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COMMUNICATION FACILITY EMP ASSESSMENT [redacted]

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Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124

30 March 1979

Topical Report for Period 1 September 1975—30 March 1979

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Safety Margin	Hardening Design Package
Survival Confidence	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents an assessment of the [redacted] facility [redacted] [redacted] to high-altitude EMP based upon electromagnetic analysis, functional analysis, and operational performance requirements.

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[redacted] SUMMARY [redacted]

[redacted] A scenario variant EMP assessment has been performed for the [redacted] facility located at [redacted]. The EMP assessment considered the equipment effects induced by EMP environments generated by high-altitude nuclear detonations. The scenario variant technique identifies the critical electrical/electronic equipment predicted to be impaired by the largest signals induced within the facility by any high-altitude nuclear EMP environment.

[redacted]

[redacted] Electromagnetic pulse hardening is recommended to insure that all critical equipments will maintain their operational capabilities during and after an EMP illumination of the facility. Hardening design packages are provided such that, if implemented, the functional capabilities of the facility will survive the most severe high-altitude EMP with [redacted] percent, or greater, confidence.

[redacted]

[redacted]

[redacted]

[redacted] TABLE OF CONTENTS

[redacted]

[redacted]

[redacted] LIST OF ILLUSTRATIONS

(U) LIST OF TABLES

[redacted]

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1.0 [redacted] INTRODUCTION

1.1 BACKGROUND

The Commander-in-Chief [redacted] and the Defense Nuclear Agency (DNA) have undertaken an Assessment of [redacted] Communications for Hardening to Electromagnetic Pulse [redacted] to assess the vulnerability of the [redacted] Control, Communications and Computer (C^4) Networks to electromagnetic pulses from high altitude nuclear bursts and to provide recommendations for hardening as may be required. [redacted] Networks are used to link [redacted] with the National Command Authority (NCA), subordinate and component headquarters, and the [redacted].

The Boeing Aerospace Company has developed and validated analytical techniques to predict the functional responses of a communications facility to the electromagnetic pulse (EMP) environments produced by a high-altitude nuclear weapon detonation scenario. The analytical capability has been applied to selected elements of the [redacted] C^4 Networks to develop response predictions in terms of upset and damage of facility equipment and functional impairments of facility communications capabilities.

This report concerns the [redacted] facility at [redacted] specifically the [redacted] and the [redacted] transmitting systems. [redacted] is used for U.S. Navy Fleet Broadcasts, and the [redacted] is a navigational aid for ships and aircraft. The [redacted] facility is part of the [redacted] chain consisting of [redacted]

An on-site survey was conducted during September 1977 to determine the EMP features and element descriptions for use in the facility analysis. Equipment configuration and operational data were gathered and used to develop the electromagnetic coupling and functional analyses of specified critical equipment. Computer models were developed to calculate the waveforms induced by EMP at significant terminals on critical equipment. The peak amplitudes of the waveforms were compared to calculated equipment damage and upset thresholds to predict the probability of the equipment surviving a most severe EMP event.

[redacted]

[redacted]

1.2 SCOPE

This report presents the element descriptions, functional analyses, element response assessments to the most severe high-altitude nuclear EMP environment, and hardening technique and concept design packages for the LF and HF receiving and [redacted] transmitting systems at the [redacted] facility on [redacted]

Hardening techniques and concept designs have been developed for each piece of critical equipment predicted to be vulnerable to the most severe nuclear EMP environment. The hardening techniques and concept designs are expected to reduce or nullify the EMP effects, thus assuring critical equipment survivability to at least the [redacted] percent confidence level. The hardening designs consider the ease of installing and monitoring the hardening devices, cost, and non-interference to normal, daily operations.

[redacted]

2.0 [redacted] PREDICTED EMP VULNERABILITY AND MISSION IMPACT [redacted]

[redacted]

[redacted] Specific assessment values for the critical equipment are listed in Appendix D, "Scenario Variant Assessment Predictions."

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

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[redacted]

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Pages 9 and 10 were deleted.

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[redacted]

[redacted]

[redacted]

[redacted]

3.0 [redacted] FACILITY HARDENING [redacted]

[redacted]

[redacted] Table 3.0-1 lists the equipment recommended for electromagnetic pulse hardening in the [redacted] facility. The table defines the techniques for hardening the equipment and the improvement expected by implementing the hardening technique.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

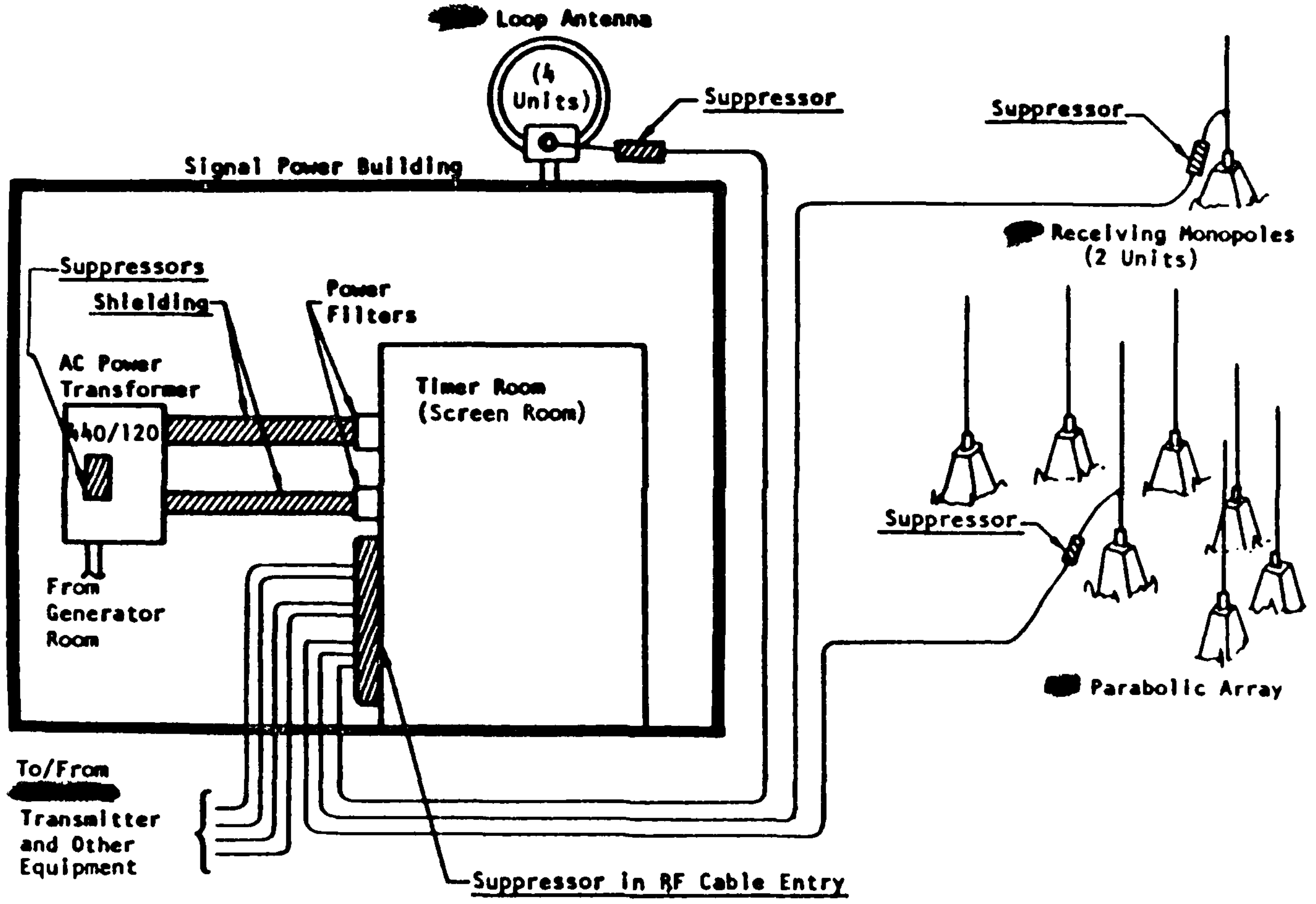


Figure 3.0-1. Conceptual installation of hardening modifications.

[redacted]

[redacted]

[redacted] The remaining material in this section defines conceptual designs for the hardening techniques recommended for installation in the [redacted] facility. The information presented includes recommended design requirements, material specifications, and installation instructions for each hardening concept. The hardening requirements are such that the modifications can be readily installed by on-site personnel. Some inspections by on-site personnel will be required to determine the proper equipment to be ordered.

[redacted]

[redacted]

3.1 [redacted] AC POWER HARDENING CONCEPT DESIGN [redacted]

3.1.1 [redacted] AC Power System Shielding [redacted]

[redacted]

[redacted]

[redacted]

3.1.1.2 [redacted] Material Requirements. [redacted] An estimated list of material is shown in Table 3.1-1. The list also provides expected costs and potential suppliers.

3.1.1.3 [redacted] Installation Requirement. [redacted] Remove the existing flexible conduit between the transformer case and power filters. Replace the flexible conduit with rigid steel conduit (see Figure 3.1-1). Assemble the conduit fittings in accordance with Appendix E, Sections E.2.1 and E.2.2. Reconnect the transformer secondary to the power filter input terminals.

[redacted]

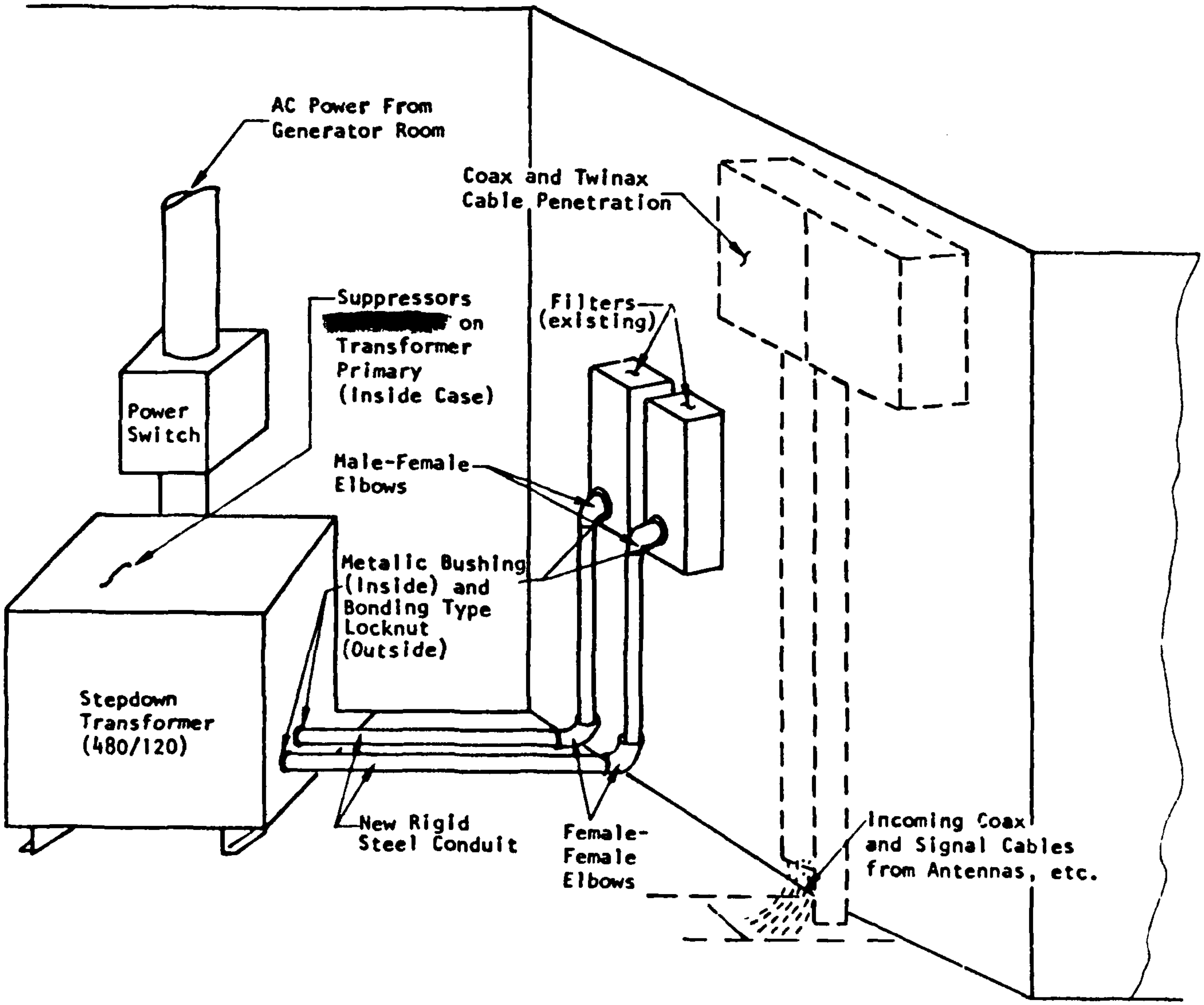


Figure 3.1-1. AC power hardening installation; timer room outside wall.

Table 3.1-1. AC power system shielding, list of material.

Item	Description	Supplier	Estimated Quantity		Approximate Cost/Unit	Total
			Per/Unit	Units		
1	Rigid steel conduit, 1" dia., galvanized	①	10 ft.	10 ft.	$15.00	$15.00
2	Rigid steel conduit, 1" dia., galvanized or zinc plated, 90° male and female elbo - Crouse-Hinds EL 396	①	2	1	$8.20	$8.20
3	Rigid steel conduit, 1" dia., galvanized or zinc plated, 90° female elbo - Crouse-Hinds EL 39	①	2	1	$6.20	$6.20
4	Bonding type locknut, T&B 143, Steel City LN-103 or Appleton BL-100	①	4	1	$2.00	$2.00
5	Metalic bushing, T&B 124, Steel City BU-403, or Appleton BU-100	①	4	1	$2.00	$2.00
6	Galvicon, cold galvanizing compound KENCO Div., Southern Coatings & Chemical Co. Sumter, South Carolina 29150	①	-	1 pint	$4.10	$4.10
7	Miscellaneous hardware ②	①	-	-	$5.00	$5.10
					Total	$42.50
	NOTES:					
①	Obtain from the nearest available source					
②	Determine type, size and quantity from existing installation and implementation of hardware design.					

3.1.2 [redacted] AC Power System EMP Suppression [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

3.1.2.2 [redacted] Material Requirements. [redacted] The estimated list of material is in Table 3.1-2. The list also provides expected costs and potential suppliers.

[redacted]

[redacted]

Table 3.1-2. AC power system EMP suppression, list of material

Item	Description	Supplier	Estimated Quantity		Approximate Cost/Unit	Total
			Per/Unit	Units		
1	Suppressor, [redacted]	①	2	1	$70.00	$70.00
2	Miscellaneous hardware ③	②	-	-	$5.00	$5.00
					Total	$75.00
	NOTES:					
①	[redacted]					
②	Obtain from the nearest available source					
③	Determine size, type, and quantity from existing installation and implementation of hardness design					

[redacted]

[redacted]

3.2 [redacted] SIGNAL INPUT HARDENING CONCEPT DESIGN [redacted]

3.2.1 [redacted] Signal Input EMP Suppression [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

3.2.1.2 [redacted] Material Requirements. [redacted] An estimated list of material is shown in Table 3.2-1. The list also provides expected costs and potential suppliers.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Table 3.2-1. Signal input EMP suppression, list of material.

Item	Description	Supplier	Estimated Quantity		Approximate Cost/Unit	Total
			Per/Unit	Units		
1	[redacted] suppressor	①	3	1	$105.00	$105.00
2	[redacted] suppressors	①	2	1	$70.00	$70.00
3	[redacted] suppressor	①	8	1	$280.00	$280.00
4	[redacted] suppressor ④ (**) part number must be completed after on-site inspection before parts can be ordered. Inser N, BNC, TWINAX in place of (**) suffix to complete part number.	①	7	1	$210.00	$210.00
5	Miscellaneous 1/8" copper sheet for mounting suppressors at antenna bases. ④	②	-	-	$200.00	$200.00
6	Miscellaneous connectors for monopole antennas ④	②	-	-	$100.00	$100.00
7	Dow Corning 3145 RT V adhesive/sealant (non-corrosive)	③	-	1 pint	$22.00	$22.00
8	Miscellaneous Hardware ④	②	-	-	$30.00	$30.00
					Total	$1017.0

NOTES:

① [redacted]

② Obtain from nearest available source

③ Dow Corning Corp., Midland, Mich. 48640

④ Determine amount, type, size, quantity, etc. from existing installation and implementation of hardness design.

[redacted]

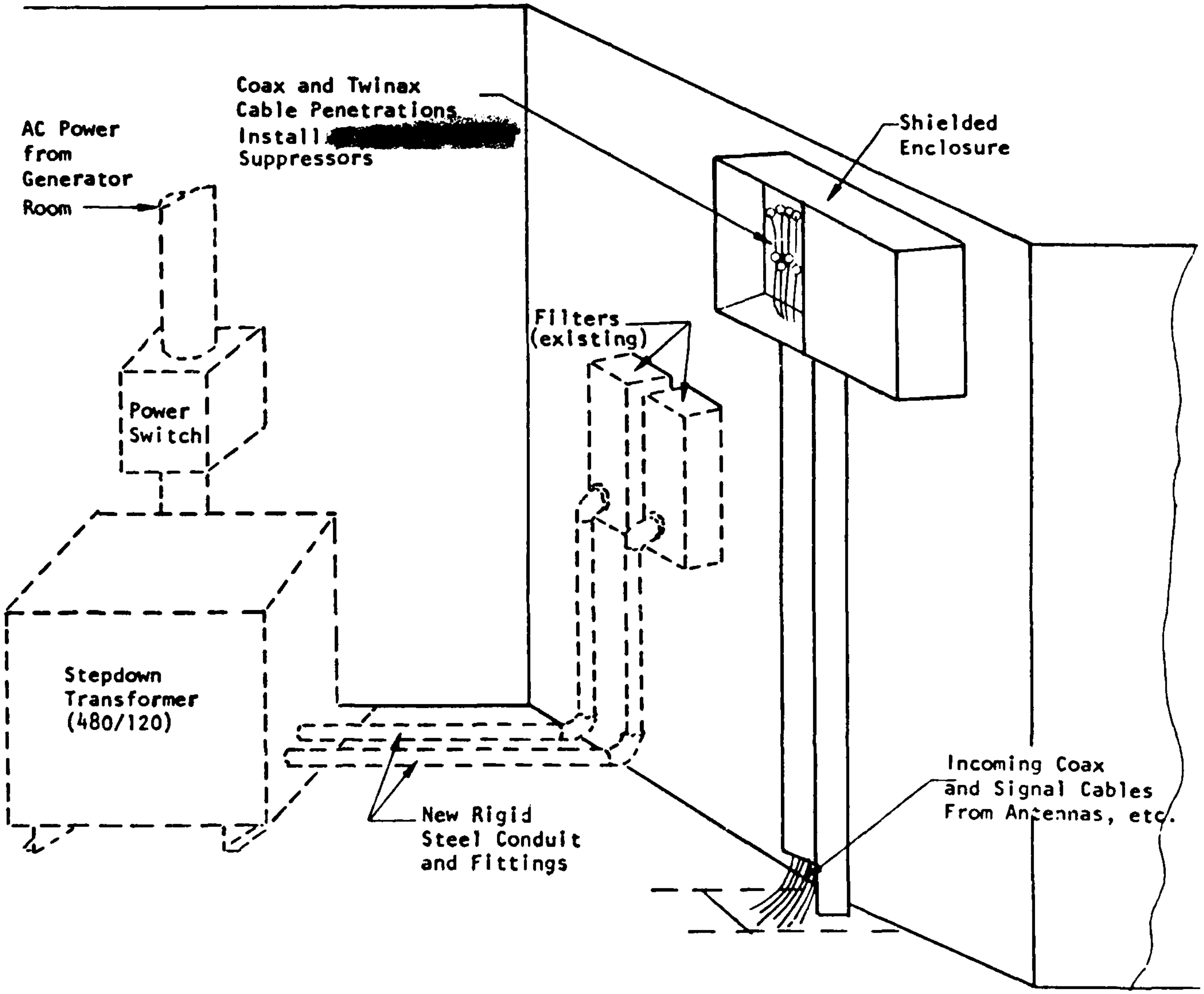
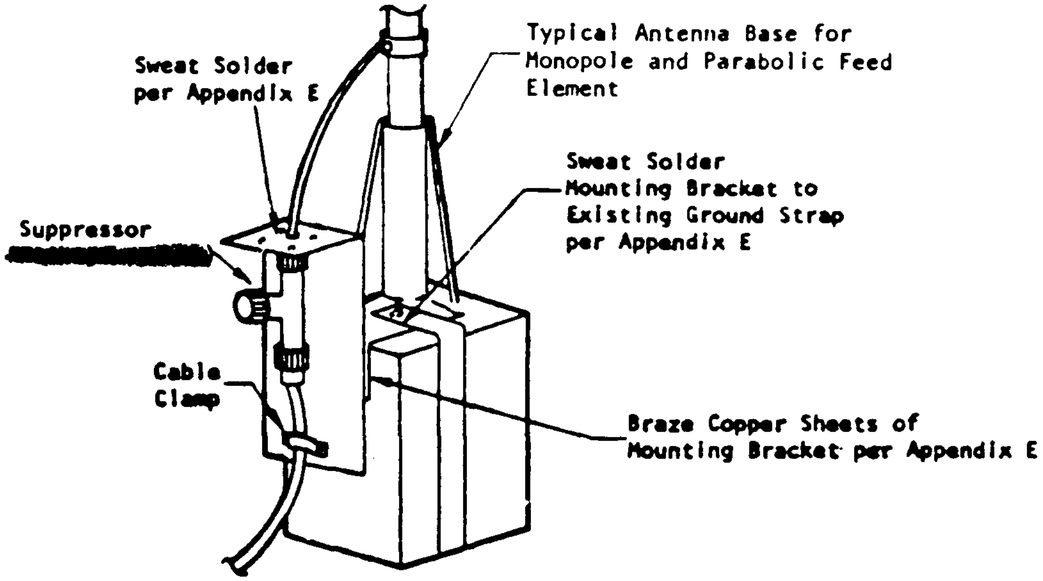


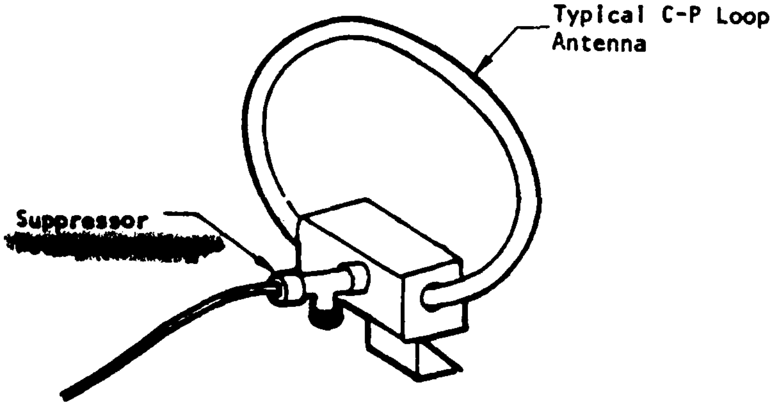
Figure 3.2-1. Signal cable suppressor installation; timer room outside wall.

[redacted]

[redacted]



Suggested installation for monopole and parabolic feed elements. Mounting bracket to be made of 1/8" copper sheet. Assemble coaxial cable and fittings per Appendix E, Severe Environment.



Suggested installation for loop antenna. Assemble coaxial cable and fittings per Appendix E, Severe Environment.

Figure 3.2-2. Suppressor installation on Clarinet-Pilgrim receive antennas.

[redacted]

[redacted] APPENDICES

The following appendices provide complementary information concerning his assessment of the [redacted]

Appendix A:	Facility Description
Appendix B:	Functional Description
Appendix C:	Electromagnetic Analysis
Appendix D:	EMP Assessment Predictions
Appendix E:	Bonding and Assembly Instructions

[redacted]

[redacted]APPENDIX A
FACILITY DESCRIPTION

A.1 GENERAL

The U.S. Coast Guard [redacted] facility on [redacted] is one of five [redacted] transmitting locations which provide both navigational and communications information to the [redacted] area. The other [redacted] facilities are located at [redacted]

A.1.1 Facility Layout

Figure A.1-1 shows the layout of the [redacted] facility. Equipment associated with the [redacted] and [redacted] systems are located in either the signal-power building or transmitter building. The signal-power building contains the [redacted] signal receivers and equipment, the [redacted] timer, and power generating equipment. The transmitter building contains two high-power [redacted] transmitters, an antenna coupler, dummy load, and incoming ac power transformers. The buildings are constructed of reinforced concrete block walls and prestressed concrete slab roofs.

Other parts of the installation include personnel barracks, water and sewage facilities, an oil storage tank farm, antennas and interconnecting conductors. Power is also supplied to an aircraft refueling facility, a meteorological facility (balloon building), aircraft warning lights, a radio beacon, and [redacted] weather facilities on the island.

A.1.2 Equipment Layout

The signal-power building is a one-story, reinforced, concrete block structure, providing a measured [redacted] attenuation to free-field EMP. The [redacted] equipment is located inside the timer room, measuring 6 meters x 6 meters x 2.5 meters high (20 ft x 20 ft x 8 ft). The timer room provides a

[redacted]

[redacted]

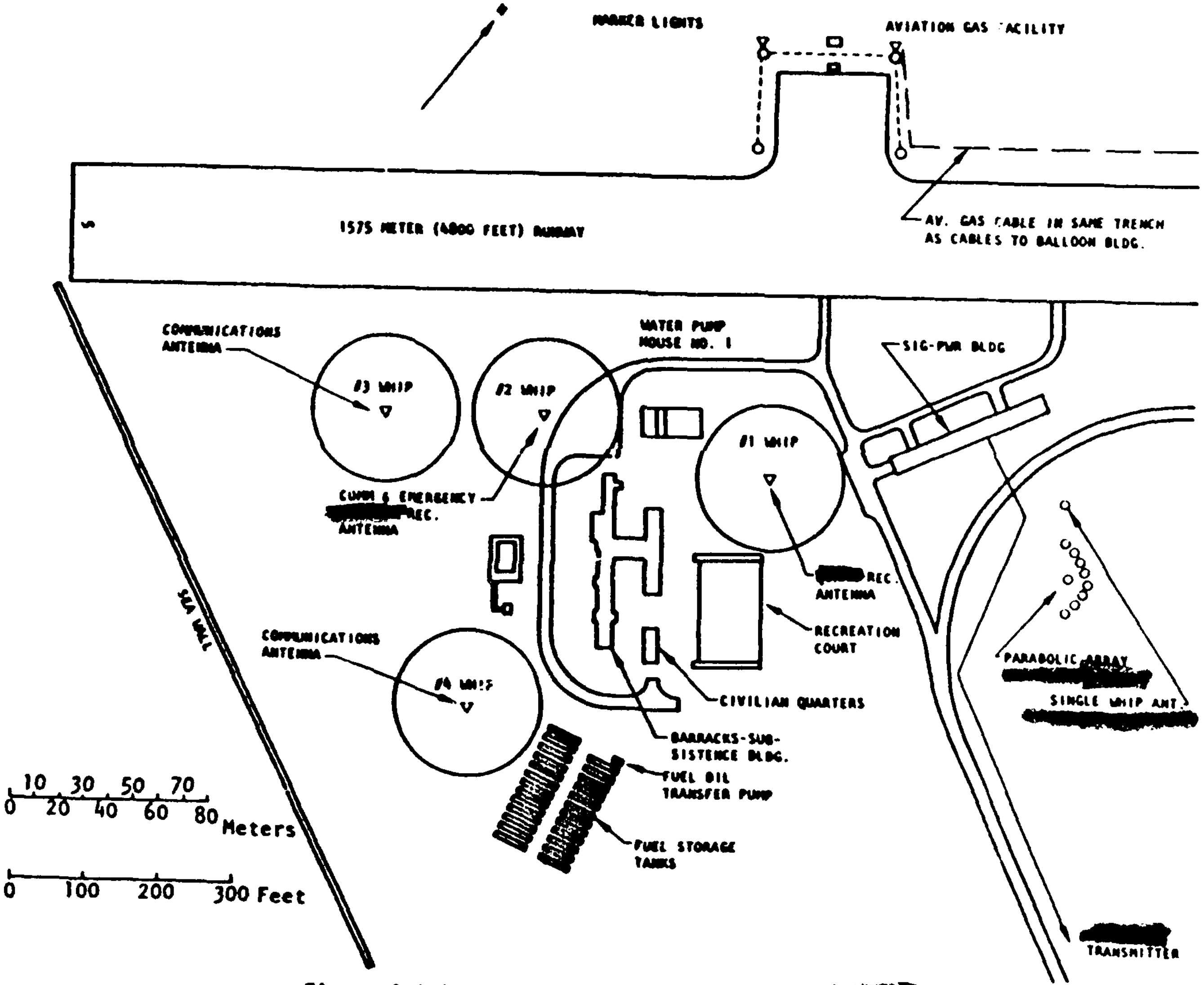


Figure A.1-1. Plot plan of the [redacted] facility.

[redacted]

measured total of [redacted] attenuation to the electromagnetic environment outside the signal-power building. Figure A.1-2 shows a floor plan of the signal-power building timer room.

The timer room contains a complete [redacted] equipment installation which includes one [redacted] timer set, one [redacted] transmitter control set, one [redacted] frequency standard rack, one recorder rack, and one auxiliary equipment rack. Also located in the room is an [redacted] transmitter control set for receiving and retransmitting the HF and LF messages by modulating the [redacted] signal.

The [redacted] transmitter building is a specially shielded concrete block structure located 463.3 meters (1520 feet) east of the signal-power building. Special shielding is required to protect the [redacted] electronics equipment from the [redacted] electromagnetic fields radiated from the [redacted] transmit antenna. The [redacted] signal is routed from the signal-power building to the transmitter building via two buried twinax cables. The transmitter building structure provides [redacted] attenuation to free-field EMP. The [redacted] transmit antenna is located adjacent to the transmitter building. The base of the transmit antenna is tied into a 457.2 meter (1500 foot) radius ground counterpoise system. Figure A.1-3 shows the layout of the transmitter building.

[redacted] receive antennas are mounted on the roof of the signal-power building, and coaxial cables route from the receive antennas through a bulkhead feedthrough panel into the timer room and to the radio receivers. A [redacted] phased-array antenna located 67 meters (220 feet) east of the signal-power building is used to receive [redacted] HF signals from [redacted] The [redacted] facility uses three [redacted] cesium frequency standards for [redacted] timing. In addition, [redacted] receives a master timing signal from [redacted] as a back-up timing for the cesium standards.

The generator room in the signal-power building contains four 636 HP [redacted] diesels and four 550 kW, 480 volt ac generators, supplying all [redacted] station power via buried cable.

[redacted]

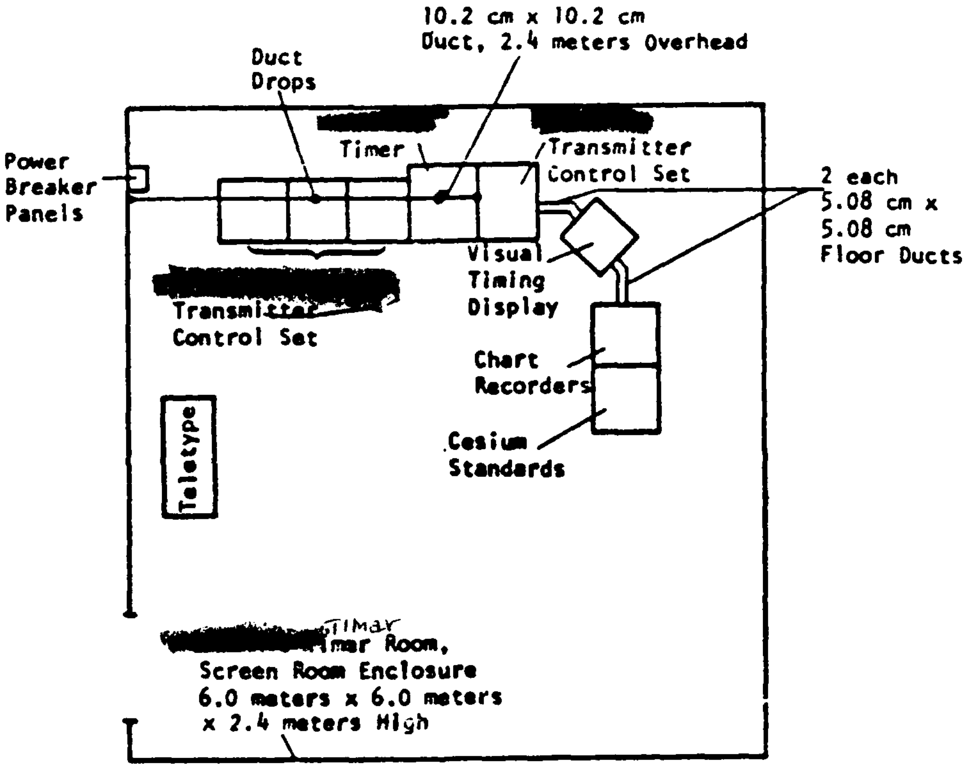


Figure A.1-2. [redacted] timer room layout, [redacted]

[redacted]

[redacted]

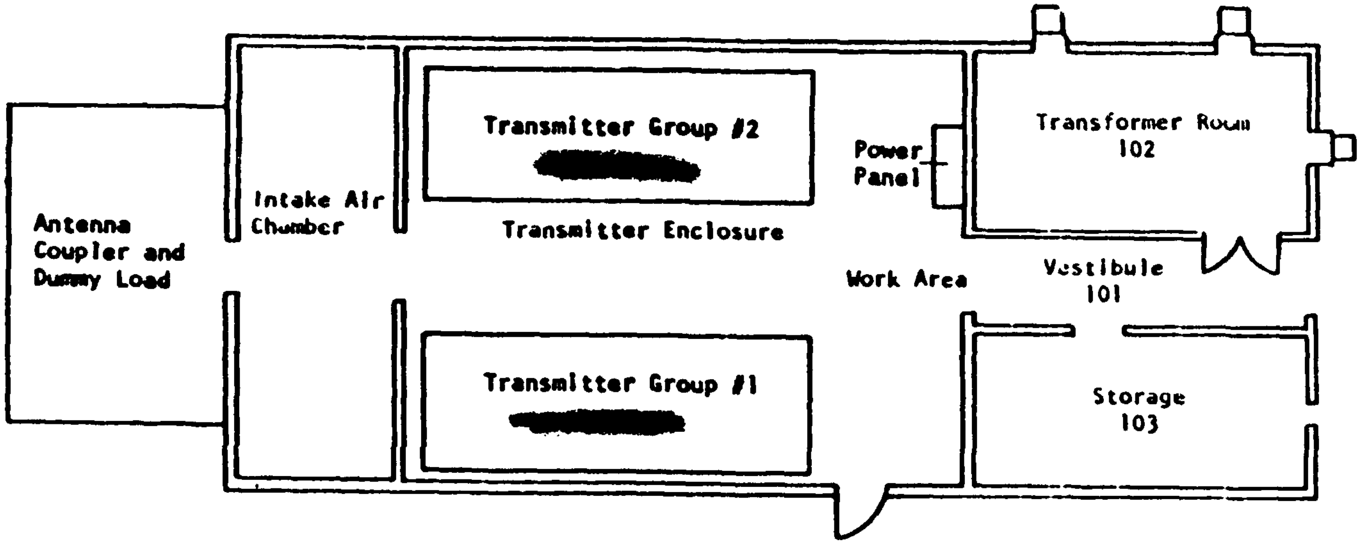


Figure A.1-3. Transmitter building layout, [redacted]

[redacted]

[redacted]

[redacted] signal and control cables between the timer room and the transmitter building are buried. Included in these cables are seven twinax signal cables (the two twinax transmitter drive cables are contained in copper tubing) and two shielded 12-wire control cables. The twinax cables enter the timer room by way of the feed-through box. The control cable shields are grounded in the floor trench at both ends and the wires are fed through capacitors at the input to the timer room.

Separate ground systems are used for the two buildings. The ground for all equipment and power circuitry in each building is provided by a buried ground system around the building periphery consisting of 3 meter long ground rods, 2 centimeters in diameter, spaced at intervals not exceeding 3 meters, connected by 2 centimeter diameter copper tubing.

[redacted]

[redacted]

[redacted] APPENDIX B
FUNCTIONAL DESCRIPTION

B.1 GENERAL

The [redacted] system radiates a [redacted] pulse train from a [redacted] vertical antenna, with a peak radiated power of [redacted] and a maximum range of [redacted]. [redacted] receivers on surface ships, aircraft, and submarines use the [redacted] signals to determine their precise geographical positions. In addition to the navigational information, the [redacted] [redacted] pulse train is modulated by the [redacted] system, superimposing Navy fleet (radio teletype) communications onto the [redacted] pulse train. [redacted] signals are received at [redacted] from several Navy facilities in the [redacted] and then retransmitted using the [redacted] system.

B.1.1 [redacted]ystem Description

[redacted] is a low-frequency radio navigation aid operating in the radio spectrum of [redacted] Although primarily employed for navigation, transmissions are used for time dissemination, frequency reference, and communications. The [redacted]ystem consists of transmitting stations in groups forming chains. At least three transmitter stations constitute a chain. One station is designated master, while others are termed secondaries. Chain coverage area is determined by the transmitted power from each station and the geometry of the stations, including the distance between the stations and their orientation. Within the coverage area, propagation of the [redacted] signal is affected by physical conditions of the earth's surface and atmosphere. The location of the five [redacted] facilities are shown in Figure B.1-1.

B.1.1.1 [redacted] Chain. All transmitters in the [redacted] system share the same radio frequency spectrum by sending out a burst of short pulses and then remaining silent for a predetermined period. Each chain within the system has a characteristic repetition interval between the pulse bursts enabling the receive equipment to be uniquely synchronized, thereby identifying the chain and the stations within the chain.

[redacted]

[redacted]

B.1.1.2 [redacted] Format. Each station in a chain is assigned a signal format based on its assigned function. The pulses consist of a [redacted] carrier that rapidly increases in amplitude in a carefully controlled manner and then decay at a specified rate forming an envelope of the signal. Each station repetitively transmits its series of closely spaced pulses, called a pulse group, at the group repetition interval assigned to the chain. When the chain is synchronized to Universal Time (UT), the master station also sets the time reference for the chain. The secondary stations transmit in turn following the master station transmissions. Each secondary is delayed in time so that no where in the coverage area will signals from one station overlap another. The number of pulses in a group, pulse spacing in a group, time of transmission, the time between repetition of pulse groups from a station, and the delay of secondary station pulse groups with respect to the master signals constitute the signal format.

In addition to providing a navigation service, the [redacted] transmission can be used for the purpose of communications. Messages for system control may be sent from station-to-station within a chain by varying certain signal format parameters of the pulse. This can be accomplished without significant adverse effect on the processing of the navigation signals in receiving equipment.

B.1.1.3 Equipment Description. The major components of the [redacted] transmitting equipment are described in the following paragraphs and are illustrated in Figure B.1-2.

A [redacted] ground station contains a [redacted] transmitting set, a transmitter automatic controller, and an antenna. The function of the ground station is to develop and transmit pulsed navigational signals on a [redacted] carrier. There are two kinds of [redacted] ground stations: a low power and a high power station. A low power ground station contains a [redacted] transmitting set [redacted], a transmitter automatic controller, and a [redacted] antenna. The peak output power of a low power station is approximately [redacted] A high power ground station contains a [redacted] transmitting set [redacted]), a transmitter automatic controller and a [redacted] antenna. The peak output power of a high power station is approximately [redacted]

[redacted]

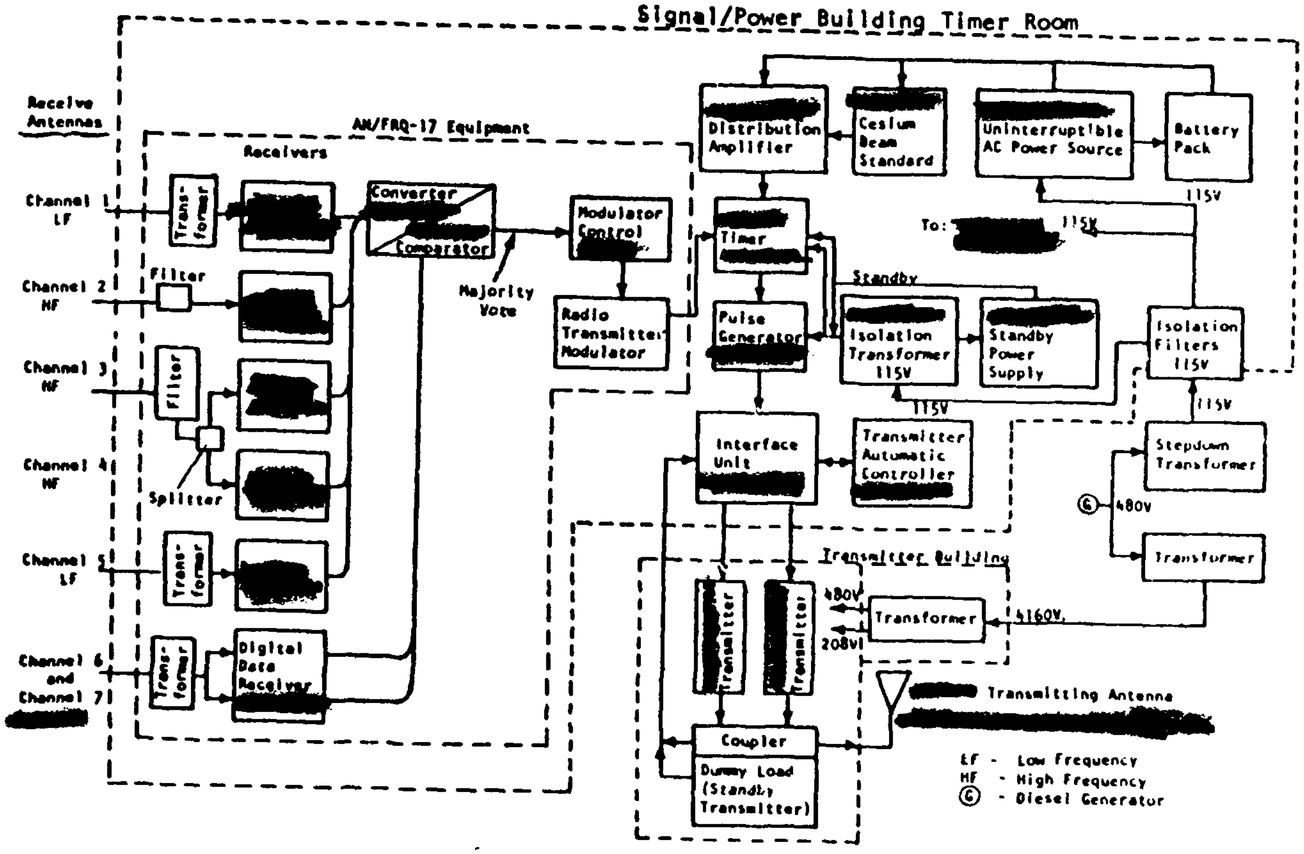


Figure B.1-2. [redacted] functional flow diagram (standard configuration).

[redacted]

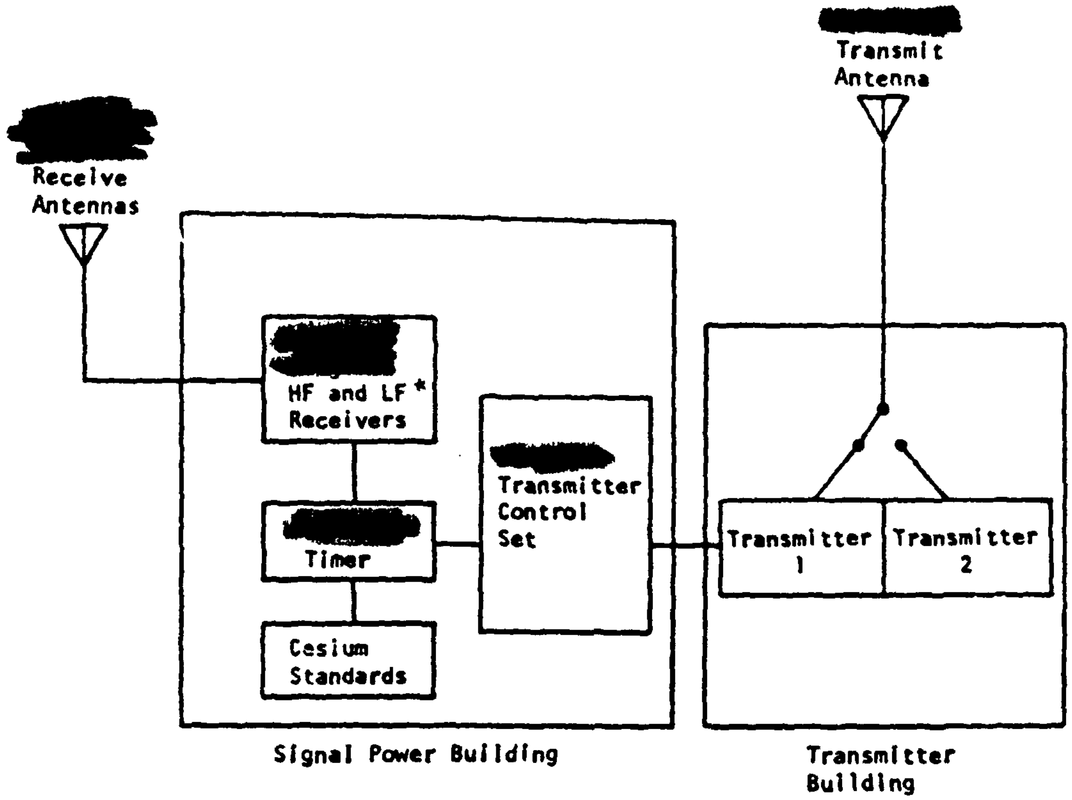
Two transmitters are contained in a [redacted] transmitting set. The transmitters are always in operation: one feeding the antenna and the other on standby operation. The transmitter on standby operation has only filament voltages applied. If the active transmitter fails, the standby transmitter can be switched to the antenna. The transmitter automatic controller, located in the signal-power building, provides the controls for switching the outputs of the two transmitters alternatively to either a dummy load or the site antenna. When either transmitter is feeding the antenna, the other is switched to the dummy load. The transmitters can be switched automatically or manually from the signal-power building, or they can be switched manually in the transmitter building.

The transmitter automatic controller [redacted] contains the pulse generating circuits using inputs from the timer [redacted] and the timing generator equipment. There are active and standby timers, cesium beam standards, and the pulse generator units. Failure of the active equipment results in automatic switch-over to standby units.

B.1.2 [redacted] System Description

[redacted] is a system which superimposes U.S. Navy Fleet Broadcast messages on the [redacted] pulse transmissions. Its purpose is to improve the reliability of Navy communications in areas covered by [redacted] The system provides this capability with minimal interference to the navigational characteristics of the [redacted] systems.

[redacted] is installed in the [redacted] chain [redacted] and uses the [redacted] Coast Guard transmitters located at the [redacted] [redacted] stations. The division and interface of the [redacted] and [redacted] equipment on [redacted] is shown in Figure B.1-3. All five [redacted] [redacted] stations are used.



*HF - High Frequency
LF - Low Frequency

Figure B.1-3. [redacted] equipment connectivity, [redacted]

The Navy Fleet Broadcast being transmitted on the [redacted] system is a radio teletype stream of binary data. Similar broadcasts are transmitted from VLF, LF, and HF stations in locations such as [redacted] using conventional FSK transmission modes.

Normally, two HF receive antenna systems are installed at each [redacted] transmitter site. One system is a nondirectional whip with one HF receiver operating from the whip. The other system is a parabolic array, consisting of an active whip and nine grounded whip reflectors to provide directivity and gain. Two HF receivers operate from this array. Three VLF receive loop antennas are normally installed at each [redacted] transmitter site. The loops provide signals for VLF receiver-channels 1 and 5, and the digital data receiver.

The [redacted] transmitter set [redacted] is capable of receiving, converting and processing up to five radio input links at one time. It is able to process two LF or VLF signals and three HF signals. In addition to handling the five radio link channels, the signal comparator portion of the [redacted] transmitter set can process two [redacted] signals. By combining three, five or seven signals of good to fair quality in a majority-vote output, an output signal can be obtained which is generally superior to that of any single channel.

B.1.2.1 Equipment Description. The major components of the transmitter control set [redacted] are described in the following paragraphs and illustrated previously in Figure B.1-2.

Five standard Navy communication receivers are supplied with the transmitter control set. Two [redacted] receivers are provided for receiving VLF and LF signals, and three [redacted] receivers are installed for HF receptions. The radio receiving set [redacted] is a LF dual conversion superheterodyne receiver; the [redacted] is a triple conversion superheterodyne receiver that provides coverage of the HF band.

[redacted]

The output of each receiver is fed to one of the five channels of the [redacted] signal data converter. Each converter channel demodulates one incoming frequency shift keyed (FSK) signal and converts the information to a digital data output.

The [redacted] digital data receiver acquires the master station [redacted] signal and any two of the secondary station [redacted] signals. The receiver processes the [redacted] signals and extracts the [redacted] information, providing digital data outputs to the signal comparator.

The [redacted] signal comparator receives seven channels of data and stores and correlates incoming digital data signals. The signal comparator can combine the correlated signals from selected channels and provide a three, five, or seven channel majority-voted output. In addition, any single input channel can be selected as the output. Five of the signal comparator channels receive inputs from the signal data converters. The other two channels are connected to the digital data receiver, providing digital information from any two of the three acquired [redacted] signals.

The [redacted] modulator control accepts the majority-voted output from the signal comparator, retimes the data to the [redacted] rate, and sends the retimed signal to the transmitter modulator unit. The [redacted] transmitter modulator accepts commands from the modulator control and phase shifts the [redacted] pulses.

B.2 [redacted] FUNCTIONAL DESCRIPTION

The equipment functional block diagram for [redacted] is shown in Figure B.2-1. Variations in the site configuration relative to the standard configuration, as defined previously, are shown in the figure and noted as follows:

[redacted]

[redacted]

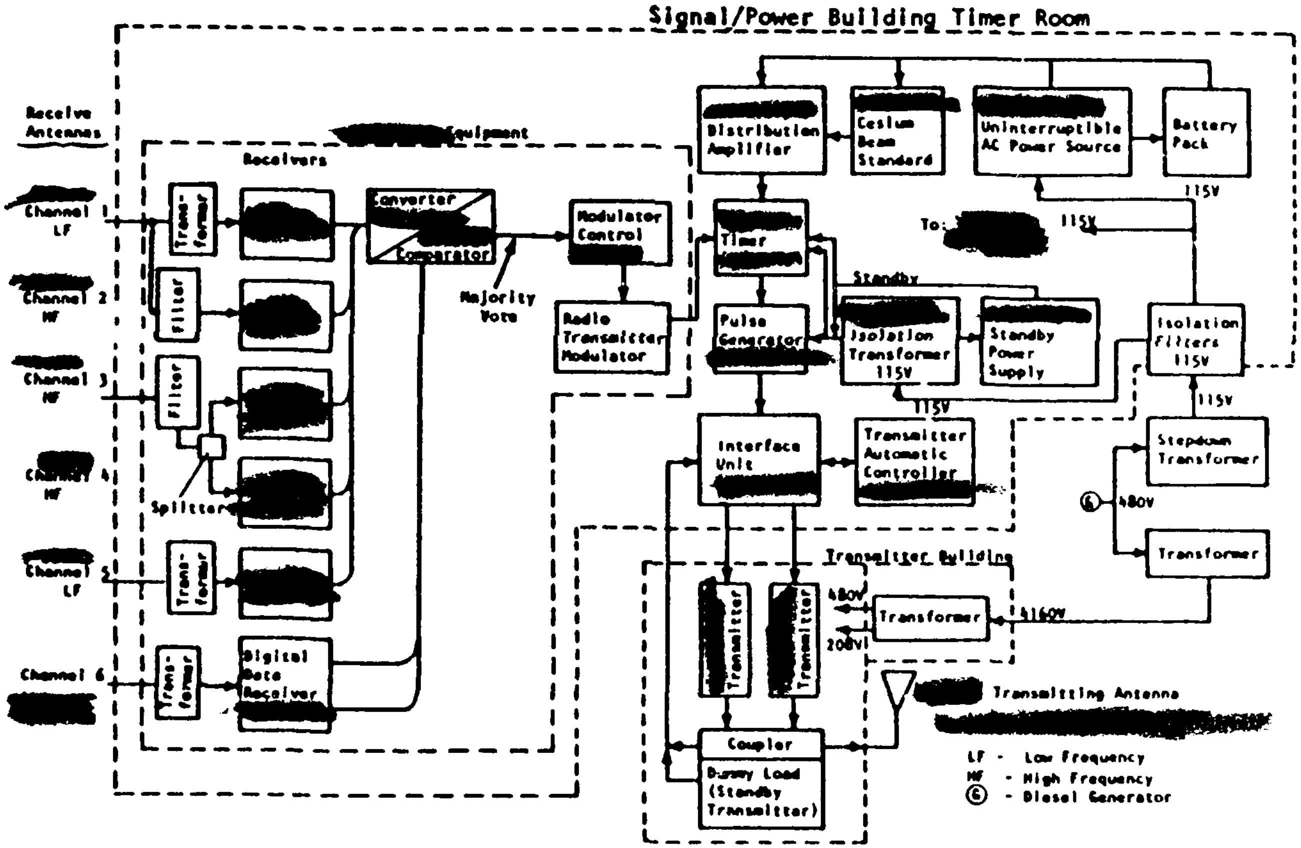


Figure B.2-1. [redacted] functional flow diagram, [redacted]

[redacted]

1) The LF receiver (channel 1) and HF receiver (channel 2) share the same antenna. Since this signal enters the cabinet by means of a coax cable, a transformer is not used on the LF channel.

2) Only one channel is utilized on the digital data receiver; therefore, only six channels are majority-voted instead of the usual seven.

The [redacted] transmitter site at [redacted] receives the two LF transmissions and three HF transmissions from [redacted] A single [redacted] signal is received from [redacted]

Results of the functional analysis indicate that the equipment listed in Table B.2-1 are critical for operating the [redacted] and [redacted] systems. Included for each critical equipment is the functional impact to [redacted] operations if the equipment is impaired.

Table B.2-1. [redacted] critical equipment response matrix, [redacted]

Critical Equipment	Functional Response
(Signal-Power Building)	
[redacted] Transmitter Control Set	
1. AN/WRR-3B VLF/LF Radio Receiving Set (2 Receiving Sets per [redacted]	1. Damage results in loss of VLF/LF receive capability in the listed channels: CH. 1 - [redacted] CH. 5 -
2. [redacted] General Purpose HF Receiver (3 Receivers)	2. Damage results in loss of HF receive capability in the listed channels: CH. 2 - [redacted] CH. 3 - CH. 4 -
3. [redacted] Digital Data Receiver (2 Channels)	3. Damage to this receiver results in loss of receive capability for [redacted] signals from [redacted] (CH. 6)
4. Data Converter, Signal Comparator & Radio Transmitter Modulator (Signal Processing Equipment)	4. Loss of power to the signal processing equipment results in loss of majority-voted output signal to the [redacted] timer. (NOTE: The output signal from the [redacted] is a composite majority-voted signal selected from six receiver input signals. Failure, due to damage, of one or mor receivers still leaves the [redacted] system operational.

Table B.2-1. [redacted] critical equipment response matrix, [redacted] (continued).

Critical Equipment	Functional Response
Frequency Standard Rack	
1. [redacted] Cesium Beam Standard [redacted] 2. Distribution Amplifier (Model 203)	There are three cesium beam standards (operational, standby, and spare). Loss of the standards results in loss of local timing and pulse generating capabilities for the [redacted] 100 kHz signal. The [redacted] power supply has a battery pack which is switched on automatically if the power supply is damaged. The power pack will supply dc power to the standard for 15 to 45 minutes.
AN/FFN-60 Transmitter Control Set (Transmitter Drive Waveform Output)	Damage to the operating unit causes a switch to standby unit. Damage to the standby results in loss of the modulated [redacted] signal to the [redacted] transmitters.
(Status and Control Lines)	Damage results in loss of ability to monitor the status of the operational and standby [redacted] transmitters and to switch them automatically. The transmitters can be switched manually in the signal-power building and/or the transmitter building.
Timer Room Filter [redacted]	Damage results in outage of all [redacted] and [redacted]-[redacted]h equipment in timer room.
Timer Room Stepdown Transformer	Damage results in outage of all [redacted] and [redacted] [redacted] equipment in timer room.

[redacted]

Table B.2-1. LORAN-C critical equipment response matrix, Marcus Island (continued).

Critical Equipment	Functional Response
(Transmitter Building)	
4160 Volt to 430 Volt Transformer	There are two transformers. Loss of one results in switching to the other. Loss of both results in loss of [redacted] and [redacted] transmissions.
[redacted] Transmitting Set (Transmitter Drive Waveform input)	Damage results in loss of the modulated [redacted] signal. Loss of the operational transmitter output signal results in the automatic or manual switching to the standby transmitter. Loss of the standby transmitter would require repair for restoring transmissions.
(Status and Control Lines)	Loss results in ability to switch transmitter remotely and automatically.

[redacted]

[redacted]

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[redacted]

[redacted] APPENDIX C
ELECTROMAGNETIC ANALYSIS

C.1 GENERAL

The [redacted] installation is similar to other stations of the [redacted] net. It is unique in that it also generates and supplies electrical power to [redacted] installations on the [redacted]

There are two major buildings in the [redacted] facility that underwent electromagnetic analysis: the transmitter building and the signal-power building. Major penetrations and coupling paths in these buildings are shown diagrammatically in Figure C.1-1.

C.1.1 Transmitter Building

The transmitter building (XB) is made of reinforced concrete blocks, with copper mesh screening providing an estimated [redacted] of shielding. All metal work about the building is grounded to protect personnel against shock hazards from the electromagnetic fields generated by the transmitters.

C.1.2 Signal-Power Building

The signal-power (S-P) building contains diesel generators supplying the ac power used at the site. The transmitter is controlled by equipment in a timer room inside the northeast corner of the building. The building is made of reinforced concrete block with rebar tied together (in part) and connected to a buried ground ring with ground rods surrounding the building. The S-P building provides an estimated [redacted] of shielding, while there is approximately [redacted] building attenuation inside the timer room.

The conductivity of the surface soil near the S-P building is quite low (about 0.001 siemens/m), but the water table should be no lower than sea level, about 10 m (33 feet) down. A conductivity value of 0.002 was used for analysis.

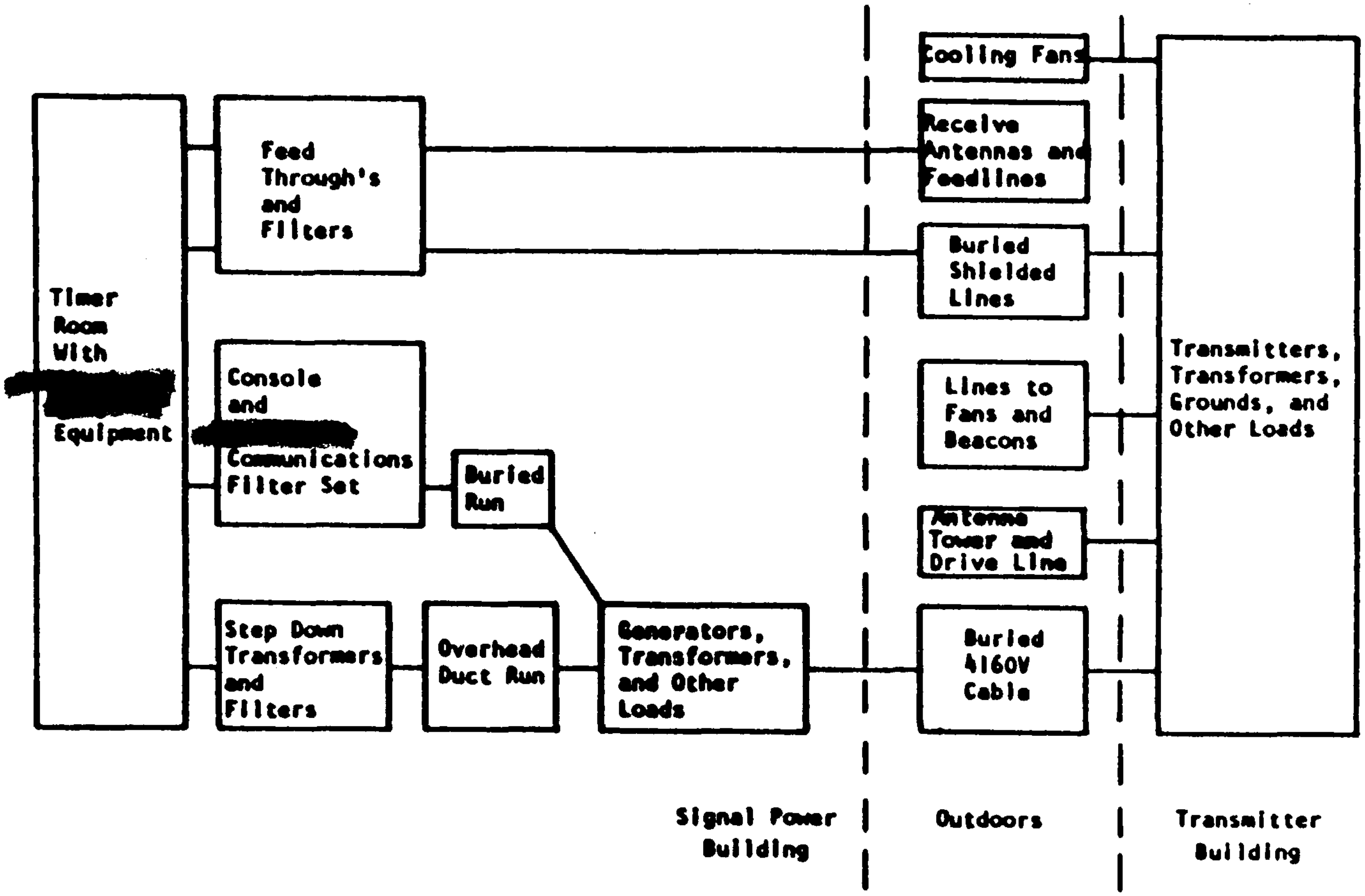

Figure C.1-1. Major penetrations and coupling paths diagram, [redacted]

[redacted]

C.2 PENETRATIONS

C.2.1 Transmitter Building

The transmitter building is penetrated by various signal lines which enter the south and east sides of the building. These include shielded coax, twinax, and alarm cables coming from the S-P building.

AC power comes from the 4160 V transformers in the S-P building via a buried cable to cutouts inside the XB, then to transformers and the main power panel in the building.

The cooling fans on the east side of the building are supplied by ac power in PVC (plastic) conduit. These lines constitute a penetration.

The tower drive line constitutes a penetration, but over-voltage protection of the tower and the high voltage design of the transmitter output stage will prevent damage by EMP transients.

C.2.2 Signal-Power Building

The signal-power building is penetrated by most of the above conductors and by others. The coax and twinax lines enter the building by a floor trench near the north corner of the building, then in ductwork to the feed-through box. These lines come from two loop antennas on the roof, two whip antennas located southeast of the timer room, various other antennas, and the transmitter building.

Another major penetration is the buried power cable from the transmitter building running to the transformers in the power room near the main power panel. Power is supplied to the timer room by an isolation/stepdown transformer in a duct. However, from the duct to the transformer and from the transformer to the filter, the lines are enclosed in flexible metal conduit, which is a poor shield to external electromagnetic fields.

[redacted]

[redacted]

Other penetrations include buried power and communication lines to the acks and other buildings.

Minor penetrations include buried water, sewer, and oil lines, and nd-powered telephone lines. To the extent these couple to critical equipment, se penetrations would act as additional grounds for equipment already well-unded.

2.3 Timer Room

The [redacted] gear is located in the timer room in the P building. Inside the timer room, penetrating fields are low because of ielding by the S-P building and by the timer room walls.

All significant penetrations of the timer room enter through three boxes d the ac power filters. The boxes are a feed-through box for coax and twinax ielded lines, a filter box for lines from the transmitter, and a [redacted] communiations filter set for communication lines from the nearby communications console.

.3 COUPLING PATHS

.3.1 Antenna Feeds and Radios

The shielded loop antennas on the roof of the S-P building feed the [redacted] gear in the timer room by shielded lines. The antenna loop areas are approximately [redacted], providing a sizable coupling area to the external EMP environment and consequently pass a large signal down the shielded antenna feed lines. The short run and small through-braid coupling coefficient ensure that transients penetrating the braid are negligible compared to those coming from the antennas.

The same holds true for the parabolic array feed line. This array will couple a large EMP transient and propagate it down the antenna feed line to the timer room feed-through box to the HF radios.

[redacted]

[redacted]

The [redacted] monopole near the array is also used. It is comparable in size to the array whip and will couple similar EMP transients.

For all channels, except channel 1, the antenna feed lines feed baluns, transformers, or filters before entering the radios. The vulnerability to damage of such components is comparable to that of the radios themselves; thus, EMP transients have been computed at the input to these devices as appropriate.

C.3.2 AC Power Lines

The ac power system is relatively exposed to EMP transients. The supply lines for the timer room isolation/stepdown transformer are not well shielded at the timer room end because of the use of flexible metal conduit.

Other parts of the ac power system will also be strongly excited by exterior cables. In contrast to other sites, the transmitter building supplies power to a radio beacon via an insulated buried cable. The building ac power system will also be excited by lines to the water cooling fans, which are enclosed in PVC (plastic) conduit.

The status and control cables are shielded and through-braid coupling will be small. Thus transients are predicted to be low. The transmitter drive waveform lines, in addition, are protected by a two-inch diameter, hollow copper pipe, which is well grounded at the transmitter end, although open at the S-P end.

C.3.3 Equipment Not Assessed

Many parts of the [redacted] gear in the timer room and parts of the transmitters have not been included in the assessment because the timer room and the van-type housing of the transmitters should provide good shielding against EMP. Consequently, only the sensitive components most directly interfacing with the penetrating lines have been treated.

[redacted]

[redacted]

In particular, the equipment in the three [redacted] cabinets receive ac power through a separate filter in the timer room. The timer, [redacted] and transmitter control set, [redacted] are protected against ac transients by a separate isolation transformer. The cesium beam clocks are buffered by the [redacted] power supplies. Thresholds and EMP transients have been computed at the input to each of these buffering elements.

[redacted]

[redacted]

APPENDIX D

[redacted] EMP ASSESSMENT PREDICTIONS [redacted]

D.1 [redacted] GENERAL [redacted]

[redacted] A scenario variant (SV) assessment technique was used for assessing the effects of EMP on the [redacted] facility. Using the SV technique provides for making element assessments and developing hardness concept design packages to provide a desired survival confidence level, for the most severe high-altitude nuclear burst EMP environment.

[redacted] The SV technique uses the nuclear environment parameters for a set of 17 burst locations to define the most severe response for each critical equipment item. Several bursts are required since the various power, signal, and control equipments will not all be maximally stressed by any one burst location. The uncertainty involved with using only 17 bursts does not seriously degrade determining the survival confidence of the facility. A detailed description and theoretical background of the SV technique is described in TN-52, "A Scenario Independent Technique for Assessing EMP Effects on Communication Facilities." The results of the facility assessment presented in this report consist of the most severe response for each critical circuit as produced by one of the 17 scenarios.

D.2 [redacted] SCENARIO VARIANT ASSESSMENT DATA [redacted]

[redacted] The scenario variant assessment predictions for the critical equipment items are provided in Table D.2-1. For each critical equipment item, the largest predicted peak voltage and associated pulse frequency are provided, as are the upset and damage thresholds. Table D.2-1 also provides the safety margin and survival confidence values for each critical equipment item. The safety margin and survival confidence predictions each depend upon the predicted peak voltage. Since the SV assessment technique defines the maximum potential EMP-induced peak voltage at the critical equipment interface, the predicted safety margin and survival confidence values are the minimum levels expected for any high-altitude nuclear EMP environment condition.

[redacted]

[redacted]

[redacted]

Pages 55 and 56 were deleted.

[redacted]

[redacted]

[redacted] The predicted safety margin is the ratio, in dB, between the threshold voltage and the predicted peak voltage. The survival confidence values were determined using the predicted safety margins and the data quality distribution which characterizes the statistical uncertainties in safety margin predictions. For the calculations used for this assessment, the data quality distribution was chosen as normally distributed with a zero mean and a standard deviation of 8 dB. This distribution was used since it is the data quality indicated from previous test experience.

[redacted]

[redacted]

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[redacted]

[redacted]

[redacted] APPENDIX E

BONDING* AND ASSEMBLY INSTRUCTIONS

E.1 BONDING

Bonding refers to the process by which a low impedance path for the flow of an electric current is established between two metallic objects.

E.1.1 Surface Platings or Treatments

Surface treatments, to include platings provided for added wearability or corrosion protection, shall offer high conductivity. Plating materials shall be electrochemically compatible with the base metals. Unless suitably protected from the atmosphere, silver and other easily tarnished metals shall not be used to plate the bond surfaces.

E.1.2 Bond Protection

All bonds shall be suitably protected against weather, corrosive atmospheres, vibrations and mechanical damage. Under dry conditions a corrosion preventive or sealant shall be applied within 24 hours of assembly of the bond materials. Under highly humid conditions, sealing of the bond shall be accomplished within one hour of joining.

E.1.3 Corrosion Protection

Each bonded joint shall be protected against corrosion by assuring that the metals to be bonded are galvanically compatible in accordance with DCA Notice 310-70-1**. Bonds shall be painted with a moisture proof paint conforming to the requirements of FED-STD T-TP-1757 or shall be sealed with a silicone or petroleum-based sealant to prevent moisture from reaching the bond area. Bonds

---

* taken from MIL-STD-188-124

**DCA Notice 310-70-1 will be replaced by MIL-HDBK-419 upon release of 419.

[redacted]

[redacted]

which are located in areas not reasonably accessible for maintenance shall be sealed with permanent waterproof compounds.

E.1.4 Vibration

Bonds shall be protected from vibration-induced deterioration by assuring that bolts and screws are torqued in accordance with DCA Notice 310-70-1.

E.1.5 Bonding Straps

Bonding straps installed across shock mounts or other suspension or support devices shall not impede the performance of the mounting device. They shall be capable of withstanding the anticipated motion and vibrational requirements without suffering metal fatigue or other means of failure. Extra care shall be utilized in the attachment of the ends of bonding straps to prevent arcing or other means of electrical noise generation with movement of the strap.

E.1.6 Bond Resistance

All bonds for ground conductors whose primary function is to provide a path for power, control, or signal currents shall have a maximum dc resistance of one milliohm. The resistance across joints or seams in metallic members required to provide electromagnetic shielding shall be one milliohm or less.

E.1.7 Clamps

Bonding clamps shall conform to AN 735 or AN 742.

E.1.8 Nuts, Bolts, and Washers

Nuts and bolts shall be capable of meeting the torque requirements of DCA Notice 310-70-1. Flat washers shall not be surface treated: they shall be protected as specified in paragraph E.1.18 and E.1.19 for corrosion control purposes. Star washers smaller than 1.2 cm (1/2 inch) shall not be used.

[redacted]

[redacted]

E.1.9 Direct Bonds

Wherever possible, bonding of metallic or other conductive members shall be accomplished by direct contact of the mating surface with the electrical path achieved by a welded, brazed, soldered, or high-compression bolted connection.

E.1.10 Welding

Permanent conditions between ferrous materials shall be welded whenever possible.

E.1.11 Brazing and Silver Soldering

Brazing or silver soldering is acceptable for the permanent bonding of copper and copper alloy materials.

E.1.12 *Bonding of Copper* to Steel

Either brazing or exothermic welding shall be used for the permanent bonding of copper conductors to steel or other ferrous structural members.

E.1.13 Soft Soldering

Soft soldering shall not be used for bonding purposes.

E.1.14 Sweat Soldering

Sweat soldering shall be used for electrical bonding only when other fasteners such as bolts or rivets are concurrently used to provide mechanical strength.

[redacted]

E.1.15 Bolting

All bonds utilizing bolts and other threaded fasteners shall conform to the minimum torque requirements given in DCA Notice 310-70-1. Inspection shall be conducted periodically. Before joining, all faying surfaces shall be prepared per paragraph E.1.18. Particular care shall be taken to provide adequate corrosion protection to all electrical bonds made with bolts and other threaded fasteners.

E.1.16 C-Clamps and Spring Clamps

C-clamps and spring clamps shall not be used for permanent or semi-permanent bonding.

E.1.17 Indirect Bonds

Where the direct joining of structural elements, equipments, and electrical paths is impossible or impractical to achieve, bonding straps or jumpers shall be used.

E.1.18 Surface Preparation

All mating surfaces which comprise the bond shall be thoroughly cleaned before joining to remove dust, grease, oil, moisture, nonconductive protective finishes, and corrosion products.

1) <u>Area to be Cleaned</u>. All bonding surfaces shall be cleaned over an area that extends at least .5 cm (1/4 in.) beyond all sides of the bonded area on the larger member.
2) <u>Paint Removal</u>. Paints, primers, and other organic finishes shall be removed from the metal.
3) <u>Inorganic Film Removal</u>. Rust, oxides, and nonconductive surface finishes such as anodize shall be removed.

[redacted]

4) Final Cleaning. After initial cleaning with chemical paint removers or mechanical abrasives, the bare metal shall be wiped or brushed with dry cleaning solvent meeting the requirements of Federal Specifications P-D-680. Surfaces not requiring the use of mechanical abrasives or chemical paint removers shall be cleaned with a dry cleaning solvent to remove grease, oil, corrosion preventives, dust, dirt, and moisture prior to bonding.
5) Clad Metals. Clad metals shall be cleaned with fine steel wool or grit in such a manner that the cladding material is not penetrated by the cleaning process. A bright, smooth surface shall be achieved. The cleaned area shall be wiped with dry cleaning solvent and allowed to air dry before completing the bond.
6) Aluminum Alloy. After cleaning of aluminum surfaces to a bright finish, a brush coating of iridite or other similar conductive finishes shall be applied to the mating surfaces.
7) Completion of the Bond. If an intentional protective coating is removed from the metal surface, the mating surfaces shall be joined within 30 minutes after cleaning.

E.1.19 Dissimilar Metals

All mating surface materials that comprise a bond shall be identified. Compression bonding with the use of bolts or clamps shall be utilized only between metals having acceptable coupling values as indicated in DCA Notice 310-70-1. When the base metals form couples that are not allowed, the metals shall be plated, coated, or otherwise protected with a conductive finish, or a material compatible with each shall be inserted between the two base metals. It shall be constructed from or plated with an appropriate intermediate metal.

[redacted]

E.1.20 Corrosion Prevention (Below Grade)

Because of galvanic corrosion between dissimilar metals, below grade and/or high moisture areas, the welded or brazed joint shall be covered with pitch or other suitable waterproof compound to inhibit corrosion.

E.2 ASSEMBLY

The following subparagraphs deal with special installations peculiar to hardness concept designs.

E.2.1 Rigid Conduit, Threaded Connections

Rigid conduit (new or old installations) used for shielding or rf returns shall be assembled as follows:

1) Cleaning. All mating surfaces for threaded connections shall be prepared as in paragraph E.1.18.
2) Assembly. Apply cold galvanizing compound* "Galvicon" to thread parts and assemble wet. Wipe off excess and let joint dry.
3) Corrosion Protection. Protect the connection as in paragraph E.1.3.

E.2.2 Rigid Conduit, Box or Cabinet Connection

Rigid conduit (new or old installations) used for shielding or rf returns shall be assembled as follows:

1) Cleaning. All faying surfaces shall be prepared as in paragraph E.1.18.

* Kenco Divison
Southern Coatings and Chemical Co., Inc.
Sumter, South Carolina 29150

[redacted]

2) Assembly. Assemble using a rigid conduit metallic bushing and bonding type lock nut.
3) Corrosion Protection. Protect the connection as in paragraph E.1.3.

E.2.3 Coaxial Cable, Severe Environment

Coaxial cable connections exposed to outdoor environments or high humidity shall be assembled as follows:

1) Cleaning. All metal surfaces shall be prepared as in paragraph E.1.18.
2) Assembly. Assemble connectors and clean as in paragraph E.1.18.
3) Corrosion Protection. Apply Dow Corning** 3145 RTV adhesive/sealant (non-corrosive) on the connector forming a seal to preclude migration of water or vapor down the cable or at the threaded portion of the connector.

E.2.4 Coaxial and Shielded Cable, Intermediate Point Bonding

Cables requiring attachment of ground straps at points other than cable ends shall be prepared as follows:

1) Cleaning. Remove at least 3 cable diameters of the protective sheath to expose the cable shield. Prepare the shield surfaces as in paragraph E.1.18 except that any solvents used for cleaning shall be compatible with the cable dielectric and the insulating material.

** Dow Corning Corporation
Midland, Michigan 48640

[redacted]