AVONDALE INDUSTRIES, INC.
SHIPYADS DIVISION

A Study of the Effects of Applying CAD–CAM Techniques to A Shipyard Sheet Metal Shop

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TECHNICAL SUMMARY

In this report, conventional and CAD-CAM manufacturing methods used in a shipyard sheet metal shop for producing duct fittings and other labor intensive products manufactured from sheet and plate are discussed. Time studies comparing the two methods as they apply to these products are presented.

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ACKNOWLEDGEMENTS

Harry Hooper, Consultant, was commissioned by Avondale Industries, Inc., Shipyards Division, to undertake a study of the effects of applying CAD-CAM techniques to a shipyard sheet metal shop production facility. The study was performed under the direction of R.A. Price, Manager, R&D Operations, Avondale Industries, Inc., Shipyards Division. Much valuable information making the completion of the study possible, was also provided by the following Avondale Shipyards trades people:

Cliff Austin, Door Plant Supervisor
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Lionel Fabalora, Supervisor of Programming
Bill French, Project Engineer
Phil Keller, Sheet Metal Mechanic .
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Don Mounsey, Programmer
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Mike Torres, Foreman, Sheet Metal Shop

In addition, guidance and support for the study was provided by:

E.A. Blanchard, Group Vice President
E.E. Blanchard, Vice President, Production

The purpose of this study was to compare conventional and CAD-CAM manufacturing methods used in a shipyard sheet metal shop. The comparison overwhelmingly favors the use of CAD-CAM techniques over the older and conventional manufacturing methods for reducing material costs and improving productivity.

It therefore meets the objectives of the National Shipbuilding Research Program, under the aspects of the Merchant Marine Act of 1970.

This project is one of many now jointly funded by the Department of Transportation, Maritime Administration and the United States Navy, cost shared by Avondale Industries, Inc., Shipyards Division, through SNAME Panel SP-1 Shipyard Facilities and Environmental Effects.

INTRODUCTION

One of the main functions of the sheet metal shop in a shipyard is to produce the duct work required for ventilating, heating and cooling the various parts of the ship. Because of the nature of this work and the craftsmen and the machine tool needs for carrying it out, the sheet metal shop becomes a likely candidate for the production of many other special metal parts needed in ship construction.

To improve the efficiency of the sheet metal shop at the Avondale Shipyard facility in New Orleans, the introduction of a CAD-CAM system was considered in 1982. As the study progressed, it became apparent that the introduction of the CAD-CAM system being considered offered other opportunities to the operation. Not only would the system automate the production of duct work fittings, but it would also help reduce the labor and time needed for producing many other parts. In addition, it was - determined that it could also serve as a DNC link between the Shipyard's IBM data base and the CNC flame cutting machines in the plate shop. See Figure 9.

As a result of that study, Avondale purchased a CYB 150 computerized sheet metal system from Cybernation of Cambridge, Massachusetts and a six roll coil line machine from Engel Industries of St. Louis, Missouri. These systems are described in Appendices Nos. 1 and 2 at the back of this report.

This study has been carried out to review the manufacturing methods used prior to the introduction of a CAD-CAM system with those that could be realized after the introduction of the new equipment in a typical shipyard.

When the equipment was initially installed, it was not only used for developing and cutting duct work parts. An effort was made to develop and cut other parts that heretofore had been very difficult and costly to produce. The parts cut were for the following product lines:

1. Duct work fittings.
2. Stainless steel galley cabinets
3. Watertight structural doors.
4. A number of miscellaneous parts produced from both ferrous and nonferrous plate.

Because of the nature of these parts, the variation in size and shape and the high degree of hand operations formerly required, the production costs were very high. Heretofore, attempts to automate the various operations had limited success.

The above four product lines have been used as a basis for this study.

DISCUSSION

In the sheet metal shop studied, there are four general manufacturing lines that use plate and sheet cut parts that it was determined could benefit from the CAD-CAM system introduced. These lines include:

1. Duct fittings.
2. Stainless steel galley cabinets.
3. Watertight structural doors..
4. Miscellaneous parts.

All of these items are built on “Just on Time” schedules that fulfill the needs of the ship section or sections being constructed at that time. By so doing, the many benefits realized far outweigh any benefits that might otherwise be realized from mass production of component parts. Some of the advantages realized are:

1. Material flow of parts to the ship section erection site can arrive on time and not cause a delay in the completion of the unit.
2. Finished product material-handling is minimized since it does not have to be stored and kept in a warehouse inventory.
3. Changes in design are caught before or early in the construction stage and corrected where otherwise there would be much expense in part change or scrapping the parts involved.

Because of the nature of many of these products, where there is little repetition in dimensions one to the other and the quantities of any one shape are low, there is a considerable amount of material handling and labor concentration in the manufacturing process. The degree of material handling between the various work stations and the type of operation required introduces a lost time factor that must be considered. Such lost time usually includes the following:

1. Job Orientation. The man assigned to the job must decide what has to be done and how it will be done.
2. Manpower Availability. When one man carries out all of the operations, he can stay with the job and follow it from machine to machine. When the number of men required varies, there is usually

a waiting time at each operation as the work force is assembled. Depending on conditions, this waiting time can vary from some small amount of time up to a half-hour or more per operation.

3. Delays in Material Movement. Such factors as aisle obstructions by other operations or availability of transportation equipment often causes delay and additional cost in man-hours spent.

In this study, an attempt is made to factor in these hidden costs which are expressed as variances and shown in man-hours for each operation.

The work involved in producing each of the product lines prior to the introduction. of the CAD-CAM system was as follows:

DUCT FITTING PRODUCTION-USING CONVENTIONAL METHODS.

The various duct fittings used in ship construction are shown on Figure 1. These fittings vary in size from approximately 6" in diameter to 48" in diameter. Regardless of size, the operations required to produce the flat cut parts for each shape are similar. Since the average size is 18", this is the size that will be used in this study for determining the man-hours required for producing the flat cut parts for each typical fitting produced.

As mentioned earlier, to meet the production needs of the ship in which these fittings are used, they are ordered and produced to satisfy the requirements of the ship unit being outfitted at that time. Therefore, during the manufacturing process, there is a mixture of the various fitting shapes and sizes flowing through the work shop at any one time. Because of the geometry of the ship, the dimensions and the shape of the fittings vary considerably. This makes it virtually impossible to standardize on fitting groups with fixed dimensions. The majority of the fittings are therefore produced as individual items.

Where conventional methods are used in the production of these fittings, they must first be developed on paper templates using descriptive geometry for the layout of many. The material is usually stocked in 4' by 10' sheets in stacks of the various gages used. This material is brought to

SHIP
DUCT WORK
FITTINGS

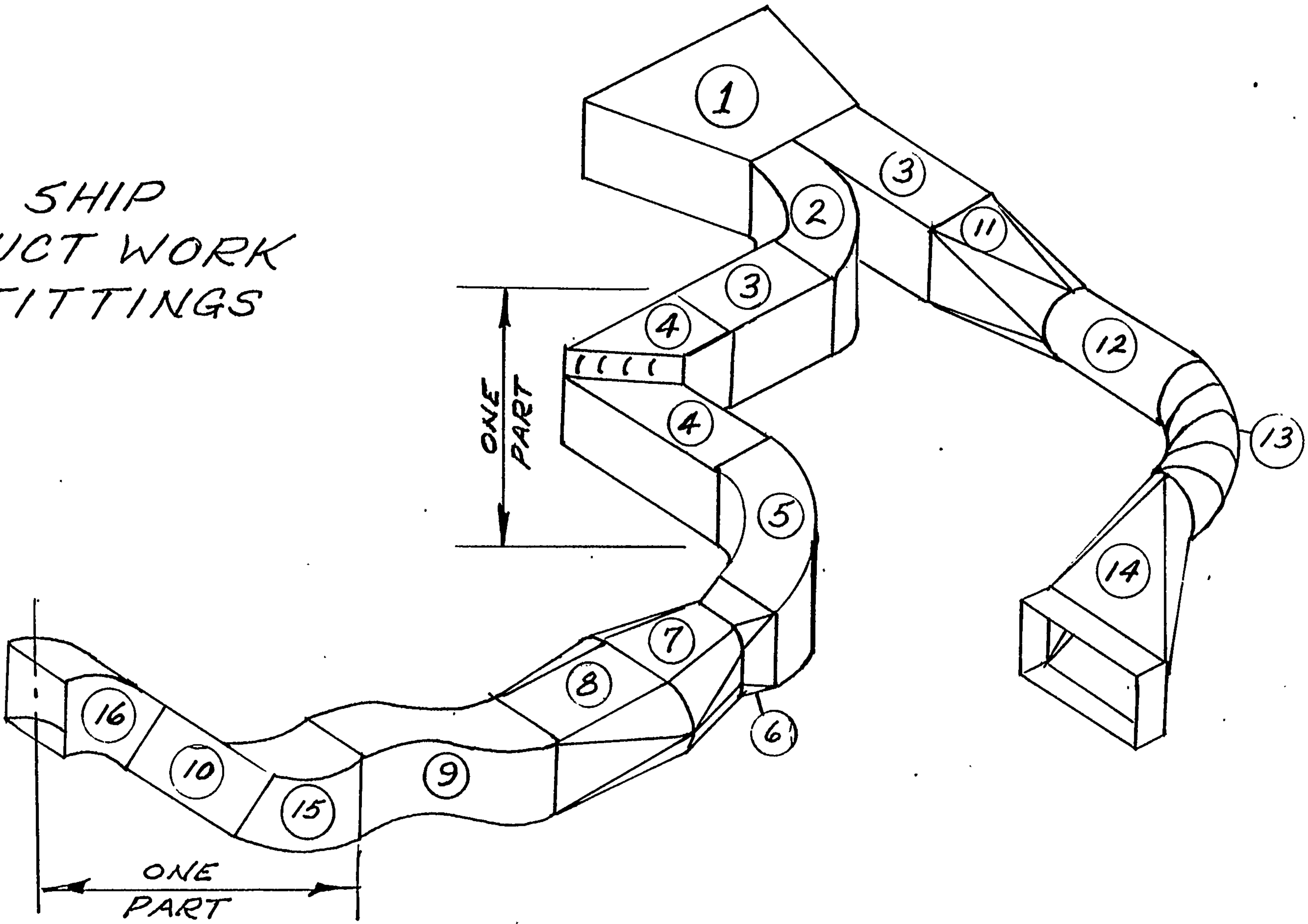


FIG. 1

the work area by lift truck and stacked vertically in a staging area close to the initial shear to be used. It is often convenient to cut these sheets into sheets 4′ by 4′ in size for ease of handling. When laying out the parts to be cut on the sheet surface, the workman has to decide what method should be used in producing the various shapes.

In the interest of saving material, creating a dense nest of the parts could be considered. However, in so doing, the amount of labor required to cut the part-might become" intensified because of the need for excessive hand powered operations in place of a power driven operation. For example, on a 48″ by 48″ by 22 gauge galvanized sheet, going from a 60% yield to an 80% yield shows a saving of $1.40. See Figure 2. At the rate of $20.00 an hour, the labor saving would represent 4 minutes of a man's time. Figure 3 illustrates the approximate amount of time required to achieve the improved yield. Referring to Figure 3, we find that in going from a 60% yield to an 80% yield would require approximately 8.4 minutes of a workman's time.

Other factors that might be considered:

1. Additional time required to cut the-part from the sheet such as using a hand shear vs. a power driven shear or nibbler.
2. Accuracy and quaiity of the resulting cut surface which may or may not require an additional conditioning operation.

When these factors are considered, it becomes obvious that in an operation of this type, the cost of material is not always the main deciding factor. In the interest of reducing labor costs, a lower part yield from the sheet becomes tolerable.

While there are no accurate figures available to document the sheet metal yield realized prior to the introduction of the CAD-CAM system, the author believes it was 70% or less in the overall operation.

The man-hours required to produce approximately one year's supply of the various fittings shown on Figure 1 using conventional manufacturing methods are listed in the tabulations on Table 1. The details from which these figures were derived are shown in Appendix No. 3 at the back of this study .

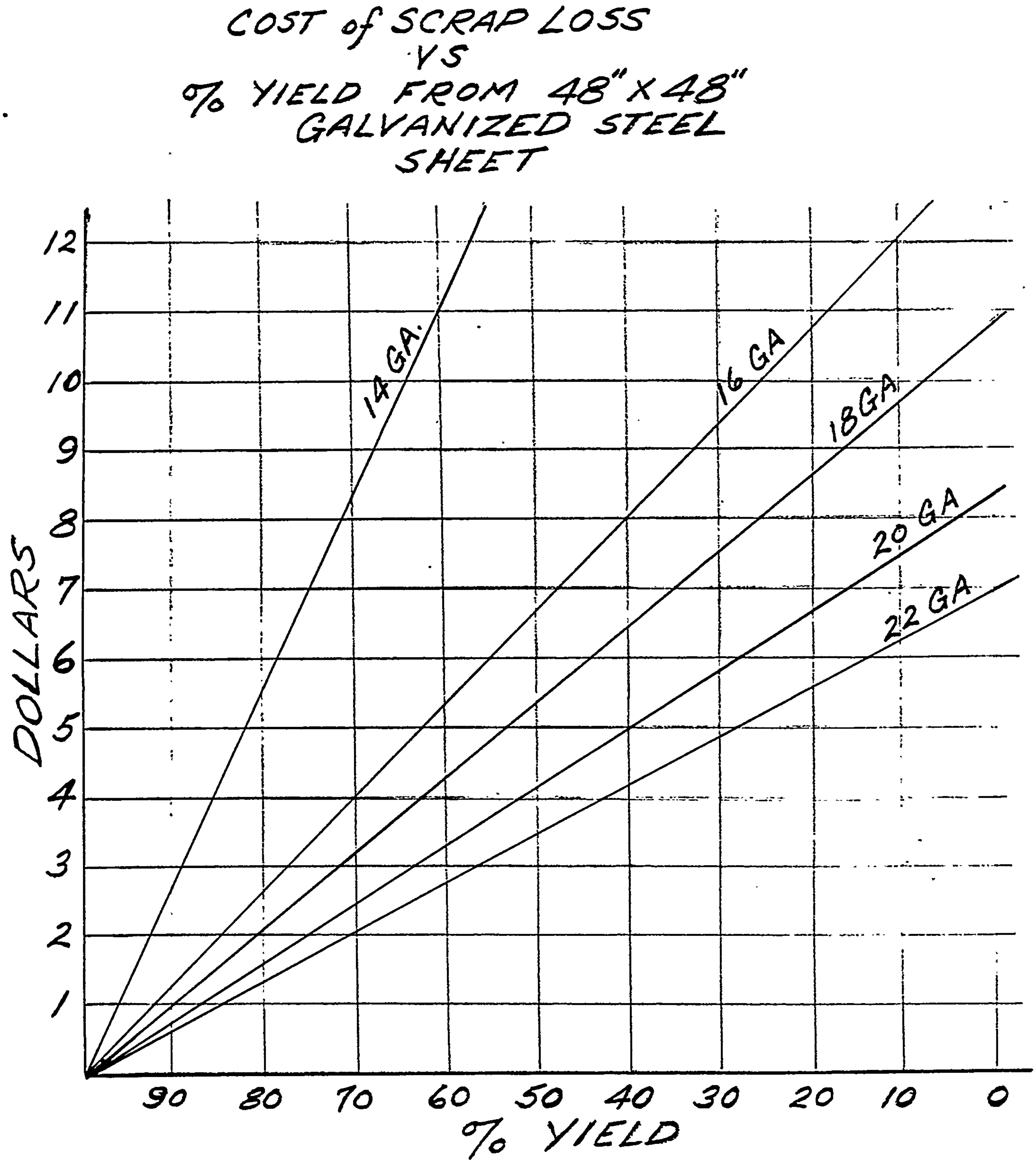

COST of SCRAP LOSS
VS
% YIELD FROM 48" X 48"
GALVANIZED STEEL
SHEET
DOLLARS
12
11
10
9
8
7
6
5
4
3
2
1
90
80
70
60
50
40
30
20
10
0
% YIELD
14 GA.
16 GA
18GA
20 GA
22 GA

Fig. 2

APPROXIMATE TIME REQUIRED TO NEST ASSORTED SHEET METAL DUCT FITTING TEMPLATES ON A 48" X 48" SHEET VS YIELD IN %

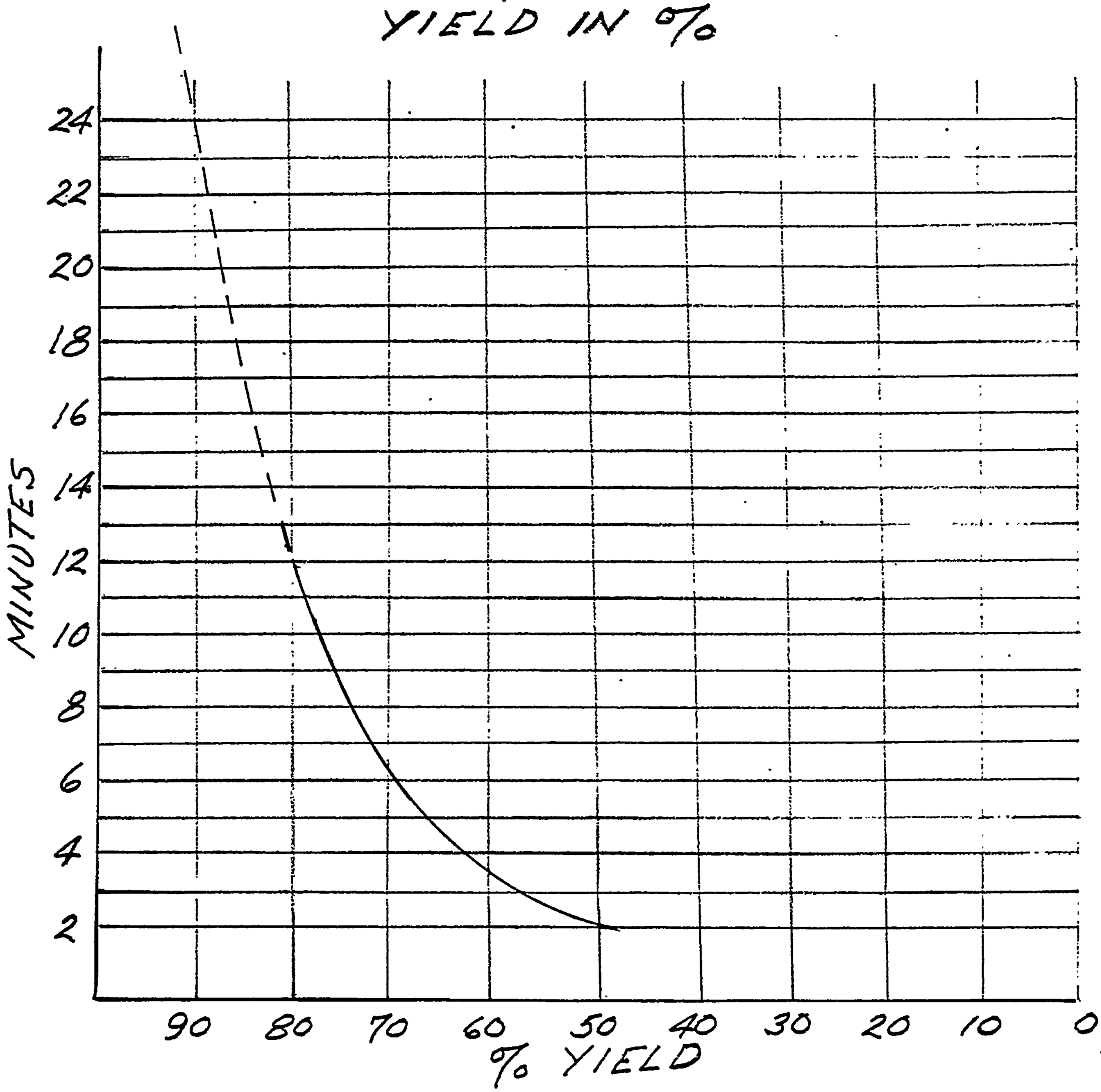


FIG. 3

Duct fitting man-hours required when
using conventional manufacturing methods.

Fitting No.	Description	Quantity Per year	Man-hours per year.
1	Transitions	900	2,925
2	90° Elbow	900	2,772
3	Straight Section	2,500	9,800
4	Vaned Elbow	40	130
5	Elbow	900	2,322
6	Square to Oval	400	1,100
7	Oval to Oval	100	483
8	Oval to Rectangle	200	766
9	Rectangle with One Offset	125	428
10	Rectangle with Two Offsets	60	335
11	Transition - Rectangular to Circular	400	1,467
12	Round Duct	900	1,728
13	Gore Pieces	150	825
14	Round to Rectangular With Double Offset	250	855
	Total	7,825	25,936

TABLE NO. 1.

DUCT FITTING PRODUCTION USING THE CAD-CAM METHODS.

With the introduction of the CAD-CAM system and the sheet metal coil line described in Appendices Nos. 1 and 2 at the back of this report, drastic changes were realized in the production of the sheet metal duct work formerly produced using the original conventional methods. These changes are explained as follows:

1. Definition of the Parts.

   When defining the fittings, it was originally necessary to develop full-scale layouts and templates for the various shapes. With many of the complex fittings, the use of descriptive geometry-was required for developing many parts. Not only did this require layout space in the loft and on the production floor, but it also required considerable time. While a few of the more simple fittings could be laid out on the production floor without need for a template, many of the others, depending on their complexity, required up to 2 1/2 hrs. each for template preparation. With the new system, layout of a fitting is no longer necessary. An operator, sitting at a keyboard in an air-conditioned office environment identifies-the fitting type by code symbol . As he observes a CRT monitor, he is prompted by the computer for entry of the key dimensional information. This is essentionally the same information that the loftsman originally started with. The computer, using this information, calculates the various offsets and automatically writes the CNC program for the part. This is then automatically stored on a hard disc ready for use in a nested program for running a plasma cutting machine.

2. Documentation of Parts.

   Originally, as the templates were prepared, they were documented and correlated according to material thickness and production needs. This was time consuming.

   With the new method being used a graphic layout is no longer required. The duct fitting information for a ship unit is all loaded into the computer in one sitting. Usually, about 50 fittings, the majority varying in shape, size and material thickness are required for a ship unit. Reading the design drawings and listing the fittings needed for the unit takes about 1 3/4 hours. Entering the fitting type and the listed information into the system by keyboard requires an additional 2 hours. By the end of 3 3/4 hours, all of the fittings required can be completely entered and the system ready to run.

3. Correlation of Parts by Material Thickness. With the conventional system formerly used, it was necessary to assign the fitting requirements according to material thickness. The CAD-CAM system recognizes the material thickness requirements and automatically separates the groupings in the computer. These groupings are stored on hard disc and are ready for use as needed.

4. Material Handling and the Preparation of the Developed Parts. As explained earlier, the sheet metal needs were originally moved from a horizontal stacked storage area to a vertical storage area ready for shearing. From here on to completion of the cut parts, considerable handling, layout, notching and shearing was performed. To conserve material, manual hand nesting was also required.

With the new method, the plasma cutting machine material work area is defined at the computer. The various sheet metal shapes are then automatically nested to fit the selected sheet size. At this time, several significant things happen. The computer automatically prepares the program and under an assigned number designation, stores it on hard disc ready for use on the production floor. In addition, a printout of the nest is automatically prepared and gummed labels are printed. Each label contains the coding required for each part and a sequence number locating the part on the finished cut sheet. In the meantime, on the work floor, the operator at the coil line is furnished with the sheet metal needs for the various nests to be cut. Selecting the material thickness in reverse order, he dials in the length of the sheet needed. These cut sheets are automatically fed from the coil system onto a transfer table from which they are moved to the plasma cutting machine’s work table. See Appendix No. 1. This represents a considerable saving in material handling, operating man-hours and shop space required.

At the machine, the operator places the plasma torch at the forward right-hand corner of the sheet to be cut. He then dials in the part number of the nested program. When the ready light shows (a matter of a few seconds), he presses the start button. At this time, the plasma torch is moved at rapid traverse to the program starting point. The torch then automatically cuts the parts at approximately 180 1PM. As the parts are cut, the operator places the gummed labels on each item. At completion, the cut parts are stacked on a pallet and the scrap skeleton is folded up and placed in a scrap tote box. Parts are then moved to the forming area by lift truck.

The man-hours required to produce the same fittings as covered by Table No. 1 but produced by the CAD-CAM system are shown in Table No. 2. The calculations for arriving at these figures are shown in Appendix No. 4.

In addition to the reduction in man-hours realized through the introduction of the coil line and the CAD-CAM system, there is a saving in the amount of material required for the production of duct fittings. As mentioned earlier, with the conventional production methods formerly used, the scrap loss appears to have been over 30% of the sheet metal purchased. With the new system, the following is realized:

1. A reduction in the size of the scrap remnant. With the conventional methods used, the metal was purchased in sheets about 4’ by 10’ in size. For convenience in handling, these were sheared into “smaller sizes. With each size used, an unusable remnant remained. This resulted in many unusable remnants finding their way to the scrap bin. With the new method, the size of the work piece being handled can remain large in size, resulting in fewer remnant pieces. In addition, the size of the large work piece can be selected to suit the job.

Duct fitting man-hours required when
using CAD-CAM and coil line systems.

Fitting No.	Description	Quantity per year	Man-hours per year
1	Transitions	900	460
2	90° Elbow	900	460
3	Straight Section	2,500	1,280
4	Vaned Elbow	40	20
5	Elbow	900	460
6	Square to Oval	400	205
7	Oval-to Oval	100	51
8	Oval to Rectangle	200	102
9	Rectangle With One Offset	125	64
10	Rectangle With Two Offsets	60	31
11	Transition - Rectangular to Circular	400	204
12	Round Duct	900	460
13	Gore Pieces	150	77
14	Round to Rectangular With Double Offset	250	128
	Total	7,825	4,002

TABLE NO. 2.

2. As explained earlier in this report, compact nesting was not always economical with the conventional methods used. with the CAD-CAM system, the computer automatically nests the parts on the work piece so that the advantages of nesting are realized with all sheets used.

While an accurate record of scrap loss is not available, the author believes that the CAD-CAM system has resulted in a material saving greater than 15% which amounts to more than 23 tons per year. See Table No. 3.

APPROXIMATE ANNUAL SHEET METAL CONSUMPTION.

Gauge	Sq. ft.	%	lbs .	%
26	640	0.4	480	0.15
24	1,382	1.0	1,382	0.44
22	12,758	9.4	15,947	5.12
20	33,671	24.7	50,506	16.22
18	1,367	1.0	2,734	0.88
16	73,616	53.9	184,040	59.10
14	5,728	4.2	17,900	5.75
12	2,491	1.8	10,898	3.50
10	4,896	3.6	27,540	8.84
	136,549	100%	-	

Annual savings in sheet metal made possible by introduction of CAD-CAM system =

$$\frac{311,427 \times 15\%+}{2,000} = 23.36 \text{ Tons} +.$$

TABLE NO. 3.

STAINLESS STEEL GALLEY CABINETS.

Typical stainless Steel dresser assemblies are shown on Figure No. 4. The operations carried out in producing the various cabinet shapes were quite similar but the time required varied depending on the size, the. number of men required to handle the material and the number of operations at each machine. Initially, the material was stored in a warehouse on the west side of the sheet metal shop. Material was transferred from this storage

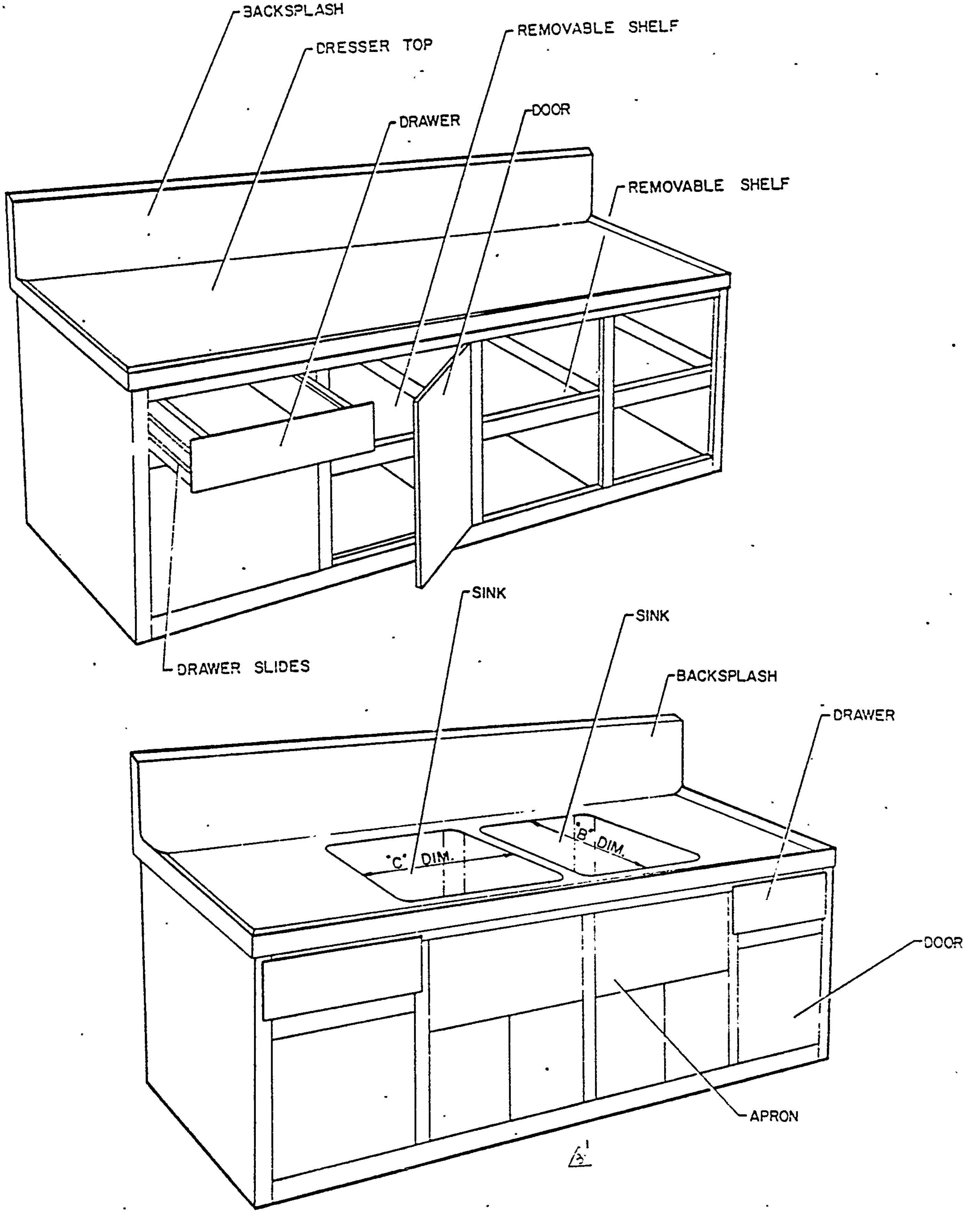

BACKSPLASH
DRESSER TOP
REMOVABLE SHELF
DRAWER
DOOR
REMOVABLE SHELF
DRAWER SLIDES
SINK
SINK
BACKSPLASH
DRAWER
"C" DIM.
"B" DIM.
DOOR
APRON

Fig. 4

area by lift truck and carried to a second storage area at the northeast corner of the shop. From this point, the material was moved on pallet by overhead crane to the first operation which was usually a layout and shearing procedure. Positioning the material in the shears and moving it to make the various cuts was done manually. Depending on the size of the sheet, this operation required up to four men for handling the material, positioning it and holding it while it was sheared. At the end of the operation, the scrap was disposed of and the cut part placed on a cart for transfer to the next work station which involved the use of a notching machine. In performing this operation, there was usually a machine setup required. To orient the material in the machine required two or three men depending on the size of the sheet and the direction of the required notches.

From this operation, the material was again moved by wagon to the next production step. In one ship, there may be up to sixteen such cabinets, each with different dimensions and some shape variations. The various stainless steel sheet metal parts required by any one galley consists of the following:

1. The back and sides commonly known as "the Wrap".
2. The Bottom.
3. The Partitions.
4. The Mullion - Top and Bottom.
5. Cabinet Doors.
6. The Shelves.
7. The Cabinet Top.

The time required to move the material to the work area and to perform the various operations necessary to deliver the flat cut parts to the forming and assembly areas are listed in Appendix No. 5.

With the introduction of the CAD-CAM system, it was found that the outside shape and the various cutouts on the flat stainless steel sheets could be performed on the plasma cutting machine used for the CAD-CAM production of duct fittings. To do this, it is necessary to program the parts, assign a part number and store the part program on the hard disc storage system of "the CFC 150 plasma cutting machine. By so doing, the stainless steel sheet can, with one material handling operation) be placed on the CFC 150 plasma machine's work table and completely cut out in one operation. From here, the finished cut part is moved to the forming area directly for further processing. The time study using the CAD-CAM system for the various parts involved is shown on Appendix No. 6. A comparison of the man-hours involved using the conventional manufacturing methods and the CAD-CAM system are shown in Table No. 4.

Summary of man-hours required to produce the flat cut components and deliver them to the forming and assembly work area.

Part	Man-hours per cabinet using conventional manufacturing methods.	Man-hours per cabinet using the CAD-CAM system.
Back and Sides	5.25	1.94
Cabinet Bottom	5.08	1.92
Cabinet Partitions	2.75	1.81
Cabinet Mullions	2.15	2.22
Cabinet Doors	2.15	1.81
Shelves	2.04	1.81
Cabinet Top	14.06	2.30
	33.48	13.81

On the basis of 24 galley cabinets per year, the difference favoring use of the CAD-CAM system is:

(33.48 - 13.81) x.24 = 472.08 man-hours.

TABLE NO. 4.

In addition to a saving in man-hours, it has been found that the finished flat cut parts are of better quality than those produced by the conventional methods because the finished product is flatter with less surface distortion effects.

WATERTIGHT STRUCTURAL DOORS.

In ship construction, there are approximately 17 different watertight door types and approximately 13 different sizes. The total number of doors used in one year may be 150 units. Typical examples of the door panels used in these assemblies are shown on Figures Nos. 5a and 5b. These panels are cut from 1/4 inch steel plate.

With the conventional manufacturing methods used in the past for producing the flat door panels, there was a considerable amount of plate handling involved. This. added many man-hours to the manufacturing process. A time study covering the preparation of the flat cut panels used is shown in Appendix No. 7.

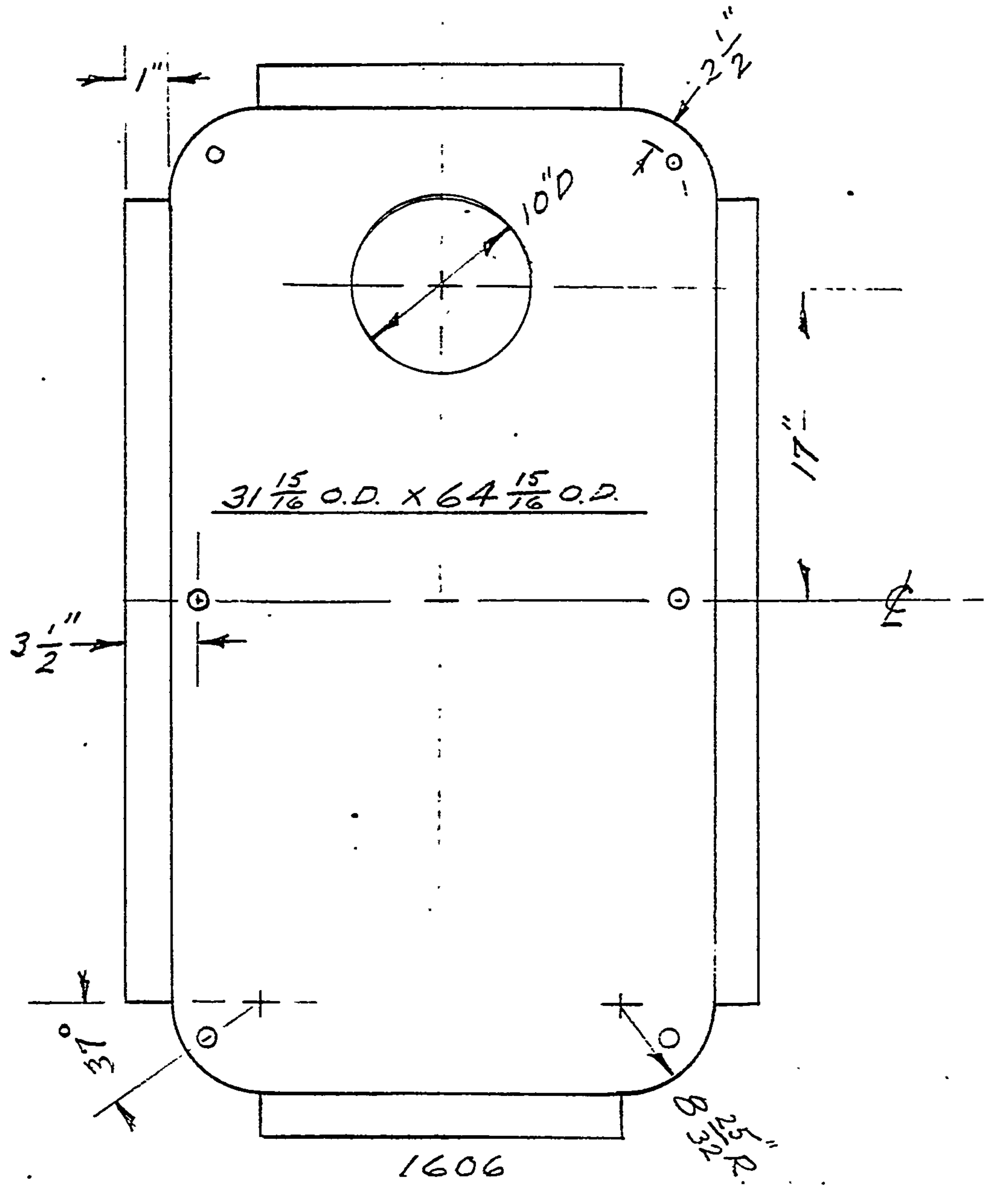
As the manufacturing department became familiar with the programming and operation of the CYB 150 CAD-CAM plasma cutting system at Avondale Shipyards, it became quite apparent that this new equipment could be applied to the preparation of the panels used in watertight door construction.

By using this system, the outside contour plus all of the cutouts of the panel could be accomplished in one operation. Such a procedure reduced the material handling man-hours required and resulted in a panel of better quality since it eliminated the plate distortion that was formerly caused by the oxy-flame burning operations. A time study covering the preparation of the watertight door panels using the CAD-CAM plasma cutting system is shown in Appendix No. 8.

Through the use of the new system in the preparation of 150 watertight door panels, the man-hours were reduced from 585 to 240. In addition to this saving, there are other hidden benefits such as:

1. Less floor space required.
2. A better fit up at assembly resulting in less time for grinding and welding.
3. A flatter panel requiring less time for straightening.
4. Less interference with other operations in the shop because several material moving operations were eliminated.

30 X 63 UNIT DOOR
6 DOG
SK-1



25 PCS. 33 1/2 X 66 1/2 X 1/4

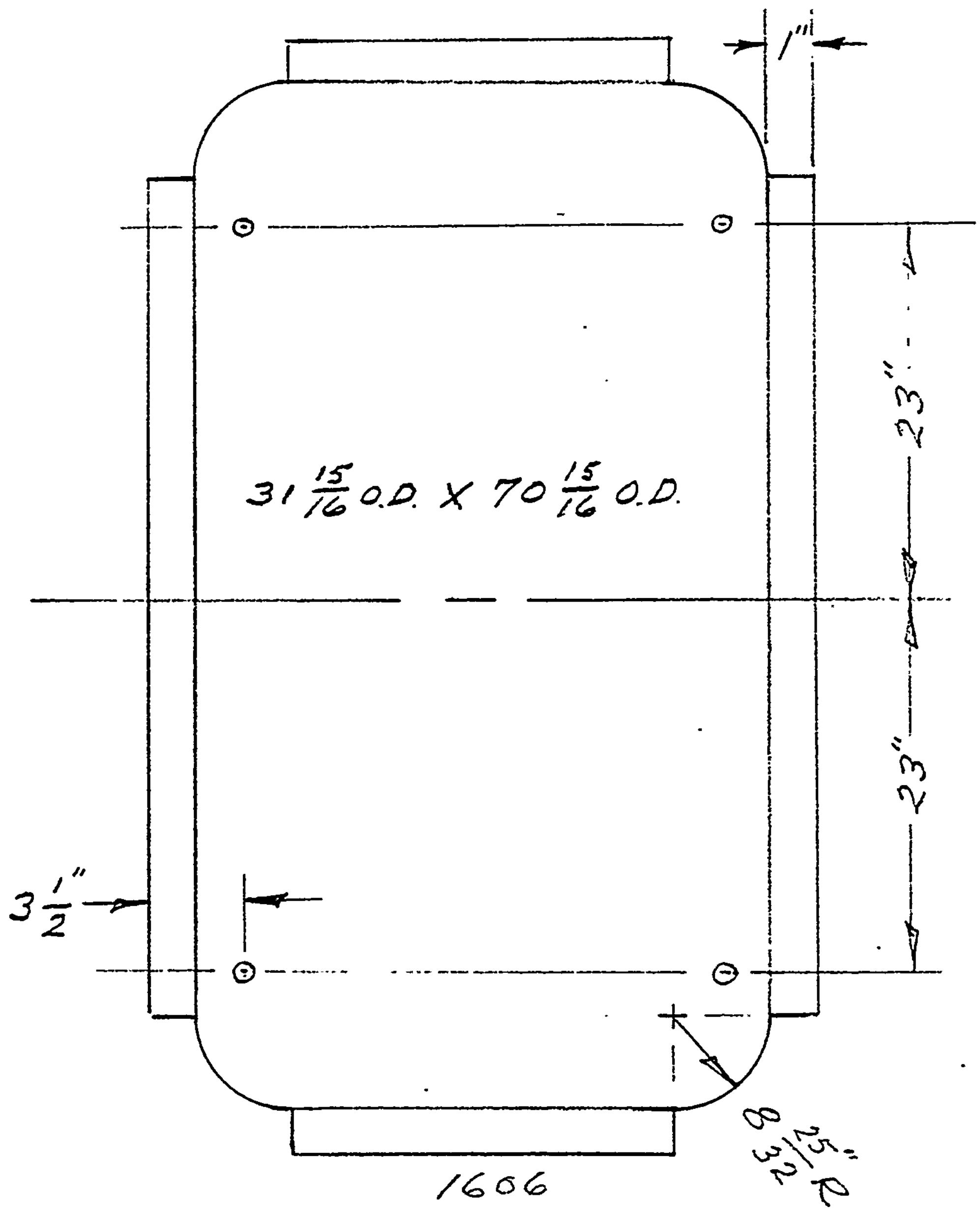
1 SHIP SET

Fig. 5a

30 X 69 A.T. DOOR

4 DOG

SK-5



1-PC $33\frac{1}{2} \times 72\frac{1}{2} \times \frac{1}{4}$

1 SHIP SET

Fig 5b

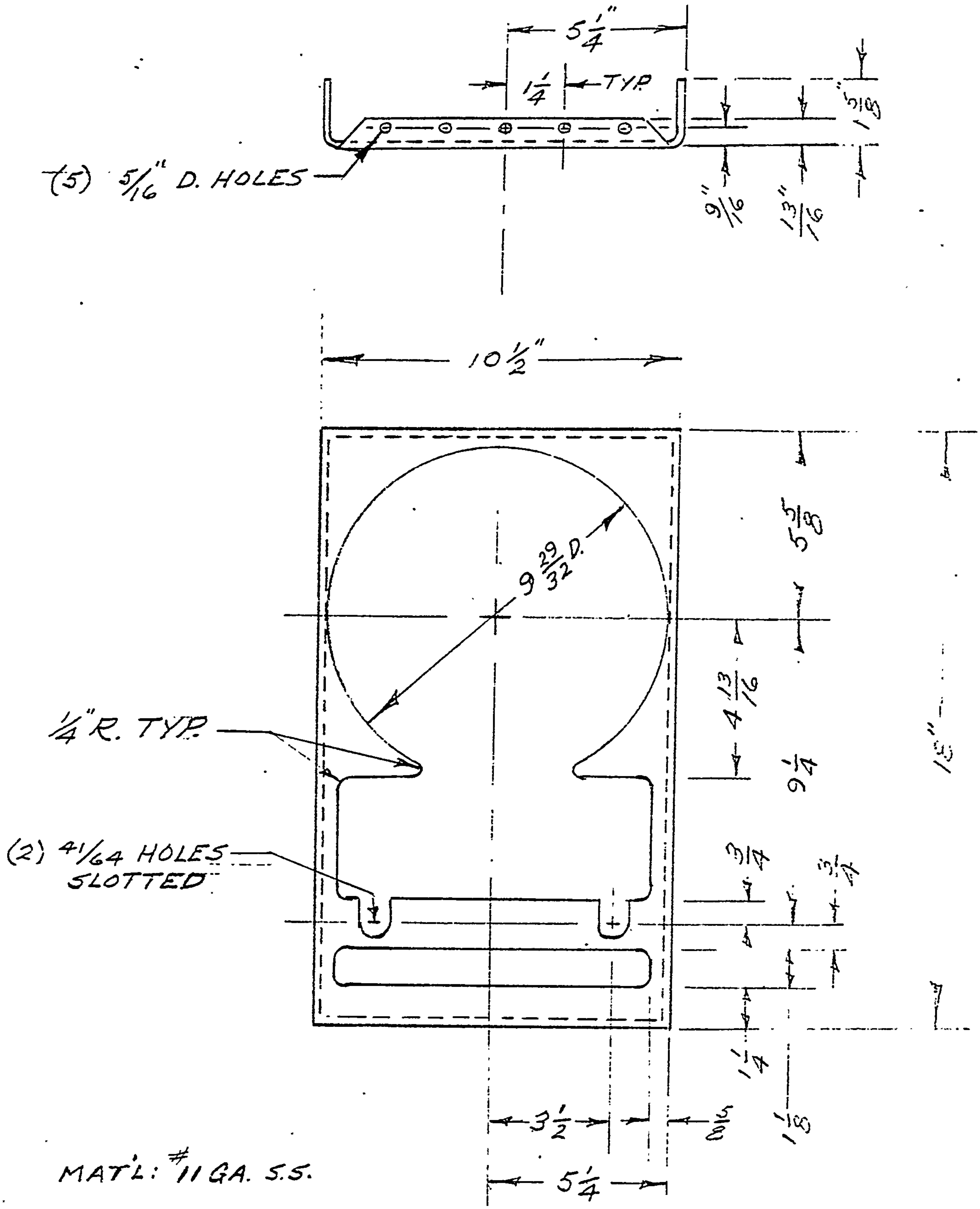
MISCELLANEOUS PARTS.

There are innumerable ferrous and nonferrous parts used in ship construction and outfitting which cannot be conveniently purchased on the open market and which cannot be economically or conveniently produced in the machine shop or the plate shop. These parts are usually assigned to the sheet metal shop for manufacture. Some examples of these parts include:

1. Gauge boards. (Figures 6a and 6b)
2. Cylinder storage racks.
3. Access Covers. (Figure 7)
4. Elbows for main engine exhausts.

A time study covering the various manufacturing procedures, when using conventional methods is shown in Appendix No. 9. With the introduction of the CAD-CAM sheet metal system at Avondale Shipyards, it soon became apparent that many of these labor intensive parts lent themselves to improved manufacturing techniques through the use of NC programming, and plasma cutting through the use of the CYB 150 CAD-CAM system. Through the use of geometric and automatic program systems, the part programs are prepared and stored on a hard disc ready for call-up and use at the plasma sheet metal cutting machine or depending on the thickness of the material, the plate shop plasma cutting machine as needed. Now, with one material handling, the flat developed shapes with all of the cutouts are prepared in a matter of a few minutes in one plasma cutting operation and readied for transport to the forming and assembly area in the sheet metal shop.

A time-study for producing the same parts shown in Appendix No. 9, but using the CAD-CAM system and plasma cutting machines is shown in Appendix No. 10. A comparison of the man-hours required to produce the flat cut parts is shown in Table No. 5.



GAGE & VALVE BOARD
8 1/2" FLUSH MOUNT

Fig. 6a

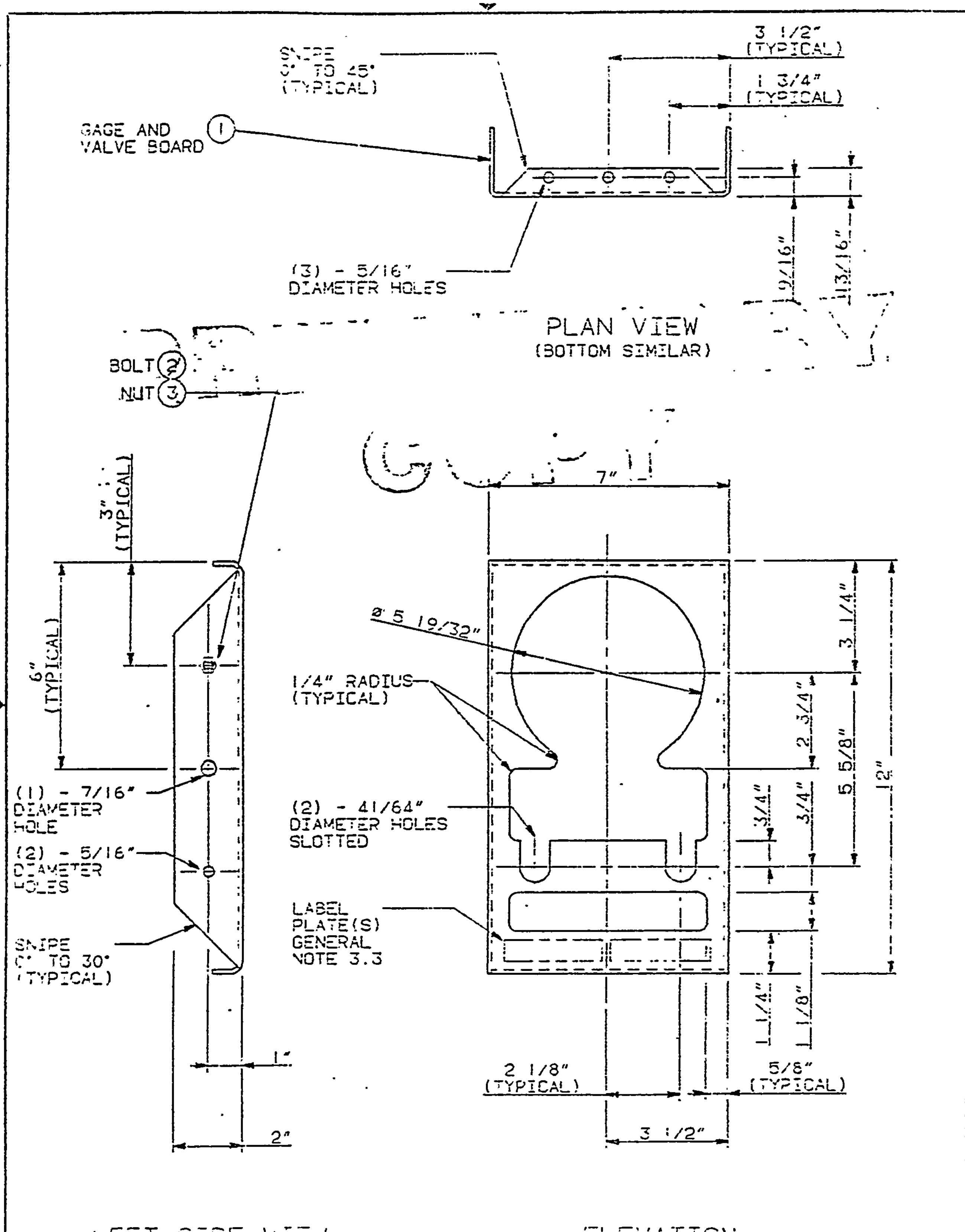
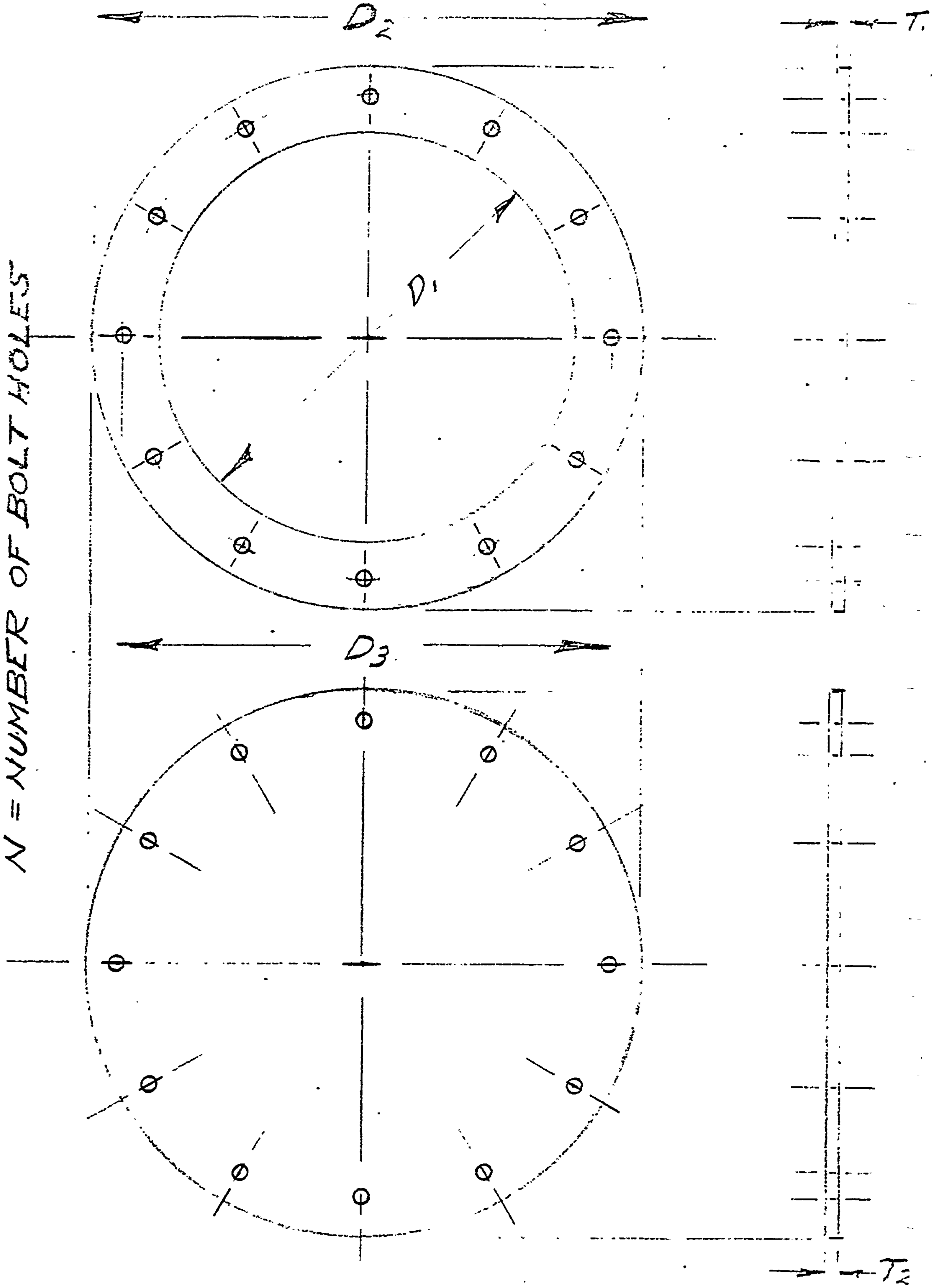

SNIPE
0° TO 45°
(TYPICAL)
3 1/2"
(TYPICAL)
1 3/4"
(TYPICAL)
GAGE AND
VALVE BOARD
1
(3) - 5/16"
DIAMETER HOLES
9/16"
13/16"
PLAN VIEW
(BOTTOM SIMILAR)
BOLT 2
NUT 3
3"
(TYPICAL)
6"
(TYPICAL)
(1) - 7/16"
DIAMETER
HOLE
(2) - 5/16"
DIAMETER
HOLES
SNIPE
0° TO 30°
(TYPICAL)
1"
2"
7"
Ø 5 19/32"
1/4" RADIUS
(TYPICAL)
(2) - 41/64"
DIAMETER HOLES
SLOTTED
LABEL
PLATE(S)
GENERAL
NOTE 3.3
3 1/4"
2 3/4"
5 5/8"
12"
3/4"
3/4"
1 1/4"
1 1/8"
2 1/8"
(TYPICAL)
5/8"
(TYPICAL)
3 1/2"
LEFT SIDE VIEW
(RIGHT SIDE SIMILAR)
ELEVATION

Fig 6b



FLANGE AND ACCESS COVER

Fig. 7

In addition to a saving in man-hours through the use of the CYB 150 CAD-CAM system, there are additional savings realized such as:

1. A saving in material required through an improved yield made possible through the use of part nesting techniques.
2. An improvement in the accuracy and surface condition of the parts produced, thus eliminating secondary conditioning operations.
3. Less distortion of the parts, thus eliminating secondary straightening operations.

Summary of man-hours required to produce a year's needs for some labor intensive miscellaneous flat cut ship parts using conventional manufacturing methods as compared to using a CAD-CAM system with a plasma cutting machine.

Product	Quantity	Man-hours using conventional methods.	Man-hours using a CAD-CAM system.
Gauge Boards	2,000	4,912	104
Cylinder Storage Racks	50	103	31
Access Covers and Mounting Rings	200	226	19
Elbows for Main Engine Exhaust	60	308	30
Total Man-hours		5,549	184

TABLE NO. 5.

SUMMARY

The man-hours required to produce the flat cut parts used in the manufacture of the product lines covered by this study are as follows:

Product Line	Man-hours per year using conventional methods.	Man-hours per year using CAD-CAM methods.
Duct Fittings	25,936	4,002
Stainless Steel . Galley Cabinets	804	331
Watertight Structural Doors	585	240
Ferrous and Non-ferrous Miscellaneous Parts .	5,549	187
Total Man-hours	32,87h	4,760

Total annual reduction in man-hours = 28,114 .

Annual reduction in sheet metal required = 23.36 Tons. (See Table No. 3)

In addition to the above, there are intangible benefits which include:

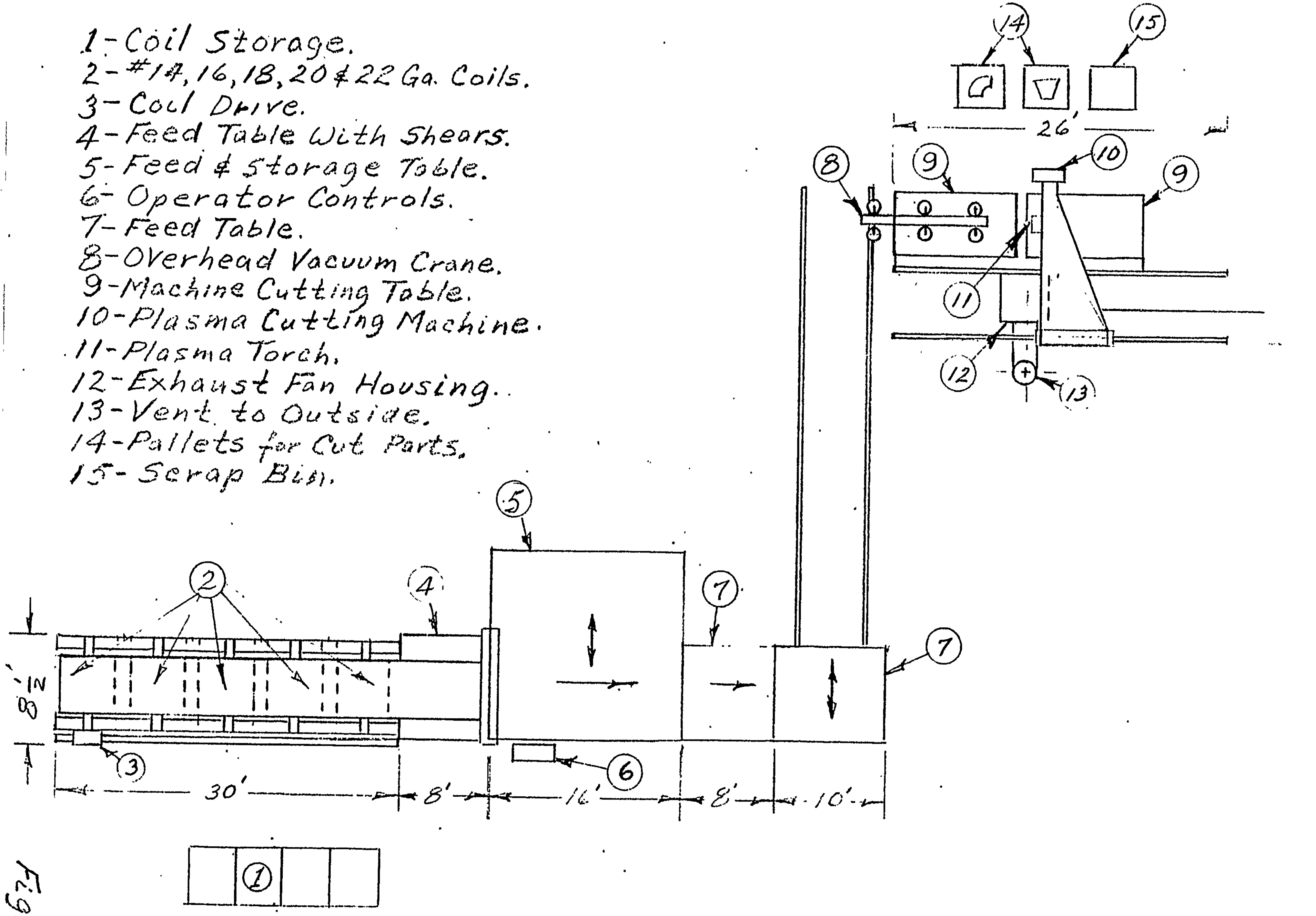
1. A reduction in product assembly time made possible by improved fit up.
2. A reduction in the amount of grinding and straightening required because of the greater accuracy realized and the reduction in sheet distortion.
3. Products with improved overall appearances.
4. A reduction in the interference with other operations in the shop because of the space consolidation and the reduction in the material handling requirements.

APPENDIX NO. 1

SHEET METAL HANDLING SYSTEM USING A COIL LINE.

To reduce the material handling costs and to increase the sheet metal yield, Avondale Shipyards installed a sheet metal coil handling system in their fabrication shop. The equipment purchased was an Engel Metal Methods machine Model 5-15 for handling up to six rolls of sheet metal each with a maximum width of 5′ and a weight of approximately 10,000 lbs. A diagram of the installation and the material flow is shown on Figure No. 8.

Depending on the production needs, coils of the various gauges of sheet metal are delivered to the staging area #1. From here, they are loaded by crane onto one of the feed rack positions as shown in #2. As the various thicknesses are required, the coil drive mechanism #3 is moved into position and coupled to the coil hub which it rotates to feed material from the coil. Material feed is controlled from the operator's console #6. As material passes over feed table #4, its length is measured to the programmed length at which point it is sheared. The sheared pieces either move onto the storage area on Table #5 or they pass onto table #7 in reverse order of need. Transfer table #7 is then moved to the plasma cutting machine position where it is unloaded as required by the overhead vacuum crane #8.



COIL LINE & PLASMA CUTTING MACHINE ARRANGEMENT

Fig. 9

APPENDIX NO. 2

THE CFC 150 COMPUTERIZED CUTTING SYSTEM.

(Ref - See Figure No. 9)

The CFC 150 consists of the following integrated items:

1. A front-office computer system including:

   a. A computer with keyboard and 10″ CRT monitor.

   b. Two dot matrix printers for alpha-numeric and graphic printouts.

   c. A 28 megabyte hard disc system and a floppy disc handler.

   d. A work table.

2. Software for producing:

   a. The developed shapes shown on Figure No. 1 for both slip fittings and welded fittings.

   b. A chop program for handling oversized parts.

   c. An automatic nesting system for efficiently selecting and arranging parts on the sheet size selected.

   d. A printout system for drawing the parts and numbering them by sequence for tie-in with the labeling system.

   e. A labeling system for producing gummed labels with identifying information for each part cut.

   f. A geometric program for handling common shapes other than duct fittings.

   13* Capability of tying into the main shipyard IBM data system and serving as a DNC link to plasma and flame cutting machines in the plate shop.

3. A plasma. cutting machine capable of handling two 60″ x 120″ metal sheets laid end to end. The machine is equipped with:

   a. A control console coupled to the front-office system via telephone line connection.

   b. A cutting table with exhaust system for operation over two 60″ x 120″ metal sheets laid end to end.

   c. A plasma cutting torch station with 50 ampere power source.

   d. Infinitely variable contour speeds up to 300 1PM.

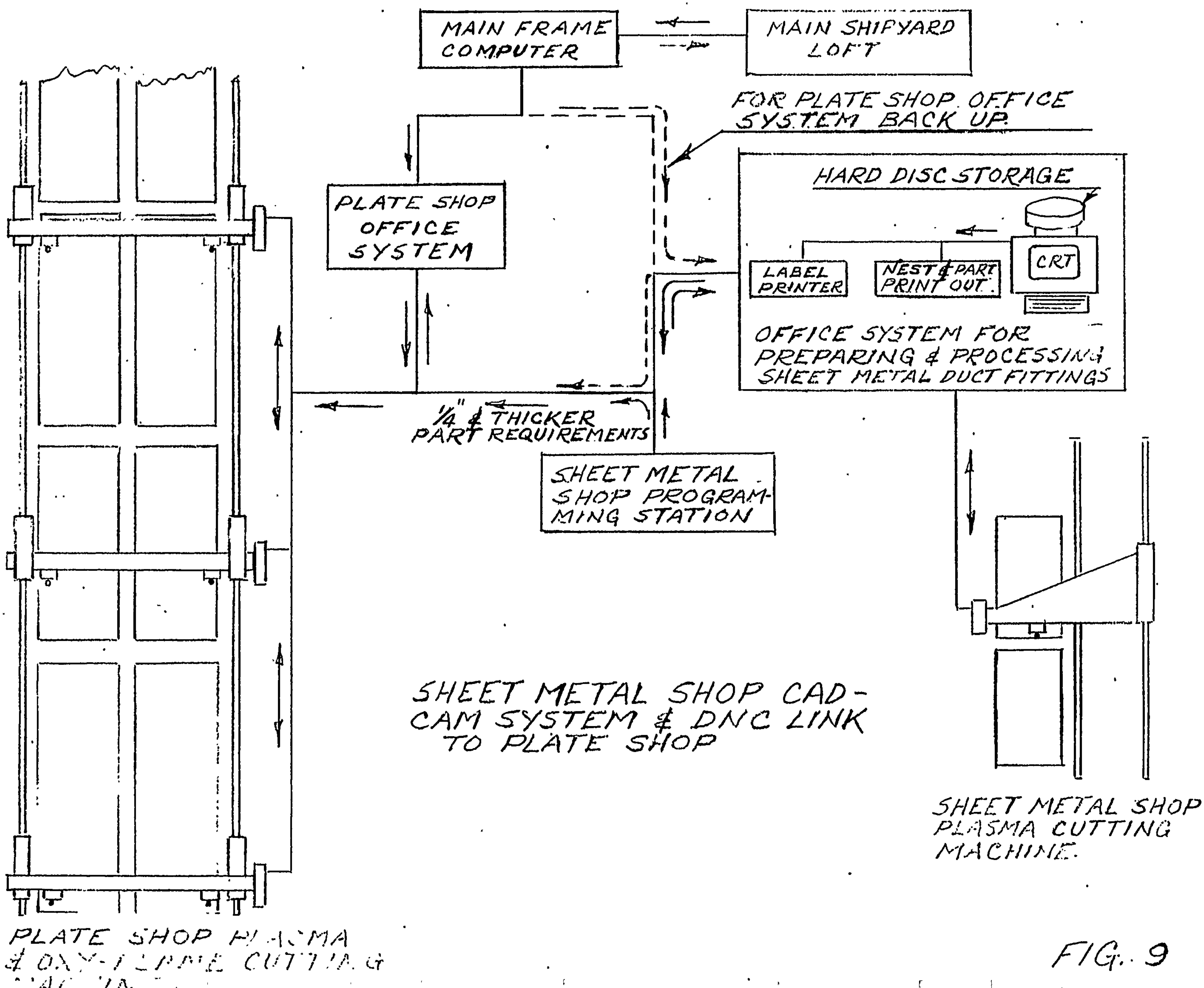

MAIN FRAME COMPUTER
MAIN SHIPYARD LOFT
FOR PLATE SHOP OFFICE SYSTEM BACK UP
HARD DISC STORAGE
PLATE SHOP OFFICE SYSTEM
LABEL PRINTER
NEST & PART PRINT OUT
CRT
OFFICE SYSTEM FOR PREPARING & PROCESSING SHEET METAL DUCT FITTINGS
1/4" & THICKER PART REQUIREMENTS
SHEET METAL SHOP PROGRAMMING STATION
SHEET METAL SHOP CAD-CAM SYSTEM & DNC LINK TO PLATE SHOP
SHEET METAL SHOP PLASMA CUTTING MACHINE
PLATE SHOP PLASMA

FIG. 9

APPENDIX NO. 3

MAN-HOURS REQUIRED TO PRODUCE A ONE-YEAR SUPPLY OF DUCT WORK FITTINGS SHOWN ON FIGURE NO. 1 USING CONVENTIONAL MANUFACTURING METHODS.

Fitting No. 1 - Transitions

Quantity produced per year: Approximately 900.
Stock sheet size used: 48″ x 120″.
40% #20 gauge and 60% #16 gauge. .
Approximate size blank per fitting: 24″ by 48″.

Operation		Man-hours
Template preparation	1 man, 1/2 hr.	1/2
Variance		1/6
Material movement from vertical storage to shears	2 men, 10 reins.	1/3
Variance		1/3
Shearing operation. Layout 4 pieces, shear and label	2 men, 50 reins.	1 2/3
2nd material handling by wagon to forming area	1 man, 10 reins.	1/6
Variance		1/12
Total		3 1/4 Man-hours

3 1/4 x 900 = 2,925 man-hours per year.

Fitting No. 2 - 90° Elbow

Quantity produced per year: approximately 900.
Material used: 40% #20 gauge, 50% #16 gauge and 10% #10 gauge.
Approximate size sheet used per fitting: 48″ by 48″.

Operation		Man-hours
Template preparation	1 man, 1/2 hr.	1/2
Material movement from vertical storage to shears	2 men, 10 reins.	1/3
Variance		1/3
Layout 4 pieces, shear and label	2 men, 50 reins.	1 2/3
2nd material handling by wagon to forming area	1 man, 10 reins.	1/6
Variance		1/12
Total		3.08 Man-hours

900 x 3.08 = 2,772 man-hours per year.

APPENDIX NO. 3 (cont'd)

'Fitting No. 3 - Straight Section

Average length: 6'.
Quantity produced per year: approximately 2,500.
No template is required for this part.

		Man-hours
Material movement from vertical storage to shears	2 men, 10 reins.	1 / 3
Variance		1/3
Shearing operation. Layout, shear and label all parts including 16 vane pieces	2 men, 1 1/2 hrs.	3
2nd Material movement by wagon	1 man, 10 reins.	1/6
Variance		1/12
		3.92

2,500 x 3.92 = 9,800 man-hours per year.

Fitting No. 4

Average size is 18" x 18".
Quantity produced per year: approximately 40.

		Man-hours
Template preparation	1 man, 1/2 hr.	1/2
Variance		1/'6
Move material from the vertical storage area to the shears	2 men, 10 reins.	1/3
Variance		1/3
Shearing operation. Layout 4 pieces, shear and label	2"men, 50 reins.	1 2/3
2nd Material handling by wagon	1 man, 10 reins.	1/5
Variance		1/12
		3.25

3.25 x 40 = 130 man-hours per year.

APPENDIX NO. 3 (cont'd)

Fitting No. 5 - Elbow

Quantity produced per year: 900
Material used: 40% 20 gauge, 50% 16 gauge and 10% 10 gauge.
Approximate size of sheet used per fitting: 2'X4'.

Operation		Man-hours
Material handling from vertical storage to shears	2 men, 10 reins.	l/3
Variance		1/3 .
Shearing Operation. Layout 4 pieces, shear and label	2 men, 50 reins	1 2/3
2nd material handling by wagon to the forming area	1 man, 10 reins.	1/6
Variance		1/12
Total		2.58

900 x 2.58 = 2,322 .man-hours per year.

Fitting No. 6

Average size is 20".
Quantity produced per year: approximately 400.
Approximate size of sheet used per fitting: 21X4'.
Material used: 40% 20 gauge, 50% 16 gauge and 10% 10 gauge. .

Operation		Man-hours
Prepare template	1 man, 1 hr.	1
Variance		1/12
Material handling from vertical storage to shears	2 men, 10 reins.	1/3
Variance		1/3
Layout., cut 2 pieces per fitting and label	1 man, 1 1/2 hrs.	1 1/2
Variance		l/6
2nd material handling from shears area by wagon to forming area	1 man, 10 reins.	1/6
Variance		1/6
Total		2 3/4

2 3/4 x 400 = 1,100 man-hours per year.

APPENDIX NO. 3 (cont'd)

Fitting No. 7

Quantity produced per year: approximately 100.
Average size is 20".
Approximate size of sheet per fitting:. 2' x 4'.
Material used: 40% 20 gauge, 50% 16 gauge and 10% 10 gauge.

Operation		Man-hours
Prepare template		2 1/2
Variance		1/6
Material handling from vertical storage to shears .	2 men, 10 reins.	1/3
Variance		1/3
Layout and cut 2 pieces per fitting. First shear the blank, then use nibbler, Pulmax, unit shears or bevel shears to cut the shapes required and label them.	1 man, 1 hr.	1
Variance .		1/6
Move the pieces by wagon to forming area		1/6
Variance		1/6
		4.83

4.83 x 100 = 483 man-hours per year.

Fitting No. 8

Quantity per year: approximately 200.
Average size is 20".
Approximate size of sheet per fitting: 21X4'.
Material used: 40% 20 gauge, 50% 16 gauge, 10% 10 gauge,

Operation		Man-hours
Prepare template		1 1/2
Variance		1/6
Move material from vertical storage-to shears	2 men, 10 reins.	1/3
Variance		1/3
Layout, shear the blank, then use the nibbler, Pulmax, unit shears or bevel shears to cut the shapes required - 2 per fitting. Label the parts.	1 man, 1 hr.	1
Variance		1/6
Move pieces by wagon to forming area	1 man, 10 reins.	1/6
Variance		1/6
		3.83

3.83 x 200 = 766 man-hours per year.

APPENDIX NO. 3 (cont'd)

Fitting No. 9 - Rectangle With One Offset

Quantity produced per year: approximately 125.
Average size is 18".
Material used: 40% 20 gauge, 50% 16 gauge and 10% 10 gauge.
Approximate size of sheet used per fitting: 2'X 4'.

Operation		Man-hours
Prepare template		1/2
Variance		1/6
Material movement from vertical storage to shears	2 men, 10 reins.	1/3
Variance		1/6
Layout 4 pieces, shear and label	2 men, 50 reins.	1 2/3
Variance		1/6
Move material by wagon to forming area	1 man, 10 reins.	1/6
Variance		1/12
		3.42

3.42 x 125 = 427.5 man-hours per year.

Fitting No. 10 - Rectangle With Two Offsets

Quantity produced per year: approximately 60.
Average size is 18".
Material used: 40% 20 gauge, 50% 16 gauge and 10% 10 gauge.
Approximate size of sheet used per fitting: 2' x 4'.

Operation		Man-hours
Prepare template	2 1/2 to 3 hrs.	2 3/4
Move material from vertical storage area to shears	2 men, 10 reins.	1/3
Variance		1/6
Shear, Layout 4 pieces, label each piece and shear	2 men, 50 reins.	1 2/3
Variance		1/6
Move-by lift truck to assembly. area		1/3
Variance		l/6
		5.58

5.58 x 60 = 335 man-hours per year.

APPENDIX NO. 3 (cont' d)

Fitting No. 11

Transition, Rectangular to Circular.
Quantity produced per year: approximately 400.
Average size is 20".
Approximate sheet size per fitting: 2' x 4'
Material used: 40% 20 gauge, 50% 16 gauge and 10% 10 gauge.

Operation		Man-hours
Prepare template	1 man, 1 hr.	1
Material movement from vertical storage location to shears	2 men, 10 reins.	1/3
Variance		1/3
Layout, cut and label	1 man, 1 1/2 hrs.	1 1/2
Variance		1/6
2nd material movement from shears area to forming operation		1/6
Variance		1/6
		3 2/3

3 2/3 x 400 = 1,467 man-hours per year.

Fitting No. 12 - Round Duct

Quantity produced per year: approximately 900.
Material used: 16 gauge, blank size is 2' x 4' per piece.
No template is required.

Operation		Man-hours
Material movement from vertical storage to shears	2 men, 10 reins.	1/3
Variance		1/3
Shearing Operation, Layout, label and shear	2 men, 30 reins.	1
'Move by wagon to the forming area .	1 man, 10 reins.	1/6
Variance		1/12
		1.92

1.92 X 900 = 1,728 man-hours per year.

APPENDIX NO. 3 (cent'd)

Fitting No. 13

Gore pieces 6" to 26" in diameter. 18" average diameter.
Quantity produced per year: approximately 150 units.

Operation		Man-hours
Prepare template		1 1/2
Move material from vertical storage area to shears	2 men, 10 reins.	1/3
Variance "		1/3
Shear, blank and then cut by Pulmax and label	1/2 hr. for each of 6 segments	3
Material movement from shears area to roll forming area		1/6
Variance		1/6
		5 1/2

5 1/2 x 150 =.825 man-hours per year.

Fitting No. 14

Round to rectangular with double offset.
Quantity produced per year: approximately 250.
Average.diameter: 10".

Operation		Man-hours
Prepare template		1 1/2 .
Move material from vertical storage area to shears	2 men, 10 reins.	1/3
Variance		1/3
Shear 3 pieces and label them, 2 cuts per piece	1 man, 1 hr.	1
Move material by wagon to forming area	1 man, 10 reins.	1/6
Variance		1/2
		3.42

3.42 x 250 = 855 man-hours per-year.

APPENDIX NO. 4

PRODUCTION OF FITTINGS USING COIL LINE AND CAD-CAM SYSTEM.

	Man-hours
Listing 50 fittings with key dimensions	1.75
Entering listed information in the computer	2.00
Variance	.50
	4.25

Man-hours per fitting = 0.085

Dispensing material ,from coil line to the machine	0.25
Variance	0.17
	0.42

Man-hours per fitting = 0.42+ 2.87* = 0.146

Producing parts by the machine:

Program call-down	0.03
Cutting the parts	0.18
Labeling parts	0.08
Remove and stack parts	0.17
Remove scrap	0.08
Variance	0.17
	0.710

Man-hours per fitting = 0.710 ÷ 2.87* = 0.247

Moving fitting parts, 10 at one time to forming area	0.17
Variance	0.17
	0.34

Man-hours per fitting = 0.34 ÷ 10 = 0.034

Total man-hours per fitting = .085 + .146 + .247 + .034 = 0.512

Total sq. ft. of sheet metal per year = 136,549
Total number of fittings produced per year = 7,825
Sheet size: 50 sq. ft. (approx.)
Average sq. ft. per fitting =136,549 ÷ 7,825 = 17.45
*Average number of fittings per sheet. = 50 ; 17.45 = 2.87

APPENDIX NO. 5

COMMISSARY PARTS USING CONVENTIONAL MANUFACTURING METHODS.

Part: Back and Sides (Wrap)

Material required: 18 ga. SS 36″ x 216″

		Man-hours
1st Material handling	2 men, 10 reins.	0.33
Variance .		0.17
Shearing operation	3 men, 15 reins.	0.75
Variance		0.50
2nd Material handling	2 men, 10 reins.	0.33
Variance		0.17
Notching operation	4 men, 30 reins.	2.00
Variance		0.33
3rd Material handling	2 men, 15 reins.	0.50
Variance		0.17
Total man-hours spent in producing and delivering the Wrap to the forming operation area:		5.25

Part: Cabinet Bottom

Material required: 18 ga. SS 36″ x 96″.

1st Material handling	2 men, 10 reins.	0.33
Variance		0.17
Shearing operation	3 men, 15 reins.	0.75
Variance		0.50
2nd Material handling	2 men, 10 reins.	0.33
Variance		0.17
Notching operation	4 men, 30 reins.	2.00
Variance		0.33
3rd Material handling	2 men, 10 reins.	0.33
Variance		0.17
Total man-hours spent in producing and delivering the Cabinet Bottom to the forming operation:		5.08

APPENDIX NO. 5 (cont'd)

Part: Cabinet Partitions - 2 per Cabinet

		Man-hours
1st Material handling	2 men, 10 reins.	0.33
Variance		0.17
Shearing Operation	2 men, 10 reins. for each partition	0.67
Variance		0.17
2nd Material handling	1 man, 15 reins.	0.25
Variance		0.08
Notching operation	. 2 men, 15 reins.	0.50
Variance		0.17
3rd Material handling	2 men, 10 reins.	0.33
Variance		0.08
Total man-hours spent in delivering cut-to-size pieces to the forming operation for one cabinet:		2.75

Part: Cabinet Mullions - Top and Bottom

Material required: 18 ga. SS 6" x 120" (2 per unit)

1st Material handling	2 men, 10 reins.	0.33
Variance		0.17
Shearing operation	2 men, 10 reins.	0.33
Variance		0.17
2nd Material handling	2 men, 6 reins.	0.20
Variance		0.20
Notching operation	2 men, 15 reins.	0.50
Variance		0.10
3rd Material operation	1 man, 5 reins.	0.08
Variance		0.07
Total man-hours spent in delivering two cut pieces to the forming and assembly operation for one cabinet:		2.15

APPENDIX NO. 5 (cent'd)

Part: Cabinet Doors - Female and Male

Material required: 18 ga. SS 48″ x 120″

		Man-hours
1st Material handling	2 men, 10-mins.	0.33
Variance		0.17
Shearing operation	2 men, 15 reins.	0.50
2nd Material handling	2 men, 6 mins.	0.20
Variance		0.20
Notching operation	2 men, 15 reins.	0.50
Variance		0.10
3rd Material handling	1 man, 5 reins.	0.08
Variance		0.07
Total man-hours spent in delivering two cut pieces to the forming and assembly operation for one cabinet:		2.15

Part: Shelves. No. per Cabinet = 3

Material required: 16 ga. SS 36″ x 48″ cut from 36″ x 144″ sheet..

		Man-hours
1st Material handling	2 men, 10″mins.	0.33
Variance		0.06
Shearing operation	2 men, 10 reins.	0.33
Variance		0.17
2nd Material handling	2 men, 6 reins.	0.20
Variance		0.20
Notching operation	2 men, 15 reins.	0.50
Variance		0.10
3rd Material handling	1 man″, 5 reins.	0.08
Variance		0.07
Total man-hours spent in delivering three cut pieces to the forming and assembly operation for one cabinet:		2.04

APPENDIX NO. 5 (cent'd)

Part: Cabinet Top

Material required: 14 ga. SS 48" x 120"

		Man-hours
1st Material handling	2 men, 10 reins.	0.33
Variance		0.17
Shearing operation	2 men, 15 reins.	0.50
2nd Material handling	2 men, 10 reins.	0.33
Variance		0.17
Notching operation	2 men, 10 reins.	0.33
Variance		0.33
3rd Material handling	2 men, 10 reins.	0.33
Variance		0.33
Welding Tabs back on part and cleanup with grinder	1 man, 1 hr.	1.
4th Material handling	2 men, 10 reins.	0.33
Variance		0.17
Layout and blue for 2 sinks	1 man, 1/2 hr.	0.50
Variance		0.08
Use portable drill press to make eight holes	2 men, 1 hr.	2.00
5th Material handling	2 men, 10 reins.	0.33
Variance		0.17
Cut out sink openings by Pulmax Nibbler Machine	4 men, 1 1/2 hrs.	6.00
6th Material handling. Move cut parts to assembly area	2 men, 10 mins.	0.33
Variance		0.33
	Total time:	14.06

GALLEY CABINETS SUMMARY

Back and Sides (Wrap)	5.25
Cabinet Bottom	5.08
Cabinet Partitions	2.75
Cabinet Mullions	2.15
Cabinet Doors	2.15
Shelves	2.04
Cabinet Top	14.06

Total man-hours required to prepare flat cut SS parts for one average galley cabinet using conventional manufacturing methods: 33.48

APPENDIX NO. 6

COMMISSARY PARTS USING CAD-CAM SYSTEM.

Part: Back and Sides (Wrap)

Material required: 18 ga. SS 36″ x 216″

		Man-hours
Preparing the program and entering it at the CFC 150 programming station		0.33
Variance		0.17
Moving the SS sheet from the storage area and placing it on the cutting table of the. CFC 150 machine	2 men, 10 reins.	0.33
Variance		0.17
Calling up the program and cutting the part.	1 man, 6 reins.	0.10
Removing the cut part and delivering it to the forming area	2 men, 15 reins.	0.50
Variance		0.17
Disposing of scrap	1 man, 10 reins.	0.17
Total man-hours spent in producing and delivering the Wrap to the forming area:		1.94

Part: Cabinet Bottom

Material required: 18 ga SS 36″ x 96″

		Man-hours
Preparing the program and entering it at the CFC 150 programming station		0.33
Variance		0.17
Moving the SS sheet from the storage area amd placing it on the cutting table of the CFC 150 machine	2 men, 10 reins.	0.33
Variance		0.17
Calling up the program and cutting the part	1 man, 5 reins.	0.08
Removing the cut part and delivering it to the forming area.	2 men, 15 reins.	0.50
Variance		0.17
Disposing of scrap	1 man, 10 reins.	0.17
Total man-hours spent in producing and delivering the average Cabinet Bottom to the forming area:		1.92

APPENDIX NO. 6 (cent 'd)

Part: Cabinet Partitions - 2 per Cabinet

		Man-hours
Preparing 'the program for the 2 partitions and entering them at the CFC 150 programming station		0.42
Variance		0.17
Moving the SS sheet from the storage area to the cutting table of the CFCC150 machine	2 men, 10 reins.	0.33
Variance		0.17
Calling up the program and cutting the parts	1 man, 8 reins.	0.13
Removing the cut parts and delivering them to the forming area	1 man, 15 reins.	0.25
Variance		0.17
Disposing of the scrap	1 man, 10 reins.	0.17
Total man-hours spent in producing and delivering the 2 Cabinet Partitions to the forming area:		1.81

Part: Cabinet Mullions - Top and Bottom

Material required: 18 ga. SS 6" x 120" (2 per unit)

Preparing the program and entering it at the CFC 150 programming station		0.42
Variance		0.17
Moving the SS sheet from the storage area and placing it on the cutting table of the CFC 150 machine	2 men, 10 reins.	0.33
Variance		0.17
Calling up the program and cutting the part	1 man, 8 reins.	0.13
Removing the parts and delivering them to the forming area.	2 men, 10 reins.	0.33
Variance		0.17
Removing the scrap and returning the remnant to the storage rack	2 men, 10 reins.	0.33
Variance		0.17
Total man-hours spent in producing and delivering the 2 Mullions to the forming area:		2.22

APPENDIX NO. 6 (cent')

Part: Cabinet Doors - Female and Male

Material required: 18 ga. SS 48″ x 120″

		Man-hours
Preparing the programs for the parts and entering them at the CFC 150 programming station		0.42
Variance		0.17
Moving the SS sheet from the storage area to the cutting table of the CFC 150 machine	2 men, 10 reins.	0.33
Variance		0.17
Calling up the program and cutting the parts	1 man, 8 reins.	0.13
Removing the cut parts and delivering them to the forming area	1 man, 15 reins.	0.25
Variance		0.17
Disposing of the scrap	1 man, 10 reins.	0.17
Total man-hours spent in producing and delivering the 2 Door Blanks to the forming area:		1.81

Part: Shelves. No. per Cabinet = 3

Material required: 16 ga. SS 36″ x 48″ cut from 36″ x 144" sheet.

		Man-hours
Preparing the program for the 3 shelves and entering it at the CFC 150 programming station		0.42
Variance		0.17
Moving the SS sheet from the storage area to the cutting table of the CFC 150 machine	2 men, 10 reins.	0.33
Variance		0.17
Calling up the program and cutting the parts	1 man, 8 reins.	0.13
Removing the cut parts and delivering them to the forming area	1 man, 15 reins.	0.25
Variance		0.17
Disposing of the scrap	1 man, 10 reins.	0.17
Total man-hours spent in producing and delivering the 3 Shelves to the forming area:		1.81

APPENDIX NO. 6 (cent'd)

Part: Cabinet Top

"Material required: 14 ga. SS 48" x 120"

		Man-hours
Preparing the program and entering it at the CFC 150 programming station		0.67
Variance		0.17
Moving the SS sheet from the storage area and placing it on the cutting table of the CFC 150 cutting machine	2 men, 10 reins.	0.33
Variance		0.17
Calling up the program and cutting the part	1 man, 7 reins.	0.12
Removing the cut part and delivering it to the forming area	2 men, 15 reins.	0.50
Variance		0.17
Disposing of the scrap	1 man, 10 reins.	0.17
Total man-hours spent in producing and delivering the flat Cabinet Top to the forming area:		2.30

GALLEY CABINETS SUMMARY

	Man-hours
Back and Sides (Wrap)	1.94
Cabinet Bottom	1.92
Cabinet Partitions	1.81
Cabinet Mullions	2.22
Cabinet Doors	1.81
Shelves	1.81
Cabinet Top	2.30

Total man-hours required to prepare flat cut SS parts for one average galley cabinet using the CAD-CAM plasma cutting system: 13.81

APPENDIX NO. 7

PRODUCTION OF WATERTIGHT DOOR PANELS USING CONVENTIONAL MANUFACTURING METHODS.

Operation	Man-hours yer door.
1. Move an 8'x40'xl/4° steel plate to cutting table and by hand torch, slit it into four 8'x1O' panels. This requires 2 men working 1 hour with a variance 10 reins. Since there are approximately 16 doors produced from one 8'x40' plate, the man-hours required per door for this operation is $\frac{2 \times 70}{60 \times 16} = 0.15$	0.15
2. Move the 8'x1O' panels to the shears by lift truck and shear them into the required panel sizes.	0.67
3. Layout the corners by hand using a soapstone marker, a square and a set of dividers.	0.83
4. Burn the contours and cutouts by hand torch using a circle cutting guide. Grind and dress the cut surfaces.	0.58
5. Layout and punch hole centers.	0.25
6. Move to hydraulic punch press and punch out holes.	1.25
7. Move the panel to the forming area.	0.17
Total hours per panel	3.90
Man-hours required for 150 panels	585

APPENDIX NO. 8

PRODUCTION OF WATERTIGHT DOOR PANELS USING THE CAD-CAM SYSTEM AND PLASMA CUTTING MACHINE.

		Man-hours
1.	Prepare the NC program using geometries and store it on a disc.	0.15
2.	Move the 8'x40' plate to the cutting.table and cut it into four 8'x1O' panels.	0.15
3.	Move the panels to the shear by lift truck and shear into door-size panel blanks.	0.67
4.	Move the door-size panel blanks to the plasma machine.	0.16
5.	Call up the program and cut the door blank including the OD and all cutouts.	0.16
6.	Remove panel from the cutting bed and dispose of scrap.	0.25
7.	Move panels, four at one time, to the assembly area by lift truck.	0.06
	Total hours per panel	1.60
	-Man-hours required for 150 panels	240

APPENDIX NO. 9

TIME STUDY FOR THE PRODUCTION OF SOME MISCELLANEOUS PARTS USING CONVENTIONAL MANUFACTURING METHODS.

Gauge Boards - See Figures Nos. 6a and 6b.
There are two sizes. The mixed quantity produced per year is 2,000 units.
Material used: #11 gauge stainless steel sheet 48″ x 120″.

No.	Operation	Time	Man-hours per piece
1.	Move material-from horizontal storage area to the shears	2 men, 10 reins.	
	Variance	2 men, 5 reins.	
		$\frac{2x15}{60} \times \frac{1}{\text{pieces per sheet}} =$	0.016
2.	Layout and shear 48″ x 120″ sheet into 32 blanks	2 men, 1 1/2 hrs.	
		$3 \div 32 =$	0.094
3.	Move materials by pallet to the band saw	1 man, 5 reins.	
	Variance	5 reins.	
		$\frac{10}{60} \times \frac{1}{32} =$	0.005
4.	Band saw the corners,	1 man, 20 reins.	0.333
5.	Punch parameter and mounting holes	1 man, 10 mins.	0.167
6.	Separate blade on Do-All saw, thread blade through the hole in the part and reweld and grind blade	1 man, 15 reins.	0.250
7.	Cut out "T" opening in part	1 man, 45 reins.	0.750
8.	Again separate the blade on the Do-All saw, thread blade through the opening and reweld and grind the blade	1 man, 15 reins.	0.250
9.	Cut out the slot	1 man, 20 reins.	0.333
10.	De-bur the part	1 man, 15 reins.	0.250
11.	Move parts to the forming area	1 man, 10 reins.	
	Variance	5 mins.	
		$\frac{15}{60} \times \frac{1}{32} =$	0.008
	Total man-hours to produce one gauge board		2.456
	Total man-hours per year = 2.456 x 2,000 =		4,912.00′

APPENDIX NO. 9 (cent'd)

Cylinder Storage Racks

Material: 3/8" mild steel plate 7" wide x 10' long.
Quantity per year: approximately 50.
Quantity per work order: 3

			Man-hours yer unit
1.	Move an 8' x 10' x 3/8" plate from storage area to the shears	2 men, 10 reins.	
	Variance	2 men, 5 reins.	
		$\frac{2 \times 1\ \ 5}{60} \times \frac{2}{3} =$.	0.167
2.	Shear three 7" x 120" strips from the plate	2 men, 20 reins	
	Variance	5 reins, 2 men	
		$\frac{2 \times 25}{60 \times 3}$ -	0.278
3.	Return the remnant *to* the storage area	2 men, 10 reins.	
		$\frac{2 \times 10}{60} \times \frac{1}{3} =$	0.111
4.	Move the three7" x 120" strips to the burning table	2 men, 10 reins.	
	Variance	2 men, 5 reins.	
		$\frac{2 \times 15}{60}$ -- $\frac{1}{3} =$	0.167
5.	Burn the circular cutouts one at a time by oxy-flame hand torch.		
	Setup time	1 man, 10 reins.	
	Starting time for each cutout 1/6 min. x 12 cutouts = 2.00 reins.		
	Burning time	20 reins.	
	Variance	5 reins.	
	Total time for burning operation	$\frac{27}{60} + \frac{10}{60 \times 3} =$	0.506
6.	Hand dress the part with a grinder and chipping hammer	30 reins.	0.500
7.	Move the racks to a storage area	1 man, 20 reins.	0.333
	Total man-hours to produce 1 storage rack element		2.062
	Approximate man-hours per year = 2.062 x 50 =		103.1

APPENDIX NO. 9 (cont'd)

Access Covers and Mounting Rings

Quantity per year: approximately 200.
Material: Mild steel plate blanks, 27″ x 18″ x 1/4″ thick.
Prepared in lots of 25 (25 covers and 25 rings).

		Man-hours Der Cover and Ring
Move 8′ x 24′ x 3/8″ mild steel plate from storage area to shears	2 men, 15 reins.	
Variance.	5 reins.	
The blank for 1 ring and 1 cover requires:	$\frac{20 \times 2}{60 \times 25}$	.026
Shear plate into fifty 18″ x 27″ blanks.	2 men, 60 reins.	
	$\frac{2}{25}$	,040
Move material to the hand torch burning table	10 reins.	
Variance	5 reins	
	= reins. 1 man	
	$\frac{15}{25}$ =	.600
Using a template guide, burn parameter of covers and ID and OD of rings		
One set requires:	20 reins.	
Variance	5 reins.	
	$\frac{25}{60}$ =	.417
De-slag parts and stack on a flat	$\frac{50 \text{ reins.}}{60 \times 25}$ = .033 man-hours	.033
Move covers to the punch and move. rings to the stud welding area	\60 ˙ 60/ 25	.013
Variance	5 ÷ (60 x 25)	.003
Total man-hours per set to move material from the storage area, process and deliver cut parts to the punch and the stud welding area		1.132
Total man-hours for 200 sets per year		226

APPENDIX NO. 9 (cont'd)

Elbows For Main Engine Exhaust

Size range: 36" and 55" diameter.
Material used: 8' x 15' x 1/4" mild steel plate.
Build in lots of 4.
Annual requirement: 60

		Man-hours
Prepare template Man-hours per set	.1 man, 5 l/2"hrs. 5 1/2 ÷ 4 =	1.375
Move plate from storage area to the shears. One plate per set	2 men, 15 reins.	1/2
Variance		1/6
Shear the plate into rectangular . blanks	3 men, 15 reins.	3/4
Variance		1/4
Move the blanks by wagon to the burning table area	2 men, 10 reins.	1/3
Variance"		1/6
Layout and center punch on lines	1 man, 60 reins.	1
Variance .	5 reins.	1/12
Move to rolls for further processing using lift truck	2 men, 10 reins.	1/3
Variance	5 reins.	1/6
Total man-hours to move material from the storage area and deliver cut sections for one set to the rolls for further processing.		5.125
Total man-hours per year = 60 x 5.125 =		307.50

APPENDIX NO. 10

TIME STUDY FOR THE PRODUCTION OF SOME MISCELLANEOUS PARTS USING THE CAD-CAM SYSTEM. .

Gauge Boards - See Figures Nos. 6a and 6b.

There are two sizes. The mixed quantity produced per year is 2,000 units.
Material used: #11 gauge stainless steel sheet 48″ x 120″.

			Man-hours per piece
1.	Program both parts and store on disc	1 man, 30 reins.	
	Variance	10 reins.	
		$\frac{40}{60} \times \frac{1}{2{,}000} -$	.00033 .
2.	Move material from horizontal storage area to the CYB 150 plasma cutting machine	$\frac{2 \times 15}{60} \times \frac{1}{32}$ per plate =	.016
3.	Call up the program and cut 32 parts	1 man, 30 reins.	
	Variance	5 reins.	
		$\frac{35}{60} \times \frac{1}{32} -$	.018 .
4.	Remove parts and scrap	1 man, 15 reins.	
		$\frac{15}{32} \times \frac{1}{60} =$	.008
	Variance	5 mins. $\frac{5}{60} \times \frac{1}{32} =$	.002
5.	Move cut parts to forming area	1 man, 15 reins.	
	Variance	5 reins.	
		$\frac{20}{60} \times \frac{1}{32} -$	.010
	Total man-hours to produce one gauge board		.054
	Total man-hours-per year = .054x 2,000 =		108.00

APPENDIX NO. 10 . (cont'd)

Cylinder Storage Racks

Material: 3/8" mild steel plate 7" wide x 120" long.
Quantity per year: approximately 50,
Quantity per work order: 3

Operation	Time	. Man-hours per unit
1. Program the part and store it on disc at the program station	1 man, 20 reins.	
"Variance	10 reins.	
	$\frac{30}{60} \times \frac{1}{3} =$	.167
2. Move a plate from the storage area and place it on an NC cutting machine bed in the -plate shop	1 man, 20 reins	
Variance	5 reins.	
	$\frac{25}{60} \times \frac{1}{3} =$	0.139
3. Call up the program and cut the parts by plasma torch	1 man, 10 mins.	
Variance	5 reins.	
	$\frac{15}{60} \times \frac{1}{3} =$	.083
4. Remove cut parts and scrap from the burning table	1 man, 15 reins.	
Variance	5 reins.	
	$\frac{20}{60} \times \frac{1}{3} -$	0.111
5. Move finished cut parts by truck to the storage area	1 man, 15 reins.	
Variance	5 reins.	
	$\frac{20}{60} \times \frac{1}{3} =$	0.111
Total man-hours required to produce one cylinder storage rack element		0.611
Approximate man-hours per year		30.55

APPENDIX NO.10 (cont 'd)

Access Covers and Mounting Rings

Using CAD-CAM system, plasma cutting machine and NC drill press.
Quantity per year: approximately 200.
Material: 1/4" mild steel plate.

			Man-hours per set.
1.	Prepare program at CAD-CAM work station and store it on hard disc Variance	1 man, 20 reins. 10 reins. $\frac{20+10}{60 \times 25} =$	0.020
2.	Move plate from storage area and place it on a plasma cutting machine bed in the plate shop Variance	1 man, 20 reins. 10 reins. $\frac{30}{60} \times \frac{1}{25} =$	0.020
3.	Call down program and cut 25 covers and 25 rings Variance	27 mins. 5 reins. $\frac{32}{60} \times \frac{1}{25} =$	0.021
4.	Remove parts, stack them and dispose of scrap Variance	25mins. 5 reins. $\frac{30}{60} \times \frac{1}{25} =$	0.020
5.	Move parts by truck to the NC drill press	$\frac{20}{60} \times \frac{1}{25} =$	0.013
	Total man-hours per set to move material from the storage area, process and deliver the cut parts		0.094
	Total man-hours to produce 200 sets (rings and covers) =		18.8

APPENDIX NO. 10 (cont'd)

Time Study For the Production of Elbows For the Main Engine Exhaust

Size ranges: 36" and 55" diameter.
Material used: 8' x 15' x 1/4" mild steel.
Build in lots of 4.
Annual requirement: 60 units.

		Man-hours yer fitting
1. Call up shape at the CAD-CAM program station, enter the key dimensional data and store the program on hard discs	1 man, 10 reins.	
Variance	10 mins.	
	$\frac{20}{60} \times \frac{1}{4}$ -	0.083
2. Load a 1/4" plate on the cutting table of the NC plasma cutting machine .	1 man, 20 reins.	
Variance	10 mins.	
	$\frac{30}{60} \times \frac{1}{4} =$	0.125
3. Call down the program and cut shapes for four fittings	1 man, 15 reins.	
Variance	5 mins.	
	$\frac{20}{60} \times \frac{1}{4}$ -	0.083
4. Remove parts from the cutting bed. Return remnant to storage area. Remove scrap and dispose of it.	1 man, 15 reins.	
Variance	5 mins.	
	$\frac{20}{60} \times \frac{1}{4} =$	0.083
5. Transport the flat cut parts to the assembly area in the sheet metal shop	1 man, 20 reins.	
Variance	10 mins.	
	$\frac{30}{60} \times \frac{1}{4} =$	0.125
Man-hours required to produce the flat cut parts for one engine exhaust elbow =		0.499
Total man-hours required for 60 elbows =		29.94