PRODUCTION OF METAL-BASED IMPLANTS FOR CYRO-FACIAL INJURIES (BLUEPRINTS)

by

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Dissertation Report submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

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November 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and the acknowledgments, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

LIM SIOW LING

ABSTRACT

The main objective of this project is to propose a design for a progressive die for the production of metal based implants for Cyro-facial injuries. The bulk of the work would be to produce the detailed design drawings or blueprints for each progressive die components and to suggest the appropriate process plans for the fabrication of the respective progressive die components. The main concentration is put in producing the blueprints of a progressive die to produce the I-shaped metal implants. Throughout the first semester, literature reviews are done to gain knowledge about the working principle of the progressive die and how to design the various die components needed in the progressive die. Other than that, literature reviews are also done to gain information about the minimum tolerances, clearances and angular relief that need to be applied to each die components to ensure the quality of the progressive die and also the metal implants that will be produced by the progressive die. The basic step in producing a progressive die is to produce the blank layout. There are many ways in laying out the scrap strip. However, for this particular project, the blanks are laid out by adopting the narrow-run, one-pass layout. To optimize the usage of the material strip while ensuring the quality of the produced implants, minimum bridge allowances are applied between blanks and between blanks and edges of the strip. After calculation, the blanking force needed to cut the blank from the strip is 33707.52 N and since the press capacities are usually in tons, a press of more than 3.789 tons should be chosen to produce this particular metal implants. Other than that, it is also found that, a total of 63 metal implants can be produced from a 1 m material strip. On the other hand, in designing the die components, care had been taken in assigning the correct clearances, angular relief, allowances and tolerances for each part of the die components. This is to ensure the success of the particular progressive die. In general, the material selected for the implants are titanium and stainless steel strips while for the die components, are tool steels, mild steel and cast steel. The main processes involved for fabricating the die components are Wire EDM and milling.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Metal-based implants, particularly in the form of miniature plates and fasteners are mainly used to treat Cyro-facial injuries such as fractures of the skull and facial bones. However, the patient will have to bear a very high cost in order to obtain this treatment since these implants had to be imported from other countries. Therefore, effort had been made to develop appropriate ways to manufacture these implants locally. One of the ways to produce these implants in large quantities is by presswork or stamping process by using the progressive die method.

A progressive die performs a series of fundamental sheet metal operations at two or more stations during each press stroke in order to develop a work piece as the strip stock moves through the die. This type of die is sometimes called cut-and-carry, follow or gang die. Each working station performs one or more distinct die operations, but the strip must move from the first through each succeeding station to produce a complete part. One or more idle stations may be incorporated in the die, not to perform work on the metal, but to locate the strip, to facilitate interstation strip travel, to provide maximum-size die sections, or to simplify their construction [3]. Before the metal implants can be manufactured in large quantities, the required progressive die components shall be fabricated beforehand. The steps in producing a progressive die are mainly part designing, estimating and quoting, tool designing, selection of raw materials, designing the die components, fabricating the particular die components and troubleshooting by comparing it to the standard requirements. Progressive die components can be fabricated with various methods such as Milling or Wire EDM (WEDM). The general material used for progressive die components is tool steel which is usually steel alloys. Detailed design drawing must be produced before fabricating the desired die components to avoid error that can be costly.

1.2 PROBLEM STATEMENT

Patients subjected to Cyro-facial injuries often have to bear a very high cost in order to obtain treatment since metal implants will have to be imported from other countries. Therefore, in order to help these patients, effort had been made to develop appropriate ways to manufacture these implants locally to reduce the cost that the patients had to bear. These implants can be manufactured by various ways such as rapid prototyping, milling, presswork and die casting. Thus, studies and analyses must be done on these ways to ensure the most cost effective way to produce these implants in large quantities is chosen.

As a continuation from the previous FYP effort, the best way that can be used to produce these implants in large quantities is by using the metal stamping process. In the metal stamping process, there are various types of dies that can be used namely, combined dies and progressive dies. And it was found out that the progressive die is the most suitable way to manufacture the metal implants. Therefore, prior to producing the required implants, the designed progressive die components for the stamping process must be fabricated in order to manufacture the respective implants. Before fabrication, the detailed design for the respective die components must be drawn and materials needed to fabricate the progressive die components and metal implants must be analyze and chosen. The next step will be the production and to perform tests on the produced metal-based implants.

1.3 OBJECTIVE AND SCOPE OF STUDY

The main objective of this project is to propose a design for a progressive die for the production of metal based implants for Cyro-facial injuries. The bulk of the work would be to produce the detailed design drawings or blueprints for each progressive die components and to suggest the appropriate process plans for the fabrication of the respective progressive die components.

The related activities are as follows:

a) Reviewing the previous design drawings and making necessary modifications by adding in the tolerance values and others to produce the blueprint for each die components.
b) Determining the best material to use for the die components.
c) Determining the type of material to be purchased for the die components and the metal implants, that is, steel block or metal sheet.
d) Determining the process plan for the fabrication of each die components.

CHAPTER 2

LITERATURE REVIEW

2.1 WORKING PRINCIPLE OF PRESSWORK

2.1.1 Introduction

Pressworking process works on the principle of applying large forces by press tools for a short time interval which results in the cutting (shearing) or deformation of the work material. The operation is generally completed by a single application of pressure, often results in the production of a finished part in less than one second.

2.1.2 General Working Principle of a Die

The cutting of metal between die components is a shearing process in which metal is stressed in shear between two cutting edges to the point of fracture or beyond its ultimate strength. The metal is subjected to both tensile and compressive stresses (Refer to Figure 2.1). Stretching beyond the elastic limit occurs, then plastic deformation, reduction in area and finally, fracturing starts through cleavage planes in the reduced area and becomes complete.

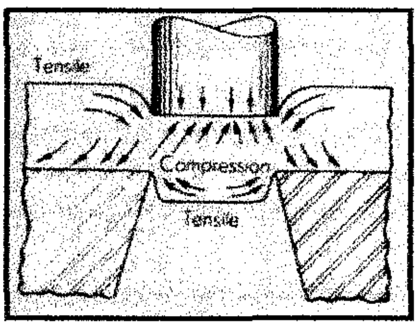


Figure 2.1 Stresses in Die Cutting [3]

The fundamental steps in shearing or cutting are shown in Figure 2.2. The pressure applied to the metal by the punch tends to deform it into the die opening. When the elastic limit is exceeded by further loading, a portion of the metal will be forced into the die opening in the form of an embossed pad on the lower face of the material. A corresponding depression results on the upper face, as indicated at A. As the load is further increased, the punch will penetrate the metal to a certain depth and force an equal portion of metal thickness into the die, as indicated at B. This penetration occurs before fracturing starts and reduces the cross-sectional area of metal through which the cut is being made. Fracture will start in the reduced area at both upper and lower cutting edges, as indicated at C. If the clearance is suitable for the material being cut, these fractures will spread toward each other and eventually meet, causing complete separation. Further travel of the punch will carry the cut portion through the stock and into the die opening.

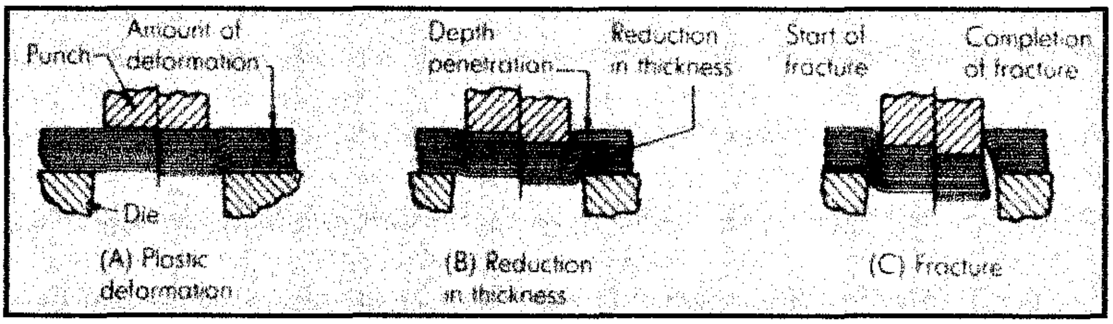


Figure 2.2 Steps in Shearing Metal [3]

2.1.3 Types of Die-Cutting Operations

Table 2.1 Types of Die-Cutting Operations

Types of Operations	Descriptions
Bending	↳ Consists of forming the metal between a suitably shaped punch and a forming block. ↳ The included angle on the tools is usually smaller than that to be produced to allow for the spring-back of the metal after forming.
Drawing	↳ Cups, shells and similar parts are produced by pushing metal through a die so that it assumes the shape of the space between the punch and the die. ↳ The spring-back of the metal causes it to foul a stripping edge on the underside of the die, to free the drawn part from the punch.
Piercing (Punching)	↳ An operation in which a round punch (or a punch of other contour) cuts a hole in the work material which is supported by a die having an opening corresponding exactly to the contour of the punch. ↳ The material (slug) cut from the work material is often scrap.
Blanking	↳ The outside contour of the workpiece is produced by removing metal from the strip by means of a punch and a die. ↳ The metal removed is the workpiece and the metal that is left is the scrap.
Lancing	↳ Combines bending and cutting along a line in the work material. ↳ Does not produce a detached slug but leaves a bent portion, or tab, attached to the work material.
Cut-off	↳ Separates the work material completely by cutting it along straight or curved lines.
Notching	↳ Cuts out various shapes from the edge of workpiece material (a blank or a part).
Shaving	↳ Is a secondary shearing or cutting operation in which the surface of a previously cut edge of a workpiece is finished or smoothed.

2.2 WORKING PRINCIPLE OF PROGRESSIVE DIES

In a progressive die, the strip is moved in stages from station to station. Different operations are performed on it at each station except at idle ones applied to provide room for components. A complete workpiece is removed from the strip at the final station. All die-cutting operations maybe performed in progressive dies. In this project, only one progressive die is needed to produce the desired metal implants. For example, piercing is done at the first station and blanking at the second station for the I-shaped metal implants. Therefore, a progressive die maybe considered as a series of different dies placed side by side with the strip passing through each successively.

2.3 MATERIALS SELECTION

2.3.1 Materials for Metal Implants

The common metal implants are made of titanium (Refer to Appendix 2) and stainless steel (Refer to Appendix 3). Unalloyed titanium is usually not very useful for structural applications since it is difficult to be weld or machined. However, titanium, unalloyed or alloyed, is considered one of the most biocompatible materials available due to some of its significant advantages over traditional metals. It is one of the best materials that can be used especially where direct contact to tissue or bone is required for example as endosseuos dental implants or porous uncemented orthopedic implants. Due to its poor shear strength, titanium and its alloys can not be used as bone screws or plates. Other than that, it also has poor surface wear properties and tends to seize when in sliding contact with itself and other metals. The detailed information on several types of titanium and titanium alloys that can be used as the Cyro-facial injuries implants can be seen in Appendix 2.

Other than titanium which is very costly and difficult to obtain, stainless steel that had undergone heat treatment process can be used. Stainless steel is easier to be obtained and it is also much cheaper compared to titanium. However, not every types of stainless steel are biocompatible. One type of the stainless steel that can be used for biomedical implants is AISI Type 316L Stainless Steel, annealed and cold drawn bar (Refer to Appendix 3). It good corrosion resistance to most chemicals, salts and acids and molybdenum content are one of the reasons it is biocompatible. Other than that, its low carbon content reduces the possibility of in vivo (the knowledge of biological development like the growth of bones) corrosion when it is used as medical implants.

2.3.2 Materials for Progressive Die Components

2.3.2.1 Types of Materials

In order to fabricate the die components that can be used to cut titanium or stainless steel, analysis on the mechanical properties of various metals need to be done to ensure that the die have better wear resistance and longer lifespan. Taken into considerations are various types of tool steels which are mainly steel alloys. Below are the lists of a few types of tool steels that can be used as the material for the required die components:

- AISI Type A2 Tool Steel
- AISI Type A6 Tool Steel
- Carpenter Micro-Melt® 10 Hardened and Tempered Tool Steel (AISI A11)
- Carpenter Micro-Melt® 9 Wear Treated Tool Steel
- Carpenter Micro-Melt® HS-30 Alloy
- Carpenter O6 Graphitic Tool Steel (AISI O6)
- Carpenter Stentor ® Alloy Tool Steel (Oil-Hard) (AISI 02)

The detailed information of all the tool steels mentioned above is to be found in Appendix 4.

2.3.2.2 Factors of Consideration

Dies and molds can be made from various materials and each dies and molds may contain several materials. There is no single material that is best for all forming applications due to the extensive range of conditions and requirements encountered in various operations. By selecting the appropriate material, work piece quality can be improved, productivity can be increased and costs can be reduced. There are a few factors that should be taken into account while selecting a proper die material. These factors are as listed below [4]:

1. The operations to be performed, including their severity, forces applied, temperatures encountered and lubricants used.
2. The work piece material, including its hardness, thickness and condition as well as the size of the work piece.
3. The production rate and quantity, accuracy and finish requirements.
4. The press or machine to be used, including its type and condition.
5. The design of the die.
6. The accuracy and rigidity of the setup.
7. The cost per part produced, based upon the material, manufacturing, heat treatment and maintenance costs, as well as the life of the die.
8. The current availability of the die material.
9. The properties of the material, including resistance to wear, heat and deformation and the ease with which it can be machined, heat treated and ground.

2.4 DESIGN FOR SHEET-METAL FORMING

2.4.1 Introduction

The first step in designing for sheet-metal forming is to lay out the blanks on the material sheet or strip exactly as it will appear after all operations have been performed. The layout of the scrap strips should be done in such a way as to minimize scrap loss. Care has to be taken in laying out the scrap strip since it will directly influence the financial success or failure of any press operation. The blank must be positioned so a maximum area of the strip is utilized in production of the stamping. The blank layout is drawn before any work is done on the die design itself. [1]

Notching a blank along one edge can results in an unbalanced force that makes it difficult to control dimensions as accurately as with blanking round the entire contour. The usual tolerances on blanked parts are ± 0.003 in. When holes are punched in metal sheet, only part of the metal thickness is sheared cleanly, therefore, a hole with tapered sides is created as shown in Figure 2.3 below.

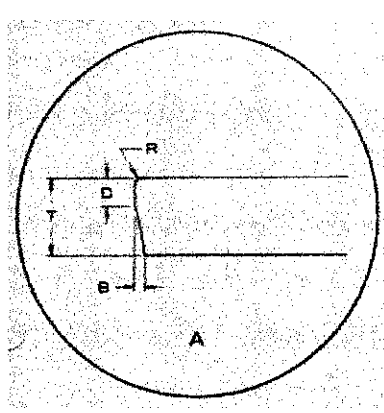


Figure 2.3 Enlarged View of Sheared Blank Edge

In the stamping process, the diameters of the punched holes should not be less that the thickness of the metal sheet or a minimum of 0.025 in. This is because smaller holes can cause excessive punch breakage. The minimum distance between holes, or between a hole and the edge of the sheet, should be at least equal to the thickness of the metal sheet. [2]

2.4.2 Scrap Strip Allowances

It is important that correct bridge allowances be applied between blanks and between blanks and edges of the strip. Excessive allowances are wasteful of material. Insufficient allowance results in a weak scrap strip subject to possible breakage with consequent slowdowns on the press line. In addition, a weak scrap area around the blank can cause dishing of the part. [1]

2.4.2.1 Scrap Strip Allowances – One Pass Layouts

Peripheries of blanks may be classified under four (4) distinct outline shapes, namely:

- Curved outlines (Refer to Figure 2.4)

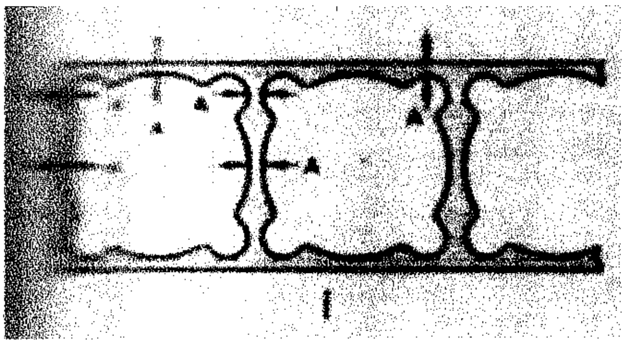


Figure 2.4 Scrap Strip Allowances for Curved Outlines [1]

For these, dimensions A are given a minimum allowance of 70 per cent of the strip thickness, T.

* Straight edges (Refer to Figure 2.5)

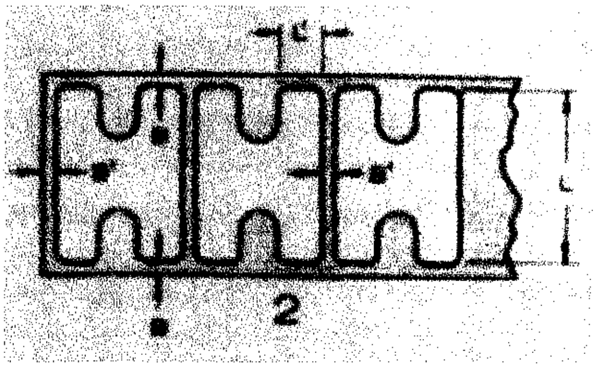


Figure 2.5 Scrap Strip Allowances for Straight Outlines [1]

Dimensions of B and B' depend upon the length of the bridge, dimensions L and L' respectively where when,

- L or L' < 2 ½ inches, B or B' = 1T, respectively.
- L or L' = 2 ½ to 8 inches, B or B' = 1 ¼ T, respectively.
- L or L' > 8 inches, B or B' = 1 ½ T, respectively.

* Parallel curves (Refer to Figure 2.6)

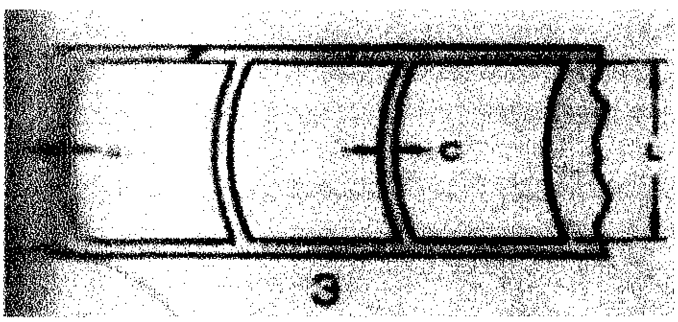


Figure 2.6 Scrap Strip Allowances for Parallel Curves Outlines [1]

The same rules apply as for straight edges where when,

- L < 2 ½ inches, C = 1 T
- L = 2 ½ to 8 inches, C = 1 ¼ T
- L > 8 inches, C = 1 ½ T

* Adjacent sharp corners (Refer to Figure 2.7)

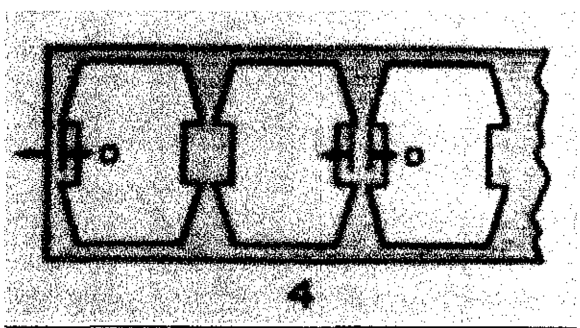


Figure 2.7 Scrap Strip Allowances for Adjacent Sharp Corners Outlines [1]

These form a focal point for fractures and minimum allowance is 1 ¼ T, dimension D on the drawing.

2.4.2.2 Minimum Allowances

Table 2.2 lists the minimum scrap bridge allowances for one-pass layouts. These values are applicable for thin gages (less than 3/64 inch) of stock where use of the previous rules would give such small allowances as to be impractical. The value for space A opposite the appropriate strip width is selected.

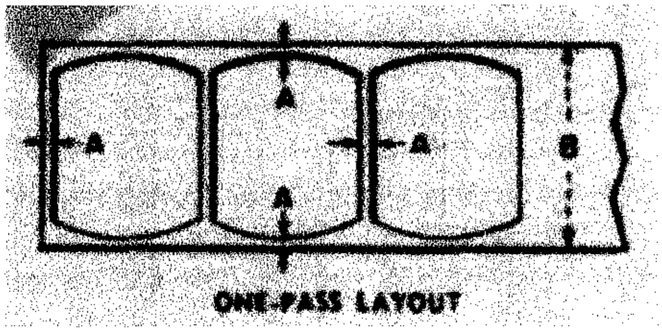


Table 2.2 Minimum Scrap Strip Allowances [1]

Strip Width B	Space A
0 to 3 in	1/32 in
3 to 6 in	1/16 in
6 to 12 in	3/32 in
Over 12 in	1/8 in

2.5 DETAIL DESIGN

Detail design is the phase where all of the details are brought together, all decisions are finalized and a decision is made by the management to release the design for production. Listed below are the principal tasks that must be completed in the detail design phase:

1. Detail drawings
2. Qualification prototype testing
3. Bill of materials
4. Decisions on make/buy
5. Detailed product specification
6. Detailed cost estimate
7. Final design review
8. Release to manufacturing

2.5.1 Detail Drawings [2]

The information that needs to be included on a detail drawing is as follows:

a. Standard views of orthogonal projection – top, front, side views
b. Auxiliary views such as sections, enlarged views or isometric views that aid in visualizing the component and clarifying the details
c. Dimensions – presented according to the GD & T standard ANSI Y14.5M
d. Tolerances
e. Material specification and any special processing instructions
f. Manufacturing details such as parting line location, draft angle, surface finish

2.5.2 Bills of Materials [2]

The bill of materials (BOM), also know as parts list is a list of each individual component in the product. The content of a BOM are as follows:

1. Parts description
2. Quantity needed for a complete assembly
3. Part number
4. Source of the part
5. Purchase order number if outsourced to a supplier
6. Name of the project engineer responsible for the detail design of each part
7. Name of the project engineer responsible for tracking the parts through manufacture and assembly

However, the Bills of Materials that will be furnished in this project includes only the first three (3) items.

2.6 DIE COMPONENTS DESIGN

2.6.1 Die Clearances

Clearance is the space between the mating members of a die set. Proper clearances between cutting edges enable fractures to meet. For optimum finish of a cut edge, proper clearance is necessary and is a function of the type, thickness and temper of the material strip. Figure 2.8 below shows the location where clearances must be applied to the blanking punch and piercing punch respectively.

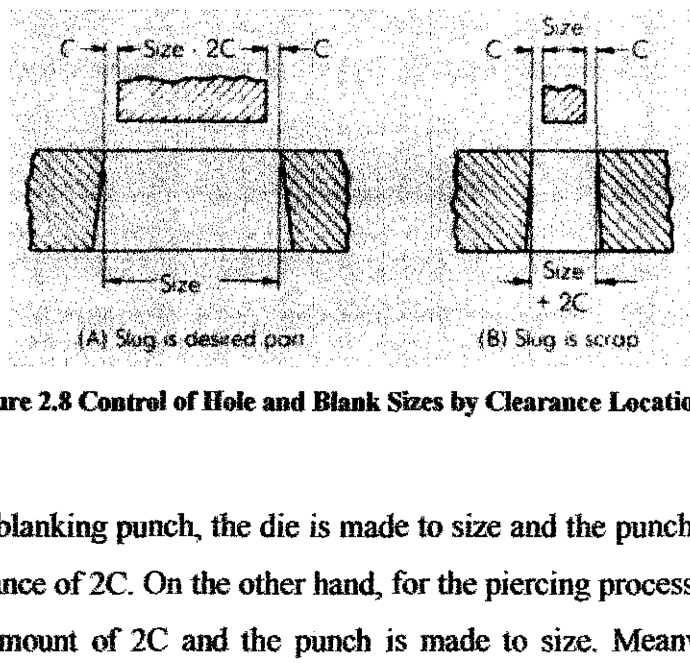


Figure 2.8 Control of Hole and Blank Sizes by Clearance Location [3]

For the blanking punch, the die is made to size and the punch is made smaller by a total clearance of 2C. On the other hand, for the piercing process, the die is made larger by the amount of 2C and the punch is made to size. Meanwhile Figure 2.9 shows the way to apply clearances for both the blanking punch and piercing punch [3]. Clearance is often applied to either the punch or the die but never to both at the same time.

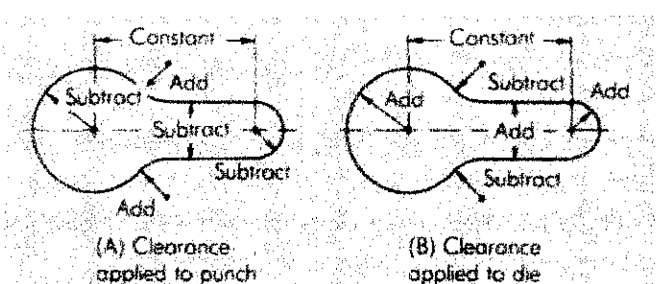


Figure 2.9 Application of Clearances [3]

2.7 DIE SET SELECTION

2.7.1 Materials

Selection of the material from which the die set is to be made will depend upon the strength requirements. There are three types of die sets as follows:

1. Semi-steel
2. All steel
3. Combination – Punch holder is semi-steel and die holder is all steel.

2.7.2 Selecting the Die Set

There are ten elements that need to be known prior to the selection of the die sets. They are as follows:

i. Make or manufacture
ii. Type
iii. Size
iv. Material
v. Thickness of die holder
vi. Thickness of punch holder
vii. Type and lengths of bushings
viii. Length of guide posts
ix. Shank diameter
x. Grade of precision

CHAPTER 3

METHODOLOGY

3.1 PROCEDURE IDENTIFICATION

3.1.1 Project Activities

The main activities that need to be done in this semester are preparing the blueprint for each die components and also the process plan to produce each die components. There are nine (9) main components for this particular progressive die. Other than that, the types of fasteners and die set needed will also be determined. The details of the project activities are as shown in Figure 3.1. On the other hand, the timeline of the project activities is as shown in the Gantt Chart of Appendix 1.

3.1.2 Steps of Designing a Die

Before a die can be fabricated, a detail design drawing must be drawn to ease the fabrication process. The main steps of die design are laying out the scrap strip, designing parts of the die, selection of die sets and preparation of Bills of Materials (BOM). Flow chart in Figure 3.2 shows the steps and sequence of die designing.

3.1.3 Steps in Fabrication of Die Components

The steps involved in fabricating the die components are shown in Figure 3.3.

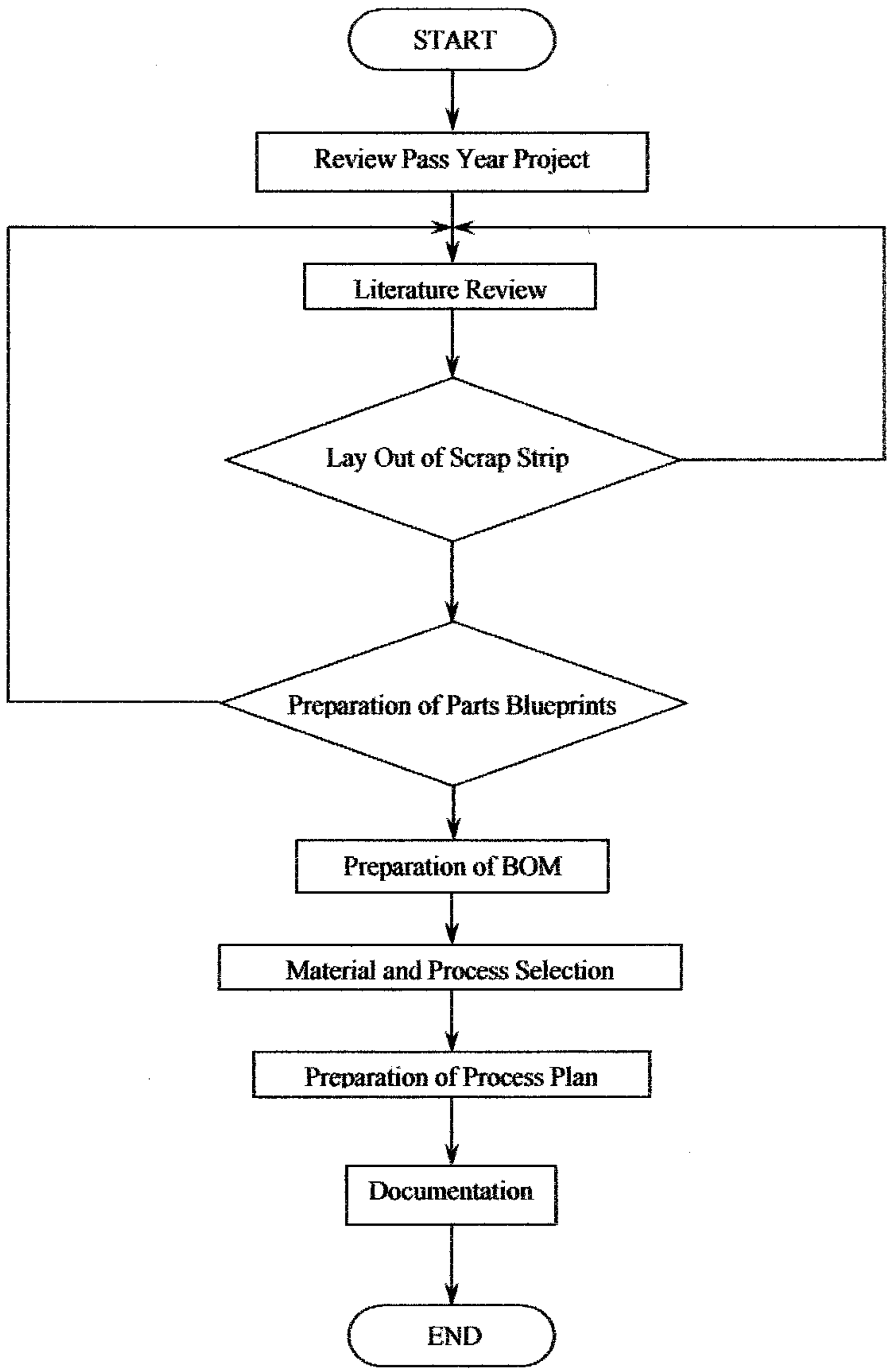


Figure 3.1 Project Activities Flow Chart

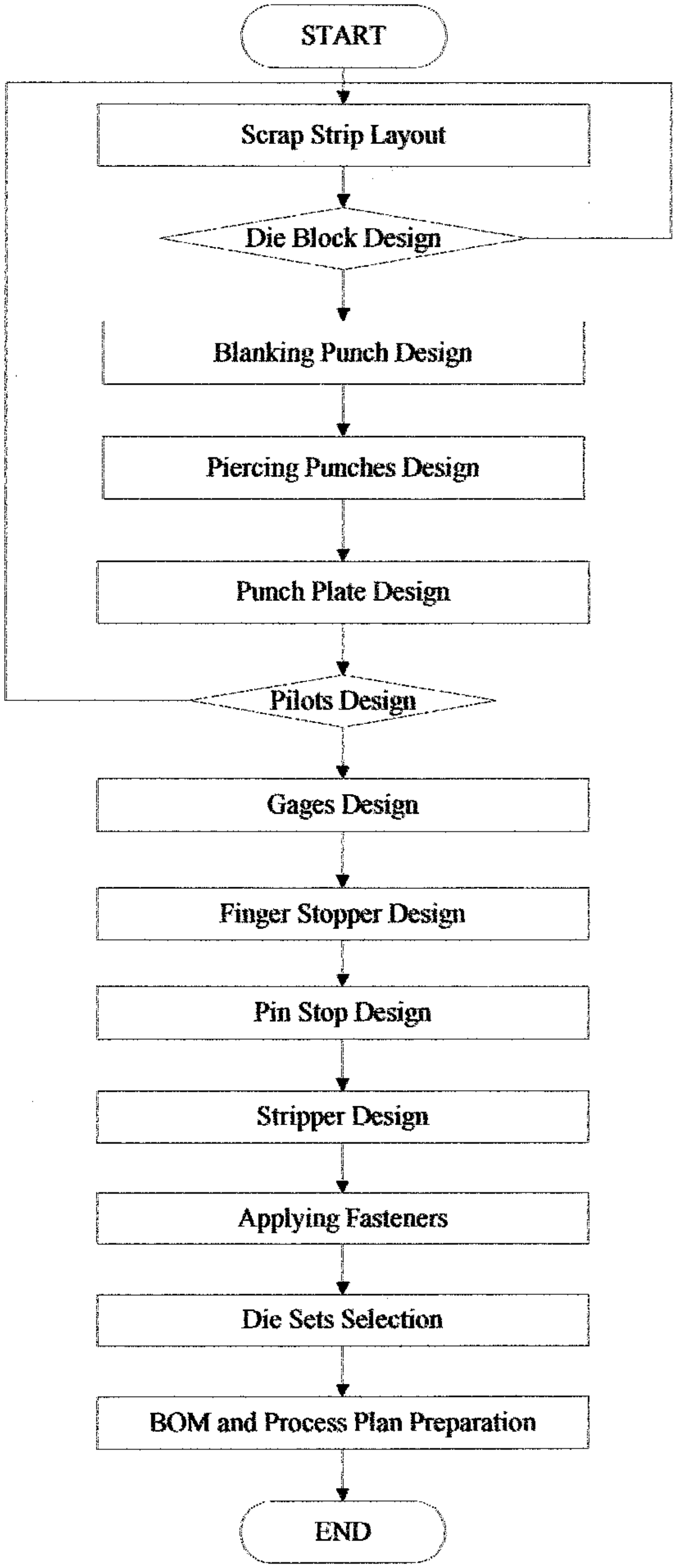


Figure 3.2 Steps in Designing a Die

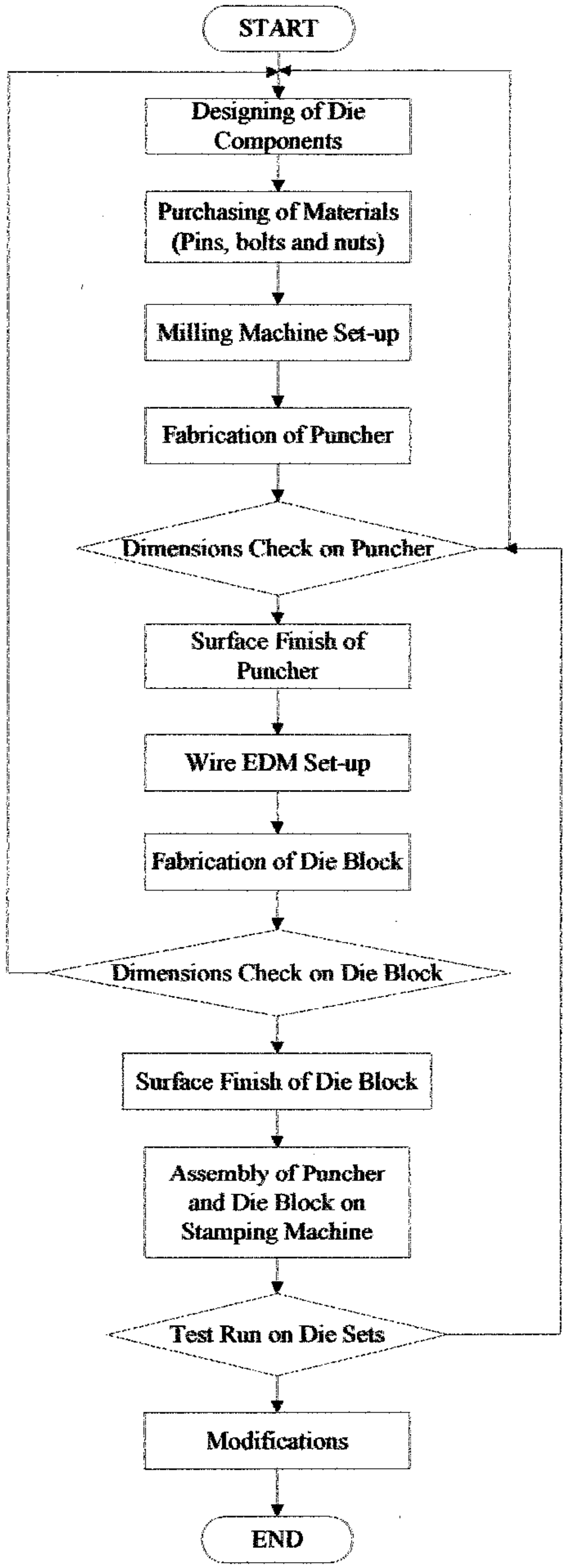


Figure 3.3 Steps in Fabrication of Die Components

CHAPTER 4

RESULTS AND DISCUSSION

4.1 REVIEW OF PAST DESIGNS

After reviewing past design and comparing it to the design of Paquin [1], there are some differences in the past designs. The past design was meant for manual metal stamping process where the stamping process and material strip feeding will be done manually by an operator. Meanwhile, the design of Paquin [1] is meant for automatic stamping process. Those main different components from the designs found are as follows (Refer to Figure 4.1):

- Pilot Nut
- Pilot
- Square Head Set Screw
- Automatic Stop

Some modifications will need to be done to the design drawing in order to adapt it for automatic stamping process. Some of the main modifications that need to be done are as follows:

1. Elimination of key hole from the stripper plate.
2. Replace the pin stop with automatic stop.
3. Include additional components such as pilot nut, pilot and square head set screw.

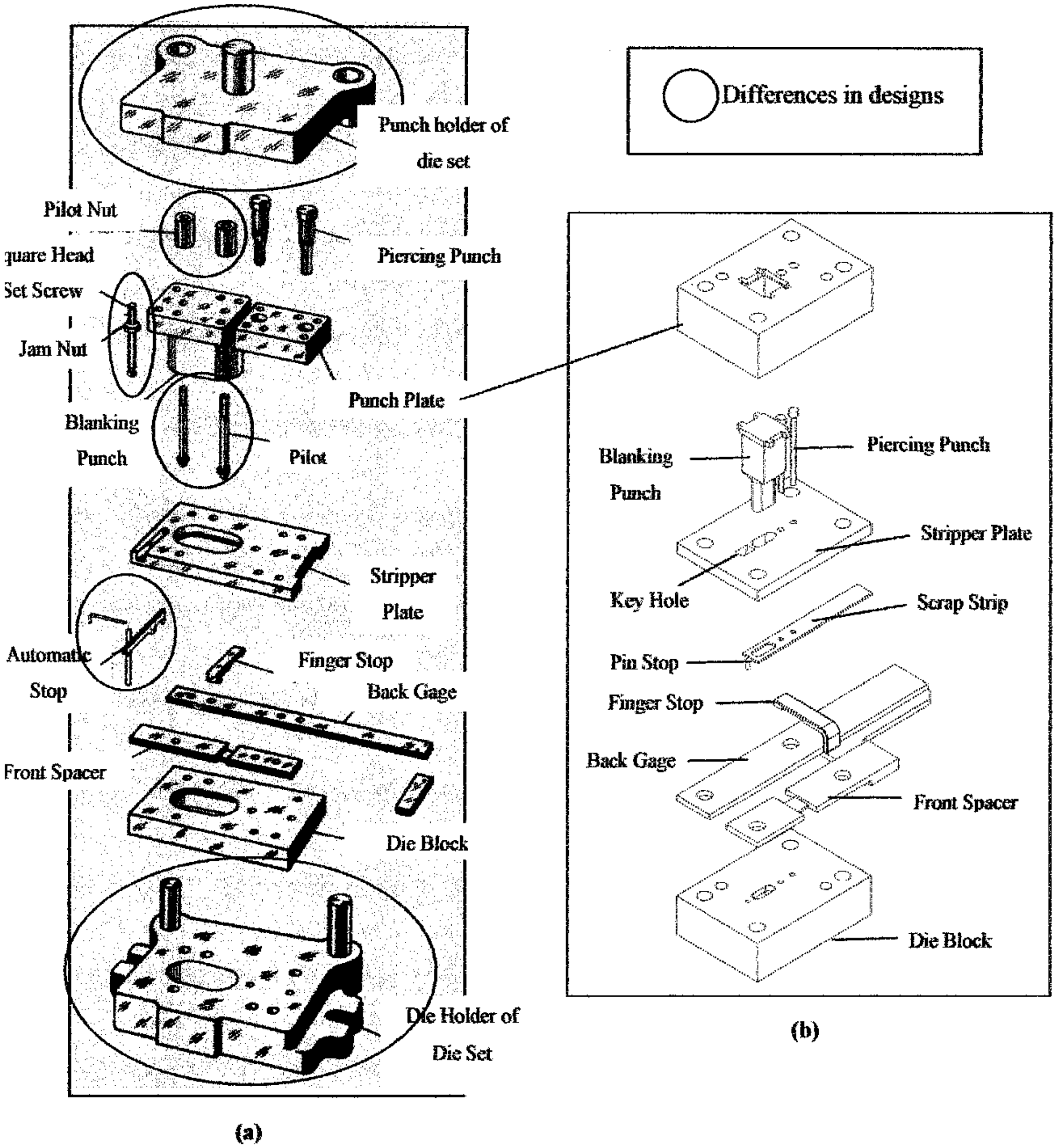


Figure 4.1 Exploded View of Die Components (a) Extracted from Reference Book [1]

(b) Extracted from Past Design [5]

4.2 MATERIAL SELECTION

From the literature review done, the materials selected for the implants and the progressive die sets are as follows:

- Metal implants – Titanium Ti-6Al-4V (Grade 5), STA and AISI Type 316L Stainless Steel.
- Progressive Die Components – AISI Type A2 Tool Steel or AISI Type O1 Tool Steel.

4.3 WORKING PRINCIPLE OF THE DESIGNED PROGRESSIVE DIE

To produce the I-shaped implants, two processes are involved that is the blanking and piercing process. The titanium strip is advanced until it comes in contact with the finger stop which has been pushed forward by the operator. Then the press is tripped and the piercing punches pierce two holes in the strip end. The finger stop is then retracted and the strip is advanced until it contacts the automatic stop. Tripping the press again causes two holes to be pierced in the strip at the first station, while at the second station; the blanking punch removes a blank from the strip and pushes it into the die block (Refer to Figure 4.2). The strip is advanced from one station to another from right to left. The acorn shaped pilots the engage the previously pierced holes to register the strip correctly before recycling.

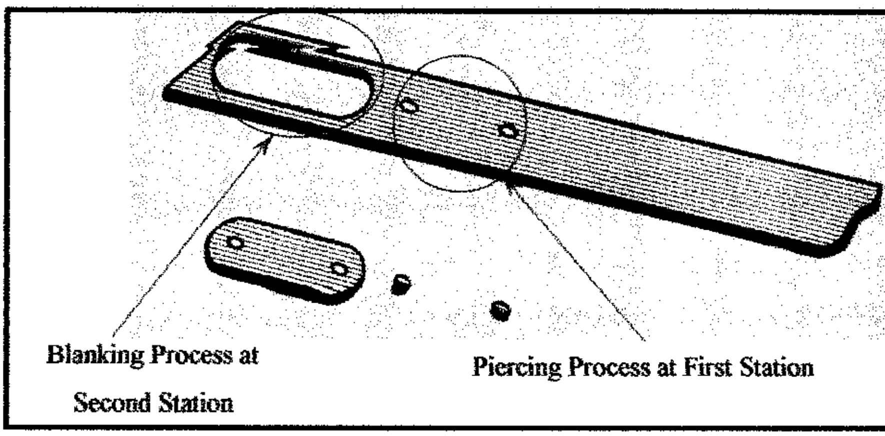


Figure 4.2 Working Principle of the Designed Progressive Die [1]

4.4 BLANK LAYOUTS

The size of the blank that will be produce by the progressive die as shown in Figure 4.3 below:

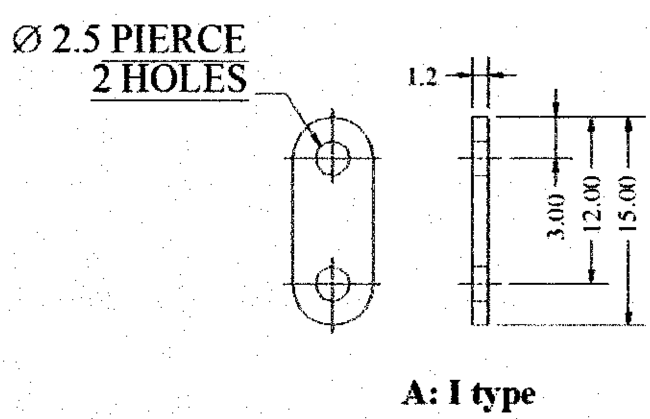


Figure 4.3 Dimensions of the Metal Implant

There are two (2) possible ways of running the strip through the die. However, for this project, the strip will be run in the narrow way as soon in Figure 4.4. Two holes will be pierced at the first station and the part will be blanked out at the second station.

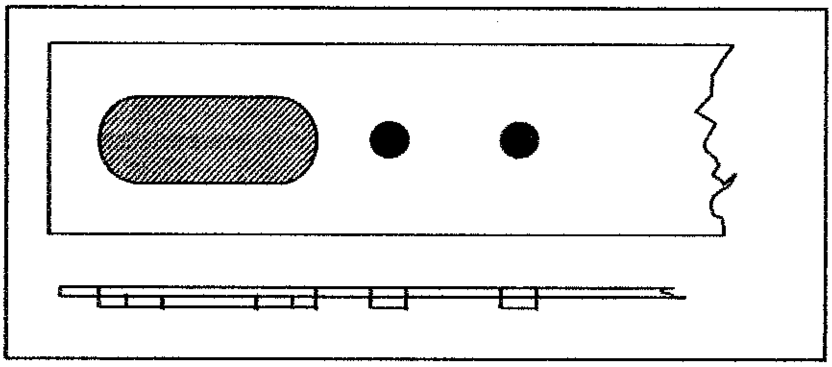
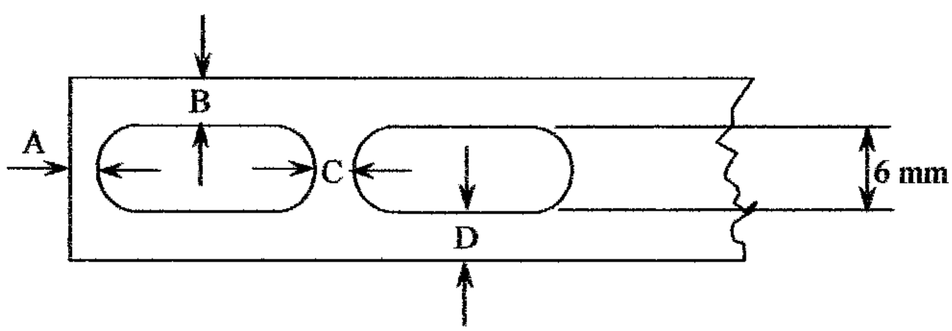


Figure 4.4 Blank Layouts Necessitating Narrow Strips

4.4.1 Minimum allowances applied to the blank layout

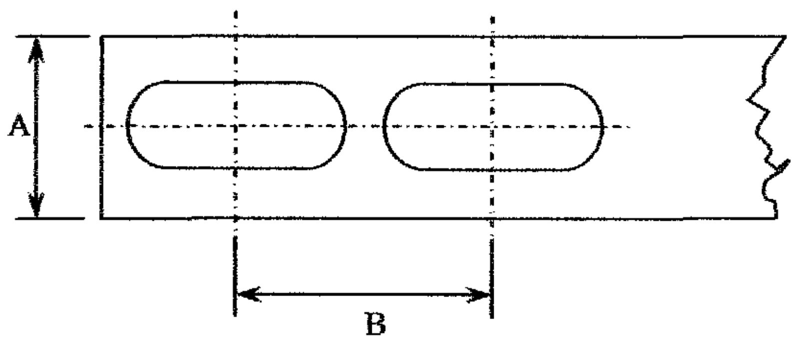


$$A = C = \frac{70}{100} x\, T = \frac{70}{100} x\, 1.2mm = \underline{\underline{0.84mm}}$$

$$B = D = 1\frac{1}{2}T = 1\frac{1}{2} x 1.2mm = \underline{\underline{1.8mm}}$$

4.4.2 Blank Area Calculations

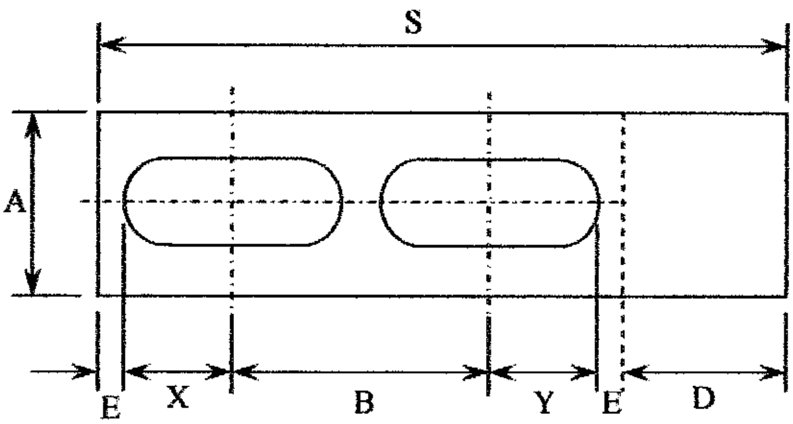
The blank is laid out for single-row, one pass positioning. Assuming that the width of the material strip used is 10 mm, the blank area (the area of the strip which is used for one part) can be calculated by the following equation:



$$Blank\ Area = A x B$$
$$= 10\,mm\,x\,15.84\,mm$$
$$= \underline{\underline{158.4\,mm^2}}$$

4.4.3 Number of Blanks per Strip

It is often necessary to determine the number of blanks in each strip to establish the extent of the waste end D. This has an influence on the blank layout, because too great a waste end is uneconomical. The number of blanks per strip for a single-pass layout can be calculated by the following equation:



Assuming the length of the strip, S = 1 m,

$$Blanks\ per\ strip,\ A = \frac{S-(X+Y+2E)}{15.84}+1$$
$$= \frac{1000-(7.5+7.5+2x0.84)}{15.84}+1$$
$$\approx 63\,blanks$$

For the waste end,

$$D = S-[B(A-1)+X+Y+2E]$$
$$= 1000-[15.84(10-1)+7.5+7.5+2x0.84]$$
$$= 840.76\,mm^2$$

4.5 BLANKING FORCE

To cut a material, a force must be applied on the area to be sheared. This force is known as the shear stress. However, the material will offers resistance to separation due to its molecular structure and this resistance is called the shear strength. Therefore, to affect cutting, the shear stress applied to the material must be greater than the shear strength. The shear strength of a titanium strip is 760 MPa. Thus, the force that must be applied by the progressive die must be greater than 760 MPa.

In order to determine the blanking force, the blank must be first calculated. For this particular implant, the area to be cute is found by multiplying the perimeter of the blank by the thickness.

$$
\begin{aligned}
Perimeter\ of\ blank &= 2\pi r + 2L \\
&= 2\pi(3) + 2(1.2) \\
&= \underline{\underline{21.25\,mm}}
\end{aligned}
$$

$$
\begin{aligned}
Perimeter\ of\ holes &= 2(\pi)(D) \\
&= 2\pi(2.5) \\
&= \underline{\underline{15.71\,mm}}
\end{aligned}
$$

$$Blanking\ Force = SPT$$

where,

$$S = shear\ strength\ of\ material$$

$$P = Perimeter\ of\ cut\ edges$$

$$T = Thickness\ of\ material\ to\ be\ cut$$

$$
\begin{aligned}
\therefore Blanking\ Force, F &= (760\,MPa)(15.71 + 21.25\,mm)(1.2\,mm) \\
&= \underline{\underline{33707.52\,N}}
\end{aligned}
$$

Since press capacities are rated in tons, the value of the blanking force should be converted in tons to ease the selection of press to be used. Therefore,

Blanking Force, F = 33707.52N = **<u>3.789 tons</u>**.

By assuming constant perimeter and shear strength, a graph of blanking force versus strip thickness can be plotted as follows:

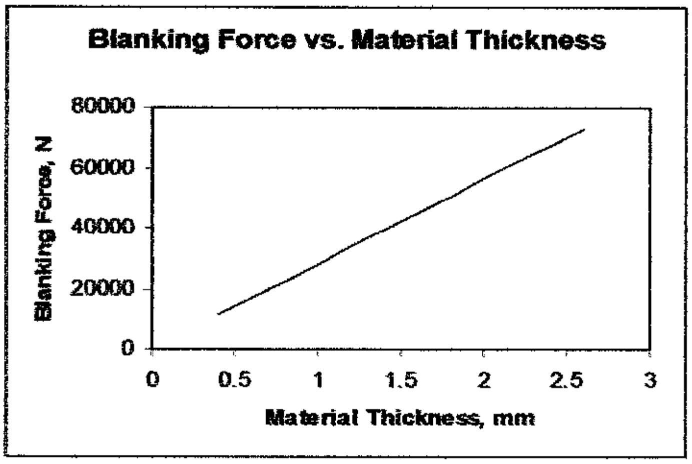


Figure 4.5 Relationship between Blanking Force and Material Thickness

4.6 DIE BLOCK DESIGN

4.6.1 Die Block Height

Table 4.1 below shows the relationship of the die block height to strip thickness.

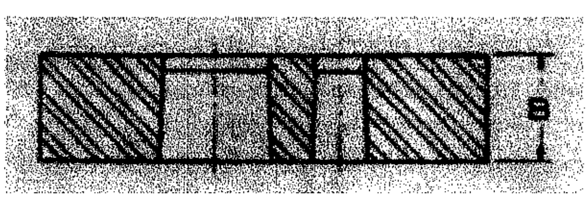


Table 4.1 Relationship of Die Block Height to Strip Thickness [1]

Strip Thickness (mm)	Die Block Height, B (mm)
0 to 1.5	24
1.5 to 3.0	28
3.0 to 4.5	35
4.5 to 6.0	40
> 6.0	47

Therefore, since the strip thickness used for the metal implants is 1.2 mm, therefore, the die block height is 24 mm.

4.6.2 Die Clearance

From the graph in Figure 4.6, clearance that should be applied is about 0.094 mm. Therefore, for blanking process, the hole in the die block will be made to the size of the implant while the clearance of 0.188 will be subtracted from each side of the blanking punch.

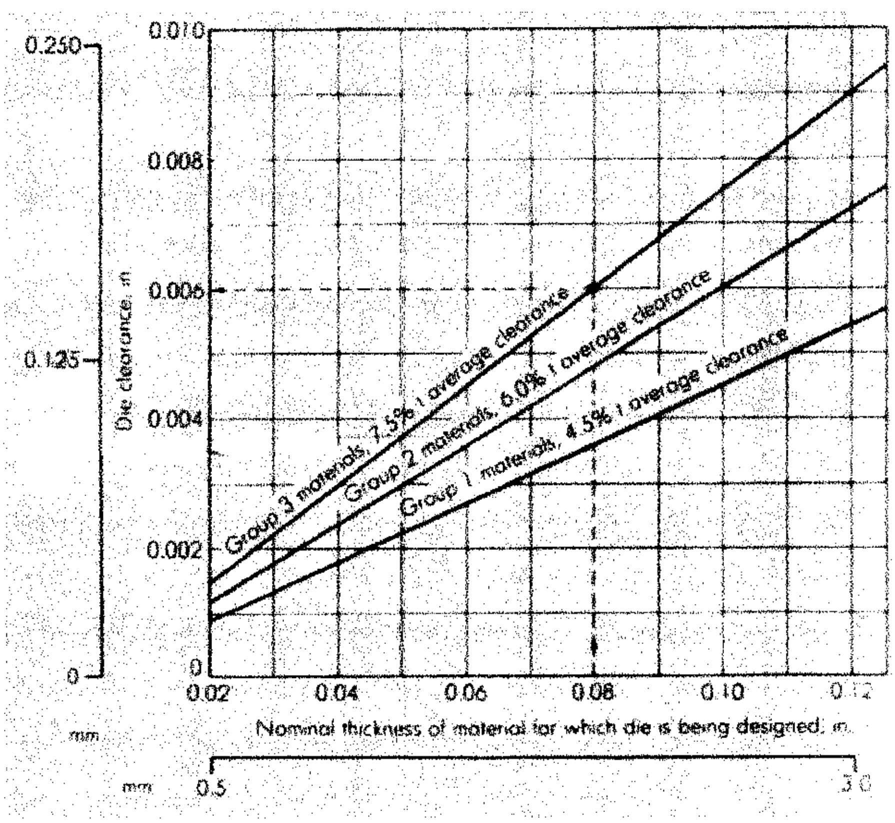


Figure 4.6 Die Clearances for Different Groups of Metals [3]

4.6.3 Straight Land and Angular Relief

Straight land is the straight portion of a die surface. On the other hand, angular relief is the clearance below the straight land introduced to enable the blank or slug to clear the die. The amount of angular relief is occasionally higher, depending mainly on stock thickness and the frequency of sharpening. Table 4.2 below lists the relationship between stock thickness and the angular relief to be applied.

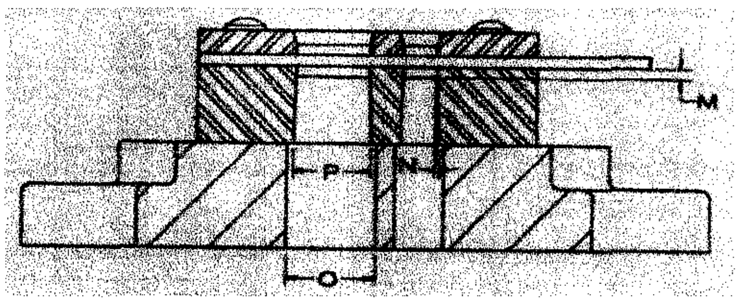


Table 4.2 Relationship between Strip Thickness and Angular Relief [1]

Strip Thickness (mm)	Angular Relief (°)
0 to 1.5	0.25
1.5 to 3.0	0.5
3.0 to 8.0	0.75
> 8.0	1.00

Therefore, for the metal implants of 1.2 mm thick, the straight land will be 3.18 mm and the angular relief to be applied to the die block is 0.25°.

4.7 BLANKING PUNCH AND PIERCING PUNCHES DESIGN

The punch body is designed to be in the square shape to prevent it from turning during the stamping process. The four small rectangles, (B) as in Figure 4.7 are applied to precisely position the punch in the punch plate.

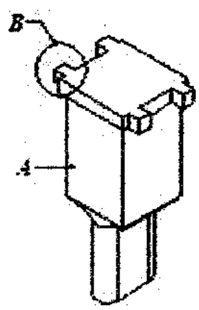


Figure 4.7 Design of the Blanking Punch [5]

The maximum allowable length of a punch can be calculated from the following equation:

$$L = \frac{\pi d}{8}\left[\frac{E}{S_s}\frac{d}{t}\right]^{1/2}$$

4.7.1 Allowable Length for Blanking Punch

The maximum allowable length for the blanking punch can be calculated by the above equation:

$$L = \frac{\pi d}{8}\left[\frac{E}{S_s}\frac{d}{t}\right]^{1/2}$$

$$= \frac{\pi(6x10^{-3})}{8}\left[\frac{2.21x10^{11}}{19x10^{6}}\frac{6x10^{-3}}{1.2x10^{-3}}\right]^{1/2}$$

$$= 0.17606m$$

$$= 176.06mm$$

Although the calculated maximum length of the blanking punch is 176.06 mm, the blanking punch is designed at a length of 45 mm only. This length is almost similar to the length of the piercing punches and is more suitable for the height of the die sets.

4.7.2 Allowable Length for Piercing Punches

$$L = \frac{\pi d}{8}\left[\frac{E}{S_s}\frac{d}{t}\right]^{1/2}$$

$$= \frac{\pi(2.5x10^{-3})}{8}\left[\frac{2.21x10^{11}}{19x10^{6}}\frac{2.5x10^{-3}}{1.2x10^{-3}}\right]^{1/2}$$

$$= 0.0483m$$

$$= \underline{\underline{48.3mm}}$$

Although the maximum allowable length of the piercing punches is 48.3 mm, the piercing punches will only be designed to be 43 mm in length. This is to provide an allowance of 5 mm between the punch plate and the punches before the first cycle of stamping process.

4.8 PUNCH PLATE DESIGN

The function of a punch plate is to hold and support piercing, notching and cut off punches. A punch plate for holding a single punch is made square and with sufficient thickness for good punch support. Punch plate thickness should be approximately 1.5 times diameter of the largest punch, that is, the blanking punch. Therefore, the punch plate thickness will be 1.5 (15) mm = 23 mm.

4.9 STRIPPER DESIGN

The function of a stripper is to remove the material strip from around blanking and piercing punches. For this particular die sets, a thicker solid stripper is used a slot which is slightly larger that the strip width is machined on the underside of the stripper. This is to ensure that when the strip travels through the die, it is located against the back edge of the slot.

Allowances must be applied to the stripper to ensure that the punches and material strips are able to move freely through the stripper. The allowances applied to the punches are 0.5 times the thickness of the material strip. The dimensions for the blanking punch hole are calculated as follows:

$$\textit{Length of blanking punch} = 15 + 0.5t = 15 + 0.5(1.2) = \underline{\underline{15.6\,mm}}$$

$$\textit{Width of blanking punch} = 6 + 0.5t = 6 + 0.5(1.2) = \underline{\underline{6.6\,mm}}$$

4.10 PILOTS DESIGN

Pilots are an important component in the operation of multiple-station dies. The most frequently used type of pilots is the shoulder pilot. Pilots are usually retained in the blanking punch by a socket pilot nut, C. Pilot holes are pierced in the first station. Then, the strip is located by the pilots at the second station. As in Figure 4.8, diameter A of the pilot is very crucial. If it is too small in relation to the hole in the strip, inaccurate parts with varying dimensions between hole and part edges will be produced. If it is too large, a tight fit in the strip will result with a consequent tendency for the blank to be pulled up out of the die hole.

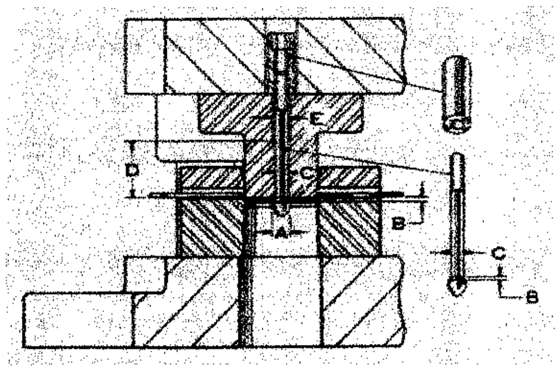


Figure 4.8 Pilot Proportions [1]

Therefore, the pilot diameter, A will be calculated as follows:

$$Diameter\ A = Diameter\ of\ piercing\ punch - \frac{3}{100} x\ Strip\ thickness$$

$$= 2.55 - 3\% x 1.2 = \underline{\underline{2.51 mm}}$$

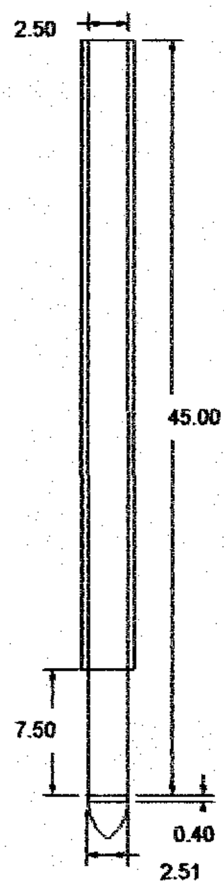


Figure 4.9 The Designed Pilot

4.11 APPLYING FASTENERS

Fasteners are an important factor to ensure the success of a designed tool. If they are not selected and applied correctly, it can become the cause of failure of the entire tool or die. For this particular project, the three (3) types of fasteners that will be used are:

- Socket cap screws – to fasten the die block and punch plate to the die sets.
- Dowel pins – to accurately position the die block and punch plate to the die sets.
- Socket button-head screws – to fasten other components like stripper, back gage and front spacer to the die block.

4.11.1 Fasteners Position

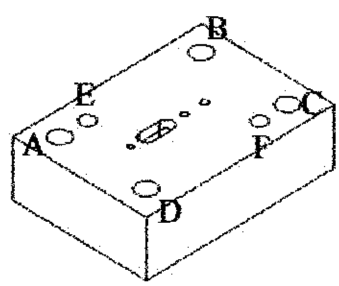


Figure 4.10 Fasteners Position on Die Block

Four tapped completely through holes (A, B, C, D) with the diameter of 6 mm are located at the corner of the die block to allocate the socket cap screws. These fasteners are used to fasten the die block to the die set. Other than that, two dowel holes, E and F, are drilled to allocate the dowel pins which are pressed into the die set and partly into the die block to prevent any possible shifting in operation. The diameter of the holes for the dowel pins are 6 mm.

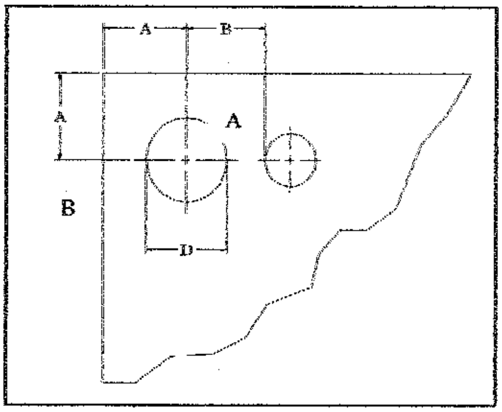


Figure 4.11 Minimum Proportions for the Spacing of Holes from Corners of Die Block [1]

The socket cap screws must be positioned at a minimum distance of 1.25D, which is 7.5 mm from the side of the die block, A. For safety purposes, the distance of 15 mm will be applied for the allocation of the socket cap screw holes, A. Meanwhile, the center distance between the socket cap screws side of the die block, B is taken to be 10 mm.

4.12 SELECTION OF A DIE SET

For this project, the die set will be manufactured. Both the punch and die holder will be made from cast steels. The dimensions for both holders are 17 x 95 x 140 mm. Holes for the blanking punch and piercing punches will be provided in the die holder respectively. The dimension of hole for the blanking punch will be 10.0 mm wide and 33.5 mm long with the tolerance of 1.5 mm to ease the removal of the blanked implants from the die block.

4.13 OTHER COMPONENTS

The design of other components such as the pin stop, finger stop, back gage and front spacer are as designed by the previous student. Not many changes are needed to be done or added to these parts, therefore, it will not be discussed in this report.

CHAPTER 5

PROCESS PLAN

5.1 BILL OF MATERIALS

Table 5.1 Bill of Materials

DET.	REQ'D	PART NAME	MAT.	SPECS. (mm)
1	1	PIN STOP	AISI Type A2 T.S.	Ø 2 x 5
2	1	DIE BLOCK	AISI Type O1 T.S.	24 x 60 x 90
3	1	STRIPPER PLATE	Mild Steel	6 x 60 x 90
4	1	PUNCH PLATE	AISI Type O1 T.S.	23 x 60 x 90
5	1	BLANKING PUNCH	AISI Type A2 T.S.	45 x 15 x 15
6	2	PIERCING PUNCH	AISI Type A2 T.S.	Ø 2.5 x 43
7	4	SOCKET CAP SCREWS	STANDARD	Ø 6 X 24
8	4	SOCKET BUTTON-HEAD SCREW	STANDARD	Ø 6 X 8
9	1	BACK GAGE	Mild Steel	7 x 60 x 165
10	1	FRONT SPACER	Mild Steel	7 x 60 x 165
11	1	FINGER STOPPER	Mild Steel	14 x 10 x 40
12	2	DOWEL PIN	STANDARD	Ø 6 x 34
13	1	DIE HOLDER	Cast Steel	17 x 95 x 140
14	1	PUNCH HOLDER	Cast Steel	17 x 95 x 140
15	2	DOWEL PIN	STANDARD	Ø 6 x 36
16	4	SOCKET CAP SCREWS	STANDARD	Ø 6 x 24
17	2	GUIDE POST	Cast Steel	Ø18 x 55

5.2 SUMMARY OF PROCESS PLAN

In general, each die components will undergo the following general processes as shown in Figure 5.1.

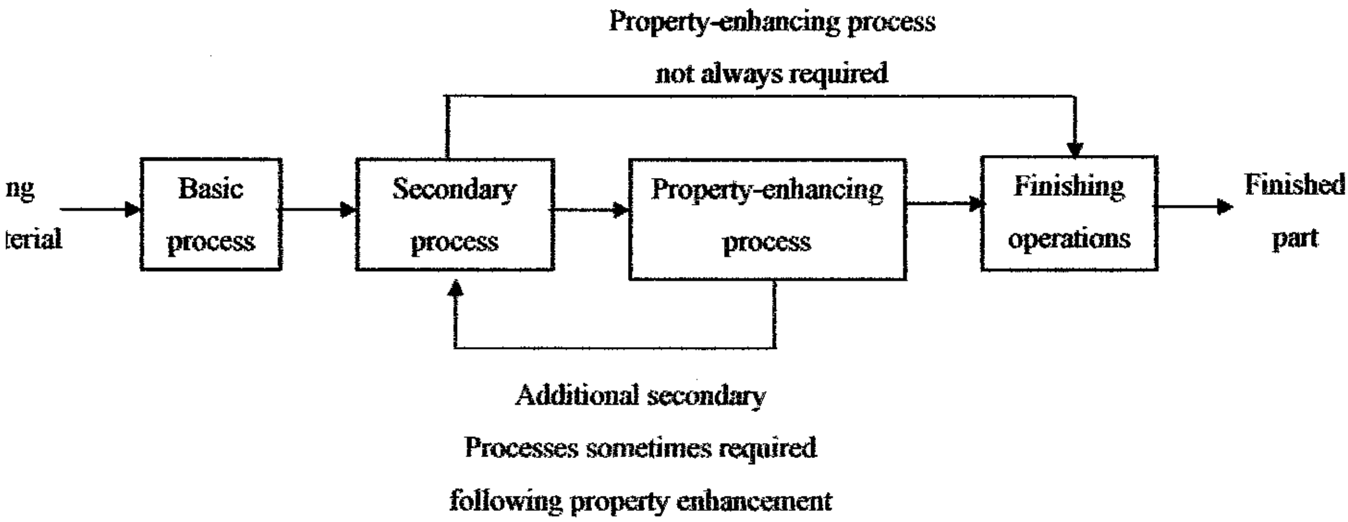


Figure 5.1 General Processes Involved in Fabrication

However, in the case of the fabrication of the die components, no process-enhancing process and finishing operations are involved. Table 5.2 summarizes the related fabrication processes for the major die components.

The summarized fabrication processes for major die components are as shown in Table 5.2 below.

Table 5.2 Summary of Process Plan for Major Die Components

PARTS	STARTING MATERIAL	BASIC PROCESS✱	SECONDARY PROCESS⅄
Punch Holder	Cast Steel	▪ Cut to size (Wire EDM) ▪ Machine to specified geometry	▪ Tapping
Die Holder	Cast Steel	▪ Cut to size (Wire EDM) ▪ Machine to specified geometry	▪ Tapping
Die Block	AISI Type O1 Tool Steel Bar Stock	▪ Cut to size (Wire EDM) ▪ Machine to specified geometry	▪ Tapping
Punch Plate	AISI Type O1 Tool Steel Bar Stock	▪ Cut to size (Wire EDM) ▪ Machine to specified geometry	▪ Tapping
Stripper Plate	Mild Steel Plate	▪ Cut to size (Wire EDM) ▪ Machine to specified geometry	▪ Tapping
Blanking Punch	AISI Type A2 Tool Steel Bar Stock	▪ Cut to size (milling) ▪ Machine to specified geometry	▪ None
Piercing Punch	AISI Type A2 Tool Steel Bar Stock	▪ Cut to size (turning) ▪ Machine to specified geometry	▪ None
Back Gage	Cast Iron Plate	▪ Cut to size (sawing) ▪ Machine to specified geometry ▪ Drilling	▪ Deburring ▪ Tapping ▪ Welding (to join with Front Spacer)
Front Spacer	Cast Iron Plate	▪ Cut to size (sawing) ▪ Machine to specified geometry ▪ Drilling	▪ Deburring ▪ Tapping
Finger Stop	Cast Iron Plate	▪ Cut to size (Wire EDM) ▪ Machine to specified geometry	▪ Bending

✱ Basic processes include cutting the raw material to size and machining it to specified geometry.

⅄ Secondary processes include processes to add additional features such screw threads for assembly purposes.

5.3 PROCESS PLAN FOR EACH DIE COMPONENTS

5.3.1 Punch Holder

Table 5.3 Process Plan for Punch Holder

Sequence	Operation/Process	Equipment	Tool
1	Cut raw material to size [17.5 x 95.5 x 140.5 mm]	Hacksaw	Hacksaw Blade
2	Mill to shape [17 x 95 x 140 mm]	Milling Machine	Plain milling cutter
3	Drill holes ϕ 15 mm [Through holes]	Drilling Machine	Drill bit ϕ 15 mm
4	Drilling ϕ 25 mm [Through holes]	Drilling Machine	Drill bit ϕ 25 mm
5	Drill holes ϕ 6 mm [Through holes]	Drilling Machine	Drill bit ϕ 6 mm
6	Tapping ϕ 6 mm	Hand taps	Taper ϕ 6 mm

5.3.2 Punch Plate

Table 5.4 Process Plan for Punch Plate

Sequence	Operation/Process	Equipment	Tool
1	Cut raw material to size [27.5 x 60.5 x 90.5 mm]	Hacksaw	Hacksaw Blade
2	Mill to shape [27x 60 x 90 mm]	Milling Machine	Plain Milling Cutter
3	Drill holes ϕ 2.5 mm [Through holes]	Drilling Machine	Drill bit ϕ 2.5 mm
4	Drilling ϕ 5 mm [Depth 3 mm]	Drilling Machine	Drill bit ϕ 5 mm
5	Drill holes ϕ 6 mm [Through holes]	Drilling Machine	Drill bit ϕ 6 mm
6	Tapping ϕ 6 mm	Hand taps	Taper ϕ 6 mm
7	Machine to specified geometry	Wire EDM	Wire Cut Tool

5.3.3 Blanking Punch

Table 5.5 Process Plan for Blanking Punch

Sequence	Operation/Process	Equipment	Tool
1	Cut raw material to size [49.0 x 18.5 x 18.5 mm]	Hacksaw	Hacksaw Blade
2	Mill to specified geometry	Milling Machine	Plain Milling Cutter

5.3.4 Piercing Punches

Table 5.6 Process Plan for Piercing Punches

Sequence	Operation/Process	Equipment	Tool
1	Straight turning raw material to size [ϕ 5 mm]	Lathe Machine	Lathe Cutting Tool
2	Facing raw material to size [46.18 mm]	Lathe Machine	Lathe Cutting Tool
3	Straight turning to specified geometry [ϕ 2.5 x 43 mm]	Lathe Machine	Lathe Cutting Tool

5.3.5 Stripper

Table 5.7 Process Plan for Stripper

Sequence	Operation/Process	Equipment	Tool
1	Cut raw material to size [6.5 x 60.5 x 90.5 mm]	Hacksaw	Hacksaw Blade
2	Mill to shape [6 x 60 x 90 mm]	Milling Machine	Plain Milling Cutter
3	Mill groove at underside [2 x 10.8 x 90 mm]	Milling Machine	Two-lip Mill Cutter
4	Drill holes ϕ 2.5 mm [Through holes]	Drilling Machine	Drill bit ϕ 2.5 mm
5	Drill holes ϕ 6 mm [Through holes]	Drilling Machine	Drill bit ϕ 6 mm
6	Tapping ϕ 6 mm	Hand taps	Taper ϕ 6 mm
7	Machine to specified geometry	Wire EDM	Wire Cut Tool

5.3.6 Pin Stop

Table 5.8 Process Plan for Pin Stop

Sequence	Operation/Process	Equipment	Tool
1	Straight turning raw material to size [ϕ 3 mm]	Lathe Machine	Lathe Cutting Tool
2	Facing raw material to size [5.5 mm]	Lathe Machine	Lathe Cutting Tool
3	Straight turning to specified geometry [ϕ 2 x 5 mm]	Lathe Machine	Lathe Cutting Tool

5.3.7 Finger Stop

Table 5.9 Process Plan for Finger Stop

Sequence	Operation/Process	Equipment	Tool
1	Cut raw material to size [3.2 x 9.0 x 49.0 mm]	Hacksaw	Hacksaw Blade
2	Mill groove [0.87 x 9.0 x 22.52 mm]	Milling Machine	Two-lip Mill Cutter
3	Bending	Bending Machine	-

5.3.8 Back Gage

Table 5.10 Process Plan for Back Gage

Sequence	Operation/Process	Equipment	Tool
1	Cut raw material to size [3.17 x 24.55 x 162.40 mm]	Hacksaw	Hacksaw Blade
2	Drill holes ϕ 6 mm [Through holes]	Drilling Machine	Drill bit ϕ 6 mm
3	Tapping ϕ 6 mm	Hand taps	Taper ϕ 6 mm
4	Machine to specified geometry	Milling Machine	Milling Cutter

5.3.9 Front Spacer

Table 5.11 Process Plan for Front Spacer

Sequence	Operation/Process	Equipment	Tool
1	Cut raw material to size [6.35 x 35.55 x 162.40 mm]	Hacksaw	Hacksaw Blade
2	Drill holes ϕ 6 mm [Through holes]	Drilling Machine	Drill bit ϕ 6 mm
3	Tapping ϕ 6 mm	Hand taps	Taper ϕ 6 mm
4	Machine to specified geometry	Milling Machine	Milling Cutter

5.3.10 Die Block

Table 5.12 Process Plan for Die Block

Sequence	Operation/Process	Equipment	Tool
1	Cut raw material to size [24.5 x 60.5 x 90.5 mm]	Hacksaw	Hacksaw Blade
2	Mill to shape [24 x 60 x 90 mm]	Milling Machine	Plain Milling Cutter
3	Drill holes ϕ 2.5 mm [Through holes]	Drilling Machine	Drill bit ϕ 2.5 mm
4	Drill holes ϕ 2 mm [Depth 5 mm]	Drilling Machine	Drill bit ϕ 2 mm
5	Drill holes ϕ 6 mm [Through holes]	Drilling Machine	Drill bit ϕ 6 mm
6	Tapping ϕ 6 mm	Hand taps	Taper ϕ 6 mm
7	Machine to specified geometry	Wire EDM	Wire Cut Tool

5.3.11 Die Holder

Table 5.13 Process Plan for Die Holder

Sequence	Operation/Process	Equipment	Tool
1	Cut raw material to size [17.5 x 95.5 x 140.5 mm]	Hacksaw	Hacksaw Blade
2	Mill to shape [17 x 95 x 140 mm]	Milling Machine	Plain Milling Cutter
3	Drill holes ϕ 6 mm [Through holes]	Drilling Machine	Drill bit ϕ 6 mm
4	Tapping ϕ 6 mm	Hand taps	Taper ϕ 6 mm
5	Machine to specified geometry	Wire EDM	Wire Cut Tool

5.3.12 Guide Posts

Table 5.14 Process Plan for Guide Posts

Sequence	Operation/Process	Equipment	Tool
1	Straight turning raw material to size [ϕ 18 mm]	Lathe Machine	Lathe Cutting Tool
2	Facing raw material to size [55 mm]	Lathe Machine	Lathe Cutting Tool

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

In conclusion, the scope of work had been changed for this semester. Instead of fabricating the particular die components, the work is concentrated more in producing the blueprints and process plan for each die components. At the first phase, a detailed study had been done in preparing the blank layout for the scrap strip. After some calculations, the blanking force that will be needed to cut the blank is 33,707.52N. However, since the press capacities are usually rated in tons, a press with a capacity of more than 3.789 tons is needed to produce this particular metal implants. Other than that, it is also found that, a total of 63 metal implants can be produced from a 1 m material strip. While laying out the blanks, care had been taken in assigning the correct minimum allowances wherever necessary to avoid material wastage and dishing of the implant. On the other hand, in designing the die components, care had been taken in assigning the correct clearances, angular relief, allowances and tolerances for each part of the die components. This is to ensure the success of the particular progressive die. In general, the material selected for the implants are titanium and stainless steel strips while for the die components, are tool steels, mild steel and cast steel. The main processes involved for fabricating the die components are Wire EDM and milling.

Below is the list of some works recommended for the continuation of this project:

1. To simulate the working principle of the designed progressive die prior to fabrication of each die components.
2. To fabricate the die components based on the detailed blueprints and process plan.
3. To test the fabricated and assemble each of the progressive die components.
4. To produce the metal implants using the fabricated progressive die sets.
5. To test the produced metal implants.

REFERENCES

1. J.R. Paquin, & R.E. Crowley, 1987, Die Design Fundamentals 2nd. Ed., New York, Industrial Press, Inc.

2. George E. Dieter, 2000, Engineering Design 3rd. Ed., New York, McGraw-Hill Higher Education.

3. Dr. John G. Nee, CMfgE, 1998, Fundamentals of Tool Design 4th Ed., United States of America, Society of Manufacturing Engineers.

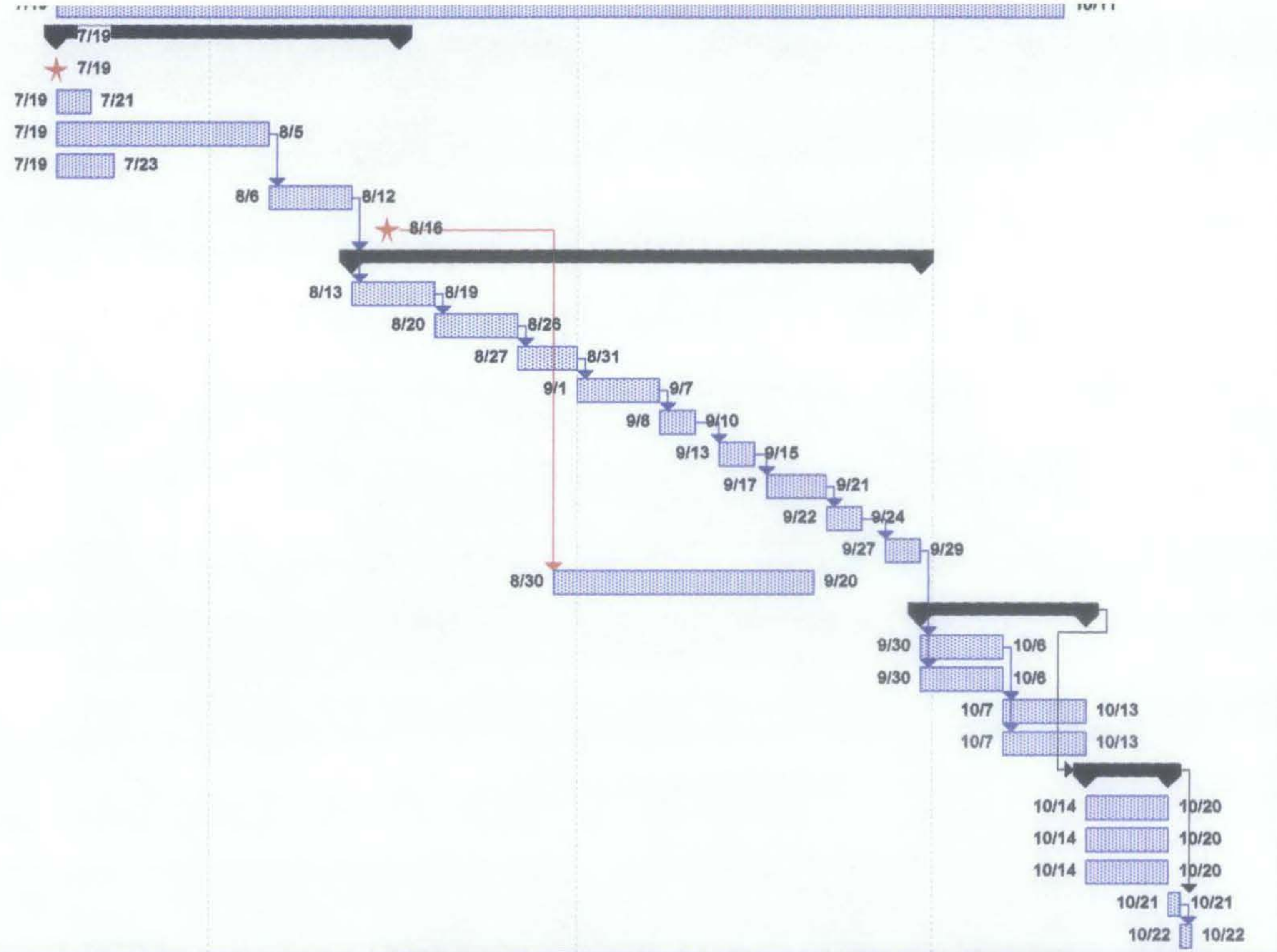
4. Danial B. Dallas, 1994, Progressive Dies: Principles and Practices of Design and Construction, United States of America, Society of Manufacturing Engineers.

5. Zahrin Affandi bin Mohd, November 2003, Development of a Progressive Die for Titanium Implant Production, Progress Report, Universiti Teknologi Petronas.

APPENDIX 1

Gantt Chart

2		**Progress Report 1**
3	✓	Change of scope of work
4		Preparation of methodology
5		Review past interim report
6		Plan for this semester's tasks
7		Calculation of implant's dimensi
8		Submission
9		**Preparation of Part Drawings**
10		Die block
11		Blanking punch
12		Piercing punch
13		Punch plates
14		Pilots
15		Gages
16		Finger stops
17		Automatic stops
18		Strippers
19		Progress Report 2
20		**Preparation of Blueprint**
21		Determining dimensions
22		Determining tolerances
23		Applying fasteners
24		Selection of die set
25		**Preparation of Process Plan**
26		Material selection
27		Preparation of bill of materials
28		Determining processes involved
29		Presentation
30		Dissertation Report



Project: Gantt Chart Sem 2
Date: Sat 11/27/04

Task		Summary		Rolled Up Progress		Project Summary	
Progress		Rolled Up Task		Split		Group By Summary	
Milestone	◆	Rolled Up Milestone	◇	External Tasks			

APPENDIX 2

Material for Metal Implants
[Titanium]

Titanium Ti-6Al-4V (Grade 5), STA

Subcategory: Alpha/Beta Titanium Alloy; Metal; Nonferrous Metal; Titanium Alloy

Component	Wt. %
Al	6
Fe	Max 0.25
O	Max 0.2
Ti	90
V	4

Applications: Blades, discs, rings, airframe, fasteners, components. Vessels, cases, hubs, forgings.. Biomedical implants.

Physical Properties	Metric	English	Comments
Density	4.43 g/cc	0.16 lb/in³	

Mechanical Properties			
Hardness, Brinell	379	379	Estimated from Rockwell C.
Hardness, Knoop	414	414	Estimated from Rockwell C.
Hardness, Rockwell C	41	41	
Hardness, Vickers	396	396	Estimated from Rockwell C.
Tensile Strength, Ultimate	1170 MPa	170000 psi	
Tensile Strength, Yield	1100 MPa	160000 psi	
Elongation at Break	10 %	10 %	
Modulus of Elasticity	114 GPa	16500 ksi	Average of tension and compression
Compressive Yield Strength	1070 MPa	155000 psi	
Notched Tensile Strength	1550 MPa	225000 psi	K_t (stress concentration factor) = 6.7
Ultimate Bearing Strength	2140 MPa	310000 psi	e/D = 2
Bearing Yield Strength	1790 MPa	260000 psi	e/D = 2
Poisson's Ratio	0.33	0.33	
Charpy Impact	23 J	17 ft-lb	V-notch
Fatigue Strength	160 MPa	23200 psi	at 1E+7 cycles, K_t (stress concentration factor) = 3.3
Fatigue Strength	700 MPa	102000 psi	Unnotched 10,000,000 Cycles
Fracture Toughness	43 MPa-m½	39.1 ksi-in½	

Shear Modulus	44 GPa	6380 ksi	
Shear Strength	760 MPa	110000 psi	Ultimate shear strength

APPENDIX 3

Material for Metal Implants
[Stainless Steel]

AISI Type 316L Stainless Steel, annealed and cold drawn bar

Subcategory: Metal; Stainless Steel; T 300 Series Stainless Steel

Component	Wt. %	Component	Wt. %	Component	Wt. %
C	0.03	Mn	2	P	0.045
Cr	17	Mo	2.5	S	0.03
Fe	65	Ni	12	Si	1

Applications: biomedical implants, chemical processing, food processing, photographic, pharmaceutical, textile finishing, marine exterior trim.

Physical Properties	Metric	English	Comments
Density	8 g/cc	0.289 lb/in³	
Mechanical Properties			
Hardness, Brinell	190	190	
Hardness, Knoop	212	212	Converted from Brinell hardness.
Hardness, Rockwell B	91	91	
Hardness, Vickers	199	199	Converted from Brinell hardness.
Tensile Strength, Ultimate	585 MPa	84800 psi	
Tensile Strength, Yield	380 MPa	55100 psi	
Elongation at Break	45 %	45 %	in 50 mm
Modulus of Elasticity	193 GPa	28000 ksi	in tension
Charpy Impact	103 J	76 ft-lb	V-notch, 30°C
Izod Impact	150 J	111 ft-lb	21°C

APPENDIX 4

Material for Die Components
[Tool Steel]

AISI Type A2 Tool Steel

Subcategory: Air-Hardening Steel; Cold Work Steel; Metal; Tool Steel

Component	Wt. %	Component	Wt. %	Component	Wt. %
C	0.95 - 1.05	Mn	Max 1	S	Max 0.03
Cr	5.13	Mo	1.15	Si	Max 0.5
Fe	91	P	Max 0.03	V	0.33

Material Notes:

High hardenability, high degree of dimensional stability in heat treatment, good wear resistance, fatigue life, toughness, and deep hardening qualities. Applications include cold forming, blanking and bending dies, forming rolls, drill bushings, knurling tools, master dies and gages.

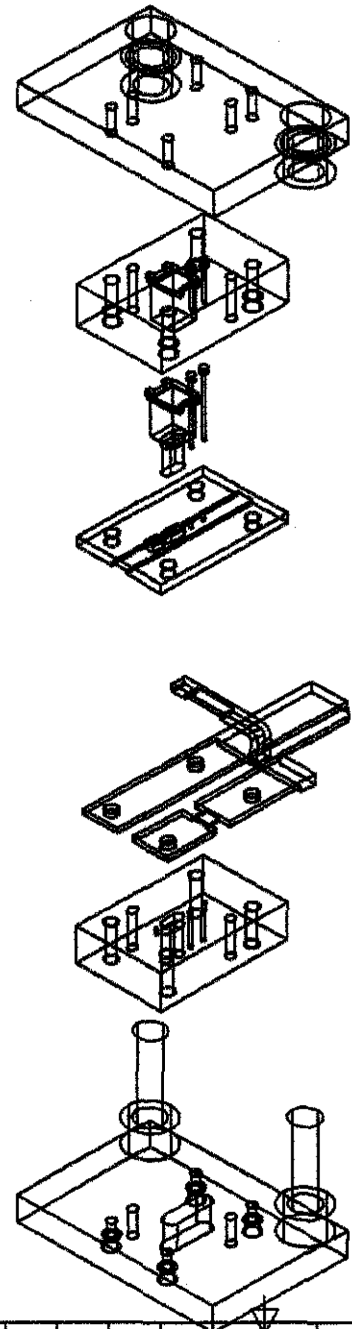
Physical Properties	Metric	English	Comments
Density	7.86 g/cc	0.284 lb/in³	

Mechanical Properties			
Hardness, Rockwell C	64	64	as air-hardened (63-65 HRC average), 60-62 HRC at 205°C, 59-61 HRC at 260°C, 58-60 HRC at 315°C, 57-59 HRC at 370°C and 425°C and 480°C, 56-58 HRC at 540°C, 50-52 HRC at 595°C, 42-44 HRC at 650°C
Modulus of Elasticity	203 GPa	29400 ksi	
Bulk Modulus	140 GPa	20300 ksi	Typical for steels.
Poisson's Ratio	0.3	0.3	Calculated
Machinability	65 %	65 %	Based on Carbon tool steel.
Shear Modulus	78 GPa	11300 ksi	Estimated from elastic modulus

Thermal Properties			
CTE, linear 250°C	10.7 µm/m-°C	5.94 µin/in-°F	at 20-100°C, 12.0 µm/m°C at 20-200°C
CTE, linear 500°C	12.7 µm/m-°C	7.06 µin/in-°F	at 20-300°C, 13.2 µm/m°C at 20-400°C, 13.7 µm/m°C at 20-500°C
CTE, linear 1000°C	14 µm/m-°C	7.78 µin/in-°F	at 20-600°C, 14.3 µm/m°C at 20-700°C, 14.4 µm/m°C at 20-750°C

APPENDIX 5

Detail Drawings
[Blueprints]



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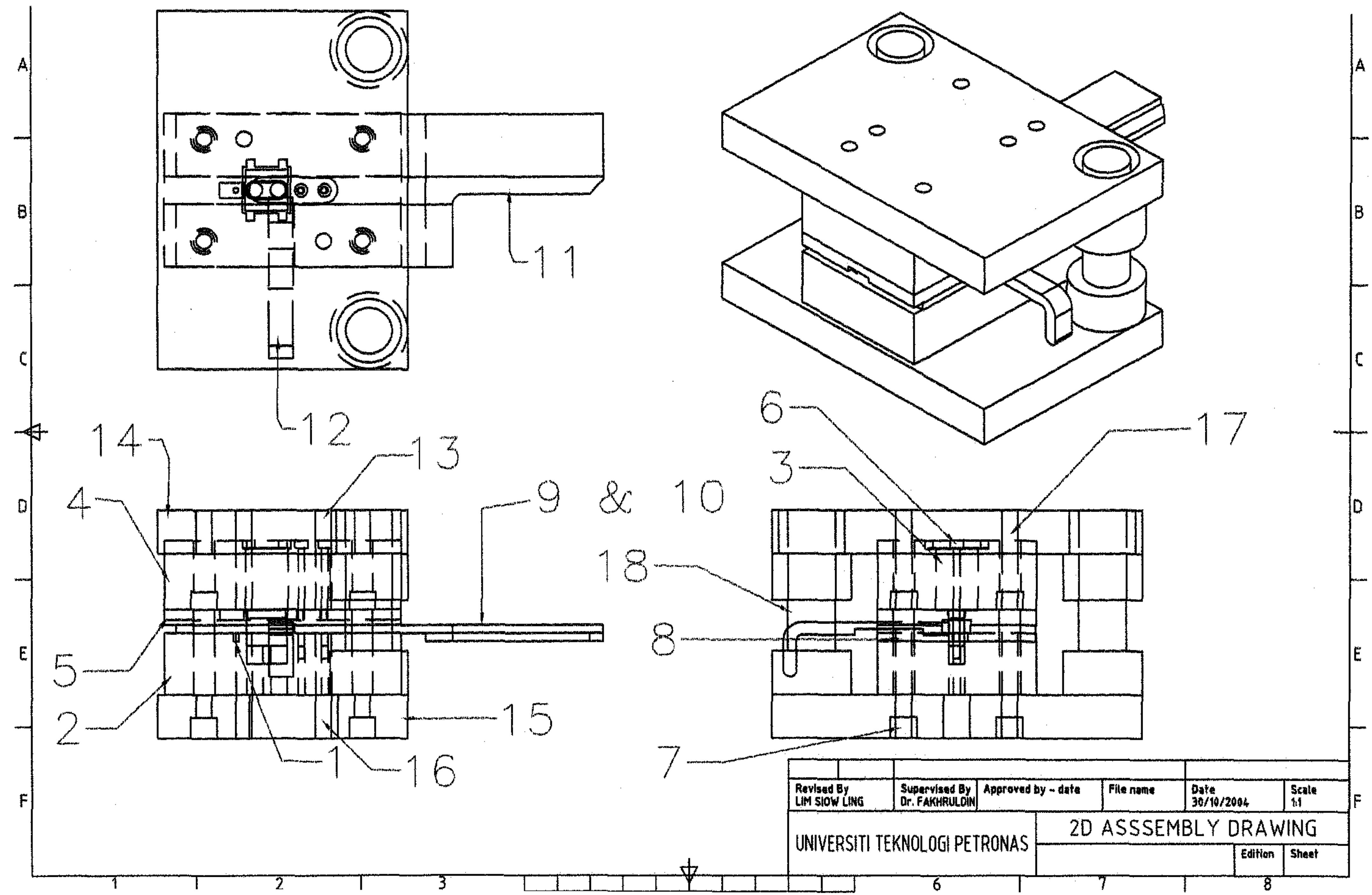

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2D ASSSEMBLY DRAWING
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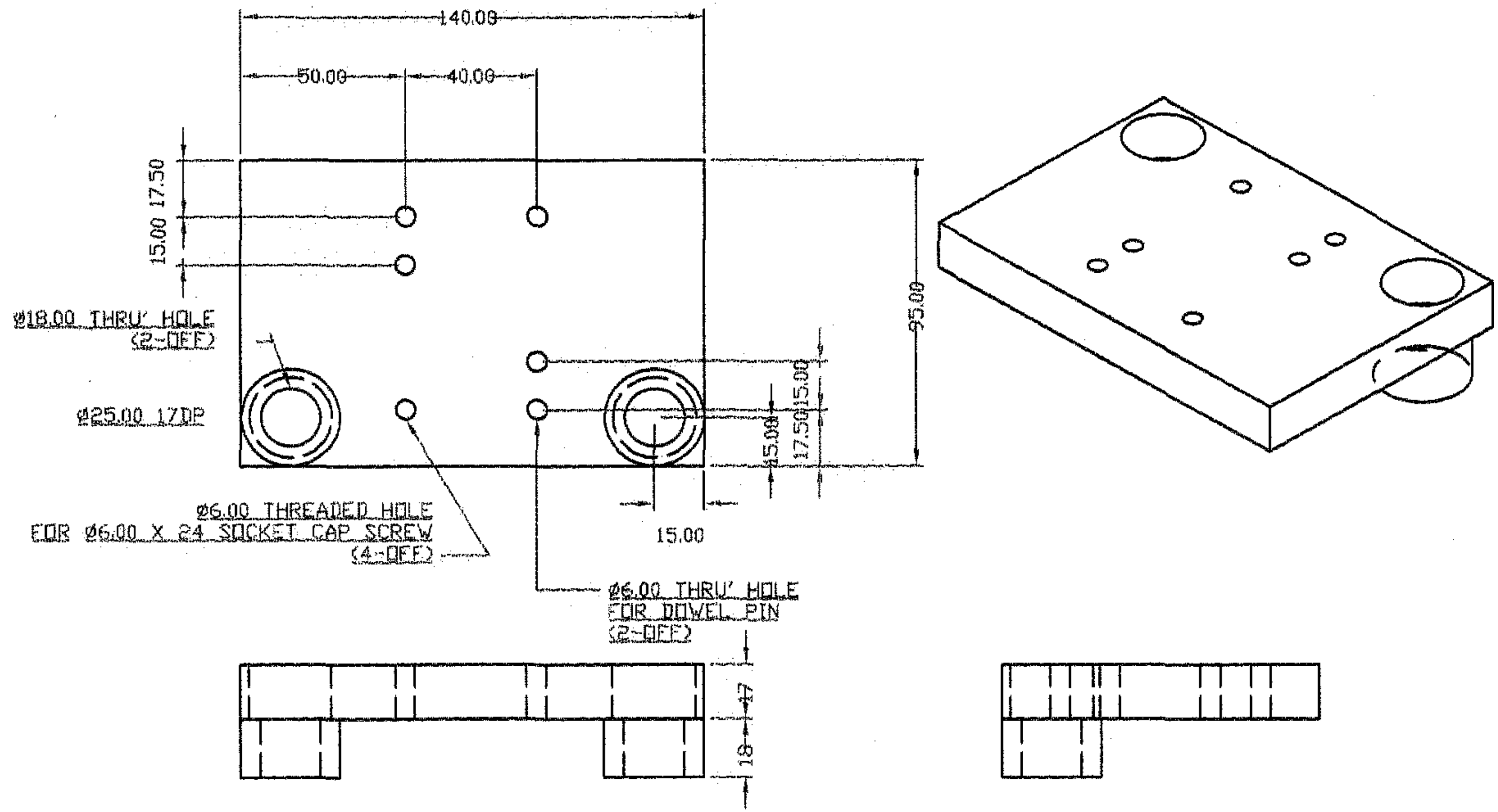

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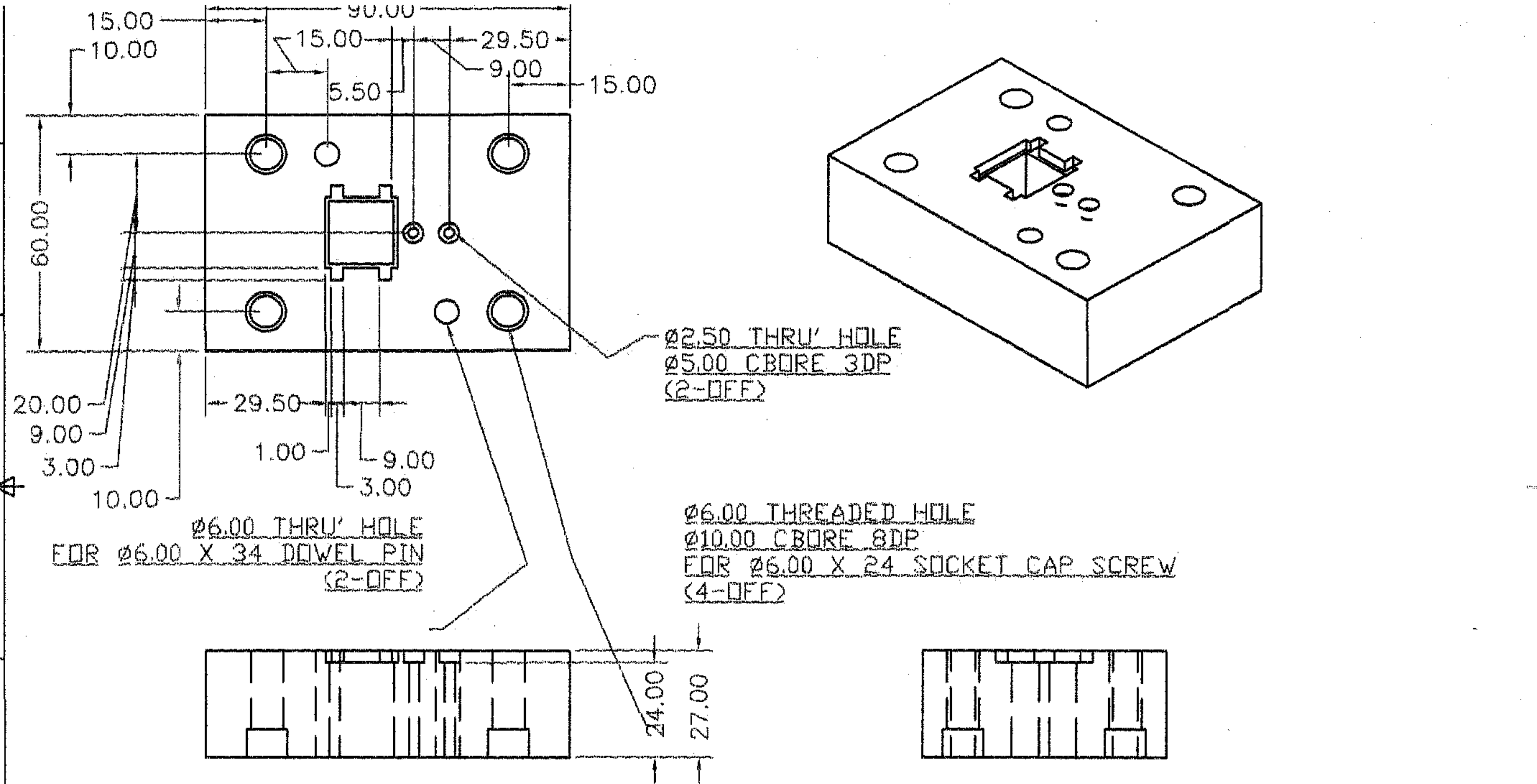

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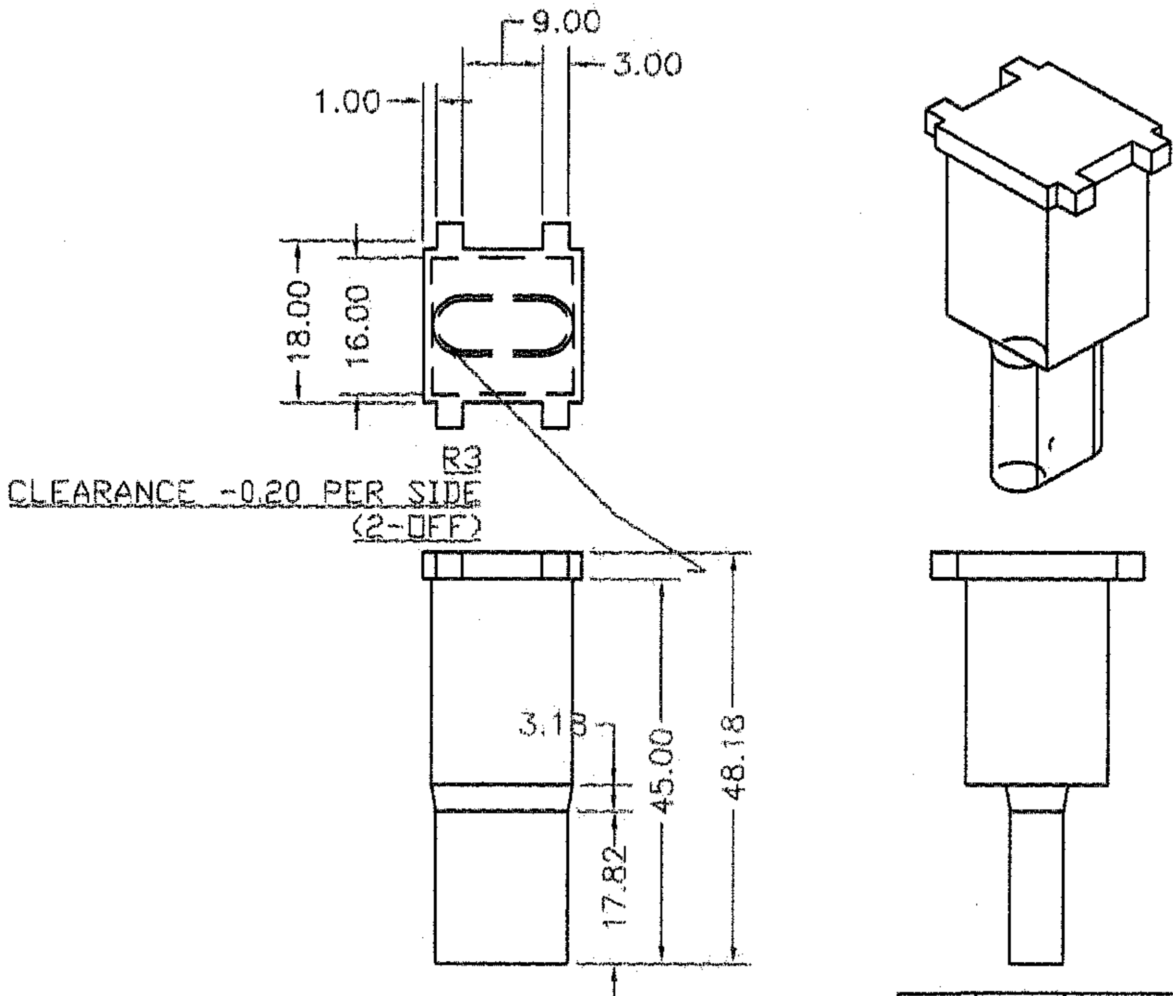

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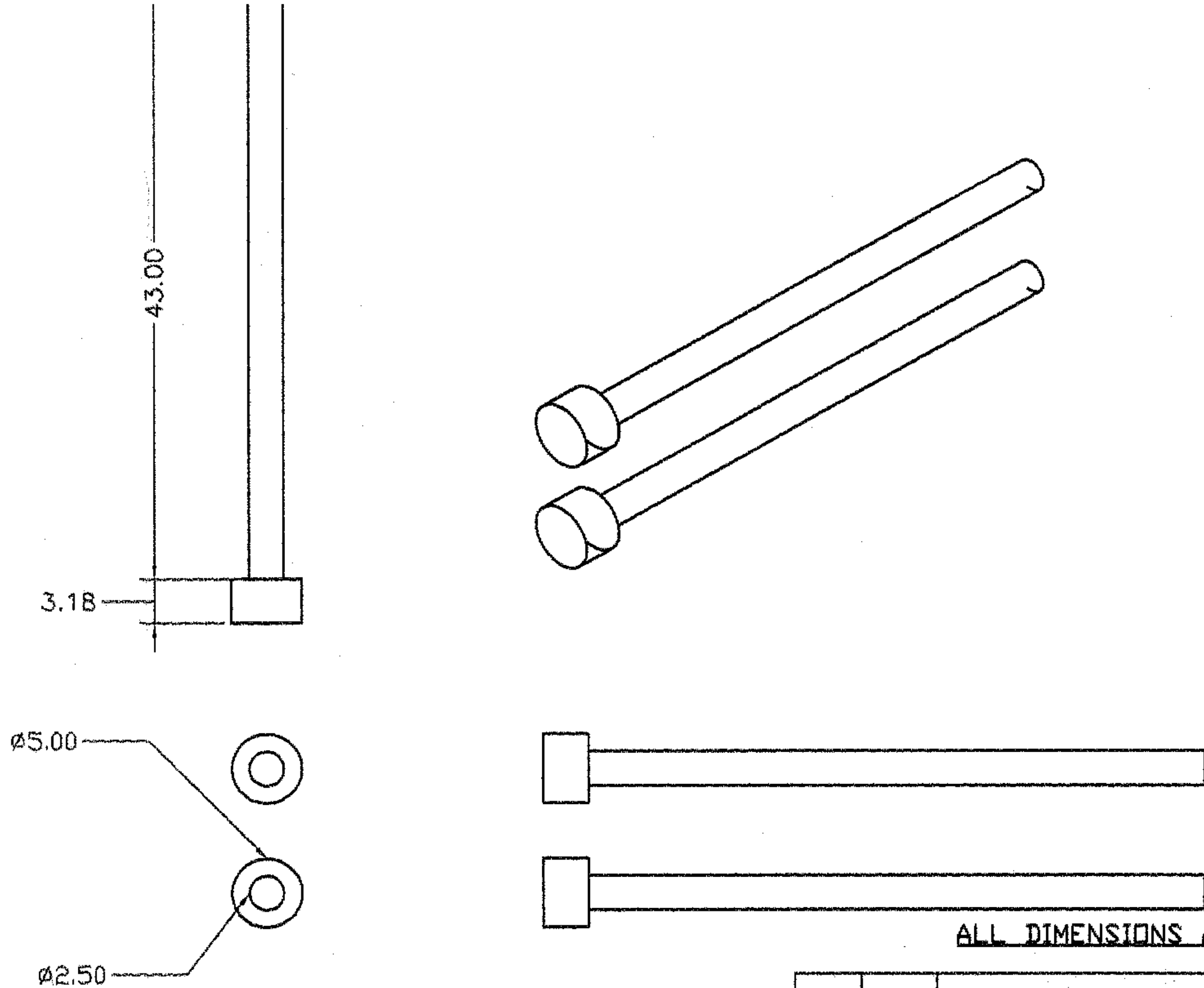

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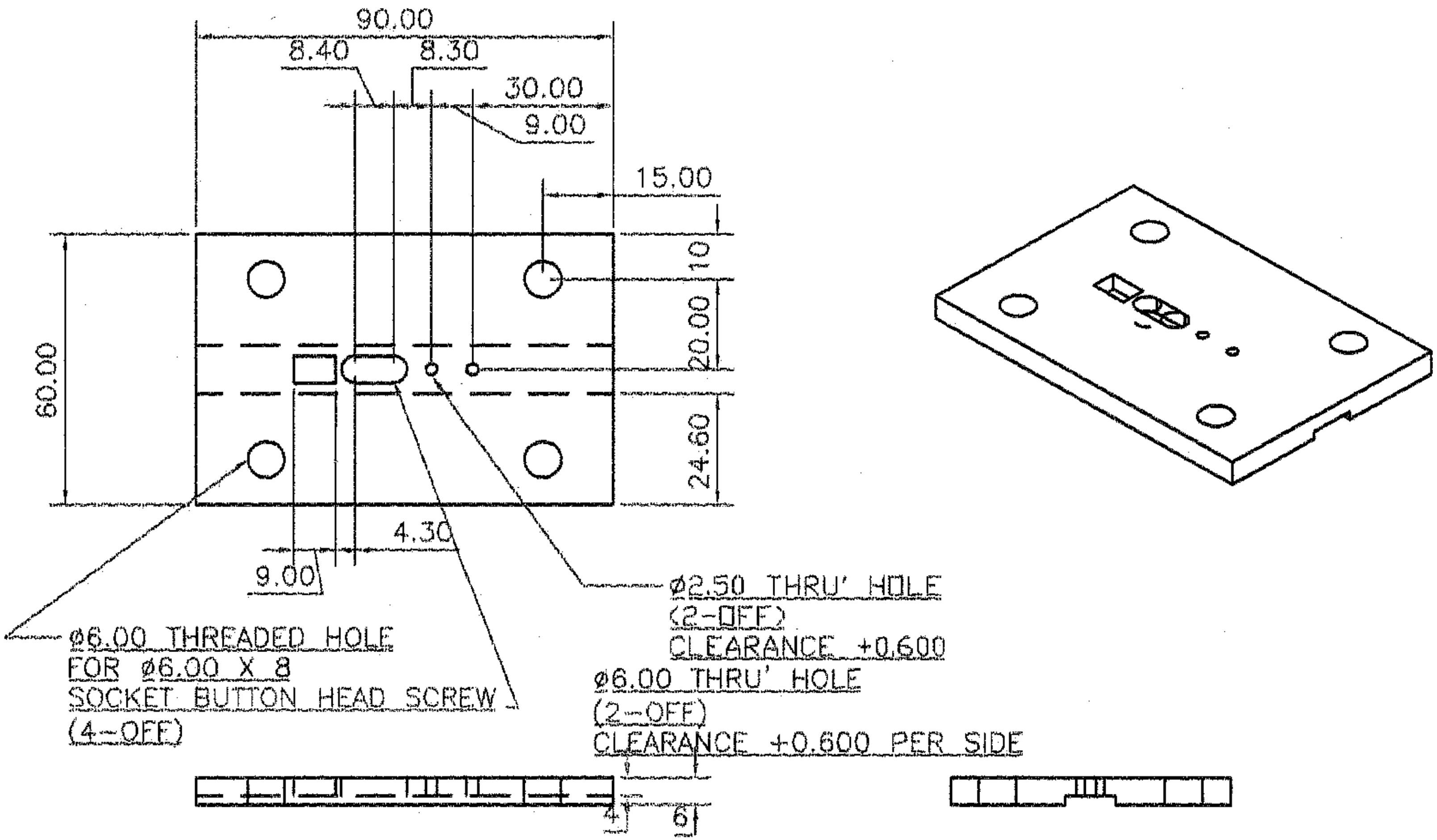

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STRIPPER PLATE

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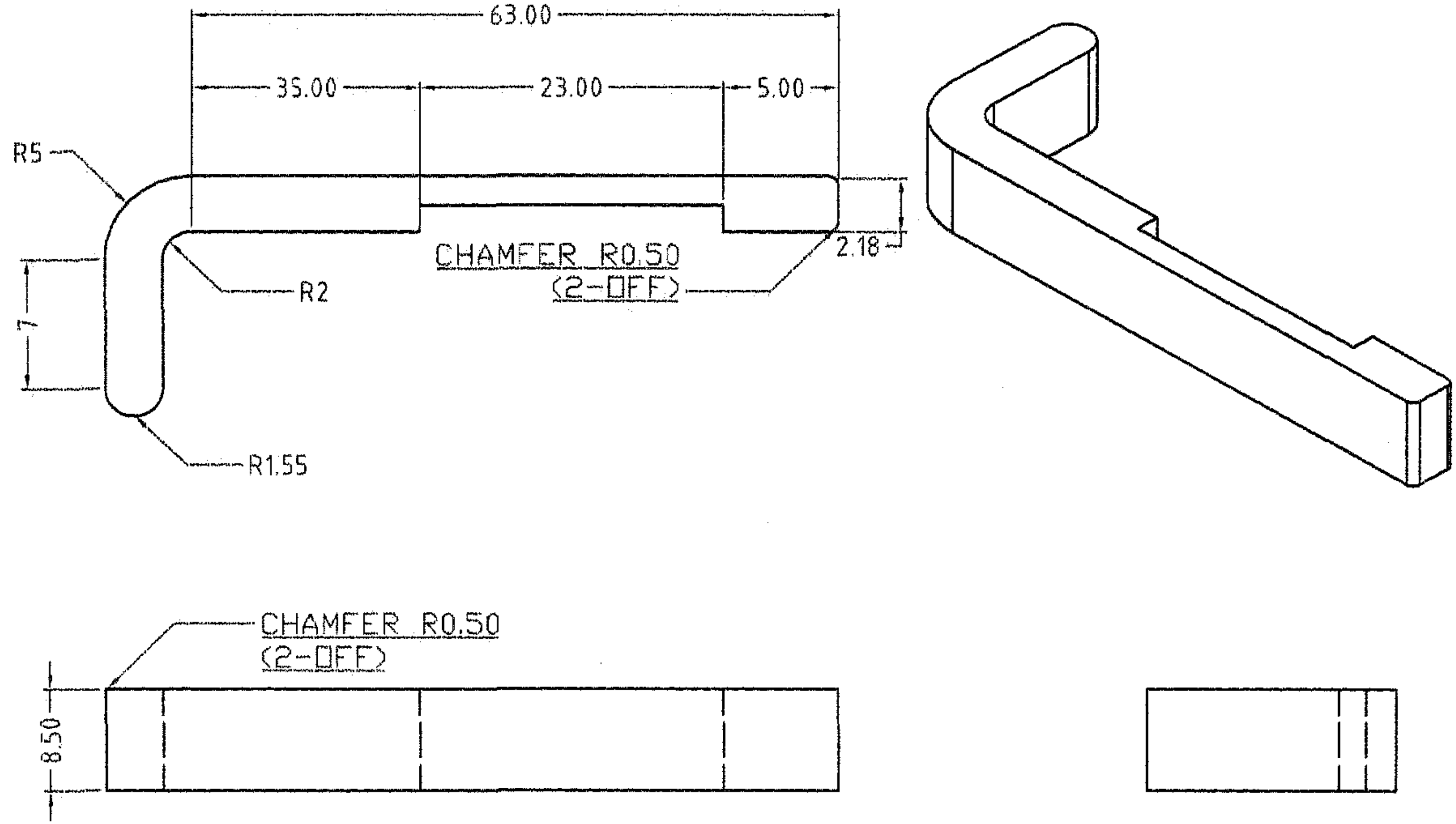

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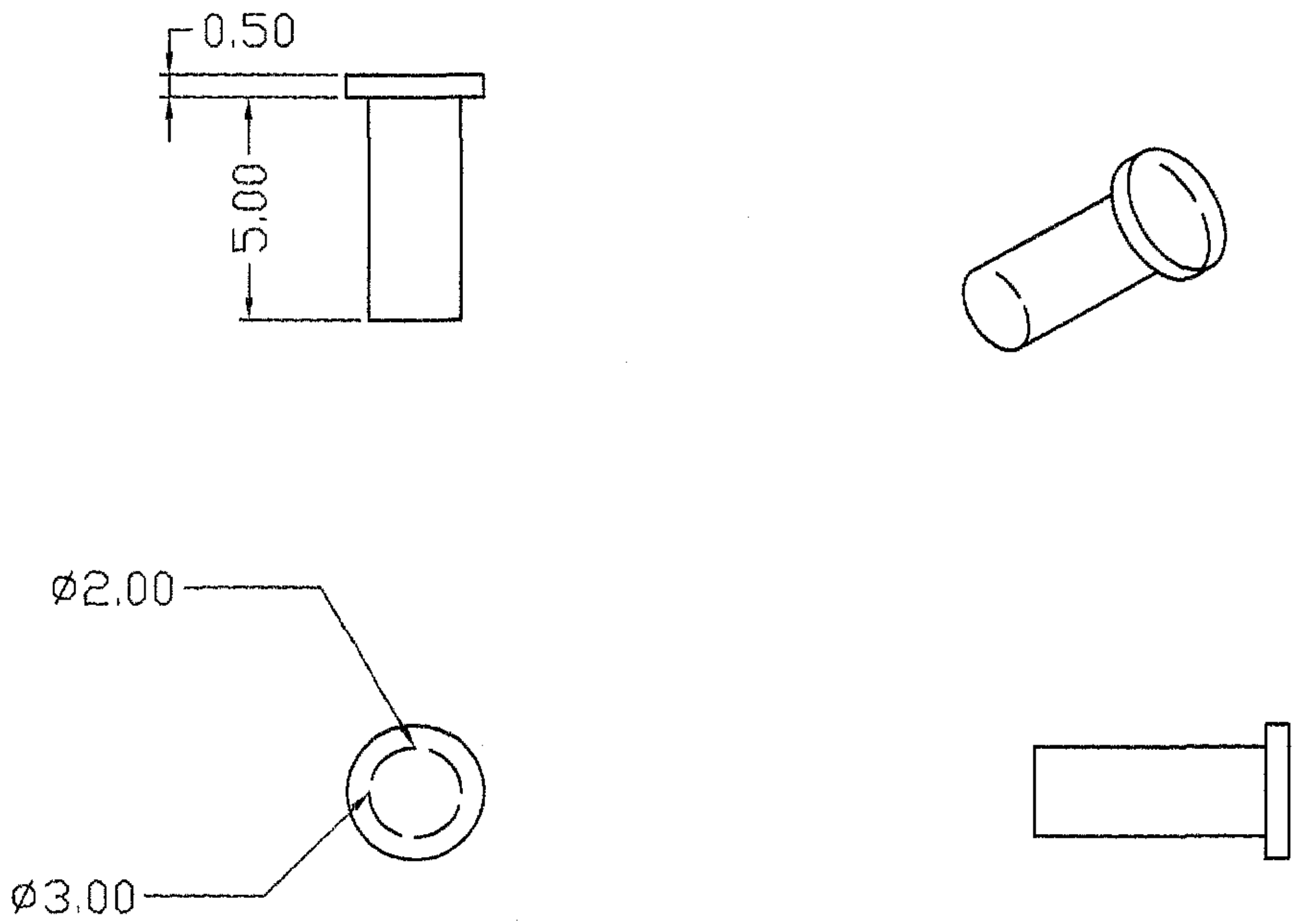

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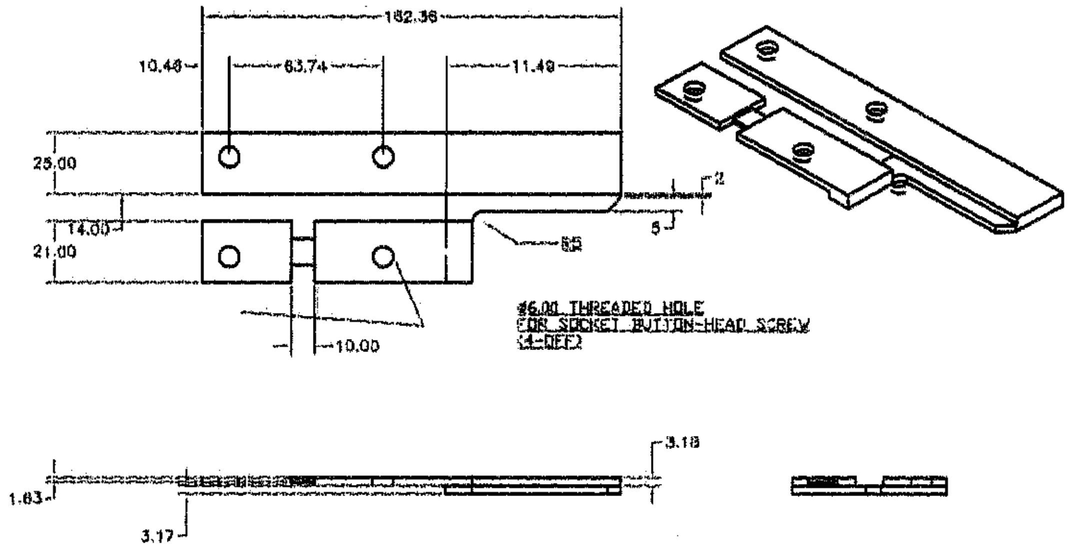

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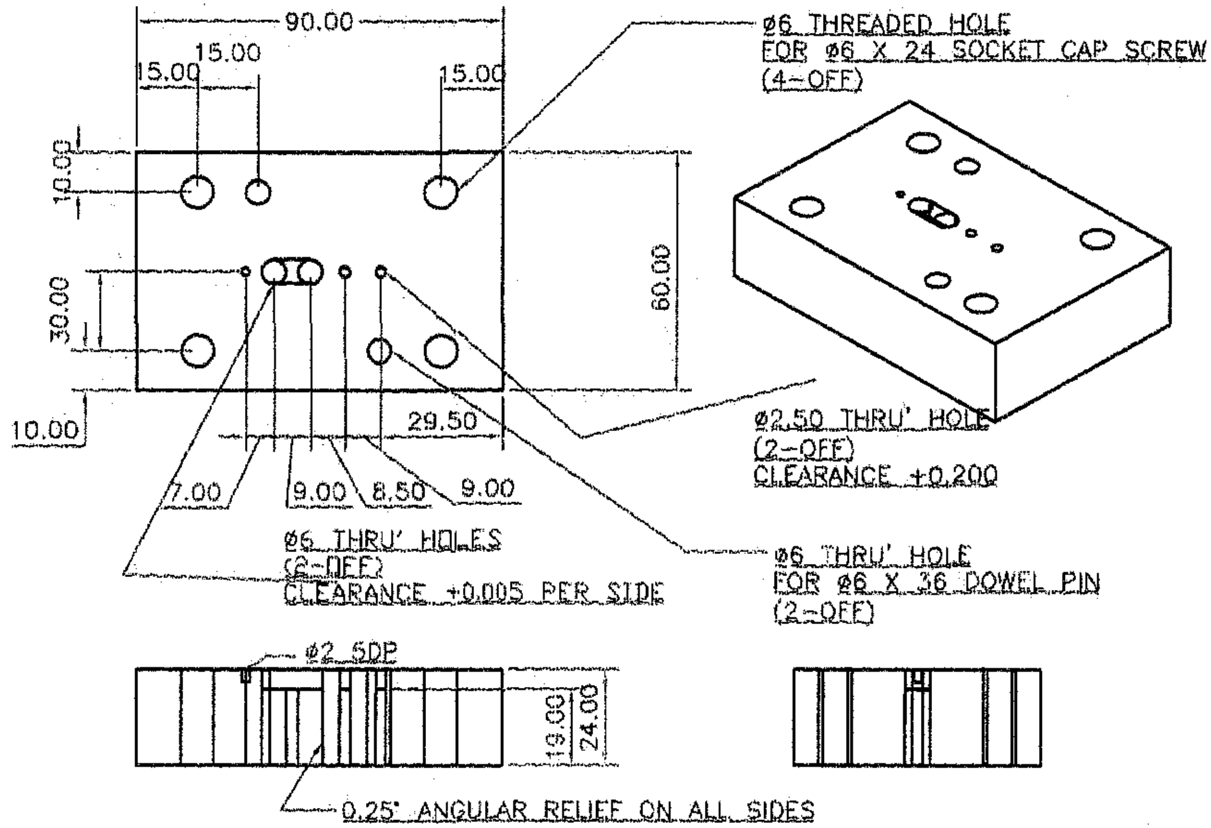

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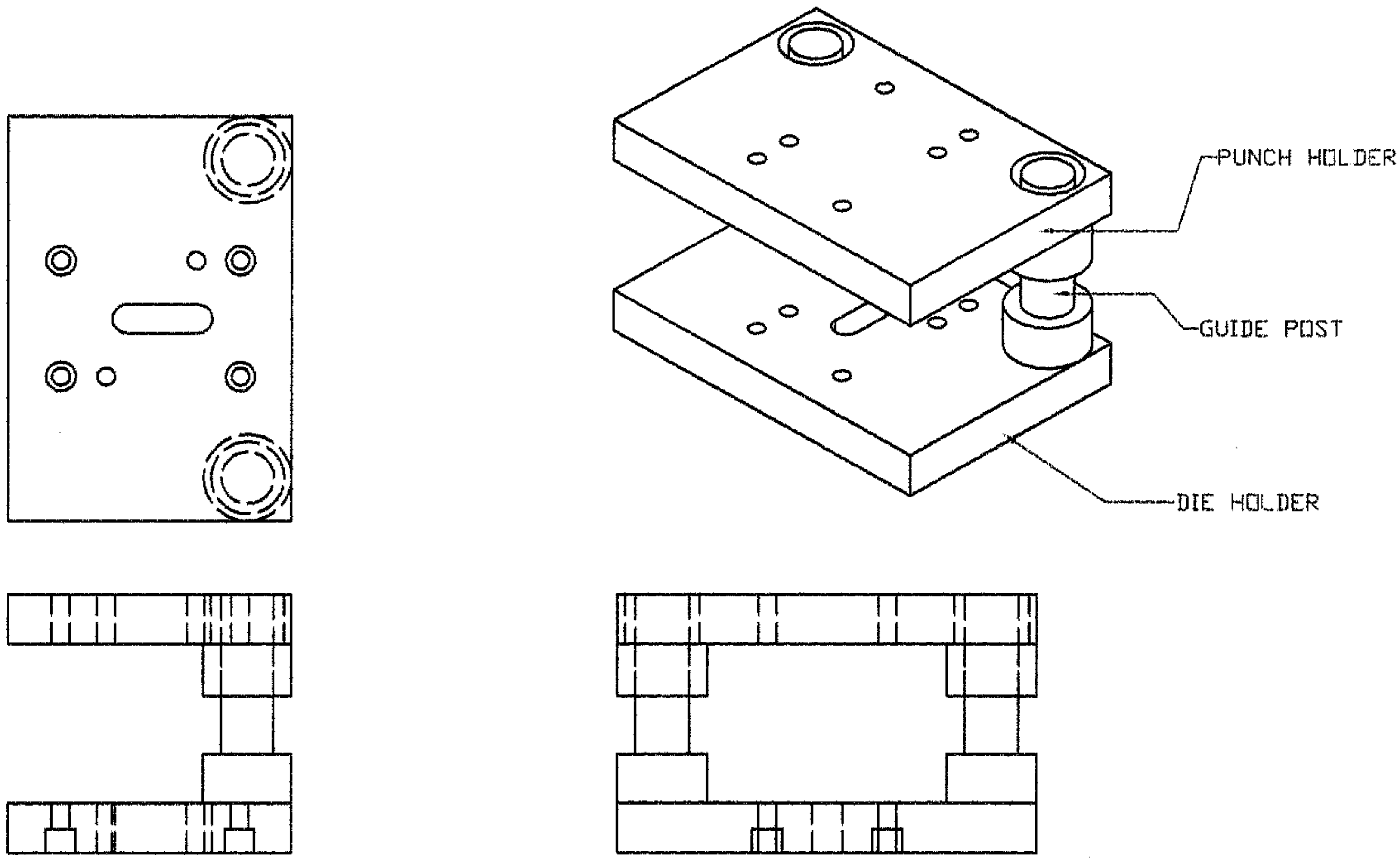

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DIE SET ASSEMBLY

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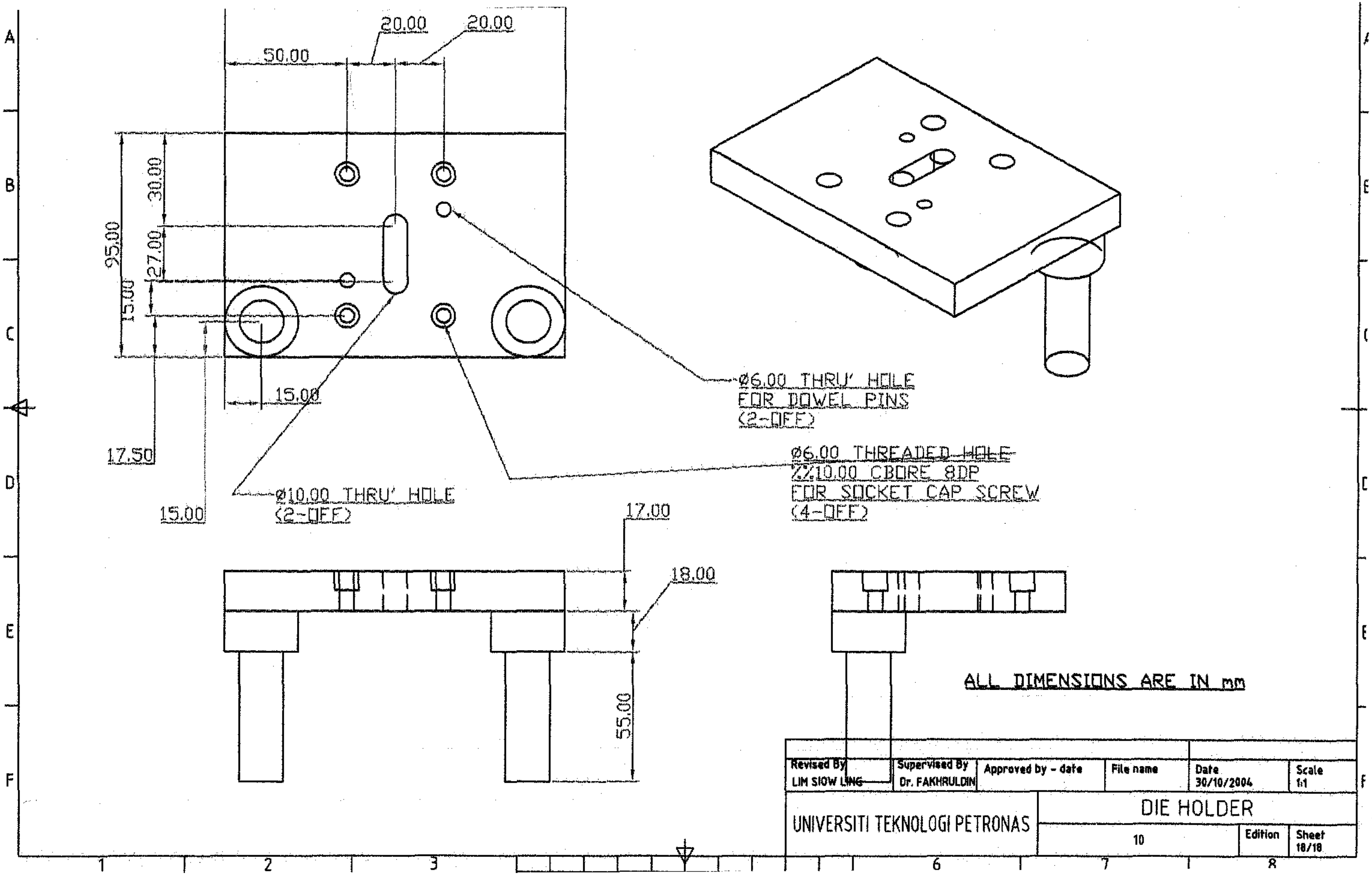
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