May 1977

# THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

## Rectangular Vent Duct Standards

U.S. Department of Commerce
Maritime Administration

in cooperation with
Todd Shipyards Corporation

# Report Documentation Page

*Form Approved*
*OMB No. 0704-0188*



| | | |
|---|---|---|
| 1. REPORT DATE<br>**MAY 1977** | 2. REPORT TYPE<br>**N/A** | 3. DATES COVERED<br>**-** |
| 4. TITLE AND SUBTITLE<br>**Rectangular Vent Duct Standards** | | 5a. CONTRACT NUMBER |
| | | 5b. GRANT NUMBER |
| | | 5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | | 5d. PROJECT NUMBER |
| | | 5e. TASK NUMBER |
| | | 5f. WORK UNIT NUMBER |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>**Naval Surface Warfare Center CD Code 2230 - Design Integration Tower Bldg 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700** | | 8. PERFORMING ORGANIZATION REPORT NUMBER |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | | 10. SPONSOR/MONITOR'S ACRONYM(S) |
| | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) |

12. DISTRIBUTION/AVAILABILITY STATEMENT
**Approved for public release, distribution unlimited**

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT<br>**unclassified** | b. ABSTRACT<br>**unclassified** | c. THIS PAGE<br>**unclassified** | **SAR** | **97** | |

**Standard Form 298 (Rev. 8-98)**
Prescribed by ANSI Std Z39-18

## FOREWORD

This is one of the many projects managed and cost shared by Todd Shipyards Corporation as part of the National Shipbuilding Research Program. The Program is a cooperative effort between the Maritime Administration's Office of Advanced Ship Development and the U.S. shipbuilding industry. The objective, described by the Ship Production Committee of the Society of Naval Architects and Marine Engineers, emphasizes productivity.

The research effort was assigned by subcontract to John J. McMullen Associates, Inc. after evaluation of several proposals. Mr. Arthur L. Lewis was the Project Manager. He was assisted by Mr. J. C. Nilsen.

In behalf of Todd Shipyards Corporation, Seattle Div. R. F. Heady was the R&D Project Manager who provided technical direction, J. F. Curtis coordinated the final editing effort, and L. D. Chirillo was the R&D Program Manager having overall cognizance.

## EXECUTIVE SUMMARY

When confronted with space limitations heat, ventilation and air conditioning (HVAC) designers must consider rectangular duct. Since size or component standards did not exist before now, such installations were mostly customized.

The standardization scheme contained herein establishes, in 2-inch increments, 106 different rectangular cross-sections which cover a useful range of applications. Further a reasonable, but reduced, number of fitting types are incorporated. These features were exploited to minimize the number of material items required and to simplify construction details.

Significant savings through use of these standards are predicted herein. But they impact on all shipbuilding disciplines in different degrees. Therefore any one functionary, e.g., a supervisory HVAC designer or a shop foreman, cannot be expected to assess the net impact of the standards on an entire shipyard. Whether a shipyard will benefit depends upon someone with an overview of all management functions requiring subordinates, representing direct and indirect cost areas, to make objective comments that can be assessed collectively.

Further, these standards are a first necessary step to apply computers for the detail design and fabrication of rectangular duct arrangements as is now being done for piping systems.

Every shipbuilder should read at least the first 6 pages. The remainder is detailed and contains comprehensive cost comparisons. It should be analyzed by experts in estimating, planning (including design and material procurement), production and performance measurement.

## *TABLE OF CONTENTS*

## *LIST OF FIGURES*



## *LIST OF TABLES*

# 1.0 INTRODUCTION

## 1.1 *General*

One reason for using standards is to better define ships' components so that risks and costs are minimized for shipbuilders and their material suppliers as well as for owners and underwriters. Standards achieve this by eliminating generalities and thus provide a basis for common understanding. But, heretofore none have been developed for rectangular vent duct. Thus the objectives of this project were to:

- develop standard sizes and components for rectangular vent duct, and to
- identify potential cost savings from such standardization.

The results include, in addition to this report, a designer's pamphlet, matching construction drawings, and a computer prepared tabulation of dimensions and quantities of required materials. Thus everything necessary for designers, planners, buyers, and craftsmen to support and utilize the standards has been developed.

The purpose of this report is to notify shipbuilders of the available standards for rectangular vent duct and to present pertinent discussions and cost analyses which will facilitate implementation.[1]

[1]A specification to invoke these standards is in Appendix H.

## 1.2 *Approach*

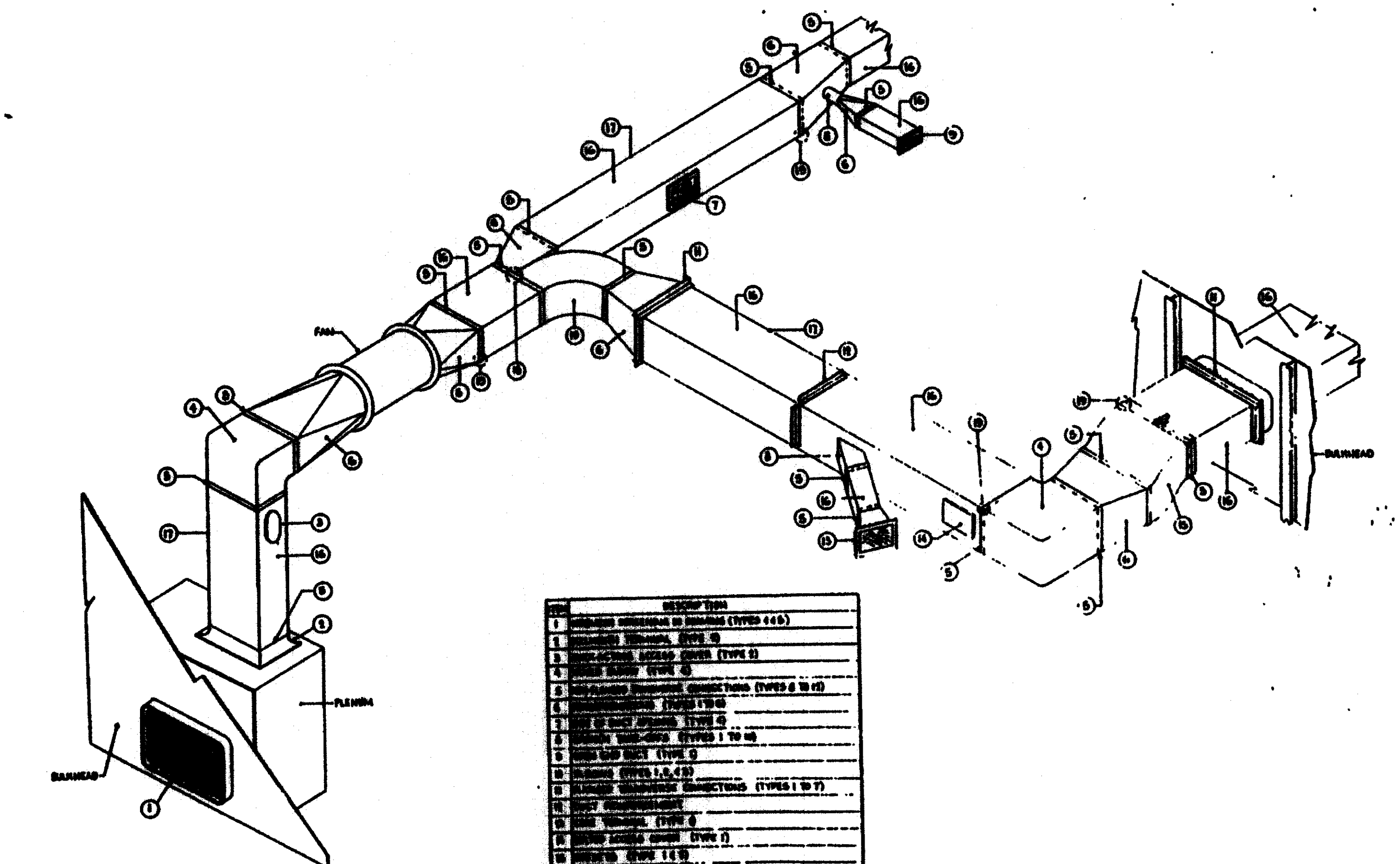
In order to produce the standards, the researcher:

- reviewed several shipsets of different ventilation systems drawings,
- searched and reviewed the literature,
- solicited and analyzed information from many vendors,
- explored the duct components used in both U.S. and foreign shoreside industries for possible adaptation in ships,
- inspected several U.S. and foreign ships to determine current practices,
- reviewed regulatory constraints and MarAd and Navy specifications,
- discussed the standardization scheme with people in the U.S. Coast Guard (MMT) and with the Public Health Service in Washington, D.C., and
- acquired an understanding of current practice in direct meetings with design and production people in seven major U.S. shipbuilding yards.

## 1.3 *Findings*

Overall costs for rectangular vent duct installations in ships could be reduced significantly through the use of standards. For example a 20% savings is estimated for such installations in a 75,000 DWT Panamax tanker. The savings are manifest in all of the required shipbuilding disciplines and mostly result from eliminating virtually all custom components and thus allowing a reduced number of line items[2] both for purchased and in-process materials.

[2]unique items which must be separately identified in drawing material lists, purchase requisitions, purchase orders, warehousing, and in work orders.




| ITEM | DESCRIPTION |
|---|---|
| 1 | [illegible] (TYPES 4 & 5) |
| 2 | [illegible] (TYPE 3) |
| 3 | [illegible] (TYPE 2) |
| 4 | [illegible] |
| 5 | [illegible] CONNECTIONS [illegible] |
| 6 | [illegible] |
| 7 | [illegible] |
| 8 | [illegible] |
| 9 | [illegible] |
| 10 | [illegible] |
| 11 | [illegible] CONNECTIONS (TYPES 1 TO 7) |
| 12 | [illegible] |
| 13 | [illegible] |
| 14 | [illegible] (TYPE 1) |
| 15 | [illegible] |
| 16 | STRAIGHT DUCT |
| 17 | [illegible] (TYPES 1 TO 6) |
| 18 | [illegible] OF DUCT AT SPLITS |
| 19 | [illegible] OF DUCT [illegible] |

*Figure 2-1*

## 2.0 DESCRIPTION OF THE STANDARDS

### 2.1 *General*

The components for which standards were developed are illustrated in Figure 2-1. Specifics of the standardization scheme are described in the Designer's Pamphlet which is reproduced in its entirety in Appendix A. This pamphlet is a catalog of standard components that is intended for HVAC[1] designers. Although complete sets of matching construction drawings and computer prepared tabulations of dimensions and quantities of required materials are available,[2] only typical pages are incorporated in Appendices B and C respectively. Regarding the construction drawings, each is complete to facilitate fabrication. They even include developed views for the layout of patterns.

As required by the research specification the standards:

- provide for normal velocities up to 4000 feet per minute, and
- cover a full range of duct sizes.
- Also, the researcher was able to incorporate some simplified construction details as compared to current practice. But, for certain elements such as basic materials and fire dampers no improvements were found.

[1]Heating, Ventilation and Air conditioning.

[2]to U.S. shipbuilders from R&D Program Manager, Todd Shipyards Corporation, Seattle Division, P.O. Box 3806, Seattle, WA 98124; otherwise when cataloged, from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

### 2.2 *Summary of Elements Standardized*

| *Element* | *Standardization* |
|---|---|
| sizes | depth and width by two-inch increments resulting in 106 different cross sections from 2" x 4" through 24" x 24" to 18" x 54"; radius corners in only three radii for most strength penetrations. |
| materials | steel in five thicknesses: 20, 16 and 11 gauge and 3/16 and 1/4 inch. |
| duct reinforcement | applicability and spacing |
| elbows | four types: full throat, half and quarter throat with and without splitters, and vaned turn |
| offsets | two types: full and half-throat radii |
| transformations | three symmetrical and three flat-sided: rectangular-to-rectangular, rectangular-to-radius corner, and rectangular-to-round |
| branch take-offs | ten types: variations of rectangular and round, normal and flared, 90° and 45°, from straight and transforming mains |
| terminals | cone and bellmouth; radius selection for the bellmouth reduced to seven dimensions |
| transverse connections | seven flanged types and five non-flanged; bolt hole spacing standardized; structural 'pop' rivets on 2-inch centers with no sealant required |
| access covers | dimensions and details |
| wire mesh screening | dimensions and details |
| tensile fasteners | 22 line items |

## 3.0 IMPACT OF THE STANDARDS

### 3.1 *In Overall Management*

The research specification required that all comment be in the context of conventional shipbuilding functions. Thus the researcher's understanding of these functions and how they interact are pertinent and are included in Appendix D.[1] But assessing the full impact requires appreciation of the entire management cycle, see Figure 3-1, because every management function benefits from the use of standards.

No matter to what degree the functions and information flows illustrated in Figure 3-1 are formalized, or even if they are not at all formalized, they must exist everywhere ships are built for profit. Decisions made in forecasting, planning, scheduling and production are controlled by information both from previous steps and from feedback obtained from subsequent steps. Standards provide the necessary common understanding which is just as critical between shipyard functionaries as it is between shipbuilders and owners. Thus, the rectangular vent duct standards will benefit estimators, schedulers and accountants by providing simplified quality information that facilitates prediction, implementation and evaluation. But, there is much greater potential benefit in planning and production.

### 3.2 *In Planning*

As used herein planning includes design of ventilation system arrangements, material procurement and resource allocations because they are interdependent.

#### 3.2.1 *Design*

Standards will lead designers away from unproductive fine-tuning of HVAC systems and reduce the number of time consuming design iterations. The fact is that many HVAC systems are built to design constraints which far exceed the accuracy of the basic flow factors. There are surprisingly wide gaps in the experimentally verified data on system losses.[2] For example, almost no test data exists for return-side takeoff losses. Also, popular rules-of-thumb introduce considerable inaccuracy in bringing loss factors from test points to design conditions.[3] Two-inch increments and the elimination of complicated components will force a reduction in the costly, spurious accuracy common in current designs. Allowances for such accuracy in a custom designed system and the need to select "the next largest" from a limited number of available fan sizes often combine to produce excessive air flow. When the flow is necessarily reduced with a damper, frequently the system becomes no more efficient than it would be if arranged with standard components that facilitate productivity.

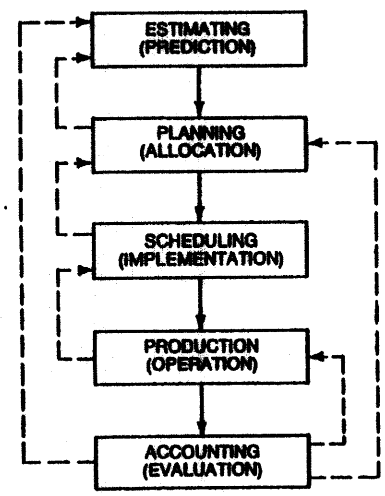



*Figure 3-1 Management Cycle*

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[1] The application of this understanding to a typical ventilation system is also included.

[2] This is discussed in Appendix E which identifies areas for future study.

[3] By strict application of the common rule-of-thumb, a 10° miter would have five times the loss of a 10° elbow - impossible!

The responsibility for much of ventilation systems' construction costs rests with HVAC designers. Sometimes a situation occurs where an extra hour or two over the budget allocated for designing certain features, can save a week's work in production. But the immediate design supervision is rarely in a position to authorize extra time. Thus frequently the opportunity for cost reduction is rationalized away. This problem is greater when the design is developed away from the shipyard. Close liaison is required between designers and fabricators for ideal cost returns. The designer's pamphlet and the matching construction drawings produced by the researcher reflect such liaison and can have continuing impact on construction costs. They already incorporate economic features suggested by shop people and they can serve as a common basis for communication to add even more productive features.

Further, preparation of the rectangular vent duct standards is a significant completed effort that is prerequisite for inputting the configurations and dimensions of each component into a computer. Thus it is now practical to regard a rectangular vent duct system as just another "piping" system and to ". . .provide pictorial output from computers through devices such as cathode ray tubes and numerically controlled plotters. Such systems have a high potential for bringing about significant reductions in the cost of plan production which represents about 2/3 of the total cost of a post contract design effort."[1] For achieving full benefit, consideration must be given to the recommendations contained in Appendix E for developing applicable computer programs.

3.2.2 *Material Procurement*

The standards feature minimization of the number of separate material line items required. For example, sheet steel is limited to only five thicknesses. This reduction in the number of different material items can save an estimated 15 to 20 percent in costs associated with purchasing, storage, retrieval and in-process control. Additional savings may come from the increase in size of bulk orders.

And, for some yards the standards permit a wider range of make-or-buy alternatives. They increase the probability that prefabricated components, and even subassemblies, will be bought from a subcontractor because the standards contribute significantly to assurances for correct dimensions and quality regardless of the point of manufacture.

[1]from a preliminary draft of the report "Improved Design Process" D. C. MacMillan for the National Shipbuilding Research Program, 31 January 1977, p. 3-46.



Because of the standards' simplicity all required material identities and quantities were easily tabulated by computer. Thus, experienced designers do not have to be concerned with preparation of material lists for standard components. The tabulation can be used by less experienced people using manual procedures. Elsewhere, shipyards can use the available[2] programs for inputting the required indentities and quantities into their own computers for preparation of material lists, requisitions, etc.

3.2.3 *Resource Allocation*

This function is made easier by the use of standards because the process of allocating manhours, materials, facilities and time has to be done only once for a particular component. Thereafter the same information can be used repeatedly.

In addition, the use of standard components increases the opportunities to elect cost saving alternatives, e.g., the ready detection of identical components and subassemblies which should be batch manufactured and of those items which should be subjected to make-or-buy analyses.[3]

Applying computers to all resource allocation tasks are greatly facilitated through use of the standards.

3.3 *In Production*

The standardization of sizes and fittings such as elbows and transformations produce cost savings because they eliminate most of the need for special cases. Thus expenditures of shop resources will be reduced for developing, storing and retrieving patterns. Further benefit accrues from having to contend with fewer material items in shops' stores. In addition, the standardization makes it practical to use the same construction drawings in ships of various sizes and types.

The construction drawings produced by the researcher anticipate all information needed by craftsmen. Preparation of end connections, notching, allowances for longitudinal and transverse seams, etc., are detailed. Pattern configuration and layout possibilities are noted along with required dimensions. This information is sufficiently detailed to facilitate digitizing developed views and automatic cutting.

[2]to U.S. shipbuilders from the R&D Program Manager, Todd Shipyards Corporation, Seattle Division, P. O. Box 3806, Seattle, WA 98124 and when cataloged from the National Technical Information Service, 5285 Port Royal Road, VA 22161.

[3]See Appendix I for a listing of potential vent duct manufacturers.

## 4.0 RATIONALE FOR SPECIFIC IMPROVEMENTS

### 4.1 *Sizes*

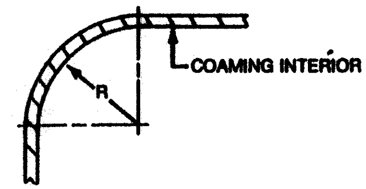
106 standard sizes were developed in 2-inch increments in both width and depth. They are given in the Designer's Pamphlet, Appendix A. Except for two cases, the sizes do not go beyond a 1 to 3 aspect ratio because higher ratios may reduce geometric integrity and increase the chance of duct "panting." The 2-inch depth sizes have a 1 to 4 limiting ratio and the 4-inch depth sizes have a 1 to 3.5; both are acceptable because of structural support from the corners. Although not used in quantity, ducts above 12-inches in depth with aspect ratios exceeding 1 to 2.5 have been included. They are frequently used in machinery spaces for the larger branches required between the main vertical trunks and the smaller distributive branches.

The number of sizes is determined in large part by the need for reasonable efficiency in splitting to standard sizes. Section 6 discusses the effects of disproportional splitting forced by the 2-inch increments in duct size. Appendix F shows the split availability for each depth and gives the duct size utilization for the first generation of splits. Utilization of standard sizes is efficient up to the 12-inch x 36-inch size; this range accommodates a large percentage of normal applications.

Ducts larger than the standard sizes are in most instances either built into the ship or have their shape determined by structure, adjacent bulkheads, space arrangements, etc. These should remain special cases.

The impact of size standardization is pervasive. Most important, it is a prerequisite for much of the simplification of components that has been accomplished. It allows component energy losses, material requirements and fabrication dimensions to be tabulated. It increases the number of like parts, decreases the likelihood of peculiar duct components, and therefore increases the possibilities for manufacturing economies in the sheet metal shop.

Figure 4-1 presents the standard and acceptable alternative radius corners for each duct depth. The standard radii will suit structural requirements for almost all strength penetrations. Cost savings may come directly from the fact that only three templates are required for the full range of sizes. Savings are assured where the use of the standard radii allows the use of an abrupt transition in lieu of a transformation. The standard radii are also prerequisite for the standardization of flanges and bolt hole spacing.




| SMALL CROSS-SECTIONAL DIMENSION OF COAMING D OR W (INCHES) | AVAILABLE RADIUS CORNERS (INCHES) | | | |
|---|---|---|---|---|
| | STANDARD | ONLY AS NECESSARY | | |
| | R1 | R2 | R3 | R4 |
| 2 | 1 | — | — | — |
| 4 | 1 | 2 | — | — |
| 6 | 1 | 3 | — | — |
| 8 | 1 | 2 | 4 | — |
| 10 | 2 | 3 | 5 | — |
| 12 | 2 | 4 | 6 | — |
| 14 | 2 | 4 | 7 | — |
| 16 | 2 | 4 | 6 | 8 |
| 18 | 3 | 5 | 7 | 9 |
| 20 | 3 | 5 | 7 | 10 |
| 22 | 3 | 6 | 8 | 11 |
| 24 | 3 | 6 | 9 | 12 |

*Figure 4-1 Radius Corner Availability*

## 4.2 *Sheet Material*

Sheet steel, either galvanized or otherwise protected, is the only material specified. Material thickness has changed only in the lighter gauge duct, 24 to 16 gauge; two gauges replace five.

The reduction in line items was made after careful study of each of the following:

- current naval and commercial marine design,
- current commercial design shoreside,
- capabilities of seaming machines,
- desire to minimize stock inventories,
- need to meet regulatory body requirements,
- demands made on materials in the shipboard environment, and
- need to meet duct stiffness criteria.

While accommodating all of these considerations, the standards call for only two gauges, 20 and 16 gauge, for materials less than 1/8-inch thick. This eliminates the use of 18, 22 and 24 gauge material. The elimination of 24 gauge will not significantly affect costs because this gauge is currently used only in duct where the largest cross-sectional dimension is less than 6 inches. Moreover, 24 gauge is not suitable for applications requiring B Class fire protection. Dividing the existing 18 gauge applications between 20 gauge and 16 gauge is an even cost trade. Similarly, the elimination of 22 gauge material is roughly an even trade because the heavier 20 gauge is both better suited to welding and less likely to be damaged in storage. Characteristics and applicability of the sheet material are shown in Table 4-1.

| COMPONENT SIZE (INCHES) (1) | GAUGE (2) | THICKNESS (INCHES) (2) | WEIGHT (LBS/FT²) (3) | COST ($/FT²) (4) |
|---|---|---|---|---|
| ALL COMPONENTS MEANT TO BE WATERTIGHT, OR EXPOSED TO WEATHER | 11 | .1233 | 5.0357 | 1.00 |
| ALL VERTICAL COMPONENTS SUBJECT TO DAMAGE (OUTSIDE OF DRY CARGO HOLDS) | 11 | .1233 | 5.0357 | 1.00 |
| ALL COMPONENTS DESIGNED TO SATISFY "A" CLASS FIRE PROTECTION REQUIREMENTS | 11 | .1233 | 5.0357 | 1.00 |
| ALL HORIZONTAL COMPONENTS IN DRY CARGO HOLDS | — | .1875 | 7.65 | 1.53 |
| ALL VERTICAL COMPONENTS IN DRY CARGO HOLDS | — | .250 | 10.2 | 2.04 |
| ALL OTHER VERTICAL EXPOSED COMPONENTS | 16 | .0635 | 2.5958 | .50 |
| ALL OTHER HORIZONTAL OR CONCEALED VERTICAL COMPONENTS WHOSE SIZE IS: | | | | |
| LESS THAN 6 | 20 | .0396 | 1.6207 | .30 |
| 6 - 12 | 20 | .0396 | 1.6207 | .30 |
| 12½ - 18 | 20 | .0396 | 1.6207 | .30 |
| 18½ - 24 | 20 | .0396 | 1.6207 | .30 |
| 24½ - 30 | 16 | .0635 | 2.5958 | .50 |
| OVER 30 | 16 | .0635 | 2.5958 | .50 |

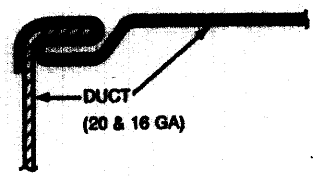
1 - LARGEST CROSS - SECTIONAL DIMENSION.
2 - MANUFACTURERS STANDARD GAUGE. THICKNESS INCLUDES GALVANIZING FOR MATERIALS LESS THAN 3/16".
3 - BASIC WEIGHT PLUS GALVANIZING FOR 11 GAUGE AND THINNER. BASIC WEIGHT ONLY FOR 3/16" AND 1/4" THICK MATERIALS.
4 - COST DATA IS FOR FEBRUARY 1976.

*Table 4-1 Sheet Material Utilization*

4.3 *Seams*

Longitudinal seams have been included in the scheme more because of their effect on transverse connections and components than because of any improvement in fabrication methods. All seven types mesh smoothly with the rest of the standards. The only significant change from current practice is the use of structural 'pop' rivets on 2-inch centers with no sealant for the Type 4 riveted seam described in the following:

*TYPE 1* is the standard Pittsburgh corner lock commonly used by shipyards for the corner longitudinal seams on rectangular straight duct, elbows, and non-radius corner transformation pieces. It is a strong seam, usually formed by machines specifically dedicated to it, and set by hand. The seam does pose problems to transverse connection methods.



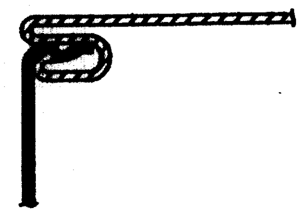

*TYPE 2* is a welded corner seam now in use by some shipyards. It is recommended where the necessary welding skills and equipment make it economically competitive. Its use can simplify transverse connections. The only change recommended would be to bend one edge to prevent welding burn-through and to aid in duct alignment. This bend isn't necessary if the yard's light-gauge welding is highly developed.[1]

*TYPE 3* is one of two types of longitudinal seams used where corner seams are not possible. This seam is seldom used in material heavier than 20 gauge. Maintaining duct size tolerance is more difficult than with other seams, and there is little play for duct alignment and adjustment.

---

[1]See Appendix A, Sheet 16, for illustration of Type 2.

*TYPE 4* is the button punch snap lock corner seam which is coming into prominent use in the commercial shoreside industry. It is formed by machines designed for the purpose. Although possible, use of this seam on elbow corners is not recommended because of the problems involved in bending the seam without affecting the locking feature. This type is, however, recommended for straight duct and non-radius corner transformation pieces in the 20 gauge material range. The lock is accomplished by pushing the two pieces together; setting or peening over by hand is not required. Cost is roughly the same as the Pittsburgh corner lock in the 20 gauge range.



*TYPE 5* is a lapped riveted or spot welded seam. It is one of the two types of longitudinal seams commonly used by shipyards where corner seaming is not possible. Its main application is on transformation pieces with radius corners. The 'pop' rivets currently used have been replaced by structural 'pop' rivets, and the rivet spacing has been changed from 1½-inches C-C to 2-inches C-C. Sealing of the rivets should be more than offset by the savings from increased spacing and elimination of sealing.[2]

*TYPE 6* is similar to Type 3 except that the materials involved are thicker, and therefore, no bend is required to prevent welding burn-through.[2]

*TYPE 7* is a butt-welded, water tight seam for thicker gauge materials only. Type 6 or Type 7 seams may be used interchangeably at the discretion of the fabrication shop.[2]

---

[2]See Appendix A, Sheet 16, for illustrations of Types 5, 6 and 7.

### 4.4 *Transverse Connections*

#### 4.4.1 *Flanged*

The standardization scheme incorporates a number of small changes to existing flange details which should save 20 or 30 percent per assembly. The savings are difficult to estimate. Some are simplified shipyard fabrication, reduced inventory control, the option of buying from outside sources, and the use of the same construction drawings for all ships.

Savings appear certain from the change to standard bolt hole spacing. This allows use of fewer templates. Only twelve are required for all possible radius corners for the standard sizes. Because many of the possible radii will seldom be needed, only three or four templates will be in constant use. Bolt hole standardization eliminates the need to fabricate flanges as mated pairs that must be kept together. The standards permit *any* two flanges of a given duct size and corner configuration to be mated, even if one is installed upside down. This encourages bulk purchases of flanges from outside sources. Savings also result from the following:

- Bolt hole size is independent of the mating flange type.
- Hex washer head bolts and flange nuts have been selected and sized to eliminate the need for washers and to allow a reasonable amount of bolt hole mismatch. (These can be bought with bearing surfaces which act as lock washers offering a more secure connection.)
- Smaller diameter fasteners are specified to further reduce costs. For example 1/4-inch bolts are substituted for the 3/8-inch presently used to connect non-watertight duct to coamings.
- Three basic types of flanges and material configurations have been reduced to two.
- For several flange types, 1/8-inch thick material is used when attached to 1/8-inch components, in place of the 3/16-inch thick material now used.
- Rivet spacing has been revised upward to 2-inch C-C from 1½-inch C-C. For this spacing structural break-mandrel type rivets must be substituted for the current non-structural type. The better rivet eliminates the widespread problem of having mandrels fall out after fabrication. Also, the practice of sealing the rivet heads is no longer required.



#### 4.4.2 *Non-flanged*

More important than flange details is the scheme's emphasis on non-flange connections. Appendix G includes a cost comparison between a flange and recommended non-flange connections. Savings may be over 50 percent in substituting non-flange for flanged.

### 4.5 *Transformations*

The Designer's Pamphlet recommends that abrupt transformations be used wherever feasible, e.g., a standard Type 2 flange can usually serve as the 'transform piece' to a radius corner coaming. The higher losses are offset by savings in fabrication costs. If the abrupt transform proves inadequate, the standards offer two gradual transforms.[1] Estimated fabrication times are in Appendix G. The designer's second choice is an equal area, rectangular-to-rectangular transform costing approximately 2.25 fabrication hours. The standard Type 2 flange again makes the transition to the radius corner coaming. The worst alternative is the rectangular-to-radius corner transform with an estimated cost of 3.75 fabrication hours.

To facilitate more frequent use of abrupt transforms, the standards hold coaming radii to the minimums which meet the strength requirements for bulkhead penetrations. Analysis showed that for commercial ships larger radii would be necessary only in very peculiar circumstances and would likely cost the shipyard two expensive transforms.

### 4.6 *Access Plates*

#### 4.6.1 *Quick-acting*

Access plates now in general use are variations of a round type, fitted with wing nuts, as shown in Figure 4-2. However, the flat-oval type, also shown in Figure 4-2, is more productive because duct preparation is limited to cutting a simple access hole; no welding is involved. Further, required material line items are reduced from five to one. This flat-oval cover is a Navy standard that has already been used in some commercial ships. See Appendix G for cost information.

#### 4.6.2 *Bolted*

No changes are proposed to the bolted access plates now in use except to offer alternative fasteners. The alternative fasteners are much less expensive (see the cost comparison, Appendix G), but not all shipyards have the presses required to seat them. Therefore their use has not been considered for estimating the cost savings available through the use of standards.

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[1]For completeness, the standards also include a rectangular-to-round transformation and flat-sided versions of the three basic types.

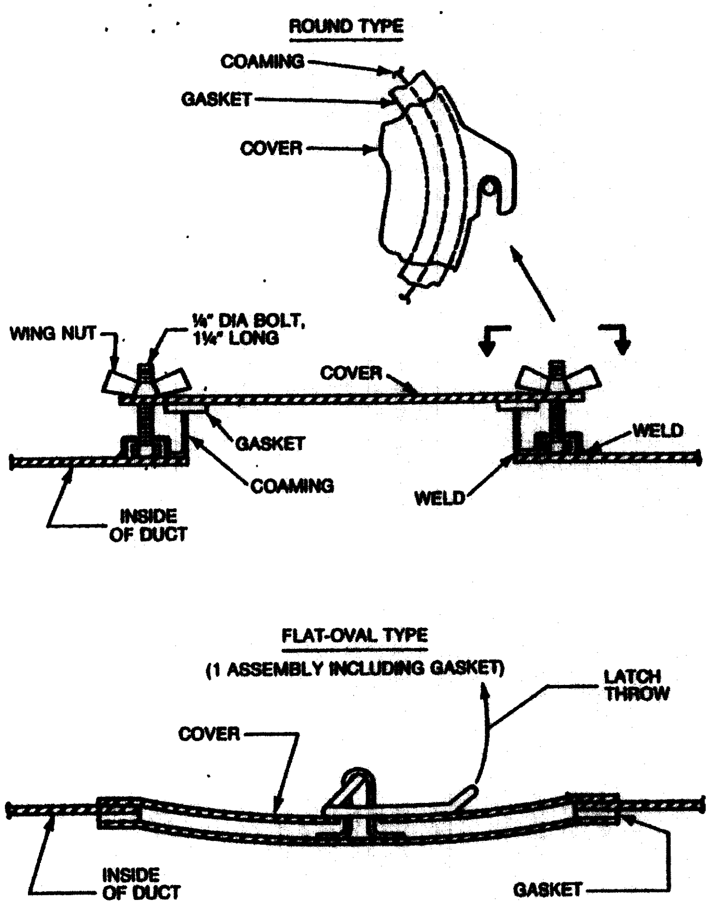


*Figure 4-2 Quick-Acting Access Plates*

### 4.7 *Bellmouth Terminals*

Bellmouth terminal design has been simplified; only seven curved templates will be required to produce the end details for all bellmouths. Referencing the developed view, Figure 4-3, the radius R is determined as shown in Table 4-2.

Cost analysis is difficult, because the fabrication procedure will remain about the same. However the increased use of templates for the end curve, allowed by the standardization, will eliminate the special curve developments presently required. A further benefit will result from the standardization of wire mesh screening which the standard bellmouth terminal permits. The detailed cost comparison, Appendix G, predicts a savings of 15 to 20 percent per bellmouth: 0.5 hours fabrication time (less 25¢ for additional material) due to reduced layout time.

### 4.8 *Wire Mesh Screening*

All rectangular openings have been standardized for which wire mesh screening may be required. These openings include open-end duct, cone terminals, bellmouths, side of duct openings, and weather openings. The dimensions of all openings and all required wire mesh screens are based on 1-inch increments. Except for weather openings, the details of the wire mesh housing, bolted locations, and corresponding screen configuration will not vary with the type of opening. No cost analysis was attempted for these improvements. But, savings are expected from the elimination of the many small changes associated with the current methods of sizing openings and from the simplification of such items as 'U' frames, retaining frames and fastening hardware.

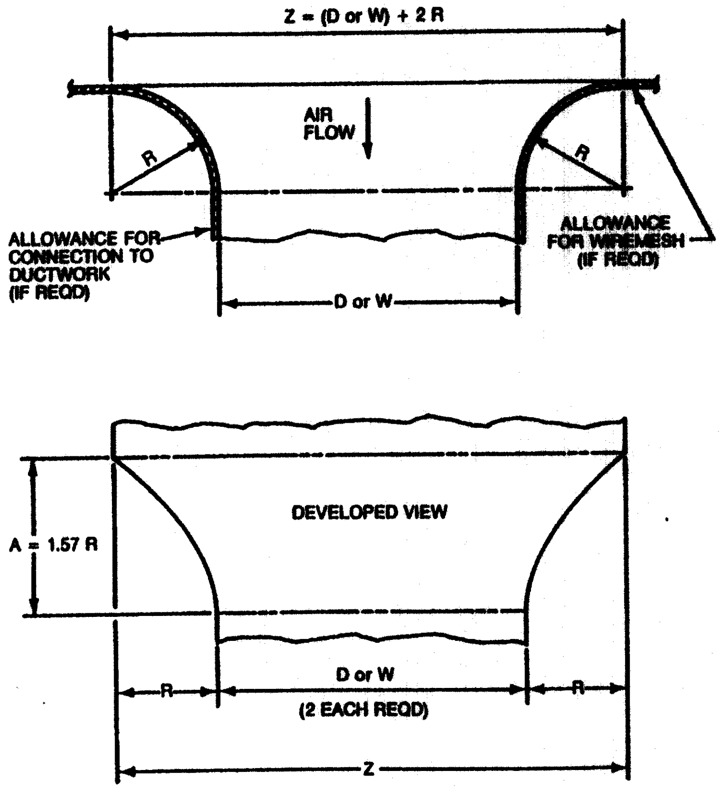


*Figure 4-3 Bellmouth Terminals*

*Table 4-2* **DETERMINING BELLMOUTH RADIUS R**

| *X (larger of D or W)* | *R* |
|---|---|
| 2" ≤ X ≤ 8" | 1" |
| 8" < X ≤ 16" | 2" |
| 16" < X ≤ 24" | 3" |
| 24" < X ≤ 32" | 4" |
| 32" < X ≤ 40" | 5" |
| 40" < X ≤ 48" | 6" |
| 48" < X ≤ 54" | 7" |

**In no case is the standards' R more than 7/8 inch different from R calculated by current methods shown in Table 4-3. The Energy Loss Factor is the same for both standard and current practice, i.e., 0.15 hv (velocity head) for all values of R.**

---

*Table 4-3* **CURRENT METHODS FOR DETERMINING RADIUS R**

| Method A: | *X (larger of D or W)* | *R* | |
|---|---|---|---|
| | X ≤ 8" | 1" | (Range of R is from 1" to 6.75") |
| | X > 8" | .125X | |

| Method B: | *Y (smaller of D or W)* | *R* |
|---|---|---|
| | for all Y | .6Y |

**(Range of R is from 1.2" to 14.4"; limited to 9.75" max. by some design shops.)**

**These current methods produce from 14 to 47 different values for R over the range of the standard sizes. By the most widely used method (Method A), R increases in 1/8-inch increments for every 1 inch increase in the maximum duct dimension.**

## 5.0 IMPACT ON PRESSURE DROP LOSSES

To determine the impact of the standards on duct pressure drop losses, a typical system was selected from one of the vessels reviewed during the first phase of this project. The system was labeled SS1 (supply system) and is shown schematically in Figure 5-1. The entire system (except for one branch for which data was not available) was calculated exactly as depicted on the vent arrangement plans. The same system was then recalculated as SS1' with the following changes:

- All duct sizes were made standard except those connecting to equipment.
- All elbows were made standard and those less than 15° angle of turn were eliminated and calculated as mitres.
- All transformation pieces between ducts and radius corner spools were eliminated, and losses for abrupt changes were calculated.
- All splits were made of standard sizes, and where this violated the proportional split concept, these were calculated to show the resulting abrupt losses.

All of the changes were investigated with respect to feasibility on the vent arrangement plans.

Table 5-1 is the tabulated comparison of pressure drop losses to each terminal point. The differences in pressure drop losses - column $\Delta P$ - shows that design to the standards had no significant impact on the efficiency of the system. Moreover, finer points such as the elimination of all transformation pieces between rectangular duct and radius corner spools were separately evaluated and shown to have little impact. The small differences in losses for the study system indicate that the design of rectangular HVAC systems to the standards is unquestionably practical.

SYSTEM SCHEMATIC - SS1

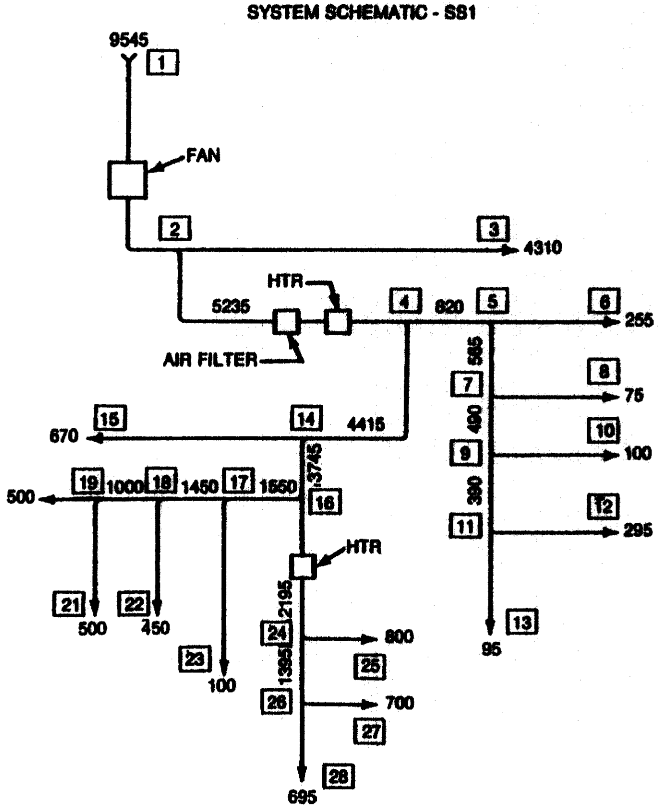


*Figure 5-1*

**TABLE 5-1**

**SS1 and SS1' - COMPARISON OF TOTAL PRESSURE DROP LOSSES TO TERMINAL POINTS**

| Terminal Point No. | Current Practice: SS1 (See Note 1) | Standards Applied: SS1' (See Note 2) | ΔP = SS1-SS1' |
|---|---|---|---|
| 3 | 1.892 | 1.927 | −.035 |
| 6 | 1.981 | 1.959 | .022 |
| 8 | 1.882 | 1.874 | .008 |
| 10 | 2.116 | 2.108 | .008 |
| 12 | 2.152 | 2.144 | .008 |
| 13 | 2.195 | 2.187 | .008 |
| 15 | 1.219 | 1.307 | −.088 |
| 20 | 2.200 | 2.228 | −.028 |
| 21 | 2.175 | 2.203 | −.028 |
| 22 | 2.159 | 2.169 | −.010 |
| 23 | NO INFORMATION AVAILABLE FOR THIS TERMINAL | | |
| 25 | 2.293 | 2.286 | .007 |
| 27 | 2.233 | 2.226 | .007 |
| 28 | 2.190 | 2.183 | .007 |

NOTE 1 - Pressure drop losses as calculated for SS1 from the vent drawing with no changes.

NOTE 2 - Pressure drop losses as calculated for SS1' from the vent drawing with the following changes:

a) All duct sizes made standard except for those connecting to equipment.

b) All elbows made standard, and those less than 15° turn eliminated and calculated as mitres.

c) All transformation pieces between ducts and radius corner spools eliminated and losses for abrupt changes calculated.

d) Abrupt losses calculated at splits where the use of standard sizes violated the proportional split concept.

NOTE 3 - Calculations were made from Navy Duct Size Factor Wheel and ASHRAE Handbook of Fundamentals - 1972.

## 6.0 PROBLEM OF DISPROPORTIONAL SPLITS

One of the main problems associated with the standardization of rectangular duct sizes is that as the number of specific sizes is reduced, the probability of disproportional splits becomes larger. This problem is really two-fold: not only do abrupt velocity changes cause dynamic energy losses, but also the uncertainty of the resulting steady state conditions becomes greater as the proportionality becomes less. The cost of additional fan energy can of course be subtracted from the savings in construction cost to get the estimated net savings. The uncertainty of resulting steady state air flow conditions, however, is not easily predetermined and can cause major difficulties during the system balance tests.

The worst effect of disproportional splitting occurs in the case of a small duct carrying air at high velocities. The worst case within the range of the proposed standard sizes and at the highest design velocity is as follows: assuming that a one inch split was previously the desired minimum and that a 4-inch x 4-inch duct carrying 444 cfm at 4000 fpm is to be divided into two ducts, a 1-inch split would divert 111 cfm proportionately. The resulting two ducts would then be 1-inch x 4-inch duct carrying 111 cfm at 4000 fpm and a 3-inch x 4-inch duct carrying 333 cfm at 4000 fpm.

Assuming that the split is made on the supply side of a system, the conditions that a 2-inch incremental splitting standard would create would be: an abrupt expansion of the 111 cfm to 2000 fpm, resulting in a dynamic loss of .25-inch $H_2O$; and an abrupt contraction of the 333 cfm to 6000 fpm, resulting in a dynamic loss of .28-inch $H_2O$. In this worst case, the resulting losses are obviously unacceptable. However, this case is not likely on the exhaust side of a system, because if standard sizes were used, their combination would presumably be another standard size.

The best case resulting from the disproportional division of a main duct carrying air at 4000 fpm would be where a 54-inch x 18-inch duct were divided into a 26-inch x 18-inch duct and a 28-inch x 18-inch duct when an equal split is required. The resulting abrupt expansion loss would be .002-inch $H_2O$, and the abrupt contraction loss would be .009-inch $H_2O$. Just as obviously, these losses are acceptable.

The above cases have been calculated assuming the highest velocity and greatest disproportionality and so reflect the greatest losses for both the worst and best cases. Most actual losses will be between the values calculated and lower than the arithmetic mean. It is estimated, therefore, that in the majority of cases the losses will be acceptable.

# APPENDIX A

## DESIGNER'S PAMPHLET

This appendix contains a catalog to facilitate a designer's selection of standard components. It must be used with the available dimensional criteria and material requirements; see Appendix C.

Any proposals for significant modification of this Appendix, or of Appendix C, should be addressed to the: R&D Program Manager, Todd Shipyards Corporation, Seattle Division, P. O. Box 3806, Seattle, WA 98124.

## INDEX



CONTINUED ON SH 2.

## REVISIONS

| REV | DESCRIPTION | DATE | APVD |
|---|---|---|---|
| | | | |

DESIGNERS PAMPHLET

NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS

| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
|---|---|---|---|
| B | 2-36233 | 4966-SK-006 | |
| SCALE | NONE | SHEET 1 OF 31 | |

## INDEX (CONTD)



CONTINUED ON SH 3.

## REFERENCES

| NO. | TITLE | IDENTIFICATION |
|---|---|---|
| 1 | BOOKLET PLAN (COMPUTER OUTPUT)-"DIMENSIONAL CRITERIA AND MATERIAL QUANTITIES IN SUPPORT OF RECT DUCT STANDARDS, CONSTRUCTION AND FABRICATION." | TODD DWG NO. |
| 2 | MILITARY STANDARD-"ABBREVIATIONS FOR USE ON DRAWINGS, SPECIFICATIONS, STANDARDS AND TECHNICAL DOCUMENTS." | MIL-STD-12C |
| 3 | "RECTANGULAR DUCT STANDARDS-CONSTRUCTION AND FABRICATION"-NATIONAL SHIPBUILDING RESEARCH PROGRAM. | TODD DWG NO. |
| 4 | UNITED STATES COAST GUARD-RULES AND REGULATIONS (AS APPLICABLE TO CLASS A & B FIRE PROTECTION). | |
| 5. | UNITED STATES PUBLIC HEALTH SERVICE PUBLICATION NO. 393-"HANDBOOK ON SANITATION OF VESSEL CONSTRUCTION" (AS APPLICABLE TO RATPROOFING). | |

| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| B | 2-36233 | 4966-SK-006 | |
| SCALE | NONE | SHEET 2 OF 31 | |

## INDEX (CONTD)

| SHEET NO. | CONTENTS |
|---|---|
| 28 | TYPE 12 (BASIC) TRANSVERSE CONN (NON-FLANGED; LATCH TYPE, NON-WATERTIGHT). |
| 29 | TYPE 12 (ALTERNATE) TRANSVERSE CONN (NON-FLANGED, LATCH TYPE, NON-WATERTIGHT). |
| | TYPE 1 ACCESS COVER (BOLTED). |
| | TYPE 2 ACCESS COVER (QUICK ACTING, FLAT-OVAL). |
| 30 | TYPE 1 WIREMESH SCREENING (OPEN-END DUCT). |
| | TYPE 2 WIREMESH SCREENING (CONE TERMINAL). |
| | TYPE 3 WIREMESH SCREENING (BELLMOUTH TERMINAL). |
| 31 | TYPE 4 WIREMESH SCREENING (SIDE-OF-DUCT). |
| | TYPE 5 WIREMESH SCREENING (IN COAMING). |
| | DUCT REINFORCEMENT. |

| APPROVAL | DATE |
|---|---|
| USCG | |
| ABS | |
| PHS | |

| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONT# | TODD DRAWING NO. | REV |
| B | 2-36233 | 4966-SK-006 | |
| SCALE NONE | | SHEET 3 OF 9 | |

## NOTES

1. **DEFINITION OF TERMS**

WATERTIGHT - THOSE DUCT COMPONENTS DESIGNED, FABRICATED AND INSTALLED, TO OFFER THE VESSEL PROTECTION AGAINST FLOODING FROM EITHER INSIDE OR OUTSIDE THE COMPONENT. THESE COMPONENTS WILL BE OF ALL WELDED CONSTRUCTION, AND SHALL HAVE EITHER WELDED TRANSVERSE JOINTS, OR BE CONNECTED WITH THE APPROPRIATE GASKETED FLANGED CONNECTIONS.

CLASS 'A' FIRE PROTECTION - THOSE DUCT COMPONENTS DESIGNED, FABRICATED, AND INSTALLED TO SATISFY CLASS 'A' FIRE PROTECTION REQUIREMENTS, AS DEFINED BY THE UNITED STATES COAST GUARD, (REF 4).

CLASS 'B' FIRE PROTECTION - THOSE DUCT COMPONENTS DESIGNED, FABRICATED, AND INSTALLED, TO SATISFY CLASS 'B' FIRE PROTECTION REQUIREMENTS, AS DEFINED BY THE UNITED STATES COAST GUARD, (REF 4).

"NON-WATERTIGHT" - THOSE DUCT COMPONENTS NOT DESIGNED TO BE WATERTIGHT. NON-WATERTIGHT DUCT COMPONENTS MAY BE EITHER AIR TIGHT OR NON-TIGHT, THE DIFFERENCE BEING THAT NON-TIGHT COMPONENTS ARE FABRICATED, SEALED, AND INSTALLED, TO OFFER MINIMAL NORMAL AIR LEAKAGE, WHILE AIRTIGHT COMPONENTS MUST USUALLY WITHSTAND A PRESSURE TEST TO ENSURE MINIMAL LEAKAGE. IT IS EMPHASIZED THAT THERE SHOULD BE NO DIFFERENCE IN THE DESIGN OF AIRTIGHT AND NON-TIGHT COMPONENTS, EXCEPT FOR THE DEGREE OF SEALING REQUIRED TO PASS THE PRESSURE TEST.

DESIGNATIONS "D" AND "W" - UNLESS OTHERWISE NOTED, THE TERMS D, W, D1, W1, ETC., AS USED HEREIN REFER TO THE INSIDE CROSS-SECTIONAL DIMENSIONS OF DUCT COMPONENTS OR OPENINGS. EXCEPT FOR ELBOWS AND OFFSETS, THE DESIGNATIONS D AND W FOR THE COMPONENT DIMENSIONS IS NOT SIGNIFICANT. FOR ELBOWS, THE SIDE OF THE ELBOW IN THE PLANE OF THE BEND (THE CHEEKS) MUST BE DESIGNATED W, AND THE OTHER SIDE (THE HEEL, THROAT, OR WRAPPER) MUST BE DESIGNATED D.

**ABBREVIATIONS AND DIMENSIONAL SYMBOLS:**

ALL WORD ABBREVIATIONS ARE IN ACCORDANCE WITH REF. 2, EXCEPT FOR THE FOLLOWING:

RC = RADIUS CORNER
C-C = CENTER TO CENTER

THE FOLLOWING LETTERS HAVE BEEN USED FOR DIMENSIONAL SYMBOLS:

R = RADIUS
L = LENGTH
TR = THROAT RADIUS
HR = HEEL RADIUS
C = IN-LINE DIMENSION FOR PREPARED TRANSVERSE SEAM
S1, S2, S3 = SPLITTER RADII
D, D1, D2, W, W1, W2 = COMPONENT CROSS-SECTIONAL DIMENSIONS
A = ANGLE OF TURN, AND DIMENSION FOR ACCESS PLATE
B = DIMENSION FOR ACCESS PLATE
X = DISPLACEMENT OF OFFSET CENTERLINE

2. **STANDARD SIZES**

THE TOTAL RANGE OF STANDARD SIZES IS SHOWN ON THE "STANDARD SIZES, MATERIAL REQUIREMENTS, AND WEIGHTS" TABLES. IT IS INTENDED THAT THESE SIZES BE UTILIZED BY THE DESIGNER FOR ALL STRAIGHT DUCTING, ELBOWS, OFFSETS, ENDS OF TRANSFORMATIONS, AND CONNECTIONS.

(CONTD ON SH 5)

| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| B | 2-36233 | 4966-SK-006 | |
| REV | SCALE NONE | | SHEET 4 OF 51 |

## NOTES

1. **DEFINITION OF TERMS**

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DESIGNATIONS "D" AND "W" - UNLESS OTHERWISE NOTED, THE TERMS D, W, D1, W1, ETC., AS USED HEREIN REFER TO THE INSIDE CROSS-SECTIONAL DIMENSIONS OF DUCT COMPONENTS OR OPENINGS. EXCEPT FOR ELBOWS AND OFFSETS, THE DESIGNATIONS D AND W FOR THE COMPONENT DIMENSIONS IS NOT SIGNIFICANT. FOR ELBOWS, THE SIDE OF THE ELBOW IN THE PLANE OF THE BEND (THE CHEEKS) MUST BE DESIGNATED W, AND THE OTHER SIDE (THE HEEL, THROAT, OR WRAPPER) MUST BE DESIGNATED D.

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HR = HEEL RADIUS
C = IN-LINE DIMENSION FOR PREPARED TRANSVERSE SEAM
S1, S2, S3 = SPLITTER RADII
D, D1, D2, W, W1, W2 = COMPONENT CROSS-SECTIONAL DIMENSIONS
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(CONTD ON SH 5)

2. (CONT'D)

A RECAP OF THAT TABLE IS AS FOLLOWS:

| D OR W (SMALL DIMENSION-INCHES) | D OR W (LARGE DIMENSION-INCHES) |
|---|---|
| 2 | 4, 6, 8. |
| 4 | 4, 6, 8,..., 14. |
| 6 | 6, 8, 10,..., 18. |
| 8 | 8, 10, 12,..., 24. |
| 10 | 10, 12, 14,..., 30. |
| 12 | 12, 14, 16,..., 36. |
| 14 | 14, 16, 18,..., 42. |
| 16 | 16, 18, 20,..., 48. |
| 18 | 18, 20, 22,..., 54. |
| 20 | 20, 22, 24. |
| 22 | 22, 24. |
| 24 | 24 |

AS MAY BE SEEN, DUCT COMPONENT CROSS-SECTIONAL SIZES HAVE BEEN STANDARDIZED TO TWO-INCH INCREMENTAL CHANGES. THESE, AND THESE ALONE, CONSTITUTE THE "STANDARD SIZES" AS PROPOSED HEREIN. IT IS EMPHASIZED THAT ALL SIZES NOT SHOWN ON THAT TABLE ARE TO BE CONSIDERED AS "NON-STANDARD". WHERE IT IS NOT POSSIBLE TO UTILIZE ONE OF THE STANDARD SIZES IN ANY PARTICULAR INSTANCE, D AND W DIMENSIONS SHALL BE BASED ON ONE-INCH INCREMENTAL CHANGES. IN NO CASE SHOULD FRACTIONAL VALUES OF D AND W BE SPECIFIED, EXCEPT WHERE EQUIPMENT CONNECTIONS SO REQUIRE. THE CONSTRUCTION AND FABRICATION DRAWINGS (REF. 3), AND COMPUTER OUTPUT (REF. 1), HAVE BEEN DEVELOPED TO SUIT THE TWO-INCH INCREMENTAL SIZE STANDARD, WITH PROVISION FOR THE ONE-INCH INCREMENTAL SIZES, IF NECESSARY. IT IS AGAIN STRESSED THAT THE "STANDARD SIZES" BE USED WHEREVER POSSIBLE.

3. DUCT MATERIAL GRADES

GRADE 1 (20 ga STEEL) - USED FOR ALL NON-WATERTIGHT DUCT COMPONENTS WHOSE LARGEST CROSS-SECTIONAL DIMENSION IS 24" OR LESS.

GRADE 2 (16 ga STEEL) - USED FOR ALL NON-WATERTIGHT DUCT COMPONENTS WHOSE LARGEST CROSS-SECTIONAL DIMENSION IS GREATER THAN 24".

GRADE 3 (11 ga STEEL) - USED FOR ALL DUCT COMPONENTS EXPOSED TO THE WEATHER, WATER-TIGHT COMPONENTS, COMPONENTS SUBJECT TO CLASS 'A' FIRE PROTECTION REQUIREMENTS, AND COMPONENTS WHICH MAY BE SUBJECT TO APPRECIABLE DAMAGE (OUTSIDE OF DRY CARGO HOLDS).

GRADE 4 (3/16" STEEL) - USED FOR ALL HORIZONTAL DUCT COMPONENTS IN DRY CARGO HOLDS.

GRADE 5 (1/4" STEEL) - USED FOR ALL VERTICAL DUCT COMPONENTS IN DRY CARGO HOLDS.
ALL OF THE ABOVE DUCT MATERIAL GRADES SATISFY CLASS 'B' FIRE PROTECTION REQUIREMENTS.

4. MATERIAL QUANTITY REQUIREMENTS - BASIC COMPONENTS

THIS PAMPHLET IS SUPPLEMENTED BY REFERENCES 1 AND 3. WHILE REFERENCE 1 LISTS MANY OF THE DUCT COMPONENT MATERIAL QUANTITY REQUIREMENTS, THE FOLLOWING INFORMATION IS ALSO NOTED:

THE MATERIAL REQUIRED FOR ANY PIECE OF STRAIGHT DUCT MAY BE APPROXIMATED BY THE FOLLOWING EQUATION (INCLUDING ALLOWANCES FOR TRANSVERSE CONNECTIONS AND LONGITUDINAL SEAMS):

(CONTD ON SH 6)

NATIONAL SHIPBUILDING RESEARCH PROGRAM
RECTANGULAR DUCT STANDARDS
SIZE B | MARAD CONTR 2-36233 | TODD DRAWING NO. 4966-SK-006 | REV
SCALE NONE | SHEET 5 OF 31
REV

**NOTES** (CONT'D)

4. (CONT'D)

$$M = \frac{(L + 2) \times (D + W + 1)}{72}$$

WHERE:

M = NET MATERIAL REQUIREMENT IN SQUARE FEET
W = "W" DIMENSION OF DUCT IN INCHES
D = "D" DIMENSION OF DUCT IN INCHES
L = LENGTH OF DUCT IN INCHES

THE MATERIAL REQUIRED FOR A TYPE 1, 2, OR 3, NON-TRANSFORMING ELBOW (WITHOUT SPLITTERS) MAY BE APPROXIMATED USING THE FOLLOWING EQUATION (INCLUDING ALLOWANCES FOR TRANSVERSE CONNECTIONS AND LONGITUDINAL SEAMS):

$$M = \left[\frac{A(2TR+W) \times (D+W+2)}{8250}\right] + \frac{D+W}{36}$$

WHERE:

M = NET MATERIAL REQUIREMENT IN SQUARE FEET
A = ANGLE OF TURN IN DEGREES
W = 'W' DIMENSION OF ELBOW IN INCHES
D = 'D' DIMENSION OF ELBOW IN INCHES
TR = THROAT RADIUS OF ELBOW IN INCHES

THE MATERIAL REQUIRED FOR A SPLITTER IN A TYPE 1, 2, OR 3, NON-TRANSFORMING ELBOW MAY BE APPROXIMATED USING THE FOLLOWING EQUATION:

$$M = \frac{D(SA+1)}{8250}$$

WHERE:

M = NET MATERIAL REQUIREMENT IN SQUARE FEET
S = SPLITTER RADIUS IN INCHES
D = 'D' DIMENSION OF ELBOW IN INCHES
A = ANGLE OF TURN IN DEGREES

THE MATERIAL REQUIRED FOR A TRANSFORMATION MAY BE APPROXIMATED USING THE FOLLOWING EQUATION (INCLUDING ALLOWANCES FOR TRANSVERSE CONNECTIONS AND LONGITUDINAL SEAMS):

$$M = \frac{\left[(D1 + D2) + (W1 + W2)\right] \times (L+2) + 2L}{144}$$

WHERE:

M = NET MATERIAL REQUIRED IN SQUARE FEET
D1 = 'D1' DIMENSION OF TRANSFORMATION IN INCHES
D2 = 'D2' DIMENSION OF TRANSFORMATION IN INCHES
W1 = 'W1' DIMENSION OF TRANSFORMATION IN INCHES
W2 = 'W2' DIMENSION OF TRANSFORMATION IN INCHES
L = 'L' DIMENSION OF TRANSFORMATION IN INCHES

SINCE THE 'L' DIMENSION USED WILL NORMALLY BE SLIGHTLY LESS THAN THE TRUE LENGTH OF THE SIDES THE EQUATION IS AN APPROXIMATION, HOWEVER, THE RESULTS WILL BE OF SUFFICIENT ACCURACY TO SATISFY MOST REQUIREMENTS. IN THIS RESPECT, IT IS RECOMMENDED THAT THE SAME EQUATION BE USED FOR CALCULATING THE MATERIAL REQUIREMENTS OF TRANSFORMATIONS BETWEEN RECTANGULAR AND NON-RECTANGULAR SHAPES, WHICH RESULTS IN A SLIGHTLY HIGHER THAN ACTUAL MATERIAL REQUIREMENT.

(CONTD ON SH 7)

NOTES (CONT'D)

5. SPLITTER LOCATION

THE CHART IN THE BUFFALO FORGE CO. HANDBOOK "FAN ENGINEERING" SHALL BE USED TO DETERMINE ELBOW SPLITTER SPACING. (EXCEPT FOR THE DOUBLE-WALL TURNING VANES USED IN THE TYPE 4 ELBOW, EQUAL-SPACED SPLITTERS WILL NOT PRODUCE THE MINIMUM ELBOW PRESSURE LOSS). SPLITTER LOCATIONS ARE ALSO LISTED IN REF 1.

6. TYPE 4 ELBOW (VANED)

THE VANED ELBOW SHOWN HAS BEEN DEVELOPED TO ACCEPT EITHER SHOP-FABRICATED OR COMMERCIALLY BOUGHT TURNING VANES AND VANE RUNNERS. THE TURNING VANES INDICATED ARE OF THE DOUBLE WALL TYPE, IN ORDER TO MINIMIZE PRESSURE LOSS. THE VANES ARE AVAILABLE WITH AND WITHOUT ACOUSTIC INSULATION BETWEEN THE WALLS. CARE MUST BE TAKEN THAT THIS TYPE OF ELBOW BE USED FOR ONLY 90°, NON-TRANSFORMING TURNS, SINCE THE VANES WILL NOT OTHERWISE PERFORM CORRECTLY. BECAUSE OF ITS SPECIALIZED NATURE, MINIMUM USE SHALL BE MADE OF THIS COMPONENT TYPE.

7. OFFSET TYPES 1 AND 2

THE USE OF ELBOW TO ELBOW OFFSETS ARE A FREQUENT OCCURENCE, AND SOME FABRICATION SHOPS PREFER TO MAKE THESE AS ONE COMPONENT. SINCE THEY ARE MADE IN ONE PIECE, THERE IS NO NEED FOR A 'C' DIMENSION ALLOWANCE BETWEEN THE TWO OFFSETTING ELBOWS. HOWEVER, GUIDANCE IN THEIR USE MUST BE OBTAINED FROM THE FABRICATION SHOP, CONCERNING THEIR PREFERENCES, LIMITATIONS DUE TO SHEET METAL STOCK, THE MAXIMUM SIZE OF COMPONENT WHICH THEY FABRICATE AS ONE PIECE, ETC.

IF USED, THE OFFSETS HAVE BEEN DEVELOPED TO BE SELECTED ON 1" INCREMENTAL CHANGES IN DUCT CENTERLINE LOCATION. FOR DESIGN PURPOSES, THE TOTAL OFFSET LENGTH MAY BE CALCULATED FROM THE EQUATIONS GIVEN. AS NOTED, THIS LENGTH DOES NOT INCLUDE THE 'C' DIMENSION ALLOWANCE REQUIRED ON EACH END OF THE COMPLETE OFFSET.

8. TRANSFORMATIONS

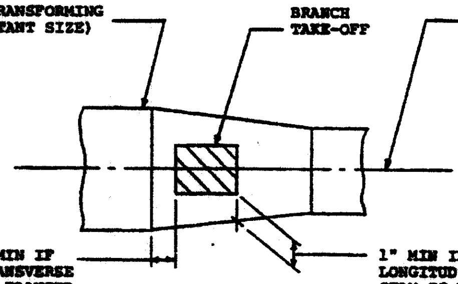
THE SELECTION OF TRANSFORMATION CONFIGURATIONS AND LENGTH IN MANY CASES WILL DEPEND ON THE SPACE AVAILABLE. AS MAY BE SEEN FROM THE PRESSURE DROP DATA REFERENCED HEREIN, THE TOTAL ENERGY LOSS IS DEPENDENT UPON THE ANGLE OF CONVERGENCE OR DIVERGENCE. WHILE A WIDE RANGE OF CONVERGING ANGLES WILL RESULT IN APPROXIMATELY THE SAME ENERGY LOSS, THIS IS NOT TRUE FOR A DIVERGING ANGLE, WHOSE ENERGY LOSS VARIES CONSIDERABLY. IT IS THEREFORE IMPORTANT TO SELECT A DIVERGING TRANSFORMATION WHOSE LENGTH WILL MINIMIZE SUCH LOSS IF POSSIBLE.

IN ADDITION TO THE ABOVE, IF A FLAT-SIDED TRANSFORMATION IS SELECTED, THE TOTAL LOSS WILL CONSIST OF THE TRANSFORMATION LOSS, PLUS THE SMALL-ANGLE MITER TURN LOSSES WHICH WILL EXIST AT EACH END OF THE TRANSFORMATION, DUE TO THE CHANGE IN DIRECTION OF THE DUCT CENTERLINE.

9. BRANCH TAKE-OFFS

THE CHOICE BETWEEN LOCATING A BRANCH TAKE-OFF ON STRAIGHT DUCT, OR ON A TRANSFORMATION, WILL DEPEND ON MANY CONSIDERATIONS, INCLUDING SUCH ITEMS AS BRANCH/MAIN AIR QUANTITY RATIOS, WHETHER THE TAKE-OFF IS LOCATED ON THE SUCTION OR DISCHARGE SIDE OF THE FAN, SPACE AVAILABILITY, ETC. IN GENERAL, IT IS RECOMMENDED THAT THE TAKE-OFF BE LOCATED ON STRAIGHT DUCT IF THE BRANCH/MAIN AIR QUANTITY RATIO IS 10 PERCENT OR LESS. IT IS ALSO RECOMMENDED THAT THE BRANCH/MAIN AIR VELOCITY RATIOS BE SELECTED TO MINIMIZE PRESSURE DROP LOSSES.

LOCATION OF TAKE-OFF (GEOMETRIC CONSIDERATIONS)




(CONTD ON SH 8)

NATIONAL SHIPBUILDING RESEARCH PROGRAM
RECTANGULAR DUCT STANDARDS

| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
|---|---|---|---|
| B | 2-36233 | 4966-SK-006 | |

SCALE NONE | SHEET 7 OF 31

## NOTES (CONT'D)

10. DUCT REINFORCEMENT

IN ORDER TO DETERMINE THE NEED FOR DUCT REINFORCEMENT, THE DESIGNER MUST FIRST DETERMINE THE STATIC PRESSURE EXISTING WITHIN THE DUCT AT VARIOUS POINTS. THE FOLLOWING DATA WILL AID IN THAT DETERMINATION:

STATIC PRESSURE AT ANY POINT ON SUCTION SIDE OF FAN

SP = -(TPL+VP)

STATIC PRESSURE AT ANY POINT ON DISCHARGE SIDE OF FAN

SP = FTP -(TPL+VP)

WHERE:

SP = STATIC PRESSURE AT ANY POINT 'a'
FTP = FAN TOTAL PRESSURE (SYSTEM CONSTANT)
TPL = TOTAL PRESSURE LOSS TO POINT 'a' (AS CALCULATED FROM THE SUCTION SIDE TERMINALS.)
VP = VELOCITY PRESSURE AT POINT 'a'

WHERE ANY OF THE FLANGED TYPE TRANSVERSE CONNECTIONS ARE USED, THEY MAY BE CONSIDERED AS DUCT REINFORCEMENT. (THIS IS ALSO TRUE OF THE S-CLIP WITH REINFORCING LEG.)

11. CONNECTIONS TO FLAT-OVAL OR RADIUS CORNER COAMINGS

IT IS RECOMMENDED THAT THE USE OF TYPES 2, 5, AND 7 FLANGE CONNECTIONS BE MINIMIZED IN FAVOR OF TYPES 1, 3, 4, AND 6 FLANGE CONNECTIONS. THE EXTENT TO WHICH THIS MAY BE ACCOMPLISHED WILL DEPEND UPON THE ACCEPTABILITY OF THE ABRUPT ENLARGEMENT AND/OR CONTRACTION ENERGY LOSSES WHICH RESULT. WHERE THE DUCT SIZE AND THE COAMING SIZE ARE SUCH THAT A TRANSFORMATION IS REQUIRED IN ANY CASE, IT IS RECOMMENDED THAT THE TRANSFORMATION BE EITHER TYPE 1 OR 4. THIS WILL ALLOW THE USE OF TYPES 1, 3, 4, AND 6, FLANGE CONNECTIONS BETWEEN THE COAMING AND TRANSFORMATION, AND WILL ALSO DEPEND UPON THE ACCEPTABILITY OF THE RESULTANT ABRUPT ENERGY LOSSES.

12. ALLOWANCE FOR TRANSVERSE CONNECTIONS

THE LETTER 'C' HAS BEEN ASSIGNED TO INDICATE WHERE THE DESIGNER MUST LEAVE ALLOWANCES FOR TRANSVERSE CONNECTIONS. 'C' REPRESENTS THE IN-LINE DIMENSIONS FOR THE PREPARED CONNECTION TYPE USED ON THE END OF THAT COMPONENT. IT DOES NOT REPRESENT THE TOTAL MATERIAL WHICH MUST BE LEFT ON THE COMPONENT FOR THE CONNECTION. THEREFORE, WHEN USING ONE OF THE TRANSVERSE TYPE CONNECTIONS, THE DIMENSION WHICH THE DESIGNER MUST ALLOW FOR WILL EQUAL THE COMBINATION OF ANY OF THE TWO TYPES SELECTED FOR THE TOTAL CONNECTION.

EXAMPLE:

TOTAL CONNECTION = TYPE 1 CONNECTION MATED TO TYPE 4 CONNECTION
TOTAL ALLOWANCE = 1/4" + 1-1/4" = 1-1/2"

THE FOLLOWING TABLE INDICATES THE TOTAL IN-LINE ALLOWANCE WHICH MUST BE PROVIDED FOR BY THE DESIGNER FOR ALL OF THE VARIOUS CONNECTION TYPES AND COMBINATIONS WHICH MAY OCCUR. ALL DIMENSIONS GIVEN ARE IN INCHES. A ZERO ENTRY INDICATES THAT THE CONNECTION COMBINATION IS POSSIBLE, AND THAT NO ALLOWANCE IS NECESSARY. A DASH (-) ENTRY INDICATES THAT THE CONNECTION COMBINATION IS NOT POSSIBLE. SHOP PREFERENCES MUST BE ESTABLISHED PRIOR TO UTILIZING ANY OF THE TRANSVERSE CONNECTION TYPES.

(CONTD ON SH 9)

## NOTES (CONT'D)

12. (CONT'D)

| TRANSVERSE CONNECTION TYPE | 1 | 2 | 3 | 4 | 5 | * 6 | * 7 | 8 | 9 | 10 | 11 | 12 (BASIC) | 12 (ALTN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1/2 | - | 1/2 | 1-1/2 | - | 1/4 | - | - | - | - | - | - | - |
| 2 | - | - | - | - | 1-1/2 | - | 1/4 | - | - | - | - | - | - |
| 3 | 1/2 | - | - | 1-1/2 | - | 1/4 | - | - | - | - | - | - | - |
| 4 | 1-1/2 | - | 1-1/2 | 2-1/2 | - | 1-1/4 | - | - | - | - | - | - | - |
| 5 | - | 1-1/2 | - | - | - | - | - | - | - | - | - | - | - |
| 6* | 1/4 | - | 1/4 | 1-1/4 | - | 0 | - | - | - | - | - | - | - |
| 7* | - | 1/4 | - | - | - | - | - | - | - | - | - | - | - |
| 8 | - | - | - | - | - | - | - | 0 | - | - | - | - | - |
| 9 | - | - | - | - | - | - | - | - | 1 | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - | 1 | - | - | - |
| 11 | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| 12 (BASIC) | - | - | - | - | - | - | - | - | - | - | - | 1/2 | - |
| 12 (ALTN) | - | - | - | - | - | - | - | - | - | - | - | - | 1 |

* - THESE CONNECTION TYPES HAVE STRENGTH LIMITATIONS. THEIR USE IS THEREFORE LIMITED, AND SUCH USE IS A SHOP DECISION ON A CASE BASIS.

THE 'C' DESIGNATION HAS BEEN INDICATED ON BOTH ENDS OF COMPONENTS REQUIRING SAME. DIFFERENT TRANSVERSE CONNECTIONS TYPES MAY BE SELECTED FOR EACH END OF THE COMPONENT. IT IS RECOMMENDED THAT THE DESIGNER INDICATE FLANGE TYPE CONNECTIONS ONLY WHERE THESE ARE ABSOLUTELY REQUIRED, SUCH AS AT CONNECTIONS TO COAMINGS OR EQUIPMENT, AND MAKE ALLOWANCE FOR THE NON-FLANGE TYPE CONNECTIONS ELSEWHERE. IF THE TRANSVERSE SEAMS ARE TO BE WELDED, NO ALLOWANCE IS NECESSARY.

(CONTD ON SH 10)

NATIONAL SHIPBUILDING RESEARCH PROGRAM
RECTANGULAR DUCT STANDARDS
SIZE B | MARAD CONTR 2-36233 | TODD DRAWING NO. 4966-SK-006 | REV
SCALE NONE | SHEET 9 OF 31

## NOTES (CONT'D)

13. TYPE 12 CONNECTION (LATCH TYPE)

WHEN UTILIZING EITHER OF THE LATCH TYPE CONNECTION DESIGNS, CARE MUST BE TAKEN TO ENSURE THAT THE LATCH ITSELF IS LOCATED ONLY ON A COMPONENT WHOSE SIDES ARE FLAT AND PARALLEL TO THE COMPONENT'S CENTERLINE. THIS PROHIBITS ITS USE ON THE CURVING PORTIONS OF AN ELBOW (THE HEEL AND THROAT), AND ON THE SLOPING SIDES OF A TRANSFORMATION. WHILE THIS RESTRICTION IS MAINLY OF INTEREST TO THE FABRICATION ACTIVITIES, IT IS NOTED HEREIN FOR INFORMATION. IT IS ALSO RECOMMENDED THAT THIS TYPE CONNECTION NOT BE UTILIZED ON COMPONENTS WHOSE LARGEST CROSS-SECTIONAL DIMENSION IS GREATER THAN 36".

14. DESIGN GUIDANCE

THE FOLLOWING RECOMMENDATIONS ARE MADE IN ORDER THAT THE VENTILATION SYSTEM DESIGN MINIMIZE FABRICATION AND INSTALLATION COSTS WHEREVER POSSIBLE.

A - EVERY ATTEMPT SHOULD BE MADE TO UTILIZE THE "STANDARD SIZES" AND COMPONENT CONFIGURATIONS SHOWN HEREIN TO MINIMIZE THE REQUIREMENT FOR SPECIAL FITTINGS.

B - WHERE PRESSURE DROP CONSIDERATIONS PERMIT, THE USE OF TRANSFORMATIONS SHOULD BE MINIMIZED AS FOLLOWS:

- USE FLANGE TYPES 1, 3, 4 AND 6 IN LIEU OF FLANGE TYPES 2, 5 AND 7, TO REDUCE THE REQUIREMENT FOR TRANSFORMATION TYPES 2 AND 5.
- WHERE POSSIBLE, COAMING CROSS-SECTIONAL DIMENSIONS SHOULD BE THE SAME AS THE CONNECTING DUCT DIMENSIONS SO THAT THE ABOVE MAY BE ACCOMPLISHED WITHOUT TRANSFORMATION.
- ONE DUCT SIZE SHOULD BE UTILIZED AS MUCH AS POSSIBLE ON ANY PARTICULAR DUCT RUN TO REDUCE THE NECESSITY OF TRANSFORMATIONS.

C - WHERE PRESSURE DROP CONSIDERATIONS PERMIT, THE USE OF AS MANY COMPONENTS OF THE SAME SIZE AND CONFIGURATION ON A PARTICULAR DUCT RUN WILL MINIMIZE PATTERN DEVELOPMENT, AND THE FABRICATION OF MORE COMPONENTS THAN ARE NECESSARY.

D - WHERE PRESSURE DROP CONSIDERATIONS PERMIT, BRANCH TAKE-OFFS SHOULD BE UTILIZED IN LIEU OF DUCT SPLITS.

15. PRESSURE DROP LOSSES - RECOMMENDED DATA SOURCES:

U.S. NAVY DESIGN DATA SHEET DDS 512-1
- ELBOW TYPES 1, 2 AND 3, AND OFFSET TYPES 1 AND 2.
- CONVERGING AND DIVERGING TRANSFORMATIONS.
- MAIN LOSS DUE TO BRANCH TAKE-OFF (MAIN SIZE CHANGING) WITH THE FOLLOWING CORRECTIONS.

ON DISCHARGE SIDE OF FAN

$$\text{LOSS} = \text{NAVY LOSS} \times \left( \frac{\text{BRANCH AIR QUANTITY}}{1/2 \text{ MAIN AIR QUANTITY UPSTREAM OF TAKE-OFF}} \right)$$

(CONTD ON SH 11)

NOTES (CONT'D)

15. (CONT'D)

ON SUCTION SIDE OF FAN

$$\text{LOSS} = \text{NAVY LOSS} \times \left(\frac{\text{BRANCH AIR QUANTITY}}{\text{1/2 MAIN AIR QUANTITY DOWNSTREAM OF TAKE-OFF}}\right)$$

BRANCH AIR QUANTITY SHOULD NOT BE GREATER THAN:
50 PERCENT OF MAIN AIR QUANTITY UPSTREAM OF TAKE-OFF ON DISCHARGE SIDE OF FAN.
50 PERCENT OF MAIN AIR QUANTITY DOWNSTREAM OF TAKE-OFF ON SUCTION SIDE OF FAN.

U. S. NAVY DUCT SIZE FACTOR WHEEL
- STRAIGHT DUCT FRICTION LOSSES.

BUFFALO FORGE COMPANY HANDBOOK "FAN ENGINEERING"
- TYPE 4 ELBOW (VANED), WITH SUITABLE CORRECTION FOR ASPECT RATIO AS GIVEN THEREIN.
- MAIN LOSS DUE TO BRANCH TAKE-OFF (CONSTANT MAIN SIZE) ON SUCTION SIDE OF FAN.

ASHRAE HANDBOOK OF FUNDAMENTALS
- TRANSFORMATIONS - EQUAL AREA.
- ABRUPT ENLARGEMENTS.
- ABRUPT CONTRACTIONS.
- BRANCH TAKE-OFF LOSSES ON DISCHARGE SIDE OF FAN.
- MAIN LOSS DUE TO BRANCH TAKE-OFFS (CONSTANT MAIN SIZE) ON DISCHARGE SIDE OF FAN.

16. COMPONENTS SHOWN HEREIN HAVE BEEN ASSIGNED "APPLICABILITY" RATINGS, AS FOLLOWS. THESE INDICATE THE HIGHEST DEGREE OF APPLICATION IN WHICH THE SPECIFIC COMPONENT MAY BE USED, UNDER THE VARIOUS REGULATORY BODIES. WHERE TWO COMPONENTS OF DIFFERENT "APPLICABILITIES" ARE CONNECTED, THE LOWER RATING MUST BE GIVEN TO THE COMBINATION.

| COMPONENT | MATERIAL | APPLICABILITY |
|---|---|---|
| STRAIGHT DUCT<br>TYPES 1 TO 4 ELBOWS<br>TYPES 1 AND 2 OFFSETS<br>TYPES 1 TO 6 TRANSFORMATIONS | 11 ga OR THICKER | WATERTIGHT<br>CLASS A FIRE PROTECTION<br>RAT PROOF |
| | 16 ga OR 20 ga | NON-WATERTIGHT<br>CLASS B FIRE PROTECTION<br>RAT PROOF |
| TYPES 1 TO 10 BRANCH TAKE-OFFS | 11 ga OR THICKER, WITH THE BRANCH AND MAIN WELDED TOGETHER | WATERTIGHT<br>CLASS A FIRE PROTECTION<br>RAT PROOF |
| | 16 ga OR 20 ga | NON-WATERTIGHT<br>CLASS B FIRE PROTECTION<br>RAT PROOF |

(CONTD ON SH 12)

NOTES (CONT'D)

16. (CONT'D)

| COMPONENT | MATERIAL | APPLICABILITY |
|---|---|---|
| TERMINALS:<br>CONE<br>BELLMOUTH<br>COAMING<br>SIDE-OF-DUCT<br>OPEN-END | -- | TIGHTNESS-NOT APPLICABLE<br>FIRE PROTECTION - NOT APPLICABLE<br>RAT PROOF - ONLY WITH ½" WIRE MESH SCREENING |
| TYPE 1 ACCESS COVER | 11 ga OR THICKER | WATERTIGHT<br>CLASS A FIRE PROTECTION<br>RAT PROOF |
| | 16 ga | NON-WATERTIGHT<br>CLASS B FIRE PROTECTION<br>RAT PROOF |
| TYPE 2 ACCESS COVER | -- | NON-WATERTIGHT<br>CLASS B FIRE PROTECTION<br>RAT PROOF |
| TYPES 1, 2, 3, and 8 TRANSVERSE CONNECTIONS | -- | WATERTIGHT<br>CLASS A FIRE PROTECTION<br>RAT PROOF |
| TYPES 4 TO 7, AND 9 TO 12 TRANSVERSE CONNECTIONS | -- | NON-WATERTIGHT<br>CLASS B FIRE PROTECTION<br>RAT PROOF |
| DUCT REINFORCEMENT | -- | NON-WATERTIGHT<br>CLASS B FIRE PROTECTION<br>RAT PROOF |
| TYPES 1 TO 5 LONGITUDINAL SEAMS | -- | NON-WATERTIGHT<br>CLASS B FIRE PROTECTION<br>RAT PROOF |
| TYPES 6 AND 7 LONGITUDINAL SEAMS | -- | WATERTIGHT<br>CLASS A FIRE PROTECTION<br>RAT PROOF |

STANDARD SIZES, MATERIAL REQUIREMENTS, AND WEIGHTS

| SIZE (INCHES) | MATERIAL REQUIRED PER LINEAR FOOT FOR STRAIGHT DUCT ($FT^2$) | WEIGHT PER LINEAR FOOT (LBS) | | | | |
|---|---|---|---|---|---|---|
| | | GRADE 1 (20 ga) | GRADE 2 (16 ga) | GRADE 3 (11 ga) | GRADE 4 (3/16") | GRADE 5 (1/4") |
| 2 x 4 | 1.0 | 1.66 | - | 5.16 | 7.81 | 10.36 |
| 2 x 6 | 1.33 | 2.20 | - | 6.86 | 10.38 | 13.77 |
| 2 x 8 | 1.67 | 2.77 | - | 8.61 | 13.04 | 17.29 |
| | | | | | | |
| 4 x 4 | 1.33 | 2.20 | - | 6.86 | 10.38 | 13.77 |
| 4 x 6 | 1.67 | 2.77 | - | 8.61 | 13.04 | 17.29 |
| 4 x 8 | 2.0 | 3.31 | - | 10.31 | 15.61 | 20.71 |
| 4 x 10 | 2.33 | 3.86 | - | 12.01 | 18.19 | 24.13 |
| 4 x 12 | 2.67 | 4.42 | - | 13.77 | 20.84 | 27.65 |
| 4 x 14 | 3.0 | 4.97 | - | 15.47 | 23.42 | 31.07 |
| | | | | | | |
| 6 x 6 | 2.0 | 3.31 | - | 10.31 | 15.61 | 20.71 |
| 6 x 8 | 2.33 | 3.86 | - | 12.01 | 18.19 | 24.13 |
| 6 x 10 | 2.67 | 4.42 | - | 13.77 | 20.84 | 27.65 |
| 6 x 12 | 3.0 | 4.97 | - | 15.47 | 23.42 | 31.07 |
| 6 x 14 | 3.33 | 5.51 | - | 17.17 | 25.99 | 34.49 |
| 6 x 16 | 3.67 | 6.08 | - | 18.92 | 28.65 | 38.01 |
| 6 x 18 | 4.0 | 6.62 | - | 20.62 | 31.22 | 41.42 |
| | | | | | | |
| 8 x 8 | 2.67 | 4.42 | - | 13.77 | 20.84 | 27.65 |
| 8 x 10 | 3.0 | 4.97 | - | 15.47 | 23.42 | 31.07 |
| 8 x 12 | 3.33 | 5.51 | - | 17.17 | 25.99 | 34.49 |
| 8 x 14 | 3.67 | 6.08 | - | 18.92 | 28.65 | 38.01 |
| 8 x 16 | 4.0 | 6.62 | - | 20.62 | 31.22 | 41.42 |
| 8 x 18 | 4.33 | 7.17 | - | 22.33 | 33.80 | 44.84 |
| 8 x 20 | 4.67 | 7.73 | - | 24.08 | 36.45 | 48.36 |
| 8 x 22 | 5.0 | 8.28 | - | 25.78 | 39.03 | 51.78 |
| 8 x 24 | 5.33 | 8.83 | - | 27.48 | 41.61 | 55.20 |
| | | | | | | |
| 10 x 10 | 3.33 | 5.51 | - | 17.17 | 25.99 | 34.49 |
| 10 x 12 | 3.67 | 6.08 | - | 18.92 | 28.65 | 38.01 |
| 10 x 14 | 4.0 | 6.62 | - | 20.62 | 31.22 | 41.42 |
| 10 x 16 | 4.33 | 7.17 | - | 22.33 | 33.80 | 44.84 |
| 10 x 18 | 4.67 | 7.73 | - | 24.08 | 36.45 | 48.36 |
| 10 x 20 | 5.0 | 8.28 | - | 25.78 | 39.03 | 51.78 |
| 10 x 22 | 5.33 | 8.83 | - | 27.48 | 41.61 | 55.20 |

STANDARD SIZES, MATERIAL REQUIREMENTS, AND WEIGHTS (CONT'D)

| SIZE (INCHES) | MATERIAL REQUIRED PER LINEAR FOOT FOR STRAIGHT DUCT ($FT^2$) | WEIGHT PER LINEAR FOOT (LBS) | | | | |
|---|---|---|---|---|---|---|
| | | GRADE 1 (20 ga) | GRADE 2 (16 ga) | GRADE 3 (11 ga) | GRADE 4 (3/16") | GRADE 5 (1/4") |
| 10 x 24 | 5.67 | 9.39 | - | 29.23 | 44.26 | 58.72 |
| 10 x 26 | 6.0 | - | 15.94 | 30.94 | 46.84 | 62.14 |
| 10 x 28 | 6.33 | - | 16.81 | 32.64 | 49.41 | 65.55 |
| 10 x 30 | 6.67 | - | 17.72 | 34.39 | 52.07 | 69.07 |
| | | | | | | |
| 12 x 12 | 4.0 | 6.62 | - | 20.62 | 31.22 | 41.42 |
| 12 x 14 | 4.33 | 7.17 | - | 22.33 | 33.80 | 44.84 |
| 12 x 16 | 4.67 | 7.73 | - | 24.08 | 36.45 | 48.36 |
| 12 x 18 | 5.0 | 8.28 | - | 25.78 | 39.03 | 51.78 |
| 12 x 20 | 5.33 | 8.83 | - | 27.48 | 41.61 | 55.20 |
| 12 x 22 | 5.67 | 9.39 | - | 29.23 | 44.26 | 58.72 |
| 12 x 24 | 6.0 | 9.94 | - | 30.94 | 46.84 | 62.14 |
| 12 x 26 | 6.33 | - | 16.81 | 32.64 | 49.41 | 65.55 |
| 12 x 28 | 6.67 | - | 17.72 | 34.39 | 52.07 | 69.07 |
| 12 x 30 | 7.0 | - | 18.59 | 36.09 | 54.64 | 72.49 |
| 12 x 32 | 7.33 | - | 19.47 | 37.79 | 57.22 | 75.91 |
| 12 x 34 | 7.67 | - | 20.37 | 39.55 | 59.87 | 79.43 |
| 12 x 36 | 8.0 | - | 21.25 | 41.25 | 62.45 | 82.85 |
| | | | | | | |
| 14 x 14 | 4.67 | 7.73 | - | 24.08 | 36.45 | 48.36 |
| 14 x 16 | 5.0 | 8.28 | - | 25.78 | 39.03 | 51.78 |
| 14 x 18 | 5.33 | 8.83 | - | 27.48 | 41.61 | 55.20 |
| 14 x 20 | 5.67 | 9.39 | - | 29.23 | 44.26 | 58.72 |
| 14 x 22 | 6.0 | 9.94 | - | 30.94 | 46.84 | 62.14 |
| 14 x 24 | 6.33 | 10.48 | - | 32.64 | 49.41 | 65.55 |
| 14 x 26 | 6.67 | - | 17.72 | 34.39 | 52.07 | 69.07 |
| 14 x 28 | 7.0 | - | 18.59 | 36.09 | 54.64 | 72.49 |

| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| B | 2-36233 | 4966-SK-006 | |
| SCALE NONE | | SHEET 13 OF 31 | |

STANDARD SIZES, MATERIAL REQUIREMENTS, AND WEIGHTS (CONT'D)

| SIZES (INCHES) | MATERIAL REQUIRED PER LINEAR FOOT FOR STRAIGHT DUCT ($FT^2$) | WEIGHT PER LINEAR FOOT (LBS) | | | | |
|---|---|---|---|---|---|---|
| | | GRADE 1 (20 ga) | GRADE 2 (16 ga) | GRADE 3 (11 ga) | GRADE 4 (3/16") | GRADE 5 (1/4") |
| 14 x 30 | 7.33 | - | 19.47 | 37.79 | 57.22 | 75.91 |
| 14 x 32 | 7.67 | - | 20.37 | 39.55 | 59.87 | 79.43 |
| 14 x 34 | 8.0 | - | 21.25 | 41.25 | 62.45 | 82.85 |
| 14 x 36 | 8.33 | - | 22.12 | 42.95 | 65.02 | 86.27 |
| 14 x 38 | 8.67 | - | 23.03 | 44.70 | 67.68 | 89.79 |
| 14 x 40 | 9.0 | - | 23.90 | 46.40 | 70.25 | 93.20 |
| 14 x 42 | 9.33 | - | 24.78 | 48.11 | 72.83 | 96.62 |
| | | | | | | |
| 16 x 16 | 5.33 | 8.83 | - | 27.48 | 41.61 | 55.20 |
| 16 x 18 | 5.67 | 9.39 | - | 29.23 | 44.26 | 58.72 |
| 16 x 20 | 6.0 | 9.94 | - | 30.94 | 46.84 | 62.14 |
| 16 x 22 | 6.33 | 10.48 | - | 32.64 | 49.41 | 65.55 |
| 16 x 24 | 6.67 | 11.05 | - | 34.39 | 52.07 | 69.07 |
| 16 x 26 | 7.0 | - | 18.59 | 36.09 | 54.64 | 72.49 |
| 16 x 28 | 7.33 | - | 19.47 | 37.79 | 57.22 | 75.91 |
| 16 x 30 | 7.67 | - | 20.37 | 39.55 | 59.87 | 79.43 |
| 16 x 32 | 8.0 | - | 21.25 | 41.25 | 62.45 | 82.85 |
| 16 x 34 | 8.33 | - | 22.12 | 42.95 | 65.02 | 86.27 |
| 16 x 36 | 8.67 | - | 23.03 | 44.70 | 67.68 | 89.79 |
| 16 x 38 | 9.0 | - | 23.90 | 46.40 | 70.25 | 93.20 |
| 16 x 40 | 9.33 | - | 24.78 | 48.11 | 72.83 | 96.62 |
| 16 x 42 | 9.67 | - | 25.68 | 49.86 | 75.48 | 100.14 |
| 16 x 44 | 10.0 | - | 26.56 | 51.56 | 78.06 | 103.56 |
| 16 x 46 | 10.33 | - | 27.44 | 53.26 | 80.64 | 106.98 |
| 16 x 48 | 10.67 | - | 28.34 | 55.01 | 83.29 | 110.50 |
| | | | | | | |
| 18 x 18 | 6.0 | 9.94 | - | 30.94 | 46.84 | 62.14 |
| 18 x 20 | 6.33 | 10.48 | - | 32.64 | 49.41 | 65.55 |
| 18 x 22 | 6.67 | 11.05 | - | 34.39 | 52.07 | 69.07 |
| 18 x 24 | 7.0 | 11.59 | - | 36.09 | 54.64 | 72.49 |
| 18 x 26 | 7.33 | - | 19.47 | 37.79 | 57.22 | 75.91 |
| 18 x 28 | 7.67 | - | 20.37 | 39.55 | 59.87 | 79.43 |
| 18 x 30 | 8.0 | - | 21.25 | 41.25 | 62.45 | 82.85 |
| 18 x 32 | 8.33 | - | 22.12 | 42.95 | 65.02 | 86.27 |
| 18 x 34 | 8.67 | - | 23.03 | 44.70 | 67.68 | 89.79 |
| 18 x 36 | 9.0 | - | 23.90 | 46.40 | 70.25 | 93.20 |

STANDARD SIZES, MATERIAL REQUIREMENTS, AND WEIGHTS (CONT'D)

| SIZE (INCHES) | MATERIAL REQUIRED PER LINEAR FOOT FOR STRAIGHT DUCT ($FT^2$) | WEIGHT PER LINEAR FOOT (LBS) | | | | |
|---|---|---|---|---|---|---|
| | | GRADE 1 (20 ga) | GRADE 2 (16 ga) | GRADE 3 (11 ga) | GRADE 4 (3/16") | GRADE 5 (1/4") |
| 18 x 38 | 9.33 | - | 24.78 | 48.11 | 72.83 | 96.62 |
| 18 x 40 | 9.67 | - | 25.68 | 49.86 | 75.48 | 100.14 |
| 18 x 42 | 10.0 | - | 26.56 | 51.56 | 78.06 | 103.56 |
| 18 x 44 | 10.33 | - | 27.44 | 53.26 | 80.64 | 106.98 |
| 18 x 46 | 10.67 | - | 28.34 | 55.01 | 83.29 | 110.50 |
| 18 x 48 | 11.0 | - | 29.22 | 56.72 | 85.87 | 113.92 |
| 18 x 50 | 11.33 | - | 30.09 | 58.42 | 88.44 | 117.33 |
| 18 x 52 | 11.67 | - | 31.0 | 60.17 | 91.10 | 120.85 |
| 18 x 54 | 12.0 | - | 31.87 | 61.87 | 93.67 | 124.27 |
| | | | | | | |
| 20 x 20 | 6.67 | 11.05 | - | 34.39 | 52.07 | 69.07 |
| 20 x 22 | 7.0 | 11.59 | - | 36.09 | 54.64 | 72.49 |
| 20 x 24 | 7.33 | 12.14 | - | 37.79 | 57.22 | 75.91 |
| | | | | | | |
| 22 x 22 | 7.33 | 12.14 | - | 37.79 | 57.22 | 75.91 |
| 22 x 24 | 7.67 | 12.70 | - | 39.55 | 59.87 | 79.43 |
| | | | | | | |
| 24 x 24 | 8.0 | 13.25 | - | 41.25 | 62.45 | 82.85 |

ALL WEIGHTS ARE BASED ON GALVANIZED STEEL (EITHER BEFORE OR AFTER FABRICATION).

MATERIAL QUANTITIES AND WEIGHTS AS LISTED ARE BASED ON WELDED LONGITUDINAL SEAMS. IF THE 20 ga AND 16 ga DUCTS ARE TO HAVE EITHER PITTSBURGH SEAMS, OR SNAP-LOCK SEAMS, THE FOLLOWING CORRECTIONS SHOULD BE MADE:

20 ga — ADD .15 $FT^2$ OF MATERIAL FOR EACH LINEAR FOOT OF SEAM.
— ADD .25 LBS FOR EACH LINEAR FOOT OF SEAM.
16 ga — ADD .15 $FT^2$ OF MATERIAL FOR EACH LINEAR FOOT OF SEAM.
— ADD .40 LBS FOR EACH LINEAR FOOT OF SEAM.

SEE NOTE NO. 3 FOR EXPLANATION OF THE VARIOUS GRADE MATERIALS.

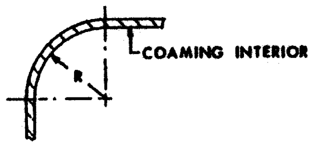
NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS

| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
|---|---|---|---|
| [illegible] | 2-36233 | 4966-SK-006 | |
| REV | SCALE NONE | SHEET 14 OF 31 | |

## RADIUS CORNER SELECTION

THE FOLLOWING TABLE HAS BEEN PREPARED FOR THE PURPOSE OF SELECTING THE RADIUS CORNERS REQUIRED FOR COAMINGS PENETRATING STRUCTURE AND IT IS INTENDED THAT IT BE UTILIZED FOR ALL SUCH PENETRATIONS.




| SMALL CROSS-SECTIONAL DIMENSION OF COAMING D OR W (INCHES) | AVAILABLE RADIUS CORNERS (INCHES) | | | |
|---|---|---|---|---|
| | R1 | R2 | R3 | R4 |
| 2 | 1 | - | - | - |
| 4 | 1 | 2 | - | - |
| 6 | 1 | 3 | - | - |
| 8 | 1 | 2 | 4 | - |
| 10 | 2 | 3 | 5 | - |
| 12 | 2 | 4 | 6 | - |
| 14 | 2 | 4 | 7 | - |
| 16 | 2 | 4 | 6 | 8 |
| 18 | 3 | 5 | 7 | 9 |
| 20 | 3 | 5 | 7 | 10 |
| 22 | 3 | 6 | 8 | 11 |
| 24 | 3 | 6 | 9 | 12 |

WHERE:
R1=THE MINIMUM RADIUS CORNER FOR THE DUCT SIZE GIVEN AND SHOULD BE UTILIZED IN ALL CASES UNLESS STRUCTURAL STRENGTH CONSIDERATIONS REQUIRE A LARGER RADIUS.

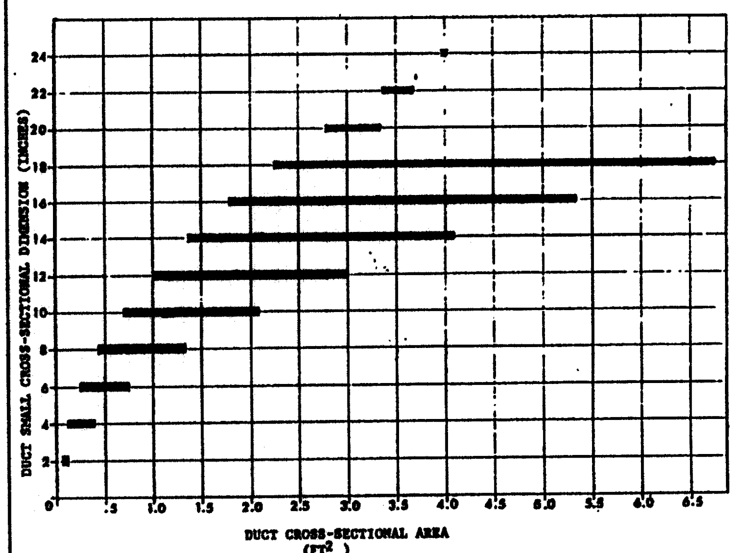
R2,R3,R4=OTHER RADIUS CORNERS AVAILABLE FOR THE DUCT SIZE GIVEN. WHERE STRUCTURAL CONSIDERATIONS REQUIRE THAT A RADIUS LARGER THAN R1 BE USED, THE SMALLEST ACCEPTABLE R SHOULD BE SELECTED FROM THESE.

THE USE OF THE SMALLEST ACCEPTABLE R IS RECOMMENDED, TO ALLOW THE ELIMINATION OF SPECIAL TRANSFORMATIONS BETWEEN THE COAMING AND DUCT.

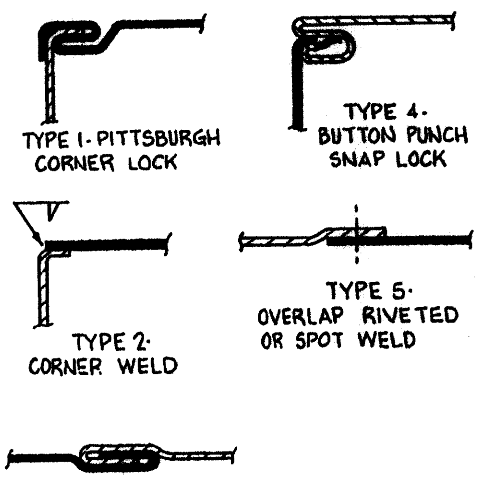
ALL RADIUS CORNERS USED MUST BE IN WHOLE NUMBERS (1", 2", 3", ETC), TO SUIT THE FLANGE BOLTING PATTERNS.

## CROSS-SECTIONAL AREAS

THE FOLLOWING CHART DEPICTS THE EXTENT OF AREA VARIATION FOR THE STANDARD DUCT SIZES, AND HAS BEEN INCLUDED FOR REFERENCE PURPOSES. THE VERTICAL AXIS REPRESENTS THE DUCT SMALL CROSS-SECTIONAL DIMENSION. THE HEAVY HORIZONTAL LINES INDICATE THE RANGE OF CROSS-SECTIONAL AREA OBTAINABLE BY HOLDING THE SMALL DIMENSION CONSTANT, AND PERMITTING THE OTHER DIMENSION TO VARY OVER THE INCREMENTAL SIZE CHANGES ALLOWED BY THE TABLE OF "STANDARD SIZES, MATERIAL REQUIREMENTS AND WEIGHTS".




| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| ■ | 2-36233 | 4966-SK-006 | |
| SCALE NONE | | SHEET 15 OF 31 | |



TYPE 1- PITTSBURGH CORNER LOCK

TYPE 4- BUTTON PUNCH SNAP LOCK

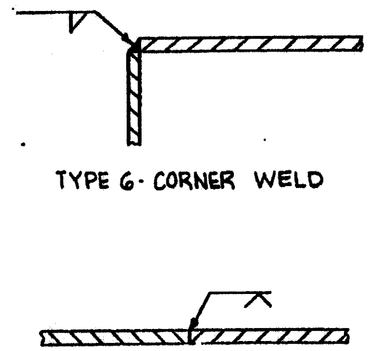
TYPE 2- CORNER WELD

TYPE 5- OVERLAP RIVETED OR SPOT WELD

TYPE 3- DOUBLE SEAM

LONGITUDINAL SEAMS
(NON-WATERTIGHT)

SHOWN FOR INFO ONLY-SEAM TYPE IS SHOP DECISION.

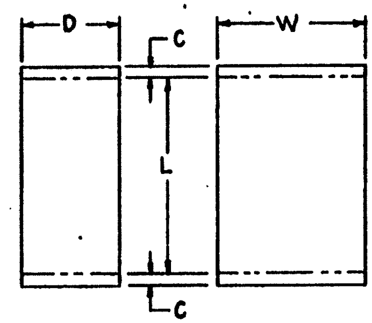


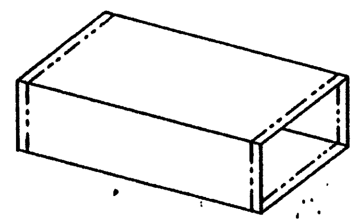
TYPE 6- CORNER WELD

TYPE 7- BUTT WELD

LONGITUDINAL SEAMS
(WATERTIGHT)

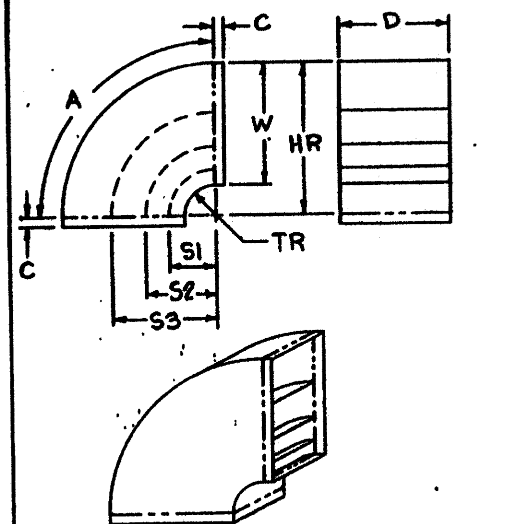
SHOWN FOR INFO ONLY- SEAM TYPE IS SHOP DECISION.



STRAIGHT DUCT

| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| B | 2-36233 | 4966-SK-006 | |
| SCALE NONE | | SHEET 16 OF 31 | |




TYPE 3 ELBOW

(QUARTER-THROAT RADIUS)

NUMBER OF SPLITTERS = 0 OR 3

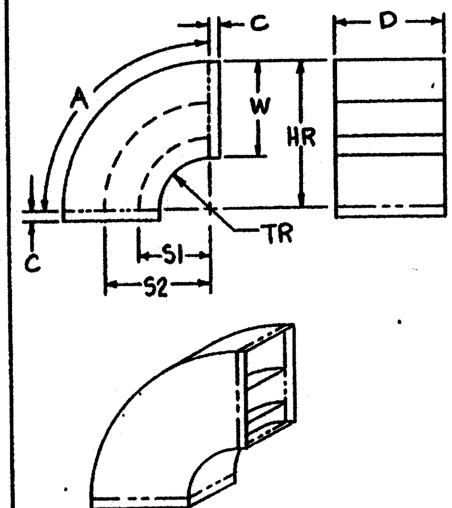
TR=W/4 MINIMUM W=8" HR=W+TR

A (WITHOUT SPLITTERS)=15°, 30°, 45°, 60°, 75°, 90°.

A (WITH SPLITTERS)=45°, 60°, 75°, 90°.

PREFERRED USAGE:

WHERE SPACE AND PRESSURE-DROP CONSIDERATIONS REQUIRE. SEE NOTE 5, OR REF 1, FOR SPLITTER RADII S1, S2, AND S3.




TYPE 2 ELBOW

(HALF-THROAT RADIUS)

NUMBER OF SPLITTERS = 0 OR 2.

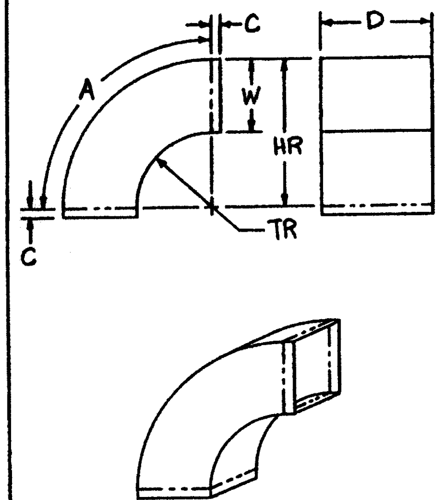
TR=W/2 MINIMUM W=4" HR=W+TR

A (WITHOUT SPLITTERS)=15°, 30°, 45°, 60°, 75°, 90°.

A (WITH SPLITTERS)= 30°, 45°, 60°, 75°, 90°.

PREFERRED USAGE:

WHERE SPACE AND PRESSURE-DROP CONSIDERATIONS REQUIRE. SEE NOTE 5, OR REF 1, FOR SPLITTER RADII S1 AND S2.




TYPE 1 ELBOW

(FULL-THROAT RADIUS)

NUMBER OF SPLITTERS = 0

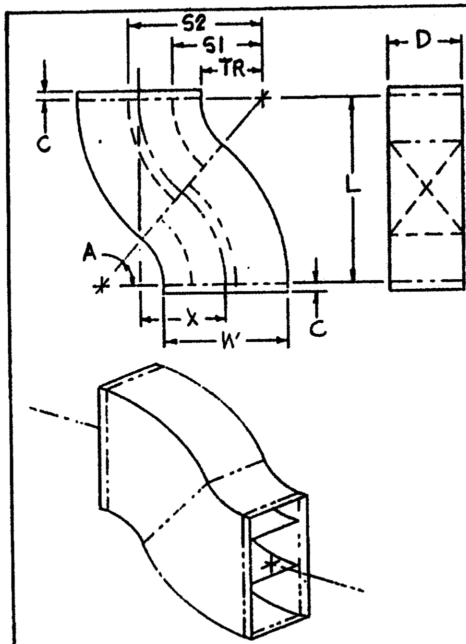
TR=W HR=W+TR

A= 15°, 30°, 45°, 60°, 75°, 90°.

PREFERRED USAGE:

IN ALL CASES WHERE SPACE AND PRESSURE-DROP CONSIDERATIONS ALLOW.

| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| B | 2-36233 | 4966-SK-006 | |
| SCALE | NONE | SHEET 17 OF 31 | |

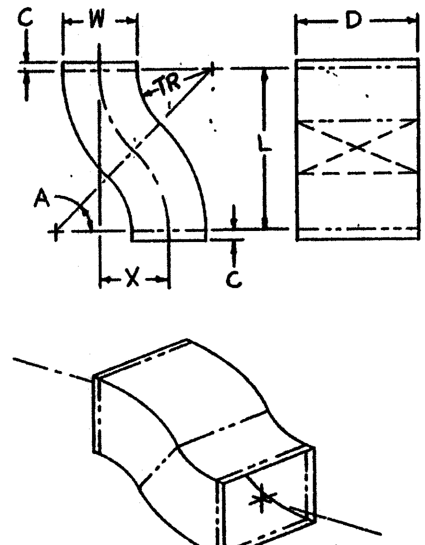



TYPE 2 OFFSET
(HALF THROAT RADII)

NUMBER OF SPLITTERS = 0 OR 2. TR = W/2. MIN W = 4". X = CENTERLINE OFFSET IN ONE-INCH INCREMENTS UP TO 2W MAX. MIN A (WITHOUT SPLITTERS): 15°. MIN A (WITH SPLITTERS) = 30°. L = $\sqrt{(4 \cdot W - X) X}$

PREFERRED USAGE:

WHERE OFFSET IS DESIRED AND SPACE AVAILABILITY DOES NOT PERMIT FULL-THROAT ELBOWS. SEE NOTE 7 FOR LIMITATIONS. SEE NOTE 5, OR REF 1, FOR SPLITTER RADII S1 AND S2.

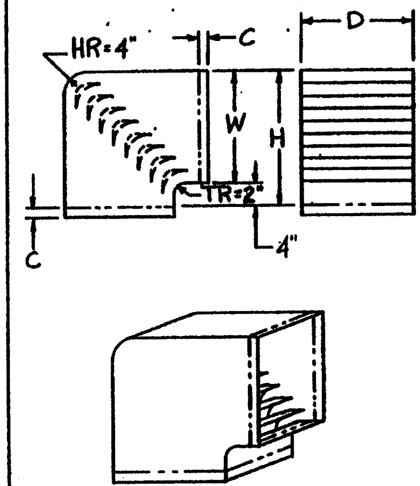



TYPE 1 OFFSET
(FULL-THROAT RADII)

NUMBER OF SPLITTERS = O. TR = W. X = CENTERLINE OFFSET IN ONE-INCH INCREMENTS UP TO 3W MAX. MINIMUM A = 15°. L = $\sqrt{(6W-X)X}$

PREFERRED USAGE:

IN ALL CASES WHERE OFFSET IS REQUIRED AND SPACE AVAILABILITY PERMITS FULL-THROAT ELBOWS. SEE NOTE 7 FOR LIMITATIONS.




TYPE 4 ELBOW
(VANED)

DOUBLE WALL VANES, VANE SPACING = 2". H = W + 4", ANGLE OF TURN = 90° ONLY. MINIMUM W = 4". MINIMUM D = 4".

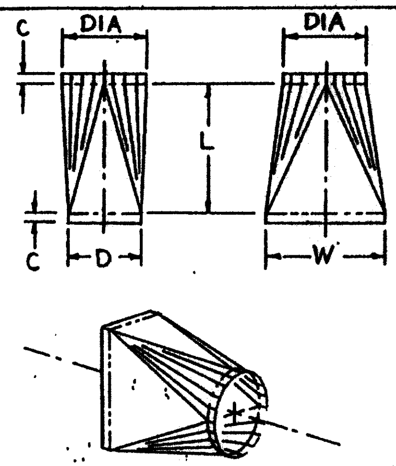
PREFERRED USAGE:

ONLY WHERE STABILIZATION OF AIR FLOW DOWNSTREAM OF TURN IS REQUIRED. SEE NOTE 6 FOR VANE INFORMATION AND LIMITATIONS.

NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS

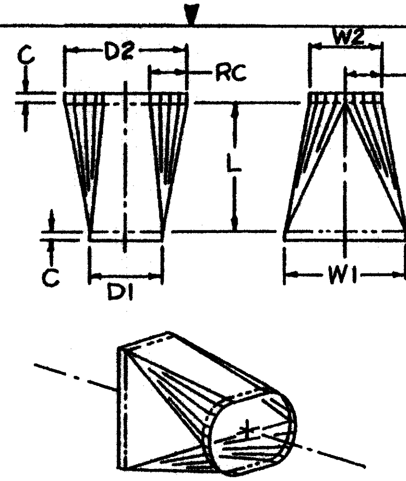
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
|---|---|---|---|
| B | 2-36233 | 4966-SK-006 | |
| REV | SCALE NONE | | SHEET 18 OF 31 |




## TYPE 3 TRANSFORMATION
(SYMMETRICAL)

**PREFERRED USAGE:**

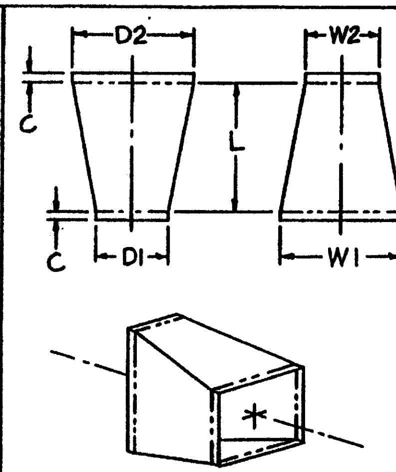
IN ALL CASES WHERE TRANSFORMATION IS REQUIRED BETWEEN RECTANGULAR AND ROUND COMPONENTS.
SEE NOTE 8 FOR LIMITATIONS.




## TYPE 2 TRANSFORMATION
(SYMMETRICAL)

**PREFERRED USAGE:**

ONLY WHERE PRESSURE-DROP CONSIDERATIONS DO NOT ALLOW USE OF FLANGE TYPES 3, AND 1, 4, OR 6 BETWEEN RECTANGULAR AND FLAT-OVAL OR RADIUS CORNER COMPONENTS.
SEE NOTE 8 FOR LIMITATIONS.

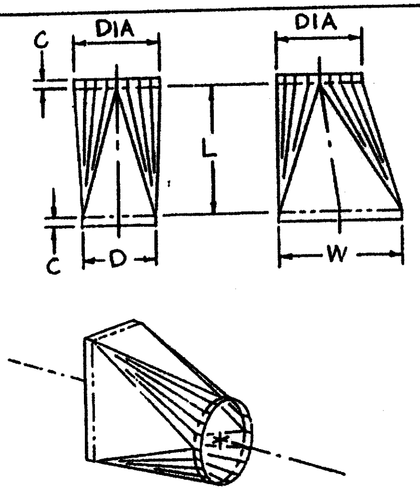



## TYPE 1 TRANSFORMATION
(SYMMETRICAL)

**PREFERRED USAGE:**

IN ALL CASES WHERE TRANSFORMATION IS REQUIRED BETWEEN RECTANGULAR COMPONENTS.
SEE NOTE 8 FOR LIMITATIONS.

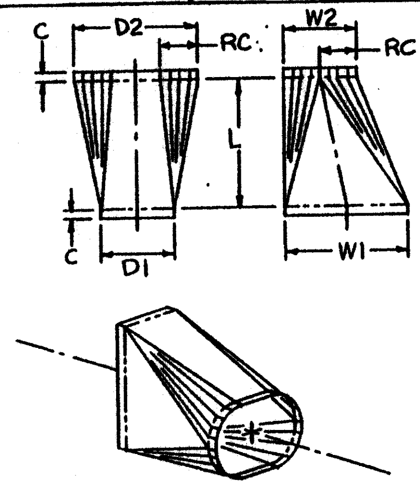
| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| B | 2-36233 | 4966-SK-006 | |
| SCALE NONE | | | SHEET 19 OF 31 |




TYPE 6 TRANSFORMATION
(FLAT-SIDED)

PREFERRED USAGE:

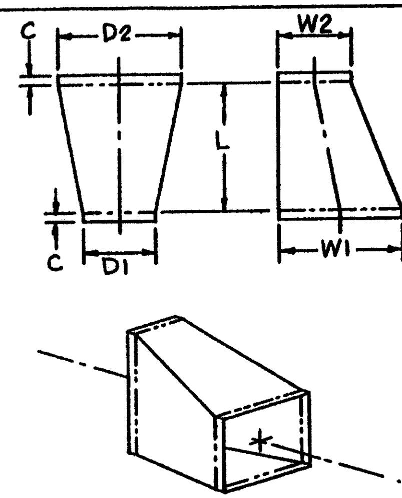
IN ALL CASES WHERE TRANSFORMATION IS REQUIRED BETWEEN RECTANGULAR AND ROUND COMPONENTS AND SPACE AVAILABILITY REQUIRES THAT ONE SIDE BE KEPT FLAT.
SEE NOTE 8 FOR LIMITATIONS.




TYPE 5 TRANSFORMATION
(FLAT-SIDED)

PREFERRED USAGE:

ONLY WHERE PRESSURE-DROP CONSIDERATIONS DO NOT ALLOW USE OF FLANGE TYPES 3, AND 1, 4, OR 6 BETWEEN RECTANGULAR AND FLAT-OVAL OR RADIUS CORNER COMPONENTS, IN COMBINATION WITH TYPE 4 TRANSFORMATION.
SEE NOTE 8 FOR LIMITATIONS.

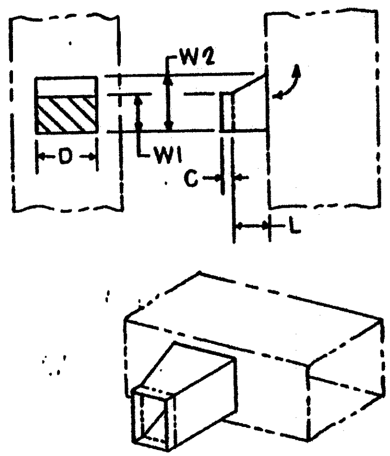



TYPE 4 TRANSFORMATION
(FLAT-SIDED)

PREFERRED USAGE:

IN ALL CASES WHERE TRANSFORMATION IS REQUIRED BETWEEN RECTANGULAR COMPONENTS AND SPACE AVAILABILITY REQUIRES THAT ONE SIDE BE KEPT FLAT.
SEE NOTE 8 FOR LIMITATIONS.

| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| B | 2-36233 | 4966-SK-006 | |
| SCALE NONE | | SHEET 20 OF 31 | |

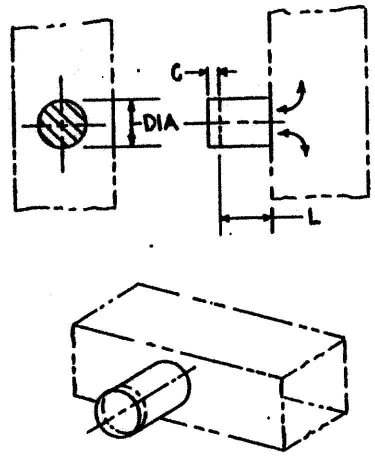



TYPE 3 BRANCH TAKE-OFF

RECT BRANCH - FLARED
RECT MAIN (CONSTANT SIZE)
TAKE-OFF ANGLE = 90°

W2 = 1.5 W1    L = .5 W1 (2.5" MIN)

SEE NOTE 9 FOR
FURTHER INFO.

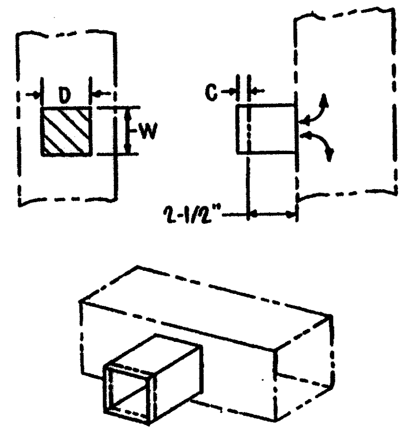



TYPE 2 BRANCH TAKE-OFF

ROUND BRANCH
RECT MAIN (CONSTANT SIZE)
TAKE-OFF ANGLE = 90°

SEE ROUND DUCT STANDARDS
FOR DIMENSIONS C AND L.

SEE NOTE 9 FOR
FURTHER INFO.




TYPE 1 BRANCH TAKE-OFF

RECT BRANCH
RECT MAIN (CONSTANT SIZE)
TAKE-OFF ANGLE = 90°

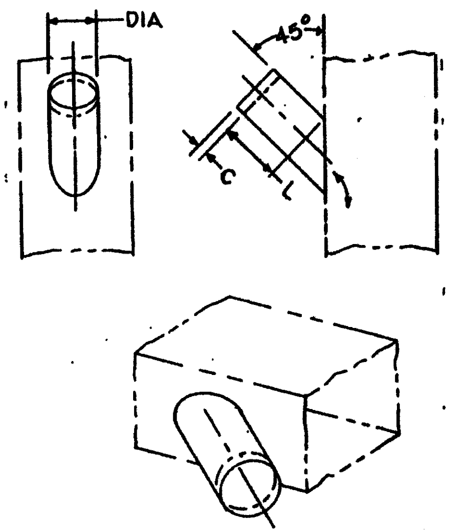
SEE NOTE 9 FOR
FURTHER INFO.

NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR-DUCT STANDARDS

| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
|---|---|---|---|
| ■ | 2-36233 | 4966-SK-006 | |

REV | SCALE NONE | SHEET 21 OF 31

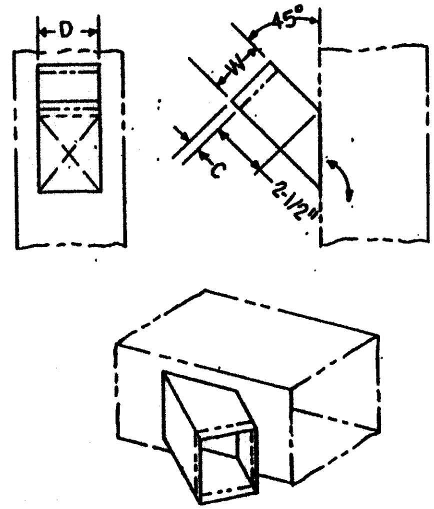



**TYPE 6 BRANCH TAKE-OFF**

ROUND BRANCH
RECT MAIN (CONSTANT SIZE)
TAKE-OFF ANGLE = 45°

SEE ROUND DUCT STANDARDS
FOR DIMENSIONS C AND L.

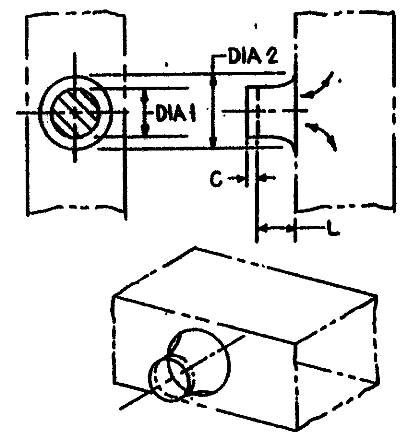
SEE NOTE 9 FOR
FURTHER INFO.




**TYPE 5 BRANCH TAKE-OFF**

RECT BRANCH
RECT MAIN (CONSTANT SIZE)
TAKE-OFF ANGLE = 45°

SEE NOTE 9 FOR
FURTHER INFO.



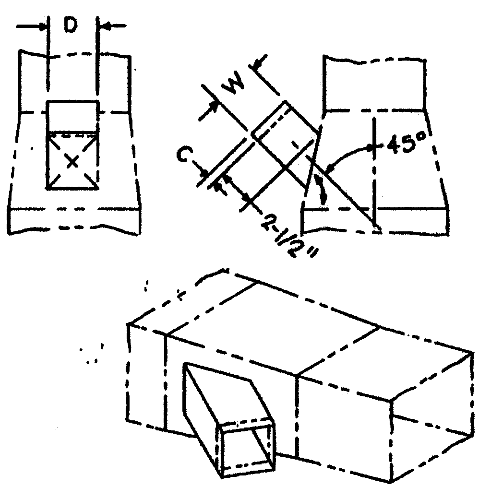

**TYPE 4 BRANCH TAKE-OFF**

ROUND BRANCH (FLARED)
RECT MAIN (CONSTANT SIZE)
TAKE-OFF ANGLE = 90°

SEE ROUND DUCT STANDARDS
FOR DIMENSIONS C, L, AND DIA 2.

SEE NOTE 9 FOR FURTHER INFO.

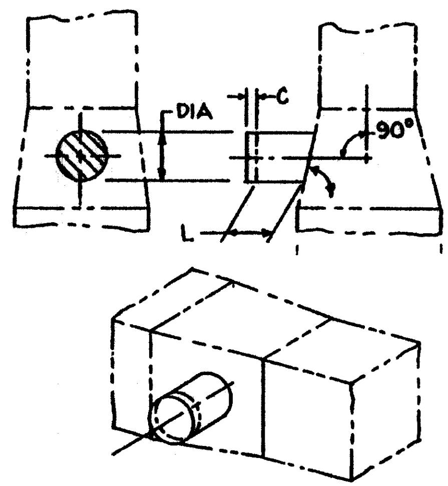
| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| ■ | 2-36233 | 4966-SK-006 | |
| SCALE | NONE | | SHEET 22 OF 31 |




TYPE 9 BRANCH TAKE-OFF

RECT BRANCH
RECT MAIN (TRANSFORMING)
TAKE-OFF ANGLE = 45°

SEE NOTE 9 FOR FURTHER INFO.

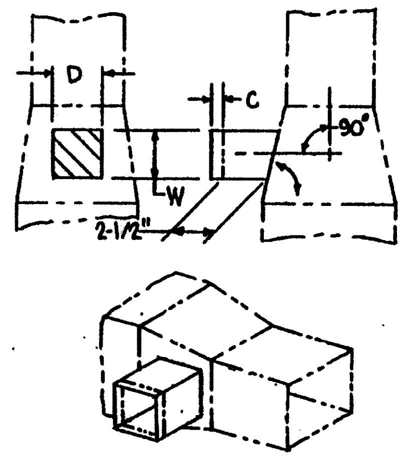



TYPE 8 BRANCH TAKE-OFF

ROUND BRANCH
RECT MAIN (TRANSFORMING)
TAKE-OFF ANGLE = 90°

SEE ROUND DUCT STANDARDS FOR DIMENSIONS C AND L.

SEE NOTE 9 FOR FURTHER INFO.

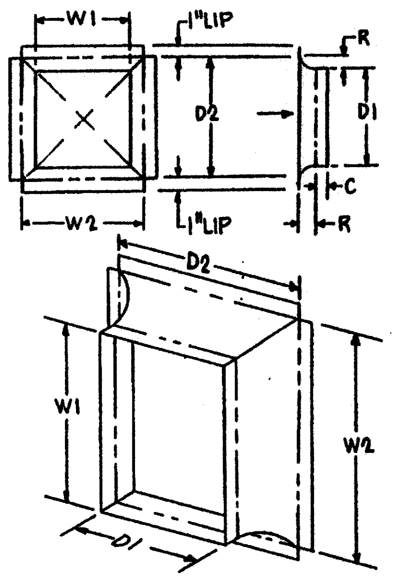



TYPE 7 BRANCH TAKE-OFF

RECT BRANCH
RECT MAIN (TRANSFORMING)
TAKE-OFF ANGLE = 90°

SEE NOTE 9 FOR FURTHER INFO.

| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| ■ | 2-36233 | 4966-SK-006 | |
| SCALE | NONE | SHEET 23 OF 51 | |

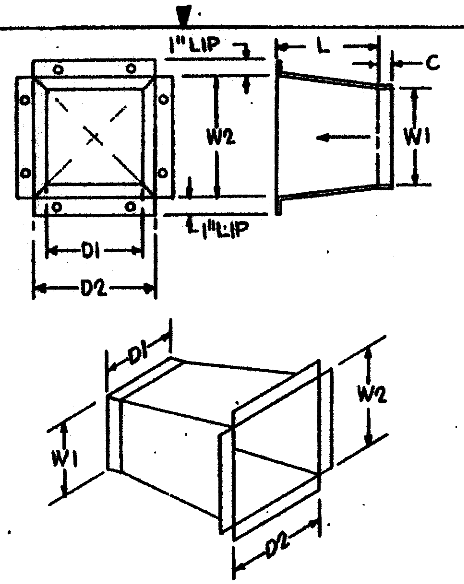



TYPE 2 TERMINAL - BELLMOUTH

D1 AND W1 = DUCT DIMENSIONS
D2 = D1 + 2R W2 = W1 + 2R

CLEARANCE FOR ONE-INCH LIP REQUIRED ONLY FOR WIRE MESH INSTALLATION.

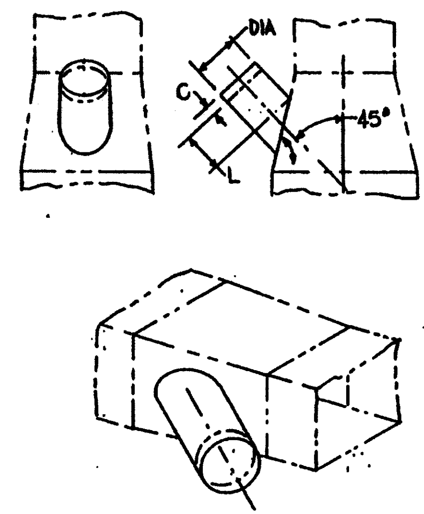
| LARGEST OF DIMENSIONS D1 OR W1 (INCHES) | R (INCHES) |
|---|---|
| 2-8 | 1 |
| 9-16 | 2 |
| 17-24 | 3 |
| 25-32 | 4 |
| 33-40 | 5 |
| 41-48 | 6 |
| 49-54 | 7 |




TYPE 1 TERMINAL - CONE

D1 AND W1 = DUCT DIMENSIONS.
D2 AND W2 = TERMINAL OPENING DIMENSIONS (WHOLE INCHES ONLY - NO FRACTIONS).

CLEARANCE FOR ONE-INCH LIP REQUIRED ONLY FOR WIRE MESH INSTALLATION.




TYPE 10 BRANCH TAKE-OFF:
ROUND BRANCH
RECT MAIN (TRANSFORMING)
TAKE-OFF ANGLE = 45°

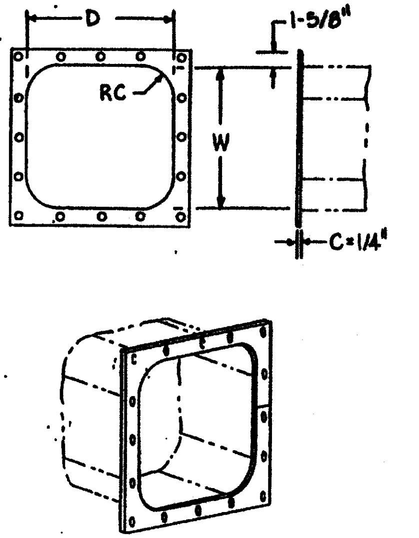
SEE ROUND DUCT STANDARDS FOR DIMENSIONS C AND L.

SEE NOTE 9 FOR FURTHER INFO.

NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS

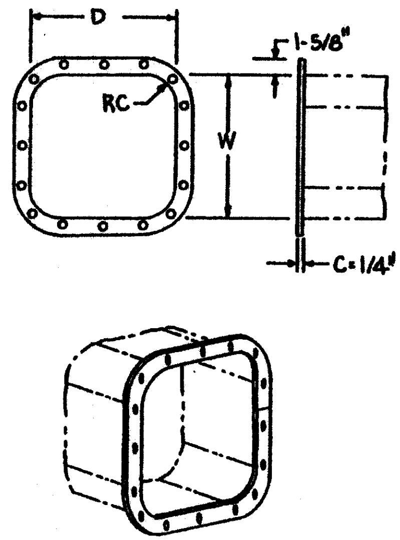
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
|---|---|---|---|
| ■ | 2-36233 | 4966-SK-006 | |
| SCALE | NONE | SHEET 24 OF 31 | |




TYPE 3 TRANSVERSE CONNECTION
(FLANGED TYPE)

FOR INSTALLATION ON FLAT-OVAL OR RADIUS CORNER COAMINGS.

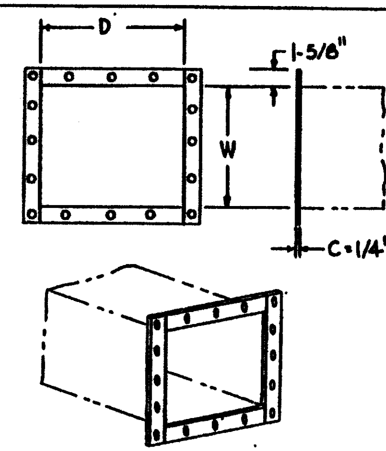
PREFERRED USAGE:
IN ALL CASES, UNLESS UNACCEPTABLE PRESSURE DROP LOSSES RESULT. USE OF THIS CONNECTION TYPE IS TO BE MAXIMIZED.




TYPE 2 TRANSVERSE CONNECTION
(FLANGED TYPE)

FOR INSTALLATION ON FLAT-OVAL OR RADIUS CORNER COAMINGS.

PREFERRED USAGE:
ONLY WHERE USE OF TYPE 3 FLANGE IS IMPRACTICAL DUE TO UNACCEPTABLE PRESSURE DROP LOSS. USE OF THIS CONNECTION TYPE IS TO BE MINIMIZED.




TYPE 1 TRANSVERSE CONNECTION
(FLANGED TYPE)

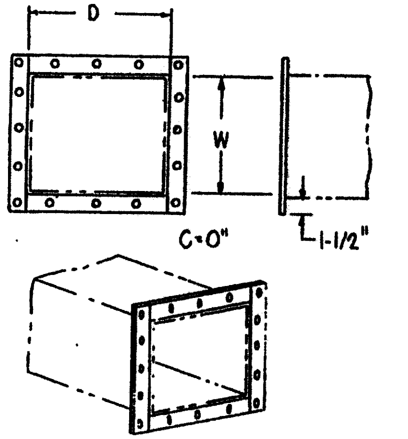
FOR INSTALLATION ON COMPONENTS MEETING CLASS 'A' FIRE PROTECTION REQUIREMENTS, AND ON WATERTIGHT COMPONENTS.

PREFERRED USAGE:
WITH TYPE 3 FLANGE WHEN CONNECTING TO FLAT-OVAL OR RADIUS CORNER COAMINGS, AND FOR CONNECTING TO FLANGE TYPE 1, 4, AND 6.

NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS

| SIZE | MARAD CONT# | TODD DRAWING NO. | REV |
|---|---|---|---|
| B | 2-36233 | A966-SK-006 | |
| SCALE NONE | | SHEET 25 OF 31 | |

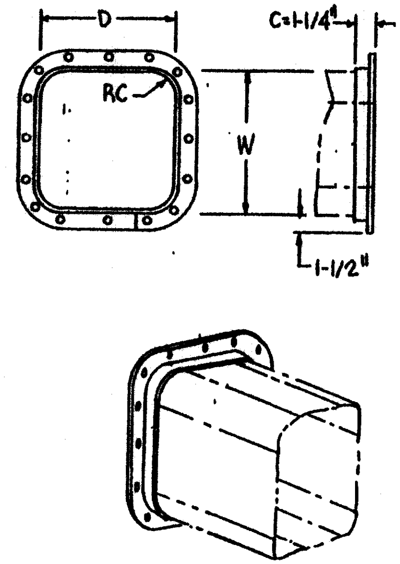



## TYPE 6 TRANSVERSE CONNECTION
(FLANGED TYPE)

FOR INSTALLATION ON NON-WATERTIGHT COMPONENTS NOT REQUIRED TO MEET CLASS 'A' FIRE PROTECTION REQUIREMENTS.

PREFERRED USAGE:

FOR CONNECTION TO EQUIPMENT AND TO FLANGE TYPES 1, 3, 4, AND 6. NOT TO BE USED WHERE CONNECTED COMPONENTS WILL BE SUBJECT TO TENSILE STRESS DURING OR AFTER INSTALLATION. UTILIZATION OF THIS TYPE IS SHOP DECISION.

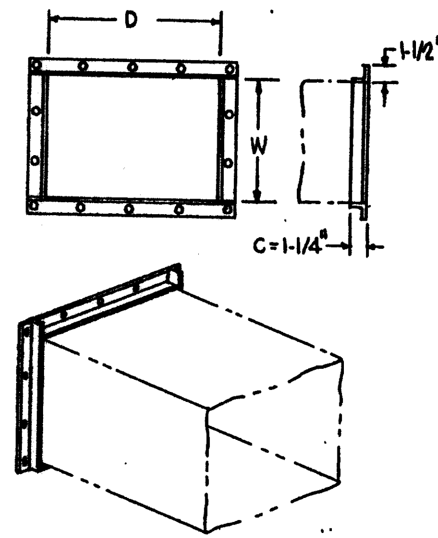



## TYPE 5 TRANSVERSE CONNECTION
(FLANGED TYPE)

FOR INSTALLATION ON NON-WATERTIGHT COMPONENTS WITH RADIUS CORNERS NOT REQUIRED TO MEET CLASS 'A' FIRE PROTECTION REQUIREMENTS.

PREFERRED USAGE:

ONLY WHEN CONNECTING TO FLANGE TYPE 2. USE SHALL BE MINIMIZED IN FAVOR OF FLANGE TYPES 3, 4 OR 6, WHERE PRESSURE DROP CONSIDERATIONS ALLOW.



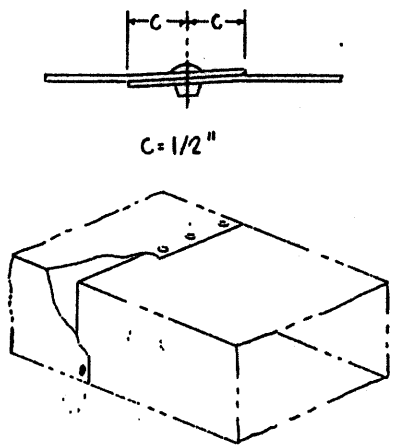

## TYPE 4 TRANSVERSE CONNECTION
(FLANGED TYPE)

FOR INSTALLATION ON NON-WATERTIGHT COMPONENTS NOT REQUIRED TO MEET CLASS 'A' FIRE PROTECTION REQUIREMENTS.

PREFERRED USAGE:

FOR CONNECTION TO EQUIPMENT, AND TO FLANGE TYPES 1, 3, 4, AND 6.

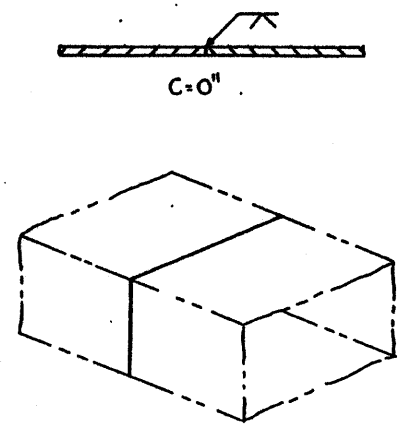
| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| ■ | 2-36233 | 4966-SK-006 | |
| SCALE | NONE | | SHEET 26 OF 31 |




TYPE 5 TRANSVERSE CONNECTION
(NON-FLANGED, OVERLAP RIVETED)

FOR CONNECTION OF NON-WATERTIGHT COMPONENTS NOT REQUIRED TO MEET CLASS 'A' FIRE PROTECTION REQUIREMENTS.

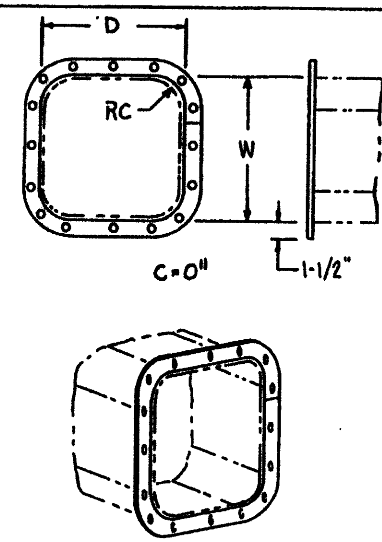
PREFERRED USAGE:
WHERE USE OF FLANGE TYPES 4 OR 6 IS NOT NECESSARY, AND WHERE PORTABILITY IS NOT REQUIRED. CHOICE BETWEEN THIS TYPE AND TYPES 10, 11, AND 12 IS SHOP DECISION




TYPE 8 TRANSVERSE CONNECTION
(NON-FLANGED, WELDED)

FOR CONNECTION OF WATERTIGHT COMPONENTS, AND OF COMPONENTS MEETING CLASS "A" FIRE PROTECTION REQUIREMENTS.

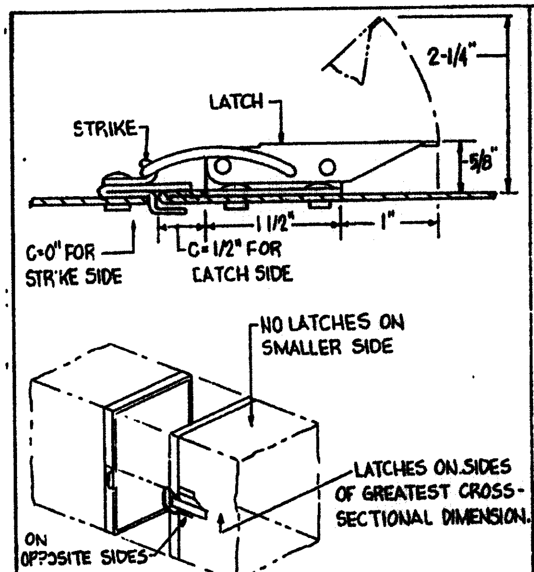
PREFERRED USAGE:
WHERE PORTABILITY IS NOT REQUIRED.




TYPE 7 TRANSVERSE CONNECTION
(FLANGED-TYPE)

FOR INSTALLATION ON NON-WATERTIGHT COMPONENTS WITH RADIUS CORNERS NOT REQUIRED TO MEET CLASS 'A' FIRE PROTECTION REQUIREMENTS.
PREFERRED USAGE: ONLY WHEN CONNECTING TO FLANGE TYPE 2. NOT TO BE USED WHERE CONNECTED COMPONENTS WILL BE SUBJECT TO TENSILE STRESS DURING OR AFTER INSTALLATION. UTILIZATION OF THIS TYPE IS SHOP DECISION.

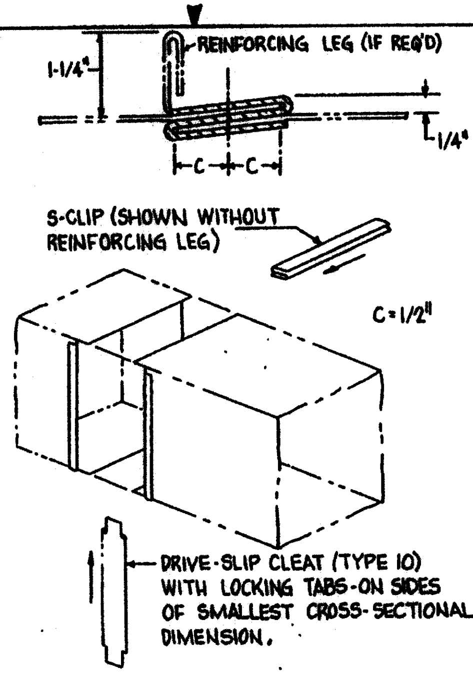
| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
|---|---|---|---|
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| ■ | 2-36233 | 4966-SK-006 | |
| SCALE | NONE | SHEET 27 OF 31 | |




TYPE 12 TRANSVERSE CONNECTION
(NON-FLANGED, LATCH TYPE-BASIC)

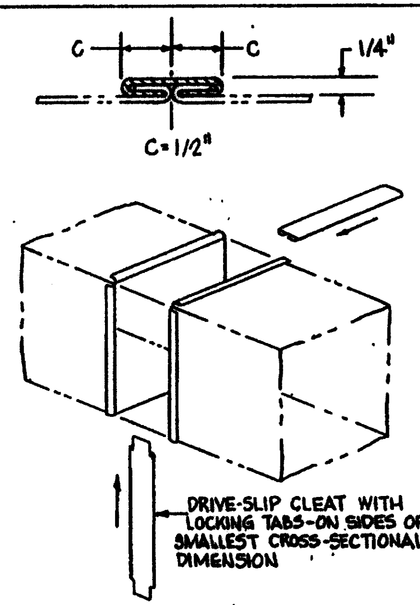
FOR CONNECTION OF NON-WATERTIGHT COMPONENTS NOT REQUIRED TO MEET CLASS 'A' FIRE PROTECTION REQUIREMENTS.
PREFERRED USAGE:
WHERE USE OF FLANGE TYPES 4 OR 6 IS NOT NECESSARY. CHOICE BETWEEN THIS TYPE AND TYPES 9, 10, 11 AND 12 (ALTERNATE) IS SHOP DECISION. SEE NOTE 13 FOR LIMITATIONS.

| SIDE OF GREATEST CROSS-SECTIONAL DIMENSION (INCHES) | NUMBER OF LATCHES REQUIRED ON EACH OF OPPOSITE SIDES |
|---|---|
| 4-12 | 1 |
| 13-24 | 2 |
| 25-36 | 3 |




TYPE 11 TRANSVERSE CONNECTION
(NON-FLANGED, S-CLIP/DRIVE-SLIP)

FOR CONNECTION OF NON-WATERTIGHT COMPONENTS NOT REQUIRED TO MEET CLASS 'A' FIRE PROTECTION REQUIREMENTS.
PREFERRED USAGE:
WHERE USE OF FLANGE TYPES 4 OR 6 IS NOT NECESSARY. CHOICE BETWEEN THIS TYPE AND TYPES 9, 10, AND 12 IS SHOP DECISION.
REINFORCING LEG ONLY NECESSARY WHERE DUCT REINFORCEMENT (STIFFENING) IS REQUIRED.



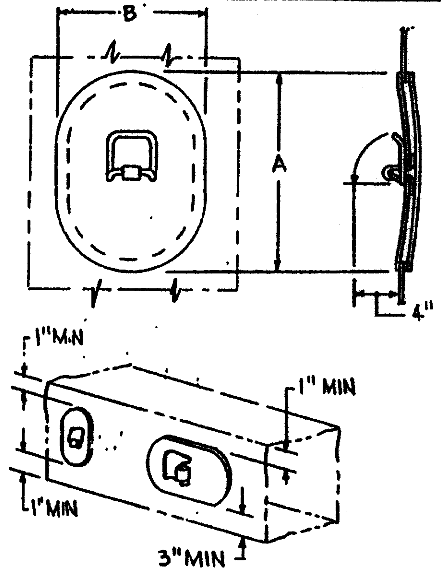

TYPE 10 TRANSVERSE CONNECTION
(NON-FLANGED, DRIVE-SLIP)

FOR CONNECTION OF NON-WATERTIGHT COMPONENTS NOT REQUIRED TO MEET CLASS 'A' FIRE PROTECTION REQUIREMENTS.
PREFERRED USAGE: WHERE USE OF FLANGE TYPES 4 OR 6 IS NOT NECESSARY. CHOICE BETWEEN THIS TYPE AND TYPES 9, 11, AND 12 IS SHOP DECISION.

NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS

| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
|---|---|---|---|
| B | 2-36233 | 4966-SK-006 | |
| REV | SCALE NONE | SHEET 28 OF 31 | |

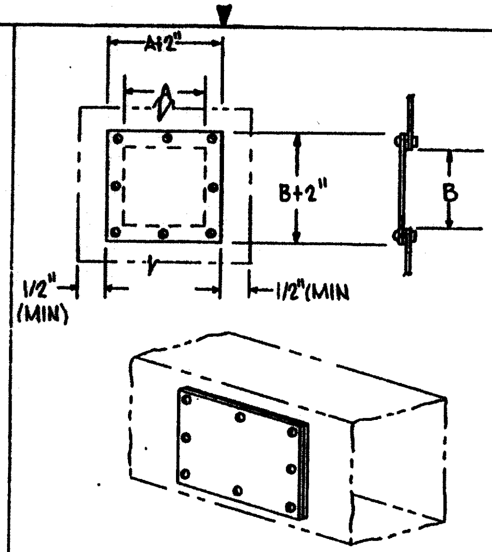



## TYPE 2 ACCESS COVER

(QUICK ACTING, FLAT-OVAL, NON-WATERTIGHT)

FOR INSTALLATION ON NON-WATERTIGHT COMPONENTS NOT REQUIRED TO MEET CLASS 'A' FIRE PROTECTION REQUIREMENTS. AVAILABLE WITH OR WITHOUT THERMAL INSULATION.

| COVER SIZE-DIM A&B (INCHES) | OPENING SIZE (INCHES) |
|---|---|
| 5X7 FLAT-OVAL | 4X6 FLAT-OVAL |
| 7X9 FLAT-OVAL | 6X8 FLAT-OVAL |




## TYPE 1 ACCESS COVER

(BOLTED-WATERTIGHT AND NON-WATERTIGHT)

FOR INSTALLATION ON COMPONENTS WHERE TYPE 2 ACCESS COVER IS NOT DESIRED.

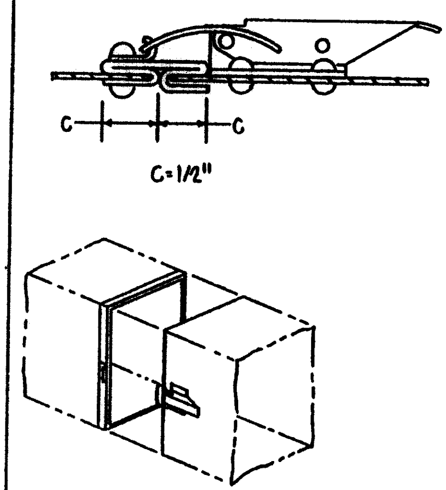
THE SMALLEST ACCESS HOLE DIMENSIONS (A AND B) ARE 4" X 6-1/2". THEREAFTER EITHER OR BOTH MAY BE INCREASED BY 2-1/2" INCREMENTS

RECOMMENDED SIZES (DIMENSIONS A AND B):

6-1/2" X 6-1/2"

9" X 9"

14" X 14"




## TYPE 12 TRANSVERSE CONNECTION

(NON-FLANGED, LATCH TYPE-ALTERNATE)

EXCEPT FOR THE 'C' DIM ON THE STRIKE SIDE, AND CONFIGURATION OF THE RETAINING CLIP, ALL INFORMATION GIVEN FOR THE TYPE 12 (BASIC) CONNECTION IS TRUE FOR THIS TYPE.

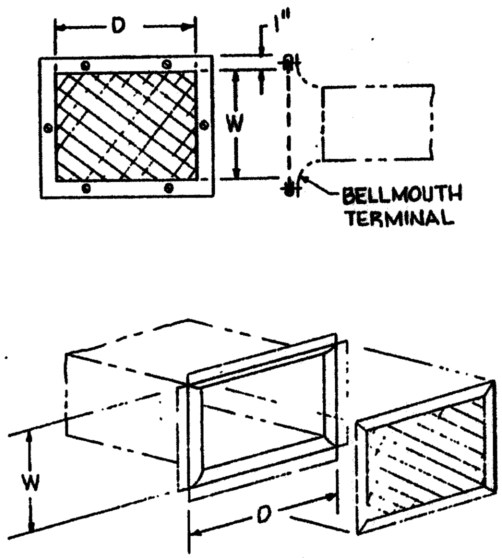
PREFERRED USAGE:

WHERE USE OF FLANGE TYPES 4 OR 6 IS NOT NECESSARY, CHOICE BETWEEN THIS TYPE AND TYPES 9,10,11, AND 12 (BASIC) IS SHOP DECISION. SEE NOTE 13 FOR LIMITATIONS.

NATIONAL SHIPBUILDING RESEARCH PROGRAM

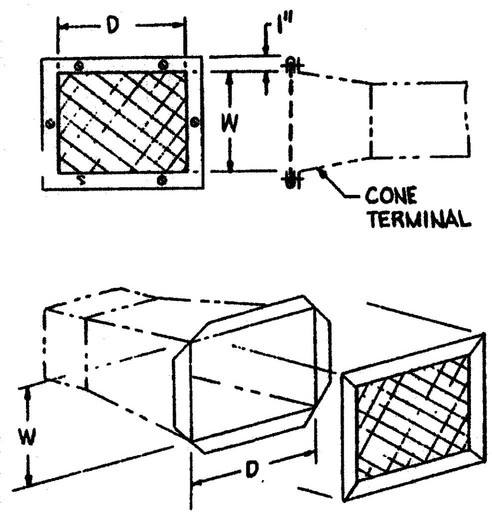
RECTANGULAR DUCT STANDARDS

| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
|---|---|---|---|
| ■ | 2-36233 | 4966-SK-006 | |
| SCALE NONE | | SHEET 29 OF 31 | |



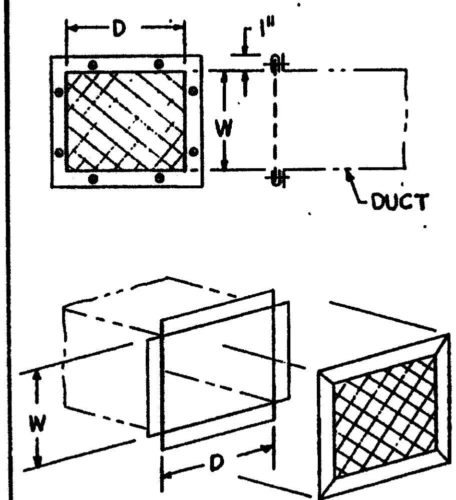

TYPE 3 WIRE MESH SCREENING
(BELLMOUTH TERMINAL)

D AND W ARE TERMINAL OPENING DIMENSIONS




TYPE 2 WIRE MESH SCREENING
(CONE TERMINAL)

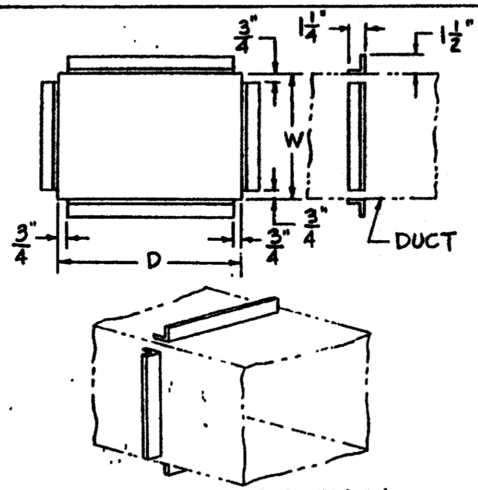
D AND W ARE TERMINAL OPENING DIMENSIONS




TYPE 1 WIRE MESH SCREENING
(OPEN-END DUCT)

D AND W ARE DUCT DIMENSIONS.

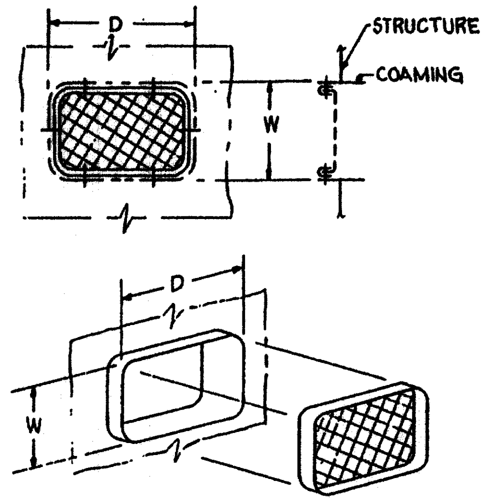
| | | | |
|---|---|---|---|
| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| B | 2-36233 | 4966-SK-006 | |
| SCALE NONE | | | SHEET 30 OF 31 |




## DUCT REINFORCEMENT
(16 AND 20 GA DUCT ONLY)

| MAXIMUM SPACING OF ANGLES (FEET) | | | | |
|---|---|---|---|---|
| SIDE CROSS-SECTIONAL DIMENSION (INCHES) | DUCT STATIC PRESSURE (INCHES-H2O) | | | |
| | -1 TO +1 | -1 TO -2 AND +1 TO +2 | -2 TO -4 AND +2 TO +4 | -4 TO -6 AND +4 TO +6 |
| 2-13 | NONE | NONE | NONE | NONE |
| 14-19 | NONE | NONE | NONE | 5* |
| 20-31 | NONE | 6* | 5 | 5 |
| 32-54 | 6 | 5 | 5 | 4 |

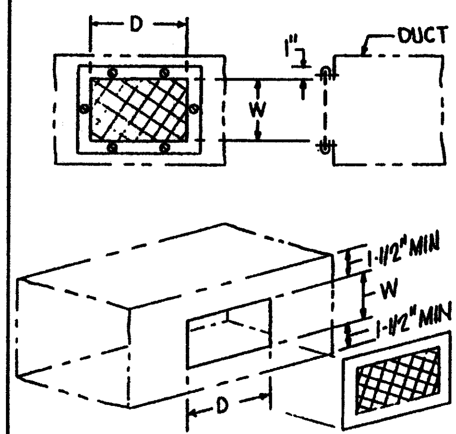
*-NONE FOR DUCT WITH CROSS-BREAKING OR BEADING.
SEE NOTE 10 FOR FURTHER INFORMATION.




## TYPE 5 WIRE MESH SCREENING
(IN COAMING)

D AND W ARE COAMING DIMENSIONS

MINIMUM D AND W = 3" x 4"




## TYPE 4 WIRE MESH SCREENING
(SIDE-OF-DUCT)

D AND W ARE OPENING DIMENSIONS

| | | | |
|---|---|---|---|
| NATIONAL SHIPBUILDING RESEARCH PROGRAM | | | |
| RECTANGULAR DUCT STANDARDS | | | |
| SIZE | MARAD CONTR | TODD DRAWING NO. | REV |
| B | 2-36233 | 4966-SK-006 | |
| REV | SCALE NONE | | SHEET 31 OF 31 |

## APPENDIX B

## SAMPLE CONSTRUCTION DRAWINGS

This appendix contains representative sheets from the Rectangular Duct Standards Construction and Fabrication Drawing. All information necessary for a sheet metal shop to fabricate the standard vent duct components is incorporated.

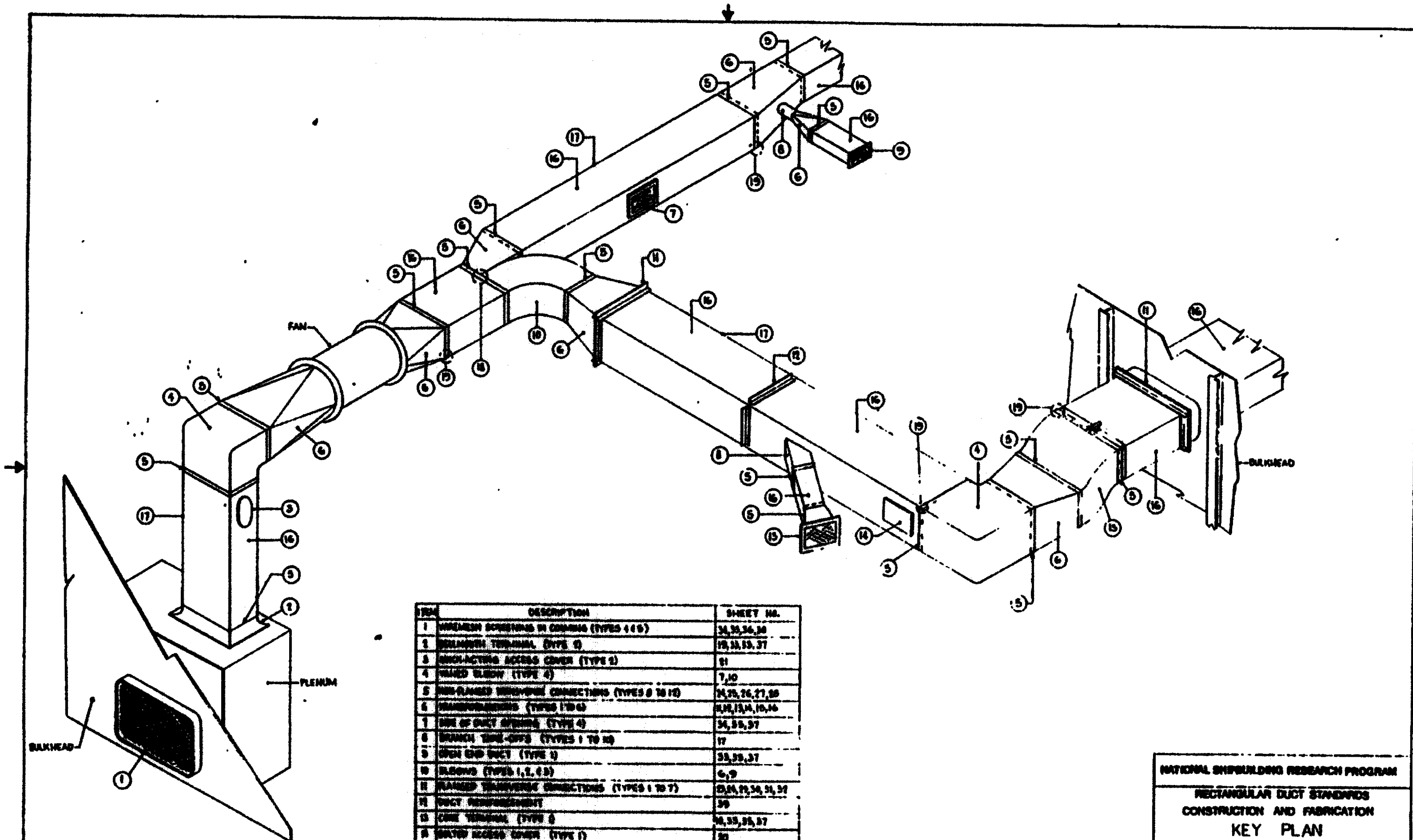
The complete Fabrication Drawing is available to U.S. shipbuilders from:

R&D Program Manager
Todd Shipyards Corporation
Seattle Division
P. O. Box 3806
Seattle, WA 98124

To others, when cataloged, the Drawing may be obtained from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

Any proposals for significant modifications should be addressed to the Todd R&D Program Manager.



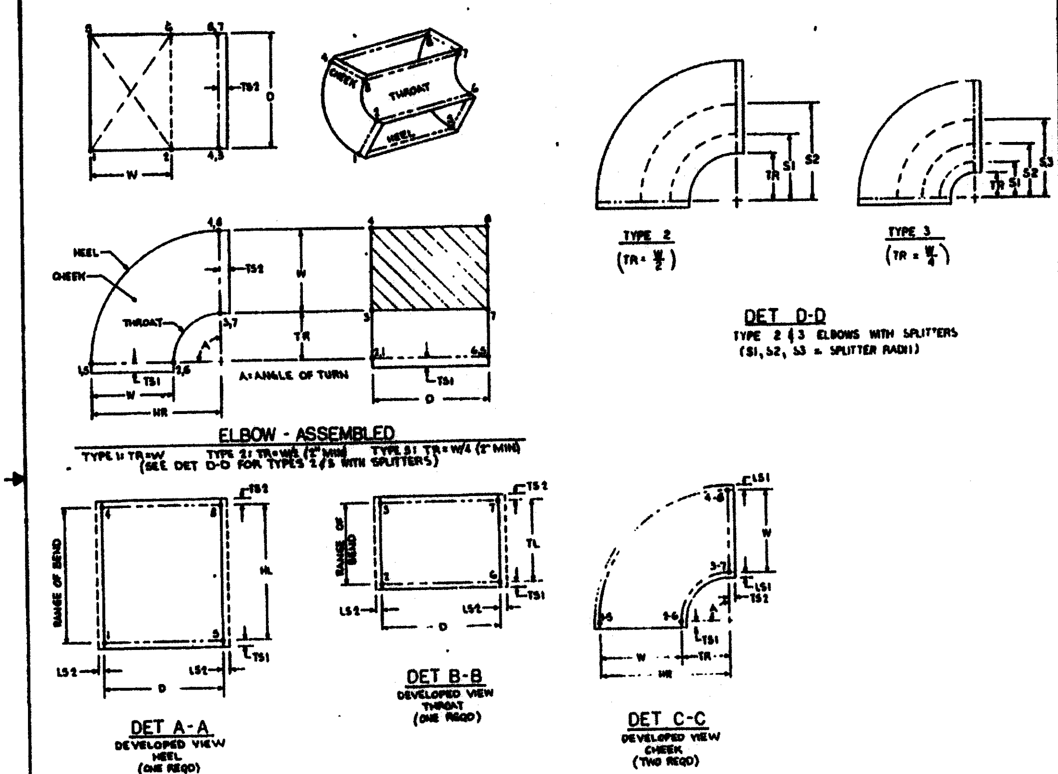

| ITEM | DESCRIPTION | SHEET NO. |
|---|---|---|
| 1 | WIREMESH SCREENING IN COAMING (TYPES 4 & 5) | 34,35,36,38 |
| 2 | BELLMOUTH TERMINAL (TYPE 1) | 19,33,35,37 |
| 3 | QUICK-ACTING ACCESS COVER (TYPE 2) | 21 |
| 4 | VANED ELBOW (TYPE 4) | 7,10 |
| 5 | NON-FLANGED TRANSVERSE CONNECTIONS (TYPES 8 TO 12) | 24,25,26,27,28 |
| 6 | REINFORCEMENTS (TYPES 1 TO 6) | 11,12,13,14,15,16 |
| 7 | SIDE OF DUCT OPENING (TYPE 4) | 34,35,37 |
| 8 | BRANCH TAKE-OFFS (TYPES 1 TO 10) | 17 |
| 9 | OPEN END DUCT (TYPE 1) | 33,35,37 |
| 10 | ELBOWS (TYPES 1, 2, & 3) | 6,9 |
| 11 | FLANGED TRANSVERSE CONNECTIONS (TYPES 1 TO 7) | 23,24,29,30,31,32 |
| 12 | DUCT REINFORCEMENT | 39 |
| 13 | CONE TERMINAL (TYPE 1) | 19,33,35,37 |
| 14 | BOLTED ACCESS COVER (TYPE 1) | 20 |
| 15 | OFFSETS (TYPE 1 & 2) | 8,9 |
| 16 | STRAIGHT DUCT | 5 |
| 17 | LONGITUDINAL SEAMS (TYPES 1 TO 6) | 22 |
| 18 | PREPARATION OF DUCT AT SPLITS | 40 |
| 19 | END OF DUCT PREPARATION | 41 |

NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS
CONSTRUCTION AND FABRICATION
KEY PLAN

| SIZE | MARAD CONTR | TODD DRAWING NO |
|---|---|---|
| D | 2 36233 | 4966 SK-007 |

REV | SCALE NONE | SHEET 4 OF 41




LIST OF MATERIAL

| PT NO | DESCRIPTION | MATERIAL | QTY | SPECIFICATION |
|---|---|---|---|---|
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## NOTES

1- SEE REF 1 FOR MATERIAL QUANTITIES & DIMENSIONAL CRITERIA.
2- ELBOW MATERIAL TYPES SHALL BE IN ACCORDANCE WITH GENERAL NOTE 2.
3- SEE SHEET 9 FOR SPLITTER DETAILS, IF REQUIRED.
4- ELBOWS OF 90° ANGLE OF TURN HAVE BEEN SHOWN. HOWEVER, CONSTRUCTION DETAILS ARE SIMILAR FOR ALL ALLOWABLE ANGLES OF TURN (15°, 30°, 45°, 60°, 75°, 90°).
5- APPLICABILITY:
   - WATERTIGHT / CLASS A FIRE PROTECTION / RAT PROOF — IF COMPONENT IS MADE OF 11 GA OR THICKER MATERIAL
   - NON WATERTIGHT / CLASS B FIRE PROTECTION / RAT PROOF — IF COMPONENT IS MADE OF 16 OR 20 GA MATERIAL
6- SEE GENERAL NOTE 5 FOR DIM TS1, TS2, LS1, LS2.

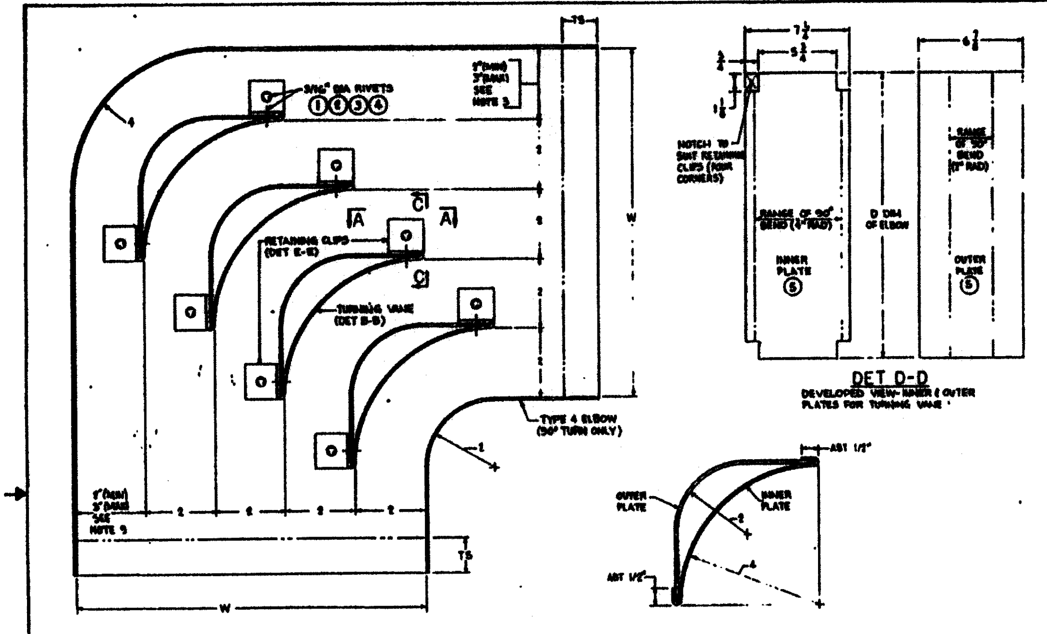
NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS
CONSTRUCTION AND FABRICATION

ELBOWS
(TYPES 1,2,& 3)

| SIZE | NAVSEA CODE | TODD DRAWING NO |
|---|---|---|
| D | 2-36233 | 4946 SK-007 |

REV | SCALE NONE | SHEET 6 OF 41



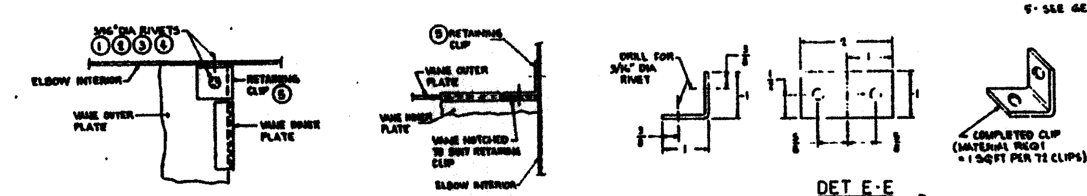

TURNING VANES-INSTALLED

DET D-D
DEVELOPED VIEW-INNER & OUTER PLATES FOR TURNING VANE

DET B-B
TURNING VANE ⑤

DET A-A
TURNING VANE ATTACHMENT TO ELBOW.

DET C-C
TURNING VANE ATTACHMENT TO ELBOW




DET E-E
RETAINING CLIP ⑤ (FOUR REQ'D PER VANE)

**LIST OF MATERIAL**

| PT NO | DESCRIPTION | MATERIAL | QTY | SPECIFICATION |
|---|---|---|---|---|
| 1 | 3/16" DIA BREAK-MANDREL STRUCTURAL BLIND RIVET, PROTRUDING HEAD, OPEN TYPE, GRIP RANGE [illegible] (FOR CONNECTION OF RETAINING CLIP TO TURNING VANE, AND FOR CONNECTION OF RETAINING CLIP TO ELBOW MADE OF 16 OR 20 GA MATERIAL) | CADMIUM PLATED STEEL-RIVET AND MANDREL | [illegible] PER VANE FOR ELBOW OF 16 OR 20 GA. 4 PER VANE FOR [illegible] GA OR THICKER ELBOW | COMMERCIAL/INDUSTRIAL QUALITY-SIMILAR TO "CHERRY" [illegible] RIVET |
| 2-4 | 3/16" DIA BREAK-MANDREL STRUCTURAL BLIND RIVET, PROTRUDING HEAD, PLATED CORE-CLOSED TYPE. | CADMIUM/PLATED STEEL-RIVET AND MANDREL | 4 PER VANE FOR [illegible] GA OR THICKER ELBOW | COMMERCIAL/INDUSTRIAL QUALITY-SIMILAR TO "[illegible]" STRUCTURAL FILLED CORE-CLOSED RIVETS. |
| 2 | GRIP - .165" (FOR CONNECTION OF RETAINING CLIP TO ELBOW MADE OF 11 GA) | | | |
| 3 | GRIP - .1875" (FOR CONNECTION OF RETAINING CLIP TO ELBOW MADE OF 3/16" PLATE) | | | |
| 4 | GRIP - .250" (FOR CONNECTION OF RETAINING CLIP TO ELBOW MADE OF 1/4" PLATE). | | | |
| 5 | 20 GA SHEET | STEEL-GALV | REF 1 | REF 7 |

## NOTES

1- SEE REF 1 FOR MATERIAL QUANTITIES NOT GIVEN ON THIS SHEET.

2- SEE SHEET 7 FOR TYPE 4 ELBOW.

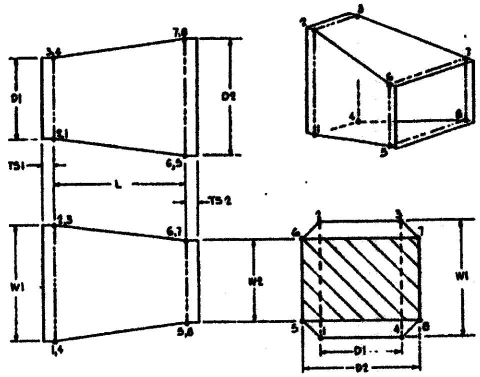
3- A TYPE 4 ELBOW OF W DIMENSION EQUAL TO TEN INCHES HAS BEEN SHOWN. THE TWO INCH SPACING BETWEEN TURNING VANES IS STANDARD. IF A NON-STANDARD ELBOW IS CALLED FOR WHOSE W DIMENSION IS AN ODD INTEGER, THE TWO INCH SPACING WILL HOLD, EXCEPT FOR THE SPACE BETWEEN THE LAST TURNING VANE AND THE ELBOW HEEL, WHICH WILL THEN BE THREE INCHES.

4- APPLICABILITY: WATERTIGHT, CLASS 'A' FIRE PROTECTION, RAT PROOF — IF ELBOW MATERIAL IS GREATER THAN 16 GA, AND PART NO 2, 3, OR 4 IS USED.
NON WATERTIGHT, CLASS 'B' FIRE PROTECTION, RAT PROOF — IF ELBOW MATERIAL IS 16 OR 20 GA

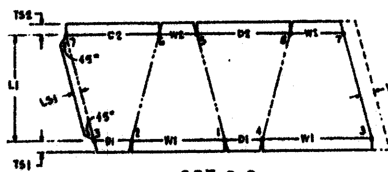
5- SEE GENERAL NOTE 5 FOR DIM TS1, TS2.

NATIONAL SHIPBUILDING RESEARCH PROGRAM
RECTANGULAR DUCT STANDARDS
CONSTRUCTION AND FABRICATION
TURNING VANES FOR TYPE 4 ELBOW

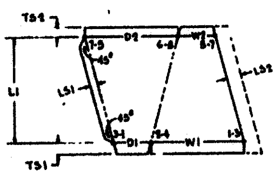
| SIZE | FSCM NO | TODD DRAWING NO |
|---|---|---|
| D | 2 36235 | 4746-[illegible]-007 |
| SCALE NONE | | SHEET 10 OF 41 |



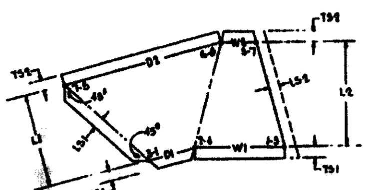

TRANSFORMATION - ASSEMBLED
RECTANGULAR TO RECTANGULAR



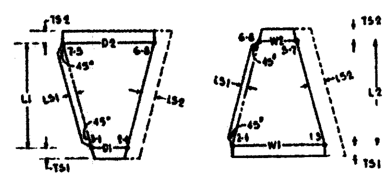
DET C-C
DEVELOPED VIEW-GENERAL CONFIGURATION-1 PIECE TRANSFORMATION
SPECIAL CASE - D1+W1=D2+W2 (ONE REQ'D)



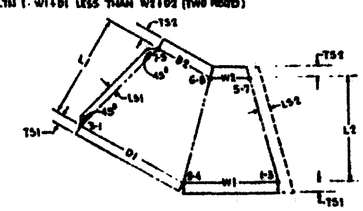
DET D-D
DEVELOPED VIEW-GENERAL CONFIGURATION-2 PIECE TRANSFORMATION
SPECIAL CASE - D1+W1=D2+W2 (TWO REQ'D)



DET A-A
DEVELOPED VIEW-GENERAL CONFIGURATION-2 PIECE TRANSFORMATION
ALTN 1 - W1+D1 LESS THAN W2+D2 (TWO REQ'D)



DET E-E
DEVELOPED VIEW-GENERAL CONFIGURATION-4 PIECE TRANSFORMATION
ALL CASES
(TWO EACH REQ'D)



DET B-B
DEVELOPED VIEW-GENERAL CONFIGURATION-2 PIECE TRANSFORMATION
ALTN 2 - W1+D1 GREATER THAN W2+D2 (TWO REQ'D)

LIST OF MATERIAL

| PT NO | DESCRIPTION | MATERIAL | QTY | SPECIFICATION |
|---|---|---|---|---|
| | | | | |

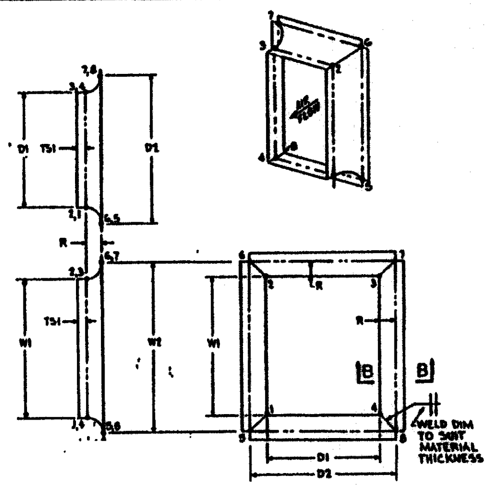
## NOTES

1. SEE GENERAL NOTE 5 FOR MATERIAL AND DIMENSIONAL CRITERIA.
2. TRANSFORMATION MATERIAL TYPES SHALL BE IN ACCORDANCE WITH GENERAL NOTE 2.
3. THE DEVELOPED VIEWS SHOWN HAVE BEEN GENERALIZED, AND ARE INTENDED ONLY TO REPRESENT THE TYPICAL CASES. THE DESIGNATION OF THE TRANSFORMATION END DIMENSIONS (D1, W1, D2 & W2) IS ARBITRARY, PROVIDED THAT THE RELATIVE DIMENSIONAL PARAMETERS ARE MAINTAINED.
4. APPLICABILITY: WATERTIGHT, CLASS 'A' FIRE PROTECTION, RAT PROOF — IF COMPONENT IS CONSTRUCTED OF 11 GA OR THICKER MATERIAL.
   NON WATERTIGHT, CLASS 'B' FIRE PROTECTION, RAT PROOF — IF COMPONENT IS CONSTRUCTED OF 16 OR 10 GA MATERIAL.
5. SEE GENERAL NOTE 5 FOR DIM TS1, TS2, LS1, LS2.

NATIONAL SHIPBUILDING RESEARCH PROGRAM
RECTANGULAR DUCT STANDARDS
CONSTRUCTION AND FABRICATION
TRANSFORMATION-SYMMETRICAL
(TYPE I)

| SIZE | FSCM NO | DWG NO |
|---|---|---|
| D | 2-36233 | 4966-SK-007 |
| SCALE NONE | | SHEET 11 OF 41 |

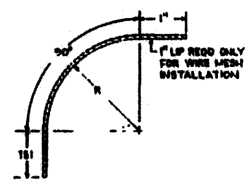
REV




TERMINAL - ASSEMBLED

| TABLE 1 (ALL DIMENSIONS IN INCHES) | | | | | | | |
|---|---|---|---|---|---|---|---|
| LARGEST CROSS-SECTIONAL THROAT DIMENSION (D1 OR W1) | R * | A | X1 | X2 | X3 | X4 | X5 |
| 2-8 | 1 | 1-9/16 | 1/4 | 1/2 | 23/32 | 7/8 | 31/32 |
| 9-16 | 2 | 3-5/32 | 17/32 | 1 | 1-13/32 | 1-23/32 | 1-15/16 |
| 17-24 | 3 | 4-23/32 | 25/32 | 1-1/2 | 2-1/8 | 2-19/32 | 2-29/32 |
| 25-32 | 4 | 6-9/32 | 1-1/32 | 2 | 2-27/32 | 3-15/32 | 3-7/8 |
| 33-40 | 5 | 7-27/32 | 1-9/32 | 2-1/2 | 3-17/32 | 4-11/32 | 4-27/32 |
| 41-48 | 6 | 9-7/16 | 1-9/16 | 3 | 4-1/4 | 5 3/16 | 5-25/32 |
| 49-56 | 7 | 11 | 1-13/16 | 3-1/2 | 4 15/16 | 6-1/16 | 6-3/4 |

* - R MUST BE THE SAME VALUE ON ALL FOUR SIDES OF ANY ONE SPECIFIC TERMINAL.

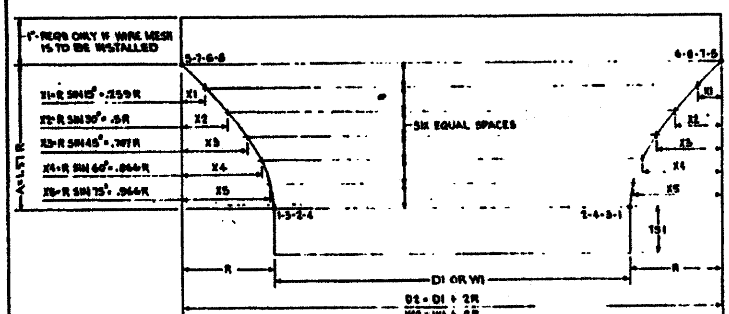



DET B-B

| LIST OF MATERIAL | | | | |
|---|---|---|---|---|
| PT NO | DESCRIPTION | MATERIAL | QTY | SPECIFICATION |

## NOTES

1 - SEE FIG. 1 FOR MATERIAL QUANTITIES.
2 TERMINAL MATERIAL TYPES SHALL BE IN ACCORDANCE WITH GENERAL NOTE 2.
3 - SEE SHEET 35 FOR WIRE MESH INSTALLATION.
4 - APPLICABILITY: TIGHTNESS — NOT APPLICABLE
FIRE PROTECTION — NOT APPLICABLE
RAT PROOF - ONLY WITH WIRE MESH INSTALLATION
5 - SEE GENERAL NOTE 5 FOR DIM TS1.




DET A-A

DEVELOPED VIEW
(FOUR REQD - TWO FOR BASIC DIMENSION D1
TWO FOR BASIC DIMENSION W1)

SEE TABLE 1 FOR DIMENSIONAL CRITERIA

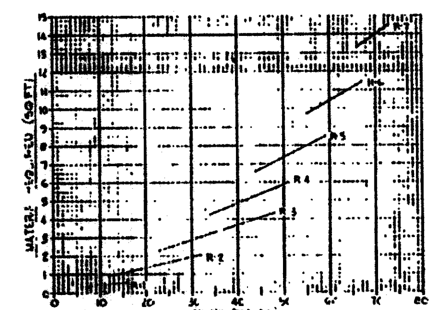


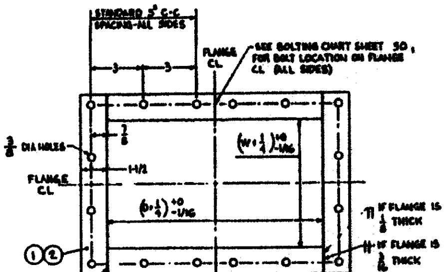

FIG. 1
NET MATERIAL REQUIREMENTS
(INCLUDES 1" LIP FOR WIRE MESH)

NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS
CONSTRUCTION AND FABRICATION
TERMINAL — BELLMOUTH
(TYPE 2)

| SIZE | MARAD CONTR | TODD DRAWING NO |
|---|---|---|
| D | 2-36233 | 4966-SK-007 |

REV | SCALE NONE | SHEET 19 OF 41



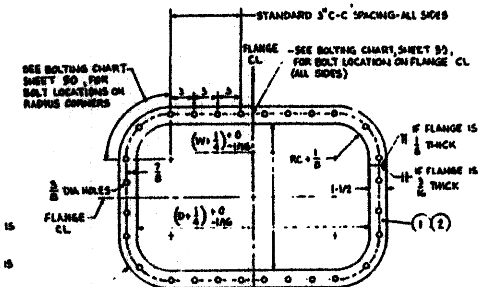

FLANGE MAY BE CONSTRUCTED OF SEVERAL PARTS AND BUTT-WELDED AS SHOWN AT THESE POINTS, OR MADE IN ONE PIECE.

## TYPE 1

(1) 1/8 THICK IF WELDED TO COMPONENT 1/8 THICK (11 GA)

(2) 3/16 THICK IF WELDED TO COMPONENT THICKER THAN 1/8

SEE TYPE 6, SHEET 24, FOR INSTALLATION ON COMPONENT MATERIALS THINNER THAN 1/8 (11 GA)



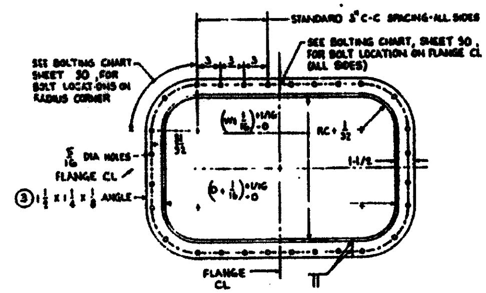

FLANGE MAY BE CONSTRUCTED OF SEVERAL PARTS BUTT-WELDED TOGETHER AS SHOWN, OR MADE IN ONE PIECE. IF WELDED TOGETHER, WELDS SHALL BE ON STRAIGHT PORTION OF FLANGE, AND SHALL NOT CROSS BOLT HOLES.

## TYPE 2

(1) 1/8 THICK IF WELDED TO COMPONENT 1/8 THICK (11 GA)

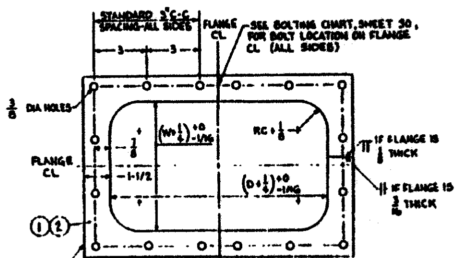
(2) 3/16 THICK IF WELDED TO COMPONENT THICKER THAN 1/8

SEE TYPE 7, SHEET 24, FOR INSTALLATION ON COMPONENT MATERIALS THINNER THAN 1/8 (11 GA)




ALL BUTT WELDS USED SHALL BE AS SHOWN-WELD SHALL BE ON STRAIGHT PORTION OF ANGLE, AND SHALL NOT CROSS BOLT HOLES.

## TYPE 5 (3)

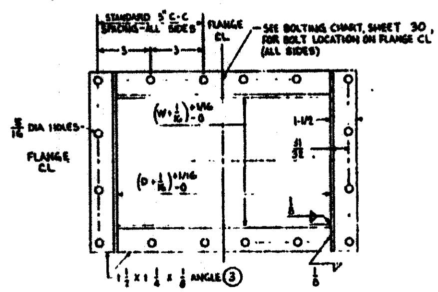



FLANGE MAY BE CONSTRUCTED OF SEVERAL PARTS, AND BUTT-WELDED TOGETHER AS SHOWN, OR MADE IN ONE PIECE. IF WELDED TOGETHER, WELDS SHALL NOT CROSS BOLT HOLES

## TYPE 3

(1) 1/8 THICK IF WELDED TO COMPONENT 1/8 THICK (11 GA)

(2) 3/16 THICK IF WELDED TO COMPONENT THICKER THAN 1/8




## TYPE 4 (3)

## NOTES

1- SEE SHEET 24 FOR LIST OF MATERIAL.

2- SEE SHEET 29 FOR TYPICAL USAGE, AND FASTENER TYPES AND SIZES.

3- SEE REF 1 FOR MATERIAL QUANTITIES.

4- APPLICATIONS:
- TYPE 1 - FLANGE TYPE CONN FOR ALL RECT COMPONENTS MADE OF 11GA OR THICKER MATERIAL. TO BE WELDED TO COMPONENT. SEE DET A-A, B-B, C-C, AND H-H, SHEET 29.
- TYPE 2 - FLANGE TYPE CONN FOR COAMINGS WITH RADIUS CORNERS. TO BE WELDED TO COAMING. SEE DET A-A, B-B, F-F, AND H-H, SHEET 29.
- TYPE 3 - FLANGE TYPE CONN FOR COMPONENTS MADE OF 11 GA OR THICKER MATERIAL, WITH RADIUS CORNERS. TO BE WELDED TO COMPONENT. SEE DET A-A, B-B, C-C, F-F, AND H-H, SHEET 29.
- TYPE 4 - FLANGE TYPE CONN FOR RECT COMPONENTS MADE OF 16 OR 20 GA MATERIAL. TO BE RIVETED TO COMPONENT. SEE DET A-A, D-D, AND E-E, SHEET 29.
- TYPE 5 - FLANGE TYPE CONN FOR COMPONENTS MADE OF 16 OR 20 GA MATERIAL, WITH RADIUS CORNERS. TO BE RIVETED TO COMPONENT. SEE DET A-A, AND D-D, SHEET 29.

5- APPLICABILITY:

| | |
|---|---|
| WATERTIGHT<br>CLASS A FIRE PROTECTION<br>HATPROOF | TYPES 1, 2, AND 3 |
| NON-WATERTIGHT<br>CLASS B FIRE PROTECTION<br>RATPROOF | TYPES 4 AND 5 |

6- BOLT-HOLE LOCATION TOLERANCES:
TYPES 1, 2, AND 3: +0", -1/32" AS MEASURED FROM FLANGE CENTERLINES.
TYPES 4 AND 5: +1/32", -0" AS MEASURED FROM FLANGE CENTERLINES.
(THERE SHALL BE NO ACCUMULATION OF TOLERANCE FROM HOLE TO HOLE.)

NATIONAL SHIPBUILDING RESEARCH PROGRAM

RECTANGULAR DUCT STANDARDS
CONSTRUCTION AND FABRICATION
TRANSVERSE CONNECTIONS
(TYPES 1 TO 5)

| SIZE | MARAD CONTR | 1000 DRAWING NO |
|---|---|---|
| D | 2 36233 | 4966-SK-007 |

REV | SCALE NONE | SHEET 23 OF 41

## APPENDIX C

## SAMPLE TABLES FOR MATERIAL QUANTITIES AND DIMENSIONS

Representative computer tabulations of material quantities and dimensions are contained in this Appendix. Also included is a sample of a computer program used to generate the tabulations.

Copies of the complete tabulations and/or programs are available to U.S. shipbuilders from:

R&D Program Manager
Todd Shipyards Corporation
Seattle Division
P. O. Box 3806
Seattle, WA 98124

Or, when cataloged, from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

Any proposals for significant modifications should be addressed to the Todd R&D Program Manager.

NOTE: The economically advantageous standard sizes, each identified with an asterisk, are established in two-inch increments and should be used unless there is special reason to do otherwise. The information presented herein is in one-inch increments only to accommodate special needs.

## INDEX



### REFERENCES

| NO. | TITLE | TODD DWG NO. |
|---|---|---|
| 1 | RECTANGULAR DUCT STANDARDS | |
| | -CONSTRUCTION AND FABRICATION | |
| 2 | RECTANGULAR DUCT STANDARDS | |
| | -DESIGNERS PAMPHLET | |
| | | |

| APPROVAL | DATE |
|---|---|
| USCG | |
| ABS | |
| PHS | |
| | |
| | |
| | |

REV

**NATIONAL SHIPBUILDING RESEARCH PROGRAM**

RECTANGULAR DUCT STANDARDS

DIMENSIONAL CRITERIA AND MATERIAL QUANTITIES IN SUPPORT OF RECTANGULAR DUCT STANDARDS - CONSTRUCTION AND FABRICATION

| SIZE | MARAD CONTR | TODD DRAWING NO. |
|---|---|---|
| — | 2-36233 | 4966-SK-008 |

SCALE ——— TITLE SHEET & 1062 DATA SHEETS

| STRAIGHT DUCT (* = STANDARD SIZE) | | | |
|---|---|---|---|
| | D DIM (IN) | W DIM (IN) | MATERIAL REQUIRED PER ONE LINEAR FOOT (SQ FT)** |
| * | 2 | 4 | 1.00 |
| | 2 | 5 | 1.17 |
| * | 2 | 6 | 1.33 |
| | 2 | 7 | 1.50 |
| * | 2 | 8 | 1.67 |
| | 3 | 4 | 1.17 |
| | 3 | 5 | 1.33 |
| | 3 | 6 | 1.50 |
| | 3 | 7 | 1.67 |
| | 3 | 8 | 1.83 |
| | 3 | 9 | 2.00 |
| | 3 | 10 | 2.17 |
| | 3 | 11 | 2.33 |
| * | 4 | 4 | 1.33 |
| | 4 | 5 | 1.50 |
| * | 4 | 6 | 1.67 |
| | 4 | 7 | 1.83 |
| * | 4 | 8 | 2.00 |

** - MATERIAL IS NET AND DOES NOT INCLUDE ALLOWANCE FOR LONGITUDINAL CORNER SEAMS. IF THESE ARE PRESENT, ADD .15 SQ FT PER LINEAR FOOT FOR EACH SUCH SEAM.

| STRAIGHT DUCT (* = STANDARD SIZE) | | | |
|---|---|---|---|
| | D DIM (IN) | W DIM (IN) | MATERIAL REQUIRED PER ONE LINEAR FOOT (SQ FT)** |
| | 4 | 9 | 2.17 |
| * | 4 | 10 | 2.33 |
| | 4 | 11 | 2.50 |
| * | 4 | 12 | 2.67 |
| | 4 | 13 | 2.83 |
| * | 4 | 14 | 3.00 |
| | 5 | 5 | 1.67 |
| | 5 | 6 | 1.83 |
| | 5 | 7 | 2.00 |
| | 5 | 8 | 2.17 |
| | 5 | 9 | 2.33 |
| | 5 | 10 | 2.50 |
| | 5 | 11 | 2.67 |
| | 5 | 12 | 2.83 |
| | 5 | 13 | 3.00 |
| | 5 | 14 | 3.17 |
| | 5 | 15 | 3.33 |
| * | 6 | 6 | 2.00 |

## ELBOWS - TYPES 1, 2, 3, AND 4

| D (IN) | W (IN) | ANGLE (DEG) | TYPE 1 ELBOW TR (IN) | TL (IN) | HR (IN) | HL (IN) | AREA (SQ FT) | TYPE 2 ELBOW TR (IN) | TL (IN) | HR (IN) | HL (IN) | AREA (SQ FT) | TYPE 3 ELBOW TR (IN) | TL (IN) | HR (IN) | HL (IN) | AREA (SQ FT) | TYPE 4 ELBOW HL (IN) | AREA (SQ FT) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * 2 | .4 | 15 | 4.0 | 1- 1 | 8.0 | 2- 4 | 0.21 | 2.0 | 0-16 | 6.0 | 1-19 | 0.14 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 |
| | | 30 | 4.0 | 2- 2 | 8.0 | 4- 7 | 0.42 | 2.0 | 1- 1 | 6.0 | 3- 6 | 0.28 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 |
| | | 45 | 4.0 | 3- 4 | 8.0 | 6-11 | 0.62 | 2.0 | 1-17 | 6.0 | 4-24 | 0.42 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 |
| | | 60 | 4.0 | 4- 5 | 8.0 | 8-14 | 0.83 | 2.0 | 2- 2 | 6.0 | 6-11 | 0.55 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 |
| | | 75 | 4.0 | 5- 6 | 8.0 | 10-18 | 1.04 | 2.0 | 2-18 | 6.0 | 7-30 | 0.69 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 |
| | | 90 | 4.0 | 6- 7 | 8.0 | 12-21 | 1.25 | 2.0 | 3- 3 | 6.0 | 9-17 | 0.83 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 |

## SPLITTER AND VANE DATA

| ANGLE (DEG) | TYPE 2 ELBOW (TWO SPLITTERS) S1 (IN) | SL1 (IN) | S2 (IN) | SL2 (IN) | AREA (SQ FT) | TYPE 3 ELBOW (THREE SPLITTERS) S1 (IN) | SL1 (IN) | S2 (IN) | SL2 (IN) | S3 (IN) | SL3 (IN) | AREA (SQ FT) | TYPE 4 ELBOW (VANES) NO. REQD | AREA (SQ FT) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0 | 0.0 |
| 30 | 3.00 | 1-19 | 4.25 | 2- 8 | 0.05 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0 | 0.0 |
| 45 | 3.00 | 2-12 | 4.25 | 3-12 | 0.08 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0 | 0.0 |
| 60 | 3.00 | 3- 6 | 4.25 | 4-15 | 0.11 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0 | 0.0 |
| 75 | 3.00 | 3-31 | 4.25 | 5-19 | 0.13 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0 | 0.0 |
| 90 | 3.00 | 4-24 | 4.25 | 6-23 | 0.16 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0 | 0.0 |

NOTES
1- *=STANDARD SIZE.
2- DIMENSIONAL NOMENCLATURE AGREES WITH THAT USED IN RECTANGULAR DUCT STANDARDS (CONSTRUCTION AND FABRICATION).
3- AREAS (NET MATERIAL REQD TO FABRICATE COMPONENT) FOR TYPES 1,2,3,AND 4 ELBOWS ASSUME PITTSBURGH TYPE LONGITUDINAL CORNER SEAMS.
4- SPLITTER AREAS INCLUDE HEM MATERIAL, WHERE APPLICABLE.
5- ZERO ENTRIES INDICATE NON-AVAILABILITY OF THE FITTING IN THAT SIZE OR ANGLE.
6- ALL COMPONENT LENGTHS (TL,HL,SL1,SL2,SL3) ARE GIVEN IN WHOLE INCHES AND 32NDS OF AN INCH. FOR EXAMPLE, A LENGTH GIVEN AS 6-5 WOULD BE 6 AND 5/32 INCHES LONG.

## OFFSETS - TYPES 1 AND 2

| | W (IN) | X (IN) | TYPE 1 OFFSET (TR= 2.0, HR= 4.0) ANGLE (DEG) | H (IN) | H1 (IN) | L (IN) | UL (IN) | WL (IN) | TYPE 2 OFFSET (TR= 0.0, HR= 0.0) ANGLE (DEG) | H (IN) | H1 (IN) | L (IN) | UL (IN) | WL (IN) | SPLITTER DATA FOR TYPE 2 OFFSET S1 (IN) | SL1 (IN) | S2 (IN) | SL2 (IN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * | 2 | 1 | 33.6 | 3 | 5 | 3-10 | 1- 5 | 3-17 | 0.0 | 0 | 0 | 0- 0 | 0- 0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 |
| | | 2 | 48.2 | 4 | 4 | 4-15 | 1-21 | 5- 2 | 0.0 | 0 | 0 | 0- 0 | 0- 0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 |
| | | 3 | 60.0 | 5 | 3 | 5- 6 | 2- 2 | 6-10 | 0.0 | 0 | 0 | 0- 0 | 0- 0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 |
| | | 4 | 70.5 | 6 | 2 | 5-21 | 2-14 | 7-14 | 0.0 | 0 | 0 | 0- 0 | 0- 0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 |
| | | 5 | 80.4 | 7 | 1 | 5-29 | 2-24 | 8-15 | 0.0 | 0 | 0 | 0- 0 | 0- 0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 |
| | | 6 | 90.0 | 8 | 0 | 6- 0 | 3- 3 | 9-15 | 0.0 | 0 | 0 | 0- 0 | 0- 0 | 0- 0 | 0.0 | 0- 0 | 0.0 | 0- 0 |

NOTES
1- *=STANDARD W DIMENSION.
2- DIMENSIONAL NOMENCLATURE AGREES WITH THAT USED IN RECTANGULAR DUCT STANDARDS (CONSTRUCTION AND FABRICATION).
3- ZERO ENTRIES INDICATE NON-AVAILABILITY OF THE FITTING IN THAT SIZE OR ANGLE.
4- ALL COMPONENT LENGTHS (L,UL,WL,SL1,SL2) ARE GIVEN IN WHOLE INCHES AND 32NDS OF AN INCH. FOR EXAMPLE, A LENGTH GIVEN AS 6-5 WOULD BE 6 AND 5/32 INCHES LONG.
5- WHERE THE LARGEST ANGLE INDICATED IS LESS THAN 90 DEGREES, THE CORRESPONDING OFFSET CHEEK IS THE LARGEST THAT CAN BE CUT (IN ONE PIECE) FROM A 4 FOOT BY 8 FOOT SHEET METAL BLANK.
6- AREAS (MATERIAL REQUIREMENTS) FOR OFFSETS AND SPLITTERS MAY BE DETERMINED BY DOUBLING THE AREA DATA GIVEN FOR 90 DEGREE ELBOWS OF THE SAME D,W,AND TR DIMENSIONS (FOUND ON PAGES 13-813), MULTIPLYING THAT QUANTITY BY THE ACTUAL OFFSET ANGLE INDICATED ABOVE, AND DIVIDING THE RESULT BY 90.

## ACCESS COVERS - TYPE 1 - BOLTED

| OPENING DIMENSIONS A (IN) | OPENING DIMENSIONS B (IN) | COVER DIMENSIONS A+2 (IN) | COVER DIMENSIONS B+2 (IN) | COVER MATERIAL REQUIREMENTS (SQ FT) | FASTENER QUANTITY (SETS) | GASKET MATERIAL REQUIREMENTS (LINEAR FEET) | FRAME MATERIAL REQUIREMENTS (LINEAR FEET) |
|---|---|---|---|---|---|---|---|
| 4.0 | 6.5 | 6.0 | 8.5 | 0.4 | 10 | 2.1 | 2.1 |
| 4.0 | 9.0 | 6.0 | 11.0 | 0.5 | 12 | 2.5 | 2.5 |
| 4.0 | 11.5 | 6.0 | 13.5 | 0.6 | 14 | 2.9 | 2.9 |
| 6.5 | 6.5 | 8.5 | 8.5 | 0.5 | 12 | 2.5 | 2.5 |
| 6.5 | 9.0 | 8.5 | 11.0 | 0.6 | 14 | 2.9 | 2.9 |
| 6.5 | 11.5 | 8.5 | 13.5 | 0.8 | 16 | 3.3 | 3.3 |
| 6.5 | 14.0 | 8.5 | 16.0 | 0.9 | 18 | 3.8 | 3.8 |
| 6.5 | 16.5 | 8.5 | 18.5 | 1.1 | 20 | 4.2 | 4.2 |
| 6.5 | 19.0 | 8.5 | 21.0 | 1.2 | 22 | 4.6 | 4.6 |
| 9.0 | 9.0 | 11.0 | 11.0 | 0.8 | 16 | 3.3 | 3.3 |
| 9.0 | 11.5 | 11.0 | 13.5 | 1.0 | 18 | 3.8 | 3.8 |
| 9.0 | 14.0 | 11.0 | 16.0 | 1.2 | 20 | 4.2 | 4.2 |
| 9.0 | 16.5 | 11.0 | 18.5 | 1.4 | 22 | 4.6 | 4.6 |
| 9.0 | 19.0 | 11.0 | 21.0 | 1.6 | 24 | 5.0 | 5.0 |
| 9.0 | 21.5 | 11.0 | 23.5 | 1.8 | 26 | 5.4 | 5.4 |
| 9.0 | 24.0 | 11.0 | 26.0 | 2.0 | 28 | 5.8 | 5.8 |

NOTES
1- DIMENSIONAL NOMENCLATURE AGREES WITH THAT USED IN RECTANGULAR DUCT STANDARDS (CONSTRUCTION AND FABRICATION).
2- EACH FASTENER SET INCLUDES ONE (1) MACHINE SCREW, AND ONE (1) CAPTIVE FASTENER.
3- FRAME MATERIAL INDICATED ABOVE IS REQUIRED ONLY FOR THE NON-TIGHT AND AIR-TIGHT ACCESS COVER (ALTN 1), AS SHOWN IN THE CONSTRUCTION AND FABRICATION DETAILS.
4- GASKET MATERIAL INDICATED ABOVE ASSUMES GASKET CUT FROM 1-INCH WIDE STRIPS, AND PROPERLY SEALED AT MATING EDGES.

## TRANSVERSE CONNECTIONS - FLANGED
### (TYPES 1,2,3,4,5,6,AND 7)

| | D (IN) | W (IN) | RC (IN) | FLANGE MATERIAL TYPE 1 (LIN FT) | FLANGE MATERIAL TYPE 2 (SQ FT) | FLANGE MATERIAL TYPE 3 (SQ FT) | FLANGE MATERIAL TYPE 4 (LIN FT) | FLANGE MATERIAL TYPE 5 (LIN FT) | FLANGE MATERIAL TYPE 6 (LIN FT) | FLANGE MATERIAL TYPE 7 (SQ FT) | FASTENERS TYPES 1,3,4,6 (SETS) | FASTENERS TYPES 2,5,7 (SETS) | RIVETS TYPE 4 (QTY) | RIVETS TYPE 5 (QTY) | GASKET MATERIAL TYPES 1,3,4,6 (LIN FT) | GASKET MATERIAL TYPES 2,5,7 (SQ FT) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * | 2 | 4 | 1 | 1.6 | 0.2 | 0.2 | 1.5 | 1.1 | 1.5 | 0.2 | 8 | 6 | 6 | 5 | 1.5 | 0.1 |
| | 2 | 5 | 1 | 1.8 | 0.2 | 0.2 | 1.7 | 1.3 | 1.7 | 0.2 | 8 | 6 | 6 | 6 | 1.7 | 0.2 |
| * | 2 | 6 | 1 | 1.9 | 0.2 | 0.2 | 1.9 | 1.4 | 1.9 | 0.2 | 10 | 8 | 8 | 7 | 1.9 | 0.2 |
| | 2 | 7 | 1 | 2.1 | 0.2 | 0.3 | 2.0 | 1.6 | 2.0 | 0.2 | 10 | 8 | 8 | 8 | 2.0 | 0.2 |
| * | 2 | 8 | 1 | 2.3 | 0.2 | 0.3 | 2.2 | 1.8 | 2.2 | 0.2 | 12 | 8 | 10 | 9 | 2.2 | 0.2 |
| | 3 | 4 | 1 | 1.8 | 0.2 | 0.2 | 1.7 | 1.3 | 1.7 | 0.2 | 8 | 6 | 6 | 6 | 1.7 | 0.2 |
| | 3 | 5 | 1 | 1.9 | 0.2 | 0.2 | 1.9 | 1.4 | 1.9 | 0.2 | 8 | 6 | 6 | 7 | 1.9 | 0.2 |
| | 3 | 6 | 1 | 2.1 | 0.2 | 0.3 | 2.0 | 1.6 | 2.0 | 0.2 | 10 | 8 | 8 | 8 | 2.0 | 0.2 |
| | 3 | 7 | 1 | 2.3 | 0.2 | 0.3 | 2.2 | 1.8 | 2.2 | 0.2 | 10 | 8 | 8 | 9 | 2.2 | 0.2 |
| | 3 | 8 | 1 | 2.4 | 0.3 | 0.3 | 2.4 | 1.9 | 2.4 | 0.3 | 12 | 8 | 10 | 10 | 2.4 | 0.2 |
| | 3 | 9 | 1 | 2.6 | 0.3 | 0.3 | 2.5 | 2.1 | 2.5 | 0.3 | 12 | 8 | 10 | 11 | 2.5 | 0.3 |
| | 3 | 10 | 1 | 2.8 | 0.3 | 0.4 | 2.7 | 2.3 | 2.7 | 0.3 | 12 | 10 | 12 | 12 | 2.7 | 0.3 |
| | 3 | 11 | 1 | 2.9 | 0.3 | 0.4 | 2.9 | 2.4 | 2.9 | 0.3 | 12 | 10 | 12 | 13 | 2.9 | 0.3 |
| * | 4 | 4 | 1 | 1.9 | 0.2 | 0.2 | 1.9 | 1.4 | 1.9 | 0.2 | 8 | 8 | 8 | 7 | 1.9 | 0.2 |

NOTES
1- *=STANDARD SIZE.
2- DIMENSIONAL NOMENCLATURE AGREES WITH THAT USED IN RECTANGULAR DUCT STANDARDS (CONSTRUCTION AND FABRICATION).
3- FLANGF MATERIAL AND RIVETS AS GIVEN ABOVE IS THAT MATERIAL REQUIRED TO FABRICATE ONE SIDE OF THE TOTAL CONNECTION, (ONE COMPLETE TYPE).
4- FASTENERS AND GASKET MATERIAL AS GIVEN ABOVE IS THAT MATERIAL REQUIRED FOR THE TOTAL CONNECTION (CNE TYPE MATED TO ANOTHER TYPE). EACH FASTENER SET INCLUDES ONE (1) MACHINE SCREW, AND ONE (1) NUT. GASKET MATERIAL FOR TYPES 1,3,4, AND 6 ASSUMES GASKFT CUT FROM 1-3/8 INCH WIDE STRIPS, AND PROPERLY SEALED AT MATING EDGES.
5- RC VALUES AS GIVEN ABOVE ARE THOSE RADIUS CORNER DIMENSIONS RECOMMENDED FOR THE CORRESPONDING DUCT SIZE, AND ARE IN AGREEMENT WITH THOSE VALUES INDICATED IN RECTANGULAR DUCT STANDARDS (DESIGNERS PAMPHLET). THE RC VALUES APPLY ONLY TO TYPES 2,3,5,AND 7. WHERE RC VALUES DIFFER FROM THOSE GIVEN, THE REQUIRED FASTENER QUANTITIES MAY BE CALCULATED FROM THE BOLT LOCATION DATA GIVEN IN THE CONSTRUCTION AND FABRICATION DETAILS. (HOWEVER, FOR THESE CASES, ALL INFORMATION AS GIVEN ABOVE MAY BE USED FOR MATERIAL ESTIMATING, WITHOUT APPRECIABLE ERROR.)

## TRANSVERSE CONNECTIONS - NON FLANGED
## (TYPES 9,10,11,12BASIC, AND 12ALTERNATE)

| | D (IN) | W (IN) | TYPE 9 RIVETS (QTY) | TYPE 10 DRIVE-SLIP CLEATS (LIN FT) | TYPE 10 DRIVE-SLIP CLEATS (SQ FT) | TYPE 11 DRIVE-SLIP CLEATS (LIN FT) | TYPE 11 DRIVE-SLIP CLEATS (SQ FT) | TYPE 11 S-CLIPS (LIN FT) | TYPE 11 S-CLIPS (SQ FT) | TYPE 12BASIC RETAINING CLIPS (LIN FT) | TYPE 12BASIC RETAINING CLIPS (SQ FT) | TYPE 12BASIC RIVETS (QTY) | TYPE 12ALTERNATE RETAINING CLIPS (LIN FT) | TYPE 12ALTERNATE RETAINING CLIPS (SQ FT) | TYPE 12ALTERNATE RIVETS (QTY) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * | 2 | 4 | 6 | 1.4 | 0.2 | 0.7 | 0.1 | 0.6 | 0.2 | 1.0 | 0.2 | 6 | 1.0 | 0.3 | 6 |
| | 2 | 5 | 6 | 1.5 | 0.3 | 0.7 | 0.1 | 0.8 | 0.2 | 1.1 | 0.2 | 10 | 1.1 | 0.3 | 6 |
| * | 2 | 6 | 8 | 1.7 | 0.3 | 0.7 | 0.1 | 1.0 | 0.3 | 1.3 | 0.2 | 10 | 1.3 | 0.4 | 6 |
| | 2 | 7 | 8 | 1.9 | 0.3 | 0.7 | 0.1 | 1.1 | 0.3 | 1.5 | 0.3 | 10 | 1.5 | 0.4 | 6 |
| * | 2 | 8 | 10 | 2.0 | 0.4 | 0.7 | 0.1 | 1.3 | 0.4 | 1.6 | 0.3 | 10 | 1.6 | 0.5 | 6 |
| | 3 | 4 | 6 | 1.5 | 0.3 | 0.8 | 0.2 | 0.6 | 0.2 | 1.1 | 0.2 | 6 | 1.1 | 0.3 | 6 |
| | 3 | 5 | 6 | 1.7 | 0.3 | 0.8 | 0.2 | 0.8 | 0.2 | 1.3 | 0.2 | 10 | 1.3 | 0.4 | 6 |
| | 3 | 6 | 8 | 1.9 | 0.3 | 0.8 | 0.2 | 1.0 | 0.3 | 1.5 | 0.3 | 10 | 1.5 | 0.4 | 6 |
| | 3 | 7 | 8 | 2.0 | 0.4 | 0.8 | 0.2 | 1.1 | 0.3 | 1.6 | 0.3 | 10 | 1.6 | 0.5 | 6 |
| | 3 | 8 | 10 | 2.2 | 0.4 | 0.8 | 0.2 | 1.3 | 0.4 | 1.8 | 0.3 | 10 | 1.8 | 0.5 | 6 |
| | 3 | 9 | 10 | 2.4 | 0.4 | 0.8 | 0.2 | 1.5 | 0.4 | 2.0 | 0.4 | 10 | 2.0 | 0.6 | 6 |
| | 3 | 10 | 12 | 2.5 | 0.5 | 0.8 | 0.2 | 1.6 | 0.4 | 2.1 | 0.4 | 14 | 2.1 | 0.6 | 10 |
| | 3 | 11 | 12 | 2.7 | 0.5 | 0.8 | 0.2 | 1.8 | 0.5 | 2.3 | 0.4 | 14 | 2.3 | 0.7 | 10 |
| * | 4 | 4 | 8 | 1.7 | 0.3 | 1.0 | 0.2 | 0.6 | 0.2 | 1.3 | 0.2 | 8 | 1.3 | 0.4 | 6 |
| | 4 | 5 | 8 | 1.9 | 0.3 | 1.0 | 0.2 | 0.8 | 0.2 | 1.5 | 0.3 | 12 | 1.5 | 0.4 | 6 |
| * | 4 | 6 | 10 | 2.0 | 0.4 | 1.0 | 0.2 | 1.0 | 0.3 | 1.6 | 0.3 | 12 | 1.6 | 0.5 | 6 |

NOTES
1- *=STANDARD SIZE.
2- DIMENSIONAL NOMENCLATURE AGREES WITH THAT USED IN RECTANGULAR DUCT STANDARDS (CONSTRUCTION AND FABRICATION).
3- ZERO ENTRIES INDICATE NON-AVAILABILITY OF CONNECTION TYPE IN THAT SIZE.
4- MATERIAL AS INDICATED ABOVE IS THAT MATERIAL REQUIRED TO FABRICATE THE TOTAL CONNECTION.
5- THE MATERIAL QUANTITY LISTED IN THE SQ FT COLUMN FOR TYPE 11 S-CLIPS IS THAT MATERIAL REQUIRED FOR THE S-CLIP WITHOUT REINFORCING LEG. IF REINFORCING LEGS ARE REQUIRED, ADD .2 SQ FT TO THE QUANTITY SHOWN FOR EACH LINEAR FOOT OF S-CLIP.

## WIRE MESH SCREENING
### (TYPES 1,2,3,4,AND 5)

| OPNG DIM | | TYPES 1 AND 4 | | | TYPE 2 | | | TYPE 3 | | | TYPE 5 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D (IN) | W (IN) | FRAME (LIN FT) | SCREEN (SQ FT) | FASTENERS (SETS) | FRAME (LIN FT) | SCREEN (SQ FT) | FASTENERS (SETS) | FRAME (LIN FT) | SCREEN (SQ FT) | FASTENERS (SETS) | RC (IN) | FRAME (LIN FT) | SCREEN (SQ FT) | FASTENERS (SETS) EXP | FASTENERS (SETS) NOT EXP |
| 2 | 4 | 1.3 | 0.1 | 2 | 0.0 | 0.0 | 0 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0.0 | 0 | 0 |
| 2 | 5 | 1.5 | 0.2 | 2 | 1.5 | 0.2 | 2 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0.0 | 0 | 0 |
| 2 | 6 | 1.7 | 0.2 | 4 | 1.7 | 0.2 | 4 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0.0 | 0 | 0 |
| 2 | 7 | 1.8 | 0.2 | 4 | 1.8 | 0.2 | 4 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0.0 | 0 | 0 |
| 2 | 8 | 2.0 | 0.3 | 4 | 2.0 | 0.3 | 4 | 0.0 | 0.0 | 0 | 0 | 0.0 | 0.0 | 0 | 0 |
| 3 | 4 | 1.5 | 0.2 | 4 | 1.5 | 0.2 | 4 | 0.0 | 0.0 | 0 | 1 | 0.8 | 0.1 | 4 | 4 |
| 3 | 5 | 1.7 | 0.2 | 4 | 1.7 | 0.2 | 4 | 0.0 | 0.0 | 0 | 1 | 1.0 | 0.2 | 4 | 4 |
| 3 | 6 | 1.8 | 0.3 | 6 | 1.8 | 0.3 | 6 | 0.0 | 0.0 | 0 | 1 | 1.1 | 0.2 | 4 | 4 |
| 3 | 7 | 2.0 | 0.3 | 6 | 2.0 | 0.3 | 6 | 0.0 | 0.0 | 0 | 1 | 1.3 | 0.2 | 4 | 4 |
| 3 | 8 | 2.2 | 0.3 | 6 | 2.2 | 0.3 | 6 | 0.0 | 0.0 | 0 | 1 | 1.5 | 0.3 | 6 | 4 |
| 3 | 9 | 2.3 | 0.4 | 6 | 2.3 | 0.4 | 6 | 0.0 | 0.0 | 0 | 1 | 1.6 | 0.3 | 6 | 4 |
| 3 | 10 | 2.5 | 0.4 | 6 | 2.5 | 0.4 | 6 | 0.0 | 0.0 | 0 | 1 | 1.8 | 0.3 | 6 | 6 |
| 3 | 11 | 2.7 | 0.4 | 6 | 2.7 | 0.4 | 6 | 0.0 | 0.0 | 0 | 1 | 2.0 | 0.3 | 8 | 6 |
| 4 | 4 | 1.7 | 0.2 | 4 | 1.7 | 0.2 | 4 | 0.0 | 0.0 | 0 | 1 | 1.0 | 0.2 | 4 | 4 |
| 4 | 5 | 1.8 | 0.3 | 4 | 1.8 | 0.3 | 4 | 0.0 | 0.0 | 0 | 1 | 1.1 | 0.2 | 4 | 4 |

NOTES
1- DIMENSIONAL NOMENCLATURE AGREES WITH THAT USED IN RECTANGULAR DUCT STANDARDS (CONSTRUCTION AND FABRICATION).
2- ZERC ENTRIES INDICATE NON-AVAILABILITY OF FITTING TYPE IN THAT SIZE.
3- EACH FASTENER SET INCLUDES ONE (1) MACHINF SCREW, AND ONE (1) NUT OR CAPTIVE FASTENER.
4- FRAPE MATERIAL FOR ALL TYPES ASSUMES FRAME CUT FROM 2-INCH WIDE STRIPS.
5- RC VALUES AS GIVEN ABOVE ARE THOSE RADIUS CORNER DIMENSIONS RECOMMENDED FOR THE CORRESPONDING OPENING DIMENSIONS, AND ARE IN AGREEMENT WITH THOSF VALUES INDICATED IN RECTANGULAR DUCT STANDARDS (DESIGNERS PAMPHLET). THE RC VALUES APPLY ONLY TO TYPE 5. WHERE RC VALUES DIFFER FROM THOSE GIVEN, THE REQUIRED FASTENER QUANTITIES MAY BE CALCULATED FROM THE BOLT LOCATION DATA GIVEN IN THE CONSTRUCTION AND FABRICATION DETAILS. (HOWEVER, FOR THESE CASES, ALL INFORMATION AS GIVEN ABOVE MAY BE USED FOR MATERIAL ESTIMATING, WITHOUT APPRECIABLE ERROR.)
6- SCREEN MATERIAL AS GIVEN ABOVE IS BASED ON CROSS-SECTIONAL DIMENSIONS OF (D+1.75)X(W+1.75), FOR TYPES 1,2,3,AND 4, AND CROSS-SECTIONAL DIMENSIONS OF (D+1)X(W+1), FOR TYPE 5. THIS AGREES WITH SCREEN DIMENSIONS AS GIVEN IN THE CONSTRUCTION AND FABRICATION DETAILS.

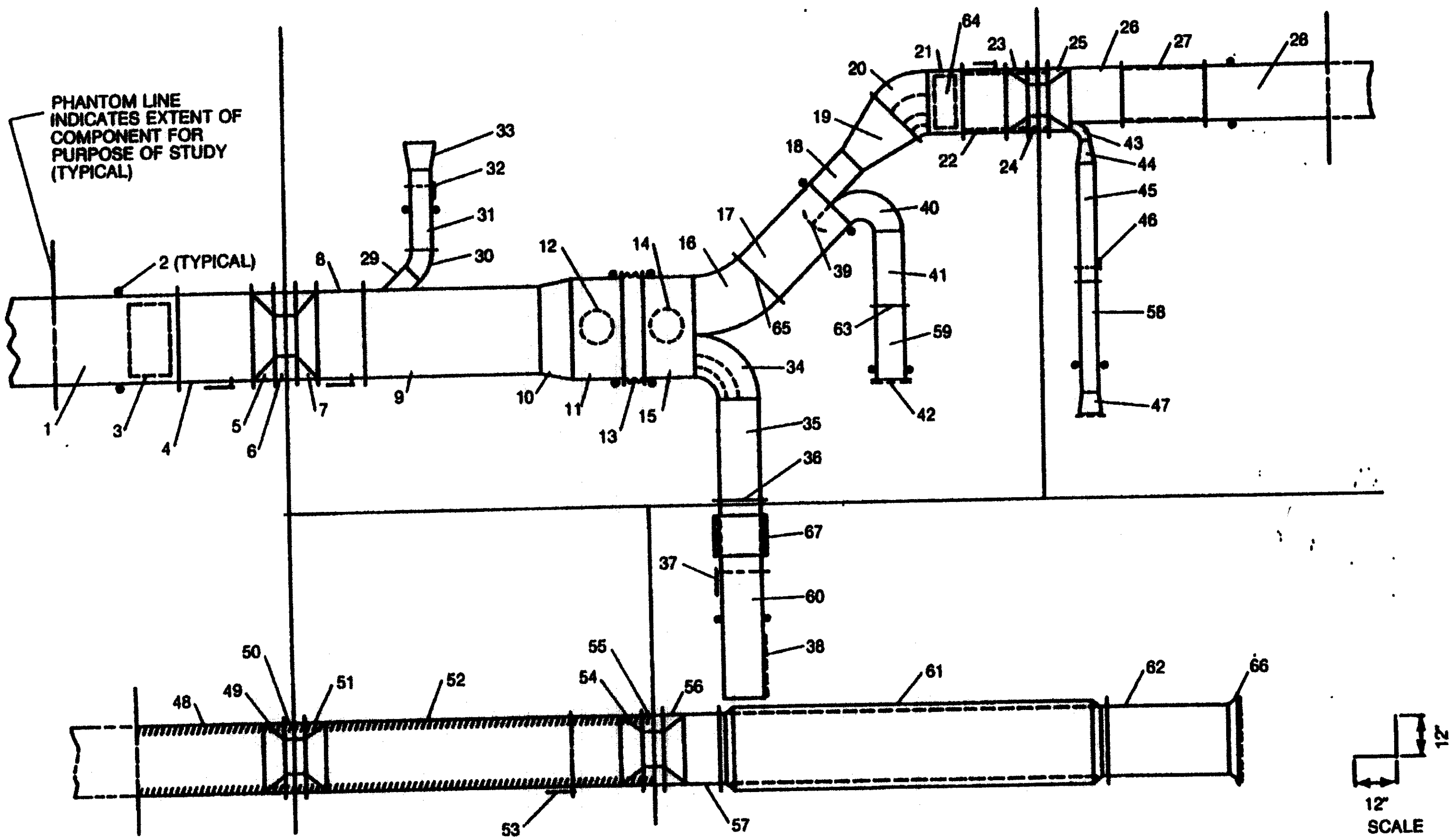
```
0001              REAL D1,W1,A
0002              INTEGER D,W,C,C1,SSD,SSW,X,WMAX,TOP
0003              TOP=0
0004              SSD=1
0005              SSW=1
0006              X=0
0007              C1=0
0008              C=1
0009              D=2
0010              W=0
0011              D1=0.
0012              W1=0.
0013              WMAX=0
0014            1 IF(D.EQ.2)GO TO 2
0015              IF(D.EQ.3)GO TO 3
0016              IF(D.EQ.4)GO TO 4
0017              IF(D.LT.19)GO TO 5
0018              IF(D.EQ.19)GO TO 6
0019              WMAX=24
0020            7 W=D
0021            8 D1=D
0022              W1=W
0023            9 IF(TOP.EQ.0)GO TO 10
0024              GO TO 11
0025            2 WMAX=8
0026           12 W=4
0027              GO TO 8
0028            3 WMAX=11
0029              GO TO 12
0030            4 WMAX=14
0031              GO TO 7
0032            5 WMAX=3*D
0033              GO TO 7
0034            6 WMAX=54
0035              GO TO 7
0036           10 WRITE(3,112)
0037          112 FORMAT(////////26X,13HSTRAIGHT DUCT/23X,19H(* = STANDARD SIZE)//31
                 1X,17HMATERIAL REGUIRED/16X,5HD DIM,2X,5HW DIM,2X,19HPER ONE LINEAR
                 2 FOOT/17X,4H(IN),3X,4H(IN),8X,9H(SQ FT)**)
0038              TOP=1
0039           11 A=(D1+W1)/6.
0040              IF((SSD.EQ.1).AND.(SSW.EQ.1))GO TJ 13
0041              WRITE(3,14)D,W,A
0042           14 FORMAT(/18X,I2,5X,I2,10X,F5.2)
0043              GO TO 15
0044           13 WRITE(3,16)D,W,A
0045           16 FORMAT(/12X,1H*,5X,I2,5X,I2,10X,F5.2)
0046           15 C1=C1+1
0047              IF(D.EQ.24)GO TO 17
0048              IF(C1.EQ.18)GO TO 18
0049           27 IF(W.EQ.WMAX)GO TO 19
0050              W=W+1
0051              W1=W
0052              IF(SSW.EQ.1)GO TO 20
```

```
0053             SSW=1
0054             GO TO 9
0055          20 SSW=0
0056             GO TO 9
0057          19 D=D+1
0058             IF(SSD.EQ.1)GO TO 21
0059             SSD=1
0060             SSW=1
0061             GO TO 1
0062          21 SSD=0
0063             GO TO 1
0064          17 IF(C.EQ.1)GO TO 22
0065             GO TO 100
0066          22 X=1
0067             GO TO 23
0068          18 IF(C.EQ.1)GO TO 24
0069             C=1
0070          29 WRITE(3,25)
0071          25 FORMAT(1H1/)
0072             C1=0
0073             IF(X.EQ.0)GO TO 26
0074             GO TO 100
0075          26 TOP=0
0076             GO TO 27
0077          24 C=0
0078          23 WRITE(3,28)
0079          28 FORMAT(/2X,55H** - MATERIAL IS NET AND DOES NOT INCLUDE ALLOWANCE
                1FOR/7X,48HLONGITUDINAL CORNER SEAMS. IF THESE ARE PRESENT,/7X,49HA
                2DD .15 SQ FT PER LINEAR FOOT FOR EACH SUCH SEAM.)
0080             GO TO 29
0081         100 CALL EXIT
0082             END
```

# APPENDIX D

## RESEARCHER'S UNDERSTANDING OF SHIPBUILDING FUNCTIONS

This appendix contains a functional breakdown of the tasks necessary to design, produce, install and test a typical shipboard HVAC system. All cost figures are in February 1976 dollars. Careful analysis of the work-flow described in this Appendix will reveal the specific areas that are impacted upon by the Rectangular Vent Duct Standards.



PHANTOM LINE INDICATES EXTENT OF COMPONENT FOR PURPOSE OF STUDY (TYPICAL)
2 (TYPICAL)
1
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
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30
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32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
12"
12"
SCALE


*Figure D-1*

## GENERAL CRITERIA

1. The numbers shown in Figure D-1 are component identification numbers. Figure D-1 does not represent a typical system presently installed on any marine design. Its purpose is to portray many of the various rectangular type components which preliminary investigation indicates may benefit from standardization in respect to size, fabrication techniques, materials used, etc.

2. Unless otherwise stated in the component description, all items are of non-watertight construction.

3. Various existing methods of component fabrication have been indicated for purposes of comparison with developed standards.

4. All non-welded seams and joints have been assumed sealed after fabrication with an approved joint sealer.

5. Standard flanges Types 1, 2 and 3 are used.

6. Unless otherwise noted, all steel has been assumed to be of the hot-dipped galvanized type, either before or after fabrication.

7. Unless otherwise noted, all bolts, nuts, washers, etc., have been assumed to be of the cadmium plated steel type.

8. Thermal insulation is 1" thick, cemented to the duct exterior, and covered with lagging cloth and vapor barrier.

9. Acoustic insulation is 1" thick, cemented to the duct interior, with the corners sealed with glass tape.

10. Bolting of all flanges has been assumed to be accomplished during the installation procedure.

11. Eighty percent of all transverse lap seam riveting has been assumed to be accomplished during the fabrication process, and twenty percent during installation.

12. Work associated with the welding of spools to ships structure has not been included since this is normally the function of specialized welding personnel.

13. For the purpose of this tudy, "Indirect Cost" includes: clerical work, drafting supplies, plan reproduction, record keeping, plan file update, and other general and administrative expenses.

14. All material costs incurred by work task 2 & 3 have been included in work task 2.

## COMPONENT IDENTIFICATION LIST

| Item No. | Description |
|---|---|
| 1. | Straight duct - 26" x 18", 36" long, with one type 2 flange. Constructed of 18 ga sheet steel with two "Pittsburgh" type seams. |
| 2. | Duct hangers, 1½" x 3/16" steel F.B., 20 required of varying lengths. |
| 3. | Bolted access plate for 12" x 21" opening, 16 ga sheet steel, with gasket and 1" x 1/8" framing ring. |
| 4. | Auto/Manual fire damper, 26" x 18", 21" long, 1/8" thick steel casing, with two type 1 flanges. |
| 5. | Transformation piece, 26" x 18" - 26" x 18", 7" R.C., 6" long, 1/8" thick steel, with two type 1 flanges, and two welded seams. |
| 6. | Spool, 26" x 18", 7" R.C., 6" long, ¼" thick steel, with two type 1 flanges, and two welded seams. |
| 7. | Same as item No. 5. |

8. Remote operator (thru-bulkhead) for item No. 4, 1/8" thick steel casing, with two type 1 flanges, 14" long.

9. Straight duct, 26" x 18", 51" long, with one type 2 flange and one lap riveted seam with item 10. Constructed of 18 ga sheet steel with two "Pittsburgh" type seams.

10. Transformation piece, 26" x 18" - 29" x 16", 9" long, 18 ga sheet steel, with two lap riveted seams for connection to items 9 & 11. Constructed with four "Pittsburgh" type seams.

11. Straight duct, 29" x 16", 15" long, with one type 2 flange and one lap riveted seam with item 10. Constructed of 18 ga sheet steel with two "Pittsburgh" type seams.

12. Access plate for 12" dia opening, 1/8" thick steel, with gasket and 16 ga sheet steel framing ring.

13. Flexible connection, 29" x 16", 5" long. Constructed of 1½" x 1½" x 1/8" steel angles, 16 ga steel ratguard, and 1/8" thick cloth inserted rubber.

14. Same as item No. 12.

15. Straight duct, 29" x 16", 15" long, with one type 2 flange, and one lap riveted seam with items 16 & 34. Constructed of 18 ga sheet steel with two "Pittsburgh" type seams.

16. Elbow, 17" x 16", 45°, 17" throat radius, with one type 3 flange and one lap riveted seam with item 15. Constructed of 20 ga sheet steel with four "Pittsburgh" type seams.

17. Straight duct, 17" x 16", 30" long, with one type 3 flange and one lap riveted seam with items 18 & 40. Constructed of 20 ga sheet steel with one welded seam.

18. Straight duct, 9" x 16", 14" long, with two lap riveted seams with items 17 & 19. Constructed of 20 ga sheet steel with one welded seam.

19. Transformation piece, 9" x 16" - 18" x 9", 18" long, 20 ga sheet steel, with one type 3 flange and one lap riveted seam with item 18. Constructed with two welded seams.

20. Elbow, 18" x 9", 45°, 4½" throat radius, three splitters, one type 3 flange, and one lap riveted seam with item 21. Constructed of 20 ga sheet steel with four welded seams.

21. Straight duct, 18" x 9", 10" long, with one type 2 flange and one lap riveted seam with item 20. Constructed of 20 ga sheet steel with one welded seam.

22. Manual fire damper, 18" x 9", 12" long, 1/8" thick steel casing, with two type 1 flanges.

23. Transformation piece, 18" x 9" - 18" x 9" F.O., 6" long. 1/8" thick steel, with two type 1 flanges, and two welded seams.

24. Spool, 18" x 9" F.O., 6" long, ¼" thick steel, with two type 1 flanges, and two welded seams.

25. Transformation piece, 18" x 9" F.O. - 18" x 9", 6" long. 20 ga sheet steel with one type 2 flange, and one lap riveted seam with items 26 & 43. Constructed with two lap riveted seams.

26. Straight duct, 15½" x 9", 15" long, with one type 2 flange, and one lap riveted seam with item 25. Constructed of 20 ga sheet steel with one welded seam.

27. Duct drain and sump, 15½" x 9", 24" long, 1/8" thick steel with two type 1 flanges.

28. Straight duct - 15½" x 9", 36" long, with one type 2 flange. Constructed of 20 ga sheet steel with two "Pittsburgh" type seams.

29. Straight duct - 6" x 10", 9" long, with two lap riveted seams with items 9 & 30. Constructed of 22 ga sheet steel, with one "Pittsburgh" type seam. Used for 45° tap connection to main.

30. Elbow, 6" x 10", 45°, 6" throat radius, with one type 3 flange and one lap riveted seam with item 29. Constructed of 22 ga sheet steel, with four "Pittsburgh" type seams.

31. Straight duct, 6" x 10", 24" long, with one type 3 flange and one lap riveted seam with item 33. Constructed of 22 ga sheet steel, with one grooved seam.

32. Shut-off damper for 6" x 10" duct, 16 ga sheet steel, with operating gear.

33. "J" terminal, 6" x 10" - 7½" x 12", 7½" long, with one lap riveted seam with item 31. Constructed of 22 ga sheet steel with one lap riveted seam.

34. Elbow, 12" x 16", 90°, 6" throat radius, two splitters, and two lap riveted seams with items 15 & 35. Constructed of 20 ga sheet steel with four "Pittsburgh" type seams.

35. Straight duct - 12" x 16", 36" long, with two lap riveted seams with items 34 & 67. Constructed of 20 ga sheet steel with two "Pittsburgh" type seams.

36. Collar plate for 12" x 16" duct, two-piece, 22 ga sheet steel, fastened to bulkhead with ¼" machine screws and nuts.

37. Shut-off damper for 12" x 16" duct, 16 ga sheet steel, with operating gear.

38. Opening, side of duct, 18" x 10", with ½" x ½" screening and retaining ring.

39. Splitter damper for 16" deep duct, 16 ga sheet steel, 8" long, with operating gear.

40. Elbow, 8" x 16", 135°, 4" throat radius, and two lap riveted seams with items 17 & 41. Constructed of 20 ga sheet steel with four "Pittsburgh" type seams.

41. Straight duct, 8" x 16", 22" long, with one type 3 flange, and one lap riveted seam with item 40. Constructed of 20 ga sheet steel with one welded seam.

42. Opening, end of duct, 8" x 16", with ½" x ½" screening and retaining ring.

43. Elbow, 2½" x 9", 90°, 2½" throat radius, and two lap riveted seams with items 25 & 44. Constructed of 22 ga sheet steel with four welded seams.

44. Transformation piece, 2½" x 9" - 5" x 5", 6" long, 22 ga sheet steel with two lap riveted seams with items 43 & 45, and two welded seams.

45. Straight duct, 5" x 5", 36" long, with one type 3 flange and one lap riveted seam with item 44. Constructed of 24 ga sheet steel with one grooved seam.

46. Balancing damper for 5" x 5" duct, 16 ga sheet steel, with operating gear.

47. "JA" terminal, 5" x 5" - 6" x 6", 6" long, with one lap riveted seam with item 58. Constructed of 24 ga sheet steel with one lap riveted seam, and ½" x ½" screening and retaining ring.

48. Straight duct, thermally insulated, 20" x 10", 36" long, with one lap riveted seam with item 49. Constructed of 18 ga sheet steel, with two "Pittsburgh" type seams.

49. Transformation piece, thermally insulated, 20" x 10" - 20" x 10" F.O., 6" long, 18 ga sheet steel, with one type 2 flange and one lap riveted seam with item 48, and two lap riveted seams.

50. Spool thermally insulated, 20" x 10" F.O., 6" long, ¼" thick steel, with two type 1 flanges, and two welded seams.

51. Transformation piece, thermally insulated, 20" x 10" - 20" x 10" F.O., 6" long, 18 ga sheet steel, with one type 2 flange and one lap riveted seam with item 52, and two lap riveted seams.

52. Straight duct, thermally insulated, 20" x 10", 86" long, with 2 lap riveted seams with items 51 & 54. Constructed of 18 ga sheet steel, and two "Pittsburgh" type seams.

53. Shut-off damper for 20" x 10" thermally insulated duct, 16 ga sheet steel, with operating gear.

54. Transformation piece, thermally insulated, 20" x 10" - 20" x 10" F.O., 6" long, 18 ga sheet steel, with one type 2 flange, one lap riveted seam with item 52, and two spot welded seams.

55. Spool, thermally insulated, 20" x 10" F.O., 6" long, ¼" thick steel, with two type 1 flanges, and two welded seams.

56. Transformation piece, 20" x 10" - 20" x 10" F.O., 6" long, 18 ga sheet steel, with one type 2 flange, one lap riveted seam with item 57, and two spot welded seams.

57. Straight duct, 20" x 10", 10" long, with one type 3 flange and one lap riveted seam with item 61. Constructed of 18 ga sheet steel, and two "Pittsburgh" type seams.

58. Straight duct, 5" x 5", 33" long, with one type 3 flange and one lap riveted seam with item 47. Constructed of 24 ga sheet steel, with one grooved seam.

59. Straight duct, 8" x 16", 22" long, with one type 3 flange. Constructed of 20 ga sheet steel with one welded seam.

60. Straight duct, 12" x 16", 44" long, with one lap riveted seam with item 67, and one end capped and lap riveted. Constructed of 20 ga sheet steel with two "Pittsburgh" type seams.

61. Straight duct, acoustically insulated, 20" x 10", 114" long, with two type 3 flanges. Constructed of 18 ga sheet steel with two "Pittsburgh" type seams.

62. Straight duct, 20" x 10", 35" long, with one type 3 flange, and one welded seam with item 66. Constructed of 18 ga sheet steel with two "Pittsburgh" type seams.

63. Orifice plate, for insertion between two type 3 flanges in 8" x 16" duct, 24 ga sheet steel.

64. Bolted access plate for 6" x 15" opening, 16 ga sheet steel, with gasket and 1" x 1/8" framing ring.

65. Headroom flange for 17" x 16" duct—two type 3 flanges modified to suit flat bottom. 1" x 1/8" steel flat bar tapping ring and 14 ga sheet steel cover plate.

66. Bellmouth exhaust terminal, for 20" x 10" duct. Constructed of 18 ga sheet steel with welded corner seams and welded seams with item 62. With ½" x ½" screening and retaining ring.

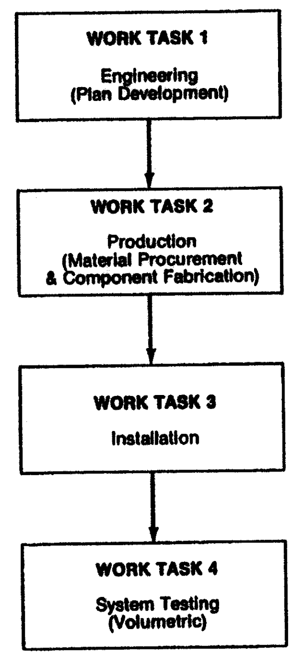
67. Special flange, for joining 12" x 16" duct. Flange 12" long with two lap riveted seams with items 35 & 60. Constructed of 20 ga sheet steel with bottom plate removable.

## MATERIAL COSTS

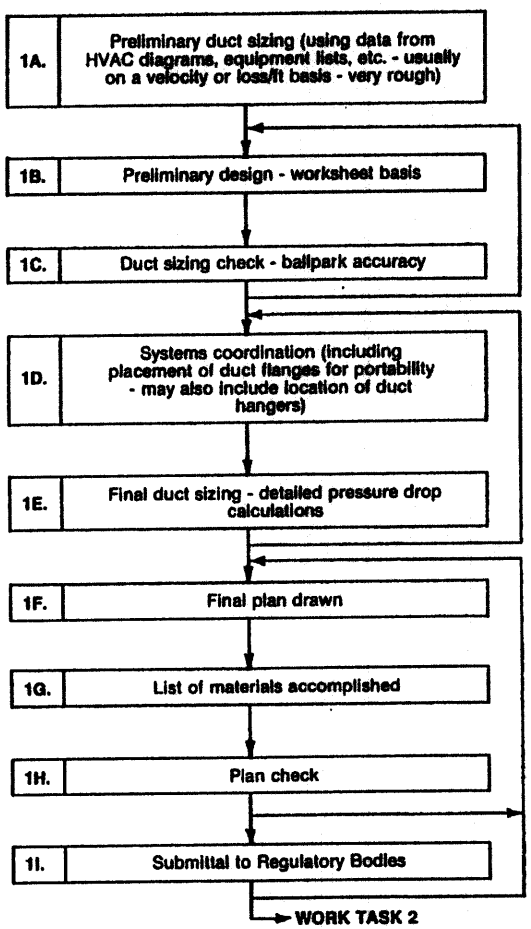
| Article & Quantity | Price ($) |
|---|---|
| 24 ga galv sheet steel, 12 $Ft^2$ | 2.50 |
| 22 ga galv sheet steel, 14.2 $Ft^2$ | 3.61 |
| 20 ga galv sheet steel, 135 $Ft^2$ | 40.39 |
| 18 ga galv sheet steel, 233 $Ft^2$ | 90.65 |
| 16 ga galv sheet steel, 10 $Ft^2$ | 4.79 |
| 14 ga galv sheet steel, 1.7 $Ft^2$ | 1.00 |
| 11 ga galv sheet steel, 50 $Ft^2$ | 47.21 |
| ¼" thick steel plate, 11 $Ft^2$ | 20.78 |
| 1⅝" x 1¼" x ⅛" galv steel angle, 73 LF | 31.43 |
| 1½" x 1½" x ⅛" galv steel angle, 8 LF | 3.44 |
| 1" x 1" x ⅛" galv steel angle, 66 LF | 18.48 |
| 1½" x 3/16" galv steel FB, 50 LF | 11.25 |
| 1½" x ¼" galv steel FB, 2.3 LF | .66 |
| 1" x 1/8" galv steel FB, 13 LF | 1.44 |
| ⅝" x 3/16" CRES FB, 6 LF | 1.44 |
| ⅝" x 1/8" CRES FB, 4 LF | .30 |
| 3/16" x 1-7/16" galv steel FB, 140 LF | 31.50 |
| ¾" IPS half-coupling, 1 required | .40 |
| Damper assemblies, balance and shut-off, 4 required - bought as units | 25.00 |
| Spacers, ⅜ tubing, ⅜" long, steel, 20 required | .30 |
| Splitter damper assembly, 1 required, bought as unit | 6.00 |
| 1" x 1/16" spring steel, cad plated, 1.5 LF | .30 |
| 1½" x .05" brass strip, 1 LF | .75 |
| Gasket, ⅛" cloth-inserted rubber, 20 $Ft^2$ | 5.00 |
| 1" half-round bar, galv steel, 1.5 LF | .50 |
| Fusible link, 1 required | .30 |
| ¾" dia shaft, CRES, 6 LF | 2.70 |
| ¾" dia std pipe, CRES, 4 LF | 1.20 |
| 3" O.D. x ⅞" I.D. CRES bearing plate, 3/16" thick, 5 required | 1.50 |
| 1¼" O.D. x ¾" I.D. CRES thrust collar, ½" thick, 4 required | 1.00 |
| 1-9/16" O.D. x 1.1" I.D. CRES thrust collar, ¾" thick, 2 required | .75 |
| ⅛" dia brass pin, 1½" long, 4 required | .40 |
| 1½" x ⅛" CRES FB, 1.4 LF | .40 |
| ¼" - 20 NC-3 RH mach screws, 1" long, 20 required | .30 |
| ¼" - 20 NC-3 hex nuts, 20 required | .20 |
| ⅜" - 16 NC-2 hex head bolts, 1" long, 504 required | 10.00 |
| #10 flat point thread cutting mach screws, ¼" long, 14 required | .15 |

| | |
|---|---|
| 3/16" - 20 NC-3 hex head bolt, ½" long, 10 required | .15 |
| 3/16" - 20 NC-3 hex nuts, 10 required | .10 |
| ⅜" - 16 NC-2 hex nuts, 504 required | 7.50 |
| Break-mandrel type "Pop" rivets, 1600 required | 15.00 |
| ¼" - 20 UNC-3B "Rivnuts," 44 required | 1.54 |
| ¼" - 20 UNC-3B RH machine screws, ¾" long, 44 required | .50 |
| ¼" - 20 NC-2 RH machine screws, ¾" long, 259 required | 2.60 |
| ¼" - 20 NC-2 RH machine screws, brass, ¾" long, 6 required | .18 |
| ¼" - 20 NC-2 hex nuts, brass, 7 required | .14 |
| Washers for ⅜" dia bolt, 462 required | 2.30 |
| ¼" - 20 NC-2 hex head machine screw, brass, 1⅛" long, 1 required | .03 |
| Washer for ¼" dia bolt, brass, 5 required | .05 |
| ¼" - 20 NC-3 hex head bolts, 1¼" long, 12 required | .15 |
| ¼" - 20 NC-3 wing nuts, 12 required | .48 |
| ¼" - 20 NC-2 hex nuts, 259 required | 2.60 |
| ¼" - 20 NC-2 hex head cone point machine screw, CRES 3/16" long, 2 required | .20 |
| Lock washer for ¼" bolt, brass, 2 required | .03 |
| #10 - 32 NC-2 hex head machine screw, CRES, 1¼" long, 3 required | .06 |
| ½" x ½" wire mesh, 6 Ft² | .90 |
| 5/32" flat CSK-head rivets, 16 required | .12 |
| ¼" - 20 NC-3 flat head machine screws, ½" long, 20 required | .20 |
| Thermal insulation, fiberglass board type, 1" thick, 67 Ft² | 20.00 |
| Acoustic insulation, fiberglass board type, 1" thick, 48 Ft² | 14.40 |
| Adhesive for cementing lagging cloth to insulation, 1 gallon | 10.00 |
| Adhesive for cementing insulation to duct, 1.5 gallons | 15.00 |
| Vaper barrier, 4 gallons | 40.00 |
| 2" glass tape, 46 LF | 4.60 |
| Lagging cloth, 71 Ft² | 7.10 |
| Duct joint sealer, 2 gallons | 30.00 |
| TOTAL MATERIAL COST = | $543.81 |

**BASIC WORK FLOW DIAGRAM**



**WORK TASK 1 - ENGINEERING (Plan Development)**



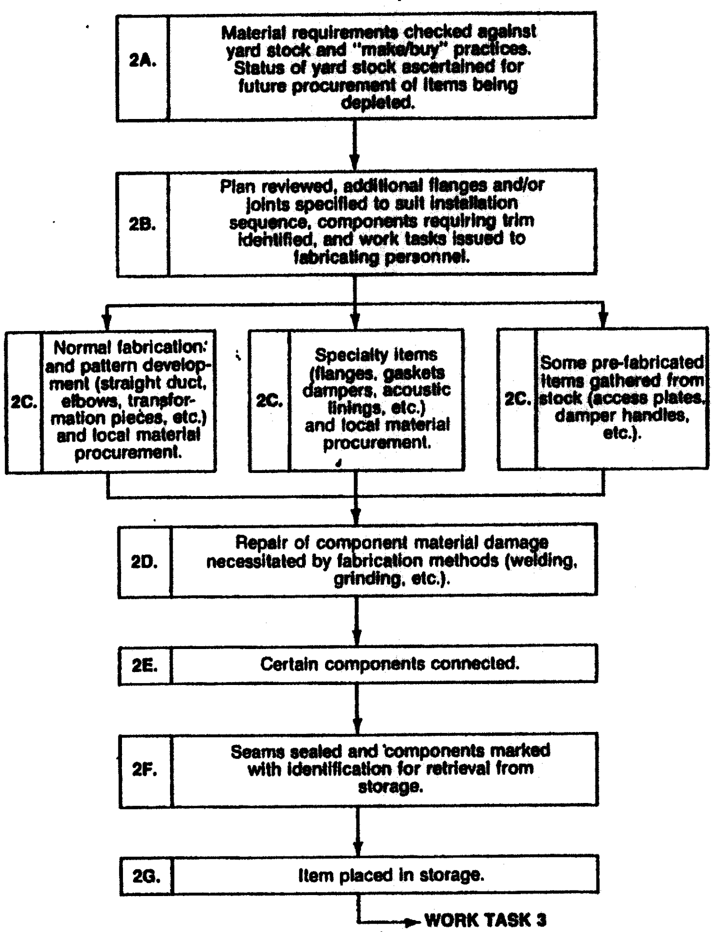

## WORK TASK 1 — COSTS

### DIRECT LABOR

| ITEM | MANHOURS | MANHOUR RATE ($) | SUBTOTALS ($) |
|---|---|---|---|
| 1a | 4 | 7.50 | 30.00 |
| 1b | 24 | 7.50 | 180.00 |
| 1c | 4 | 7.50 | 30.00 |
| 1d | 24 | 7.50 | 180.00 |
| 1e | 12 | 7.50 | 90.00 |
| 1f | 28 | 7.50 | 210.00 |
| 1g | 12 | 7.00 | 84.00 |
| 1h | 4 | 10.00 | 40.00 |
| 1i | — | — | — |
| | DIRECT LABOR | = | 844.00 |
| | DIRECT MATERIAL | = | — |
| | INDIRECT COST* | = | 675.20 |
| | TOTAL COST | = | $1519.20 |

* 80% of Direct Labor

**WORK TASK 2 - PRODUCTION (Material Procurement and Component Fabrication)**




## WORK TASK 2 — COSTS

### DIRECT LABOR

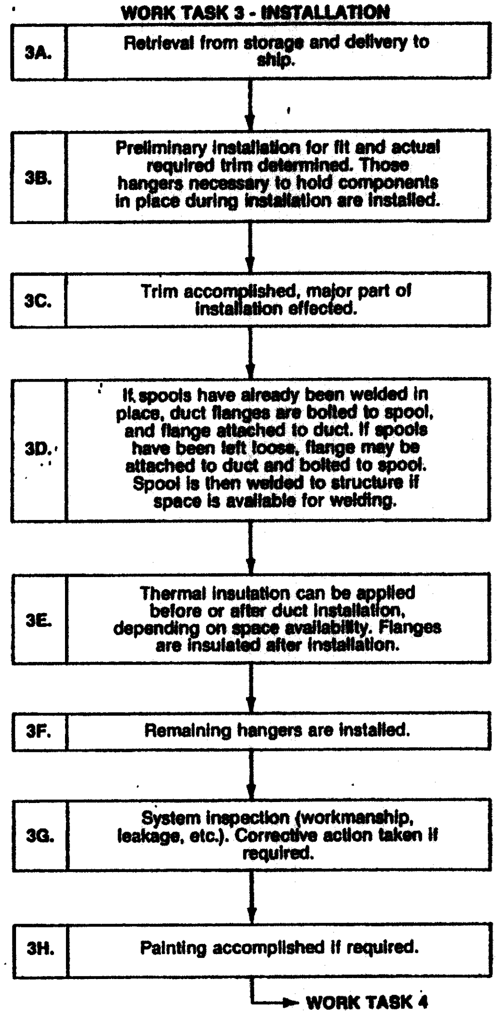
| ITEM | MANHOURS | MANHOUR RATE ($) | | SUBTOTALS ($) |
|---|---|---|---|---|
| 2a | 12 | 6.50 | | 78.00 |
| 2b | 16 | 8.50 | | 136.00 |
| 2c | 266 | 7.00 | | 1862.00 |
| 2d | 8 | 6.50 | | 52.00 |
| 2e | 16 | 7.00 | | 112.00 |
| 2f | 8 | 6.50 | | 52.00 |
| 2g | 2 | 6.50 | | 13.00 |
| | DIRECT LABOR | | = | 2305.00 |
| | DIRECT MATERIAL | | = | 543.81 |
| | INDIRECT COST* | | = | 1152.50 |
| | TOTAL COST | | = | $4001.31 |

* 50% of Direct Labor

MANHOURS — WORK TASK 2C (COMPONENT FABRICATION)

| Item No. | Manhours | Item No. | Manhours | Item No. | Manhours |
|---|---|---|---|---|---|
| 1 | 3.0 | 24 | 4.0 | 47 | 3.0 |
| 2 | 10.0 | 25 | 4.5 | 48 | 2.0 |
| 3 | 2.5 | 26 | 3.0 | 49 | 3.0 |
| 4 | 24.0 | 27 | 8.0 | 50 | 4.0 |
| 5 | 4.5 | 28 | 3.0 | 51 | 3.0 |
| 6 | 4.0 | 29 | 3.0 | 52 | 3.0 |
| 7 | 4.5 | 30 | 3.0 | 53 | 1.5 |
| 8 | 16.0 | 31 | 4.0 | 54 | 3.0 |
| 9 | 4.0 | 32 | 1.0 | 55 | 4.0 |
| 10 | 2.5 | 33 | 1.5 | 56 | 3.0 |
| 11 | 3.0 | 34 | 4.0 | 57 | 4.0 |
| 12 | 3.5 | 35 | 1.0 | 58 | 3.0 |
| 13 | 6.0 | 36 | 1.0 | 59 | 3.0 |
| 14 | 3.5 | 37 | 1.0 | 60 | 2.0 |
| 15 | 4.0 | 38 | 2.0 | 61 | 8.0 |
| 16 | 4.0 | 39 | 1.0 | 62 | 4.0 |
| 17 | 4.0 | 40 | 3.0 | 63 | 1.0 |
| 18 | 2.0 | 41 | 3.0 | 64 | 2.5 |
| 19 | 3.5 | 42 | 2.0 | 65 | 4.0 |
| 20 | 6.0 | 43 | 2.5 | 66 | 3.5 |
| 21 | 3.0 | 44 | 2.5 | 67 | 2.0 |
| 22 | 16.0 | 45 | 2.5 | | |
| 23 | 4.5 | 46 | 1.0 | TOTAL | 266.0 |

WORK TASK 3 - INSTALLATION




WORK TASK 3 — COSTS

DIRECT LABOR

| ITEM | MANHOURS | MANHOUR RATE ($) | SUBTOTALS ($) |
|---|---|---|---|
| 3a | 6 | 6.00 | 36.00 |
| 3b | 24 | 7.00 | 168.00 |
| 3c | 20 | 7.00 | 140.00 |
| 3d | 12 | 7.00 | 84.00 |
| 3e | 8 | 7.50 | 60.00 |
| 3f | 6 | 7.00 | 42.00 |
| 3g | 4 | 9.00 | 36.00 |
| 3h | 8 | 6.50 | 52.00 |

| | | |
|---|---|---|
| DIRECT LABOR | = | 618.00 |
| DIRECT MATERIAL | = | — |
| INDIRECT COST* | = | 247.20 |
| TOTAL COST | = | $865.20 |

* 40% of Direct Labor

**WORK TASK 4 - SYSTEM TESTING (Volumetric)**

| | |
|---|---|
| 4A. | All fans serving in any way the spaces served by the system to be tested are operated. All doors are placed in their normally closed or open position. |
| 4B. | All dampers and valves on the system to be tested which are normally open are fully opened. Any dampers or valves on the system to be tested which are normally closed are fully closed. |
| 4C. | Volumetric readings are taken on all terminals of the system to be tested. |
| 4D. | If no serious underdelivery exists, balancing dampers, splitter dampers, and orifice plates, are adjusted until all terminals are found to supply (or exhaust) the specific air quantities (within an allowable tolerance range). |
| 4E. | If an unallowable underdelivery exists on one or more terminals, the system is adjusted as good as possible. If, after investigation of such items as fan speed, fan electrical characteristics, duct blockage, etc., the cause of the the underdelivery is not found, the problem is returned to the engineering group for analysis and corrective action. |

## WORK TASK 4 — COSTS

### DIRECT LABOR

| ITEM | MANHOURS | MANHOUR RATE ($) | SUBTOTALS ($) |
|---|---|---|---|
| 4a | 2 | 8.00 | 16.00 |
| 4b | 1 | 8.00 | 8.00 |
| 4c | 2 | 8.00 | 16.00 |
| 4d | 8 | 8.00 | 64.00 |
| 4e | — | — | — |

| | | |
|---|---|---|
| DIRECT LABOR | = | 104.00 |
| DIRECT MATERIAL | = | — |
| INDIRECT COST* | = | 31.20 |
| TOTAL COST | = | $135.20 |

* 30% of Direct Labor

### SUMMARY — COSTS

| Work Task | Direct Labor ($) | Direct Material ($) | Indirect Cost ($) | Sub-Total ($) |
|---|---|---|---|---|
| 1 | 844.00 | — | 675.20 | 1519.20 |
| 2 | 2305.00 | 543.81 | 1152.50 | 4001.31 |
| 3 | 618.00 | — | 247.20 | 865.20 |
| 4 | 104.00 | — | 31.20 | 135.20 |
| TOTALS | $3871.00 | $543.81 | $2106.10 | $6520.91 |

Note — Due to the wide variance existing throughout the industry in labor rates and indirect costs, only the material costs and manhour estimates are considered to be significant factors of reasonable reliability.

## APPENDIX E

## AREAS FOR FUTURE STUDY

The researcher's recommendation for areas of future study that have the greatest potential for cost savings are discussed herein.

### INTRODUCTION

The following discussion presents proposals and recommendations for areas of future study. Many of these can be reduced or increased in scope, depending upon the reviewing activity. However, John J. McMullen Associates, Inc. (JJMA) considers that these items are representative of the areas of greatest potential cost savings and/or improvement for American-built merchant ships.

Certain of the proposed recommendations are a result of encountering unresolved problems whose resolution is beyond the scope of this project. Others have been suggested to afford the shipbuilding industry cost-saving innovations and practices similar to those generally available to shoreside design and construction activities.

### DUCT PRODUCTION AND FABRICATION

As part of this project, detailed research has been directed towards the practices followed in the commercial shoreside HVAC industry. Certain of the information gathered in this effort has been associated with the layout, work and material flow, and machinery used within sheet metal shops, with regard to minimizing costs. While it is obvious that the problems faced by a shipyard are more complex than those encountered ashore, it would seem that certain of the principles are especially significant to duct standardization and cost savings. It is therefore recommended that a study be undertaken to determine if a feasible production line type of duct fabrication process may be developed to suit the diversity of the marine industry. While some shipyards might already be utilizing such a concept JJMA suggests that the additional advice of experts in the field of shoreside sheet metal fabrication, work flow processes, and manufacturing of associated machinery, may result in additional economical advantages. Any such effort would have to be undertaken with due respect to agreements and contracts between shipyards and their union associations. If agreeable to those concerned, the study should be accomplished through joint input from shipyard fabrication personnel and from an organization experienced in studies of this type.

In conjunction with the above recommendation, JJMA also suggests that shipyard personnel associated with sheet metal fabrication be given the opportunity to review and comment on some of the new machinery, tools, and sheet metal forming methodology now available. While JJMA is primarily concerned with the design phase of most projects, and shop personnel are more closely involved with the actual details and problems of fabrication and construction, there are several innovative devices now on the market, both motor-driven and manual, that offer the promise of increased productivity. There is also an abundance of fabricated parts and ducting components which are available. JJMA has found that an excellent source of such items, and articles associated with the commercial sheet metal trades, is "SNIPS" Magazine, Inc. Included in this review should be an investigation of some of the recent developments regarding the internal environment of workshops where operations are performed which give off toxic or annoying fumes (welding, burning, etc.). The energy shortage has resulted in designs which are directed at least cost/energy usage. The concepts involved with such designs are not unknown to shipyard personnel, however, some of the new hardware may be.

### PRESSURE DROP TEST PROGRAM

It is proposed that a testing program be instituted to determine the pressure drop losses associated with duct branch take-offs (taps), especially on the return/exhaust side of HVAC systems. While branch take-off losses on the supply side of systems have been fairly well determined and documented (at least for round duct), return-side losses have not been subjected to the same degree of resolution. Most of the trade data sources state this condition, and where factors are given, they are noted to be only those generally used and not substantiated by a testing program. While the U.S. Navy gives values in their Design Data Sheets, an examination of these will indicate that they are unsatisfactory for all branch/main air ratios. Many design organizations utilizing these Design Data Sheets revise these values to suit such ratios. But the results of these revised values have not been confirmed.

The main objectives of the proposed testing program are:

- Determine duct take-off pressure drop losses for branch and main sections, on both the supply and return side of systems.
- Determine the geometric relationships of branch to main configurations which result in the least pressure drop losses, and which are most easily constructed.
- Determine the pressure drop loss variations between single and multiple take-off connections at the same point on the main section.
- The above to be determined for both symmetrical and non-symmetrical take-off connections (connecting ducts centerline relationship), with equal and unequal air velocities in the branch and main ducts.
- Testing and analyses to cover the full range of air velocities normal to marine projects, for both round and rectangular ducts and combinations thereof, and for the full range of expected branch/main air quantity and velocity ratios.

The results of such a testing program will make available to system designers data more reliable than what they presently use, and will therefore eliminate some of the problems encountered during system test and balance procedures. In addition, a basic contribution of the program—should configurations be found with reasonably low pressure drop losses—would be the elimination of many of the split mains now used in favor of the more easily constructed take-off concept. This would not only result in savings to the fabrication activities, but would also give the system designer more freedom of choice. The above would also serve to further reduce (perhaps significantly) the number of specific sizes as proposed in the basic standardization program.

## COMPUTER PROGRAMS

Although there are numerous duct pressure drop computer programs available for use by commercial shoreside HVAC design activities, there is a definite lack of a comprehensive program to suit marine HVAC installations. The low air velocities generally found in shoreside installations, the different design parameters, (space availability, system function, length of run, equipment types, specific air flow conditions, duct component type, etc.), and the actual basis of calculations, make the use of programs designed for shoreside installations impractical for marine installations unless substantial program revision, review and in many cases, rework, is accomplished.

There are programs available which were developed for marine installations by various design agents and shipyard design functions. However, from review and use of certain of these, JJMA feels that none are fully responsive to the limiting design conditions peculiar to marine installations, especially when considered in respect to standardized duct sizes and components, and to cost savings from fabrication and installation activities.

It is therefore proposed that a pressure drop program be developed specifically for marine designs, and that it consist of a two-stage procedure. The first stage would give preliminary sizing information to the designers for use during the initial design phase. The second stage would produce the final pressure drop calculations and duct sizes subsequent to the systems design/coordination phase. The two stages should be so organized, and the initial stage so developed that any differences in their duct size outputs (due to changes necessary during the coordination phase of design) are small enough to be accommodated without the need for repeated systems coordination.

The program should be developed to create a standard of HVAC system air flow performance for American shipbuilding interests, and be arranged so that any necessary program changes/adjustments at later dates may be easily incorporated. It should include an extensive input data checking procedure, be capable of accommodating both complete and partial systems, be capable of achieving system balance within the constraints of the proposed standard sizes and components, and accomplish the necessary evaluations to maximize cost savings in the fabrication and installation activities. It is estimated that a savings of 75 percent would ultimately result in the design activity alone (over the cost resulting from hand calculations) through the use of such a computer program. The development of this program could also include provision for two other functions; HVAC noise calculations, and system material requirements. This would further reduce the need for hand calculation, and in the case of noise calculations, would also reduce the extent of any corrective action after system installation and testing.

It is also proposed that a computer program be developed to perform space heating/cooling load calculations on a standard basis for merchant ships. The program should have, as a major part of its contents, all "U" factor information as set forth in the S.N.A.M.E. Technical and Research Bulletin 4-7, "Thermal Insulation Report." It should be capable of selecting summer, winter, and change-over, "U" factor values, and of interpolating between end values as given in the cited report. As with the proposed duct pressure-drop computer program, it should have an extensive input data checking procedure, and be capable of printing out all pertinent outputs in a format easily utilized by design personnel. Major design parameter values which may change from ship to ship (weather conditions, personnel loadings, space temperatures, glass transmittance values, etc.) should be read by the computer as problem input variables so that the program is as versatile as possible.

## THERMAL INSULATION

At present, the U.S. Navy is eliminating thermal insulation on supply side air conditioning ductwork, depending on the relationship existing between the dry bulb temperature of the air within the duct and the wet bulb temperature of the air surrounding the duct. Further, in areas where this relationship would necessitate insulation, the system designer has the option of either specifying insulation or providing by-pass air on the system so that insulation is not required. Thermal insulation on the return side of an air conditioning system is, in general, not required. Thermal insulation requirements on ducting of supply and exhaust systems is specified in section 509 of the U.S. Navy General Specifications, with an easily followed format. JJMA has noted the effect of minimizing insulation on Naval ships in accomplishing various tasks for the Naval Ship Engineering Center. Except for some specific instances, little condensation has been observed. One observation within a scullery showed that the occurrence of condensation on uninsulated ductwork was dependent on the existence of paint on the exterior surface of the ducting. Immediately after space usage, condensation was observed on painted supply duct, but none on unpainted galvanized steel duct on the same system.

Based on the above, it is proposed that a study be undertaken to determine the minimum thickness and type of insulation required for duct work commensurate with condensation and heat transfer considerations. The basic objective is to reduce, or eliminate, as much of the presently required thermal insulation as possible.

Thermal insulation on all duct cannot be eliminated totally. However, for many cases where elimination is not possible, the amount required can be reduced. In addition, for borderline cases, the application of an insulating paint or similar coating may serve the purpose. Since the application of insulation is a costly item, requiring in many cases considerations such as vapor sealing, portable pieces for flanges, access plates, etc., the need for such a study seems evident.

## HVAC EQUIPMENT

There have been substantial advances in HVAC equipment design to suit the commercial shoreside trade in the past 15 years, as well as broad developments in methods and concepts for protecting material from adverse environmental conditions. These should be investigated with respect to their particular application to marine projects. New equipment types have been designed and built for the U.S. Navy, including larger cooling coils and a new family of sizes of fan coil units. These items should also be investigated for applicability to commercial marine projects.

In conjunction with the above, it is proposed that a study be undertaken to review, update, and/or change, the type of HVAC equipment presently required for installation on American flag ships. Few equipment manufacturers have been responding to requests for bids on marine projects. Some have stated that they do not wish to bid on marine projects due to the specialties involved, and the increasing costs and scarcities of certain of the materials required to meet specifications.

One of the common problems faced by equipment manufacturers is that of tooling and work scheduling to suit marine requirements, and of having large periods of time in which the need for their product is not in reasonable demand. It may be desirable to have equipment types which, except for military shock grading, are applicable for both naval and commercial marine designs. Trade-off analyses should be accomplished concerning items such as adjustable pitch direct drive vaneaxial fans (similar to the Buffalo Forge Co. "Adjustax" series) which may be adjusted for capacity control after installation. The trade-offs should include the extra cost for such equipment versus the time saved during the system testing and balancing procedures.

A study of this type should be accomplished through a joint effort of both equipment manufacturers and representatives of the marine design field. Owners' requirements and crew and operating personnel complaints should serve as an input to such a study as well as survey reports of equipment installed on existing ships of various ages.

## CONSTRUCTION DETAILS

It is the opinion of JJMA that there is a definite need to establish a standard booklet of construction details, resulting in the simplification of existing methods and the minimization of the number of source materials. As part of this development, cognizance should be taken of the large selection of components and associated hardware available from the various American manufacturers. In addition, all construction details should be so arranged that make/buy decisions will not affect connecting components, or the component into which the bought item is to be inserted, if such is the case.

## SPECIFICATIONS

It is proposed that the standard Marad specification format for Section 7 (Insulation, Linings, and Battens) insofar as compartment thermal and acoustic insulation is concerned, Section 12 (Air Conditioning, Heating and Ventilation), and Section 64 (Machinery Space Ventilation), be rewritten similar to the format used in the U.S. Navy specifications, Section 509 (Thermal Insulation and Acoustic Absorptive Treatment for Ducts and Trunks), section 512 (Air Conditioning, Ventilation and Heating), and Section 635 (Thermal Insulation and Acoustic Absorptive Treatment of Compartments for Surface Ships). In addition, any such redevelopment of Section 12 of the standard Marad specification should contain a definitive set of instructions regarding the U.S. Coast Guard's fire protection requirements as applicable to HVAC systems, and an explanation of rat proofing requirements for interspace protection.

In conjunction with this effort, it is also recommended that a compartment insulation chart be developed similar to that found in Section 635 of the U.S. Navy specifications, and a Design Criteria Manual be developed for merchant ships, similar in format and content to that developed by the U.S. Navy, "Air Conditioning, Ventilation and Heating Design Criteria Manual for Surface Ships of the United States Navy" (N.S. 0938-018-0010).

This recommendation has been made in the belief that a more explicit set of specifications will better serve both the design functions and the shipowners, as well as facilitate checking by the owners' representatives. Some of the ambiguities and arguments which presently occur will vanish. A redevelopment of the specifications can be made in such a manner as to easily accommodate any specific changes found desirable for any particular ship.

## CONCLUSION

In making the above proposals and suggestions, JJMA realizes that some personnel, intimately associated with marine type HVAC installations, will strongly disagree with the degree of economic savings and benefits to the ship. It is also true that design, fabrication, and installation practices differ between the various shipyards, and therefore what benefits one may be found costly to another. JJMA has attempted to analyze the proposals in a manner to assure that effort has been directed toward the formulation of cost reducing innovations. All comments, arguments, and counter-proposals from American shipyard personnel and from the shipbuilding industry are not only welcome, but necessary in furthering the cost saving features of the National Shipbuilding Research Program studies.

## APPENDIX F

### DUCT SIZE UTILIZATION — FIRST GENERATION OF SPLITS

This is a listing of first-generation standard splits from standard duct.

| STANDARD DUCT SIZE | | STANDARD SPLITS | |
|---|---|---|---|
| DEPTH(IN.) | WIDTH(IN.) | DEPTH OF SPLITS (INCHES) | WIDTH OF SPLITS (INCHES) |
| 2 | 4 | — | — |
| | 6 | — | — |
| | 8 | — | 4 |
| 4 | 4 | 2 | 2 |
| | 6 | 2 | 2,4 |
| | 8 | 2 | 2,4,6 |
| | 10 | — | 2,4,6,8 |
| | 12 | — | 2,4,6,8,10 |
| | 14 | — | 2,4,6,8,10,12 |
| 6 | 6 | 2,4 | 2,4 |
| | 8 | 2,4,6 | 2,4,6 |
| | 10 | — | 2,4,6,8 |
| | 12 | — | 2-10 in 2 inch increments |
| | 14 | — | 2-12 in 2 inch increments |
| | 16 | — | 2-14 in 2 inch increments |
| | 18 | — | 2-16 in 2 inch increments |
| 8 | 8 | 2,4,6 | 2,4,6 |
| | 10 | 4 | 2,4,6,8 |
| | 12 | 4 | 2-10 in 2 inch increments |
| | 14 | 4 | 2-12 in 2 inch increments |
| | 16 | — | 2-14 in 2 inch increments |
| | 18 | — | 2-16 in 2 inch increments |
| | 20 | — | 2-18 in 2 inch increments |
| | 22 | — | 2-20 in 2 inch increments |
| | 24 | — | 2-22 in 2 inch increments |

| STANDARD DUCT SIZE | | STANDARD SPLITS | |
|---|---|---|---|
| DEPTH(IN.) | WIDTH(IN.) | DEPTH OF SPLITS (INCHES) | WIDTH OF SPLITS (INCHES) |
| 10 | 10 | 4,6 | 4,6 |
| | 12 | 4,6 | 4,6,8 |
| | 14 | 4,6 | 4,6,8,10 |
| | 16 | — | 4-12 in 2 inch increments |
| | 18 | — | 4-14 in 2 inch increments |
| | 20 | — | 4-16 in 2 inch increments |
| | 22 | — | 4-18 in 2 inch increments |
| | 24 | — | 4-20 in 2 inch increments |
| | 26 | — | 4-22 in 2 inch increments |
| | 28 | — | 4-24 in 2 inch increments |
| | 30 | — | 4-26 in 2 inch increments |
| 12 | 12 | 4,6,8 | 4,6,8 |
| | 14 | 4,6,8 | 4,6,8,10 |
| | 16 | 6 | 4-12 in 2 inch increments |
| | 18 | 6 | 4-14 in 2 inch increments |
| | 20 | — | 4-16 in 2 inch increments |
| | 22 | — | 4-18 in 2 inch increments |
| | 24 | — | 4-20 in 2 inch increments |
| | 26 | — | 4-22 in 2 inch increments |
| | 28 | — | 4-24 in 2 inch increments |
| | 30 | — | 4-26 in 2 inch increments |
| | 32 | — | 4-28 in 2 inch increments |
| | 34 | — | 4-30 in 2 inch increments |
| | 36 | — | 4-32 in 2 inch increments |
| 14 | 14 | 4,6,8,10 | 4,6,8,10 |
| | 16 | 6,8 | 4-12 in 2 inch increments |
| | 18 | 6,8 | 4-14 in 2 inch increments |
| | 20 | — | 4-16 in 2 inch increments |
| | 22 | — | 4-18 in 2 inch increments |
| | 24 | — | 4-20 in 2 inch increments |
| | 26 | — | 4-22 in 2 inch increments |
| | 28 | — | 4-24 in 2 inch increments |
| | 30 | — | 4-26 in 2 inch increments |
| | 32 | — | 4-28 in 2 inch increments |
| | 34 | — | 4-30 in 2 inch increments |
| | 36 | — | 4-32 in 2 inch increments |
| | 38 | — | 4-34 in 2 inch increments |
| | 40 | — | 4-36 in 2 inch increments |
| | 42 | — | 4-38 in 2 inch increments |

| STANDARD DUCT SIZE | | STANDARD SPLITS | |
|---|---|---|---|
| DEPTH(IN.) | WIDTH(IN.) | DEPTH OF SPLITS (INCHES) | WIDTH OF SPLITS (INCHES) |
| 16 | 16 | 6,8,10 | 6,8,10 |
| | 18 | 6,8,10 | 6-12 in 2 inch increments |
| | 20 | 8 | 6-14 in 2 inch increments |
| | 22 | 8 | 6-16 in 2 inch increments |
| | 24 | 8 | 6-18 in 2 inch increments |
| | 26 | — | 6-20 in 2 inch increments |
| | 28 | — | 6-22 in 2 inch increments |
| | 30 | — | 6-24 in 2 inch increments |
| | 32 | — | 6-26 in 2 inch increments |
| | 34 | — | 6-28 in 2 inch increments |
| | 36 | — | 6-30 in 2 inch increments |
| | 38 | — | 6-32 in 2 inch increments |
| | 40 | — | 6-34 in 2 inch increments |
| | 42 | — | 6-36 in 2 inch increments |
| | 44 | — | 6-38 in 2 inch increments |
| | 46 | — | 6-40 in 2 inch increments |
| | 48 | — | 6-42 in 2 inch increments |
| 18 | 18 | 6,8,10,12 | 6,8,10,12 |
| | 20 | 8,10 | 6-14 in 2 inch increments |
| | 22 | 8,10 | 6-16 in 2 inch increments |
| | 24 | 8,10 | 6-18 in 2 inch increments |
| | 26 | — | 6-20 in 2 inch increments |
| | 28 | — | 6-22 in 2 inch increments |
| | 30 | — | 6-24 in 2 inch increments |
| | 32 | — | 6-26 in 2 inch increments |
| | 34 | — | 6-28 in 2 inch increments |
| | 36 | — | 6-30 in 2 inch increments |
| | 38 | — | 6-32 in 2 inch increments |
| | 40 | — | 6-34 in 2 inch increments |
| | 42 | — | 6-36 in 2 inch increments |
| | 44 | — | 6-38 in 2 inch increments |
| | 46 | — | 6-40 in 2 inch increments |
| | 48 | — | 6-42 in 2 inch increments |
| | 50 | — | 6-44 in 2 inch increments |
| | 52 | — | 6-46 in 2 inch increments |
| | 54 | — | 6-48 in 2 inch increments |

| STANDARD DUCT SIZE | | STANDARD SPLITS | |
|---|---|---|---|
| DEPTH(IN.) | WIDTH(IN.) | DEPTH OF SPLITS (INCHES) | WIDTH OF SPLITS (INCHES) |
| 20 | 20 | 8,10,12 | 8,10,12 |
| | 22 | 8,10,12 | 8,10,12,14 |
| | 24 | 8,10,12 | 8,10,12,14, 16 |
| 22 | 22 | 8,10,12,14 | 8,10,12,14 |
| | 24 | 8,10,12,14 | 8,10,12,14,16 |
| 24 | 24 | 8,10,12,14,16 | 8,10,12,14,16 |

# APPENDIX G

## COST ANALYSIS

Costs for various transverse connections, transformation pieces, access plates and a bellmouth terminal are itemized herein. Costs are in February 1976 dollars.

1.0 Cost Analysis: Flanged vs. Non-Flanged Transverse connections, comparison basis = 12-inch by 24-inch duct

1.1 Flanged Type 4A; riveted angle flange, reinforced

| Net material required: | Cost ($) |
|---|---|
| • 1" X 1" X 1/8" steel angle, 4-26" lengths | 2.17 |
| • 1" X 1" X 1/8" steel angle, 4-12" lengths | 1.00 |
| • 28-1/4" 20 NC RH MS, 3/4" LG | .45 |
| • 28-1/4" 20 NC hex nuts | .31 |
| • 2-72" X 1" 20 ga additional material on duct components | .30 |
| • 88-3/16" dia "pop" rivets | 1.58 |
| • 76" strip of 1" wide, 1/8" thick gasket | .21 |
| • Duct sealer (2-72" lengths & 88 rivet heads) | 2.00 |
| Total material costs = | $8.02 |

| Fabrication effort required: | Time (Min) |
|---|---|
| • Measure and cut 4-26" lengths of angle | 15 |
| • Measure and cut 4-12" lengths of angle | 15 |
| • Weld 8 corners | 120 |
| • Drill or punch 56-11/32" dia holes in angles | 30 |
| • Drill or punch 88-3/16" dia holes in angles | 40 |
| • Drill 88-3/16" dia holes in components[1] | 40 |
| • Install and set 88-3/16" dia "pop" rivets[1] | 45 |
| • Seal 88 rivet heads[1] | 20 |
| • Seal 2-72" lengths[1] | 20 |
| • Measure and cust 2-26" X 1" and 2-12" X 1" lengths of gaskets[1] | 15 |
| • Align gasket on flange and drill 28-9/32" dia holes[1] | 10 |
| Total time required = | 370 Min. |

[1]Dependent on the shipyard, a high percentage of these tasks may be accomplished aboard ship during the installation procedure.

| Installation effort required: | Time (Min)[2] |
|---|---|
| • Align components, install and tighten 28-1/4" dia nuts and bolts | 60 |
| Total time required = | 60 Min. |

1.2 Non-flanged Types 10 & 11, drive cleat/S-clip

1.2.1 Types 10 & 11

Drive cleats assumed on 12" side of component, and S-clip assumed on 24" side of component.

| Net material required: | Cost ($) |
|---|---|
| • 2-15' X 2-1/4" strips of 20 ga steel (Drive cleats) | .14 |
| • 2-24" X 3-1/2" strips of 20 ga steel (S-clips) | .35 |
| • Duct sealer (2-72" lengths) | 1.80 |
| • 4-1" X 24" 20 ga additional material on duct components | .20 |
| • 4-1" X 12" 20 ga additional material on duct components | .10 |
| Total material cost = | $2.59 |

| Fabrication effort required: | Time (Min) |
|---|---|
| • Measure and cut 2-15" X 2-1/4" pieces of 20 ga steel | 10 |
| • Notch to suit locking tabs (4) | 20 |
| • Bend over form to shape 2 drive cleats | 20 |
| • Measure and cut 2-24" X 3-1/2" pieces of 20 ga steel | 15 |
| • Notch to suit component corner connections | 20 |
| • Bend over form to shape 2 S-clips | 30 |
| • Bend 4-12" X 1/2" tabs on components | 40 |
| Total time required = | 155 Min |

| Installation effort required: | Time (Min)[2] |
|---|---|
| • Align components and install 2 S-clips | 10 |
| • Install side drive cleats and bend 4 locking tabs over | 20 |
| • Seal 2-72" lengths | 20 |
| Total time required = | 50 Min. |

1.2.2 Type 11A; drive cleat/S-clip, reinforced

Drive cleats assumed on 12" side of component, and S-clips with transverse reinforcement assumed on 24" side of component.

[2]Average time, assuming some difficulty due to limited space.

| Net Material required: | Cost ($) |
|---|---|
| • Same as for non-flange types 10 & 11 | 2.59 |
| • *Plus* 2 additional 24" X 2½" strips of 20 ga steel | .25 |
| Total material cost = | $2.84 |

| Fabrication effort required: | Time (Min) |
|---|---|
| • Same as for non-flange types 10 & 11 | 155 |
| • *Plus* the additional work required to form the reinforcing part of the S-clips | 20 |
| Total time required = | 175 Min |

| Installation effort required: | Time (Min) |
|---|---|
| • Same as for non-flange types 10 & 11 | 50 |
| Total time required = | 50 Min |

### 1.3 Non-Flanged Type 9; riveted slip joint

Cost analysis based on riveted joint[1]

| Net material required: | Cost ($) |
|---|---|
| • 2 - 1" X 72" 20 ga additional material on duct components | .30 |
| • 76 - 3/16" dia "pop" rivets | 1.80 |
| • Duct sealer (1 - 72" length) | .90 |
| Total material costs = | $3.00 |

| Fabrication effort required: | Time (Min) |
|---|---|
| • Drill 4-3/16" dia holes in end of one component | 5 |
| • Attach 2 components and drill through 4 holes into second component | 10 |
| • Set 4 - 3/16" dia "pop" rivets | 5 |
| • Drill remaining 72 - 3/16" holes through both components | 70 |
| • Set remaining 72 - 3/16" dia "pop" rivets | 40 |
| • Seal 72" length | 10 |
| Total time required = | 140 Min |

[1]Net material cost and fabrication effort would be somewhat less for a spot-welded connection than for a riveted connection. However, most shops do not have the specialized welding equipment necessary for this purpose.



Installation effort required: None. It is not field connected. It is totally fabricated in the shop.

### 1.4 Non-Flanged Type 12; clip & strike latch

#### 1.4.1 Type 12

Latches and strikes on 24" side of components, therefore, 4 required (2 on each 24" side)

| Net material required: | Cost ($) |
|---|---|
| • 4 - latches | 1.20 |
| • 4 - strikes | .20 |
| • 4-⅛" dia cotter pins, 1" long | .10 |
| • 1" X 72" strip of 20 ga steel (additional on component which carries the latches) | .15 |
| • 72" X 2¼" strip of 20 ga steel (for retaining clip) | .34 |
| • 24 - 3/32" dia round head rivets | .24 |
| • 38 - 3/16" dia "pop" rivets | .90 |
| • Duct sealer (2 - 72" lengths) | 1.80 |
| Total material cost = | $4.93 |

| Fabrication effort required: | Time (Min) |
|---|---|
| • Measure and cut 2-24" X 2¼" strips of 20 ga steel | 15 |
| • Notch to suit component corner seams (4) | 10 |
| • Shape 2 - 24" lengths of retaining clip | 30 |
| • Measure and cut 2 - 12" X 2¼" strips of 20 ga steel | 10 |
| • Notch to suit component corner seams (4) | 10 |
| • Shape 2 - 12" lengths of retaining clip | 20 |
| • Drill or punch 38 - 3/16" dia rivet holes in retaining clips | 40 |
| • Drill 38 - 3/16" dia rivet holes in component | 40 |
| • Install and set 38 "pop" rivets | 20 |
| • Peen end of component carrying latch over ½" (72" long) | 40 |
| • Locate latches and strikes and drill 24 - 3/32" dia rivet holes | 30 |
| • Install and set 24 rivets (with rivet set) | 25 |
| • Seal 72" length | 10 |
| Total time required = | 300 Min |

| Installation effort required: | Time (Min) |
|---|---|
| • Seal 72" length of retaining clip | 10 |
| • Bring components together and secure latches | 10 |
| • Install and set 4 cotter pins | 5 |
| Total time required = | 25 Min |

1.4.2 Type 12A (with reinforcement)

Latches and strikes on 24" side of components, therefore, 4 required (2 on each 24" side)

| Net material required: | Cost ($) |
|---|---|
| • 4 - latches | 1.20 |
| • 4 - strikes | .20 |
| • 4 - ⅛" dia cotter pins, 1" long | .10 |
| • 72" X 3½" strip of 20 ga steel (for retaining clip) | .53 |
| • 24 - 5/32" dia round head rivets | .24 |
| • 22 - 3/16" dia "pop" rivets | .52 |
| • Duct sealer (2 - 72" lengths) | 1.80 |
| Total material cost = | $4.59 |

| Fabrication effort required: | Time (Min) |
|---|---|
| • Measure and cut 2 - 24" X 3½" strips of 20 ga steel | 15 |
| • Notch to suit component corner seams (4) | 10 |
| • Shape 2-24" lengths of retaining clip | 40 |
| • Measure and cut 2 - 12" X 3½" strips of 20 ga steel | 10 |
| • Notch to suit component corner seams (4) | 10 |
| • Shape 2-12" lengths of retaining clip | 30 |
| • Drill or punch 22 - 3/16" dia rivet holes in retaining clips | 25 |
| • Drill 22 - 3/16" dia rivet holes in component | 25 |
| • Install and set 22 "pop" rivets | 15 |
| • Locate latch and strikes and drill 24 - 5/32" dia rivet holes | 30 |
| • Install and set 24 rivets (with rivet set) | 25 |
| • Seal 72" length | 10 |
| Total time required = | 245 Min |

| Installation effort required: | Time (Min) |
|---|---|
| • Same as for non-flange type 12 | 25 |
| Total time required = | 25 Min |

1.5 Summary: Flanged versus Non-flanged Connections
(12" x 24" component size)

| | material cost | fabricate time | install time |
|---|---|---|---|
| Base: Current Type 4A, riveted angle flange, reinforced | $8.02 | 370 min. | 60 min. |
| Standard Type 10/11, drive cleat/S-clip | 2.59 | 155 | 50 |
| Standard Type 11A, drive cleat/ S-clip reinforced | 2.84 | 175 | 50 |
| Standard Type 9, riveted slip joint | 3.00 | 140 | N/A |
| Standard Type 12, clip and strike latch | 4.93 | 300 | 25 |
| Standard Type 12A, clip and strike latch | 4.59 | 245 | 25 |

2.0 Transformation Piece

2.1 Type 1

Material has been considered a trade-off with Type 2.

Fabrication method has been assumed to be based on a two-piece transformation, and two-Pittsburgh corner locks.

| Fabrication effort required: | Time (Min) |
|---|---|
| • Calculate L2 and L3 | 15 |
| • Layout 1/2 pattern on sheet metal | 15 |
| • Add allowance for corner locks and transverse connections | 10 |
| • Cut out piece | 15 |
| • Use cut-out piece for template of second piece and scribe on sheet metal | 5 |
| • Cut second piece | 15 |
| • Cut necessary corner notches | 10 |
| • Run corner locks and single locks (2 each) | 20 |
| • Bend each piece (2 bends) | 10 |
| • Assemble transformation and bend over two corner locks | 20 |
| Total time required = | 135 Min |

2.2 Type 2

Material cost has been considered a trade-off with Type 1.

Fabrication method has been assumed to be based on a two-piece transformation, and two-riveted, spot welded, or grooved seams.

| Fabrication effort required: | Time (Min) |
|---|---|
| • Calculate 1.2 & 1.3 | 15 |
| • Determine length of bend lines within radius corner area | 30 |
| • Determine distance between bend lines at intersection with plane perpendicular to air flow at radius corner end of transformation | 10 |
| • Layout 1/4 pattern and use to scribe two - 1/2 layouts on sheet metal | 40 |
| • Add allowance for corner locks and Transverse connections | 10 |
| • Cut out two pieces | 30 |
| • Cut necessary corner notches | 10 |
| • Bend each of two pieces along bend lines to 90° (4 such bends) | 40 |
| • Align 2-transformation halves and clamp together | 10 |
| • Drill 20 - 3/16" dia holes | 20 |
| • Set 20 - 3/16" dia "pop" rivets | 10 |
| Total time required = 225 Min | |

3.0 Quick-Acting Access Plates

3.1 Round Access Plate (assume 8" dia opening — 5 locking bolts)

| Net material requirements: | Cost ($) |
|---|---|
| • 1/8" thick steel (cover) | .45 |
| • 1/8" thick gasket | .16 |
| • 5 - 1/4" dia hex head machine screws, 1-1/4" long | .02 |
| • 5 - 1/4" dia wing nuts | .04 |
| • 16 ga coaming | .28 |
| Total material cost = $.95 | |

| Fabrication effort required: | Time (Min) |
|---|---|
| • Scribe cover on 1/8" plate and cut out | 20 |
| • Cut access hole in duct component | 10 |
| • Cut out coaming | 10 |
| • Form coaming | 10 |
| • Shape coaming leg in way of machine screws to lock hex heads (5) | 20 |
| • Weld coaming to duct | 15 |
| • Cut out and attach gasket | 10 |
| Total time required = 95 Min | |

3.2 Alternate Fasteners for Bolted Access Plates

| *Watertight Duct* (gasketed access cover) | Cost ($) |
|---|---|
| Present Practice: | |
| • 3/8" dia hex head bolt, 1" long | .04 |
| • Countersunk "RIVNUT" with locking feature[1] | .72 |
| Cost per fastener assembly = $.76 | |
| Proposed Change: | |
| • 5/16" dia hex head bolt, 1" long | .03 |
| • "KWIK-THRED" self-clinching fastener[2] | .06 |
| Cost per fastener assembly = $.09 | |

| *Air tight duct* (gasketed access cover) | Cost ($) |
|---|---|
| Present Practice: | |
| • 1/4" dia RH MS, 3/4" long | .02 |
| • Countersunk "RIVNUT" with locking feature[1] | .30 |
| Cost per fastener assembly[3] = $.32 | |
| Proposed Change: | |
| • 1/4" dia RH MS, 3/4" long | .02 |
| • "KWIK-THRED" self-clinching fastener[2] | .05 |
| Cost per fastener assembly = $.07 | |

---

[1]Only that effort involved with the flaired portion of the bellmouth has been listed, since the remaining work will not be affected.

[2]Development of one end curve has been assumed, which will serve as template for all 8 such curves required.

[3]Template of end curve assumed available from set of seven master templates.

4.0 Bellmouth Terminal (D = 12", W = 18")

Material for flair (by current Method A), R = 2-1/4", V = 3.53":

| | Cost ($) |
|---|---|
| • 2 - 3.53" x 22.5" 20 ga steel | .33 |
| • 2 - 3.53" x 16.5" 20 ga steel | .24 |
| Total cost (flair) = | $.57 |

| Fabrication effort for flair (by current Method A):[1] | *Time (Min)* |
|---|---|
| • layout 2-18" sides with end curves[2] | 40 |
| • layout 2-12" sides with end curves[2] | 10 |
| • Cut out 4 components | 30 |
| • Bend 4 components to required radius | 30 |
| • Weld 4 corners | 40 |
| Total time required = | 150 Min |

Material for flair (by standards) R = 3", V = 4.71":

| | Cost ($) |
|---|---|
| • 2 - 4.71" x 24" 20 ga steel | .47 |
| • 2 - 4.71" x 18" 20 ga steel | .35 |
| Total cost (flair) | $.82 |

| Fabrication effort for flair (by standards):[1] | Time (Min) |
|---|---|
| • layout 2-18" sides with end curves[3] | 10 |
| • layout 2-12" sides with end curves[3] | 10 |
| • Cut out 4 components | 30 |
| • Bend 4 components to required radius | 30 |
| • Weld 4 corners | 40 |
| Total time required = | 120 Min |

[1]Only that effort involved with the flaired portion of the bellmouth has been listed, since the remaining work will not be affected.
[2]Development of one end curve has been assumed, which will serve as template for all 8 such curves required.
[3]Template of end curve assumed available from set of seven master templates.

## APPENDIX H

## SPECIFICATION TO INVOKE STANDARDS FOR RECTANGULAR VENT DUCTS

This is a recommended specification for owners or designers who wish to invoke the standards in new construction. It is a modification of the Maritime Administration Standard Specification for Cargo Ship Construction, Section 12, Article 10, 'Trunks, Ducts, Accesses and Hoods.'

10. *TRUNKS, DUCTS, ACCESSES & HOODS*

*Duct Air Velocities*

(a) *Air Conditioning Systems*
5000 f.p.m. maximum, except that 6000 f.p.m. may be used in short branches close to the fan discharge when necessary to absorb static pressure.

(b) *Mechanical Ventilation Systems (Supply and Exhaust)*
In areas where quiet operation is essential, 2000 f.p.m. maximum. Where space conditions necessitate, local velocities may be as high as 2500 f.p.m.

In areas where quiet operation is not essential, duct velocities may exceed 2000 f.p.m. as approved, provided the fan size and rated horsepower are not increased to accomplish this.

(c) *Cargo Hold Mechanical Supply Systems*
3500 f.p.m. maximum.

*Central Cargo Hold Dehumidification Dry Air Ducts*
2000 f.p.m. maximum.

(d) *Machinery Ventilation Systems (Supply and Exhaust)*
3500 f.p.m. maximum.

(e) *Natural Vent Ducts - Serving Mechanically Ventilated Spaces (Supply or Exhaust - Direct or Indirect)*
1000 f.p.m. for less than 4000 c.f.m.
1250 f.p.m. for between 4000 - 6000 c.f.m.
1500 f.p.m. for more than 6000 c.f.m.

(f) *Natural Vent Ducts - Serving Naturally Ventilated Spaces*
800 f.p.m. (assumed for sizing of ducts)

*Definition of Requirements*

| | |
|---|---|
| Watertight | Duct components designed and fabricated to offer the vessel protection against flooding from either inside or outside the component. These shall be of all welded construction and shall have either welded transverse joints, or properly gasketed flange joints. |
| Non-tight | Duct components not required to be watertight. These shall be designed and fabricated so as to offer minimal air leakage. |
| Air-tight | Duct components designed and fabricated similar to non-tight components, but sealed to pass a suitable pressure test. |
| "A" Class Fire Protection | Duct components designed and fabricated to offer "A" Class fire protection, as defined by USCG Regulations. |
| "B" Class Fire Protection | Duct components designed and fabricated to offer "B" Class fire protection, as defined by USCG Regulations. |
| Drip-tight | Duct components designed and fabricated so that occasional water introduced into the system weather openings will not seep through the duct seams. |

*Material Requirements*

Duct components shall be made of hot-dipped, galvanized sheet steel (or otherwise suitably protected, as approved). The minimum thickness of the duct material shall be determined by the diameter for round ducts, or the largest cross-sectional dimension for rectangular ducts, as follows:

| | |
|---|---|
| 20 USSG (.0359 inch) | All non-tight and air-tight ducts 24 inches or less. Satisfies "B" Class fire protection requirements. |
| 16 USSG (.0598 inch) | All non-tight and air-tight ducts over 24 inches. Satisfies "B" Class fire protection requirements. |
| 11 USSG (.1196 inch) | All duct components exposed to weather. |
| | All water-tight duct components. |
| | All duct components satisfying "A" Class fire protection requirements. |
| | All duct components subject to damage (outside of cargo holds). |
| 3/16 inch | All horizontal duct components in cargo holds. |
| 1/4 inch | All vertical duct components in cargo holds. |

Spiral wound non-tight and air-tight round duct, up to 12 inches diameter, may be 22 USSG (.0299 inch). This also satisfies "B" Class fire protection requirements.

*Size, Fabrication and Installation Requirements*

Where possible, rectangular duct component sizes, design, fabrication, connections, coaming corner radii, and duct access, shall be in accordance with the "Designers Pamphlet" and "Construction Drawings" as developed for the National Shipbuilding Research Program regarding rectangular duct standards, Todd Seattle Drawing Nos. 4966 SK - 006 and - 007 respectively. (Refer U.S. Department of Commerce Contract 2-36233.)

Round ducts, depending on usage (non-tight, air-tight, watertight, etc.), may be of the spiral wound, welded, riveted, seamless, or grooved seam types. Where required for air-tightness, an approved fire resistive high velocity duct sealer or tape may be used.



All installed watertight, air-tight, and drip-tight duct-work shall be proven so prior to the installation of insulation.

Built-in trunk construction shall not be used for ducts having less than one square foot cross-sectional area, and smaller dimension less than 9 inches.

All ducts passing over electrical equipment shall be either of watertight construction, or made drip-tight by welding or soldering the longitudinal seams on the bottom of the duct. Ducts shall be arranged to preclude non-welded transverse duct connections over electrical equipment. In addition, such ductwork shall be insulated and vapor sealed, where an analysis of the dry bulb temperature inside the duct and the dew point temperature outside the duct indicates that condensation can occur on the outside surfaces of the duct.

Access holes with suitable cover plates shall be provided for cleaning and maintenance of equipment and ducts.

Hinged doors for access shall be provided as follows:

(1) Entrance to plenums for servicing filters.

(2) Both sides of cooling coils.

(3) At discharge side of axial fans larger than 24 inch diameter.

(4) In joiner ceilings for access to concealed equipment (heaters, access plates, valves, vents, controls, dampers, etc.) size shall be at least 24 inch x 24 inch, and location shall favor equipment most frequently requiring inspection and servicing.

Provision shall be made for making ducts portable where required.

Flexible duct connections shall be used at room air mixing boxes. These connections shall be limited to 24 inch length.

All openings on the lowest weather decks shall have hinged watertight metal covers, except for air lift type openings fitted with louvers which may be furnished with protective covers as specified in Section 22. Covers shall be provided for all openings exposed to the weather.

Turning vanes or bar grids shall be provided to achieve uniform air flow to registers, grilles and diffusers.

Gaylord exhaust ventilators or equal of the latest design (including quick release automatic fire damper, automatic hot water cleaning facilities, necessary hot water and drain piping, and grease extracting facilities) shall be provided over the ranges, fryers, griddles, steam kettles, steam cookers and bake ovens.

# APPENDIX I

## SURVEY OF FABRICATORS

A survey of a representative cross-section of U.S. sheet metal fabricators was conducted to solicit comments concerning construction/fabrication of the standard rectangular duct fittings and components, and then willingness to furnish and/or stock the components.

Various manufacturers of commercial shoreside ventilation ductwork and associated parts and components were contacted and discussions were undertaken concerning their fabrication of various components for marine application, utilizing a set of standardized component types and construction detail plans for guidance.

The manufacturers were selected from advertisements in trade journals, and from information given by regional SMACNA (Sheet Metal and Air Conditioning Contractors National Association Inc.) offices. The only criteria for selection was a reasonable proximity to sea coasts or the Great Lakes.

In order to provide a standardized format for review with proposed fabricators, the following items served as a basis for discussion:

- Standard Components - Straight Duct
  Elbows
  Vaned Turns
  Transformations
- Transverse Connection Types - Flanges
  Drive-Cleats
  S-Clips
  Riveting
- Longitudinal Seams - Pittsburgh
  Snap-Lock
  Weld
- Duct Materials - Steel, galvanized or otherwise suitably protected.
- Size limitations due to shop capacity.
- Tolerances required by standard plans.
- Required lead time.
- Quote on prices for standard components.

Certain of the manufacturers expressed little interest in the concept primarily due to the gauge limitations of their shop's sheet metal forming machinery. Those interested and willing to manufacture the standardized duct and components are listed herein. Some have had previous experience with government contracts, and are therefore experienced in working within the limits established by specification requirements. In addition, the manufacturers listed have machinery capable of forming the 20 gauge and 16 gauge duct, and most have welding facilities for the heavier thicknesses.

Insofar as lead time is concerned, the fabricators indicated that this will depend on the size of the order, the number of different components required and the work loading existing in the various shops at the time or order. Most manufacturers were of the opinion that such work could be initiated in a timely fashion.

Concerning price quotations, it is generally their opinion that this would depend on the actual construction requirements (the actual request to bid on a particular contract), since the duct size variance is so great. Those manufacturers specializing in parts and components, such as transverse connections, vanes, vane runners, etc., would be able to price these items on a per-pound or per-foot basis, if they were provided with the necessary details.

All of the manufacturers listed stated that, given a copy of the design and construction standards, they would be willing to review these and comment in general regarding any thoughts they might have, and any simplification/changes they may recommend.

The following list comprises those contacted who expressed interest in the fabrication of duct and/or associated components for marine use. The listing constitutes approximately 50 percent of the companies contacted. It is emphasized that this is a very small sampling of the many sheet metal fabricators available and it is believed that many of those not contacted would also be willing to fabricate the standard duct and components.

| Company Name | Location | Telephone No. |
|---|---|---|
| Advance Sheet Metal Company | Seattle, Washington | 206/622-8390 |
| Arco Heating and Air Conditioning Co. | Cleveland, Ohio | 216/663-8915 |
| Cain Manufacturing Inc. | Birmingham, Alabama | 205/322-0353 |
| Chambers Sheet Metal Company | Woodbury Heights, New Jersey | 609/848-4774 |
| Cleats Manufacturing Company | Chicago, Illin | 312/521-0300 |
| Hahnel Bros. Co. | Lewiston, Maine | 207/784-6477 |
| Holaday Parks Fabricators | Seattle, Washington | 206/763-8500 |
| Holzer Sheet Metal Company | New Orleans, Louisiana | 504/525-8134 |
| Juniper Industries, Inc. | New York, New York | 212/326-2546 |
| James A. Nelson Co. | San Francisco, Calif. | 415/431-8202 |
| Spears-Gutknecht Enterprises, Inc. | New Orleans, Louisiana | 504/822-3182 |