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FIELD EVALUATION OF THE SHOCK PULSE TECHNIQUE TO UH-1H SERIES H--ETC(U)

JUN 74 T C MAYER, E F COVILL, J A GEORGE DAAJ01-72-A-0027

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USAAVRADCOM TR 78-2

AD A054906

FIELD EVALUATION OF THE SHOCK PULSE TECHNIQUE TO UH-1H SERIES HELICOPTERS

TIMOTHY C. MAYER
EDWARD F. COVILL
JOHN A. GEORGE
J. THOMAS HARRINGTON

5 JUNE 1974

FINAL REPORT

PREPARED FOR

DIRECTORATE FOR DEVELOPMENT AND ENGINEERING
U. S. ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
P. O. BOX 209
ST. LOUIS, MO. 63166

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Shock Pulse readings were taken on four (4) models of the UH-1, (Models: C, M, D and H) using an off-the-shelf SKF, MEPA-10A. readings were collected on the tailrotor driveshaft hanger bearings and the forty two degree tailrotor gearbox.

The shock pulse technique works on the principle that a discrete fault, such as a pit or a spall, will cause repetitive impacts of short duration.

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These impacts will cause shock waves to propagate through the bearing structure causing a pulse displacement input to an accelerometer, suitably, attached to the bearing structure. The output of the accelerometer passes through a high gain amplifier tuned at the resonant frequency of the accelerometer (this amplifier then acts as a sharp band-pass filter). After the signal is processed the output is displayed on a counter which provides the frequency of peaks above any desired peak amplitudes.

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June 3, 1974

U.S. Army Aviation Systems Command
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ATTENTION: M. J. Rodgers
Contracting Officer
AMSAV-PPNS

REFERENCE: BOA DAAJ01-72-A-0027(P6C)
DO DAAJ01-72-A-0027-0002(P6C)

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If you have any questions or comments, please do not hesitate to contact the undersigned.

Sincerely,

J. Thomas Harrington

J. Thomas Harrington
Director of Research

JTH/kmf

Enclosures - 4

FINAL REPORT

FIELD EVALUATION OF THE SHOCK PULSE TECHNIQUE TO UH-1H SERIES HELICOPTERS

TIMOTHY C. MAYER
EDWARD F. COVILL
JOHN A. GEORGE
J. THOMAS HARRINGTON

PARKS COLLEGE OF SAINT LOUIS UNIVERSITY
CAHOKIA, ILLINOIS

JUNE 5, 1974

BOA DAAJ01-72-A-0027(P6C)
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The College appreciates the assistance of the 281st Aviation Company stationed at Bi-State Airport, Cahokia, Illinois, and the Bell Helicopter Company during the contract period.

John A. George
Technical Director

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1.0 INTRODUCTION

The U.S. Army Aviation Systems Command has an on-going program to develop a system which will automatically accomplish inspection, diagnostic and prognostic maintenance functions on related subsystems of the UH-1 helicopter. Past efforts (references 1, 2, 3) have included the collection of vibration data with a subsequent analysis of the resulting Power Spectral Densities to determine the condition of the helicopter powertrain.

Another approach, particularly in determining bearing condition, is to use the shock pulse techniques. When a bearing race or rolling element contains a descrete fault, such as a pit or spall, the rolling contact between this fault and the other rolling elements will result in repetitive impacts of short duration. As a result of these impacts, a shock wave propagates through the structure. The shock pulse travels through the bearing and causes a pulse displacement input to an accelerometer. The output of the accelerometer is passed through a high gain amplifier tuned at the resonant frequency of the accelerometer. This amplifier acts as a very sharp band-pass filter. After the signal is suitably processed, the output is displayed on a counter which provides the frequency of peaks above any desired peak amplitudes.

An evaluation of the feasibility of using pulse techniques to the UH-1 series helicopters was conducted by the College (4). A standard off-the-shelf SKF, Industries Model MEPA-10A Shock Pulse Meter was employed to construct shock emission envelopes of shock rate versus shock level.

The preliminary study concentrated primarily on the hanger bearings of the tail rotor assembly on a UH-1 helicopter. Shock emission data was collected from laboratory tests and ground runs on "good" and "bad" bearings. In addition, some data was collected at various flight conditions on the 42° gearbox. The data, although limited in nature, showed the technique to be promising. Subsequently, the College was placed under contract to collect additional data and correlate the shock pulse signatures with teardown analysis. This report concerns itself with this effort.

UH-1 type helicopters were made available by the 281st Aviation Company, co-stationed at the Bi-State Airport, Cahokia, Illinois and Scott Air Force Base. Data was collected on four models: UH-1H, UH-1D, UH-1M, and UH-1C. The federal stock number for all hanger bearings and for those on the 42° gearboxes is the same for these series of helicopters. Differences are in the number of hanger bearings with the UH-1H and UH-1D having four hanger bearings while the UH-1M and UH-1C has three. All tests were ground runs at N_2 = 4600 rpm.

The aircraft were available on a non-interference basis, i.e., no modification could be made to the airframe which would result in the aircraft being in a non-flyable status. The maintenance personnel assigned through the "AMSA 44" shop were not to be used directly because of work interference. Work connected in running the aircraft as well as accelerometer placement and graph data collection had to be made without interference with the normal maintenance routine or flight operations.

As in the preliminary evaluation, the method employed to analyse bearings consisted of constructing a plot of shock rate versus shock level. The rate level found became the first point plotted on the ordinate at a value level of one. A threshold varying dial on the MEPA-10A meter housing ranges from a level of one to ten thousand in a logrithmic scale. As the threshold is increased, successive rates were plotted until the curve crossed the abscissa axis. The value at the intercept becomes then the highest potentiometer level at which at least one shock pulse per second can be measured. In plotting the data points of the shock emission envelope, a period of integration time is allowed to insure accuracy. This integration time is noted in the left hand margin of each of the graphical presentations. The rate is given in a pulses per second and the level obtained is in relation to the potentiometer level which is a function of the accelerometer used. The curves drawn were then compared to the general curve forms of different types of damage and, coupled with the rate and values obtained, an assessment of bearing condition was made. In addition, selected hanger bearings and 42° gearboxes were removed for teardown analysis be Bell Helicopter Company.

2.0 STATISTICAL DATA OF FIELD COLLECTION

2.1 HANGER BEARINGS

Twenty-nine hanger bearing assemblies were tested in this phase with the MEPA-10A system. This data, which includes originally installed and replacement bearings, is given in Figures 2 through 30. Of the hanger bearings tested, 8 were removed for teardown analysis.

The range of shock rates were 55 - 340 pulses/second with a mean rate of 184 and a standard deviation of 86. Forty-five percent of hanger bearings tested were between 100 - 200 and 21% between 300 - 350. As can be seen, the greatest portion of bearings tested resulted in moderate rates and no unusual or excessive rates were measured.

The potentiometer levels of hanger bearings varied considerably more than rates; the range of levels were found to fall between 45 and 6000 units. With such a wide divergence of levels, a large deviation is to be expected. The mean of levels measured was 558 with a standard deviation of 1192. Sixty-nine percent of the levels were between 45 - 200 which indicates that generally a level existed which could be considered normal. Seventeen percent of the levels were in excess of 1000.

After a hanger bearing was replaced with a new or zero time rebuilt, another test was made, wherever possible, to determine the change in rate and levels.

It was found that the range of levels of new bearings was 50 - 100, an extreme decrease from previous range of 45 - 6000. The new hanger bearings had a mean level of 66 which is significantly lower than the level of the total bearings tested. The standard deviation is 41 which reflects a considerable decrease from the 1192 standard deviation of levels of the total population of hanger bearings tested.

The rates of shock found in the four replacement hanger bearings tested ranged from 190 - 320 which corresponds favorably with the rate data of hanger bearings prior to their replacement. The mean rate of 242 and standard deviation of 72 also is of the same magnitude of the bearings tested prior to those removed for teardown analysis.

When all hanger bearings are considered, minus those which were removed for analysis, the mean potentiometer level dropped from 558 to 189. The standard deviation also experienced a considerable decrease from 1192 to 240. This illustrates that the bearings removed for teardown were those exhibiting a significant variation from the normal. Table 2.1 gives a listing of the relavent hanger bearing data and Table 2.2 is a summary of the hanger bearing statistical data.

Of interest, is the data presented in Figure 14. According to the plotted data, the bearing would be classified as satisfactory. However, the bearing was removed by an aircraft technical inspector due to "excessive play." Also shown is data collected from the same bearing on the laboratory bench set-up. The data still appears satisfactory and the teardown analysis did not show significant damage level.

2.2 42° GEARBOX

Shock pulse data was collected on nine different 42° gearboxes. The 42° gearbox consists of two bearing packages, one used for the input drive quill and the other used on the output drive quill assembly. Some difficulty was originally experienced in accelerometer placement which accounts for the fact that only 16 bearing assemblies were measured. Figures 31 through 39 give rate versus potentiometer level for the input and/or output quills.

The 42° gearboxes proved to be quite consistant in their shock emission data obtained. Because of the relative similarity of the data, difficulty arose in determining what excessive levels were. Four of the nine gearboxes which were evaluated were removed for teardown analysis. The gearboxes were removed primarily because of peculiarities in the curve shape rather than excessive deviation of the shock rate or potentiometer level from the mean.

The mean rate of shock pulse information collection was 221 pulses/sec. with a range of rates running from 75 - 600 inclusively. Seventy-five percent of all 42° gearboxes tested had rate levels between 75 - 300 with a standard deviation of 151. Potentiometer levels of the bearings ranged between 45 - 300 with a mean of 133. Of the quill bearings tested, 75% of these fell between 50 - 200 with a standard deviation of 70. Table 2.3 and 2.4 summarize the 42° gearbox data.

DATA OBTAINED FROM FIELD ANALYSIS

HANGER BEARINGS

Aircraft		Position	Serial No.	Hours		Potentiometer Level	Shock Pulse Rate	Date	Comment
No.	Type			TSN	TSO				
16264	UH-1H	#3	A20-67523	806	404	600	340	13 NOV 73	Removed for Teardown Analysis
16264	UH-1H	#4	A20-60933			85	100	13 NOV 73	
59771	UH-1D	#3	A20-69969			90	170	14 NOV 73	
59771	UH-1D	#4	A20-23720			65	150	14 NOV 73	
13740	UH-1H	#3	A20-27256		UNK	45	100	14 NOV 73	
13740	UH-1H	#4	A20-44738		306	55	150	14 NOV 73	
16264	UH-1H	#3	A20-55994			95	175	19 NOV 73	New Replacement Bearing
16197	UH-1H	#3	A20-48180		225	110	220	27 NOV 73	
16197	UH-1H	#4	A20-19152		225	70	120	27 NOV 73	
01087	UH-1H	#3	A20-43391		488	900	300	28 NOV 73	Removed for Teardown Analysis
01087	UH-1H	#4	A20-37362		501	45/175(Lab)	300/85(Lab)	28 NOV 73	Removed for Teardown Analysis
15949	UH-1H	#3	A20-64459		427	1750	150	28 NOV 73	Removed for Teardown Analysis
15949	UH-1H	#4	A20-64906		427	550	280	28 NOV 73	Removed for Teardown Analysis
59519	UH-1M	#1	A20-44891			700	95	30 NOV 73	
59519	UH-1M	#2	A20-57910			175	150	30 NOV 73	
59519	UH-1M	#3	A20-11446		144	1200	Needle Swing 10-300	30 NOV 73	Removed for Teardown Analysis

TABLE 2.1

DATA OBTAINED FROM FIELD ANALYSIS

HANGER BEARINGS

Aircraft		Position	Serial No.	Hours		Potentiometer Level	Shock Pulse Rate	Date	Comment
No.	Type			TSN	TSO				
66-1087	UH-1H	#3	A20-10705			75	200	30 NOV 73	New Replacement Bearing
15949	UH-1H	#3	--			70	200	30 NOV 73	New Replacement Bearing
15949	UH-1H	#4	--			50	220	30 NOV 73	New Replacement Bearing
15200	UH-1M	#1	A20-29105		143	50	170	6 DEC 73	
15200	UH-1M	#2	A20-22817		143	55	60	6 DEC 73	
15200	UH-1M	#3	A20-10877		143	50	170	6 DEC 73	
15190	UH-1M	#1	A20-56617		80	400	200	12 DEC 73	
15190	UH-1M	#2	A20-46146		80	150	100	12 DEC 73	
15190	UH-1M	#3	A20-53737		80	58	70	12 DEC 73	
16879	UH-1H	#3	A20-26745		403	2500	220	12 DEC 73	Removed for Teardown Analysis
16879	UH-1H	#4	A20-31225		403	5500	300	12 DEC 73	Removed for Teardown Analysis
13740	UH-1H	#3	A20-27256		UNK	46	150	27 NOV 73	Repeat of Hanger Bearing 14 NOV 73
13740	UH-1H	#4	A20-44738		306	60	100	27 NOV 73	Repeat of Hanger Bearing 14 NOV 73

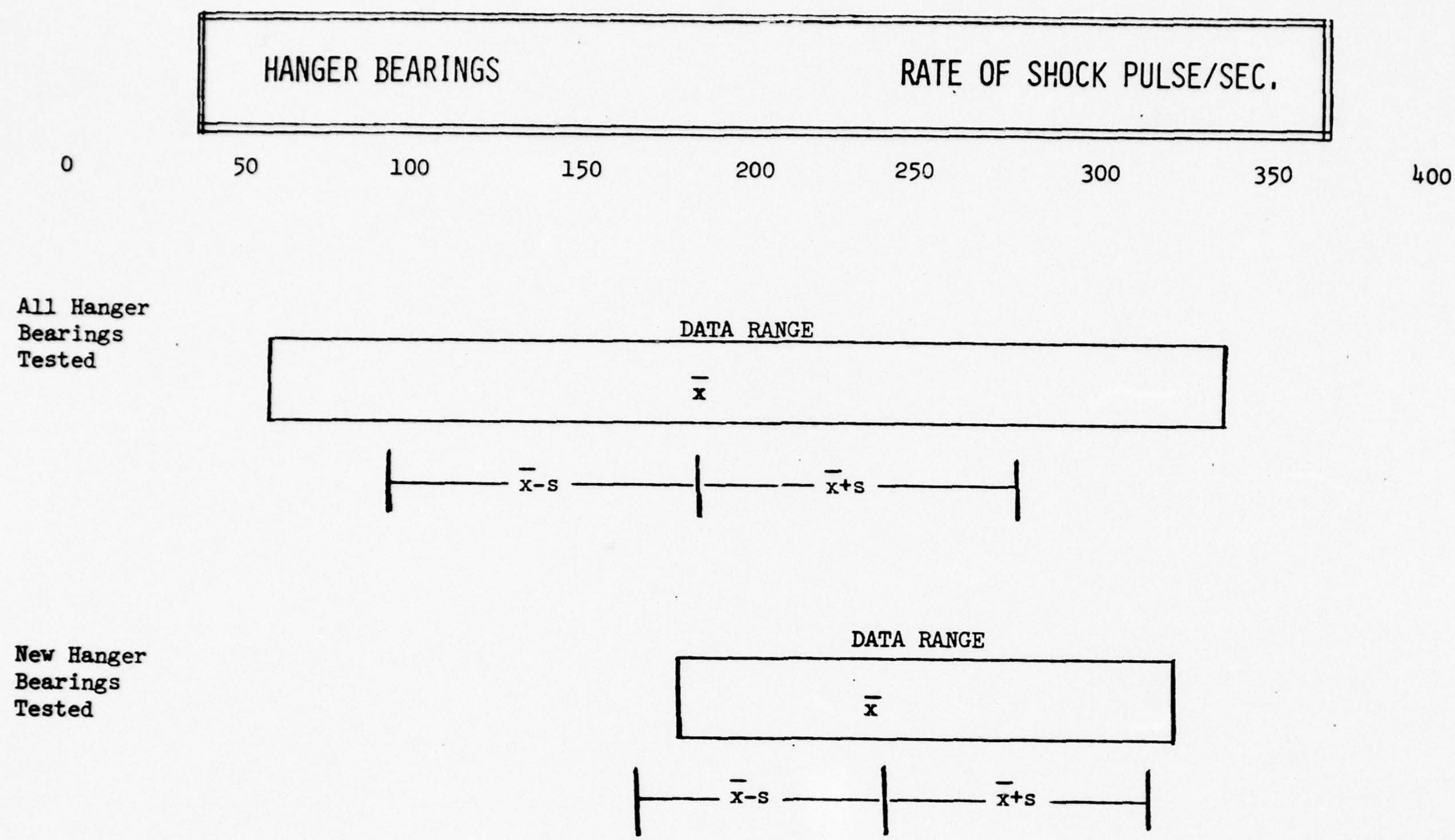

HANGER BEARINGS
RATE OF SHOCK PULSE/SEC.
0
50
100
150
200
250
300
350
400
All Hanger Bearings Tested
DATA RANGE
x̄
x̄-s
x̄+s
New Hanger Bearings Tested
DATA RANGE
x̄
x̄-s
x̄+s

TABLE 2.2

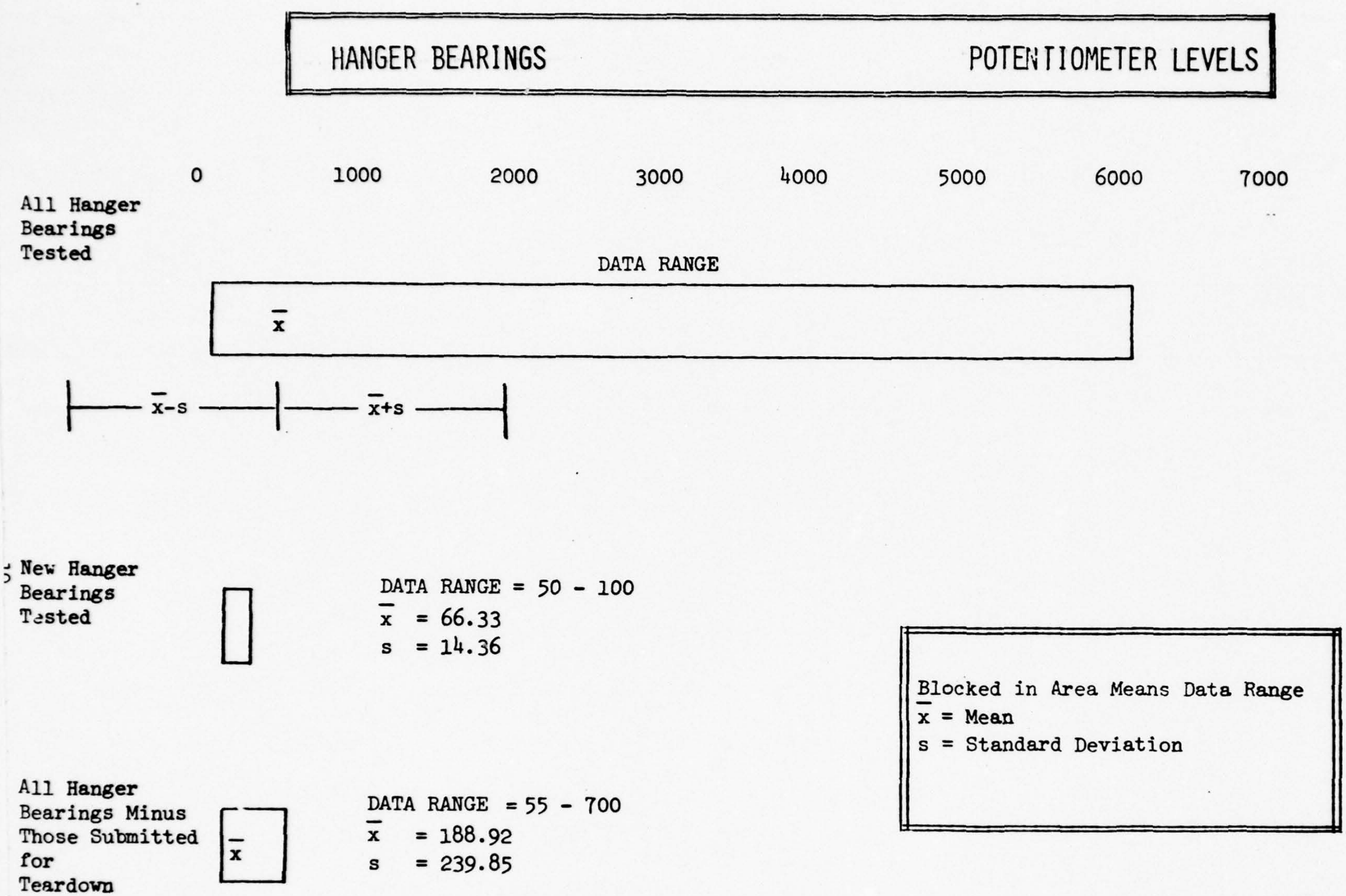

HANGER BEARINGS
POTENTIOMETER LEVELS
0
1000
2000
3000
4000
5000
6000
7000
All Hanger Bearings Tested
DATA RANGE
x
x-s
x+s
New Hanger Bearings Tested
DATA RANGE = 50 - 100
x = 66.33
s = 14.36
Blocked in Area Means Data Range
x = Mean
s = Standard Deviation
All Hanger Bearings Minus Those Submitted for Teardown
x
DATA RANGE = 55 - 700
x = 188.92
s = 239.85

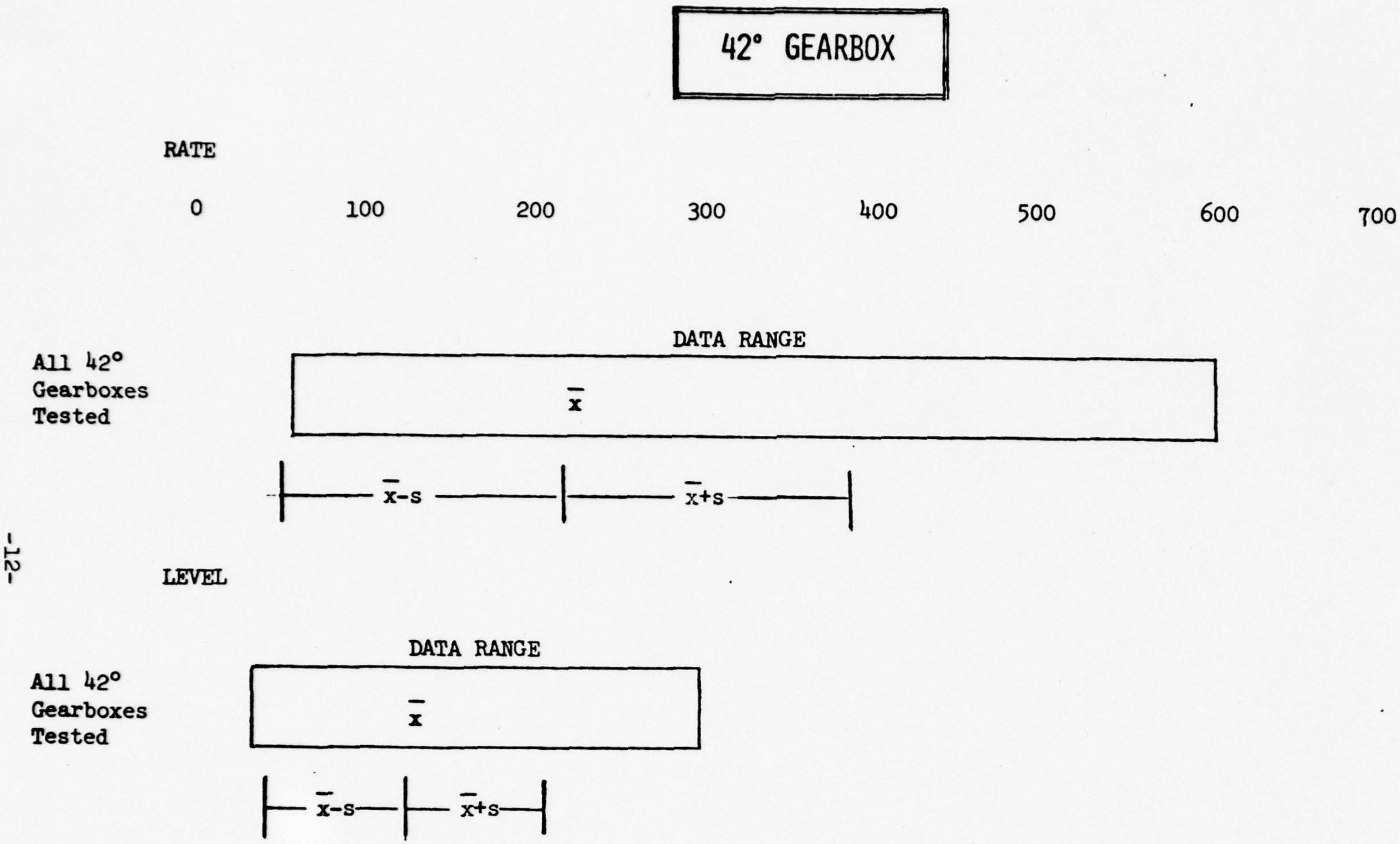
TABLE 2.2

DATA OBTAINED FROM FIELD ANALYSIS

GEARBOXES

Aircraft		Position	Serial No.	Hours		Pot. Level	Shock Pulse Rate	Date	Comment
No.	Type			TSN	TSO	Input/Output	Input/Output		
13740	UH-1H	42° G/B	A13-1097			65/55	100/80	27 NOV 73	
16197	UH-1H	42° G/B	BBB-289		225	75/80	150/85	27 NOV 73	
01087	UH-1H	42° G/B	B13-3886		727	75/UNK	150/UNK	28 NOV 73	
15949	UH-1H	42° G/B	B13-5346			105/105	150/75	28 NOV 73	
59519	UH-1M	42° G/B	ABB-1742			50/40	240/200	30 NOV 73	
15200	UH-1M	42° G/B	ABB-6012	298	298	150/200	700/110	6 DEC 73	
15771	UH-1H	42° G/B	ABB-2667		1042	150/300	150-300/240	6 DEC 73	
15190	UH-1M	42° G/B	AB-1101		148	90/190	150-240/300	12 DEC 73	
16879	UH-1H	42° G/B	B13-3800		569	UNK/190	UNK/400-500	13 DEC 73	

TABLE 2.3



42° GEARBOX
RATE
0
100
200
300
400
500
600
700
All 42° Gearboxes Tested
DATA RANGE
x̄
x̄-s
x̄+s
LEVEL
All 42° Gearboxes Tested
DATA RANGE
x̄
x̄-s
x̄+s

TABLE 2.4

3.0 TEARDOWN AND CORRELATION AND RESULTS

Appendix I of this report is the results of an analysis made by Bell Helicopter Company (BHC) which was necessary to complete the data for evaluation of the MEPA-10A shock pulse technique.

The BHC report contains the results of a teardown analysis of hanger bearing assemblies and 42° gearboxes which were analysed in the field test and of these, 12 assemblies were submitted for analysis.

The 12 assemblies analysed are reviewed from; first, the amount of damage evident at teardown, second, the MEPA-10A shock emission profile, third, the photo evidence of the damage present, fourth, a comparison between shock profile and teardown results.

A definite correlation seems to exist in the case of the most severely damaged bearing assemblies between damage found, and shock profile. In the areas where minor damage is found, it becomes increasingly difficult to make a definite correlation with shock profiles. Defects exist in all bearing assemblies to some extent and it is in a study of the amount of damage, not whether damage exists, that is of concern.

Unfortunately, no data which related the physical condition of the bearings to the degree of damage found, was reported. Whether the damage in any particular case would be severe enough to consider failure as eminent, or merely the onset of damage, was not indicated in the BHC analysis.

The SKF plot of shock emission is developed through a relationship of rate of shock pulses per second versus level of shock. This relationship when plotted, lends itself to a relatively non-subjective determination. The evidence resulting from a teardown can only be conclusive in a determination of condition when coupled with additional information as to flight worthiness.

In instances of damage in bearing assemblies, the rate or potentiometer level may not be exclusively the only criteria valid in condition determination. The changes in the slope of the shock emission curve may also be a determining fact. For example, gearboxes ABB-6012 and AB-2267 manifested brinelling in one or the other quill assembly which correlated closely to a slope irregularity in the shock emission. Neither gearbox had potentiometer levels or rates of shock which could be considered high in comparison to the average gearbox tested.

As previously mentioned, the method of accelerometer attachment used did not allow discrimination between the three bearings, two balls, and one roller, which comprise a quill assembly of the 42° gearbox. The only comparison which that can validly be assumed is in any damage in the quill versus any exhibited shock profile irregularities for that quill. A continuation of data collection will be made to attempt more specific results in accelerometer placement.

Hanger Bearing Serial #A20-11446 (Fig. 10) was removed for analysis because of the high potentiometer level of 1200 plotted and the excessive needle swing present in plotting the curve. This was the only hanger bearing which manifested such excessive needle swing on the MEPA-10A shock analysis. Reviewing the teardown data from BHC, a general good condition is reported with the only damage being corrosion in two places in the outer race. The inability to plot a smooth curve for this hanger bearing cannot be explained at this time. It is the only assembly tested which appears not to correlate with the teardown evidence. On several occasions, needle swing was found in plotting a portion of the curve in the analysis of gearbox assemblies. The swing in these cases was minimal and usually confined to between two or three points on the curve, not the entire curve. More data should be collected to determine how this needle swing affects curve plotting and whether temperature or low electric power supply could be the cause of excessive swing. The slight needle swing found in some of the gearbox assemblies, it is felt, could be because of the multiple bearing and gear assemblies present in the quills as well as accelerometer placement.

The color coded normalizing graph is included in this report for the hanger bearings (Fig. 1). This graph is based on the data collected to date. Those bearings which reached a level of severe damage are easily correlated as were the bearings which were new or in good working order. The mean level of the new hanger bearings is 66 with a standard deviation of 14. Considering the consistency of this data, we estimate a level for acceptable shock emission of 500 units would encompass both new bearings as well as those with only slight damage.

Those bearings which registered levels indicating a severity which demonstrated moderate amounts of damage, or damage which must be watched for an exceedance, were placed in a zone from levels of 500 - 1500. This category is difficult to determine because of the very nature of the diagnostic equipment. If the premise is valid that all bearings are damaged to some extent and the amount is the determining factor, then any estimate of severity must consider the consequence of failure. Bearing damage is insidous and progressive in nature. If the damage is of the type resulting from metal failure of a component of the bearing, then total failure can occur rapidly. Damage to the cage of the rolling elements can cause the type of failure which is both dramatic and rapid. A spall is the type of damage which may allow for many hours of safe operation after the spall occurs due to the rolling elements continuing their path over, or through the damage.

The MEPA-10A appears to have the ability to pick up most types of bearing damage. To determine the condition of a bearing as it approaches an area of exceedance, several readings should be taken over a period of time on a questionable bearing to track its failure rate. If a bearing exhibits high shock characteristics, then tracking its shock emission will give an indication of the rapidity with which it might proceed to a heavily damaged condition.

One of the factors of bearing analysis to be considered is that heretofore the method used to make an initial determination was in either subjective "feel" or in the measurement of some movement or play. In either case it was necessary to remove the bearing from the assembly to either feel it or to disassemble it for teardown. The movement in radial or axial play, it was shown, cannot be considered in bearing determination using the MEPA-10A system. (Fig. 14).

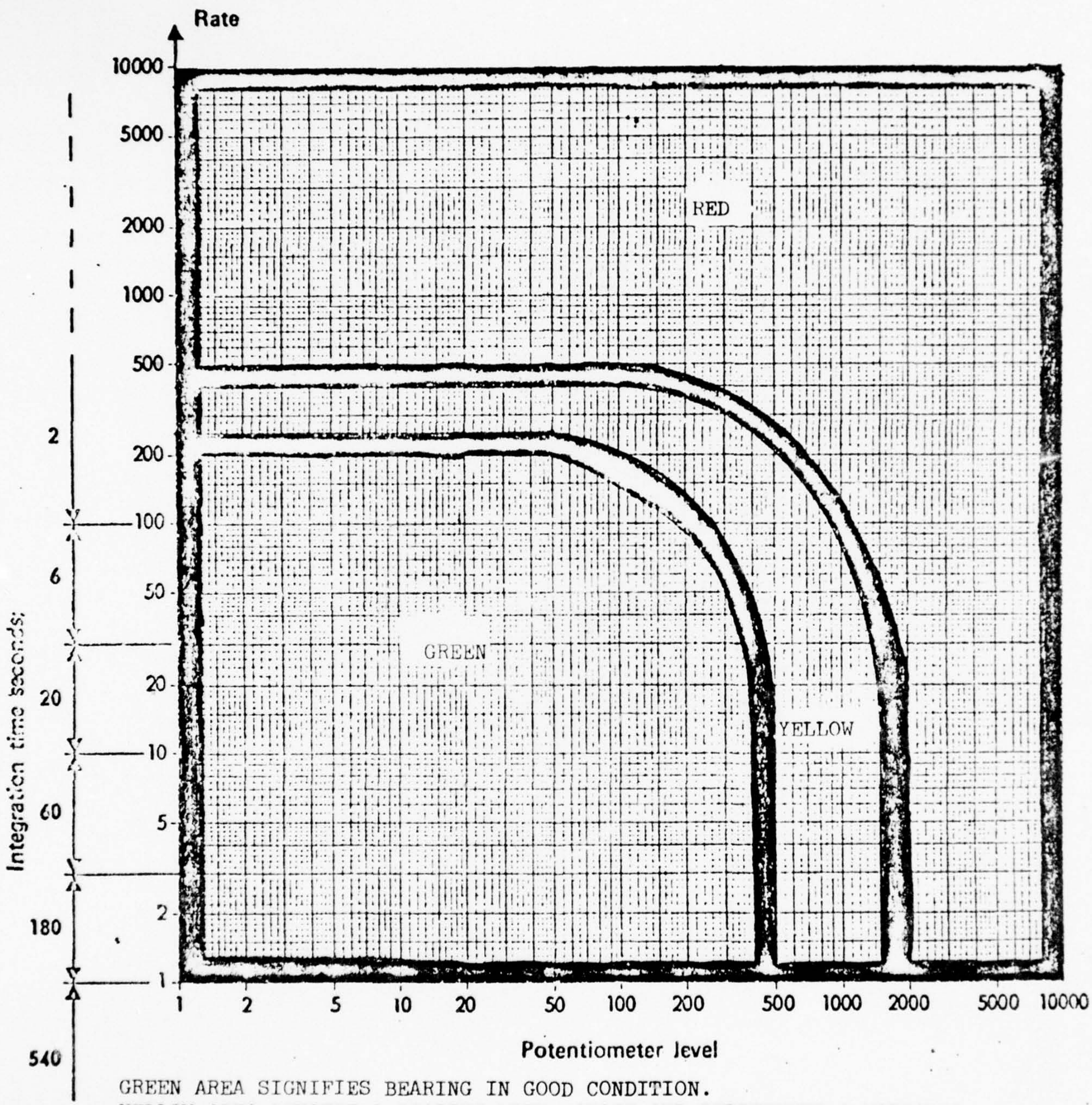
The SKF MEPA-10A system is a dynamic check of the bearings performance while operational and does not depend on subjective determination to generate the data to be used in its analysis. Subjectivitity occurs only in categoriaing the MEPA-10A's data. The following graphs and pictorial evidence of teardown are assembled in this section in entirety to facilitate correlation.

3.1 HANGER BEARINGS

The following bearing assemblies were analysed and if the bearing exceeded what was felt to be normal conditions, the assembly was removed for analysis. Whenever possible, the bearing which was used to replace those removed for teardown, was also tested to insure the shock signature was reduced to acceptable levels in the new assembly.

GRAPH FOR BEARING ASSEMBLIES

ANALYSED IN FIELD EVALUATION OF SHOCK PULSE TECHNIQUES



GREEN AREA SIGNIFIES BEARING IN GOOD CONDITION.

YELLOW AREA DENOTES A BEARING WITH DAMAGE AND REPRESENTS A MARGINAL CONDITION AREA.

RED AREA SIGNIFIES A BEARING WITH DAMAGE IN EXCESS OF THAT WHICH WE FEEL WOULD BE ACCEPTABLE.

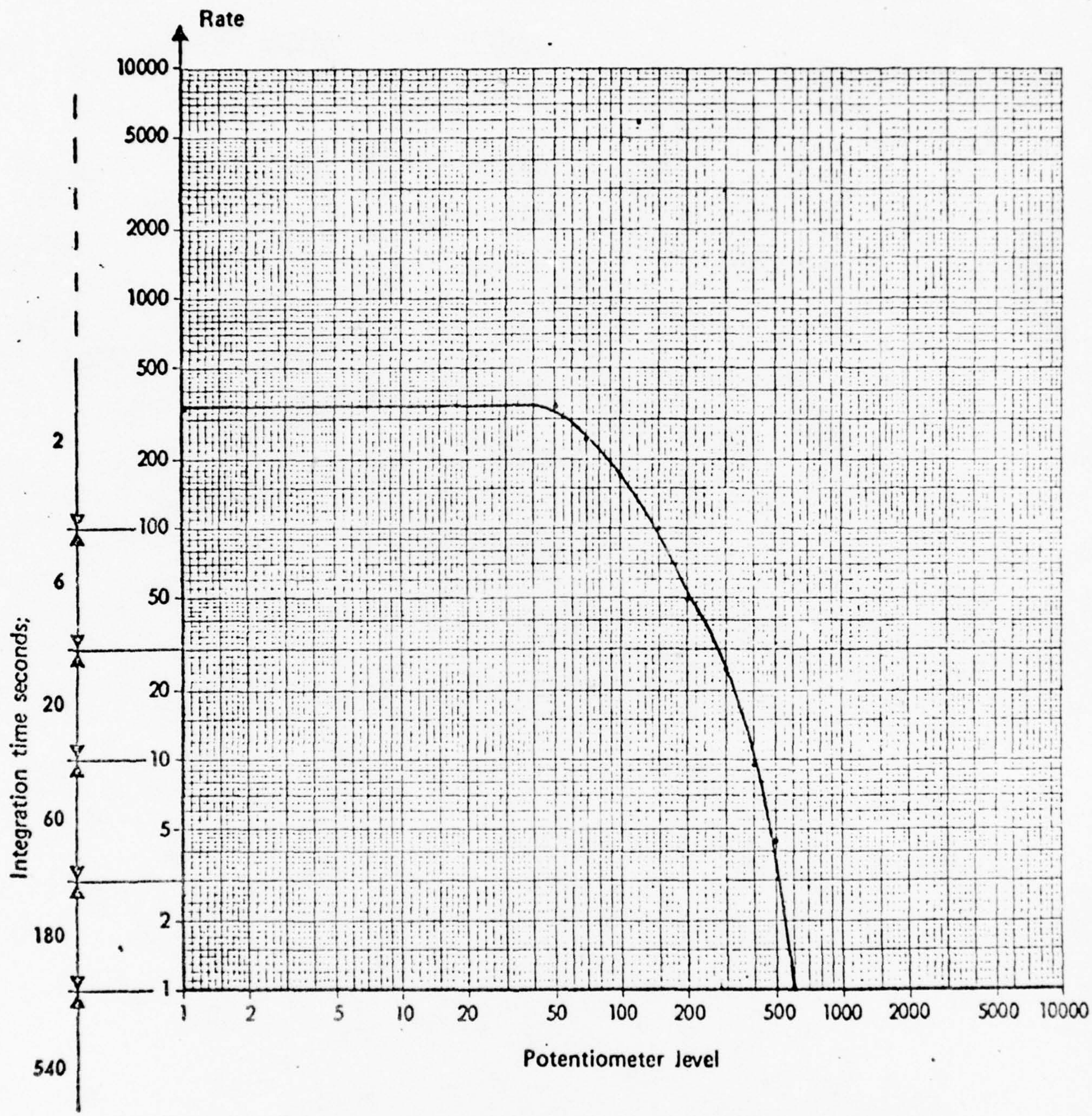
NOTE: SPECIFIC LIMITS OF COLORED AREAS COULD CHANGE, DEPENDING ON A GREATER COLLECTION OF DATA.

FIG. 1

NUMBER 3 HANGER BEARING UH-1H

TAIL #16264

TEST CONDUCTED 13 NOV 1973 AT BI STATE AIRPORT



BEARING SERIAL #A20-67523 REMOVED FOR PHYSICAL ANALYSIS.

FIG. 2

HANGER BEARING #A20-67523

404 hour since overhaul: 806 since new. "General condition good."

Corrosion evident in outer race adjacent to most balls, scratches across race adjacent to corrosive area.

SKF analysis showed shock level of 600 with shock rate of 340. Bearing damage appears to be caused by normal wear and use exposed to the general environment. Damage could not be considered excessive. Considering the teardown analysis of the bearing correlated with the MEPA-10A depiction, we would consider the depiction in rate and level would be approaching an unacceptable condition.

FIG. 2A

NUMBER 4 HANGER BEARING

UH-1H TAIL #16264

TEST CONDUCTED 13 NOV 1973 AT BI-STATE AIRPORT

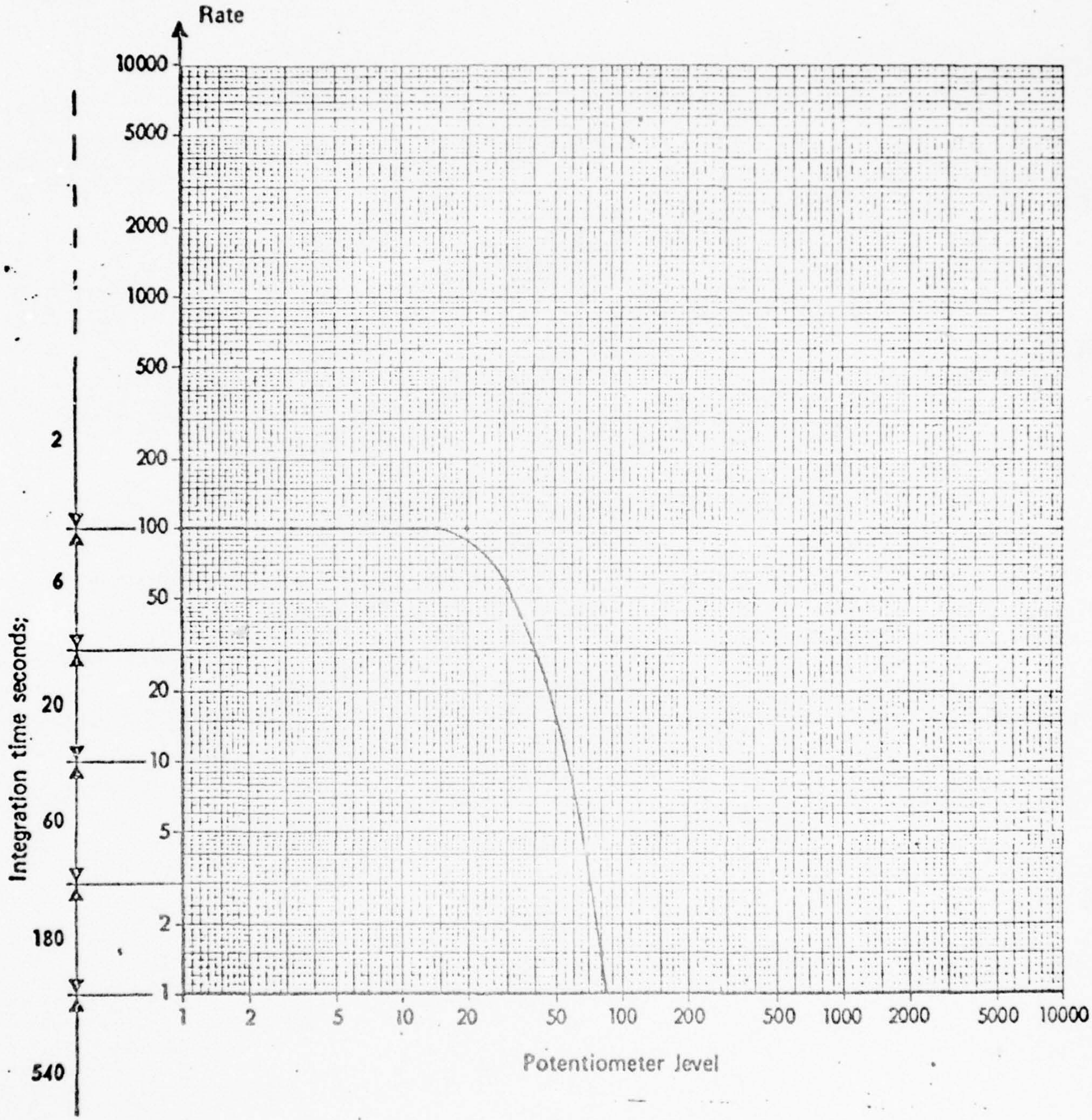


FIG. 3

NUMBER 3 HANGER BEARING

UH-1D TAIL #59771

TEST CONDUCTED 14 NOV 1973 AT BI-STATE AIRPORT

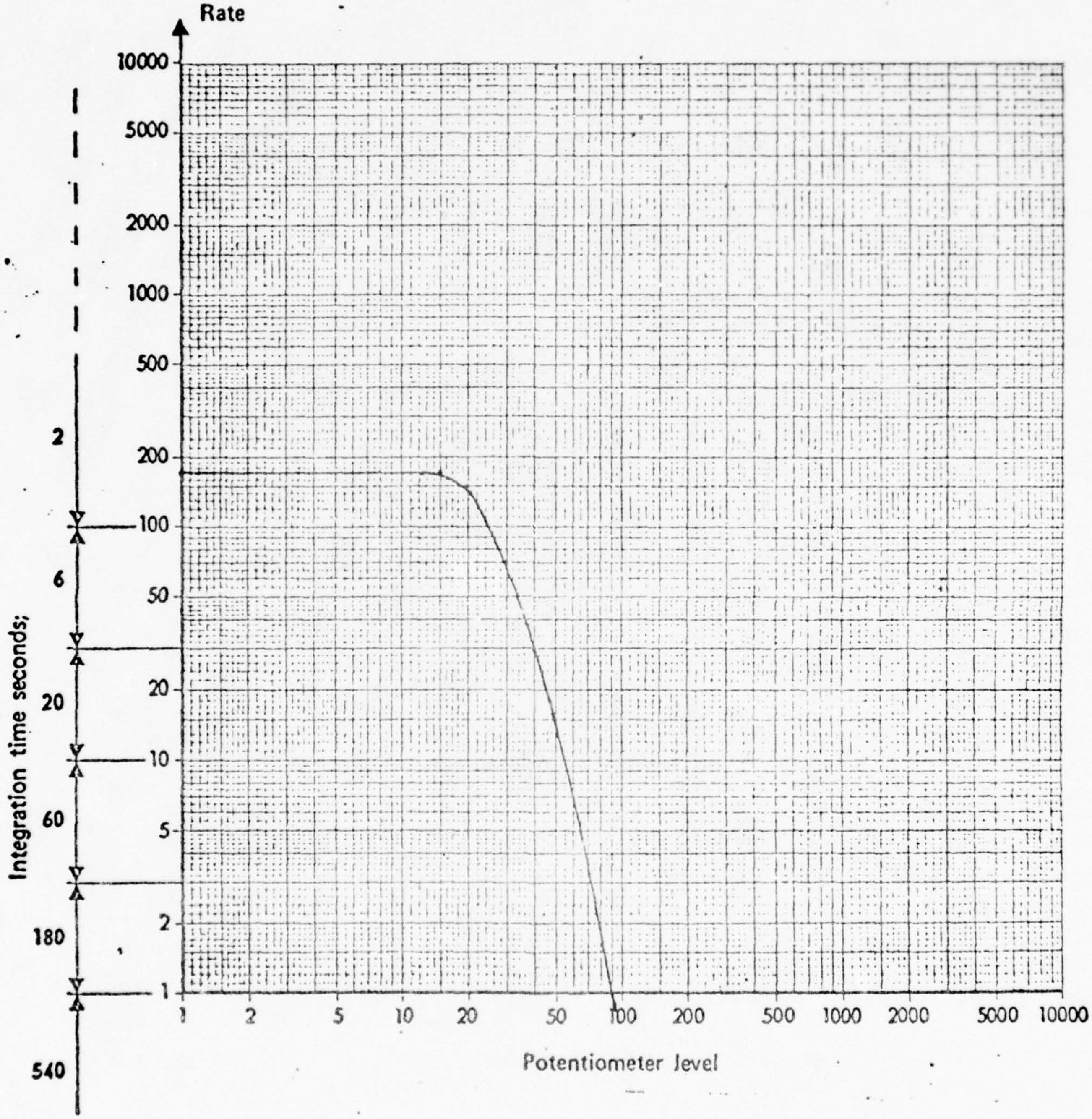


FIG. 4

NUMBER 4 HANGER BEARING

UH-1D TAIL #59771

TEST CONDUCTED 14 NOV 1973 AT BI-STATE AIRPORT

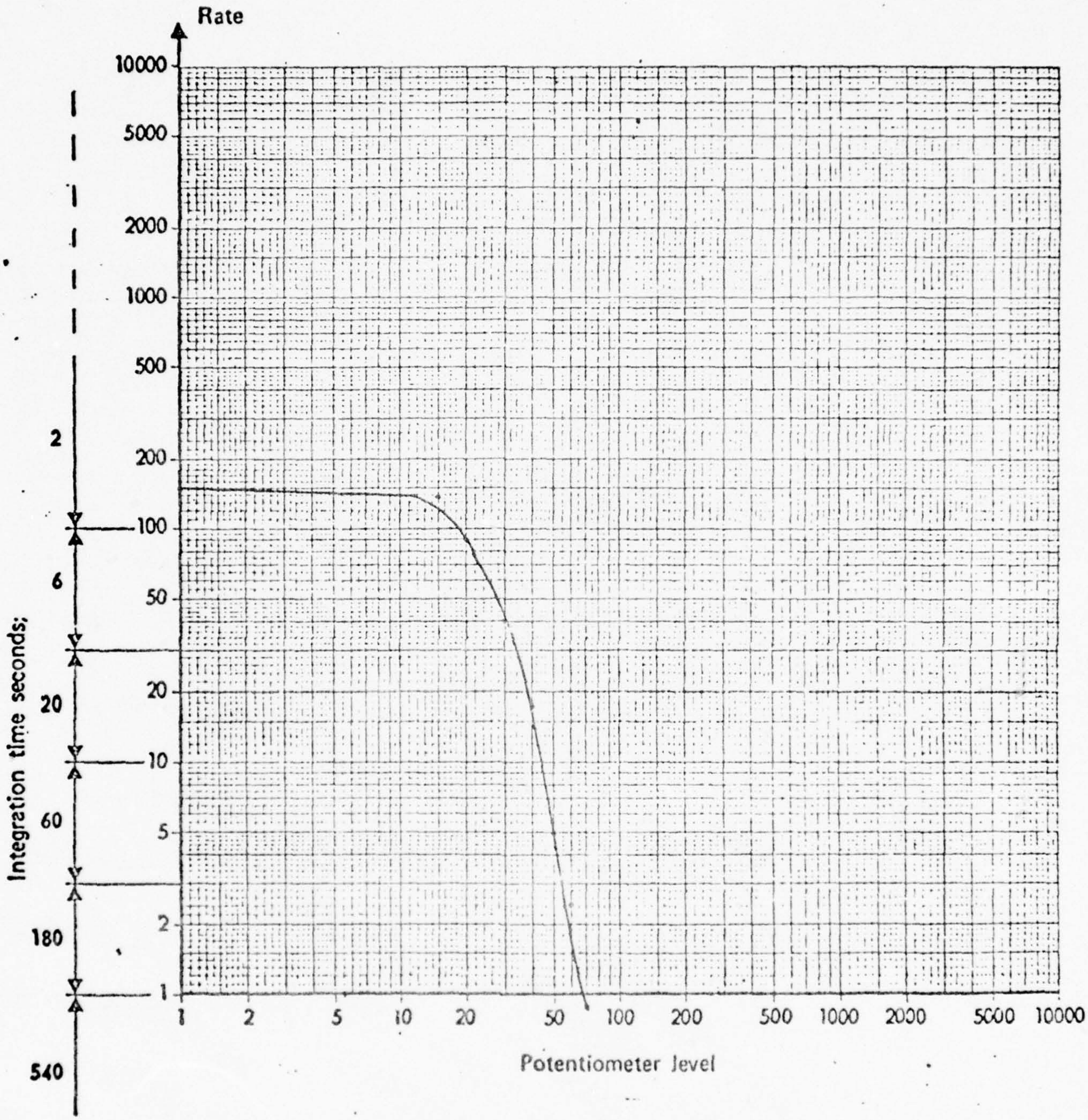


FIG. 5

NUMBER 3 HANGER BEARING

UH-1H TAIL #13740

TEST CONDUCTED 14 NOV 1973 AT BI-STATE AIRPORT

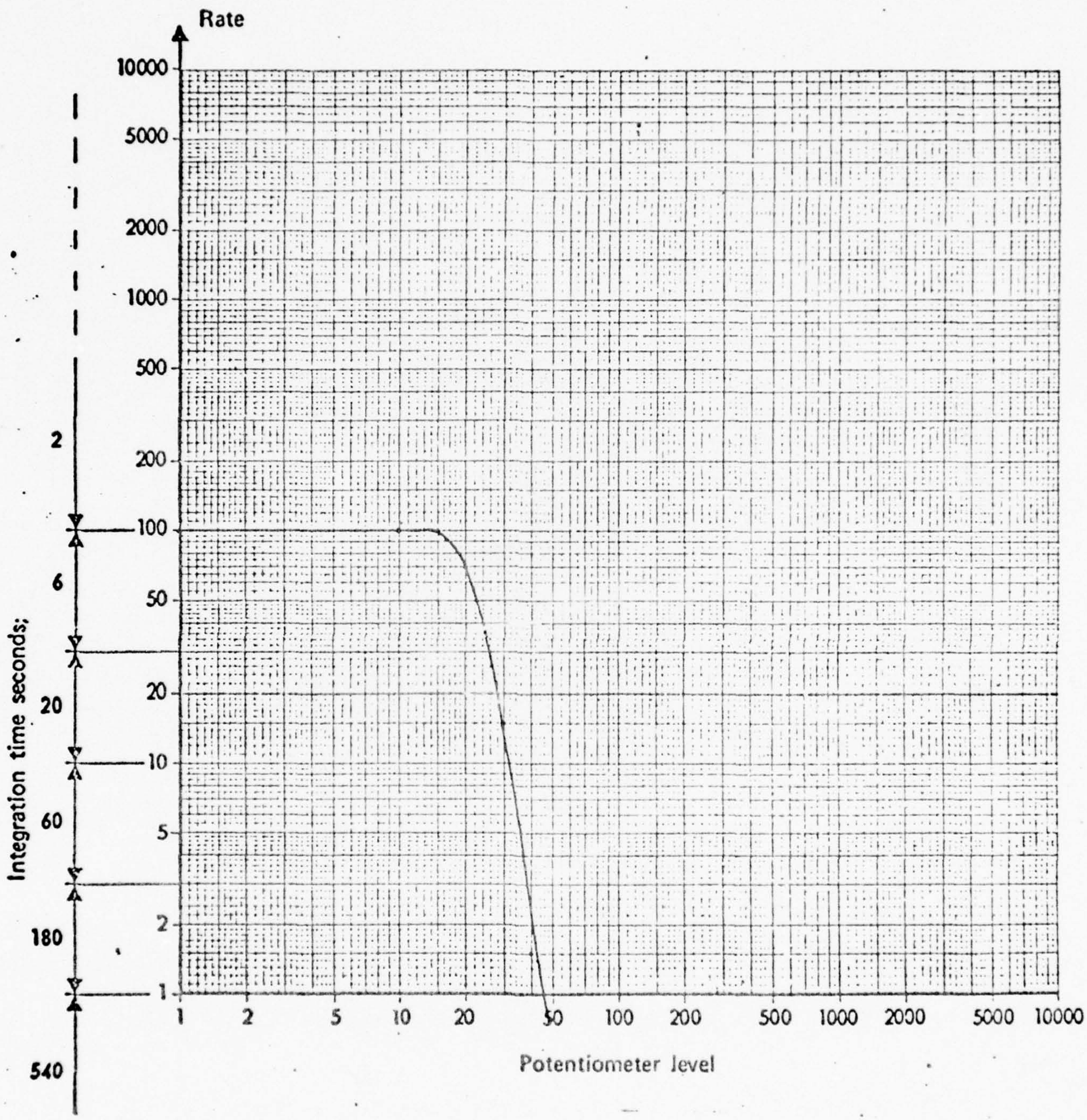


FIG. 6

NUMBER 4 HANGER BEARING

UH-1H TAIL #13740

TEST CONDUCTED 14 NOV 1973 AT BI-STATE AIRPORT

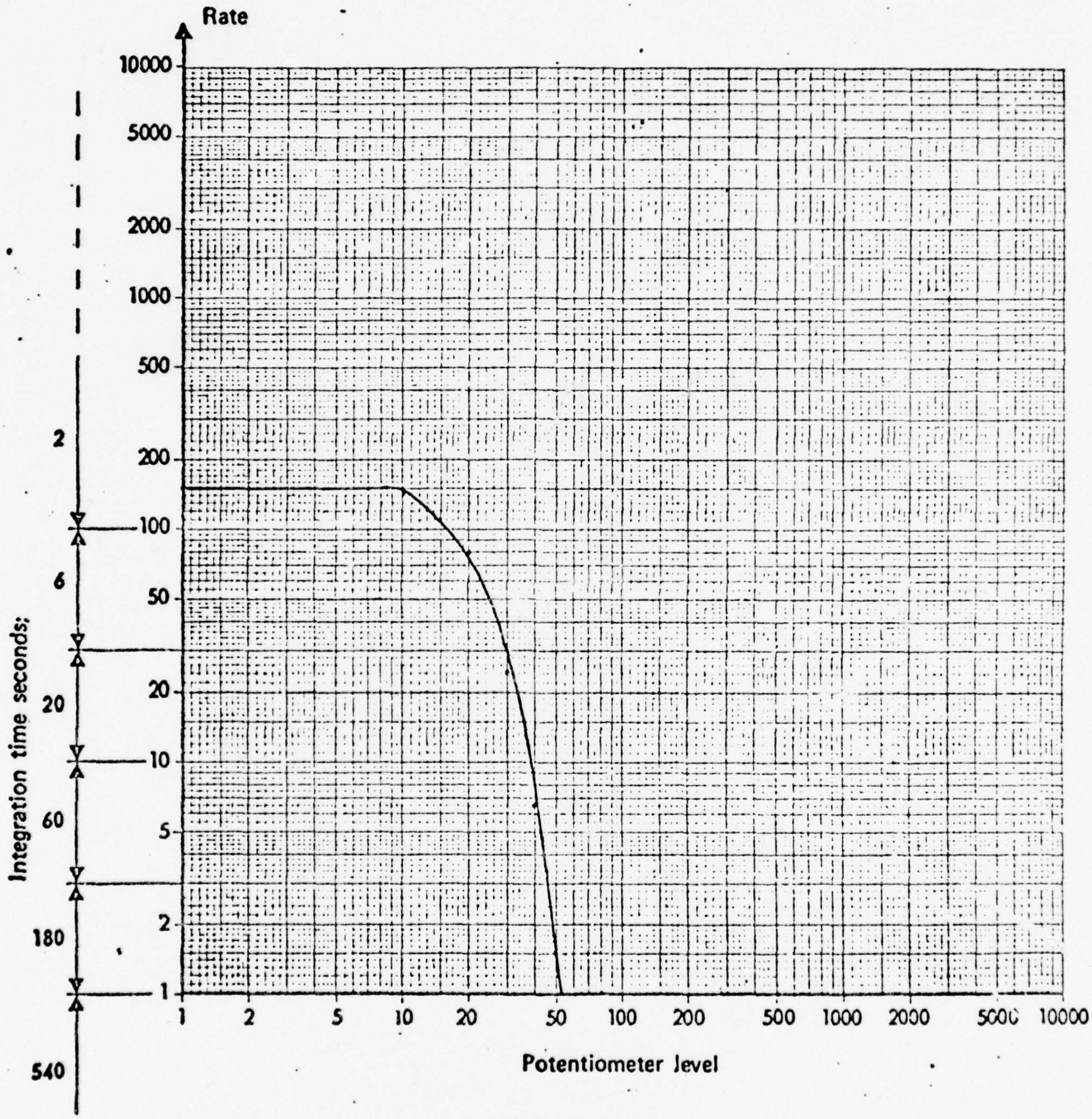
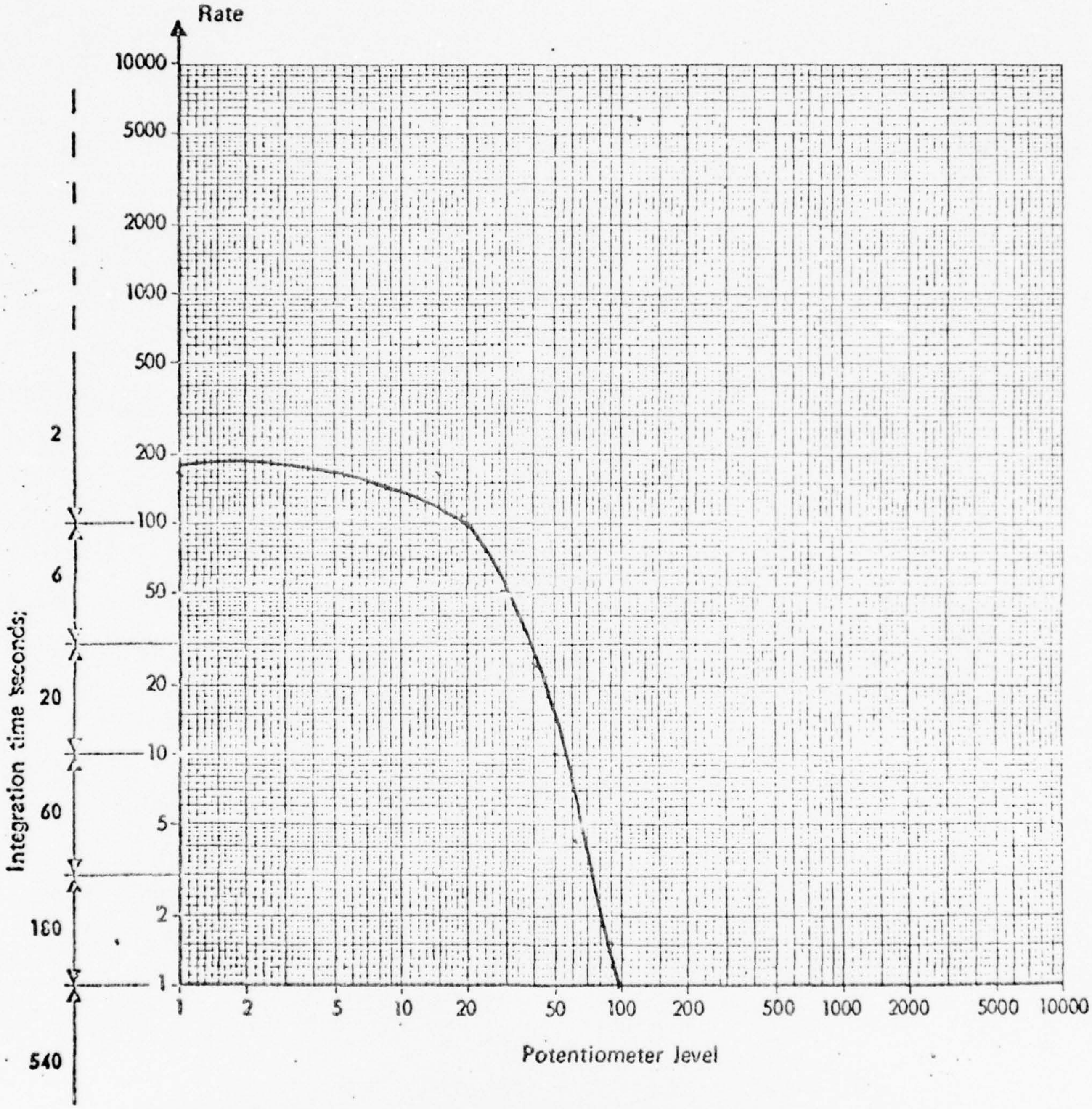


FIG. 7

NUMBER 3 HANGER BEARING UH-1H

TAIL #16264

TEST CONDUCTED 19 NOV 1973 AT BI STATE AIRPORT



REPEAT OF #3 HANGER BEARING POSITION AFTER INSTALLATION OF NEW BEARING.

FIG. 8

NUMBER 3 HANGER BEARING

UH-1H TAIL #16197

TEST CONDUCTED 27 NOV 1973 AT SCOTT AFB

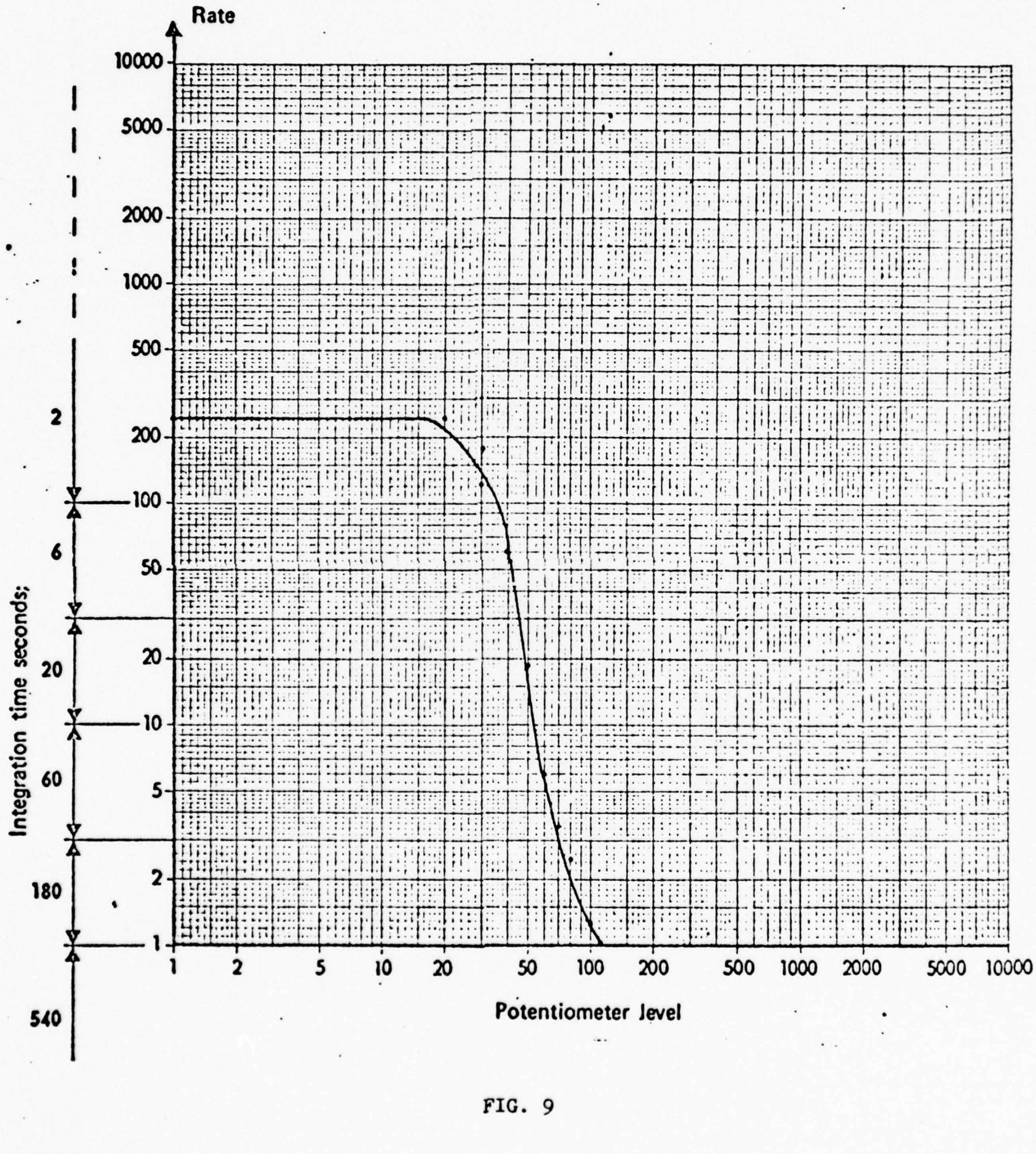


FIG. 9

NUMBER 4 HANGER BEARING

UH-1H TAIL #16197

TEST CONDUCTED 27 NOV 1973 AT SCOTT AFB

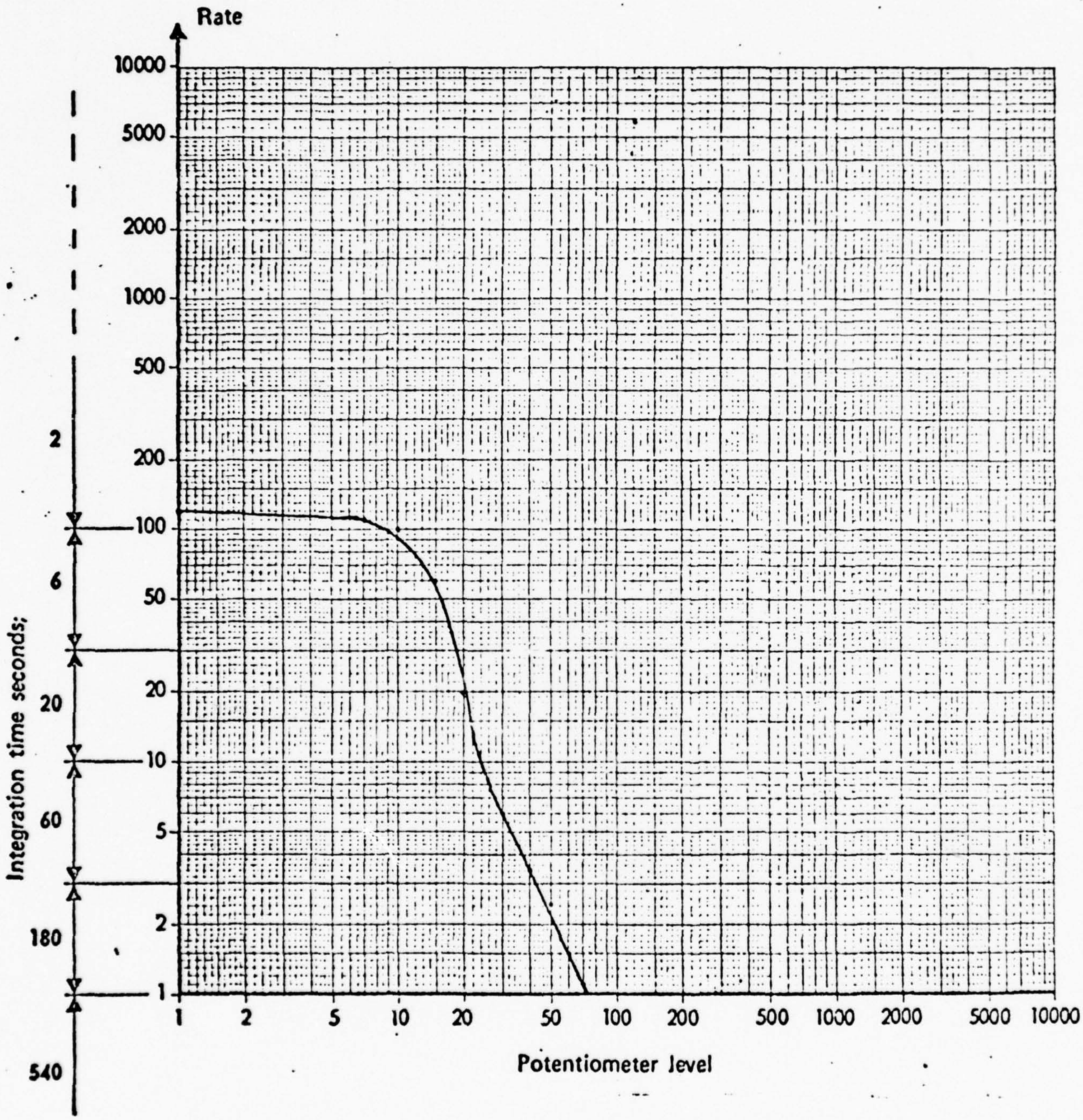


FIG. 10

NUMBER 3 HANGER BEARING UH-1H

TAIL #13740

TEST CONDUCTED 27 NOV 1973 AT SCOTT AFB

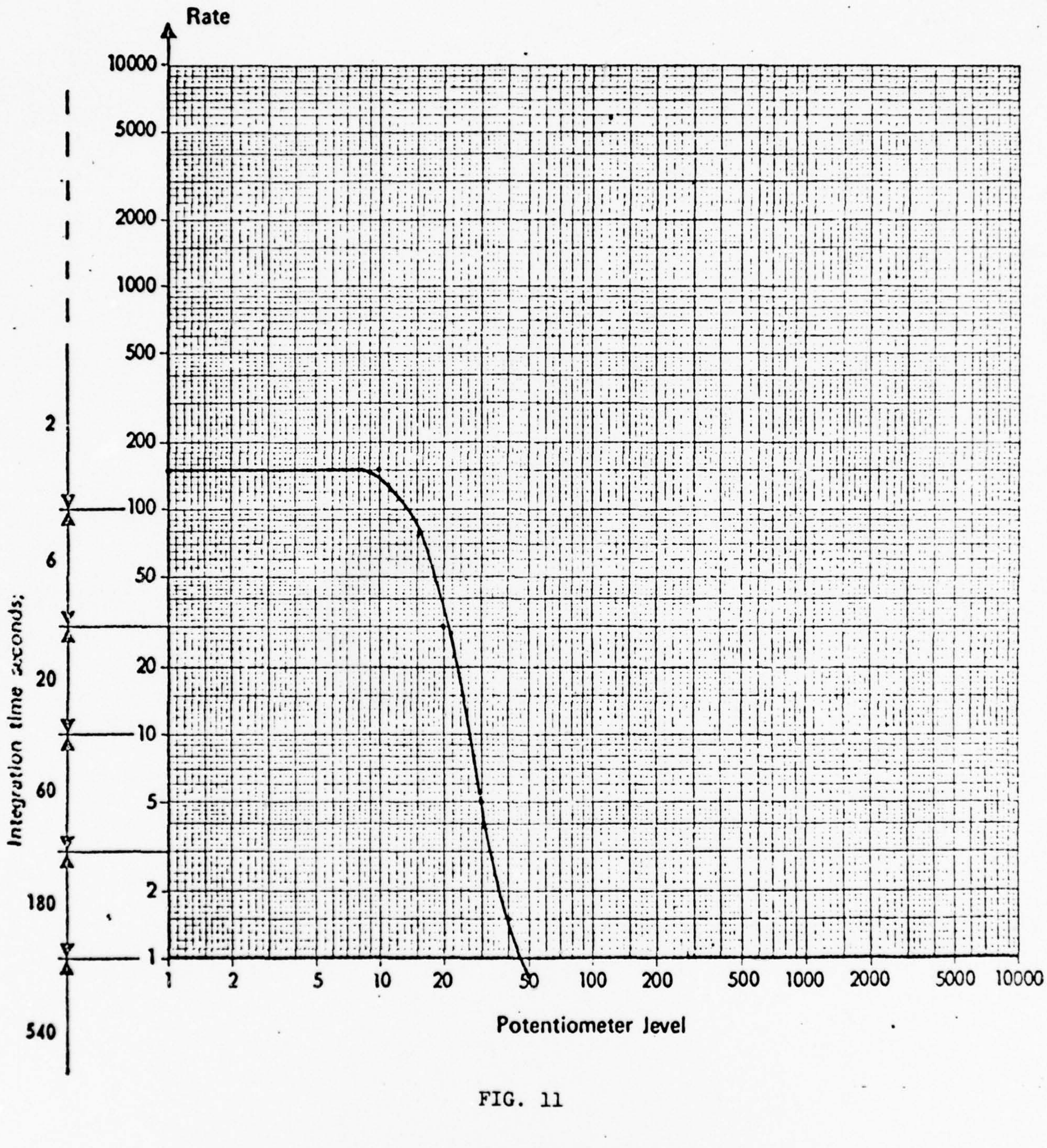


FIG. 11

NUMBER 4 HANGER BEARING UH-1H

TAIL #13740

TEST CONDUCTED 27 NOV 1973 AT SCOTT AFB

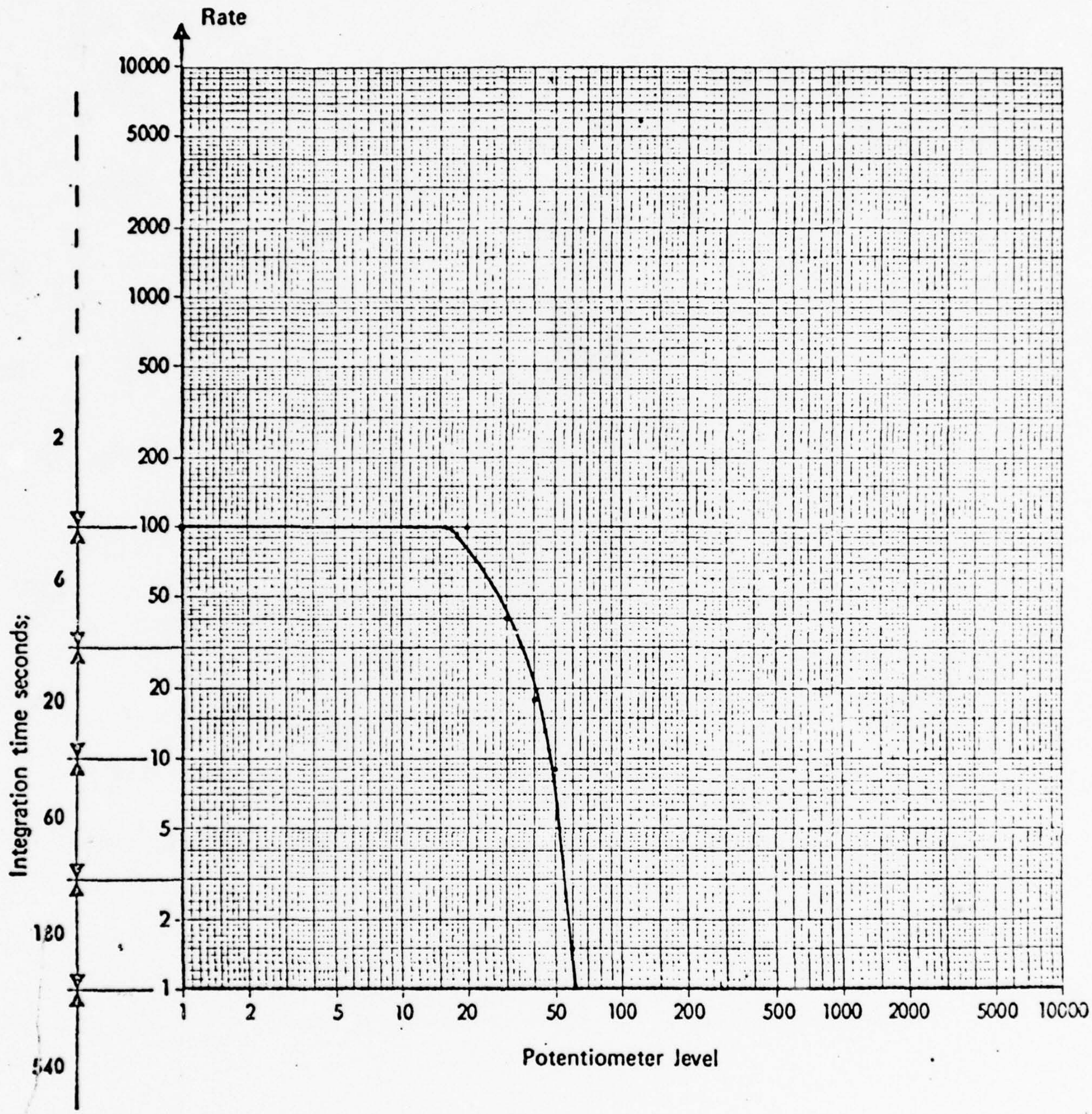


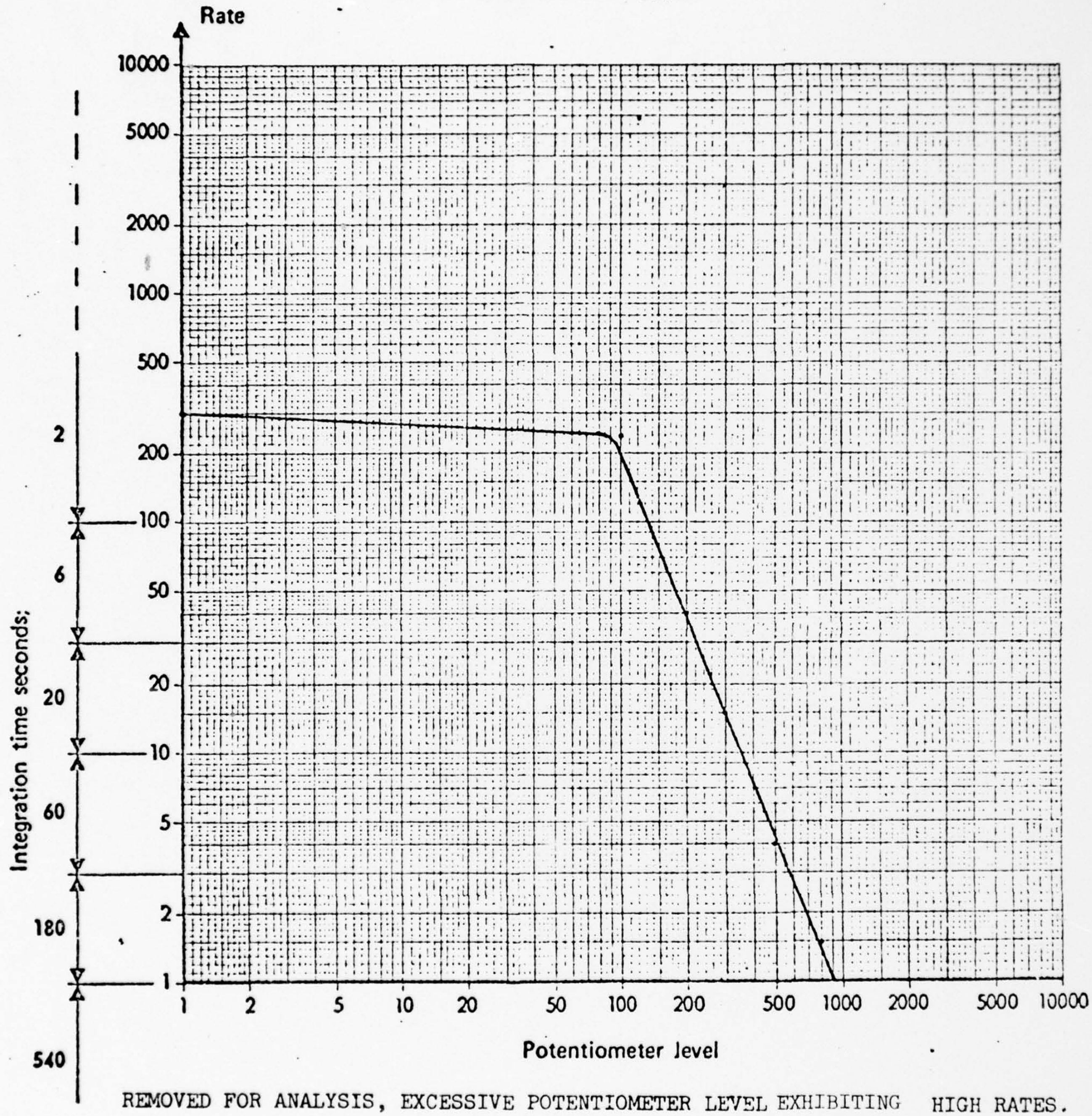
FIG. 12

NUMBER 3 HANGER BEARING UH-1H

TAIL #66-01087

TEST CONDUCTED 28 NOV 1973 AT SCOTT AFB

BEARING SERIAL #A20-43391



REMOVED FOR ANALYSIS, EXCESSIVE POTENTIOMETER LEVEL EXHIBITING HIGH RATES.

FIG. 13

HANGER BEARING #A20-43391

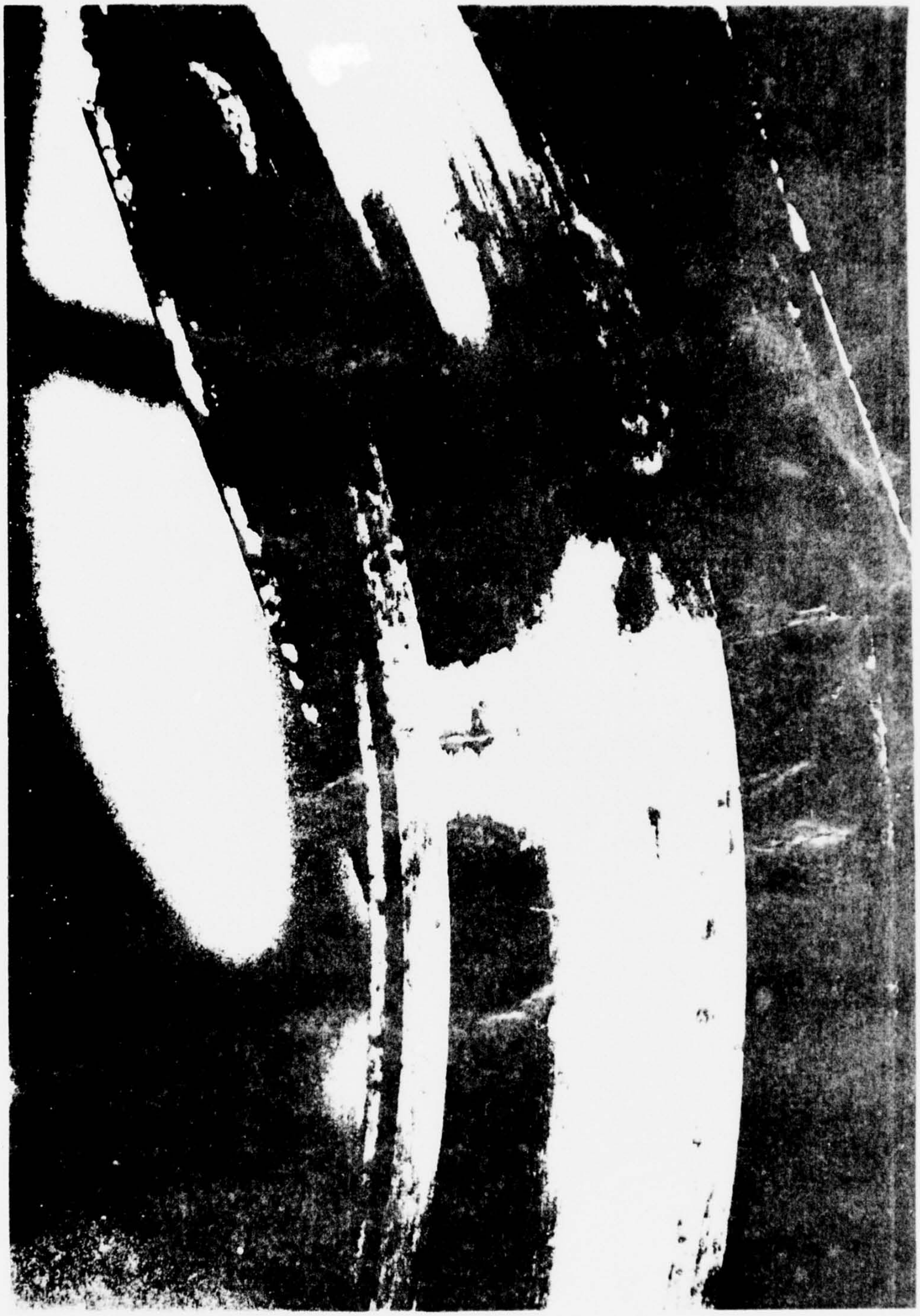
788 hours since new with 488 hours use in last installation.

The outer race of this bearing showed evidence of corrosion and pitting.

No damage was apparent in the inner race, however, one ball had corrosion.

The MEPA-10A shock analysis of this bearing showed high levels of damage. The level reached of 900 is in the higher 20% of the readings taken of all hanger bearings tested. Rate level of 300 is not excessive considering the bearings tested. Reviewing the MEPA-10A depiction, this bearing would fit in a classification showing damage requiring action.

FIG. 13A



A20-43391 - Corrosion on Outer Race.

FIG. 13B

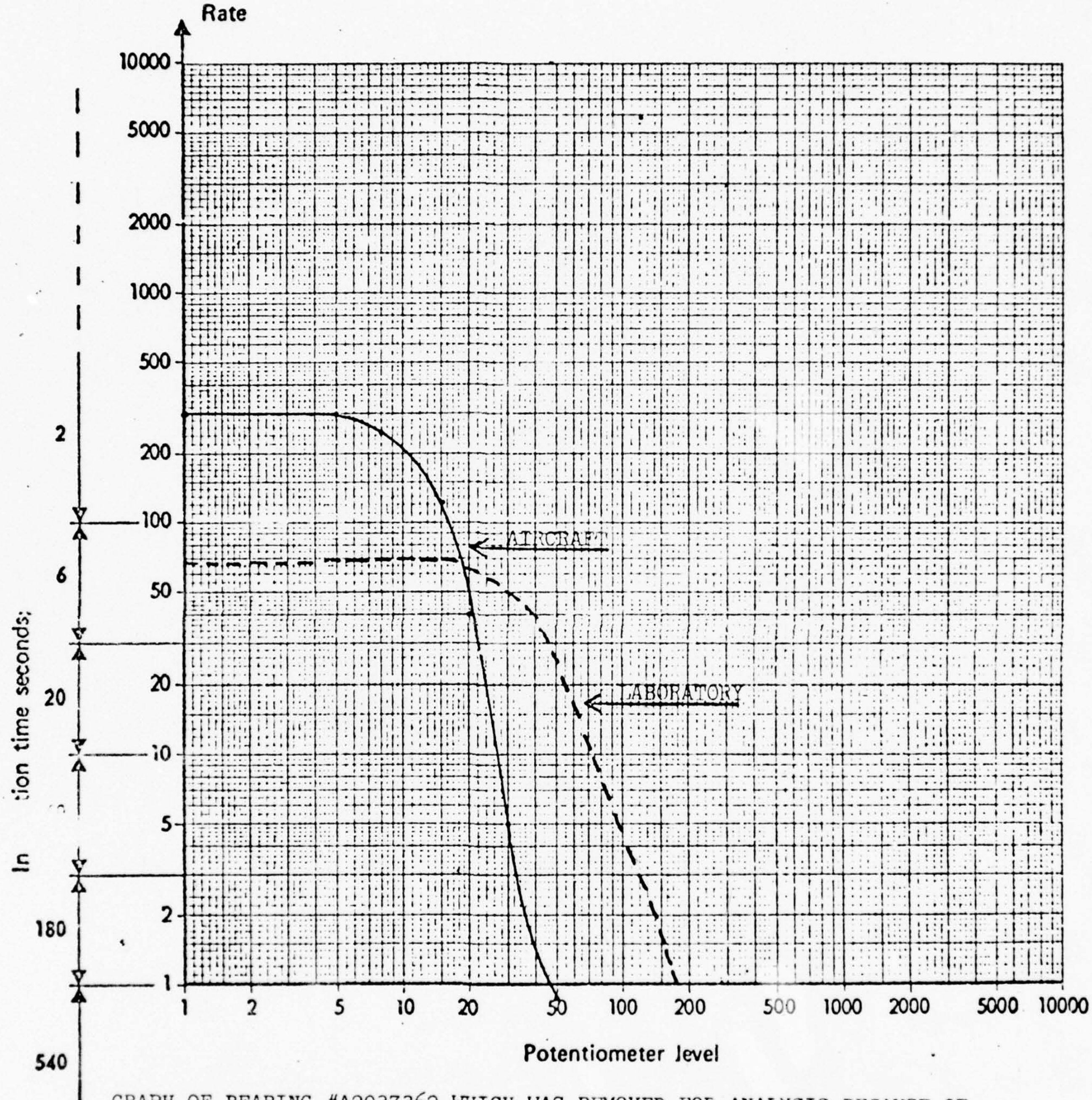
A20-43391 - Corrosion on Ball:

FIG. 13C

4 HANGER BEARINGS

UH-1H TAIL #66-01087

TEST CONDUCTED 28 NOV 1973



GRAPH OF BEARING #A2037362 WHICH WAS REMOVED FOR ANALYSIS BECAUSE OF EXCESSIVE PLAY DISCOVERED BY AN AIRCRAFT TECHNICAL INSPECTOR - ONE GRAPH MADE ON AIRCRAFT, THE OTHER IN LABORATORY AT APPROXIMATELY THE SAME RPM. (14 DEC 1973).

FIG. 14

HANGER BEARING #A20-37362

2549 hours usage since new with 501 hours since overhaul and in last installation.

Very light pitting was evident in both the inner and outer race. No defects were found in the balls according to the Bell Helicopter report and no pictures were taken of the bearing.

This bearing did not show any excessive readings in either rate or potentiometer level according to the MEPA-10A system.

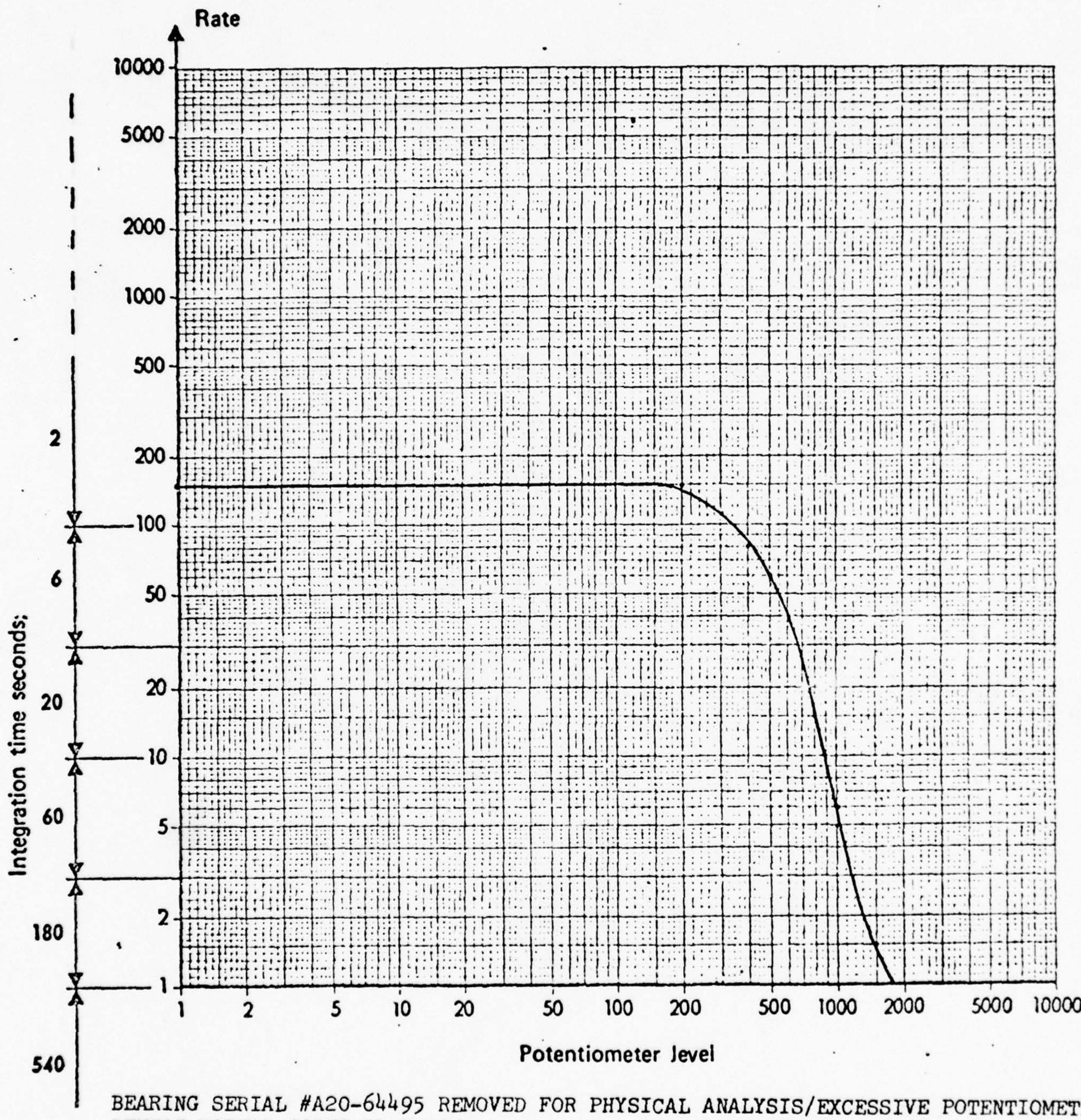
The reason this bearing was removed was because it exceeded the movement tolerance allowed by normal maintenance procedures according to a maintenance technical inspector. Two shock tests were performed on this bearing; one in the aircraft prior to its removal and the other on a bench test configuration. In either test, the rate or potentiometer level did not exceed normal levels.

FIG. 14A

NUMBER 3 HANGER BEARING UH-1H

TAIL #15949

TEST CONDUCTED 28 NOV 1973 AT SCOTT AFB



BEARING SERIAL #A20-64495 REMOVED FOR PHYSICAL ANALYSIS/EXCESSIVE POTENTIOMETER LEVELS NORMAL RATES OF SHOCK.

FIG. 15

HANGER BEARING #A20-64495

427 hours usage since new.

Both the outer and inner race of the bearing showed evidence of corrosion and pitting. Corrosion was also apparent on several of the balls of this bearing.

The MEPA-10A analysis revealed an excessive potentiometer level of approximately 1800. We would consider a level this high cause for replacement.

The pictoral evidence of damage on the outer race and balls appears to definitely warrant a replacement of this assembly.

FIG. 15A

A20-64495 - Corrosion
Damage on Ball Bearing.

FIG. 15B

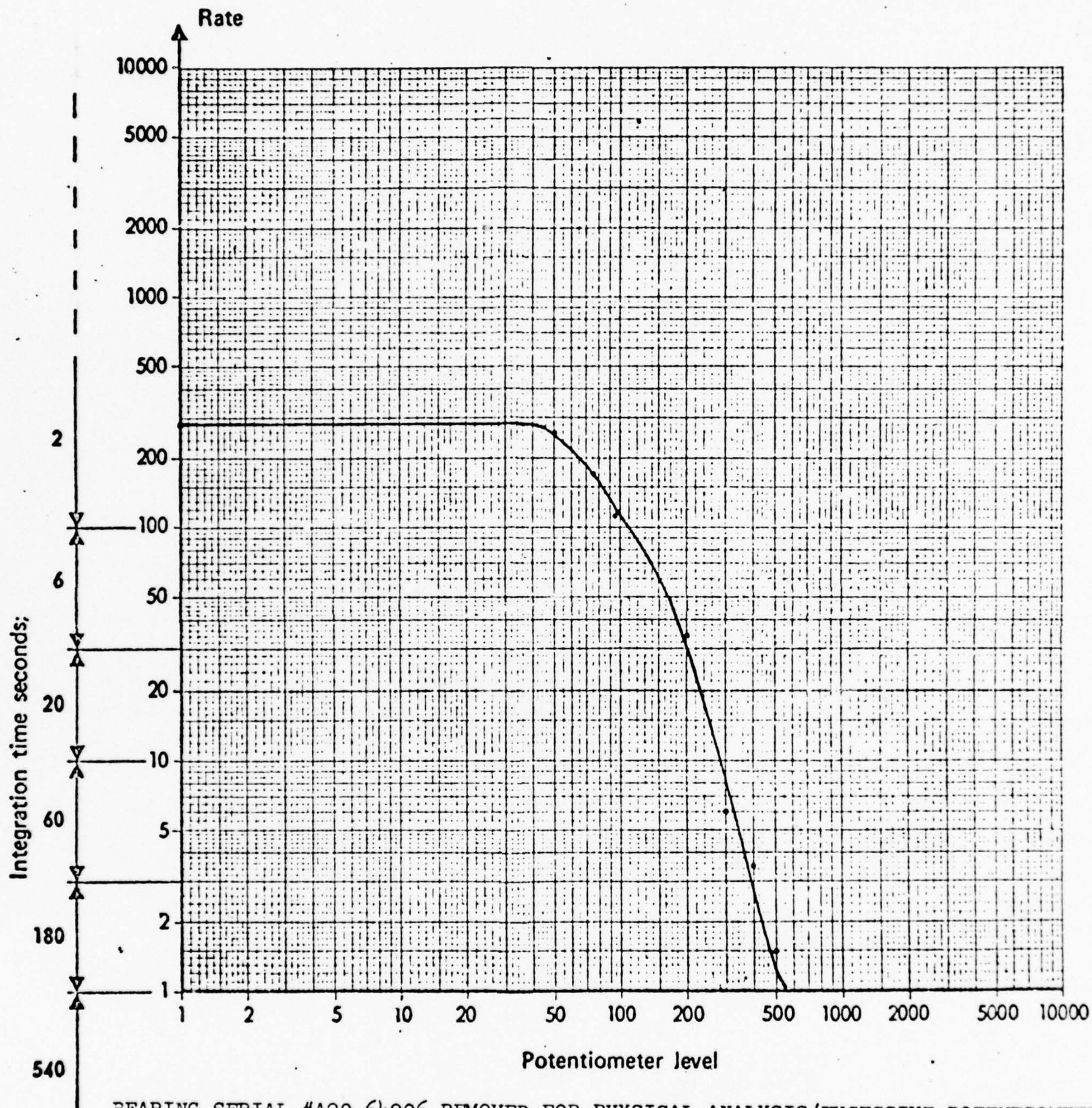
A20-6495 - Corrosion and Pitting on Outer Race.

FIG. 15C

NUMBER 4 HANGER BEARING UH-1H

TAIL # 15949

TEST CONDUCTED 28 NOV 1973 AT SCOTT AFB



BEARING SERIAL #A20-64906 REMOVED FOR PHYSICAL ANALYSIS/EXCESSIVE POTENTIOMETER LEVELS.

FIG. 16

HANGER BEARING #A20-64906

601 hours of usage with 427 hours usage in the last installation.

Pitting was evident in the outer race of this bearing as well as corrosion and pitting on one ball of the rolling element. No defects were found in the inner race of the bearing.

The MEPA-10A shock depiction had a level of 550 and rate of 290. This rate and level while higher than the mean level measured, would not be considered excessive but would be considered approaching an unacceptable condition.

FIG. 16A

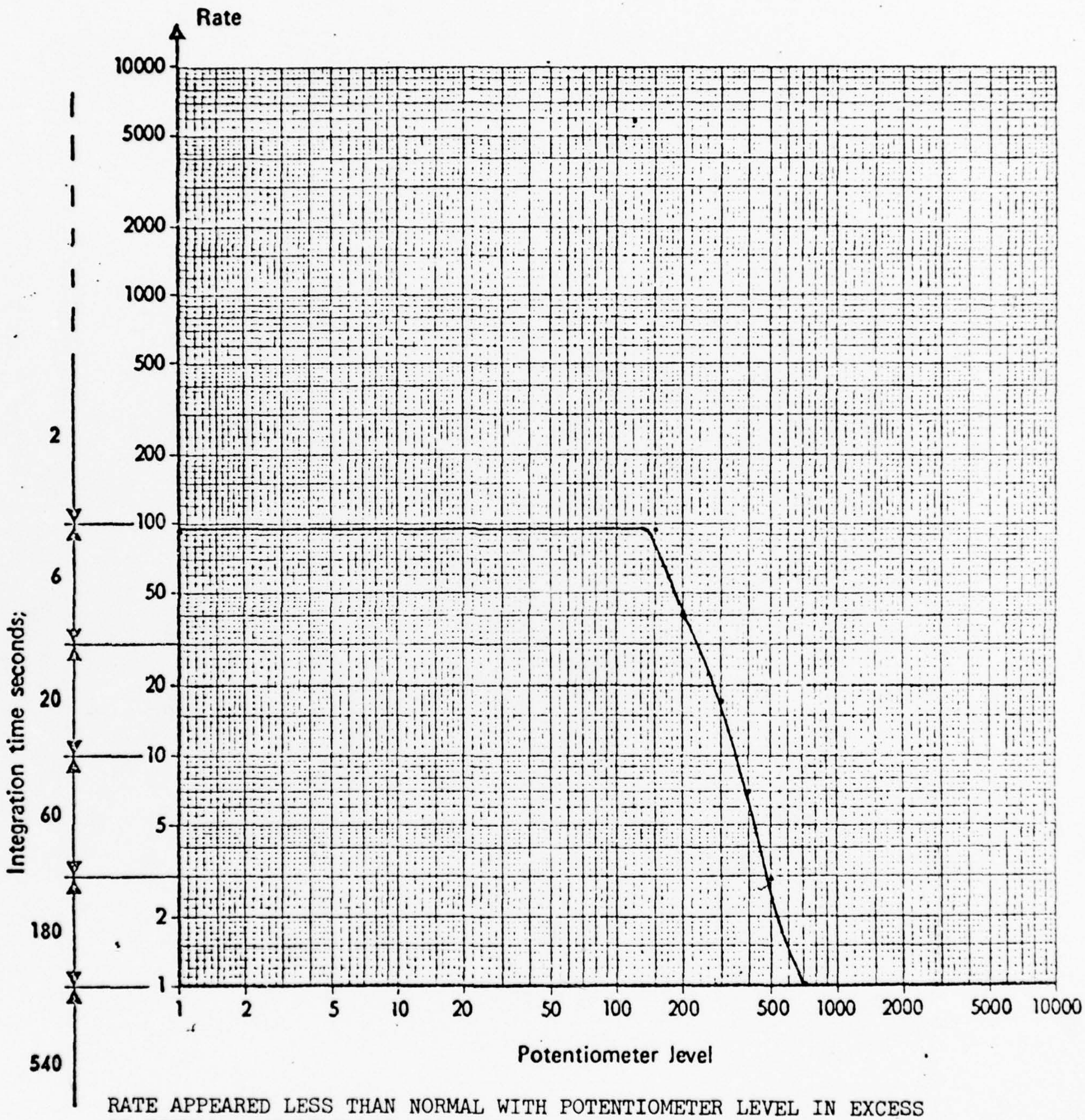
A20-64906 - Corrosion on Outer Race.

FIG. 16B

NUMBER 1 HANGER BEARING

UH-1M TAIL #59519

TEST CONDUCTED 30 NOV 1973 AT SCOTT AFB



RATE APPEARED LESS THAN NORMAL WITH POTENTIOMETER LEVEL IN EXCESS OF NORMAL. BEARING WAS NOT REMOVED FOR PHYSICAL ANALYSIS.

FIG. 17

NUMBER 2 HANGER BEARING

UH-1M TAIL #59519

TEST CONDUCTED 30 NOV 1973 AT SCOTT AFB

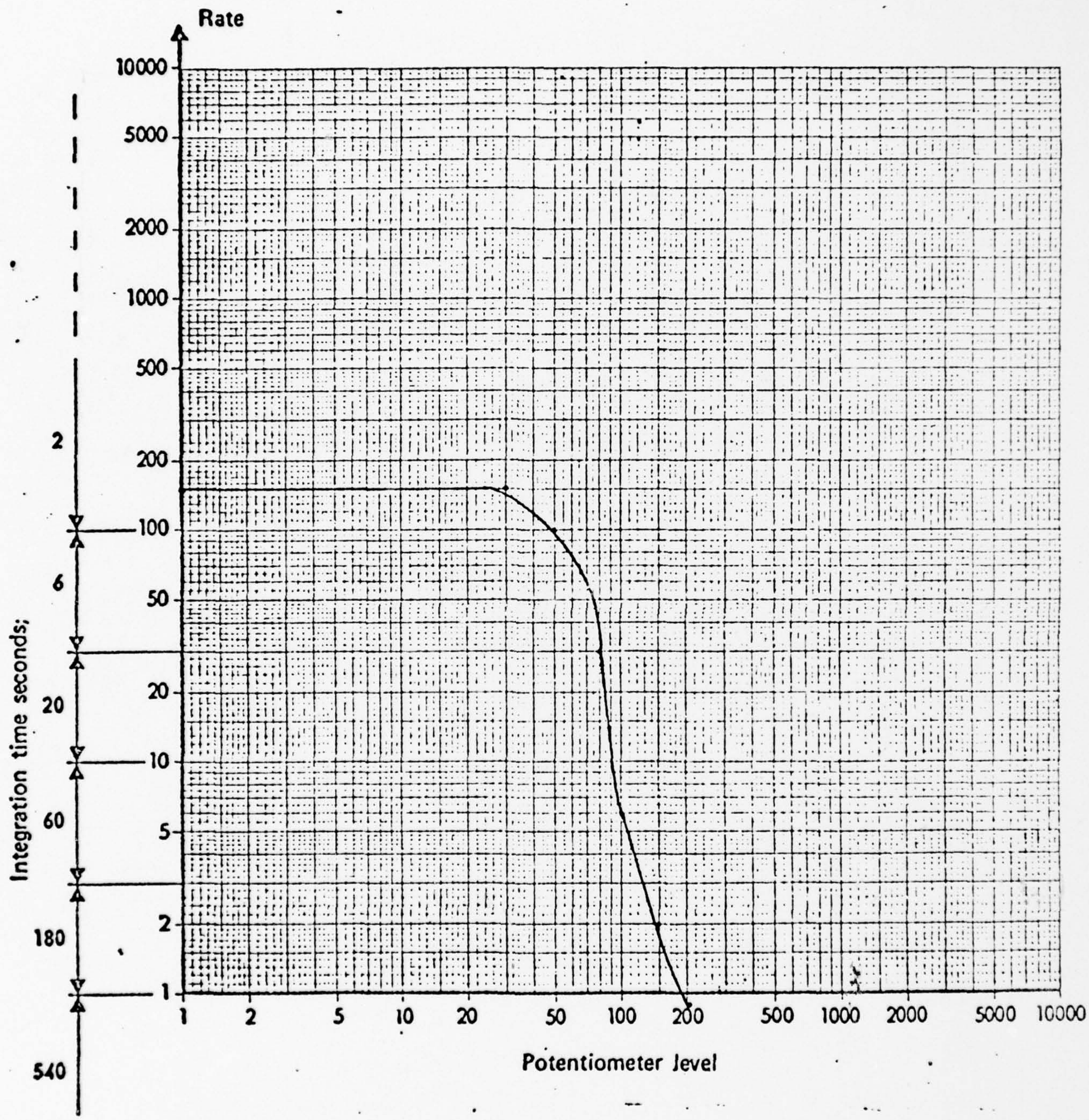


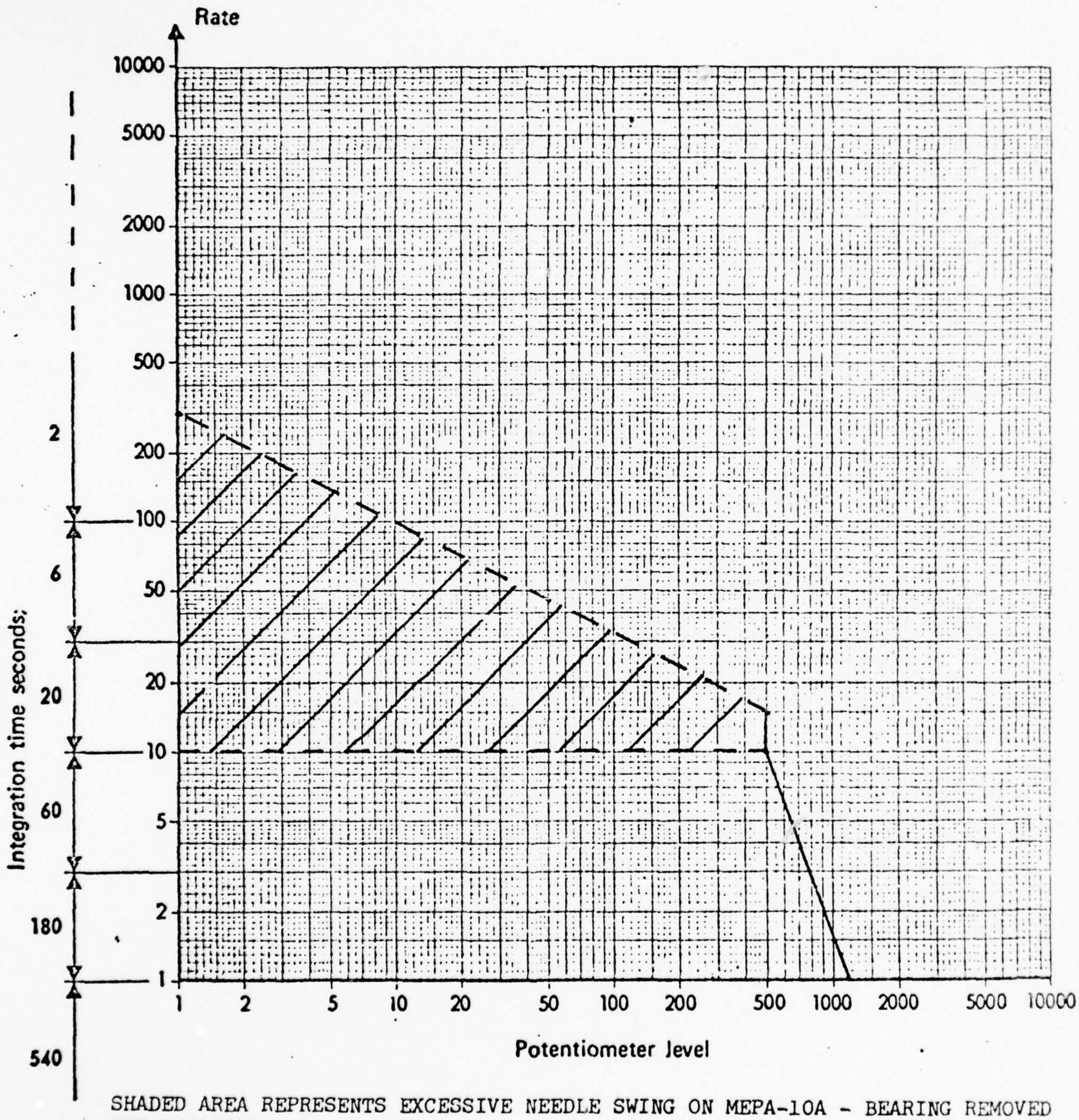
FIG. 18

NUMBER 3 HANGER BEARING

UH-1M TAIL #59519

BEARING SERIAL #A20-11446

TEST CONDUCTED 30 NOV 1973 AT SCOTT AFB



SHADED AREA REPRESENTS EXCESSIVE NEEDLE SWING ON MEPA-10A - BEARING REMOVED FOR ANALYSIS.

FIG. 19

NOTE: SCALPED AREA DENOTES NEEDLE SWING.

HANGER BEARING #A20-11446

144 hours since overhauled.

Teardown analysis yielded a bearing condition described as "general condition good, bearing feels smooth."

Some corrosion is evident in two places in the outer race. The teardown data indicates a bearing in normal condition.

The MEPA-10A analysis shows an excessive needle swing in rate depiction ranging from a rate of 10 to 300. The potentiometer level of 1200 would be considered high and excessive when compared to the other bearings evaluated. It was for this reason the assembly was removed for analysis. The cause of excessive needle swing in measurement of shock rate is not known. The plot of this bearing was not made up of defined points which the curve developed through, and thus differs from other bearings which exhibited some needle movement. Teardown information would lead to the conclusion that the bearings was in a serviceable condition.

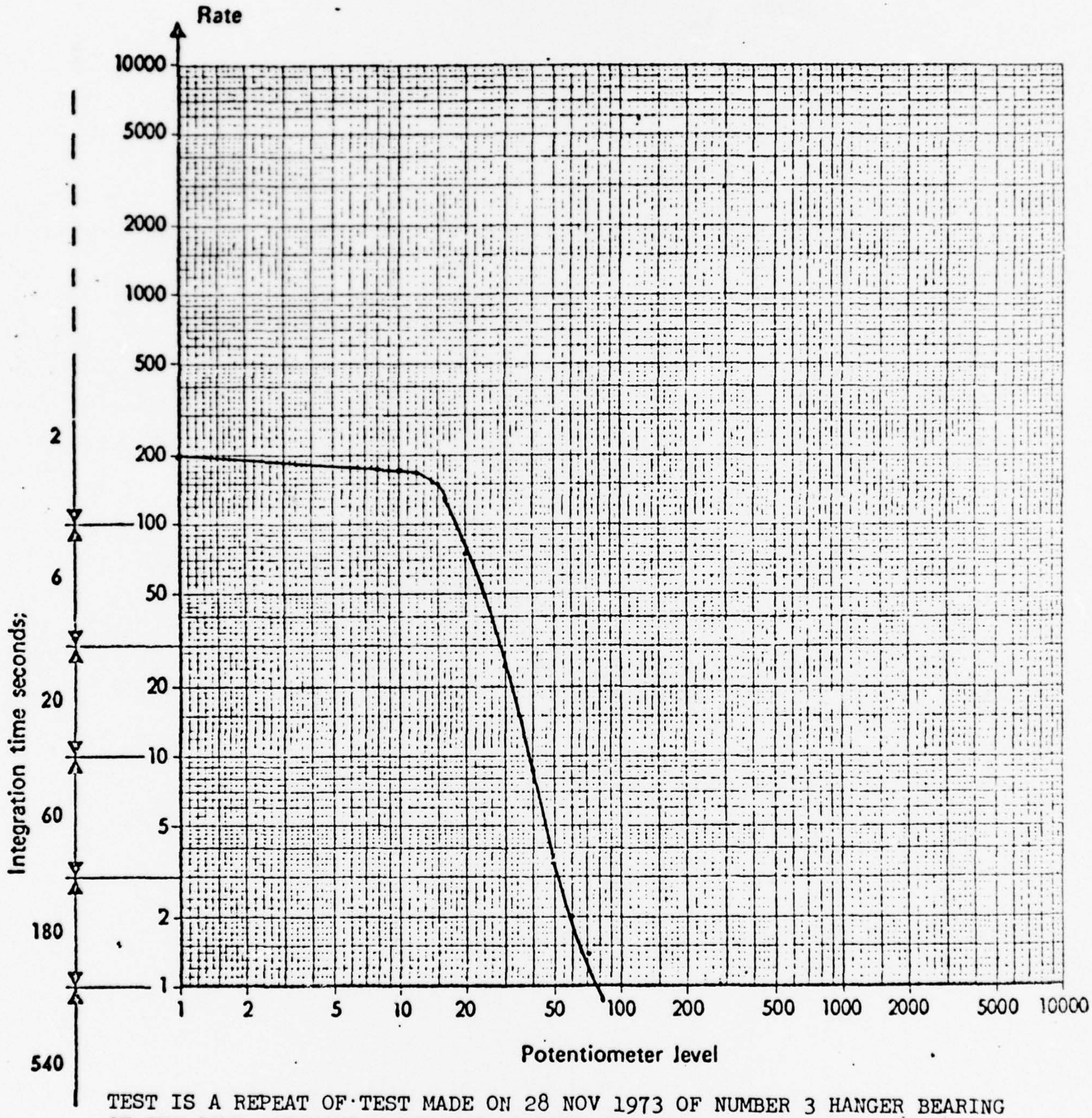
The ability of the MEPA-10A to plot a curve of shock emission which did not have the erratic nature seen in this curve is desirable, in order to confirm the bearing condition. Possible reasons for the excessive needle swing includes an ambient air temperature below 30°F and the possibility of a less than sufficient power source.

FIG. 19A

NUMBER 3 HANGER BEARING (NEW BEARING)

UH-1H TAIL #66-1087

TEST CONDUCTED 30 NOV 1973 AT SCOTT AFB



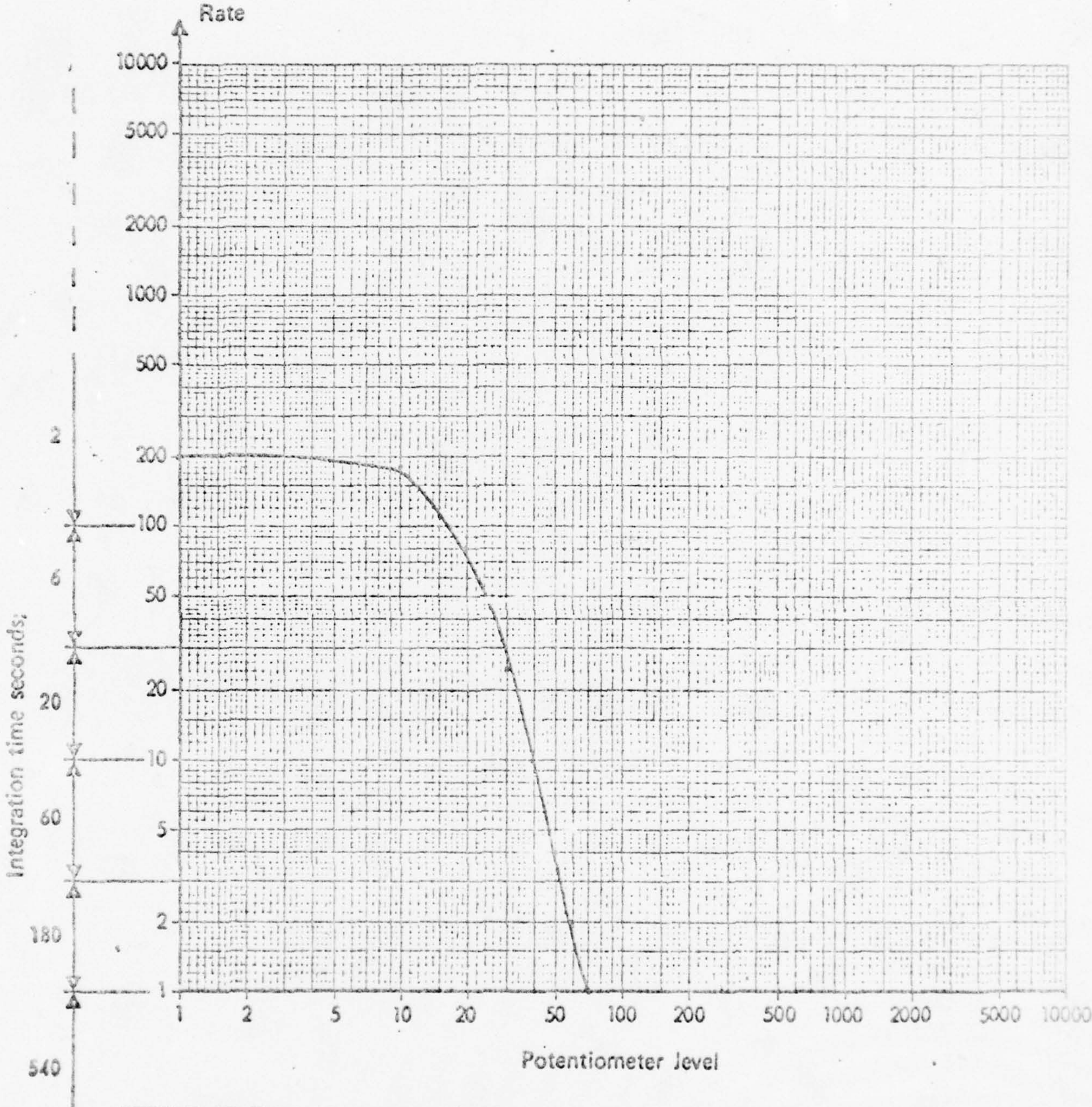
TEST IS A REPEAT OF TEST MADE ON 28 NOV 1973 OF NUMBER 3 HANGER BEARING OF THE SAME AIRCRAFT WHICH WAS REMOVED FOR TEAR DOWN ANALYSIS.

FIG. 20

NUMBER 3 HANGER BEARING UH-1H (NEW BEARING)

TAIL #15949

TEST CONDUCTED 30 NOV 1973 AT SCOTT AFB



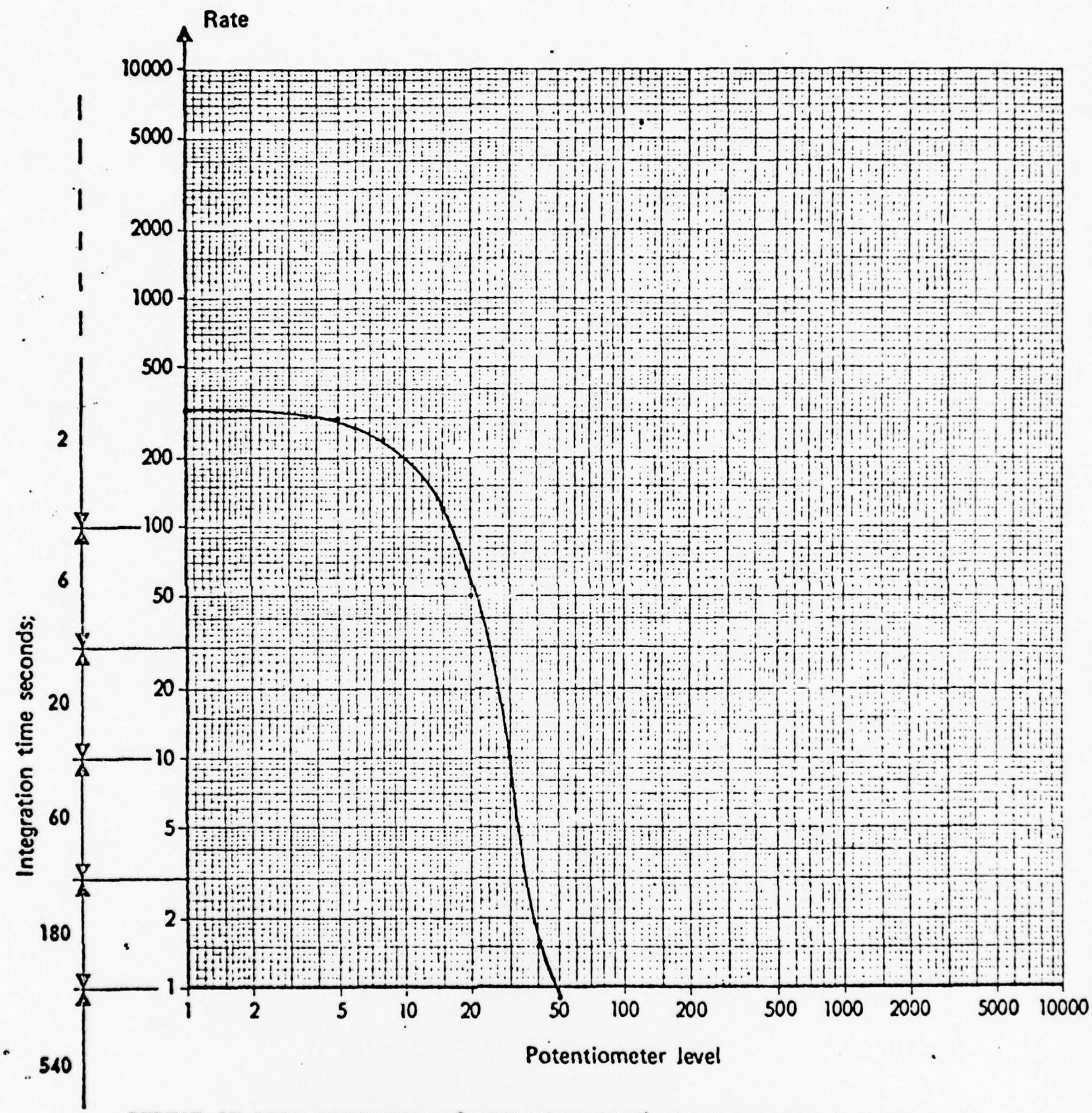
REPEAT OF TEST CONDUCTED 28 NOV 1973 ON #3 HANGER BEARING WHICH WAS REMOVED FOR PHYSICAL ANALYSIS.

FIG. 21

NUMBER 4 HANGER BEARING UH-1H (NEW BEARING)

TAIL #15949

TEST CONDUCTED 30 NOV 1973 AT SCOTT AFB



REPEAT OF TEST CONDUCTED 28 NOV 1973 ON #4 HANGER BEARING WHICH WAS REMOVED FOR PHYSICAL ANALYSIS.

FIG. 22

NUMBER 1 HANGER BEARING

UH-1M TAIL #15200

TEST CONDUCTED 6 DEC 1973 AT SCOTT AFB

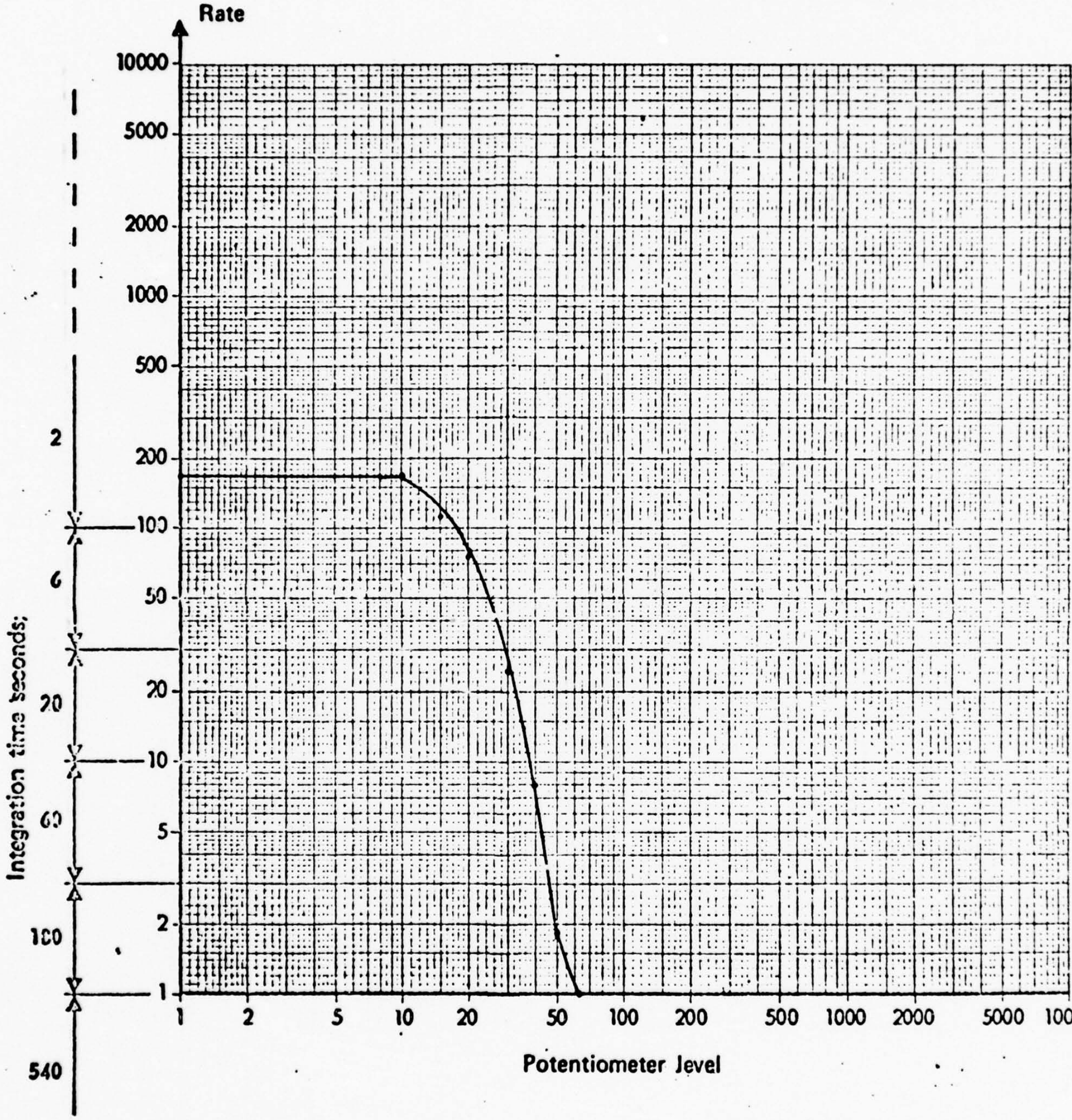


FIG. 23

NUMBER 2 HANGER BEARING

UH-1M TAIL #15200

TEST CONDUCTED 6 DEC 1973 AT SCOTT AFB

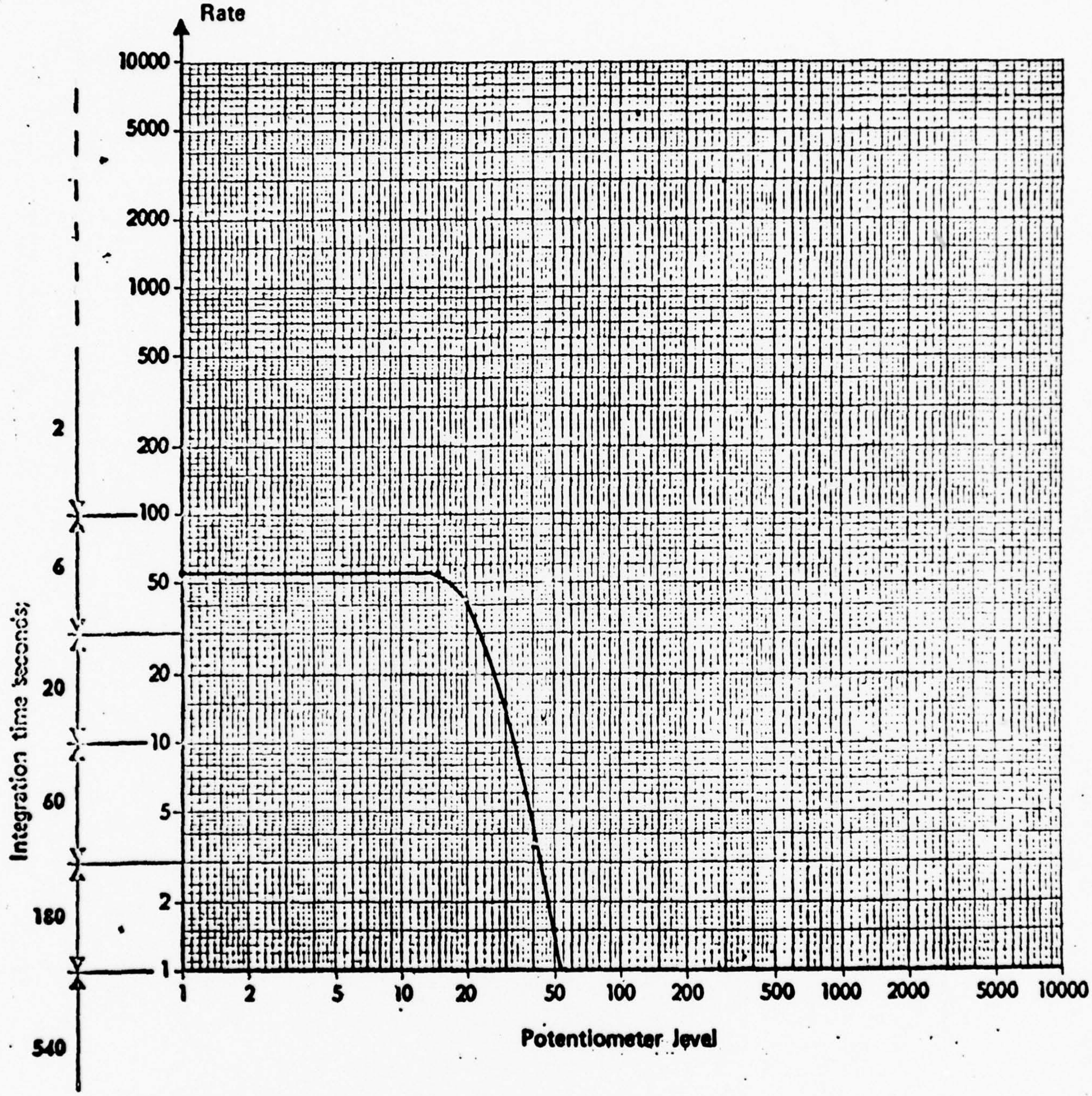


FIG. 24

NUMBER 3 HANGER BEARING

UH-1M TAIL #15200

TEST CONDUCTED 6 DEC 1973 AT SCOTT AFB

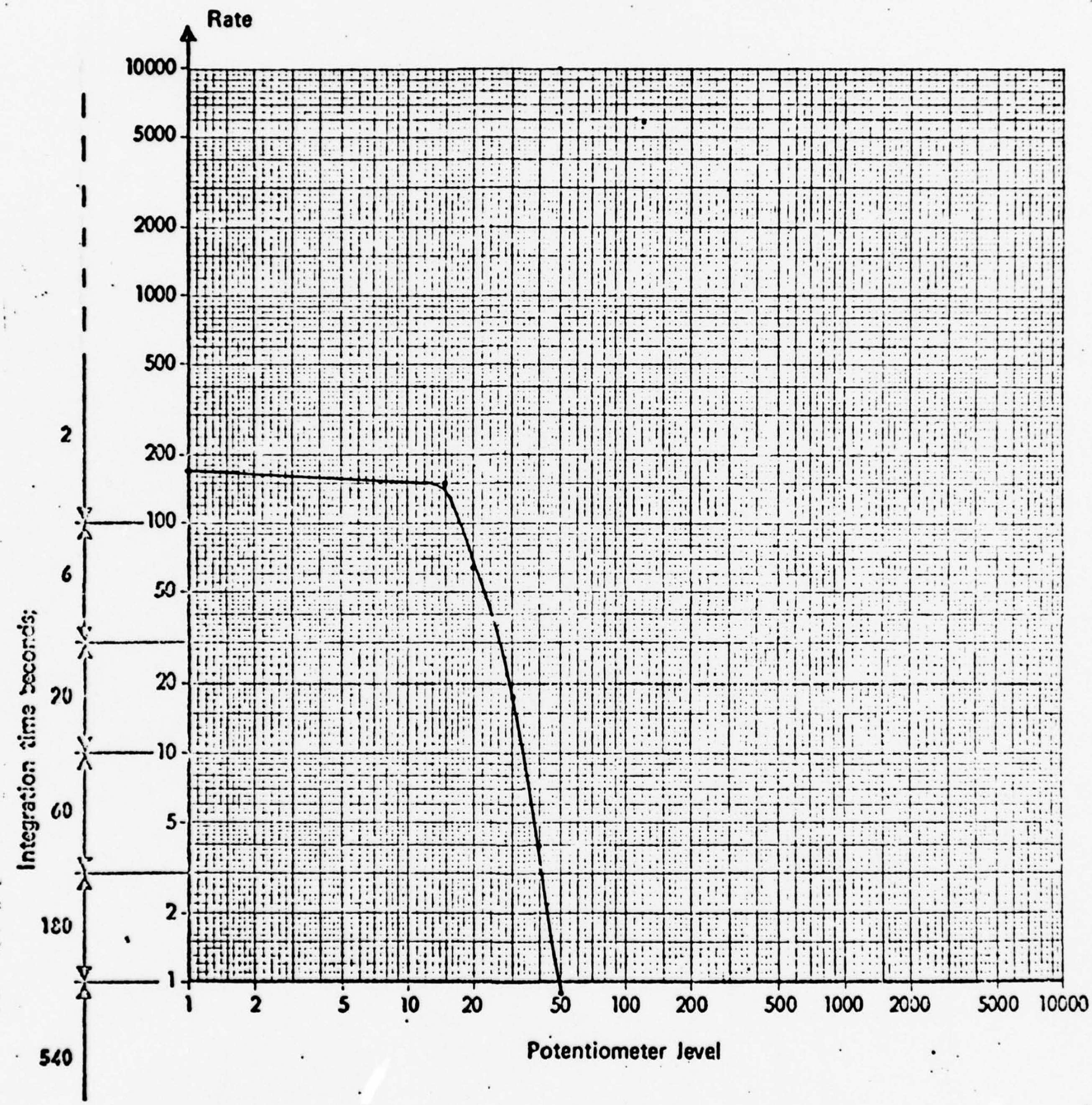
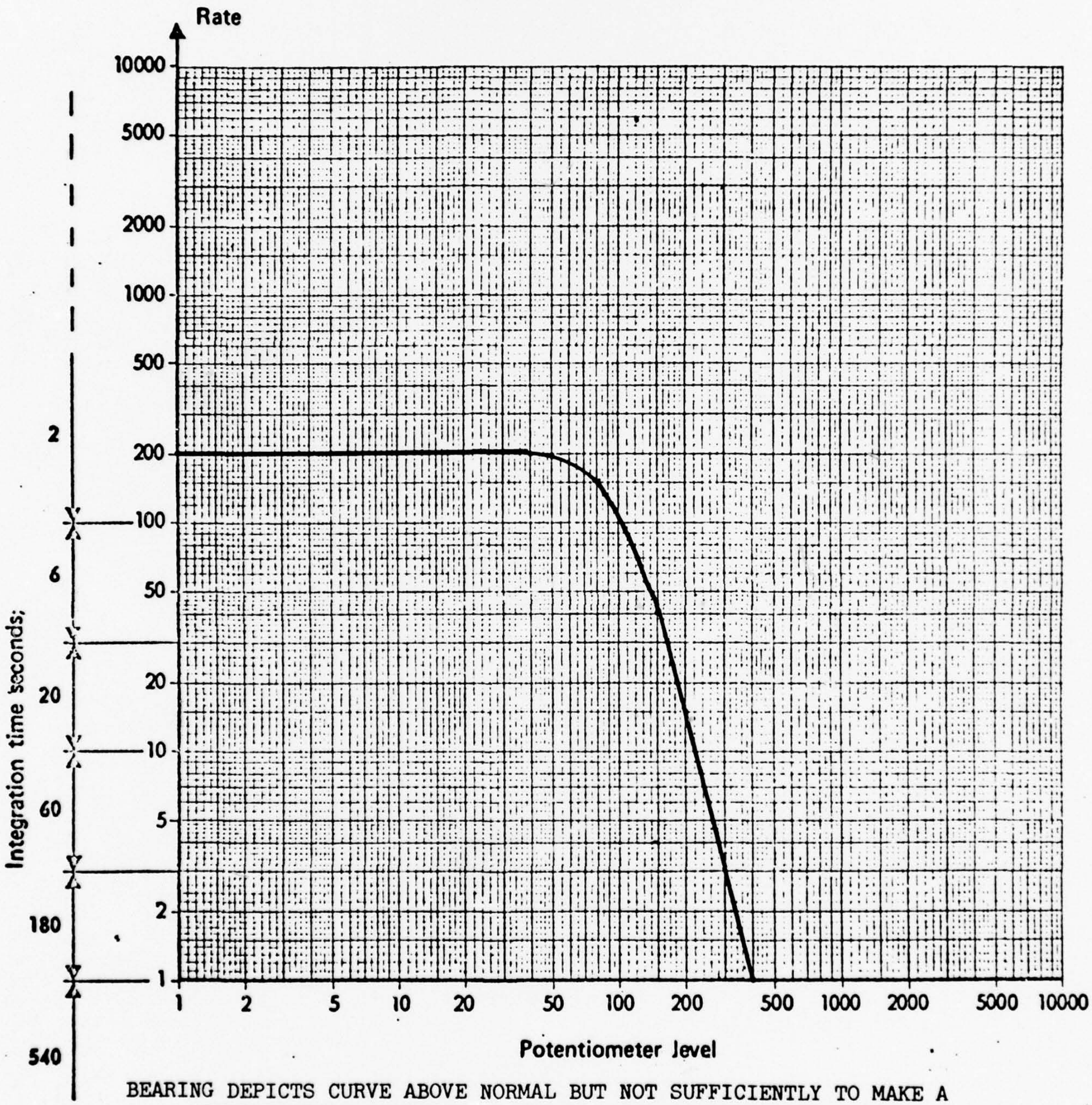


FIG. 25

NUMBER 1 HANGER BEARING

UH-1M TAIL #66-15190

TEST CONDUCTED 12 DEC 1973 AT BI-STATE AIRPORT

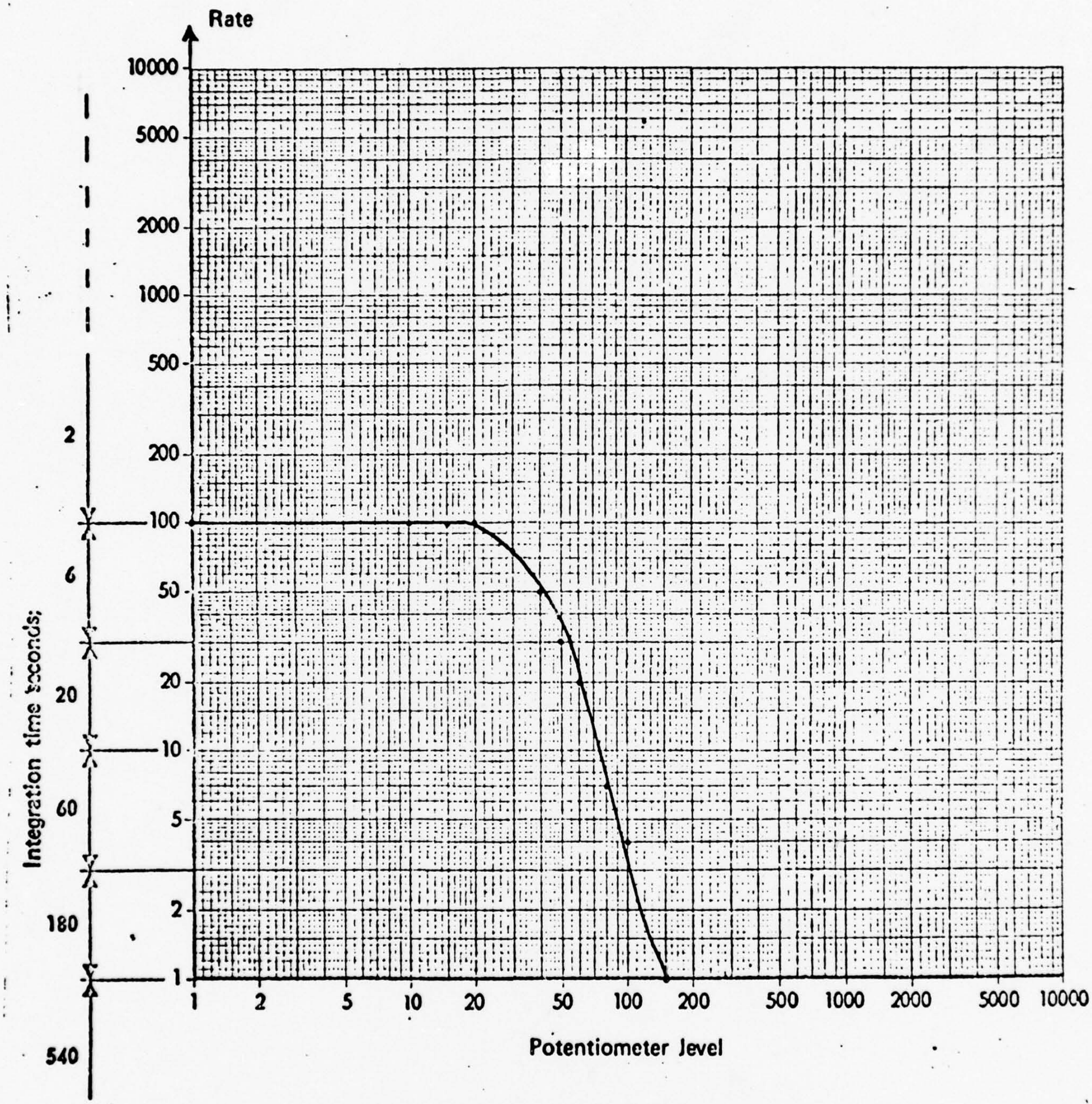


BEARING DEPICTS CURVE ABOVE NORMAL BUT NOT SUFFICIENTLY TO MAKE A DETERMINATION THAT THIS BEARING IS EXCESSIVELY DAMAGED.

FIG. 26

UH-1M TAIL #66-15190

TEST CONDUCTED 12 DEC 1973 AT BI-STATE AIRPORT



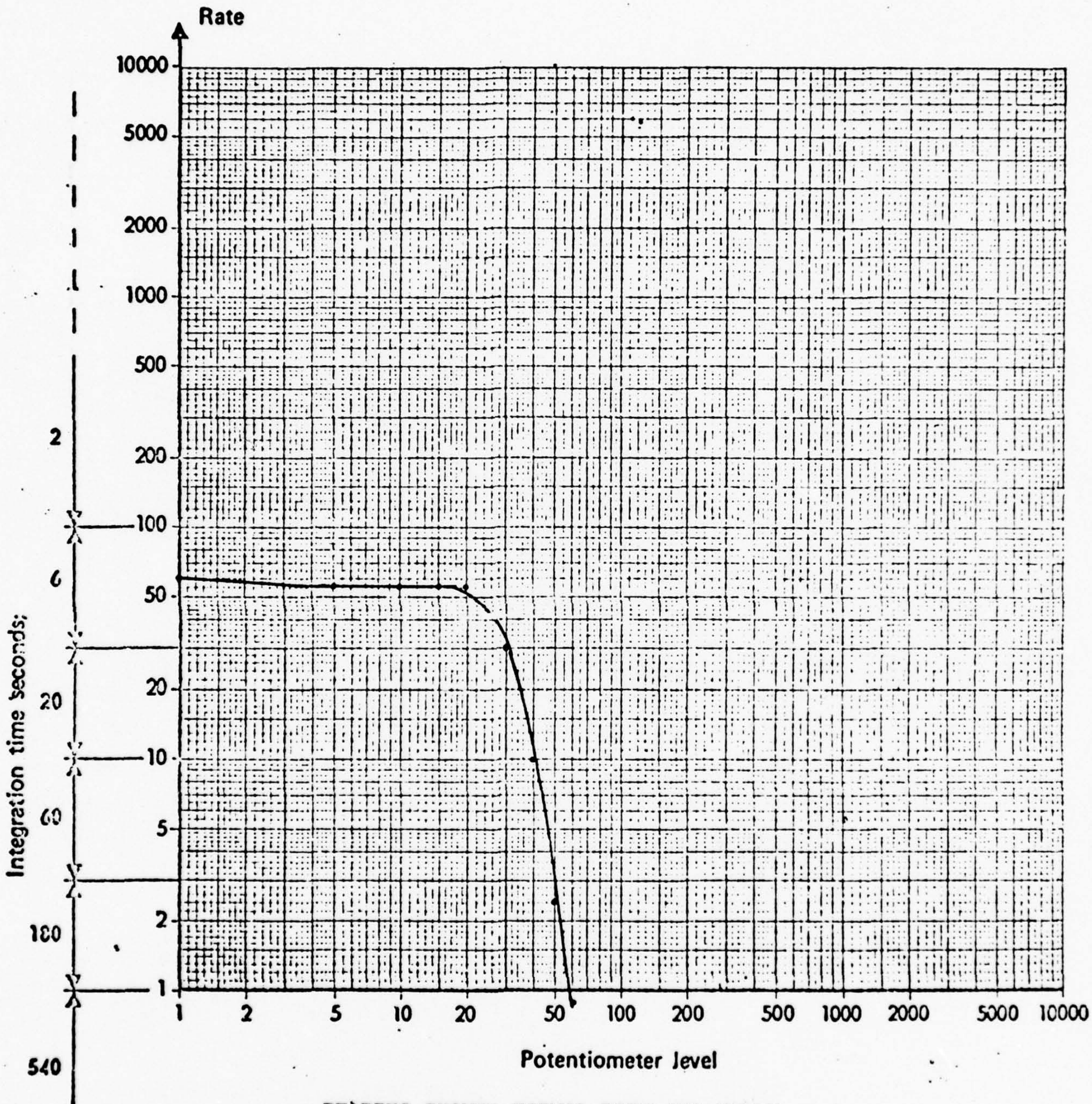
BEARING SHOWED NORMAL RATE AND VALUE.

FIG. 27

NUMBER 3 HANGER BEARING

UH-1M TAIL #66-15190

TEST CONDUCTED 12 DEC 1973 AT BI-STATE AIRPORT



BEARING SHOWED NORMAL RATE AND VALUE.

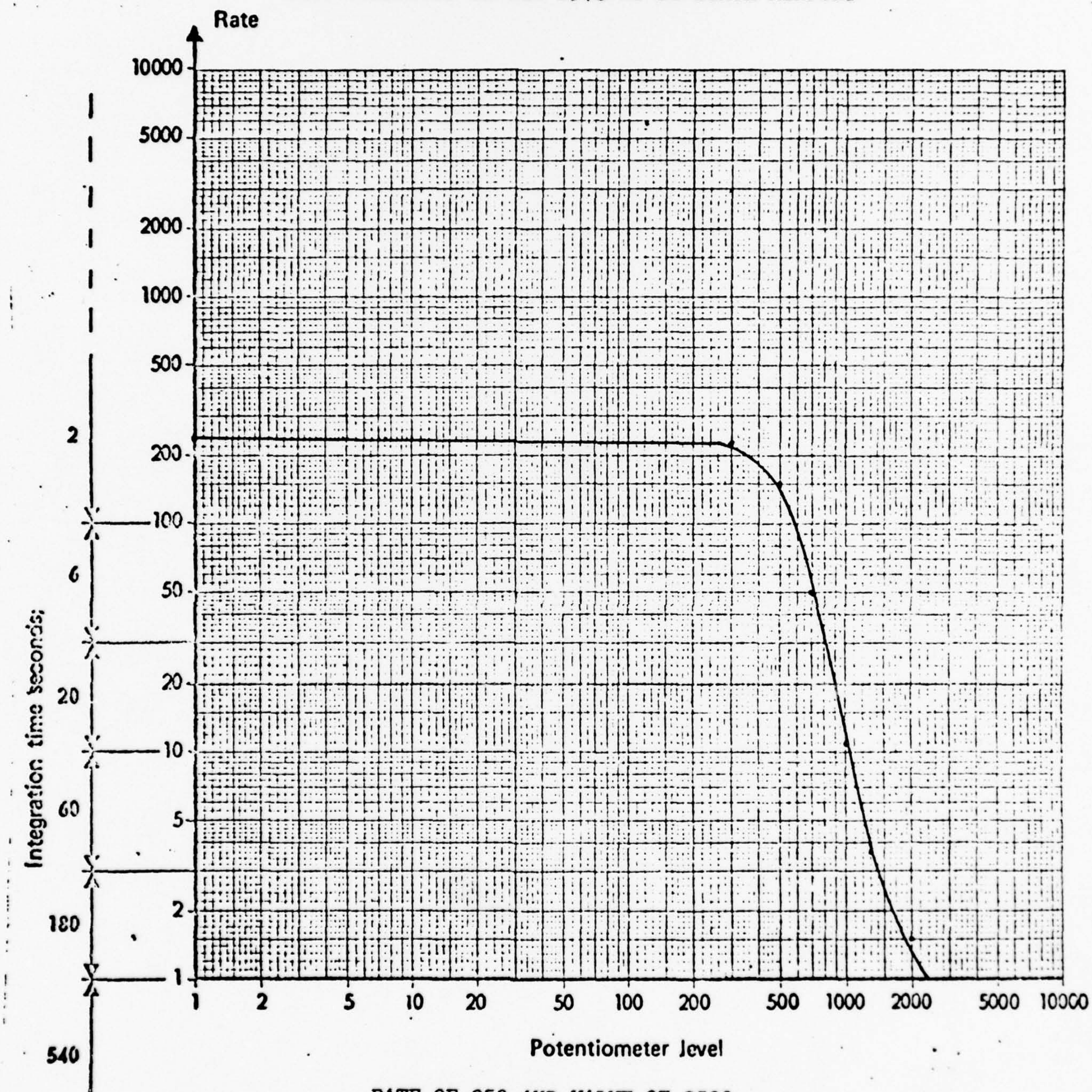
FIG. 28

NUMBER 3 HANGER BEARING

UH-1H TAIL #66-16879

BEARING SERIAL #A20-26745

TEST CONDUCTED 12 DEC 1973 AT BI-STATE AIRPORT



RATE OF 250 AND VALUE OF 2500
BEARING REMOVED FOR ANALYSIS

FIG. 29

HANGER BEARING #A20-26745

2970 hours usage since new with no overhauls and 403 hours in last installation.

Both corrosion and pitting are evident on the outer race of this bearing. No defects were noted on the inner race, however, the rolling element also had evidence of corrosion and pitting.

The potentiometer level of 2500 reached was the second highest of all bearings tested although the rate attained was not excessive at 250. The plot of the curve derived from the MEPA-10A shock analysis system would warrant the conclusion that this bearing would be considered excessively damaged when compared to the normal amount of shock emission of all bearings tested. Pictured damaged in the outer race would seem to indicate a bearing which was damaged to the point overhaul is warranted.

FIG. 29A

A20-26745 - Corrosion and Pitting on Outer Race.

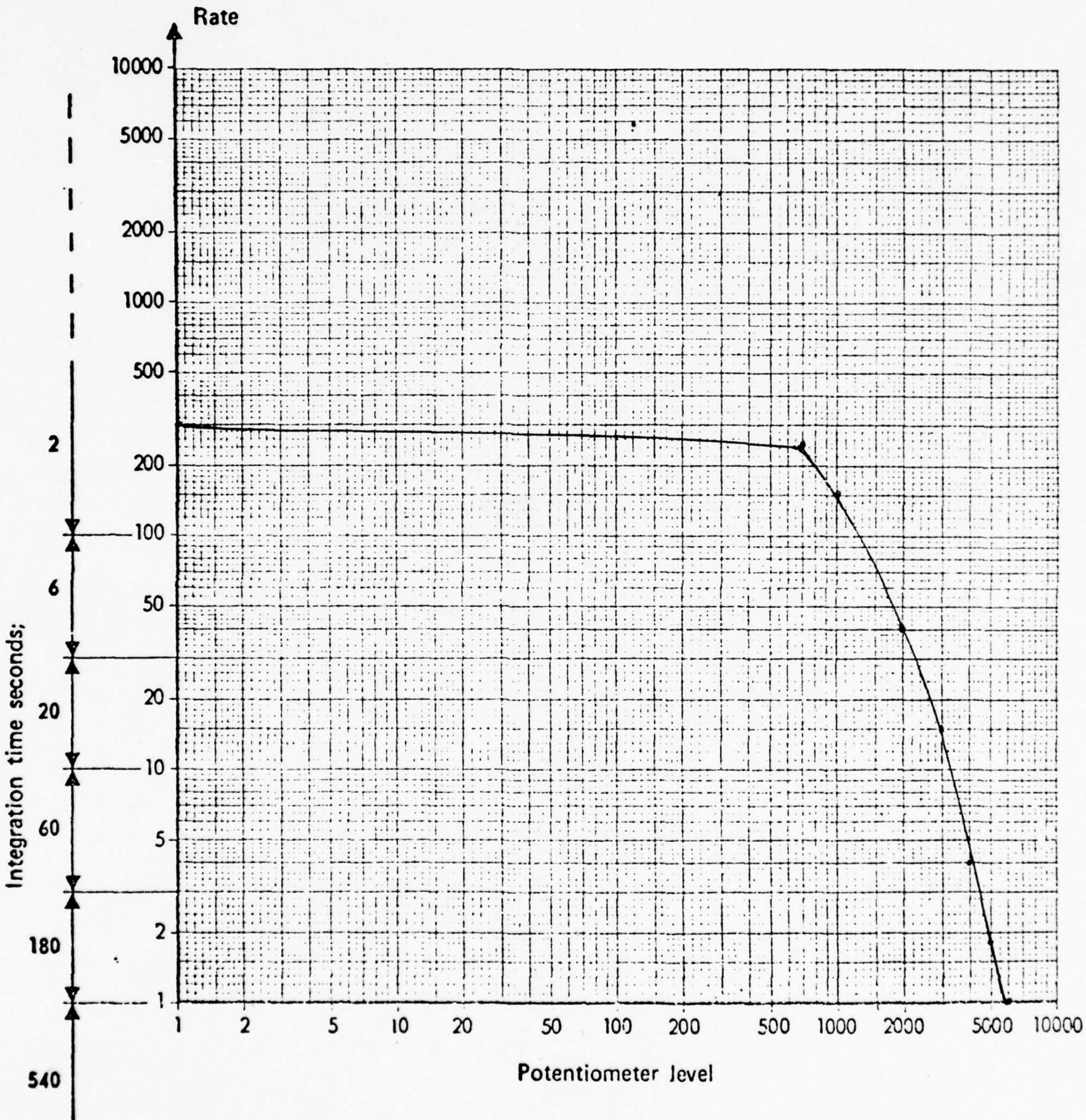
FIG. 29B

NUMBER 4 HANGER BEARING

UH-1H TAIL #66-16879

BEARING SERIAL #A20-31225

TEST CONDUCTED 12 DEC 1973 AT BI-STATE AIRPORT



RATE OF 300 AND VALUE OF EXCESS OF 6,000
BEARING REMOVED FOR ANALYSIS

FIG. 30

HANGER BEARING #A20-31225

703 hours usage since new with 403 hours usage in the last installation.

The teardown report stated "bearing rotated roughly before teardown." Corrosion and pitting was in evidence in all the bearing elements, inner and outer races as well as rolling element damage. Damage can be clearly seen in the teardown photos and this bearing must be considered as excessively damaged.

The MEPA-10A shock profile showed the highest potentiometer level recorded on this bearing. A level of 6500 should be considered excessive and with the photo and teardown data reviewed, this bearing must be placed in a severely damaged category.

FIG. 30A

A20-31225 - Corrosion and Pitting on Outer Race.

FIG. 30B

A20-31225 - Corrosion and Pitting on Ball.

FIG. 30C

A20-31225 - Corrosion
Damage to Inner Race.

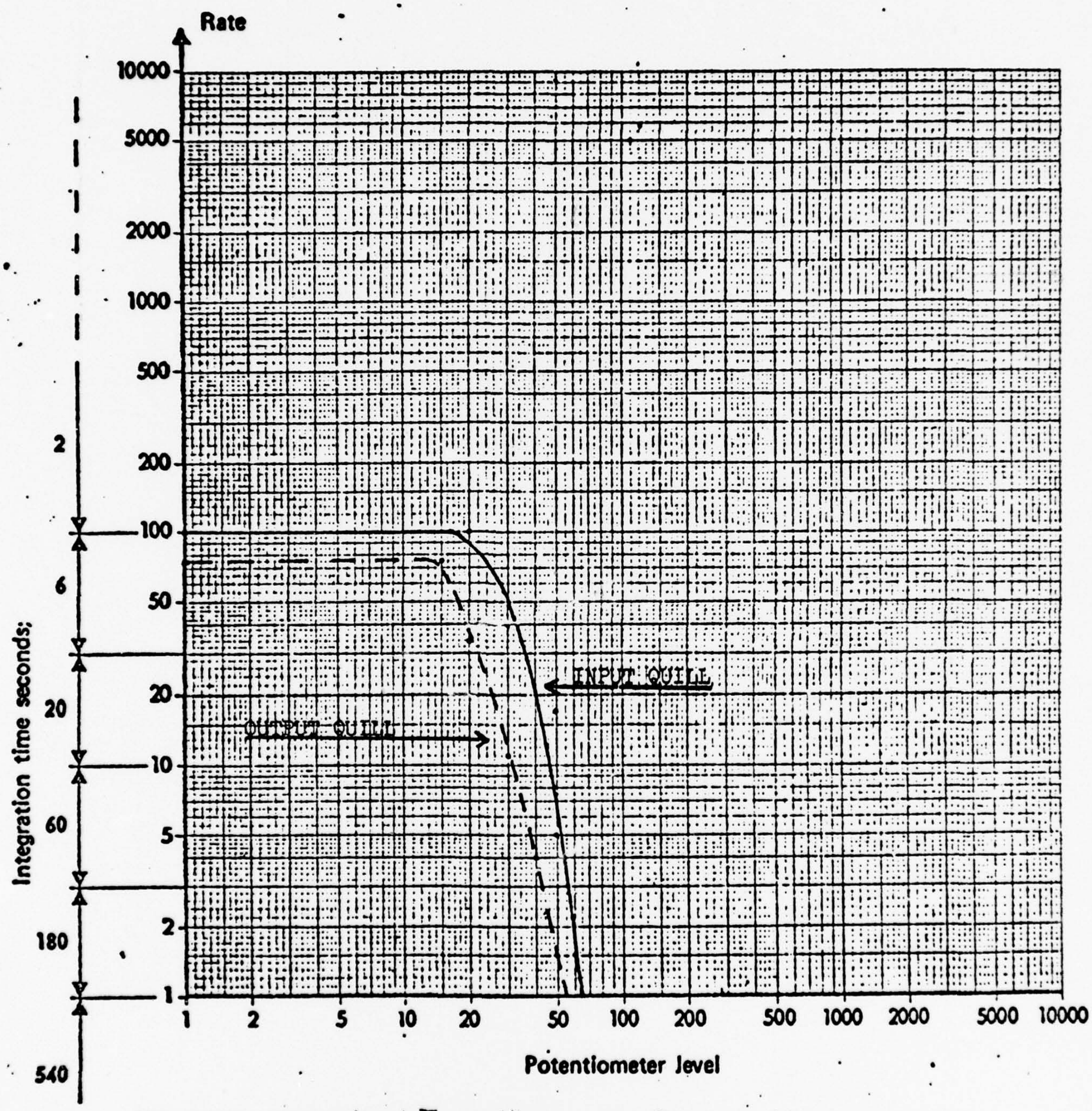
FIG. 30D

3.2 42° GEARBOX

42° GEARBOX

UH-1H TAIL #13740

TEST CONDUCTED 27 NOV 1973 AT SCOTT AFB



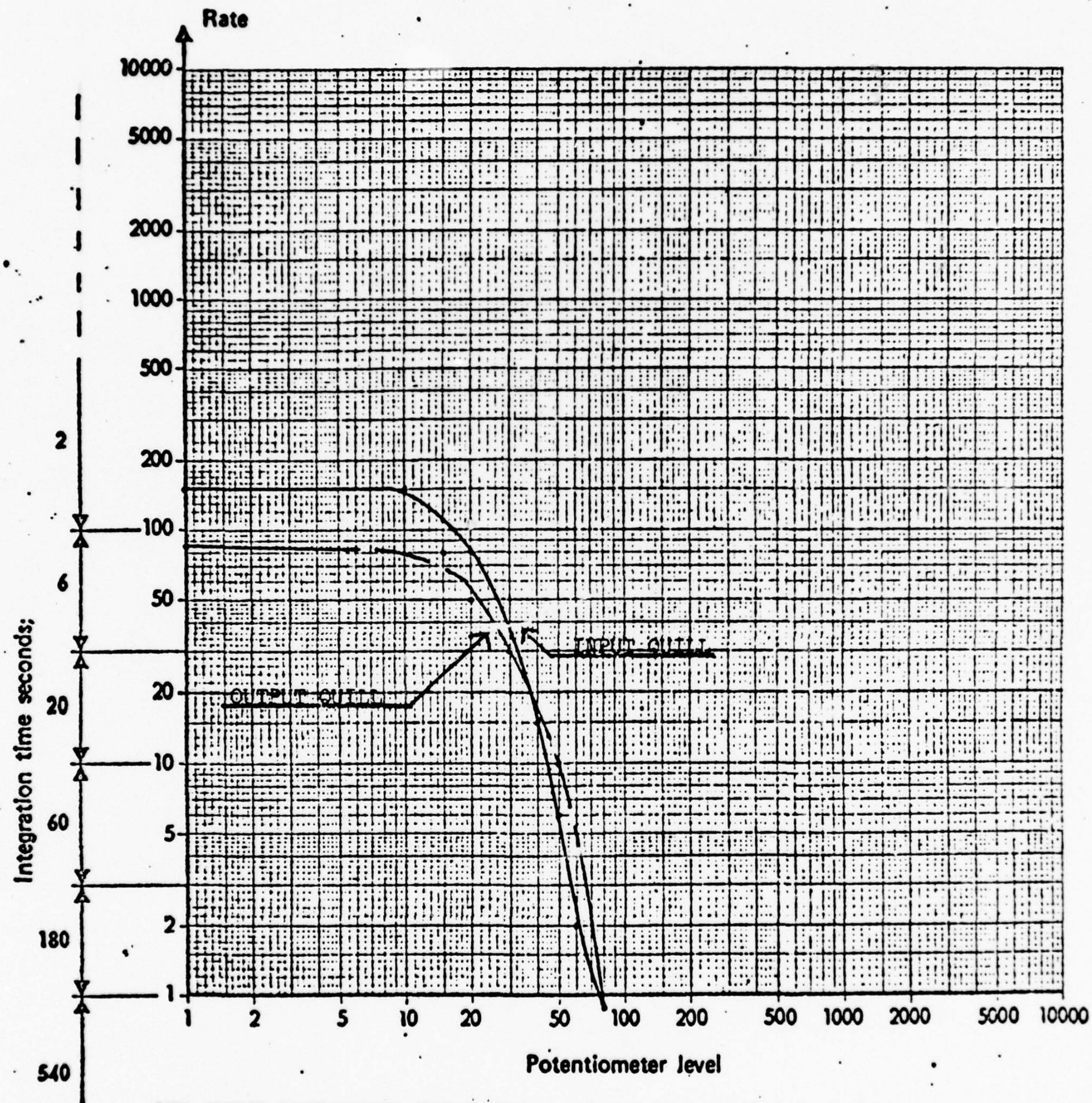
ONE CURVE DEPICTS INPUT DIRVE QUILL, THE OTHER THE OUTPUT DRIVE QUILL

FIG. 31

42° GEARBOX

UH-1H TAIL #16197

TEST CONDUCTED 27 NOV 1973 AT SCOTT AFB



ONE CURVE REPRESENTS INPUT DRIVE QUILL, THE OTHER THE OUTPUT DRIVE QUILL.

FIG. 32

42 GEARBOX

UH-1H TAIL #66-01087

INPUT DRIVE QUILL

TEST CONDUCTED 28 NOV 1973 AT SCOTT AFB

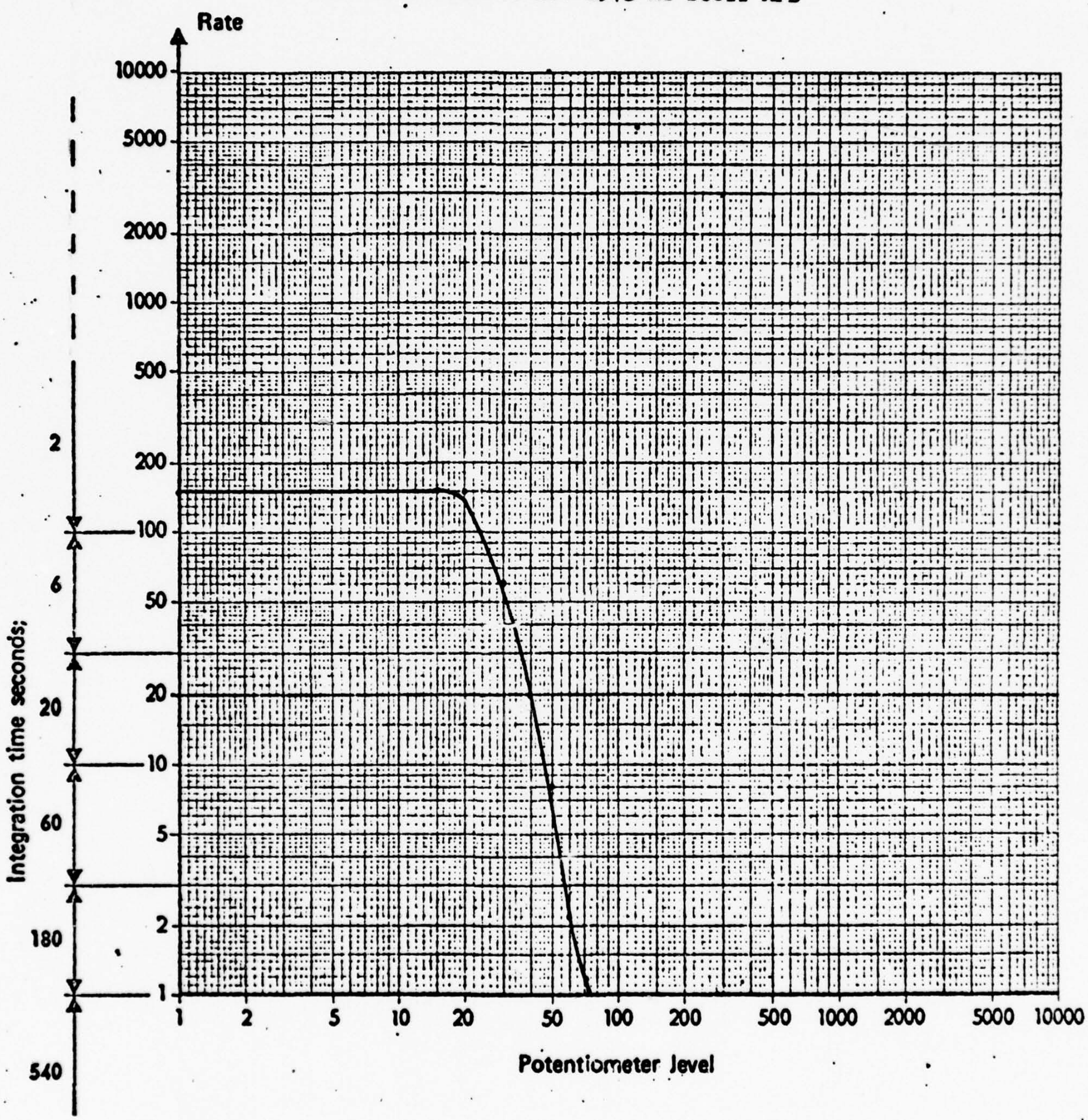
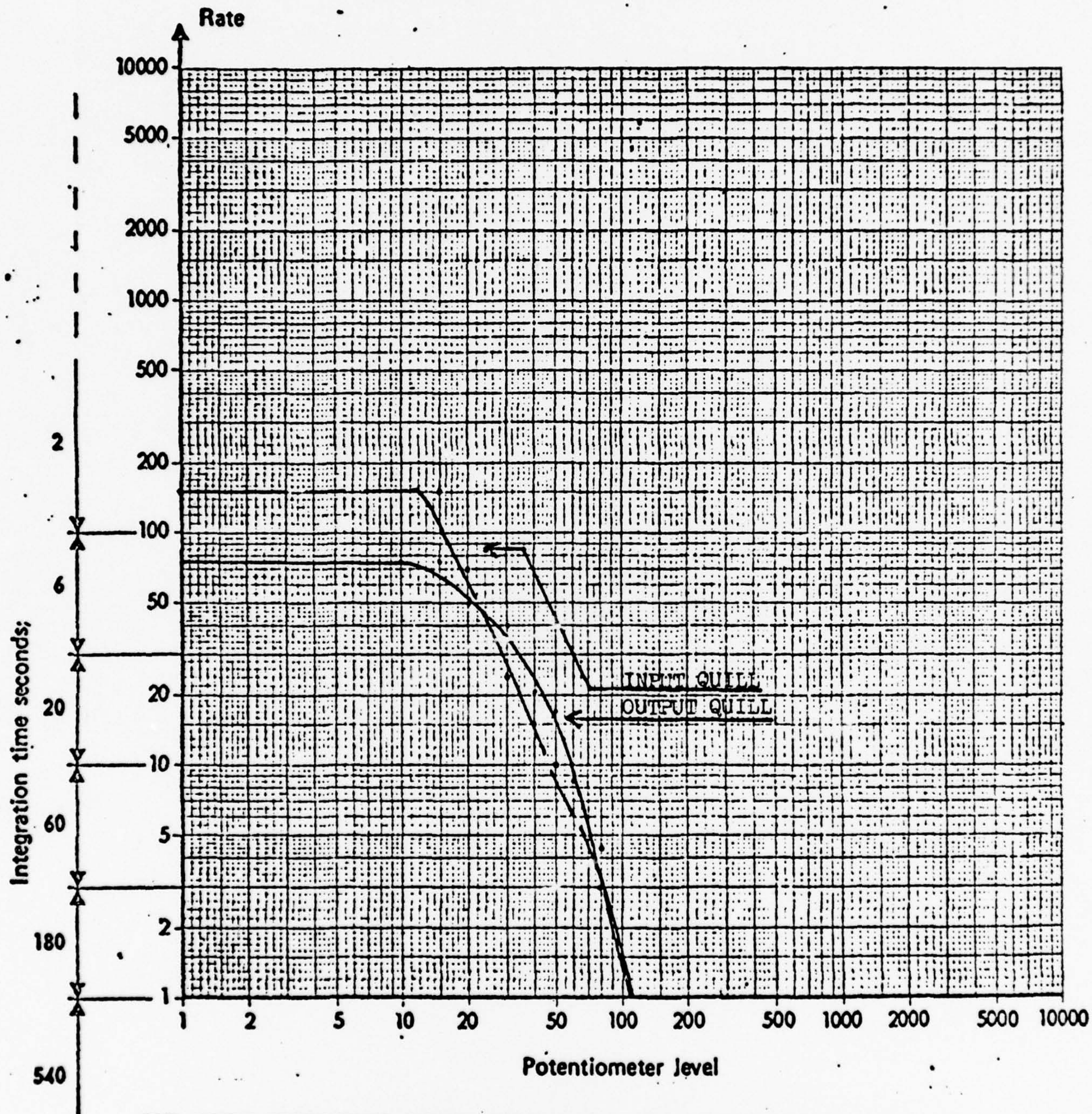


FIG. 33

42° GEARBOX

UH-1H TAIL #15949

TEST CONDUCTED 28 NOV 1973 AT SCOTT AFB

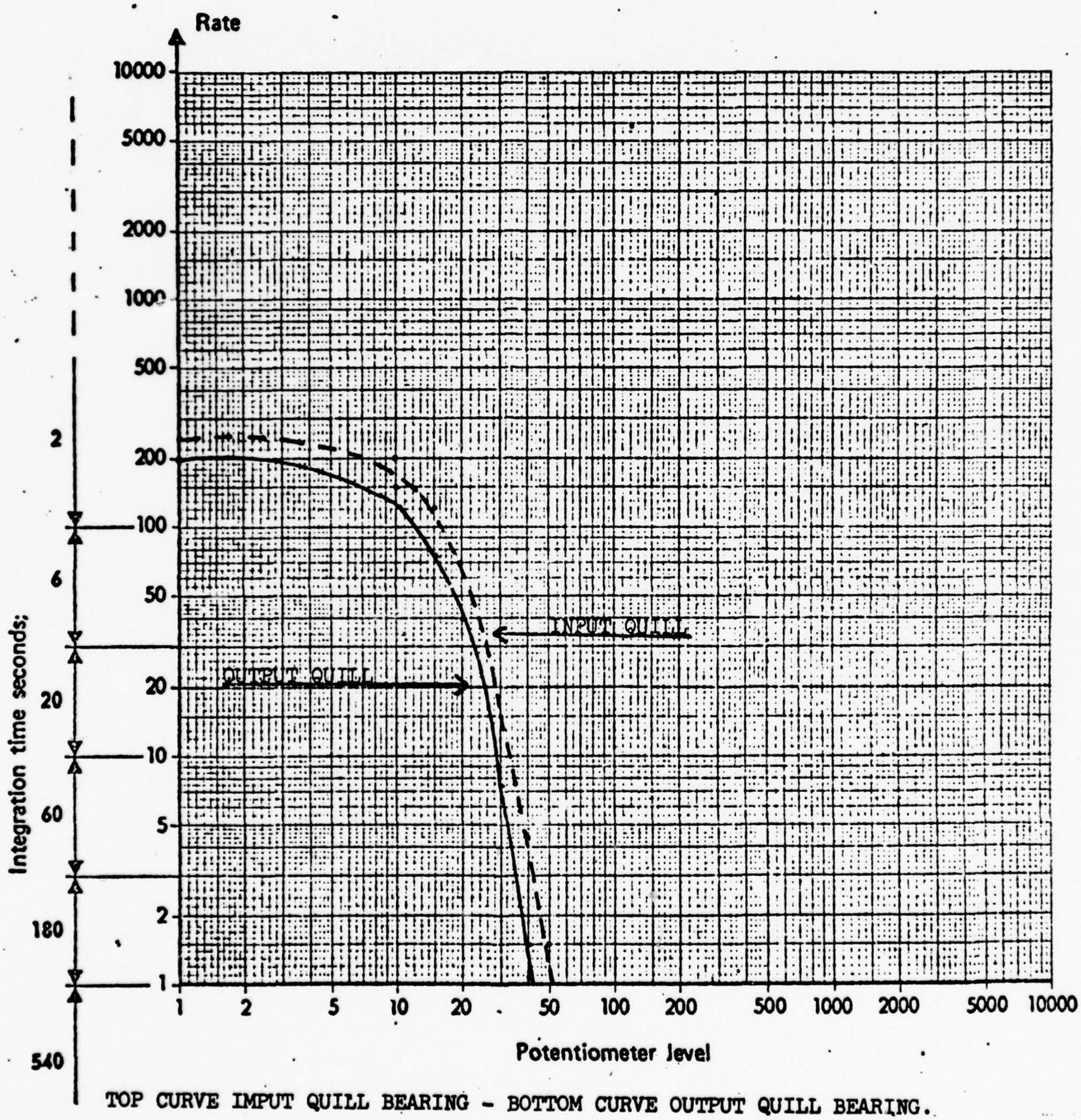


ONE CURVE REPRESENTS INPUT DRIVE QUILL, THE OTHER OUTPUT DRIVE QUILL

FIG. 34

42° GEARBOX UH-1M TAIL #59519

TEST CONDUCTED 30 NOV 1973 AT SCOTT AFB



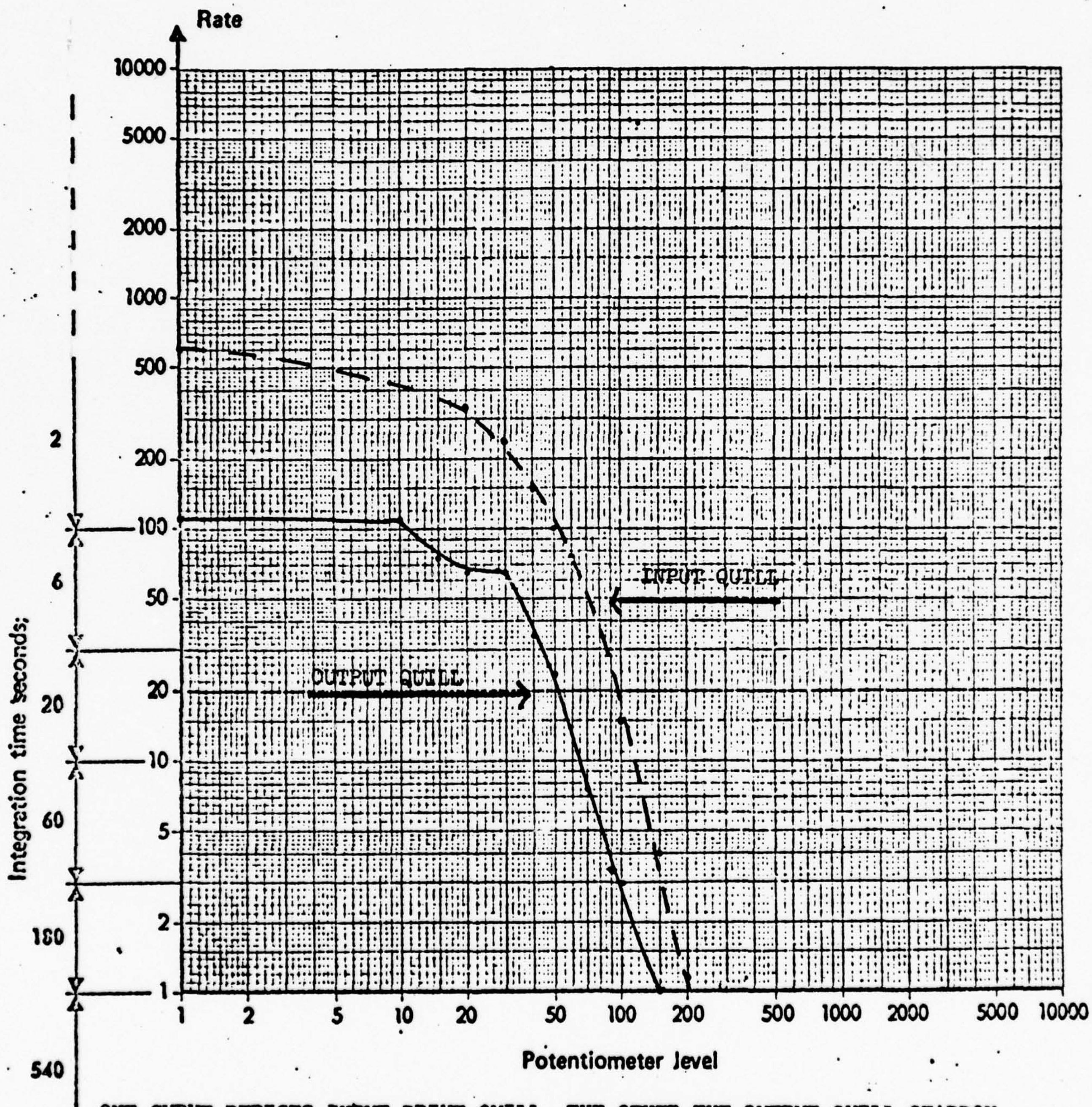
TOP CURVE IMPUT QUILL BEARING - BOTTOM CURVE OUTPUT QUILL BEARING.

FIG. 35

42° GEARBOX

UH-1M TAIL #15200

TEST CONDUCTED 6 DEC 1973 AT SCOTT AFB



ONE CURVE DEPICTS INPUT DRIVE QUILL, THE OTHER THE OUTPUT QUILL GEARBOX REMOVED FOR TEARDOWN ANALYSIS.

ABB6012 - GEARBOX SERIAL NUMBER

FIG. 36

42° GEARBOX #ABB-0612

298 hours since new.

The bearings in the output drive quill (S/N 12-737) were stated as feeling smooth, however, brinelling was found on the load side of the inner races. The bearings operated over the damage and the rolling element path is now continuous.

The bearing in the input drive quill (S/N 76-961) had no evidence of damage or deterioration during teardown.

The MEPA-10A shock profile reveals a marked difference between the input and output drive quills. No damage was found on the input quill and the curve of its shock rate vs. level is smooth and has no sharp slope changes in its plot. Damage was noted in the output quill and by examining the slope of the curve plotted an irregularity in the plotted curve can be noted. The change in the slope of the curve could be caused by the rolling elements operating over the brinelling found on the load side of the inner race.

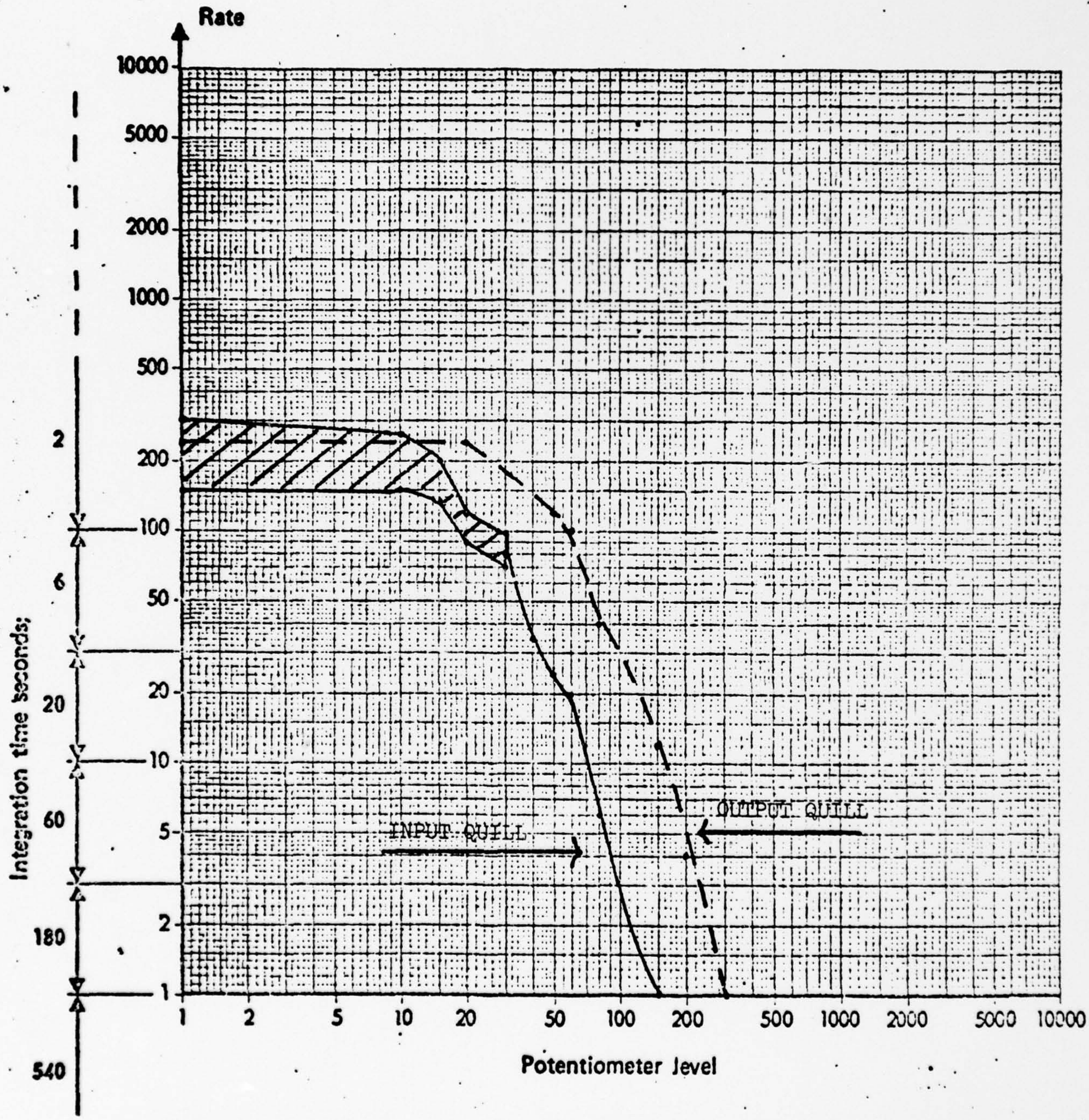
The curve plotted for the input bearings of the 42° Gearbox ABB-2667 yielded a curve irregularity in plotting the shock emission and in this case brinelling was also evident in the teardown analysis which further warrants the collection of more data on the effects of brinelling on shock plotting.

FIG. 36A

42° GEARBOX

UH-1H TAIL #69-15771

TEST CONDUCTED 6 DEC 1973 AT SCOTT AFB



ONE CURVE REPRESENTS INPUT QUILL, THE OTHER THE OUTPUT QUILL GEARBOX REMOVED FOR TEARDOWN ANALYSIS.

NOTE: SCALPED AREA DENOTES NEEDLE SWING.

ABB2667 - GEARBOX SERIAL NUMBER

FIG. 37

42° GEARBOX ABB-2667

No overhauls recorded with 1042 hours usage since new and in last installation. Input gear #33446-9 showed acceptable wear pattern. Input outer ball bearing and input inner ball bearings numbered 85065 both exhibit false brinelling marks.

Some light scratches were evident on the input roller bearing.

Output gear #33347-10 showed an acceptable wear pattern on the gear.

Both the output ball bearings #85263 exhibited a small pit with the outer ball bearing also showing a small scratch.

No defects were found on the outer roller bearing.

The MEPA-10A shock depcition of the 42° Gearbox ABB-2667 shows a marked difference between the input and output drive quill. Since the accelerometer placements were on the outer portions of the drive quills, no definite analysis can be made of any of the component parts of the quills or the specific gear assembly. The only conclusions which can be arrived at are with reference to the complete quill assemblies.

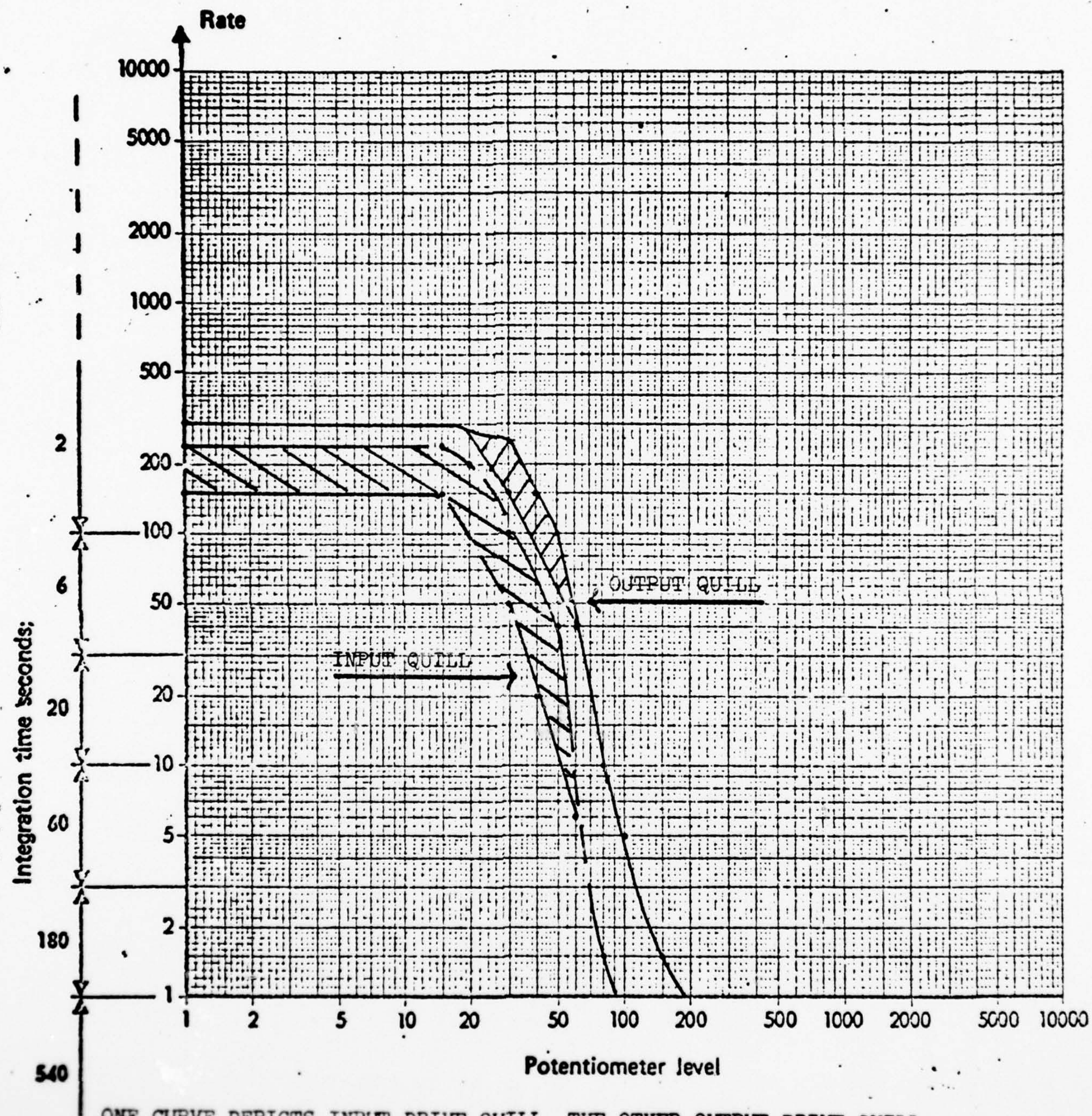
The input quill shock analysis curve shows changes in slope which could be indicative of some damage or obstruction encountered in the rolling elements or their paths.

False brinelling marks on both input ball bearings which was found [illegible] may account for the irregularity in the curve plotting of the input quill. However, at this time no conclusion can [illegible] made with- [illegible] of false brinelling in general, and [illegible]

42° GEARBOX

UH-1M TAIL #66-15190

TEST CONDUCTED 12 DEC 1973 AT BI-STATE AIRPORT



ONE CURVE DEPICTS INPUT DRIVE QUILL, THE OTHER OUTPUT DRIVE QUILL.
GEARBOX REMOVED FOR TEARDOWN ANALYSIS.

NOTE: SCALPED AREA DENOTES NEEDLE SWING.

AB 1101 GEARBOX SERIAL NUMBER

FIG. 38

42° GEARBOX #ABB-1101

Two prior overhauls with 1725 hours since new and 148 hours usage since last overhauled.

Teardown evidence yield pits in all bearings of the input drive quill, corrosion and pitting was found on the output quill bearings of the gearbox. Radial scratches were found on the output quill roller bearing.

Shock emission profiles for both input and output quill packages had some needle swing which was the main reason for removing this gearbox for teardown. There is little difference in the curve shapes of both bearing assemblies and neither had abnormally high rate or potentiometer level. The needle swing in rate analysis was felt could have masked curve irregularities related to bearing damage.

FIG. 38A

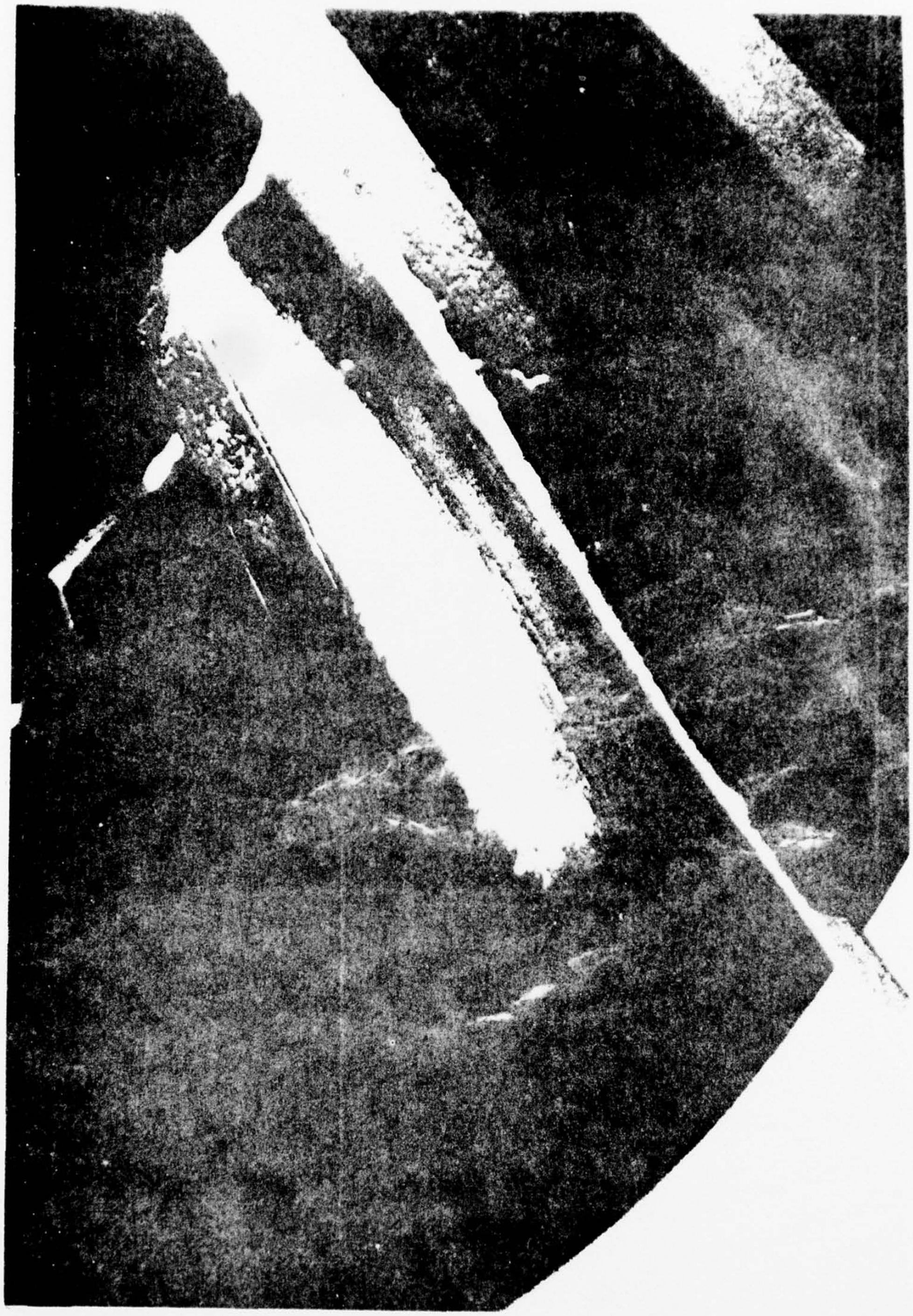


ABB-1101 - Output Gear Pattern.

FIG. 38B

ABB-1101 - Output, Inner Bearing Corrosion Damage on Outer Race.

FIG. 38C

ABB-1101 - Output, Inner Bearing,
Corrosion on Ball.

FIG. 38D

ABB-1101 - Output, Outer Bearing, Corrosion and Pitting on Outer Race.

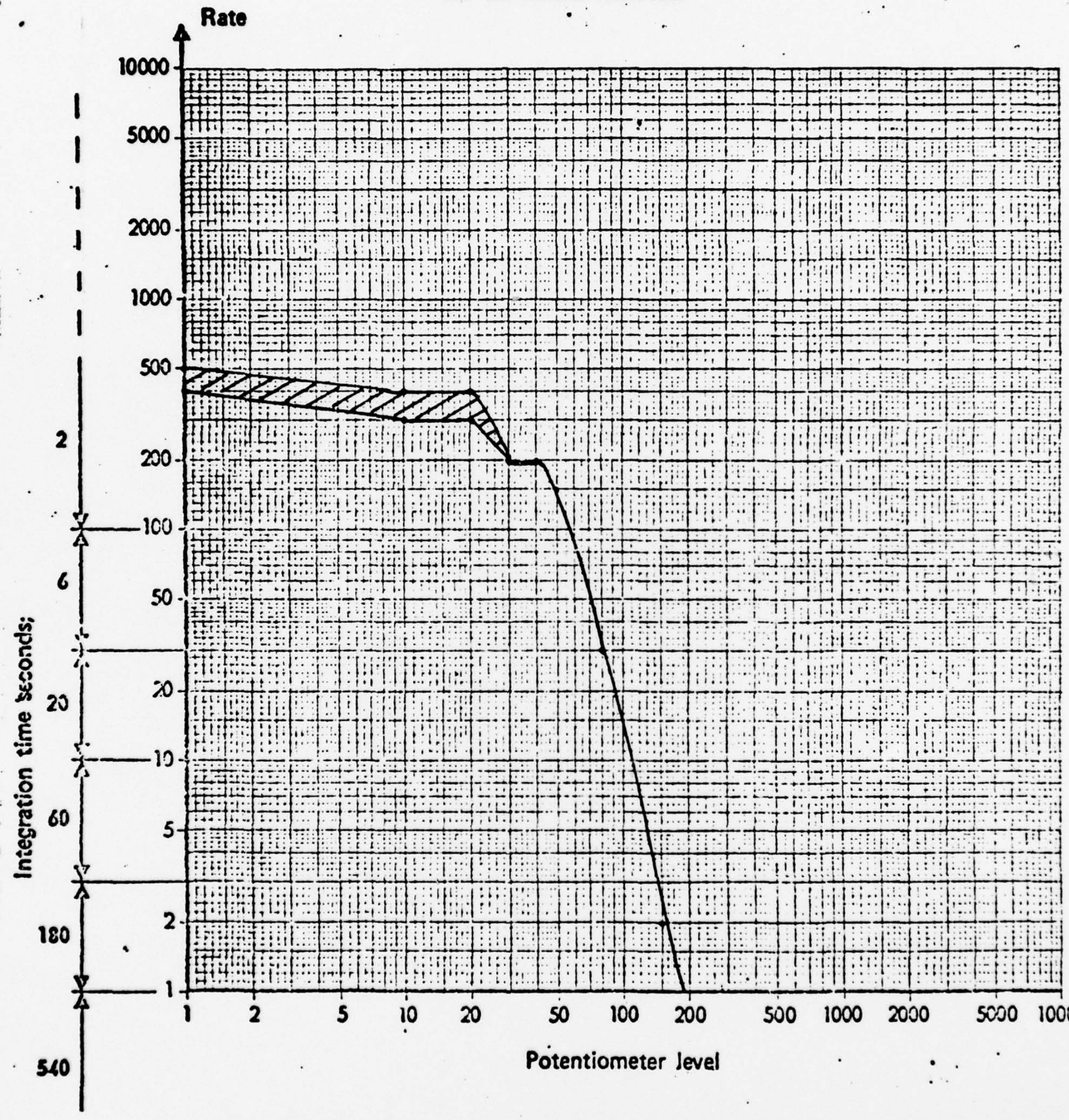
FIG. 38E

42° GEARBOX

UH-1H TAIL #66-16879

TEST CONDUCTED 13 DEC 1973

AT BI-STATE AIRPORT



CURVE REPRESENTS THE OUTPUT DRIVE QUILL. GEARBOX REMOVED FOR TEARDOWN ANALYSIS.

NOTE: SCALPED AREA DENOTES NEEDLE SWING.

GEARBOX B13-3800

FIG. 39

42° GEARBOX #B13-3800

1893 hours usage since new with 569 hours usage since overhauled.

The output quill bearing was the only one analysed with the MEPA-10A. The teardown information regarding the output quill was the only information considered.

Small pits and scratches were found on the outer ball bearing #27184 and the inner ball bearing had a few small scratches on the balls.

The MEPA-10A shock profile of the output bearing of the quill assembly showed some irregularities in the curve shape. Needle swing again accounts for part of the manifested irregularities and the rate of 500 was considered high compared with normal. Teardown information showed that while some damage was evident, no severe damage existed.

FIG. 39A

B13-3800 - Output Gear Pattern.

FIG. 39B

4.0 CONCLUSIONS AND RECOMMENDATIONS

The correlation between graphical depiction and teardown analysis found in this report is based on the previous tests of the MEPA-10A system of shock pulse analysis and a review of the methods currently used to determine condition by teardown. An attempt was made to construct a normalizing graph to categorize a hanger bearing by condition. Three sections were employed in the effort to classify bearing condition:

1. Green area signifies a bearing in good condition.
2. Yellow area denotes a bearing with dome damage and represents a marginal area.
3. Red area signifies a bearing with damage in excess of that which is felt would be acceptable.

By overlaying the graphs of bearings plotted, an idea of probable bearing condition can be attained.

The criteria for determination is based on a limited amount of data and any further data collection would necessarily increase the reliability of which a condition determination can be made.

The 42° gearbox analysis did not yield any extreme conditions of wear or damage. Considering the high reliability of the 42° gearbox, the probability of finding one with excessive damage is low.

Based on laboratory tests (4), the use of the oscilloscope coupled with the MEPA-10A in determining bearing health provides little useful information.

In the areas of significant hanger bearing damage, the correlation between the data obtained from the MEPA-10A shock analysis and teardown information appears to correlate closely. The ease with which a hanger bearing or 42° gearbox quill assembly can be evaluated is apparent over the present system of "feel" or "play" because it can be evaluated in position on the aircraft. The use of the MEPA-10A as a diagnostic tool has been proven in locating bearings which were excessively damaged even though installed on operational aircraft.

Due to the short length of time (6 weeks) during which this study has been undertaken, a less than desireable amount of bearing units were analysed. The aircraft (UH-1 series) were available but due to the initial engineering problem of accelerometer attachment as well as inclement weather, and the fuel shortage, were all factors which reduced the number of bearings which could be tested. The study of hanger bearings and 42° gearboxes should be expanded to broaden the statistical base. It would be desireable to have data on implanted bearings with severe damage that is, close to failure. However, the non-interference constraints precluded this with the Reserve helicopters.

REFERENCES

1. James Provenzano, John Games, Al Wyrostek, Art Ostheimer, Jack Young; "UH-1H AIDAPS Test Bed Program", Vol. I, II; USAAVSCOM Technical Report 72-18, August, 1972.

2. Robert R. Butcher, Russel Kirby, Jr., John Nakakihara, T.C. Watkins; "UH-1H Test Bed Program", Vol. I, II; USAAVSCOM Technical Report 72-19, June, 1972.

3. John A. George, Richard M. Andres, J. Thomas Harrington; "Parks College UH-1H AIDAPS Program, Interim Report". Parks College of Saint Louis University, Cahokia, Illinois, August, 1973.

4. Edward F. Covill, Timothy C. Mayer, John A. George; "Preliminary Evaluation of the Shock Pulse Technique to UH-1 Series Helicopters, Draft Report". Parks College of Saint Louis University, Cahokia, Illinois, January, 1974.

APPENDIX

AD-A054 906 PARKS COLL OF SAINT LOUIS UNIV CAHOKIA ILL F/G 1/3
FIELD EVALUATION OF THE SHOCK PULSE TECHNIQUE TO UH-1H SERIES H--ETC(U)
JUN 74 T C MAYER, E F COVILL, J A GEORGE DAAJ01-72-A-0027
UNCLASSIFIED USAAVRADCOM-TR-78-2 NL

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DATE
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7-78
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BELL
HELICOPTER COMPANY
POST OFFICE BOX 482 · FORT WORTH, TEXAS 76101
A textron COMPANY

December 21, 1973
81:DVC:dc-1291

To: U. S. Army Aviation Systems Command
P. O. Box 209
St. Louis, Missouri 63119

Attention: Mr. Bob Stenberg
AMSAV-ERS

Copies to: Mr. C. E. Braddock
Transmission Design Group
BHC

Mr. J. Murphy
Reliability Group
BHC

Subject: Disassembly-Inspection of Returned Bearing Hangers and 42° Gearbox

Note: Only the discrepant items are mentioned.

Tail Rotor Drive Hanger, 204-040-600-9

S/N A20-11446
144 hours since overhaul
204-040-623-1 bearing, S/N E9202

General condition good, bearing feels smooth. Upon sectioning outer ring for inspection, some evidence of corrosion is apparent on two places in the outer race.

S/N A20-67523
404 hours since overhaul; 806 since new

General condition good, bearing feels smooth. Corrosion in outer race adjacent most balls, has operated over damage. Two lines (scratches) across race adjacent one corrosion area.

BELL HELICOPTER COMPANY

42° Gearbox, 204-040-003-37

S/N ABB-06012
298 hours since new

204-040-143-1 bearings, S/N 12-737 (output end)

Bearing feels smooth, disassembly reveals brinelling on load side of inner rings, has operated over damage and ball path is now continuous. No pitting or spalling.

S/N 76-961 (input end)

Shows no damage or deterioration.

The components will be preserved and returned to Mr. Harrington (Parks College) at a later date.

D. V. Cleveland
Transmission Design Group
Plant 5A

BELL HELICOPTER COMPANY

Inter-Office Memo

March 6, 1974
81:WDN:dc-1365

Memo to: Mr. J. Murphy

Copies to: Messrs. C. Braddock, D. Cleveland, L. Hopfensperger, E. Roseler, ECF

Subject: ANALYTICAL INSPECTION OF UNITS RECEIVED FROM PARKS COLLEGE

A total of nine (9) 204-040-600-9 hanger assemblies and six (6) 204-040-003-37 42° gearbox assemblies have been received by BHC from Parks College for analytical inspection. Inspection has been completed on the following units:

42° Gearboxes - P/N 204-040-003-37
S/N's - ABB-1101
ABB-2667
B13-2582, strike damage
B13-3800
BBB-958, strike damage
ABB-06012*

Hanger Assemblies - P/N 204-040-600-9
S/N's - A20-11446*
A20-26745
A20-31225
A20-37362
A20-43391
A20-49549
A20-64495
A20-64906
A20-67523*

The results of these inspections are as follows:

42° Gearbox - P/N 204-040-003-37

Gear Housing #BBB-958

One Prior Overhaul

Usage since new - 487 hours

Usage since overhaul - 22 hours

* These items covered previously in letter 81:DVC:dc-1291 to Mr. Bob Stenberg.

Input Gear #A015 - Pattern low and towards heel.

Input Outer Ball Bearing #3978A - No defects.

Input Inner Ball Bearing #3978A - False brinelling marks on outer race - One ball with scratches.

Input Roller Bearing #144562 - Radial scratches on rollers.

Output Gear #A006 - Pattern towards heel.

Output Outer Ball Bearing #4337A - False brinelling marks.

Output Inner Ball Bearing #4337A - No defects.

Output Roller Bearing #144128 - Some scratches.

42° Gearbox - Part No. 204-040-003-37

Gear Housing #ABB-2667

No Prior Overhauls

Usage Since New - 1042 hours.

Usage Since Last Installation - 1042 hours

Input Gear #33446-9 - Acceptable pattern.

Input Outer Ball Bearing #85065 - False brinelling marks.

Input Inner Ball Bearing #85065 - False brinelling marks.

Input Roller Bearing #214665 - Some slight scratches.

Output Gear #33347-10 - Acceptable pattern.

Output Outer Ball Bearing #85263 - One small pit and one small scratch.

Output Inner Ball Bearing #85263 - One small pit in inner race.

Output Roller Bearing #214701 - No defects.

42° Gearbox - Part No. 204-040-003-37

Gear Housing #B13-3800

One Prior Overhaul

Usage Since New - 1893 hours

Usage Since Overhaul - 569 hours

Input Gear #6332 - Pattern low and towards heel.

Input Outer Ball Bearing #63226 - Small pits.

Input Inner Ball Bearing #63226 - Small pits.

Input Roller Bearing #143366 - Few small pits.

Output Gear #2590 - Pattern towards heel (Figure 7).

Output Outer Ball Bearing #27184 - Small pits and scratches.

Output Inner Ball Bearing #27184 - Few small scratches on balls.

Output Roller Bearing #108087 - Small radial scratches on rollers.

42° Gearbox - Part No. 204-040-003-37

Gear Housing #B13-2582

Two Prior Overhauls

Usage Since New - 2103 hours

Usage Since Overhaul - 1253 hours

Input Gear #7089 - Pattern too far towards heel.

Input Outer Ball Bearing #5936H - Some pitting.

Input Inner Ball Bearing #5936H - Spall on inner race (Figure 1).

Input Roller Bearing #2202 - Some pitting.

Output Gear #7256 - Pattern high and towards heel, scoring on addendum tip of heel (Figure 2).

Output Outer Ball Bearing #6018H - Scratches and pits.

Output Inner Ball Bearing #6018H - Scratches and pits.

Output Roller Bearing #100394 - Some small pits.

42° Gearbox - Part No. 204-040-003-37

Gear Housing #ABB-1101

Two Prior Overhauls

Usage Since New - 1725 hours

Usage Since Overhaul - 148 hours

Input Gear #27427 - Pattern low.

Input Outer Ball Bearing #56073 - Small pits.

Input Inner Ball Bearing #56073 - Few pits.

Input Roller Bearing #210073 - Few pits.

Output Gear #27821 - Pattern too high and too far towards toe (Figure 6).

Output Outer Ball Bearing #56775 - Corrosion and pitting throughout bearing (Figure 5).

Output Inner Ball Bearing #56775 - Corrosion and pitting throughout bearing (Figures 3 and 4).

Output Roller Bearing #209959 - Radial scratches.

42° Gearbox - Part No. 204-040-003-37

Gear Housing #ABB-06012

No defects were found.

<u>Hanger Assembly - Part No. 204-040-600-9</u>

Serial No. A20-11446

No defects were found.

<u>Hanger Assembly - Part No. 204-040-600-9</u>

Serial No. A20-67523

No defects were found.

<u>Hanger Assembly - Part No. 204-040-600-9</u>

Serial No. A20-64906

No Overhauls

Usage Since New - 601 hours

Usage Since Last Installation - 427 hours

Outer Race - Pitted areas from corrosion (Figure 14).

Inner Race - No defects.

Balls - Corrosion with one ball pitted.

<u>Hanger Assembly - Part No. 204-040-600-9</u>

Serial No. A20-64495

No Overhauls

Usage Since New - 427 hours

Usage Since Last Installation - 427 hours

Outer Race - Corrosion and pitting (Figure 11).

Inner Race - Corrosion and pitting.

Balls - Corrosion on several balls (Figure 10).

Hanger Assembly - Part No. 204-040-600-9

Serial No. A20-37362

One Prior Overhaul

Usage Since New - 2549 hours

Usage Since Overhaul - 501 hours

Usage in Last Installation - 501 hours

Outer Race - Few areas of very light pitting.

Inner Race - Few areas of very light pitting.

Balls - No defects.

Hanger Assembly - Part No. 204-040-600-9

Serial No. A20-31225

No Overhauls

Usage Since New - 703 hours

Usage in Last Installation - 403 hours

Bearing rotated roughly before teardown.

Outer Race - Corrosion areas with pitting (Figure 17).

Inner Race - Corrosion areas with pitting (Figure 18).

Balls - Corrosion areas with pitting (Figure 16).

Hanger Assembly - Part No. 204-040-600-9

Serial No. A20-43391

No Overhauls

Usage Since New - 788 hours

Usage in Last Installation - 488 hours

Outer Race - Corrosion and pitting (Figure 13).

Inner Race - No defects.

Balls - One ball with corrosion (Figure 12).

Hanger Assembly - Part No. 204-040-600-9

Serial No. A20-49549

Time Change - 600 hours

Outer Race - Corrosion and pitting (Figure 9).

Inner Race - Corrosion and pitting (Figure 8).

Balls - Corrosion on several balls.

Hanger Assembly - Part No. 204-040-600-9

Serial No. A20-26745

No Overhauls

Usage Since New - 2970 hours

Usage in Last Installation - 403 hours

Outer Race - Corrosion with pitting (Figure 15).

Inner Race - No defects.

Balls - Corrosion with pitting.

W. D. Nichols
Transmission R & D Lab