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CWCD-1000/1010 SONIC ANALYZER WITH CH-47A/B HELICOPTER CAPABILITY

By

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July 1969

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

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CURTISS-WRIGHT CORPORATION
AEROSPACE EQUIPMENT DIVISION
CALDWELL, NEW JERSEY

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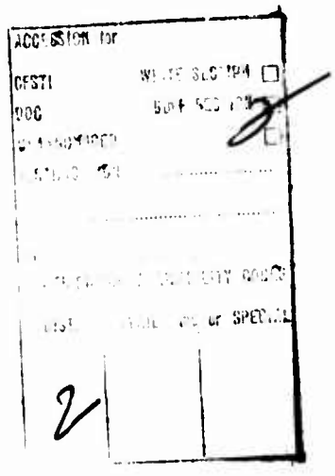

DEPARTMENT OF THE ARMY
HEADQUARTERS US ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA 23604

The effort reported herein represents a part of an overall program to derive techniques that may be used in the development of diagnostic and inspection equipment for Army aircraft maintenance.

This report presents the results of the investigation of the use of acoustical energy measurement and analysis to determine the mechanical condition of the propulsion system of the CH-47 model helicopter. The results of the program indicate that a sonic analyzer can be developed into a useful tool in the maintenance of Army aircraft.

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July 1969

CWCD-1000/1010 SONIC ANALYZER WITH CH-47A/B HELICOPTER CAPABILITY

Final Report
C-3055

by

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Prepared by

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FORT EUSTIS, VIRGINIA

SUMMARY

The purpose of the work encompassed in this report was (1) to fabricate an automated diagnostic sonic analyzer, (2) to design and fabricate a CH-47A/B helicopter plug-in module with both T55 engine and CH-47A/B helicopter power train components capability, and (3) to design and fabricate an auxiliary microphone switch box.

The methods employed in achieving this work consisted of (1) analyzing mechanical data to determine the frequencies of the rotating components, (2) performing a microphone survey and locking frequency investigation, (3) analyzing the acoustical data to develop spectral familiarity and to establish initial analyzer programming and system compatibility, and (4) conducting a field application program utilizing the automated sonic analyzer to correlate analyzer indications with the mechanical condition of the rotating components and to establish analyzer limits.

As a result of the work accomplished under this program, a Curtiss-Wright model CWCD-1000 Sonic Analyzer with a CWCD-1010 automation unit, developed under Naval Air Systems Command Contract NOw 66-0704f, was fabricated and delivered to the Army together with a CWCD-1020 microphone auxiliary switch box. The CH-47A/B acoustic plug-in module, delivered with the analyzer, was designed and fabricated under this program to incorporate the T55 engine (models T55-L-5 and T55-L-7) and CH-47A/B helicopter power train components (forward and aft rotor transmissions and combining transmission) capability. The component limits for the aft rotor transmission were established during the three-month field application program conducted at Henchy Army Air Field, Fort Rucker, Alabama. An additional four-month study was conducted in the Curtiss-Wright laboratory to evaluate the complete CH-47A/B helicopter dynamic system utilizing the tape recordings made during the three-month field application program. As a result of this study, tentative component limits have been established. However, a considerable amount of additional data will be required to confirm these limits.

The utilization of the CWCD-1000/1010 Sonic Analyzer and the CWCD-1020 switch box by ground maintenance personnel at military installations will reduce the aircraft downtime by eliminating unnecessary troubleshooting as now being practiced under conventional inspection methods. As the confidence level in the CWCD-1000/1010 analyzer is increased, the time between periodic inspections may also be increased.

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LIST OF SYMBOLS AND ABBREVIATIONS

ACC	Accessory
BEV	Bevel
Brg	Bearing
$C_{1, 2, 3....n}$	Compressor rotor - subscript denotes compressor stage number
C_C	Centrifugal compressor rotor
CARR	Carrier
CHAN	Channel
CHK	Check
COMPR	Compressor
COND	Condition
COOl	Cooling
d_1	Bearing inner race diameter, inches
d_2	Bearing outer race diameter, inches
db	Decibel
d_B	Bearing rolling element diameter, inches
Dia	Diameter
Diff	Differential
Dr	Drive
f_1	Bearing frequency caused by irregularity on inner raceway, Hz
f_2	Bearing frequency caused by irregularity on outer raceway, Hz
f_B	Bearing frequency caused by spin of rolling element, Hz
f_B'	Bearing frequency caused by rough spot on rolling element, Hz

$3f_{B'}$	Third harmonic of $f_{B'}$, Hz
f_{BEV}	Rotational frequency of bevel drive gear shaft, Hz
$2f_{BEV}$	Second harmonic of f_{BEV}, Hz
f_{I}	Fundamental rotational frequency of 1st stage planetary gear train, Hz
f_{II}	Fundamental rotational frequency of 2nd stage planetary gear train, Hz
f_{P_I}	Rotational frequency of 1st stage planetary gear shaft, Hz
$f_{P_{II}}$	Rotational frequency of 2nd stage planetary gear shaft, Hz
f_{R}	Fundamental rotational frequency of engine, gear shaft or bearing shaft, Hz
$2f_{R}$	Second harmonic of f_{R}, Hz
f_{R_o}	Rotational frequency of output gear shaft, Hz
f_{R_I}	Rotational frequency of input gear shaft, Hz
f_{S_I}	Rotational frequency of 1st stage sun gear shaft, Hz
$f_{S'_I}$	Rotational frequency of 1st stage sun gear shaft relative to carrier, Hz
$f_{S_{II}}$	Rotational frequency of 2nd stage sun gear shaft, Hz
$f_{S'_{II}}$	Rotational frequency of 2nd stage sun gear shaft relative to carrier, Hz
f_{T}	Bearing frequency due to rotation of train of rolling elements, Hz
Fund	Fundamental
$Fund_{I}$	Fundamental rotational frequency of 1st stage planetary gear train, Hz
$Fund_{II}$	Fundamental rotational frequency of 2nd stage planetary gear train, Hz
Fwd	Forward

GR	Gear
HYDR	Hydraulic
Hz	Hertz, frequency equivalent to 1 cycle per second
L.O.	Lube Oil Pump
m	Number of bearing rolling elements
MIKE	Microphone
MRC	Marlin-Rockwell Company
Mv	Millivolt
N_1	Gas producer rotor speed, rpm
N_2	Power turbine rotor speed, rpm
N.D.	New Departure
No.	Number
NORM	Normalize
OUT	Output
PWR	Power
Ref	Reference
REL	Relative
rpm	Revolutions per minute
rps	Revolutions per second
S/B	Sideband
SKF	SKF Industries, Inc.
$T_{1, 2, 3}$	Turbine rotor - subscript denotes turbine stage number
THR	Thrust
TR	Train
XMSN	Transmission

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INTRODUCTION

The purpose of the work included in this report was to fabricate and evaluate a CWCD-1000/1010 Sonic Analyzer and a CWCD-1020 switch box with the capability of analyzing the CH-47A/B helicopter dynamic components system, including the T55-L-5,-7 engine.

To accomplish this program, it was necessary (1) to perform a mechanical analysis of all rotating components of the CH-47A/B helicopter, for the calculation of the expected acoustic frequencies; (2) to compile an acoustic handbook listing these acoustic frequencies; (3) to conduct an acoustic survey of a number of CH-47A/B helicopters to determine the optimum microphone locations and to establish the best locking frequency; (4) to perform a laboratory analysis of all acoustic recordings for identification of engine components; (5) to design and fabricate an acoustic plug-in module with CH-47A/B helicopter complete dynamic component system capability to be utilized with the CWCD-1000/1010 Sonic Analyzer; (6) to fabricate a CWCD-1000 Sonic Analyzer with a CWCD-1010 automation unit (designed under Navy contract NOw 66-0704f); (7) to design and fabricate a microphone auxiliary switch box; (8) to perform a field evaluation of the CWCD-1000/1010 Sonic Analyzer and CWCD-1020 switch box; and (9) to perform a laboratory analysis of the data recorded in the field to establish tentative component limits for the complete CH-47A/B helicopter dynamic component system.

The objectives of this report are (1) to present the results of the work performed in the application of the CWCD-1000/1010 Sonic Analyzer and the CWCD-1020 switch box to the complete CH-47A/B helicopter dynamic component system, (2) to present the results of the design and development of the CH-47A/B helicopter acoustic plug-in module and the CWCD-1020 microphone auxiliary switch box, and (3) to describe the CWCD-1000 Sonic Analyzer and the CWCD-1010 automation unit, including the design concepts.

The Curtiss-Wright Corporation has been engaged in the research and development of a new technique for diagnosing engine malfunctions since early 1960. A new concept for analyzing jet engines and power transmission systems, designated the Diagnostic Sonic Analysis Technique, has been developed together with the design and fabrication of 4 analyzer models under previous Government contracts (USN Bu Weps Contracts NOw 60-074c, NOw 62-0721c, NOw 65-0094f, and NOw 66-0704f). In addition to these Navy contracts, company-funded research and development programs between Government contracts led to the development of the frequency ratio generator, intermediate frequency amplifier, and plug-in module circuitry. Under the U.S. Army, USAAVLABS Contract DA 44-177-AMC-249(T), a gear study was made of power transmission systems; and under USAAVLABS Contract DA 44-177-AMC-446(T), a CWEA-4 Sonic Analyzer with UH-1 helicopter capability was delivered to the Army. Other completed U.S. Navy contracts include the following:

Contract No.	Description
NOw 66-0631d	J65 Engine Compressor Surge Control Program
N62269-67-C-0159	J52 Engine Analyzer
N62269-68-C-0040	CH-46 Helicopter Dynamic System

Current projects include the following Government contracts as well as analyzer evaluations for both Eastern and National Airlines:

U.S. Navy Contracts	Description
N62269-68-C-0420	Field evaluation of 10 CWEA-3 Sonic Analyzers
U.S. Army Contracts	
DAAJ01-68-C-1824(31)	CWEA-4 Sonic Analyzer - T53 Engine Field Evaluation

The effective date of the contract discussed in this report was 22 June 1967.

DISCUSSION

DATA ACQUISITION AND ANALYSIS

Mechanical Data and Analysis

The mechanical data for the various rotating components of the model CH-47A/B helicopter were obtained from the Department of the Army;[1] from the blueprint files at the U.S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia; and from various bearing manufacturers. The type of data required for a mathematical analysis of the rotating components included the following:

1. Operating speeds of engines and helicopter transmissions.
2. Gear train configurations and number of teeth on gears.
3. Accessories, their location, and, their internal assemblies.
4. Bearing types, dimensions, and number of rolling elements.
5. Helicopter engine installations and transmission locations.

Utilizing the mechanical data as obtained above, the predicted frequencies of the various rotating components of the CH-47A/B helicopter transmissions and the T55-L-5,-7 engines were calculated as shown in Appendix I. These predicted frequencies are tabulated in Tables I through XXXIV, and an explanation of the tables is given in Appendix II.

The gear and bearing arrangement for the T55 engines and the CH-47 helicopter transmissions is shown in Figures 1 through 5.

Acoustic Data and Analysis

Microphone Location Survey

Microphone surveys of models CH-47A and CH-47B helicopters were conducted (1) to determine the minimum number of microphones required for complete signal coverage of the CH-47A/B helicopter dynamic system, and (2) to determine the component signals to be utilized for rpm tracking.

Ten helicopters were surveyed utilizing a magnetic tape recorder and 4 condenser-type microphones to record the data. A portable narrow-band panoramic frequency analyzer was used for analysis of the recorded data. A list of the helicopters surveyed is shown in Table XXXV. During the surveys, the microphones were located at various positions adjacent to the engines, the 90-degree gearbox, the forward and aft rotor transmissions, and the combining transmission. Signals

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1 Technical Manual No. 55-1520-209-20P, dated March 1967.

were compared at both ground idle and flight idle power conditions, and orientation of the microphones was changed according to concentration of rotating components within each power train. Based on the analysis of these data, the optimum locations of the microphones in the CH-47A/B helicopter were determined to be as follows:

Microphone No.	Figure No.	Microphone Location
1	6	No. 1 engine - opposite accessory gearbox (aimed through lower aft corner of cowling grille).
2	7	No. 2 engine - opposite accessory gearbox (aimed through lower aft corner of cowling grille).
3	8 and 9	Aft rotor transmissions - 1st stage planetary (opposite bevel input-synchronizing shaft).
4	8 and 9	Aft rotor transmission - 2nd stage planetary (opposite 2nd stage ring gear).
5	9	Aft rotor transmission - accessory transmission (opposite gearbox mounting flange).
6	10	Combining transmission - (opposite aft synchronizing shaft).
7	11	Forward rotor transmission - 1st stage planetary (opposite bevel input-synchronizing shaft).
8	11	Forward rotor transmission - 2nd stage planetary (opposite 2nd stage ring gear).

Although these 8 microphone positions represented a compromise to simplify installation of the microphones in limited access areas, examination of the gear train signals using wave-form analyzer equipment indicated 90 percent coverage of the major rotating components. In many cases there was some overlapping of prominent signals between adjacent microphones.

As a result of this survey, a requirement for an 8-position microphone switching unit was indicated to facilitate rapid connection

to the 3-channel CWCD-1000/1010 Sonic Analyzer. A further requirement indicated the need for special mounting hardware and bracketry to attach microphone holders to the airframe in each location.

In comparing the sound spectra at various engine speeds, it was found that signal quality was improved by mechanical loading at higher rpm. The flight idle condition was selected for analysis of the CH-47A/ helicopter as defined below:

Helicopter Component	Speed (RPM)	Tachometer Setting
Engine N_1 gas producer rotor	14040	75%
Engine N_2 power turbine rotor	15166	230 rpm (rotary-wing)

For valid comparison of data, these speeds were closely maintained during the second survey series, and microphone positions were duplicated.

Further data analysis indicated that the following component signals are suitable for acoustic locking based on consistent signal characteristics at the established microphone locations.

Spool Lock	Component	Microphone No.	Frequency @ Flight Idle
N_1	No. 1 or No. 2 engine accessory transmission main spur train	1 or 2	2047 Hz
N_2	Forward or aft rotor transmission input spiral bevel train	3 or 7	3415 Hz

Utilizing a variable phase-lock filter, laboratory studies verified the selection of these signals as advantageous for speed variations from 70 to 75% N_1 and 220 to 230 rpm N_2.

RPM Tracking Tests

A single plug-in phase-lock module design was proposed, based on the speed settings selected above, and utilizing the following tracking frequencies:

RPM Dependent Components	Locking Frequency	Multiplier	Tracking Frequency
N_1	2047 Hz	x4	8188 Hz
N_2	3415 Hz	x3	10245 Hz

Operation of both the CH-47A and CH-47B aircraft at flight idle indicated that N_1 speeds of both engines could be simultaneously set within 73 to 75 % at a main rotor speed of 230 rpm, depending upon atmospheric conditions. Speed drift during a 5-minute duration recording (one switch mode-three microphones) was found to be generally less than 1/2%, so that tracking range requirements did not exceed $\pm$3%.

Module capture range within $\pm$2% was considered to be desirable because of tachometer inaccuracies and speed droop between Nos. 1 and 2 engines at a given power setting. Phase-lock tests using recorded data from a total of 12 survey recordings were satisfactory in all cases where microphones 1, 2, and 3 were positioned as above. In most cases, microphones 4, 7, and 8 also proved to be satisfactory for N_2 lock.

Spectral Familiarization

A spectral analysis was made of the microphone survey recordings (see Table XXV) to confirm the presence of the 2 signals proposed for the N_1 and N_2 locking frequencies and also to determine the identity and characteristics of the various component signals. The results of this analysis confirmed that the engine and transmission components selected for acoustic locking during the microphone survey are valid. The major rotating components of the engine, the 90-degree gearbox, the forward and aft rotor transmissions, and the combining transmission were also identified.

N_1 Locking Signal

A spectrogram, obtained from helicopter serial number 66-19139, of the No. 1 engine accessory drive section using microphone No. 1 is shown in Figure 12. This spectrogram shows the relatively strong signal (2047 Hz @ the flight idle power setting) exhibited by the N_1 main accessory drive gear train as compared with the background noise level and is typical of spectrograms obtained from other helicopters. The consistently strong signal-to-noise ratio exhibited by this component together with the absence of any other discrete signals in the near vicinity confirms the selection of this component as an excellent N_1 locking signal.

N_2 Locking Signal

A spectrogram, obtained from helicopter serial number 63-7911, of the aft rotor transmission using microphone No. 3 is shown in Figure 13. This spectrogram shows the relatively strong signal (3415 Hz @ the flight idle power setting) exhibited by the aft rotor transmission input bevel gear train and confirms the selection of this component as the N_2 locking frequency. This spectrogram is typical of those produced for the forward rotor transmission utilizing microphone No. 7 and of spectrograms obtained from other helicopters for both the forward and aft rotor transmissions.

Transmissions - General

In order to compare frequencies and to evaluate component signals for each microphone location, a frequency analysis was undertaken for each major transmission area. Using the narrow-band panoramic spectrum analyzer equipment, amplitude versus frequency charts were

obtained to verify the presence of known signals and to provide base data for later evaluation of gain limits using a laboratory CWCD-1000 analyzer.

An overall comparison of predominant gear train signals showed a wide amplitude variation in the CH-47A/B spectrum. In the case of transmission spectrograms, a variation in background noise was noted between different aircraft with consistent signal/noise amplitudes for identical signals. In addition, signal changes caused by the effects of mechanical loading affected amplitude levels, which are standardized for N_1 speeds at 75%, or nominal torque at 225 rotor rpm, on both engines.

Main Rotor Transmissions and Combining Transmission

In the case of the main power transmissions, strong fundamental and harmonic signals were noted at tooth contact frequencies, accompanied by families of sidebands at predictable modulation frequencies. Examples of this sideband generation are shown in Figures 14, 15, 16, and 17, all taken from data run at the nominal power setting of 75% N_1 and 230 N_2 rotor rpm.

Main Rotor Transmissions - Planetary Gear Trains

In the case of the forward and aft rotor transmission planetary gear trains, the sun planet and shaft frequencies modulated both fundamental discrete signals. Comparison of data at various engine torques indicated that the percentage of modulation remained constant for a given degree of mechanical loading or torque at uniform rpm. The degree of modulation increased in linear proportion to torque, showing that repeatable sideband limits could be set for constant power levels. The mechanism by which sideband amplitudes differed between transmissions could therefore be related to component malfunction or degradation, resulting in abnormal internal loading.

Combining Transmission

In addition to the main power bevel gear train, a stable pattern of sideband generation was noted at odd and even orders of input and output shaft speeds. Although overlapping in frequency, and in some cases nonexistent, it was found that consistent amplitudes were present when torques matched between Nos. 1 and 2 engines. At 75% N_1 speeds, even-order sidebands appeared at consistently higher levels for the input shaft, and odd-order sidebands were more pronounced for output shaft modulation, thus limiting the number of signals believed to be of diagnostic value. Noise levels were found to be unusually high in this vicinity of the spectrum.

No. 1 and No. 2 Engine Transmissions

Main spiral bevel train fundamental signals were apparent for both gearboxes, but harmonics or sidebands did not appear. A typical spectrogram of the No. 1 engine spectrum is shown in Figure 18.

CH-47A/B Helicopter Component Rejection Limits

The analyzer component gain settings, which determine the component condition level as read on the condition meter, are established in two phases of the overall program. The initial limits are derived from the analyses of recorded data which are obtained during the early phases or component familiarization portion of the program. These values may also be referred to as the preliminary field testing limits. In those cases where the program provides for field evaluation or testing of the analyzer, these initial limits are further refined and/or revised to establish component condition levels under actual field conditions. The preliminary work and result of tests accomplished under previous phases of programs have shown that the engine is treated as a collection of bearings, gear trains, accessories, compressors and turbine stages. However, in the case of helicopter transmissions, this reasoning and the methods of analyses become slightly exaggerated and difficult to apply. The collection of parts may be existent in comparable mechanical arrangement, but various orders of signal generation and their related amplitudes tend to be inherently dependent upon input/output forces and allowable factors such as tolerances, alignment, and mass. Although experimental transmission gains have been formulated for those signals which appear to be indicators of component integrity, there still exist unpredictable signal consistencies due to the sympathetic relationship of parts, which is not yet fully understood. Continued experiments coupled with the disassembly inspection of suspect components identified by out-of-limit readings will result in clarification of analyses methods and will establish criteria which may be applied for monitoring the mechanical integrity of components as integrated into a transmission assembly.

The program to establish CH-47A/B helicopter engine and transmission component gain limits was divided into three phases:

1. Preliminary condition limits

   These limits were established utilizing the CH-47A/B helicopter data recorded at Fort Rucker, Alabama, during the initial surveys conducted in August and December 1967. In the analyses of these data, components were selected which had previously been identified in spectrogram analysis, and which appeared to be stable and of consistent amplitude.

2. Interim condition limits

   These limits resulted from refinement of preliminary limits using data obtained from the CH-47A/B helicopter field evaluation program at Fort Rucker, Alabama, during May, June, and July 1968 and incorporated program changes derived from the analyses of recorded data using the delivered CWCD-1000 analyzer.

3. Final condition limits

   These limits were established as a result of an additional four-month study of the recorded data obtained during the three-month field evaluation program.

The analyses of these data consisted of establishing a gain setting required to produce a half-scale deflection of the condition level meter for the rotating components associated with the N_1 and N_2 sections of the engine as well as with the forward and aft rotor transmissions and the combining transmission. These gain values are subsequently revised to correspond to low meter read-out for low or normal component signals and high meter read-out for those same component signals found to have greater amplitudes.

In aiming at interim and final gain limit values, different methods were used for each type of transmission. Simple gear trains (such as engine nosebox bevel trains) produced a single fundamental tone corresponding to the tooth contact frequency with little or no harmonic content. More complex gear trains (such as planetary rotor transmissions) generated a complicated pattern of discrete signals which consisted of families of sidebands related to tooth contact signals by interacting internal shaft and gear speeds.

In the preparation of program logs, three types of gain limits were defined:

1. Comparison of signal amplitudes, or measurement of signal levels relative to normalization noise level.

2. Sideband or harmonic ratio, or ratio between sideband or harmonic amplitude relative to ambient noise, and carrier signal level relative to ambient or normalization noise.

3. Difference between sideband or harmonic and carrier signal level, measured by signal amplitudes relative to normalization noise.

The frequencies found to be significant for each mechanical component and which also showed consistent levels for the data examined are summarized in the program logs presented below.

1. Program No. 2011 - Aft Rotor Transmission

   a. Amplitude limits - input spiral bevel, 1st and 2nd stage planetary gear trains (refer to items 4-10, 21-27, and 40-42, Table XXXIII).

   b. Sideband differences (ratio of sideband to carrier amplitude) - input spiral bevel, 1st and 2nd stage planetary gear trains (refer to items 11-20, 28-38, and 43-50, Table XXXIII).

2. Program No. 2021 - Forward Rotor Transmission

   a. Amplitude limits - input spiral bevel, 1st and 2nd stage planetary gear trains (refer to items 4-10, 21-27, and 40-42, Table XXXIV).

   b. Sideband differences (ratio of sideband to carrier amplitude) - input spiral bevel, 1st and 2nd stage planetary gear trains (refer to items 11-20, 28-38, and 43-50, Table XXXIV).

3. Program No. 2031 - Combining Transmission

   a. Amplitude limits - spiral bevel power and lube oil pump drive gear trains (refer to items 4-7, Table XXXV).

   b. Sideband differences (ratio of sideband to carrier amplitude) - spiral bevel power gear train (refer to items 8-22, Table XXXV).

4. Program No. 2041 - No. 1 and No. 2 Engine Transmissions

   a. Amplitude limits - main spiral bevel gear train (refer to items 4, 5, 44, and 45, Table XXXVI).

   b. Amplitude limits - all power train bearings (refer to items 6-35 and 46-75, Table XXXVI).

5. Program No. 2051 - Aft and Forward Rotor Transmissions

   Amplitude limits - all power train bearings (refer to items 4-57 and 59-112, Table XXXVII).

6. Program No. 2061 - Combining Transmission

   Amplitude limits - major power train bearings (refer to items 5-46, Table XXXVIII).

7. Program No. 2071 - No. 1 and No. 2 Engine Components

   a. Sideband ratios - primary compressor and turbine rotor stages (refer to items 7-14, 28-35, 57-64, and 78-85, Table XXXIX).

   b. Amplitude limits - all main bearings and major accessory drive gear trains (refer to items 66-76 and 87-95, Table XXXIX - Note: omit items 16-26 and 37-45 which are not at the optimum microphone location).

8. Program No. 2081 - Aft Rotor Transmission Accessory Transmission Components

   a. Amplitude limits - all gear trains (refer to items 4-10, Table XL).

b. Amplitude limits - major gear trains and bearings (refer to items 11-70, Table XL).

Punched automation tapes were prepared for each of these logs, and the scope of each is such that an average of 9 minutes is required to scan automatically. Further experience with operation and teardown of malfunction transmissions is needed to shorten present data requirements.

Uniformity of Data

Combining Transmission

During initial surveys, 7 runs were taken at different engine power settings (230 rotor rpm) to correlate loading effect with sideband development. The analyzer readings were later taken against both input and output shaft modulation frequencies up to the 8th order. The results of 4 runs are shown in Figure 19, which gives an irregular pattern of amplitudes generally increasing with engine torque, and tending to diminish in strength at higher orders. Unmatched engine outputs tend to produce wide variations between successive orders of shaft speeds, while a smooth bell curve asymptotic to the average noise level was produced for constant even loading. Sideband limits were derived from this curve, and since the fundamental gear mesh signal repeated in amplitude within $\pm$ 2 db, readings are normalized to this signal instead of to the noise amplitude.

Figure 20 presents a series of runs utilized to establish the gain limits for the combining transmission fundamental (including the 2nd harmonic) gear frequency.

Aft and Forward Rotor Transmission

In the same manner as for the combining transmission, preliminary limits were set on the three-tooth contact signals (fundamental, 2nd and 3rd harmonics) for the forward and aft rotor transmissions. The average deviation of signal/normalized noise ratio was approximately $\pm$ 4 db from a mean value, with a substantial difference between data taken at the same torque levels. When signal/fundamental differences were plotted for the same data, a deviation of only $\pm$ 2 db was noted. The limits are therefore based on both systems, and more extensive data will be needed to ascertain which is more suitable for malfunction detection. Both are included in program logs for future use.

Selection of Aircraft Components for Analysis

Approximately nine hundred rotating components and fourteen hundred associated sonic frequencies were found to exist for the CH-47A/B helicopter power trains and engines. Early in the program it was possible to eliminate fifty percent of these signals as being insignificant or nonexistent, thus requiring preliminary limits on only seven hundred associated sonic frequencies.

As a result of component selection conferences with USAAVLABS personnel, and by the process of elimination, these sonic frequencies were reduced to 540 items. These items were subsequently organized into several analysis programs for punched tape programming to provide tapes of convenient lengths for ease of operation. The information contained on these tapes is summarized below.

Program No.	Description	No. of Components	Refer to Table No.
2011	Aft Rotor Transmission - gear trains	51	XXXIII
2021	Forward Rotor Transmission - gear trains	51	XXXIV
2031	Combining Transmission - gear trains	23	XXXV
2041	No. 1 and No. 2 Engine Transmissions - gear trains and bearings	76	XXXVI
2051	Forward and Aft Rotor Transmissions - bearings	120	XXXVII
2061	Combining Transmission - bearings	52	XXXVIII
2071	No. 1 and No. 2 Engine Components	96	XXXIX
2081	Aft Rotor Accessory Transmission - gear trains and bearings	71	XL

Microphone Normalization

All microphones are normalized prior to analyzer operation to standardize amplitude readings of all engine/transmission component signals. Normally, this is accomplished by selecting the lowest background noise level at a frequency in the overall system noise spectrum that does not contain any discrete signals. Analysis of the survey data showed that wide noise variation in the CH-47A/B spectrum required selection of a region in the median noise area so that measurement of high-amplitude signals did not exceed the analyzer dynamic range. In addition, two reference gain levels (30 db and 40 db) were chosen to permit analysis of two separate helicopter systems, namely, engines and transmissions.

A thorough analysis of survey data established the CH-47A/B normalization frequency as 5853 Hz for all microphones when using an N_2 locking signal. This requires the following gain settings according to the frequency region of interest.

Program No.	Mike No.	Ratio Set	Gain I - Gain II
2011	3, 4	0.4444	10 - 30
2021	7, 8	0.4444	10 - 30
2031	6	0.4444	10 - 20
2041	1, 2	0.4444	10 - 20
2051	3, 4, 7, 8	0.4444	10 - 30
2061	6	0.4444	10 - 20
2071	1, 2	0.4444	10 - 20
2081	3, 4	0.4444	10 - 20

Although there is a substantial variation in noise level between microphones at low frequencies (less than 2000 Hz), only small adjustments are required to maintain half-scale deflection of the analyzer condition meter at 5853 Hz.

PLUG-IN MODULE DESIGN

The operation of the phase locked loop is as described in the instruction manual.[2] A block diagram for the phase locked filter is presented in Figure 21. The tracking capability of the loop is based on capturing the signal of a component on the aircraft and then using this signal to monitor the variation of the engine speed (within $\pm$ 3% of idle) while remaining synchronous with the aircraft. The signals used to lock onto the CH-47A/B helicopter are 2047 and 3415 Hz for the N_1 and N_2 spools, respectively, as discussed previously. However, to meet the operating range requirements of the CWCD-1000 analyzer, these N_1 and N_2 locking frequencies were converted into analyzer tracking frequencies as follows:

Engine Spool	Locking Frequency	Multiplier	Tracking Frequency
N_1	2047 Hz	x4	8188 Hz
N_2	3415 Hz	x3	10245 Hz

These tracking frequencies are then used as a reference to monitor all the rotating components on the helicopter.

Based on the above specifications, an acoustic plug-in module was designed and fabricated for the CWCD-1000 Sonic Analyzer to provide CH-47A/B helicopter capability.

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2 Operation and Maintenance Manual, CWCD-1000/1010 Sonic Analyzer, August 1968.

DESCRIPTION OF CWCD-1000 SONIC ANALYZER, CWCD-1010 AUTOMATION UNIT, AND CWCD-1020 MICROPHONE AUXILIARY SWITCH BOX

CWCD-1000 Sonic Analyzer

A complete description and operation of the CWCD-1000 Sonic Analyzer is presented in the instruction manual delivered with the analyzer. A complete parts list is also included in this manual. The CWCD-1000 analyzer is basically the same as the CWEA-4 analyzer delivered to the Army under USAAVLABS Contract DA 44-177-AMC-446(T). However, many of the design changes for the CWEA-4 analyzer, recommended in USAAVLABS Technical Report 68-28, have been incorporated in the design of the CWCD-1000 analyzer. Some of the major improvements include: modification of the intermediate frequency amplifier circuitry to obtain better dynamic range, improved locking capability, improved operation at higher ambient temperatures, and increased battery capacity.

A photograph of the CWCD-1000 analyzer with the CWCD-1010 automation unit is shown in Figure 22.

CWCD-1010 Automation Unit

The theory of operation for the CWCD-1010 automation unit, including a typical punched tape program, is discussed in USAAVLABS Technical Report 68-28, dated May 1968.

CWCD-1020 Microphone Auxiliary Switch Box

Eight microphones are used for analysis of all CH-47A/B helicopter components. To facilitate rapid analysis and convenience in installation, connections to the three CWCD-1000 input channels are made through a CWCD-1020 microphone auxiliary switch box, as shown in Figure 23. This switching unit is housed in a portable carrying case, which also contains the CH-47A/B mounting hardware and bracketry. A photograph of the CWCD-1020 switch box is shown in Figure 24. Each microphone is connected through its extension cable to the corresponding input socket on the switching unit. Standard 3-foot analyzer input cables are used to connect the switching unit and the analyzer input channels.

Instruction Manuals

The following two instruction manuals were prepared for the operation and maintenance of the CWCD-1000/1010 Sonic Analyzer and the CWCD-1020 Switch Box:

1. Operation and Maintenance Manual, model CWCD-1000 Sonic Analyzer with model CWCD-1010 Automation Unit and CH-47A Plug-In Module P/N 177611.

2. Acoustic Handbook, CH-47A/B Helicopter Engines and Power Train Mechanical Data and Fundamental Frequencies of Rotating Components.

The purpose of the Operation and Maintenance Manual is self-explanatory. The purpose of the Acoustic Handbook is to provide ready reference to mechanical information and frequency data essential for sonic analysis of the CH-47A/B helicopter complete dynamic system. This handbook includes the following information:

1. Cutaway and exploded views of the T55-L-5,-7 engines and the CH-47A/B transmissions.

2. General arrangement configuration of the various helicopter sections.

3. Gear train schematics for the engines, combining transmission, forward rotor transmission, and aft rotor transmission.

4. Tabulations of the predicted frequencies of the rotating components, including the actual ratios required in the operation of the CWCD-1000/1010 analyzer.

5. Microphone locations for the engines installed in the CH-47A/B helicopter as well as for the various helicopter transmissions.

FIELD APPLICATION PROGRAM

The model CWCD-1000 Sonic Analyzer with the CWCD-1010 automation unit and the CWCD-1020 microphone auxiliary switch box were operated at the U.S. Army Aviation Center, Fort Rucker, Alabama, during the period from 3 May to 31 July 1968. The purpose of this program was (1) to evaluate the performance of the analyzer under operational conditions on the flight line in both the manual and automatic modes; (2) to further refine the component gain limits and acquire sufficient recorded data to properly establish gain levels for the engines, engine transmissions, and the helicopter power train transmissions; and (3) to familiarize USAAVLABS personnel with the microphone arrangement and analysis procedures.

In the course of this program, a series of 12 CH-47A/B helicopters were run at Fort Rucker, Alabama. Experience was gained in the use of all 8 microphones for analysis of each transmission, and particular attention was given to facilitating rapid microphone attachment and power supply/switching unit connection. Under normal conditions, setup time required 10 to 15 minutes, and a full complement of data could be recorded within a 20- to 25-minute run-up period, allowing about 50% of this time for a brief, live analysis of a particular component group using a single program tape. Approximately one hour is required for a complete helicopter analysis using punched tapes in the automatic or semiautomatic modes.

During this field evaluation, analyzer operation was satisfactory, and it was possible to maintain helicopter speed settings well within the analyzer tracking range of $\pm$ 3%. Capture range of $\pm$ 2-1/2% was found to be ample and within the tachometer accuracy tolerances. Since combining transmission gain limits are valid only at equal engine torques, the N_1 rpm meter readings can be compared for a validity check when matched engines are

installed. All power transmission limits are dependent upon holding engine torques between 220 and 230 indicated rotor rpm.

A summary of the aircraft analyzed during the field program, including aircraft, engine, and transmission identification, is presented in Table XLI.

LABORATORY ANALYSIS OF RECORDED FIELD EVALUATION DATA

During the three-month field evaluation program at Fort Rucker, Alabama, the analysis of the CH-47A/B helicopter was mainly concentrated on the aft rotor transmission, although preliminary gain limits were established for the complete helicopter dynamic system.

This program was extended an additional four months in order to perform a laboratory analysis of the recorded data taken during the three-month field evaluation program. During this four-month laboratory study, a complete analysis was made of the engines, engine transmissions, combining transmission, and the forward and aft rotor transmissions. As a result of this analysis, the preliminary limits established during the three-month field evaluation program were revised. These revisions have been included in the following program logs:

Program No.	Helicopter Component	Reference Table
2011	Aft Rotor Transmission	XXXIII
2021	Forward Rotor Transmission	XXXIV
2031	Combining Transmission	XXXV
2041	No. 1 and No. 2 Engine Transmission	XXXXVI
2051	Aft and Forward Rotor Transmissions	XXXVII
2061	Combining Transmission	XXXVIII
2071	No. 1 and No. 2 Engine Components	XXXIX
2081	Aft Rotor Transmission Accessory Transmission Components	XL

These program logs and the corresponding punched tapes were utilized with the CWCD-1000/1010 automated analyzer at Fort Eustis, Virginia, during the period from 13 November to 15 November 1968, for the purpose of final limits evaluation and instruction in field use.

As a result of the analysis of CH-47A helicopter No. 61-9109 at Fort Eustis during the above period, some minor changes in the program logs (Nos. 2011, 2021, 2031, 2041, 2051, 2061, 2071, and 2081) were indicated. These corrections are shown in Tables XLV through LII. These changes were incorporated in the punched tapes. New program numbers were assigned to these tapes as follows:

Experimental Tapes		Current Tapes	
Program No.	Table No.	Program No.	Table No.
2011	XXXIII	2012	XLII
2021	XXXIV	2022	XLIII
2031	XXXV	2032	XLIV
2041	XXXVI	2042	XLV
2051	XXXVII	2052	XLVI
2061	XXXVIII	2062	XLVII
2071	XXXIX	2072	XLVIII
2081	XL	2082	XLIX

CONCLUSIONS

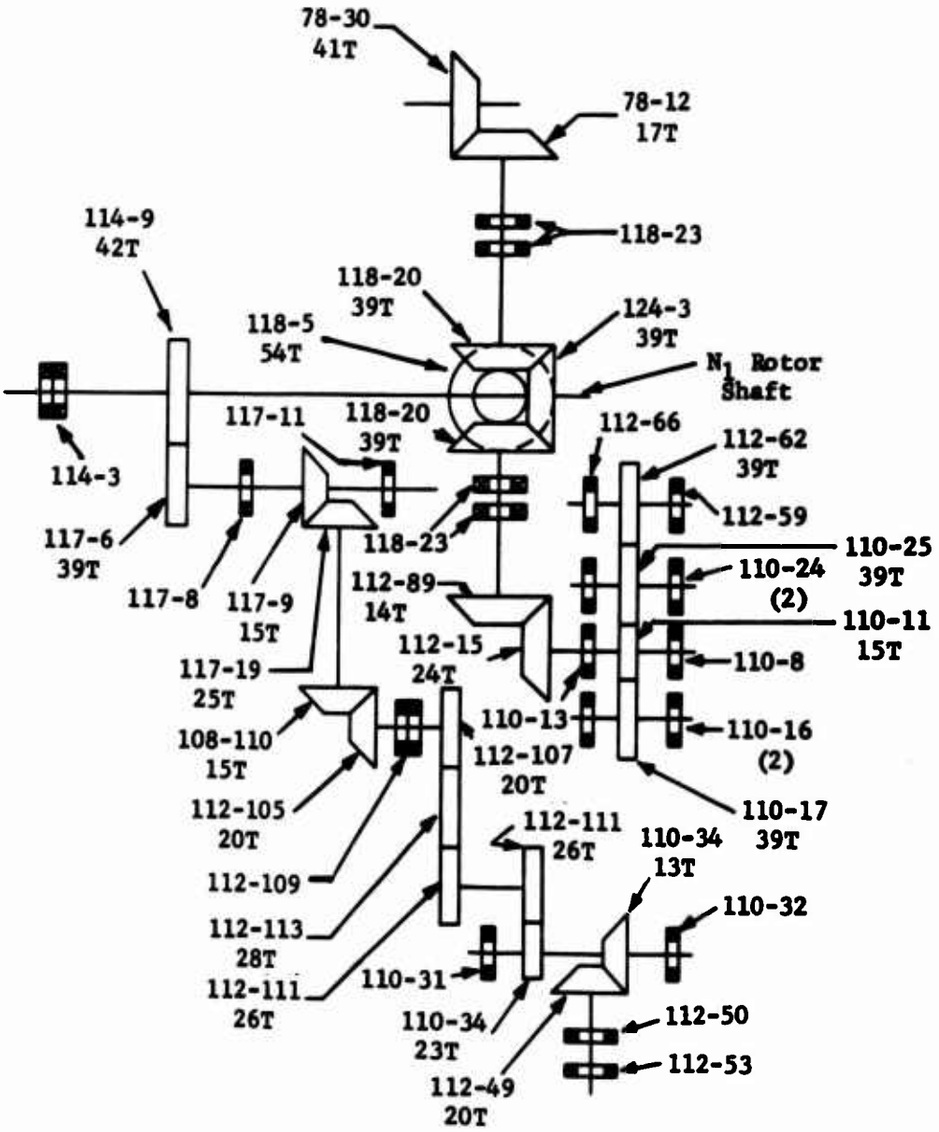
The Curtiss model CWCD-1000 Sonic Analyzer with the CWCD-1010 automation unit shows good potential as a successful indicator of power train component anomalies for the model CH-47A/B helicopters based on the satisfactory performance and operational characteristics exhibited during the field application program.

Final gain limits were established for the CH-47A/B helicopter complete dynamic system, which were consistent for all helicopters analyzed. However, a future program should be conducted to verify these gain limits by a teardown inspection of components with an indicated malfunction.

The incorporation of the CWCD-1020 microphone auxiliary switch box greatly enhanced the operation of the analyzer by reducing the time required for the 8 microphone connections and, consequently, the overall analysis time.

Due to the considerable amount of time required to scan the 540 items contained in the 8 program tapes, a more extensive investigation of a selected list of components which exhibit a history of chronic failure may be desirable in order to reduce the analysis time.

Starter Drive



Code: (118-20) Reference Program Index
Tables VI - XI

Figure 1. Gear and Bearing Arrangement - Engine Accessory and Drives T55-L-5,-7.

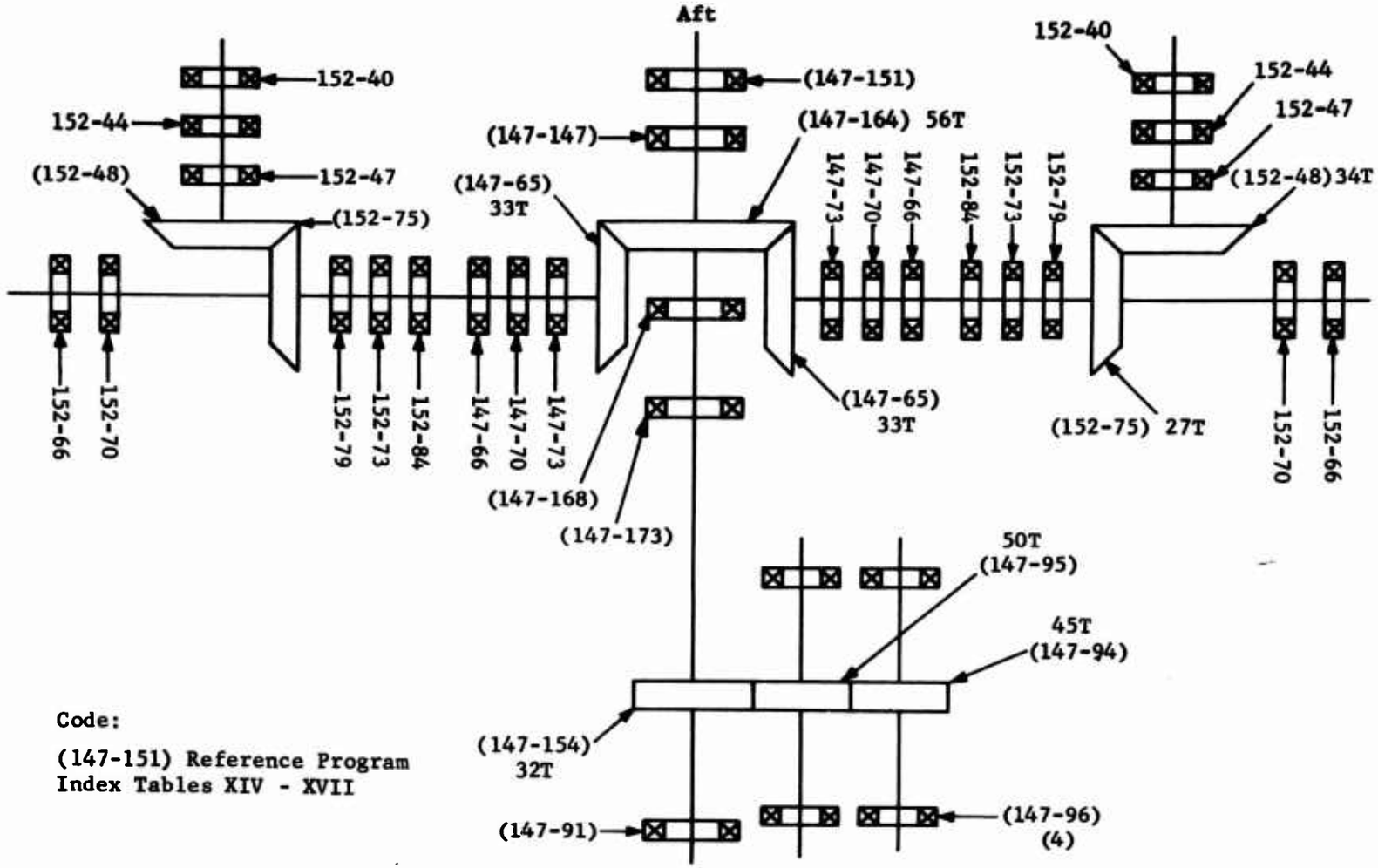
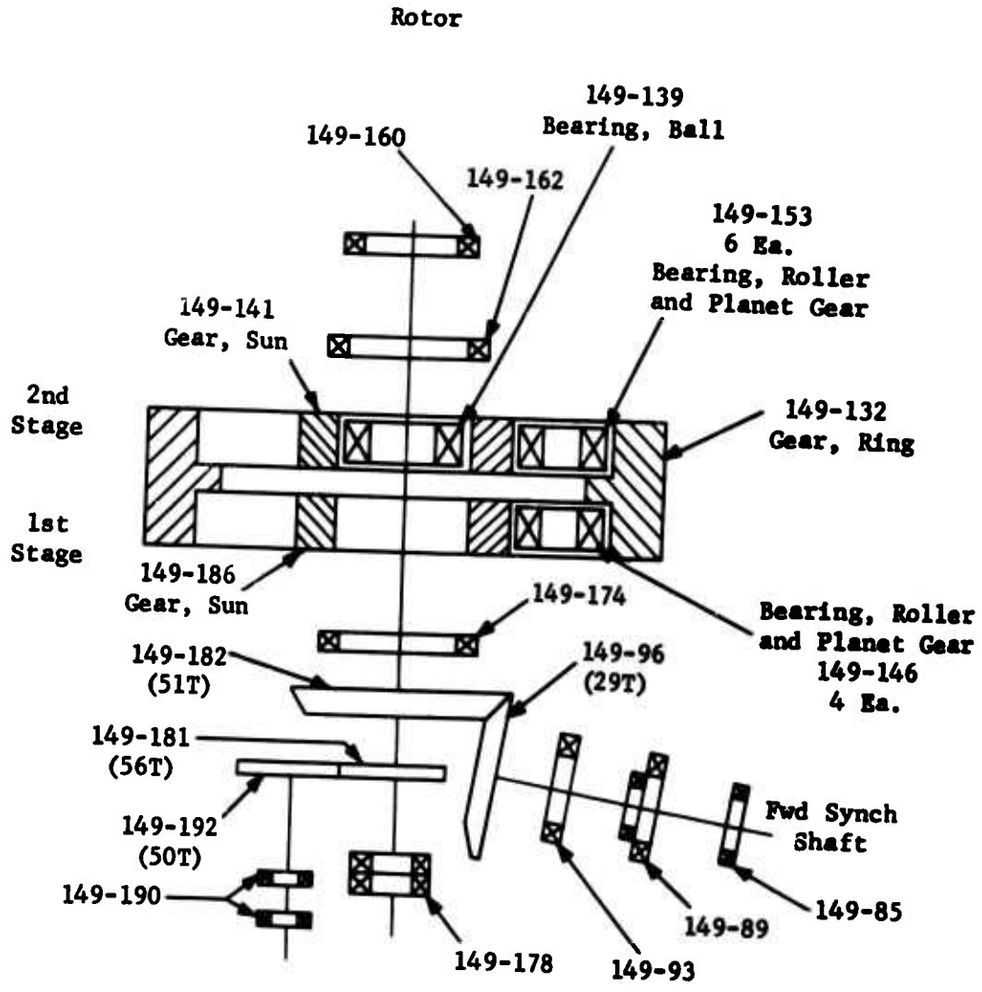
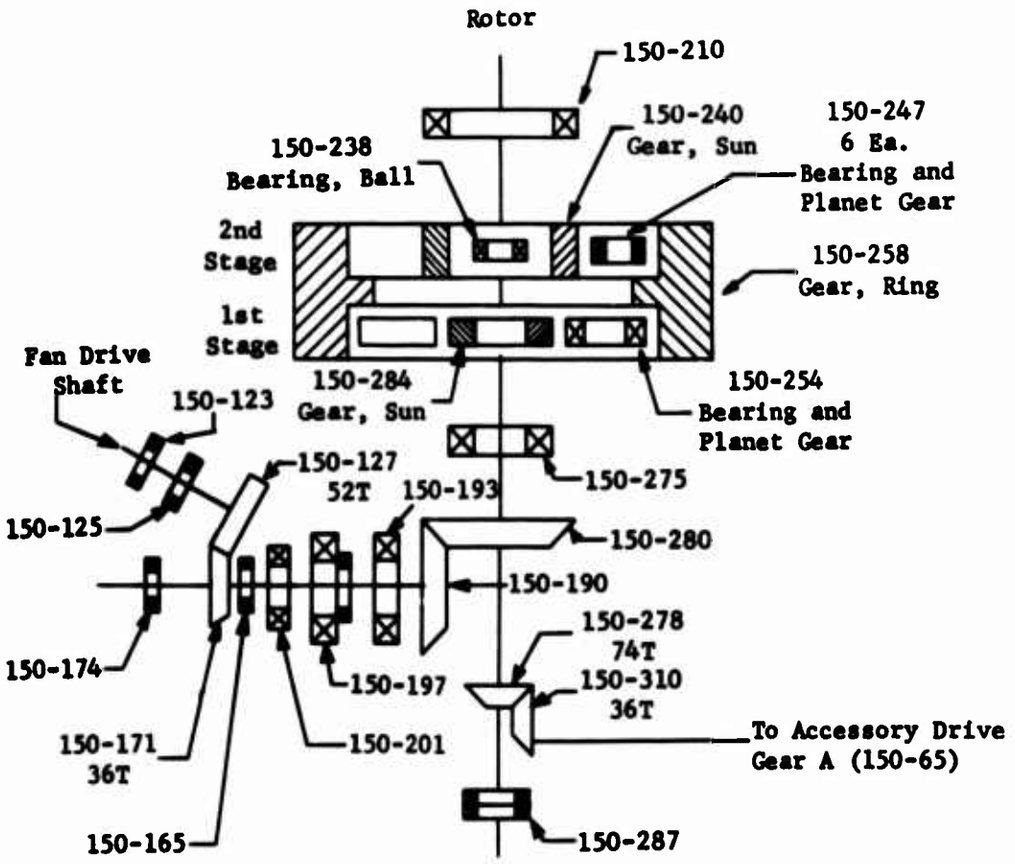


Figure 2. Gear and Bearing Arrangement - Engine 90° Transmissions and CH-47A/B Helicopter Combining Transmission.



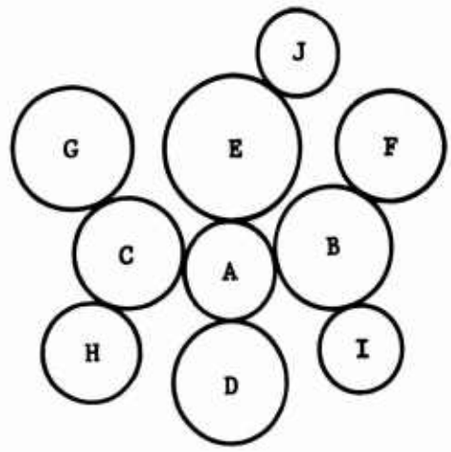
Code: (149-160) Reference Program Index Tables XXVII - XXX

Figure 3. Gear and Bearing Arrangement - CH-47A/B Forward Rotor Transmission.



Code: (150-210) Reference Program Index Tables XXI - XXIV

Figure 4. Gear and Bearing Arrangement - CH-47A/B Helicopter Aft Rotor Transmission.



View Looking Toward Accessories

Item	Program Index	Description
A	150-65	Gear, Spur, Accessory Drive, Aft - 30 Teeth
	150-67	Bearing, Ball, Annular - 2 Each
B	150-75	Gear, Spur, Idler, Accessory Drive, Aft - 36 Teeth
	150-77	Bearing, Ball, Annular - 2 Each
C	150-75	Gear, Spur, Idler, Accessory Drive, Aft - 36 Teeth
	150-77	Bearing, Ball, Annular - 2 Each
D	150-68	Gear, Spur, Hydraulic Motor - 31 Teeth
	150-70	Bearing, Ball, Annular - 2 Each
E	150-60	Gear, Spur, Lubricating Oil Pump Drive - 53 Teeth
	150-61	Bearing, Ball, Annular - 2 Each
F	150-57	Gear, Spur, Hydraulic Pump No. 2 Drive - 62 Teeth
	150-58	Bearing, Ball, Annular - 2 Each
G	150-57	Gear, Spur, Hydraulic Pump No. 1 Drive - 62 Teeth
	150-53	Bearing, Ball, Annular - 2 Each
H	150-72	Gear, Spur, Pinion, Alternator No. 1 Drive - 29 Teeth
	150-73	Bearing, Ball, Annular - 2 Each
I	150-72	Gear, Spur, Pinion, Alternator No. 2 Drive - 29 Teeth
	150-73	Bearing, Ball, Annular - 2 Each
J	150-54	Gear, Spur, Axial Piston Pump Drive - 53 Teeth
	150-55	Bearing, Ball, Annular - 2 Each

Code: (150-65) Reference Program Index Tables XXIII and XXIV

Figure 5. Gear and Bearing Arrangement - Accessory Drive Gearbox - CH-47A/B Helicopter Aft Rotor Transmission Assembly.

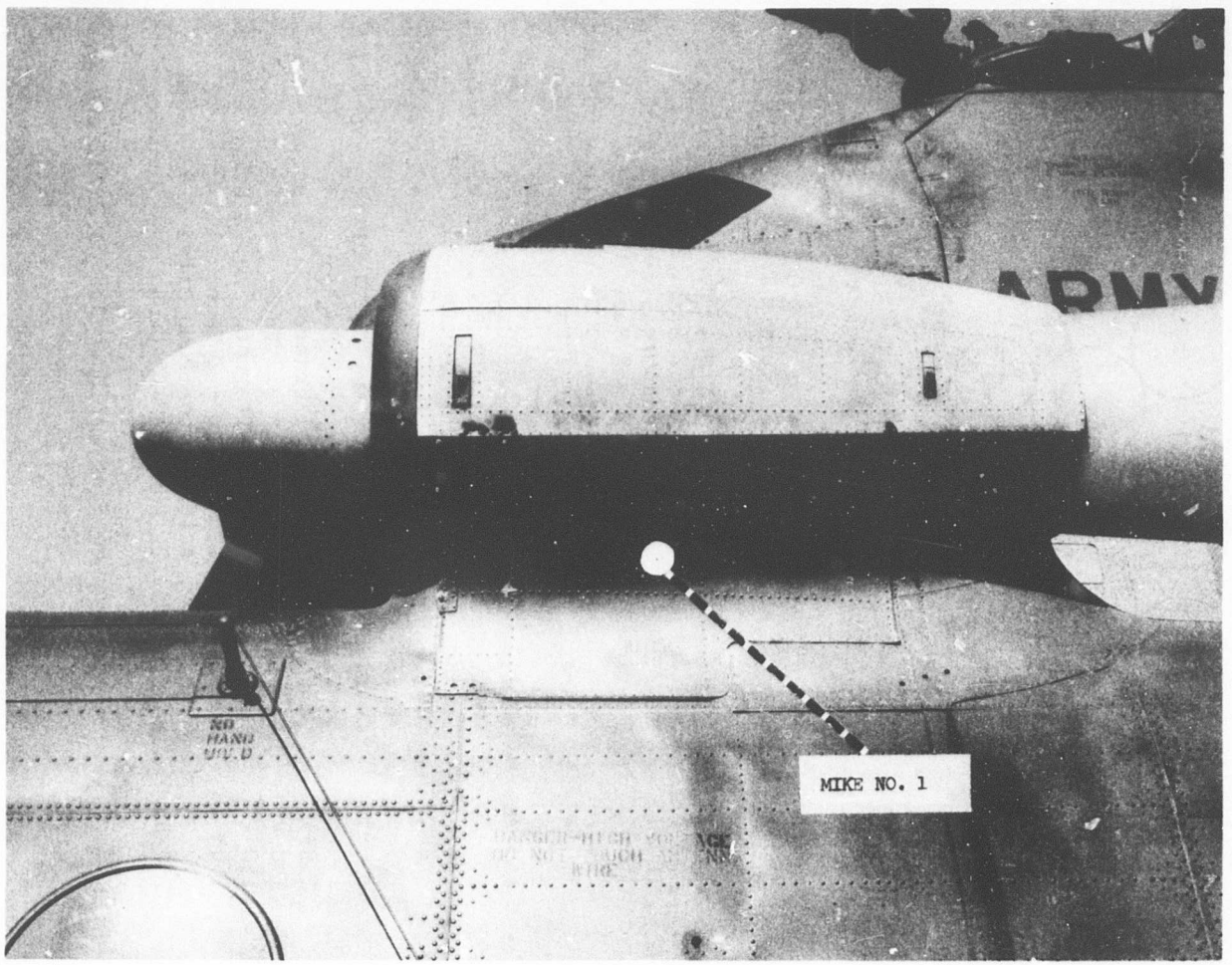


Figure 6. Location of Microphone No. 1, No. 1 Engine, CH-47A/B Helicopter.

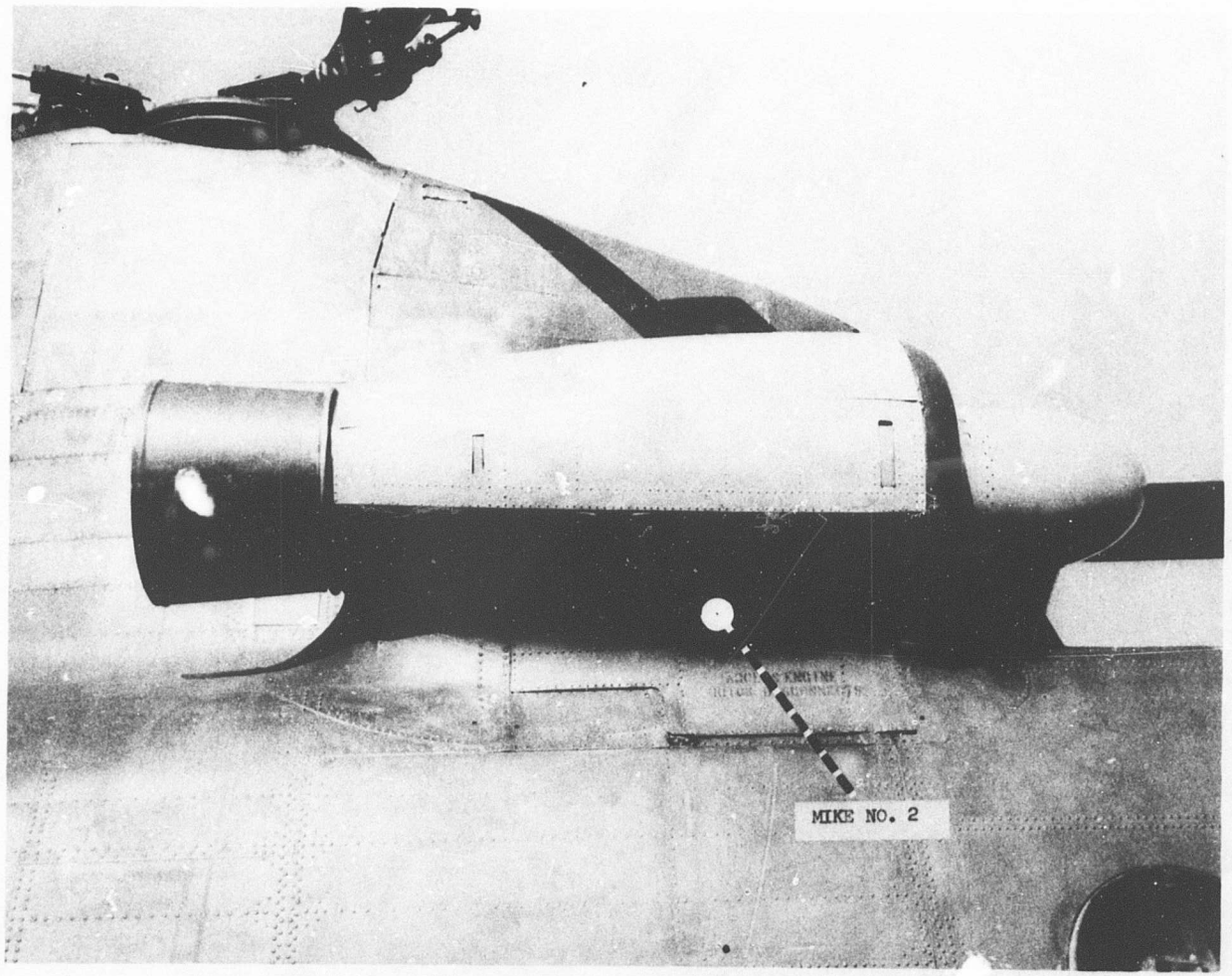


Figure 7. Location of Microphone No. 2, No. 2 Engine, CH-47A/B Helicopter.

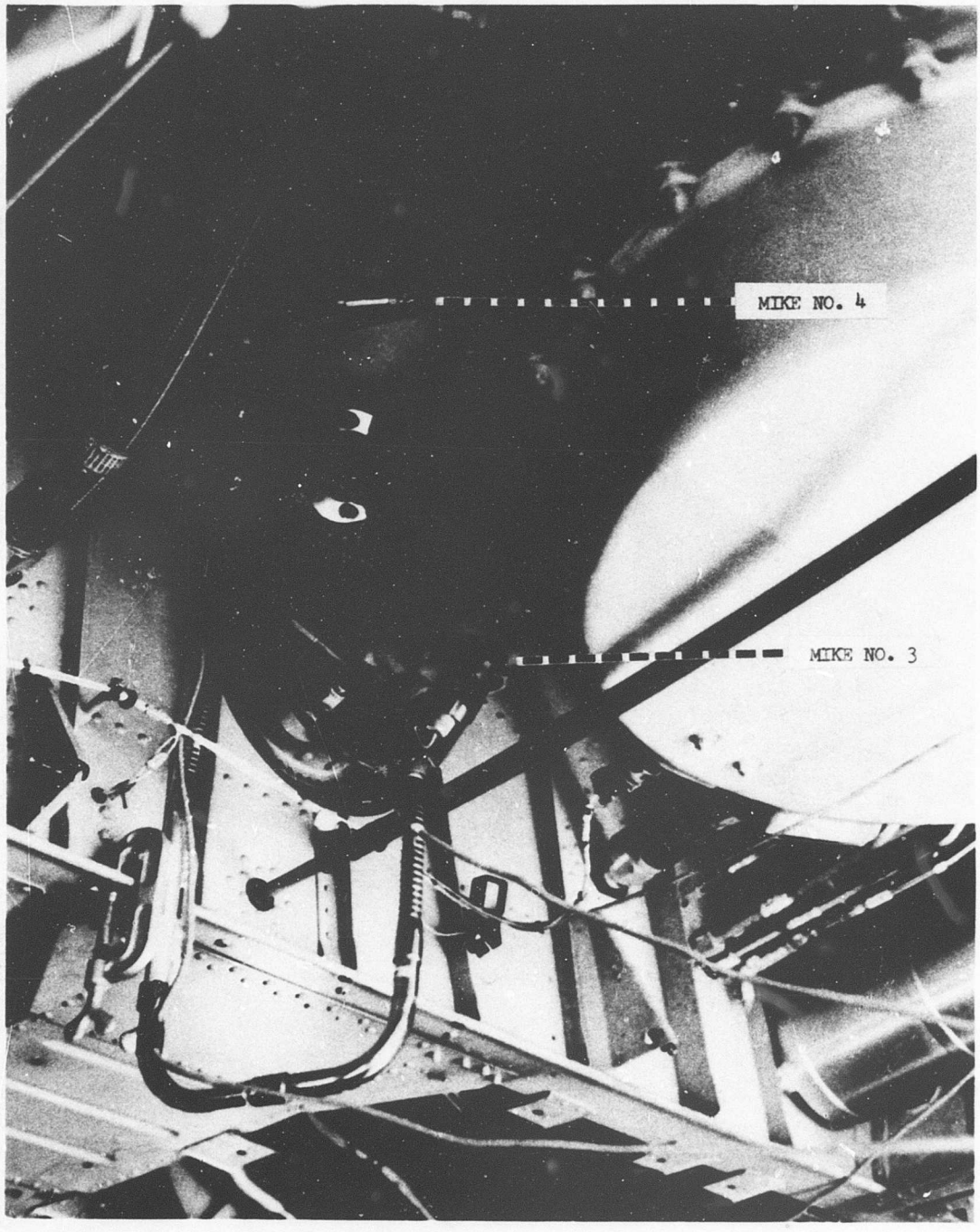


Figure 8. Location of Microphones Nos. 3 and 4, Aft Rotor Transmission, Ch-47A/B Helicopter.

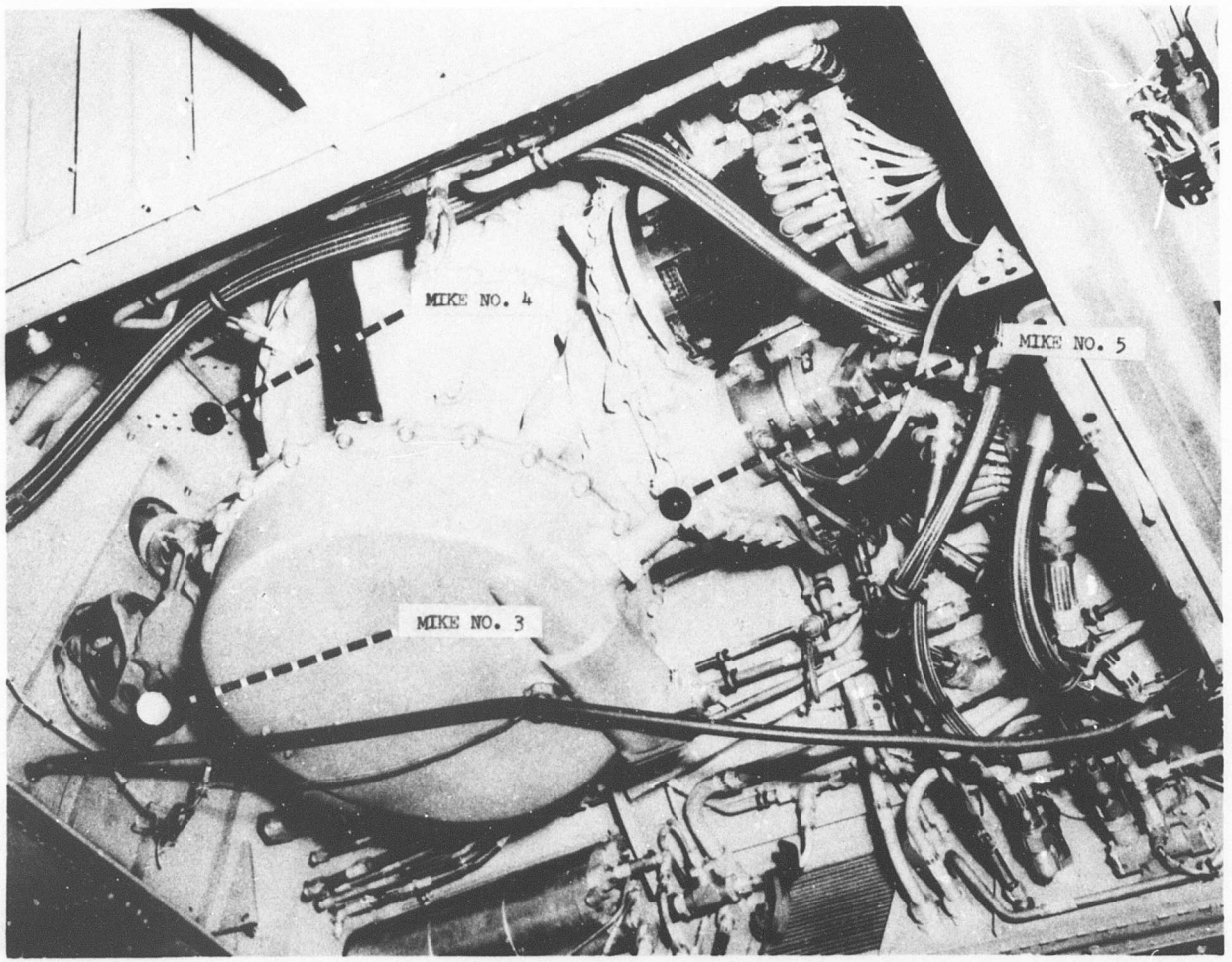


Figure 9. Location of Microphones Nos. 3, 4, and 5, Aft Rotor Transmission, CH-47A/B Helicopter.

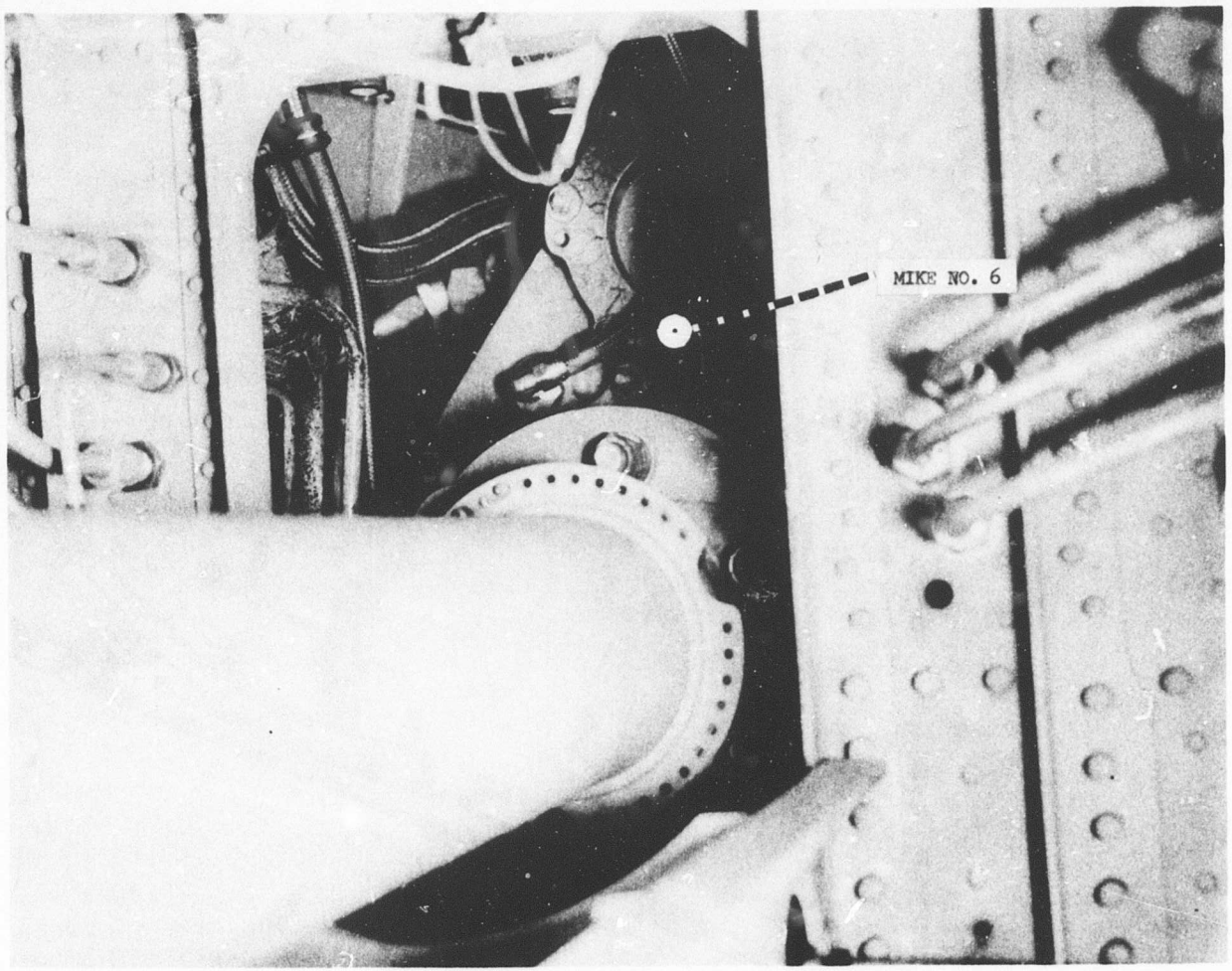


Figure 10. Location of Microphone No. 6, Combining Transmission, CH-47A/B Helicopter.

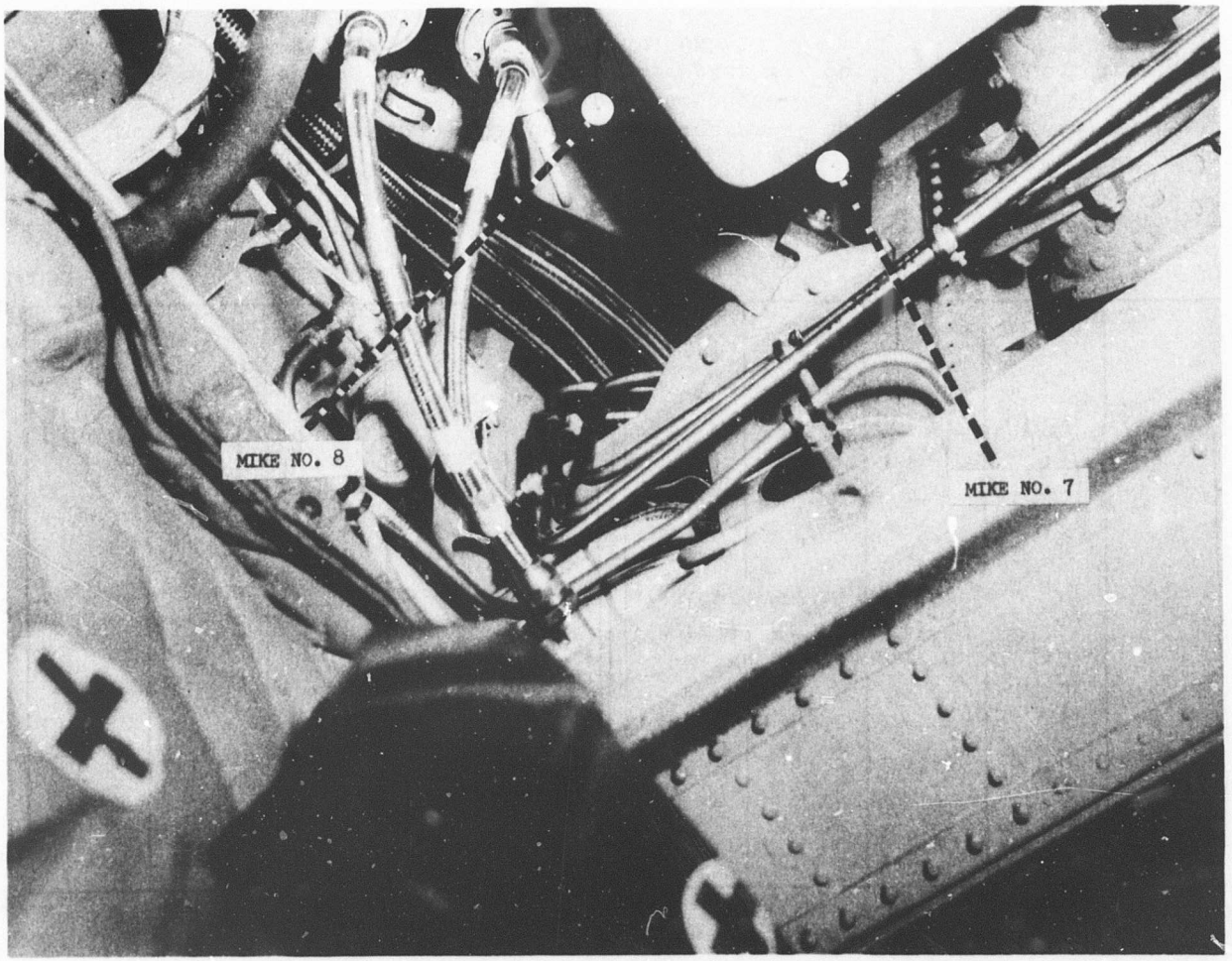


Figure 11. Location of Microphones Nos. 7 and 8, Forward Rotor Transmission, CH-47A/B Helicopter.

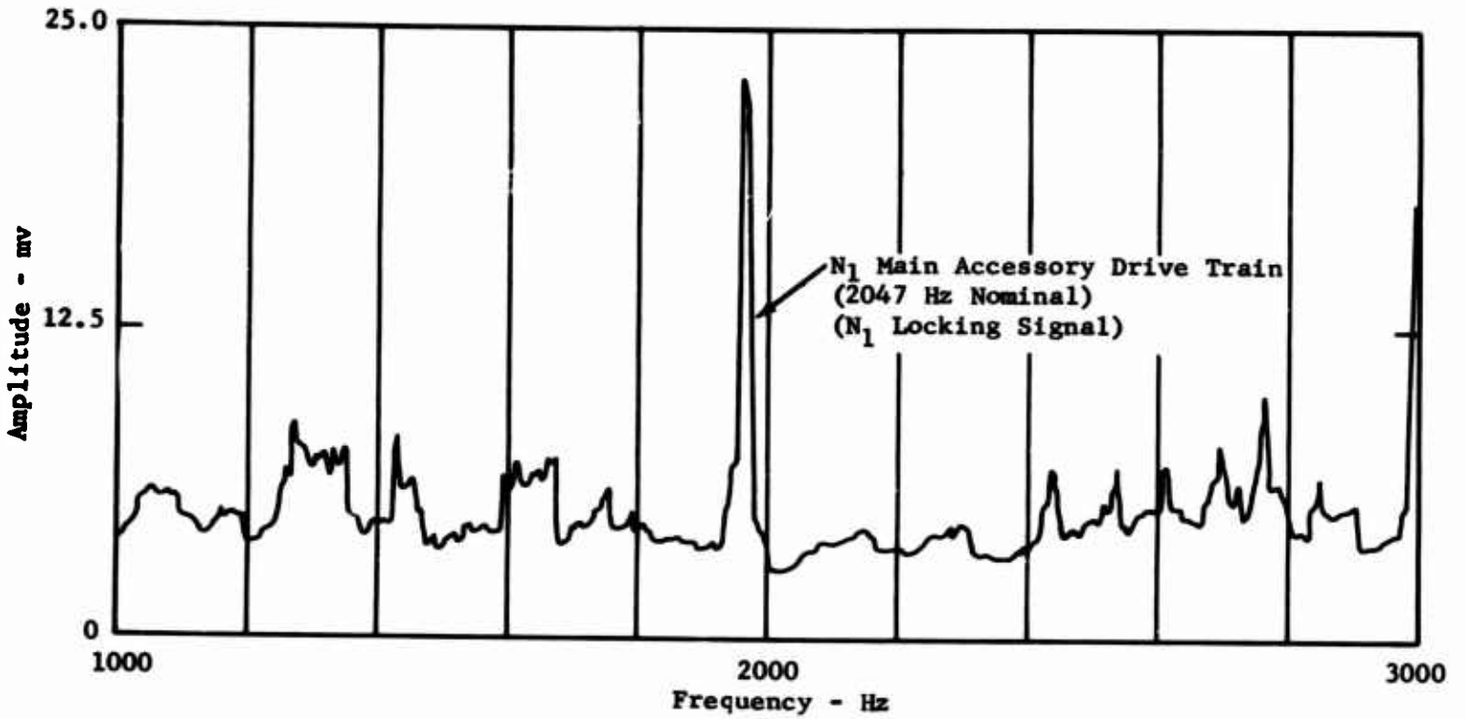


Figure 12. Amplitude vs. Frequency Spectrogram of No. 1 Engine, Main Accessory Drive Gear Train (Microphone No. 1) Showing the N_1 Locking Signal - CH-47B Helicopter No. 66-19139, Flight Idle Power Setting, Recording No. CH2-13.

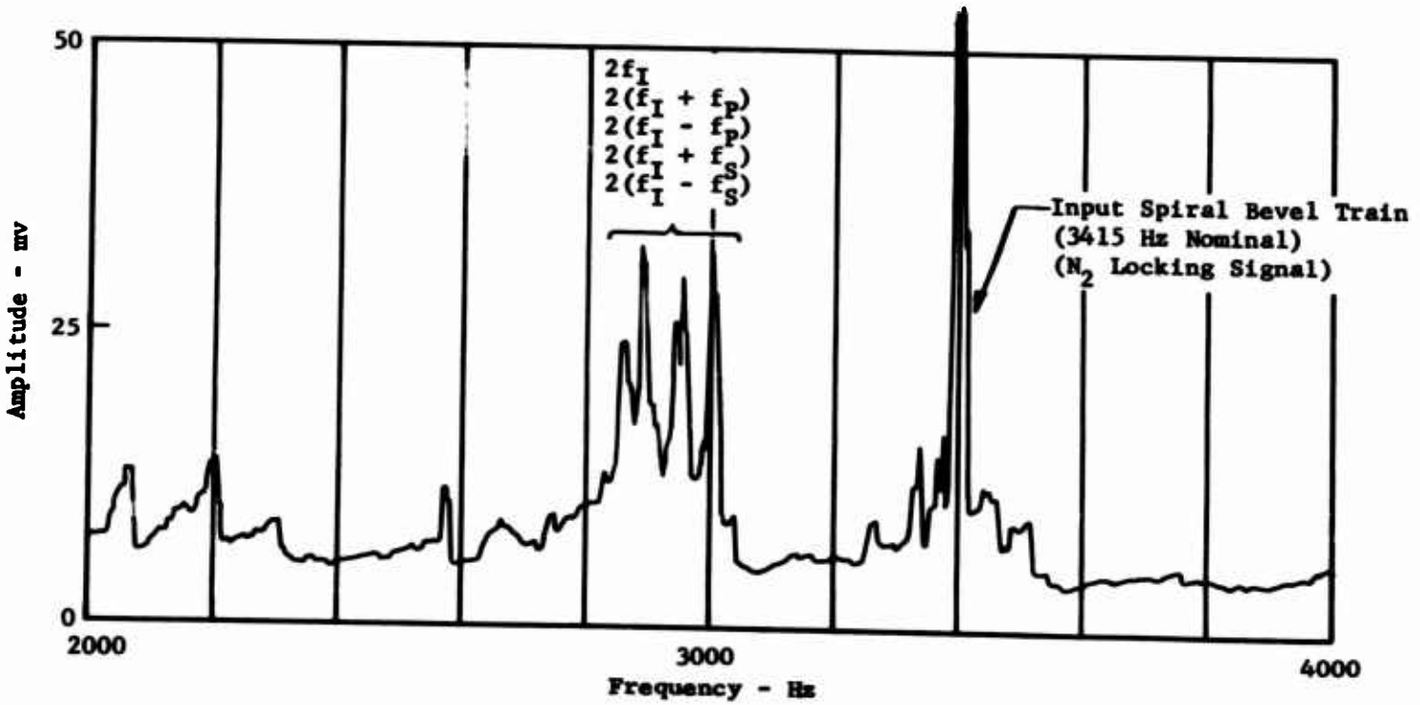


Figure 13. Amplitude vs. Frequency Spectrogram of Aft Rotor Transmission, 1st Stage Planetary Gear Train (Microphone No. 3) Showing the N_2 Locking Signal - CH-47A Helicopter No. 63-7911, Flight Idle Power Setting, Recording No. CH2-10.

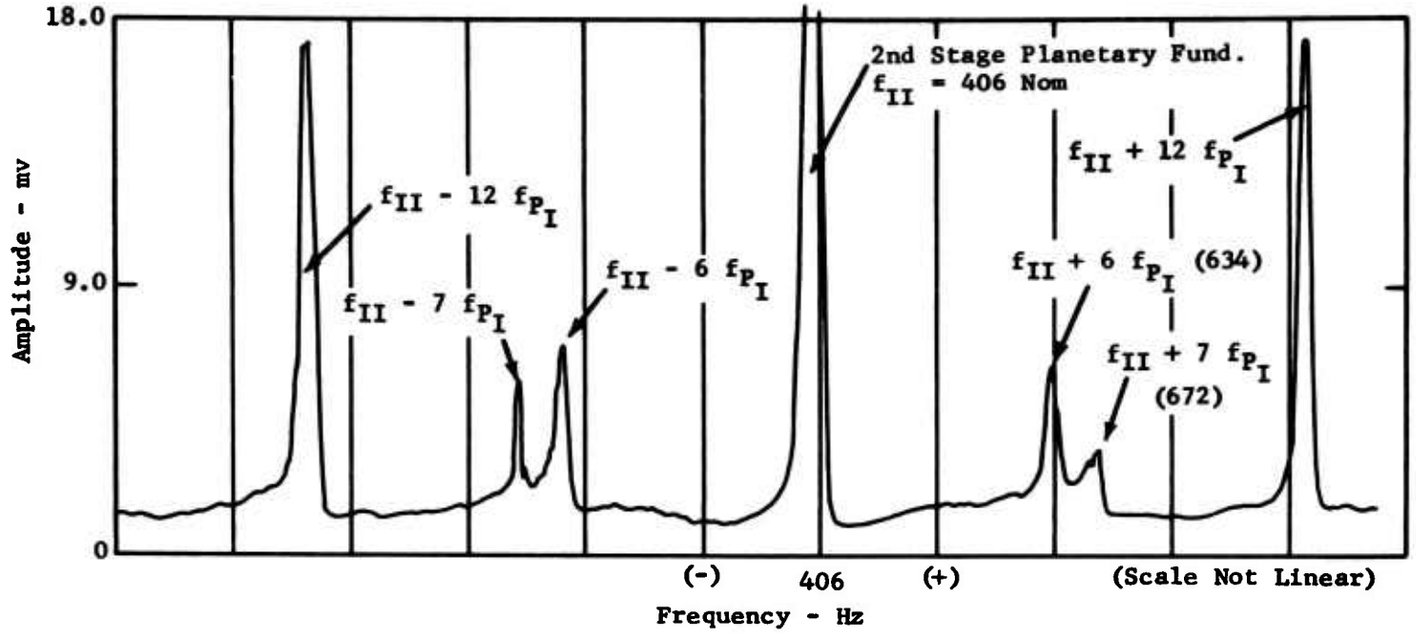


Figure 14. Amplitude vs. Frequency Spectrogram of Aft Rotor Transmission, 2nd Stage Planetary Gear Train (Microphone No. 3) Showing Sidebands - CH-47A Helicopter, Flight Idle Power Setting, Recording No. CH1-12.

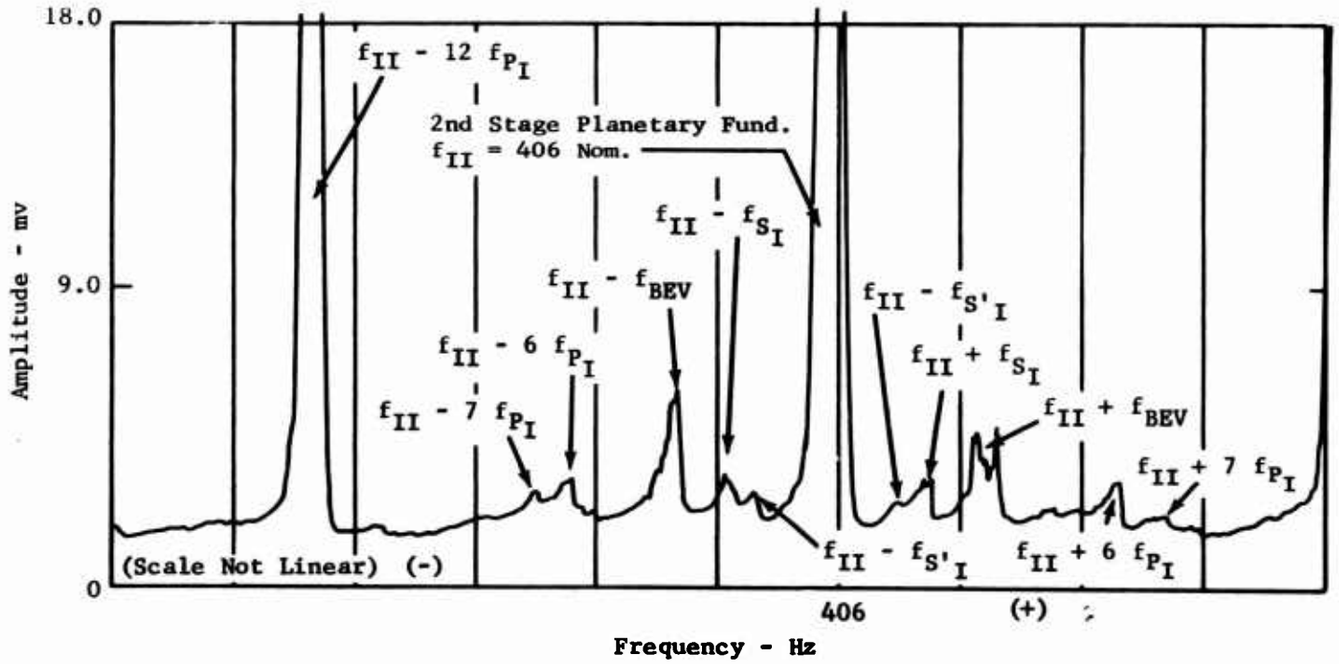


Figure 15. Amplitude vs. Frequency Spectrogram of Aft Rotor Transmission, 2nd Stage Planetary Gear Train (Microphone No. 4) Showing Sidebands - CH-47A Helicopter, Flight Idle Power Setting, Recording No. CH1-12.

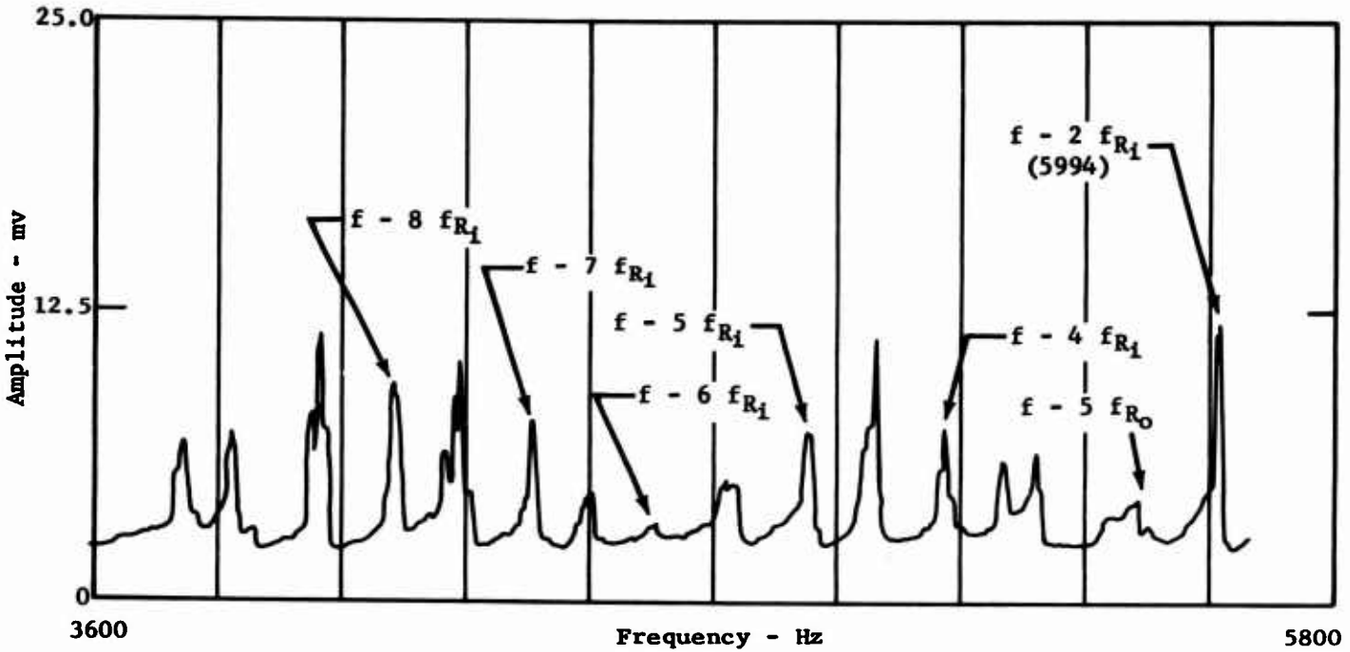


Figure 16. Amplitude vs. Frequency Spectrogram of Combining Transmission (Microphone No. 6) Showing Sidebands - CH-47A Helicopter, Flight Idle Power Setting, Recording No. CH1-12.

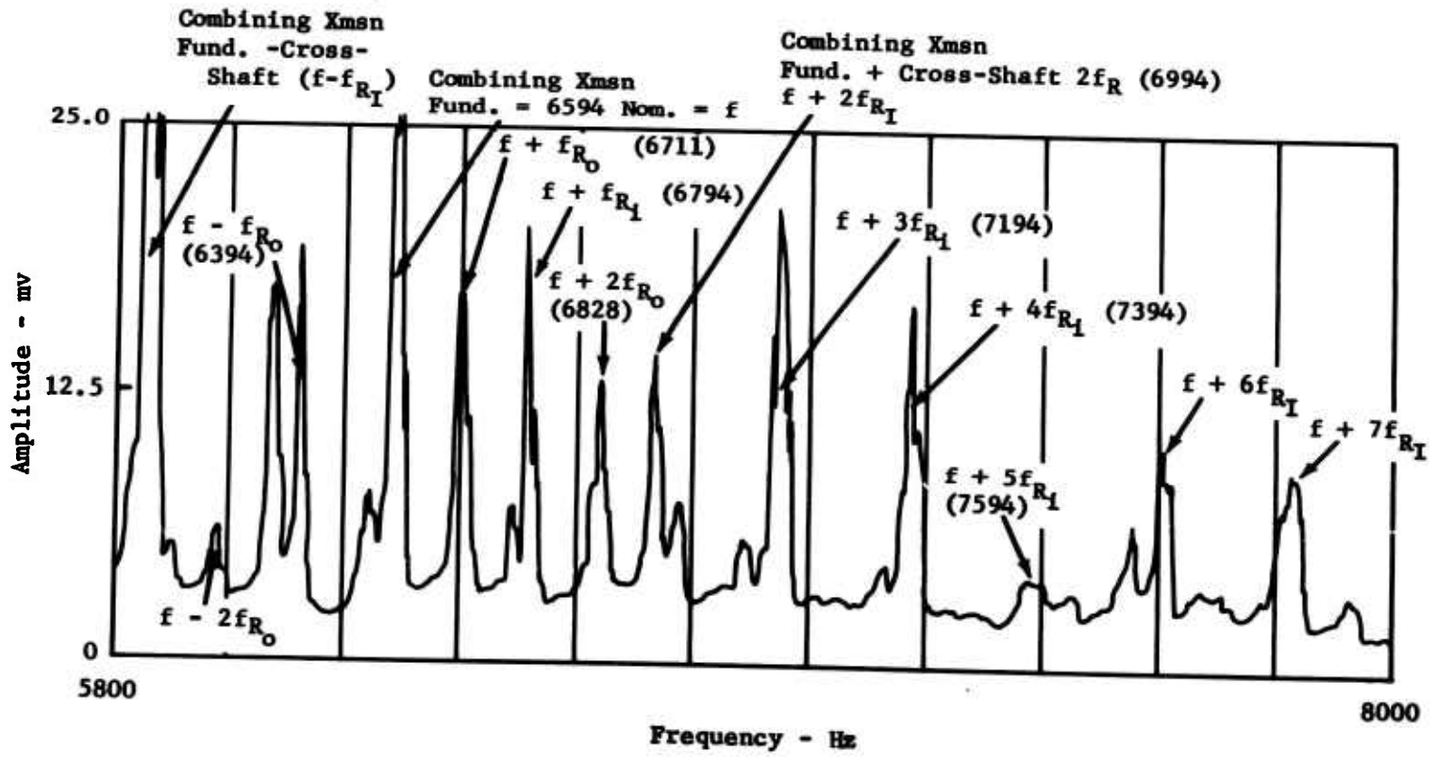


Figure 17. Amplitude vs. Frequency Spectrogram of Combining Transmission (Microphone No. 6) Showing Sidebands - CH-47A Helicopter, Flight Idle Power Setting, Recording No. CH1-12.

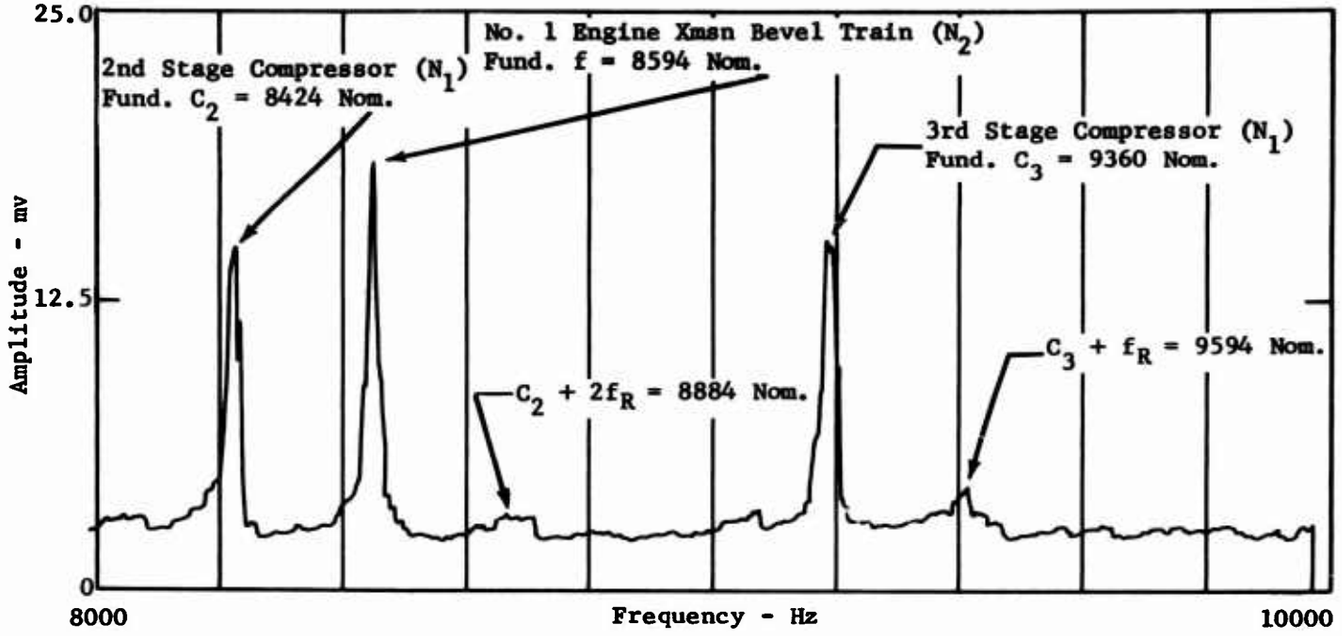


Figure 18. Amplitude vs. Frequency Spectrogram of No. 1 Engine (Microphone No. 1) Showing a Typical Engine Spectrum - CH-47A Helicopter No. 61-2408, Flight Idle Power Setting, Recording No. CH2-15.

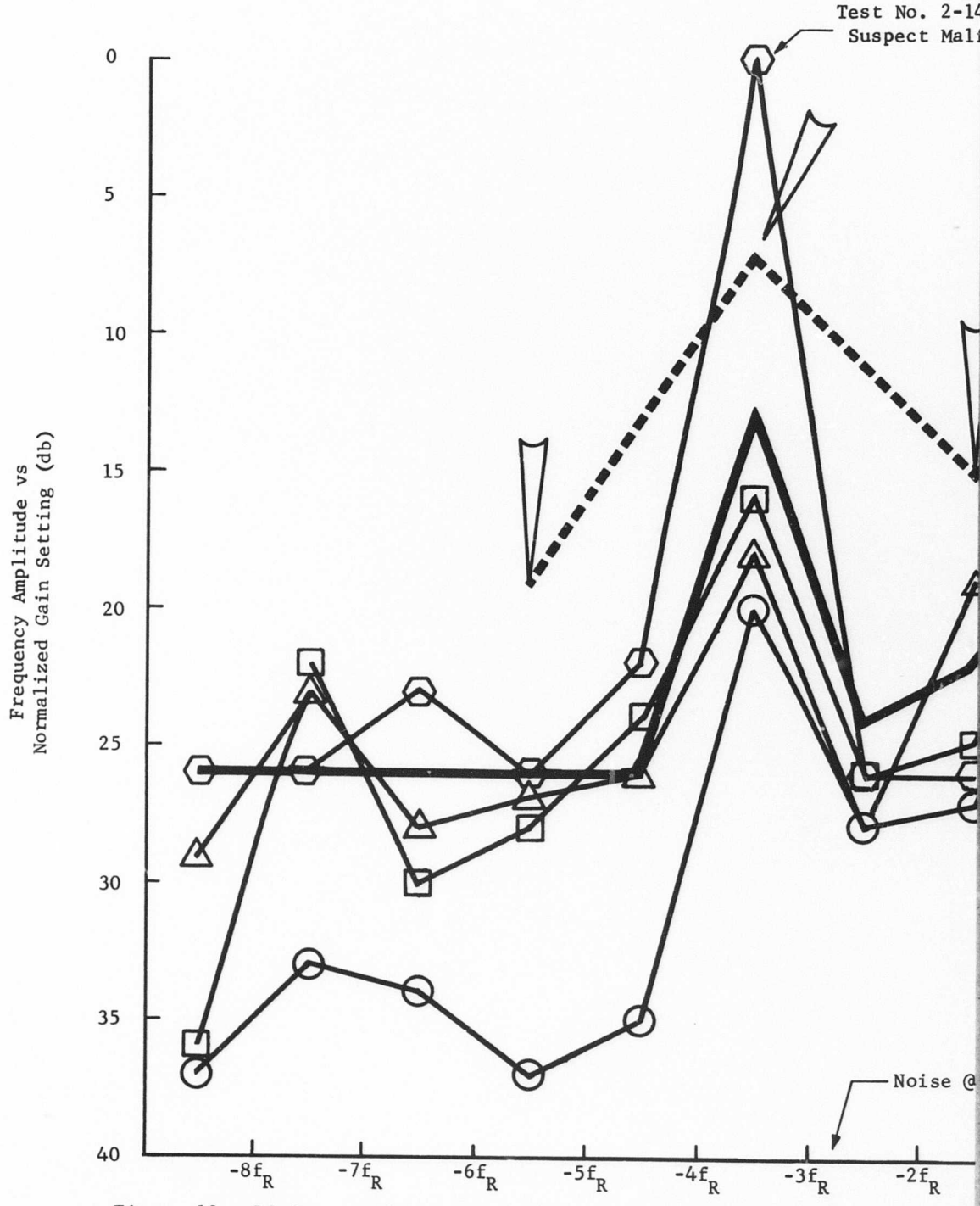
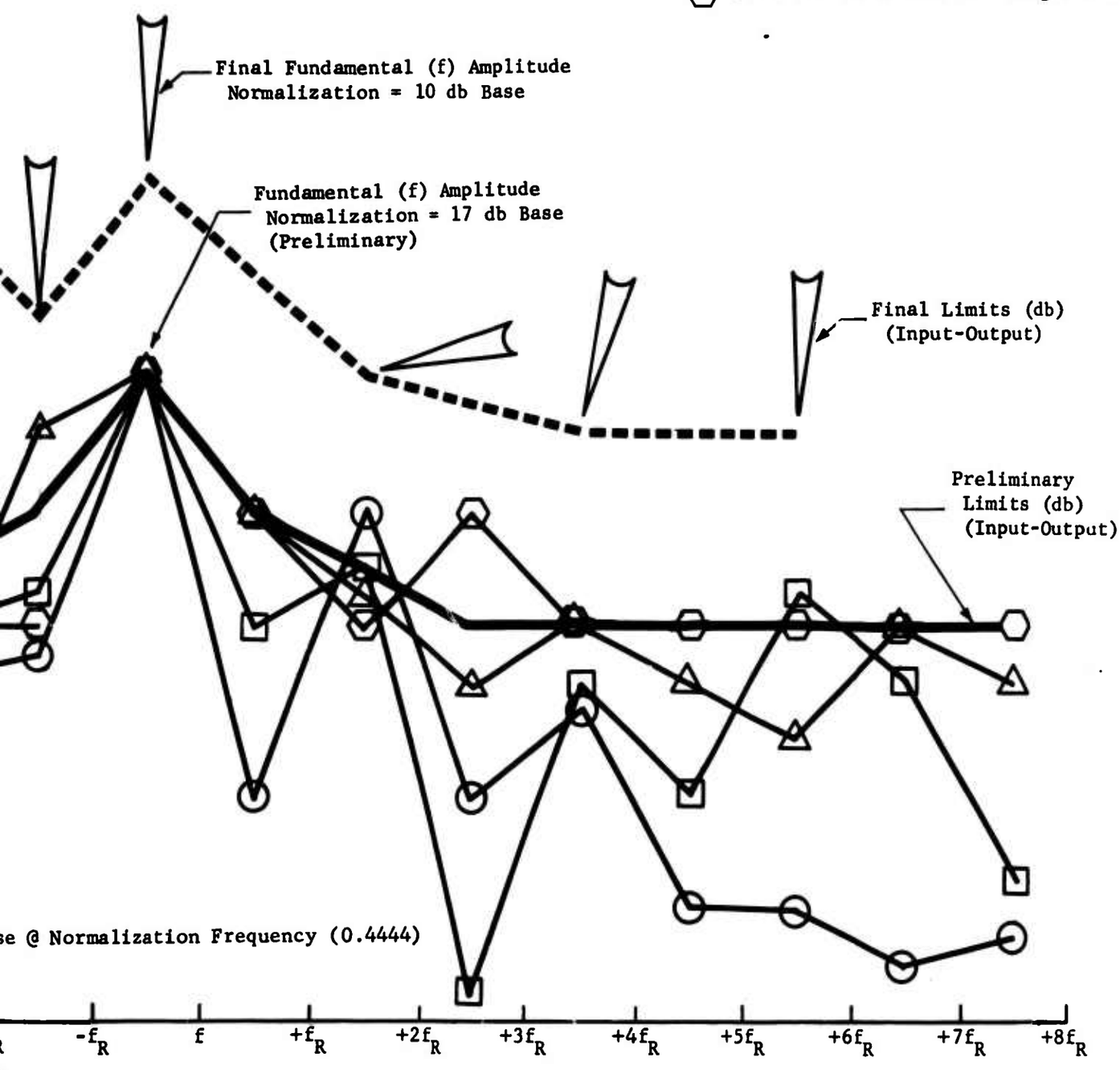


Figure 19. Limits - Sideband Frequencies - Input/Output Shaft CH-47A/B Helicopter Combining Transmission.

A

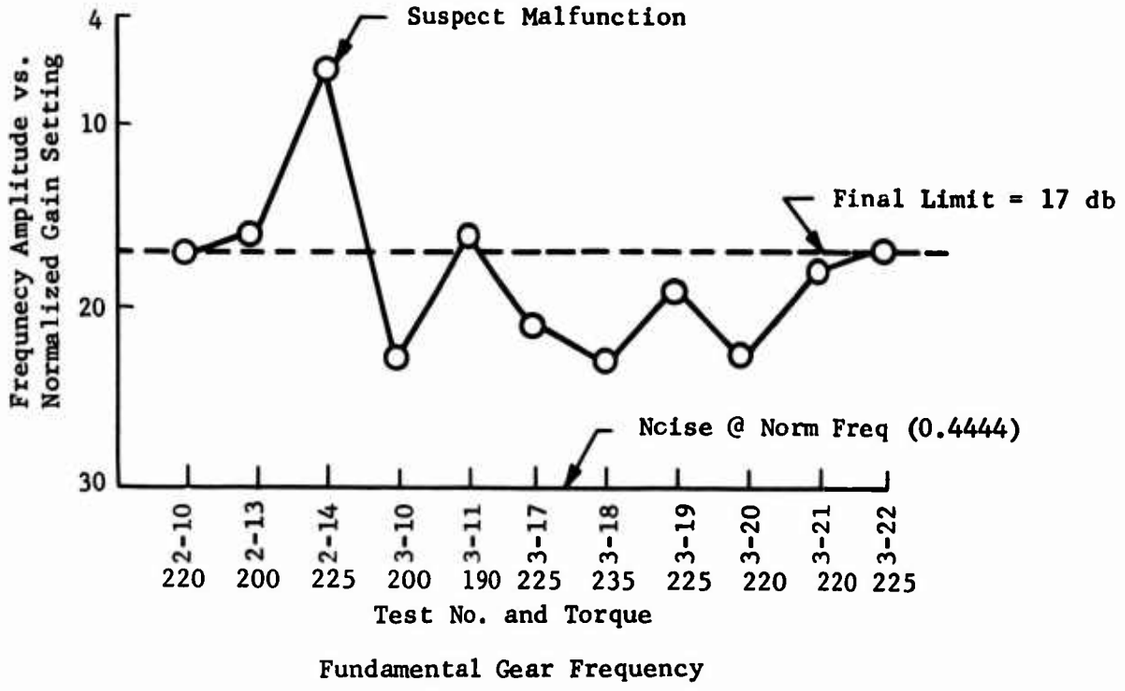
2-14
Malfunction

Code: ⊙ = 190 lb. in x 1000 = ξ Teng/2 @ 230 Rotor RPM
□ = 200 lb. in x 1000 = ξ Teng/2 @ 230 Rotor RPM
△ = 220 lb. in x 1000 = ξ Teng/2 @ 230 Rotor RPM
⬡ = 225 lb. in x 1000 = ξ Teng/2 @ 230 Rotor RPM

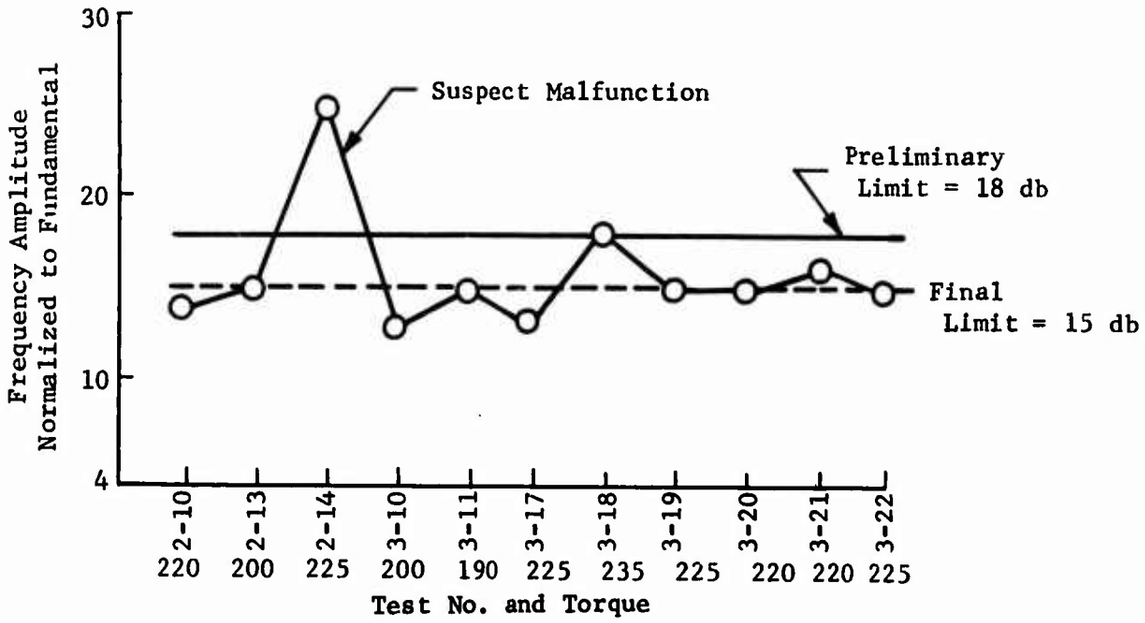


B

13



Fundamental Gear Frequency



Fundamental Gear Frequency x2 Ratio to Fundamental

Figure 20. Limits - Fundamental Gear Frequency CH-47A/B Combining Transmission.

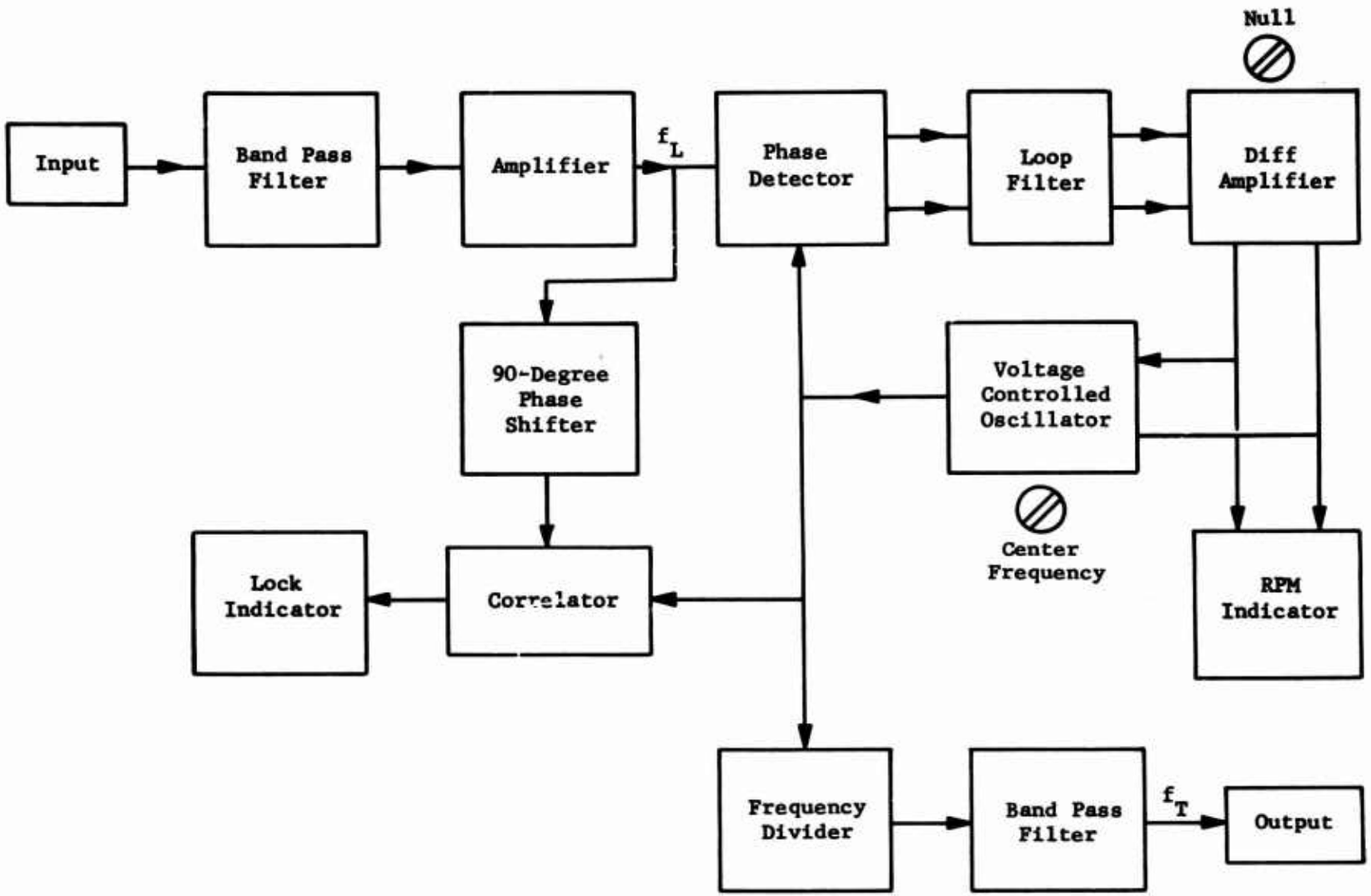


Figure 21. Block Diagram - Phase Locked Filter.

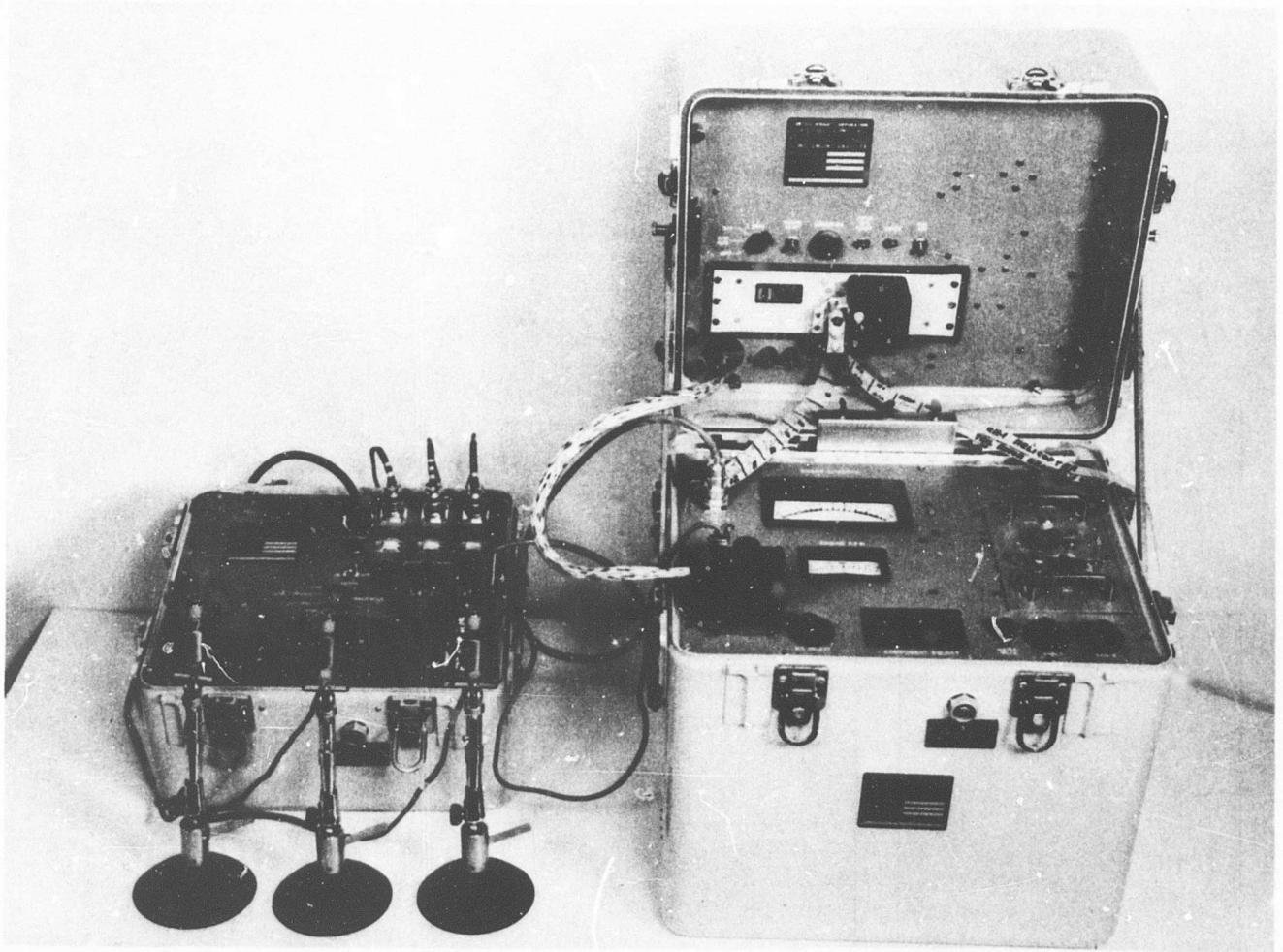
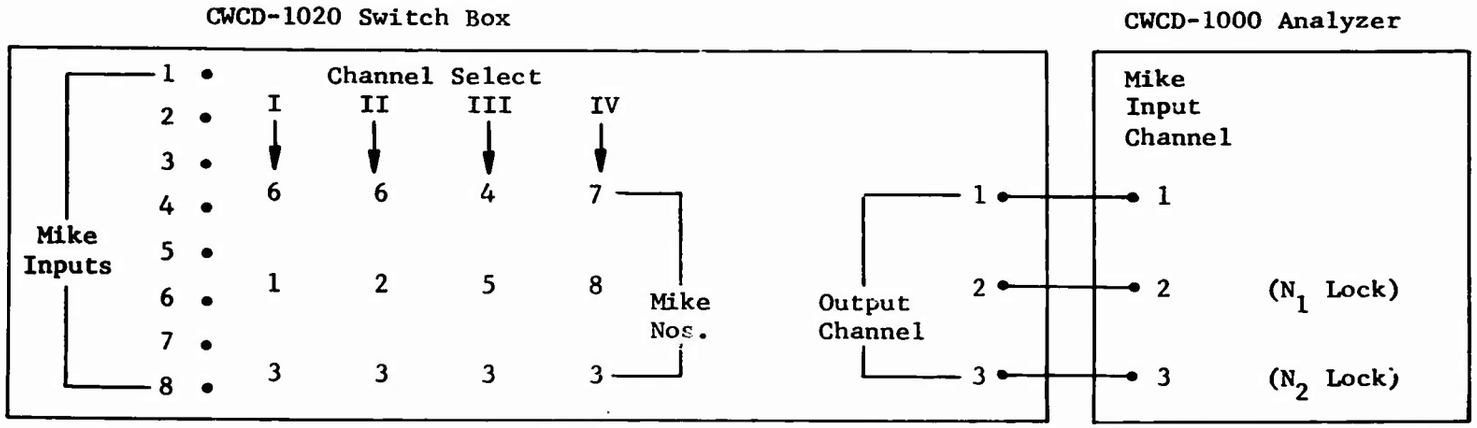


Figure 22. CWCD-1000 Sonic Analyzer Instrumentation, Power Supply, and CWCD-1010 Automation Unit.



Mike No.	Location
1	No. 1 Engine
2	No. 2 Engine
3	Aft Rotor Xmsn - 1st Stage
4	Aft Rotor Xmsn - 2nd Stage
5	Aft Rotor Xmsn - Accessory Gearbox
6	Combining Xmsn
7	Forward Rotor Xmsn - 1st Stage
8	Forward Rotor Xmsn - 2nd Stage

Figure 23. Microphone Switching Arrangement - CWCD-1020 Switch Box.

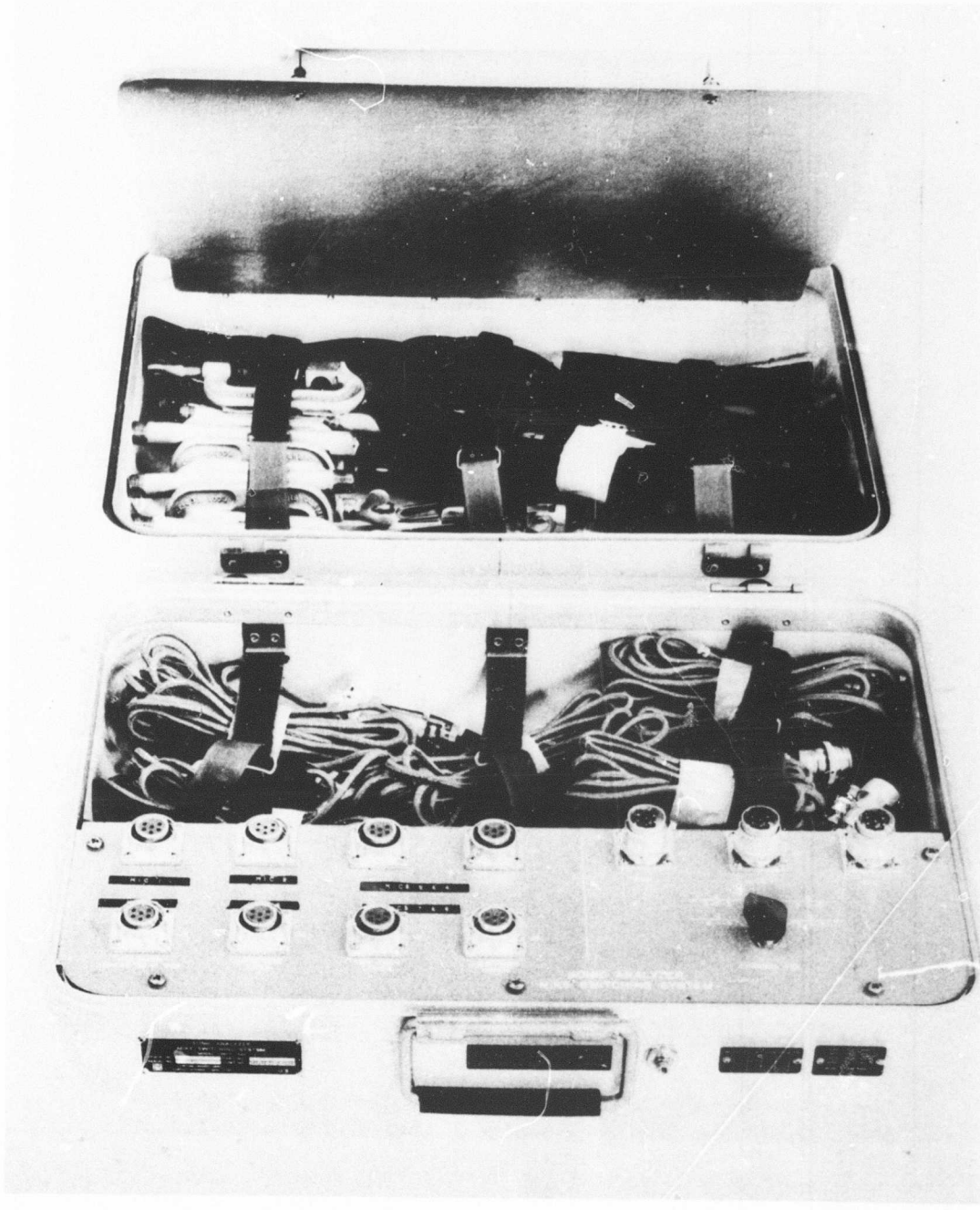


Figure 24. CWCD-1020 Microphone Auxiliary Switch Box.

TABLE I. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, GAS PRODUCER SECTION, COMPRESSOR BLADE PASSAGE (N_1-RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)*		Decimal Ratio	Octal Ratio
1-1	N. A.	124-23-1	2-100-021-02	1ST STAGE	C_1	6552	0.800195	0.6315
1-2	N. A.	124-23-2		COMPRESSOR	C_1+f_R	6786	0.828773	0.6503
1-3	N. A.	124-23-3		(28 BLADES)	C_1+2f_R	7020	0.857352	0.6670
1-4	N. A.	124-23-4			C_1-f_R	6318	0.771617	0.6130
1-5	N. A.	124-23-5			C_1-2f_R	6084	0.743038	0.5743
2-6	N. A.	124-28-1	2-100-022-02	2ND STAGE	C_2	8424	1.028822	1.0166
2-7	N. A.	124-28-2		COMPRESSOR	C_2+f_R	8658	1.057401	1.0353
2-8	N. A.	124-28-3		(36 BLADES)	C_2+2f_R	8892	1.085979	1.0540
2-9	N. A.	124-28-4			C_2-f_R	8190	1.000244	1.0001
2-10	N. A.	124-28-5			C_2-2f_R	7956	0.971665	0.7614
3-11	N. A.	124-34-1	2-100-023-03	3RD STAGE	C_3	9360	1.143136	1.1112
3-12	N. A.	124-34-2		COMPRESSOR	C_3+f_R	9594	1.171714	1.1277
3-13	N. A.	124-34-3		(40 BLADES)	C_3-f_R	9126	1.114557	1.0725
4-14	N. A.	124-40-1	2-100-024-03	4TH & 5TH STAGES	C_{4-5}	11232	1.371763	1.2763
4-15	N. A.	124-40-2	2-100-025-02	COMPRESSOR	$C_{4-5}+f_R$	11466	1.400341	1.3150
4-16	N. A.	124-40-3		(48 BLADES)	$C_{4-5}-f_R$	10998	1.343185	1.2576
5-17	N. A.	124-52-1	2-100-026-02	6TH & 7TH STAGES	C_{6-7}	11700	1.428920	1.3335
5-18	N. A.	124-52-2	2-100-027-02	COMPRESSOR	$C_{6-7}+f_R$	11934	1.457498	1.3522
5-19	N. A.	124-52-3		(50 BLADES)	$C_{6-7}-f_R$	11466	1.400341	1.3150

TABLE I - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)*		Decimal Ratio	Octal Ratio
6-20	N. A.	124-63-1	2-100-180-13	CENTRIFUGAL STAGE	C_C	7956	0.971665	0.7614
6-21	N. A.	124-63-2		(34 BLADES)	C_C+f_R	8190	1.000244	1.0001
6-22	N. A.	124-63-3			C_C-f_R	7722	0.943087	0.7427
7-23	N. A.	124-23-6		1ST STAGE - 2ND	$2C_1$	13104	1.600390	1.4633
7-24	N. A.	124-23-7		HARMONIC	$2C_1+f_R$	13338	1.628969	1.5020
7-25	N. A.	124-23-8			$2C_1-f_R$	12870	1.571812	1.4446
8-26	N. A.	124-28-6		2ND STAGE - 2ND	$2C_2$	16848	2.057645	-
8-27	N. A.	124-28-7		HARMONIC	$2C_2+f_R$	17082	2.086223	-
8-28	N. A.	124-28-8			$2C_2-f_R$	16614	2.029066	-
9-29	N. A.	124-23-9		ADDITIONS	C_1+C_2	14976	1.829018	1.6504
9-30	N. A.	124-23-10			C_2+C_3	17784	2.171958	-
9-31	N. A.	124-23-11			C_1+C_3	15912	1.943331	1.7430

* Based on 75.0% N1 Speed; f_R = 234.0 rps

TABLE II. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, GAS PRODUCER TURBINE SECTION, BLADE PASSAGE (N_1 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)*		Decimal Ratio	Octal Ratio
1-1	N. A.	124-90-1	2-120-001-55	1ST STAGE TURBINE	T_1	19656	2.400586	-
1-2	N. A.	124-90-2	2-120-001-54	ROTOR (84 BLADES)	T_1+f_R	19890	2.429164	-
1-3	N. A.	124-90-3			T_1-f_R	19422	2.372007	-

* Based on 75. 0% N_1 Speed; f_R = 234. 0 rps

TABLE III. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, POWER TURBINE SECTION, BLADE PASSAGE (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)*		Decimal Ratio	Octal Ratio
1-1	N. A.	128-34-1	2-140-001-34	2ND STAGE TURBINE	T_2	16682	1.628306	1.5016
1-2	N. A.	128-34-2		ROTOR (66 BLADES)	$T_2 \cdot f_R$	16935	1.653001	1.5163
1-3	N. A.	128-34-3			$T_2 - f_R$	16429	1.603611	1.4650
2-4	N. A.	128-24-1	2-140-002-41	3RD STAGE TURBINE	T_3	14155	1.381649	1.3033
2-5	N. A.	128-24-2		ROTOR (56 BLADES)	$T_3 \cdot f_R$	14408	1.406344	1.3200
2-6	N. A.	128-24-3			$T_3 - f_R$	13902	1.356954	1.2666

* Based on 230.0 Rotor RPM; f_R = 252.8 rps

TABLE IV. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, MAIN ROTOR SHAFT BEARINGS, COMPRESSOR (N_1 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)*	Decimal Ratio	Octal Ratio
1-1	N. A.	124-5-1	2-300-001-02	NO. 2 MAIN BEARING	f_R	234	0.028578	0.0165
1-2	N. A.	124-5-2	(Fafnir	COMPRESSOR SHAFT,	f_T	96	0.011724	0.0060
1-3	N. A.	124-5-3	MM214VM	FORWARD	f_B	639	0.078041	0.0500
1-4	N. A.	124-5-4	5MSR E8784)		f_B'	1278	0.156082	0.1177
1-5	N. A.	124-5-5	(Ball Dia	- d_B = 0.6875	$3f_B'$	3835	0.468368	0.3576
1-6	N. A.	124-5-6	No. Balls	- m = 15	f_1	2067	0.252442	0.2012
1-7	N. A.	124-5-7	Raceway	- d_1 = 3.188	f_2	1444	0.176355	0.1322
				- d_2 = 4.563				
			Shaft RPS	- f_R = 234.13)				
2-8	N. A.	124-78-1	2-300-004-02	NO. 3 MAIN BEARING	f_R	234	0.028578	0.0165
2-9	N. A.	124-78-2	(SKF 456535)	COMPRESSOR SHAFT,	f_T	105	0.012823	0.0065
2-10	N. A.	124-78-3		AFT	f_B	1127	0.137640	0.1064
2-11	N. A.	124-78-4	(Roller Dia	- d_B = 0.435	f_B'	2254	0.275280	0.2150
2-12	N. A.	124-78-5	No. Rollers	- m = 18	$3f_B'$	6763	0.825964	0.6467
2-13	N. A.	124-78-6	Raceway	- d_1 = 3.798	f_1	2324	0.283829	0.2213
2-14	N. A.	124-78-7		- d_2 = 1.668	f_2	1891	0.230947	0.1662
			Shaft RPS	- f_R = 234.13)				

* Based on 75.0% N_1 Speed

TABLE V. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, MAIN ROTOR SHAFT BEARINGS, POWER TURBINE (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)*	Decimal Ratio	Octal Ratio
1-1	N. A.	128-47-1	2-300-006-02	NO. 1 MAIN BEARING	f_R	253	0.024694	0.0145
1-2	N. A.	128-47-2	(MRC R-109-	TURBINE SHAFT,	f_T	110	0.010736	0.0054
1-3	N. A.	128-47-3	KE-302)	FORWARD	f_B	931	0.090873	0.0561
1-4	N. A.	128-47-4	(Roller Dia	- d_B = 0.3150	f_B'	1862	0.181747	0.1350
1-5	N. A.	128-47-5	No. Rollers	- m = 18	$3f_B'$	5585	0.545143	0.1271
1-6	N. A.	128-47-6	Raceway	- d_1 = 2.0472	f_1	2578	0.251634	0.2007
1-7	N. A.	128-47-7		- d_2 = 2.6772	f_2	1972	0.192484	0.1421
			Shaft RPS	- f_R = 252.766)				
2-8	N. A.	128-7-1	2-300-011-02	NO. 4 MAIN BEARING	f_R	253	0.024694	0.0145
2-9	N. A.	128-7-2	(Fafnir	TURBINE SHAFT, AFT	f_T	103	0.010053	0.0051
2-10	N. A.	128-7-3	AAMM213-		f_B	651	0.063543	0.0404
2-11	N. A.	128-7-4	3-SMBR-DT		f_B'	1302	0.127086	0.1011
2-12	N. A.	128-7-5	(E-7103))		$3f_B'$	3905	0.381161	0.3031
2-13	N. A.	128-7-6	(Ball Dia	- d_B = 0.6875	f_1	2094	0.204392	0.1505
2-14	N. A.	128-7-7	No. Balls	- m = 14	f_2	1445	0.141044	0.1102
			Raceway	- d_1 = 2.991				
				- d_2 = 4.366				
			Shaft RPS	- f_R = 252.766)				

* Based on 230.0 Rotor RPM

TABLE VI. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, ACCESSORY DRIVE SECTION GEAR TRAINS (N_1-RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	1	124-3-1	2-100-058-02	INNER BEVEL MAIN	Fund	9126	1.114557	1.0725
1-2	1	124-3-2		DRIVE	X2	18252	2.229115	-
1-3	1	124-3-3			X3	27378	3.343673	-
1-4	1	124-3-4		(f_R = 234 Hz)	$+f_R$	9360	1.143136	1.1112
1-5	1	124-3-5			$+2f_R$	9594	1.171714	1.1277
1-6	1	124-3-6			$-f_R$	8892	1.085979	1.0540
1-7	1	124-3-7			$-2f_R$	8658	1.057401	1.0353
1-8	1	118-5-1	2-070-005-02	(f_R = 169 Hz)	$+f_R$	9295	1.135197	1.1052
1-9	1	118-5-2			$+2f_R$	9464	1.155837	1.1176
1-10	1	118-5-3			$-f_R$	8957	1.093917	1.0601
1-11	1	118-5-4			$-2f_R$	8788	1.073277	1.0454
1-12	1	118-20-1	2-070-024-01	(f_R = 234 Hz)	$+f_R$	9360	1.143136	1.1112
1-13	1	118-20-2			$+2f_R$	9594	1.171714	1.1277
1-14	1	118-20-3			$-f_R$	8892	1.085979	1.0540
1-15	1	118-20-4			$-2f_R$	8658	1.057401	1.0353
2-16	1	112-89-1	2-080-147-01	OUTER ACCESSORY	Fund	3276	0.400097	0.3147
2-17	1	112-89-2		DRIVE BEVEL	X2	6552	0.800195	0.6316
2-18	1	112-89-3			X3	9828	1.200293	1.1464
2-19	1	112-89-4		(f_R = 234 Hz)	$+f_R$	3510	0.428676	0.3334
2-20	1	112-89-5			$+2f_R$	3744	0.457254	0.3521
2-21	1	112-89-6			$-f_R$	3042	0.371519	0.2762
2-22	1	112-89-7			$-2f_R$	2808	0.342940	0.2575

TABLE VI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
2-23	1	110-15-1	2-080-013-03	(f_R = 137 Hz)	$+f_R$	3413	0.416829	0.3253
2-24	1	110-15-2			$+2f_R$	3550	0.433561	0.3360
2-25	1	110-15-3			$-f_R$	3139	0.383365	0.3042
2-26	1	110-15-4			$-2f_R$	3002	0.366634	0.2736
3-27	1	110-11-1	2-080-016-02	ACCESSORY	Fund	2047	0.250000	0.2000
3-28	1	110-11-2		TRANSMISSION	X2	4094	0.500000	0.4000
3-29	1	110-11-3		MAIN TRAIN	X3	6141	0.750000	0.6000
3-30	1	110-11-4		(f_R = 137 Hz)	$+f_R$	2184	0.266731	0.2105
3-31	1	110-11-5			$+2f_R$	2321	0.283463	0.2211
3-32	1	110-11-6			$-f_R$	1910	0.233268	0.1673
3-33	1	110-11-7			$-2f_R$	1773	0.216536	0.1567
3-34	1	110-17-1	2-080-009-02	(f_R = 53 Hz)	$+f_R$	2100	0.256472	0.2033
3-35	1	110-17-2			$+2f_R$	2153	0.262945	0.2065
3-36	1	110-17-3			$-f_R$	1994	0.243527	0.1745
3-37	1	110-17-4			$-2f_R$	1941	0.237054	0.1713
3-38	1	110-25-1	2-080-019-04	(f_R = 53 Hz)	$+f_R$	2100	0.256472	0.2033
3-39	1	110-25-2			$+2f_R$	2153	0.262945	0.2065
3-40	1	110-25-3			$-f_R$	1994	0.243527	0.1745
3-41	1	110-25-4			$-2f_R$	1941	0.237054	0.1713
3-42	1	112-62-1	2-080-021-06	(f_R = 53 Hz)	$+f_R$	2100	0.256472	0.2033
3-43	1	112-62-2			$+2f_R$	2153	0.262945	0.2065
3-44	1	112-62-3			$-f_R$	1994	0.243527	0.1745
3-45	1	112-62-4			$-2f_R$	1941	0.237054	0.1713

TABLE VII. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, ACCESSORY DRIVE SECTION BEARINGS (N_1 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	1	118-23-1	2-300-031-01	RADIAL BEVEL SHAFT	f_R	234	0.028578	0.0165
1-2	1	118-23-2	(Vendor		f_T	100	0.012212	0.0062
1-3	1	118-23-3	Unknown)		f_B	810	0.098925	0.0625
1-4	1	118-23-4	(Ball Dia	- d_B = 0.1875	f_B'	1620	0.197850	0.1452
1-5	1	118-23-5	No. Balls	- m = 13	$3f_B'$	4860	0.593551	0.4577
1-6	1	118-23-6	Raceway	- d_1 = 1.1365	f_1	1737	0.212139	0.1545
1-7	1	118-23-7		- d_2 = 1.5115	f_2	1306	0.159501	0.1215
			Shaft RPS	- f_R = 234.13)				
2-8	N. A.	118-6-1	2-300-005-02	ACCESSORY BEVEL	f_R	169	0.020639	0.0125
2-9	N. A.	118-6-2	(MRC	SHAFT, INNER	f_T	70	0.008549	0.0043
2-10	N. A.	118-6-3	R-105-KD-		f_B	464	0.056668	0.0350
2-11	N. A.	118-6-4	300)		f_B'	929	0.113458	0.0721
2-12	N. A.	118-6-5	(Roller Dia	- d_B = 0.250	$3f_B'$	2786	0.340254	0.2562
2-13	N. A.	118-6-6	No. Rollers	- m = 14	f_1	1392	0.170004	0.1270
2-14	N. A.	118-6-7	Raceway	- d_1 = 1.1673	f_2	975	0.119076	0.0750
				- d_2 = 1.6673				
			Shaft RPS	- f_R = 169.09)				

TABLE VII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
3-15	N. A.	118-10-1	2-300-023-02	ACCESSORY BEVEL	f_R	169	0.020639	0.0125
3-16	N. A.	118-10-2	(Fafnir	SHAFT, OUTER	f_T	70	0.008549	0.0043
3-17	N. A.	118-10-3	P9105K-		f_B	463	0.056546	0.0350
3-18	N. A.	118-10-4	E-8211)		f_B'	926	0.113092	0.0717
3-19	N. A.	118-10-5	(Ball Dia	- d_B = 0.250	$3f_B'$	2778	0.339276	0.2556
3-20	N. A.	118-10-6	No. Balls	- m = 10	f_1	995	0.121519	0.0762
3-21	N. A.	118-10-7	Raceway	- d_1 = 1.1633	f_2	696	0.085002	0.0534
				- d_2 = 1.6633				
				Shaft RPS - f_R = 169.09)				

TABLE VIII. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, ACCESSORY TRANSMISSION BEARINGS (N_1 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
1-1	1	110-13-1	2-300-024-02	BEVEL DRIVE SHAFT,	f_R	137	0.016731	0.0105
1-2	1	110-13-2	(Fafnir	OUTER	f_T	57	0.006961	0.0035
1-3	1	110-13-3	PM9106K-		f_B	392	0.047874	0.0304
1-4	1	110-13-4	MBR-E-8164)		f_B'	784	0.095749	0.0610
1-5	1	110-13-5	(Ball Dia	- d_B = 0.28125	$3f_B'$	2353	0.287371	0.2231
1-6	1	110-13-6	No. Balls	- m = 11	f_1	878	0.107230	0.0667
1-7	1	110-13-7	Raceway	- d_1 = 1.381	f_2	624	0.076209	0.0470
				- d_2 = 1.944				
			Shaft RPS	- f_R = 136.58)				
2-8	1	110-8-1	2-300-009-02	BEVEL DRIVE SHAFT,	f_R	137	0.016731	0.0105
2-9	1	110-8-2	(Fafnir	INNER	f_T	54	0.006595	0.0033
2-10	1	110-8-3	9102KE-		f_B	321	0.039203	0.0241
2-11	1	110-8-4	821D)		f_B'	642	0.078407	0.0501
2-12	1	110-8-5	(Ball Dia	- d_B = 0.1875	$3f_B'$	1927	0.235344	0.1704
2-13	1	110-8-6	No. Balls	- m = 9	f_1	740	0.090376	0.0562
2-14	1	110-8-7	Raceway	- d_1 = 0.732	f_2	489	0.059721	0.0365
				- d_2 = 1.108				
			Shaft RPS	- f_R = 136.58)				

TABLE VIII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-15	1	110-16-1	1-300-005-01	POWER CONTROL	f_R	53	0.006472	0.0033
3-16	1	110-16-2	(MRC 1905-	SHAFT	f_T	22	0.002686	0.0013
3-17	1	110-16-3	S-304)		f_B	154	0.018808	0.0115
3-18	1	110-16-4		(Ball Dia - d_B = 0.21875	f_B'	308	0.037616	0.0232
3-19	1	110-16-5		No. Balls - m = 11	$3f_B'$	924	0.112848	0.0716
3-20	1	110-16-6		Raceway - d_1 = 1.1002	f_1	337	0.041157	0.0251
3-21	1	110-16-7		- d_2 = 1.5376	f_2	241	0.029433	0.0171
				Shaft RPS - f_R = 52.53)				
4-22	1	110-24-1	2-300-021-02	OIL PUMP DRIVE	f_R	53	0.006472	0.0033
4-23	1	110-24-2	(MRC 104-	SHAFT	f_T	21	0.002564	0.0013
4-24	1	110-24-3	KS-301)		f_B	123	0.015021	0.0076
4-25	1	110-24-4		(Ball Dia - d_B = 0.2500	f_B'	246	0.030043	0.0173
4-26	1	110-24-5		No. Balls - m = 9	$3f_B'$	737	0.090009	0.0561
4-27	1	110-24-6		Raceway - d_1 = 0.9705	f_1	285	0.034807	0.0217
4-28	1	110-24-7		- d_2 = 1.4705	f_2	188	0.022960	0.0136
				Shaft RPS - f_R = 52.53)				

TABLE VIII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
5-29	1	112-66-1	1-300-004-01	FUEL FILTER DRIVE	f_R	53	0.006472	0.0033
5-30	1	112-66-2	(MRC 1903-	SHAFT, OUTER	f_T	22	0.002686	0.0013
5-31	1	112-66-3	S-301)		f_B	151	0.018441	0.0114
5-32	1	112-66-4		(Ball Dia - d_B = 0.15625	f_B'	302	0.036883	0.0227
5-33	1	112-66-5		No. Balls - m = 11	$3f_B'$	907	0.110771	0.0706
5-34	1	112-66-6		Raceway - d_1 = 0.7690	f_1	338	0.041279	0.0251
5-35	1	112-66-7		- d_2 = 1.0814	f_2	240	0.029311	0.0170
				Shaft RPS - f_R = 52.53)				
6-36	1	112-59-1	1-300-005-01	FUEL FILTER DRIVE	f_R	53	0.006472	0.0033
6-37	1	112-59-2	(MRC 1905-	SHAFT, INNER	f_T	22	0.002686	0.0013
6-38	1	112-59-3	S-304)		f_B	154	0.018808	0.0115
6-39	1	112-59-4		(Ball Dia - d_B = 0.21875	f_B'	308	0.037616	0.0232
6-40	1	112-59-5		No. Balls - m = 11	$3f_B'$	924	0.112848	0.0716
6-41	1	112-59-6		Raceway - d_1 = 1.1002	f_1	337	0.041157	0.0251
6-42	1	112-59-7		- d_2 = 1.5376	f_2	241	0.029433	0.0171
				Shaft RPS - f_R = 52.53)				

TABLE IX. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, ACCESSORY DRIVE AND TRANSMISSION, GEAR TRAINS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	1	114-9-1	2-020-054-11	TORQUEMETER	Fund	10620	1.036603	1.0226
1-2	1	114-9-2		ACTUATING DRIVE	X2	21240	2.073206	-
1-3	1	114-9-3			X3	31860	3.109809	-
1-4	1	114-9-4		(f_R = 253 Hz)	$+f_R$	10873	1.061298	1.0373
1-5	1	114-9-5			$+2f_R$	11126	1.085993	1.0540
1-6	1	114-9-6			$-f_R$	10367	1.011908	1.0061
1-7	1	114-9-7			$-2f_R$	10114	0.987213	0.7714
1-8	1	117-6-1	2-030-007-02	(f_R = 272 Hz)	$+f_R$	10892	1.063152	1.0403
1-9	1	117-6-2			$+2f_R$	11164	1.089702	1.0557
1-10	1	117-6-3			$-f_R$	10348	1.010053	1.0051
1-11	1	117-6-4			$-2f_R$	10076	0.983504	0.7674
2-12	1	117-9-1	2-030-012-02	OVERSPEED DRIVE	Fund	4083	0.398535	0.3140
2-13	1	117-9-2		BEVEL, INNER	X2	8166	0.797071	0.6301
2-14	1	117-9-3			X3	12249	1.195607	1.1441
2-15	1	117-9-4		(f_R = 272 Hz)	$+f_R$	4355	0.425085	0.3315
2-16	1	117-9-5			$-f_R$	3811	0.371986	0.2764
2-17	1	117-19-1	2-030-014-02	(f_R = 163 Hz)	$+f_R$	4246	0.414446	0.3242
2-18	1	117-19-2			$-f_R$	3920	0.382625	0.3037

TABLE IX - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-19	1	108-110-1		OVERSPEED CONTROL	Fund	2450	0.239141	0.1724
3-20	1	108-110-2		BEVEL, OUTER	X2	4900	0.478282	0.3647
3-21	1	108-110-3			X3	7350	0.717423	0.5573
3-22	1	108-110-4		(f_R = 163 Hz)	$+f_R$	2613	0.255051	0.2025
3-23	1	108-110-5			$+2f_R$	2776	0.270961	0.2126
3-24	1	112-105-1	2-080-031-03	(f_R = 122 Hz)	$-f_R$	2328	0.227232	0.1643
3-25	1	112-105-2			$-2f_R$	2206	0.215324	0.1562
4-26	1	112-107-1	2-080-032-02	OVERSPEED CONTROL	Fund	2450	0.239141	0.1724
4-27	1	112-107-2		DRIVE IDLER TRAIN	X2	4900	0.478282	0.3647
4-28	1	112-107-3		AND CLUSTER	X3	7350	0.717423	0.5573
4-29	1	112-107-4		(f_R = 122. Hz)	$+f_R$	2613	0.255051	0.2025
4-30	1	112-107-5			$-f_R$	2328	0.227232	0.1643
4-31	1	112-113-1	2-080-036-02	(f_R = 87 Hz)	$+f_R$	2537	0.247632	0.1766
4-32	1	112-113-2			$-f_R$	2363	0.230649	0.1661
4-33	1	112-111-1	2-080-043-02	(f_R = 94 Hz)	$+f_R$	2444	0.238555	0.1721
4-34	1	112-111-2			$-f_R$	2356	0.229965	0.1656
4-35	1	110-34-1	2-080-144-01		$+f_R$	2557	0.249585	0.1776
4-36	1	110-34-2		(f_R = 107 Hz)	$-f_R$	2343	0.228696	0.1651
5-37	1	110-34-3	2-080-145-01	TACHOMETER DRIVE	Fund	1385	0.135187	0.1052
5-38	1	110-34-4		BEVEL	X2	2770	0.270375	0.2123
5-39	1	110-34-5			X3	4155	0.405563	0.3175
5-40	1	110-34-6		(f_R = 107 Hz)	$+f_R$	1492	0.145632	0.1125
5-41	1	110-34-7			$-f_R$	1278	0.124743	0.0777
5-42	1	112-49-1		(f_R = 69 Hz)	$+f_R$	1454	0.141922	0.1105
5-43	1	112-49-2			$-f_R$	1316	0.128452	0.1016

TABLE X. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, ACCESSORY DRIVE SECTION BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	1	114-3-1	2-300-028-01	POWER OUTPUT SHAFT	f_R	253	0.024694	0.0145
1-2	1	114-3-2	(MRC 1911-		f_T	111	0.010834	0.0054
1-3	1	114-3-3	SD-1301-T)		f_B	1057	0.103172	0.0647
1-4	1	114-3-4		(Ball Dia - d_B = 0.3125	f_B'	2114	0.206344	0.1515
1-5	1	114-3-5		No. Balls - m = 16	$3f_B'$	6342	0.619033	0.4750
1-6	1	114-3-6		Raceway - d_1 = 2.3378	f_1	2261	0.220693	0.1610
1-7	1	114-3-7		- d_2 = 2.9628	f_2	1784	0.174133	0.1311
				Shaft RPS - f_R = 252.766)				
2-8	1	117-8-1	2-300-017-01	OVERSPEED DRIVE	f_R	272	0.026549	0.0155
2-9	1	117-8-2	(Fafnir	SHAFT,	f_T	100	0.009760	0.0050
2-10	1	117-8-3	PM 9100 K-	INTERMEDIATE	f_B	478	0.046656	0.0277
2-11	1	117-8-4	E-8211)		f_B'	956	0.093313	0.0576
2-12	1	117-8-5		(Ball Dia - d_B = 0.1875	$3f_B'$	2870	0.280136	0.2173
2-13	1	117-8-6		No. Balls - m = 7	f_1	1205	0.117618	0.0742
2-14	1	117-8-7		Raceway - d_1 = 0.5210	f_2	700	0.068326	0.0430
				- d_2 = 0.8960				
				Shaft RPS - f_R = 272.208)				

TABLE X - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-15	1	117-11-1	2-300-022-01	OVERSPEED DRIVE	f_R	272	0.026549	0.0155
3-16	1	117-11-2	(N.D.	SHAFT, THRUST	f_T	97	0.009468	0.0047
3-17	1	117-11-3	R4AXR1C09)		f_B	438	0.042752	0.0257
3-18	1	117-11-4		(Ball Dia - d_B = 0.1406	f_B'	876	0.085505	0.0536
3-19	1	117-11-5		No. Balls - m = 6	$3f_B'$	2627	0.256417	0.2032
3-20	1	117-11-6		Raceway - d_1 = 0.3519	f_1	1050	0.102489	0.0644
3-21	1	117-11-7		- d_2 = 0.6331	f_2	583	0.056905	0.0351
				Shaft RPS - f_R = 272.208)				

TABLE XI. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, ACCESSORY TRANSMISSION SECTION BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
1-1	1	112-109-1	1-300-003-01	OVERSPEED CONTROL	f_R	122	0.011908	0.0061
1-2	1	112-109-2	(MRC 1902-	DRIVE, OUTER BEVEL	f_T	50	0.004880	0.0024
1-3	1	112-109-3	S-301)	SHAFT	f_B	321	0.031332	0.0200
1-4	1	112-109-4	(Ball Dia	- d_B = 0.15625	f_B'	641	0.062567	0.0400
1-5	1	112-109-5	No. Balls	- m = 10	$3f_B'$	1923	0.187701	0.1401
1-6	1	112-109-6	Raceway	- d_1 = 0.6902	f_1	726	0.070863	0.0442
1-7	1	112-109-7		- d_2 = 1.0028	f_2	499	0.048706	0.0307
			Shaft RPS	- f_R = 122.497)				
2-8	1	112-113-1	1-300-004-01	OVERSPEED CONTROL	f_R	87.5	0.008540	0.0043
2-9	1	112-113-2	(MRC 1903-	DRIVE, IDLER GEAR	f_T	36	0.003513	0.0016
2-10	1	112-113-3	S-301)		f_B	252	0.024597	0.0145
2-11	1	112-113-4	(Ball Dia	- d_B = 0.15625	f_B'	503	0.049097	0.0311
2-12	1	112-113-5	No. Balls	- m = 11	$3f_B'$	1510	0.147388	0.1134
2-13	1	112-113-6	Raceway	- d_1 = 0.7690	f_1	562	0.054856	0.0341
2-14	1	112-113-7		- d_2 = 1.0814	f_2	400	0.039043	0.0240
			Shaft RPS	- f_R = 87.496)				

TABLE XI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-15	1	112-111-1	1-300-004-01	OVERSPEED CONTROL	f_R	94	0.009175	0.0046
3-16	1	112-111-2	(MRC 1903 -	DRIVE, IDLER	f_T	39	0.003806	0.0020
3-17	1	112-111-3	S-301)	CLUSTER	f_B	271	0.026451	0.0154
3-18	1	112-111-4	(Ball Dia	- d_B = 0.15625	f_B'	542	0.052903	0.0331
3-19	1	112-111-5	No. Balls	- m = 11	$3f_B'$	1626	0.158711	0.1212
3-20	1	112-111-6	Raceway	- d_1 = 0.7690	f_1	606	0.059150	0.0362
3-21	1	112-111-7		- d_2 = 1.0814	f_2	431	0.042069	0.0254
			Shaft RPS	- f_R = 94.228)				
4-22	1	110-31-1	1-300-003-01	OVERSPEED CONTROL	f_R	106.5	0.010395	0.0053
4-23	1	110-31-2	(MRC 1902-	OUTPUT, SPUR END	f_T	43	0.004197	0.0021
4-24	1	110-31-3	S-301)		f_B	279	0.027232	0.0160
4-25	1	110-31-4	(Ball Dia	- d_B = 0.15625	f_B'	557	0.054367	0.0337
4-26	1	110-31-5	No. Balls	- m = 11	$3f_B'$	1672	0.163201	0.1234
4-27	1	110-31-6	Raceway	- d_1 = 0.7690	f_1	631	0.061591	0.0374
4-28	1	110-31-7		- d_2 = 1.0814	f_2	434	0.042362	0.0256
			Shaft RPS	- f_R = 106.517)				

TABLE XI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
5-29	1	110-32-1	1-300-005-01	OVERSPEED CONTROL	f_R	106.5	0.010395	0.0053
5-30	1	110-32-2	(MRC 1905-	OUTPUT, BEVEL END	f_T	44	0.004294	0.0022
5-31	1	110-32-3	S-3404)		f_B	312	0.030453	0.0175
5-32	1	110-32-4	(Ball Dia	- d_B = 0.21875	f_B'	625	0.061005	0.0372
5-33	1	110-32-5	No. Balls	- m = 11	$3f_B'$	1874	0.182918	0.1355
5-34	1	110-32-6	Raceway	- d_1 = 1.1002	f_1	683	0.066666	0.0421
5-35	1	110-32-7		- d_2 = 1.5376	f_2	489	0.047730	0.0304
			Shaft RPS	- f_R = 106.517)				
6-36	1	112-50-1	1-300-004-01	TACHOMETER	f_R	69	0.006734	0.0034
6-37	1	112-50-2	(MRC 1903-	DRIVE SHAFT, INNER	f_T	29	0.002830	0.0014
6-38	1	112-50-3	S-301)		f_B	199	0.019424	0.0120
6-39	1	112-50-4	(Ball Dia	- d_B = 0.15625	f_B'	398	0.038848	0.0237
6-40	1	112-50-5	No. Balls	- m = 11	$3f_B'$	1195	0.116642	0.0736
6-41	1	112-50-6	Raceway	- d_1 = 0.7690	f_1	445	0.043435	0.0262
6-42	1	112-50-7		- d_2 = 1.0814	f_2	316	0.030844	0.0176
			Shaft RPS	- f_R = 69.236)				

TABLE XI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
7-43	1	112-53-1	1-300-004-01	TACHOMETER DRIVE	f_R	69	0.006743	0.0034
7-44	1	112-53-2	(MRC 1903-	SHAFT, OUTER	f_T	29	0.002830	0.0014
7-45	1	112-53-3	S-301)		f_B	199	0.019424	0.0120
7-46	1	112-53-4		(Ball Dia - d_B = 0.15625	f_B'	398	0.038848	0.0237
7-47	1	112-53-5		No. Balls - m = 11	$3f_B'$	1195	0.116642	0.0736
7-48	1	112-53-6		Raceway - d_1 = 0.7690	f_1	445	0.043435	0.0262
7-49	1	112-53-7		- d_2 = 1.0814	f_2	316	0.030844	0.0176
				Shaft RPS - f_R = 69.236)				

TABLE XII. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS T55-L-5, -7 ENGINES, ACCESSORIES (N_1 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	N. A.	72-12	014081-011 -02	LUBE OIL AND SCAVENGING PUMP (7 teeth), Dual Element (Shaft Speed = 53. 0 RPS)	Fund	371	0.045312	0.0350
					X2	742	0.090624	0.0717
					X3	1113	0.135936	0.1055
					X4	1484	0.181248	0.1346

TABLE XIII. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, ENGINE TRANSMISSIONS (NO. 1, NO. 2) GEAR TRAINS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	2	152-48-1	114D6044-10	SPIRAL BEVEL TRAIN	Fund	8594	0.838848	0.6554
1-2	2	152-48-2			X2	17188	1.677696	1.5330
1-3	2	152-48-3			X3	25772	2.515568	2.4100
1-4	2	152-48-4		(f_R = 252.8 Hz)	$+f_R$	8847	0.863543	0.6721
1-5	2	152-48-5			$+2f_R$	9100	0.888238	0.7066
1-6	2	152-48-6			$+3f_R$	9353	0.912933	0.7233
1-7	2	152-48-7			$-f_R$	8341	0.814153	0.6407
1-8	2	152-48-8			$-2f_R$	8088	0.789458	0.6242
1-9	2	152-48-9			$-3f_R$	7835	0.764763	0.6074
1-10	2	152-75-1	114D6086-2	(f_R = 199.8 Hz)	$+f_R$	8794	0.858369	0.6674
1-11	2	152-75-2			$+2f_R$	8994	0.877891	0.7014
1-12	2	152-75-3			$+3f_R$	9194	0.897413	0.7134
1-13	2	152-75-4			$-f_R$	8394	0.819326	0.6434
1-14	2	152-75-5			$-2f_R$	8194	0.799804	0.6314
1-15	2	152-75-6			$-3f_R$	7994	0.780283	0.6174

TABLE XIV. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, ENGINE TRANSMISSIONS (NO. 1 and NO. 2) BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	2	152-40-1	114DS652-1	PINION, OUTBOARD		f_R	252	0.024597	0.0145
1-2	2	152-40-2	(SKF)			f_T	100	0.009760	0.0050
1-3	2	152-40-3		(Roller Dia -	d_B = 0.8268	f_B	591	0.057686	0.0354
1-4	2	152-40-4		No. Rollers -	m = 12	f_B'	1181	0.115275	0.0730
1-5	2	152-40-5		Raceway -	d_1 = 3.2073	$3f_B'$	3544	0.345924	0.2611
1-6	2	152-40-6			d_2 = 4.8609	f_1	1827	0.178330	0.1332
1-7	2	152-40-7		Shaft RPS -	f_R = 252.77)	f_2	1206	0.117715	0.0742
2-8	2	152-44-1	114DS641-1	PINION GEAR,		f_R	252	0.024597	0.0145
2-9	2	152-44-2	(MRC)	INTERMEDIATE		f_T	99	0.009663	0.0050
2-10	2	152-44-3		(Ball Dia -	d_B = 0.8750	f_B	555	0.054172	0.0336
2-11	2	152-44-4		No. Balls -	m = 12	f_B'	1109	0.108247	0.0673
2-12	2	152-44-5		Raceway -	d_1 = 3.1554	$3f_B'$	3328	0.324841	0.2463
2-13	2	152-44-6			d_2 = 4.9054	f_1	1846	0.180185	0.1342
2-14	2	152-44-7		Shaft RPS -	f_R = 252.77)	f_2	1187	0.115861	0.0733
				Contact Angle	= 29°				
3-15	2	152-47-1	114DS653-1	PINION, INBOARD		f_R	252	0.024597	0.0145
3-16	2	152-47-2	(SKF)			f_T	101	0.009858	0.0050
3-17	2	152-47-3		(Roller Dia -	d_B = 0.8661	f_B	606	0.059150	0.0362
3-18	2	152-47-4		No. Rollers -	m = 12	f_B'	1213	0.118399	0.0745
3-19	2	152-47-5		Raceway -	d_1 = 3.46336	$3f_B'$	3639	0.355197	0.2657
3-20	2	152-47-6			d_2 = 5.19564	f_1	1820	0.177647	0.1330
3-21	2	152-47-7		Shaft RPS -	f_R = 252.77)	f_2	1213	0.118399	0.0745

TABLE XIV - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
4-22	2	152-73-1	114DS647-1	CLUTCH SHAFT,	f_R	200	0.019521	0.0120
4-23	2	152-73-2	(MRC)	INBOARD	f_T	90	0.008784	0.0044
4-24	2	152-73-3		(Ball Dia - d_B = 0.2756	f_B	1025	0.100048	0.0632
4-25	2	152-73-4		No. Balls - m = 26	f_B'	2050	0.200097	0.1464
4-26	2	152-73-5		Raceway - f_1 = 2.5788	$3f_B'$	6151	0.600390	0.4633
4-27	2	152-73-6		- f_2 = 3.1300	f_1	2849	0.278086	0.2163
4-28	2	152-73-7		Shaft RPS - f_R = 199.83)	f_2	2347	0.229087	0.1652
5-29	2	152-79-1	114DS249-1	CLUTCH SHAFT,	f_R	200	0.019521	0.0120
5-30	2	152-79-2	(MRC)	OUTBOARD	f_T	86	0.008394	0.0042
5-31	2	152-79-3		(Roller Dia - d_B = 0.2756	f_B	727	0.070961	0.0443
5-32	2	152-79-4		No. Rollers - m = 16	f_B'	1454	0.141922	0.1105
5-33	2	152-79-5		Raceway - d_1 = 1.7669	$3f_B'$	4362	0.425768	0.3320
5-34	2	152-79-6		- d_2 = 2.3181	f_1	1814	0.177061	0.1325
5-35	2	152-79-7		Shaft RPS - f_R = 199.83)	f_2	1383	0.134992	0.1051
6-36	2	152-70-1	114DS644-2	OUTPUT SHAFT,	f_R	200	0.019521	0.0120
6-37	2	152-70-2	(SKF)	INTERMEDIATE	f_T	79	0.007711	0.0040
6-38	2	152-70-3		(Roller Dia - d_B = 0.70866	f_B	465	0.045387	0.0272
6-39	2	152-70-4		No. Rollers - m = 12	f_B'	930	0.090775	0.0564
6-40	2	152-70-5		Raceway - d_1 = 2.7357	$3f_B'$	2790	0.272327	0.2133
6-41	2	152-70-6		- d_2 = 4.1531	f_1	1446	0.141142	0.1102
6-42	2	152-70-7		Shaft RPS - f_R = 199.83)	f_2	952	0.092923	0.0575

TABLE XIV - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
7-43	2	152-66-1	114DS643-1	OUTPUT SHAFT,	f_R	200	0.019521	0.0120
7-44	2	152-66-2	(Fafnir)	UPPER	f_T	86	0.008394	0.0042
7-45	2	152-66-3		(Ball Dia - d_B = 0.40625	f_B	688	0.067154	0.0423
7-46	2	152-66-4		No. Balls - m = 13	f_B'	1376	0.134309	0.1046
7-47	2	152-66-5		Raceway - d_1 = 2.4482	$3f_B'$	4127	0.402830	0.3162
7-48	2	152-66-6		- d_2 = 3.2606	f_1	1484	0.144851	0.1121
7-49	2	152-66-7		Shaft RPS - f_R = 199.83)	f_2	1114	0.108735	0.0675
8-50	2	152-84-1	114DS645-4	OUTPUT SHAFT,	f_R	200	0.019521	0.0120
8-51	2	152-84-2	(SKF)	LOWER	f_T	92	0.008979	0.0045
8-52	2	152-84-3		(Roller Dia - d_B = 0.3740	f_B	1220	0.119082	0.0750
8-53	2	152-84-4		No. Rollers - m = 26	f_B'	2440	0.238164	0.1720
8-54	2	152-84-5		Raceway - d_1 = 4.2227	$3f_B'$	7319	0.714397	0.5556
8-55	2	152-84-6		- d_2 = 4.9707	f_1	2809	0.274182	0.2143
8-56	2	152-84-7		Shaft RPS - f_R = 199.83)	f_2	2386	0.232894	0.1672

TABLE XV. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, COMBINING TRANSMISSION GEAR TRAINS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	2	147-164-1	114D5056-1	SPIRAL BEVEL, MAIN	Fund	6594	0.643631	0.5114
1-2	2	147-164-2		POWER	X2	13188	1.287262	1.2231
1-3	2	147-164-3			X3	19782	1.930893	1.5345
1-4	2	147-164-4		(f_{R_O}= 117.8 Hz)	$+f_{R_O}$	6712	0.655148	0.5173
1-5	2	147-164-5			$+2f_{R_O}$	6830	0.666666	0.5253
1-6	2	147-164-6			$+3f_{R_O}$	6948	0.678184	0.5332
1-7	2	147-164-7			$-f_{R_O}$	6476	0.632113	0.5035
1-8	2	147-164-8			$-2f_{R_O}$	6358	0.620595	0.4756
1-9	2	147-164-9			$-3f_{R_O}$	6240	0.609077	0.4677
1-10	2	147-65-1	114D5047-7	(f_{R_I}= 199.8 Hz)	$+f_{R_I}$	6794	0.663152	0.5234
1-11	2	147-65-2			$+2f_{R_I}$	6994	0.682674	0.5354
1-12	2	147-65-3			$+3f_{R_I}$	7194	0.702196	0.5474
1-13	2	147-65-4			$-f_{R_I}$	6394	0.624109	0.4774
1-14	2	147-65-5			$-2f_R$	6194	0.604587	0.4654
1-15	2	147-65-6			$-3f_R$	5994	0.585065	0.4534
2-16	2	147-154-1	114D5068-1	LUBE OIL PUMP	Fund	3768	0.367789	0.2742
2-17	2	147-154-2		DRIVE	X2	7536	0.735578	0.5705
2-18	2	147-154-3			X3	11304	1.103367	1.0647
2-19	2	147-154-4		(f_{R_O}= 117.8 Hz)	$+f_R$	3886	0.379306	0.3022
2-20	2	147-154-5			$+2f_R$	4004	0.390824	0.3101
2-21	2	147-154-6			$-f_R$	3650	0.356271	0.2663

TABLE XV - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
2-22	2	147-154-7	114D5068-1	LUBE OIL PUMP	$-2f_R$	3532	0.344753	0.2604
2-23	2	147-95-1		DRIVE	$+f_R$	3844	0.375207	0.3001
2-24	2	147-95-2		(f_R = 75.4 Hz)	$+2f_R$	3920	0.382625	0.3037
2-25	2	147-95-3			$-f_R$	3692	0.360370	0.2704
2-26	2	147-95-4			$-2f_R$	3616	0.352952	0.2646
2-27	2	147-94-1		(f_R = 83.7 Hz)	$+f_R$	3852	0.375988	0.3004
2-28	2	147-94-2			$+2f_R$	3936	0.384187	0.3046
2-29	2	147-94-3			$-f_R$	3684	0.359590	0.2701
2-30	2	147-94-4			$-2f_R$	3600	0.351390	0.2637
2-31	2	147-65-3A		SPIRAL BEVEL, MAIN	$+4f_{R_I}$	7394	0.721717	0.5614
2-32	2	147-65-3B		POWER	$+5f_{R_I}$	7594	0.741239	0.5734
2-33	2	147-65-3C		(f_{R_I} = 199.8 Hz)	$+6f_{R_I}$	7794	0.760761	0.6054
2-34	2	147-65-3D			$+7f_{R_I}$	7994	0.780283	0.6174
2-35	2	147-65-3E			$+8f_{R_I}$	8194	0.799804	0.6314
2-36	2	147-65-6A			$-4f_{R_I}$	5794	0.624109	0.4774
2-37	2	147-65-6B			$-5f_{R_I}$	5594	0.604587	0.4654
2-38	2	147-65-6C			$-6f_{R_I}$	5394	0.585065	0.4534
2-39	2	147-65-6D			$-7f_{R_I}$	5194	0.565544	0.4414
2-40	2	147-65-6E			$-8f_{R_I}$	4994	0.546022	0.4274
2-41	2	147-164-6A		(f_{R_O} = 117.8 Hz)	$+4f_{R_O}$	7066	0.689702	0.5411
2-42	2	147-164-6B			$+5f_{R_O}$	7184	0.701220	0.5470
2-43	2	147-164-6C			$+6f_{R_O}$	7302	0.712737	0.5547
2-44	2	147-164-6D			$+7f_{R_O}$	7420	0.724255	0.5626
2-55	2	147-164-6E			$+8f_{R_O}$	7538	0.735773	0.5706
2-56	2	147-164-9A			$-4f_{R_O}$	6122	0.597559	0.4617

TABLE XV - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
2-57	2	147-164-9B			$-5f_{R_O}$	6004	0.586041	0.4540
2-58	2	147-164-9C			$-6f_{R_O}$	5886	0.574524	0.4461
2-59	2	147-164-9D			$-7f_{R_O}$	5768	0.563006	0.4402
2-60	2	147-164-9E			$-8f_{R_O}$	5650	0.551488	0.4323

TABLE XVI. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, ENGINE COMBINING TRANSMISSION BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
1-1	2	147-91-1	114DS548-1	FORWARD OUTPUT	f_R	118	0.011517	0.0057
1-2	2	147-91-2	(MRC114-KS)	SHAFT, FORWARD	f_T	51	0.004978	0.0024
1-3	2	147-91-3	(Ball Dia	- d_B = 0.5000	f_B	408	0.039824	0.0243
1-4	2	147-91-4	No. Balls	- m = 24	f_B'	815	0.079551	0.0506
1-5	2	147-91-5	Raceway	- d_1 = 3.0320	$3f_B'$	2445	0.238653	0.1722
1-6	2	147-91-6		- d_2 = 4.0320	f_1	1613	0.157442	0.1205
1-7	2	147-91-7	Shaft RPS	- f_R = 117.75)	f_2	1213	0.118399	0.0745
2-8	2	147-173-1	114DS549-1	FORWARD OUTPUT	f_R	118	0.011517	0.0057
2-9	2	147-173-2	(MRC R114-	SHAFT, AFT	f_T	52	0.005075	0.0025
2-10	2	147-173-3	KEX)		f_B	523	0.051049	0.0321
2-11	2	147-173-4	(Roller Dia	- d_B = 0.3937	f_B'	1046	0.102098	0.0642
2-12	2	147-173-5	No. Rollers	- m = 13	$3f_B'$	3140	0.306490	0.2347
2-13	2	147-173-6	Raceway	- d_1 = 3.1490	f_1	850	0.082967	0.0524
2-14	2	147-173-7		- d_2 = 3.9370	f_2	680	0.066373	0.0420
			Shaft RPS	- f_R = 117.75)				

TABLE XVI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-15	2	147-173-1	114DS550-1	COUPLING SHAFT	f_R	118	0.011517	0.0057
3-16	2	147-173-2	(Fafnir		f_T	54	0.005270	0.0026
3-17	2	147-173-3	MM9319-K-		f_B	639	0.062371	0.0377
3-18	2	147-173-4	MBRE-7843)		f_B'	1279	0.124841	0.0777
3-19	2	147-173-5	(Roller Dia	- d_B = 0.40625	$3f_B'$	3837	0.374524	0.2776
3-20	2	147-173-6	No. Rollers	- m = 19	f_1	1221	0.119180	0.0750
3-21	2	147-173-7	Raceway	- d_1 = 4.043	f_2	1016	0.099170	0.0626
				- d_2 = 4.856				
			Shaft RPS	- f_R = 117.75)				
4-22	2	147-168-1	114DS545-1	BEVEL OUTPUT	f_R	118	0.011517	0.0057
4-23	2	147-168-2	(SKF 454724)	SHAFT	f_T	53	0.005173	0.0025
4-24	2	147-168-3	(Roller Dia	- d_B = 0.40625	f_B	558	0.054465	0.0337
4-25	2	147-168-4	No. Rollers	- m = 18	f_B'	1116	0.108931	0.0676
4-26	2	147-168-5	Raceway	- d_1 = 3.4848	$3f_B'$	3346	0.326598	0.2472
4-27	2	147-168-6		- d_2 = 4.2973	f_1	1170	0.114202	0.0724
4-28	2	147-168-7	Shaft RPS	- f_R = 117.75)	f_2	949	0.092630	0.0573
5-29	2	147-147-1	114DS544-1	AFT OUTPUT SHAFT	f_B	118	0.011517	0.0057
5-30	2	147-147-2	(MRC 9112-	INTERMEDIATE	f_T	51	0.004978	0.0024
5-31	2	147-147-3	UK)		f_B	433	0.042264	0.0255
5-32	2	147-147-4	(Ball Dia	- d_B = 0.40625	f_B'	865	0.084431	0.0532
5-33	2	147-147-5	No. Balls	- m = 18	$3f_B'$	2596	0.253391	0.2016
5-34	2	147-147-6	Raceway	- d_1 = 2.6336	f_1	1201	0.117227	0.0740
5-35	2	147-147-7		- d_2 = 3.4462	f_2	918	0.089604	0.0557
			Shaft RPS	- f_R = 117.75)				

TABLE XVI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
6-36	2	147-151-1	114DS543-1	AFT OUTPUT SHAFT,	f_R	118	0.011517	0.0057
6-37	2	147-151-2	(MRC	REAR	f_T	52	0.005075	0.0025
6-38	2	147-151-3	R-112-KE)		f_B	500	0.048804	0.0310
6-39	2	147-151-4	(Roller Dia	- d_B = 0.3543	f_B'	1000	0.097608	0.0620
6-40	2	147-151-5	No. Rollers	- m = 22	$3f_B'$	3001	0.292923	0.2260
6-41	2	147-151-6	Raceway	- d_1 = 2.6969	f_1	1446	0.141142	0.1102
6-42	2	147-151-7		- d_2 = 3.4055	f_2	1145	0.111761	0.0712
			Shaft RPS	- f_R = 117.75)				
7-43	2	147-66-1	114DS642-2	BEVEL GEARSHAFT,	f_R	199	0.019424	0.0120
7-44	2	147-66-2	(SKF454719)	OUTBOARD	f_T	72	0.007027	0.0035
7-45	2	147-66-3	(Roller Dia	- d_B = 1.031	f_B	373	0.036408	0.0225
7-46	2	147-66-4	No. Rollers	- m = 11	f_B'	746	0.072816	0.0452
7-47	2	147-66-5	Raceway	- d_1 = 3.000	$3f_B'$	2237	0.218350	0.1576
7-48	2	147-66-6		- d_2 = 5.362	f_1	1409	0.137530	0.1063
7-49	2	147-66-7	Shaft RPS	- f_R = 199.8)	f_2	788	0.076915	0.0473
8-50	2	147-70-1	114DS541-2	BEVEL GEARSHAFT,	f_R	199	0.019424	0.0120
8-51	2	147-70-2	(SKF454723)	INTERMEDIATE	f_T	76	0.007418	0.0036
8-52	2	147-70-3	(Ball Dia	- d_B = 1.031	f_B	396	0.038653	0.0236
8-53	2	147-70-4	No. Balls	- m = 11	f_B'	792	0.077306	0.0475
8-54	2	147-70-5	Raceway	- d_1 = 3.000	$3f_B'$	2376	0.231918	0.1666
8-55	2	147-70-6		- d_2 = 5.362	f_1	1360.7	0.132845	0.1040
8-56	2	147-70-7	Shaft RPS	- f_R = 199.8)	f_2	837	0.081698	0.0517
			Contact Angle	= 27°30'				

TABLE XVI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency	(Hz)	Decimal Ratio	Octal Ratio
9-57	2	147-73-1	114DS542-3	BEVEL GEARSHAFT,	f_R	199	0.019424	0.0120
9-58	2	147-73-2	(SKF456657)	INBOARD	f_T	99	0.009663	0.0050
9-59	2	147-73-3	(Roller Dia	- d_B = 0.4687	f_B	1040	0.101512	0.0640
9-60	2	147-73-4	No. Rollers	- m = 18	f_B'	2079	0.202928	0.1477
9-61	2	147-73-5	Raceway	- d_1 = 4.4526	$3f_B'$	6238	0.608882	0.4676
9-62	2	147-73-6		- d_2 = 5.3900	f_1	1970	0.192288	0.1424
9-63	2	147-73-7	Shaft RPS	- f_R = 199.8)	f_2	1627	0.158809	0.1212
10-64	2	147-96-1	114DS252-1	ACCESSORY IDLER	f_R	75	0.007320	0.0036
10-65	2	147-96-2	(Fafnir JM206	SHAFT	f_T	30	0.002928	0.0014
10-66	2	147-96-3	KMBR E-7842)		f_B	175	0.017081	0.0106
10-67	2	147-96-4	(Ball Dia	- d_B = 0.3750	f_B'	350	0.034163	0.0214
10-68	2	147-96-5	No. Balls	- m = 9	$3f_B'$	1050	0.102489	0.0644
10-69	2	147-96-6	Raceway	- d_1 = 1.4444	f_1	409	0.039921	0.0244
10-70	2	147-96-7		- d_2 = 2.193	f_2	269	0.026256	0.0154
			Shaft RPS	- f_R = 75.36)				
11-71	2	147-96-8	114DS252-1	LUBE OIL PUMP	f_R	84	0.008199	0.0042
11-72	2	147-96-9	(Fafnir JM206	SHAFT	f_T	33	0.003221	0.0015
11-73	2	147-96-10	KMBR E-7842)		f_B	194	0.018936	0.0116
11-74	2	147-96-11	(Ball Dia	- d_B = 0.3750	f_B'	389	0.037969	0.0234
11-75	2	147-96-12	No. Balls	- m = 9	$3f_B'$	1167	0.113909	0.0723
11-76	2	147-96-13	Raceway	- d_1 = 1.4444	f_1	454	0.044314	0.0266
11-77	2	147-96-14		- d_2 = 2.193	f_2	299	0.029184	0.0170
			Shaft RPS	- f_R = 83.74)				

TABLE XVII. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, COMBINING TRANSMISSION ACCESSORIES (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	N.A.	157-9	114D8450-2	COMBINING TRANSMISSION OIL COOLING FAN (14 Blades) (f_R = 81.52)	Fund	1141	0.111371	0.1111
					X2	2282	0.222742	0.1643
					X3	3423	0.334113	0.2531
					$+f_R$	1223	0.119365	0.1153
					$-f_R$	1059	0.103360	0.1021

TABLE XVIII. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, AFT SYNCHRONIZING SHAFT BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	N. A.	155-11-1	114DS340-1	SYNCHRONIZING DRIVE		f_R	117.8	0.011498	0.0057
1-2	N. A.	155-11-2	(Fafnir	SHAFT		f_T	53.7	0.005270	0.0026
1-3	N. A.	155-11-3	JMM9313K			f_B	655	0.063933	0.0406
1-4	N. A.	155-11-4	MBR E-7843)			f_B'	1311	0.127964	0.1014
1-5	N. A.	155-11-5	(Ball Dia	- d_B	= 0.28125	$3f_B'$	3933	0.383894	0.3044
1-6	N. A.	155-11-6	No. Balls	- m	= 19	f_1	1219	0.118984	0.0747
1-7	N. A.	155-11-7	Raceway	- d_1	= 2.874	f_2	1019	0.099463	0.0627
				- d_2	= 3.436				
			Shaft RPS	- f_R	= 117.76)				

TABLE XIX. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, FORWARD SYNCHRONIZING SHAFT BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
1-1	N. A.	155-47-1	114DS340-1	SYNCHRONIZING DRIVE	f_R	117.8	0.011498	0.0057
1-2	N. A.	155-47-2	(Fafnir	SHAFT	f_T	54	0.005270	0.0026
1-3	N. A.	155-47-3	JMM9313K		f_B	655	0.063933	0.0406
1-4	N. A.	155-47-4	MBR E-7843)		f_B'	1311	0.127964	0.1014
1-5	N. A.	155-47-5	(Ball Dia	- d_B = 0.28125	$3f_B'$	3933	0.383894	0.3044
1-6	N. A.	155-47-6	No. Balls	- m = 19	f_1	1219	0.118984	0.0747
1-7	N. A.	155-47-7	Raceway	- d_1 = 2.874	f_2	1019	0.099463	0.0627
				- d_2 = 3.436				
			Shaft RPS	- f_R = 117.76)				

TABLE XX. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, AFT ROTOR TRANSMISSION GEAR TRAINS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	4	150-190-1	114D2045-5	INPUT BEVEL DRIVE	Fund	3415	0.333333	0.2525
1-2	4	150-190-2			X2	6830	0.666666	0.5253
1-3	4	150-190-3			X3	10245	1.000000	1.0000
1-4	4	150-190-4		($f_R = f_{BEV} = 117.76$ Hz)	$+f_R$	3533	0.344851	0.2605
1-5	4	150-190-5			$+2f_R$	3651	0.356368	0.2664
1-6	4	150-190-6			$+3f_R$	3769	0.367886	0.2743
1-7	4	150-190-7			$-f_R$	3297	0.321815	0.2446
1-8	4	150-190-8			$-2f_R$	3179	0.310297	0.2367
1-9	4	150-190-9			$-3f_R$	3061	0.298779	0.2310
1-10	4	150-280-1	114D2062-1	($f_R = 66.96$ Hz)	$+f_R$	3482	0.339873	0.2560
1-11	4	150-280-2			$+2f_R$	3549	0.346412	0.2613
1-12	4	150-280-3			$+3f_R$	3616	0.352952	0.2646
1-13	4	150-280-4			$-f_R$	3348	0.326793	0.2473
1-14	4	150-280-5			$-2f_R$	3281	0.320253	0.2440
1-15	4	150-280-6			$-3f_R$	3214	0.313714	0.2405
1-16	4	150-190-10	114D2045-5	($f_R = 117.76$ Hz)	$(X2)+f_R$	6948	0.678184	0.5332
1-17	4	150-190-11			$(X2)-f_R$	6712	0.655148	0.5173
1-18	4	150-280-7	114D2062-1	($f_R = 66.96$ Hz)	$(X2)+f_R$	6897	0.673206	0.5305
1-19	4	150-280-8			$(X2)-f_R$	6763	0.660126	0.5220

TABLE XX - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
2-20	4	150-284-1	114D2066-1	1ST STAGE PLANETARY	$Fund_I$	1483	0.144753	0.1121
2-21	4	150-284-2			$X2_1 = 2f_I$	2966	0.289507	0.2242
2-22	4	150-284-3			$X3 = 3f_I$	4449	0.434260	0.3363
2-23	4	150-284-4		($fS_I = f_R = 66.96$ Hz)	$+fS_I$	1550	0.151293	0.1154
2-24	4	150-284-5			$+2fS_I$	1617	0.157833	0.1206
2-25	4	150-284-6			$-fS_I$	1416	0.138213	0.1066
2-26	4	150-284-7			$-2fS_I$	1349	0.131673	0.1033
2-27	4	150-284-8		($fS'_I = 52.97$ Hz)	$+fS'_I$	1536	0.149926	0.1146
2-28	4	150-284-9			$+2fS'_I$	1589	0.155100	0.1173
2-29	4	150-284-10			$-fS'_I$	1430	0.139580	0.1074
2-30	4	150-284-11			$-2fS'_I$	1377	0.134407	0.1047
2-31	4	150-254-1	114D2076-1	($fP_I = 38.03$ Hz)	$+fP_I$	1521	0.148462	0.1140
2-32	4	150-254-2			$+2fP_I$	1559	0.152171	0.1157
2-33	4	150-254-3			$-fP_I$	1445	0.141044	0.1102
2-34	4	150-254-4			$-2fP_I$	1407	0.137335	0.1063
2-35	4	150-284-12	114D2066-1	($fS_I = f_R = 66.96$ Hz)	$(X2)+fS_I$	3033	0.296046	0.2275
2-36	4	150-284-13			$(X2)-fS_I$	2899	0.282967	0.2207
2-37	4	150-284-14		($fS'_I = 52.97$ Hz)	$(X2)+fS'_I$	3019	0.294680	0.2267
2-38	4	150-284-15			$(X2)-fS'_I$	2913	0.284333	0.2215
2-39	4	150-254-5	114D2076-1	($fP_I = 38.03$ Hz)	$(X2)+fP_I$	2980	0.290873	0.2247
2-40	4	150-254-6			$(X2)-fP_I$	2952	0.288140	0.2234

TABLE XX - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
2-41	4	150-284-16	114D2045-5	(f_{BEV} = 117.76 Hz)	f_I+f_{BEV}	1601	0.156271	0.1200
2-42	4	150-284-17			f_I+2f_{BEV}	1719	0.167789	0.1257
2-43	4	150-284-18			f_I+3f_{BEV}	1837	0.179307	0.1336
2-45	4	150-284-19			f_I-f_{BEV}	1365	0.233236	0.1042
2-46	4	150-284-20			f_I-2f_{BEV}	1247	0.121718	0.0762
2-47	4	150-284-21			f_I-3f_{BEV}	1129	0.110200	0.0703

TABLE XX - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-41	4	150-240-1	114D2077-1	2ND STAGE PLANETARY	$Fund_{II}$	406	0.039629	0.0242
3-42	4	150-240-2			$X2 = 2f_{II}$	812	0.079258	0.0505
3-43	4	150-240-3			$X3 = 3f_{II}$	1218	0.118887	0.0747
3-44	4	150-240-4		(fS_{II}= f_R = 13.99 Hz)	$+fS_{II}$	420	0.040995	0.0250
3-45	4	150-240-5			$+2fS_{II}$	434	0.042362	0.0256
3-46	4	150-240-6			$-fS_{II}$	392	0.038262	0.0235
3-47	4	150-240-7			$-2fS_{II}$	378	0.036896	0.0227
3-48	4	150-240-8		(fS'_{II}= 10.16 Hz)	$+fS'_{II}$	416	0.040605	0.0246
3-49	4	150-240-9			$+2fS'_{II}$	426	0.041581	0.0252
3-50	4	150-240-10			$-fS'_{II}$	396	0.038653	0.0236
3-51	4	150-240-11			$-2fS'_{II}$	386	0.037676	0.0232
3-52	4	150-247-1	114D2084-1	(fP_{II}= 12.31 Hz)	$+fP_{II}$	418	0.040800	0.0247
3-53	4	150-247-2			$+2fP_{II}$	430	0.041971	0.0254
3-54	4	150-247-3			$-fP_{II}$	394	0.038457	0.0236
3-55	4	150-247-4			$-2fP_{II}$	382	0.037286	0.0231
3-56	4	150-240-12	114D2077-1	(fS_{II}= f_R = 13.99 Hz)	$(X2)+fS_{II}$	826	0.080624	0.0512
3-57	4	150-240-13			$(X2)-fS_{II}$	798	0.077891	0.0477
3-58	4	150-240-14		(fS'_{II}= 10.16 Hz)	$(X2)+fS'_{II}$	822	0.080234	0.0511
3-59	4	150-240-15			$(X2)-fS'_{II}$	792	0.077306	0.0475
3-60	4	150-247-5	114D2084-1	(f_{PII}= 12.31 Hz)	$(X2)+fP_{II}$	824	0.080429	0.0511
3-61	4	150-247-6			$(X2)-fP_{II}$	800	0.078086	0.0550

TABLE XX - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
4-62	4	150-284-16	114D2077-1	PLANETARY	(f_I+f_{II})	1889	0.184382	0.1363
4-63	4	150-284-17	114D2084-1	ADDITIONS	X2	3778	0.368765	0.2746
4-64	4	150-284-18		(1ST & 2ND STAGES)	X3	5667	0.553147	0.4332
4-65	4	150-284-19			X4	7556	0.737530	0.5715
4-66	4	150-284-20		(1st Stage f_{S_I}=66.96 Hz)	$+f_{S_I}$	1956	0.190922	0.1416
4-67	4	150-284-21			$-f_{S_I}$	1822	0.177842	0.1330
4-68	4	150-284-22		(2nd Stage f_S=13.99 Hz)	$+f_{S_{II}}$	1903	0.185749	0.1371
4-69	4	150-284-23			$-f_{S_{II}}$	1875	0.183016	0.1356
4-70	4	150-284-24		(1st Stage f_{P_I}=38.03 Hz)	$+f_{P_I}$	1927	0.188091	0.1402
4-71	4	150-284-25			$-f_{P_I}$	1851	0.180673	0.1344
4-72	4	150-284-26		(2nd Stage f_P=12.31 Hz)	$+f_{P_{II}}$	1901	0.185553	0.1370
4-73	4	150-284-27			$-f_{P_{II}}$	1877	0.183211	0.1356
4-74	4	150-284-28		(1st Stage $f_{S'_I}$ = 52.97 Hz)	$+f_{S'_I}$	1942	0.189555	0.1410
4-75	4	150-284-29			$-f_{S'_I}$	1836	0.179209	0.1336
4-76	4	150-284-30		(2nd Stage $f_{S'_{II}}$ = 10.16 Hz)	$+f_{S'_{II}}$	1899	0.185358	0.1367
4-77	4	150-284-31			$-f_{S'_{II}}$	1879	0.183406	0.1357
4-78	4	150-284-32		(2nd Stage F_{II} and 1st	$f_{II}+6f_{P_I}$	634	0.061883	0.0375
4-79	4	150-284-33		Stage f_{P_I} Modulations)	$f_{II}-6f_{P_I}$	178	0.017374	0.0107
4-80	4	150-284-34			$f_{II}+7f_{P_I}$	672	0.065592	0.0415
4-81	4	150-284-35			$f_{II}-7f_{P_I}$	140	0.013665	0.0070
4-82	4	150-284-36			$f_{II}+12f_{P_I}$	862	0.084138	0.0531
4-83	4	150-284-37			$f_{II}+18f_{P_I}$	1090	0.106393	0.0664
4-84	4	150-284-38			$f_{II}+24f_{P_I}$	1318	0.128648	0.1017

TABLE XXI. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, AFT ROTOR TRANSMISSION BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	4	150-287-1	114DS242-1	ROTOR SHAFT, LOWER		f_R	67	0.006539	0.0033
1-2	4	150-287-2	(MRC	THRUST		f_T	29	0.002830	0.0014
1-3	4	150-287-3	7116KRDF)			f_B	265	0.025866	0.0152
1-4	4	150-287-4	(Ball Dia	-	d_B = 0.5000	f_B'	530	0.051732	0.0324
1-5	4	150-287-5	No. Balls	-	m = 21	$3f_B'$	1590	0.155197	0.1174
1-6	4	150-287-6	Raceway	-	d_1 = 3.5200	f_1	791	0.077208	0.0474
1-7	4	150-287-7		-	d_2 = 4.5200	f_2	616	0.060126	0.0366
			Shaft RPS	-	f_R = 66.96)				
2-8	4	150-275-1	114DS243-1	MAIN ROTOR SHAFT		f_R	67	0.006539	0.0033
2-9	4	150-275-2	(MRC			f_T	31	0.003025	0.0014
2-10	4	150-275-3	R-1930-EX)			f_B	374	0.036505	0.0226
2-11	4	150-275-4	(Roller Dia	-	d_B = 0.6299	f_B'	747	0.072913	0.0453
2-12	4	150-275-5	No. Rollers	-	m = 30	$3f_B'$	2242	0.218838	0.1600
2-13	4	150-275-6	Raceway	-	d_1 = 6.4562	f_1	1094	0.106783	0.0665
2-14	4	150-275-7		-	d_2 = 7.7165	f_2	915	0.089311	0.0556
			Shaft RPS	-	f_R = 66.96)				

TABLE XXI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-15	4	150-254-1	114DS244-13	1ST STAGE PLANET	f_R	38	0.003708	0.0017
3-16	4	150-254-2	(SKF		f_T	16	0.001561	0.0006
3-17	4	150-254-3	454713A)		f_B	139	0.013567	0.0070
3-18	4	150-254-4	(Roller Dia	- d_B = 0.6299	f_B'	278	0.027135	0.0157
3-19	4	150-254-5	No. Rollers	- m = 18	$3f_B'$	833	0.081307	0.0515
3-20	4	150-254-6	Raceway	- d_1 = 4.0538	f_1	388	0.037872	0.0233
3-21	4	150-254-7		- d_2 = 5.5136	f_2	296	0.028892	0.0166
			Shaft RPS	- f_R = 38.03)				
			Contact	= 80				
4-22	4	150-238-1	114DS250-1	1ST STAGE	f_R	10	0.000976	0.0004
4-23	4	150-238-2	(Fafnir	CARRIER, INTER-	f_T	4.6	0.000448	0.0002
4-24	4	150-238-3	PMM9321K	SHAFT	f_B	53.1	0.005183	0.0025
4-25	4	150-238-4	MBR E-7842)		f_B'	106	0.010346	0.0052
4-26	4	150-238-5	(Ball Dia	- d_B = 0.46875	$3f_B'$	319	0.031137	0.0200
4-27	4	150-238-6	No. Balls	- m = 18	f_1	100	0.009760	0.0050
4-28	4	150-238-7	Raceway	- d_1 = 4.476	f_2	83	0.008101	0.0041
				- d_2 = 5.413				
			Shaft RPS	- (diff) = 10.16)				

TABLE XXI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
5-29	4	150-247-1	114DS258-3	2ND STAGE PLANET	f_R	12	0.001171	0.0005
5-30	4	150-247-2	(SKF		f_T	5	0.000488	0.0002
5-31	4	150-247-3	456716C)		f_B	33	0.003221	0.0015
5-32	4	150-247-4	(Roller Dia -	d_B = 0.8071	f_B'	66	0.006442	0.0032
5-33	4	150-247-5	No. Rollers -	m = 14	$3f_B'$	199	0.019424	0.0120
5-34	4	150-247-6	Raceway -	d_1 = 3.6800	f_1	102	0.009956	0.0051
5-35	4	150-247-7	-	d_2 = 5.2940	f_2	71	0.006930	0.0034
			Shaft RPS -	f_R = 12.31				
6-36	4	150-210-1	114DS274-1	2ND STAGE	f_R	3.83	0.000373	0.0002
6-37	4	150-210-2	(Fafnir	CARRIER, OUTPUT	f_T	1.82	0.000177	0.0001
6-38	4	150-210-3	AAM9250K2	SHAFT	f_B	36.8	0.003591	0.0017
6-39	4	150-210-4	MBRE-9060)		f_B'	73.6	0.007183	0.0035
6-40	4	150-210-5	(Roller Dia -	d_B = 0.5625	$3f_B'$	221	0.021571	0.0130
6-41	4	150-210-6	No. Rollers -	m = 31	f_1	62.5	0.006100	0.0031
6-42	4	150-210-7	Raceway -	d_1 = 10.263	f_2	56.3	0.005495	0.0027
			-	d_2 = 11.388				
			Shaft RPS -	f_R = 3.833)				

TABLE XXI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
7-43	4	150-201-1	114DS262-1	INPUT GEAR SHAFT,	f_R	118	0.011517	0.0057
7-44	4	150-201-2	(MRC	OUTER	f_T	51	0.004978	0.0024
7-45	4	150-201-3	MR-122-KE)		f_B	426	0.041581	0.0252
7-46	4	150-201-4	(Roller Dia	- d_B = 0.7480	f_B'	852	0.083162	0.0525
7-47	4	150-201-5	No. Rollers	- m = 20	$3f_B'$	2555	0.249389	0.1775
7-48	4	150-201-6	Raceway	- d_1 = 4.7638	f_1	1337	0.130502	0.1027
7-49	4	150-201-7		- d_2 = 6.2598	f_2	1018	0.099365	0.0627
			Shaft RPS	- f_R = 117.76)				
8-50	4	150-197-1	114DS241-1	INPUT GEAR SHAFT,	f_R	118	0.011517	0.0057
8-51	4	150-197-2	(Fafnir	DUAL, INTER-	f_T	48	0.004685	0.0023
8-52	4	150-197-3	3AAMM222	MEDIATE	f_B	296	0.028892	0.0166
8-53	4	150-197-4	WOMBR DF		f_B'	592	0.057784	0.0355
8-54	4	150-197-5	E-7846 Outer)		$3f_B'$	1775	0.173255	0.1306
8-55	4	150-197-6	(Ball Dia	- d_B = 1.1250	f_1	982	0.095851	0.0611
8-56	4	150-197-7	No. Balls	- m = 14	f_2	666	0.065007	0.0412
			Raceway	- d_1 = 4.744				
				- d_2 = 6.994				
			Shaft RPS	- f_R = 117.76)				

TABLE XXI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency	(Hz)	Decimal Ratio	Octal Ratio
8-57	4	150-197-8	(Fafnir	INPUT GEAR SHAFT,	f_R	118	0.011517	0.0057
8-58	4	150-197-9	3AAMMF	DUAL, INTER-	f_T	52	0.005075	0.0025
8-59	4	150-197-10	9122 WI3	MEDIATE	f_B	465	0.045387	0.0272
8-60	4	150-197-11	MBRDF		f_B'	929	0.090678	0.0563
8-61	4	150-197-12	E-7846 Inner)		$3f_B'$	2787	0.272035	0.2132
8-62	4	150-197-13	(Ball Dia	- d_B = 0.6875	f_1	1457	0.142215	0.1107
8-63	4	150-197-14	No. Balls	- m = 22	f_2	1134	0.110688	0.0705
			Raceway	- d_1 = 4.823				
				- d_2 = 6.198				
			Shaft RPS	- f_R = 117.76)				
9-64	4	150-193-1	114DS240-2	INPUT GEAR SHAFT,	f_R	118	0.011517	0.0057
9-65	4	150-193-2	(SKF 456650)	INNER THRUST	f_T	50	0.004880	0.0024
9-66	4	150-193-3	(Roller Dia	- d_B = 1.0236	f_B	370	0.036115	0.0224
9-67	4	150-193-4	No. Rollers	- m = 16	f_B'	740	0.072230	0.0447
9-68	4	150-193-5	Raceway	- d_1 = 5.5704	$3f_B'$	2221	0.216788	0.1567
9-69	4	150-193-6		- d_2 = 7.6176	f_1	1088	0.106198	0.0663
9-70	4	150-193-7	Shaft RPS	- f_R = 117.76)	f_2	796	0.077696	0.0476

TABLE XXII. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, AFT ROTOR TRANSMISSION, ACCESSORY DRIVE AND TRANSMISSION, GEAR TRAINS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	4	150-171-1	114D2056-1	OIL COOLING FAN	Fund	4239	0.413762	0.3237
1-2	4	150-171-2		BEVEL TRAIN AFT	X2	8478	0.827525	0.6476
1-3	4	150-171-3		XMSN	X3	12717	1.241288	1.1734
1-4	4	150-171-4		(f_R = 117.76)	$+f_R$	4357	0.425280	0.3316
1-5	4	150-171-5			$+2f_R$	4475	0.436798	0.3375
1-6	4	150-171-6			$-f_R$	4121	0.402244	0.3160
1-7	4	150-171-7			$-2f_R$	4003	0.390727	0.3100
1-8	4	150-127-1	114D2169-1	(f_R = 81.52)	$+f_R$	4321	0.421766	0.3300
1-9	4	150-127-2			$+2f_R$	4403	0.429770	0.3340
1-10	4	150-127-3			$-f_R$	4157	0.405758	0.3176
1-11	4	150-127-4			$-2f_R$	4075	0.397755	0.3135
2-12	4	150-278-1	114D2063-1	ACCESSORY DRIVE	Fund	4955	0.483650	0.3675
2-13	4	150-278-2		BEVEL, AFT	X2	9910	0.967301	0.7572
2-14	4	150-278-3			X3	14865	1.450951	1.3467
2-15	4	150-278-4		(f_R = 66.96)	$+f_R$	5022	0.490190	0.3730
2-16	4	150-278-5			$+2f_R$	5089	0.496730	0.3763
2-17	4	150-278-6			$-f_R$	4888	0.477110	0.3642
2-18	4	150-278-7			$-2f_R$	4821	0.470571	0.3607
2-19	4	150-310-1	114D2091-1	(f_R = 137.64)	$+f_R$	5093	0.497120	0.3764
2-20	4	150-310-2			$+2f_R$	5231	0.510590	0.4053
2-21	4	150-310-3			$-f_R$	4817	0.470180	0.3606
2-22	4	150-310-4			$-2f_R$	4679	0.456710	0.3517

TABLE XXII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-23	5	150-65-1	114D2106-1	ACCESSORY DRIVE	Fund	4129	0.403025	0.3163
3-24	5	150-65-2		MAIN TRAIN	X2	8258	0.806051	0.6346
3-25	5	150-65-3			X3	12387	1.209077	1.1530
3-26	5	150-65-4		(f_R = 137.64)	$+f_R$	4267	0.416495	0.3252
3-27	5	150-65-5			$+2f_R$	4405	0.429965	0.3341
3-28	5	150-65-6			$-f_R$	3991	0.389555	0.3074
3-29	5	150-65-7			$-2f_R$	3853	0.376085	0.3004
3-30	5	150-75-1	114D2108-1	(f_R = 114.70)	$+f_R$	4244	0.414250	0.3241
3-31	5	150-75-2			$+2f_R$	4359	0.425475	0.3317
3-32	5	150-75-3			$-f_R$	4014	0.391800	0.3105
3-33	5	150-75-4			$-2f_R$	3899	0.380575	0.3027
3-34	5	150-57-1	114D2132-1	(f_R = 66.60)	$+f_R$	4196	0.409565	0.3216
3-35	5	150-57-2			$+2f_R$	4263	0.416105	0.3250
3-36	5	150-57-3			$-f_R$	4062	0.396486	0.3130
3-37	5	150-57-4			$-2f_R$	3995	0.389946	0.3075
3-38	5	150-54-1	114D2178-1	(f_R = 77.91)	$+f_R$	4207	0.410639	0.3222
3-39	5	150-54-2			$+2f_R$	4285	0.418252	0.3261
3-40	5	150-54-3			$-f_R$	4051	0.395412	0.3124
3-41	5	150-54-4			$-2f_R$	3973	0.387798	0.3064
3-42	5	150-72-1	114D2107-1	(f_R = 142.22)	$+f_R$	4271	0.416886	0.3254
3-43	5	150-72-2			$+2f_R$	4413	0.430746	0.3344
3-44	5	150-72-3			$-f_R$	3937	0.389165	0.3072
3-45	5	150-72-4			$-2f_R$	3845	0.375305	0.3001

TABLE XXII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-46	5	150-68-1	114D2109-1	ACCESSORY DRIVE	$+f_R$	4262	0.416007	0.3250
3-47	5	150-68-2		MAIN TRAIN	$+2f_R$	4395	0.428989	0.3335
3-48	5	150-68-3		(f_R = 133.20)	$-f_R$	3996	0.390043	0.3076
3-49	5	150-68-4			$-2f_R$	3863	0.377061	0.3010
3-50	5	150-60-1	114D2110-1	(f_R = 77.91)	$+f_R$	4207	0.410639	0.3222
3-51	5	150-60-2			$+2f_R$	4285	0.418252	0.3261
3-52	5	150-60-3			$-f_R$	4051	0.395412	0.3124
3-53	5	150-60-4			$-2f_R$	3973	0.387798	0.3064

TABLE XXIII. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, AFT ROTOR TRANSMISSION, ACCESSORY DRIVE AND TRANSMISSION, BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
1-1	4	150-174-1	114DS257-1	OIL COOLER BEVEL	f_R	118	0.011517	0.0057
1-2	4	150-174-2	(MRC	PINION, OUTER	f_T	52	0.005075	0.0025
1-3	4	150-174-3	R-112-KD)		f_B	500	0.048804	0.0310
1-4	4	150-174-4	(Roller Dia	- d_B = 0.3543	f_B'	1000	0.097608	0.0620
1-5	4	150-174-5	No. Rollers	- m = 22	$3f_B'$	3001	0.292923	0.2260
1-6	4	150-174-6	Raceway	- d_1 = 2.6969	f_1	1446	0.141142	0.1102
1-7	4	150-174-7		- d_2 = 3.4055	f_2	1145	0.111761	0.0712
			Shaft RPS	- f_R = 117.76)				
2-8	4	150-165-1	114DS251-1	OIL COOLER BEVEL	f_R	118	0.011517	0.0057
2-9	4	150-165-2	(Fafnir	PINION, INNER	f_T	53	0.005173	0.0025
2-10	4	150-165-3	M9318KMBR		f_B	611	0.059638	0.0364
2-11	4	150-165-4	E7843)		f_B'	1221	0.119180	0.0750
2-12	4	150-165-5	(Ball Dia	- d_B = 0.4063	$3f_B'$	3664	0.357637	0.2671
2-13	4	150-165-6	No. Balls	- m = 18	f_1	1161	0.113323	0.0720
2-14	4	150-165-7	Raceway	- d_1 = 3.846	f_2	959	0.093606	0.0577
				- d_2 = 4.659				
			Shaft RPS	- f_R = 117.76)				

TABLE XXIII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-15	4	150-125-1	114DS253-1	OIL COOLER BEVEL	f_R	82	0.008003	0.0041
3-16	4	150-125-2	(MRC	DRIVE, LOWER	f_T	34	0.003318	0.0016
3-17	4	150-125-3	R-206-D)		f_B	227	0.022157	0.0133
3-18	4	150-125-4		(Roller Dia - d_B = 0.3150	f_B'	455	0.044411	0.0266
3-19	4	150-125-5		No. Rollers - m = 14	$3f_B'$	1364	0.133138	0.1041
3-20	4	150-125-6		Raceway - d_1 = 1.4960	f_1	670	0.065397	0.0414
3-21	4	150-125-7		- d_2 = 2.1260	f_2	471	0.045973	0.0274
				Shaft RPS - f_R = 81.52)				
4-22	4	150-123-1	114DS252-1	OIL COOLER BEVEL	f_R	82	0.008003	0.0041
4-23	4	150-123-2	(Fafnir	DRIVE, UPPER	f_T	32	0.003123	0.0015
4-24	4	150-123-3	JM206K		f_B	189	0.018448	0.0114
4-25	4	150-123-4	MBR E7842)		f_B'	379	0.036993	0.0230
4-26	4	150-123-5		(Ball Dia - d_B = 0.3750	$3f_B'$	1136	0.110883	0.0706
4-27	4	150-123-6		No. Balls - m = 9	f_1	443	0.043240	0.0261
4-28	4	150-123-7		Raceway - d_1 = 1.444	f_2	291	0.028404	0.0164
				- d_2 = 2.194				
				Shaft RPS - f_R = 81.52)				

TABLE XXIII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency	(Hz)	Decimal Ratio	Octal Ratio
5-29	N. A.	157-14-1	(No Vertol #)	OIL COOLER BLOWER	f_R	82	0.008003	0.0041
5-30	N. A.	157-14-2	(MRC 204 SZ)	SHAFT, LOWER	f_T	31	0.003025	0.0014
5-31	N. A.	157-14-3	(Ball Dia	- d_B = 0.3125	f_B	160	0.015617	0.0080
5-32	N. A.	157-14-4	No. Balls	- m = 8	f_B'	320	0.031234	0.0180
5-33	N. A.	157-14-5	Raceway	- d_1 = 0.9841	$3f_B'$	961	0.093801	0.0600
5-34	N. A.	157-14-6		- d_2 = 1.6091	f_1	407	0.039726	0.0243
5-35	N. A.	157-14-7	Shaft RPS	- f_R = 81.52)	f_2	249	0.024304	0.0144
6-36	N. A.	157-13-1	(No Vertol #)	OIL COOLER BLOWER	f_R	82	0.008003	0.0041
6-37	N. A.	157-13-2	(MRC 205 SZ)	SHAFT, UPPER	f_T	31	0.003025	0.0014
6-38	N. A.	157-13-3	(Ball Dia	- d_B = 0.3125	f_B	160	0.015617	0.0100
6-39	N. A.	157-13-4	No. Balls	- m = 8	f_B'	320	0.031234	0.0200
6-40	N. A.	157-13-5	Raceway	- d_1 = 0.9841	$3f_B'$	961	0.093801	0.0600
6-41	N. A.	157-13-6		- d_2 = 1.6091	f_1	407	0.039726	0.0243
6-42	N. A.	157-13-7	Shaft RPS	- f_R = 81.52)	f_2	249	0.024304	0.0143
7-43	N. A.	150-303-1	114DS265-1	ACCESSORY DRIVE	f_R	138	0.013469	0.0067
7-44	N. A.	150-303-2	(MRC R-	QUILL SHAFT,	f_T	59	0.005758	0.0030
7-45	N. A.	150-303-3	106-KEX)	FORWARD	f_B	450	0.043923	0.0264
7-46	N. A.	150-303-4	(Roller Dia	- d_B = 0.2500	f_B'	900	0.087847	0.0550
7-47	N. A.	150-303-5	No. Rollers	- m = 16	$3f_B'$	2701	0.263640	0.2070
7-48	N. A.	150-303-6	Raceway	- d_1 = 1.4226	f_1	1266	0.123572	0.0772
7-49	N. A.	150-303-7		- d_2 = 1.9232	f_2	936	0.091361	0.0566
			Shaft RPS	- f_R = 137.64)				

TABLE XXIII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
8-50	N. A.	150-295-1	114DS247-1	ACCESSORY DRIVE	f_R	138	0.013469	0.0067
8-51	N. A.	150-295-2	(SKF 453931)	GEAR SHAFT, AFT	f_T	63	0.009224	0.0046
8-52	N. A.	150-295-3	(Roller Dia	- d_B = 0.315	f_B	811	0.118740	0.0746
8-53	N. A.	150-295-4	No. Rollers	- m = 30	f_B'	1623	0.237628	0.1715
8-54	N. A.	150-295-5	Raceway	- d_1 = 3.425	$3f_B'$	4868	0.712737	0.5547
8-55	N. A.	150-295-6		- d_2 = 4.055	f_1	2238	0.327672	0.2476
8-56	N. A.	150-295-7	Shaft RPS	- f_R = 137.64)	f_2	1891	0.276866	0.2156
9-57	N. A.	150-307-1	114DS249-1	ACCESSORY DRIVE	f_R	138	0.013469	0.0067
9-58	N. A.	150-307-2	(MRC R-	QUILL SHAFT, AFT	f_T	59	0.005758	0.0030
9-59	N. A.	150-307-3	107-KEX)		f_B	467	0.045583	0.0273
9-60	N. A.	150-307-4	(Ball Dia	- d_B = 0.2756	f_B'	934	0.091166	0.0565
9-61	N. A.	150-307-5	No. Balls	- m = 16	$3f_B'$	2801	0.273401	0.2140
9-62	N. A.	150-307-6	Raceway	- d_1 = 1.6333	f_1	1260	0.122986	0.0770
9-63	N. A.	150-307-7		- d_2 = 2.1851	f_2	942	0.091947	0.0571
			Shaft RPS	- f_R = 137.64)				
10-64	N. A.	150-292-1	114DS248-1	ACCESSORY DRIVE	f_R	138	0.013469	0.0067
10-65	N. A.	150-292-2	(MRC 115-KS)	GEAR SHAFT, AFT	f_T	60	0.005856	0.0030
10-66	N. A.	150-292-3	(Ball Dia	- d_B = 0.5000	f_B	504	0.049194	0.0311
10-67	N. A.	150-292-4	No. Balls	- m = 14	f_B'	1008	0.098389	0.0623
10-68	N. A.	150-292-5	Raceway	- d_1 = 3.2287	$3f_B'$	3024	0.295168	0.2271
10-69	N. A.	150-292-6		- d_2 = 4.2287	f_1	1093	0.106686	0.0665
10-70	N. A.	150-292-7	Shaft RPS	- f_R = 137.64)	f_2	834	0.081405	0.0515

TABLE XXIII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
11-71	5	150-67-1	114DS255-1	ACCESSORY DRIVE	f_R	138	0.013469	0.0067
11-72	5	150-67-2	(MRC 107-KS)	GEAR	f_T	58	0.005661	0.0027
11-73	5	150-67-3	(Ball Dia	- d_B = 0.3125	f_B	407	0.039726	0.0243
11-74	5	150-67-4	No. Balls	- m = 11	f_B'	815	0.079551	0.0506
11-75	5	150-67-5	Raceway	- d_1 = 1.5882	$3f_B'$	2444	0.238555	0.1721
11-76	5	150-67-6		- d_2 = 2.2132	f_1	881	0.085993	0.0540
11-77	5	150-67-7	Shaft RPS	- f_R = 137.64)	f_2	633	0.061786	0.0375
12-78	5	150-77-1	114DS256-1	ACCESSORY DRIVE	f_R	115	0.011224	0.0056
12-79	5	150-77-2	(MRC 106-KS)	IDLER GEAR	f_T	47	0.004587	0.0023
12-80	5	150-77-3	(Ball Dia	- d_B = 0.3125	f_B	295	0.028794	0.0166
12-81	5	150-77-4	No. Balls	- m = 10	f_B'	590	0.057589	0.0354
12-82	5	150-77-5	Raceway	- d_1 = 1.3535	$3f_B'$	1770	0.172767	0.1304
12-83	5	150-77-6		- d_2 = 1.9785	f_1	681	0.066471	0.0420
12-84	5	150-77-7	Shaft RPS	- f_R = 114.70)	f_2	466	0.045485	0.0272
13-85	5	150-73-1	114DS255-1	ALTERNATOR DRIVE	f_R	142	0.013860	0.0071
13-86	5	150-73-2	(MRC 107-KS)	PINION	f_T	59	0.005758	0.0030
13-87	5	150-73-3	(Ball Dia	- d_B = 0.3125	f_B	421	0.041093	0.0250
13-88	5	150-73-4	No. Balls	- m = 11	f_B'	842	0.082186	0.0521
13-89	5	150-73-5	Raceway	- d_1 = 1.5882	$3f_B'$	2525	0.246461	.1762
13-90	5	150-73-6		- d_2 = 2.2132	f_1	911	0.088921	0.0554
13-91	5	150-73-7	Shaft RPS	- f_R = 142.22)	f_2	654	0.063836	0.0405

TABLE XXIII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
14-92	5	150-70-1	114DS256-1	HYDRAULIC MOTOR	f_R	133	0.012981	0.0065
14-93	5	150-70-2	(MRC 106-KS)	DRIVE GEAR	f_T	54	0.005270	0.0026
14-94	5	150-70-3	(Ball Dia	- d_B = 0.3125	f_B	343	0.033479	0.0211
14-95	5	150-70-4	No. Balls	- m = 10	f_B'	685	0.066861	0.0422
14-96	5	150-70-5	Raceway	- d_1 = 1.3535	$3f_B'$	2055	0.200585	0.1466
14-97	5	150-70-6		- d_2 = 1.9785	f_1	791	0.077208	0.0474
14-98	5	150-70-7	Shaft RPS	- f_R = 133.20)	f_2	541	0.052806	0.0330
15-99	5	150-58-1	114DS256-1	HYDRAULIC PUMP	f_R	67	0.006539	0.0033
15-100	5	150-58-2	(MRC 106-KS)	DRIVE GEAR	f_T	27	0.002635	0.0013
15-101	5	150-58-3	(Ball Dia	- d_B = 0.3125	f_B	171	0.016691	0.0104
15-102	5	150-58-4	No. Balls	- m = 10	f_B'	343	0.033479	0.0211
15-103	5	150-58-5	Raceway	- d_1 = 1.3535	$3f_B'$	1028	0.100341	0.0633
15-104	5	150-58-6		- d_2 = 1.9785	f_1	395	0.038555	0.0236
15-105	5	150-58-7	Shaft RPS	- f_R = 66.60)	f_2	270	0.026354	0.0154
16-106	5	150-55-1	114DS256-1	AXIAL PISTON PUMP	f_R	78	0.007613	0.0037
16-107	5	150-55-2	(MRC 106-KS)	DRIVE GEAR	f_T	32	0.003123	0.0015
16-108	5	150-55-3	(Ball Dia	- d_B = 0.3125	f_B	200	0.019521	0.0120
16-109	5	150-55-4	No. Balls	- m = 10	f_B'	401	0.039141	0.0240
16-110	5	150-55-5	Raceway	- d_1 = 1.3535	$3f_B'$	1202	0.117325	0.0741
16-111	5	150-55-6		- d_2 = 1.9875	f_1	463	0.045192	0.0271
16-112	5	150-55-7	Shaft RPS	- f_R = 77.91)	f_2	316	0.030844	0.0176

TABLE XXIII - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
17-113	5	150-61-1	114DS256-1	LUBE OIL PUMP DRIVE	f_R	78	0.007613	0.0037
17-114	5	150-61-2	(MRC 106-KS)	GEAR	f_T	32	0.003123	0.0015
17-115	5	150-61-3	(Ball Dia	- d_B = 0.3125	f_B	200	0.019521	0.0120
17-116	5	150-61-4	No. Balls	- m = 10	f_B'	401	0.039141	0.0240
17-117	5	150-61-5	Raceway	- d_1 = 1.3535	$3f_B'$	1202	0.117325	0.0741
17-118	5	150-61-6		- d_2 = 1.9785	f_1	463	0.045192	0.0271
17-119	5	150-61-7	Shaft RPS	- f_R = 77.91)	f_2	316	0.030844	0.0176

TABLE XXIV. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, AFT ROTARY WING DRIVE SHAFT BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
1-1	N. A.	154-20-1	114DS349-1	AFT ROTOR SHAFT	f_R	3.833	0.000374	0.0002
1-2	N. A.	154-20-2	(Fafnir AAM		f_T	1.68	0.000163	0.0001
1-3	N. A.	154-20-3	9134-4		f_B	15	0.001464	0.0006
1-4	N. A.	154-20-4	MBRE-9203)		f_B'	30	0.002928	0.0014
1-5	N. A.	154-20-5	(Ball Dia	- d_B = 1.0625	$3f_B'$	90	0.008784	0.0044
1-6	N. A.	154-20-6	No. Balls	- m = 21	f_1	45	0.004392	0.0022
1-7	N. A.	154-20-7	Raceway	- d_1 = 7.4020	f_2	35	0.003416	0.0016
				- d_2 = 9.5270				
			Shaft RPS	- f_R = 3.833)				

TABLE XXV. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, FORWARD ROTOR TRANSMISSION GEAR TRAINS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)	Decimal Ratio	Octal Ratio
1-1	3	149-96-1	114D1044-8	INPUT BEVEL DRIVE	Fund f_{BEV} 3415	0.333333	0.2525
1-2	3	149-96-2			X2 6830	0.666666	0.5253
1-3	3	149-96-3			X3 10245	1.000000	1.0000
1-4	3	149-96-4		(f_R = 117.76 Hz)	$+f_R$ 3533	0.344851	0.2605
1-5	3	149-96-5			$+2f_R$ 3651	0.356368	0.2664
1-6	3	149-96-6			$+3f_R$ 3769	0.367886	0.2743
1-7	3	149-96-7			$-f_R$ 3297	0.321815	0.2446
1-8	3	149-96-8			$-2f_R$ 3179	0.310297	0.2367
1-9	3	149-96-9			$-3f_R$ 3061	0.298779	0.2310
1-10	3	149-182-1	114D1053-1	(f_R = 66.96 Hz)	$+f_R$ 3482	0.339873	0.2560
1-11	3	149-182-2			$+2f_R$ 3549	0.346412	0.2613
1-12	3	149-182-3			$+3f_R$ 3616	0.352952	0.2646
1-13	3	149-182-4			$-f_R$ 3348	0.326793	0.2473
1-14	3	149-182-5			$-2f_R$ 3281	0.320253	0.2440
1-15	3	149-182-6			$-3f_R$ 3214	0.313714	0.2405
1-16	3	149-96-10	114D1044-8	(f_R = 117.76 Hz)	$(X2)+f_R$ 6948	0.678184	0.5332
1-17	3	149-96-11			$(X2)-f_R$ 6712	0.655148	0.5173
1-18	3	149-182-7	114D1053-1	(f_R = 66.96 Hz)	$(X2)+f_R$ 6897	0.673206	0.5305
1-19	3	149-182-8			$(X2)-f_R$ 6763	0.660126	0.5220

TABLE XXV - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
2-20	3	149-186-1	114D1043-1	1ST STAGE PLANETARY	Fund f_I	1483	0.144753	0.1121
2-21	3	149-186-2			X2 = $2f_I$	2966	0.289507	0.2242
2-22	3	149-186-3			X3 = $3f_I$	4449	0.434260	0.3363
2-23	3	149-186-4		(f_S = f_R = 66.96 Hz)	$+f_S$	1550	0.151293	0.1154
2-24	3	149-186-5			$+2f_S$	1617	0.157833	0.1206
2-25	3	149-186-6			$-f_S$	1416	0.138213	0.1066
2-26	3	149-186-7			$-2f_S$	1349	0.131673	0.1033
2-27	3	149-186-8		(f_S' = 52.97 Hz)	$+f_S'$	1536	0.149926	0.1146
2-28	3	149-186-9			$+2f_S'$	1589	0.155100	0.1173
2-29	3	149-186-10			$-f_S'$	1430	0.139580	0.1074
2-30	3	149-186-11			$-2f_S'$	1377	0.134407	0.1047
2-31	3	149-146-1	114DS244-13	(f_P = 38.03 Hz)	$+f_P$	1521	0.148462	0.1140
2-32	3	149-146-2			$+2f_P$	1559	0.152171	0.1157
2-33	3	149-146-3			$-f_P$	1445	0.141044	0.1102
2-34	3	149-146-4			$-2f_P$	1407	0.137335	0.1063
2-35	3	149-186-12	114D1043-1	(f_S = f_R = 66.96 Hz)	(X2)+f_S	3033	0.296046	0.2275
2-36	3	149-186-13			(X2)-f_S	2899	0.282967	0.2207
2-37	3	149-186-14		(f_S' = 52.97 Hz)	(X2)+f_S'	3019	0.294680	0.2267
2-38	3	149-186-15			(X2)-f_S'	2913	0.284333	0.2215
2-39	3	149-146-5	114DS244-13	(f_P = 38.03 Hz)	(X2)+f_P	3004	0.293216	0.2261
2-40	3	149-146-6			(X2)-f_P	2928	0.285797	0.2223

TABLE XXV - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
2-41	3	149-186-16	114D1044-8	(f_{BEV} = 117.76 Hz)	f_I+f_{BEV}	1601	0.156271	0.1200
2-42	3	149-186-17			f_I+2f_{BEV}	1719	0.167789	0.1257
2-43	3	149-186-18			f_I+3f_{BEV}	1837	0.179307	0.1336
2-44	3	149-186-19			f_I-f_{BEV}	1365	0.233236	0.1042
2-45	3	149-186-20			f_I-2f_{BEV}	1247	0.121718	0.0762
2-46	3	149-186-21			f_I-3f_{BEV}	1129	0.110200	0.0703

TABLE XXV - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-41	3	149-141-1	114D2077-1	2ND STAGE PLANETARY	Fund f_{II}	406	0.039629	0.0242
3-42	3	149-141-2			X2 = $2f_{II}$	812	0.079258	0.0505
3-43	3	149-141-3			X3 = $3f_{II}$	1218	0.118887	0.0747
3-44	3	149-141-4		($f_S = f_R$ = 13.99 Hz)	$+f_S$	420	0.040995	0.0250
3-45	3	149-141-5			$+2f_S$	434	0.042362	0.0256
3-46	3	149-141-6			$-f_S$	392	0.038262	0.0235
3-47	3	149-141-7			$-2f_S$	378	0.036896	0.0227
3-48	3	149-141-8		(f_S' = 10.16 Hz)	$+f_S'$	416	0.040605	0.0246
3-49	3	149-141-9			$+2f_S'$	426	0.041581	0.0252
3-50	3	149-141-10			$-f_S'$	396	0.038653	0.0236
3-51	3	149-141-11			$-2f_S'$	386	0.037676	0.0232
3-52	3	149-153-1	114DS258-3	(f_P = 12.31 Hz)	$+f_P$	418	0.040800	0.0247
3-53	3	149-153-2			$+2f_P$	430	0.041971	0.0254
3-54	3	149-153-3			$-f_P$	394	0.038457	0.0236
3-55	3	149-153-4			$-2f_P$	382	0.037286	0.0231
3-56	3	149-141-12	114D2077-1	($f_S = f_R$ = 13.99 Hz)	(X2)+f_S	826	0.080624	0.0512
3-57	3	149-141-13			(X2)-f_S	798	0.077891	0.0477
3-58	3	149-141-14		(f_S' = 10.16 Hz)	(X2)+f_S'	822	0.080234	0.0511
3-59	3	149-141-15			(X2)-f_S'	792	0.077306	0.0475
3-60	3	149-153-5	114DS258-3	(f_P = 12.31 Hz)	(X2)+f_P	824	0.080429	0.0511
3-61	3	149-153-6			(X2)-f_P	800	0.078086	0.0500

TABLE XXV - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
4-62	3	149-186-16	114D2077-1	PLANETARY	(f_I+f_{II})	1889	0.184382	0.1363
4-63	3	149-186-17	114DS258-3	ADDITIONS (1ST &	X2	3778	0.368765	0.2746
4-64	3	149-186-18		2ND STAGES)	X3	5667	0.553147	0.4332
4-65	3	149-186-19			X4	7556	0.737530	0.5715
4-66	3	149-186-20		(1st Stage f_{S_I}= 66.96 Hz)	$+f_{S_I}$	1956	0.190922	0.1416
4-67	3	149-186-21			$-f_{S_I}$	1822	0.177842	0.1330
4-68	3	149-186-22		(2nd Stage $f_{S_{II}}$= 13.99 Hz)	$+f_{S_{II}}$	1903	0.185749	0.1371
4-69	3	149-186-23			$-f_{S_{II}}$	1875	0.183016	0.1356
4-70	3	149-186-24		(1st Stage f_{P_I}= 38.03 Hz)	$+f_{P_I}$	1927	0.188091	0.1402
4-71	3	149-186-25			$-f_{P_I}$	1851	0.180673	0.1344
4-72	3	149-186-26		(2nd Stage $f_{P_{II}}$= 12.31 Hz)	$+f_{P_{II}}$	1901	0.185553	0.1370
4-73	3	149-186-27			$-f_{P_{II}}$	1877	0.183211	0.1356
4-74	3	149-186-28		(1st Stage $f_{S'_I}$=52.97 Hz)	$+f_{S'_I}$	1942	0.189555	0.1410
4-75	3	149-186-29			$-f_{S'_I}$	1836	0.179209	0.1336
4-76	3	149-186-30		(2nd Stage $f_{S'_{II}}$=10.16 Hz)	$+f_{S'_{II}}$	1899	0.185358	0.1367
4-77	3	149-186-31			$-f_{S'_{II}}$	1879	0.183406	0.1357
4-78	3	149-186-32		(2nd Stage f_{II} and 1st	$f_{II}+6f_{P_I}$	634	0.061883	0.0375
4-79	3	149-186-33		Stage f_{P_I} Modulations)	$f_{II}-6f_{P_I}$	178	0.017374	0.0107
4-80	3	149-186-34			$f_{II}+7f_{P_I}$	672	0.065592	0.0415
4-81	3	149-186-35			$f_{II}-7f_{P_I}$	140	0.013665	0.0070
4-82	3	149-186-36			$f_{II}+12f_{P_I}$	862	0.084138	0.0531
4-83	3	149-186-37			$f_{II}+18f_{P_I}$	1090	0.106393	0.0664
4-84	3	149-186-38			$f_{II}+24f_{P_I}$	1318	0.128648	0.1017

TABLE XXVI. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, FORWARD ROTOR TRANSMISSION BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	3	149-178-1	114DS143-1	ROTOR SHAFT, LOWER		f_R	67	0.006539	0.0033
1-2	3	149-178-2	(Fafnir	THRUST		f_T	28	0.002733	0.0013
1-3	3	149-178-3	3M215	(Roller Dia - d_B	= 0.6875	f_B	191	0.018643	0.0114
1-4	3	149-178-4	WIMBRDF	No. Rollers - m	= 15	f_B'	381	0.037188	0.0230
1-5	3	149-178-5	E-7844)	Raceway - d_1	= 3.346	$3f_B'$	1144	0.111664	0.0711
1-6	3	149-178-6		- d_2	= 4.721	f_1	588	0.057393	0.0353
1-7	3	149-178-7		Shaft RPS - f_R	= 66.96)	f_2	417	0.040702	0.0247
2-8	3	149-174-1	114DS243-1	MAIN ROTOR SHAFT		f_R	67	0.006539	0.0033
2-9	3	149-174-2	(MRC R-			f_T	31	0.003025	0.0014
2-10	3	149-174-3	1930-EX)			f_B	374	0.036505	0.0226
2-11	3	149-174-4	(Roller Dia - d_B	= 0.6299		f_B'	747	0.072913	0.0453
2-12	3	149-174-5	No. Rollers - m	= 30		$3f_B'$	2242	0.218838	0.1600
2-13	3	149-174-6	Raceway - d_1	= 6.4562		f_1	1094	0.106783	0.0665
2-14	3	149-174-7	- d_2	= 7.7165		f_2	915	0.089311	0.0556
			Shaft RPS - f_R	= 66.96)					

TABLE XXVI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
3-15	3	149-146-1	114DS244-13	1ST STAGE PLANET	f_R	38	0.003709	0.0017
3-16	3	149-146-2	(SKF		f_T	16	0.001561	0.0006
3-17	3	149-146-3	454713A)		f_B	139	0.013567	0.0070
3-18	3	149-146-4	(Roller Dia -	d_B = 0.6299	f_B'	278	0.027135	0.0157
3-19	3	149-146-5	No. Rollers -	m = 18	$3f_B'$	833	0.081307	0.0515
3-20	3	149-146-6	Raceway -	d_1 = 4.0538	f_1	388	0.037872	0.0233
3-21	3	149-146-7	-	d_2 = 5.5136	f_2	296	0.028892	0.0166
			Shaft RPS -	f_R = 38.03)				
			Contact Angle	= 8°				
4-22	3	149-139-1	114DS250-1	1ST STAGE CARRIER	f_R	10	0.000976	0.0004
4-23	3	149-139-2	(Fafnir PMM	INTERSHAFT	f_T	4.6	0.000448	0.0002
4-24	3	149-139-3	9321K MBR		f_B	53.1	0.005183	0.0025
4-25	3	149-139-4	E-7842)		f_B'	106	0.010346	0.0052
4-26	3	149-139-5	(Ball Dia -	d_B = 0.46875	$3f_B$	319	0.031137	0.0200
4-27	3	149-139-6	No. Balls -	m = 18	f_1	100	0.009760	0.0050
4-28	3	149-139-7	Raceway -	d_1 = 4.476	f_2	83	0.008101	0.0041
			-	d_2 = 5.413				
			Shaft RPS (diff.)	= 10.16)				

TABLE XXVI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
5-29	3	149-153-1	114DS258-3	2ND STAGE PLANET	f_R	12	0.001171	0.0005
5-30	3	149-153-2	(SKF 456716C)		f_T	5	0.000488	0.0002
5-31	3	149-153-3	(Roller Dia	- d_B = 0.8071	f_B	33	0.003221	0.0015
5-32	3	149-153-4	No. Rollers	- m = 14	f_B'	66	0.006442	0.0032
5-33	3	149-153-5	Raceway	- d_1 = 3.6800	$3f_B'$	199	0.019424	0.0120
5-34	3	149-153-6		- d_2 = 5.2940	f_1	102	0.009956	0.0051
5-35	3	149-153-7	Shaft RPS	- f_R = 12.31	f_2	71	0.006930	0.0034
				=				
6-36	3	149-162-1	114DS144-1	2ND STAGE	f_R	3.83	0.000373	0.0002
6-37	3	149-162-2	(SKF 453958)	CARRIER, OUTPUT	f_T	1.82	0.000177	0.0001
6-38	3	149-162-3		SHAFT	f_B	36.8	0.003591	0.0017
6-39	3	149-162-4	(Ball Dia	- d_B = 0.5625	f_B'	73.6	0.007183	0.0035
6-40	3	149-162-5	No. Balls	- m = 31	$3f_B'$	221	0.021571	0.0130
6-41	3	149-162-6	Raceway	- d_1 = 10.263	f_1	62.5	0.006100	0.0031
6-42	3	149-162-7		- d_2 = 11.388	f_2	56.3	0.005495	0.0027
			Shaft RPS	- f_R = 3.833)				
7-43	3	149-160-1	114DS145-1	OUTPUT ROTOR SHAFT	f_R	3.83	0.000373	0.0002
7-44	3	149-160-2	(SKF 456649)	UPPER	f_T	1.75	0.000170	0.0001
7-45	3	149-160-3	(Roller Dia	- d_B = 0.6693	f_B	21	0.002049	0.0010
7-46	3	149-160-4	No. Rollers	- m = 30	f_B'	43	0.004197	0.0021
7-47	3	149-160-5	Raceway	- d_1 = 6.8106	$3f_B'$	128	0.012493	0.0063
7-48	3	149-160-6		- d_2 = 8.1492	f_1	63	0.006149	0.0031
7-49	3	149-160-7	Shaft RPS	- f_R = 3.833)	f_2	53	0.005173	0.0025

TABLE XXVI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency	(Hz)	Decimal Ratio	Octal Ratio
7-50	3	149-85-1	114DS262-1	INPUT BEVEL GEAR	f_R	118	0.011517	0.0057
7-51	3	149-85-2	(MRC MR-	SHAFT, OUTER	f_T	51	0.004978	0.0024
7-52	3	149-85-3	122-KE)		f_B	426	0.041581	0.0252
7-53	3	149-85-4		(Roller Dia - d_B = 0.7480	f_B'	852	0.083162	0.0525
7-54	3	149-85-5		No. Rollers - m = 20	$3f_B'$	2555	0.249389	0.1775
7-55	3	149-85-6		Raceway - d_1 = 4.7638	f_1	1337	0.130502	0.1027
7-56	3	149-85-7		- d_2 = 6.2598	f_2	1018	0.099365	0.0627
				Shaft RPS - f_R = 117.76)				
8-57	3	149-89-1	114DS241-1	INPUT GEAR SHAFT,	f_R	118	0.011517	0.0057
8-58	3	149-89-2	(Fafnir	DUAL INTERMEDIATE	f_T	48	0.004685	0.0023
8-59	3	149-89-3	3AAMM222		f_B	296	0.028892	0.0166
8-60	3	149-89-4	WOMBR DF		f_B'	592	0.057784	0.0355
8-61	3	149-89-5	E-7846 Outer)		$3f_B'$	1775	0.173255	0.1306
8-62	3	149-89-6		(Ball Dia - d_B = 1.1250	f_1	982	0.095851	0.0611
8-63	3	149-89-7		No. Balls - m = 14	f_2	666	0.065007	0.0412
				Raceway - d_1 = 4.744				
				- d_2 = 6.994				
				Shaft RPS - f_R = 117.76)				

TABLE XXVI - Continued

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
8-64	3	149-89-8	114DS241-1	INPUT GEAR SHAFT,	f_R	118	0.011517	0.0057
8-65	3	149-89-9	(Fafnir	DUAL INTERMEDIATE	f_T	52	0.005075	0.0025
8-66	3	149-89-10	3AAMMF9122		f_B	465	0.045387	0.0272
8-67	3	149-89-11	WI3MBR DF		f_B'	929	0.090678	0.0563
8-68	3	149-89-12	E-7846 Inner)		$3f_B'$	2787	0.272035	0.2132
8-69	3	149-89-13	(Ball Dia	- d_B = 0.6875	f_1	1457	0.142215	0.1107
8-70	3	149-89-14	No. Balls	- m = 22	f_2	1134	0.110688	0.0705
			Raceway	- d_1 = 4.823				
				- d_2 = 6.198				
			Shaft RPS	- f_R = 117.76)				
9-71	3	149-93-1	114DS240-2	INPUT GEAR SHAFT,	f_R	118	0.011517	0.0057
9-72	3	149-93-2	(SKF 456650)	INNER THRUST	f_T	50	0.004880	0.0024
9-73	3	149-93-3	(Roller Dia	- d_B = 1.0236	f_B	370	0.036115	0.0224
9-74	3	149-93-4	No. Rollers	- m = 16	f_B'	740	0.072230	0.0447
9-75	3	149-93-5	Raceway	- d_1 = 5.5704	$3f_B'$	2221	0.216788	0.1567
9-76	3	149-93-6		- d_2 = 7.6176	f_1	1088	0.106198	0.0663
9-77	3	149-93-7	Shaft RPS	- f_R = 117.76)	f_2	796	0.077696	0.0476

TABLE XXVII. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, FORWARD ROTOR TRANSMISSION ACCESSORY DRIVE GEAR TRAINS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description	Frequency (Hz)		Decimal Ratio	Octal Ratio
1-1	3	149-181-1	114D1066-1	LUBE OIL PUMP DRIVE	Fund	3750	0.366032	0.2733
1-2	3	149-181-2			X2	7500	0.732064	0.5667
1-3	3	149-181-3			X3	11250	1.098096	1.0622
1-4	3	149-181-4		(f_R = 66.96 Hz)	$+f_R$	3817	0.372571	0.2766
1-5	3	149-181-5			$+2f_R$	3884	0.379111	0.3021
1-6	3	149-181-6			$-f_R$	3683	0.359492	0.2700
1-7	3	149-181-7			$-2f_R$	3616	0.352952	0.2646
1-8	3	149-192-1	114D1067-1	(f_R = 75.00 Hz)	$+f_R$	3825	0.373352	0.2771
1-9	3	149-192-2			$-2f_R$	3900	0.380673	0.3027
1-10	3	149-192-3			$-f_R$	3675	0.358711	0.2675
1-11	3	149-192-4			$-2f_R$	3600	0.351390	0.2637

TABLE XXVIII. FREQUENCIES AND ACOUSTIC LOCK RATIOS, MODELS CH-47A/B HELICOPTERS, FORWARD ROTOR TRANSMISSION ACCESSORY DRIVE BEARINGS (N_2 - RELATED)

Item	Ref Figure	Program Index	Part Number (Vendor)	Component Description		Frequency (Hz)	Decimal Ratio	Octal Ratio
1-1	3	149-190-1	114DS255-1	LUBE OIL PUMP DRIVE	f_R	75	0.007320	0.0036
1-2	3	149-190-2	(MRC 107-KS)	SHAFT	f_T	31	0.003025	0.0014
1-3	3	149-190-3	(Ball Dia	- d_B = 0.3125	f_B	222	0.021669	0.0131
1-4	3	149-190-4	No. Balls	- m = 11	f_B'	444	0.043339	0.0262
1-5	3	149-190-5	Raceway	- d_1 = 1.5882	$3f_B'$	1332	0.130014	0.1025
1-6	3	149-190-6		- d_2 = 2.2132	f_1	480	0.046852	0.0300
1-7	3	149-190-7	Shaft RPS	- f_R = 74.995)	f_2	345	0.033674	0.0212

TABLE XXIX. INDEXED SUMMARY OF SONIC FREQUENCIES - CH-47A/B HELICOPTERS

Reference Table	Title - Components	Ratio To Engine Rotor Speed	Frequency (Hz)
I	T55-L-5, -7 GAS PRODUCER SECTION, COMPRESSOR ROTOR BLADE PASSAGE	(N_1)	
	C_1	28.0000 N_1	6552
	C_2	36.0000 N_1	8424
	C_3	40.0000 N_1	9360
	C_{4-5}	48.0000 N_1	11232
	C_{6-7}	50.0000 N_1	11700
	C_C	34.0000 N_1	7956
II	T55-L-5, -7 GAS PRODUCER SECTION, TURBINE ROTOR BLADE PASSAGE	(N_1)	
	T_1	84.0000 N_1	19656
III	T55-L-5, -7 POWER TURBINE SECTION, ROTOR BLADE PASSAGE	(N_2)	
	T_2	66.0000 N_2	16682
	T_3	56.0000 N_2	14155
VI	T55-L-5, -7 ACCESSORY DRIVE TRAINS GEAR TOOTH CONTACT	(N_1)	
	Inner Bevel Main Drive	39.0000 N_1	9126
	Outer Accessory Drive Bevel	14.0000 N_1	3276
	Accessory Xmsn Main Train (N_1 Locking Signal)	8.7500 N_1	2047

TABLE XXIX - Continued

Reference Table	Title - Components	Ratio To Engine Rotor Speed	Frequency (Hz)
IX	T55-L-5, -7 ACCESSORY DRIVE AND XMSN TRAINS, GEAR TOOTH CONTACT	(N_2)	
	Torquemeter Actuating Drive	42.0151 N_2	10620
	Overspeed Drive Bevel, Inner	16.1532 N_2	4083
	Overspeed Control Bevel, Outer	9.6927 N_2	2450
	Overspeed Control Drive Idler Train and Cluster	9.6927 N_2	2450
	N_2 Tachometer Drive Bevel (not used)	5.4794 N_2	1385
XIV	ENGINE XMSNS (NO. 1, NO. 2), GEAR TRAIN, TOOTH CONTACT	(N_2)	
	Spiral Bevel Train	33.9997 N_2	8594
XVI	COMBINING TRANSMISSION GEAR TRAINS, TOOTH CONTACT	(N_2)	
	Spiral Bevel, Main Power	26.0873 N_2	6594
	Lube Oil Pump Drive	14.9070 N_2	3768
	Lube Oil Pump Drive	13.9734 N_2	3532
XXI	AFT ROTOR TRANSMISSION GEAR TRAIN TOOTH CONTACT	(N_2)	
	Input Bevel Drive (N_2 Locking Signal)	13.5105 N_2	3415
	1st Stage Planetary (f_I)	5.8671 N_2	1483
	2nd Stage Planetary (f_{II})	1.6062 N_2	406
XXIII	AFT ROTOR TRANSMISSION ACCESSORY DRIVE AND XMSN GEAR TRAIN TOOTH CONTACT	(N_2)	
	Oil Cooling Fan Bevel	16.7704 N_2	4239
	Accessory Drive Bevel, Aft	19.6031 N_2	4955
	Accessory Drive Main Train	16.3352 N_2	4129

TABLE XXIX - Continued

Reference Table	Title - Components	Ratio To Engine Rotor Speed	Frequency (Hz)
XXVII	FORWARD ROTOR XMSN GEAR TRAIN TOOTH CONTACT	(N_2)	
	Input Bevel Drive (N_2 Locking Signal)	13.5105 N_2	3415
	1st Stage Planetary (f_I)	5.8671 N_2	1483
	2nd Stage Planetary (f_{II})	1.6062 N_2	406
XXIX	FORWARD ROTOR XMSN ACCESSORY DRIVE GEAR TRAIN TOOTH CONTACT	(N_2)	
	Lube Oil Pump Drive N_2 Tachometer Drive	14.8358 N_2	3750

TABLE XXX. FUNDAMENTAL ROTATIONAL SHAFT SPEEDS - CH-47A/B HELICOPTERS

Table Reference	Shaft Identification	Ratio To Engine Rotor Speed	Speed (RPS)
I	T55-L-5, -7 COMPRESSOR ROTOR	1.00000 N_1	234.00
II	T55-L-5, -7 POWER TURBINE ROTOR	1.00000 N_2	252.77
VI	T55-L-5, -7 ENGINES N_1 ACCESSORY DRIVE AND XMSN		
	N_1 Gas Producer Bevel Pinion	1.00000 N_1	234.00
	Inner Bevel, Idler	0.72222 N_1	169.00
	Radial Bevel Accessory Drive	1.00000 N_1	234.00
	Radial Bevel Starter Drive	1.00000 N_1	234.00
	Outer Accessory Drive Bevel	0.58333 N_1	136.50
	Power Control Drive	0.22435 N_1	52.50
	Oil Pump Drive	0.22435 N_1	52.50
	Fuel Filter Drive	0.22435 N_1	52.50
IX	T55-L-5, -7 ENGINES N_2 ACCESSORY DRIVE AND XMSN		
	Torquemeter Actuating Sleeve	1.00000 N_2	252.77
	Overspeed Drive Shaft, Inner	1.07690 N_2	272.21
	Overspeed Drive Shaft, Radial	0.64615 N_2	163.33
	Overspeed Control Drive Shaft, Outer Bevel	0.48461 N_2	122.50
	Overspeed Control Drive Idler	0.34615 N_2	87.50
	Overspeed Control Drive Idler Cluster	0.37278 N_2	94.23
	Overspeed Control Output Bevel Drive	0.42140 N_2	106.52
	N_2 Tachometer Drive Shaft	0.27391 N_2	69.24
XIV	ENGINE XMSNS, NOS. 1 & 2		
	Input Bevel Pinion	1.00000 N_2	252.77
	Output Bevel Driven	0.79061 N_2	199.84

TABLE XXX - Continued

Table Reference	Shaft Identification	Ratio To Engine Rotor Speed	Speed (RPS)
XXIII	AFT ROTOR XMSN, ACCESSORY DRIVE AND ACCESSORY XMSN		
	Accessory Drive Quill	0.54453 N_2	137.64
	Accessory Drive Idler, (2) each	0.45378 N_2	114.70
	Flight Control Hydraulic Pump Drive, (2) each	0.26348 N_2	66.60
	Hydraulic Motor Drive	0.52697 N_2	133.20
	Alternator Drive	0.56269 N_2	142.23
	Axial Piston Pump Drive	0.30823 N_2	77.91
	Lube Oil Pump Drive		
XXVII	FORWARD ROTOR XMSN		
	Input Bevel Pinion (Aft Synchronizing Shaft)	0.46588 N_2	117.76
	Bevel Ring & 1st Stage Sun Gear (High Speed)	0.26491 N_2	66.96
	1st Stage Sun (relative to 1st Stage Carrier)	0.20596 N_2	52.97
	1st Stage Sun (relative to 2nd Stage Carrier)	0.24976 N_2	63.13
	1st Stage Planets (relative to 1st Stage Carrier)	0.15046 N_2	38.03
	1st Stage Carrier & 2nd Stage Sun	0.05535 N_2	13.99
	2nd Stage Sun (relative to Stationary Ring Gear)	0.05535 N_2	13.99
	2nd Stage Sun (relative to 2nd Stage Carrier)	0.04020 N_2	10.16
	2nd Stage Sun (relative to 1st Stage Carrier)	(Common)	0.00
	2nd Stage Planets (relative to 2nd Stage Carrier)	0.04870 N_2	12.31
	2nd Stage Carrier (Output & Aft Rotary-Wing Drive Shaft)	0.01515 N_2	3.85

TABLE XXX - Continued

Table Reference	Shaft Identification	Ratio To Engine Rotor Speed	Speed (RPS)
XVI	ENGINE COMBINING XMSN		
	Input Bevel Drive	0.79061 N_2	199.84
	Output, Forward and Bevel	0.46588 N_2	117.76
	Mixture Idler Shaft	0.29814 N_2	75.36
	L.O. Pump Drive Shaft	0.33125 N_2	83.73
XIX, XX	FORWARD AND AFT SYNCHRONIZING SHAFTS		
	Forward Synchronizing Shaft	0.46588 N_2	117.76
	Aft Synchronizing Shaft	0.46588 N_2	117.76
XXI	AFT ROTOR XMSN		
	Input Bevel Pinion (Aft Synchronizing Shaft)	0.46588 N_2	117.76
	Oil Cooling Blower Bevel	0.32251 N_2	81.52
	Accessory Drive Quill	0.54453 N_2	137.64
	Bevel Ring & 1st Stage Sun Gear (High Speed)	0.26491 N_2	66.96
	1st Stage Sun (relative to 1st Stage Carrier)	0.20596 N_2	52.97
	1st Stage Sun (relative to 2nd Stage Carrier)	0.24976 N_2	63.13
	1st Stage Planets (relative to 1st Stage Carrier)	0.15046 N_2	38.03
	1st Stage Carrier & 2nd Stage Sun	0.05535 N_2	13.99
	2nd Stage Sun (relative to Stationary Ring Gear)	0.05535 N_2	13.99
	2nd Stage Sun (relative to 2nd Stage Carrier)	0.04020 N_2	10.16
	2nd Stage Sun (relative to 1st Stage Carrier)	(Common)	0.00
	2nd Stage Planets (relative to 2nd Stage Carrier)	0.04870 N_2	12.31
	2nd Stage Carrier (Output & Aft Rotary-Wing Drive Shaft)	0.01515 N_2	3.83

TABLE XXX - Continued

Table Reference	Shaft Identification	Ratio To Engine Rotor Speed	Speed (RPS)
XXIX	FORWARD ROTOR XMSN ACCESSORY DRIVE		
	N_2 Tachometer Drive Shaft		
XXVI	FORWARD AND AFT ROTARY WING DRIVE SHAFTS		
	Forward Rotary Wing Drive Shaft	0.01515 N_2	3.83
	Aft Rotary Wing Drive Shaft	0.01515 N_2	3.83

TABLE XXXI. SUMMARY - CH-47A COMPOUND PLANETARY SPEEDS*
(Forward & Aft Rotor Transmissions are Identical in Gear Ratios)

Gear Data	1st Stage	2nd Stage
T_S = No. of Teeth - Sun Gear	28	40
T_P = No. of Teeth - Planet	39	33
T_R = No. of Teeth - Ring Gear	106	106
W_S = Angular Speed of Sun Relative to Ring Gear (Input)	66.96 RPS	13.99 RPS
W'_S = Angular Speed of Sun Relative to Carrier = $(W_S - W_C)$	52.97 RPS	10.16 RPS
W_P = Angular Speed of Planet Relative to Carrier	38.03 RPS	12.31 RPS
W_R = Angular Speed of Ring Gear	0	0
W_C = Angular Speed of Carrier Relative to Ring Gear (Output)	13.99 RPS	3.83 RPS
W_S/W_C = Overall Speed Reduction	4.786	3.6499
Planetary Tooth Contact Frequency	1.483 Hz	406.2 Hz
$(W_P T_P = W_C T_R = W'_S T_S = (W_S - W_C) T_S$		
Tooth Contact Frequency of Spiral Bevel Input Drive Train	3415 Hz	-
n = No. of Planet Gears/Stage	4	6

*Based on 230 RPM Rotor Speed, N_2 - Related

TABLE XXXII. MODEL CH-47A/B HELICOPTERS RECORDED DURING MICROPHONE SURVEY AT U. S. ARMY AVIATION CENTER, FORT RUCKER, ALABAMA

Recording No.	Helicopter No.	Engine No. 1 Serial No.	Engine No. 2 Serial No.
1-10	66-19115	-	-
1-11	63-7911	-	-
1-12	61-2123	-	-
1-13	61-2123	-	-
1-14	61-2123	-	-
2-10	63-7911	LE-01158	LE-01164
2-11	61-2415	LE-05769	LE-04440
2-12	61-9003	LE-04110	LE-04234
2-13	61-9139	LE-05564	LE-05576
2-14	62-2114	LE-01042	LE-01108
2-15	61-2408	LE-05743	LE-04839
2-16	61-2423	LE-05740	LE-01092

TABLE XXXIII. ACOUSTIC LOG SHEETS - CH-47A/B HELICOPTER, SONIC ANALYZER PROGRAM NO. 2011

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
1	Start AFT Rotor XMSN Trains				2			Start	0
2	Clear				2			Clear	0
3	N2 Calibrate	3	3	3	2	0.2257	05-20	Peak	0
4	Mike 3 Noise Normalize	3	3	3	2	0.4444	10-30	Set 5	0
5	Input Spiral Bevel Fund	3	3	3	2	0.2525	04-10	Read	0
6	2nd Harmonic Monitor	3	3	3	2	0.5253	07-20	Read	0
7	Sideband Monitor	3	3	3	2	0.2446	08-20	Read	0
8		3	3	3	2	0.2605	08-20	Read	0
9		3	3	3	2	0.2473	06-20	Read	0
10		3	3	3	2	0.2560	06-20	Read	0
11	Fund Normalize	3	3	3	2	0.2525	00-10	Set 5	0
12	2nd Harmonic Ratio	3	3	3	2	0.5253	03-20	Read	0
13	Sideband Ratios	3	3	3	2	0.2367	06-20	Read	0
14	Bevel Input	3	3	3	2	0.2446	04-20	Read	0
15		3	3	3	2	0.2560	04-20	Read	0
16		3	3	3	2	0.2613	06-20	Read	0
17	1st Stage Sun	3	3	3	2	0.2440	06-20	Read	0
18		3	3	3	2	0.2473	02-20	Read	0
19		3	3	3	2	0.2560	02-20	Read	0
20		3	3	3	2	0.2613	06-20	Read	0
21	Mike 3 Noise Normalize Check	3	3	3	2	0.4444	10-30	Set 5	0
22	1st Stage Planetary Fund	3	3	3	2	0.1121	10-00	Read	0
23	2nd Harmonic Monitor	3	3	3	2	0.2242	03-20	Read	0
24	Sideband Monitor	3	3	3	2	0.1066	04-20	Read	0
25		3	3	3	2	0.1154	01-20	Read	0
26		3	3	3	2	0.1102	03-20	Read	0

TABLE XXXIII - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
27		3	3	3	2	0.1140	08-10	Read	0
28	Fund Normalize	3	3	3	2	0.1121	00-10	Set 5	0
29	Sideband Ratios	3	3	3	2	0.1033	06-20	Read	0
30	1st Stage Sun	3	3	3	2	0.1066	04-20	Read	0
31		3	3	3	2	0.1154	01-20	Read	0
32		3	3	3	2	0.1206	04-20	Read	0
33	1st Stage Planets	3	3	3	2	0.1063	06-20	Read	0
34		3	3	3	2	0.1102	03-20	Read	0
35		3	3	3	2	0.1140	08-10	Read	0
36		3	3	3	2	0.1157	02-40	Read	0
37	1st Stage Sun Rel Carr	3	3	3	2	0.1074	08-20	Read	0
38		3	3	3	2	0.1146	08-10	Read	0
39	Mike 3 Noise Normalize	3	3	3	2	0.4444	10-30	Chk 5	0
40	Mike 4 Noise Normalize	3	4	1	2	0.4444	10-30	Set 5	0
41	2nd Stage Planetary Fund	3	4	1	2	0.0242	09-10	Read	0
42	2nd Harmonic Monitor	3	4	1	2	0.0505	06-20	Read	0
43	Fund Normalize	3	4	1	2	0.0242	00-10	Set 5	0
44	Sideband Ratios	3	4	1	2	0.0236	03-10	Read	0
45	2nd Stage Planets	3	4	1	2	0.0247	02-10	Read	0
46	1st Stage Planets	3	4	1	2	0.0375	04-10	Read	0
47		3	4	1	2	0.0531	01-10	Read	0
48		3	4	1	2	0.1017	03-10	Read	0
49		3	4	1	2	0.0070	05-10	Read	0
50		3	4	1	2	0.0415	03-10	Read	0
51	Clear				2			Clear	0

TABLE XXXIV. ACOUSTIC LOG SHEETS - CH-47A/B HELICOPTER, SONIC ANALYZER PROGRAM NO. 2021

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
1	Start Fwd Rotor XMSN Trains				2			Start	
2	Clear				2			Clear	0
3	N2 Calibrate	4	7	1	2	0.2257	05-20	Peak	0
4	Mike 3 Noise Normalize	4	7	1	2	0.4444	10-30	Set 5	0
5	Input Spiral Bev Fund	4	7	1	2	0.2525	04-10	Read	0
6	2nd Harmonic Monitor	4	7	1	2	0.5253	07-20	Read	0
7	Sideband Monitor	4	7	1	2	0.2446	09-20	Read	0
8		4	7	1	2	0.2605	09-20	Read	0
9		4	7	1	2	0.2473	07-20	Read	0
10		4	7	1	2	0.2560	07-20	Read	0
11	Fund Normalize	4	7	1	2	0.2525	00-10	Set 5	0
12	2nd Harmonic Ratio	4	7	1	2	0.5253	03-20	Read	0
13	Sideband Ratios	4	7	1	2	0.2367	08-20	Read	0
14	Bevel Input	4	7	1	2	0.2446	05-20	Read	0
15		4	7	1	2	0.2560	05-20	Read	0
16		4	7	1	2	0.2613	08-20	Read	0
17	1st Stage Sun	4	7	1	2	0.2440	07-20	Read	0
18		4	7	1	2	0.2473	03-20	Read	0
19		4	7	1	2	0.2560	03-20	Read	0
20		4	7	1	2	0.2613	07-20	Read	0
21	Mike 3 Noise Normalize Check	4	7	1	2	0.4444	10-30	Set 5	0
22	1st Stage Planetary Fund	4	7	1	2	0.1121	10-00	Read	0
23	2nd Harmonic Monitor	4	7	1	2	0.2242	03-20	Read	0
24	Sideband Monitor	4	7	1	2	0.1066	10-10	Read	0
25		4	7	1	2	0.1154	10-10	Read	0
26		4	7	1	2	0.1102	08-10	Read	0

TABLE XXXIV - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
27		4	7	1	2	0.1140	04-10	Read	0
28	Fund Normalize	4	7	1	2	0.1121	00-10	Set 5	0
29	Sideband Ratios	4	7	1	2	0.1033	06-20	Read	0
30	1st Stage Sun	4	7	1	2	0.1066	00-20	Read	0
31		4	7	1	2	0.1154	00-20	Read	0
32		4	7	1	2	0.1205	06-20	Read	0
33	1st Stage Planets	4	7	1	2	0.1063	04-20	Read	0
34		4	7	1	2	0.1102	08-10	Read	0
35		4	7	1	2	0.1140	04-10	Read	0
36		4	7	1	2	0.1157	01-20	Read	0
37	1st Stage Sun Rel Carr	4	7	1	2	0.1074	05-20	Read	0
38		4	7	1	2	0.1146	06-10	Read	0
39	Mike 7 Noise Normalize Check	4	7	1	2	0.4444	10-30	Chk 5	0
40	Mike 8 Noise Normalize	4	8	2	2	0.4444	10-30	Set 5	0
41	2nd Stage Planetary Fund	4	8	2	2	0.0242	09-10	Read	0
42	2nd Harmonic Monitor	4	8	2	2	0.0505	06-20	Read	0
43	Fund Normalize	4	8	2	2	0.0242	00-10	Set 5	0
44	Sideband Ratios	4	8	2	2	0.0236	03-10	Read	0
45	2nd Stage Planets	4	8	2	2	0.0247	02-10	Read	0
46	1st Stage Planets	4	8	2	2	0.0375	04-10	Read	0
47		4	8	2	2	0.0531	01-10	Read	0
48		4	8	2	2	0.1017	03-10	Read	0
49		4	8	2	2	0.0070	05-10	Read	0
50		4	8	2	2	0.0415	03-10	Read	0
51	Clear			2	2			Clear	0

TABLE XXXV. ACOUSTIC LOG SHEETS - CH-47A/B HELICOPTER, SONIC ANALYZER PROGRAM NO. 2031

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
1	Start Comb XMSN Gear Trains				2			Start	0
2	Clear				2			Clear	0
3	N2 Calibrate	0	0	0	2	0.2257	05-20	Peak	0
4	Mike 6 Normalize	1	6	1	2	0.4444	10-20	Set 5	0
5	Spiral Bevel Pwr Tr Fund	1	6	1	2	0.5114	07-10	Read	0
6	2nd Harmonic Monitor	1	6	1	2	1.2231	01-30	Read	0
7	L O Pump Dr Tr Monitor	1	6	1	2	0.2742	01-30	Read	0
8	Fund Normalize	1	6	1	2	0.5114	00-10	Set 5	0
9	2nd Harmonic Ratio	1	6	1	2	1.2231	05-20	Read	0
10	S/B 2nd Upper Input	1	6	1	2	0.5354	07-10	Read	0
11	S/B 4th Upper Input	1	6	1	2	0.5614	09-10	Read	0
12	S/B 6th Upper Input	1	6	1	2	0.6054	09-10	Read	0
13	S/B 1st Lower Input	1	6	1	2	0.4774	05-10	Read	0
14	S/B 3rd Lower Input	1	6	1	2	0.4534	00-07	Read	0
15	S/B 5th Lower Input	1	6	1	2	0.4274	09-10	Read	0
16	S/B 2nd Upper Output	1	6	1	2	0.5253	07-10	Read	0
17	S/B 4th Upper Output	1	6	1	2	0.5411	09-10	Read	0
18	S/B 6th Upper Output	1	6	1	2	0.5547	09-10	Read	0
19	S/B 1st Lower Output	1	6	1	2	0.5035	05-10	Read	0
20	S/B 3rd Lower Output	1	6	1	2	0.4677	08-10	Read	0
21	S/B 5th Lower Output	1	6	1	2	0.4540	09-10	Read	0
22	Fund Norm Check	1	6	1	2	0.5114	00-10	Check 5	0
23	Clear				2			Clear	0

TABLE XXXVI. ACOUSTIC LOG SHEETS - CH-47A/B HELICOPTER, SONIC ANALYZER PROGRAM NO. 2041

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
1	Start No. 1 Engine XMSN				2				0
2	Clear				2				0
3	N2 Calibrate	1	1	2	2	0.2257	05-20	Peak	0
4	Mike 1 Normalize	1	1	2	2	0.4444	10-20	Set 5	0
5	Spiral Bev Tr Fund	1	1	2	2	0.6554	07-20	Read	0
6	Pinion Brg Outboard	1	1	2	2	0.0730	02-30	Read	0
7	652-1	1	1	2	2	0.2611	01-30	Read	0
8		1	1	2	2	0.1332	03-30	Read	0
9		1	1	2	2	0.0742	04-30	Read	0
10					2				0
11	Pinion Brg Intermediate	1	1	2	2	0.0673	04-30	Read	0
12	641-1	1	1	2	2	0.2463	01-30	Read	0
13		1	1	2	2	0.1342	02-30	Read	0
14		1	1	2	2	0.0733	03-30	Read	0
15					2				0
16	Pinion Brg Inboard	1	1	2	2	0.0745	01-30	Read	0
17	653-1	1	1	2	2	0.2657	02-30	Read	0
18		1	1	2	2	0.1330	04-30	Read	0
19		1	1	2	2	0.0745	04-30	Read	0
20					2				0
21	Output Brg Inter	1	1	2	2	0.0564	06-30	Read	0
22	644-2	1	1	2	2	0.2133	01-30	Read	0
23		1	1	2	2	0.1102	04-30	Read	0
24		1	1	2	2	0.0575	04-30	Read	0
25					2				0
26	Output Brg Upper	1	1	2	2	0.1046	04-30	Read	0

TABLE XXXVI - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
27	643-1	1	1	2	2	0.3162	01-30	Read	0
28		1	1	2	2	0.1121	02-30	Read	0
29		1	1	2	2	0.0675	06-30	Read	0
30					2				0
31	Output Brg Lower	1	1	2	2	0.1720	02-30	Read	0
32	645-4	1	1	2	2	0.5556	02-30	Read	0
33		1	1	2	2	0.2143	01-30	Read	0
34		1	1	2	2	0.1672	02-30	Read	0
35	Mike 1 Normalize Check	1	1	2	2	0.4444	10-20	Set 5	0
36	Clear				2				0
37	Start				2				0
38	Start				2				0
39	Start				2				0
40	Start				2				0
41	Start No. 2 Engine XMSN				2				0
42	Clear				2				0
43	N2 Calibrate	2	2	2	2	0.2257	05-20	Peak	0
44	Mike 1 Normalize	2	2	2	2	0.4444	10-20	Set 5	0
45	Spiral Bev Tr Fund	2	2	2	2	0.6554	07-20	Read	0
46	Pinion Brg Outboard	2	2	2	2	0.0730	07-20	Read	0
47	652-1	2	2	2	2	0.2611	01-30	Read	0
48		2	2	2	2	0.1332	08-20	Read	0
49		2	2	2	2	0.0742	07-20	Read	0
50					2				0
51	Pinion Brg Intermediate	2	2	2	2	0.0673	07-20	Read	0
52	641-1	2	2	2	2	0.2463	06-20	Read	0
53		2	2	2	2	0.1342	09-20	Read	0

TABLE XXXVI - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
54		2	2	2	2	0.0733	07-20	Read	0
55		2	2	2	2				0
56	Pinion Brg Inboard	2	2	2	2	0.0745	08-20	Read	0
57	653-1	2	2	2	2	0.2657	08-20	Read	0
58		2	2	2	2	0.1330	01-30	Read	0
59		2	2	2	2	0.0745	07-20	Read	0
60		2	2	2	2				0
61	Output Brg Inter	2	2	2	2	0.0564	07-20	Read	0
62	644-2	2	2	2	2	0.2133	00-30	Read	0
63		2	2	2	2	0.1102	00-30	Read	0
64		2	2	2	2	0.0575	01-30	Read	0
65					2				0
66	Output Brg Upper	2	2	2	2	0.1046	09-30	Read	0
67	643-1	2	2	2	2	0.3162	02-30	Read	0
68		2	2	2	2	0.1121	07-20	Read	0
69		2	2	2	2	0.0675	01-30	Read	0
70		2	2	2	2				0
71	Output Brg Lower	2	2	2	2	0.1720	02-30	Read	0
72	645-4	2	2	2	2	0.5556	02-30	Read	0
73						0.2143	02-30	Read	0
74						0.1672	02-30	Read	0
75	Mike 2 Normalize Check	2	2	2	2	0.4444	10-20	Read	0
76	Clear				2				0

TABLE XXXVII. ACOUSTIC LOG SHEETS - CH-47A/B HELICOPTER, SONIC ANALYZER PROGRAM NO. 2051

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
1	Start Brgs Aft Rotor XMSN	1			2				0
2	Clear				2				0
3	N2 Calibrate	3	0	0	2	0.2257	05-20	Peak	0
4	Mike 4 Normalize	3	4	1	2	0.4444	10-30	Set 5	0
5	Mike 3 Normalize	3	3	3	2	0.4444	10-30	Set 5	0
6	Rotor Shaft Lower Thrust	3	3	3	2	0.0324	01-30	Read	0
7	242-1	3	3	3	2	0.1174	00-30	Read	0
8		3	3	3	2	0.0474	09-20	Read	0
9		3	3	3	2	0.0366	05-20	Read	0
10					2				0
11	Main Rotor Shaft	3	3	3	2	0.0453	00-30	Read	0
12	243-1	3	3	3	2	0.1600	03-30	Read	0
13		3	3	3	2	0.0665	03-30	Read	0
14		3	3	3	2	0.0556	02-30	Read	0
15					2				0
16	1st Stage Planet	3	3	3	2	0.0157	00-30	Read	0
17	244-13	3	3	3	2	0.0515	06-20	Read	0
18		3	3	3	2	0.0233	04-20	Read	0
19		3	3	3	2	0.0166	09-20	Read	0
20					2				0
21	1st Stage Carr Intershft	3	3	3	2	0.0052	07-20	Read	0
22	250-1	3	3	3	2	0.0200	08-20	Read	0
23		3	3	3	2	0.0050	06-20	Read	0
24		3	3	3	2	0.0041	06-20	Read	0
25					2				0
26	2nd Stage Planet	3	4		2	0.0032	09-20	Read	0

TABLE XXXVII - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
27	258-3	3	4	1	2	0.0120	05-20	Read	0
28		3	4	1	2	0.0051	08-20	Read	0
29		3	4	1	2	0.0034	04-30	Read	0
30					2				0
31	2nd Stage Carr Output	3	4	1	2	0.0035	04-30	Read	0
32	274-1	3	4	1	2	0.0130	06-20	Read	0
33		3	4	1	2	0.0031	06-30	Read	0
34		3	4	1	2	0.0027	05-30	Read	0
35					2				0
36	Input Gearshaft Outer	3	3	3	2	0.0525	01-20	Read	0
37	262-1	3	3	3	2	0.1775	02-30	Read	0
38		3	3	3	2	0.1027	00-30	Read	0
39		3	3	3	2	0.0627	01-30	Read	0
40					2				0
41	Input Gearshaft Dual Int	3	3	3	2	0.0355	05-20	Read	0
42	241-1 Outer	3	3	3	2	0.1306	09-20	Read	0
43		3	3	3	2	0.0611	04-30	Read	0
44		3	3	3	2	0.0412	00-30	Read	0
45					2				0
46	Input Gearshaft Dual Int	3	3	3	2	0.0563	02-30	Read	0
47	241-1 Inner	3	3	3	2	0.2132	00-30	Read	0
48		3	3	3	2	0.1107	00-20	Read	0
49		3	3	3	2	0.0705	02-30	Read	0
50					2				0
51	Input Gearshaft Inner Thr	3	3	3	2	0.0447	08-20	Read	0
52	240-2	3	3	3	2	0.1567	03-30	Read	0
53		3	3	3	2	0.0663	03-30	Read	0

TABLE XXXVII - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
54		3	3	3	2	0.0476	01-30	Read	0
55					2				0
56	Mike 4 Norm Check	3	4	1	2	0.4444	10-30	Set 5	0
57	Mike 3 Norm Check	3	3	3	2	0.4444	10-30	Set 5	0
58	Clear Fwd Rotor XMSN Follow				2				0
59	Mike 8 Normalize	4	8	2	2	0.4444	10-30	Set 5	0
60	Mike 7 Normalize	4	7	1	2	0.4444	10-30	Set 5	0
61	Rotor Shaft Lower Thrust	4	7	1	2	0.0230	01-30	Read	0
62	143-1	4	7	1	2	0.0711	08-30	Read	0
63		4	7	1	2	0.0353	06-30	Read	0
64		4	7	1	2	0.0247	07-30	Read	0
65					2				0
66	Main Rotor Shaft	4	7	1	2	0.0453	06-30	Read	0
67	243-1	4	7	1	2	0.1600	00-30	Read	0
68		4	7	1	2	0.0665	06-30	Read	0
69		4	7	1	2	0.0556	07-30	Read	0
70					2				0
71	1st Stage Planet	4	7	1	2	0.0157	02-30	Read	0
72	244-13	4	7	1	2	0.0515	03-30	Read	0
73		4	7	1	2	0.0233	04-30	Read	0
74		4	7	1	2	0.0166	05-30	Read	0
75					2				0
76	1st Stage Carrier	4	7	1	2	0.0052	03-30	Read	0
77	250-1	4	7	1	2	0.0200	02-30	Read	0
78		4	7	1	2	0.0050	05-30	Read	0
79		4	7	1	2	0.0041	05-30	Read	0
80					2				0

TABLE XXXVII - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
81	2nd Stage Planet	4	8	2	2	0.0032	03-30	Read	0
82	258-3	4	8	2	2	0.0120	00-30	Read	0
83		4	8	2	2	0.0051	02-30	Read	0
84		4	8	2	2	0.0034	03-30	Read	0
85					2				0
86	2nd Stage Carr Output	4	8	2	2	0.0035	03-30	Read	0
87	274-1	4	8	2	2	0.0130	00-30	Read	0
88		4	8	2	2	0.0031	03-30	Read	0
89		4	8	2	2	0.0027	03-30	Read	0
90					2				0
91	Input Gearshaft Outer	4	7	1	2	0.0525	03-30	Read	0
92	262-1	4	7	1	2	0.1775	06-30	Read	0
93		4	7	1	2	0.1027	03-30	Read	0
94		4	7	1	2	0.0627	06-30	Read	0
95					2				0
96	Input Gearshaft Dual Int	4	7	1	2	0.0355	04-30	Read	0
97	241-1 Outer	4	7	1	2	0.1306	05-30	Read	0
98		4	7	1	2	0.0611	05-30	Read	0
99		4	7	1	2	0.0412	04-30	Read	0
100									0
101	Input Gearshaft Dual Int	4	7	1	2	0.0563	03-30	Read	0
102	241-1 Inner	4	7	1	2	0.2132	05-30	Read	0
103		4	7	1	2	0.1107	01-30	Read	0
104		4	7	1	2	0.0705	05-30	Read	0
105									0
106	Input Gearshaft Inner Thr	4	7	1	2	0.0447	05-30	Read	0
107		4	7	1	2	0.1567	07-30	Read	0

TABLE XXXVII - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
108		14	7	1	2	0.0663	07-30	Read	0
109		14	7	1	2	0.0476	04-30	Read	0
110									0
111	Mike 8 Normalize Check	4	8	2	2	0.4444	10-30	Set 5	0
112	Mike 7 Normalize Check	4	7	1	2	0.4444	10-30	Set 5	0
113	Clear				2			Clear	0

TABLE XXXVIII. ACOUSTIC LOG SHEETS - CH-47A/B HELICOPTER, SONIC ANALYZER PROGRAM NO. 2061

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
1	Start Brgs Combining XMSN	-	-	-	2	-	-	Start	0
2	Clear	-	-	-	2	-	-	Clear	0
3	N2 Calibrate	1	0	0	2	0.2257	05-20	Peak	0
4	Mike 3 Normalize	1	3	3	2	0.4444	10-20	Set 5	0
5	Mike 6 Normalize	1	6	1	2	0.4444	10-20	Set 5	0
6	Fwd Output Shaft Fwd	1	6	1	2	0.0506	05-20	Read	0
7	548-1	1	6	1	2	0.1722	09-20	Read	0
8		1	6	1	2	0.1205	08-20	Read	0
9		1	6	1	2	0.0745	04-20	Read	0
10					2				0
11	Fwd Output Shaft Aft	1	6	1	2	0.0642	06-20	Read	0
12	549-1	1	6	1	2	0.2347	07-20	Read	0
13		1	6	1	2	0.0524	04-20	Read	0
14		1	6	1	2	0.0420	07-20	Read	0
15					2				0
16	Coupling Shaft	1	6	1	2	0.0777	09-20	Read	0
17	550-1	1	6	1	2	0.2776	08-20	Read	0
18		1	6	1	2	0.0750	07-20	Read	0
19		1	6	1	2	0.0626	06-20	Read	0
20					2				0
21	Aft Output Shaft Interm	1	6	1	2	0.0532	05-20	Read	0
22	544-1	1	6	1	2	0.2016	07-20	Read	0
23		1	6	1	2	0.0740	06-20	Read	0
24		1	6	1	2	0.0557	08-20	Read	0
25					2				0
26	Aft Output Shaft Rear	1	6	1	2	0.0620	07-20	Read	0

TABLE XXXVIII - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
27	543-1	1	6	1	2	0.2260	06-20	Read	0
28		1	6	1	2	0.1102	06-20	Read	0
29		1	6	1	2	0.0712	08-20	Read	0
30					2	-	-	-	0
31	Bevel Gearshaft Outboard	1	6	1	2	-	-	-	0
32	642-2	1	6	1	2	-	-	-	0
33		1	6	1	2	-	-	-	0
34		1	6	1	2	-	-	-	0
35					2	-	-	-	0
36	Bevel Gearshaft Intermediate	1	6	1	2	0.0475	06-20	Read	0
37	541-2	1	6	1	2	0.1666	06-20	Read	0
38		1	6	1	2	0.1040	08-20	Read	0
39		1	6	1	2	0.0517	07-20	Read	0
40					2				0
41	Bevel Gearshaft Inboard	1	6	1	2	0.1477	08-20	Read	0
42		1	6	1	2	0.4676	04-20	Read	0
43		1	6	1	2	0.1424	05-20	Read	0
44		1	6	1	2	0.1212	08-20	Read	0
45					2				0
46	Mike 6 Normalize Check	1	6	1	2	0.4444	10-20	Read	0
47	Clear	-	-	-	2	-	-	Clear	0

TABLE XXXIX. ACOUSTIC LOG SHEETS - CH-47A/B HELICOPTER, SONIC ANALYZER PROGRAM NO. 2071

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
1	Start No. 1 Engine Components	-	-	-	2	-	-	Start	0
2	Clear	-	-	-	2	-	-	Clear	0
3	N1 Calibrate	1	1	2	1	0.2735	05-20	Peak	0
4	N2 Calibrate	1	1	2	2	0.2257	05-20	Peak	0
5	Mike 1 Normalize	1	1	2	2	0.4444	10-20	Set 5	0
6	Noise Store	1	1	2	1	0.4444	10-20	Store	0
7	C2 Fund Store	1	1	2	1	1.0166	09-10	Store	0
8	+FR S/B Ratio	1	1	2	1	1.0353	10-20	Reject 2:1	0
9	-FR S/B Ratio	1	1	2	1	1.0001	10-20	Reject 2:1	0
10	Clear				1			Clear	0
11	Noise Store	1	1	2	1	0.4444	10-20	Store	0
12	C2 Fund Store	1	1	2	1	1.1112	07-20	Store	0
13	+FR S/B Ratio	1	1	2	1	1.1277	09-20	Reject 2:1	0
14	-FR S/B Ratio	1	1	2	1	1.0725	09-20	Reject 2:1	0
15	Clear				1			Clear	0
16	No. 2 Main Brg 3FB'	1	1	2	1	0.3576	08-20	Read	0
17	001-02 F1	1	1	2	1	0.2012	07-20	Read	0
18	F2	1	1	2	1	0.1322	04-20	Read	0
19	No. 3 Main Brg 3FB'	1	1	2	1	0.6467	08-20	Read	0
20	004-02 F1	1	1	2	1	0.2213	05-20	Read	0
21	F2	1	1	2	1	0.1662	07-20	Read	0
22	Inner Bevel Main Dr Train	1	1	2	1	1.0725	08-20	Read	0
23	Outer Accy Dr Bevel Tr	1	1	2	1	0.3147	07-20	Read	0
24	Accy Main Train	1	1	2	1	0.2000	02-20	Read	0
26	Mike 1 Normalize Check	1	1	2	2	0.4444	10-20	Set 5	0

TABLE XXXIX - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
27	Noise Store	1	1	2	2	0.4444	10-30	Store	0
28	T2 Fund Store	1	1	2	2	1.5015	10-20	Store	0
29	+FR S/B Ratio	1	1	2	2	1.5163	07-20	Reject 2:1	0
30	-FR S/B Ratio	1	1	2	2	1.4650	07-20	Reject 2:1	0
31	Clear				2			Clear	0
32	Noise Store	1	1	2	2	0.4444	10-30	Store	0
33	T3 Fund Store	1	1	2	2	1.3033	05-30	Store	0
34	+FR S/B Ratio	1	1	2	2	1.3200	07-30	Reject 2:1	0
35	-FR S/B Ratio	1	1	2	2	1.2666	07-30	Reject 2:1	0
36	Clear	1	1	2	2			Clear	0
37	No. 1 Main Brg 3FB'	1	1	2	2	0.4271	09-20	Read	0
38	006-02 F1	1	1	2	2	0.2007	09-20	Read	0
39	F2	1	1	2	2	0.1424	01-30	Read	0
40	No. 2 Main Brg 3FB'	1	1	2	2	0.3031	09-20	Read	0
41	011-02 F1	1	1	2	2	0.1505	09-20	Read	0
42	F2	1	1	2	2	0.1102	08-20	Read	0
43	Torquemeter Actuating Dr Tr	1	1	2	2	1.0226	08-20	Read	0
44	Overspeed Drive Bevel Inner	1	1	2	2	0.3140	04-30	Read	0
45	Overspeed Control Bev Idler	1	1	2	2	0.1724	00-30	Read	0
46	Clear	1	1	2	2	-	-	Clear	0
47	Start	-	-	-	1	-	-	Start	0
48	Start	-	-	-	1	-	-	Start	0
49	Start	-	-	-	1	-	-	Start	0
50	Start	-	-	-	1	-	-	Start	0
51	Start No. 2 Engine Compt	-	-	-	2	-	-	Start	0
52	Clear	-	-	-	2	-	-	Clear	0
53	N1 Calibrate	2	2	2	1	0.2735	05-20	Peak	0

TABLE XXXIX - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
54	N2 Calibrate	2	2	2	2	0.2257	05-20	Peak	0
55	Mike 1 Normalize	2	2	2	2	0.4444	10-20	Set 5	0
56	Noise Store	2	2	2	1	0.4444	10-30	Store	0
57	C2 Fund Store	2	2	2	1	1.0166	05-20	Store	0
58	+FR S/B Ratio	2	2	2	1	1.0353	10-20	Reject 2:1	0
59	-FR S/B Ratio	2	2	2	1	1.0001	10-20	Reject 2:1	0
60	Clear				1			Clear	0
61	Noise Store	2	2	2	1	0.4444	10-20	Store	0
62	C3 Fund Store	2	2	2	1	1.1112	08-20	Store	0
63	+FR S/B Ratio	2	2	2	1	1.1277	09-20	Reject 2:1	0
64	-FR S/B Ratio	2	2	2	1	1.0725	09-20	Reject 2:1	0
65	Clear				1			Clear	0
66	No. 2 Main Brg 3FB'	2	2	2	1	0.3576	04-30	Read	0
67	001-02 F1	2	2	2	1	0.2012	03-30	Read	0
68	F2	2	2	2	1	0.1322	02-30	Read	0
69	No. 3 Main Brg 3FB'	2	2	2	1	0.6467	03-30	Read	0
70	004-02 F1	2	2	2	1	0.2213	02-30	Read	0
71	F2	2	2	2	1	0.1662	01-30	Read	0
72	Inner Bevel Main Dr Train	2	2	2	1	1.0725	04-30	Read	0
73	Outer Accy Dr Bevel Tr	2	2	2	1	0.3147	03-30	Read	0
74	Accy Main Train	2	2	2	1	0.2000	04-30	Read	0
76	Mike 2 Normalize Check	2	2	2	2	0.4444	10-20	Set 5	0
77	Noise Store	2	2	2	2	0.4444	10-30	Store	0
78	T2 Fund Store	2	2	2	2	1.5016	10-20	Store	0
79	+FR S/B Ratio	2	2	2	2	1.5163	07-20	Reject 2:1	0
80	-FR S/B Ratio	2	2	2	2	1.4650	07-20	Reject 2:1	0
81	Clear				2			Clear	0

TABLE XXXIX - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
82	Noise Store	2	2	2	2	0.4444	10-30	Store	0
83	T3 Fund Store	2	2	2	2	1.3033	05-30	Store	0
84	+FR S/B Ratio	2	2	2	2	1.3200	07-30	Reject 2:1	0
85	-FR S/B Ratio	2	2	2	2	1.2666	07-30	Reject 2:1	0
86	Clear	2	2	2	2			Clear	0
87	No. 1 Main Brg 3FB'	2	2	2	2	0.4271	09-20	Read	0
88	006-02 F1	2	2	2	2	0.2007	00-30	Read	0
89	F2	2	2	2	2	0.1424	01-30	Read	0
90	No. 4 Main Brg 3FB'	2	2	2	2	0.3031	02-30	Read	0
91	011-02 F1	2	2	2	2	0.1505	02-30	Read	0
92	F2	2	2	2	2	0.1102	09-20	Read	0
93	Torquemeter Actuating Dr Tr	2	2	2	2	1.0226	01-30	Read	0
94	Overspeed Drive Bevel Inner	2	2	2	2	0.3140	03-30	Read	0
95	Overspeed Control Bevel Idler	2	2	2	2	0.1724	00-30	Read	0
96	Clear	2	2	2	2			Clear	0

TABLE XL. ACOUSTIC LOG SHEETS - CH-47A/B HELICOPTER, SONIC ANALYZER PROGRAM NO. 2081

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
1	Start Aft Rotor Accy XMSN			0	2			Start	0
2	Clear			0	2			Clear	0
3	N2 Calibrate	0	0	0	2	0.2257	05-20	Peak	0
4	Mike 5 Normalize	3	5	2	2	0.4444	10-20	Set 5	0
5	Oil Cool Fan Bev Tr Fund	3	5	2	2	0.3237	05-20	Read	0
6	2nd Harmonic Monitor	3	5	2	2	0.6476	07-30	Read	0
7	Accy Dr Bevel Tr Fund	3	5	2	2	0.3675	08-20	Read	0
8	2nd Harmonic Monitor	3	5	2	2	0.7572	08-30	Read	0
9	Accy Dr Main Tr Fund	3	5	2	2	0.3163	02-30	Read	0
10	2nd Harmonic Monitor	3	5	2	2	0.6346	09-30	Read	0
11	Oil Cool Bev Pinion Brg Out	3	5	2	2	0.0620	06-20	Read	0
12	257-1	3	5	2	2	0.2260	02-20	Read	0
13		3	5	2	2	0.1102	07-10	Read	0
14		3	5	2	2	0.0712	05-20	Read	0
15	Clear				2			Clear	0
16	Oil Cool Bev Pin Brg Inner	3	5	2	2	0.0750	03-20	Read	0
17	251-1	3	5	2	2	0.2671	07-20	Read	0
18		3	5	2	2	0.0720	04-20	Read	0
19		3	5	2	2	0.0577	07-20	Read	0
20	Clear				2			Clear	0
21	Accy Dr Quill Bearing Fwd	3	5	2	2	0.0550	02-20	Read	0
22	265-1	3	5	2	2	0.2070	04-20	Read	0
23		3	5	2	2	0.0772	04-20	Read	0
24		3	5	2	2	0.0566	05-20	Read	0
25	Clear				2			Clear	0
26	Accy Dr Gearshaft Brg Aft	3	5	2	2	0.1715	07-20	Read	0

TABLE XL - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
27	248-1	3	5	2	2	0.5547	05-30	Read	0
28		3	5	2	2	0.2476	03-20	Read	0
29		3	5	2	2	0.2156	04-20	Read	0
30	Clear				2			Clear	0
31	Accy Dr Gear Main Brg	3	5	2	2	0.0506	01-20	Read	0
32	255-1	3	5	2	2	0.1721	06-20	Read	0
33		3	5	2	2	0.0540	09-10	Read	0
34		3	5	2	2	0.0375	02-20	Read	0
35	Clear				2			Clear	0
36	Accy Dr Idler Gear Brg	3	5	2	2	0.0354	04-10	Read	0
37	256-1	3	5	2	2	0.1304	05-20	Read	0
38		3	5	2	2	0.0420	03-20	Read	0
39		3	5	2	2	0.0272	03-20	Read	0
40	Clear				2			Clear	0
41	Alternator Dr Pinion Brg	3	5	2	2	0.0521	07-10	Read	0
42	255-1	3	5	2	2	0.1762	06-20	Read	0
43		3	5	2	2	0.0554	09-10	Read	0
44		3	5	2	2	0.0405	08-10	Read	0
45	Clear				2			Clear	0
46	Hydr Motor Dr Gear Brg	3	5	2	2	0.0422	03-20	Read	0
47	256-1	3	5	2	2	0.1466	06-20	Read	0
48		3	5	2	2	0.0474	03-20	Read	0
49		3	5	2	2	0.0330	04-20	Read	0
50	Clear				2			Clear	0
51	Hydr Pump Dr Gear Brg	3	5	2	2	0.0211	03-20	Read	0
52	256-1	3	5	2	2	0.0633	06-20	Read	0
53		3	5	2	2	0.0236	04-20	Read	0

TABLE XL - Continued

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
54		3	5	2	2	0.0154	03-20	Read	0
55	Clear				2			Clear	0
56	Axial Piston Pump Dr Gr Brg	3	5	2	2	0.0240	03-20	Read	0
57	Lube Oil Pump Dr Gear Brg	3	5	2	2	0.0741	02-20	Read	0
58	256-1	3	5	2	2	0.0271	03-20	Read	0
59		3	5	2	2	0.0176	03-20	Read	0
60	Clear				2			Clear	0
61	Accy Dr Quill Shaft Brg Aft	3	5	2	2	0.0565	05-20	Read	0
62	249-1	3	5	2	2	0.2140	04-20	Read	0
63		3	5	2	2	0.0770	05-20	Read	0
64		3	5	2	2	0.0571	05-20	Read	0
65	Clear	3	5	2	2			Clear	0
66	Accy Drive Gearshaft Aft	3	5	2	2	0.0623	05-20	Read	0
67	248-1	3	5	2	2	0.2271	02-20	Read	0
68		3	5	2	2	0.0665	07-20	Read	0
69		3	5	2	2	0.0515	00-20	Read	0
70	Mike 5 Normalize Check	3	5	2	2	0.4444	10-20	Check 5	0
71	Clear				2			Clear	0

TABLE XLI. MODEL CH-47A/B HELICOPTER RECORDED DURING EVALUATION PROGRAM AT U.S. ARMY AVIATION C FORT RUCKER, ALABAMA

Record No.	Date Recorded	Heli-copter Model	Heli-copter No.	Engine No. 1 Serial No.	Engine No. 2 Serial No.	No. 1 90° Gearbox S/N	No. 2 90° Gearbox S/N	Forwa XMSI S/N
3-10	5-13-68	CH-47A	62-2114	LE-05617	LE-05646	A-11-480	A-11-613	A-7-3
3-11	5-15-68	CH-47B	61-19123	LE-04885	LE-04364	A-11-1223	A-11-791	A-7-1
3-12	5-20-68	CH-47B	61-19123	LE-04885	LE-04364	A-11-1223	A-11-791	A-7-1
3-13-1	5-28-68	CH-47B	66-19124	LE-05721	LE-04713	A-11-1063	A-11-496	A-7-6
3-13-2	5-28-68	CH-47B	66-19124	LE-05721	LE-04713	A-11-1063	A-11-496	A-7-6
3-14	5-29-68	CH-47A	61-2422	LE-04137	LE-05750	A-11-1120	A-11-356	A-7-4
3-15-1	6-3-68	CH-47A	66-19005	LE-04755	LE-05530	A-11-203	A-11-569	A-7-2
3-15-2	6-3-68	CH-47A	66-19005	LE-04755	LE-05530	A-11-203	A-11-569	A-7-2
3-16	6-5-68	CH-47A	63-7912	LE-04175	LE-05597	A-11-213	A-11-808	A-7-1
3-17	6-7-68	CH-47A	62-2137	LE-04889	LE-04162	A-11-533	A-11-52	A-7-6
3-18	6-11-68	CH-47B	66-19119	LE-05761	LE-04234	A-11-622	A-11-289	A-7-9
3-19	6-17-68	CH-47B	66-19139	LE-04688	LE-04261	A-11-1243	A-11-511	A-7-6
3-20	7-9-68	CH-47A	61-2422	LE-04765	LE-05750	A-11-1120	A-11-356	A-7-4
3-21	7-15-68	CH-47A	66-19003	LE-05633	LE-04539	A-11-462	A-11-48	A-9-6
3-22	7-17-68	CH-47B	66-19120	LE-04103	LE-04962	A-11-141	A-11-13	A-7-7

TABLE XLI. MODEL CH-47A/B HELICOPTER RECORDED DURING THE FIELD EVALUATION PROGRAM AT U.S. ARMY AVIATION CENTER, FORT RUCKER, ALABAMA

Heli-copter No.	Engine No. 1 Serial No.	Engine No. 2 Serial No.	No. 1 90° Gearbox S/N	No. 2 90° Gearbox S/N	Forward XMSN S/N	Aft XMSN S/N	Comb. Box S/N	Mike No.
2114	LE-05617	LE-05646	A-11-480	A-11-613	A-7-324	A-9-418	A-8-157	8
19123	LE-04885	LE-04364	A-11-1223	A-11-791	A-7-129	A-9-571	A-8-567	8
19123	LE-04885	LE-04364	A-11-1223	A-11-791	A-7-129	A-9-571	A-8-567	8
19124	LE-05721	LE-04713	A-11-1063	A-11-496	A-7-666	A-9-573	A-8-85	3
19124	LE-05721	LE-04713	A-11-1063	A-11-496	A-7-666	A-9-573	A-8-85	3
2422	LE-04137	LE-05750	A-11-1120	A-11-356	A-7-423	A-9-486	A-8-665	3
19005	LE-04755	LE-05530	A-11-203	A-11-569	A-7-25	A-9-217	A-8-191	3
19005	LE-04755	LE-05530	A-11-203	A-11-569	A-7-25	A-9-217	A-8-191	3
7912	LE-04175	LE-05597	A-11-213	A-11-808	A-7-172	A-9-362	A-8-21	3
2137	LE-04889	LE-04162	A-11-533	A-11-52	A-7-661	A-9-567	A-8-562	3
19119	LE-05761	LE-04234	A-11-622	A-11-289	A-7-96	A-9-235	A-8-156	3
19139	LE-04688	LE-04261	A-11-1243	A-11-511	A-7-671	A-9-595	A-8-582	8
2422	LE-04765	LE-05750	A-11-1120	A-11-356	A-7-423	A-9-486	A-8-665	8
19003	LE-05633	LE-04539	A-11-462	A-11-48	A-9-683	A-9-393	A-8-468	8
19120	LE-04103	LE-04962	A-11-141	A-11-13	A-7-738	A-9-726	A-8-564	8

B

TABLE XLII. CORRECTIONS TO ACOUSTIC LOG SHEETS - CH-47A HELICOPTER, SONIC ANALYZER PROGRAM NO. 2011

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
3	N2 Calibrate	0	0	0	2	0.2257	05-20	Peak	0
51	Lock Check Input Spiral Bevel	3	3	3	2	0.2525	00-20	Peg Meter	06
52	Clear				2			Clear	02

TABLE XLIII. CORRECTIONS TO ACOUSTIC LOG SHEETS - CH-47A HELICOPTER, SONIC ANALYZER PROGRAM NO. 2021

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
3	N2 Calibrate	0	0	0	2	0.2257	05-20	Peak	0
51	Lock Check Input Spiral Bevel	4	3	3	2	0.2525	00-20	Peg Meter	06
52	Clear				2			Clear	02

TABLE XLIV. CORRECTIONS TO ACOUSTIC LOG SHEETS - CH-47A HELICOPTER, SONIC ANALYZER PROGRAM NO. 2031

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
23	Lock Check Input Spiral Bevel	1	3	3	2	0.2525	00-20	Peg Meter	06
24	Clear				2			Clear	02

TABLE XLV. CORRECTIONS TO ACOUSTIC LOG SHEETS - CH-47A HELICOPTER, SONIC ANALYZER PROGRAM NO. 2041

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
3	N2 Calibrate	0	0	0	2	0.2257	05-20	Peak	0
10	Lock Check, Input Spiral Bev	1	3	3	2	0.2525	00-20	Peg Meter	06
43	N2 Calibrate	0	0	0	2	0.2257	05-20	Peak	0
50	Lock Check Input Spiral Bevel	2	3	3	2	0.2525	00-20	Peg Meter	06

TABLE XLVI. CORRECTIONS TO ACOUSTIC LOG SHEETS - CH-47A HELICOPTER, SONIC ANALYZER PROGRAM NO. 2051

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
3	N2 Calibrate	0	0	0	2	0.2257	05-20	Peak	0
20	Lock Check. Input Spiral Bevel	3	3	3	2	0.2525	00-20	Peg Meter	06
55	Lock Check. Input Spiral Gears	3	3	3	2	0.2525	00-20	Peg Meter	06
85	Lock Check. Input Spiral Gears	4	3	3	2	0.2525	00-20	Peg Meter	06
110	Lock Check. Input Spiral Gears	4	3	3	2	0.2525	00-20	Peg Meter	06

TABLE XLVII. CORRECTIONS TO ACOUSTIC LOG SHEETS - CH-47A HELICOPTER, SONIC ANALYZER PROGRAM NO. 2061

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
3	N2 Calibrate	0	0	0	2	0.2257	05-20	Peak	0
25	Lock Check. Input Spiral Bevel	1	3	3	2	0.2525	00-20	Peg Meter	06
45	Lock Check. Input Spiral Bevel	1	3	3	2	0.2525	00-20	Peg Meter	06

TABLE XLVIII. CORRECTIONS TO ACOUSTIC LOG SHEETS - CH-47A HELICOPTER, SONIC ANALYZER PROGRAM NO. 2071

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
3	N1 Calibrate	0	0	0	1	0.2735	05-20	Peak	0
4	N2 Calibrate	0	0	0	2	0.2257	05-20	Peak	0
24	Accy Main Train	1	1	2	1	0.2000	08-10	Read	0
25	Lock Check (Accy Main Train)	1	1	2	1	0.2000	05-20	Peg Meter	06
53	N1 Calibrate	0	0	0	1	0.2735	05-20	Peak	0
54	N2 Calibrate	0	0	0	2	0.2257	05-20	Peak	0
74	Accy Main Train	2	2	2	1	0.2000	04-20	Read	0
81	Lock Check Accy Main Tr	2	2	2	2	0.2000	05-30	Peg Meter	06

TABLE XLIX. CORRECTIONS TO ACOUSTIC LOG SHEETS - CH-47A HELICOPTER, SONIC ANALYZER PROGRAM NO. 2081

Item No.	Component Description	Mode	Mike	Chan	Lock N	Ratio Set	Gains I-II	Cond Limit	Cond Level
40	Lock Check Input Spiral Bevel	3	3	3	2	0.2525	00-20	Peg Meter	06
71	Lock Check Input Spiral Bevel	3	3	3	2	0.2525	00-20	Peg Meter	06
72	Clear				2				02

APPENDIX I
SAMPLE CALCULATIONS

The following sample calculations are based on data from model T55-L-5 engine:

1. Compressor

   Example: 1st stage = 28 blades, N_1 = 14040 RPM

   (a) Fundamental rotational frequency

   $$f_R = \frac{\text{Speed of compressor rotor, N1 (RPM)}}{60} = \frac{14040}{60} = 234.0 \text{ RPS}$$

   (b) Compressor rotor blade passage frequency

   $C_1 = f_R$ x no. of rotor blades = 234.0 x 28 = 6552 Hz

2. Accessory Transmission Main Gear Train

   Example: Inner bevel main drive gear, 39 teeth (Ref 124-3, Figure 1); inner bevel main driven gear, 39 teeth (Ref 118-20, Figure 1); outer accessory drive bevel gear, 14 teeth (Ref 112-89, Figure 1); outer accessory driven bevel gear, 24 teeth (Ref 112-15, Figure 1); accessory transmission main drive gear, 15 teeth (Ref 110-11, Figure 1); N_1 = 234 RPS.

   (a) RPS of Accessory Transmission Main Drive Gear

   $$\text{RPS} = N_1 \times \frac{\text{no. of teeth on drive gear}}{\text{no. of teeth on driven gear}}$$

   $$\text{RPS} = 234 \times \frac{39}{39} \times \frac{14}{24} = 136.5 \text{ RPS}$$

   (b) Rotational Frequency of Accessory Transmission Main Drive Gear

   f = RPS x no. of gear teeth

   f = 136.5 x 15 = 2047 Hz

3. Bearing Formulae

   Example: No. 2 Main Engine Bearing, N1 = 14040 RPM, d_B = 0.6875", d_1 = 3.188", d_2 = 4.563" and m = 15

   (a) Fundamental rotational frequency

   $$f_R = \frac{\text{RPM of shaft}}{60} = \frac{14040}{60} = 234 \text{ RPS}$$

(b) Frequency caused by irregularity on inner race

$$f_1 = f_R \; m \frac{d_2}{d_1 + d_2}$$

$$= 234 \times 15 \times \frac{4.563}{3.188 + 4.563} = 2067 \text{ Hz}$$

(c) Frequency caused by irregularity on outer race

$$f_2 = f_R \; m \frac{d_1}{d_1 + d_2}$$

$$= 234 \times 15 \times \frac{3.188}{3.188 + 4.563} = 1444 \text{ Hz}$$

(d) Frequency caused by spin of rolling element

$$f_B = f_R \frac{d_2}{d_B} \quad \frac{d_1}{d_1 + d_2}$$

$$= 234 \times \frac{4.563}{0.6875} \times \frac{3.188}{3.188 + 4.563} = 639 \text{ Hz}$$

(e) Frequency caused by rough spot on rolling element

$$f_B' = 2 \; f_B = 2 \times 639 = 1278 \text{ Hz}$$

(f) Frequency due to rotation of train of rolling elements

$$f_T = \frac{f_2}{m} = \frac{1444}{15} = 96 \text{ Hz}$$

4. Octal Ratios

Example: Component frequency (1st stage compressor) = 6552 Hz
Tracking frequency = 8188 Hz

(a) Decimal ratio

$$\text{Decimal ratio} = \frac{\text{component frequency}}{\text{tracking frequency}} = \frac{6552}{8188} = 0.800195$$

(b) Octal Ratio

Convert the decimal ratio to an octal ratio as follows:

(1) The number to the left of the decimal ratio is the first number of the octal number.

(2) Multiply all digits to the right of the decimal point in the decimal ratio by 8. The number to the left of the decimal point in this product is the first number to the right of the decimal point in the octal number.

(3) Multiply all digits to the right of the decimal point in the product obtained in (2) by 8. The number to the left of the decimal point in this product is the second number to the right of the decimal point in the octal number.

(4) Continue this process until the desired number of decimal places for the octal ratio is obtained.

(5) Round off last decimal place using the number 4 as the mid-point since these numbers are to base 8.

Example: Decimal ratio = 0.800195

Multiply 0.800195 x 8 = 6.401560
0.401560 x 8 = 3.212480
0.212480 x 8 = 1.699840
0.699840 x 8 = 5.598720
0.598720 x 8 = 4.789760

Therefore, Octal Ratio = 0.6315 rounded off to 4 decimal places.

APPENDIX II
EXPLANATION OF TABLES*

Octal ratio settings, corresponding to rotating component frequencies at analysis speeds, are tabulated against component description for each mechanical section of the CH-47A/B helicopters power trains and T55-L-5,-7 engines.

For convenience in parts identification and reference, each listing contains:

Item No. - Numerical listing by mechanical grouping and subgrouping within the tables.

Ref-Figure - Cross-reference of mechanical grouping to figure number where illustration or mechanical schematic may be found.

Program Index - Cross-reference of individual component to related part in Department of the Army TM 55-1520-209-20P Organizational Maintenance Repair Parts and Special Tool Lists. This number is identical to the "Figure and Index Number" listed in the Army TM.

Part Number (Vendor) - Federal part number, as listed in TM 55-1520-209-20P followed by vendor or manufacturer's part number, where applicable.

Frequency - Frequency symbol and value.

The source reference for parts identification is Department of the Army TM 55-1520-209-20P, dated March 1967.

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* Reference pages 44-115

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13. ABSTRACT

The purpose of the work encompassed in this report was (1) to fabricate an automated diagnostic sonic analyzer, (2) to design and fabricate a CH-47A/B helicopter plug-in module with both T55 engine and CH-47A/B helicopter power train components capability, and (3) to design and fabricate an auxiliary microphone switch box.

The methods employed in achieving this work consisted of (1) analyzing mechanical data to determine the frequencies of the rotating components, (2) performing a microphone survey and locking frequency investigation, (3) analyzing the acoustical data to develop spectral familiarity and to establish initial analyzer programming and system compatibility, and (4) conducting a field application program utilizing the automated sonic analyzer to correlate analyzer indications with the mechanical condition of the rotating components and to establish analyzer limits.

As a result of the work accomplished under this program, a Curtiss-Wright model CWCD-1000 Sonic Analyzer with a CWCD-1010 automation unit, developed under Naval Air Systems Command Contract NOw 66-0704f, was fabricated and delivered to the Army together with a CWCD-1020 microphone auxiliary switch box. The CH-47A/B acoustic plug-in module, delivered with the analyzer, was designed and fabricated under this program to incorporate the T55 engine (models T55-L-5 and T55-L-7) and CH-47A/B helicopter power train components (forward and aft rotor transmissions and combining transmission) capability. The component limits for the aft rotor transmission were established during the three-month field application program conducted at Henchy Army Air Field, Fort Rucker, Alabama. An additional four-month study was conducted in the Curtiss-Wright laboratory to evaluate the complete CH-47A/B helicopter dynamic system utilizing the tape recordings made during the three-month field application program. As a result of this study, tentative component limits have been established. However, a considerable amount of additional data will be required to confirm these limits.

The utilization of the CWCD-1000/1010 Sonic Analyzer and the CWCD-1020 switch box by ground maintenance personnel at military installations will reduce the aircraft downtime by eliminating unnecessary troubleshooting as now being practiced under conventional inspection methods. As the confidence level in the CWCD-1000/1010 analyzer is increased, the time between periodic inspections may also be increased.

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