production incorporation on aircraft 68-18461 and 69-18464 through 69-18471. This ECP, designed to eliminate cracking of tail rotor blade trailing edges, incorporated the re-spacing of ribs in the pocket assembly in order to strengthen the pocket. The new blade created by this change, P/N 65161-00001-041, replaced the -045 blade.

3. In December 1968, an engineering change (number not available) was released to delete the bonded abrasion strip, P/N 65160-00008-101, from the tip cap assembly and nickel plate the leading edge to (1) reduce erosion rate and (2) eliminate peeling by eliminating a separately bonded strip on the tip cap. The plating utilized was a hard nickel, Rockwell DPH 450, with 5/8 inch maximum thickness.

4. Provision for repair of tail rotor blade fairings, including combat damage, is contained in Chapter 8, TM 55-1520-21?-35/1, per MFR of 23 April 1970. Since the root fairing is a nonstructural element of the blade and hence does not affect blade integrity, properly repaired blades can be kept in service.

Data Sources:

1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 13, 14, 17, 18, 19, 20, 22.

Cross References:

TMS	Problem Number
UH-1	04-1
AH-1	-
CH-47	-
CH-54	-
OH-6	04-2
OH-58	-

Helicopter TMS: CH-54A,B
Problem No.: 04-3

Problem Title: Rotor Brake Shaft Seal Assembly Failures

Problem Description:

A. Component Identification -

Seal Assembly, P/N C40-801505-2

B. Description of Failure -

Seal deterioration includes cracking, chipping, pitting, blistering, and out-of-flat condition.

C. Cause of Failure -

A primary cause of seal deterioration and failure is vibration caused by an unbalanced condition of the rotor brake disc.

Earlier investigations of the problem also indicated that improper maintenance was a contributing factor to seal deterioration. Failure of maintenance personnel to coat the carbon-faced seals with petrolatum prior to installation led to the deposit of harmful oils (from mechanics' hands) on the seals during installation. Also, failure to observe proper care in installation led to scratching of seals, which hastens deterioration.

D. Period and Duration of Problem -

1968 to present

E. Failure Rate Data -

1. MTBF as shown in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report is 672 hours, based on 47,993 CH-54A flying hours in the period 1 January 1968 - 30 September 1970.

2. Ft. Rucker demand data shows an MTBR of 241 hours for failures requiring replacement. This is based on 11 replacements during the year ending 30 April 1971, covering approximately 2650 flying hours.

F. Mission and Deployment Factors -

Common to all missions and deployments

Problem No.: 04-3 (Continued)

Problem Impact:

A. Safety Factors -

One CH-54A precautionary landing was attributed to leakage of the C40-801605-2 seal.

B. Maintenance Workload Factors -

Seal assembly repair/replacement is performed at the direct support maintenance level. Average maintenance manhour requirement is 5.6 manhours.

Action	M/H	Level of Maint.
Replace	5 - 6	Direct Support

C. Aircraft Availability Factors -

Average downtime for seal maintenance is 4.0 hours, assuming a two-man crew.

Remedial Action:

Carbon seal leaks have been investigated by both the contractor and seal manufacturer. Results, while not conclusive, indicate that seal failure is primarily due to vibration resulting from disc imbalance (see Cause of Failure above). At present, the contractor is awaiting authorization to submit an ECP covering the installation of a thick rotor brake disc which would significantly lower disc imbalance force from a maximum of 50 lb to 2 lb.

Data Sources:

1,2,3,4,5,9,11,17,18,20,22.

Cross References:

TMS	Problem Number
UH-1	04-3, 04-5, 04-7
AH-1	04-5
CH-47	04-5
CH-54	04-4, 04-5, 04-6, 04-8, 04-11, 06-2
OH-6	-
OH-58	04-2

Helicopter TMS: CH-54A
Problem No.: 04-4

Problem Title: Rotor Brake Support Assembly (Bracket) Cracking

Problem Description:

A. Component Identification -

Support Assembly (Bracket), P/N 6465-20016-012

B. Description of Failure -

Support assembly cracking in the area of the bend radii.

C. Cause of Failure -

Support assembly cracking has been attributed to vibration loads beyond the structural design limits of the bracket.

D. Period and Duration of Problem -

1968 to 1971

E. Failure Rate Data -

1. MTBF for P/N 6465-20016-012 as reported in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report, 15 December 1970, is 558 hours, based on 86 failures over 47,993 flying hours.

2. MTBR for the -012 bracket at Ft. Rucker, based on removals during the year ending 30 April 1971, is 376 hours. Data do not indicate if these brackets had been relocated to the work deck as noted in Remedial Action, below.

F. Mission and Deployment Factors -

Common to all missions and deployments; however, most occurrences were reported from Vietnam (52%) and CONUS (46%).

Problem Impact:

A. Safety Factors -

No mishaps were attributed to support assembly failures during the period 1 January 1967 - 31 March 1971.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace	1.0 - 2.0	Organizational

Problem No.: 04-4 (Continued)

C. Aircraft Availability Factors -
Aircraft downtime for bracket maintenance is approximately 2.0 - 2.5 hours.

Remedial Action:

1. ECP F8039, October 1969, incorporates an improved rotor brake system on production aircraft CH-54A 69-18469 and subsequent and on CH-54B 69-18462 and subsequent. Available data on ECP F8039 show that the existing support bracket, P/N 6465-20016-013 (.071 in. aluminum), was to be replaced by a physically interchangeable, structurally strengthened support bracket, P/N 6465-20016-013 (.071 in. MIL-S-5059 steel), to provide improved mounting. However, TM 55-1520-217-34P, Feb 1971, shows the -013 bracket applicable only to the B model.

2. Remedial action for aircraft not affected by ECP F8039 consisted of relocation of rotor brake package, P/N 71428, and the -012 support bracket from the main gearbox LH input to the work deck in order to alleviate support bracket cracking. Instructions and specifications for support bracket relocation are contained in TB 750-992-2, 27 April 1970.

Data Sources:

5,8,11,13,17,18,19,20,21,22,23.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	-
CH-54	04-3, 04-5, 04-6, 04-8
OH-6	-
OH-58	-

Helicopter TMS: CH-54A
Problem No.: 04-5

Problem Title: Main Rotor Brake Disc Failures

Problem Description:

A. Component Identification -

Disc, P/N 6435-20196-102

B. Description of Failure -

1. Rotor brake discs bind and crack. In one case, high-frequency vibrations in the main gearbox input assembly were eliminated when the brake disc and attaching flange (P/N 6435-20064-100) were replaced.

2. Deterioration of brake discs is characterized by excessive wear, dishing, warping, and cracking/crazing.

C. Cause of Failure -

Disc failures appear to result from frequent utilization of discs at the limit of their design capability. Dishing and warping impair the dynamic balance of the disc and its ability to run true, thereby adding to the vibration level of the main gearbox input assembly.

D. Period and Duration of Problem -

1969 to present

E. Failure Rate Data -

1. MTBF as . orted in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report is 3692 hours.

2. Based on issues at Ft. Rucker during the year ending 30 April 1971, MTBR is 527 hours.

F. Mission and Deployment Factors -

Data are not available on the deployment characteristics of disc failures. Reported problems exist at Ft. Rucker, where student pilot operation results in frequent utilization of disc at limit of design capability.

Problem No.: 04-5 (Continued)

Problem Impact:

A. Safety Factors -

One CH-54A Class 4 mishap (incident) was due to rotor disc failure. Occurrence was in the CONUS training base.

B. Maintenance Workload Factors -

Disc maintenance can be performed at the organizational level of maintenance. Average time per disc maintenance event is 3.0 manhours.

Action	M/H	Level of Maint.
Replace	2.5 - 3.5	Organizational

C. Aircraft Availability Factors -

Average aircraft downtime per maintenance event is 1.5 - 2.0 hours, assuming a two-man crew.

Remedial Action:

1. In addition to the requirement to measure brake disc thickness and run-out each time the linings are changed (per TM 55-1520-217-20/1-1), the requirement to inspect the brake disc for wear and run-out within limits every 100 hours was added to sequence number 4.22 of TM 55-1520-217-20 PMP/1, May 1969.

2. ECP F8039, Increased Main Engine Idle Torque, October 1969, provided for numerous rotor brake system modifications on production CH-54A and B aircraft (CH-54A 69-18464 & subsequent; CH-54B 69-18462 & subsequent). This change includes a lighter weight disc (19 lb vs. 32 lb on the existing disc) and thicker brake linings to compensate for the reduction in disc thickness.

Data Sources:

1, 2, 3, 4, 5, 6, 7, 10, 11, 13, 17, 18, 19, 20, 21, 22, 23.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	-
CH-54	04-3, 04-4, 04-6, 04-8
OH-6	-
OH-58	-

Helicopter TMS: CH-54A
Problem No.: 04-6

Problem Title: Rotor Brake Assembly Puck Failures

Problem Description:

A. Component Identification -

	P/N
Brake Assembly	6435-20196-101
Brake Lining (Puck)	9420642

B. Description of Failure -
Brake assembly pucks experiencing premature failures due to excessive wear, cracking.

C. Cause of Failure -
Rotor brake system exposed to greater loads than those in design specifications. Greater brake loads result from rotor speed brake engagements at higher speeds than originally intended.

D. Period and Duration of Problem -
1968 to present.

E. Failure Rate Data -

1. Mean time between failure, as reported in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report, is 1352 component hours (based on two pucks per aircraft) or 676 aircraft hours. This MTBF is based on 71 failures per 47,993 flying hours.

2. Twenty-three brake pucks were replaced at Ft. Rucker during the year ending 30 April 1971. Based on approximately 2633 flying hours, this indicates an MTBR of 229 component hours, or 115 aircraft hours.

F. Mission and Deployment Factors -
Common to all missions and deployments. While a number of people interviewed stated their belief that this problem was localized to Ft. Rucker, data indicate that numerous occurrences have been reported from all deployments.

Problem No.: 04-6 (Continued)

Problem Impact:

A. Safety Factors -
No mishaps were attributed to brake puck failures.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace	2.5 - 3.5	General Support

C. Aircraft Availability Factors -
Average downtime per maintenance event is 1.9 hours.

Remedial Action:

ECP F8039, July 1969, Increased Main Engine Idle Torque, provides for an improved rotor brake package on production CH-54A aircraft 69-18469 and subsequent. This ECP incorporates a low-energy (soft) stop while maintaining the existing capability of reacting the torque of the engine at ground idle, as necessary.

Data Sources:

1,2,3,4,5,6,9,11,13,17,18,19 20,22.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	-
CH-54	04-3, 04-4, 04-5
OH-6	-
OH-58	-

Helicopter TMS: CH-54A
Problem No.: 04-7

Problem Title: Main Gearbox Oil Cooler Assembly Failures and Malfunctions

Problem Identification:

A. Component Identification

	P/N
V-Belt	3V600
Upper Pulley Assy (Obsolete)	6435-60020-010
Upper Pulley Assy	6435-60020-011
Upper Pulley (Obsolete)	6435-60020-100
Upper Pulley	6435-60020-103
Pulley (matched set) (Obsolete)	6435-60026-100
Pulley (matched set)	6435-60026-101
Idler Pulley Assy	6435-60063-041
Idler Pulley Bearing	SB1133-1

B. Description of Failure -

1. Belts stretch and slip around pulleys, resulting in belt deterioration, and excessive pulley wear.
2. Idler pulley bearing wearing excessively.

C. Cause of Failure -

1. Foreign material - sand, dirt, grit - frequently becomes imbedded in belts and acts as an abrasive agent on belts and pulleys.
2. Installation of unmatched belt pairs results in unequal tension, with consequent slippage, unequal belt loads, and overheating. Use of unmatched belt pairs has been attributed both to receipt of unmatched replacement-belt pairs and to failure to install matched pairs when available.
3. Idler pulley bearing wear due to abrasive contaminants, mostly sand and dirt.

D. Period and Duration of Problem -
Early deployment to present

E. Failure Rate Data -

1. MTBFs of subject components as reported in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report are:

Problem No.: 04-7 (Continued)

	P/N	MTBF (hours)
V-Belts	3V600	727
Upper Pulley	6435-60020-010, -011 -100, -103	1333
Lower Pulley	6435-60026-100, -101	4799
Idler Pulley Assembly	Including SB1133-1 Bearing	1600

2. The MTBR of pulleys and bearings at Ft. Rucker, based on issues during the year ending 30 April 1971, are:

	P/N	Issues	MTBR (hours)
Upper Pulley	6435-60020-103	6	442
Lower Pulley	6435-60026-101	6	442
Idler Pulley	6435-60063-041	6	442
Idler Pulley (Bearing)	SB1133-1	9	589

No usage of V-Belts was shown in the Ft. Rucker data.

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -
This problem does not constitute a safety hazard. USABAAR data for the period 1 January 1967 through 31 March 1971 do not show any aircraft mishaps attributable to main gearbox oil cooler failures.

B. Maintenance Workload Factors -
Replacement of V-belts and upper and lower pulleys is accomplished at the organizational level of maintenance. Replacement of the idler pulley assembly and idler bearing are accomplished at the direct support level.

Average maintenance manhour factors are:

Action	M/H	Level of Maint.
Replace:		
V-Belts	2.5 - 3.0	Organizational
Upper Pulley	1.5 - 2.0	Organizational
Lower Pulley	3.5 - 4.0	Organizational
Idler Pulley	2.0 - 2.5	Direct Support
Idler Pulley Bearing	1.0 - 1.5	Direct Support

Problem No.: 04-7 (Continued)

C. Aircraft Availability Factors -

Average aircraft downtime for maintenance of the above referenced components is:

	Hours*
V-Belt	2.0
Upper Pulley	1.5
Lower Pulley	3.0
Idler Pulley	1.6
Idler Pulley Bearing	1.4

Remedial Action:

1. Replacement of V-Belt, P/N 3V600, by P/N 6435-60254-041, which consists of vendor matched belts.
2. The following pulley part changes have been made, but specific details are not available:
   a. Lower Pulley - P/N 6435-60026-100 (CH-54A application) replaced by P/N 6435-60026-101, with both CH-54A and B application.
   b. Upper Pulley Assembly and Pulley - P/N 6435-60020-010 and -100, assembly and pulley respectively (CH-54A application), replaced by the -011 assembly and the -103 pulley (both with CH-54A and B application).

Data Sources:

5, 6, 7, 8, 10, 11, 13, 17, 18, 20, 22.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	04-4
CH-47	04-6
CH-54	04-11
OH-6	04-3, 04-5
OH-58	04-1, 04-3

* Assuming a two-man crew

Helicopter TMS: CH-54A,B
Problem No.: 04-8

Problem Title: Main Gearbox N1 Input Carbon Seal Failures

Problem Description:

A. Component Identification -

	P/N
Seal Assembly (Carbon Seal)	C40-801644-2
O-Ring	MS 29561-258

B. Description of Failure -
Transmission fluid leaking from seal assembly.

C. Cause of Failure -
1. Seals and O-rings improperly sealed.
2. Seal deterioration, characterized by cracking, chipping, blistering, and out-of-flat condition.
3. Improper handling and installation of carbon seals (failure to lubricate). Most failures have been occurring in the No. 1 or LH input assembly which houses the rotor brake assembly. Vibration resulting from an unbalanced rotor brake disc is also felt to be a contributing cause of failure.

D. Period and Duration of Problem -
1968 to present

E. Failure Rate Data -
1. MTBF for the C40-801644-2 seal on the CH-54A as given in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report is 3555 seal hours, or 1778 aircraft hours (based on two seal assemblies per aircraft).
2. MTBR for this seal at Ft. Rucker, based on seal replacements only, is 220 hours, or 110 aircraft hours. Although most seal failures have been reported as occurring on the No. 1 input assembly, the data do not indicate on which assembly these seal replacements were made. It is also possible that many of these replacements were made in the course of the 200-hour inspection of the splined coupling (P/N 6435-20150-100). Ft. Rucker MTBR data are based primarily on CH-54A data. Usage by TMS is not included in the parts usage printouts.

Problem No. 04-8 (Continued)

F. Mission and Deployment Factors -
Common to all missions and deployments.

Problem Impact:

A. Safety Factors -
One Class 5 mishap - forced landing - was attributed to failure of the No. 1 input seal.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace Seal	8.0 - 10.0	Direct Support

C. Aircraft Availability Factors -
Average downtime for maintenance is approximately 5 hours, based on a two-man crew.

Remedial Action:

Investigation and analysis of carbon seal failures by the contractor and seal vendor; results contained in Contractor Problem Item Report No. 74-763. No conclusive results were established in the course of the investigation, but strong evidence pointed to vibration as a primary contributing cause for these carbon seal failures.

Data Sources:

1,2,3,4,5,6,8,11,17,18,20,21,22,23.

Cross References:

TMS	Problem Number
UH-1	04-3, 04-5, 04-7
AH-1	04-2, 04-5
CH-47	04-5
CH-54	04-3, 04-4 04-5, 04-11, 06-2
OH-6	04-3
OH-58	04-2

Helicopter TMS: CH-54A
Problem No.: 04-9

Problem Title: Main Gearbox Oil Contamination and Plug Deterioration

Problem Description:

A. Component Identification -

	P/N
Main Gearbox	6435-20400-047
Plug	6435-20209-101

B. Description of Failure -

Numerous cases of water contamination of main gearbox oil have been reported. In some cases, the -101 main rotor shaft plug was dislodged and fell into the main gearbox sump, where it was pulverized, contaminating the oil system.

Water has accumulated in the main gearbox upper housing cap, on top of the garlock seal, around the main rotor shaft, and in the main gearbox sump.

Water contamination of main gearbox oil results in circulation of water through the gearbox during operation, and significant reduction of lubricant film strength so that the lubricant is unable to support the normal imposed loading.

Other reported damage to main gearbox components from water contamination includes failure of oil pressure switches, P/N 6435-20248-010, -011, due to water corrosion. Failure of these switches in turn has resulted in main gearbox operation with inadequate oil pressure and subsequent major damage.

C. Cause of Failure -

1. Cork plug P/N 6435-20209-11:
   a. Failures due to plug material assuming a "set" after repeated heating and cooling of the drive shaft.
   b. Insufficient bonding resin remaining on plugs after installation.
2. Upper cap drain hole clogged due to dirt, grease, etc., preventing proper drainage.
3. In one instance, five of seven aircraft were found to have water in the main gearbox sump after being air transported. Although the main rotor fairing had been removed in

each case, the top of the shaft under the reservoir was dry. This suggested condensation due to temperature and pressure changes during shipment.

4. Emulsification of water and oil - greaselike substances clog components; e.g., the finger strainer screen and main level gear shaft assembly were affected on one aircraft.

5. Failure of maintenance personnel to keep main rotor shafts covered during maintenance when the main rotor head and/or the main rotor fairing is removed.

6. Failure of oil pressure switch assemblies from water-induced corrosion due to water entry between the switch housing and male cannon connector plug as called for in the assembly specification. The absence of the required potting compound allows moisture and water entry into the assembly.

D. Period and Duration of Problem -
1968 to present

E. Failure Rate Data -

1. MTBF of the -047 main gearbox, as shown in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report, is 787 hours for all causes.

2. The same referenced report shows an MTBF of 23,996 hours for the -101 plug. However, this part has been replaced by ECP action (see Remedial Action), and it is felt that the MTBF shown is not consistent with the problem severity, as stated in field visits and confirmed by the ECP action.

3. TB 750-992-3, Equipment Improvement Report and Maintenance Digest, August 1970, in discussing this problem, notes that three main gearboxes were destroyed as a result of oil contamination (water in oil), as well as major damage to one aircraft and total loss of another from the same cause.

F. Mission and Deployment Factors -

Common to all missions and deployments. While humid, rainy areas increase the probability that moisture and water will enter the main gearbox, particularly during maintenance, it is noted that the loss of an aircraft to this cause occurred in Europe, where frequency of rain, high humidity, and unimproved maintenance areas are less than in Vietnam.

Problem No.: **04-9 (Continued)**

Problem Impact:

A. **Safety Factors -**

As noted above, one aircraft was lost due to oil contamination, and another suffered major damage. Three other mishaps (forced and precautionary landings) were attributed to main gearbox malfunctions. The mishap data, however, do not indicate the causes of these malfunctions.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace:		
Gearbox	40.0 - 50.0	Direct Support
Plug	4.5 - 5.5	Direct Support
Oil Pump	5.0 - 7.0	Direct Support

C. Aircraft Availability Factors -

1. Main gearbox replacement requires approximately 2 days for accomplishment.

2. Plug replacement requires approximately 2.5 hours of downtime, assuming a two-man crew.

3. Replacement of the oil pump assembly requires approximately 6 hours of downtime, assuming a two-man crew.

Remedial Action:

1. AMSAV-R-EW letter, 6 May 1969, Subj: Main Gearbox Contamination, Communication Number 12. This letter emphasizes proper maintenace procedures (covering main rotor shaft when fairing is removed) and establishes intermediate (25-hour) oil sump check for water-in-oil contamination.

2. ECP F8147, January 1970, authorizes retrofit incorporation of a new cork plug assembly, P/N 6435-20209-041, to replace the -101 assembly on all contractor delivered CH-54A main gearboxes. The new plug assembly incorporates a greater diameter to accommodate a breather assembly which permits venting of the main gearbox shaft. The new plug utilizes EC-1751 epoxy cement to bond it into position on the shaft at a location 1.25 inches from the top, which is 6.00 inches above the -101 plug assembly location.

Problem No.: 04-9 (Continued)

3. Message, AMC PM-HLS, 3 February 1970, authorizes installation of an oil bypass configured vane type oil pump assembly, P/N 6435-20556-101, on all aircraft in Vietnam equipped with interim vane type (less oil bypass) pump P/N 6435-20510-101. The interim -101 pump replaced all existing gear type pumps, P/N 6435-20007-010, on 6435-20400 series CH-54A main gearbox assemblies. Selection of a vane type pump was predicated on its known high reliability when operating with contaminated fluids.

4. ECP F8143, January 1970, provides for production incorporation of the 6435-20556-101 vane type pump on CH-54B aircraft 69-18462 and subsequent, and authorizes the incorporation of this pump on all other CH-54 main gearboxes at overhaul. This ECP also constitutes authorization for the installation of 6435-20556-101 vane type pumps in Vietnam, noted above.

Data Sources:

5,6,9,11,13,17,19,20,21,22 23.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	-
CH-54	-
OH-6	-
OH-58	-

Helicopter TMS: CH-54A,B
Problem No.: 04-10

Problem Title: Tail Rotor Bearing Support Assembly Viscous Damper Leaking

Problem Description:

A. Component Identification -
Viscous Damper, P/N 6435-60028-010

B. Description of Failure -
Two modes of failure have been reported: leakage of the damping fluid from the support assembly, and excessive vibration of the viscous dampers on run-up.

C. Cause of Failure -
1. Improperly serviced viscous dampers affect the normal self-centering motion of the tail drive shaft and cause leakage in the liner (P/N 6435-60033-100) area. Drive shaft misalignment due to improper shimming of the Thomas couplings tends to roll the edge of the rubber strip (P/N 6435-60030-100) away from the spacer (P/N 6435-60032-100). When this occurs, the viscous damper fluid can leak from the cavity of the rubber strip when the drive shaft rotates. Since there is generally adequate sealing when the drive shaft is dormant, often the sealing failure cannot be detected. This results in frequent servicing of the dampers (fluid replacement) rather than correction of the underlying cause.
2. The rubber casing (P/N 6435-60030-100) is subject to deterioration from environmental factors such as temperature, sun, etc.

D. Period and Duration of Problem -
1968 to present

E. Failure Rate Data -
1. Based on 23 issues of support assemblies at Ft. Rucker during the year ending 30 April 1971, mean time between replacement is 576 component hours. Since there are five support assemblies per aircraft, this means that viscous damper replacement was required on the average of every 115 aircraft flying hours.

Problem No.: 04-10 (Continued)

2. Component mean time between failures, as reported in the Sikorsky 11th Quarterly Reliability/Maintainability Report, 15 December 1970, is 1610 component hours and 322 aircraft hours. These figures are based on 149 failures over 47,993 flying hours covering a 33-month period through September 1970. For the final quarter of the period studied (1 July - 30 September 1970), the component MTBF was 834 component hours and 167 aircraft hours.

F. Mission and Deployment Factors -
This problem is common to all missions and deployments.

Problem Impact:

A. Safety Factors -
No mishaps were attributable to this problem.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace	1.0 - 6.0 *	Direct Support
Repair	4.5 - 5.5	Direct Support
Service	.5 - .8	Organizational

C. Aircraft Availability Factors -
Average elapsed maintenance downtime for assembly maintenance is 2 hours to 1 day, depending on the location of the damper and type of maintenance.

Remedial Actions:

1. Problem investigation and analysis discussed in EIR Digests.

2. Criteria for removal and replacement of viscous dampers were included in Change 7 to TM 55-1520-217-20. Instructions for proper stacking and shimming of the Thomas couplings were shown in Chapter 7, TM 55-1520-217-35.

3. Sikorsky Product Support Letter SSD 6435IC214.1, 23 July 1970, suggested removal of all primer/paint from the outer spacer (P/N 6435-60032-100).

* Depending on damper location.

Problem No.: 04-10 (Continued)

4. ECP PV8173 submitted in February 1971 for an Improved Bonded Tail Drive Shaft Bearing Viscous Damper. This change would incorporate a bag type viscous damper similar to those used on Sikorsky S-61 and S-65 aircraft. Disposition of the ECP is not known at this time.

Data Sources:

3,4,5,6,8,10,11,13,17,18,19,20,21,22,23.

Cross References:

TMS	Problem Number
UH-1	01-1, 04-1
AH-1	01-1, 04-1
CH-47	04-6
CH-54	04-11
OH-6	04-1
OH-58	04-1

Helicopter TMS: CH-54A
Problem No.: 04-11

Problem Title: Tail Rotor Head Assembly - Seal Leakage and Pitch Change Link Assembly Failures

Problem Description:

A. Component Identification -

	P/N
Tail Rotor Head Assembly	65110-07000-013
Tail Rotor Pitch Change Link Assembly	65113-07100-041

B. Description of Failure -

1. Tail rotor head assemblies leaked oil at sleeve and spindle seals. Seal lips (P/N 6410-33336-101 and 65112-07010-101) experienced excessive wear. Spindle assemblies had deep score marks on the shoulders.

2. Pitch change link assembly rod end bearings were worn excessively, resulting in binding and vibration in the directional control system. Rod end bearing assembly fractured at the root of the first thread.

C. Cause of Failure -

1. Tail rotor head assembly oil leakage. Teardown of tail rotor head assemblies at contractor's overhaul facility showed that spindle seals were contaminated with an oil/sand mixture. The abrasive action of these contaminants resulted in excessive wear of seal lips and consequent oil leakage; abrasive action of these contaminants also accounted for spindle scoring.

2. Pitch change link assembly:

   a. Contributing causes of bearing failures are misalignment, inadequate lubrication, size of bearing ball which limits angular displacement, and bearing material.

   b. Fracturing of rod ends has been attributed to excessive wear and/or binding of the rod end bearing which resulted in fatigue of the threaded shank. Rod end bearing misalignment is also a contributory cause since it allows a metal-to-metal contact between the neck portion of the rod end and the bearing ball. This results in a binding load to the rod end shank, inducing fatigue.

Problem No.: 04-11 (Continued)

D. Period and Duration of Problem -

1. Tail rotor head assembly leakage: 1968-1970.
2. Pitch change link assembly: 1967 to present.

E. Failure Rate Data -

1. The USAAVSCOM Major Item Removal Frequency Report (MIRF) shows mean time to removal for failures of the tail rotor head assembly (P/N 65110-07000-013) of 368 hours, based on 11 removals of new items. Failure codes 307 (oil leak) and 381 (leaking) accounted for 8 of the 11 removals. Only 2 items with one prior overhaul were reported as removed, both for leaking (code 381). MTR for these two items was 178 hours.

2. Mean time between failure data, as reported in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report, based on 47,993 flying hours, are:

a. Tail rotor head assembly, P/N 65110-07000-013 - 241 hours.
b. Pitch change link assembly, P/N 65113-07100-041 - 353 hours.

F. Mission and Deployment Factors -

Problems are common to all missions and deployments. Rod end bearing failures and tail rotor head seal failures, however, are aggravated by operations in sandy environments.

Problem Impact:

A. Safety Factors -

No mishaps were attributed to tail rotor assembly leakages. However, pitch change link assembly failures constitute a serious safety problem. One CH-54A was lost due to pitch change link failure, which resulted in grounding of the fleet until modification of the link assembly was accomplished (see below, Remedial Actions).

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace tail rotor head	12.0 - 15.0	Direct Support
Replace pitch change link	1.0 - 1.5	Organizational
Repair tail rotor head	5.0 - 10.0	Direct Support
Repair pitch change link	2.0 - 2.5	Organizational

Problem No.: 04-11 (Continued)

C. **Aircraft Availability Factors** -

1. Average downtime for tail rotor assembly repair, assuming a two- to three-man crew; is 3.0 - 3.5 hours; replacement of the tail rotor head assembly entails approximately 4.0 - 5.0 hours of downtime.

2. Downtime for pitch change link assembly replacement or repair is 1 to 2 hours, assuming a two-man crew.

Remedial Actions:

1. Analyses and discussions of tail rotor head assembly and pitch change link assembly problems have been carried in the Equipment Improvement Report and Maintenance Digest (EIR Digest) (TB 750-992 series), as follows:

   a. TB 750-992-4, 1st Quarter, FY 1968.
   b. TB 750-992-1, 2nd Quarter, FY 1968.
   c. TB 750-992-1, 2nd Quarter, FY 1970.
   d. TB 750-992-3, 4th Quarter, FY 1970.
   e. TB 750-992-1, 1st Quarter, FY 1971.
   f. TB 750-992-2, 2nd Quarter, FY 1971.

2. Detailed inspection instructions and rod end bearing wear limits were incorporated in:

   a. TM 55-1520-217-20 PMI, 9 May 1969.
   b. TM 55-1520-217-20/1-1, April 1969.
   c. TM 55-1520-217-20 PMD, 9 May 1969.
   d. TM 55-1520-217-35/1-2, Appendix C, April 1969.

3. TB 55-1615-217-20/1, Inspection of Tail Rotor Head Assemblies (65110-07000 series), was issued 21 April 1970; TB 55-1615-217-20/2, Inspection of Tail Rotor Head Pitch Change Link Assembly Rod End Bearings, was issued 5 May 1970.

4. ECP F810R1, April 1970, provided for retrofit incorporation of several design changes in the tail rotor head assembly (P/N 65110-07000-013). The changes were intended to establish a 2000-hour TBO for CH-54A tail rotor head assemblies.

Improvements included replacement of the existing link assembly (P/N 65113-07100-041) with a physically interchangeable link assembly (P/N 6410-30401-041). The new link assembly provided for an increased rod end diameter (increased from 3/8 inch to 1/2 inch) and a corresponding increase in

Problem No.: 04-11 (Continued)

barrel segment of the link. New rod end assemblies (6410-30403-041, and -042) were also provided, featuring second-generation PTFE liner bearings (P/N SB5302-102). Bearing ball size was increased to allow for increased angular displacement.

The rod end at the pitch beam assembly interface was modified to include an integral counterweight to maintain link alignment. An improved sleeve (P/N 65112-07003-102), spindle (P/N 65112-07001-105), and hub (65111-07201-103) were provided to avert possible fretting of rotor components and to provide greater protection against entry of foreign contaminants.

5. ECP F8101R2, September 1970, incorporated an improved pitch link assembly (P/N 6410-30401-042) on all installed and serviceable spare CH-54A tail rotor assemblies and was implemented by MWO 55-1615-248-20/1. The approved -042 pitch link assembly replaced P/N 6410-30401-041 and was physically interchangeable (in sets only) with assembly P/N 65113-07100-041. New rod end assemblies (P/Ns 6410-30403-043 and -044) were included.

Data Sources:

2,3,4,5,6,8,10,11,13,14,16,17,19,20,22.

Cross References:

TMS	Problem Number
UH-1	04-1, 04-4, 04-5, 04-7, 04-8, 04-9, 04-10
AH-1	04-1, 04-4, 04-5
CH-47	04-5, 04-6
CH-54	04-3, 04-7, 04-8, 04-10 06-2, 18-1
OH-6	04-5
OH-58	04-1, 04-2, 04-3

Helicopter TMS: CH-54A,B
Problem No.: 04-12

Problem Title: Generator Failures

Problem Description:

A. Component Identification -

	P/N
Generator, Tachometer	GEU7A
Generator	28B139-33A

B. Description of Failure -

1. Tach generator P/N GEU7A fails to give tachometer indications. The most common failure modes are internal electrical failure and shaft shearing. Other modes of failure include connector plug threads stripping, rear seal leaking, and slipring breaking off.

2. Generator P/N 28B139-33A fails due to shearing of generator shaft, P/N 1531453-1.

C. Cause of Failure -

1. Exact cause of tach generator failures is undetermined, pending an engineering investigation of the problem.

2. Shaft shearing of the -33A generator results from improper transmission freewheel unit separation. Freewheel unit malfunctions result in generator deceleration followed by high acceleration forces which place excessive torque on the generator shaft, resulting in shaft shearing.

D. Period and Duration of Problem -
From early deployment to present

E. Failure Rate Data -

1. The AVSCOM MIRF Report, covering the period 1 January 1964 - 30 June 1970, presents removal data on only four generators - all P/N 28B139-33A. All were removed for shearing (code 585) at a mean life of 150 hours.

2. MTBF of the GEU7A generator is 1600 component hours, or 533 aircraft hours, as reported in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report. Component MTBF is based on three generators per aircraft - one for each engine and one on the main gearbox.

3. MTBF for the -33A generator, as reported in the above referenced Sikorsky report, is 2594 component hours, or 1297 aircraft hours, based on two generators per aircraft.

4. Based on issues only, MTBR of the -33A generator at Ft. Rucker is 1060 component hours or 530 aircraft hours.

5. Ft. Rucker usage data does not distinguish between GEU7A generator application on UH-1 and CH-54 aircraft. Based on both UH-1 and CH-54 applications, MTBR of the GEU7A generator is 527 aircraft hours.

F. Mission and Deployment Factors -
Common to all missions and deployments.

Problem Impact:

A. Safety Factors -
Generator failures do not constitute a safety hazard. They do, however, necessitate precautionary landings. USABAAR mishap data for the period 1 January 1967 through 31 March 1971 show only precautionary landings due to generator failure (P/N 28B139-33A) resulting from shaft shearing. However, discussions of this problem in the literature, e.g., EIR Digests, and with field personnel indicate that the frequency of precautionary landings for this cause is probably higher than reported to USABAAR.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace GEU7A generator	1.0 - 1.5	Organizational
Replace 28B139-33A generator	1.8 - 2.2	Organizational

C. Aircraft Availability Factors -
Aircraft downtime for generator maintenance is approximately 3.0 hours.

Remedial Actions:

ECP F8041, June 1968, provided flame plating of the freewheel unit housing to provide a more wear-resistant surface. This ECP also included direct pressurized lubrication of the freewheel unit to minimize wear characteristics.

Problem No.: 04-12 (Continued)

Although this ECP reduces freewheel unit malfunctions, and consequently reduces -33A generator failures, problems with GEU7A generators apparently have not been resolved by this ECP.

Data Sources:

2,3,4,5,6,8,10,13,14,17,18,19,20,21,22,23.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	-
CH-54	-
OH-6	-
OH-58	-

Helicopter TMS: CH-54A
Problem No.: 06-1

Problem Title: Hoist Pump Malfunctions

Problem Description:

A. Component Identification -
Pump, Hoist, P/N 6465-20021-101

B. Description of Failure -
Malfunctions include sluggishness, failure to provide the required pressure, failure of the hoist pump microswitch to break contact, and failure of the pump to operate.

C. Cause of Failure -
Causes of failure include internal leakage, malfunction of pump microswitch due to hoist wiring circuit deficiencies, corrosion of the microswitch, and shorting of the microswitch from water and moisture accumulation. Location of the microswitch prevents drying and results in moisture-induced failures.

D. Period and Duration of Problem -
Early deployment to present

E. Failure Rate Data -
1. Mean time to removal of hoist pumps as reported in the AVSCOM MIRF Report is 332 hours, based on 17 removals. Major cause of removal was internal failure.
2. MTBF as reported in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report is 979 hours.
3. Based on issues at Ft. Rucker, MTBR for failures requiring component replacement is 439 hours.

F. Mission and Deployment Factors -
Common to all missions and deployments. Moisture problems with the pump microswitch are more prevalent in Vietnam.

Problem Impact:

A. Safety Factors -
USABAAR data show one incident (Class 4 mishap) and one precautionary landing (Class 6 mishap) due to hoist pump failures.

Problem No.: 06-1 (Continued)

B. Maintenance Workload Factors -

Malfunction or failure of the hoist pump, including microswitch failures, requires replacement of the pump.

Action	M/H	Level of Maint.
Replace	12	Organizational

C. Aircraft Availability Factors -

Downtime for pump replacement is about one day, assuming a two-man crew.

Remedial Action:

The EIR Digest (TB 750-992-1) for the 2nd Quarter, FY 1969, recommended that the hoist 3-way control valve, 4-way control valve, and brake control valve be checked independently; it also provided instructions for checking.

Data Sources:

3,4,5,6,8,10,13,14,17,18,20,22.

Cross References:

TMS	Problem Number
UH-1	06-1
AH-1	06-3
CH-47	06-1
CH-54	06-2, 06-3, 06-4
OH-6	-
OH-58	-

Helicopter TMS: CH-54A
Problem No.: 06-2

Problem Title: Cargo Hoist Lines Manifold and Housing Assembly (Banjo Fitting) O-Ring Leakage

Problem Identification:

A. Component Identification -

Numerous banjo fittings are used in CH-54A hydraulic systems, most of which have had reported occurrences of seal leakage. A major area of seal failure has been the cargo hoist installation, involving MS28775-026 O-rings. Components in the cargo hoist installation which use these rings are:

	P/N
Manifold	6465-62056-103
Housing, Manifold	6465-62057-101
Housing, Manifold	6465-62057-102
Manifold	6465-62087-105
Manifold	6465-62087-106

B. Description of Failure -

Leakage of hydraulic fluid due to deterioration of O-rings. Cracks in the banjo fittings have also been reported.

C. Cause of Failure -

Seal leakage results from deterioration of seals due to vibration. Deterioration of seals is aggravated by improper maintenance practices during installation which result in pinching of the seals or seals being forced out of seal grooves.

D. Period and Duration of Problem -

Early deployment to present

E. Failure Rate Data -

Because of the large number of applications of O-rings (and the quantities used), specific failure rates (MTBF) based on available data are not considered representative of the problem severity. Additionally, there is also a considerable variance between recorded failures and field experience as established by visits and interviews. In general, field experience, as stated in interviews with maintenance personnel, indicates a much higher failure rate than records show.

Problem No.: 06-2 (Continued)

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -
No aircraft mishaps were attributed to O-ring failures.

B. Maintenance Workload Factors -
Replacement of O-rings requires complete disassembly of banjo fitting assembly, stoning and polishing of any damage to O-ring grooves in housing and/or O-ring seal area or manifold, and cleaning, lubrication, and reassembly. Approximately 4 manhours are required for seal replacement.

C. Aircraft Availability Factors -
Downtime ranges from 3 to 4 hours for seal replacement, using a two-man crew.

Action	Hours	Level of Maint.
Replace O-rings	4	Organizational

Remedial Action:

1. EIR F8074R1, November 1968, Elimination of Banjo Fitting P/N 6465-62057-101, provided for the installation of improved fittings, new tube assemblies, and re-routing of tube assemblies to provide greater protection from maintenance damage. Field retrofit was provided by MWO 55-1520-217-30/38, March 1969.

2. EIR Digest (TB 750-992-3), 4th Quarter, FY 1968, provided recommended maintenance procedures for correction of banjo fitting discrepancies.

Data Sources:

1,2,3,4,5,6,7,10,13,15,16,17,19,20,22.

Problem No.: 06-2 (Continued)

Cross References:

TMS	Problem Number
UH-1	06-1
AH-1	04-5, 06-3
CH-47	06-1
CH-54	04-3, 04-8, 04-11 06-1, 06-3, 06-4
OH-6	-
OH-58	-

Helicopter TMS: CH-54A,B
Problem No.: 06-3

Problem Title: AFCS Servo Assembly Malfunctions

Problem Description:

A. Component Identification -

	P/N
AFCS Servo Assembly, CH-54A	S6265-62551-10
AFCS Servo Assembly, CH-54B	S6265-62551-23
Servo Valve (010-26631), CH-54A,B	S6165-63552-40
Servo Valve (010-26331), CH-54A,B	S6165-63552-222
Servo Valve (010-26334), CH-54A,B	S6165-63552-277

B. Description of Failure -

1. AFCS hydraulic servo assembly failures and malfunctions include servos out of time, open loop spring on the yaw and collective servos out of adjustment, servo hunting, and pedal damper malfunctioning. Servo malfunctions result in improper pedal and control operation, including pedal creep, poor pedal return, restricted pedal movement, collective stick creep, and binding of the collective stick.

2. The AFCS servo assembly constitutes a primary maintenance problem due to the requirement for extensive trouble-shooting. Trouble-shooting difficulties are complicated by the electrical/hydraulic/mechanical interfaces of the assembly. The Sikorsky 1st Quarterly CH-54B Reliability/Maintainability Report ranks the AFCS servo assembly highest in unscheduled maintenance manhours and maintenance elapsed time.

C. Cause of Failure -

1. Improper and/or inadequate maintenance, i.e., improper adjustment or balancing of open loop spring, improper centering of spool valve.

2. Contamination of spool valve and pedal damper. In some cases, this results from maintenance when the servo assembly is removed from the aircraft. In one instance, a clogged servo pedal damper filter in the AFCS servo was attributed to failure of utility pump P/N 66 WAP200 and subsequent clogging of filter P/N S6165-63559, which left contaminants in the system.

Problem No.: 06-3 (Continued)

D. Period and Duration of Problem -
Early deployment to present.

E. Failure Rate Data -

1. MTBF of the CH-54A -10 AFCS servo assembly as shown in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report is 1091 hours.

2. MTBF of the CH-54B -23 AFCS servo assembly as shown in the Sikorsky 1st Quarterly CH-54B Reliability/Maintainability Report is 355 hours.

3. Parts usage data from Ft. Rucker for the year ending 30 April 1971 show that replacement of the CH-54A -10 servo assembly was required every 527 hours, exclusive of any failures corrected by repair of the assembly on the aircraft.

4. The AVSCOM MIRF Report shows a mean time to removal for failed CH-54A -10 AFCS servo assemblies of 521 hours. The major cause of removal was internal failure.

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -

During the period 1 January 1967 through 31 March 1971, no aircraft mishaps were attributed to AFCS servo assembly malfunctions. However, servo assembly malfunctions which impede pedal and control movement constitute a potentially dangerous situation, particularly when trouble-shooting involves flying the aircraft (including hovering).

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace CH-54A servo	11 - 12	Direct Support
Replace CH-54B servo	Unknown - insufficient data.	Direct Support
Repair servos	Varies widely depending on troubleshooting problems and type of repair required.	Mostly Direct Support; some minor repair at Organizational

Problem No.: 06-3 (Continued)

C. Aircraft Availability Factors -

Average downtime for replacement of the CH-54A AFCS servo assemblies is 5 - 6 hours using a 2- to 3-man crew.

Remedial Actions:

1. ECP P8170 was submitted March 1971 to provide AFCS amplified maintainability improvements. Final status is not known.

2. ECP P8175 was submitted June 1971 to provide for incorporation of redundant structures in AFCS servo valve input link. Final status is not known.

Data Sources:

1,2,3,4,5,6,8,11,13,14,17,18,19,20,21,22,23.

Cross References:

TMS	Problem Number
UH-1	06-1
AH-1	06-1, 06-2, 06-3
CH-47	06-1
CH-54	06-1, 06-2 06-4, 19-1
OH-6	-
OH-58	11-1

Helicopter TMS: CH-54A,B
Problem No.: 06-4

Problem Title: Hydraulic System Failures

Problem Description:

A. Component Identification -

Component and part failures in the various CH-54 hydraulic systems constitute a major cause of aircraft maintenance and downtime. The large number of such parts and components precludes specific identification by part number. Some of these have been treated as individual problems in this study; for instance, AFCS servos. A complete listing of hydraulic problem areas would include servos, cylinders, pumps, filters, valves, motors, lines and tubes, reservoirs, manifolds, housings, seals, and fittings. Hydraulic components and parts which have caused reliability and maintainability problems include the following:

	P/N
Tube Assemblies	6465-62050-025, -026,
	6465-62051-026, -061, -062, -063, -064
	6465-62052-053, -054, -056
	6465-62053-043, -044, -045, -046, -048, -051, -079
	6465-62068-043, -044, -048, -050, -059, -060, -062, -063
Hose Assemblies	SS40-1A1 50000
	SS40-7C 114000
	SS45-1C 051000
	SS45-3E 172000
	SS45C-3E214000
Housings and Manifolds	6464-62056-101, -102, -103, -105 (manifold)
	6465-62057-101, -104(housing)
	HP 610100-3N10 (manifold)
Pumps: 66W Series, including:	66WAP200-utility & makeup
	66WA400-1st stage hydraulic
	66WBK300-2nd stage hydraulic
Other Pumps	6465-20018-101-utility
	6465-20021-101-hoist

Problem No.: 06-4 (Continued)

	P/N
Servos, Actuators, Cylinders, Valves	S6265-62551-10,-23,AFCS servo assy S1565-20421-10, main rotor servo 6425-61036-012,-014, power boost cylinder 19740-1, 4-way hydraulic valve 217363-01, valve assy
Other	"MS" type O-rings, 66W series pumps 2061-8, hydraulic filter assy 1356-644116, hydraulic accumulator S1505-2469, fluid tank 58-12, hydraulic pressure reducer valve

B. Description of Failure -

Typical failure modes include cracking, breaking, and leaking of lines, tubes, hoses and their attachment fittings. Servos leak, malfunction, and suffer internal failures; valves suffer internal failures and become inoperable. Similar failures occur to pumps, particularly leakage. Seals and O-rings leak, filters are susceptible to clogging, and filter assemblies fail to bypass.

C. Cause of Failure -

1. Lines, hoses, tubing. Numerous failures are due to fatigue loading of fittings as a result of overtorquing. In some instances, poor-quality welding (during production) has been uncovered. Lines are susceptible to damage during maintenance, particularly during removal and installation. Lines vibrate and chafe due to clamping methods using phenolic support assemblies. Pressure surges above the rated PSI for the system frequently cause hydraulic lines to fracture. Pressure surges have also caused failures of the engine hydraulic start motor. Personnel stepping on lines is a frequently cited contributory cause of line failures.

2. A primary cause of servo and pump failures is dynamic and static leakage due to seal failure, particularly "MS" series O-rings. Pump leakage has resulted in overheating and

Problem No.: 06-4 (Continued)

destruction of seals. Pump leakage also occurs via pump drain lines due to mismated sealing surfaces, damaged sealing surfaces, and damaged or defective seal springs and O-rings. Abrasive contaminants are a major source of seal deterioration and failure. Other causes of pump and servo failures are vibration, internal wear, and switch failures.

D. Period and Duration of Problem -
Early deployment to present

E. Failure Rate Data -
Failure data is not available for most hydraulic components, particularly lines, hoses, tubes, fittings, rings, etc., and those items requiring adjustment and repair as opposed to replacement. Some hydraulic components at Ft. Rucker having a high number of failures (requiring replacement) during the year ending 30 April 1971 are:

	P/N	MTBR (A/C hrs)
Main Rotor Servo	S1565-20421-10	177
AFCS Servo*	S6265-62551-10	527
Hydraulic Servo Cylinder	6465-62100-019	1325
Pump**	6465-20021-101	439
Pump	66WAP200	530
Pump	66WA400	883

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -
Based on mishap data for the period 1 January 1967 to 31 March 1971, hydraulic failures accounted for approximately 8 of the 33 reported mishaps for other than engine failures and malfunctions.

All except one of these mishaps were precautionary landings. The exception was a Class 4 mishap (incident) due to a hoist pump failure. One mishap (precautionary landing) was

* See Problem 06-3
** See Problem 06-1

Problem No.: 06-4 (Continued)

attributed to improper maintenance; the other incidents were due to material failure.

B. Maintenance Workload Factors -

Approximately 88% of hydraulic maintenance events require 4 manhours or less. This includes replacement and repair. Many of these can be performed at the organizational level of maintenance. Manhour requirements for correction of hoist pump, banjo fittings, and AFCS servo failures have been given in problems 06-1, 06-2, and 06-3. Some other components with above-average time to replace are:

Action	P/N	Avg M/H	Level of Maint.
Repair/ Replace:			
Elbow tube	MS24394D10	7.5 - 8.5	Organizational
Valve hoist control	19740-1	25.0 -30.0	Organizational
Pressure tube, hoistup	6465-62051 -061	4.5 - 5.5	Organizational
Manifold	6465-62056 -103	4.5 - 5.5	Organizational

Based on data developed in the Sikorsky Reliability/Maintainability Reports, approximately 9.3% of maintenance manhours required for correction of CH-54A primary failures is attributable to hydraulic systems. Approximately 44% of hydraulic maintenance is required by the cargo hoist hydraulic system, followed by utility hydraulics (20%) and AFCS servos (10.7%).

At Ft. Rucker, it is estimated that approximately 8% of CH-54A total maintenance manhours is on hydraulic systems. For the CH-54B, hydraulic systems account for approximately 15% of total maintenance manhours, almost twice the percentage required by CH-54A hydraulic systems.

Major contributors to cargo hoist hydraulic unscheduled maintenance manhour requirements have been:

Problem No.: 06-4 (Continued)

	P/N	% of Manhours
Packing Pre-formed (O-rings)	MS 28775-026	6.0
Valve Hoist Control	19740-1	24.9
Pump Hoist	6465-20021-101	12.5
Tube	6465-62051-061	29.8
Tube	6465-62051-062	7.8
Manifold	6465-62056-103	3.3

C. Aircraft Availability Factors -

Approximately 10% of total CH-54A downtime for unscheduled maintenance is attributable to hydraulic system failures. The major source of this downtime is the cargo hoist hydraulic system, which accounts for 51% of the hydraulic system downtime for unscheduled maintenance. Utility system hydraulics account for 21% and AFCS servos 10%.

Remedial Action:

1. ECP 8059, August 1967, replaced phenolic support assemblies with rubber support block assemblies for hydraulic tubing mounting to eliminate failure of lines due to vibration and chafing. Production incorporation was on aircraft 68-18450 and subsequent, with retrofit by MWO 55-1520-217-20/2, December 1968.

2. ECP F8074R, March 1969, provided for the elimination of multi-piece banjo fittings to eliminate leakage, and rerouting of lines installed on the upper fuselage deck to reduce exposure and damage from personnel during maintenance. Thirteen tube assemblies and three flexible hose assemblies were replaced by this rerouting. Also added were 36 block assemblies, six protective covers, and a walk assembly. Change was effective on aircraft 69-18462, 69-18463, 69-18472 and subsequent, and retrofit was by MWO 55-1520-217-30/38.

3. The following ECPs have been submitted and are pending disposition:

a. F8169, Primary Servo Improved Strength Bypass Valve - submitted May 1971.

b. P8175, Incorporation of Redundant Structures in AFCS Servo Valve Input Link - submitted June 1971.

Problem No.: 06-4 (Continued)

c. PV 8177, Wheel Brake Boost Cylinder Improvements - submitted May 1971.

4. The vendor of 66W series pumps has installed Viton "A" O-rings in place of "MS" type O-rings because of their greater durability.

Data Sources:

1,2,3,4,5,6,8,10,13,14,15,16,17,18,19,20,21,22,23.

Cross References:

TMS	Problem Number
UH-1	06-1
AH-1	06-1, 06-2, 06-3
CH-47	06-1
CH-54	06-1, 06-2, 06-3
OH-6	-
OH-58	11-1

Helicopter TMS: CH-54A
Problem No.: 17-1

Problem Title: Cargo Hoist Assembly Limit Safety Switch Failures

Problem Description:

A. Component Identification -
Limit Safety Switch, P/N 21EN 12-12

B. Description of Failure -
Limit switch fails to control cable operation, during both reel-in and reel-out operation.

C. Cause of Failure -
1. Internal failure of limit switch due to vibration and internal wear.
2. Cable operations which impair the proper functioning of the switch. In one case, the hoist cable bound against the cover assembly, P/N 6435-63052-081, forcing the plate, P/N S6035-63117, to contact the switch and stop hoist operations. Removal of the -63117 plate from the aircraft caused subsequent failure of the limit switch and resulted in the hoist's continuing its cycle until the motor sheared. Damage resulted to the hoist, main gearbox, and forward fuselage in the hoist well.
3. Pilot or crew error in operating the hoist.

D. Period and Duration of Problem -
1969 to present

E. Failure Rate Data -
MTBF for the 21EN 12-12 limit safety switch is 8998 component hours based on three units per aircraft. This MTBF reflects primary switch failures, not failure of the switch to perform its function. As noted above, most failures of the limit safety switch to perform its function result as secondary failures due to cable operation, and from pilot or crew errors, not from primary switch failures.

F. Mission and Deployment Factors -
Occurrences of this problem have been reported from CONUS and RVN.

Problem No.: 17-1 (Continued)

Problem Impact:

A. Safety Factors -

USABAAR records show one major accident (Class 2 mishap), one incident, and two precautionary landings attributed to hoist assembly failures. However, none of these failures was specifically identified to safety limit switch failures. The limit switch failure resulting in the main gearbox and hoist well damage was described in field visits and the EIR Digest (TB 750-992-4) for the 1st Quarter, FY 1970.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace switch	1.0 - 1.5	Direct Support

C. Aircraft Availability Factors -

Aircraft downtime for limit safety switch replacement is approximately 1 hour, using two men.

Remedial Actions:

1. Information on the limit safety switch and its safety functions has been included in TM 55-1520-217-10 and -20 to preclude unwarranted adjustments and modifications to this safety feature.

2. A procedure for stopping continuing hoist reel-outs due to switch malfunctions is contained in TM 55-1520-217-10. It consists of pulling the interlock circuit breaker. However, this requires rapid pilot response if damage is to be averted, and as such, it is inferior to fail-safe type mechanisms.

3. ECP F8145, covering improvements to cargo stock release system, is pending. This ECP is intended to eliminate problems with the cable cover assembly, P/N 6435-63052-081, which impairs the proper operation of the safety limit switch.

Data Sources:

2,3,4,5,6,8,11,13,17,19,20,22.

Problem No.: 17-1 (Continued)

Cross References:

TMS	Problem Number
UH-1	-
AH-1	-
CH-47	-
CH-54	-
OH-6	-
OH-58	-

Helicopter TMS: CH-54A,B
Problem No.: 18-1

Problem Title: APP Clutch and Adapter Assembly Failures

Problem Description:

A. Component Identification -

	P/N	A/C
Clutch Assembly	S6137-91000-015	CH-54A
Clutch Assembly	S6137-91000-017	CH-54A,B
Adapter Assembly	S6137-64355-1	CH-54A,B
Bearing	SB1125-1	CH-54A,B
Housing Seal	S6137-91504-101	CH-54A,B

B. Description of Failure -

1. Clutch assembly leaks oil due to failure of the -101 housing seal. Oil leakage has resulted in premature removals of clutch assemblies since the amount of assembly oil loss was not known.

2. The SB1125-1 bearing is used in both the clutch housing and the adapter assembly. Bearings are rough and/or corroded and suffer deterioration to the extent that they fall apart.

3. Clutch assemblies fail extensively, necessitating frequent removal and replacement and excessive maintenance support.

C. Cause of Failure -

1. The cause of failure of the -101 housing seal has not been specifically identified. Tests of seals performed under the direction of the contractor indicate that probable contributing causes are:

   a. Excessive interference fit between the seal and housing.
   b. Pressing the seal into the clutch housing at room temperature.

The result of these two contributing causes is distortion of the seal, which results in leakage either through the seal's preformed packing or past the seal face.

2. Failure of the SB1125-1 bearings (both the clutch input bearing and the two adapter assembly bearings) has been attributed primarily to material degradation due to environmental factors. The outer seal of the input bearing deteriorates from exposure to weather elements.

Problem No.: 18-1 (Continued)

Deterioration of the outer seal allows entry of water, moisture, sand, etc., which work through the bearing, causing roughness to bearing balls and subsequent inner seal failure. Failure of the inner seal allows grit and carbon from the clutch shoe facing to accumulate within the bearing and serve as abrasive agents.

The adapter assembly bearings are exposed to the same environmental stresses as the input bearing, with the result that the outer seals also deteriorate, followed by rapid degradation of the bearing.

D. Period and Duration of Problem -
From early deployment to present

E. Failure Rate Data -
1. Mean times to removal for failure of P/N S6137-91000-015 clutch assemblies as shown in the AVSCOM MIRF Report (1 January 1964 through 30 June 1970) are:
a. New - 164 hours (71 removals)
b. One prior overhaul - 94 hours (nine removals)
2. Based on parts usage (issues) of the -017 clutch assembly at Ft. Rucker during the year ending April 1971, MTBR is 189 hours.
3. MTBF of the -015 clutch assembly, reflecting primary failures on the CH-54A, as shown in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report, is 343 hours, based on 140 failures.
MTBF of the -017 clutch assembly used on the CH-54B as reported by Sikorsky Aircraft is 355 hours, based on five failures, two of which were for leaking.

F. Mission and Deployment Factors -
Common to all missions and deployments, but aggravated by environments in which abrasive contaminants and moisture are prevalent.

Problem Impact:

A. Safety Factors -
No aircraft mishaps were attributed to APP clutch failures during the period 1 January 1967 to 31 March 1971.

Problem No.: 18-1 (Continued)

B. Maintenance Workload Factors -

APP clutch installation maintenance is performed at the direct support maintenance level. Average repair manhour requirements for correction of primary failures are:

Action	M/H	Level of Maint.
Replace SB1125-1 bearing	1.5 - 2.5	Direct Support
Replace S6137-64355-1, adapter assembly	2.5 - 3.0	Direct Support
Replace S6137-91000-015, 017, APP clutch	3.0 - 4.0	Direct Support
Replace S6137-91504-101, housing seal	3.5 - 4.5	Direct Support

C. Aircraft Availability Factors -

Average aircraft downtime for accomplishment of the above maintenance using a two-man crew is:

	Hours
1. Bearing	2.0
2. Adapter Assembly	2.5
3. APP clutch	2.5
4. Housing seal	5.0

Remedial Actions:

1. A test program was conducted under the prime contractor's auspices during late 1969 and early 1970 for the development of a new housing seal. At the present time, the -101 housing seal is still used.

2. In 1968 the contractor deleted one vendor of the SB1125-1 bearing, due to persistent failure of the vendor's bearing seals.

3. ECP F8102, September 1968, provided for production incorporation of a new clutch assembly, P/N S6137-9100-017, on production models CH-54B 69-18472 and subsequent, with retrofit accomplished by attrition. This ECP provided for the following changes:

a. Replacement of the clutch assembly SB1125-1 bearing by a new bearing, SB1125-2. The -2 bearing is physically interchangeable with the -1 bearing and contains Armalon (R) seals on the inner and outer sides for improved protection against contamination.

Problem No.: 18-1 (Continued)

b. The existing three pivot bolts were replaced by three strengthened bolts and a spacer to allow the shoe lining assembly pivot to move freely during normal clutch operation.

c. An oil collector was added to measure any clutch oil leakage.

4. Incorporation of the improved SB1125-2 bearing in the APP adapter assembly was accomplished through a Class 2 production change and retrofit through spares attrition.

Data Sources:

1,2,5,6,8,11,13,14,17,18,19,20,21,22,23.

Cross References:

TMS	Problem Number
UH-1	04-4, 04-8, 04-9, 04-10
AH-1	04-4, 04-5
CH-47	04-6
CH-54	04-11
OH-6	04-5
OH-58	04-1, 04-2, 04-3

Helicopter TMS: CH-54A,B
Problem No.: 19-1

Problem Title: AFCS and AFCS Component Failures and Malfunctions

Problem Description:

A. Component Identification -

	P/N
Amplifier, Control (566359-7)	6490-60105-101
Stick Assembly, Remote	6490-60131-011
Sensor, Lateral and Fore-and-Aft (CH-54A)	S6190-60030
Sensor, Collective (CH-54A)	S6190-60030-1
Sensor, Lateral and Fore-and-Aft (CH-54B)	S6190-60030-1

B. Description of Failure -

1. Sensors malfunction, fail.

2. The control amplifier receives signals from the sensors and transmits them to the AFCS servos, which activate main and tail rotor controls. Numerous modes of failure of the control amplifier occur, including failure of AFCS to hold heading, yaw channel inoperative, yaw erratic, yaw kick, and hardover in yaw channel.

3. The most frequent remote stick failures are (1) hardover in normal yaw mode, (2) remote stick inoperative, and (3) yaw channel inoperative.

C. Cause of Failure -

1. Causes of sensor failures and malfunctions were not ascertainable. AFCS sensor unreliability, however, was generally conceded by field personnel to be the primary cause of AFCS problems.

2. Identification of the cause of failure of the control amplifier is complicated by the black-box characteristics of the AFCS system, which frequently results in intermittent, nonrepeatable system malfunctions. A primary source of amplifier control failures is failure of the collective, yaw, and roll AFCS modules, and the yaw rate gyro. Most failures are reported against the roll AFCS module. Vibration has been cited as a contributing cause of control amplifier component failures.

Problem No.: 19-1 (Continued)

3. Data were not available on causes of remote stick failures.

D. Period and Duration of Problem -
Early deployment to present

E. Failure Rate Data -
1. MTBF for primary failures as reported in the Sikorsky 11th Quarterly CH-54A Reliability/Maintainability Report are:

	P/N	Hours
Sensor	S6190-60030	2823 (A/C)
Amplifier Control	6490-60105-101	552 (Component)
Remote Stick	6490-60131-011	658 (Component)

2. Failure rate data on CH-54B sensors has not yet been developed.

F. Mission and Deployment Factors -
Common to all missions and deployments

Problem Impact:

A. Safety Factors -
No aircraft mishaps during the period 1 January 1967 through 31 March 1971 were attributed to this problem area.

B. Maintenance Workload Factors -

Action	M/H	Level of Maint.
Replace/adjust sensor	4.0 - 5.0	Direct Support
Replace/adjust amplifier control	1.0 - 2.0	Direct Support
Replace/adjust remote stick	1.5 - 2.5	Direct Support

C. Aircraft Availability Factors -
Average downtime for maintenance action on the above components, assuming a two-man crew, is:

	Hours
1. Sensor	3.0 - 4.0
2. Amplifier control	1.0 - 1.5
3. Remote stick	1.5 - 2.0

Problem No.: 19-1 (Continued)

Remedial Action:

1. ECP 8026, April 1967, modified AFCS pedal switches, with implementation by retrofit per MWO 55-1520-217-30/12.

2. ECP F8159, July 1969, provided an improved AFCS control rod, with implementation by retrofit per MWO 55-1520-217-30/45.

3. ECP F8170, to provide AFCS amplified maintainability improvements, was submitted March 1971; action pending.

4. ECP F8119R1, Aft Pilot's Electric Control Stick Automatic Beeper, submitted for correction of remote stick malfunctions, was disapproved in March 1971.

Data Sources:

1,2,3,4,5,6,8,12,15,16,17,19,20,21,22,23.

Cross References:

TMS	Problem Number
UH-1	-
AH-1	11-2
CH-47	19-1
CH-54	06-3
OH-6	-
OH-58	-

DATA SOURCES - CH-47A,B,C ANALYSES

1. APJ trip report, U.S. Army Aviation Center, Ft. Rucker, Ala., 1,2, and 4 June 1971.
2. APJ trip report, USAAVSCOM, St. Louis, Mo., 7-11 June 1971.
3. APJ trip report, HLH Project Manager's Office, St. Louis, Mo., 9 June 1971.
4. APJ trip reports, USABAAR, Ft. Rucker, Ala., 1 June and 12 July 1971.
5. APJ trip report, Boeing Company, Vertol Division, Philadelphia, Pa., 20 September 1971.
6. APJ trip report, New Cumberland Army Depot, Pa., 22-23 September 1971.
7. TM 55-1520-209-34P Series.
8. TM 55-1520-209-20P Series.
9. TM 55-1520-227-35 Series.
10. TM 11-1520-209-20 Series.
11. TM 11-1520-209-35 Series.
12. TM 11-1520-209-35P Series.
13. USABAAR Mishap Data, CH-47A,B,C - 1 January 1967 through 31 March 1971.
14. USABAAR report, CH-47 Accident Summary, 1 July 1966 through 30 June 1967.
15. New Cumberland Army Depot, Aircraft Maintenance Information Bulletin Series, January 1966 through April 1971.
16. USAAVSCOM report, Major Item Removal Frequency, CH-47A Fleet, January 1, 1964 through June 30, 1970.
17. DA Pamphlet No. 310-7, U.S. Army Index of Modification Work Orders, February 1971.
18. U.S. Army Aviation Test Board Report of Test, USATECOM Projects Nos. 4-3-0200-02-R and 4-3-0200-04-R, Service, Direct and High Elevation Tests of the CH-47A Helicopter, November 1963.

19. U.S. Army Aviation Test Board report, Initial-Production Test of CH-47C/T55-1-7C Helicopter, Final Report, July 1969.

20. U.S. Army Aviation Test Board report, Service Test of the CH-47C Helicopter, November 1969.

21. TB 750-992 Series, Equipment Improvement Report and Maintenance Digest (Rotor Wing Aircraft), 3rd Quarter, FY 1968 through 2nd Quarter, FY 1971.

22. Boeing-Vertol report, CH-47A,B and C Series Helicopter Rotor Blade Failure and Scrap Rate Data Analysis, First Draft, prepared for USAAVLABS, 1971.

23. Boeing-Vertol reports, U.S. Army CH-47B/C Engineering Field Evaluation Program, Quarterly Evaluation Report Number Six, December 1969, and Final Progress/Status Meeting Report, January 1970.

24. Boeing-Vertol Pamphlet, CH-47 Service Experience Review. Undated.

25. Boeing-Vertol Document, Engineering Change Proposal Status, 1971.

26. New Cumberland Army Depot Document, Aircraft Configuration Listing, August 1971.

27. APJ Report 501-3, Flat Rate Manual, CH-47A Organizational Maintenance, August 1967.

28. U.S. Army Aviation Center, Ft. Rucker, Ala., CH-47A,B,C Helicopter Parts Usage, Year Ending 30 April 1971.

DATA SOURCES - CH-54A,B ANALYSES

1. APJ trip report, U.S. Army Air Mobility Research and Development Laboratory, Eustis Directorate, Ft. Eustis, Va., 27 and 28 May 1971.

2. APJ trip report, U.S. Army Aviation Center, Ft. Rucker, Ala., 1,2, and 4 June 1971.

3. APJ trip report, USAAVSCOM, St. Louis, Mo., 7-11 June 1971.

4. APJ trip report, Heavy Lift Helicopter Project Manager's Office, St. Louis, Mo., 10 June 1971.

5. APJ trip report, Sikorsky Aircraft, Stratford, Conn., 22 September 1971.

6. APJ trip report, New Cumberland Army Depot, Pa., 23 September 1971.

7. TM 55-1520-217-20P Series.

8. TM 55-1520-217-34P Series.

9. TM 55-1520-217-35P Series.

10. TM 55-1520-217-20.

11. TM 55-1520-217-35.

12. TM 11-1520-217-20.

13. TB 750-992 Series, Equipment Improvement Report and Maintenance Digest (Rotor Wing Aircraft), Third Quarter, FY 1968 through Second Quarter, FY 1971.

14. USAAVSCOM report, Major Item Removal Frequency, 1 January 1964 through 30 June 1971.

15. New Cumberland Army Depot, Aircraft Maintenance Information Bulletin Series, January 1966 through April 1971.

16. DA Pamphlet No. 310-7, U.S. Army Equipment Index of Modification Work Orders, February 1971.

17. USABAAR Mishap Data, CH-54A,B, 1 January 1967 through 31 March 1971.

18. CH-54A,B Helicopter Parts Usage, year ending 30 April 1971, U.S. Army Aviation Center, Ft. Rucker, Ala.

19. ECP Status Report, Sikorsky Aircraft.

20. Sikorsky Aircraft report, CH-54A Operations Reliability/ Maintainability Engineering Program Accomplishment Report, Ser -64272-1, 10 April 1968, with monthly update revisions through 15 September 1970.

21. Sikorsky Aircraft report, CH-54B Operations Reliability/ Maintainability Engineering Program Accomplishment Report, Ser -64340, 15 June 1971, with monthly update revisions through 15 September 1971.

22. Sikorsky Aircraft, Operations Reliability/Maintainability Engineering Program Quarterly Evaluation Report, CH-54A, Ser -64276, 10 May 1968 through 15 December 1970.

23. Sikorsky Aircraft, Operations Reliability/Maintainability Engineering Program Quarterly Evaluation Report, CH-54B, Ser -64344, 15 August 1971.

Distribution
Not Shot

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) American Power Jet Company 705 Grand Avenue Ridgefield, New Jersey	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

IDENTIFICATION AND ANALYSIS OF ARMY HELICOPTER RELIABILITY AND MAINTAINABILITY PROBLEMS AND DEFICIENCIES
VOLUME III - CARGO HELICOPTERS (CH-47, CH 54)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report

5. AUTHOR(S) (First name, middle initial, last name)

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William K. Krauss
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6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April 1972	126	41

8a. CONTRACT OR GRANT NO. DAAJ02-71-C-0051	9a. ORIGINATOR'S REPORT NUMBER(S) USAAMRDL Technical Report 72-11C
b. PROJECT NO.	
c. Task 1F162205A11903	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	APJ 670-4

10. DISTRIBUTION STATEMENT

Distribution limited to U.S. Government agencies only; test and evaluation; April 1972. Other requests for this document must be referred to the Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia 23604.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
Volume III of a 4-volume report	Eustis Directorate U.S. Army Air Mobility R&D Laboratory Fort Eustis, Virginia

13. ABSTRACT

This volume presents discussions of a series of reliability and maintainability problems related to Army Cargo Helicopters (CH-47, CH-54). A detailed discussion of the standard format used for problem presentation and of the various analysis elements within the standard format is provided in Volume I.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Component failure						
Failure modes						
Failure rates						
Safety factors						
Component maintenance workload						
Aircraft availability						
Aircraft reliability						
Aircraft maintenance						
Remedial actions						
AH-1						
UH-1						
TH-1						
CH-47						
CH-54						
OH-6						
OH-58						