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CONTAINERIZED COMMAND/CONTROL SPACES: A  
FEASIBILITY STUDY

J. M. McGarrah, et al

Naval Academy  
Annapolis, Maryland

July 1973

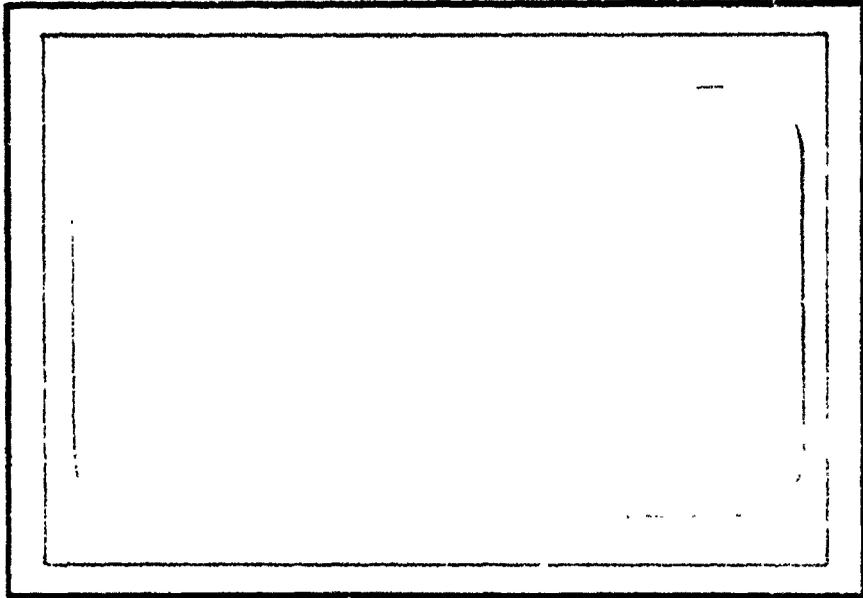
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A FEASIBILITY STUDY

FINAL REPORT

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CONTAINERIZED COMMAND/CONTROL SPACES

A FEASIBILITY STUDY

FINAL REPORT

by a Midshipman Design Team

Midn. J. M. McGarrah  
Project Manager

Midn. F. J. Brasco  
Midn. O. P. Keifer  
Midn. H. L. Seedorf  
Midn. M. S. Skorich  
Midn. P. G. Vining

UNITED STATES NAVAL ACADEMY  
Naval Systems Engineering Department  
Mechanical Engineering Department  
Annapolis, Maryland 21402

### ABSTRACT

Specific questions pertaining to the modularization of Command and Control spaces aboard a naval combatant ship are addressed. An 8' x 8' x 20' container is used. Container construction, configuration, attachments, and arrangements are discussed. Fluid, power, and data flow problems are examined. Selection matrices for each area are presented and specific recommendations made.

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## PREFACE

Many studies have been conducted concerning the feasibility and desirability of a modularized warship. Previous studies, however, have neglected certain hardware items which are essential to the workability of a modularized ship.

At the invitation of the Naval Ship Engineering Center, Code 6110.16, a design team was formed to study possible solutions to these aspects of the modularization problem. Specific tasks were set forth in NAVSEC Task Order 6110.16 - 34 HGB2. The group's participation was in conjunction with a senior engineering design course directed at involving midshipmen in real problems, rather than purely academic ones.

It is the intent of this report, therefore, to focus on the hardware considerations intrinsic to the design and attachment of the container to the superstructure and to determine solutions for the fluid, power and data flow interface problems.

## INTRODUCTION

The design team was divided into three groups, each working on a specific area of the problem. The areas of investigation were: 1) the module and its attachments, 2) the electrical and data flow interface, and 3) the fluid flow interface. In each area a number of alternative solutions were examined. The principal method of evaluation of these alternatives involved the establishment of a selection matrix. In this method a number of relevant evaluation criteria were established for each system under consideration. Each criterion was assigned a weighting factor (0 to 1.0) based on its relative importance in the judgment of the group. Each alternative was then rated (1 to 10) on how well it met each of the evaluation criteria, again in the judgment of the group. For example, in a certain system the criterion of flexibility might be assigned a weighting factor of 0.3 and the alternatives of steel and rubber might be assigned ratings of 1 and 9 (based on 1-very stiff and 10-very flexible). Weighted ratings, the product of the relative ratings and their weighting factors (0.3-rubber, 2.7-steel), are summed to provide a

total rating for each alternative. The alternative with the highest total rating was considered the optimum solution.

In the interest of simplicity, the design was limited to a single Command and Control System, the requirements of which are shown in Appendix A. This system, specified by NAVSEC, 6110.16 is based on general characteristics of a typical Command and Control System but apply to no specific naval ship. Module size is limited to 8' x 8' x 20'.

This report is organized by sections based on the areas of the problem definition. Recommendations for future work by USNA design teams are included in Section 7.0. Technical and supplemental data are included in the appendices.

#### 1.0 CONTAINER SELECTION

As the task order specified the container size, two variables remained to be evaluated; container material and container construction method.

The candidate materials for construction of the containers were mild steel, HTS, stainless steel and aluminum. Gibbs and Cox<sup>1\*</sup> stated that a steel container (mild steel) would be more durable and would cost 25 to 30% less than a comparable aluminum unit. The point was also made that the use of stainless steel would largely eliminate the maintenance problems involved in using steel.

This analysis, however, was conducted using aluminum containers. They are approximately half the weight, are easier to maintain than mild steel and less expensive than stainless steel. However, a detailed trade off study of aluminum versus other materials was not made nor was the corrosion problem of coupling aluminum to steel adequately studied.

The second variable, container construction, suggested two alternatives: standard containers, such as the Freuhauf and Craig Corporation vans, or convertible containers i.e., containers with removable side panels.

1. "T&E Ship Rapid Refit Study," Gibbs and Cox, Inc. Rpt 17551-59-808 (1-644), 16 March 1973.

\* Additional uncited references are listed in the Bibliography at the end of the text, pages 101 to 103.

Table 1-1 summarizes the advantages and disadvantages of convertible containers as compared to completely hardened containers. Weighing the relative merits and deficiencies of convertible containers, it is the conclusion of this group that the advantages involved outweigh the disadvantages relative to a standard container. Therefore, removable panels are a strongly recommended feature.

A special extrusion is specified for the basic skeletal framing. The fact that a large number of containers would be built suggests that this added cost could spread out over the number of units built, bringing unit acquisition costs down to a more acceptable level.

The use of aluminum containers mounted on an HTS deck presents a possibility of galvanic corrosion at the interface of the two materials. The galvanic incompatibility of aluminum and a carbon steel (i.e. mild steel or HTS) is high; however the incompatibility between aluminum and a stainless steel is not as severe, especially when there is no continuous intimate contact with sea water.

The recommended solution is to maintain the use of aluminum throughout the container structure and the connecting twist lock corner fitting. The interface would be achieved by welding the aluminum twist lock base to the aluminum face of an explosively bonded aluminum-steel mounting pad which is in turn welded to the steel deck. The use of aluminum in the twist lock assembly is subject to development of fittings with adequate hardness. An alternate solution would be to use stainless twist lock fittings and provide the galvanic isolation by the use of explosively-bonded panels welded to the interior faces of the twist lock corner fitting where the aluminum corner posts and floor beams would be welded.

Details of the recommended convertible container configurations are shown in Figures 1-1 through 1-5\*

\*Figures will be found on pages 44 to 89.

Table 1-1

ADVANTAGES AND DISADVANTAGES

of

CONVERTIBLE CONTAINERS

ADVANTAGES

- 1) More standardized frame construction would permit lower unit acquisition cost than if two different modules have to be developed
- 2) Panel removal would reduce system weight
- 3) Panel removal would greatly increase the number of possible deck plans
- 4) Panel removal would greatly enhance system habitability
- 5) With panels removed, adjoining containers could be securely connected using bolt holes in each container provided for panel attachment
- 6) Ease of access for equipment replacement and repair
- 7) Personnel access would be improved
- 8) Interface problems would be simplified
- 9) Hardened panels could be attached only when necessary, saving weight.

DISADVANTAGES

- 1) Not as rigid
- 2) Total refit time would be fractionally longer
- 3) Construction tolerances would have to be closer
- 4) Complexity would increase cost
- 5) Not currently available, whereas conventional containers are stock items (Chesapeake Instrument, Craig, Fruehauf).

## 2.0 ATTACHMENTS

The word attachments refers to the actual physical connections used to secure the containers. It includes both container-to-deck and container-to-container connections.

### 2.1 Container-To-Deck Attachments

One of the most important questions in the analysis of the modularized ship is how the container will be attached and held to the deck.

The following five alternative methods, each having its own advantages and disadvantages were considered:

- 1) permanent foundation with an intermediate mounting frame
- 2) twist locks with raised permanent deck sockets
- 3) twist locks using a dimpled plate to build a foundation or a raised deck socket
- 4) a battle hardened crib secured with Nelson Studs
- 5) the use of intermediate mounting angles and clips

Since the ability to stack the modules was considered of prime importance, it was included as a criterion in the selection matrix.

#### 2.1.1 Method (1) - Permanent Foundation with an Intermediate Mounting Frame

Method (1) is illustrated in Figure 2-1 standard medium steel angles are permanently welded to the steel deck. The aluminum face of an explosively bonded aluminum-steel mounting plate is welded to the base of the module (not shown in figure). A medium steel channel is welded to the steel face of the mounting plate. The flanges of the channel and the angle are then through-bolted to effect the connection. A similar method was used by The Chesapeake Instrument Corporation as the

method of attachment for its towed array control module.

### 2.1.2 Method (2) Twist Locks with Raised Permanent Deck Sockets

To preserve the strength of the deck and to reduce initial costs, raised deck sockets welded to an explosively bonded deck mounting plate are recommended instead of deck sockets which are recessed into the deck. The use of raised sockets indicates the existence of a space, a void, between the deck and the bottom of the module. Consequently, maintenance is a disadvantage of this method. Great difficulty would be experienced trying to maintain the deck area beneath the raised container if container remained in place for long periods of time. Corrosion is reduced in the recommended total system through the elimination of weather effects on the module (see Section 5).

Two types of deck sockets with related twist locks are illustrated in Figure 2-2. Modules would be attached with twist locks to deck sockets welded to the deck. The quick connect and disconnect feature of the twist locks enhances the system's rapid refit capabilities.

### 2.1.3 Method (3) - Twist Locks Using Either Dimpled Plates to Build a Foundation or a Raised Deck Socket

This alternative is very similar to the previous one. It was considered because of its one obvious added advantage. If all attachments are removed from this configuration, the deck will be completely clear of obstructions. The use of dimpled plates will tend to increase the time of refit, however, and increase cost and maintenance requirements.

In this method of attachment the containers would be secured to the deck through the use of twist locks and deck sockets. An erected twist lock foundation capped by an explosively bonded plate could also be used such as the standardized foundation structure illustrated in Figure 2-3.

#### 2.1.4 Method (4) - Battle Hardened Crib Secured with Nelson Studs

Method (4) provides a battle hardened crib for each module (Figure 2-4). Each crib is attached to the deck by Nelson Studs, and the module is bolted into the crib. Nelson Studs are used instead of direct welding which is more costly and time consuming. Details of a Nelson Stud are shown in Figure 2-5. Galvanic corrosion isolation would be difficult to effect in this alternative.

#### 2.1.5 Method (5) - Intermediate Mounting Angles and Clips

Illustrated in Figure 2-6, this method employs much the same philosophy as Method (1). It boasts the obvious advantages of a reduced cost and fewer obstacles on the deck. To accommodate this method of attachment, the deck must be reinforced beneath the clips. As in Method (1) galvanic corrosion isolation is achieved by means of an explosively bonded aluminum-steel mounting plate welded to the base of the module.

### 2.2 EVALUATION OF ALTERNATIVES

The five alternatives were evaluated by means of a selection matrix (Matrix 2.1)\*. Three criteria were weighted heavily and considered most important; speed of assembly, speed of disassembly, and adaptability to stacking. Twist locks used in conjunction with Method (2) was evaluated as the most desirable alternative. Method (1) is considered a feasible alternative. Standard deck sockets (Figure 2-7) would be welded to an explosively bonded aluminum-steel deck mounting plate as described previously.

\*Selection Matrices will be found on pages 91 to 99.

### 2.3 CONTAINER-TO-CONTAINER ATTACHMENTS

It is desirable that all attachments be standardized so that the container-to-deck attachments can also be used to secure one container to another. Since twist locks were selected as the most desirable deck attachment it was investigated as a means for attaching stacked containers.

A method of stacking was chosen which is similar to that used on existing merchant container ships (Figure 2-8). A rectangular mounting block fitted at each corner of the module, serves as the base for the twist lock. A locking piece is inserted between two blocks, twisted and jammed by means of a removable rod to achieve the locking action. Because adjacent stacks of modules must be mounted flush to each other, the access to the twist locks must be from the interior of the module. The removable rod and a hammer are the only tools needed.

The materials considered for the twist locks were stainless steel and aluminum (6200 series). Aluminum has certain advantages: less costly, less corrosive, and more easily machined than stainless steel. Stainless steel is stronger than aluminum but would react galvanically with the aluminum modules. The yield strength of stainless steel is 150 ksi while that of aluminum is 75 ksi. Because of strength requirements, stainless steel appears to be more desirable, but, unfortunately, the effects of the galvanic reaction all but eliminates stainless steel as an alternative. It is the recommendation of this group that the selection of an appropriate material be the subject of further investigation by a follow-on group. It is suggested that a high tensile strength aluminum alloy be one such material studied. (see Sections 1 & 5).

### 2.4 RECOMMENDATIONS

It is recommended that a system of deck sockets and rectangular

twist locks be used as deck attachments. The recommended twist lock design is to be such that it can also be used for vertical container-to-container attachments. The twist lock design will prove simple, standardized, and reliable. It is compatible with the entire modularized system and will enhance rapid refit capabilities.

It is recommended that material selection be the subject of a subsequent study.

### 3.0 ELECTRICAL AND DATA INTERFACES

#### 3.1 Introduction

The electrical interfaces can be divided into three basic sections

- (1) Power flow
- (2) Data flow
- (3) Radio-frequency energy flow

For the purposes of this report, it is helpful to deal with each of these topics separately.

#### 3.2 Power Connections

##### 3.2.1 Introduction

For each command and control module, there is a need of power. For the system considered in this report, two power supplies are needed:

- (1) 3  $\phi$ , 115 volts, 60 hz.
- (2) 3  $\phi$ , 115 volts, 400 hz.

It was found (See Appendix B) that #0 wire, one for each phase would be sufficient to supply power for two containers. The actual connectors can be divided into four separate groups. They are as follows:

- (1) In-box connections
- (2) Electro-magnetic connectors
- (3) Quick-connect type connectors
- (4) Power line connectors, similar to those used for city power distribution.

### 3.2.2 In-Box Connections.

The simplest solution to the power interface problem is in-box connections. The power cable is fed through a hole into a power distribution box. Each wire is then connected to its appropriate destination. Figure 3-1 shows one such connection.

There are presently several types of physical connectors that can be used with in-box type connections. The wire can be bent around a screw which is tightened to form a good connection. Metallic connectors, which are hook-shaped, or U-shaped may be attached to the cable and inserted under a screw which is then tightened to form a good connection. The wire can also be inserted into a hole, through which a screw passes to force the wire against one side of the hole, thereby making good contact (see Figure 3-2). Each of these solutions have their advantages and disadvantages, and are discussed in Appendix A-3.2.

In-box connections can be made watertight. Presently the accepted method is to use an insert which is watertight against the cable and watertight against the hole through which the cable passes (See Figure 3-3).

In-box connections are used widely today. They are used exclusively in domestic power distribution for houses and are projected to be used even in the modular house construction of the future. Chesapeake Instrument Corporation presently uses in-box connections, with watertight inserts for their vans. These vans are presently being used by the Navy and the in-box connections are very reliable.

The advantages and disadvantages of in-box connections are:

**Advantages:**

- (1) Safety, no "live" end to be touched
- (2) Negligible corrosion
- (3) No skills required for hook-up.

**Disadvantages:**

- (1) Highly inductive power factor
- (2) Larger and more massive than conventional connectors
- (3) Large losses
- (4) Produces stray magnetic field.

### 3.2.4 Quick-Connect Connectors

There are a variety of contact shapes that are suitable for quick-connect connectors (See Figure 3-5). Each type of contact has its advantages and disadvantages; however, for the purpose of this report, the actual advantages and disadvantages of each type of contact were not considered in detail.

Quick-connect connectors are made to connect one or many wires and come in a variety of configurations (See Figure 3-6). In a multiple wire connector, there is a matrix of contacts, one for each wire. Presently, there are multiwire connectors made from 2 to 200 contact positions. Multiwire connectors are usually made so that they will insert in only one orientation. The chance, then, of crossing wire between the origins and destinations are minimized.

The advantages and disadvantages of the quick-connect connectors are:

**Advantages:**

- (1) Multiple wire for speed and to avoid mistakes in hook-up
- (2) Waterproof
- (3) Reliable
- (4) Changeable contact points for easy maintenance.

Disadvantages:

- (1) Corrosion can occur if contact is not complete

### 3.2.5 Domestic Power Line Connectors.

There are several connectors currently used for city power distribution (See Figure 3-7 for one example). For the purposes of this report, only those which could be disconnected were considered.

The advantages and disadvantages of the power line connectors are:

Advantages:

- (1) Can disconnect with load on
- (2) High current carrying capacity
- (3) Water tight.

Disadvantages:

- (1) Possibility of reversing phase order
- (2) No changeable contact points.

### 3.2.6 Evaluation of Alternatives

In order to determine which connection procedure would be most suitable, a selection matrix was developed. The following type connectors were evaluated (See Matrix 3.1):

- (1) In-box connections (Figure 3.1)
- (2) Electro-magnetic connectors (Figure 3.4)
- (3) Amphenol MS-40-60A (Figures 3.9 through 3.11)
- (4) API Ampower connector (Figure 3.6)
- (5) ITT Blackburn power cable connector (Figure 3.7)
- (6) Elastimold power distribution connectors (Figure 3.8)

The matrix criteria are self explanatory except for the following:

- (1) Capacity. This term includes both the ampere rating of the connector and the number of phases it could carry

- (2) Foolproofness. This term is an evaluation of the ease of reversing some of the power cables. This is particularly important for equipment which uses three phase power sources. A reversal of the phase order could cause much damage to the equipment. It is therefore desirable to have one connector connect all power sources.

In this evaluation, the Amphenol MS-40-60A multiwire connector had the highest rating. The following is a summary of the features of this connector:

- (1) Contains 6 cable positions
- (2) Uses #0 cable
- (3) Watertight
- (4) Presently on the shelf and manufactured in several configurations  
(See Figures 3-9 to 3-11)

NOTE: The manufacturers cited here were selected at random and the connectors are merely representative of connectors presently produced. For a more complete listing of manufacturers, see Electrical Engineers Master Catalog, United Technical Publications, 1973.

### 3.3 DATA LINK CONNECTIONS

#### 3.3.1 Introduction

In Command and Control spaces, much data must flow between the modules and to other parts of the ship. This section deals with the data flow interface problem. The connections can be divided into three general categories:

- (1) In-box connections
- (2) Multiwire, quick-connect connectors
- (3) Multiplexed data systems

In the analysis of the data flow problem, the most attractive multiwire connector will be determined through the use of a selection matrix. Next, the multiplexing concept will be discussed and two multiplex units will be compared to the optimum multi-wire connector in another selection matrix. Recommendations will follow.

### 3.3.2 In-Box Connections

In-box connections are conceptually the simplest type of connection. They consist of a maze of wires inserted through a hole in a watertight box. Each wire is then connected to its appropriate destination. For a more detailed explanation, see Section 3.2.2.

The obvious disadvantages of this system for data links is time of connection and the probability of errors in connections. Considering the hundreds of wires that must be connected, this system is very slow and lacks reliability.

### 3.3.3. Multi-Wire, Quick-Connect Connectors

Multiwire, quick-connect connectors are presently manufactured in a variety of configurations and sizes (See Figure 3-12). These connectors can presently carry up to 200 positions and more could be incorporated into one connector if necessary. For a more detailed explanation of quick connect connectors, see Section 3.2.4.

### 3.3.4 Evaluation of Alternatives

In order to determine which type of connection would be most suitable, a selection matrix was again developed (See Matrix 3.2). The following connectors were evaluated:

- (1) In-box connector (Figure 3-1).
- (2) Square multiwire connector, API "DDE" (Figure 3-12).
- (3) Square multiwire connector, AMP 200 Dualatch (Figure 3-12).
- (4) Round multiwire connector, Amphenol MS 32-414 (Figure 3-12).

In the evaluation, the AMP 200 Dualatch connector was rated highest. The other multiwire connectors were very close, indicating that all are suitable alternatives.

The characteristics of the AMP Dualatch are:

- (1) 200 wire positions
- (2) Vibration proof
- (3) Both plug and socket have same type contacts (See Figure 3-13)

NOTE: The manufacturers cited here were selected at random and the connectors are merely representative of connectors presently produced. For a more complete listing of manufacturers, see Electrical Engineers Master Catalog, United Technical Publications, Inc., 1973.

### 3.4 MULTIPLEX DATA SYSTEMS

#### 3.4.1 Introduction

A ship is a very complex weapons system. It houses communications systems, weapons systems, and navigation systems, each of which requires its own data link system. The maze of wiring and connectors that are required for such systems has caused this group to search for a system which may simplify data flow aboard the modular ship.

A system which reduces the number of data connections and wires is the "time multiplexing" system currently in use by the Bell System. Telephone companies all over the country utilize this multiplexing system to carry up to 24 voice conversations at once over just two pairs of 22 gauge wire. Each of these 24 voice conversations could easily be replaced by a data signal. Each data signal could be further modified

to carry up to 12 frequency modulated signals. The two pairs of 22 gauge wire could then be used to carry 288 different data signals at once (24 channels @ 12 FM signals per channel). Ships have not used this type data system. Instead, they have customarily relied upon a network of wires that passes data from a source to the appropriate destination along an individual transmission line, each signal having its own line.

#### 3.4.2 Evaluation of Multiplexing Systems Compared to Direct Wire Systems

A comparison of the multiplexed system and the network of wires was made (See Matrix 3.3). The evaluation matched the data link system selected in Section 3.3.4 above with two proposed configurations for the multiplexed system (See Figure 3-14).

Multiplex #1 (See Figure 3-15) assumed two centralized locations for the multiplexing unit. This configuration would require all data to be brought from its source to the multiplexing unit where it would be time coded and sent to the demultiplexing unit. At the demultiplexing unit each signal would be separated from the other signals on the multiplexed line and sent via its own transmission line to the appropriate destination. Each centralized location would have the ability to send and receive multiplexed data.

Multiplex #2 (See Figure 3-16) is a configuration similar to Multiplex #1, but has a few variations. Multiplex #2 requires the same two centralized multiplexing locations, but reduces the terminal transmission lines by introducing intermediate demultiplexing units at or near the appropriate signal destination. This system requires fewer wires than Multiplex #1, but more demultiplexing units.

The comparison placed heavy emphasis on three evaluation criteria: combat worthiness, complexity, and reliability. Of these, combat worthiness warrants further definition. This term is the quality of a system which reflects its vulnerability in a combat situation. The multi-

plexing systems, for example, were not deemed very combat worthy since they are composed of very sensitive equipment and would have to carry many vital data signals on one or two lines. The installation of multiplex systems could easily cause the entire ship to be crippled as a result of one well placed hit.

#### 3.4.2 Recommendations

From the evaluation matrix (See Matrix 3.3), this design group has concluded that multiplexed systems are not appropriate for modular ship applications. It is recommended that the conventional data link network be used.

NOTE: Interface connectors for the recommended system are discussed in Section 3.3.

### 3.5 RADIO FREQUENCY ENERGY FLOW

#### 3.5.1 Introduction

This report will be concerned with that portion of the electromagnetic spectrum which would be used in the Navy's radar systems. Specific frequencies are not discussed.

#### 3.5.2 The Basic Carrier

Five types of transmission methods were investigated (Figure 3-17)

- (1) Waveguides.
- (2) Coaxial cables.
- (3) Parallel-conductor lines.
- (4) The shielded pair of wires.

(5) The twisted pair of wires (not shown in Fig.)

Only two of the five alternatives were considered appropriate for energy transmission in the form used by a radar system going to and from the antenna. These two methods of transmission waveguides and coaxial cables, were compared in a selection matrix (See Matrix 3.4). Heaviest emphasis was placed upon the transmission losses experienced by the configuration and its flexibility both at sea and during refit.

Both the coaxial line and waveguide were extremely close in comparison. The coaxial line proved to have excessive attenuation when the energy was of high frequency and was to be carried for long distances (greater than 3 or 4 feet).

The container interface may be crossed using a bulkhead flange (See Figure 3-18) and a flexible waveguide (See Figure 3-19). These particular connectors were produced by Waveline, Inc., West Caldwell, New Jersey. Coaxial cable may be used as a substitute for the interface connector.

### 3.6 SYSTEM LAYOUT FOR ELECTRICAL CONNECTIONS

#### 3.6.1 Introduction

Four electrical system arrangements were considered. The best arrangement depends greatly on the container configuration and container placement. The chosen electrical system arrangement should, however, be compatible with any container configuration and arrangement.

The four configurations are:

- (1) Container-to container, plug leads passed beneath a false floor.
- (2) Container-to-container, plug leads externally inserted (Fig.3-21)
- (3) Long, umbilical cable with outlets for each container (Fig.3-22)
- (4) Plug in system with a cable located at the site of each container (Fig.3-23).

### 3.6.2 Layout 1 - Container-To-Container, Plug Leads Passed Beneath A False Floor

Arrangement 1 is a container-to-container type connection (See Figure 3-20). Each container receives power and data links from the containers next to it via short jumper cables. Connections are made through access doors fitted in the false floor. These containers which are on the outside receive power from the ship. This system requires a permanent ship structure adjacent to each layer of modules. Watertightness is a problem with this system, and if the modules are exposed to weather, the area around the holes used for passing wires must be sealed. The advantages and disadvantages of Arrangement 1 are:

#### Advantages:

- (1) Simple
- (2) Reliable
- (3) Connections can be made on all four sides

#### Disadvantages:

- (1) Not intrinsically watertight
- (2) Cable passage limited to horizontal directions

### 3.6.3 Arrangement 2, Container-To-Container, Plug Leads Externally Inserted

Arrangement 2 is a container-to-container type connections (See Figure 3-21). Each container receives power and data flow from the containers above, below, and on each side. This system should be particularly applicable to an entirely modularized superstructure, because of the vertical flow capacity and the intrinsic watertight integrity. The advantages and disadvantages of Arrangement 2 are:

**Advantages:**

- (1) Vertical flow capacity.
- (2) Intrinsically watertight.

**Disadvantages:**

- (1) Flow limited to two directions horizontally.
- (2) Useable space used for recessed connector area.

3.6.4 Arrangement 3. Long Umbilical Cable with Outlets for Each Container.

Arrangement 3 consists of a long umbilical cable with an outlet for each container (See Figure 3-22). The umbilical cable could originate in the permanent ship's structure and extend to the last module in the row.

The basic system would have a space which acts as a data control. Information would then be cross-patched to various stations needing a particular data link. This system could be used with conventional or multiplexed data systems. The advantages and disadvantages of Arrangement 3 are:

**Advantages:**

- (1) Centralized data collection space.

**Disadvantages:**

- (1) Very complicated.
- (2) Space used for umbilical cable recesses.

3.6.5 Arrangement 4. Plug-In System with a Cable at Each Container Site

Arrangement 4 consists of a permanent passageway with cable connectors extending out of the floor at the site of each container. Permanent cables and data lines would be installed under the false floor in the passage way (See Figure 3-23). As in Arrangement 3, the data for each module is centralized and cross-patched to various parts of the ship. The advantages and disadvantages of Arrangement 4 are:

Advantages:

- (1) Easy to connect.
- (2) Centralized data system, particularly well suited to a multiplexed data system.

Disadvantages:

- (1) Complicated.
- (2) Inflexibility on the number of container sites.
- (3) Must have a passageway adjacent to each module.

### 3.6.6. Evaluation of Alternatives

The four system alternatives compared were in a selection matrix (See Matrix 3.5). The matrix is straight forward; however, one important criteria was omitted: the total system compatibility. Since the four layouts were rated very close in the selection matrix, the final design arrangement was chosen on the basis of total design compatibility. Because the final containerized configuration incorporated a one foot false bottom floor and open side panels, Arrangement 1 was selected for the final design. For a complete discussion on Arrangement 1, see Section 3.6.2.

## 3.7 CONCLUSIONS AND RECOMMENDATIONS

### 3.7.1 Introduction

The conclusions and recommendations are broken into the following five sections:

- (1) Power connectors
- (2) Data connections
- (3) Multiplexing
- (4) Radio frequency energy interfaces
- (5) Electrical system arrangement.

### 3.7.2 Power Connectors

The power requirements for the Command and Control system specified by NAVSEC requires No. 0 cable for each phase to supply two containers. It is recommended to use No. 0 or larger power cables for each phase.

It is desirable and recommended to have all power links in one connector to help avoid system damage due to phase reversals.

It is desirable to have watertight connectors.

The Amphenol MS 40-60A connector design is fully satisfactory for the power connector, for the system analyzed in this report. If larger power connectors were needed, they could presently be produced.

### 3.7.3 Data Connectors

There are presently available multiwire connectors suitable for data flow connections. All multiwire connectors were found satisfactory if they contain enough wire positions to accommodate all data links in a minimum number of connectors. In-box connections are not satisfactory.

### 3.7.4 Multiplexing

Multiplexing units are highly vulnerable to failure in a combat situation. The systems involved would be extremely complex, additional personnel would be required, and cost and weight are high. Multiplexing is not recommended for data flow.

### 3.7.5 Radio Frequency Energy Interfaces

The wave guide is the most desirable method of carrying RF energy. Coaxial cable is a useable substitute. Other methods of carrying energy are unsatisfactory.

Where flexibility is needed, a flexible waveguide is recommended. Flexibility waveguides should not be bent at a radius less than twice the wavelength of transmitted energy. Coaxial cable may be used if the distance is short.

Since losses in coaxial cable are fairly high and losses in waveguides are only slightly less, it is recommended to restrict the use of R-F carriers to the shortest distances possible.

### 3.7.6 Electrical System Arrangement

Due to the need for compatibility with the container and container arrangement, connections made under the false floor with jumper cables are recommended. This system is simple, reliable and easily maintained.

## 4.0 FLUID FLOW INTERFACES

### 4.1 WATER FLOW

#### 4.1.1 Introduction

The system parameters provided by NAVSEC (Appendix A) show the requirement for low pressure water flow. The water is required for cooling and drinking purposes. This section presents the various alternative solutions to the water flow problem.

#### 4.1.2 Evaluation of the Alternatives

Seven currently available methods were evaluated as shown in the selection matrix (See Matrix 4.1). The four criteria the group considered most important were reliability, replacement (including ease and time of replacement), cost, and weight. The seven methods evaluated were:

- (1) Plastic tubing - this is a lightweight and inexpensive material. Although somewhat limited in temperature range, it should withstand all module conditions.
- (2) Hydraulic hose - a very dependable material, however quite costly.
- (3) Steel piping - ordinary steel piping as available off the shelf was the material considered here.
- (4) Copper piping - it is used extensively in much domestic plumbing, and has proved effective.
- (5) Aluminum tubing - it is lightweight, yet offers the strength advantages of metal. It presents a galvanic corrosion problem when coupled to steel hull piping.
- (6) Rubber hose - systems offer flexibility and simplicity.
- (7) Flex (Aeroquip) - flexible and strong, it is a material in wide use in the Navy.

#### 4.1.3 The Recommended Solution

The design group's recommendation based on the results of the selection matrix analysis is the use of polyvinyl chloride (PVC) plastic pipe with an inside diameter of 1.5". This size is sufficient for the flow requirement of 15 gallons per minute (See Appendix A). PVC is acceptable as long as the temperature variation is within 20° of room temperature as specified in the model system.

#### 4.1.4 Further Recommendations

The design group obtained insufficient data for water purity requirements for electronic equipment. It is recommended that this be evaluated in detail in subsequent studies.

## 4.2 PIPE FITTINGS

### 4.2.1 Introduction

Various types of fittings (See Section 4.2.2) were evaluated without regard to their compatibility with the recommended alternative in Section 4.1

### 4.2.2. Evaluation of Alternatives

The seven alternative methods of connecting pipes were evaluated:

- (1) Compression fittings - This design has proved to be easy to install, reuseable, and comes in a variety of materials (See Figure 4-1).
- (2) Quick-disconnect fittings - Limited to use with hose. It also has been found to be susceptible to shock loading (See Figure 4-2).
- (3) Welds - Limited to use with steel (See Figure 4-3).
- (4) Unions - The design is quite simple and can be used with all materials (See Figure 4-4).
- (5) Flanges - With the exception of hydraulic and rubber hose, this method is widely used (See Figure 4-5).
- (6) Brazed fittings - Commonly used for joining non-ferrous materials in restricted temperature and pressure ranges. This design utilizes an alloy insert which is melted to fill a small annular space between the pipe and the fitting. It is reuseable with new alloy inserts (See Figure 4-6).
- (7) Flared fittings - Commonly used in systems made of tubing. They provide good connections without threading, welding, or soldering (See Figure 4-7).

In the fittings matrix (See Matrix 4.2), replacement and reliability were considered more important than cost.

#### 4.2.3 Recommendations

The results of the selection matrix indicate that the compression fitting is the most suitable general purpose piping connector for the modularized ship application. In regard to the selection of PVC piping in Section 4.2.3 it is noted that compression fittings are available for this type of piping.

#### 4.2.4 Further Recommendations

It is further recommended that shock loading characteristics of all fittings be evaluated in detail in subsequent studies. Insufficient data were obtained on this problem.

### 4.3 AIR FLOW

#### 4.3.1 Introduction

The system parameters show the requirement for low pressure air flow for environmental purposes and for heat dissipation of the system (See Appendix A).

#### 4.3.2 Recommended Solution

The use of standard Navy ducting is recommended. It was found that a 7" x 7" duct with an air flow rate of 250 cfm (See Appendix C) is adequate for meeting system requirements. The ducting will be connected

by a flexible diaphragm coupling. The conditioned air may be ducted either from a permanent system on the ship to the modules or from modularized air-conditioning units.

#### 4.4 PLACEMENT IN THE MODULE

The ducting and piping will be placed in the one foot false floor of each module (See Figure 4-8). These components will be used as branch main lines from primary main lines of a central system. Branch pipes connect individual pieces of equipment to the branch lines through the floor. There will be sufficient space for electrical and data lines.

### 5.0 TOTAL SYSTEM CONCEPT

#### 5.1 INTRODUCTION

In the course of this analysis, a set of axioms, factors judged by the design group to be of special importance in the design of any containerized system for shipboard use, was developed. These axioms are summarized in Table 5-1, and served as a guide in the development of the total container system design concept.

#### 5.2 GENERAL ANALYSIS PROCEDURE

The analysis was conducted in the following manner:

- (1) Major system parameters were defined.
- (2) A volume requirement for the command and control spaces aboard a typical 6700 ton combatant was extrapolated from existing data.
- (3) Four alternative containerized configurations were developed which embodied the major system parameters.

Table 5-1

TOTAL SYSTEM CONCEPT

AXIOMS

1. Spaces not subject to frequent change such as ship's company accommodations, messing facilities, heads, office spaces and galleys should not be containerized.
2. Maximum continuity of the bulkhead deck should be preserved.
3. Watertight openings in the bulkhead deck should be minimized.
4. Volumes above the bulkhead deck lend themselves more readily to containerization than volumes below.

- (4) A conventional superstructure of the same capacity was devised from data on existing ships.
- (5) A weight trade off was determined for each configuration comparing the four alternatives to the conventional ship.
- (6) A value matrix was constructed.
- (7) Observations and conclusions were made.

### 5.3 DEFINITION OF SYSTEM PARAMETERS

The analysis of any problem can be elucidated by defining a set of parameters or principal characteristics which may be varied systematically. In this case, the major questions which require resolution through an examination of alternatives are:

- (1) Container support. Should the containers be stacked on top of one another as is the current commercial practice or be placed in a framework?
- (2) Lateral restraint. Should the container attachments be designed to withstand the full transverse loading due to the rolling motion of the ship, or should lateral restraint be provided by permanent hardened ship structure?
- (3) Shipboard loading/off-loading of containers. What should be the best way to load and unload the containers?
- (4) Hardening. Should the containers themselves be hardened or placed in a hard structure which is a permanent part of the ship?
- (5) Bridge structure treatment. The navigation bridge would have to be elevated for visibility and rigidly supported. Should the structure be conventional or containerized?

For the purpose of developing alternatives, four containerized Command and Control system configurations were designed which incorporate the parametric variations suggested by the problems posed above.

#### 5.4 DEVELOPMENT OF A GENERALIZED MODEL SHIP

##### 5.4.1 Model Ship Particulars

In order to accurately determine the weight trade-offs involved in applying the container concept to warship design, it became necessary to define a strictly hypothetical ship with a conventional aluminum deck house and reasonable particulars. These particulars are summarized in Table 5-2.

##### 5.4.2 Volume Requirement

A total useable cubic of 59,000 cubic feet would adequately house the necessary Command and Control spaces for the model ship. This would require 45 8' x 8' x 20' foot containers.

##### 5.4.3 Conventional Superstructure Weight

Structural drawings of a modern high-speed warship with an aluminum deckhouse were obtained and a weight per cubic foot of enclosed volume determined. This figure did not include:

- a. Installed equipment.
- b. Outfitting.
- c. Ladders.
- d. Doors, hatches, and related fittings.
- e. Smoke stack or antenna mast weight.
- f. Transverse bulkheads.

Table 5-2.

MODEL SHIP PARTICULARS

$L_{PP}$	=	500 ft	$C_B$	=	.50
B	=	52 ft	$C_M$	=	.78
T	=	18 ft	$C_P$	=	.63
D	=	40 ft	$\Delta / (.01L)^3$	=	47.65
$\Delta$	=	6700 T.	KG	=	22 ft above $\Phi$
Trial $V/\sqrt{L}$ = 1.4					

Installed SHP = 65000 HP

Table 5-3

ALTERNATIVE WEIGHT TRADE-OFFS

	<u>Added Wgt.</u>	<u>Added HP</u>	<u>Speed Loss</u>
Configuration I	30 tons	315 HP	.051 knot
Configuration II	22 tons	231 HP	.038 knot
Configuration III	5 tons	52 HP	.009 knot
Configuration IV	44 tons	462 HP	.075 knot

The trade-off involved would be one, not both of these.

Since all of these items except the transverse bulkheads would be common to all arrangements considered and thus would not affect the total weight differences between arrangements, they could be eliminated from the weight analysis. The weight per cubic foot of enclosed volume was determined to be 1.5 pounds.

In considering the problem of the transverse bulkheads, three types of conventional superstructure stiffened plate system were developed. A stiffened front panel strong enough to withstand 20 psi wave impact loading was selected, with a weight of 10.4 lb/ft<sup>2</sup>. Over-blast, gun and missile-blast were not considered. The rear panel weight was set at 5.6 lb/ft<sup>2</sup>. The interior transverse bulkheads were considered to weigh 75% of the after transverse bulkhead, or 4.2 lb/ft<sup>2</sup>. Using these figures, the weight of the superstructure was determined to be 90 tons.

## 5.5 ALTERNATIVE DEFINITION AND DESCRIPTION

### 5.5.1 Configuration 1.

A hardened bridge shell with three levels of internal framing is provided. This structure provides support and lateral restraint for 32 of the modules (i.e. they are not stacked directly on each other. The hardened shell permits the use of "soft" containers with removable interior panels. A removable rear panel for the bridge house provides weather tightness access for container loading. The remaining 13 partially hardened containers would be placed aft of the hardened bridge structure and stacked two high on a similar framework. Figure 5-1 is a general system layout.

### 5.5.2 Configuration II

The entire bridge structure is made up of completely hardened modules. The containers are stacked directly on top of each other. A platform structure is erected for personnel access and service provision. The two major differences between this and Configuration I are that there is no framing for the modules and that the containers themselves must sustain the wave impact and vertical and transverse dynamic loadings which would be absorbed by the framing and panels of Configuration I. Weather tightness is achieved by keeping all the interior panels in place. Refer to Figures 5-2 and 5-3 for general arrangement and platform detail.

### 5.5.3 Configuration III

All containers are placed aft of a conventional hardened bridge structure. The containers are stacked on top of each other, three high, and two platform structures, port and starboard provides personnel access, service provision, and lateral restraint to the containers against transverse dynamic loadings. A removable roof panel is fitted above the container bay, furnishing weather-tightness and permitting the removal of many interior panels. Two major differences between this and Configuration II are the presence of a hardened conventional bridge structure and the lateral restraint afforded all of the containers by the platform system. The chief difference between Configurations III and I is that the bridge structure in Configuration III does not house any modules. Refer to Figures 5-4 through 5-8 for arrangements.

### 5.5.4 Configuration IV

A skeletal framework similar to that in Configuration I is provided

for container support. The major difference is that there is no stiffened plating enclosing the skeletal framework. In this case, as in Configuration II, the containers themselves must withstand the wave impact loadings and removal of interior panels is precluded. The major difference between Configurations IV and II is that the containers are not stacked. Refer to Figure 5-1 for the system arrangement.

## 5.6 EVALUATION OF ALTERNATIVES

### 5.6.1 General Procedure

Each configuration was compared to the conventional model ship to determine the weight trade-off involved. This was accomplished in the following manner:

1. Weights for each of the container configurations were derived.
2. Using unchanged ship stability as a criterion, a rise in KG was found for each configuration, assuming that the difference in weight between the conventional structure and the configuration could be considered as an added weight placed high in the ship.
3. This rise in KG was compensated for by an increase in beam ultimately requiring either an increase in installed SHP to maintain the original performance level, or accepting a drop in top speed.

### 5.6.2 Weight Analysis

In the configurations discussed, two types of containers are used:

- (1) A hardened convertible container in which "soft" panels on sides exposed to wave impacts are replaced by "hardened" panels with heavier plating to withstand the higher loadings. The weight of such a container is estimated to be 4500 lbs based on the Chesapeake Instrument Corp. towed array monitoring van. This is the only existing container seen directly by the design team suitable for housing a combat system.
  
- (2) A "soft" convertible container with no "hardened" panels. A weight of 3000 lbs is based on data from a Craig Corp. Electrical Shelter. The weight of the removable "soft" panels is 4.2 lbs/ft<sup>2</sup>.

### 5.6.3 Configuration Weights

A tabulation of the weights for Configuration I is shown below:

#### Bridge Shell

Front panel	5.3 tons
Side panels	12.5
Rear panels	3.2
Roof panel	6.0
Framing	48.0
Containers (bridge)	28.0
Containers (aft)	17.0
(incl. roof panel aft)	<hr/>
Total system weight	120.0 tons

Using a similar procedure, the weights of the other configurations were determined to be 112 tons for Config. II, 95 tons for

Config. III, and 134 tons for Config. IV.

#### 5.6.4 Effect of Weight Increase

Using an original KG of 22 feet and a hull girder depth of 40 feet, the added weight of each configuration was assumed to be concentrated 12 feet above the main strength deck. Comparing the model ship to an existing combatant, it was assumed that the variation of certain non-dimensional parameters between similar ships would be small. Two such parameters used for the model ship derived from an existing ship are:

$$KB/T = .6 \qquad BMxT/B^2 = .094$$

KB is assumed to remain constant. A one foot rise in KG would require a one foot increase in KM, to maintain GM at its initial value. For the model ship with the initial KG, BM was calculated as 14.12 feet. Increasing this to 15.12 feet resulted in a new beam of approximately 54 feet. Thus, a one foot rise in KG requires a two foot increase in beam to maintain the same value of GM.

From Series 64 data it was found that a one foot increase in beam would result in a  $.015 \times 10^{-3}$  increase in the total resistance coefficient at 30 knots. Again assuming that similar type ships would have similar parameters, the wetted surface of the subject ship was extrapolated from existing data. The resistance and EHP were then calculated. Assuming a constant propulsive coefficient of .60 the change in required installed SHP to maintain performance was determined to be about 226 horsepower per foot increase in beam.

For 1 ton of added weight, the increase in KG was on the order of .005 feet. The beam increase to compensate for this imposed a requirement for an additional 1 horsepower.

One further trade-off was involved in the analysis. The displacement of the ship would increase due to the added weight. This would

result in either:

- (1) An additional SHP requirement of 9.5 HP/ton over that to compensate for the increase in beam, or
- (2) A loss of .0015 knots in trial speed per ton of added weight.

Table 5.3 lists the alternative trade-offs imposed by each configuration. It should be noted that not one of the configurations would call for more than a 3/4% increase in installed SHP or, alternatively, more than a .075 knot speed loss.

## 5.7 EVALUATION MATRIX

### 5.7.1 Evaluation Criteria

Using the weight figures from Table 5-3 and other criteria, the evaluation matrix, Matrix 5.1 was developed. Two of the criteria merit further explanation: system useability and system surviveability.

System useability was defined to include system flexibility and system habitability. Flexibility was defined as the ease with which a variety of deck plans and internal space arrangement could be accommodated. System habitability was defined as the relative comfort and convenience with which a member of the ship's company could work in the space. Also considered in this concept of habitability is the possible lack of acceptance that container configuration would receive by the officers and men on board. The removable interior panel feature greatly improves a system's score in this area.

System survivability included:

- (1) Water tight integrity.
- (2) Ability to survive weather damage.
- (3) System vulnerability, defined for our purpose as the amount of system effectiveness lost for each hit on system scored by hostile fire.

None of the configurations fared particularly well in system vulnerability. This was due to the fact that the containers, and therefore the majority of the ship's Command and Control functions would be concentrated along a relatively short portion of the superstructure.

#### 5.7.2 Recommended Configuration

The most effective configuration as derived from matrix 5.1 was Configuration III.

A cost analysis of the alternative configurations was not made. However, if it is assumed that cost is directly related to weight and complexity then it may be inferred that Configuration III will also prove to be the most cost effective.

Five questions were posed in defining the system parameters. The design team is now in a position to answer these questions:

- (1) Container Support. The stacked container system appears to be the most attractive.
- (2) Lateral Restraint. The permanent platform structure erected to provide lateral restraint, personnel access, and service distribution is recommended.
- (3) Shipboard Loading-Off Loading. Vertical access through a removable roof panel is the most direct method.
- (4) Hardening. Hardening which is part of the permanent ship's structure is preferred over using individually hardened container panels.
- (5) Bridge Structure Treatment. The advantages of employing a conventional bridge structure suggest its inclusion in the total system concept.

## 5.8 OBSERVATIONS AND CONCLUSIONS

### 5.8.1 Observations

- (1) The stacked container system appears to be the most attractive.
- (2) It is advantageous to provide a platforming system for lateral restraint, personnel access and service distribution.
- (3) Vertical access through a removable roof panel is the most direct method of loading and off-loading the containers.
- (4) Hardening which is part of the permanent ship's structure is recommended over the use of individually hardened container panels.
- (5) A conventional bridge structure housing no modules is desirable.
- (6) The weight trade-off involved in adopting the container concept is not prohibitive.

### 5.8.2 Conclusions

- (1) The concept of using containers to provide a modularized Command/Control system is feasible from the point of view of the ship's structure, arrangements, stability and powering.
- (2) Adoption of a convertible container configuration with removable side panels is strongly recommended.

## 6.0 SUMMARY OF CONCLUSIONS

Containerization of Command and Control spaces on board a naval combatant ship is feasible implementing current state-of-the art technology and utilizing containers with removable side panels.

It is recommended that the containers be placed in a hardened bay with conventional bridge structure forward and a platform structure providing passageways, access and lateral restraint on both sides and aft of the container bay. A removable overhead stiffened panel covering the container bay is recommended for vertical access to the bay and for weather tightness. Within the bay the containers would be stacked on each other without intermediate supporting structure and would be fastened to each other both vertically and laterally. Vertical attachment and deck attachment by means of twist lock fasteners is recommended.

The use of umbilical cords run through a one foot false floor in each module is recommended for electrical and data flow. Multiwire connectors are currently available and ready for use.

It is recommended that plastic pipe, with compression type fittings, be used for water flow. And, standard rectangular ducting be used for air flow. These systems will also be passed through the one foot false floor.

## 7.0 RECOMMENDATIONS FOR SUBSEQUENT DESIGN TEAMS

The following areas are recommended for further study by future design teams:

- (1) The investigation of containerization of weapons systems and other shipboard systems.
- (2) Galvanic corrosion between aluminum and steel, especially pertaining to twist locks and module-deck interfaces.
- (3) Power factor compensation for electrical flow.
- (4) Security requirements for data transfer.
- (5) Shock loading characteristics for types of piping, tubing, and hose considered.
- (6) Water purity requirements for system components.
- (7) A more detailed cost analysis.
- (8) EMF problems generated by the many bolted panels used in each module.

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FIGURES

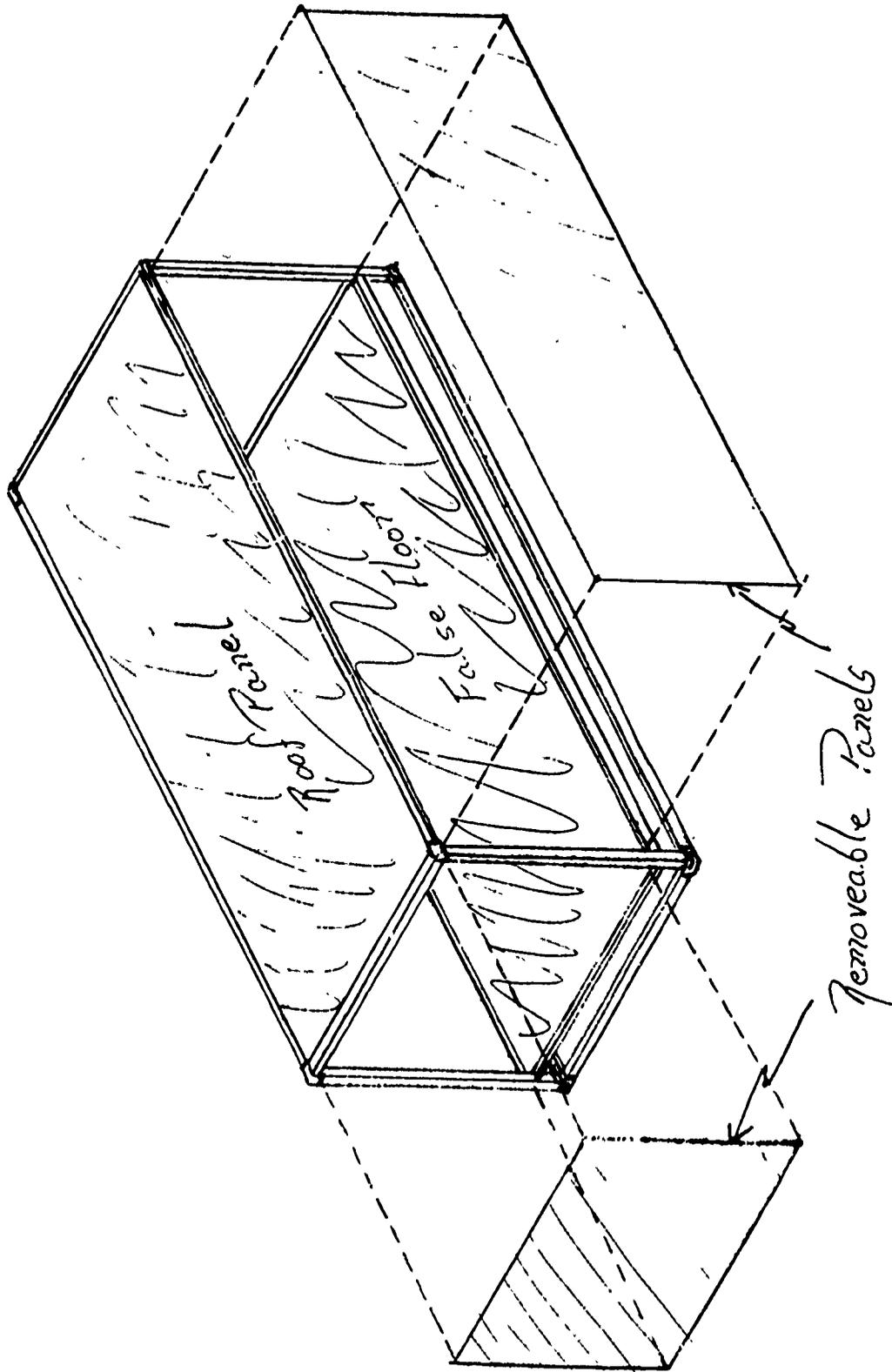
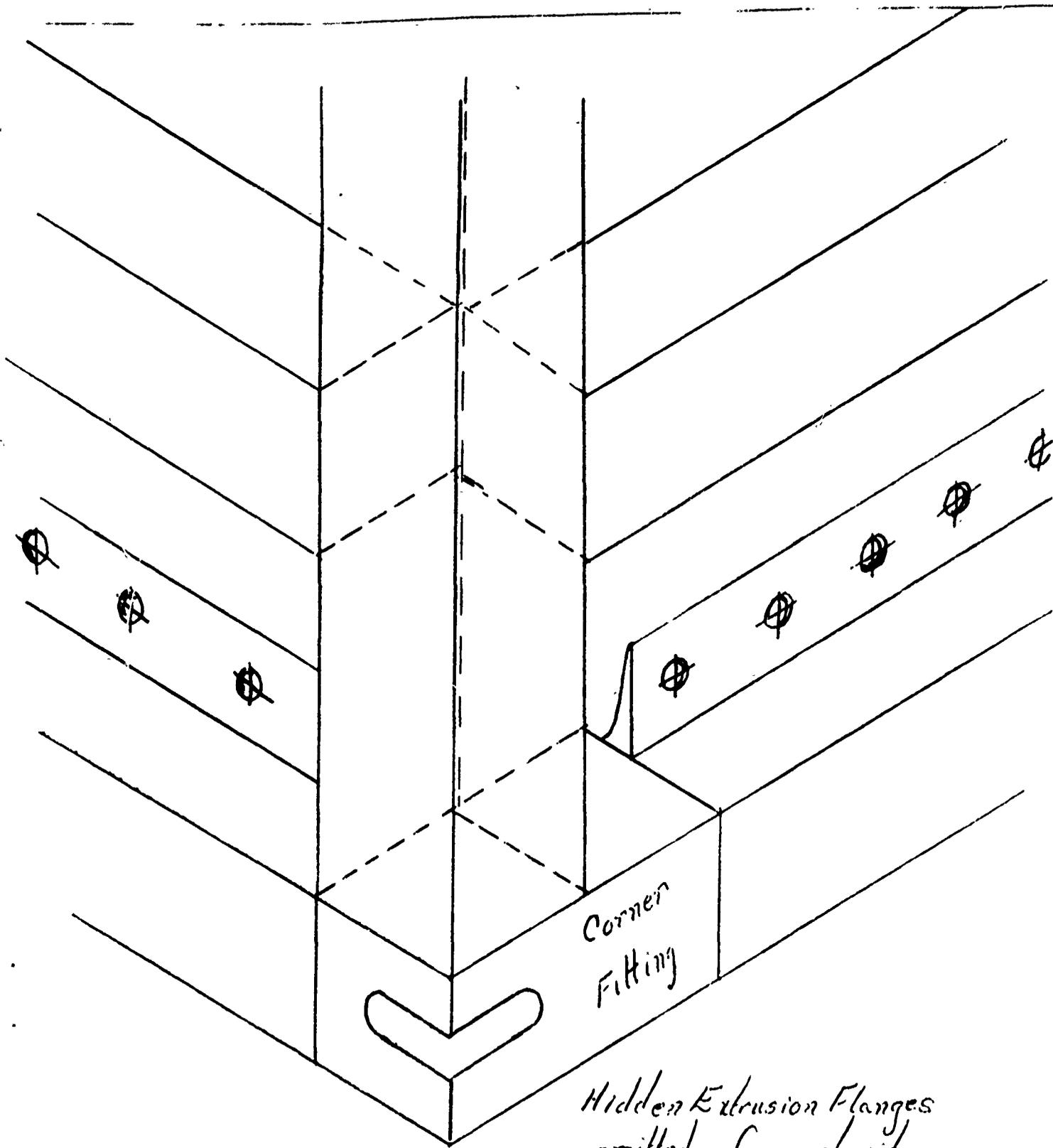
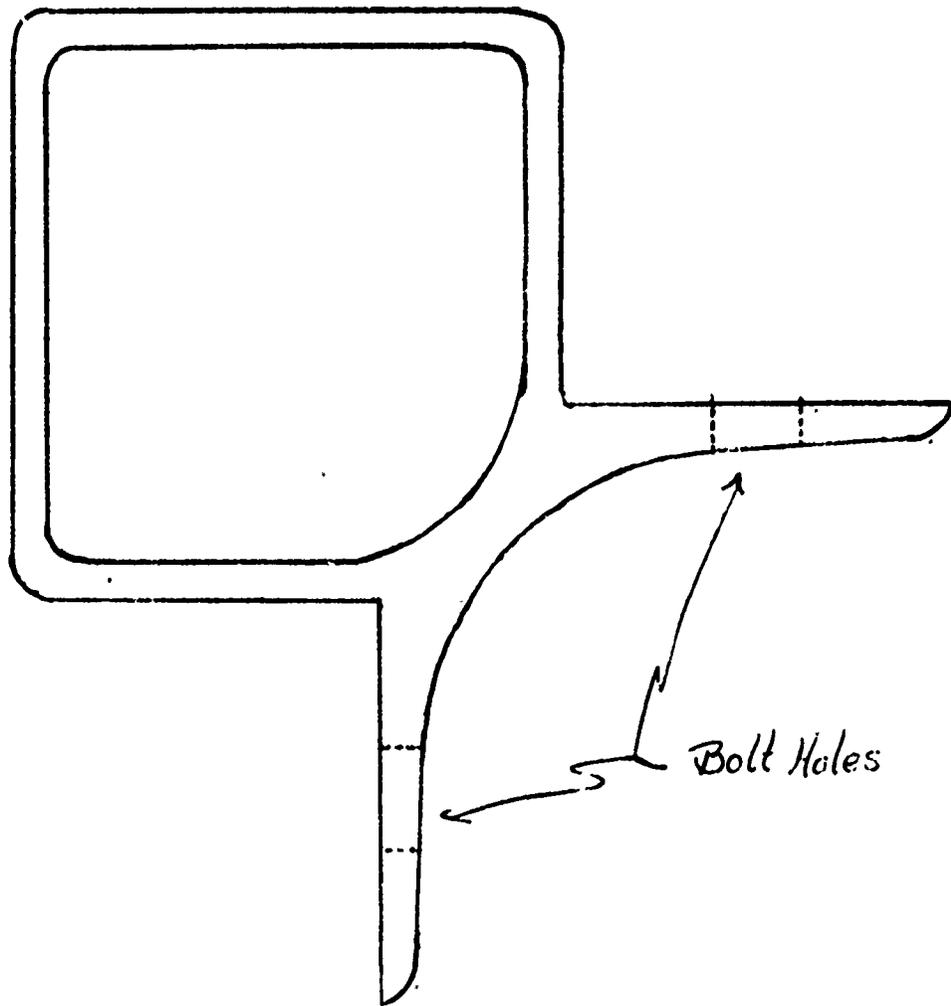


FIG 1-1 OVERALL APPEARANCE OF SELECTED VAN



*Hidden Extrusion Flanges  
omitted for clarity*

FIG 1-2 BOTTOM CORNER DETAIL



Used for corner posts, false floor edge supports, roof edge supports, & container-bottom edge beams

FIG 1-3 EXTRUDED SHAPE CROSS SECTION

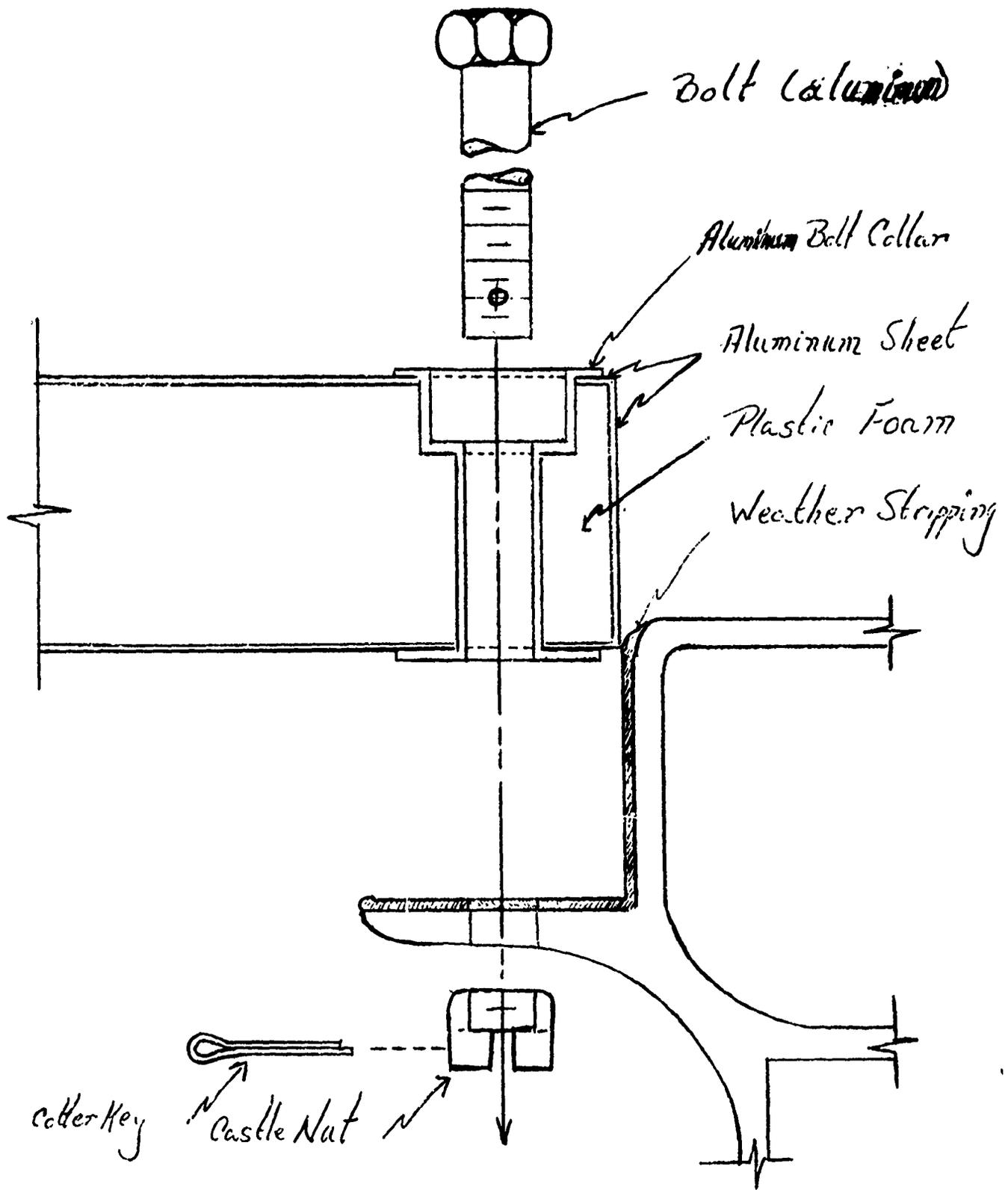


FIG 1-4 PANEL/CORNER POST CONNECTION

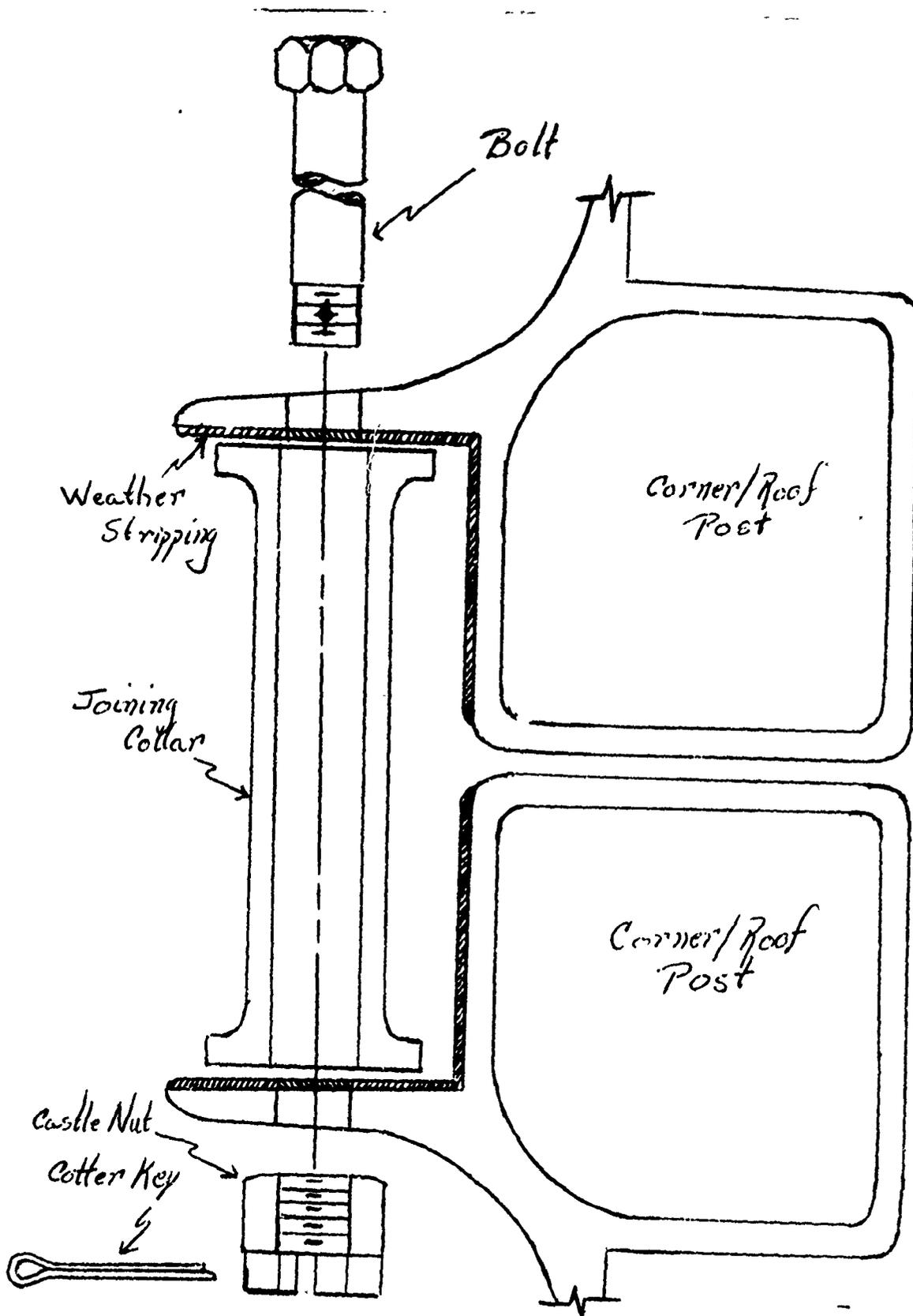


FIG 1-5 CONTAINER INTERCONNECTION DETAIL

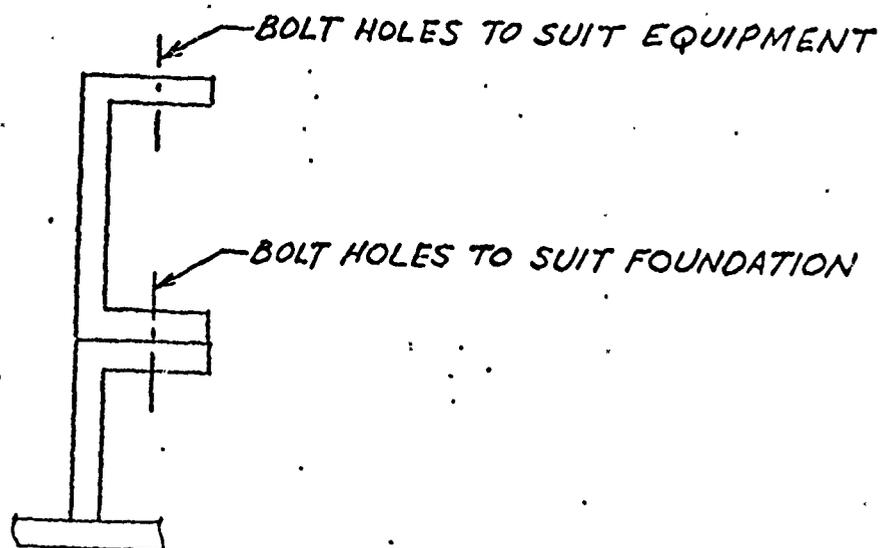
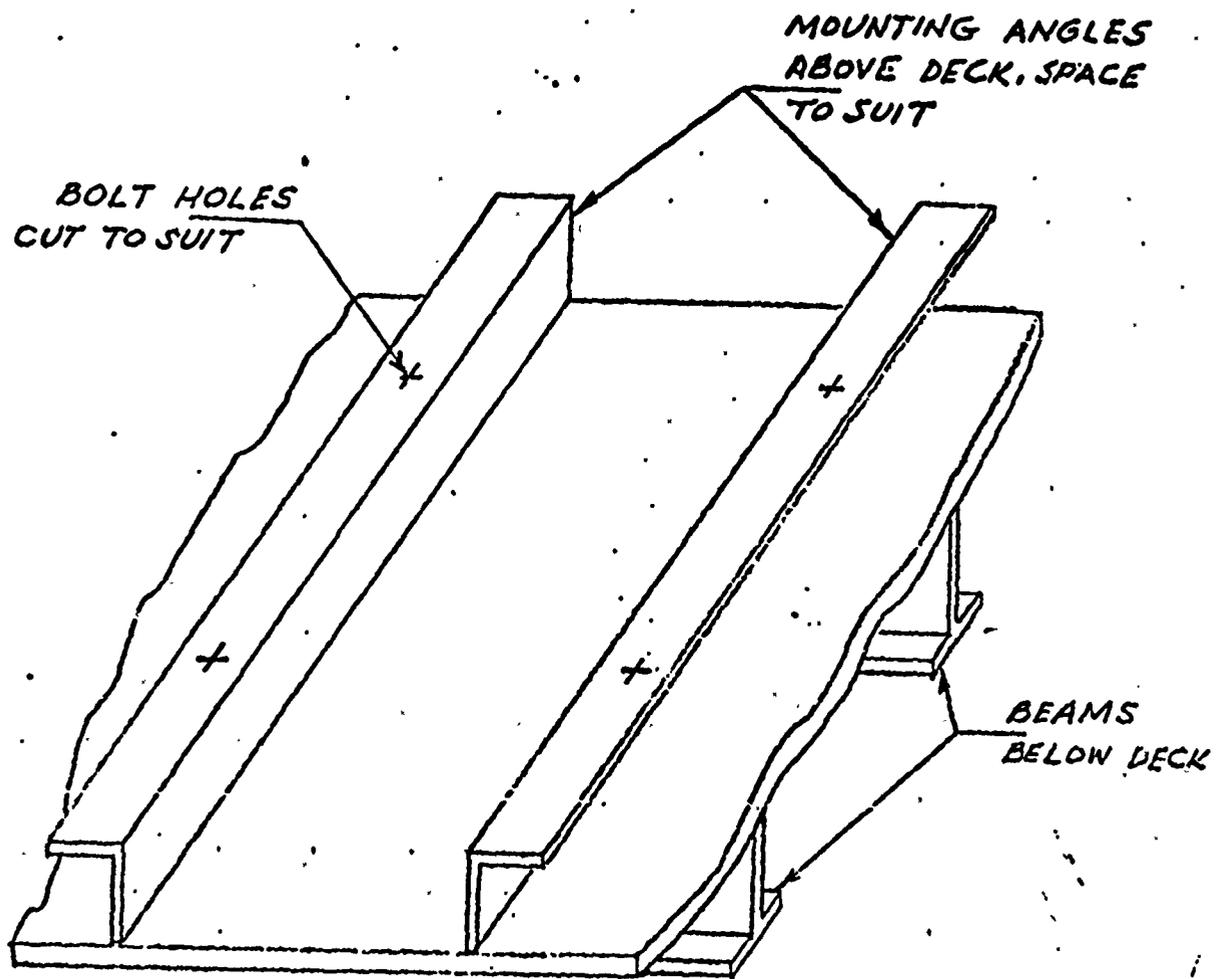


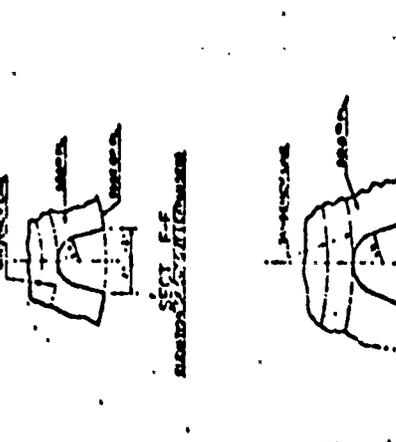
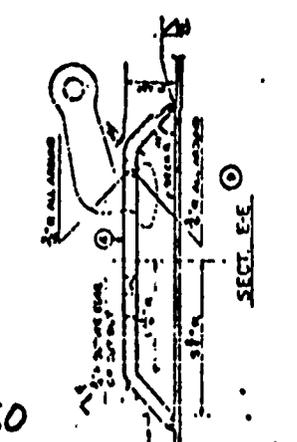
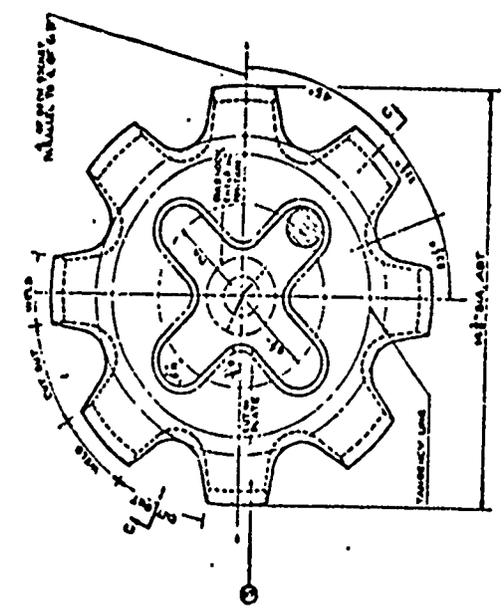
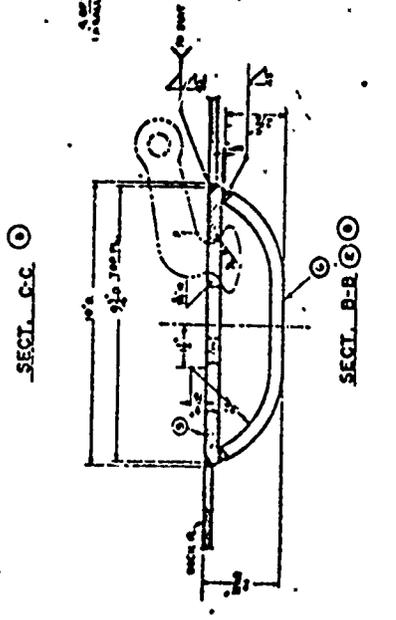
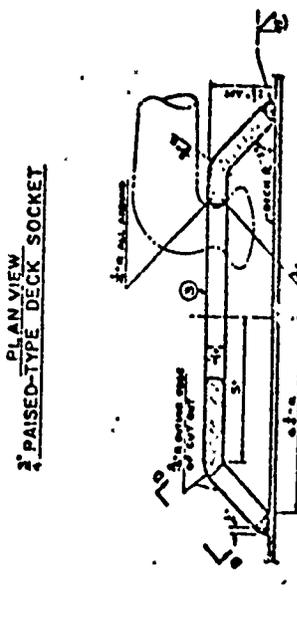
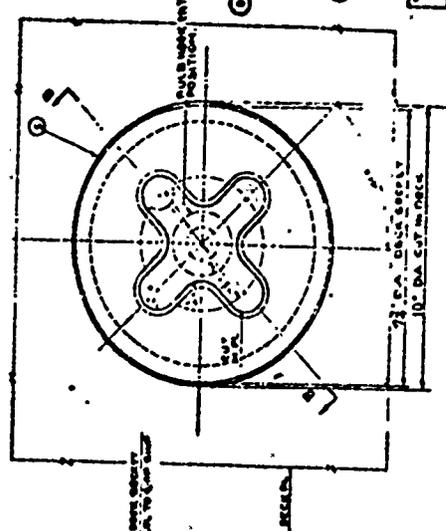
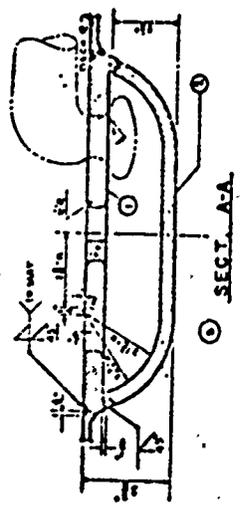
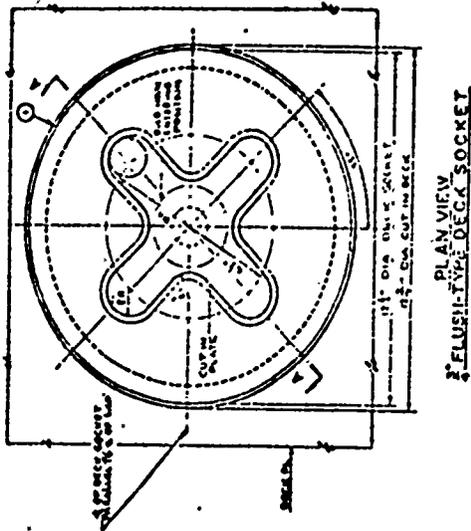
FIG 2-1 PERMANENT FOUNDATION WITH  
INTERMEDIATE MOUNTING FRAME

**REVISIONS**

NO.	DESCRIPTION	DATE
1	DESIGN CHANGES	1944
2	DESIGN CHANGES	1944
3	DESIGN CHANGES	1944
4	DESIGN CHANGES	1944
5	DESIGN CHANGES	1944
6	DESIGN CHANGES	1944
7	DESIGN CHANGES	1944
8	DESIGN CHANGES	1944
9	DESIGN CHANGES	1944
10	DESIGN CHANGES	1944

**LIST OF MATER. QUANTITIES FOR ONE SOCKET**

NO.	NAME	QTY.	UNIT
1	STEEL PLATE, 1/2" THICK	1.00	SQ. FT.
2	STEEL PLATE, 1/4" THICK	1.00	SQ. FT.
3	STEEL PLATE, 1/8" THICK	1.00	SQ. FT.
4	STEEL PLATE, 1/16" THICK	1.00	SQ. FT.
5	STEEL PLATE, 1/32" THICK	1.00	SQ. FT.
6	STEEL PLATE, 1/64" THICK	1.00	SQ. FT.
7	STEEL PLATE, 1/128" THICK	1.00	SQ. FT.
8	STEEL PLATE, 1/256" THICK	1.00	SQ. FT.
9	STEEL PLATE, 1/512" THICK	1.00	SQ. FT.
10	STEEL PLATE, 1/1024" THICK	1.00	SQ. FT.



**FIG 2-2 TWIST LOCKS AND DECK SOCKETS**

**GENERAL NOTES**

1. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
2. THE WEIGHTS SHOWN ARE APPROXIMATE AND ARE FOR INFORMATION ONLY.
3. WEIGHTS SHOWN ARE APPROXIMATE AND ARE FOR INFORMATION ONLY.

**REFERENCE DRAWINGS**

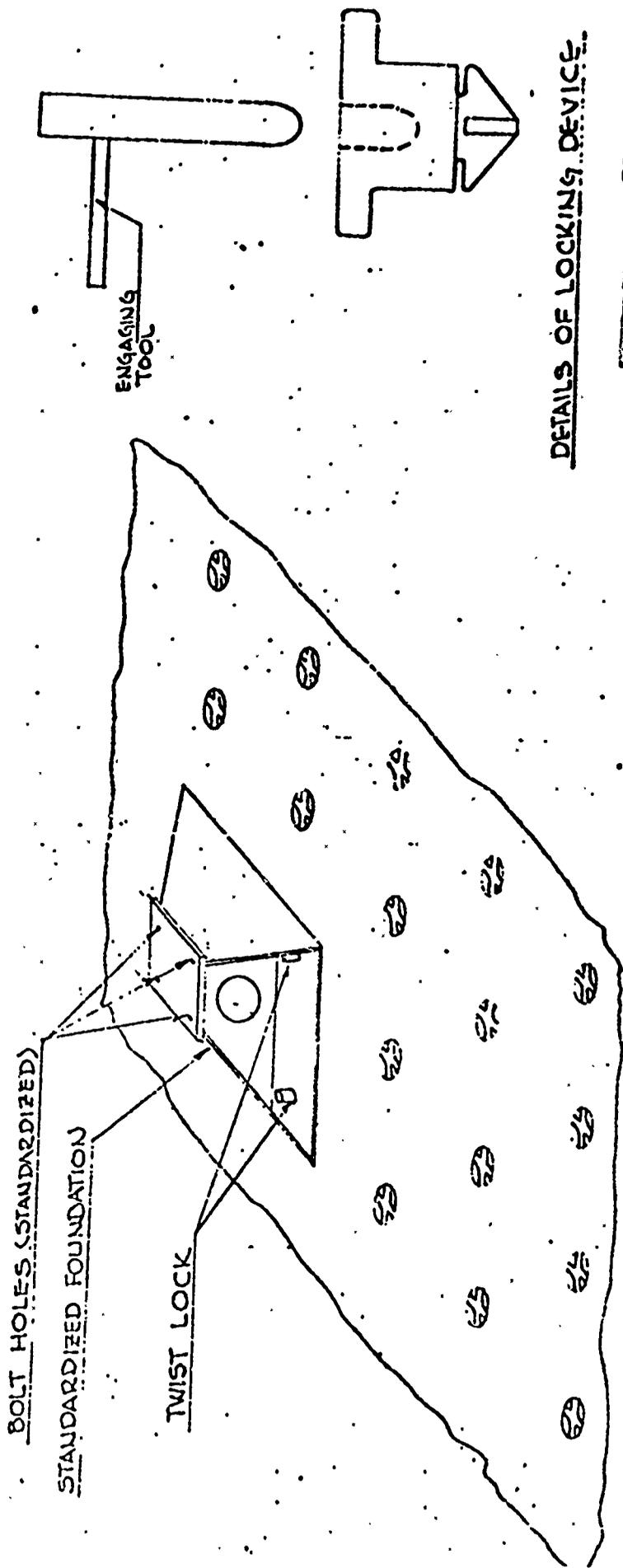
- 1. 100-10000-1
- 2. 100-10000-2
- 3. 100-10000-3
- 4. 100-10000-4
- 5. 100-10000-5
- 6. 100-10000-6
- 7. 100-10000-7
- 8. 100-10000-8
- 9. 100-10000-9
- 10. 100-10000-10

**REPRODUCED FROM COPY**

**BUREAU OF SHIPS**

**VEHICLE LASHING SOCKETS**

NO.	DESCRIPTION	DATE
1	DESIGN CHANGES	1944
2	DESIGN CHANGES	1944
3	DESIGN CHANGES	1944
4	DESIGN CHANGES	1944
5	DESIGN CHANGES	1944
6	DESIGN CHANGES	1944
7	DESIGN CHANGES	1944
8	DESIGN CHANGES	1944
9	DESIGN CHANGES	1944
10	DESIGN CHANGES	1944



SCHEMATIC  
DIMPLE DECK SOCKET LAYOUT

FIG 2-3 DIMPLED PLATES AND FOUNDATION

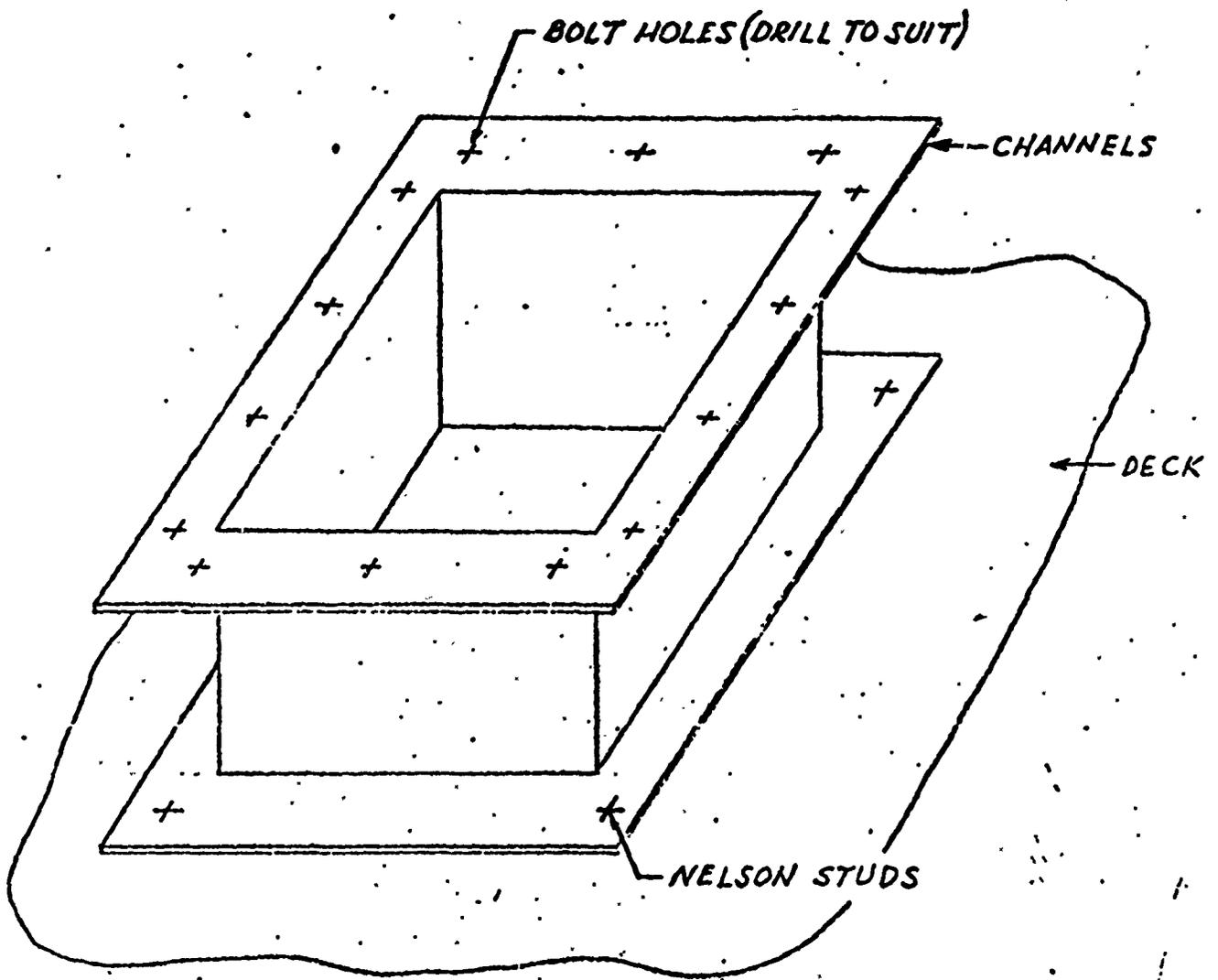
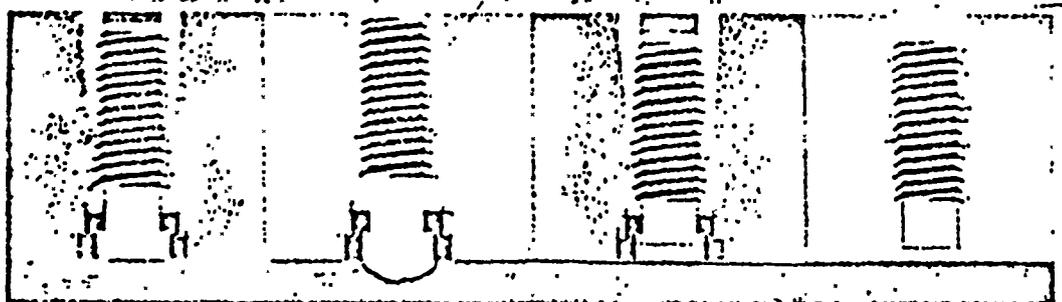


FIG 2-4 BATTLE HARDENED CRIB AND  
NELSON STUDS

Another alternative to welding a foundation to the deck is the use of the Nelson solid flux stud. This solid flux stud has a conical weld base providing a natural arc shape that assures uniform burnoff. The flux is very accurately located in the stud center and locked into place. The fusion process is described as follows:



HOW STUDS ARE WELDED . . . 1. Fluxed-end of stud is placed in contact with work. 2. Stud is automatically retracted to produce an arc. 3. Stud is plunged into pool of molten metal. 4. Operation completed. Stud is welded to work.

FIG 2-5 USE OF NELSON STUDS

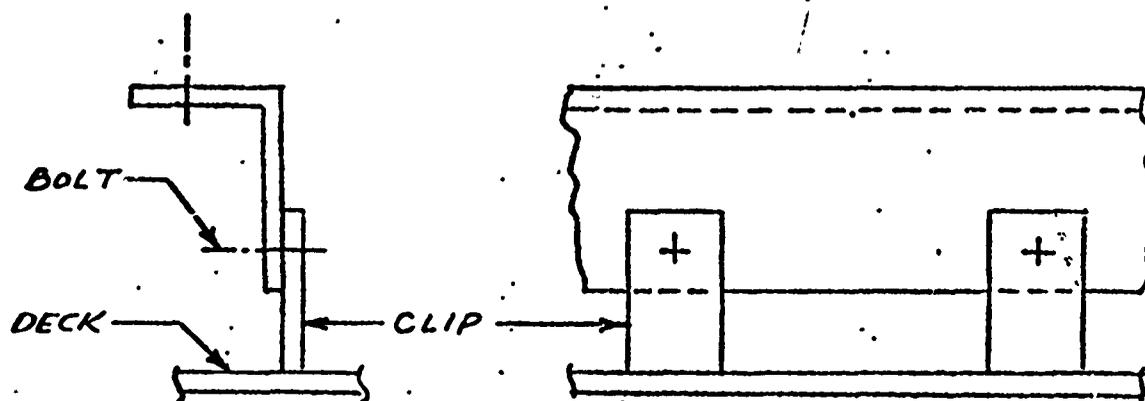
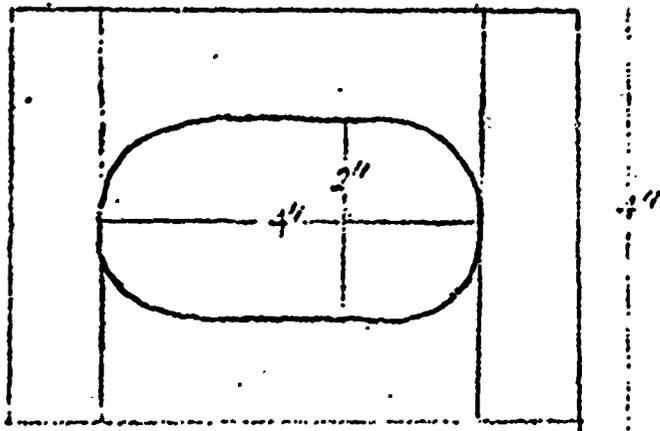
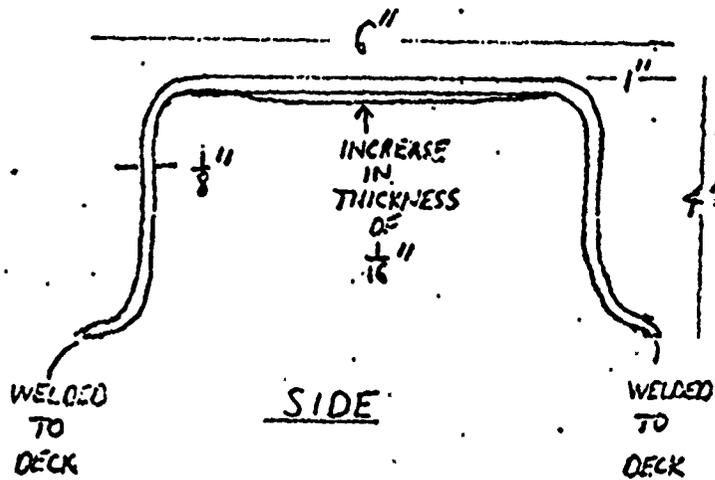


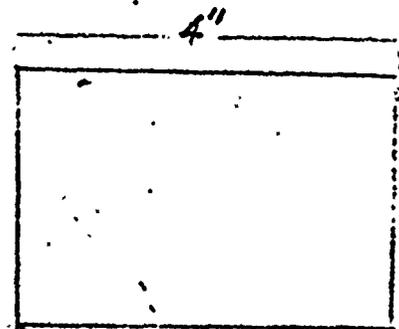
FIG 2-6 INTERMEDIATE MOUNTING ANGLES  
AND CLIPS



TOP



SIDE



FRONT

FIG 2-7 PERMANENT DECK SOCKETS

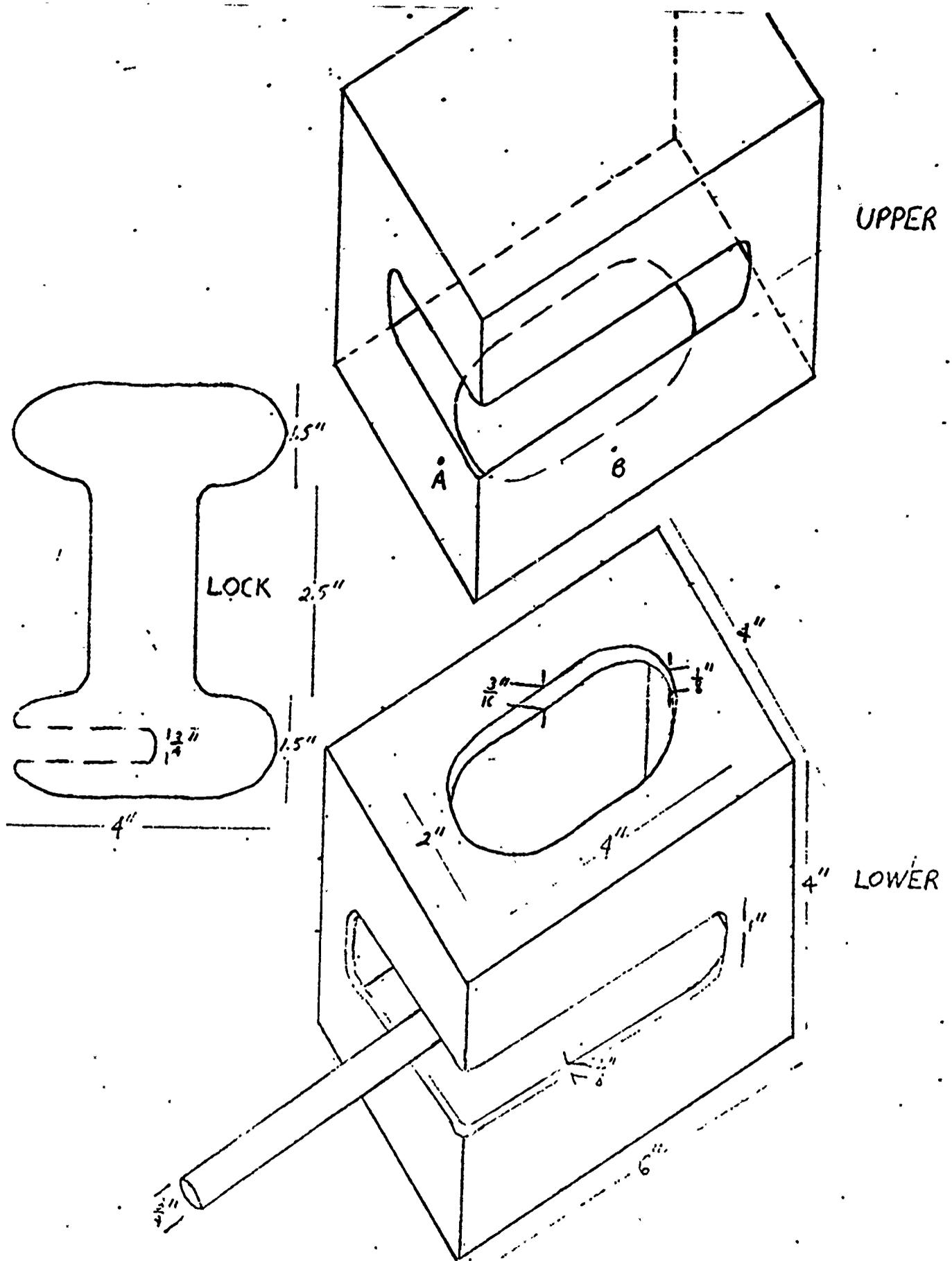


FIG 2-8 CONNECTING 'TWIST' LOCK

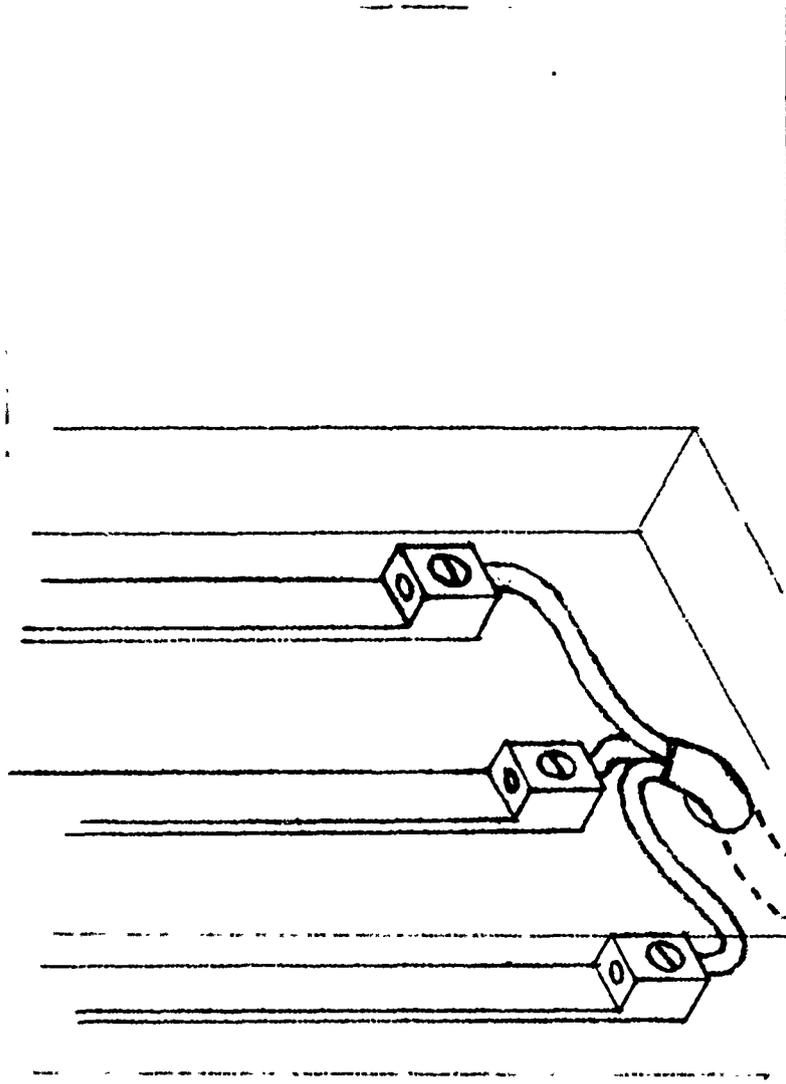


FIG 3-1-1 IN-BOX CONNECTION

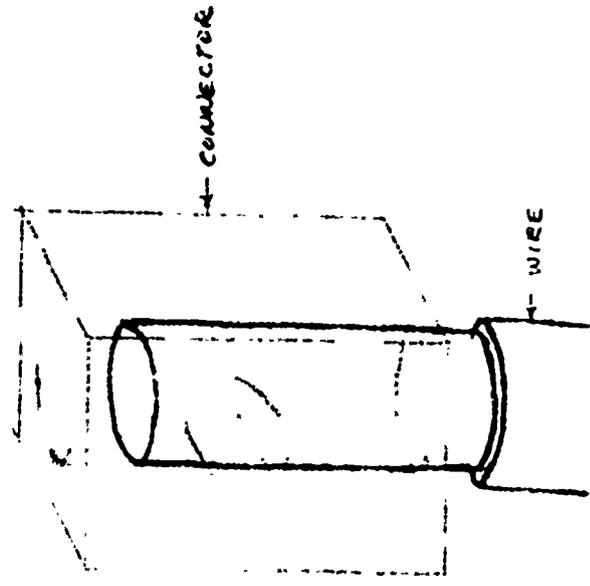
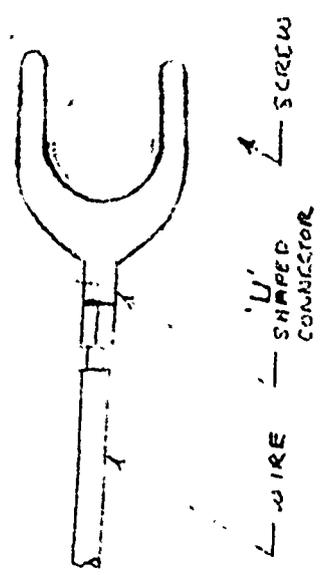
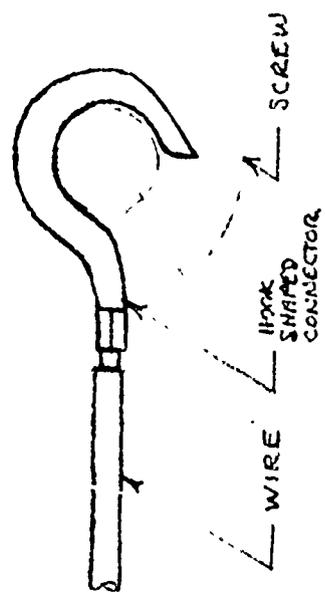
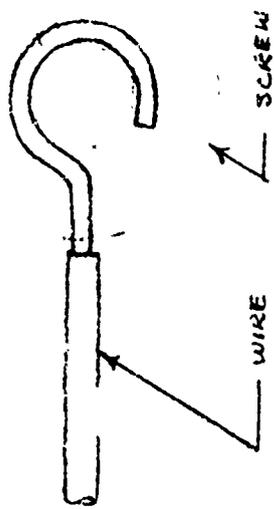


FIG 3-2 WIRE CONNECTIONS

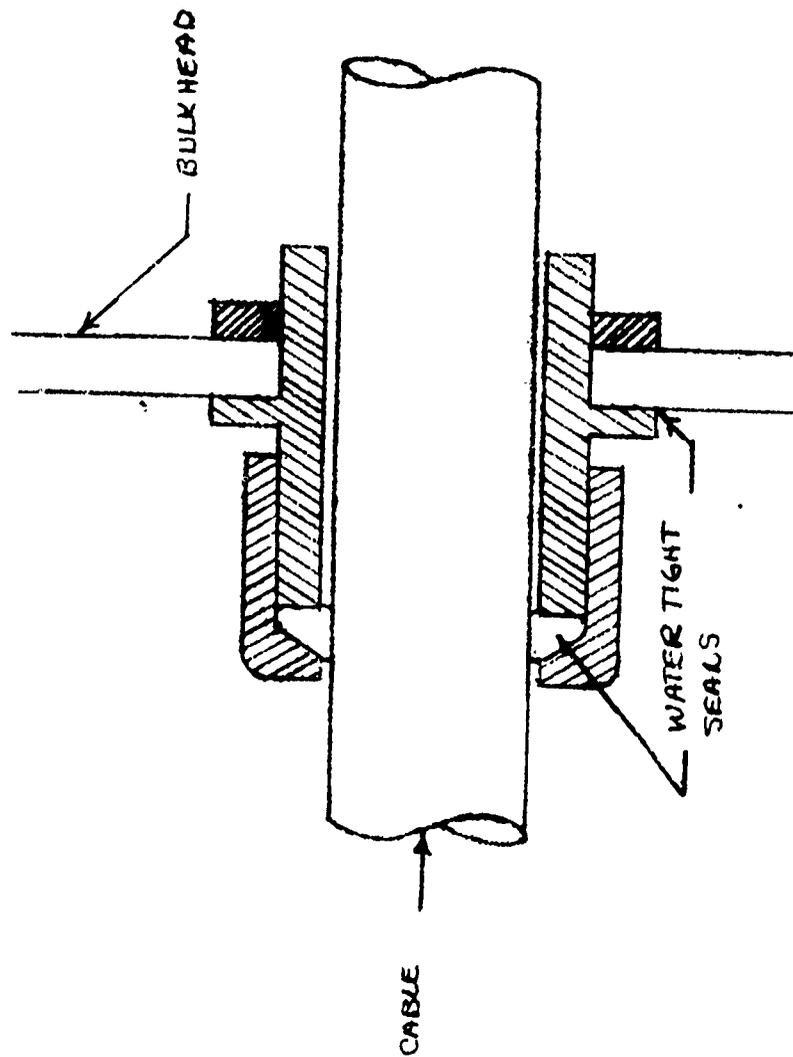


FIG 3-3 WATERTIGHT INSERT

$$\frac{N_{PRI}}{N_{SEC}} = 1$$

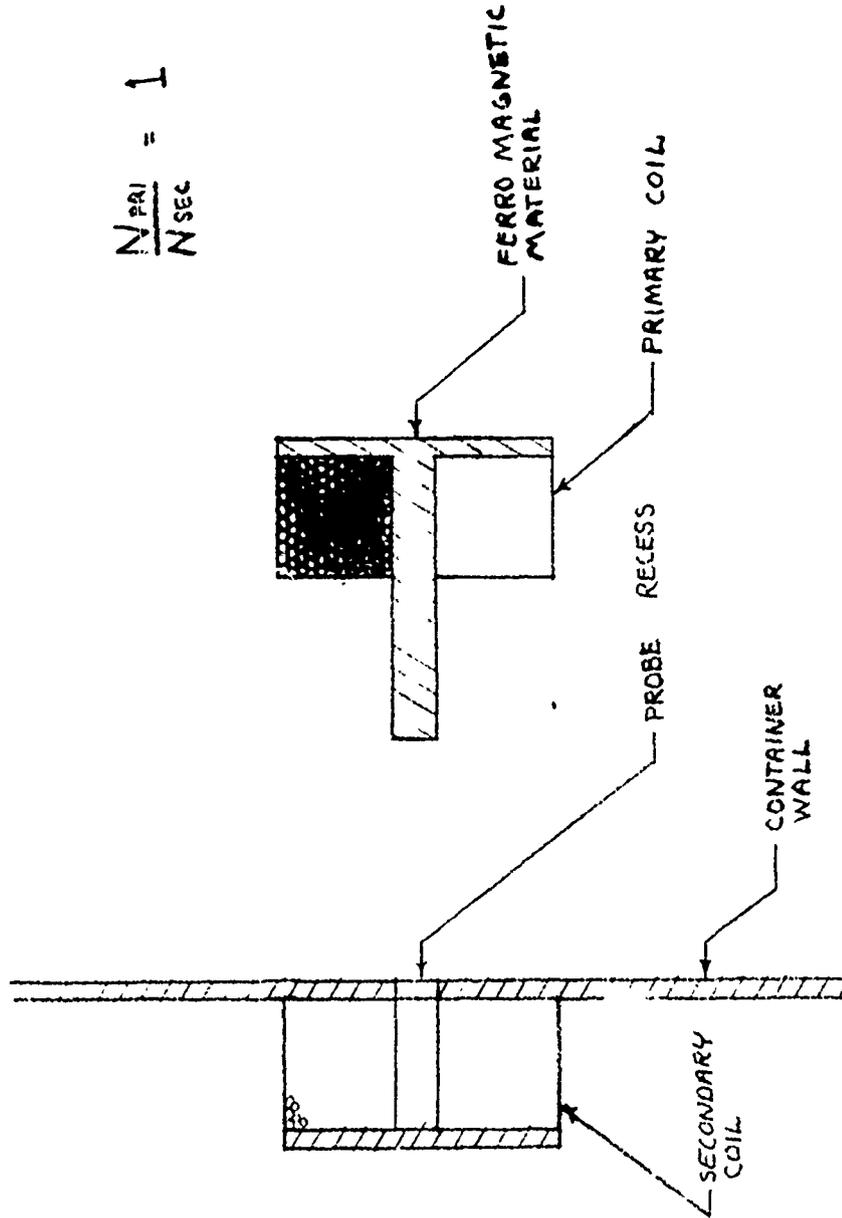
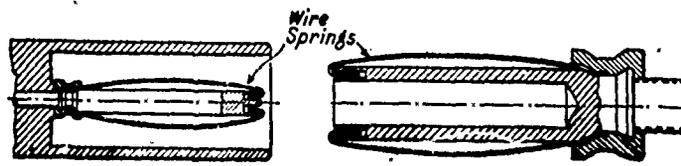
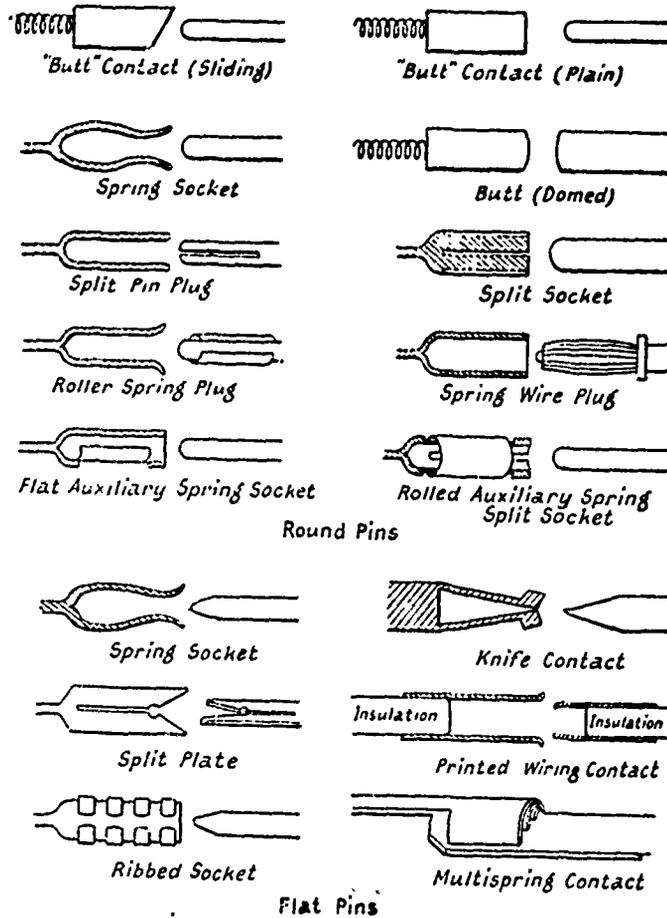
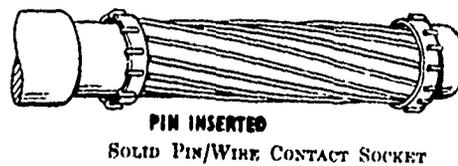
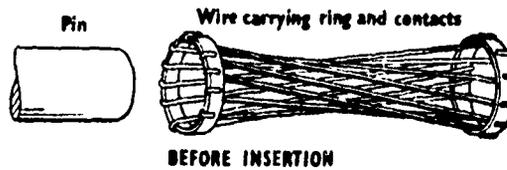


FIG 3-4 ELECTRO-MAGNETIC CONNECTOR

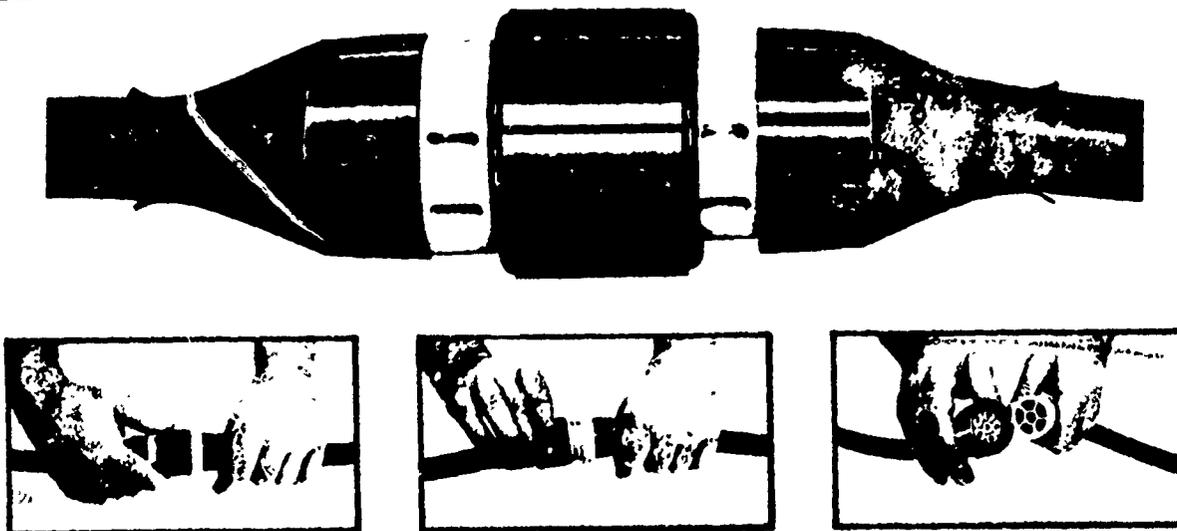
**PLUGS AND SOCKETS**



**PLUG WITH RESILIENT MATING PARTS FOR HIGH CURRENT CARRYING**



(FROM CONNECTORS, RELAYS, AND SWITCHES; DUMMER & HYDE)



API AMPPOWER MULTIPLE CONNECTOR.

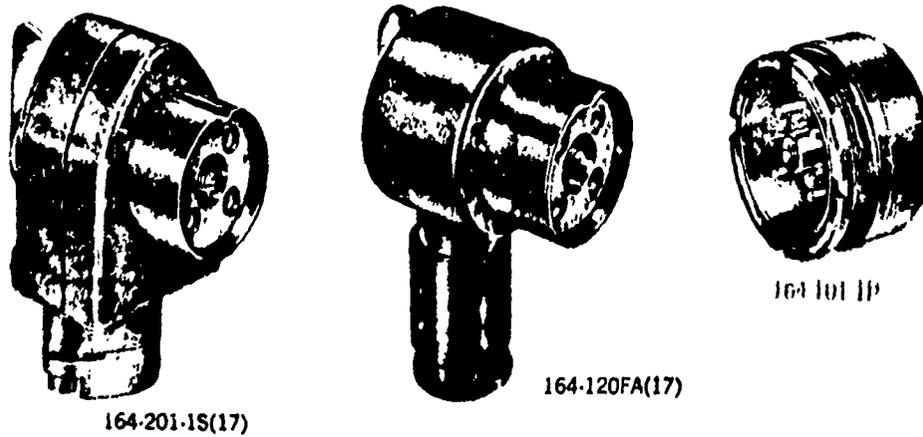


FIG 3-6 MULTIWIRED CONNECTORS SUITABLE FOR POWER CONNECTORS

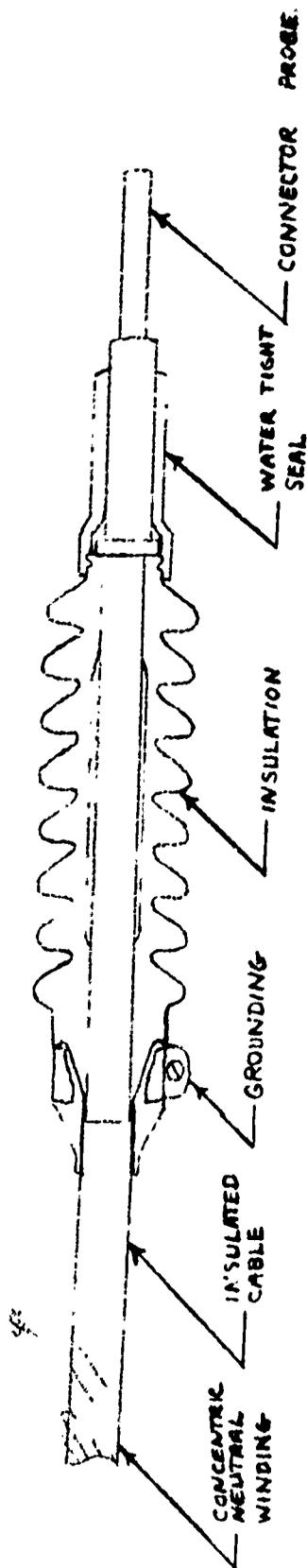
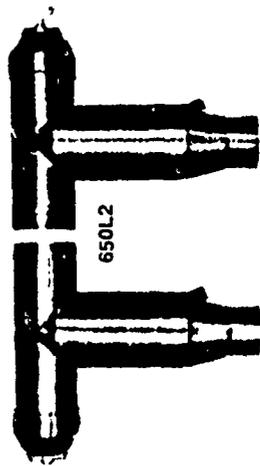


FIG 3-7 ITT-BLACKBURN POWER CABLE CONNECTOR

### 600 Amp Modular Splices (Disconnectible)



650L2

- Molded rubber: fully shielded.
  - Plug-together design
  - 100% production test.
  - 650L1—600 amp dead-end.
  - 650L2—2-way splice
  - 650L3—3-way splice.
  - 650L4—4-way splice.
- Voltage class .....thru 25 kv  
 Current rating .....600 amps  
 Cable insulation range .....875" to 1,785"  
 Conductor range .... .2/0 Al/Cu thru 1000 MCM Al

### 600 Amp/200 Amp Taps (Loadbreak)

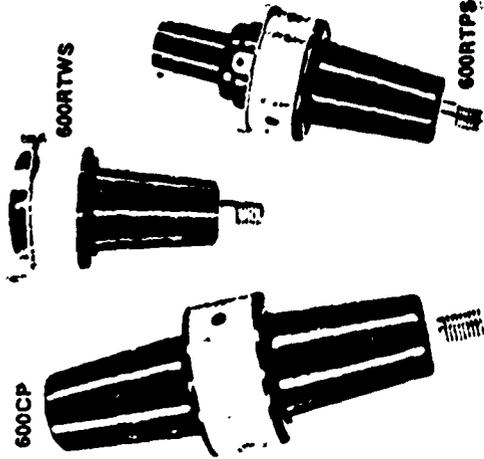


650L12

- Molded rubber: fully shielded.
- Plug-together design.
- 100% production test.
- 650L10—600 amp connector, 200 amp loadbreak tap.
- 650L11—600 amp connector with two 200 amp loadbreak taps.
- 650L12—2-way 600 amp splice with 200 amp loadbreak tap.
- 650L13—2-way 600 amp splice with two 200 amp loadbreak taps.
- 650L14—3-way 600 amp splice with 200 amp loadbreak tap.

Voltage class .....thru 25 kv phase to phase  
 Current rating .....600 amps on 650LR products  
 200 amps on 160 series products  
 200 amps on 260 series products  
 Cable insulation range .....650LR: .875" to 1,785"  
 160 series: .495" to .985"  
 260 series: .625" to 1,240"  
 Conductor range .....650LR: 2/0 Al/Cu thru 1000 MCM Al  
 160 series: No. 4 Al/Cu thru 4/0 Al/Cu  
 260 series: No. 4 Al/Cu thru 4/0 Al/Cu

### 600 Amp Modular Splice and 200 Amp Tap Accessories



- 600CP—connecting plug used for joining two 650LR elbows.
- 600RTP and RTPS—reducing tap plugs used with 650LR to permit 200 amp non-loadbreak taps. (Both accept 150 series non-loadbreak connectors.)
- 600RTW and RTWS—reducing tap wells are used with the 650LR to permit 200 amp loadbreak or non-loadbreak taps. (Bushing inserts are installed in the tap wells.)
- 100% production test.

FIG 3-8 ELASTIMOLD CONNECTORS

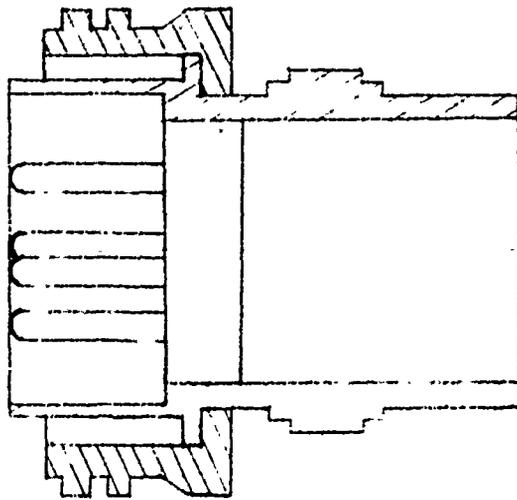


FIG 3-9. AMPHENOL MS-40-60A. MALE CONNECTOR (CROSS SECTION)

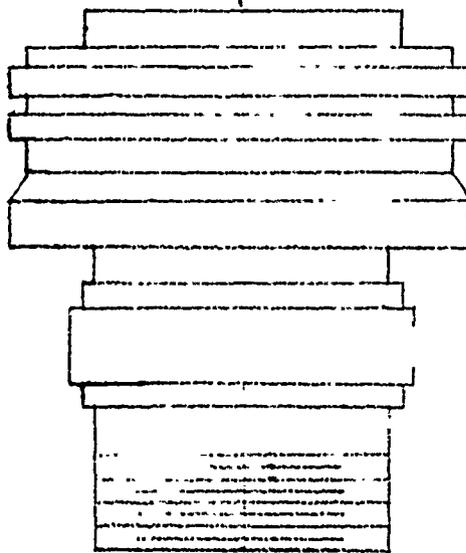
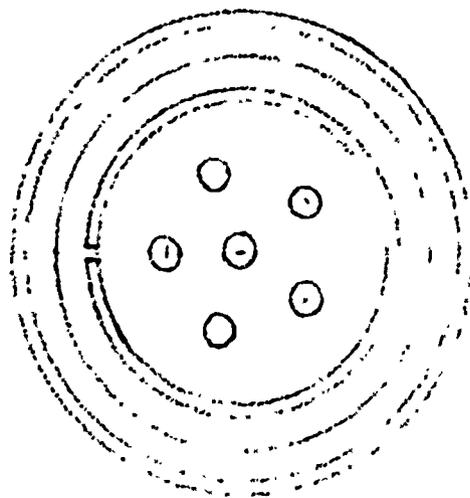


FIG 3-10. AMPHENOL MS-3106A STRAIGHT PLUG CONNECTOR

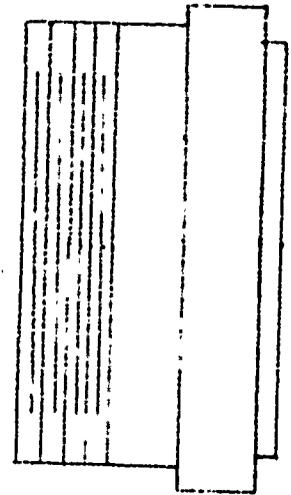
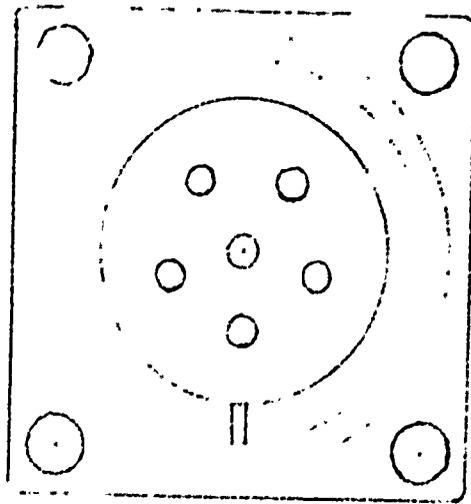
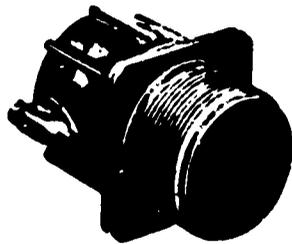


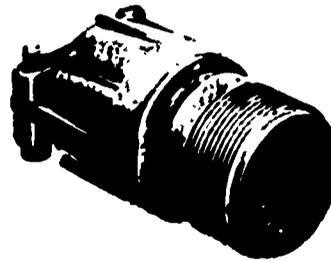
FIG. 3-11 AMPHENOL MS-3102A BOX RECEPTACLE



MS 3100 E



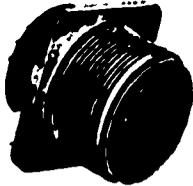
MS 3100 R



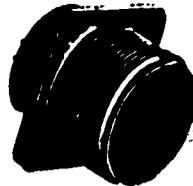
MS 3101 E



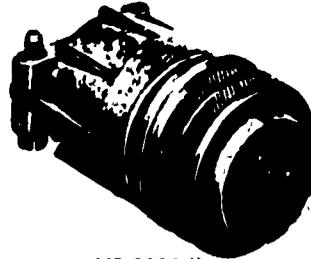
MS 3101 R



MS 3102 E



MS 3102 R

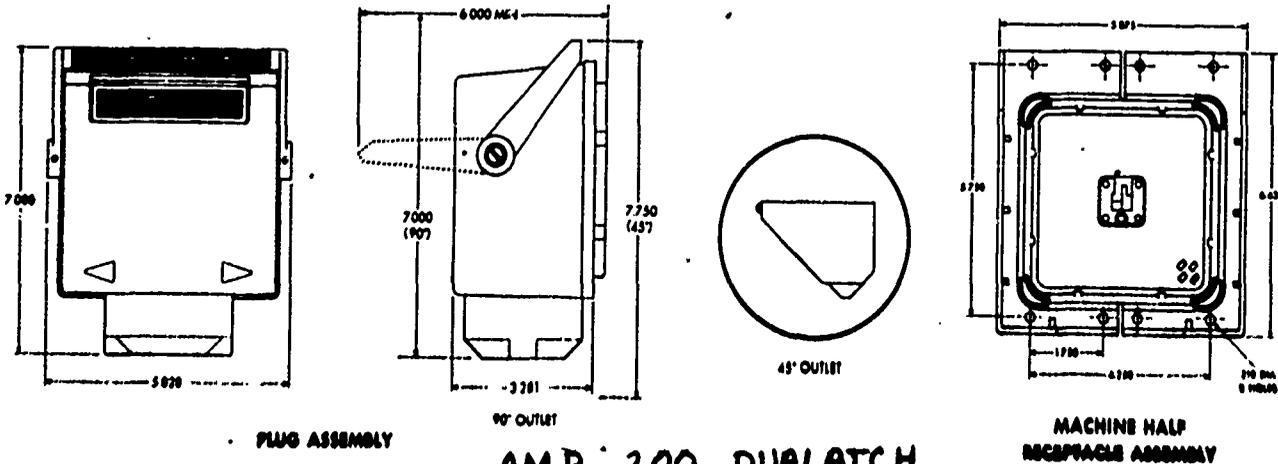


MS 3106 E



MS 3106 R

APPENDIX



AMP 200 DUALATCH

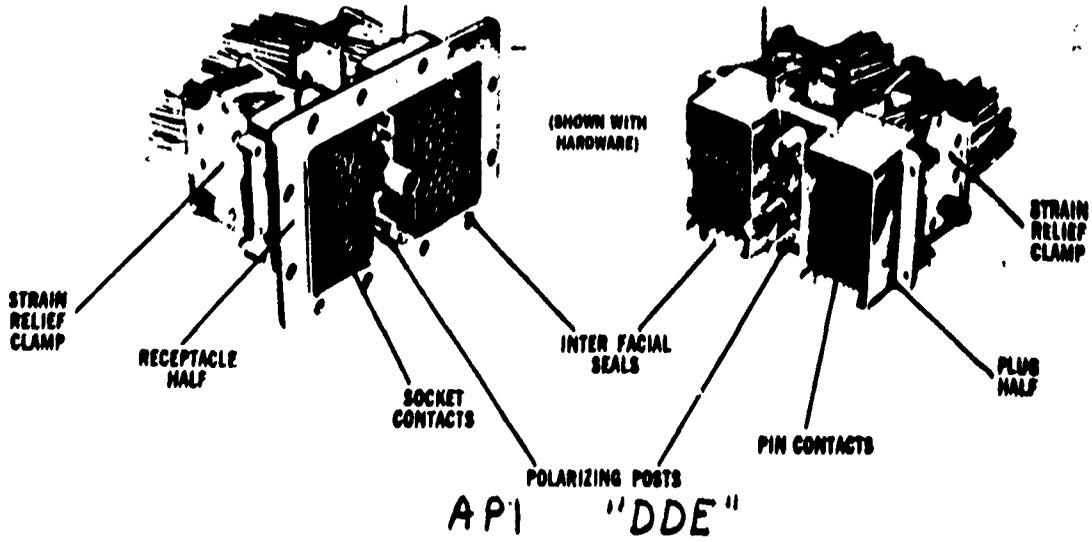


FIG 3-12 MULTIWIRE CONNECTORS SUITABLE FOR DATA CONNECTIONS

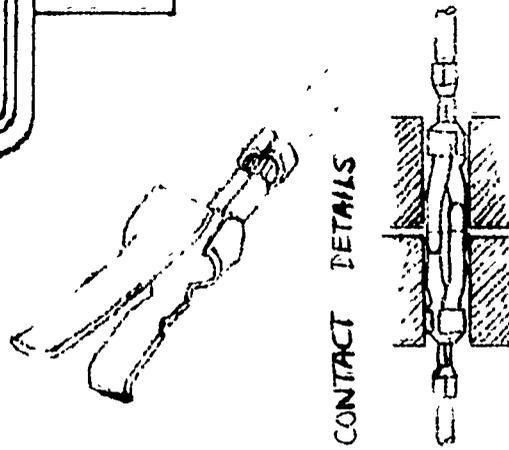
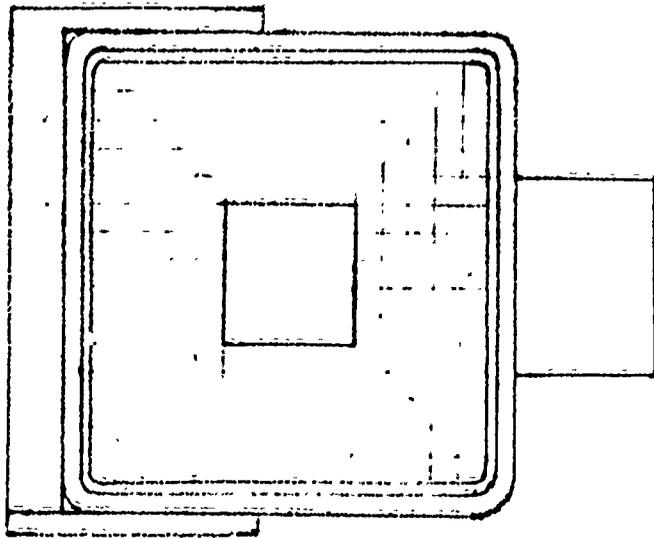
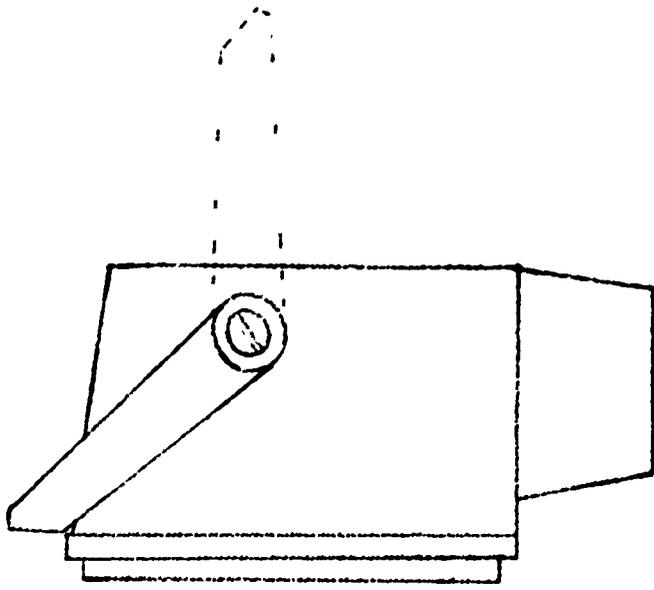


FIG 3-13 AMP DUALATCH 200 POSITION CONNECTOR

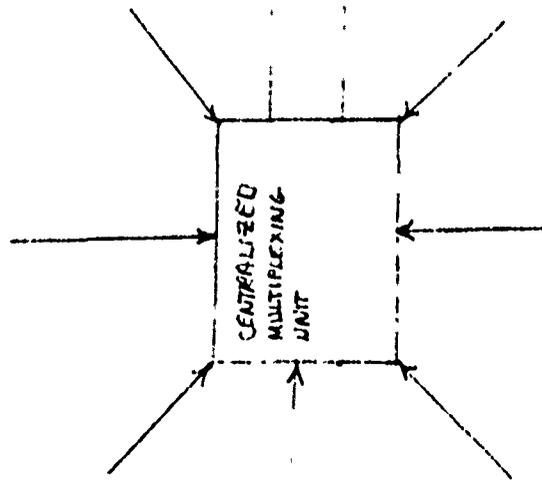
## MULTIFLEX

1. 24 separate data signals may be transmitted at one time on just two pairs of wire (22 gauge) using a 24 channel multiplexing system. (The system may be modified to carry 12 frequency multiplexed signals on each of the 24 time modulated channels; 288 signals at once.)
2. Transmission lines are easily and quickly connected.
3. The system is proven.  
(The Bell System)
4. Additional transmission lines are required to carry the data to and from centralized multiplexing rooms (2).  
OR  
A different orientation requires that multiplexing units be placed at sources of data and at the desired destination.
5. One standard D-1 multiplexing bank which is currently in use by telephone companies would:
  - a) cost about 36000 with associated test equipment.
  - b) weigh about 500 pounds.
  - c) require trained operators and technicians.
6. Places the ship in a very vulnerable position. Should the system be forced out of commission all systems dependent on it for data transfer would go down. It would require a back-up system of perhaps a network of wires or another multiplex system.

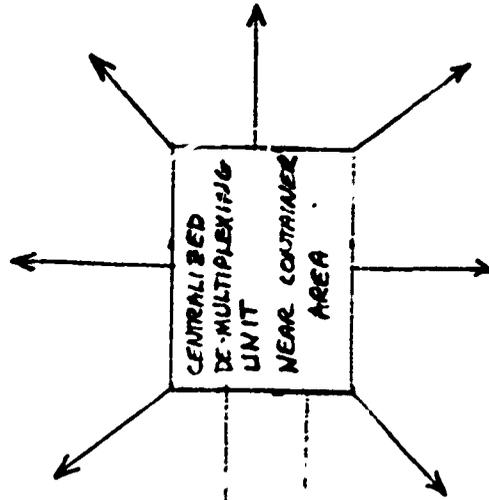
## WIRE MATRIX NON-MULTIFLEX

1. Each data signal requires its own transmission line.
2. Transmission lines are easily connected. Time to connect all of the lines is dependent on the number of lines.
3. The system is proven.  
(Navy and civilian shipping)
4. Signals travel from sources to appropriate destinations along individual transmission lines.
5. No extra hardware is needed.
6. Ship's systems are to a large degree independent of one another.

FIG 3-14 COMPARISON OF MPX vs. CONVENTIONAL SYSTEM



DATA FLOW IN



DATA FLOW TO  
CONTAINERS

FIG 3-15 MULTIPLEX SYSTEM #1

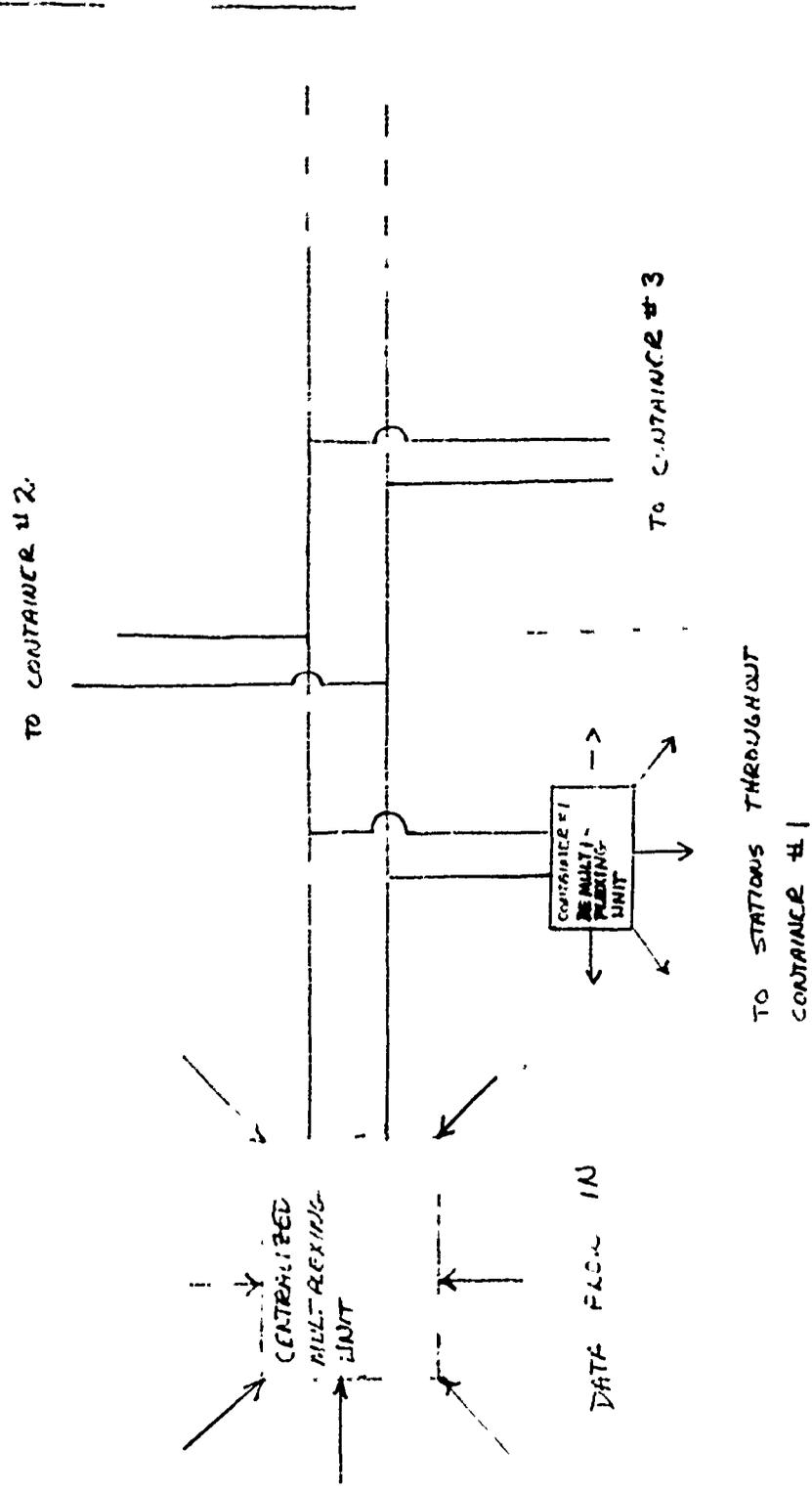
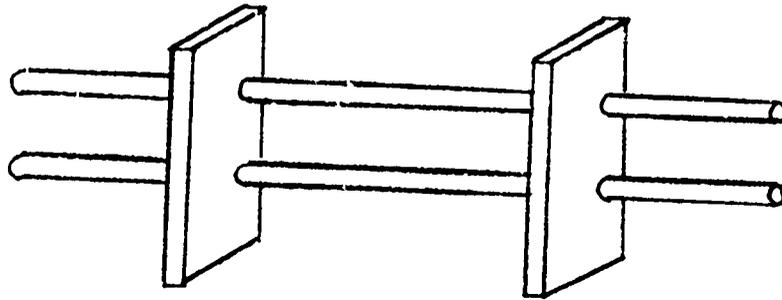
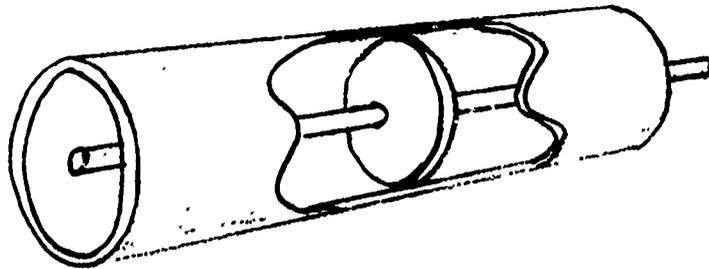


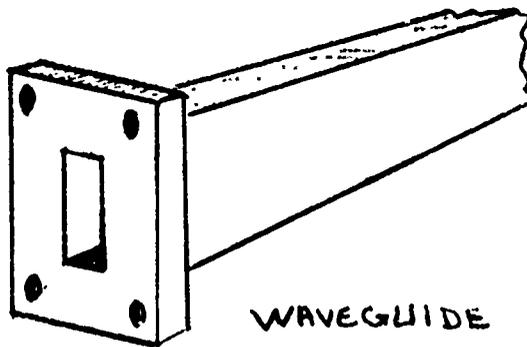
FIG 3-16 MULTIPLEX SYSTEM #2



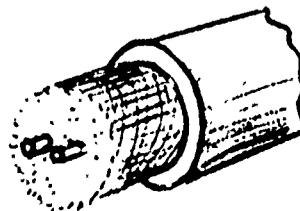
PARALLEL-CONDUCTOR LINE



COAXIAL LINE



WAVEGUIDE



SHIELDED PAIR

FIG 3-17 TRANSMISSION LINES

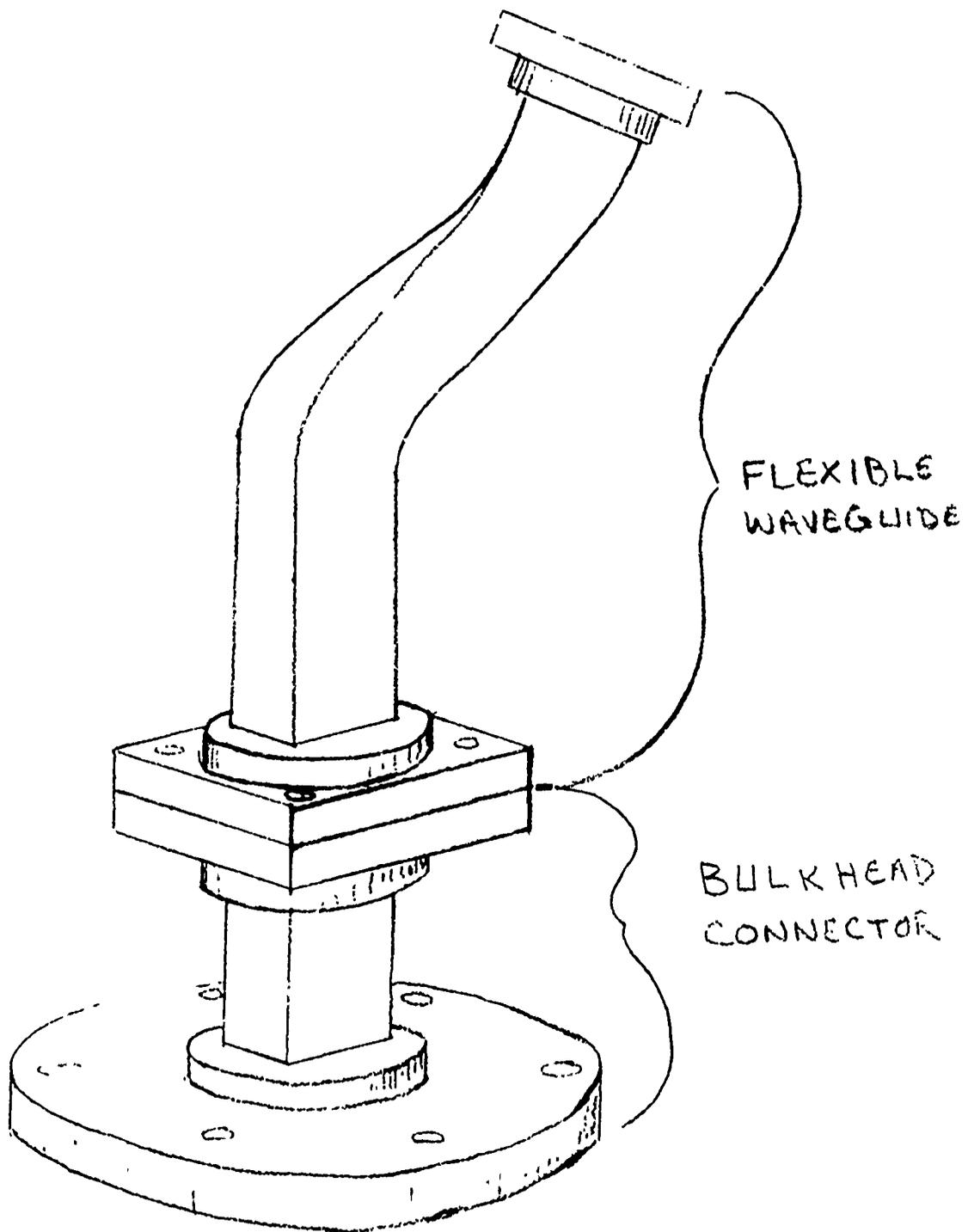
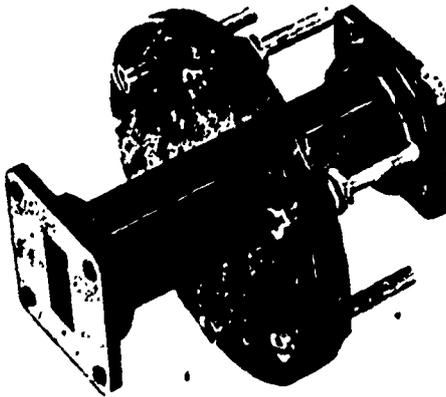


FIG 3-18 WAVEGUIDE INTERFACE CONFIGURATION

# Bulkhead Flange Pressurized Unit



The bulkhead flange assembly is a component used to carry a waveguide transmission line through a cabinet siding, wall or similar paneling. This unit is designed primarily for use in conducting the waveguide line through a wall of a pressurized cabinet.

These bulkhead assemblies are constructed of brass and are silver brazed for high strength. The units are easily adapted to various thicknesses of walls. They are designed to withstand pressures of 30 pounds per square inch. A neoprene rubber flange gasket is incorporated. Standard waveguide flange connectors are provided as listed in the chart below. Finish is Grey Enamel.

Model No.	Waveguide O.D. Size	Frequency Range GHz	Equivalent Flange Type	Maximum VSWR	Insertion Length
268	3.00 x 1.50	2.60 to 3.95	UG-53/U	1.03	7½
2968	2.418 x 1.273	3.30 to 4.90	CMR-229	1.05	7½
368	2.00 x 1.00	3.95 to 5.85	UG-149A/U	1.03	6
5968	1.718 x .923	4.90 to 7.05	CMR-159	1.05	6
468	1.50 x .75	5.85 to 8.20	UG-344/U	1.03	5
568	1.25 x .625	7.05 to 10.0	UG-51/U	1.03	4
668	1.00 x .50	8.20 to 12.4	UG-39/U	1.03	4
7668	.850 x .475	10.0 to 15.0	WR-75	1.05	4
768	.702 x .391	12.4 to 18.0	UG-419/U	1.04	3½
5168	.590 x .355	15.0 to 22.0	WR-51	1.05	3½
868	.500 x .250	18.0 to 26.5	UG-595/U	1.05	3
1068	.360 x .220	26.5 to 40.0	UG-599/U	1.05	2½

Exclusive of wall thickness

## 1 MICROTECH RIGID AND FLEXIBLE WAVEGUIDE

At its modern, 30,000 square foot plant in Cheshire, Conn., Microtech manufactures a comprehensive, quality line of flexible waveguides, solid state pin diode switches and attenuators. Microtech's flexible waveguides include:

The seamless corrugated type, which can be bent to small radii, is highly stable and assures superior, RF leak-free operation.

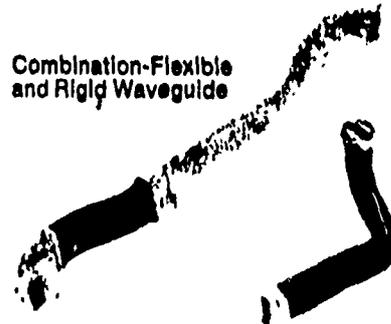
The soldered convoluted type, for maximum bending with minimum leakage, is excellent for misalignment applications where moderate vibration prevails. It is particularly efficient and economical in tight-bend radii installations.

The interlocked flexible type, the only flexible waveguide fully interlocked in all four walls, is the strongest type of flexible waveguide. It is excellent for high power applications and provides the added advantage of elongation and compression.

Microtech has deep engineering and manufacturing experience in combining flexible and rigid waveguides to achieve the optimum in a system.

Microtech designs and produces double ridged waveguide assemblies and components, which it supplies in both flexible and rigid types.

Combination-Flexible and Rigid Waveguide



Flexible Waveguide

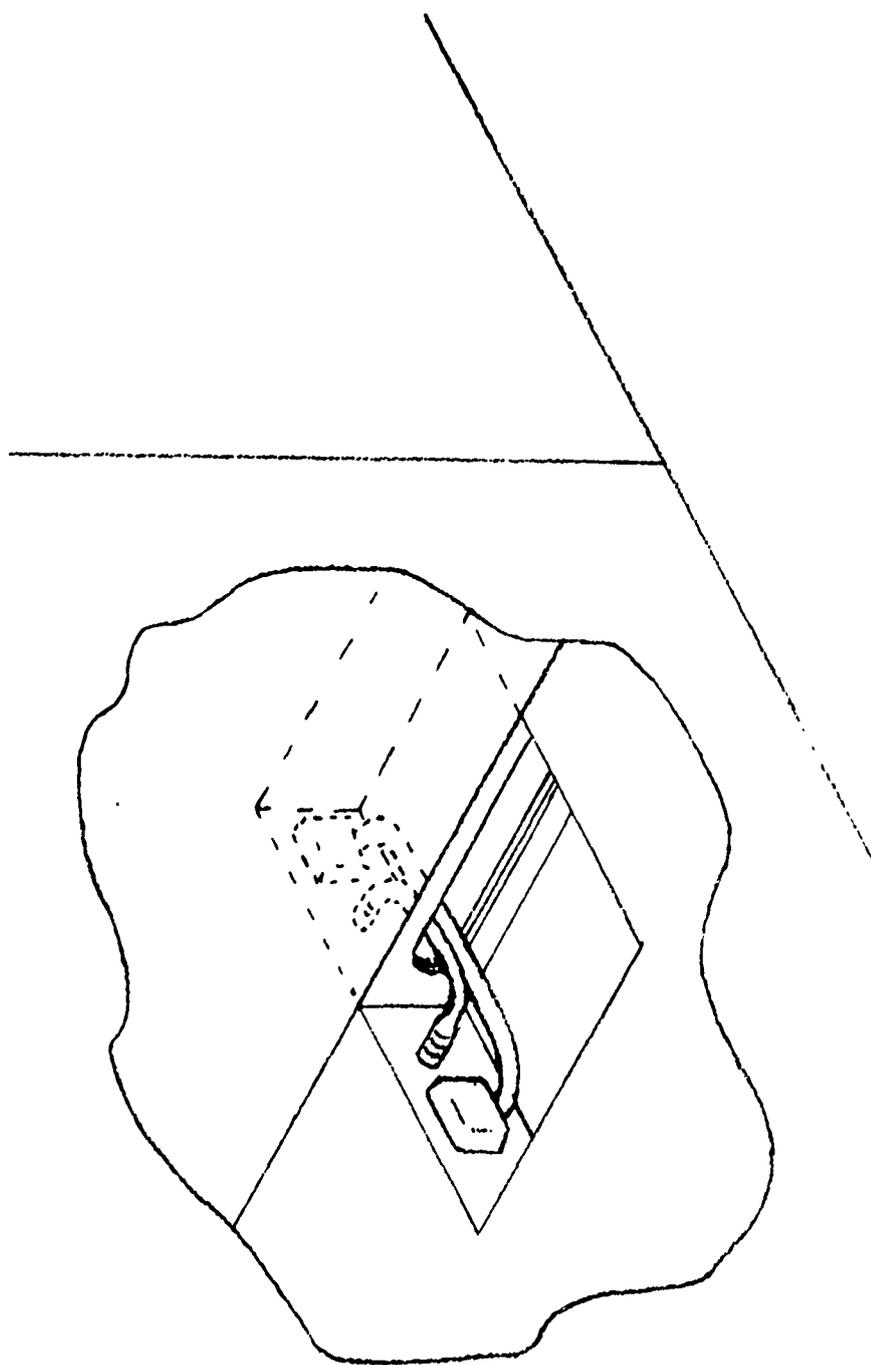


FIG 3-20 ELECTRICAL SYSTEM ARRANGEMENT #1

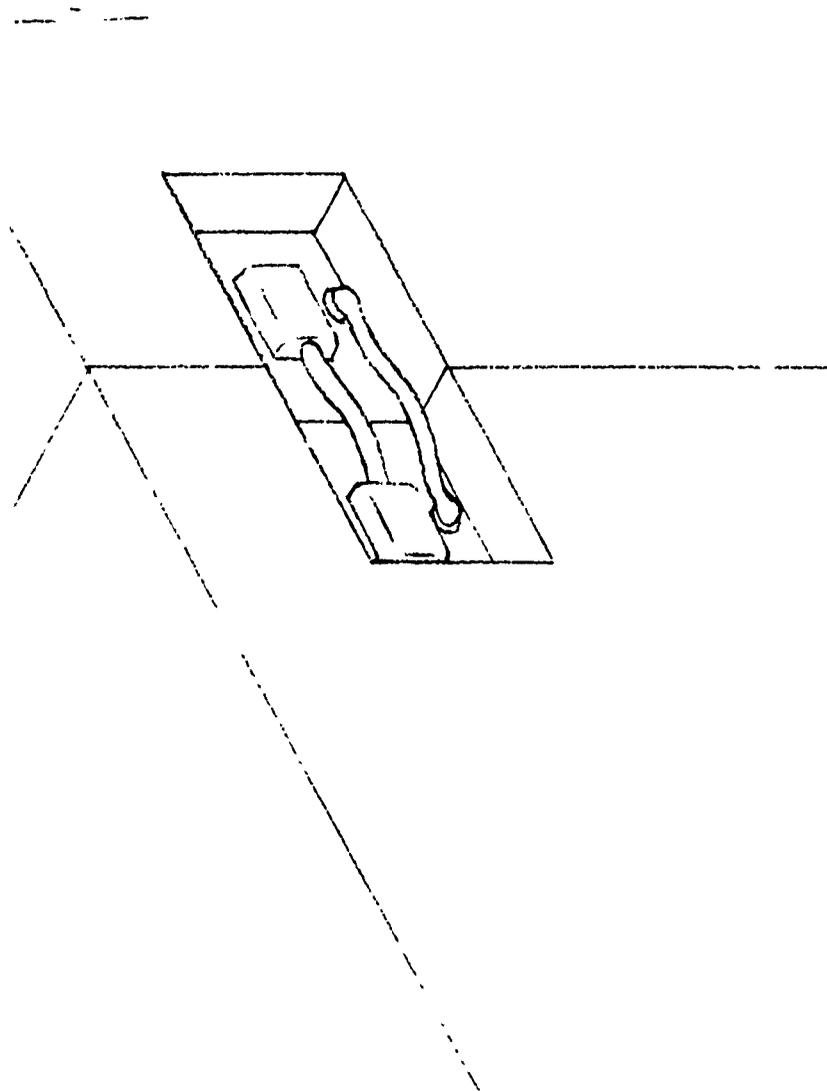


FIG. 3-21 ELECTRICAL SYSTEM ARRANGEMENT #2

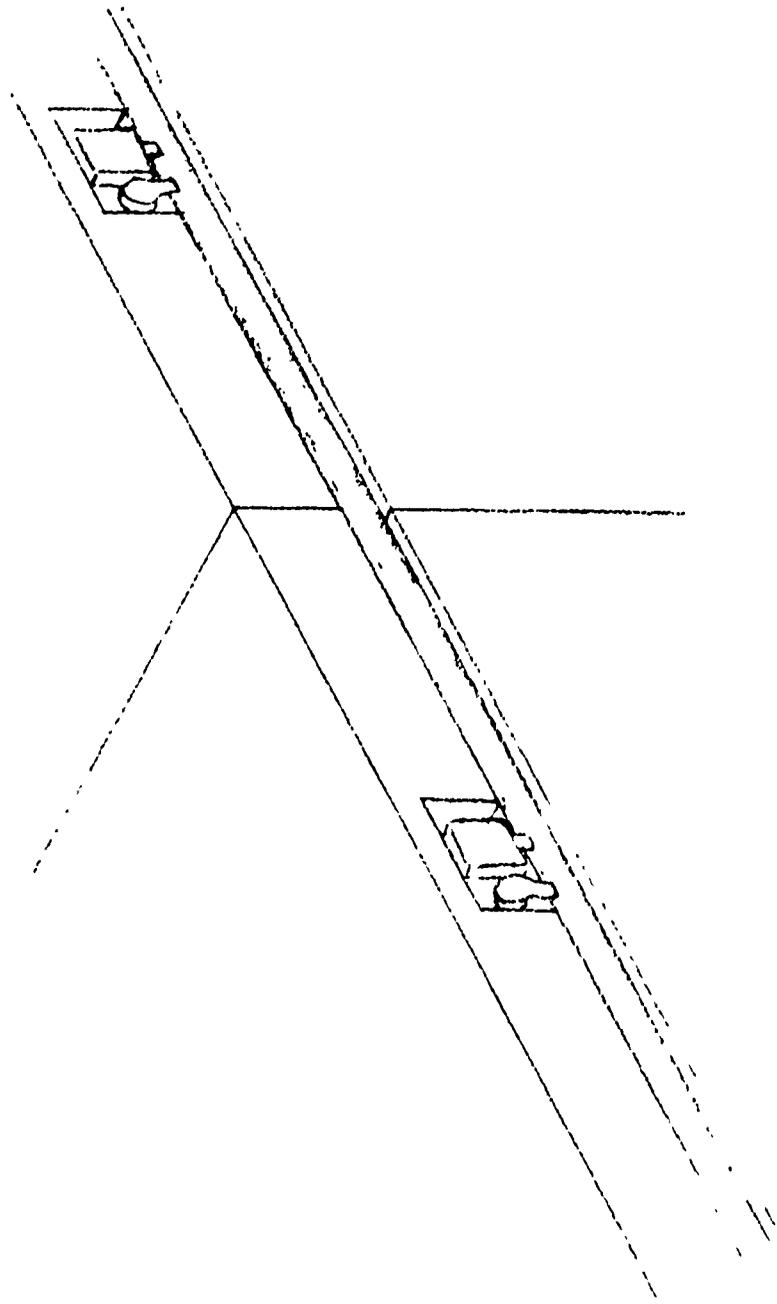


FIG 3-22. ELECTRICAL SYSTEM LAYOUT #3

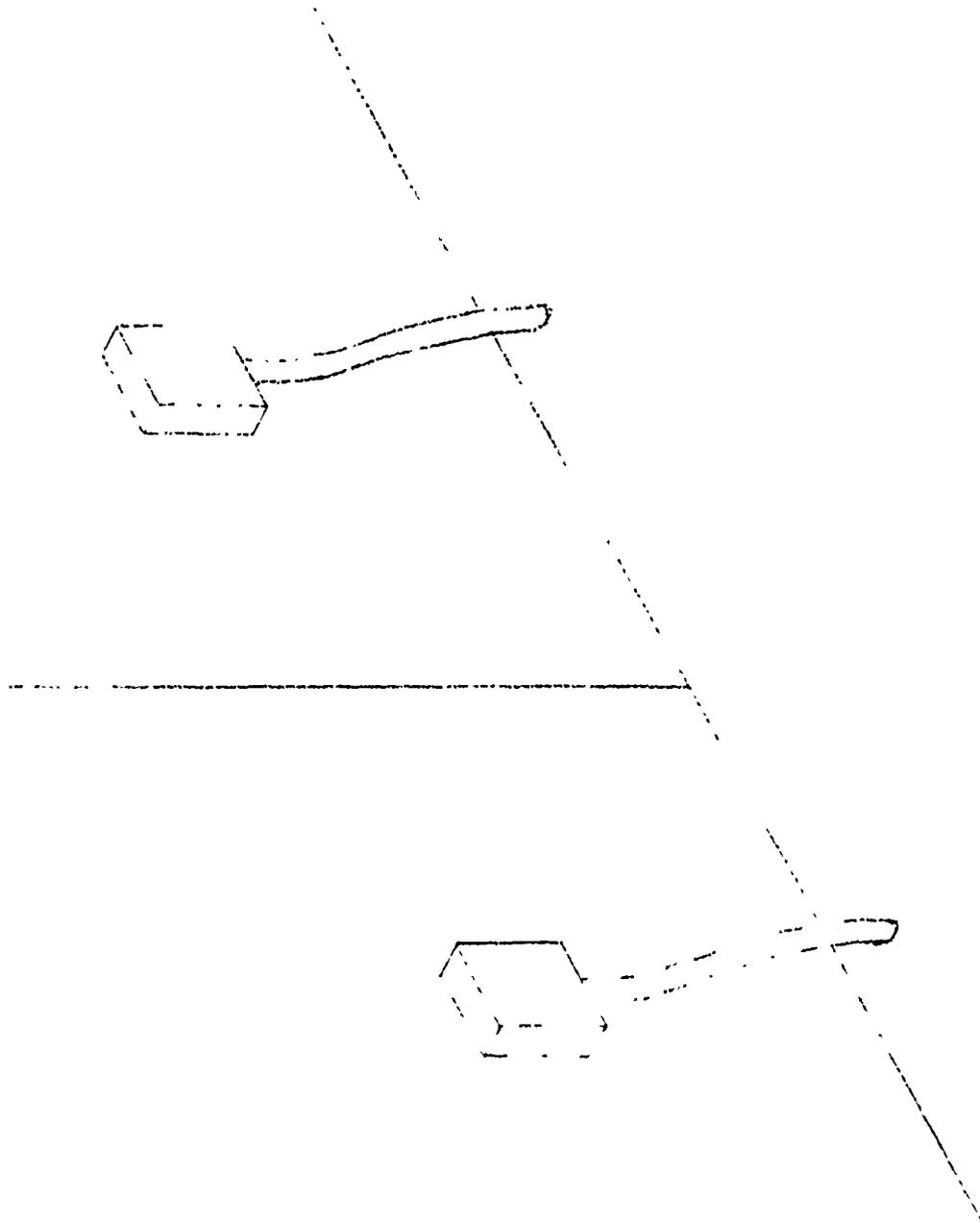
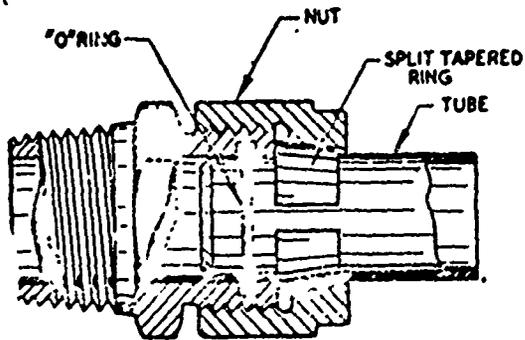


FIG 3-23. ELECTRICAL SYSTEM ARRANGMENT #4



**COMPRESSION**

This design is of the "O" ring and split sleeve type and is approved by J.I.C. and S.A.E. It is reusable and allows considerable tolerance in the length of tube cut and squareness of cut. The "O" ring must be compatible with the fluid used in the system.

**COMPRESSION**

This design is proving satisfactory for plastic tubing. It is easy to install, reusable and comes in a variety of materials including steel and plastic.

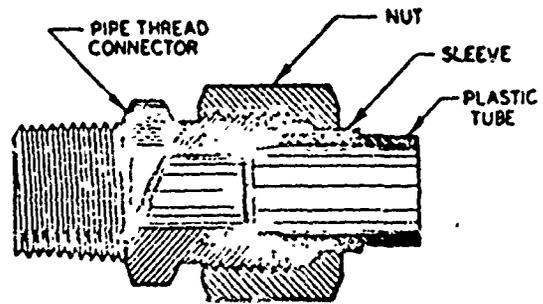
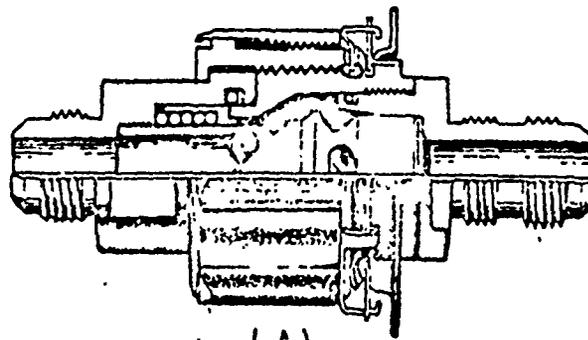
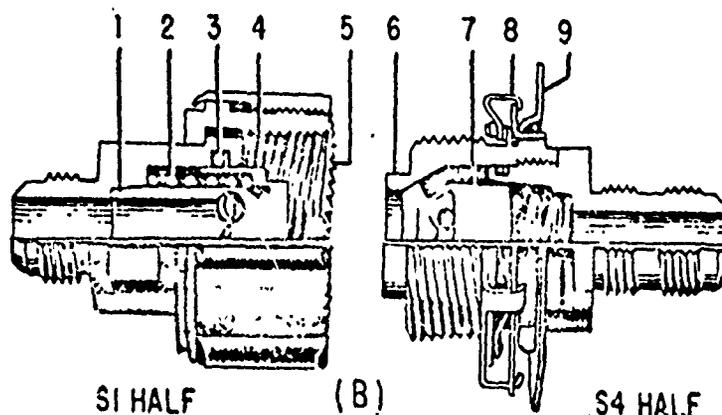


FIG. 4-1. COMPRESSION FITTINGS



(A)



- |                     |                     |
|---------------------|---------------------|
| 1. Tubular valve.   | 6. Protruding nose. |
| 2. Valve spring.    | 7. Poppet valve.    |
| 3. O-ring packing.  | 8. Lock spring.     |
| 4. Sleeve.          | 9. Mounting flange. |
| 5. Union nut teeth. |                     |

FIG. 4-2. QUICK-DISCONNECT FITTINGS

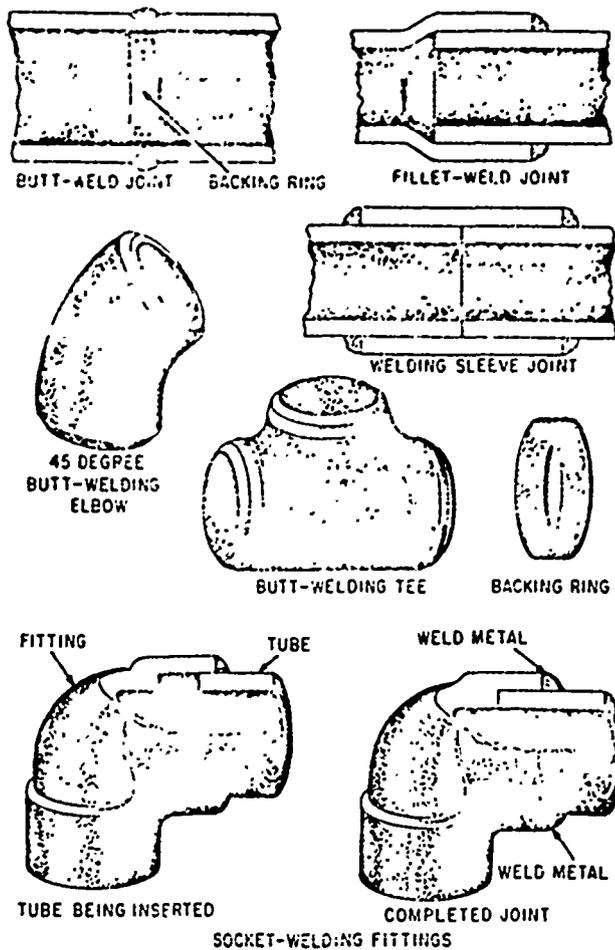


FIG. 4-3. WELDED JOINTS



FIG. 4-4. UNIONS

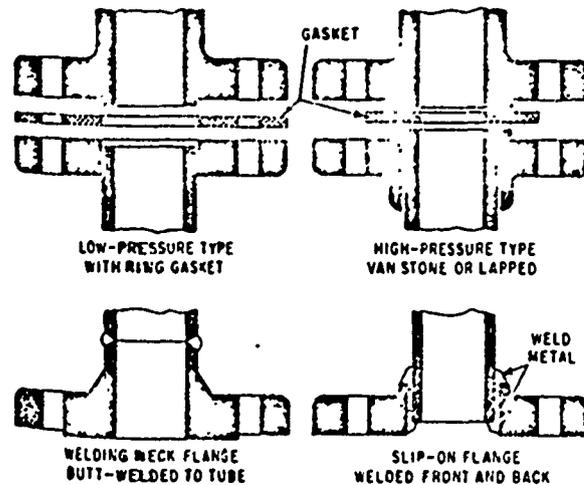


FIG. 4-5. FLANGED CONNECTIONS

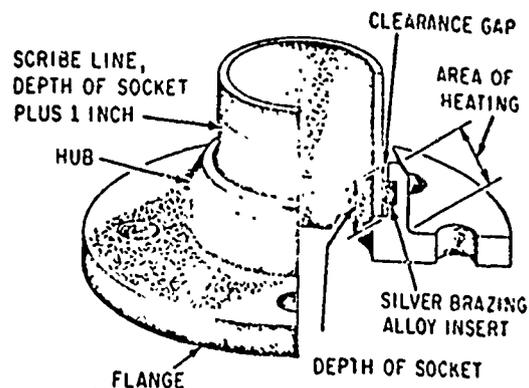
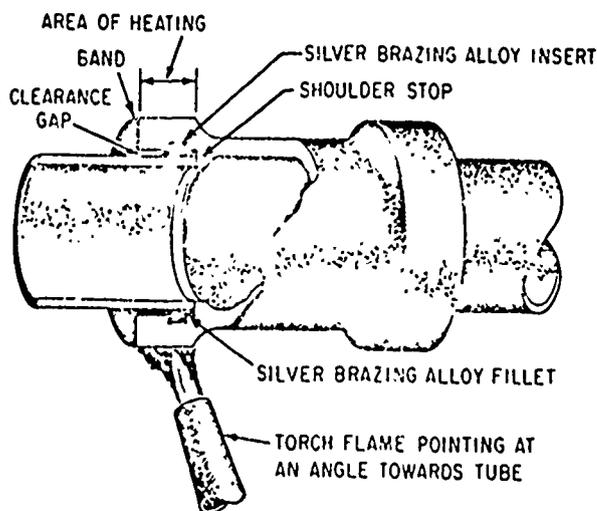
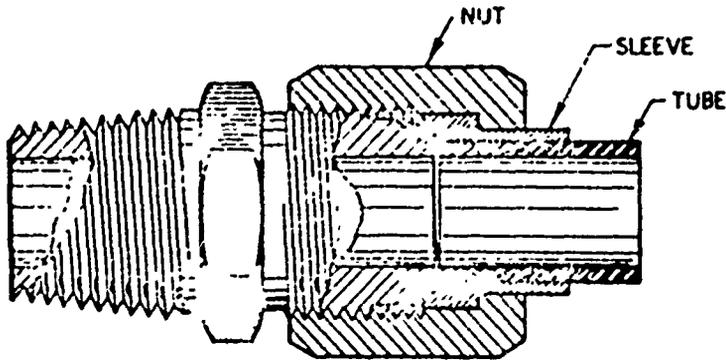


FIG. 4-6. BRAZED FITTINGS

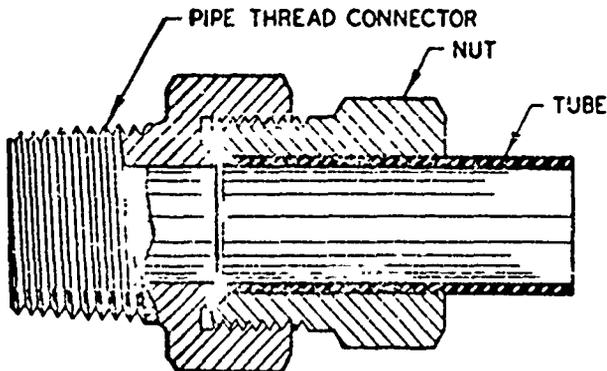
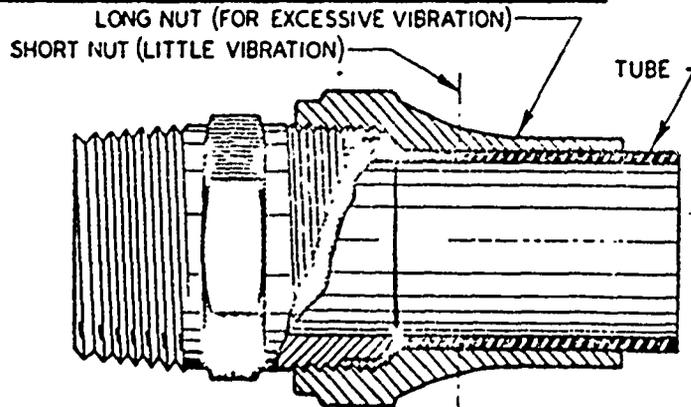


### 37° FLARE

The 37° Flare provides excellent results for connections when tubing is flarable. The free floating sleeve supports tube and dampens vibration. Approved by Underwriters Laboratories, SAE JIC and ASME. This type of connector is reusable, does not twist during assembly and requires low assembly torque.

### 45° FLARE

The 45° Flare may be used with flarable tubing and will withstand pressures up to 5,000 PSI. This design is approved by Underwriters Laboratories, A.S.A., A.S.M.E., J.I.C., and S.A.E. It is reusable and available at comparatively low cost.

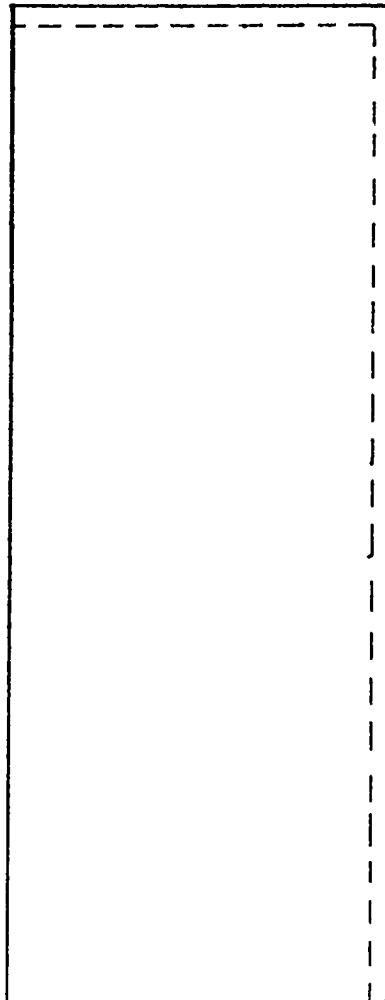


### 45° INVERTED FLARE

The 45° inverted Flare provides protection for seat and threads which are recessed. It is reusable, low cost, and fits in tight places. This design is also approved by UL, A.S.A., A.S.M.E., J.I.C. and S.A.E.

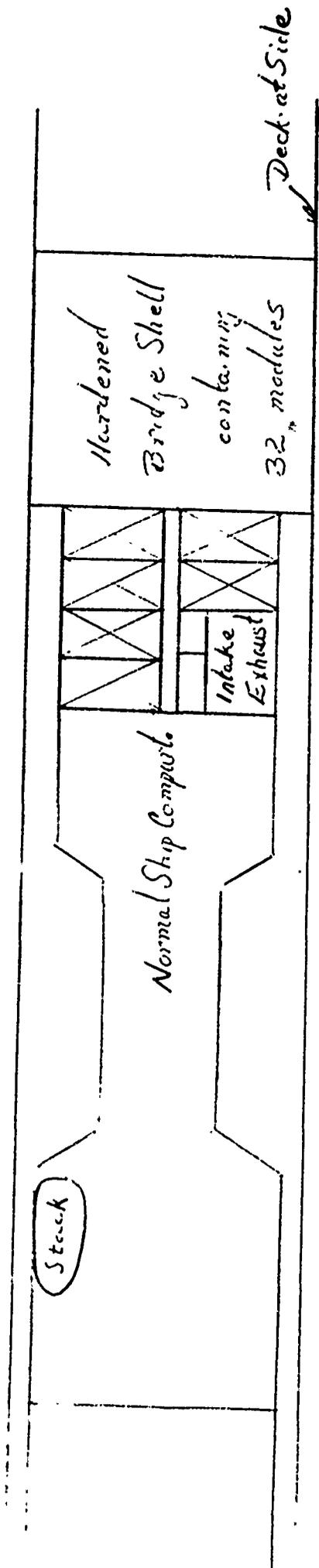
FIG. 4-7  
FLARED FITTINGS

ARRANGEMENT  
ALLOWS CONNECTIONS  
BETWEEN MODULES,  
AND BETWEEN SHIP AND  
MODULE, FOR ANY  
NUMBER OR ARRANGEMENT  
OF MODULES



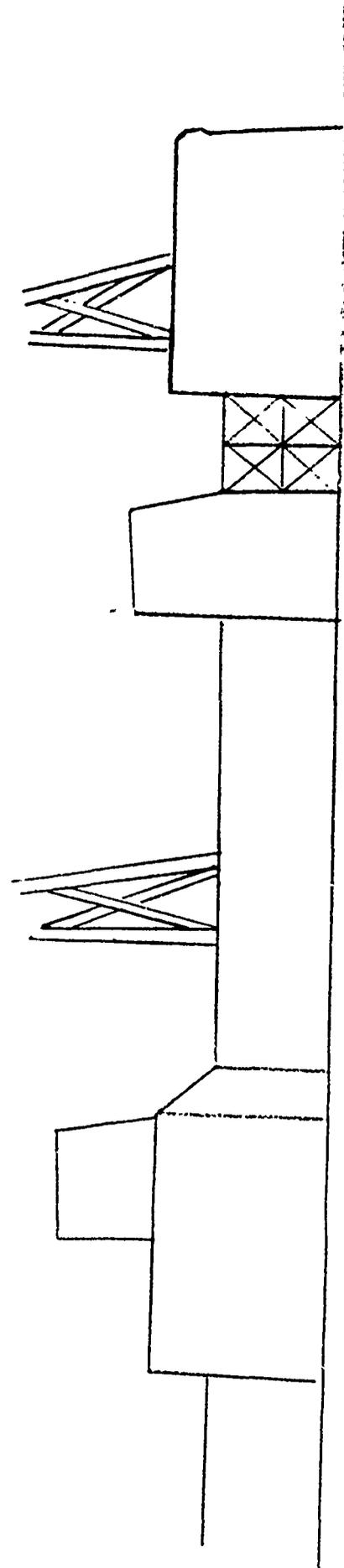
DUCTING AND  
PIPING SHOWN  
HERE WILL BE  
USED FOR BRANCH  
MAIN. PRIMARY  
MAIN LINES  
WILL CONNECT  
AT PLATFORMS.  
SECONDARY BRANCH  
LINES WILL RUN  
FROM THESE BRANCH  
MAIN LINES TO  
DIFFERENT POSITIONS  
IN MODULE, BASED ON  
EQUIPMENT POSITIONS

FIG 4-8 PLACEMENT OF DUCTING AND PIPING  
IN THE MODULE FLOOR

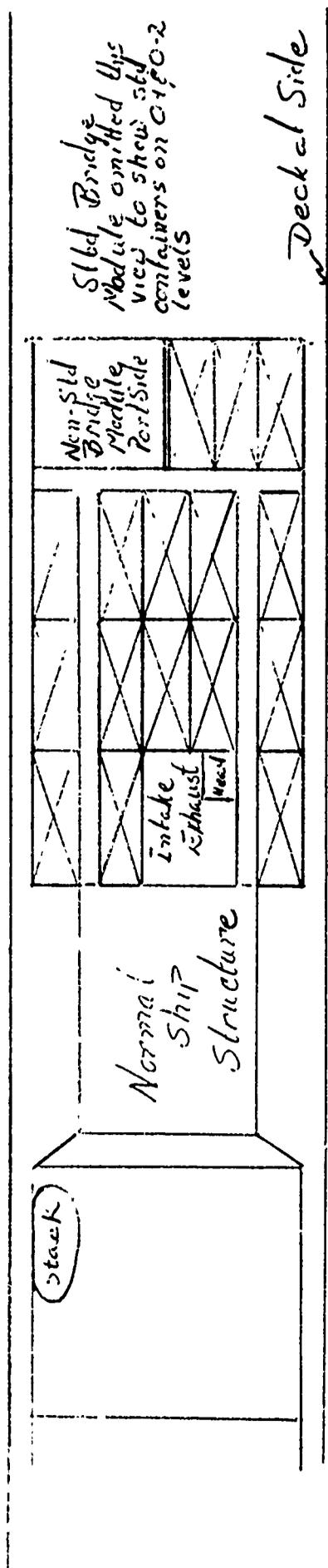


*Top View showing container placement*

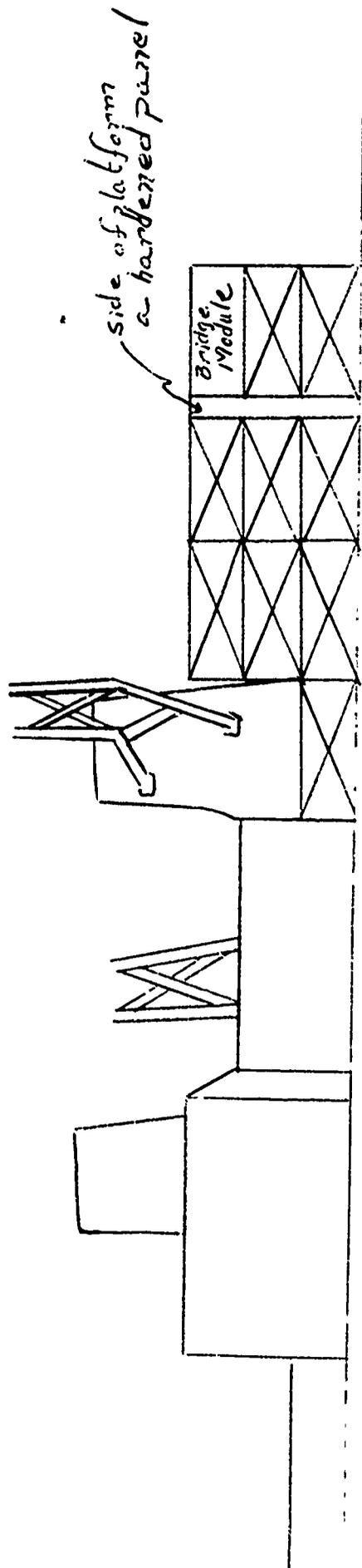
FIG 5-1 RELATIVE SPACE OCCUPIED BY CONTAINERS-CONFIG. I-IV



*Profile View showing container placement*



Top View showing container placement



Profile View showing container placement

FIG 5-2 RELATIVE SPACE OCCUPIED BY CONTAINERS-CONFIG. II

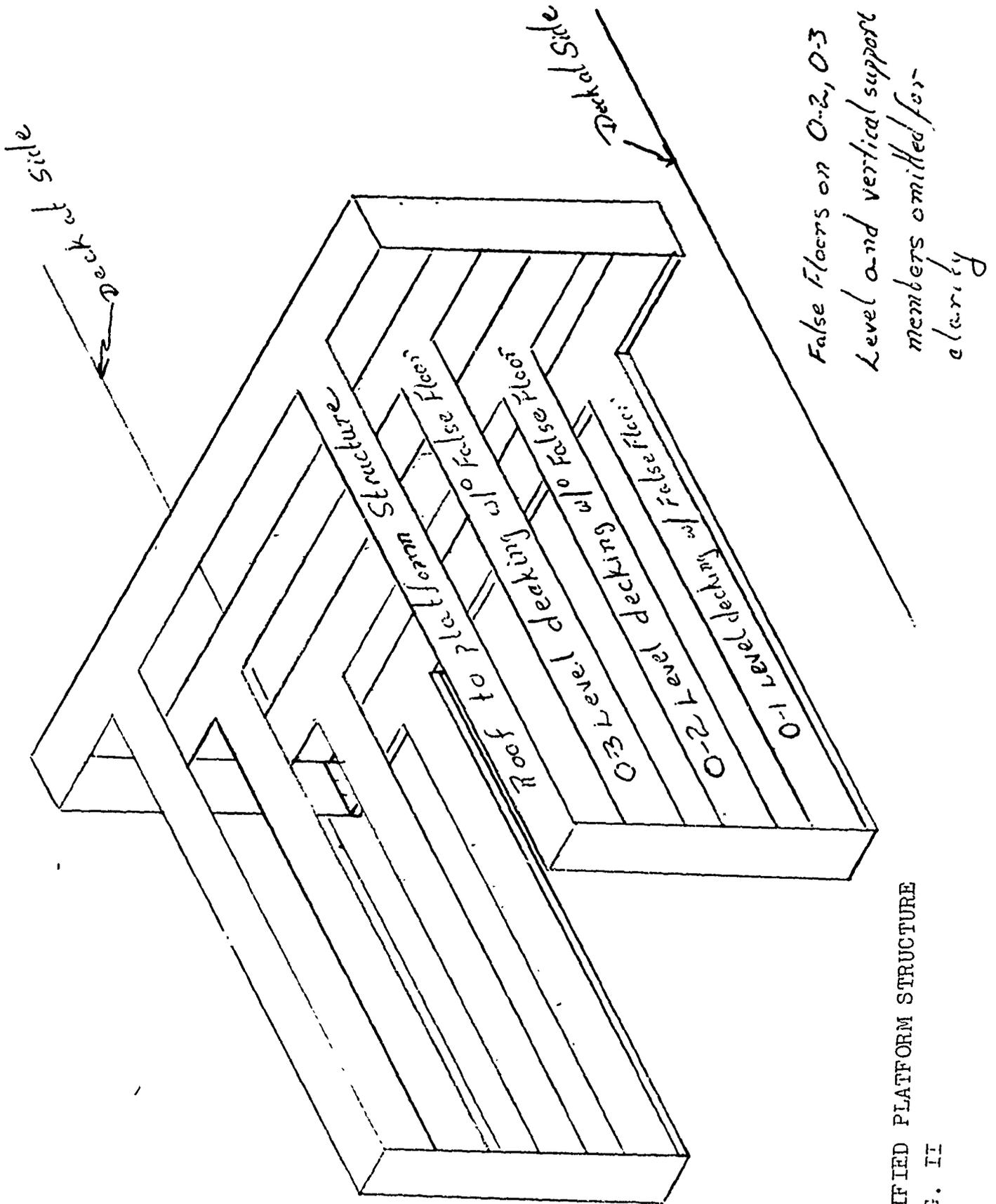
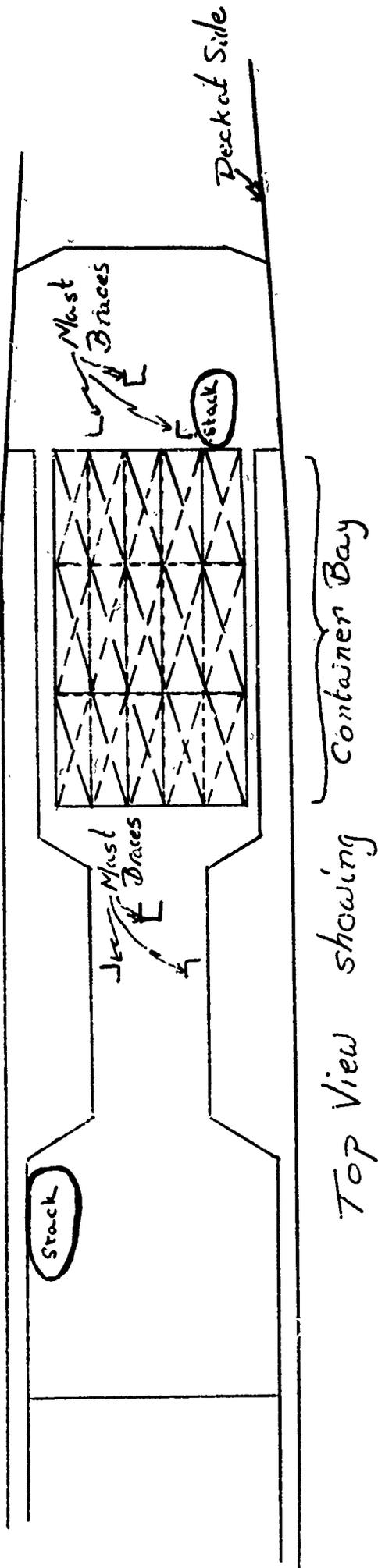
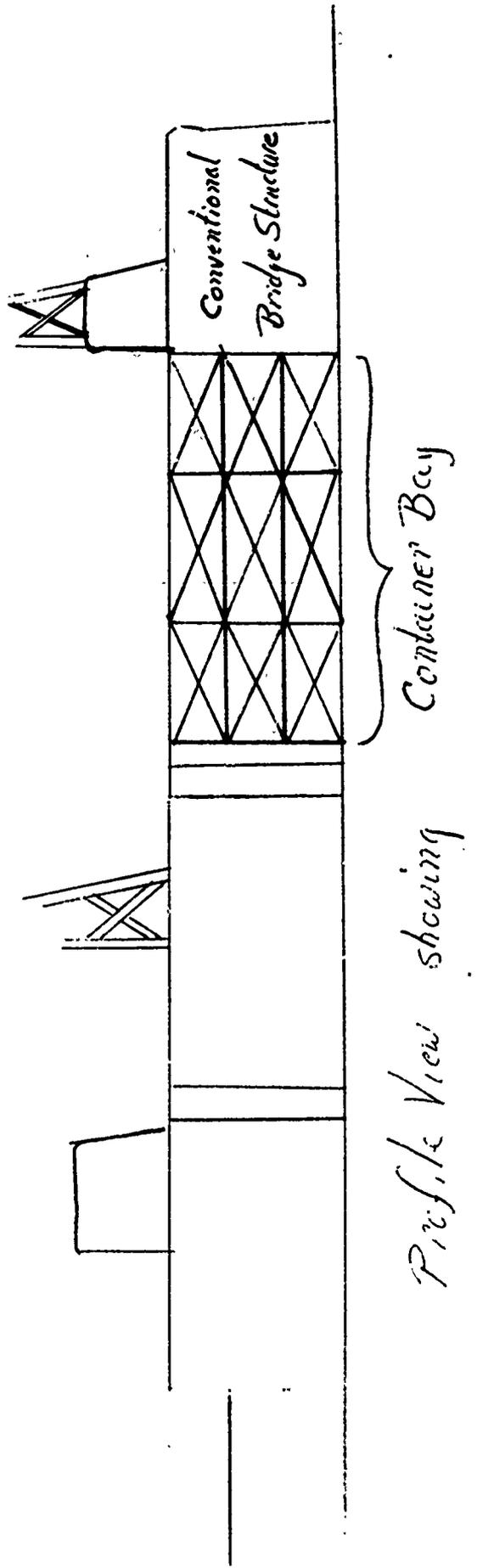


FIG 5.3 SIMPLIFIED PLATFORM STRUCTURE  
 CONFIG. II



*Top View showing Container Bay*

FIG 5.4 RELATIVE SPACE OCCUPIED BY CONTAINERS -CONFIG. III



*Profile View showing Container Bay*

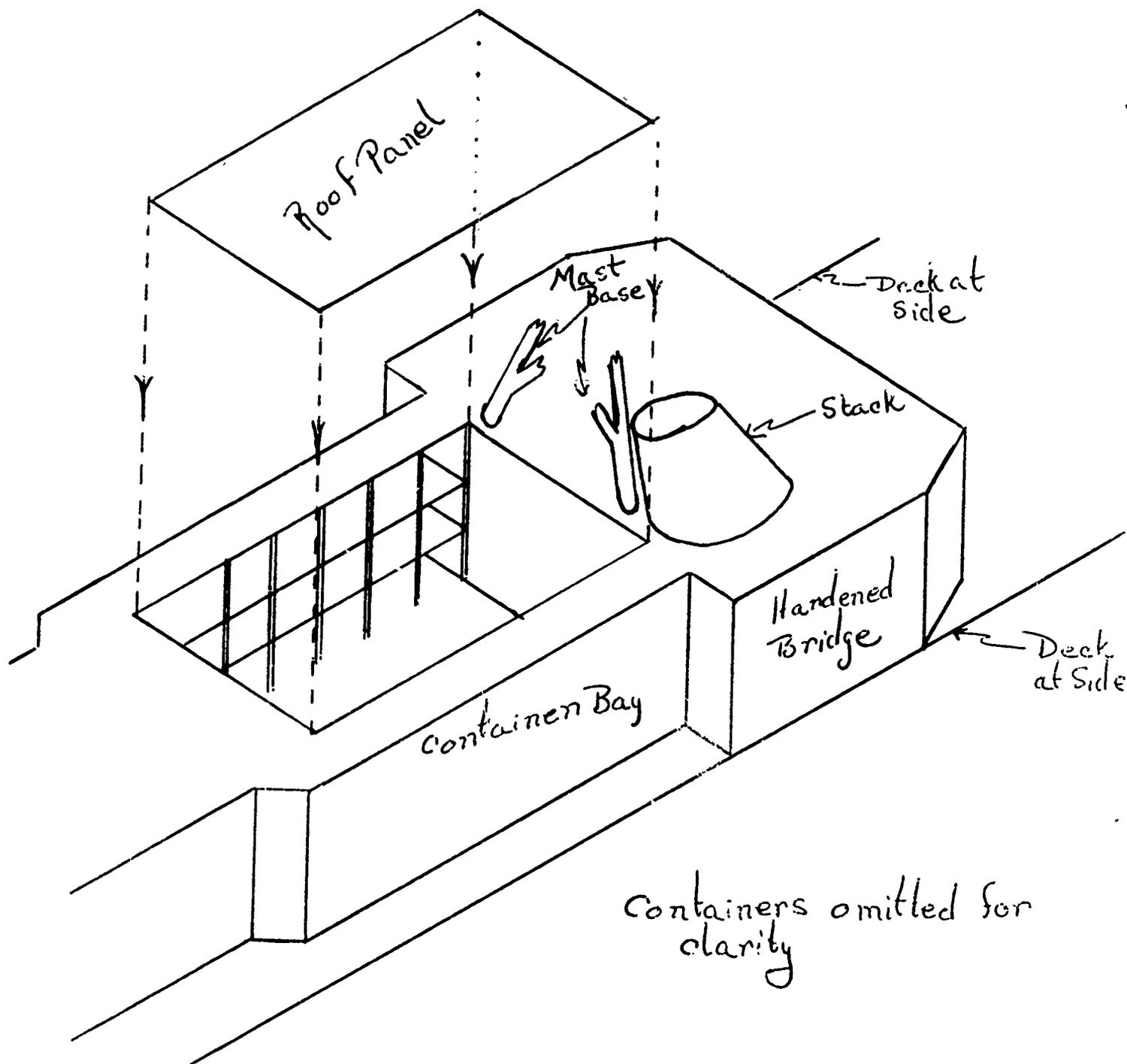


FIG 5-5 GENERAL VIEW — CONTAINER BAY, CONFIG III

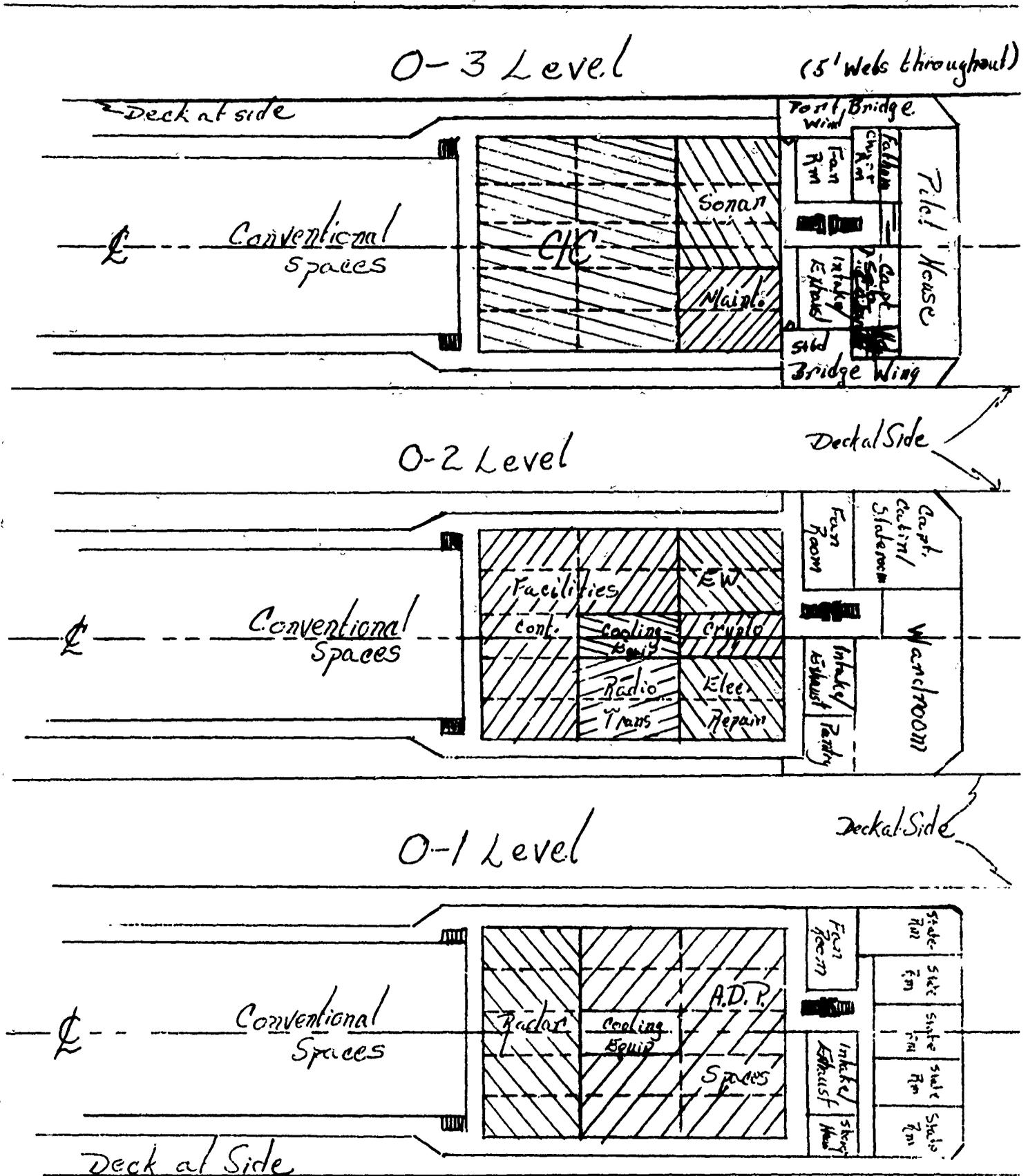


FIG 5-6 ARRANGEMENTS — CONFIGURATION III

SELECTION MATRICES

## CONTAINER ATTACHMENT SELECTION MATRIX

	REL. RATINGS						WEIGHTING FACTOR	WEIGHTED RATINGS				
	PEPM FOUND with INTERMED. MOUNTING FRAMES	TWIST LOCKS with PEPM RAISED DECK SOCKETS	TWIST LOCKS with DIMPLED PLATE	NELSON STUDS & CRIB	INTERMED. MOUNTING ANGLES & CLIPS	PEPM FOUND, ETC.		TWIST LOCKS w/ PEPM RAISED SOCKETS	TWIST LOCKS with DIMPLED PLATE	NELSON STUDS & CRIB	INTERMED. MOUNTING ANGLES & CLIPS	
ASSEMBLY SPEED	8	10	7	6	8	1.0	8	10	7	6	8	
COST	6	10	9	5	7	.6	3.6	6	5.4	3	4.2	
DISASSEMBLY SPD.	9	10	9	9	9	1.0	9	10	9	9	9	
MAINTENANCE	10	8	5	10	10	.4	4	3.2	2	4	4	
REUSABILITY	8	10	10	5	8	.4	3.2	4	4	2	3.2	
DECK OBSTRUCT.	4	6	10	7	6	.2	.8	1.2	2	1.4	1.2	
STACKING FEAS.	10	6	6	6	4	1.0	10	6	6	6	4	
WEIGHT	4	7	6	10	6	.4	1.6	2.8	2.4	4	2.4	
TOTALS							40.2	43.2	37.8	35.4	36.0	

MATRIX 2.1

# POWER CONNECTOR SELECTION MATRIX

	REL. RATINGS						WEIGHTING FACTOR	WEIGHTED RATINGS					
	IN BOX CONNEX.	ELECTR. MAG. CONNEX.	AMPHENOL MS-40-60A	API AMPPOWER	ITT ELAN EVERY CABLE	ITT M-40-60A CON.		IN BOX CONNEX.	ELECTR. MAG. CONNEX.	AMPHENOL	API	ITT-BLACKBURN	ELECTR. MAG. CONNEX.
WIND & PROOF	5	5	5	5	5	5	.3	1.5	1.5	1.5	1.5	1.5	1.5
CAPACITY	10	6	10	7	3	6	.5	5	3	5	3.5	1.5	3
SAFETY	3	8	7	7	3	8	.5	1.5	4	3.5	3.5	1.5	4
PERFORMANCE	5	1	5	5	5	5	.2	1	.2	1	1	1	1
CONV.	5	3	4	4	4	4	.1	.5	.3		.4	.4	.4
TIME OF CONNEX.	1	7	10	10	8	8	1	1	7	10	10	8	8
VIBRATION PROOF	5	2	5	5	3	3	.4	2	.8	2	2	1.2	1.2
MAINTENANCE	8	3	9	6	8	6	.2	1.6	.6	1.8	1.2	1.6	.3
CONNECTIONS	7	8	5	5	5	5	.2	1.4	1.6	1	1	1	1
SKILL REQUIRED	3	5	5	6	5	5	.2	.6	1	1.2	1.2	1	1
PROOF	2	2	5	5	2	2	.6	1.2	1.2	3	3	1.2	1.2

TOTALS

17.3	21.2	30.4	28.3	19.9	22.6
------	------	------	------	------	------

MATRIX 3.1

## DATA LINK CONNECTOR SELECTION MATRIX

	REL. RATINGS				WEIGHTING FACTOR	WEIGHTED RATINGS			
	IN-BOX CONNEX.	API "DDE"	AMP 200-DURALOCK	AMPHENOL MS-32-414		IN-BOX CONNEX.	API "DDE"	AMP 200-DURALOCK	AMPHENOL MS-32-414
WATER-PROOF	5	2	2	5	.2	1.0	.4	.4	1.0
CAPACITY	10	6	8	4	.5	5	3	4	2
COST	6	4	4	3	.1	.6	.4	.4	.3
SAFETY	3	5	5	5	.5	1.5	2.5	2.5	2.5
PROVEN	5	5	5	5	.2	1.0	1.0	1.0	1.0
TIME FOR CONNEX.	1	7	7	7	1.0	1.0	7.0	7.0	7.0
VIBRATION PROOF	5	5	5	5	.4	2.0	2.0	2.0	2.0
MAINTENANCE	3	5	5	5	.3	.9	1.5	1.5	1.5
CORROSION RESIST.	6	4	4	4	.2	1.2	.8	.8	.8
ENV. RES'D IN USE	1	5	5	5	.2	.2	1.0	1.0	1.0
EXP. PROOF	1	5	5	5	.6	.6	3.0	3.0	3.0

TOTALS      

15	22.6	23.6	22.1
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MATRIX 3.2

## MULTIPLEX vs. WIRE NETWORK SELECTION MATRIX

	REL. RATINGS			WEIGHTING FACTOR	WGT'D. RATINGS		
	MULTIPLEX I	MULTIPLEX II	WIRE NETWORK		MULTIPLEX I	MULTIPLEX II	WIRE NETWORK
QUAN of WIRE REQ'D.	4	5	3	.4	1.6	2.0	1.2
TIME to CONNECT	9	9	8	.6	5.4	5.4	4.8
PROVEN	9	4	9	.4	3.6	1.6	3.6
COST	3	2	8	.8	2.4	1.6	6.4
WEIGHT	4	4	8	.6	2.4	2.4	4.8
ADD'L PERS. REQMT.	4	4	9	.4	1.6	1.6	3.6
RELIABILITY	9	9	9	.9	8.1	8.1	8.1
COMPLEXITY	3	3	7	.4	2.7	2.7	6.3
CONDNl WORTHINESS	1	2	7	1.0	1.0	2.0	7.0

MPX I ~ TWO CENTRALIZED "MPX"ING UNITS.

MPX II - MPX'ERS AT SIGNAL SOURCES,  
DE "MPX"ERS AT SIGNAL DESTINATION.

WIRE NETWORK ~ EACH SIGNAL FOLLOWS AN INDIVIDUAL TRANS. LINE.

28.8	27.4	45.8
------	------	------

TOTALS

MATRIX 3.3

## R-F TRANSMISSION SELECTION MATRIX

	REL. RATINGS		WEIGHTING FACTOR	WGT'D. RATINGS	
	COAXIAL CABLE	WAVEGUIDE		COAXIAL CABLE	WAVEGUIDE
FLEXIBILITY at SEA	9	8	.4	3.6	3.2
FLEXIBILITY for THERM	8	8	.7	5.6	5.6
EASE of CONNECTION	8	6	.6	4.8	3.6
RADIATION LOSSES	9	9	.7	6.3	6.3
DIELECTRIC LOSSES	5	9	.5	2.5	4.5
COPPER LOSSES	4	8	.6	2.4	4.8
SIZE	8	6	.4	3.2	2.4
WEIGHT	6	7	.2	1.2	1.4
DURABILITY	8	6	.5	4.0	3.0
ATTENUATION EFFECTS	5	8	.7	3.5	5.6
RELIABILITY	7	7	.5	3.5	3.5

TOTALS 40.6 43.9

MATRIX 3.4'

# POWER SYSTEM LAYOUT SELECTION MATRIX

	REL. RATINGS				WEIGHTING FACTOR	WEIGHTED RATINGS			
	#1- LEADS THROUGH FALSE FLOOR	#2- EXTERNAL LEADS	#3- UMBILICAL CABLE	#4- PLUG-IN AT SITE OF EACH COW		# 1	# 2	# 3	# 4
FLEXIBILITY	7	7	5	4	.5	3.5	3.5	2.5	2
SIMPLICITY	5	5	6	3	.5	2.5	2.5	3	1.5
ACCESSIBILITY & MAINTENANCE	8	5	9	8	.6	4.8	3	5.4	4.8
SAFETY	5	5	5	5	.8	4	4	4	4
RELIABILITY	5	5	5	5	.7	3.5	3.5	3.5	3.5
FOOL PROOF	5	5	5	5	.4	2	2	2	2
<b>TOTALS</b>						<b>20.3</b>	<b>18.5</b>	<b>20.4</b>	<b>17.8</b>

MATRIX 3.5

## WATER PIPE SELECTION MATRIX

	RELATIVE RATINGS							WEIGHTING FACTOR	WEIGHTED RATINGS						
	PLASTIC TUBING	HYDRAULIC HOSE	STEEL PIPING	COPPER PIPING	ALUMINUM PIPING	RUBBER HOSE	FLEX (AERQUIP)		PLASTIC TUBING	HYDRAULIC HOSE	STEEL PIPING	COPPER PIPING	ALUMINUM PIPING	RUBBER HOSE	FLEX (AERQUIP)
RELIABILITY	8	10	10	10	10	7	10	1.0	8	10	10	10	10	7	10
INSTALLMENT	7	9	6	6	5	10	8	1.0	7	9	6	6	5	10	8
FLEXIBILITY	6	9	2	3	3	10	8	.7	4.2	6.3	1.4	2.1	2.1	7	5.6
CORROSION RESIS.	10	9	4	4	7	7	4	.7	7	6.3	2.8	2.8	4.9	4.9	2.8
EXPANSION	1	4	10	7	4	2	9	.2	.2	.8	2	1.4	.8	.4	1.8
COST	10	2	8	7	5	4	3	1.0	10	2	8	7	5	4	3
WEIGHT	10	8	6	5	8	9	6	1.0	10	8	6	5	8	9	6
ELEC. COND.	10	8	5	1	2	10	6	.5	5	4	2.5	.5	1	5	3
"PAINT"ABILITY	3	3	6	4	3	1	5	.1	.3	.3	.6	.4	.3	.1	.5
FLUID FRIC. FAC.	10	9	3	5	6	9	2	.5	5	4.5	1.5	2.5	3	4.5	1
HEAT COND.	1	4	6	10	7	2	6	.4	.4	1.6	2.4	4	2.8	.8	1.4
MAT'L LIFE.	3	5	7	7	7	2	7	.6	1.8	3	4.2	4.2	4.2	1.2	4.2

TOTALS

58.9	55.8	47.4	45.9	47.1	53.9	48.3
------	------	------	------	------	------	------

MATRIX 4.1

# PIPE FITTING SELECTION MATRIX

	RELATIVE RATINGS							WEIGHTING FACTOR	WEIGHTED RATINGS						
	COMPRESS. FITTING.	QUICK-DISCONNECT	WELD (STEEL)	UNIONS	FLANGES	BARBED FITTING	FLARED FITTING		COMPRESS. FITTING	QUICK-DISCONNECT	WELD (STEEL)	UNIONS	FLANGES	BARBED FITTING	FLARED FITTING
RELIABILITY	9	8	10	7	7	9.5	9	1.0	9	8	10	7	7	9.5	9
REPLACEMENT	9	10	4	7	6	5	9	1.0	9	10	4	7	6	5	9
COST	8	7	6	9	10	6	8	.5	4	3.5	3	4.5	5	3	4
TOTALS									22	21.5	17	18.5	18	17.5	22

MATRIX 4.2

## TOTAL SYSTEM SELECTION MATRIX

	REL. RATINGS				WEIGHTING FACTOR	WGT'D. RATINGS			
	CONFIG. I	CONFIG. II	CONFIG. III	CONFIG. IV		CONFIG. I	CONFIG. II	CONFIG. III	CONFIG. IV
USEABILITY	9	7.5	10	5.5	1.0	9.00	7.50	10.00	5.50
BENEFIT TIME	5	9	10	6	.85	4.25	7.65	8.50	5.10
SURVIVABILITY	9	5	10	5	.75	6.75	3.75	7.50	3.75
SERVICE PROVISION	10	6	5	10	.65	6.50	3.90	3.25	6.50
PERS. ACCESS	6	10	8	6	.60	3.60	6.00	4.80	3.60
SERVICEABILITY	7	9	8	10	.60	4.20	5.40	4.80	6.00
SIMPLICITY	5	9	10	5	.55	2.75	4.95	5.50	3.30
WEIGHT	7	8	10	5	.50	3.50	4.00	5.00	2.50
MAINT SUPPORT	9.5	6	10	8	.40	3.80	2.40	4.00	3.70
CONFIGURATION TOTALS						44.35	45.55	59.35	39.95

MATRIX 5.1

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TOTAL REQUIREMENTS

Total Equipment Volume.....663.85 cubic ft.  
Total Maintenance Volume.....1041.72 cubic ft.  
Total Equipment Floor Space.....176.34 square ft.  
Total Maintenance Floor Space.....250.06 square ft.  
Total Power #1 Requirements (60 Hz).....28.365 kilowatts.  
Total Power #2 Requirements (400 Hz).....22.790 kilowatts.  
Total Weight.....14.677 tons  
Total Heat Dissipated for Air.....166244 BTU/HR.  
Total Heat Dissipated for Water.....39377 BTU/HR.  
Total Air Flow.....0 cubic ft/min.  
Total Water Flow .....15 gallons/min

APPENDIX A

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APPENDIX B

ELECTRICAL AND DATA FLOW INTERFACES

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## CALCULATIONS FOR POWER REQUIREMENTS

$$P = \frac{V I}{\text{RMS RMS}}$$

$$V_{\text{RMS}} = .707 V_{\text{MAX}}$$

$$I_{\text{RMS}} = .707 I_{\text{MAX}}$$

$$P = (.707)^2 V_{\text{MAX}} I_{\text{MAX}}$$

OR

$$I_{\text{MAX}} = \frac{P}{(.707)^2 V_{\text{MAX}}}$$

$$V_{\text{MAX}} = 115 \text{ Volts}$$

$$\frac{I_{\text{MAX}}}{\phi} = \frac{P}{3(.707)^2 V_{\text{MAX}}}$$

### SYSTEM REQUIREMENTS

$$\frac{\text{POWER REQUIRE}}{\text{NUMBER OF MODULES}} = \frac{\text{POWER}}{\text{MODULE}}$$

REQUIRED TO POWER THE SYSTEM

$$I_{(60 \text{ Hz})} = \frac{16.95}{3(.707)^2 (115)}$$

$$I_{(60 \text{ Hz})} = 98.3 \text{ AMPS}$$


---

$$P_{(60 \text{ Hz})} = \frac{28.356 \text{ KW}}{1.67}$$

$$= 16.95 \text{ KW/MODULE}$$

$$I_{(400 \text{ Hz})} = \frac{13.7}{3(.707)^2 (115)}$$

$$\frac{I_{(400 \text{ Hz})}}{\phi} = 79.5 \text{ AMPS}$$


---

$$P_{(400 \text{ Hz})} = \frac{22.790 \text{ KW}}{1.67}$$

$$= 13.7 \text{ KW/MODULE}$$

SINCE #0 CABLE IS CAPABLE OF CARRYING 245 AMPS,  
 #0 CABLE IS CAPABLE OF SUPPLYING POWER TO TWO  
 CONTAINERS.

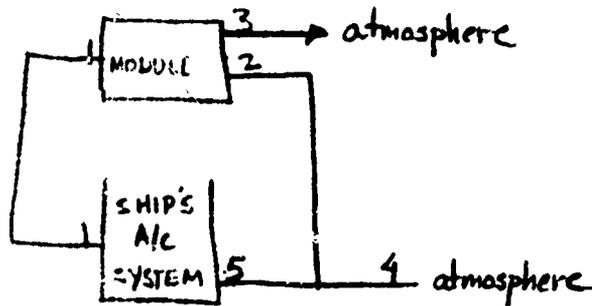
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APPENDIX C

FLUID FLOW INTERFACES

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# ROUGH AIR CONDITIONING CALCULATIONS



Ref: " "

$$\sum \dot{q} = \sum \dot{m}_w h_w - \dot{m}_a (h_2 - h_1)$$

Let  $T_2 = 65^\circ\text{F}$  (dry bulb temperature)  
 $T_2$  (wet bulb) =  $54.1^\circ\text{F}$   
 $h_2 = 22.75 \text{ BTU/lba}$  (enthalpy)  
 $w_2 = .0065$  (humidity ratio)  
 $H = 50\%$  (relative humidity)

$T_4 = 88^\circ\text{F}$  (dry bulb)  
 $H = 70\%$

$\frac{\text{lb moisture}}{\text{lb dry air}}$

$T_1 = 62^\circ\text{F}$  (dry bulb)  
 $H = 55\%$

use mass flow rate  $\dot{m}_a = 250 \text{ cfm} = 202,500 \text{ lba/hr}$   
 $(250 \frac{\text{ft}^3}{\text{min}}) \left( \frac{60 \text{ min}}{\text{hr}} \right) \left( \frac{13 \text{ lba}}{\text{ft}^3} \right) = 202,500 \text{ lba/hr}$

$\dot{m}_w = \dot{m}_a (\Delta w)$  use  $\dot{m}_w = 1.05$

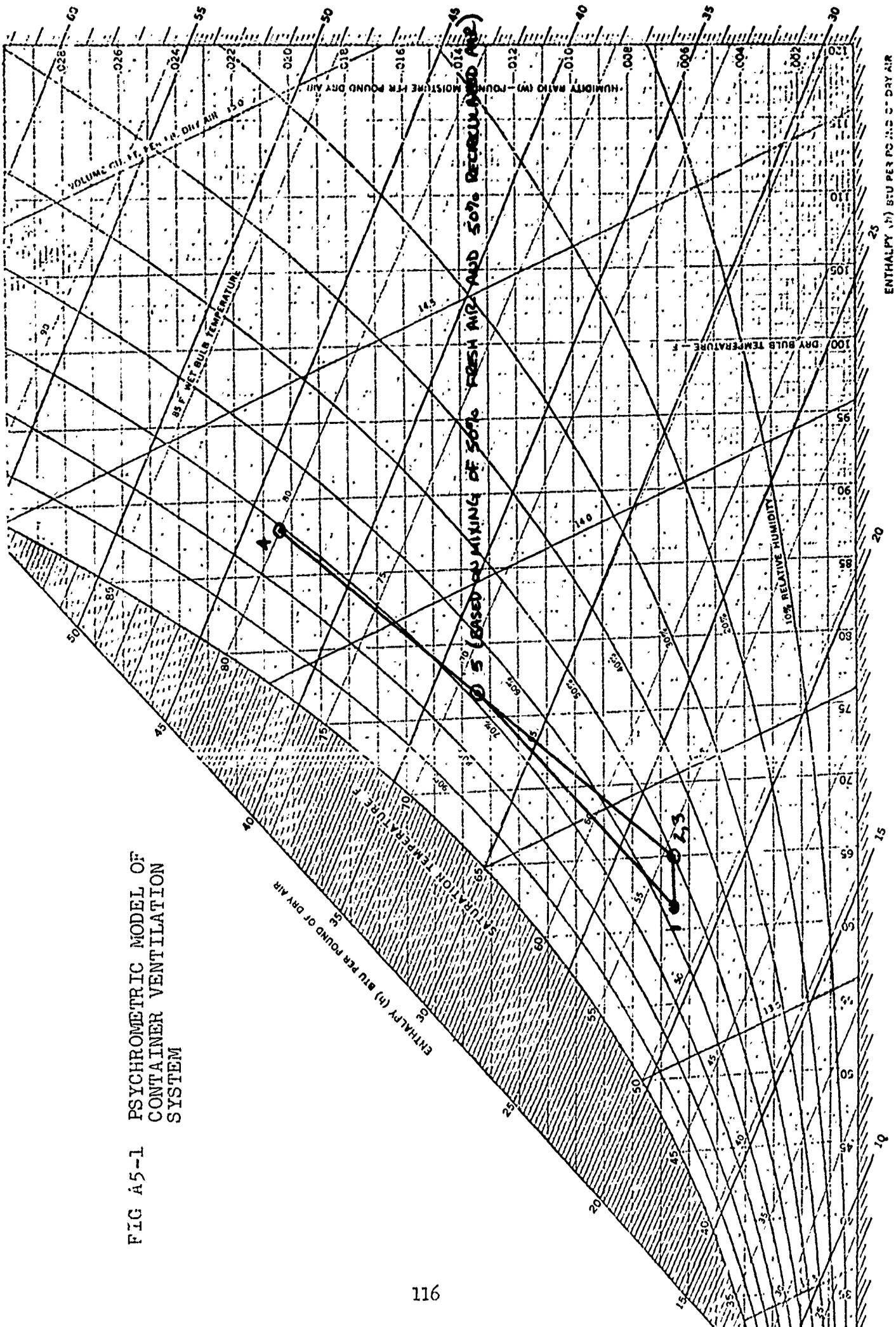
$$1.05 = 202,500 (.0065 - w_1)$$

$$w_1 = .0065 - \frac{1.05}{202,500} \approx .0065$$

See Figure A5-1 for air conditioning cycle

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FIG A5-1 PSYCHROMETRIC MODEL OF CONTAINER VENTILATION SYSTEM



A FEASIBILITY STUDY  
of  
THE INSTALLATION OF 8x8x20 CONTAINERS  
ABOARD WARSHIPS

INTERIM REPORT - THE STATE OF THE ART

16 March 1973

Midshipman Design Team

Midn. J. McGarrah, Project Manager  
Midn. F. Brasco  
Midn. O. Keifer  
Midn. H. Seedorf  
Midn. M. Skorich  
Midn. P. Vining

United States Naval Academy  
Annapolis, Maryland

APPENDIX D

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## SUMMARY

The majority of the literature on modularity in warship design suggests that structural and interface problems connected with using 8x8x20 containers aboard ship can be solved. Although there is no single unit extant which possesses all of the desired characteristics, a few good examples exist. The Chesapeake Instrument Corporation is presently building a 7x10x20 hardened aluminum van used as a monitoring and recording center for their towed array system as installed aboard destroyer escorts and certain large minesweepers. Railroad cars and pre-fabricated kitchens pass electricity across an interface. Off-the-shelf items such as contacts, connectors, conduits, piping and duct-work are available. The applicability to the problem of these concepts and components is discussed in subsequent sections of this report.

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## STATE-OF-THE-ART IN SPECIFIC PROBLEM AREAS

Four problems are being addressed: construction and load requirements of the container itself, container-to-deck and container-to-container attachments, electrical and data flow, and fluid and mechanical flow. Each has its own problems and level of development. All are essential to the problem solution.

### CONSTRUCTION

Currently, there are two main sources from which data on shipboard containers can be drawn: studies done by private industry for the Navy on container concepts applicable to warship systems and the container ship cargo fleet. The former is a good source of general conceptual information, the latter of construction and strength details.

On containerized commercial carriers, the vans are often stacked six or seven high. Henry (1)\*, 1966, stated that the containers were designed to withstand a 45 ton weight per corner. This indicates that present container frame construction practices result in a frame strong enough for our purposes.

The 7x10x20 van used by Chesapeake Instrument Corporation is completely hardened and thus of immediate interest to this state-of-the-art discussion. It is built of an aluminum frame and panels comprised of two thin aluminum sheets with styrene foam laminated between the sheets.

\*-Indicates a reference, listed at the end of the paper.

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Aluminum use aboard ship has increased of late and much progress has been made in the area of joining steel and aluminum(2). It is consistent with the state-of-the-art to examine an aluminum container as a feasible alternative.

Most of the other government sponsored work has been conceptual in nature. Booze-Allen Applied Research(3) and Wheeler Industries(4) have both conducted feasibility studies and come to the general conclusion that the modular concept could be applied to warship design and construction.

#### ATTACHMENTS

Two main sources can be cited for practical attachment of modules to the deck of a ship. The Gruman Aerospace Corporation(5) and (6) proposed the use of engaging lugs which would be twist-locked. The Chesapeake Instrument Corporation has used a system of I-beams and guy wires to attach their van to the fantail of the ship. The only other proposed idea was direct welding. Most reports failed to deal directly with this phase of the modular problem, but assumed it could be done.

Reference (5) dealt with the problem of attachment, suggesting the use of ISC twist locks to secure the containers. This has not been attempted in a practical situation, but data from Meek (7) indicates that the couplers might work.

The Chesapeake approach was to provide skids on the bottom of the van and a series of I-beams welded to the deck. The skids were then belted to the beams and the top corners of the van secured with guy wires and turn-buckles.

#### ELECTRICAL AND DATA CONNECTIONS

There are many good sources of information in this field, ranging from catalogs (8), (9), (10) listing and describing various connectors and selectors, to books (11) and magazine articles (12), (13) discussing

various connector types and interface arrangements.

The state-of-the-art in electrical and data flow can be broken down into three categories:

1. Developments of modular type units which have power/data interfaces.
2. Connectors presently being manufactured suitable for the sea environment.
3. Wave guide connectors.

Two studies have been made on modularizing prefabricated kitchens (12), (13). Both of these have electrical interfaces, however, they seem to use in-box connections, not concerning themselves with water-tight integrity or security.

Another type of modular system is the railroad car. They receive power in one of three ways:

1. Overhead, by means of a pantograph.
2. Contact with conducting rails using a hot shoe.
3. Flexible cable jumpers with water tight, quick acting connectors.

The first two methods do not account for transmission security.

One novel way of supplying power to a van is used by Chesapeake Instrument Corporation. The only type of power interface required is a 440 three-phase umbilical cable. The van has a self-contained power converter system which supplies the van with the various types of power required. The estimated time of hook-up is 15 minutes.

The second area of study discussed here is again broken down into three specific areas:

1. Contact type connectors.
2. Screw-in or bolt-connectors.
3. Male-female connectors.

These are discussed at length in References (8), (9), and (11). The first type are merely end-on contacts held in place by springs. The second type uses a fork or hook shaped piece of metal and is inserted on the shank of the screw. The head, when screwed in holds the connector in place. Male-female connectors are the most complex of the three. All

three types of connectors maximize current flow and minimize impedance by having as large a contact area as possible. Many off-the-shelf connectors today show promise for shipboard use.

Wave guides are the biggest interface problem in this area of study. They can be made flexible as is the general practice in aircraft (14). This is limited by distortion factors which limit the radius of curvature to be greater than twice the wavelength of the transmitted radiation (14). A choke connection could possibly solve the interface problem by eliminating the need for the modules to touch each other.

#### FLUID AND MECHANICAL CONNECTIONS

The flow of liquid and air across the interfaces is critical, especially in the command and control spaces. Fortunately, there is sufficient literature available on the subject of transferring these commodities. The use of hydraulic hoses and present hose connection practices are addressed by Holzbock (15). Goehring (16) describes different uses for pipe aboard ship and also mentions additional types of and uses for hose. Holland and Chapman (17) discuss factors to be considered in pumping fluids, as well as types of equipment used for that purpose. Elonka and Johnson (18) give good practical data on hydraulics and related equipment.

Ventilation is the primary air flow system required in this problem. Although there exists no really rapid-connecting ventilation duct, many suitable examples of flex-types are available. The air conditioning duct on the Chesapeake Instrument Corp. van is an excellent example; another one is the ventilation duct used by workers under city streets.

Flow of cooling water for electronic gear, drinking water, and steam are other considerations in this area. Existing connections are numerous, offering a wide variety to choose from. The following table indicates some of the types of piping and fittings in use today.

LIST OF HOSE

Type	Service	Location	Remarks
Metallic Flexible Steel, Galvanized	Steam	Machinery spaces	Fitted with male and female couplings
Water Hose Wrapped	Washing Down		Fitted with male and female couplings
Rubber Suction Hose	Bilge Suction; Pumping Out Boilers		Fitted with male and female couplings
Metallic Flexible Bronze	Lubricating Oil Filling	Filling connection	Fitted with male and female couplings
Rubber Air Hose, Wrapped	Pneumatic Tools	Various shops and machinery spaces	Fitted with male and female couplings
Fire Hose	Fire Protection	Placed to give coverage throughout the ship	Fitted with male and female couplings
Garden Hose	Sanitary	Galley	Fitted with male and female couplings
Cotton Rubber Lined, Wire Reinforced	Fuel Oil Filling	Filling connection	

CONCLUDING REMARKS

There exists presently sufficient hardware and data to obtain a viable solution to the problem at hand.

The objective of this group is to examine, identify, and evaluate system components against certain basic criteria, consistent with sound engineering practice, and develop one or more alternatives to compare to present design and construction practice. Once this is done, the group can make valid recommendations based on actual calculations and system analysis, from a practical engineering outlook.

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