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DEC 78 K E NORMAN, H A NEWTON, W H HAMMER
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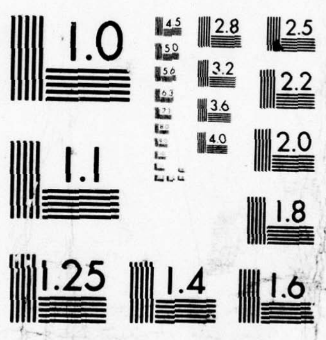

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This report describes and provides guidance for the installation of the Firing Cutout Interference Eliminator in the MARK 75 gun mount on USS PEGASUS (PHM 1).

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FOREWORD

This is the final report on the implementation of an interference eliminator on the MARK 75 gun mount on USS PEGASUS (PHM 1) to allow improved target engagement over the bow. Installation and evaluation were completed during the week of 22 May 1977 as authorized by Naval Sea Systems Command (NAVSEA) work request WRN0002477WR76012. The system was modified in May 1978 to relocate the 28 VDC power source from the gun system to the ship hydrofoil control system as recommended by the Weapons Systems Explosive Safety Review Board (WSESRB).

Development of the interference eliminator was accomplished with the help of personnel from the Ballistic Systems and Engineering Branch (G61), Weapons Systems Department, and the Systems Safety Engineering Branch (N41), Combat Systems Department.

Appendix A of this report was written by Mr. H. A. Newton (G61) and Appendix C by Mr. W. H. Hammer (N41).

This document has been reviewed by Mr. G. C. Blount and Mr. J. W. Ebbets of the Combat Systems Design and Engineering Division, Combat Systems Department.

Released by:

G. O. MILLER, Head
Combat Systems Department

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ILLUSTRATIONS

INTRODUCTION

USS PEGASUS (PHM 1), a patrol hydrofoil missile ship, is armed with the 76-mm/62-caliber MARK 75 MOD 1 gun mount. Although the major role of this gun is antiaircraft engagement, it is also used against surface targets.

Currently, the MARK 75 gun has pointing and firing cutout (P&FCO) systems that prevent it from firing at or physically striking the ship's structure or equipment. On PHM, the gun's firing cutout (FCO) system prevents firing into the zone occupied by the stowed forward hydrofoil. However, due to P&FCO system operational limitations, the FCO system also prevents firing in this zone when the hydrofoil is deployed and the zone is unoccupied, even though the gun could be safely fired in most of this area. The ability to fire into this zone would enhance the engagement capability against surface targets over the ship's bow.

The Naval Surface Weapons Center (NSWC) was tasked by the Naval Sea Systems Command (NAVSEA, PMS-303) to develop a dual firing zone capability for the MARK 75 to improve the ship's engagement capability by providing additional firing area when the hydrofoil is deployed.[1] This development resulted in the interference eliminator discussed herein.

This report describes implementation of the interference eliminator and provides guidance for its installation.

BACKGROUND

The MARK 75 gun mount pointing and firing cutout (P&FCO) systems consist of

1. A cam-actuated FCO system
2. An electronic pointing cutout (PCO) system
3. A cam-actuated PCO backup system
4. An electrical depression limit stop system and positive stop

The interference eliminator discussed herein affects the cam-actuated FCO and PCO backup systems.

The MARK 75 gun FCO and PCO backup systems consist of a series of cam-actuated microswitches and associated logic circuitry that allow or prevent gun pointing and firing. These cam-switch arrangements, located in the gun train and elevation synchro boxes, operate in synchronization with gun mount

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[1] Karl E. Norman and William M. Lebow, *PHM Class MARK 75 MOD 1 Engagement Capability Improvement Study*, Naval Surface Weapons Center, Dahlgren Laboratory Technical Report NSWC/DL TR-3614, Dahlgren, VA, February 1977.

motion. Whenever the gun barrel crosses a cutout zone boundary, the cam controlling that boundary actuates its microswitch to prevent firing and/or further gun mount motion.

An FCO solenoid is controlled by the cutout cam/microswitch logic circuitry. When the gun is pointing in a safe-to-fire zone, the cutout cam/microswitch logic circuitry is complete and the solenoid is energized, allowing the gun to fire. When the gun enters an FCO zone, the circuitry opens, the solenoid deenergizes, and the firing pin is blocked. The gun cannot fire until trained or elevated out of the FCO zone.

The PCO backup system operates in conjunction with the electronic PCO system. In normal operation of the electronic PCO system, the PCO backup cams never come into action; they merely provide a backup in case of electronic system failure. If the electronic PCO system fails, the PCO backup cams actuate when the gun trains or elevates into a PCO zone. This removes power from the gun drive motors and causes the gun to coast to a stop. Further information on these systems can be found in OP 4343.[2]

DISCUSSION

The objective of this task was to develop a means of switching from one firing cutout zone to another in response to a signal provided by a source external to the gun mount. The interference eliminator accomplishes this objective.

When the PHM's forward hydrofoil deploys and locks, an electrical signal is generated to energize a relay which switches an alternate set of FCO cams into operation. This set of cams allows the gun to fire in the FCO sector vacated by the hydrofoil. When the hydrofoil is not deployed and locked, the electrical signal is removed, the relay deenergizes, and cams that protect the hydrofoil are activated.

A circuit diagram of the interference eliminator is shown in Figure 1. Figure 2 illustrates the alternate FCO zones developed for USS PEGASUS' MARK 75 gun mount equipped with the interference eliminator. The circuit operates as follows:

1. When the hydrofoil is not deployed and locked, cam groups 4, 6, 8, and 10 (which control zone steps 4, 6, 8, and 10 on Figure 2) are activated and provide a four-step FCO zone which protects the hydrofoil in its stowed position.

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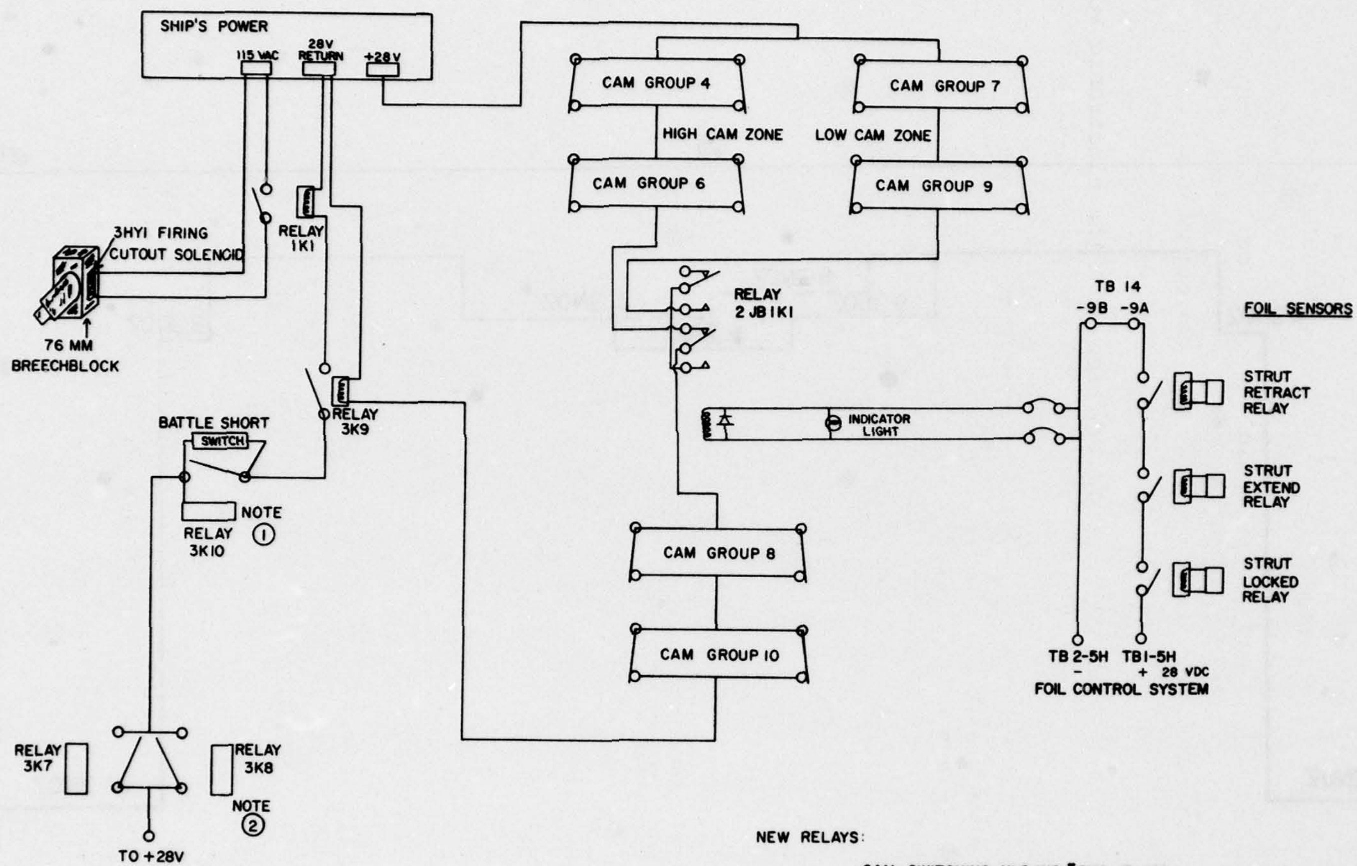
2 Ordnance Publication, *76-mm/62-Caliber Gun Mount MARK 75 MODs 0 and 1; Description and Operation*, Preliminary Naval Sea Systems Command OP 4343, Washington, DC, May 1974.



NEW RELAYS:

CAM SWITCHING: HI G INC. #2HA-1B-126 CRYSTAL CAM RELAY

FOIL SENSING: MS-27400 QUALIFIED RELAYS

NOTES:

① ENERGIZED WHEN MOUNT IS SYNCHRONIZED WITH REMOTE TRAIN AND ELEVATION ORDERS.

② ENERGIZED WHEN FIRING SWITCH IS CLOSED

Figure 1. Interference Eliminator Circuit

LEGEND:

1. SOLID LINES REPRESENT FIRING CUTOUT ZONE IF FORWARD HYDROFOIL IS STOWED.
2. DASHED LINES REPRESENT MODIFICATION OF FIRING CUTOUT ZONE IF FORWARD HYDROFOIL IS DEPLOYED AND LOCKED.

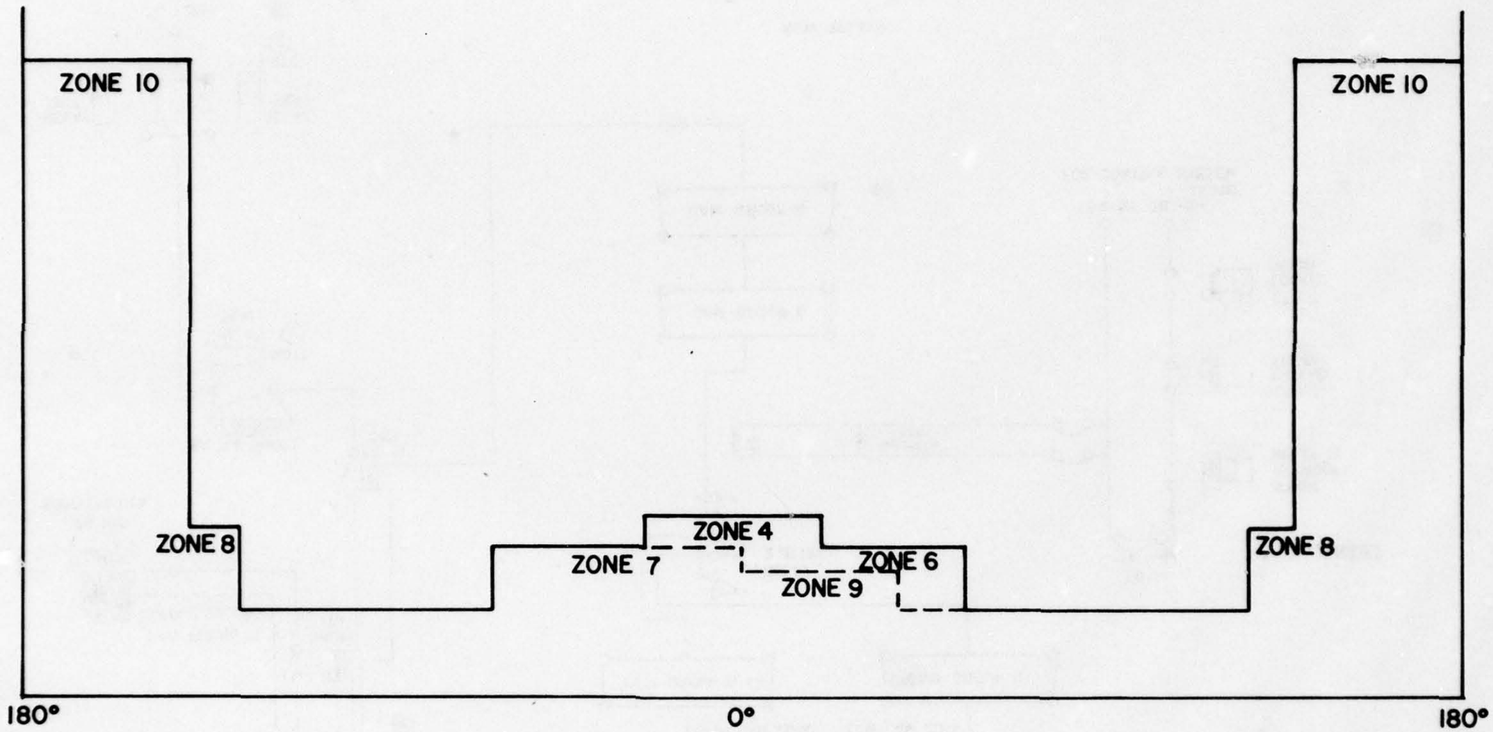


Figure 2. Firing Cutout Zone with Interference Eliminator

2. When the hydrofoil is deployed and locked, position sensors located in the hydrofoil control system provide a set of switch closures which allows +28 VDC to be supplied to a cam switching relay. Alternate cam groups 7 and 9 (which control zone steps 7 and 9 on Figure 2) are then activated while cam groups 4 and 6 are deactivated.

Cam groups 7 and 9, normally part of the MARK 75 PCO backup circuit, were spare since they were not being used in the PHM 1 installation. Implementation of the interference eliminator was accomplished by rewiring the cam-switch sets to be used as part of the FCO systems.

The interference eliminator was first installed on a MARK 75 gun mount at the Naval Surface Weapons Center, Dahlgren Laboratory (NSWC/DL) for test and evaluation. Procedures for installation and checkout were developed and are presented in Appendixes A and B, respectively.

A detailed systems safety analysis was performed and the results were presented to the Weapons Systems Explosive Safety Review Board (WSESRB). Appendix C discusses the findings of this analysis. The WSESRB approved the installation of the interference eliminator on board PHM 1 provided that:

1. An indicator light be placed in the cam-switch relay circuit prior to shipboard evaluation to indicate actuation of the optional FCO zone. The WSESRB stressed the importance of adequate communication between the Combat Information Center (CIC) and the gun local control panel.

2. The interference eliminator circuit be modified after evaluation and acceptance of the PHM 1 by the Navy to introduce the +28 VDC power source at the position sensor relays in the hydrofoil control system. This would eliminate the hazard of a short circuit at the cam-switch relay or the cable connector.

The interference eliminator was installed on the PHM 1 MARK 75 gun mount during the week of 22 May 1977. The indicator light (recommendation 1 above) was incorporated during the installation. Relocation of the 28 VDC power source (recommendation 2) was deferred until the week of 21 May 1978 because of scheduling problems.

CONCLUSIONS

The results of the PHM 1 installation tests have proven the operability of the interference eliminator. The interference eliminator allows the gun to fire to +2:00' over the bow in lieu of +6:00' when the hydrofoil is deployed and locked, thus improving the forward engagement capability.

APPENDIX A

INTERFERENCE ELIMINATOR INSTALLATION

BY

H. A. NEWTON

NSWC/DL
(CODE G61)

The MARK 75 interference eliminator allows switching from one firing cutout (FCO) zone to another on the basis of a signal provided by a source external to the gun mount. In the case of USS PEGASUS (PHM 1), the external source is the ship's forward hydrofoil control system.

The purpose of the interference eliminator is to improve the gun's engagement capability. This is accomplished by allowing the gun to fire through the area previously occupied by the hydrofoil in its stowed position. An electrical signal from the hydrofoil control system energizes a relay that switches an alternate set of FCO cams into operation. This cam set allows the gun to fire into the area vacated by the now deployed and locked hydrofoil. When the hydrofoil is not deployed and locked, the relay is deenergized thus switching into operation FCO cams that protect it in the stowed position.

Following is a discussion of the procedure for implementing the interference eliminator:

Gun Synchro Boxes

1. Remove the synchro boxes.

a. Move the gun to the stowed position (0° train, 0° elevation) and verify the gun position by checking the readings on the train and elevation dial indicators in the synchro boxes.

b. Remove both the train and elevation synchro boxes by removing the screws clamping the base retaining ring to the gun mount and disconnecting the cable connector from the side of the box.

Once the synchro boxes are removed from the gun mount and the protective cover is removed, the necessary wiring modifications may be made. Figures A-1 and A-2 show schematically FCO and pointing cutout (PCO) backup cam switches as installed by the manufacturer. Figures A-3 and A-4 show schematically the FCO and PCO backup cam switches modified for the interference eliminator. The wiring changes to be made in the synchro boxes are:

Train Synchro Box

1. Remove the jumper connecting the normally open (NO) contact of switch #5 (SOB-3) and common (C) of switch #7.

2. Add new lead from C of switch #7 to pin w of connector J105.

3. Remove jumper connecting the NO contact of switch #7 (SOB-4) and C of switch #9.

4. Add new lead from C of switch #9 of pin w of connector J105.

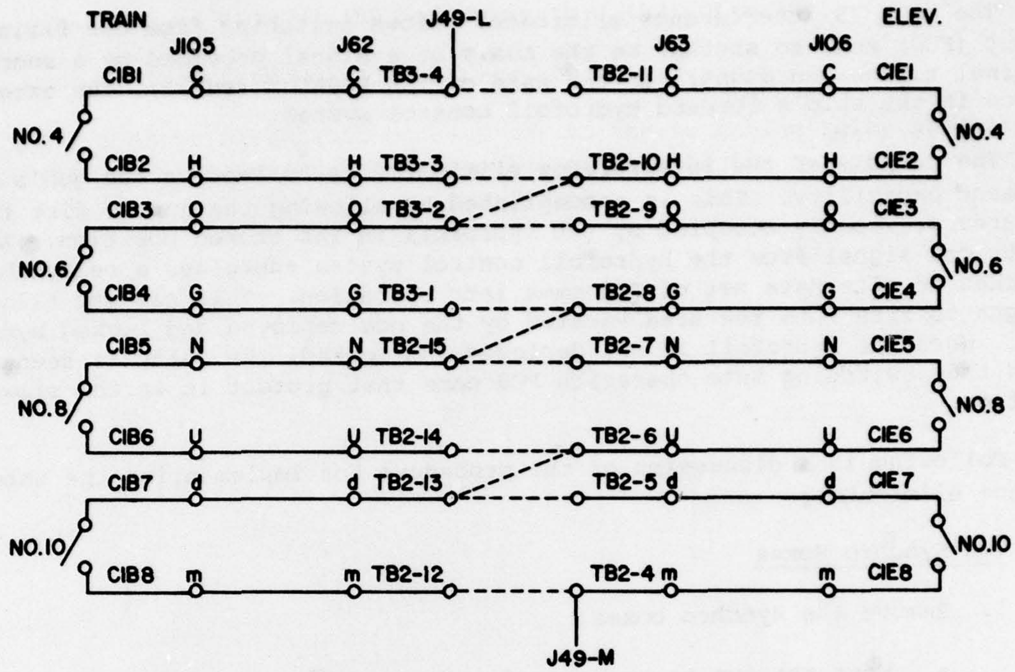


Figure A-1. Original Firing Cutout Cam Circuit

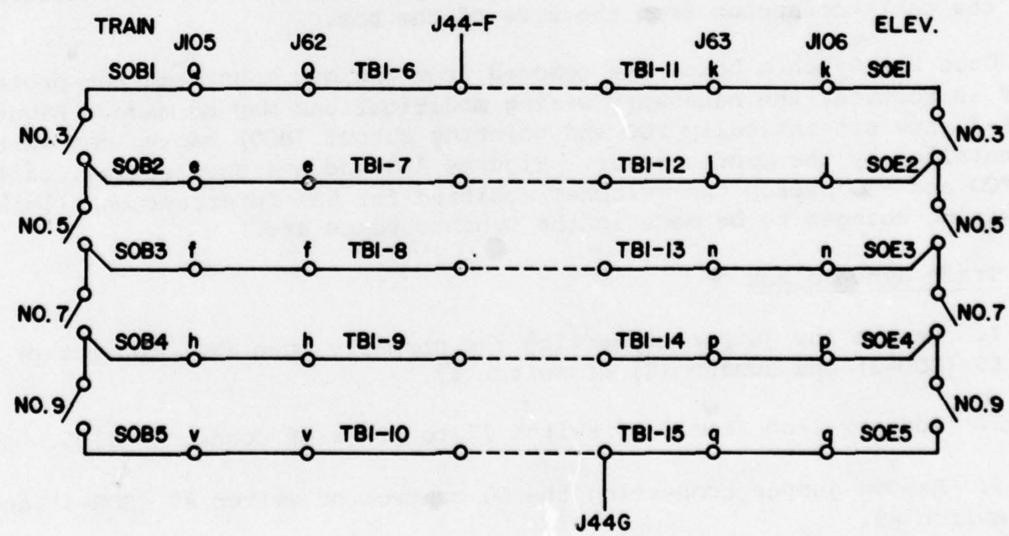


Figure A-2. Original Pointing Cutout Backup Cam Circuit

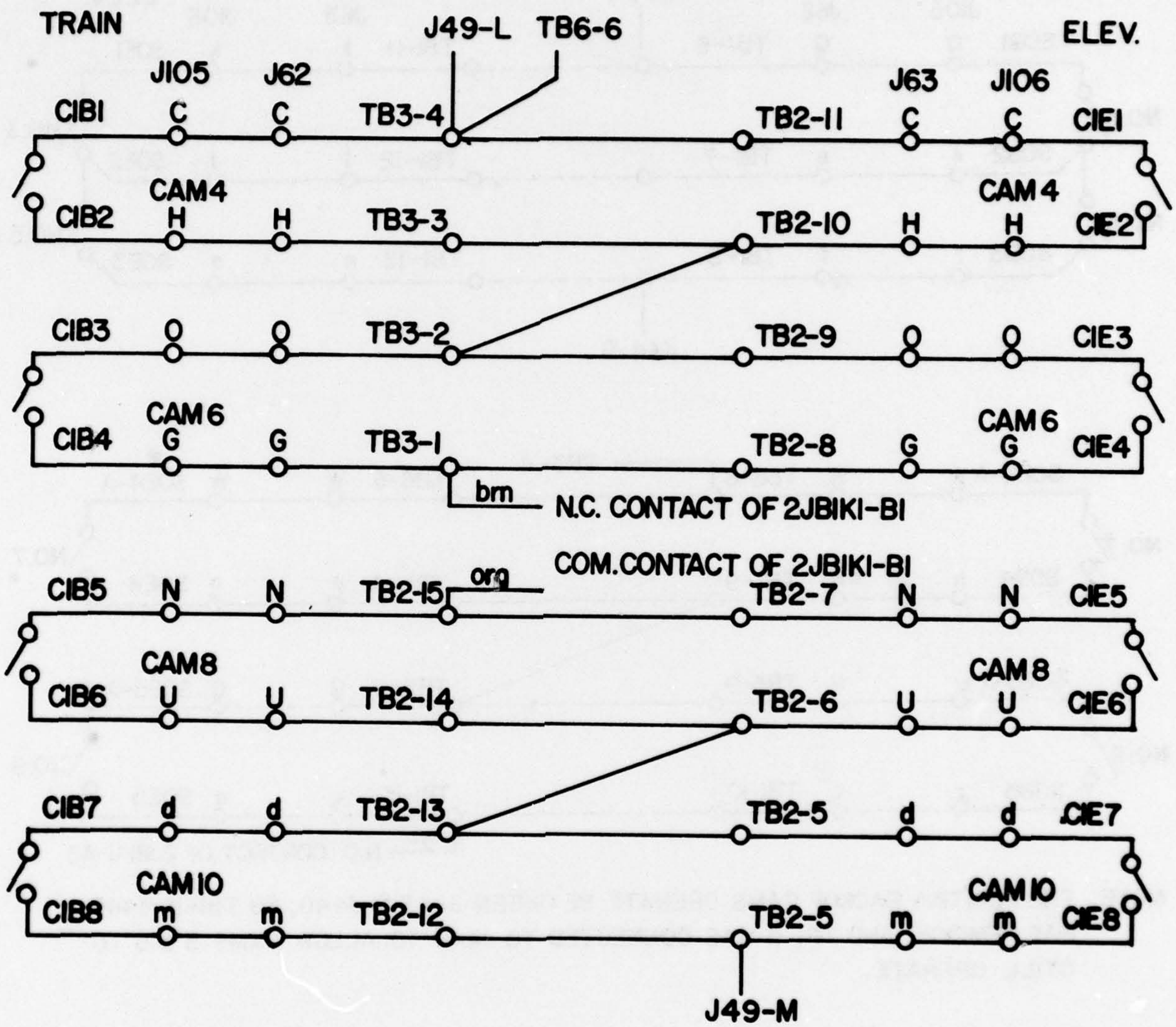
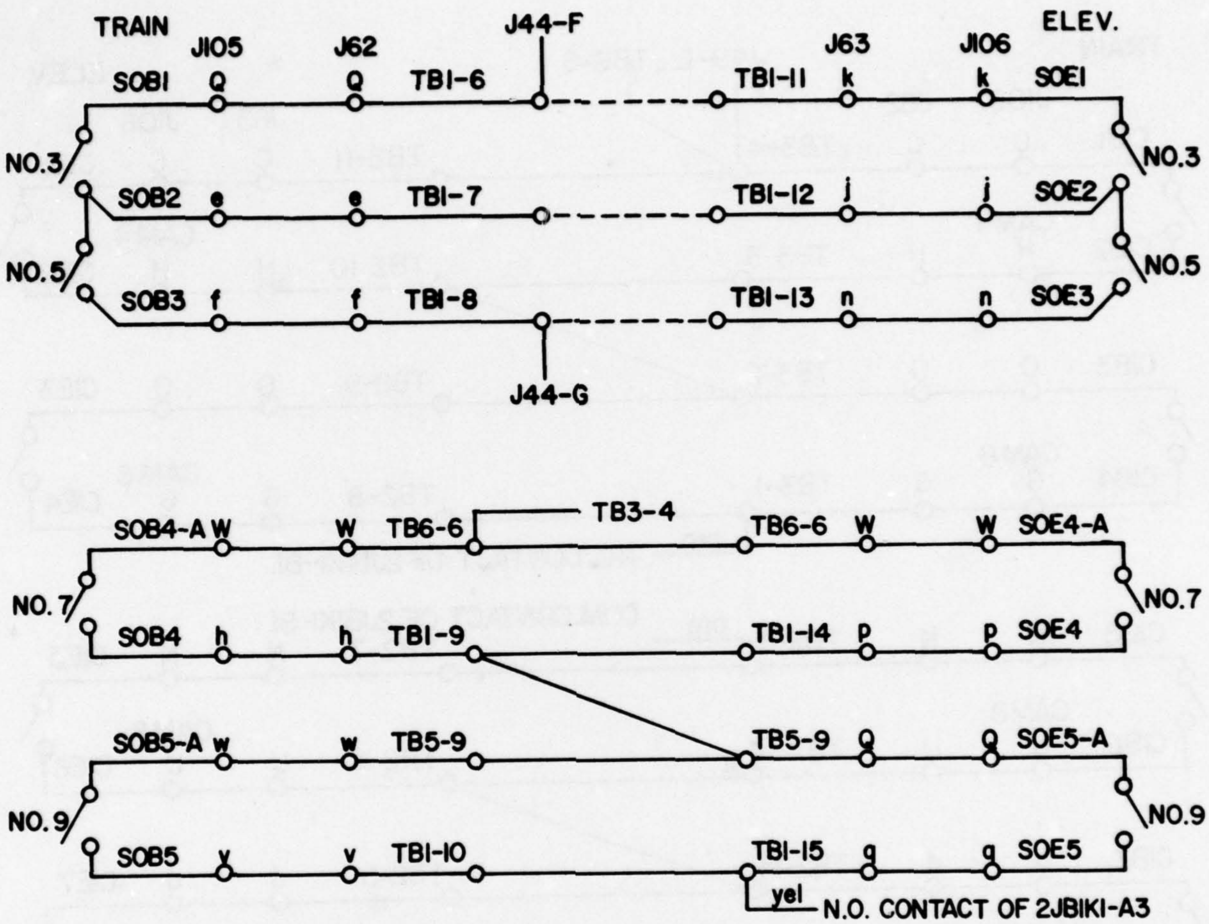


Figure A-3. Modified Firing Cutout Cam Circuit



NOTE: THE POINTING BACKUP CAMS OPERATE BETWEEN J44F & J44G, SO TB1-15/J44G WAS REMOVED AND TB1-8 WAS CONNECTED TO J44G TO ALLOW CAMS 3 & 5 TO STILL OPERATE.

Figure A-4. Modified Pointing Cutout Backup Cam Circuit

Elevation Synchro Box

1. Remove the jumper connecting the NO contact of switch #5 (SOE-3) and C of switch #7.

2. Add new lead from C of switch #7 to pin w of connector J106.

3. Remove the jumper connecting the NO contact of switch #7 (SOE-4) and C of switch #9.

4. Add new lead from C of switch #9 to pin Q of connector J106.

Local Control Panel (LCP)

1. Mount new connector on lower left-hand end of LCP.

2. Connect lead wire from TB8-8 to pin A of connector.

3. Remove lead J3-il from TB6-8 and insulate.

4. Connect lead wire from TB6-8 to pin B of connector.

5. Mount 28-V lamp on LCP and connect pin 1 to TB6-8 and pin 2 to TB8-8.

Junction Box 2JB1

1. Connect jumper from TB3-4 to TB6-6.

2. Connect jumper from TB1-9 to TB1-14.

3. Connect jumper from TB1-9 to TB5-9.

4. Move lead J44-G from TB1-10 to TB1-8.

5. Add new lead from w of J62 to TB5-9.

6. Remove jumper from TB3-1 and TB2-15.

7. Mount switching relay in appropriate space.

8. Remove lead J62-R from TB7-12 and insulate.

9. Connect lead from X1 of relay to TB7-12.

10. Connect lead from X2 of relay to TB4-4.

11. Connect lead from NC (B1) of relay to TB3-1.

12. Connect lead from C (B2) of relay to TB2-15.

13. Connect lead from NO (B3) of relay to C (A2) of relay.

14. Connect lead from NO (A3) of relay to TB1-15.

Figure A-5 shows electrical connections to the switching relay installed in 2JB1. Figure A-6 shows the comprehensive circuit of the switching relay.

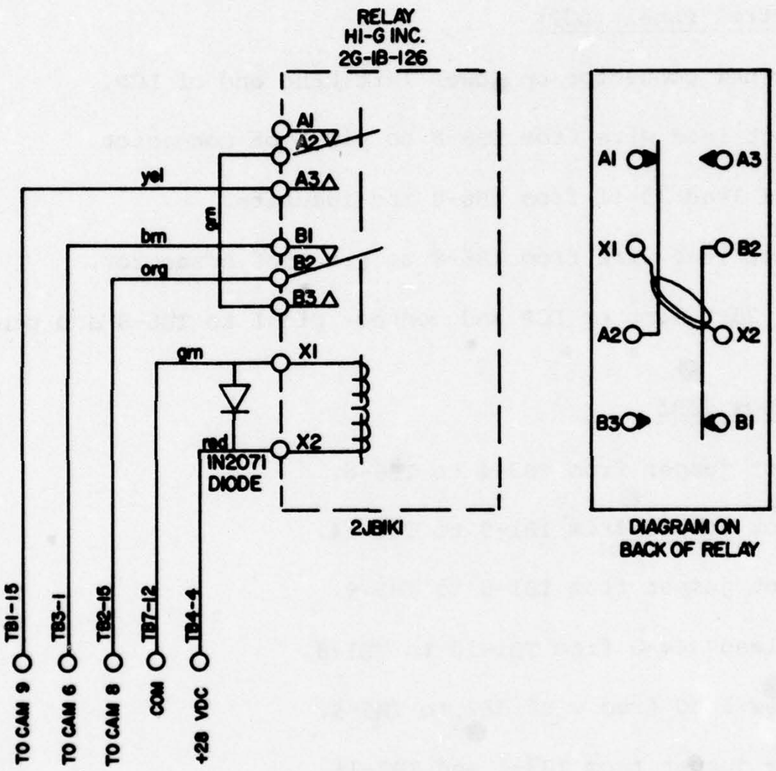
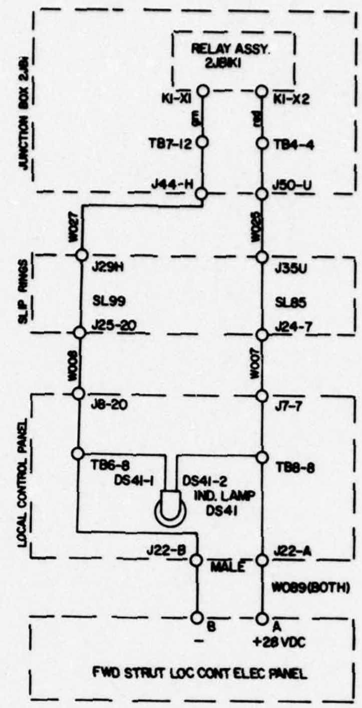


Figure A-5. Relay Installed in Junction Box 2JB1



WIRING FROM RELAY TO FORWARD STRUT LOCAL CONTROL ELECTRICAL PANEL

Figure A-6. Firing Cutout Changeover Relay

Table A-1 provides a list of components required for the interference eliminator.

Table A-1. Interference Eliminator Components

Component	Quantity	Designation	Manufacturer's P/N
Relay	1	2JB1K1	HI-G, Inc. 2G-1B-126
Diode (in relay assy.)	1	-	IN2071
Circuit breaker	1	CB1	Texas Instruments TI 6752-204-2 1/2
28-V lamp	1	DS41	Dialight Corp. 177-8430-0976-503
Connector	1	J22	a. MS3108A 12S-3S b. MS3102A 12S-3P

APPENDIX B

INTERFERENCE ELIMINATOR TEST PROCEDURE

PURPOSE: To verify that the gun's pointing and firing cutout (P&FCO) mechanisms and the interference eliminator have been properly manufactured, installed, and adjusted to ensure safe operation and firing of the gun mount.

ESTIMATED TEST TIME: Six hours

TIMES PERFORMED: Once

PREREQUISITES: The gun will be battery aligned. Both the gun and the forward hydrofoil must be operational. The gun must be operational in both the local and remote control modes.

SPECIAL CONDITIONS:

1. Roped-off and red-flagged danger area around MARK 75 gun mount.

2. Communications between gun operator and observer.

METHOD: The MARK 75 gun system P&FCO systems shall be tested as follows:

1. Test the electronic pointing cutout (PCO) system. The gun shall be energized and set at maximum depression and slowly trained 360°. The observer and gun operator shall verify that the gun barrel safely contours around all interfering ship structure. After verification at slow speed, the gun shall be trained at maximum depression at maximum train rate. The observer and gun operator shall verify that the gun barrel safely contours around all interfering ship structures.

2. Test the cam-actuated PCO backup system. The gun shall be energized and handcranked through 360° elevation. The observer and gun operator shall verify each PCO backup cam switch actuation point with its respective PCO zone boundary.

3. Test the cam-actuated firing cutout (FCO) system. The gun shall be energized and slowly trained or elevated across each FCO zone boundary. The observer and gun operator shall verify FCO switch actuation as the gun both enters and leaves the FCO zone.

4. Test the electrical upper and lower elevation limit stop system and positive stops.

a. The gun shall be deenergized and handcranked to the upper and lower elevation positive stops. The observer and gun operator shall observe and record the respective elevation angles.

b. The gun shall be energized and the upper and lower elevation limit stops tested. The observer shall record the respective elevation angles.

Proper operation of the elevation electric limit stops will show the limit stop position just above the lower elevation positive stop or below the upper elevation positive stop.

5. Test the interference eliminator (gun in local control).

a. The gun shall be energized and slowly trained or elevated across each FCO zone boundary with the forward hydrofoil in the stowed position. The observer and gun operator shall verify FCO switch actuation as the gun both enters and leaves the FCO zone.

b. The gun shall be energized and slowly trained or elevated across each FCO zone boundary with the forward hydrofoil in the deployed and locked position. The observer and gun operator shall verify FCO switch actuation as the gun both enters and leaves the FCO zone.

c. The gun shall be energized and slowly trained or elevated across each FCO zone boundary with the forward hydrofoil in some position other than stowed or fully deployed and locked. The observer and gun operator shall verify FCO switch actuation as the gun both enters and leaves the FCO zone.

d. The gun shall be energized and trained to an azimuth and elevation angle above the upper elevation boundary of the interference eliminator FCO zone boundary and below the upper elevation boundary of the hydrofoil stowed zone, with the forward hydrofoil deployed and locked. The hydrofoil shall be cycled out of the deployed and locked position. The observer and gun operator shall verify that there is a NO FIRE indication on the gun control panel.

e. With the gun set as in (d) above, the power shall be shut down in the foil position indicator line to simulate a power failure. The observer and gun operator shall verify that there is a NO FIRE indication on the control panel.

6. Test the interference eliminator (gun in remote control).

a. Repeat steps (a) through (e) in section 5 above while operating the gun remotely.

PARAMETERS TESTED:

1. Electronic PCO system

2. Cam-actuated PCO system

3. Cam-actuated FCO system

4. Electrical lower and upper elevation limit stop system and positive stops

5. Interference eliminator

APPENDIX C

SAFETY ANALYSIS OF AN INTERFERENCE ELIMINATOR

FOR THE MARK 75 GUN MOUNT ON THE PHM 1

BY

W. H. HAMMER (CODE N41)

NSWC/DL

INTRODUCTION

The patrol hydrofoil missile ship (PHM 1) is armed with the 76-mm/62-caliber MARK 75 gun mount. Although the major role of the gun is antiaircraft engagement, it is used against surface targets as well. Currently, the gun has a group of firing cutout (FCO) and pointing cutout (PCO) cams that prevent it from firing at certain obstacles on the deck or from striking obstructions to the gun barrel.

In a specific case, these FCO cams prevent the gun from firing into a discrete zone occupied by the front hydrofoil when the hydrofoil is in the stowed position, i.e., the PHM is hull-borne. Unfortunately, the cams also prevent firing into the zone when the hydrofoil is down and the zone is unoccupied. It would be a tactical advantage to be able to fire into this zone when the hydrofoil is down. The ship would have more flexibility in the engagement of surface targets.

To remedy this problem, the Naval Surface Weapons Center, Dahlgren Laboratory (NSWC/DL) was tasked by the Naval Sea Systems Command (NAVSEA) to design a dual cam system. With the foil up (stowed), the existing FCO zone would be engaged. When the hydrofoil is lowered, a second, lower zone would be engaged allowing the gun to fire into the now unoccupied front hydrofoil zone. This report documents the safety analysis performed on the dual cam or interference eliminator system.

SYSTEM DESCRIPTION

The FCO system on the MARK 75 is similar in nature to that of most other gun mounts. Train and elevation synchronization boxes that monitor the exact position of the mount and barrel at all times are located in the mount. These boxes contain a series of stationary microswitches interconnected with a control circuit for the gun. Cams located in the boxes rotate with the movement of the mount and barrel. The cams are precut so that when the gun trains or elevates into a zone into which the gun should not fire, the microswitches open or break continuity in the firing control circuit.

The MARK 75 mount has an FCO solenoid located on the gun that is controlled by the cam/microswitch circuitry. When this solenoid is energized (normal operating condition) by a complete circuit through the cam switches, the gun can fire. When the gun enters an FCO zone, the FCO solenoid deenergizes, and the firing pin is blocked. The gun cannot fire until trained or elevated out of the FCO zone.

The modified system (interference eliminator) uses two microswitch groups in the PCO backup system that are unused in the PHM 1 application. New cams were cut for these groups and wiring connections rearranged to form two new FCO cam groups. These new groups form an FCO zone that will allow the gun to be fired when depressed an additional 5° while pointing forward. A cam switching relay that will select the proper forward cam set, depending on whether the hydrofoil is up or down, was added to the circuit. The cam switching relay is energized by activation of three sensors in the hydrofoil control system. When the hydrofoil is in the up position, this relay is deenergized, and the existing or high cam zone is engaged. When the hydrofoil is down, the relay is energized, and the new low cam zone is energized. Figure C-1 is a schematic representation of the cam zones activated under the two conditions. Figure C-2 is a schematic of the proposed interference eliminator and the associated circuitry necessary to activate it.

SAFETY ANALYSIS

Analyses performed on the 76-mm interference eliminator consisted of a preliminary hazard analysis to identify specific hazards in the system and a fault tree analysis to determine critical paths that can lead to a specific hazard. These analyses are discussed in the following sections.

PRELIMINARY HAZARD ANALYSIS (PHA)

A PHA identifies possible hazards brought about by failures at specific points in the system. In such an analysis, all hazards are considered, even those of minimal consequence. Three such minimal hazards exist, classified as Category I hazards in accordance with MIL-STD-882. Two of these hazards are the result of contact failures in the cam switching relay. The contacts of this relay are arranged as shown in Figure C-3.

Figure C-3 shows the position of the cam switching relay in the deenergized position, with the high cam zone activated. If contact NC-1 fails in the closed position, the high cam zone ie engaged regardless of the position of the hydrofoil. This represents what might be termed a reliability failure.

When the hydrofoil goes down, the coil energizes, contact NC-1 switches to NO-2, and NC-2 switches to NO-1. This engages the low cam zones. If NO-2 fails closed when the hydrofoil returns to the raised position, the whole cam control circuit is deactivated and the gun will not fire. The relay has to be replaced to activate the cutout system.

If NO-2 fails in the closed position, a much more serious situation exists. The low cam zone is partially activated, regardless of the hydrofoil position. The relay appears to function normally; however, only one additional failure, that of NO-1 failing closed, is necessary to permanently engage the low cam zone. The gun can then be fired into the front hydrofoil when the hydrofoil is in the raised position.

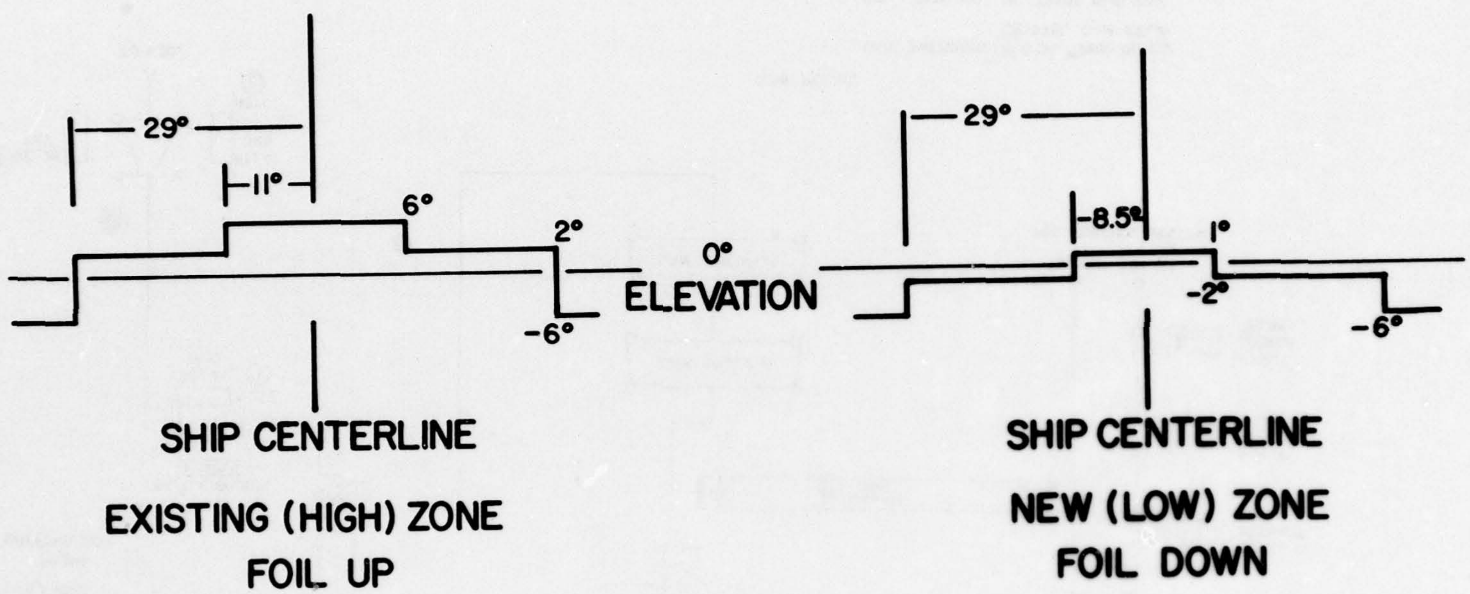
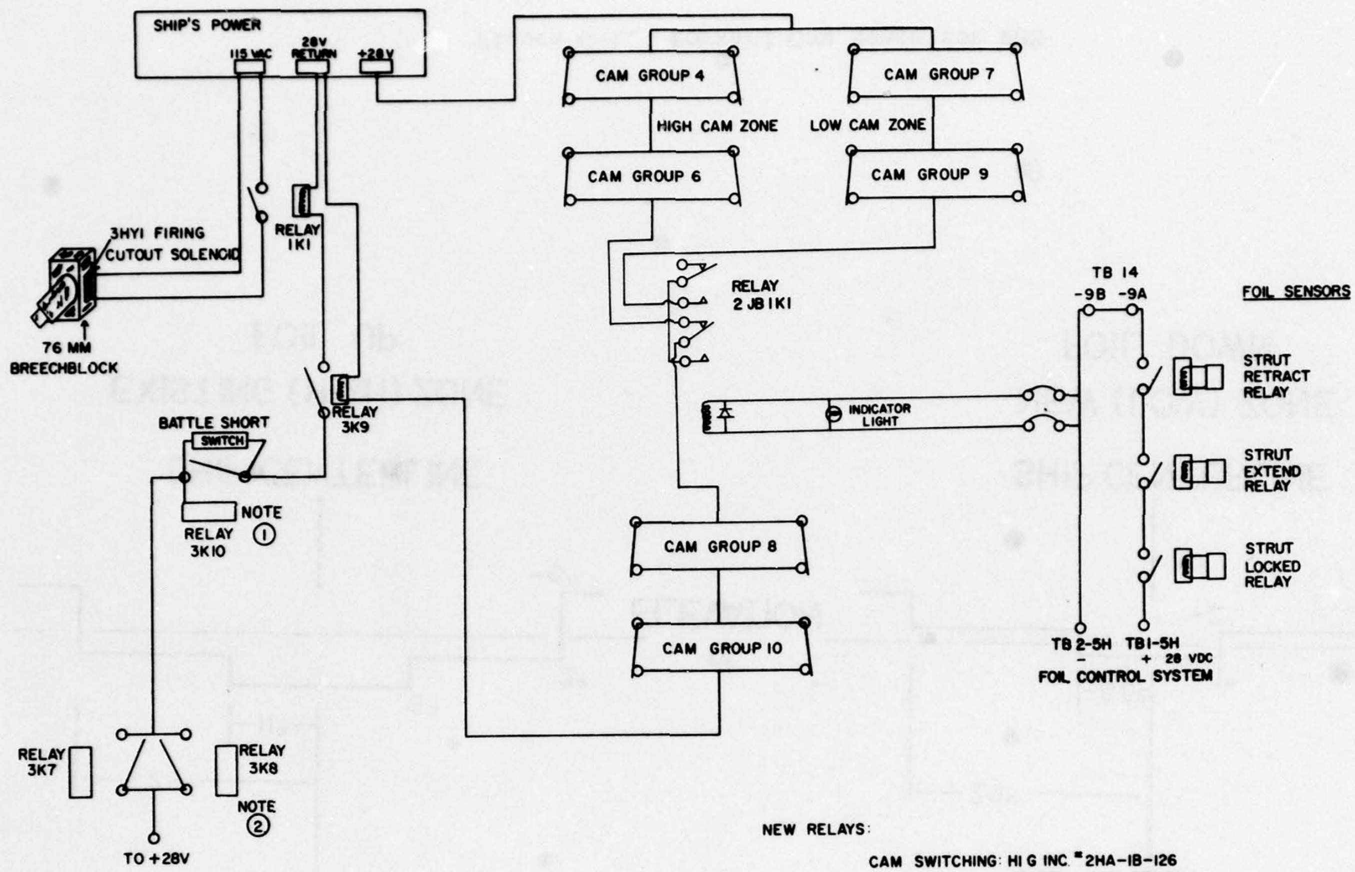


Figure C-1. Forward Cam Zones for PHM



NEW RELAYS:

CAM SWITCHING: HI G INC. #2HA-1B-126 CRYSTAL CAM RELAY

FOIL SENSING: MS-27400 QUALIFIED RELAYS.

NOTES:

① ENERGIZED WHEN MOUNT IS SYNCHRONIZED WITH REMOTE TRAIN AND ELEVATION ORDERS.

② ENERGIZED WHEN FIRING SWITCH IS CLOSED.

Figure C-2. Interference Eliminator Circuit

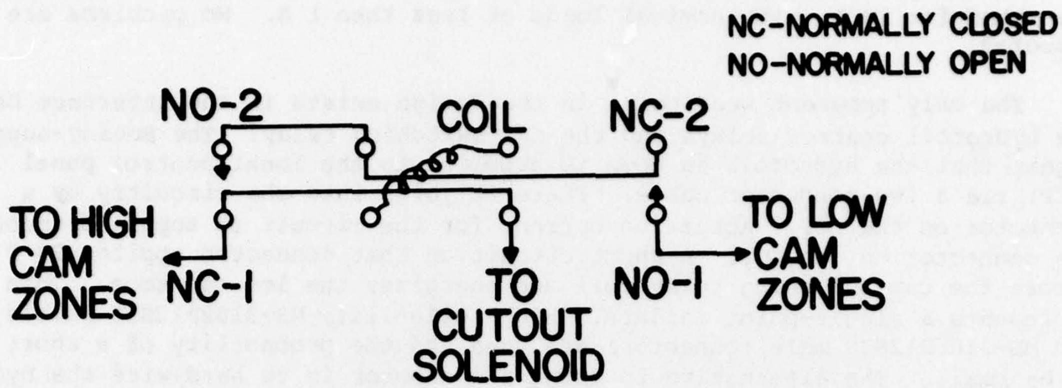


Figure C-3. Relay Contacts

Contact failures are felt to be a very low-probability event in this instance. The cam switching relay, manufactured by HI-G, Incorporated, is a high-reliability relay. Although it is not a military standard (MS)-qualified relay, much of the technology used in making military quality relays is used in its manufacture. The relay used is one normally existing as a spare relay in the 76-mm mount and is identical to others used in the MARK 75. Its 4-A contact rating and nominal 300-mA contact load in operation will eliminate all of the normal problems associated with contact failure. Hazards associated with contact failure are therefore felt to be controlled.

The cam switching relay is controlled by magnetic sensors on the hydrofoil mechanism. These activate three MS-qualified relays (MS-27400) connected in series. When contacts of these three relays close, current is applied to the coil of the cam switching relay, activating the low cam zone. If one of the three relays fails in the open position, the interference eliminator is deactivated; i.e., the high cam zone is activated at all times. This produces the third Category I hazard of the system. If one contact of the three fails closed, a somewhat more serious situation exists. All three sensors sense a different motion of the hydrofoil as it lowers. If one of the sensors is bypassed due to relay contacts failing closed, part of the safety redundancy of the system is bypassed (a Category II hazard in accordance with MIL-STD-882). If all three fail closed, the low cam zone is activated at all times, a Category IV or potentially catastrophic hazard. It is also possible that the sensors controlling the relay coils could fail, causing the relay contacts to close. However, one relay contact closes upon coil deenergization, and the other two close upon coil energization. The proper sequence of failures to cause all three contacts to close at the same time is felt to be remote.

Again, the hazards generated by relay contact failure are felt to be controlled by the choice of high-reliability (MS-27400) relays. Contacts are rated for 10 A, with nominal loads of less than 1 A. No problems are expected.

The only apparent weak point in the design exists in the interface between the hydrofoil control relays and the cam switching relay. The Boeing-supplied signal that the hydrofoil is down is supplied to the local control panel (LCP) via a two-conductor cable. There it joins into the circuitry by a connector on the LCP. Actuation current for the circuit is supplied through the connector on the LCP. A short circuit on that connector applies 28 V across the cam switching relay coil and energizes the low cam zone. This represents a single-point failure. High-reliability MS-3102R12S3S female and MS-3106R12S3P male connectors are used and the probability of a short is felt to be small. The alternative to using a connector is to hard-wire the hydrofoil controls into the circuit. Because of the design of the installation, the cable from the hydrofoil controls must be routed into some exposed areas that would subject it to a certain amount of handling. This handling could conceivably pull the cable loose from connections directly to the LCP terminal boards despite appropriate strain relief mounting. Failure to use the connector could increase the chance of shorting the supply voltage to the cam switching relay coil. Since design alternatives to eliminate this hazard are unrealizable, it is recommended that a warning light be placed in the circuit to show when the cam switching coil is activated (see Figure C-4). If the connector malfunctions and activates the coil, the presence of the foil in the up position will make this immediately obvious.

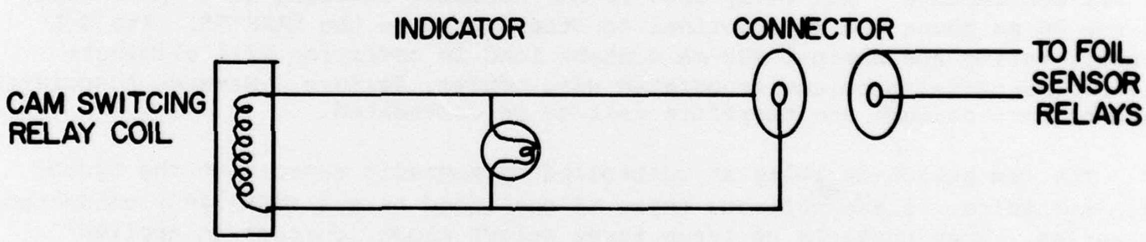


Figure C-4. Cam Switching Relay Activation Indicator

In summary, several potential failures were found that would result in Category I hazards. One single-point (connector) failure, one dual-point (cam switching relay) failure, and one three-point (foil control relays) failure were found, all of which would result in Category IV hazards. All are felt to be controllable by the use of a warning light or by the use of high-quality, high-reliability devices, all operating at current levels far below their maximum capacity. Failures necessary to produce a hazard should be very low-probability events.

FAULT TREE ANALYSIS (FTA)

An FTA is essentially a logic diagram of all or a portion of a system. Its purpose is not, however, to diagram how the system functions, but how it can malfunction to produce a specific fault event. An FTA has been performed on the complete, existing MARK 75 FCO system. This analysis, contained in NWL Technical Report TR-2941 of May 1973,* investigates both the mechanical operation of the FCO solenoid and the electrical operation of the cam system. Since implementation of the interference eliminator affects only the electrical operation of the cam system, only that portion is addressed in this analysis. The FTA of Figure C-5 addresses the schematic of Figure C-2. The specific hazard addressed is that of firing the MARK 75 into the front hydrofoil when the front hydrofoil is raised.

A computer analysis was performed to find the "cut sets" or shortest paths from a failure to the top fault event. Seven single-point failures were found that could lead to firing into the front hydrofoil. Five of these hazards, which exist in the current design and are not a function of the introduction of the interference eliminator, are

1. A short circuit that would energize relay 3K9
2. Contacts of relay 3K9 fail-closed
3. A short circuit that energizes relay 1K1
4. Contacts of relay 1K1 fail-closed
5. A short circuit that activates the FCO solenoid

It is emphasized that these hazards exist already in the MARK 75 mount cam system and are considered by the WSESRB to be controllable by the use of high-reliability components. An additional single-point failure introduced by the interference eliminator is that of a short circuit that energizes the cam switching relay. The design of the circuitry is such that this should be a very low-probability occurrence. The last single-point failure is that of a short in the connector located in the LCP. As discussed in the PHA, this hazard can be controlled by the use of a warning light to indicate relay energization.

Numerous two-point failures exist that could cause the top event. However, these are almost all mechanical malfunctions in the cam system itself and are hazards that already exist in all gun mounts controlled by a cam system.

One other possible two-point failure is that of the contacts of the cam switching relay failing in the normally open position, energizing the low cam zone at all times. As addressed in the PHA, this is felt to be controllable by the use of a high-reliability relay.

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* L. H. Jackson, *MARK 75 MOD 0 76-mm/62-Caliber Gun Mount Safety Evaluation Report,* Naval Weapons Laboratory Technical Report NWL TR-2941, Dahlgren, VA, May 1973.

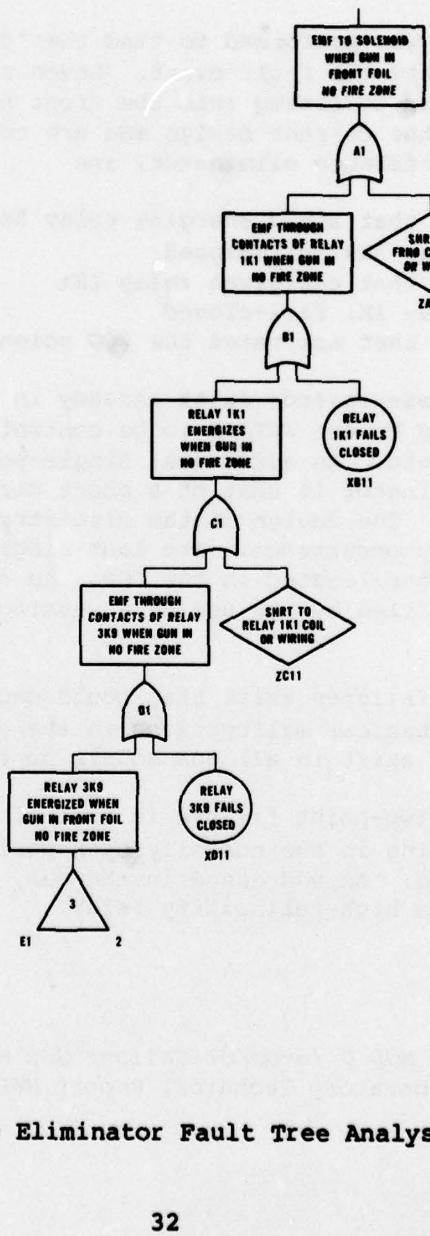

Figure C-5. Interference Eliminator Fault Tree Analysis (Sheet 1 of 4)

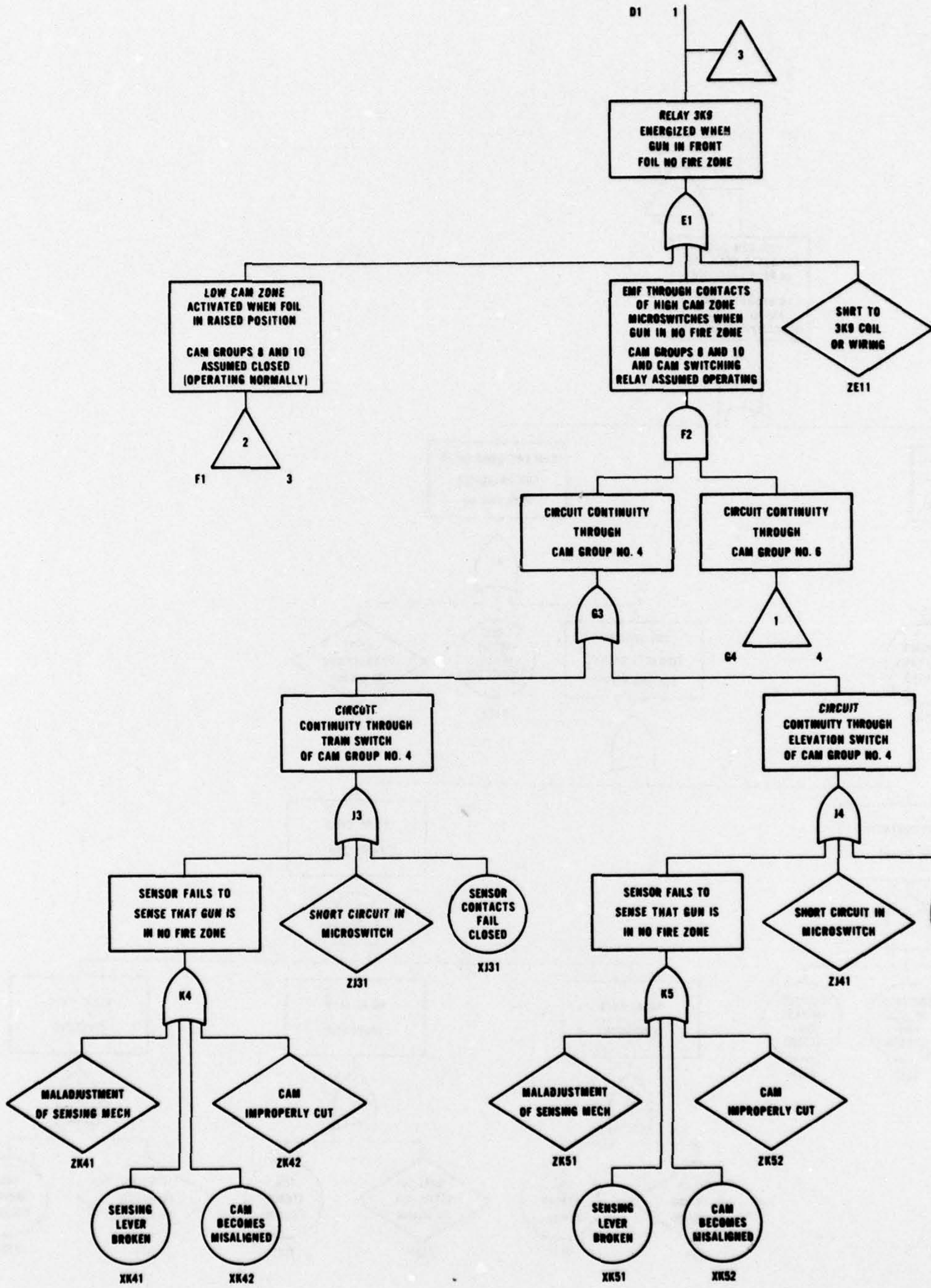

Figure C-5. Interference Eliminator Fault Tree Analysis (Sheet 2 of 4)

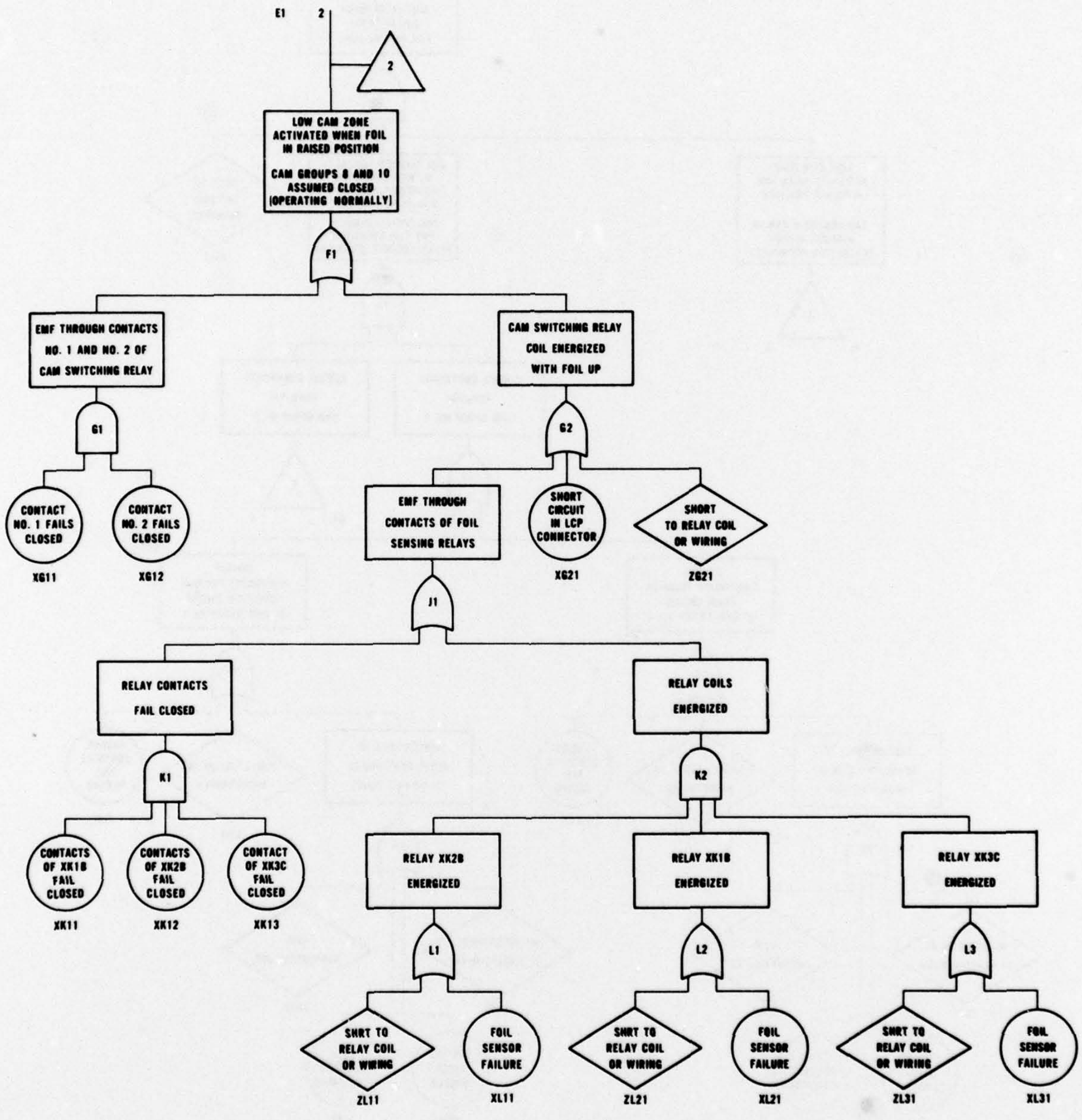

Figure C-5. Interference Eliminator Fault Tree Analysis (Sheet 3 of 4)

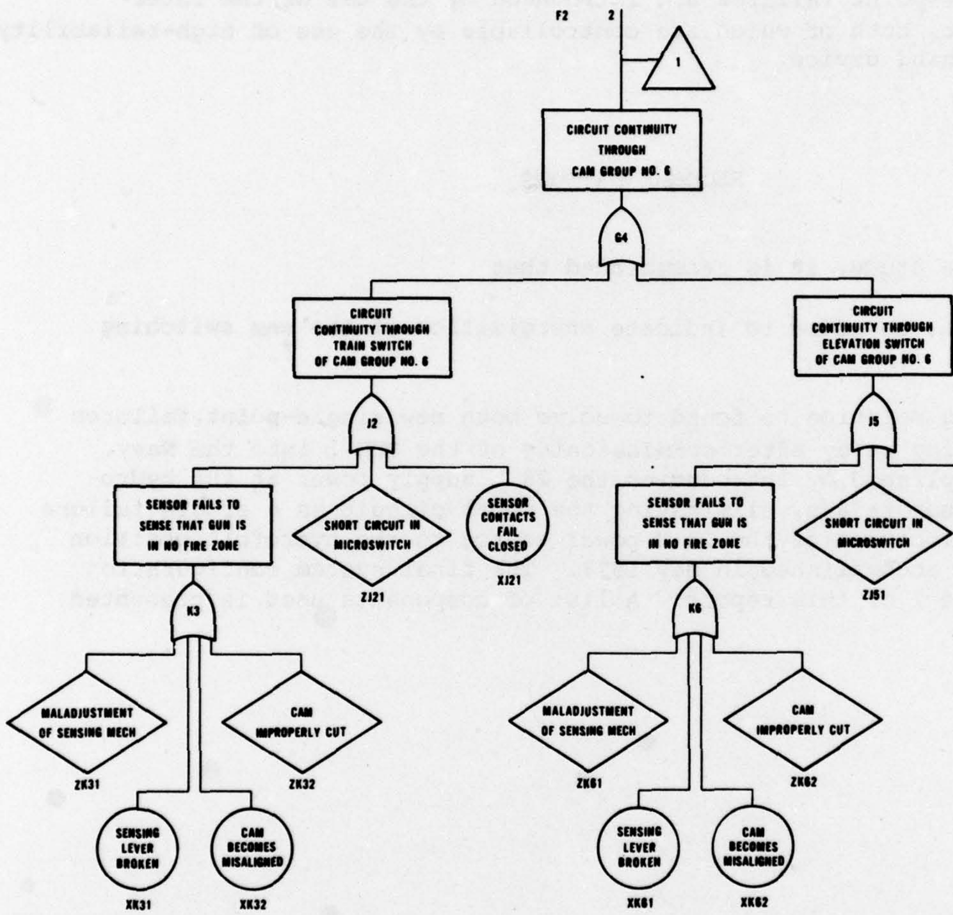

Figure C-5. Interference Eliminator Fault Tree Analysis (Sheet 4 of 4)

CONCLUSIONS

Based on the above study, it is concluded that

1. Use of the interference eliminator does not significantly degrade the safety of the existing cam system since failure modes are identical to those already existing in the present cam system.

2. Two new single-point failures are introduced by the use of the interference eliminator, both of which are controllable by the use of high-reliability hardware or a warning device.

RECOMMENDATIONS

Based on the above study, it is recommended that

1. A warning light be added to indicate energization of the cam switching relay.

2. An engineering solution be found to solve both new single-point failures in the cam switching relay after commissioning of the PHM 1 into the Navy. This may be accomplished by introducing the 28 V supply power at the hydrofoil position sensor relays, eliminating the short circuit as a single failure mode. (NOTE: Relocation of the 28 V power source to the hydrofoil position sensor relays was accomplished in May 1978. The final system configuration is shown in Figure 1 of this report. A list of components used is presented in Table A-1.)

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