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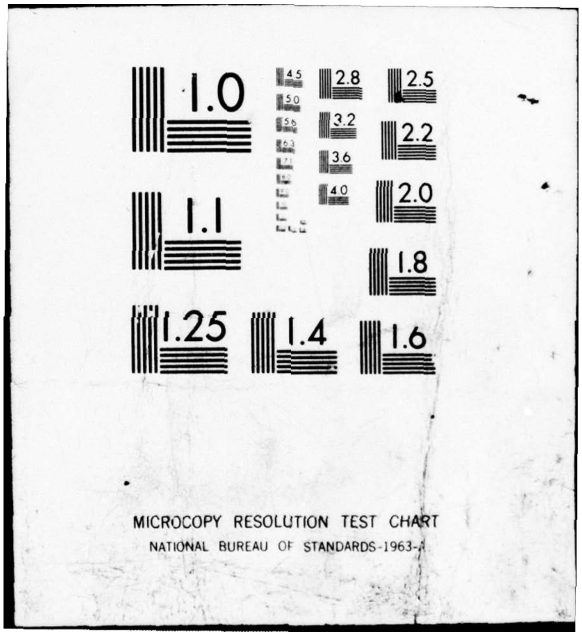
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RELIABILITY PREDICTION OF THE AN/BQS-4/4A SONAR DETECTING-RANGING SET

August 1967

Prepared for
Naval Ship Engineering Center
Norfolk Division
Norfolk, Virginia
under Contract No. N00189-67-C0488

ARINC RESEARCH CORPORATION

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Under Contract N00189-67-C0488, ARINC Research Corporation completed the following tasks on the AN/BQS-4/4A Sonar equipment:

- Performance of a "Method D" prediction in accordance with NAVSHIPS 93820, "Handbook for the Prediction of Shipboard and Shore Electronic Equipment Reliability"
- Identification of areas of unnecessary equipment complexity, misapplica-

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) tion of parts, and marginal design

- Determination of individual part replacement rates in accordance with Vitro Laboratories Technical Note 1744.00-2
- Development of reliability block diagrams for the equipment

This report documents the performance and results of the tasks.

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(6) RELIABILITY PREDICTION OF THE
AN/BQS-4/4A SONAR DETECTING-RANGING SET.

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Under Contract N00189-67-C0488, ARINC Research Corporation completed the following tasks on the AN/BQS-4/4A Sonar equipment:

- Performance of a "Method D" prediction in accordance with NAVSHIPS 93820, "Handbook for the Prediction of Shipboard and Shore Electronic Equipment Reliability"
- Identification of areas of unnecessary equipment complexity, misapplication of parts, and marginal design
- Determination of individual part replacement rates in accordance with Vitro Laboratories Technical Note 1744.00-2
- Development of reliability block diagrams for the equipment

This report documents the performance and results of the tasks.

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SUMMARY

ARINC Research Corporation performed a "Method D" prediction on the AN/BQS-4/4A Sonar equipment using the techniques of NAVSHIPS 93820, "Handbook for the Prediction of Shipboard and Shore Electronic Equipment Reliability". The prediction was made for all modes of equipment operation.

Within the constraints of the "Method D" prediction, areas of unnecessary equipment complexity, misapplication of parts, and marginal design were investigated.

Individual component replacement rates were determined from the failure rates predicted during the "Method D" effort. Adjustment factors for converting the failure rates to replacement rates were obtained from Vitro Laboratories Technical Note 1744.00-2, 30 April 1963.

Reliability block diagrams were developed for each equipment mode of operation.

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CONTENTS

1. INTRODUCTION

ARINC Research Corporation, under the provisions of Contract N00189-67-C0488, completed the following tasks on the AN/BQS-4/4A,* Sonar Detecting-Ranging Set:

- Performance of a "Method D" prediction in accordance with NAVSHIPS 93820, "Handbook for the Prediction of Shipboard and Shore Electronic Equipment Reliability". This prediction was performed for all modes of equipment operation and for worst-case conditions.
- Identification, within the limits of the "Method D" prediction, of areas of unnecessary equipment complexity, misapplication of parts, and marginal design. Lists of both overstressed components and document deficiencies were compiled.
- Determination of individual part replacement rates on the basis of the "Method D" predicted failure rates. Adjustment factors for converting predicted failure rates to replacement rates were obtained from Vitro Laboratories Technical Note 1744.00-2.
- Development of a reliability block diagram for each mode of equipment operation. In developing these diagrams, ARINC Research used the technical information and the prediction techniques presented in the following technical data package (as specified in Contract N00189-67-C0488):

  (1) One copy of NAVSHIPS 93530, Volume 1, Complementary Technical Manual for Sonar Detecting-Ranging Set, AN/BQS-4 and AN/BQS/4A (U) (Confidential)

  (2) One copy of NAVSHIPS 93530, Volume 2, Complementary Technical Manual for Sonar Detecting-Ranging Set, AN/BQS-4 and AN/BQS-4A (U) (Confidential)

  (3) One copy of NAVSHIPS 93530 Volume 3, Complementary Technical Manual for Sonar Detecting-Ranging Set, AN/BQS-4 and AN/BQS-4A (U) (Confidential)

  (4) One copy of NAVSHIPS 92792A, Technical Manual for Sonar Listening Set, AN/BQR-2B (U) (Confidential)

  (5) One copy of Allowance Parts List 54068200 for AN/BQS-4 Sonar Detecting and Ranging Set

* Paragraph 1-3, of NAVSHIPS 93530, Vol. 1, 28 December 1959, indicates the factory and field changes applicable to this equipment.

(6) One copy of Appendix F (Replacement Rate Tables) from Vitro Laboratories Technical Note 1744.00-2, 30 April 1963

(7) One copy of NAVSHIPS 93820, Handbook for the Prediction of Shipboard and Shore Electronics Equipment Reliability

For the assignment of failure rates and replacement rates to equipment components, data in the referenced documents were used. Where these documents did not provide failure or replacement rates for specific components, ARINC Research obtained these rates from other sources.

2. APPROACH

The basic "Method D" prediction techniques are presented in the NAVSHIPS 93820 Handbook. These prediction procedures were incorporated into a comprehensive equipment-analysis program designed to provide detailed equipment failure-rate data, MTBF figures, individual part-replacement rates, equipment and document problem areas, and realistic mode-of-operation reliability block diagrams. Additional data sources were consulted, as necessary, to obtain failure rate and replacement-rate data not contained in the basic technical data package.

A functional reliability diagram was constructed for each mode of operation. These diagrams depict the effect of failure of items of equipment on the system's functional capability. They were developed by analysis of the functional relationships among items of equipment and analysis of schematics and technical manual descriptions of the system's operation.

A functional block (FB) includes items of equipment that are required to perform a function. A functional-block group (FBG) includes functional blocks that are required to perform a higher-level function, and thus it is more complex than an individual functional block.

The components comprising each reliability functional block are listed in the appendix by circuit symbol within part type, within functional-block subdivision. The parts lists include severity levels,* failure rates, and replacement rates.

* Component severity level is the ratio between actual component electrical rating (volts, amperes, watts) and the applied stress, expressed as a percentage.

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3. FINDINGS

3.1 "Method D" Prediction

3.1.1 Failure Rates Obtained by ARINC Research

A failure rate for the permanent-magnet loudspeakers associated with the AN/BQS-4/4A equipment was not included in the NAVSHIPS 93820 Handbook. Thus the failure rate of the permanent magnet of the speaker was assigned as the component failure rate (worst-case condition). This rate, 5.650 failures per million hours, was obtained from the following source:

Bureau of Naval Weapons
Failure Rate Data Handbook (FARADA)
U.S. Naval Ordnance Laboratory
Corona, California
Original Issue - 1 June 1962

The failure rate assigned to bandpass filters Z-4401 through Z-4448 (for which no schematic is provided in the data package) was determined by combining the failure rates listed in NAVSHIPS 93820 for the components of a typical constant-K bandpass filter.* This failure rate, 1.47 failures per million hours, is within the range of bandpass-filter failure rates listed in FARADA** (44.99 failures per million hours for shipboard-submarine application) and in the ARINC Research publication, "Reliability Engineering,"† (0.654 failures per million hours for shipboard application).

3.1.2 Calculated Equipment Failure Rate

Table 1 is a complete tabulation of functional-block (FB) failure rates and MTBF values. The individual block and equipment failure rates and MTBF values are summations of appropriate component failure rates. The individual component failure rates are listed in the appendix in their corresponding FB tables. To facilitate calculation of the failure rate for any functional block on the reliability block diagrams, the tables are assigned the same numeric designator as the FB block on the reliability diagrams.

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*Electronic Designers' Handbook, R.W. Landee, D.C. Davis, A.P. Albrech, McGraw-Hill Book Co., Inc., New York, 1957. The failure rate for this filter is

$$\lambda = \begin{matrix} 3 \times 0.37 \text{ (capacitors)} \\ + 3 \times 0.12 \text{ (inductors)} \end{matrix} = 1.47 \text{ failures/million hours}$$

**Failure Rate Data Handbook (FARADA), Tri-Service and NASA Failure Rate Data Program, 1 June 1966.

† Reliability Engineering, ARINC Research Corporation, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1964.

TABLE 1 PREDICTED FUNCTIONAL-BLOCK FAILURE RATES AND MTBF VALUES				
Functional Block	Failure Rate		MTBF	
	Calculated	Adjusted*	Calculated	Adjusted*
1. Transmitter and Muting Circuit	479.07	526.98	2087.3	1897
2. Power Supplies (BQS-4)	547.4	602.14	1826.8	1661
3. Timing Circuits	319.17	351.09	3133.1	2848
4. Scan Switch Assembly	406.58	447.24	2459.5	2236
5. Receiver	153.54	168.89	6512.9	5921
6. Gain Control	23.30	25.63	4291.8	39017
7. Cursor	174.29	191.72	5737.5	5216
8. Hydrophones	194.8	214.28	5133.4	4667
9. Hydrophone Preamplifiers	1510.8	1661.88	661.9	602
10. Power Supplies (BQR-2B)	316.4	348.04	3160.5	2873
11. Recorder Switch Assembly	327.1	359.81	3057.1	2779
12. Recorder Servo	102.10	112.31	9794.3	8904
13. Clipper Detector (Recorder)	181.8	199.98	5500.5	5001
14. Azimuth Indicator (Audio)	34.73	38.20	28793	26178
15. Azimuth Indicator (Video)	94.30	103.73	10604	9640
16. Recorder	145.54	160.09	6870.9	6246
17. Manual Switch Assembly	327.1	359.81	3057.1	2779
18. Manual Servo	80.27	88.30	12457	11325
19. Automatic Control	60.95	67.05	16406	14914
20. Clipper Detector (Manual)	227.88	250.67	3586.8	3989
21. Manual Control (BQR-2B)	7.16	7.88	139964	126900
22. Manual Control (BQS-4)	3.06	3.37	326797	296736
23. Audio Amplifier (BQR-2B)	84.44	92.89	11842	10765
24. Audio Amplifier (BQS-4)	15.67	17.25	63816	57971
25. Audio Filter	11.17	12.29	89525	81367
26. Audio Mixer	36.89	40.59	27107	24673
27. Azimuth Range Indicator (Audio)	34.73	38.20	28793	26178
28. Azimuth Range Indicator (Video)	98.44	108.29	10158	9234
29. Main Scope	56.72	62.40	17630	16026
30. Servos AN/BQS-4 or	(265.8)	(292.38)	(3762)	(3420)
Servos AN/BQS-4A	(174.51)	(191.96)	(5730)	(5209)
31. Test Equipment and Nonessential Parts	248.21	273.03	4028	3663
Summation:	6478.2 6569.4	7126.0 7226.4		
Overall System MTBF ($\frac{10^6}{\text{Failure Rate}}$):			154.4 152.2	140.3 138.4
* Adjustment Factor = 1.1.				

3.1.3 Calculated Equipment MTBF

Because of the additional servo system in the AN/BQS-4 configuration, the MTBF values for the AN/BQS-4 are slightly different from those of the AN/BQS-4A. Each of the MTBF values presented for the AN/BQS-4 or AN/BQS-4A has been multiplied by the applicable adjustment factor (1.1 for Sonar equipment)* listed in NAVSHIPS 93820.

The failure rates and MTBF values determined for each mode of operation of the AN/BQS-4 and AN/BQS-4A are summarized in Table 2.

TABLE 2

FAILURE RATES AND MTBF VALUES BY OPERATING MODE

Operating Mode	Failures Per Million Hours		Mean Time Between Failures (Hours)	
	Without Recorder	With Recorder	Without Recorder	With Recorder
PPI Mode (Figure 1)				
AN/BQS-4	5352.8	6058.8	186.8	165.0
AN/BQS-4A	5252.4	5958.4	190.4	167.8
A-Scan (Figure 2)				
AN/BQS-4	4774.1	5480.1	209.5	182.5
AN/BQS-4A	4673.6	5379.6	214.0	185.9
Listing Mode (Figure 3)				
AN/BQS-4	4480.2	5186.2	223.2	192.8
AN/BQS-4A	4479.7	5185.7	223.2	192.8
AN/BQR-2B/C Listing Set (Figure 4)	2718.5	3424.5	367.8	292.0

3.2 Equipment/Document Deficiencies

3.2.1 Areas of Unnecessary Equipment Complexity and Marginal Design

In the evaluation of equipment complexity, two separate factors must be recognized: (1) unnecessary complexity in equipment design techniques, and (2) unnecessary complexity in redundant functions.

Since this portion of the equipment evaluation was accomplished as part of the work associated with the "Method D" prediction, the depth of the analysis was necessarily not that of a separate design-analysis program. However, within this limitation, ARINC Research determined that there are instances of unnecessary

*The adjustment factors in NAVSHIPS 93820 are included to compensate for adjustment-type failures associated with four general categories of equipment.

design complexity in the AN/BQS-4/4A equipment.

One aspect of the AN/BQS-4/4A design that may contribute to problems of reliability and maintainability was noted during the prediction effort. The synchronous-mechanical drive mechanism for the listening/scanning function is a complex arrangement of slip rings and sensing brushes that normally will exhibit low reliability and contribute undesirable audio-frequency noise that lowers overall system sensitivity. While this complex sensing method may have been the most practical device for the scanning function at the time of system design, present solid-state techniques could be employed to produce a digitized scan function that would have higher reliability and a lower inherent noise level.

Study of the redundant functions in the AN/BQS-4/4A equipment indicates that one major but questionable redundancy is the need for two operators when the system is in operation. This redundancy could be eliminated by transferring controls peculiar to the C-2588/BQS-4 or the C-2735/BQS-4A Control Indicator to the control indicator for the AN/BQR-2B/C. Other functions within the AN/BQS-4/4A Control-Indicator cabinets, including the recorder rack could be located in a remote, unmanned rack. Such a change should be justified on a cost-effectiveness basis; however, this is outside the scope of the "Method D" prediction task, and pertinent supporting data were not furnished to ARINC Research.

The recording function of the AN/BQR-2B/C Listening Set provides one redundant method of determining bearing. A requirement for this function cannot be specifically discerned from a design analysis of the equipment. Tactical considerations unknown to ARINC Research may dictate the use of this method.

3.2.2 Parts Misapplication

Instances of misapplication of parts (marginal design) are recorded in Table 3. This listing is restricted to parts stressed in excess of 70 percent of maximum ratings.* The stress level of all components is given on the work sheets in the appendix.

3.2.3 Document Deficiencies

The document discrepancies described in Table 4 are representative of the types of errors (inconsistency between documents, omissions, errors, unidentifiable changes) discovered during the equipment analysis. Because they were so numerous, all discrepancies may not be contained in this list. In addition, numerous entries of apparent equipment modifications (as exemplified by the pen-and-ink entry, "...RC20GF204J" on page 7-34 of NAVSHIPS 93530, Volume 3, Section 7, Sonar Detecting-Ranging Set, AN/BQS-4 and AN/BQS-4A) could not be identified as official document changes.

* This value was established during a meeting of ARINC Research and NAVSECNORDIV Reliability Engineering Division representatives, 28 February 1967.

TABLE 3

OVERSTRESSED COMPONENTS, AN/BQS-4/4A

Component Location	Circuit Symbol	Stress Level (Percent)	Component Location	Circuit Symbol	Stress Level (Percent)
Transmitter (1.1)	C 5034	71	Recorder Servo (continued) (12)	C 717	70
	C 5106	75		V 705	73
	C 5110	98		V 706	73
	C 5111	75		V 706	84
	C 5113	75		V 707	75
	C 5114	83	Clipper Detector (13)	R 239	85
	C 5301	84		R 240	85
	C 5302	84	Azimuth Indicator (14)	R 284	77
	R 5048	127		R 851	110
	R 5055	74	Azimuth Indicator (15)	R 814	72
	R 5136	84		R 822	72
	R 5149	146	Automatic Control (19)	C 312	71
	R 5150	146		R 428	74
Power Supplies (2)	C 2514	76	Clipper Detector (20)	C 308	71
	C 2516	75		C 347	71
	C 6001	100		C 348	71
	C 6002	84		C 349	71
	C 6003	84		C 350	71
	R 853	70		R 315	92
	R 6002	356		R 316	92
	R 6004	356		R 381	114
	R 6009	87		R 382	111
	R 6011	330	Manual Control (21)	C 501	100
	R 6012	330	Audio Amplifier (23)	C 232	71
Timing Circuits (3a)	C 2105	76		C 233	71
	R 2150	84	Audio Mixer (26)	R 2815	81
	R 2171	73	Main Scope (29)	R 2281	81
	R 2196	82		V 2256	90
	R 2135	90		V 2257	90
	R 2136	90	Servos (30)	C 4003	100
	R 2137	90		R 713	71
Timing (A Scan) (3b)	R 2196	83		V 4530-2	125
Receiver (5)	R 2320	92		V 4507-2	72
	R 2324	81		V 4530-1	125
	R 2370	96		V 4507-1	72
	R 2832	144	Test Set (31.1)	C 4602	77
Cursor (7A)	C 2517	83		C 4606	75
	R 2260	81		R 4605	156
	R 2392	262		V 4602	81
Power Supplies (10)	R 411	74	Test Circuit (31.3)	R 186	122
	R 412	74		R 187	136
	C 808	75			
	R 853	71			
Recorder Servo (12)	C 721	80			
	C 722	80			

TABLE 4

DOCUMENT DISCREPANCIES - AN/BQS-4/4A

NAVSHIPS 93530, Volume 2, pp. 5-15 and 5-69, 5-70. In Step 18, secondary test point (D), a voltage is to be measured between TP-5107 and ground, TP-5108. Test point (D), pp. 5-69, 5-70, indicates that this measurement is to be taken between TP-5107 and some unidentifiable point associated with V5111.

NAVSHIPS 93530, Volume 2, pp. 5-19 and 5-69, 5-70. In Step 35, secondary test point (H_2), a voltage is to be read between T-5102-2 and ground (unspecified test point). Test point (H_2), pp. 5-69, 5-70, indicates that this reading is to be taken between T-5102-5 or 6 and one end of coil, L-5101.

NAVSHIPS 93530, Volume 2, pp. 5-59 and 5-99, 5-100. In Step 5, test point (YY_2), p. 5-59, the voltage from T-4602 pin 3 to ground and from pin 4 to ground is to be read.

According to schematic drawing, Figure 5-35, pp. 5-99, 5-100, pin 4 of T-4602 is grounded. (In all probability, the directions should have read "...and from pin 5 to ground...")

NAVSHIPS 93530, Volume 2, pp. 5-75, 5-76 and 5-111, 5-112. On schematic Figure 5-29, pp. 5-75, 5-76, pins 1, 2, 5, and 7 are listed as active elements of tube V2325 (5726). In Figure 5-45, pp. 5-111, 5-112, the voltage/resistance listings for V2325 (5726) show values for pins 1, 3, 4, 5.

NAVSHIPS 93530, Volume 2, pp. 5-75, 5-76 and 5-111, 5-112. On schematic Figure 5-29, pins 2 and 7 of V2317 are tied to -150Vdc source through R2364.

In voltage/resistance listings for V2317, Figure 5-45, pp. 5-111, 5-112, pins 2 and 7, respectively, list -145 and 145.

NAVSHIPS 93530, Volume 3, Section 7, p. 7-9 NAVSHIPS 93530, Volume 2, pp. 5-75, 5-76 According to the listing for C2308, p. 7-9, NAVSHIPS 93530, Volume 3, Section 7, the capacitor is "NOT USED". Figure 5-29, pp. 5-75, 5-76, NAVSHIPS 93530, Volume 2, lists C2308 as a 0.01-µf coupling capacitor to V2319.

NAVSHIPS 93530, Volume 3, Section 7, p. 7-35 NAVSHIPS 93530, Volume 2, pp. 5-75, 5-76. The listing for R2818, p. 7-35, NAVSHIPS 93530, Volume 3, Section 7 indicates that the resistor is "NOT USED". Figure 5-29, pp. 5-75, 5-76, NAVSHIPS 93530, Volume 2, lists R2818 (7.5K ohms) as part of the cathode circuit of V2327A.

NAVSHIPS 93530, Volume 3, Section 7, p. 7-43, NAVSHIPS 93530, Volume 2, pp. 5-93, 5-94, and 5-106, NAVSHIPS 93530, Volume 3, Section 7, p. 7-43, and NAVSHIPS 93530, Volume 2, pp. 5-93, 5-94, list V2403 as a 5R4WGB. NAVSHIPS 93530, Volume 2, p. 5-106, lists V2403 as a 5Y3WGA.

NAVSHIPS 93530, Volume 3, Section 7, p. 7-25, NAVSHIPS 93530, Volume 2, pp. 5-77, 5-78. The listing for R2277 on p. 7-25, NAVSHIPS 93530, Volume 3, Section 7, indicates that this resistor is "NOT USED". Figure 5-3, NAVSHIPS 93530, Volume 2, pp. 5-77, 5-78, indicates that R2277 is a 50K-ohm resistor. NOTE: The same type of discrepancy as that mentioned in items 7 and 9 was noted for the following components:

R2291	R2393	R2223	R2377
R2258	C2190	R2271	C4504

NAVSHIPS 93530, Volume 3, Section 7, pp. 7-32, 7-30, 7-28, NAVSHIPS 93530, Volume 2, pp. 5-95, 5-96. On page 33, NAVSHIPS 93530, Volume 3, R2533 is listed "SAME AS R2366". R2366 is listed as 27,000-ohm RC32GF273J resistor. Schematic Figure 5-34, pp. 5-95, 5-96, NAVSHIPS Volume 2, shows R2533 as a 29,000-ohm resistor.

NAVSHIPS 93530, Volume 3. Authority for the following "pen and ink" changes is not listed:

(1) p. 7-28 R2369 From NOT USED to SAME AS R2131

(2) p. 7-32 R2533 From SAME as 2411 to SAME AS 2306

(3) P. 7-32 R2557 From NOT USED to USED

(4) p. 7-34 R2805 From RC20GF250J to RC20GF204J

(5) p. 7-75 R5138 From NOT USED to R3158 - 910K ohms

NAVSHIPS 93530, Volume 3, Section 7, p. 7-32, NAVSHIPS 93530, Volume 2, pp. 5-81, 5-82. The listing for R2555 on p. 7-32, NAVSHIPS 93530, Volume 2, shows it to be a 100-ohm resistor (RC32GF101J). Schematic, Figure 5-31, pp. 5-81, 5-82, NAVSHIPS 93530, Volume 2, shows R2555 as a 100K-ohm resistor.

NAVSHIPS 93530, Volume 2, p. 5-104. The voltage/resistance values for V4504, p. 5-104, are both labeled as V4504 and V4503.

3.3 Part Replacement Rates

Replacement rates were taken from Vitro Laboratories Technical Note 1744.00-2. The most striking omission from this document was that of the replacement rate for transistors. After extensive review of transistor reliability and application information the following authority was found to be both technically compatible with the current evaluation and of sufficient scope to provide realistic data:

> John E. Shwop and Harold J. Sullivan*, Editors, Semiconductor Reliability, Engineering Publishers, Elizabeth, New Jersey, 1961, Chapter 22, "Semiconductor Failures Versus Removals."

The transistor replacement-to-failure ratio of 2.465:1 determined from this source was used in the appendix to derive the replacement rate for all transistor entries.

A replacement rate for frequency-determining crystals is not included in the Vitro document. After careful consideration of the application of crystals in the AN/BQS-4/4A (in single rather than multiple installations) and of test provisions to monitor crystal performance, it was determined that the most feasible replacement-to-failure ratio for this component was 1:1.

The correction factor of 1.5 was applied since the price of this item is less than $15.** This procedure is employed in all replacement rate entries for crystals in the AN/BQS-4/4A.

3.4 Functional Reliability Diagrams

From operational data contained in NAVSHIPS 93530, Volumes 1 and 2, the following modes of operation were determined to be representative of actual equipment performance: PPI (echo ranging and single ping), A-Scan (single ping), Listening (BQS-4/4A), and Listening (BQR-2B/C). The corresponding functional reliability diagrams are shown in Figures 1, 2, 3, and 4 respectively.

The PPI mode consists of two types of operations -- echo ranging and single ping. In the echo-ranging operation the transmissions are keyed automatically by the timing circuit, whereas in the single-ping operation the transmissions are keyed manually. The timing circuits are required for the performance of other functions in both operations. The single-ping operation requires the use of an additional switch and a load resistor. These two additional components do not cause a significant change in reliability. Therefore, both operations are represented by the functional reliability diagram for the PPI mode.

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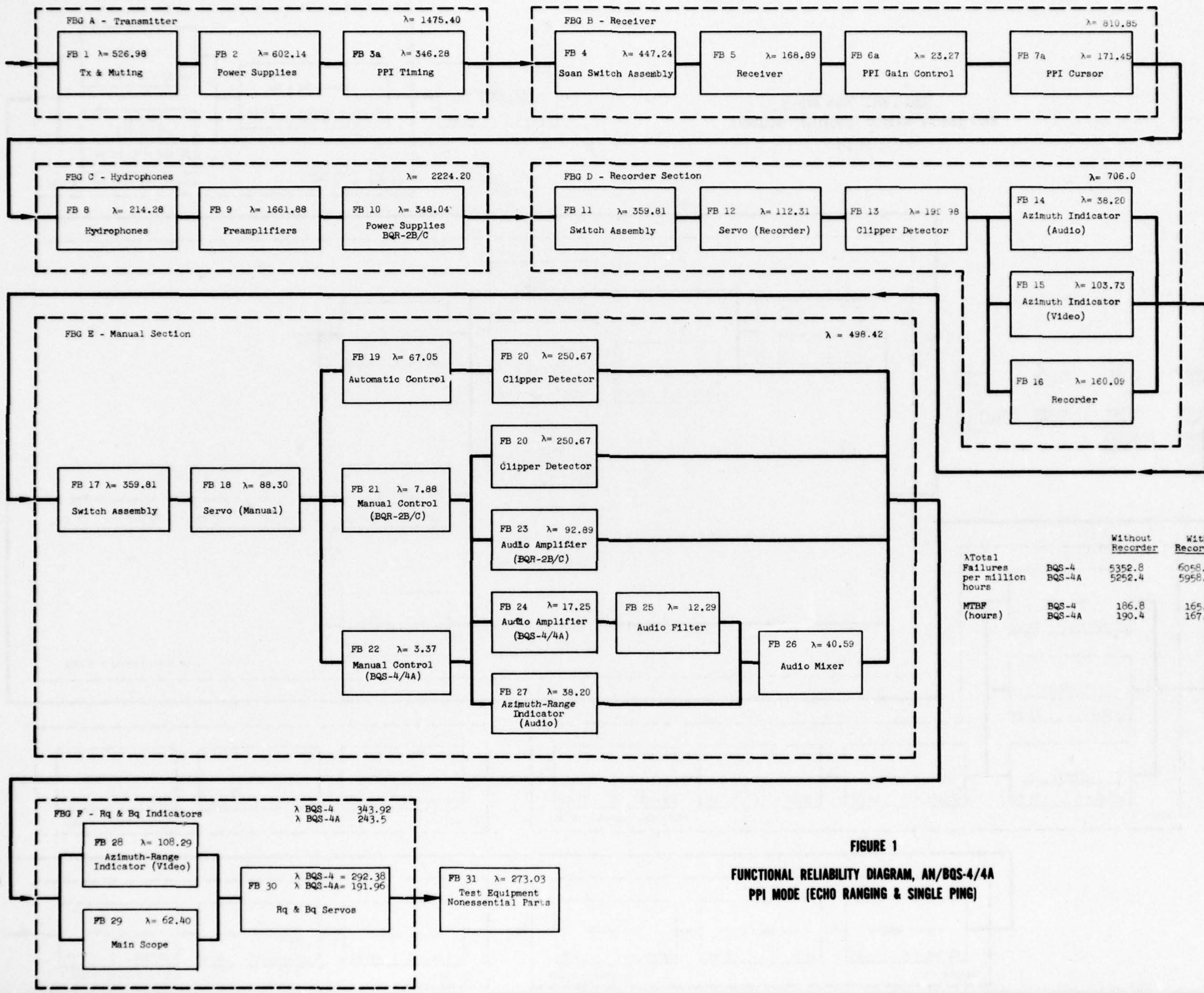
* Mr. Shwop is with the Industrial Preparedness Activity, U.S. Army Signal Supply Agency. Mr. Sullivan is a research scientist at New York University.

** Appendix F, Vitro Laboratories Technical Note 1744.00-2, 30 April 1963. The replacement rates in this document require a correction factor of 1.5 for items with a unit price of less than $15.00. For those items with a unit price of $15.00 or over, no correction factor is necessary.

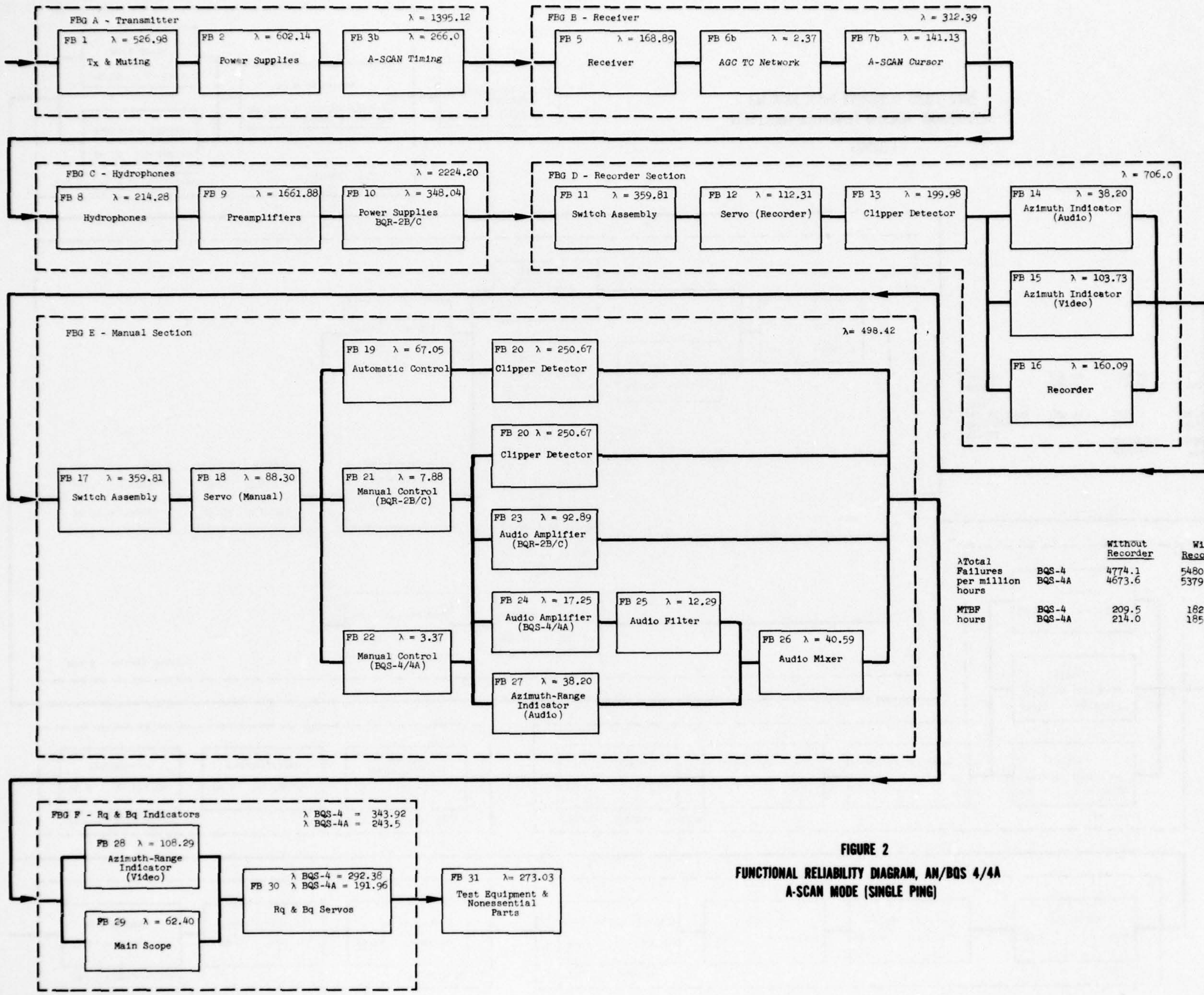
Care was taken to include within each functional block only parts that can cause the function to fail. Other nonessential components were listed in a separate block with the test equipment. This functional block (test equipment and nonessential parts) was included in the overall system MTBF calculation to give the worst case. It should not be included when the mission reliability of the system is being determined.



		Without Recorder	With Recorder
λTotal Failures per million hours	BQS-4	5352.8	6058.8
	BQS-4A	5252.4	5958.4
MTBF (hours)	BQS-4	186.8	165.0
	BQS-4A	190.4	167.8

FIGURE 1

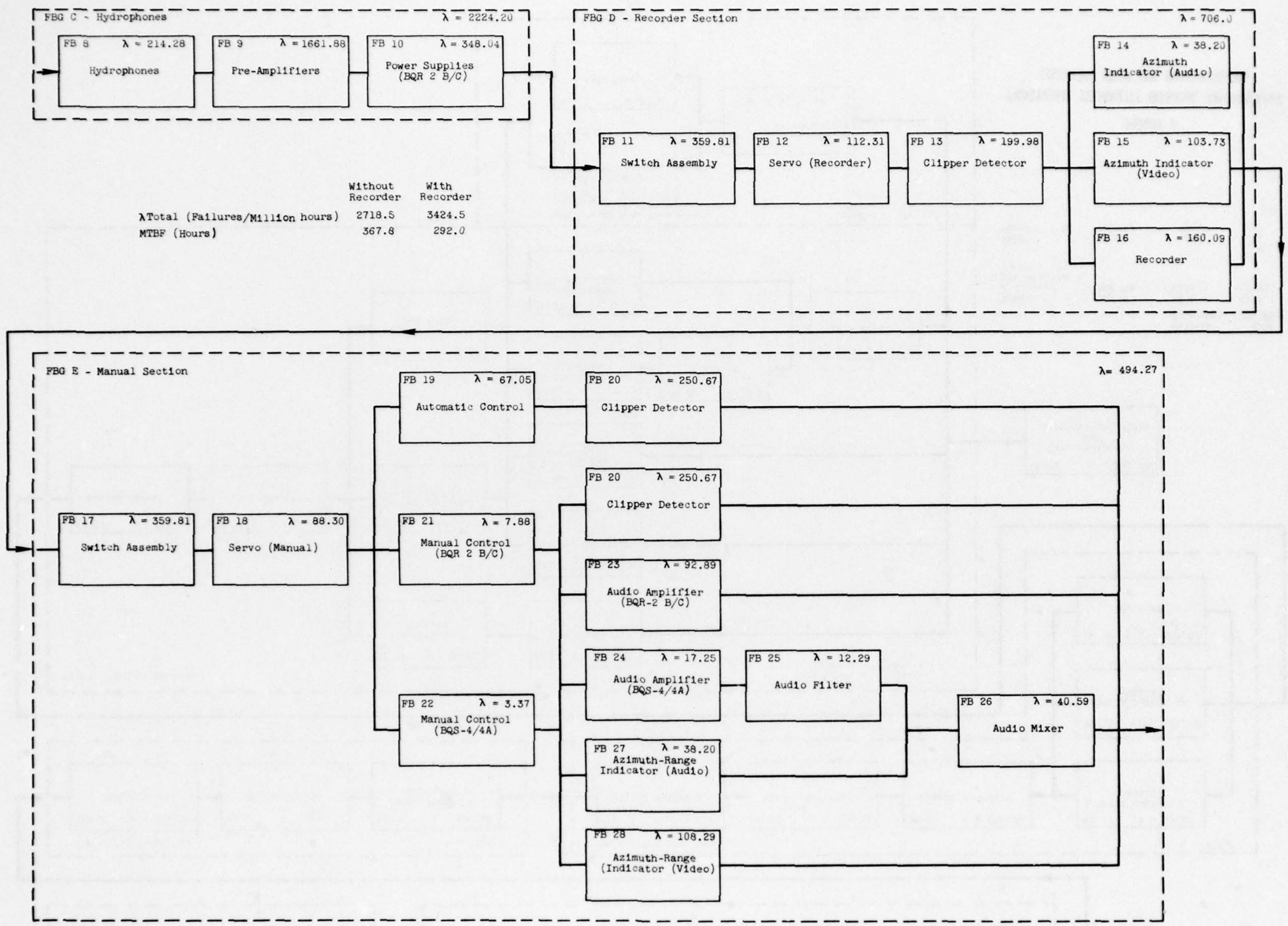
FUNCTIONAL RELIABILITY DIAGRAM, AN/BQS-4/4A PPI MODE (ECHO RANGING & SINGLE PING)



		Without Recorder	With Recorder
λTotal Failures per million hours	BQS-4	4774.1	5480.1
	BQS-4A	4673.6	5379.6
MTBF hours	BQS-4	209.5	182.5
	BQS-4A	214.0	185.9

FIGURE 2

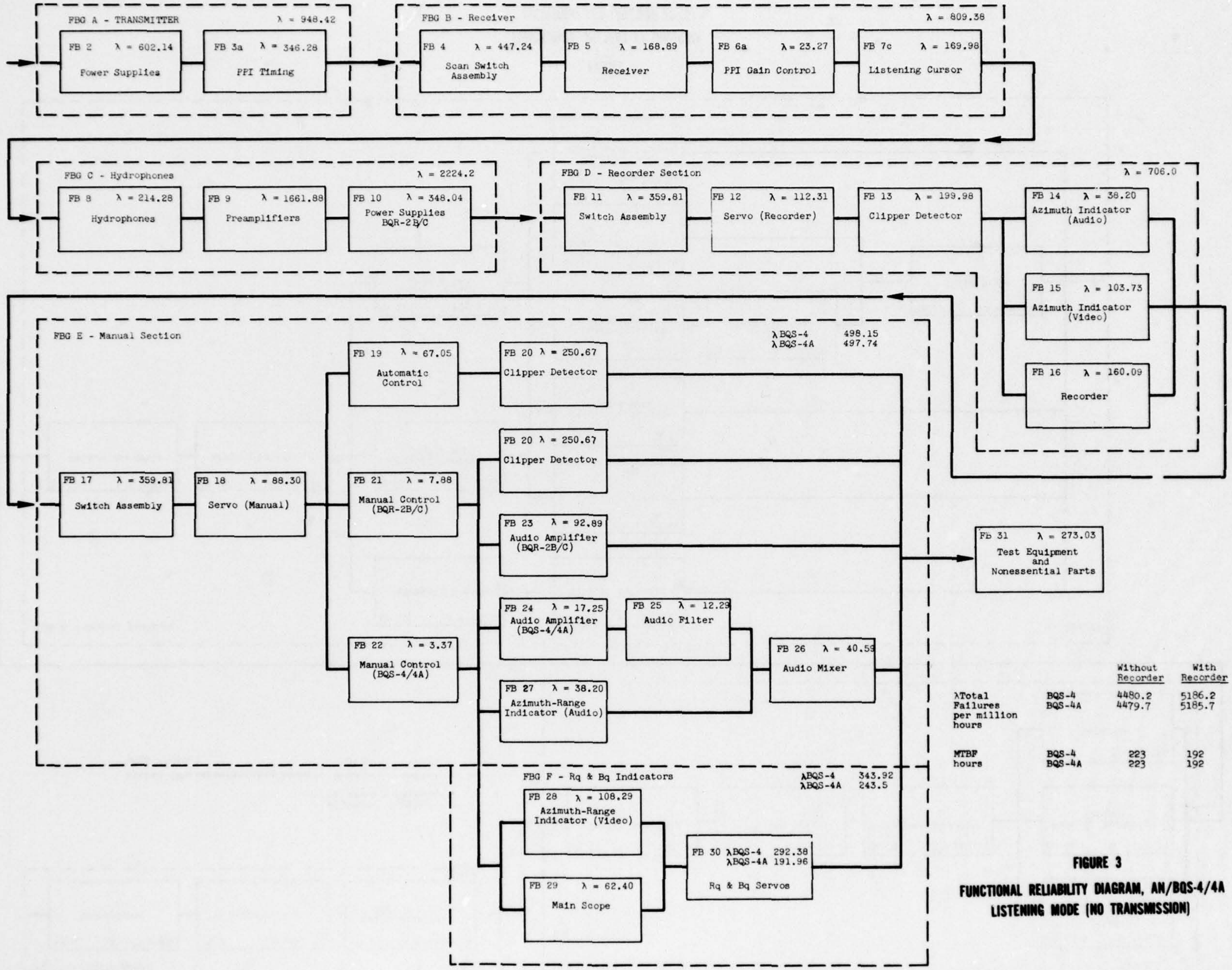
FUNCTIONAL RELIABILITY DIAGRAM, AN/BQS 4/4A A-SCAN MODE (SINGLE PING)



	Without Recorder	With Recorder
λTotal (Failures/Million hours)	2718.5	3424.5
MTBF (Hours)	367.8	292.0

FIGURE 4

FUNCTIONAL RELIABILITY DIAGRAM
LISTENING SET (AN/BQR-2B/C)



		Without Recorder	With Recorder
λTotal Failures per million hours	BQS-4	4480.2	5186.2
	BQS-4A	4479.7	5185.7
MTBF hours	BQS-4	223	192
	BQS-4A	223	192

FIGURE 3

FUNCTIONAL RELIABILITY DIAGRAM, AN/BQS-4/4A LISTENING MODE (NO TRANSMISSION)

4. CONCLUSIONS

The conclusions reached as a result of the tasks described in this report are as follows:

- There is unnecessary design complexity in the AN/BQS-4/4A, particularly in the synchronous drive for the listening/scanning function and in the multiple control consoles.
- Several components (listed in Table 3) in the AN/BQS-4/4A equipment are stressed beyond their rated values.
- A review of technical manuals for the AN/BQS-4/4A reveals numerous errors (as exemplified by the listing in Table 4). The currency of the documents is questionable, because of the numerous manual entries.
- The MTBF calculated for the AN/BQS-4/4A is comparable to that given for active Sonar Sets in Table 1 of NAVSHIPS 93820. The slightly lower MTBF can be attributed to the additional recording equipment used for continuous monitoring and not to frequently failing functions.

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5. RECOMMENDATIONS

The following recommendations are offered:

- Components in the AN/BQS-4/4A that exhibit overstressing should undergo on-equipment testing to confirm the overstress conditions. Documented component failures should be reviewed to assist in determining if the apparent overstressed areas are in fact contributing to equipment failures.
- The technical manuals associated with the AN/BQS-4/4A should be corrected, with particular emphasis on the following:
  - Consistency between documents
  - Proper listing of official changes
- The feasibility of converting from the present synchronous mechanical-drive mechanism to a state-of-the-art digitized scan technique should be investigated.
- Consideration should be given to the impact that combining the functions of the two control indicators into one unit would have on cost-effectiveness, increases in reliability, maintainability improvements, and operational employment.

APPENDIX

WORK SHEETS

This appendix presents work sheets used to derive failure and replacement rates for the AN/BQS-4/4A Sonar system.

For ease in locating components, the tables for this appendix are numbered to correspond to the functional blocks of the reliability diagrams. Components are listed in alpha-numerical order by function. A decimal point in a table number indicates additional units within the same functional block. The unit failure rates are summed, and the total failure rate for each functional block is given.

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