DESIGN DATA SHEET
DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND

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DDS 072-4 HULL, MECHANICAL, AND ELECTRICAL SYSTEMS SURVIVABILITY

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FIGURES

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072-4-a. References

(1) Section 072 of General Specifications for Ships of the United States Navy.

(2) MIL-STD-1629 - Procedures for Performing a Failure Mode Effects and Criticality Analysis.

(3) DI-R-7085 - Data Item Description: Failure Mode, Effects, and Criticality Analysis Report.

072-4-b. Scope

This design data sheet provides guidelines in performing survivability analysis of vital Hull, Mechanical and Electrical (HM&E) Systems during the detail design phase of surface combatant ships. The design data sheet offers a five step procedure and sample damage tolerance analysis.

The guidelines in this design data sheet are intended to assist shipbuilders in the performance of the deactivation diagram/damage tolerance analysis as required in section 072 of the general specifications for ships of the United States Navy. The contents of this design data sheet do not modify or supersede any of these requirements but rather, offer a procedure which may be used by the shipbuilder to complete the deactivation diagram/damage tolerance analysis. It is further intended that these guidelines apply throughout the detail design process from contract award to ship delivery.

072-4-c. Definitions

Key Terms. Included in this section are terms and definitions to facilitate the use of this design data sheet:

Survivability. The capability of a weapons systems to continue to carry out its designated mission in a combat threat environment; it is a function of both susceptibility and vulnerability.

Susceptibility. The composite of numerous factors that indicate the probability of a system being hit by a given threat.

Vulnerability. The extent of degradation that a system experiences after having been subjected to combat damage.

Segregation and Isolation. The capability for functionally separating damaged from non-damaged services and vital from non-vital services especially in a hostile environment.

Choke Point. A choke point is a location where, due to insufficient separation, system redundancy is compromised.

Deactivation Diagrams. Design specific diagrams which depict the various grouping of equipments that must be operable to support specific levels of ship mission readiness.

Deactivation Diagram - Damage Tolerance Analyses. Analyses conducted by which the locations of each of the components and distributive runs in a system are combined with the deactivation diagrams to determine whether the survivability and separation requirements have been met for the complete system.

Condition Zebra. Set prior to going to sea or entering port, during wartime. Set immediately, and without further orders, when manning general quarters stations. Set to localize and control fire and flooding when not at general quarters.

072-4-d. Acronyms and Abbreviations. The following acronyms and abbreviations used in this design data sheet are defined:

AAW	Anti-Air Warfare
AMR	Auxiliary Machinery Room
ASW	Anti-Submarine Warfare
CIC	Combat Information Control
COMM	Communications
DMEA	Damage Mode Effects Analysis
FMEA	Failure Mode Effects Analysis
HM&E	Hull, Mechanical and Electrical
HVAC	Heating, Ventilation and Air Conditioning
IFF	Identification, Friend or Foe
SSGTG	Ship's Service Gas Turbine Generator
WAR	Weapons Area Reconfiguration
WCS	Weapons Control System

072-4-e. Design Guidelines for HM&E Survivability Analysis Procedure

General Design Principles and Procedures. During the initial stages of the design of shipboard systems, general design principles to enhance the survivability should be exercised to the maximum extent possible. General design principles include provisions for:

Separation of redundant systems.

Isolation of non-redundant systems.

Concentration, localization and shielding/armoring or vital non-redundant systems from areas of potential hazard.

The survivability of HM&E systems is determined by the functional design of the system and by the location of the portion of a system, without any redundancy, the location of components and the amount of protection determines the vulnerability, or target size, of the system. The sample procedure illustrated in this design data sheet consists of a five step process and further illustrates two key survivability characteristics (Redundancy and Separation) inherent in each system and also shows how the survivability of each system affects the overall mission area survivability. These five steps are described in this section of the design data sheet and consist of:

Step 1: Develop Deactivation Diagrams

Step 2: Identify physical location of all systems components

Step 3: Impose damage modes upon the System Layout. Identify "Destroyed" Components.

Step 4: Modify Deactivation Diagrams to reflect impact of lost components on System/Mission area.

Step 5: Summarize results, identify all damage modes resulting in a loss of mission.

072-4-f. Step 1: Develop Deactivation Diagrams

A deactivation diagram depicts all the functional elements of a system or mission area which are required for the operation of that system or mission area. These elements are displayed in their proper flow sequence (series and parallel) so that the redundancies/non-redundancies of the system are illustrated. A system is considered operational if an unbroken path can be traced through the diagram from beginning to end.

There are three levels of deactivation diagrams:

(1) mission area
(2) primary or combat system
(3) HM&E support system.

The mission area deactivation diagram identifies those primary/combat systems which, when operational, comprise mission capability. Figure 1 illustrates a typical AAW Mission Area Deactivation Diagram with vital components and redundancy relationships in the system.

The primary/combat system deactivation diagram identifies those equipments required to be functioning inorder for the system to be operational. Figures 2 and 3 illustrate this next level using the SPY-ID Radar System as an example. Additionally, this deactivation diagram indicates the HM&E support system inputs required for each equipment.

The HM&E support system deactivation diagrams will be developed by the shipbuilder. (Per section 072 of the General Specification for Ships,, these deactivation diagrams are to be prepared in accordance with task 101 of MIL-STD-1629.) A deactivation/diagram is prepared for each HM&E system supporting a primary/combat system as indicated by the applicable primary/combat system deactivation diagram. It should be noted that in addition to identifying those components (source and distributive) which comprise the system the deactivation diagram should:

1. Indicate support systems required. For example, cooling water system deactivation diagram should show electrical power support (power panel No. and normal and alternate power sources) required to operate circulating pumps.

2. Indicate the "user" equipment (primary/combat) system equipment) it supports. For example, the dry air system deactivation diagram should show support to radar transmitters.

Figure 4 illustrates a typical HM&E Support System Deactivation Diagram for the Antenna Cooling.

TYPICAL DEACTIVATION DIAGRAMS
AAW AREA

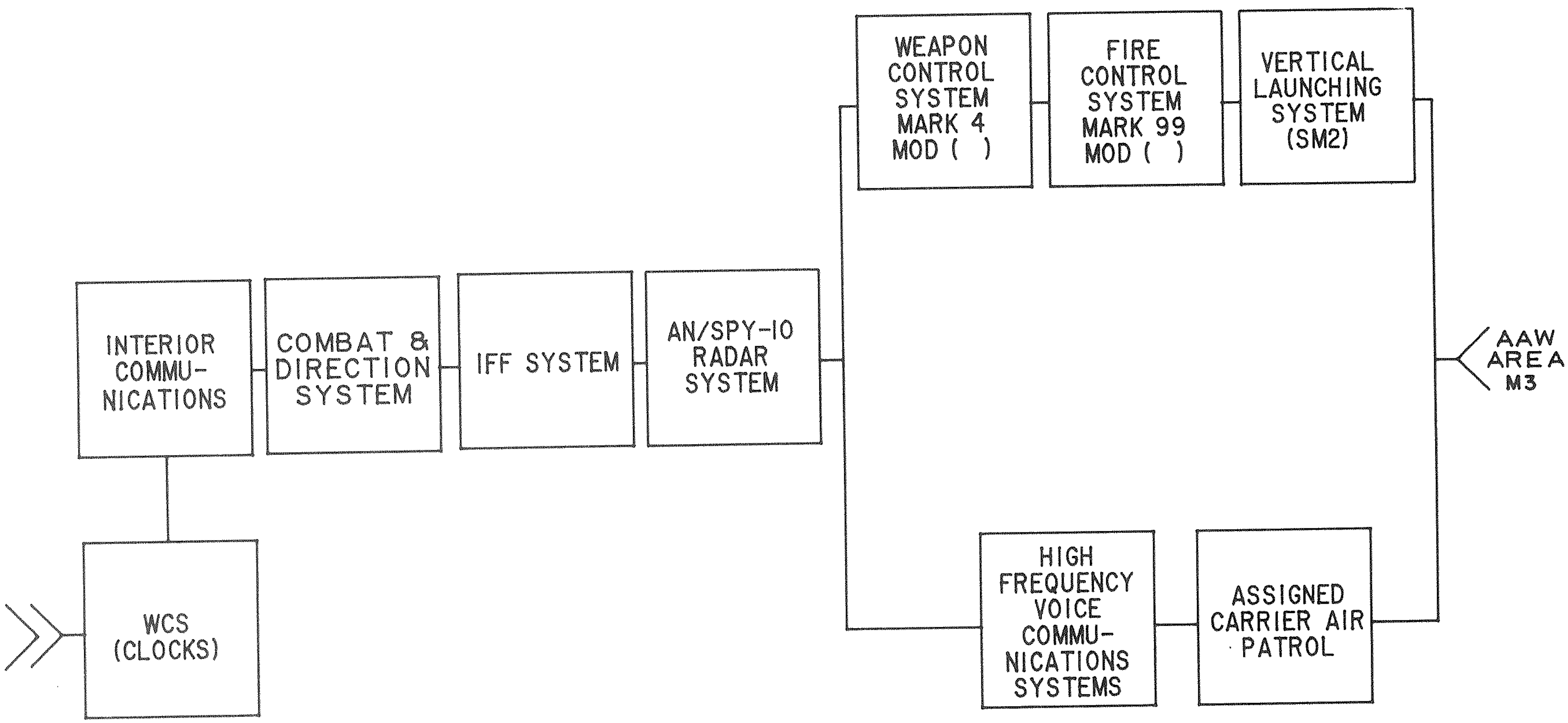


FIGURE 1 MISSION AREA DEACTIVATION DIAGRAM

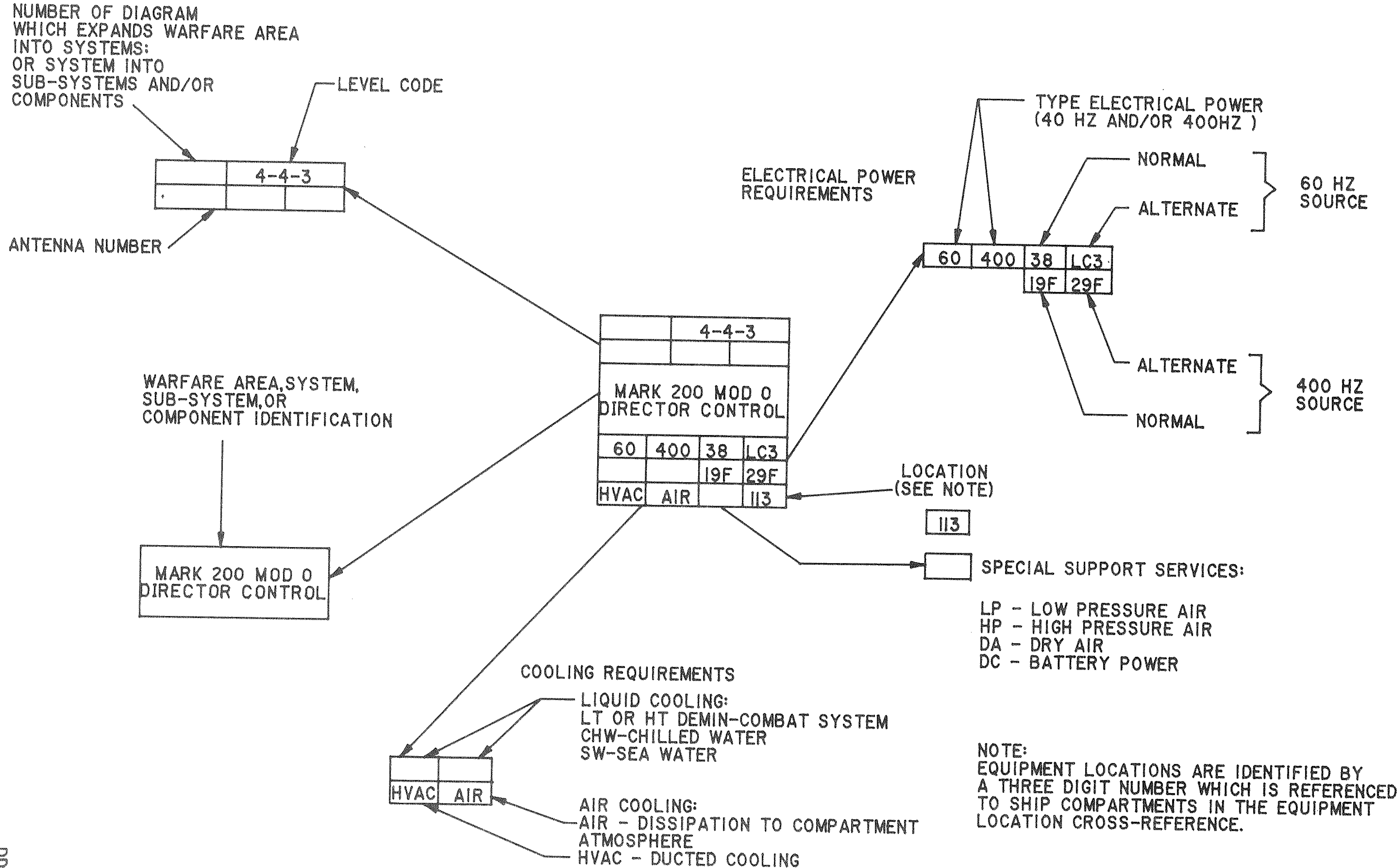


FIGURE 2 DEACTIVATION DIAGRAM BLOCK BREAKDOWN

TYPICAL DEACTIVATION DIAGRAM-AN/SPY-ID RADAR SYSTEM

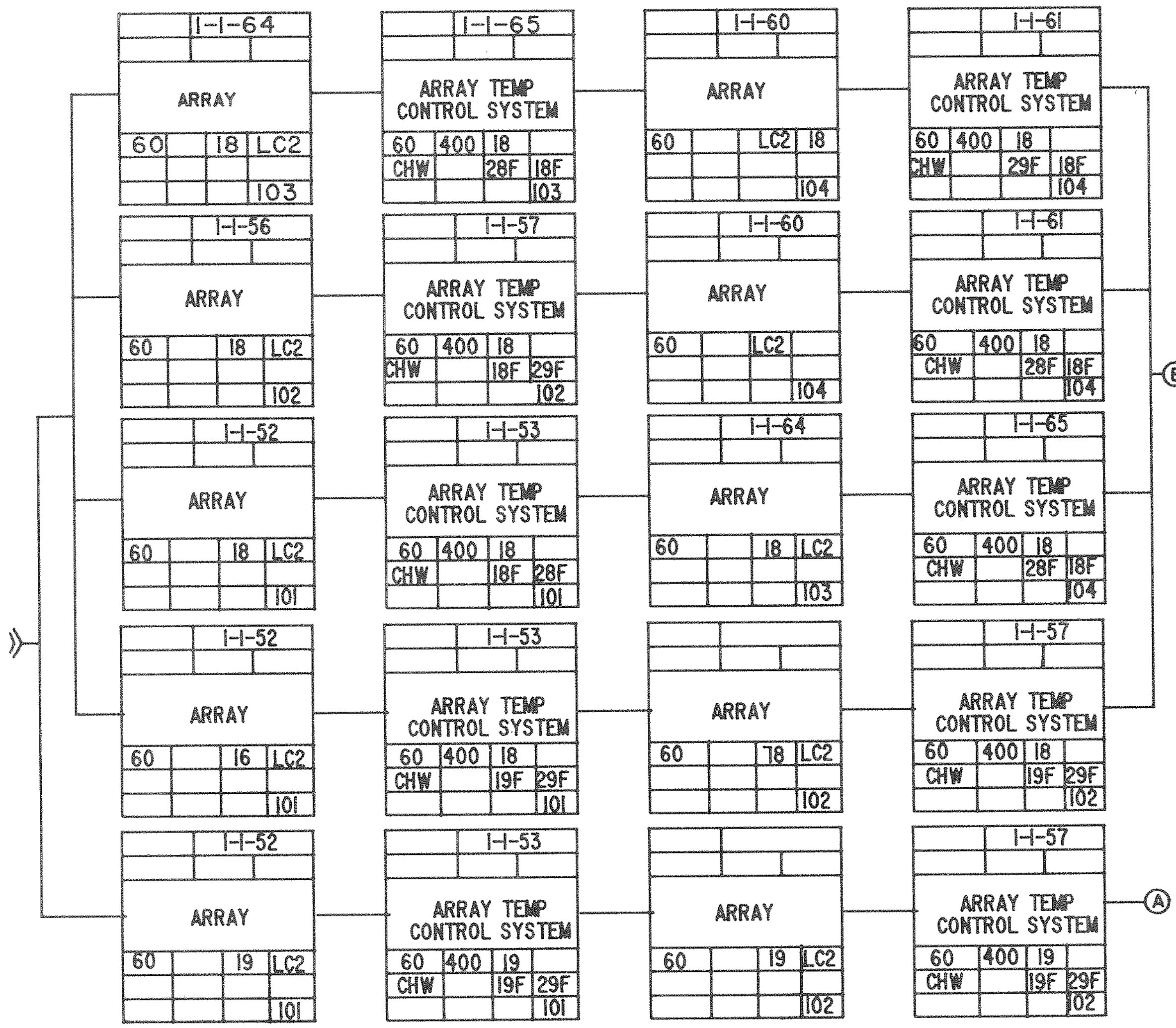
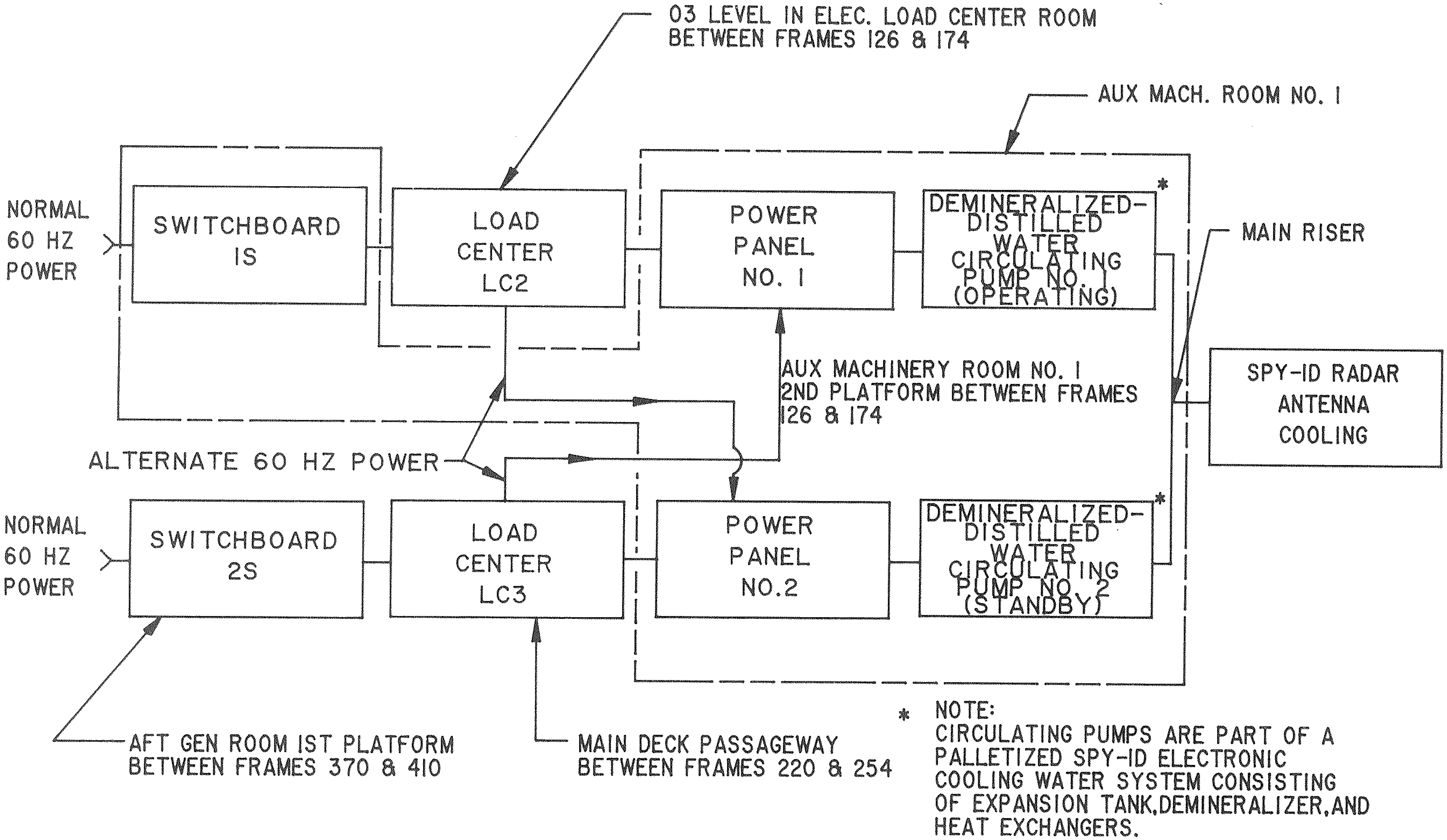


FIGURE 3 PRIMARY/COMBAT SYSTEM DEACTIVATION DIAGRAM



DDS 072-4

FIGURE 4 DEMINERALIZED COOLING WATER SYSTEM FOR SPY-1D RADAR
HM & E SUPPORT SYSTEM-ELECTRICAL DEACTIVACTION DIAGRAM

In the HM&E systems, the electrical power (60 & 400 HZ) is significantly more detailed than the fluid systems (cooling water, dry air, HVAC). The reasons for this are:

ELECTRICAL	FLUID
A. Virtually all combat system components require electrical support.	A. Only a select few combat system components require fluid system support.
B. Each vital "user" (power panel/dist box) has a separate, discrete (Norm & alter. cabling).	B. Distribution system for "users" is usually shared (equipment served by risers off a common main).

Because of the direct support of the electrical power system to primary/combat systems, it is helpful to arrange a power panel deactivation diagram in the same flow sequence as the combat system deactivation diagram, see Figure 5. The analysis which supports the identification of the power panels shown in Figure 5 is also included and is shown in Tables I and II respectively.

An analysis of the completed deactivation diagram should be performed in order to:

1. Identify all singularly vital (non-redundant) components. Due to their lack of redundancy, these components should be afforded some measure of physical protection. The degree of this protection will be based, in part, on the impact of the loss of the particular component on system and mission area performance, which can be directly determined from the deactivation diagrams.

2. Ensure compatible levels of redundancy throughout the deactivation diagram hierarchy. An example of incompatible redundancy is shown in Figure 6 where power panel 02-116-1 appears in both redundant legs of the power panel deactivation diagram. This defeats the redundancy inherent in the combat system deactivation diagram.

TABLE I - Example of Deactivation Diagram Analysis Data

60 HZ SOURCES FOR POWER PANELS VITAL TO THE RADAR SYSTEM

Power Panels	Normal Supply	Alternate Supply
2-126-2	1S	LC2
2-126-4	1S	LC1
2-130-2	1S	LC2
2-130-4	2-130-2	
03-127-1	1S	
03-127-2	1S	
03-128-1	1S	LC2
03-128-2	1S	LC2
03-128-3	03-128-1	
03-128-4	03-128-2	
03-155-1	1S	LC2
03-155-2	1S	LC2
03-155-3	03-155-1	
03-155-4	03-155-2	

Notes:

(1) 1S: Switchboard
(2) LC: Loadcenter
(3) Refer to Figure 5 for diagram

TABLE II - Example of Deactivation Diagram Analysis Data

400 HZ SOURCES FOR POWER PANELS VITAL TO THE RADAR SYSTEM

Power Panels	Normal Supply	Alternate Supply
1-126-3	1-126-1 (Normal - 2SF, Alternate - 1SF)	
1-126-4	1-126-2 (Normal - 1SF, Alternate - 2SF)	
2-126-2	2SF	1SF
2-126-4	1SF	2SF
03-127-1	1SF	2SF
03-127-3	03-127-1	
03-140-1	1SF	2SF
03-140-2	2SF	1SF
03-140-3	03-140-1	
03-140-4	03-140-2	

Notes:

(1) SF: Static Frequency Converter
(2) Refer to Figure 5 for Diagram

TYPICAL ELECTRICAL SYSTEM DEACTIVATION DIAGRAM
SPY-ID RADAR SYSTEM

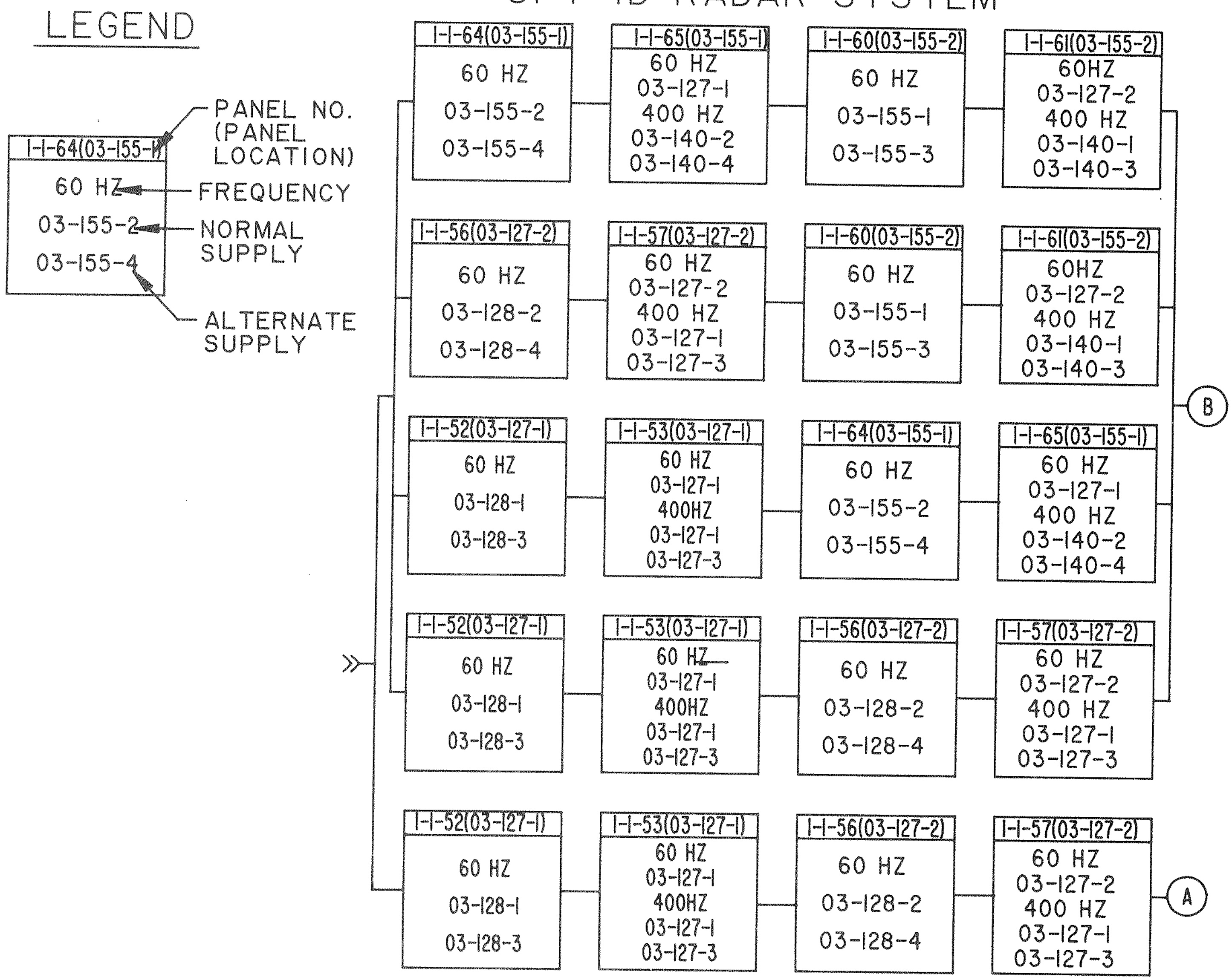


FIGURE 5 EXAMPLE OF AN ELECTRICAL SYSTEM DEACTIVATION DIAGRAM

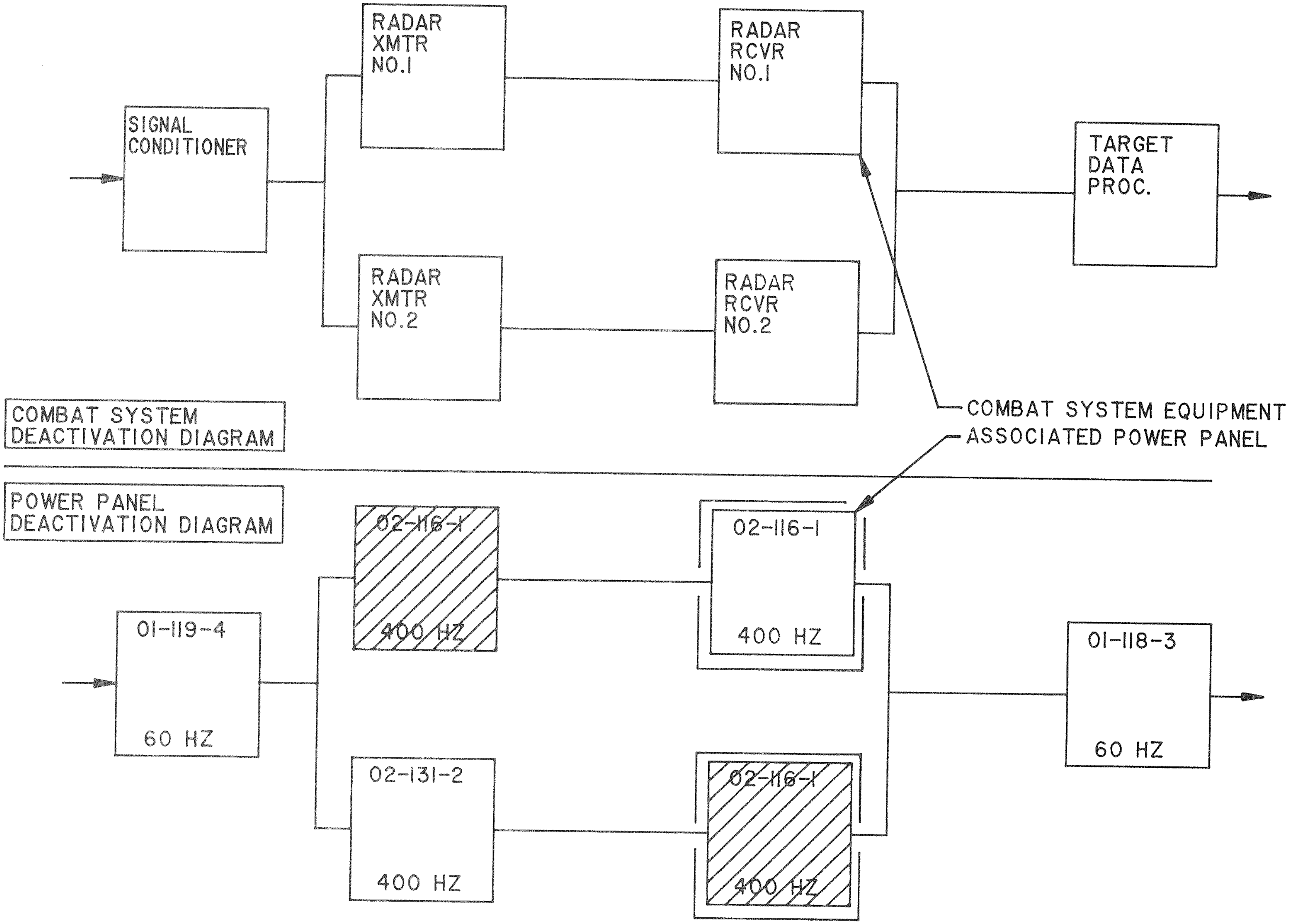


FIGURE 6 EXAMPLE OF INCOMPATIBLE REDUNDANCY IN ELECTRICAL EQUIPMENT DEACTIVATION DIAGRAM

072-4-g. Step 2: Physical Location of System Components

The functional redundancies of a system may be evaluated by analyzing the deactivation diagrams as described above. A complete survivability assessment requires that the physical separation between each of the redundant components also be evaluated. This is to ensure that a single "HIT" will not disable the redundant portions of a system.

To determine the actual separation between components, a physical layout of each system is required. Such a layout should identify the actual, installed shipboard location of:

- All sources (air conditioning (A/C) plants, switchboards, load centers, fire pumps, etc.).
- All distribution elements (piping, normal & alternate cable runs, power panels, etc.).
- All secondary support required (e.g., seawater cooling system to A/C plant).
- Isolation and segration features.
- Connections to user equipment.

In other words, the layout should be a physical representation of the components of the deactivation diagram.

The location for each of the above items are then identified from the appropriate design drawing.

The configuration of each system should be represented in the general quarters condition, with all "zebra" fittings closed and non-vital services secured.

Each of the system layouts should be shown on the mission area isometrics (per Section 072 of General Specifications for Ships). However, for the purposes of analysis a computer coding which identifies system component versus physical location may be advantageous.

Each completed isometric drawing should be reviewed to reveal any obvious "choke points" within the system. A choke point is a location where, due to insufficient separation, system redundancy is compromised.

072-4-h. Step 3: Impose Damage Modes

Analysis of the deactivation diagrams and isometric drawings will reveal the degree of redundancy and separation provided in the installed systems. A more rigorous analysis is required to ascertain the degree of damage tolerance of the ship. This is achieved by imposing specific damage modes, in a systematic manner, on the various systems. The damage modes to be considered are identified in Section 072f of the General Ships Specifications, which involve the following steps:

1. All HM&E system sources in any single compartment are assumed to be lost.

2. Consider the loss of any HM&E system located in a volume bounded by the side shell, a vertical plane through an imaginary line extending beyond the centerline of the ship up to, but not including 8-feet off the opposite sideshell (assume 8'-0" is maintained throughout the contour of the shell down to the centerline of the ship), a 60 foot length along the ship (35-feet in the superstructure), and extending from the baseline to the uppermost deck of the ship. This damage mode is illustrated in Figure 7.

3. Each 60 foot length along the ship shall be centered bewteen the main transverse watertight bulkheads, the number of 60 foot lengths is determined by the number of watertight subdivisions. The forwardmost subdivision containing the chain locker should not be considered. Port side volumes are separate from starboard side volumes. The shipbuilder should identify those 60 foot lengths along the ship where damage results in a loss of mission capability. This damage mode is illustrated in Figure 8.

The damage tolerance analysis is to be performed in accordance with Task 104 (Damage mode effects analysis) of MIL-STD-1629. For each damage mode, the components "LOST" of each system should be recorded (see Table III).

072-4-i. <u>Step 4: Modify Deactivation Diagram</u>

To determine the effects of each damage mode considered. The deactivation diagrams are modified to show "LOST" components. (See Figure 9).

The impact of each damage mode is then traced through the hierarchy of the deactivation diagrams: combat system, (Figure 10) and mission area (Figure 11). These effects will then be summarized as shown in Table IV.

072-4-j. <u>Step 5: Summarize Results</u>

The results of the shipbuilder's analysis will be documented in the Deactivation Diagram - Damage tolerance Analysis Report which will include all required deactivation diagrams and isometric drawings. The report will summarize all damage modes and indicate those modes which result in loss of mission area capability or loss of fire fighting capability.

(See paragraph 072-4-k. for firefighting analysis). The summary should indicate the cause of the loss and may take the form of a bar graph where the horizontal scale represents length of the ship (Figure 12).

For those damage modes which result in loss of mission area or firefighting capability or if an HM&E survivability deficiency is discovered, the shipbuilder shall prepare a Survivability Analysis Report. The report shall describe the deficiency, cite the specification sections involved, determine how the design could be changed to incorporate the specification separation requirements, impact of such a change on the ship, recommend a course of action, provide alternative course of action, and provide the rationale for the recommended course of action.

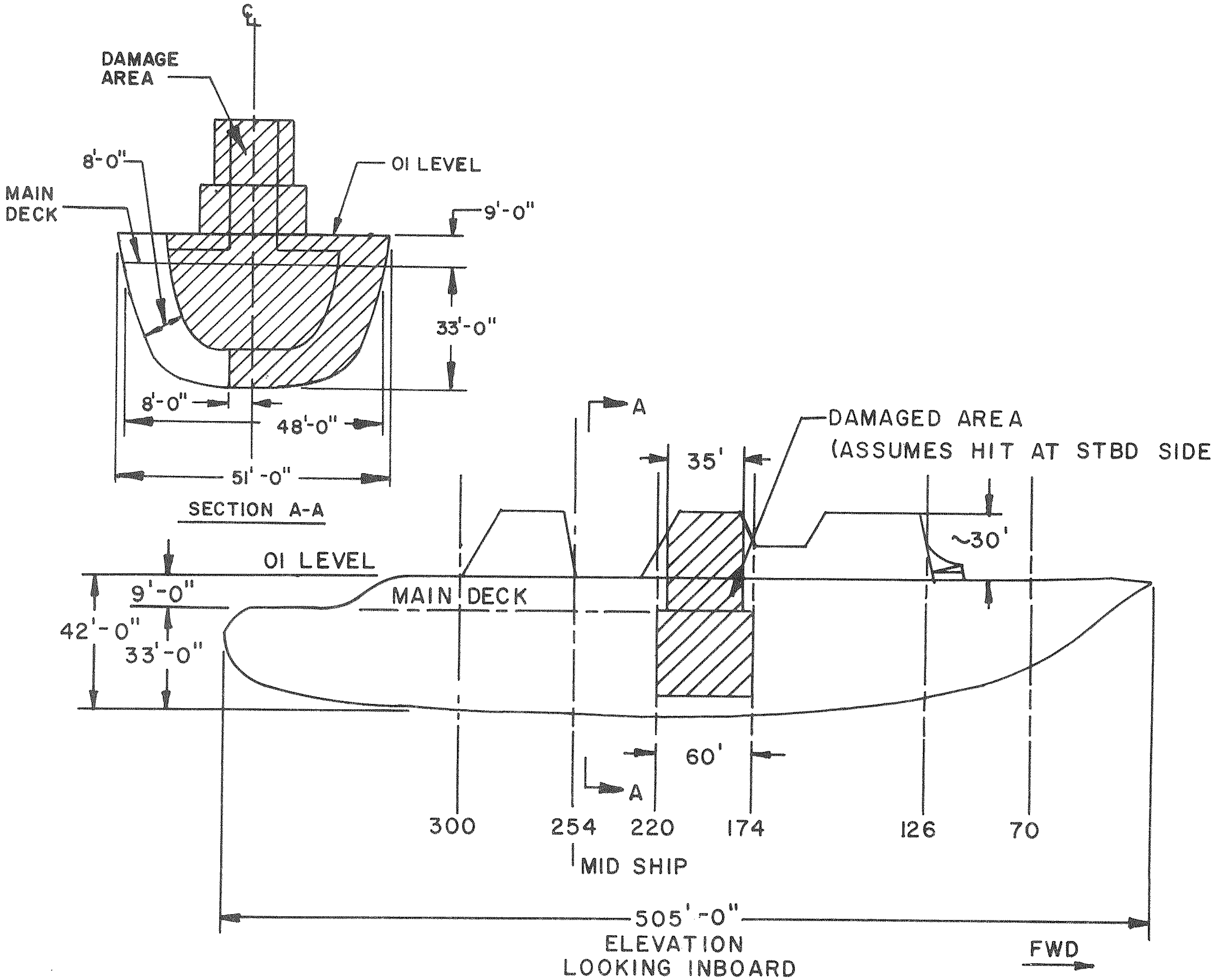
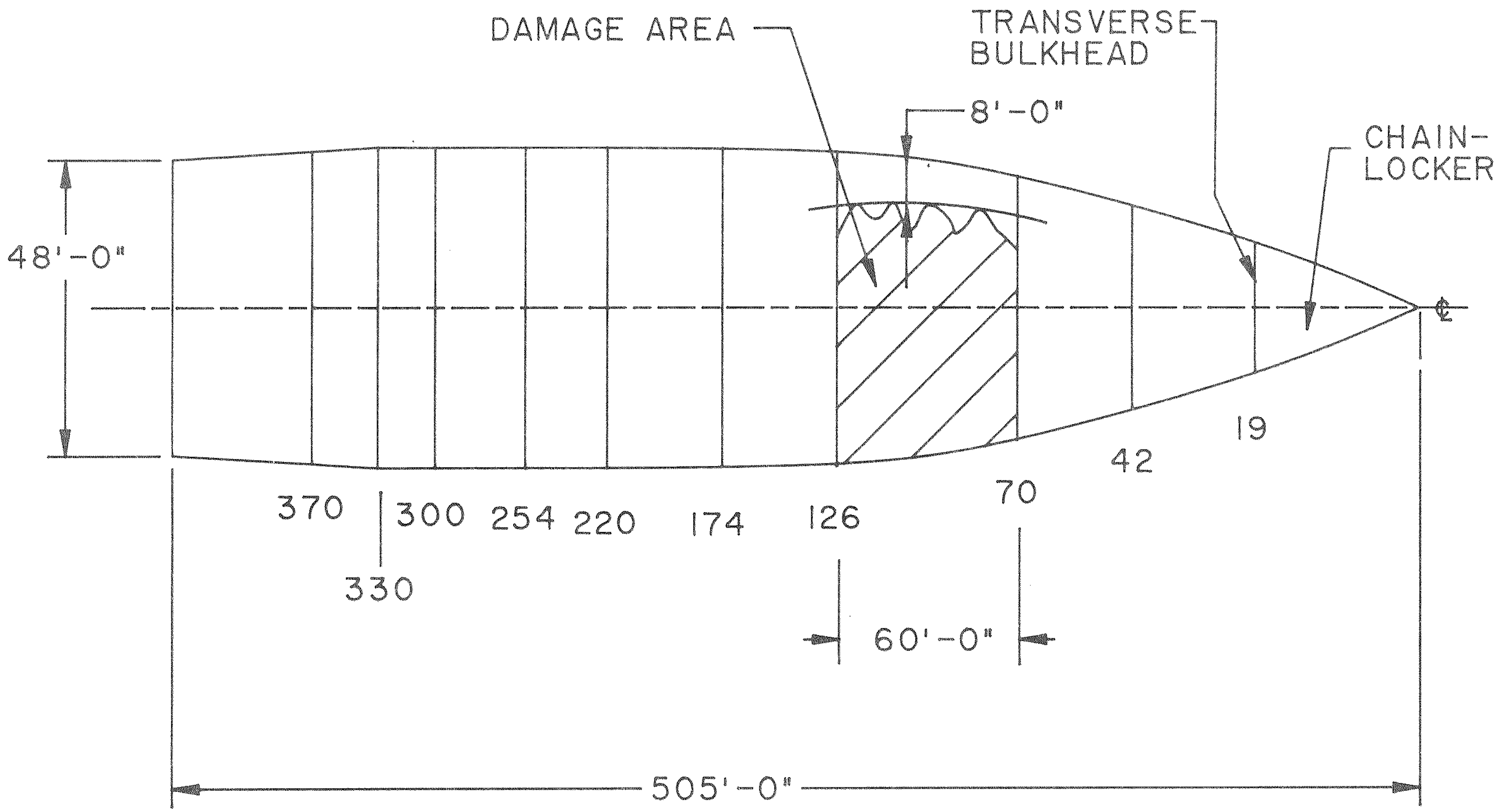


FIGURE 7 TYPICAL DAMAGE MODE FOR 60-FOOT LENGTH VOLUMES AND 35-FOOT ABOVE SUPERSTRUCTURE



PLAN VIEW MAIN DECK

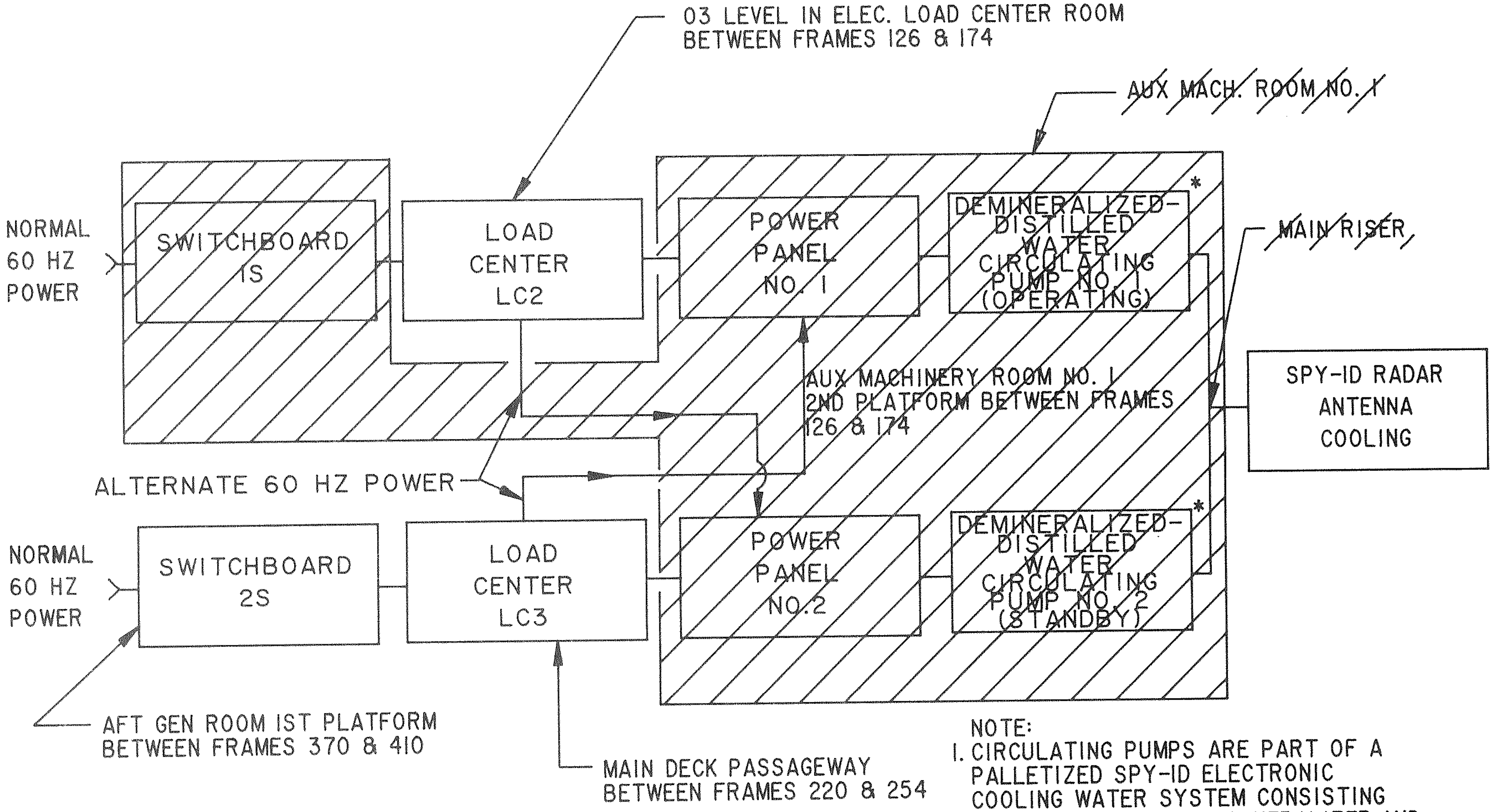
FIGURE 8 TYPICAL DAMAGE MODE FOR 60 FOOT LENGTH VOLUMES BETWEEN TRANSVERSE (WATERTIGHT) BULKHEADS

TABLE III List of Lost Components

Damage Mode No. 10 - STBD - FR 126 - 174

Demineralized Water	Sources:	Circulating Pumps Nos. 1 & 2 Aux. Machinery Room No. 1 Note: Entire Skid Lost
	Distribution:	Main (Frame 126) Riser to SPY-1D Antenna Cooling
Electric Power Support for Demineralized Water	Sources:	Switchboard 1S, Panel #1 and Panel #2.
	Distribution:	Normal 60 HZ power distribution to Power Panel #1.

Note: Reference Figure 9



NOTE:
1. CIRCULATING PUMPS ARE PART OF A PALLETIZED SPY-1D ELECTRONIC COOLING WATER SYSTEM CONSISTING OF EXPANSION TANK,DEMINERALIZER,AND HEAT EXCHANGERS.
2. DAMAGE MODE NO.10
STARBOARD-SINGLE HIT ±
AUXMACH. ROOM #1(FR 126-174)
////= COMPONENTS DESTROYED

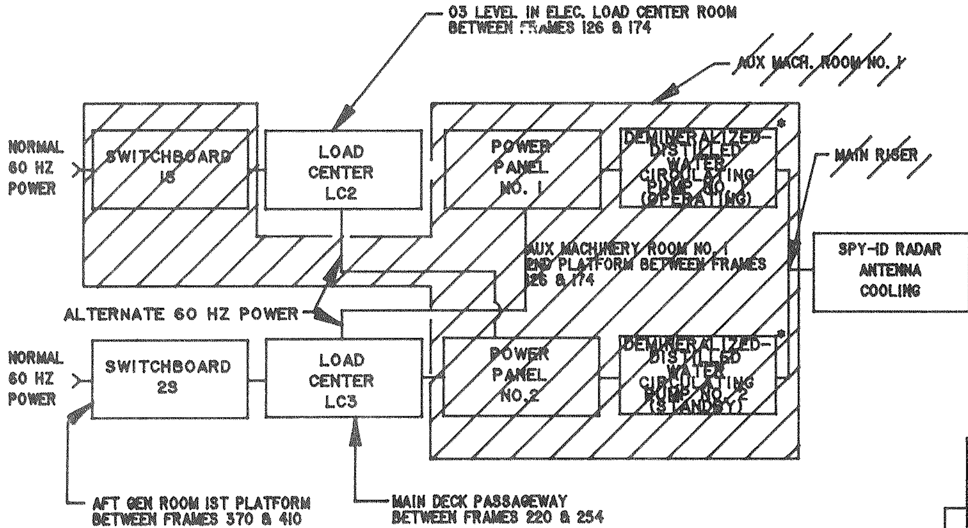
FIGURE 9 DEMINERALIZED COOLING WATER SYSTEM FOR SPY-1D RADAR
HM & E SUPPORT SYSTEM-ELECTRICAL MODIFIED DEACTIVACTION DIAGRAM

SPY-ID RADAR SYSTEM

NOTES:

1. CIRCULATING PUMPS ARE PART OF A PALLETIZED SPY-ID ELECTRONIC COOLING WATER SYSTEM CONSISTING OF EXPANSION TANK, DEMINERALIZER, AND HEAT EXCHANGERS.

2. DAMAGE MODE NO.10
   STARBOARD-SINGLE HIT
   AUX MACH. ROOM #1(FR 126-174)
   //// = COMPONENTS DESTROYED



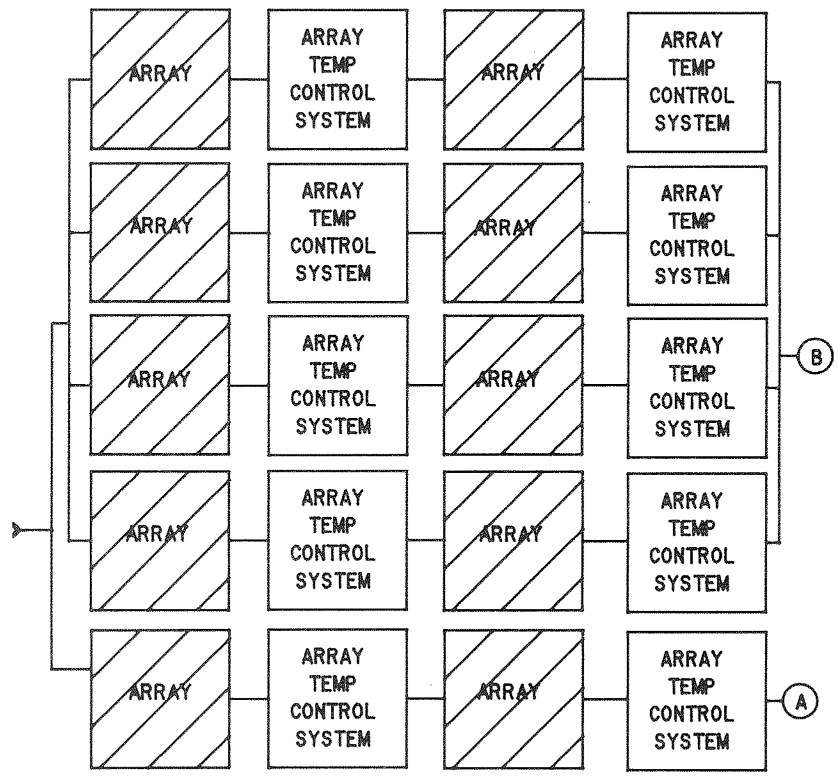


FIGURE 10 PRIMARY/COMBAT SYSTEM MODIFIED DEACTIVATION DIAGRAM

TYPICAL DEACTIVATION DIAGRAMS
AAW AREA

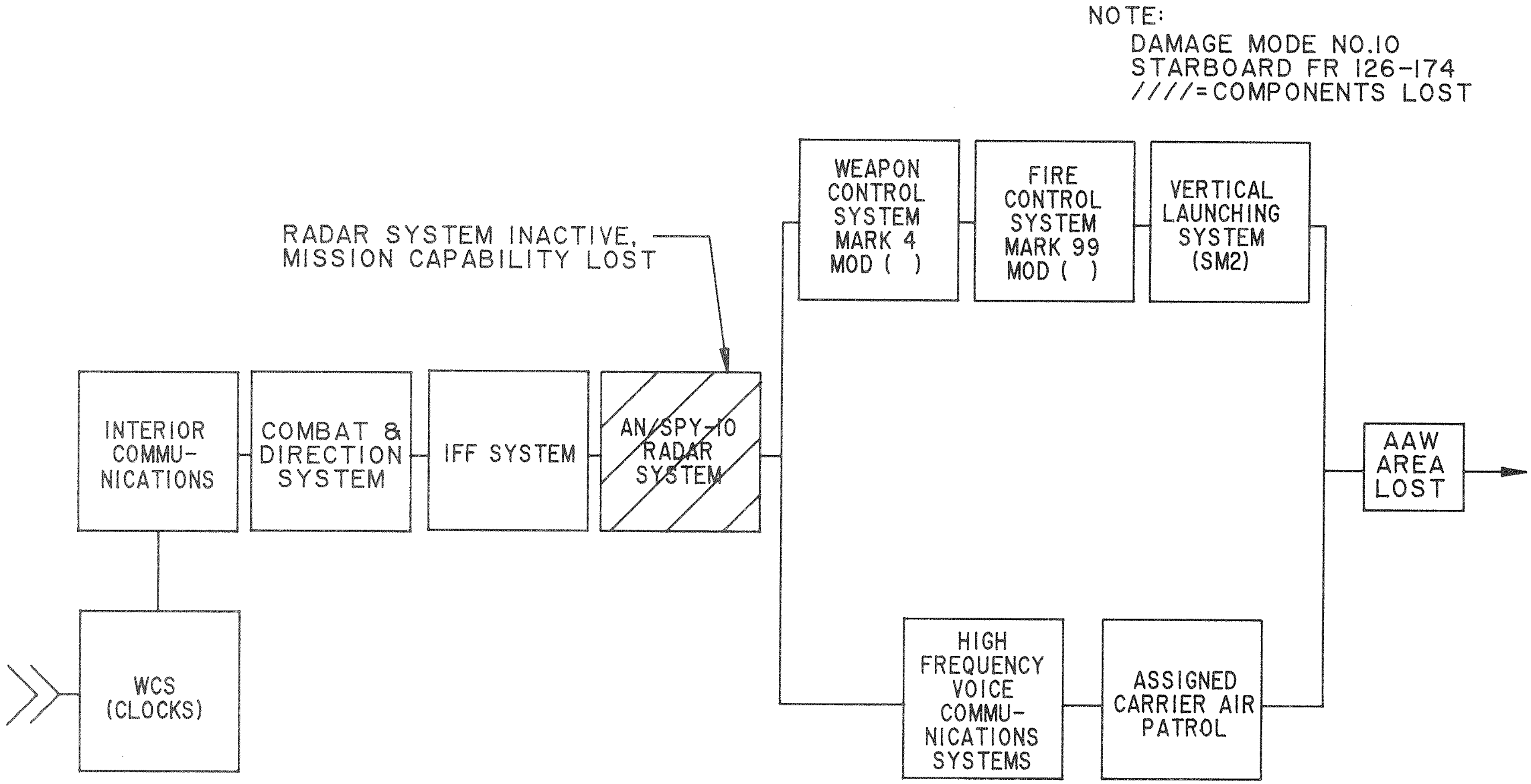


FIGURE II MISSION AREA DEACTIVATION DIAGRAM

TABLE IV **DAMAGE MODE AND EFFECTS ANALYSIS**

SYSTEM Demineralized Water

INDENTURE LEVEL HM&E

REFERENCE DRAWING ____

MISSION AAW

DATE ____

SHEET ____ **OF** ____

COMPILED BY ____

APPROVED BY ____

IDENTIFICATION NUMBER	ITEM/FUNCTIONAL IDENTIFICATION (NOMENCLATURE)	FUNCTION	FAILURE MODES AND CAUSES	MISSION PHASE/ OPERATIONAL MODE	SEVERITY CLASS.	DAMAGE MODE	DAMAGE EFFECTS			REMARKS
							LOCAL EFFECTS	NEXT HIGHER LEVEL	END EFFECTS	
	SPY-1D Cooling Water System	Source				No. 10	Lost			
	Circulating Pump No.1	Source				No. 10	Lost			
	Circulating Pump No. 2	Source				No. 10	Lost			
	Main FR 126	Dist.				No. 10	Lost			
	Riser to Ant. Clg.	Dist.				No. 10	Lost	Radar System	Out	Mission area - Lost
	SWBD 1S	Support				No. 10	Lost			
	Power Panel #1	Support				No. 10	Lost			
	Power Panel #2	Support				No. 10	Lost			

PLAN VIEW-AUXILARY MACHINERY ROOM #1 AT 14'-9" LEVEL

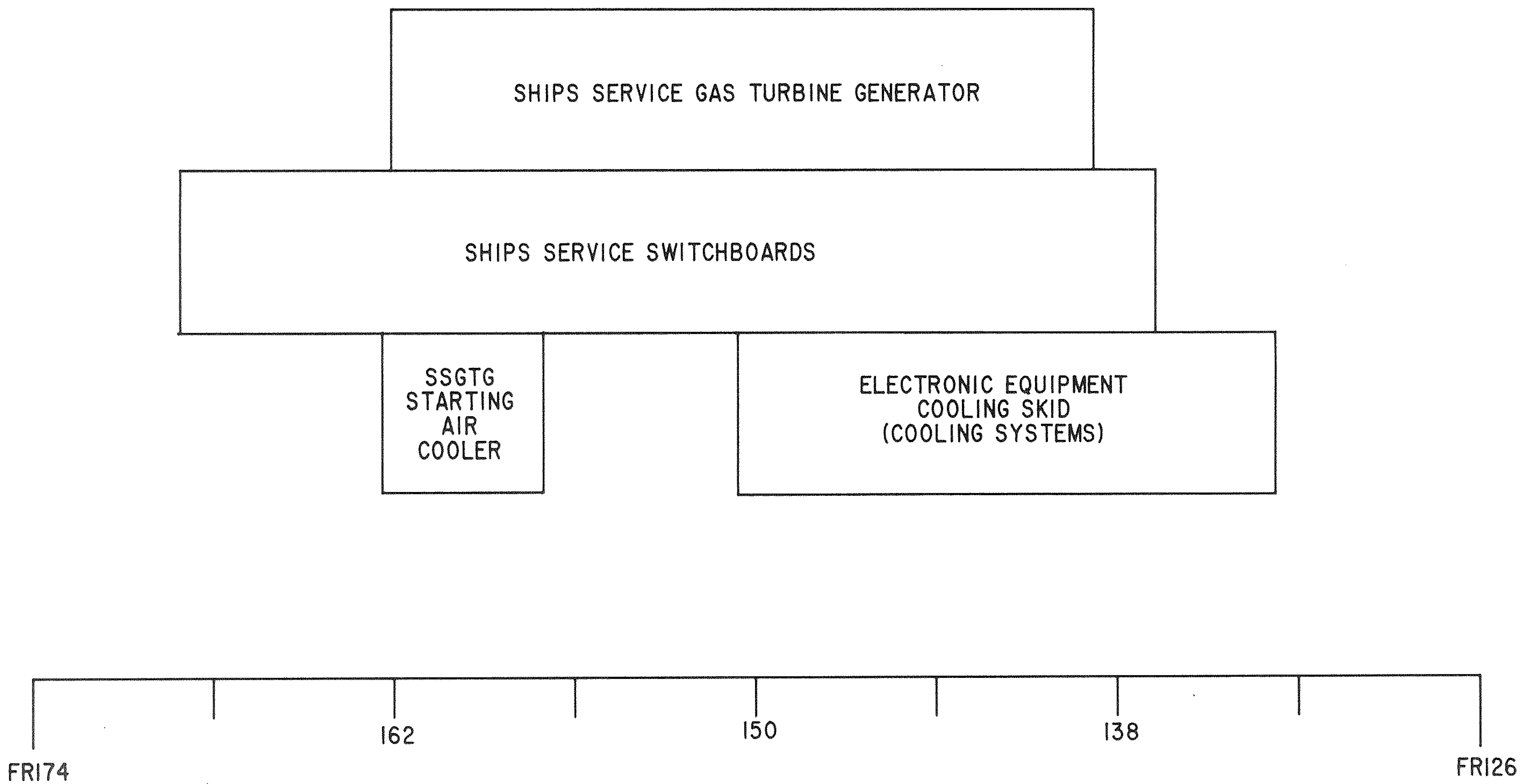


FIGURE 12
AAW SUPPORT SYSTEMS
DEACTIVATION PROFILE
(STARBOARD SIDE)

072-4-k. Firefighting Analysis

The survivability assessment for firefighting systems will follow the same procedure as that for HM&E support systems. However, there will be only a single level of deactivation diagrams to analyze.

The firefighting systems "users" are components of the firefighting system itself. Typical users for firefighting systems are:

- o Fire Plugs
- o AFFF Hose Reels
- o Magazine and Perimeter Sprinkling Nozzles
- o HALON Nozzles

Likewise Typical Sources Are:

- o Firepumps
- o AFFF Proportioners
- o HALON Bottles

072-4-l. Firefighting System Single Damage Mode

Because of their system configuration and Separation, it is unlikely that a single damage mode will completely deactivate an entire firefighting system. It is likely, however, that the capacity of the firefighting system can be reduced to a point where it is no longer able to successfully cope with the fire resulting from the given damage mode.

072-4-m. Loss of Firefighting System

The following damaged conditions should be interpreted as a "loss" of a firefighting system when damage modes identified in Section 072 of the Ships Specifications are considered.

1. Both distribution mains lost

2. More than 50 percent of sources lost

3. An entire deck level or 30 percent of the length of the ship is without service from a firefighting system

4. Other losses which significantly reduce capacity of a system.

If the firemain also provides cooling water support to the combat system, the analysis of that support is done as part of the overall HM&E support of combat systems as covered eariler in this design data sheet.