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NRL REPORT F-3417

FR-3417

# FULL SCALE SHOCK TESTS - USS NIAGARA APA87

## PART 2 - FAILURES IN ELECTRONIC EQUIPMENT

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# FULL SCALE SHOCK TESTS - USS NIAGARA APA87
## PART 2 - FAILURES IN ELECTRONIC EQUIPMENT

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February 15, 1949

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## ABSTRACT

The electrical and mechanical failures on 30 identical units of Navy Model BN electronic equipment during full-scale underwater noncontact explosions against the USS NIAGARA APA87 are described. No major mechanical failures were encountered. Practically all failures were attributed to improper location or inadequate design of a few selected components. In general, the equipment could be made to function properly after each explosion by making minor mechanical or electrical repairs.

The identical equipments are being subjected to shock produced by laboratory shock machines in an effort to correlate laboratory produced shock with field conditions.

## PROBLEM STATUS

This is an interim report on this problem; work is continuing.

## AUTHORIZATION

NRL Problem F03-07R (BuShips Problem SRD 1509-48).

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# FULL SCALE SHOCK TESTS - USS NIAGARA APA87
# PART 2 - FAILURES IN ELECTRONIC EQUIPMENT

## INTRODUCTION

During the summer of 1948 full-scale underwater noncontact-explosion tests were conducted against the USS NIAGARA APA87 in the Chesapeake Bay. The Naval Research Laboratory, as one of the participating laboratories, was interested in the effect of shock on electronic equipment, and the effectiveness of shock mountings.

This report summarizes the failures noted on 30 identical units of electronic equipment mounted in various locations throughout the ship, as a result of explosive shock. The analysis of the shock motions at the base of the equipments, and the correlation of the failures noted in the full scale shock trials with failures produced on identical equipments by laboratory shock machines are in progress and will be the subject of a future report.

This report is one of a series. Part 1 - Techniques and Instrumentation, NRL Report No. F-3404 describes the test procedure, the instrumentation employed during the tests, and the purposes of the various measurements. Subsequent reports will present additional data as they are analyzed.

## DESCRIPTION OF NAVY TYPE BN RADIO EQUIPMENT

The electronic equipment chosen for study during the full-scale shock tests was the Navy Model BN Radio Equipment. This equipment is an interrogator-responsor equipment intended for use and in conjunction with radar equipment to identify friendly craft equipped with suitable complementary apparatus.

Essentially, the Model BN equipment is a transmitter and receiver with a common power supply. The equipment is housed in a reinforced sheet-metal box 16½ inches wide, 18 inches deep, and 12½ inches high. The weight of the equipment and the housing is 156 pounds. A total of 24 vacuum tubes are

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used in the equipment. The types of tubes used and the number of each employed are listed in the following tabulation.

| Tube Type | Number employed |
|---|---|
| 6J6 | 1 |
| 6J4 | 1 |
| 6J5 | 1 |
| 6AC7 | 9 |
| 6H6 | 3 |
| 6E5 | 1 |
| 6AG7 | 1 |
| 6SN7 | 2 |
| 6L6G | 2 |
| 15E | 1 |
| 3B24 | 1 |
| 5U4G | 1 |

As it was not possible to procure a sufficient number of these equipments from regular Navy sources, 50 partially completed units were purchased from a war-surplus establishment and shipped to the Laboratory for final assembly and checking. The Bureau of Ships supplied the tubes and power transformers which were the principal missing items. A small assembly line was set up at the Laboratory to expedite the work.

## LOCATION AND MOUNTING OF EQUIPMENTS

The 30 Model BN equipments were mounted in groups of three units (Figure 1) at 10 different locations throughout the ship. These 10

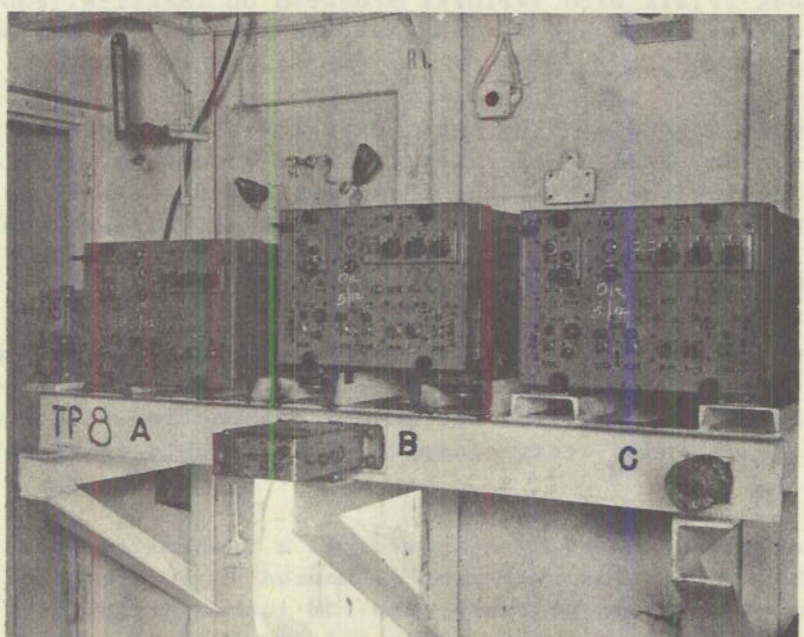


Figure 1- Mounting of BN Equipments

locations were designated as Test Positions 1-10 and they are fully described in Part 1 - Techniques and Instrumentation, NRL Report No. F-3404. Each of the three units located at each test position was supported by a different mounting arrangement. One unit was bolted securely to the mounting bracket without resilient mounts, and was designated as Mounting A. The second unit was supported on mounts providing about one inch of rubber, and was designated Mounting B. The third unit was supported on mounts providing approximately 3/8 inch of rubber, and was designated Mounting C. This third mounting plan is used extensively for supporting electronic equipment on naval vessels. The lowest natural frequency of vibration in any direction was above 20 cps for both mounting plans B and C. A mounting bracket for the three units was constructed according to Figure 2. For deck mounting, the two channels of the bracket were welded to the deck. For bulkhead mounting, the rear channel was welded to the bulkhead, and the front channel was supported by triangular gussets. Figure 1 shows three units on the bulkhead-supported mounting bracket.

In addition to the Model BN equipments, a British-type velocity meter, two multifrequency reed gages, and two peak-reading accelerometers were attached to the mounting bracket to determine the motions to which the equipment was subjected during shock. Lead deflection gages were mounted adjacent to the shock-mounted equipments to record the maximum deflection across the shock mounts.

## TEST PROCEDURE

Each Model BN equipment was checked for normal electrical operation before each explosion shot. The equipments were not energized during the explosions. Immediately after each explosion the units were checked for external mechanical failures, and then for normal electrical operation. After all electrical and mechanical failures were noted, the equipments were restored to their original condition as far as practicable.

A portable test unit was constructed to check the operation of the transmitter and receiver sections of the equipment separately. This test unit consisted of a pulse generator capable of triggering the transmitter section with a rectangular-shaped pulse of 20-volts peak, 20-microseconds duration, and a repetition rate of 250 cps. The r-f output of the transmitter was fed into an artificial load to measure the power output. The same pulse generator was also used to modulate a r-f signal generator whose output was fed through an attenuator to the receiver section of the equipment. The video output of the receiver was monitored by headphones.

## DESCRIPTION OF FAILURES

The component that sustained the most failures in the Model BN equipment during the underwater explosion program was the 15E (V23) vacuum tube. This tube is used as the pulsed oscillator in the transmitter portion of the Model BN equipment and is mounted in the oscillator assembly by means of its filament leads which come directly through the glass envelope of the tube. Most of the envelope breakage of this tube occurred where the glass envelope was sealed to the filament leads. Other failures of this vacuum tube were [redacted]nt, no emission, and loss of vacuum.

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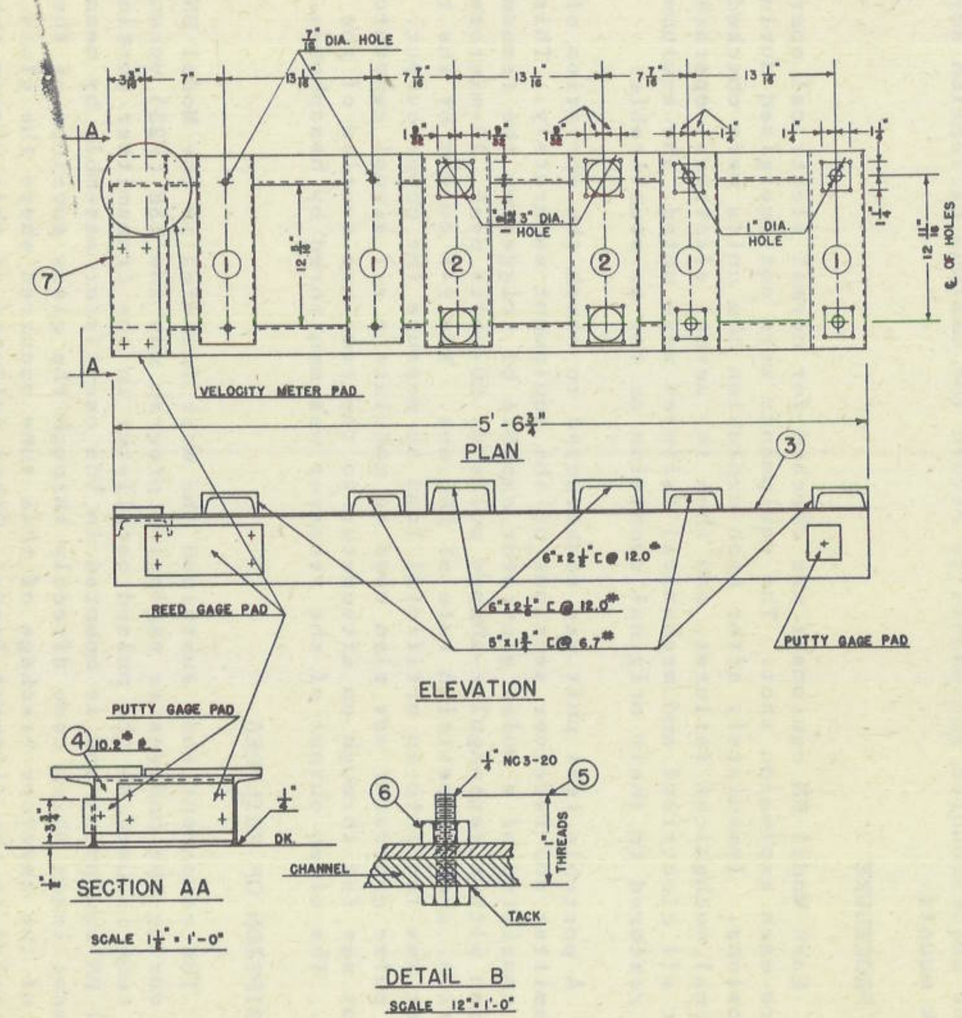
# MOUNTING BRACKET
## ELECTRONIC EQUIPMENT




| MATERIAL REQUIRED FOR ONE VESSEL | | | | | | |
|---|---|---|---|---|---|---|
| PC. NO. | NAME | MAT'L. | STOCK NO. | NO. REQ'D | TOTAL MAT'L. | SHOP ROUTING |
| 1 | 5x1 3/4"x6.7# ⊏ 16 5/16" Lg. | M.S | 48C570 | 40 | 3 Lengths Req'd. | 11 |
| 2 | 6x2 1/2"x12.0# ⊏ 16 11/16" Lg. | " | 48C635-20 | 20 | 8 " " | 11 |
| 3 | " " " 5'-6 3/4" Lg. | " | " " | 20 | Cut From Pc. 2 | 11 |
| 4 | 10.2# ℄ 3 3/4 x 12 11/16" | " | ——— | 10 | Scrap | 11 |
| 5 | 1/4" Bolt — 1" Long | Steel | 43B16354 | 360 | | 11 |
| 6 | 1/4" Hex. Bolts | " | " " | 360 | | 11 |
| 7 | 5"x1 3/4"x6.7# ⊏ 12 3/4" Lg. | M.S | 48C570 | 10 | Cut From Pc. 1 | |

## GENERAL NOTES

1. WELD ALL CONNECTIONS 100%
2. ASSEMBLE WITH 1/4" BOLT PC. NO. 5 IN PLACE SEE DETAIL B
3. TOTAL OF 10 FNDS. REQUIRED
4. FND. TO BE LEVEL & PARALLEL WITH ℄
5. ALL GAGES SHOWN FURNISHED BY N.R.L. TO BE SECURED BY MACHINE SCREWS

**Figure 2 - Part of NNSY Drawing No. APA87-S1113-SK627735**

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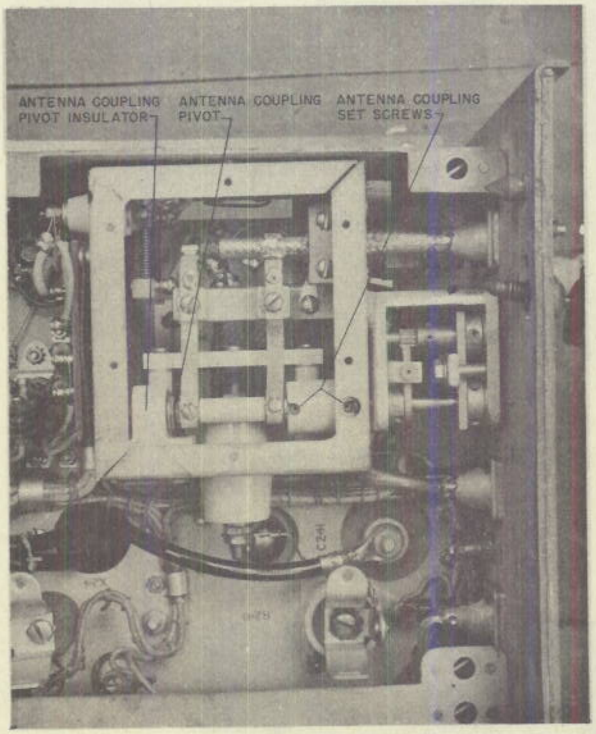
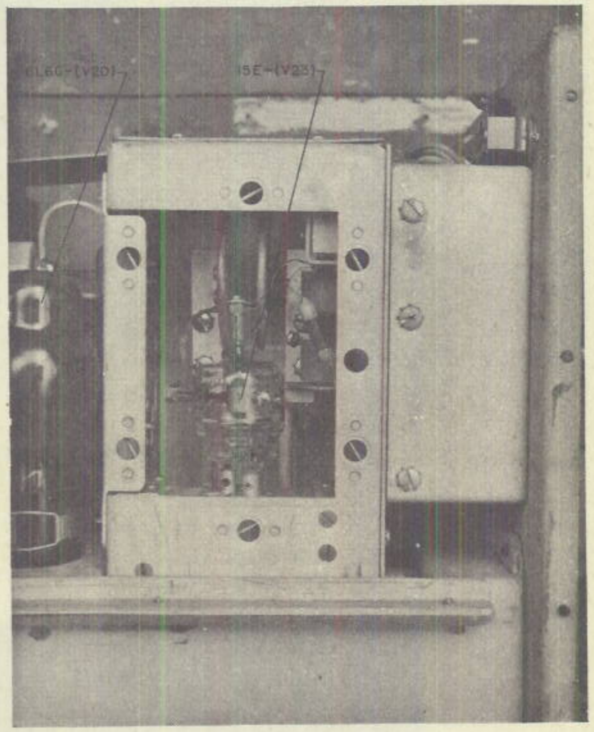
Many failures of the variable-antenna coupling loop located in the transmitter-oscillator assembly were encountered. The loop became dislodged from its pivot and shorted out the oscillator high-voltage plate supply. (See Figure 3.) The force holding the coupling loop in place at its pivot was applied by a coiled spring imbedded in a small ceramic insulator which is fastened to one side of the oscillator assembly case. Figure 4 shows the details of the antenna coupling-loop assembly.




Bottom View



Side View

Figure 3 - BN Oscillator Assembly Showing Components which Failed

The filament structure of the type 3B24 (V24) high-vacuum high-voltage rectifier tube could not withstand many of the shocks encountered during the program. This was indicated by the large number of disintegrated filaments found in this tube after many explosions. The other failures of this tube type were found to be loss of emission, loss of vacuum, and envelope breakage (Figure 5).

A total of 11 power transformers failed during the tests. These transformers (T251 - Navy No. 301201) failed principally from breakage of the transformer leads from the core windings to the case feed-thru insulators. The windings and the laminated core of this transformer are secured to the bottom mounting plate of the oil-filled protecting case by two right-angle brackets (Figure 6). These brackets and the transformer assembly act as a cantilever beam supported by one side of the transformer housing. There was approximately 1/4 inch clearance between the unsupported end of the transformer and the housing, so that during a severe shock, that end of the transformer was

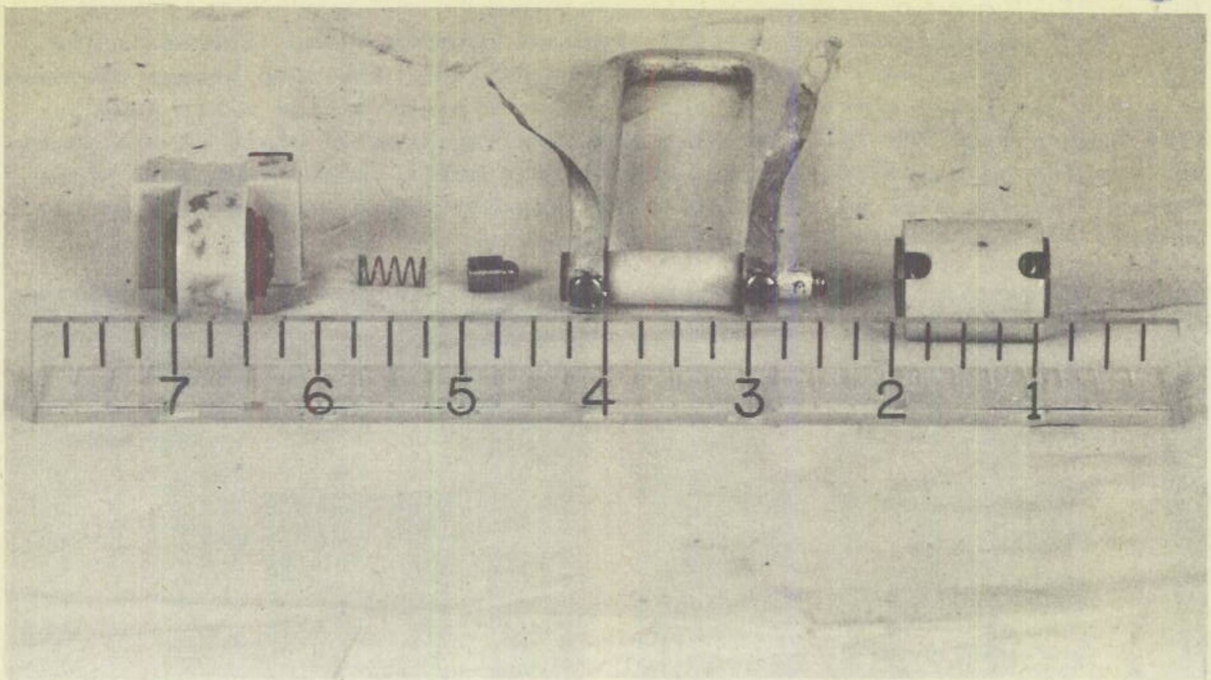



Figure 4 - Disassembly of Antenna Coupling

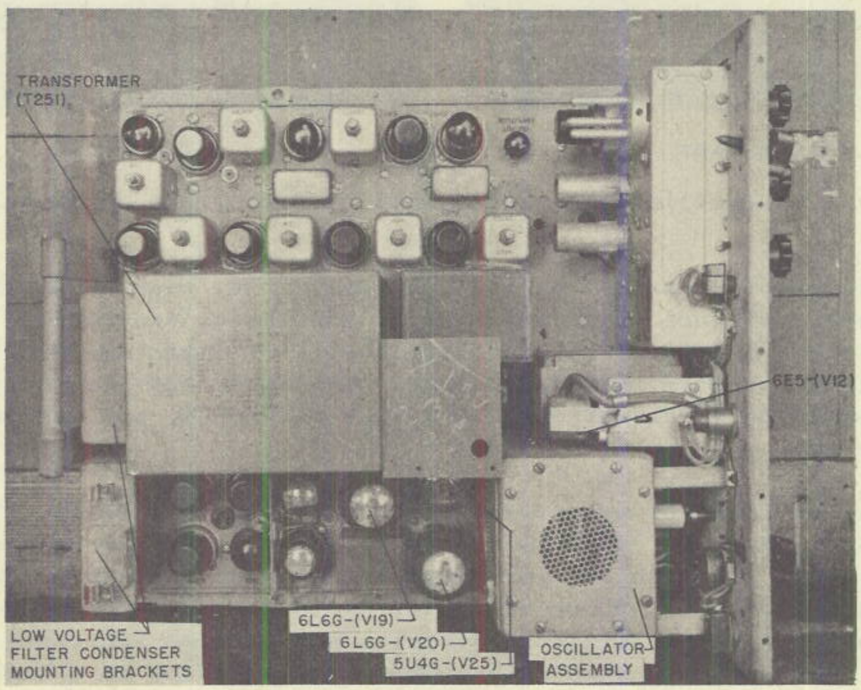



Figure 5 - Top View of BN Equipment Showing Components which Failed

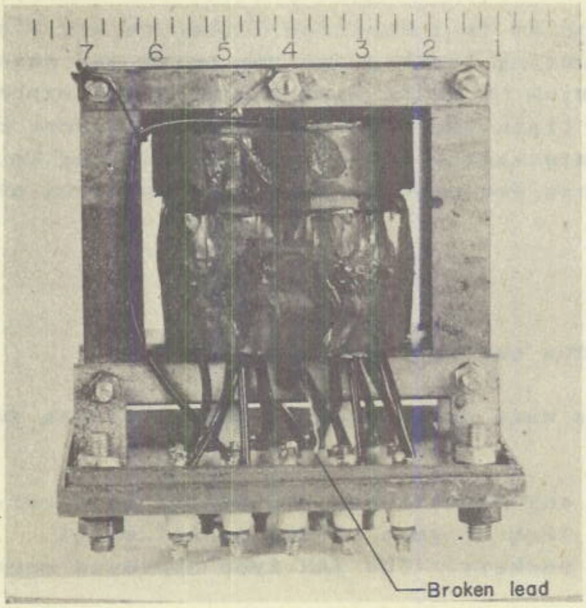


Figure 6 - Power Transformer with Case Removed

able to vibrate with 1/2 inch excursion. This vibration back and forth probably fatigued the lead wires causing the apparent transformer failures. The probability of failure was increased by the fact that the leads between the windings and the terminal board were multistrand copper wires, tinned a considerable portion of their lengths. This greatly stiffened those sections and increased the chances of fatigue where the lead was soldered to the feed-thru insulator.

Envelope breakage of the type 5U4G(V25) and 6L6G (V20) vacuum tubes was due primarily to the close proximity of these tubes to the side of the oscillator assembly, so that during shock these tubes would collide with the assembly causing fracture of the glass envelopes.

The mounting brackets for the low-voltage filter condensers failed many times. This failure was due to weak spade lugs which were fastened to the clamp by two rivets. The cross section of the spade lugs around the rivets was very small, and all clamp failures were due to the lugs failing under tension. Only a small number of spare condenser clamps were available and it was necessary to modify the clamps for the equipments located in Test Position 2. The spade lugs were brazed to the original steel clamp. No failures of this type were noted after these modified clamps were installed.

The type 6E5 (V12) magic-eye indicator-tube assembly came loose a number of times. This tube and socket are held in place by a wing nut on a bolt through a slot. This entire assembly is employed in many broadcast receivers and was never designed for shock resistant service.

The chart of equipment failures, Figure 7, lists an intermittent electrical defect. An equipment failure was listed in this class if the equipment failed to operate properly when first energized after a shot. The equipment would ordinarily be withdrawn from the housing for a detailed inspection, whereupon the equipment would function normally. If no visible defects were observed, and no further intermittent operation was observed after a few minutes of operation, the equipment would again be secured in its housing. It was later discovered that many of these intermittent electrical failures were probably due to loose or intermittent contacts of transformer leads inside the transformer cases. Small motions produced when the units were withdrawn would restore contact and the equipment would operate normally. Figure 8 presents graphically the total number of failures of each type.

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More equipment failures were noted at Test Position 2 than at any other position. This was expected as the mounting bracket for the units was secured to the outer framing inside the hull below the water line where it was exposed to the direct explosion wave. Table 1 lists the total number of failures occurring at each test position. It is interesting to note that excluding Test Positions 1 and 2, the number of failures for each of the three mounting plans was approximately equal.

## CONCLUSIONS

A number of interesting conclusions can be drawn from the data.

1. No failures of receiving-type tubes were encountered. This includes two miniature types.

2. Tube clamps were not installed on any metal tubes except the receiver-oscillator type 6J5. Despite the lack of tube clamps on all metal tubes, no tubes came out of their sockets. The JAN type approved socket was used in the equipment.

3. The type 3AG fuse holder with a manufacturer's designation of Type HKM was unsatisfactory. At least four cases of breakage due to internal mechanical failure were observed.

4. The method of mounting the type 6E5 (V-12) magic-eye tube on a slotted bracket with wing nut and bolt was unsatisfactory. Such construction should be avoided, as the tube socket came loose from the mounting bracket as a result of shock.

5. The failure to provide adequate clearance around the type 6L6G and 5U4G vacuum tubes accounted for a great many failures. It cannot be stressed too strongly that adequate clearance of a minimum of 1/2 inch around each vacuum tube is absolutely essential. No amount of ruggedization of the internal structure of a tube will be of any benefit if the envelopes are broken from impact with adjacent objects.

6. Most of the filament failures occurred in the directly-heated filament-type tubes such as the 3B24 and the 15E. The heater-cathode tube types withstood shock much better.

7. The support of the power transformer in its oil tight case was mechanically poor. An additional support at the opposite end of the case would have eliminated the excessive motion and reduced transformer failures.

8. Except for the defects mentioned above, the mechanical design of the equipment was good. The case was adequate and did not fail until structural damage of the ship adjacent to the equipment mounting bracket became apparent

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| TEST POSITION: NUMBER AND LOCATION | MOUNTING PLAN | SHOT: NUMBER | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 13A | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | WEIGHT (lbs) | 250 | 600 | 1200 | 600 | 1200 | 600 | 600 | 600 | 600 | 250 | 1200 | 1200 | 640 | 640 | 1200 | 1200 | 1200 | 1200 | 250 | 1200 | 1200 | 250 | 320 | 250 | 250 | 250 |
| | | DISTANCE (ft) | 325 | 325 | 325 | 325 | 325 | 185 | 185 | 185 | 325 | 185 | 220 | 185 | 185 | 185 | 155 | 124 | 110 | 88 | 131 | 170 | 120 | 105 | 65 | 0 | 46 | 0 |
| | | DEPTH (ft) | 70 | 70 | 70 | 70 | 70 | 70 | 17 | 70 | 17 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 53 | 110 | 134 | 110 | 134 | 134 | 119 | 65 |
| 1 11' below W.L. FR90 24' stbd of ℄ | A | | | | 6E | | 6E | 1B | | 1A | | | | | | | 6D | | 1D-11 | CANCELED | 11 | | 1A-11 | FAILED TO DETONATE | 11 | | 11 | |
| | B | | 15 | 7A | | | | | | | | | | | | | 1C | | | | | | 5D | | | | 15 | ● |
| | C | | | | | | | | | | 1A | | | | | | 1A | | 1A | | 15 | | | | | | | |
| 2 7' below W.L. FR-87 on stbd framing | A | | | 3D | 1D-3D | 1A | 1A-10 | * | | 1D-2A-16 | 1B | 1D-3D | * | 1D-2A | 11 | | 1D-2A-11 | 1D-2A-11 | 11 | | | | * | | 2A-6E | 2A | 2A-5D | |
| | B | | 1B | | | | | | | | | | 1A-14 | 1A | | | 6D-11 | 11 | 11 | | | | | | 6E-11 | | 1D-2A | ● |
| | C | | | | 1D | | | 3D-13-14 | | 3D-10 | | | 11-14 | 1D-5C | 1D | | 1A-15 | * | 1D-5A-8B | | | 1D | 1D-11 | | 11 | 11 | | |
| 3 1' above W.L. FR-83 15' stbd of ℄ | A | | | | | | | | | | | | | | 10 | | | | 1D | | | | 1A | | | | | |
| | B | | | | | | | | | | | | 8D | | | | | | | | | | | | | | | ● |
| | C | | | | | | | | | | | | | | | | | | | | | 1B | | | | | | |
| 4 14' above W.L. FR-87 on ℄ | A | | | | | | | | | | | 8A | | | | | 8B | | | | | | 15 | | 8B | | | |
| | B | | | | | 1C | | | | | | | | | | | | | | | 8B | | 15 | | | | | |
| | C | | | | | 6A | | | | | | | | | | | 15 | | | | | | | | | | | |
| 5 14' above W.L. FR-83 9' stbd of ℄ | A | | 15 | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | C | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 39' above W.L. FR-83 5' stbd of ℄ | A | | | | | 2B | | | | | | | | | | | | | | | | | 8B | | | | | |
| | B | | | | | | | 15 | | 8B | | | | | | | | | | | 10 | 9-10 | | | | | | |
| | C | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 37' above W.L. FR-80 6' stbd of ℄ | A | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | 9 | | | | | | | | | | | 6A | 10 | | | | 12 | | | 10 | | |
| | C | | | | 8A | | | | | | | | 8B | | | | | | 3D | | | | | | | | 11 | 5E |
| 8 41' above W.L. FR-80 10' stbd of ℄ | A | | | | | | | | | | | | | | | | | 10 | | | | | 10 | | | | | 15 |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | C | | | | | | | | | | | | 9 | | | | | | | | | | | | | | | |
| 9 8' above W.L. FR-64 on ℄ | A | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | C | | | | | 15 | | | | | | | | | | | | | | | | | | | | | | |
| 10 26' above W.L. FR-37 18' stbd of ℄ | A | | | | 15 | | | | | | | | | | | | | 10 | | | | | | | | | | |
| | B | | | | | | | | | | | | | | | | | | 8C | | | | | | | | | |
| | C | | | | | 9 | | | | | | | | | | | | | | | 2C | | | | | | | |
| | | | | | | | | * 1D-3D 6E-14 | | | | | * 1D-3D 5D-14 | | | | | * 1D-2A-3A 5D-11 | | | | | * 1D-2D-5D 6D-11-4D | | | | | |

## FAILURE CODE

Charge – HBX-1
Distance measured from starboard plating
Depth measured from surface of water

1- 15E Vacuum tube (V23)
2- 3B24 " " (V24)
3- 5U4G " " (V25)
4- 6L6G " " (V19)
5- 6L6G " " (V20)
6- 6E5 " " (V12)
7- 6H6 " " (V11)
8- Power transformer (T251)
9- Broken fuse holder
10- Antenna coupling loose (set screws)

11- Antenna coupling out of pivot
12- Antenna coupling lock loose (set screws)
13- Antenna pivot insulator broken
14- Low voltage filter condenser mounting brackets broken
15- Intermittent electrical defect
16- Oscillator assembly damaged beyond repair

**VACUUM TUBES**

A- Filament open
B- Gassy
C- No emission
D- Envelope broken
E- Out of mounting

**POWER TRANSFORMER**

A- High voltage open
B- Low voltage open
C- High voltage rectifier filament winding open
D- High voltage leakage

●- Test positions 1, 2, and 3 inaccessible following shot 25.

Figure 7 - Failure Chart for BN Equipments

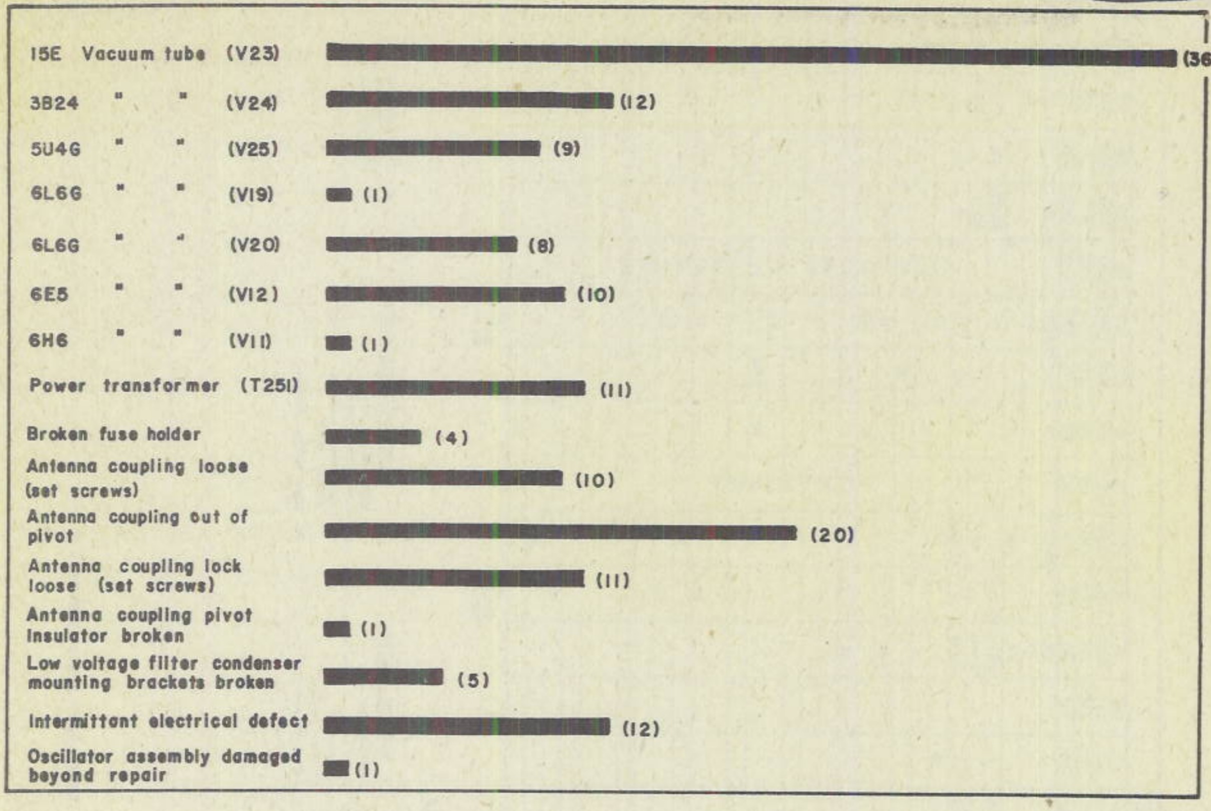


Figure 8- Comparison of Failures in BN Equipments

TABLE I

Total BN Failures at Each Test Position
vs
Type of Mounting

| Test Pos. / Mount | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 12 | 41 | 3 | 4 | 1 | 2 | 0 | 3 | 0 | 2 | 68 |
| B | 5 | 12 | 1 | 3 | 0 | 5 | 5 | 0 | 0 | 1 | 32 |
| C | 4 | 26 | 1 | 2 | 0 | 0 | 5 | 1 | 1 | 2 | 42 |