FORGING TECHNOIOGY -- AS APPLIED TO AUTOMOBILE INDUSTRY

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1. INTRODUCTION

Metals and alloys have the ability to be formed into useful shapes by Plastic Deformation. In this process they also develop a wide range of properties particularly strength and toughness. The working of the metals into shapes by means of forging methods refines grain structure, develops inherent strength giving characteristics, improves physical properties and produces structural uniformity free from hidden internal defects. Moreover, the special feature of flow lines along the contour of the forging produce marked directional properties. These features in forgings give the automobile designers increased confidence regarding the reliability of the vehicle.

2. FEATURES OF FORGINGS PECULIAR TO AUTOMOBILE

An automobile vehicle has to carry loads at high speed and has to be light enough to ensure fuel economy. In this regard the following points regarding forgings are noteworthy:

(a) forged components have made possible many design to accommodate higher loads and greater stresses,

(b) because of close tolerances, automated machining lines can be used to machine these at faster rate,

(c) because of the use of hot-rolled products as input, reliability of internal structure is ensured. As indicated earlier, grain flow characteristics of forgings give improved properties of strength, ductility and resistance to impact and fatigue,

(Ref.Fig.1)

(d) because of the controlled sequence of production steps consistency of material composition and structure is assumed from piece to piece and better response to heat treatment is achieved,

(e) with the elimination of internal discontinuities, low rejection rates, better machinability, less machining allowances -- cost of production of aggregates is reduced considerably,

(f) saving in weight of parts is achieved due to the inherent characteristic of higher strength to weight ratio.

Hence many models of auto and trucks contain over 200 separate forgings.

(Ref.Fig.2)

Familiar examples of these items are

Engine components: crank shafts, connecting rods, rocker arms, cam shafts.

Transmission: gear blanks, gear shift levers, drive shaft, main shaft, propeller shaft yokes, flanges brake levers.

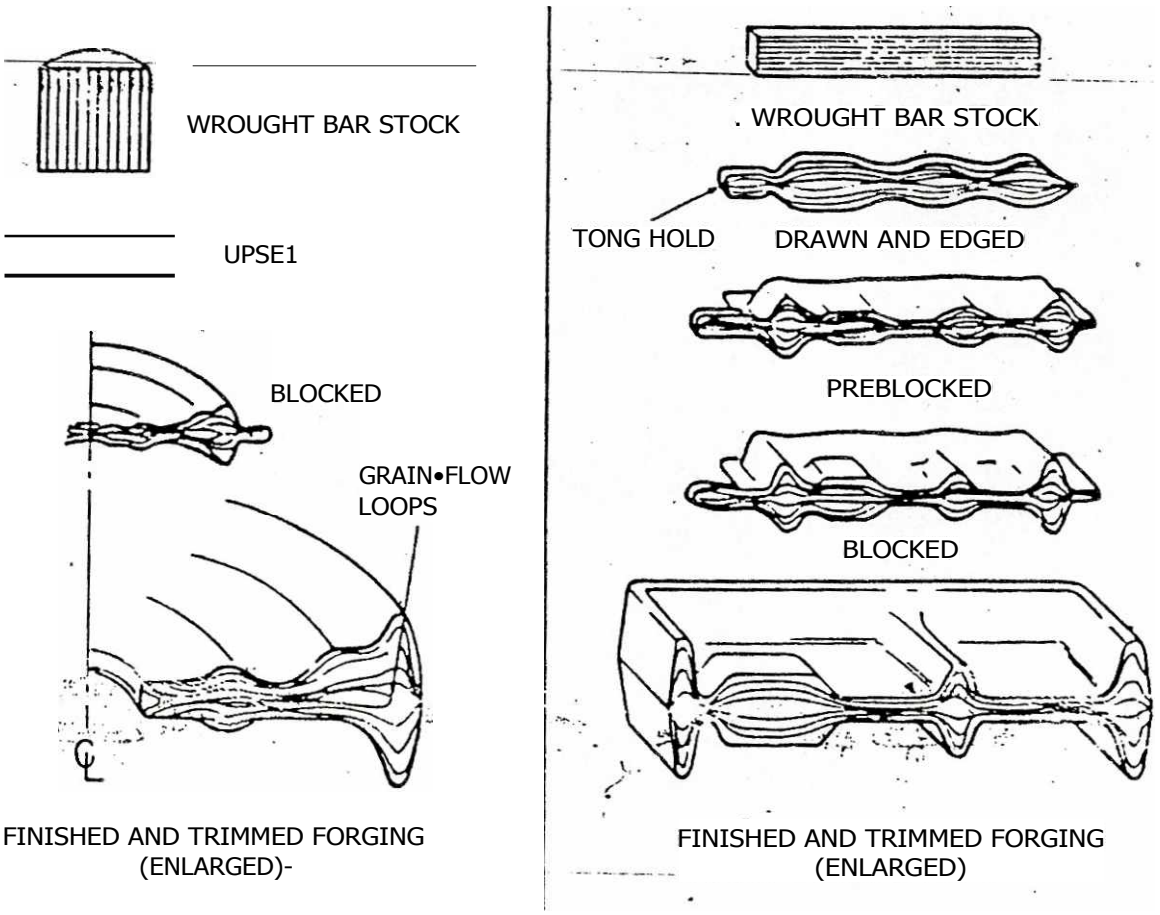
Steering: steering shafts, steering levers, pitman arms.

Front axle: front axle beams, stub axles, front hubs.

Rear axle: rear axle shafts, differential cases and covers, crown wheels and pinions, differential gears etc.

(Ref.Fig.3)

In the light of the above it is interesting to know as to how these forgings are manufactured.



Typical sequence of steps in forging a disc shape.

. Typical sequence of steps in forging a rib and web shape.

FIG.1.

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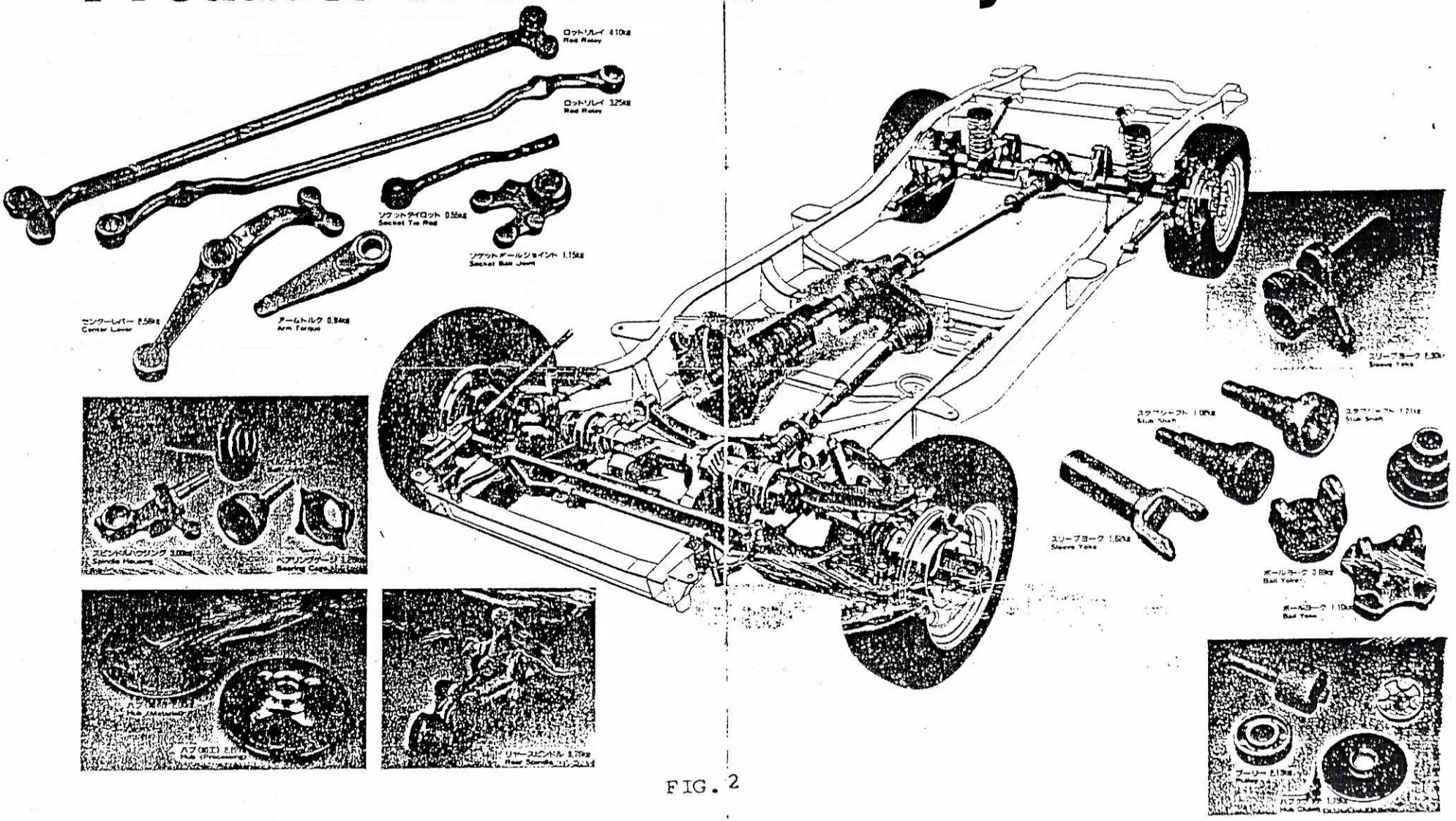

FIG. 2

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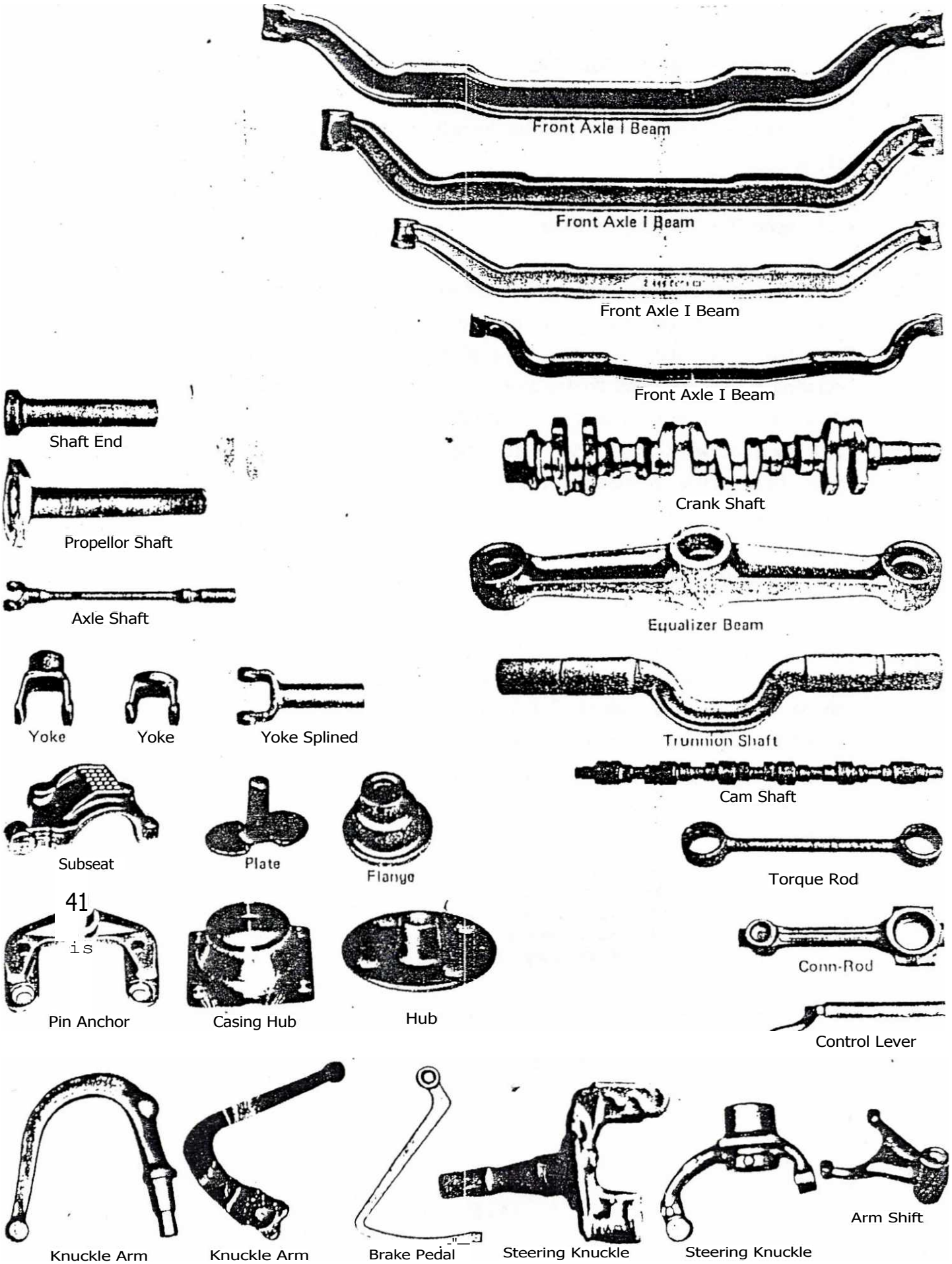

FIG.

3. TYPES OF FORGING PROCESSES

Forging processes can be broadly classified as open die and close die.

3.1 Open Die Forging Process

This process consists of hammering heated metal between a pair of flat dies. For obtaining the desired rough shapes the skill of the operator in manipulating the work piece is essential. At times some helping tools are used to improve the shapes and for special purposes. This is suitable to the type of production where quantities are small and sizes of work are large. The type of products produced on these open frame type pheumatic power hammers are shafts, rings, discs, large gear blanks etc.

3.2 Close Die Forging Process

This consists of hammering or pressing heated bars or billets within close impressioned dies. These impressions impart the desired shape to the work pieces. In view of the many variables in this process such as material temperature, die condition, machine load, complexity of job, die lubrication etc the process consists of several stages of manufacture:

Billet heating
Reduce rolling or fullering
Bending or flattening (if necessary)
Blocker or mould
Finish forging

° Billet heating (to around 1250°C) is done in forge furnaces which may be either box type pusher, walking beam, rotary hearth or induction furnaces.

VaPS FOR DEVELOPMENT OF FORGINGS

MACHINE PART DRAWING + SCHEDULE

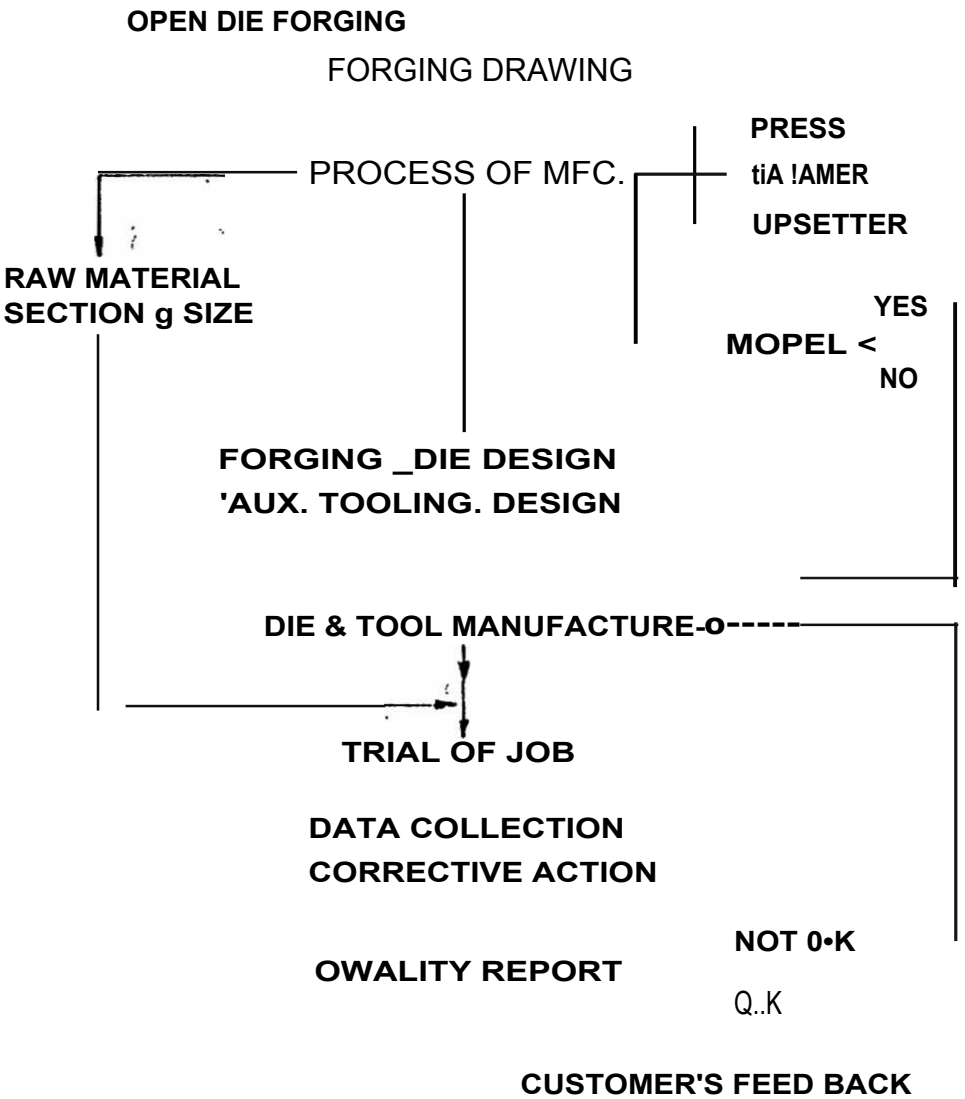

FIG. 4

- Reduce-rolling is done to distribute the metal to suit forging shape in a separate rolling machine.

- Flattening, bending, blocking and finish forging operations are done in the main forging unit i.e Press or a Hammer.

- Trimming and hot coining operations are done on auxiliary units.

- Heat treatment, shot blasting, grinding etc are the finishing operations, which are done in separate equipments.

- Automobile forgings are made by close die forging process and hence it is essential to elaborate the various features of this technology.

  In the first instance designs of the forged part, die and tool design are to be considered.

  (Ref.Fig.4)

- Broadly speaking, adding material around the contours of machined piece profile constitutes the design of forged part.

  (Ref.Fig.5)

4. STEPS FOR THE DESIGN OF FORGED PART

4.1 **Parting Line**

Die parting line is the plane which divides the top and bottom dies in a close die forging. This depends upon the ease of die filling, forging equipment, grain flow, jib locations and trimming facility.

Proper parting line avoids deep impressions that might cause die breakage. This also avoids side thrusts which could cause excessive mismatch in forgings (Ref.Fig.6).

4.2 Draft Angles

Draft angles are necessary on all forgings to permit removal of forgings from dies and to assist in achieving desired metal flow. It

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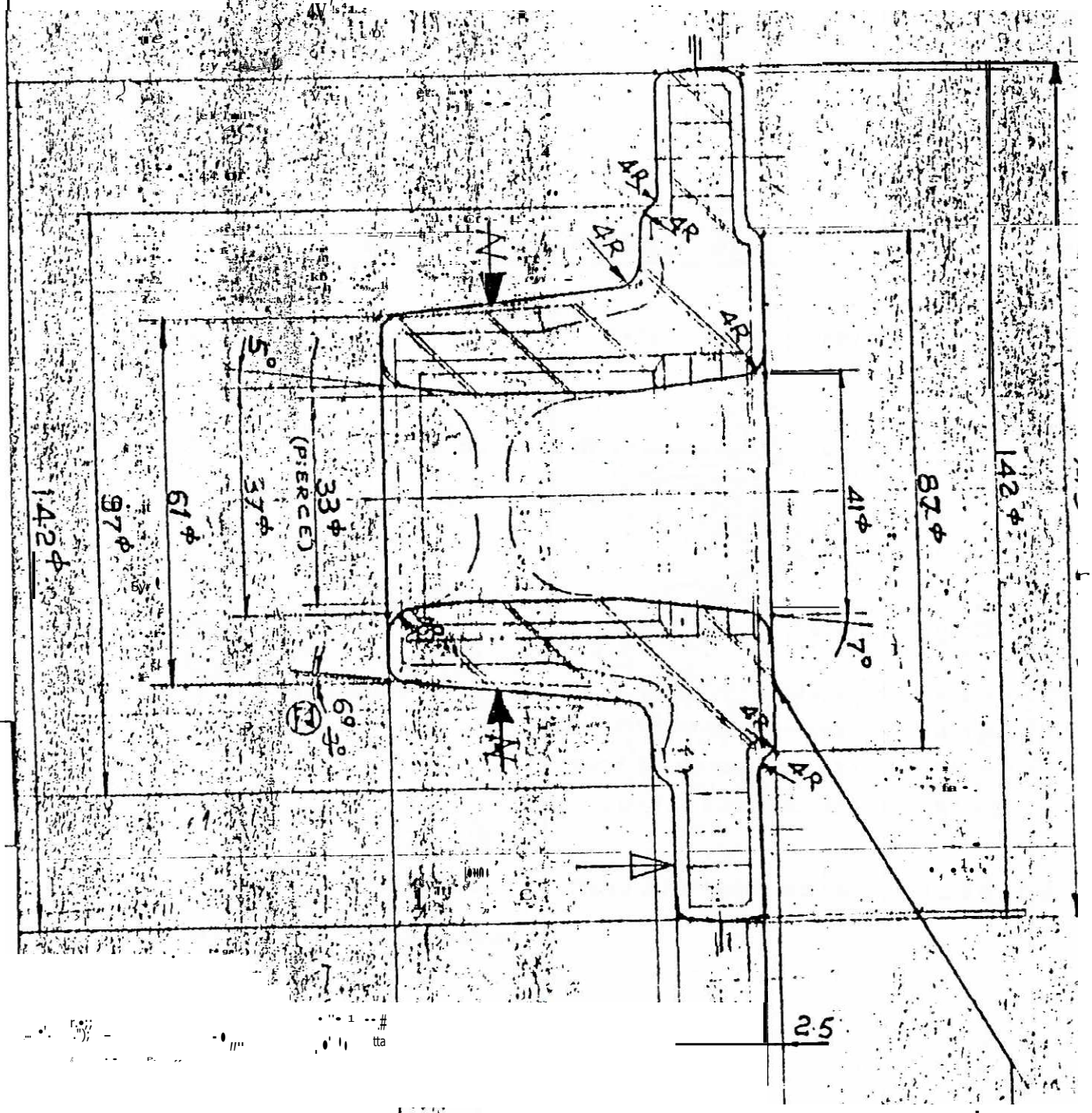
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is a common practice to follow 3 to 5°C in steel forgings. Excessive draft angles call for more machining allowances. Forging equipment also plays a vital part in ascertaining the draft angle. Small draft angles can be used on press forging dies which have the ejection systems whereas hammer dies are designed with increased draft angles (Ref.Fig.7).

4.3 **Webs and Ribs**

A web is a part of the forging lying parallel to the forging plane, whereas a rib is perpendicular to it. For keeping the forging weight minimum, the size of these webs and ribs are to be kept under control, but smaller sizes are influenced by the forging equipment and the forging temperature. The locations of the parting line and the fillet radii also affect these (Ref.Fig.8).

4.4 **Fillet and Corner Radii**

Fillet and corner radii greatly affect the metal flow in a die. Good fillet radii smoothen out the metal flow and avoid defects of overlaps bigger fillet radii increase the machining allowances and weight of the forgings. For achieving smaller fillet radii multi impression design is considered.

The choice of corner radii is also an important factor because small corner radii will cause die breakages. This also depends upon forging weight (Ref.Fig.9).

4.5 **Machining Allowances**

Machining allowances are controlled by the complexity of the forging, forging weight, forging equipment and type of furnaces used. Forging process also controls the machining allowances (Ref.Fig.10).

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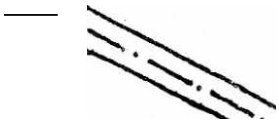

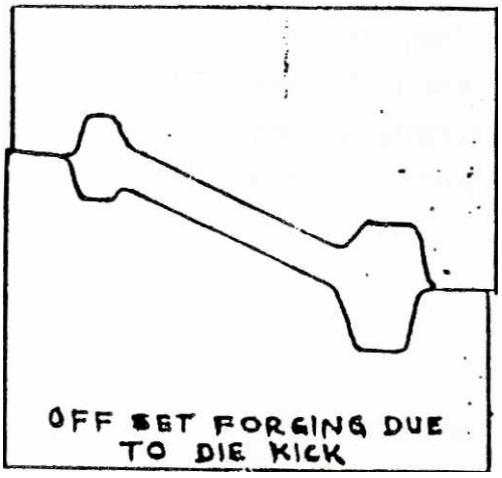

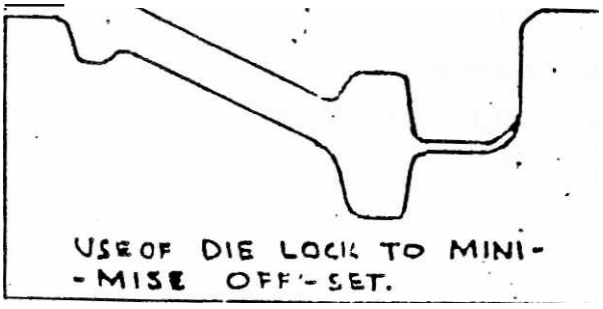

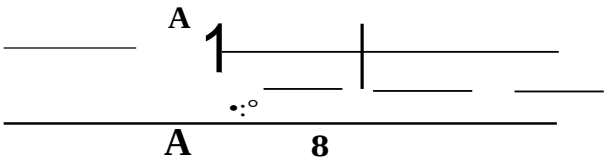

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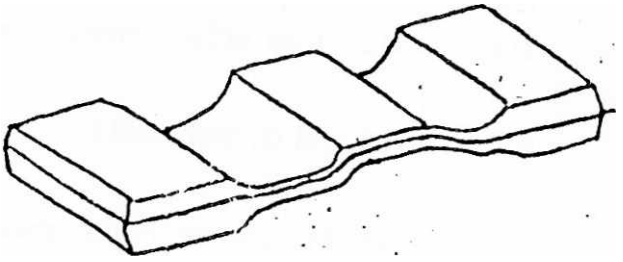

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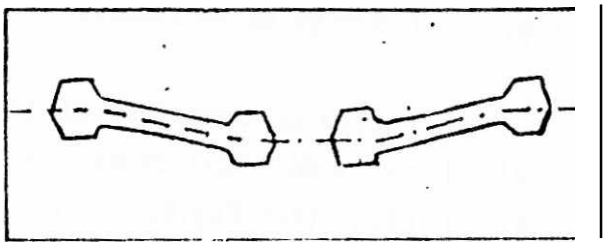

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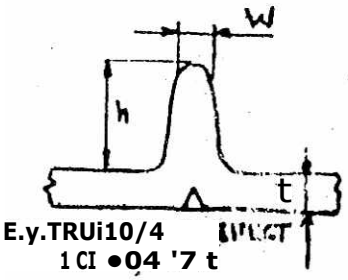

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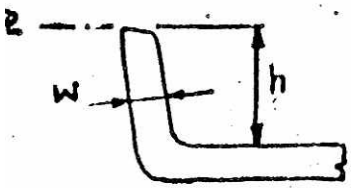

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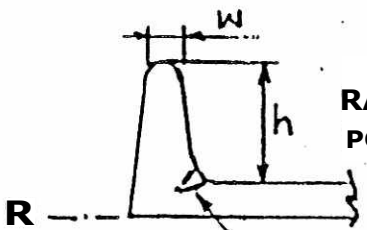

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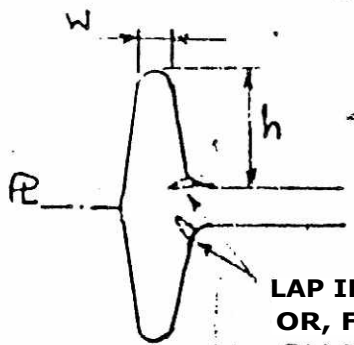

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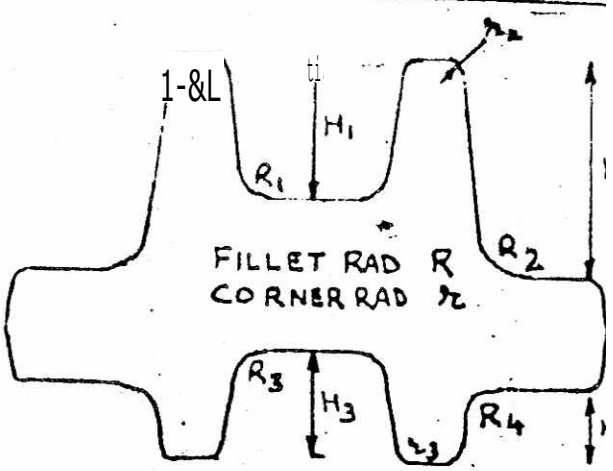

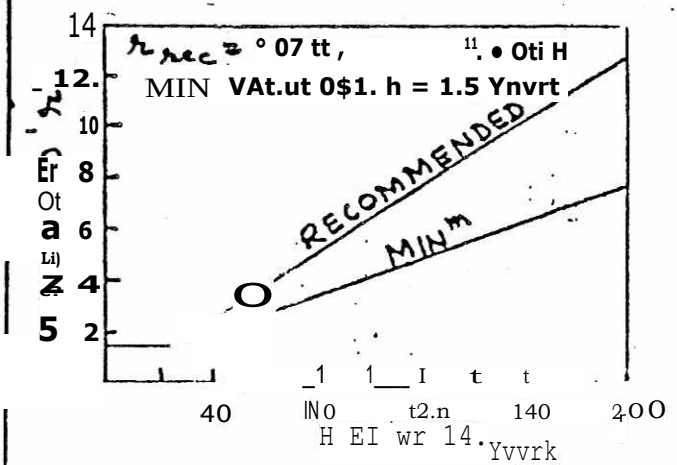

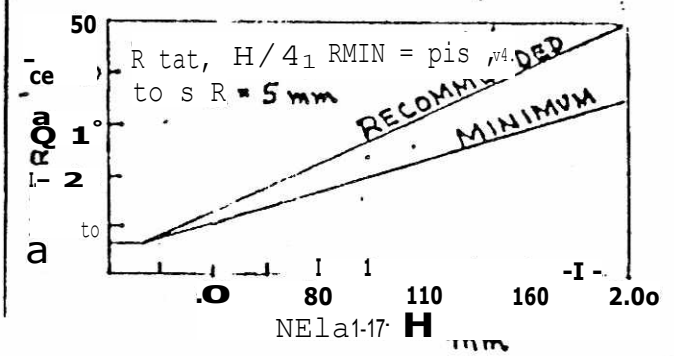

FIG. 9

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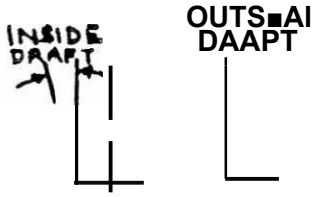

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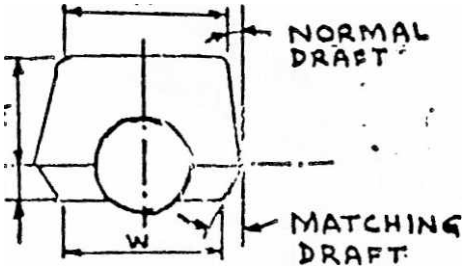

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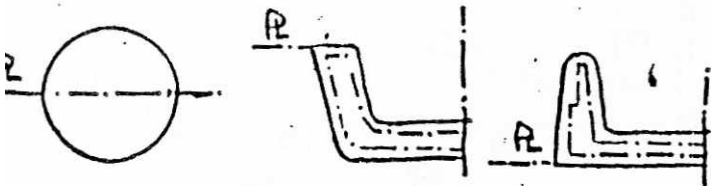

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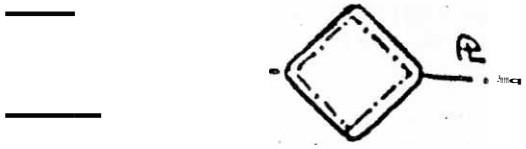

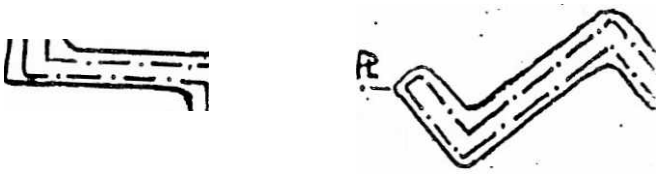

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FIG. 7

4.6 Forging Tolerances

As in other manufacturing processes, there are limitations to the degree of precision which is practicable in the forgings. Experience shows that dimensional variations in forgings are common dependent upon the weight, complexity of shape and materials.

Based on the above concept and other factors such as die wear, die closure, mismatch etc (Ref.Fig.11) tolerances as per IS:3469 have been determined for practical use.

4.7 Shapes for Forging

Spherical and block like shapes are the easiest to forge in the impressioned dies. Parts with thin and long sections are more difficult because they have more surface area per unit volume. Vertical bosses such as ribs are harder to forge them laterd projections.

The increase in load during the progress of forging is gradual initially, but shoots up as the forging gets filled up (Ref.Fig.12).

5. DIE DESIGN PARAFEITRS

There are no fixed rules for the design of closed die forging dies since different approaches can often produce acceptable forgings. There are certain guide-lines and principles, developed by many years of practical experience which is followed will maximise the probability of producing sound forgings with the greatest economy. The following factors help to produce good forgings.

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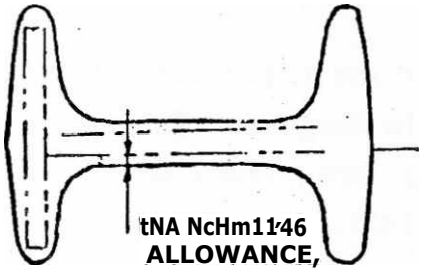

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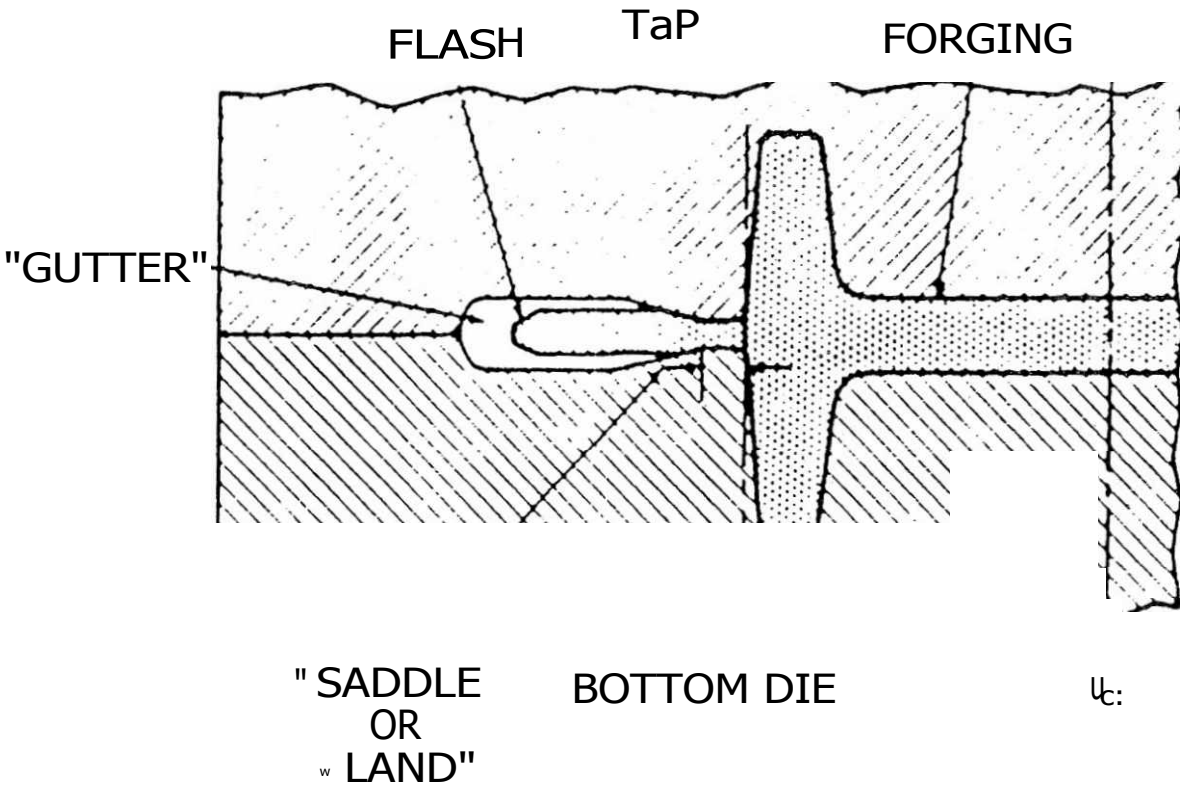

12. Example of conventional flash gutter design.

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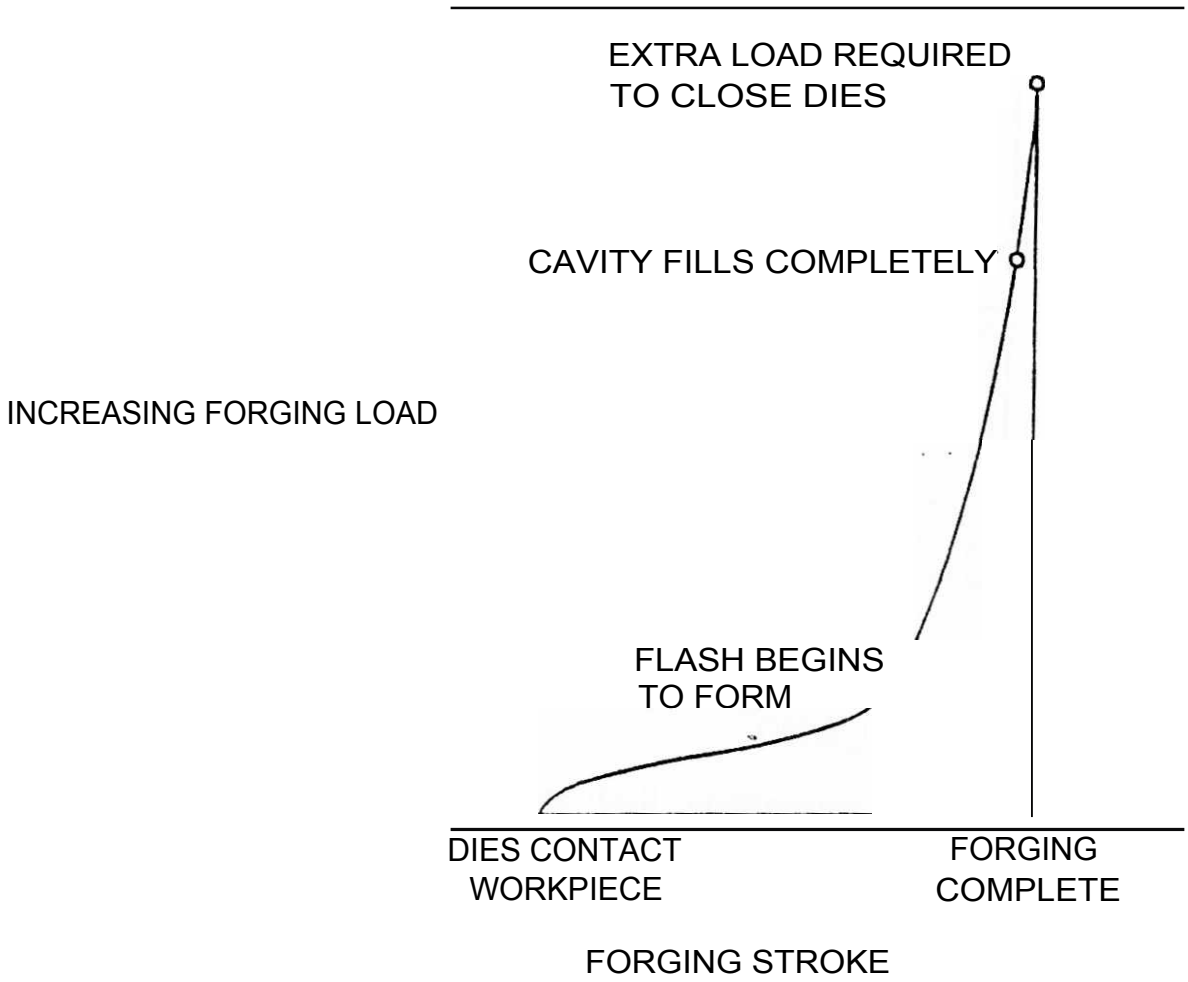

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FIG.12

5.1 Flash Land and Flash Gutter Design

Flash land is the zone outside the forging impression which plays a vital part in the forging process. On the one hand it restricts the metal from running out without filling the die cavities and on the other hand excess metal extrudes through the constriction after filling up i.e at an intermediate stage the flash land restricts the side ways metal flow and at final stages it allows the excess metal to come out after filling these impression.

The flash gutter is designed in such a way that it is adequate to accept the excess metal extruded through the flash land.

5.2 **Fuller or Roll Design**

The object of fullering is to reduce the cross sectional area of the forging stock and to elongate it to redistribute metal prior to further performing or forging operations.

5.3 **Bender Design**

Many forgings after rolling must be bent before being presented to the blocker or finisher impression. The general basic shape of the bending tool is governed by the plan view of the forging.

5.4 **Blocker or Mould Design**

Where multiple impression dies are used for long running jobs the life of the finishing impression can be greatly extended by incorporating a blocker impression. The blocker impression converts a fullered or rolled use more closely to the final required shape and facilitates filling up of deep cavities by providing surplus metal at necessary points in the die. To prevent chopping of the blocked use

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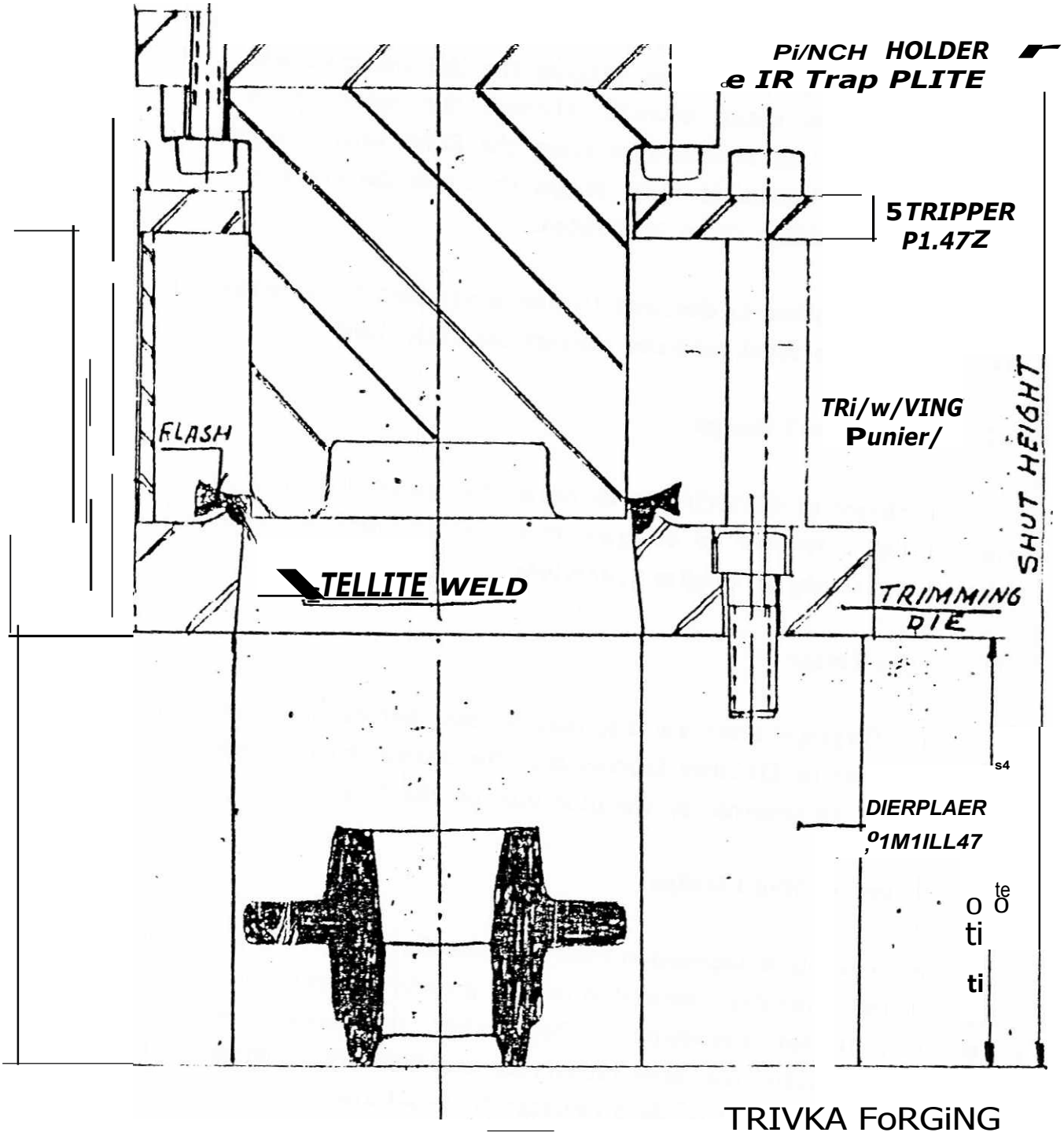

TRIVKA FoRGiNG

12B

by finisher die impression this is made narrower by 0.5 to 1.0 mm and for ensuring filling up this reduced width is compensated by depth of the blocker impression greater than that of the finisher by 1 to 1.5 mm.

5.5 Trimming Die Design

Trimming operation is done to remove the flash from the forging. Piercing operation also performs this function in round forgings. This is divided in three categories -- Close Trimming, Normal Trimming and Loox Trimming.

The trimming punch is made to suit the forging profile and the trimming die profile matches with the parting line profile (priphens) (Figs.12-13).

5.6 Hot Coining Die Design

These are basically similar to finisher dies but the parting line radii are blended. This operation removes the distortion caused by the trimming operation.

The above principles are applied in the case of hammer, press or upset forging die design.

(a) **Hammer forging die design: A** pair of die is needed to perform the operation -- one for the Anvil and the other for the Ram. The dies are made to the shape required on special die sinking machines. The number of impressions or steps in the dies through which heated metal is successfully worked depends upon the shape of the forged piece. The final forging is made by the impact of top and bottom dies. In this case multiple number of blows is required (Ref.Fig.131./4)

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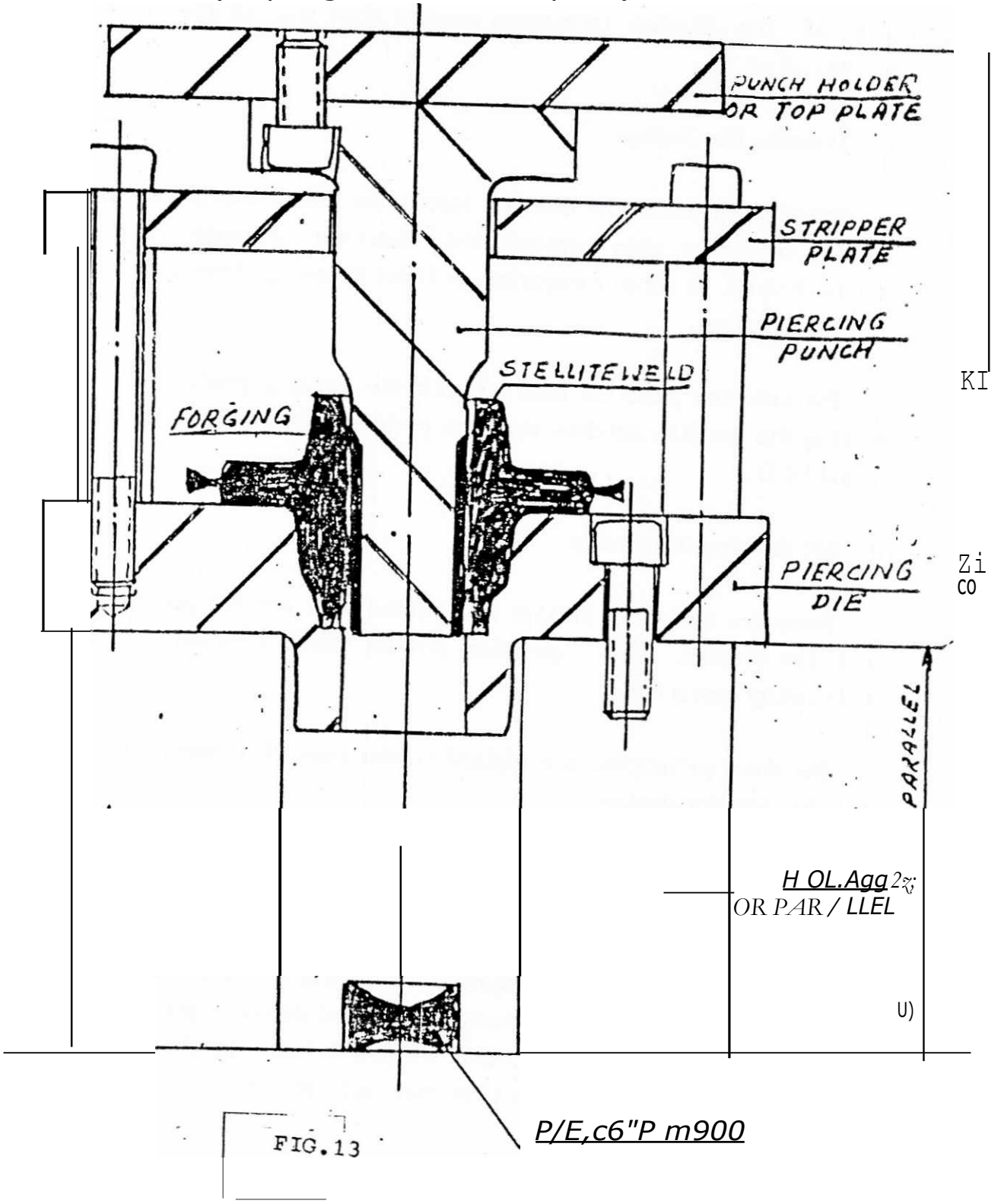

FIG. 13

(b) Press forging die design: By using closed impression dies and with the single stroke of Ram at each stage the forgings are made. Most of the total energy of the forging press is transmitted to the metal. The sequence of operations usually consists of preliminary scale breaking, followed by blocking which displaces and locates the stock so that there will be minimum flow, flash and abrasion to the dies in the final forming operation. Ejectors are used to remove the forgings from the dies (Ref . Fig .15,16 .

(c) Upset forging die design: The closed impressioned dies that are used with the upsetting machines are designed to grip the metal (bar stock) by the use of stationary and movable side ram and allowing the header Ram to push the metal into the impressioned cavities, like Drop or Press forging. This operation may be completed in more than one step for developing the finished shape. Upset forging is carried out without draft and in some cases without flash. One of the fundamental rules of this design is to keep the unsupported length of the heated bar not more than 3 times the diameter of the bar. If longer length is required the diameter of the impression should not exceed 11/2 times the diameter of the bar. Thus the heated bar is upset by successive forming operations. These operations increase the bar's diameter and shorten the length successively (Ref.Fig.17).

6. FORGING EQUIPMENTS

Although there are various types of equipment including auxiliary equipment, the main forging equipments can be grouped into three categories.

- HAMMERS which are energy restricted machines.
- MECHANICAL FORGING PRESSES - which are stroke restricted machines.

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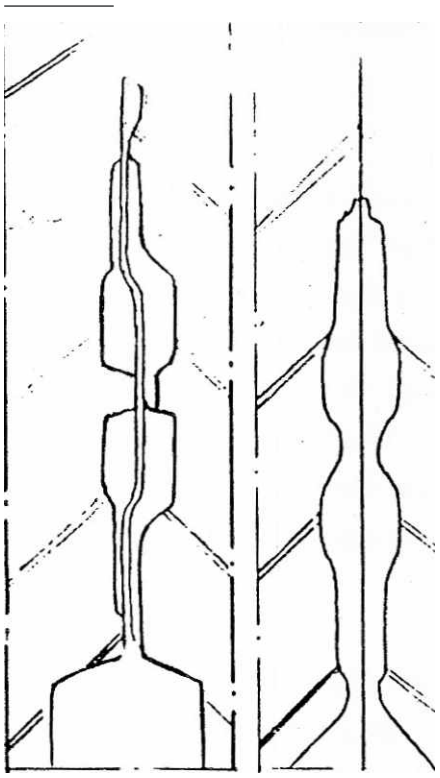

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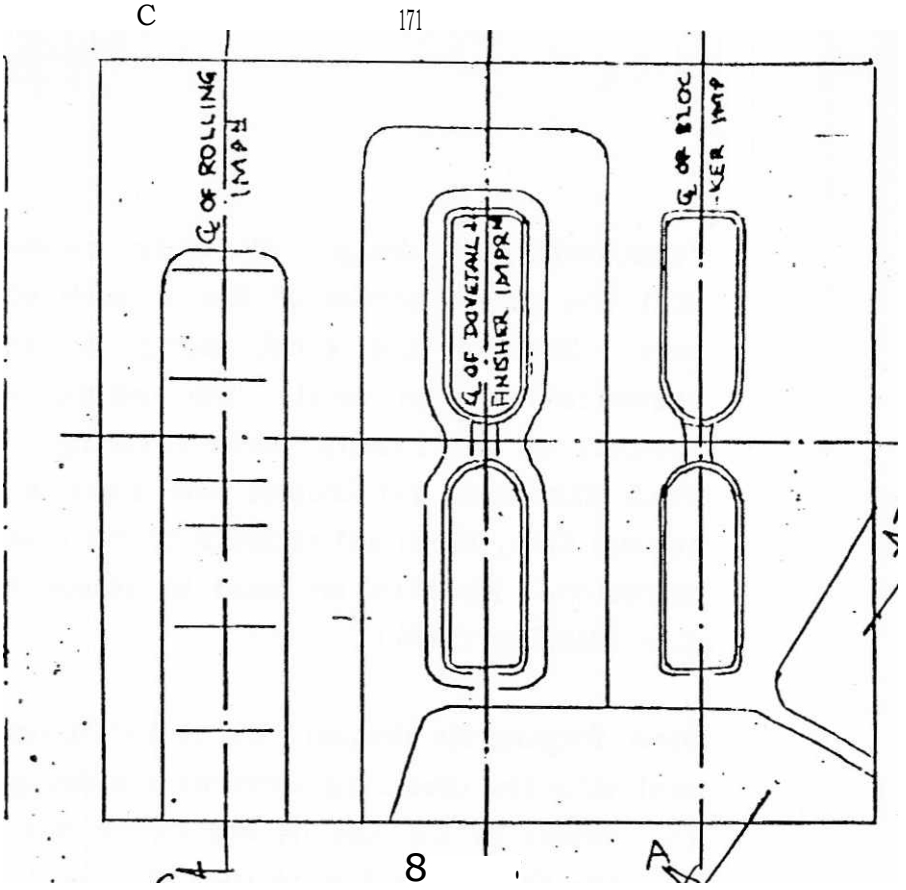

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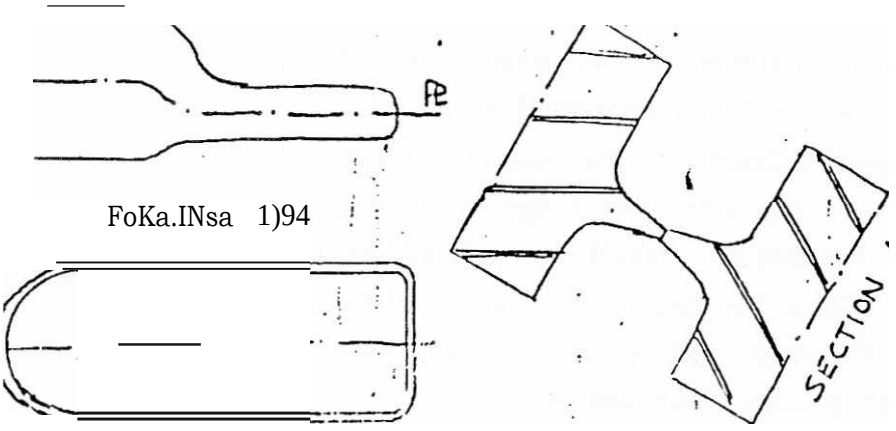

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FIG.14

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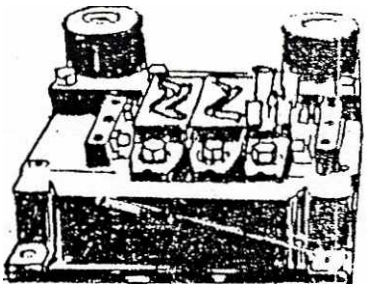

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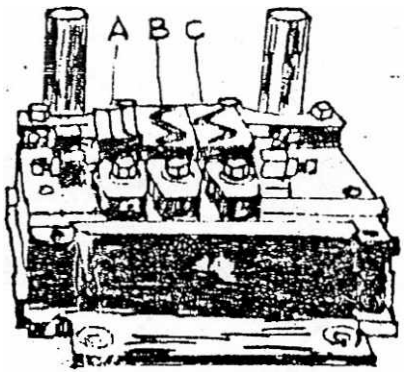

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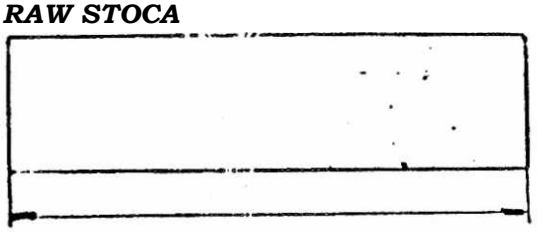

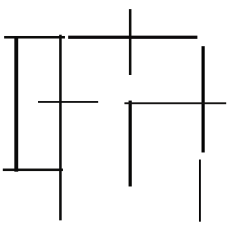

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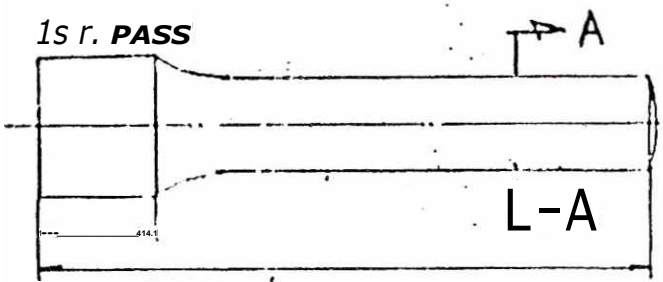

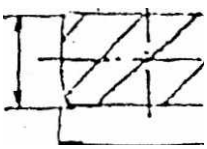

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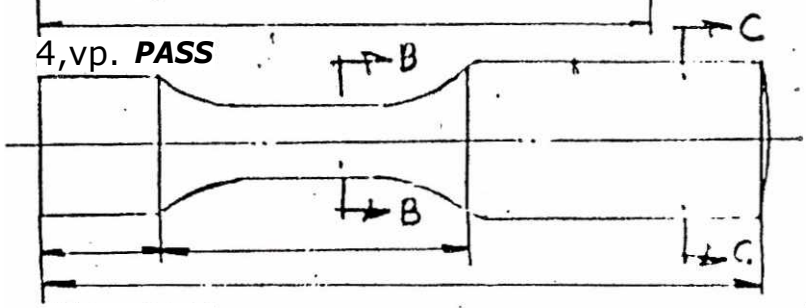

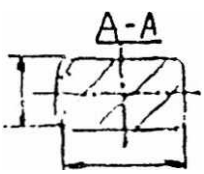

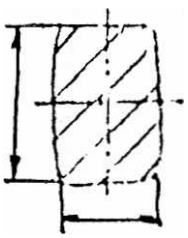

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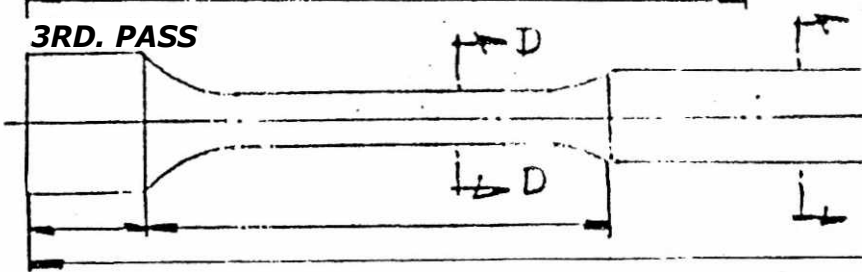

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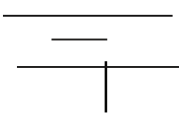

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FIG. 15 •

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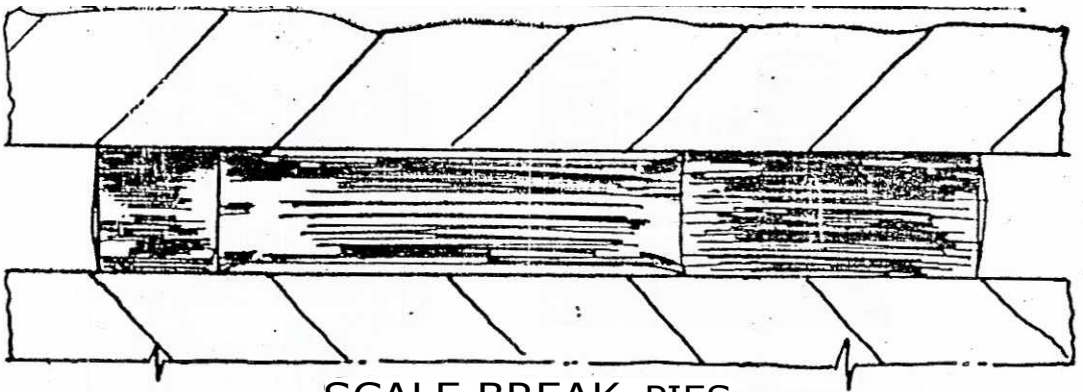

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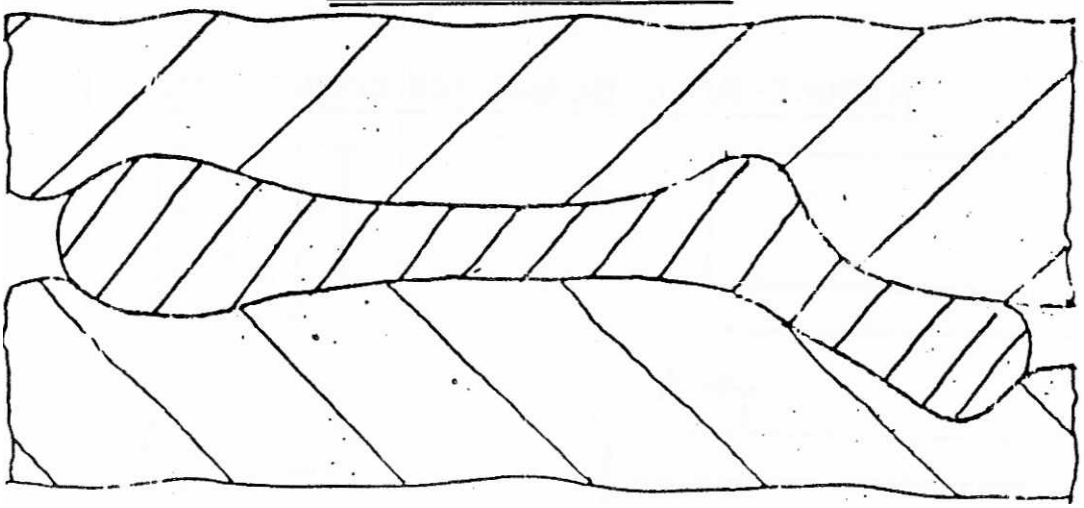

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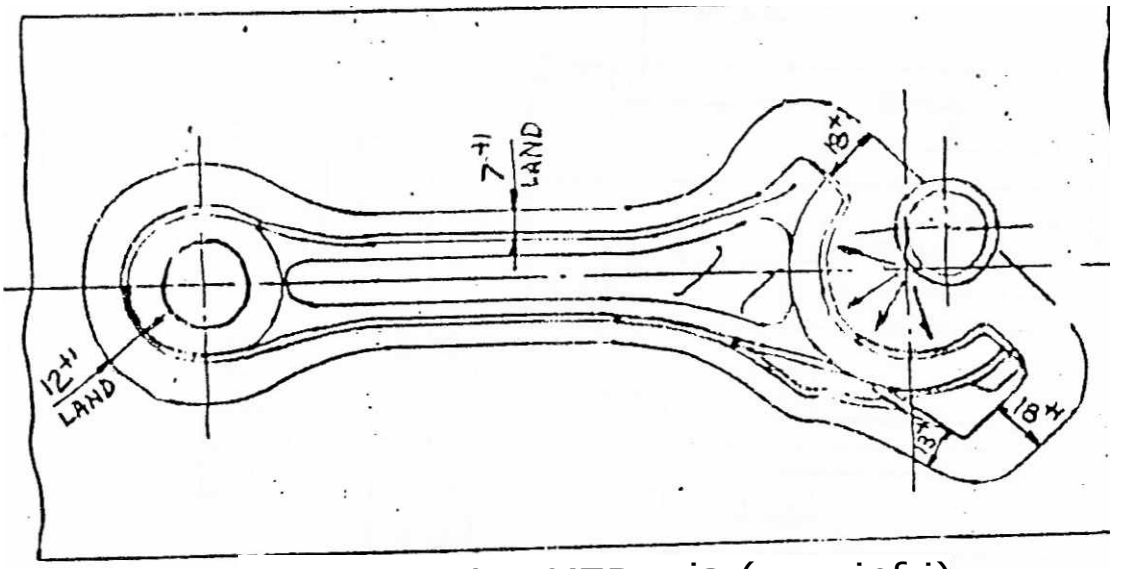

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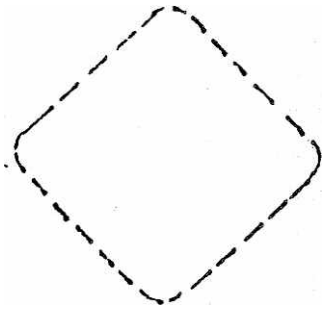

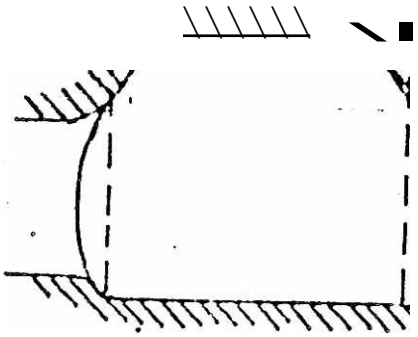

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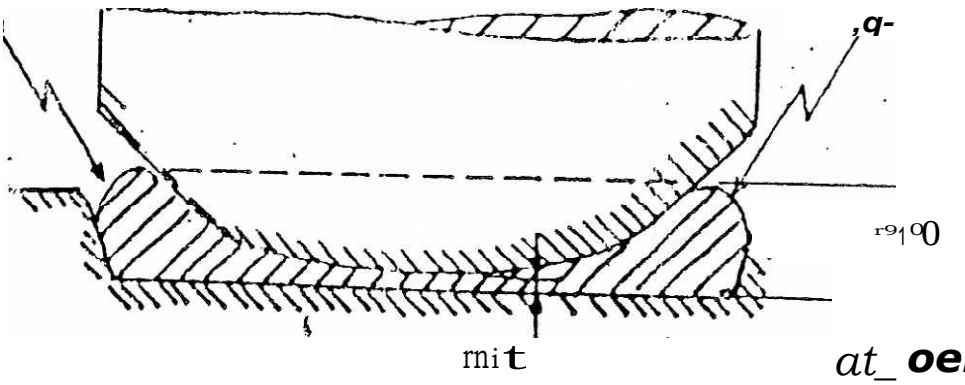

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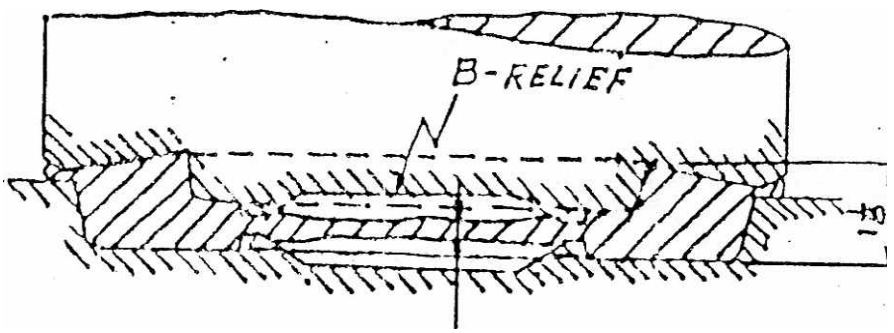

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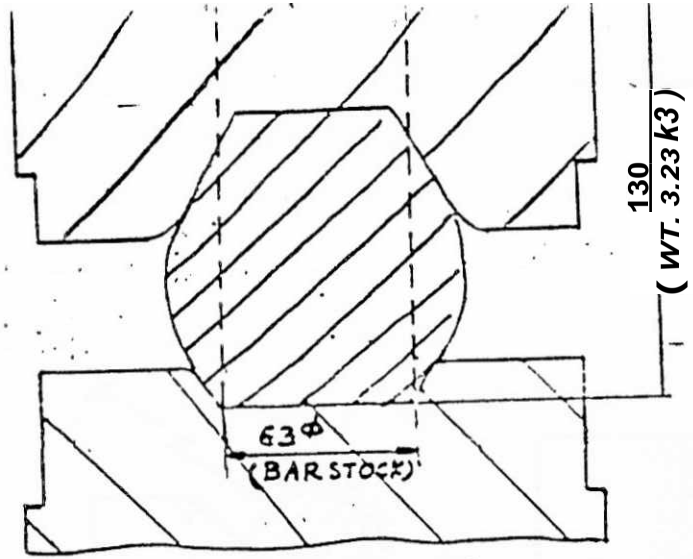

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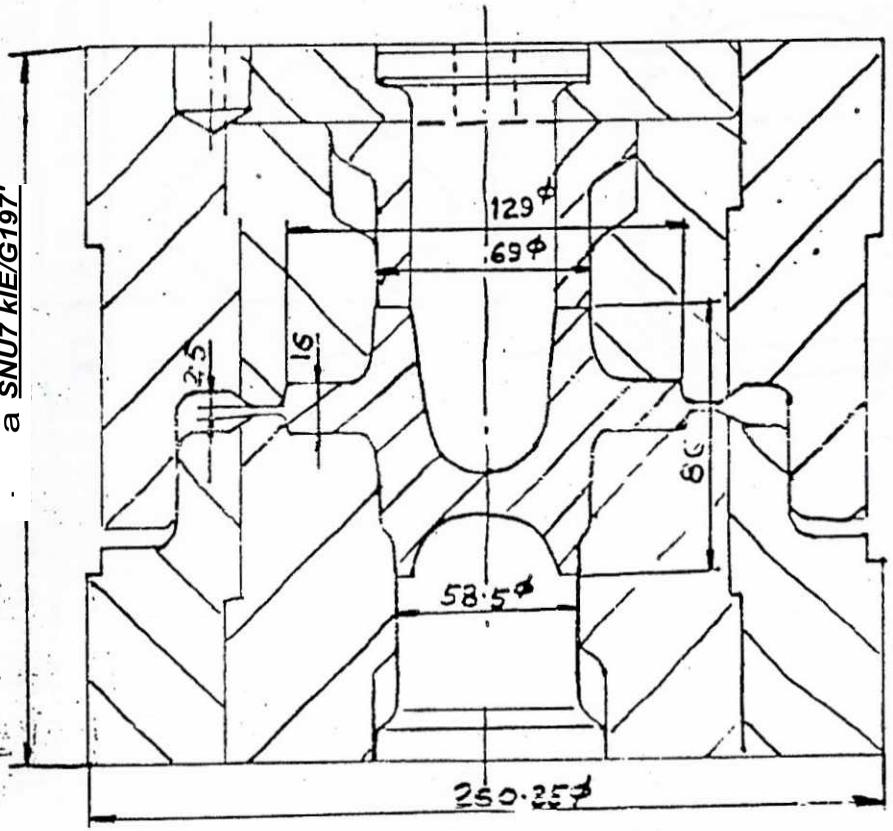

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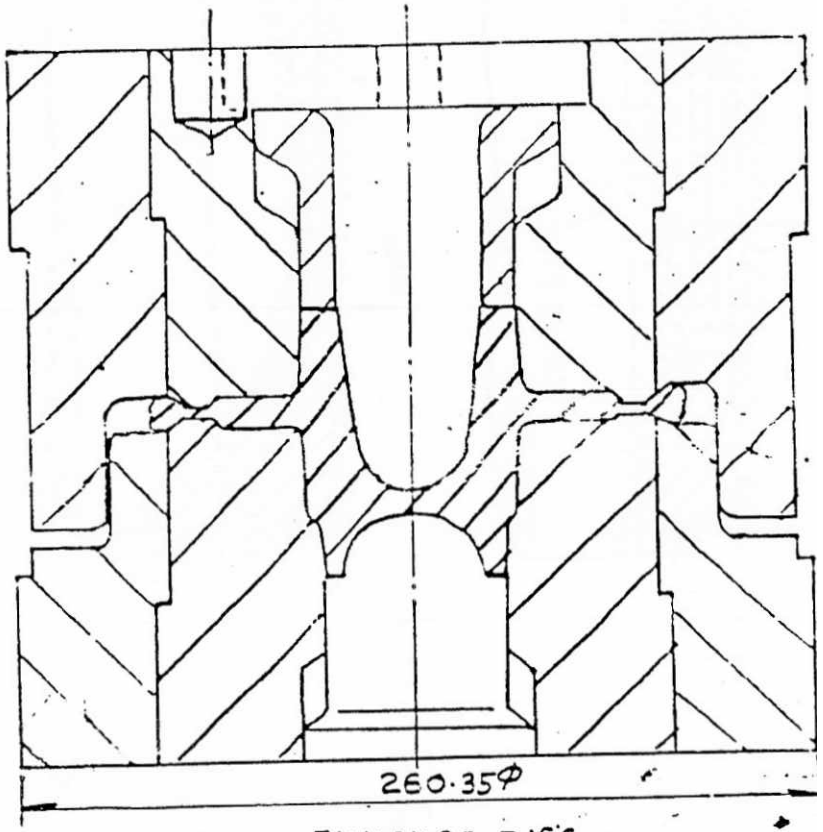


FINISHER DIES

FIG.16

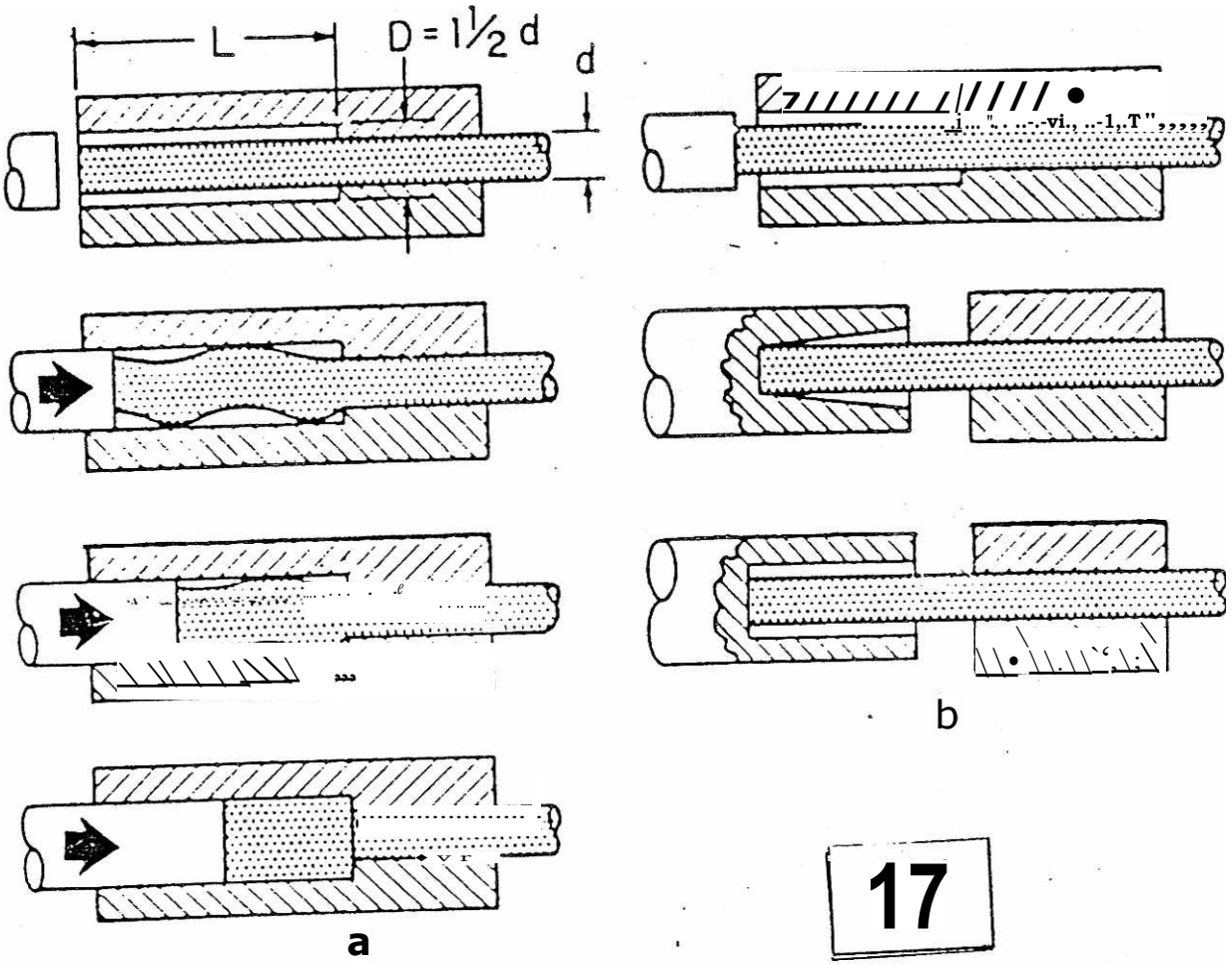


FIG.17 Schematic diagram of typical operations involving upsetting to a limited diameter.

-- HYDRAULIC PRESSES - which are load restricted machines.

6.1 **Energy Restricted Machines**

In energy restricted machines the deformation energy is derived from the moving body. During a forging blow deformation of work piece takes place until all the available energy is used up. Further deformation can be accomplished by striking further blows.

DROP HAMMERS, DOUBLE ACTING HAMMERS, COUNTERBLOW HAMMERS, FRICTION SCREW PRESSES come under this category (Ref.Fig.18)

6.2 **Stroke Restricted Machines**

Stroke restricted forging machines derive their initial drive from a rotating eccentric mechanism which imparts linear movement to a Ram by means of a connecting device.

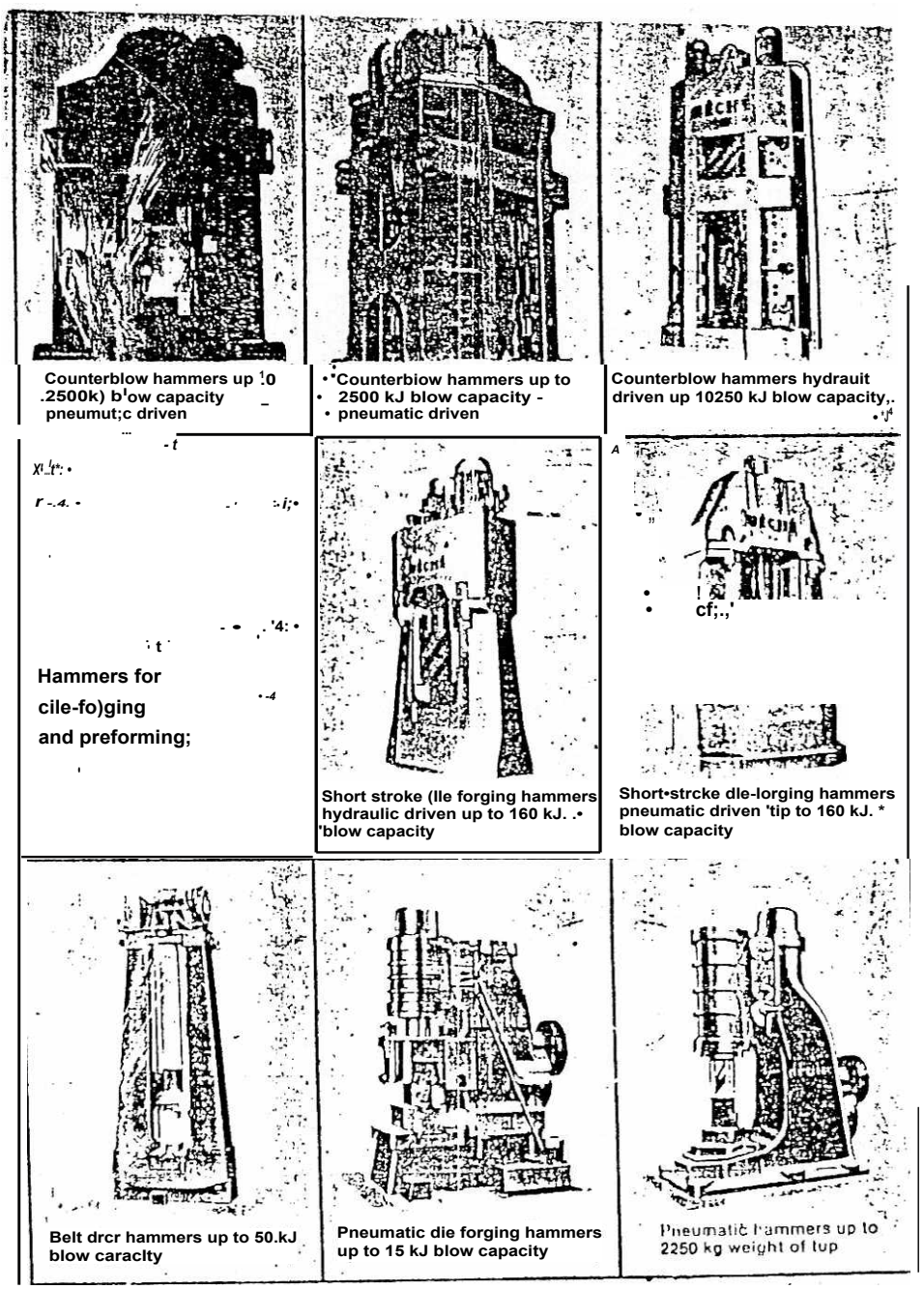
CRANK AND ECCENTRIC PRESSES, KNUCLE-JOINT PRESSES, WEDGE PRESSES AND HORIZONTAL UPSETTERS belong to this category (Ref.Fig.19)

6.3 **Load Restricted Machines**

The Hydraulic Press is a load restricted machine since the maximum load can be developed at any position within the available stroke. Here the load depends upon the oil pressure and the speed or Ram Travel is proportional to the rate at which oil is supplied to the cylinder.

7. **SOME EXAMPLES OF FORGING PROCESSES**

Fig.20 - Shows flow chart


Counterblow hammers up 10 .2500k) b'ow capacity pneumut;c driven
Counterblow hammers up to 2500 kJ blow capacity - pneumatic driven
Counterblow hammers hydrauit driven up 10250 kJ blow capacity,.
Hammers for cile-fo)ging and preforming;
Short stroke (lle forging hammers hydraulic driven up to 160 kJ. blow capacity
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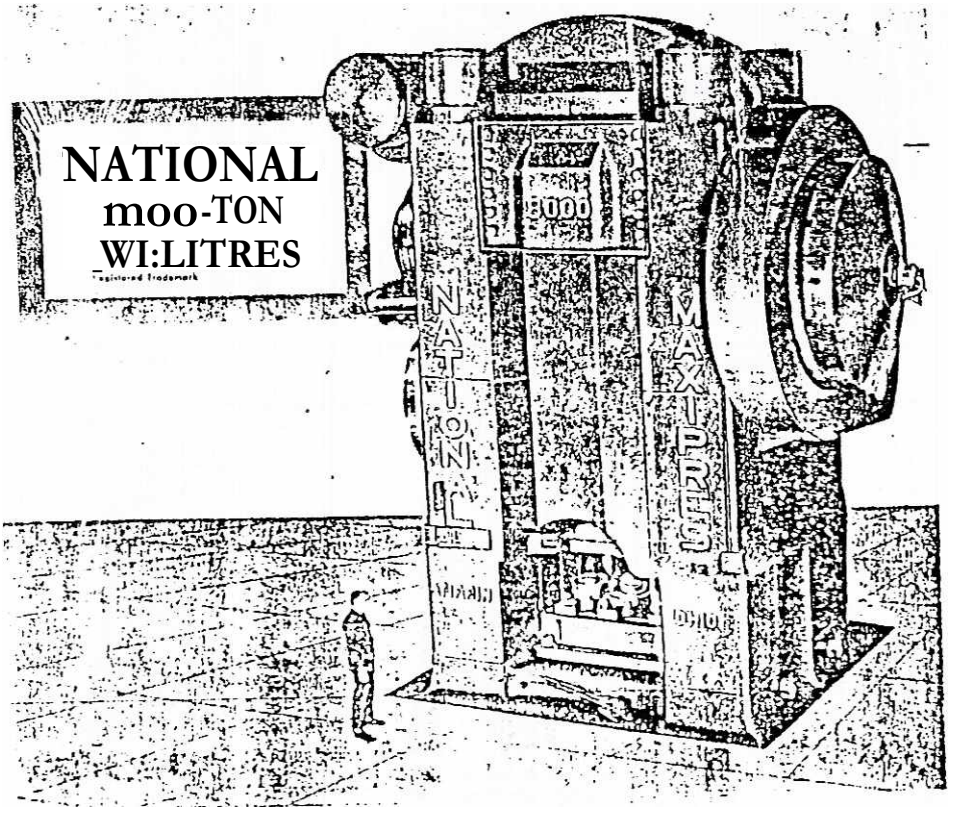
Belt drcr hammers up to 50.kJ blow caraclty
Pneumatic die forging hammers up to 15 kJ blow capacity
Pneumatic hammers up to 2250 kg weight of tup

FIG. 18



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THE NATIONAL MACHINERY COMPANY, TIFFIN. 01110, U.S.A.

Pioneers of Hot and Cold Forging Machinery Since 1874

F1G.19

Flow Chart

component: 1210 Steering Arm

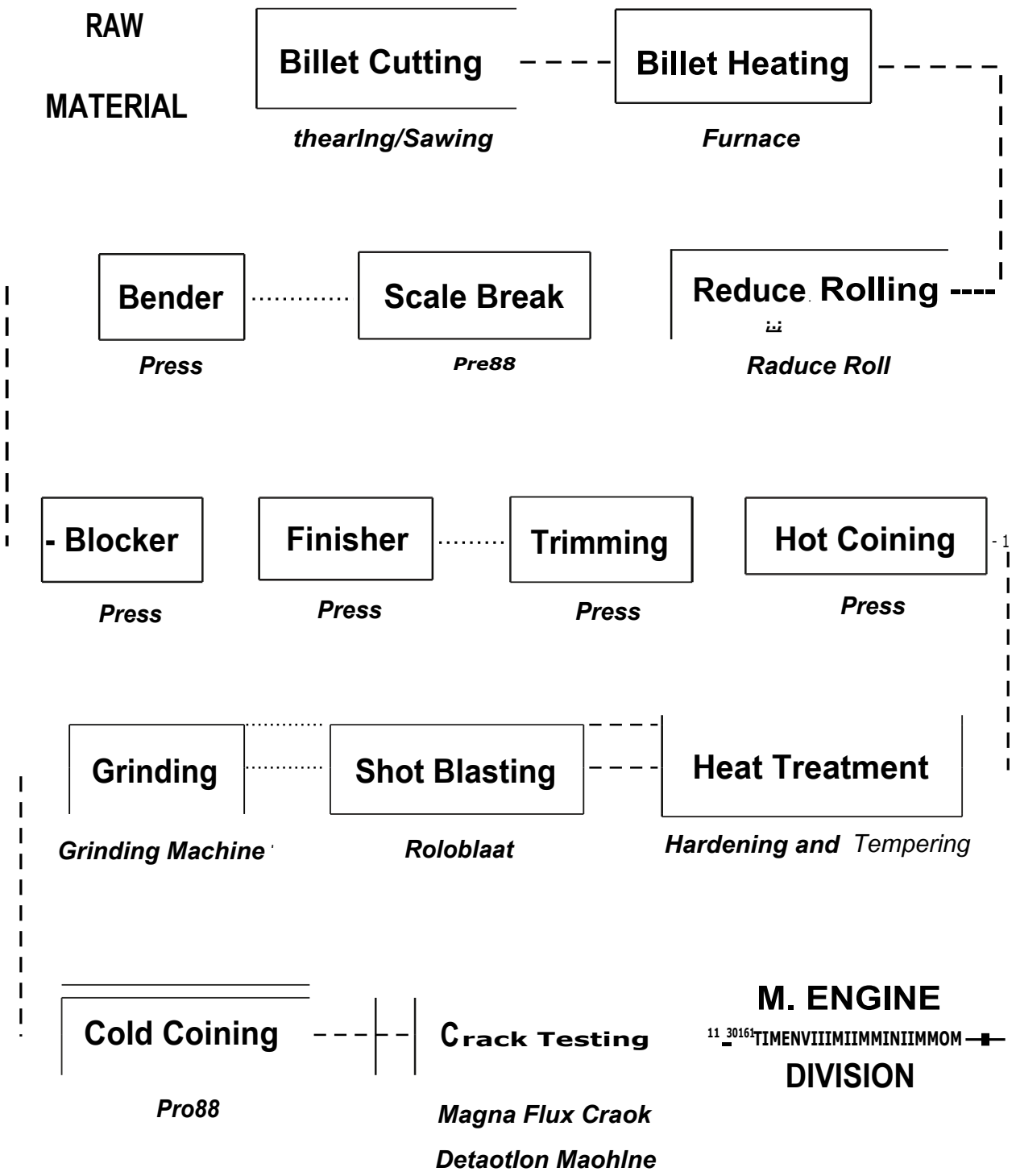

FIG.2

4.32

Fig.21 - Shows the manufacturing stages of Steering Arm Forging on a 2000 T Forging Press

Fig.22 - Shows process sequence of 4 cylinder Crankshaft on 6000 T Forging Press

Fig.23 Shows process sequence of Front Hub on 12,000 lb Erie Hammers

Fig.24 - Shows manufacturing sequence of Stub Axle on 12,000 lb Erie Hammers

Fig.25 - Shows the manufacturing sequence of Rear Axle Shaft on 5" upsetter

8. RECENT DEVELOPMENTS IN FORGING

As far as latest developments in forging technology are concerned these are: Orbital Forging, Cross Rolling, Cold and Warm Extrusion. Automation of Forging Presses and Hammers also form part of this.

Advances in the field are also taking place in the area of CAD/CAN where the die development time is considerably reduced.

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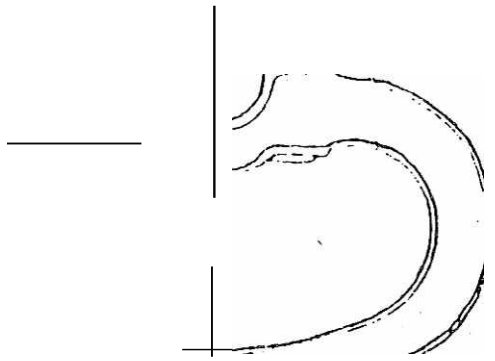

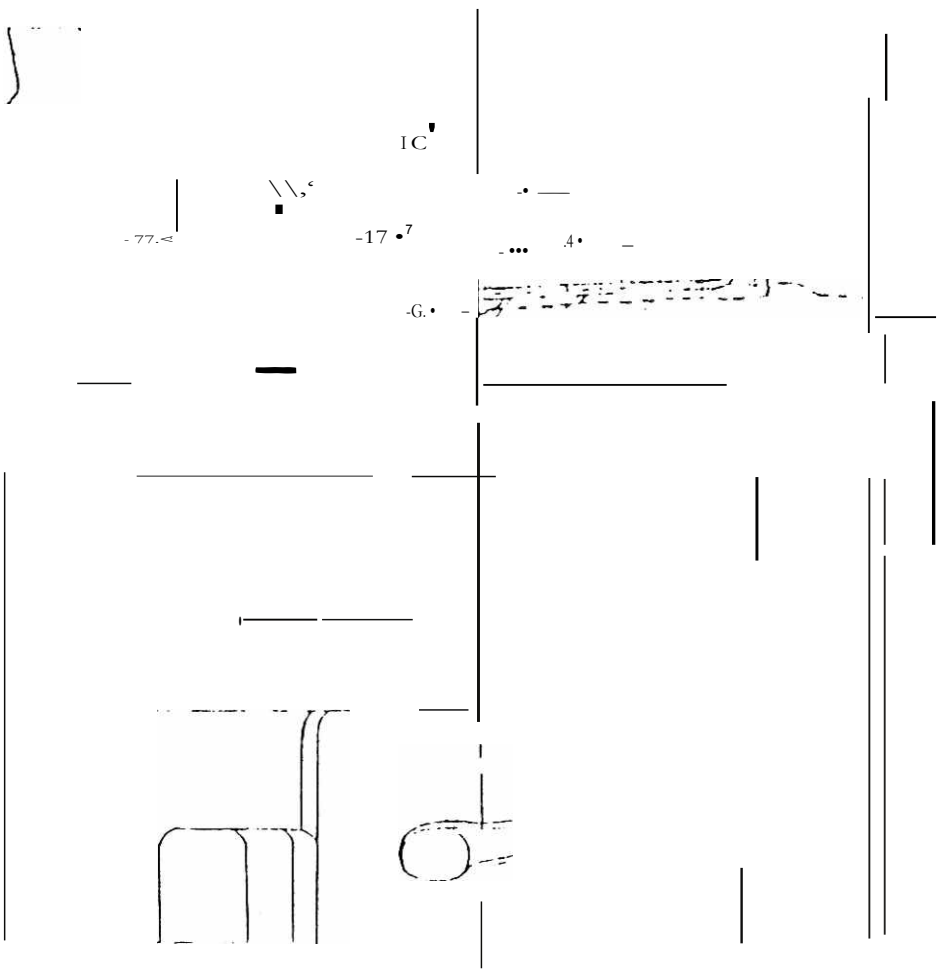

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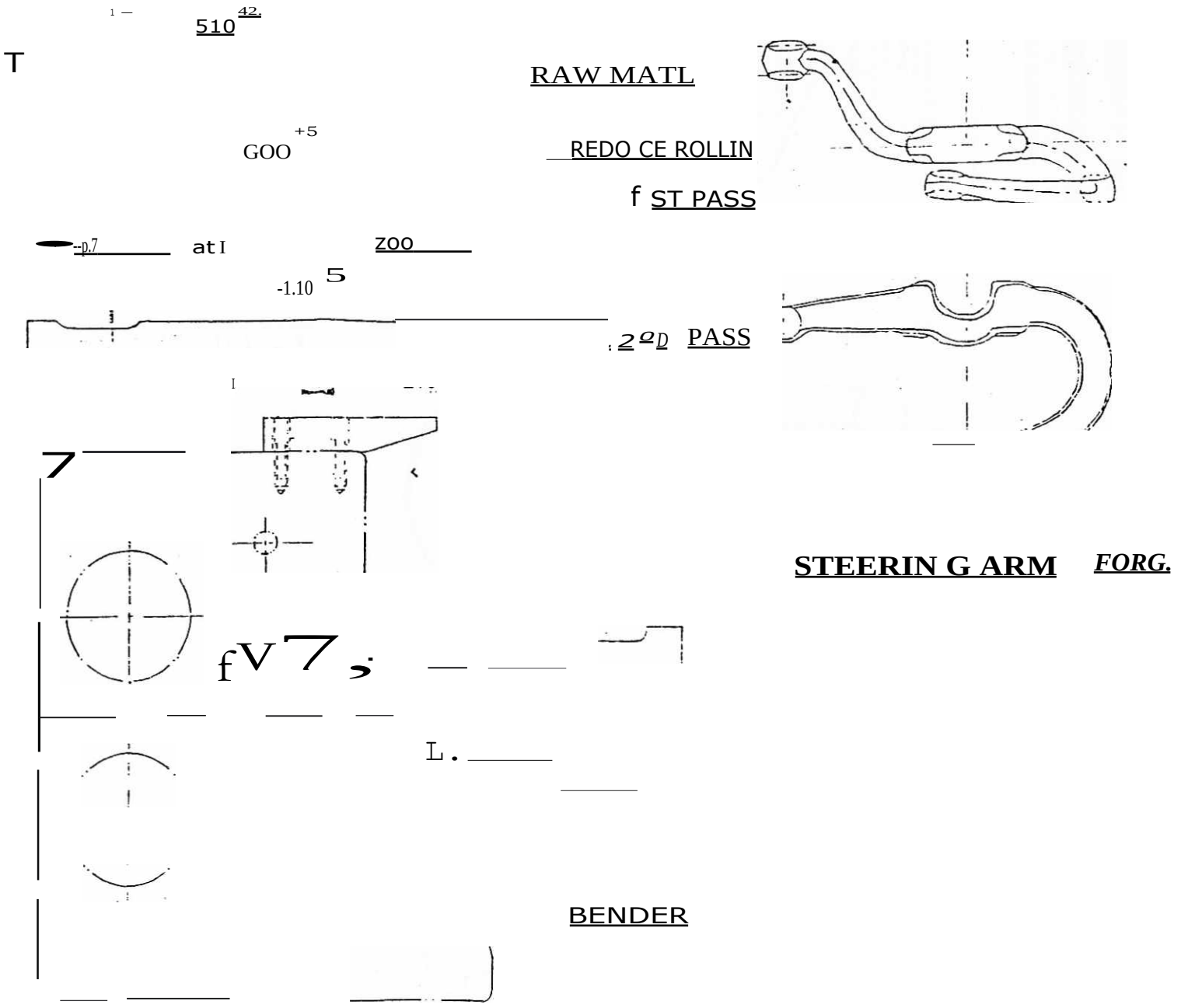
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FIG.21 (CO NM)

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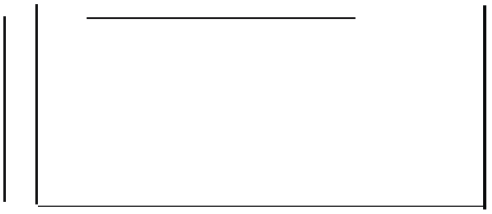

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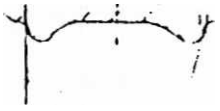

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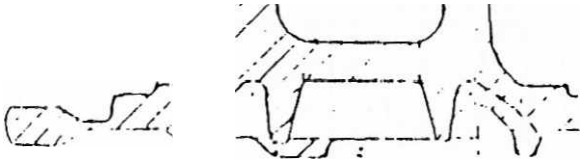

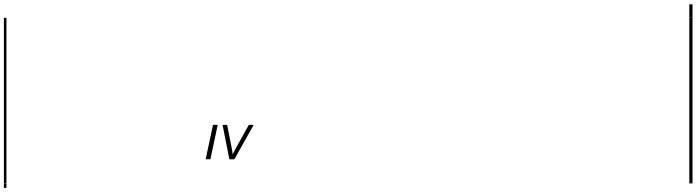

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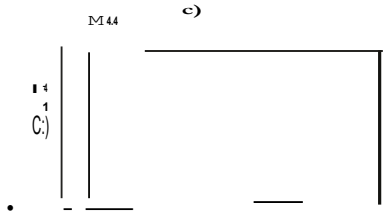

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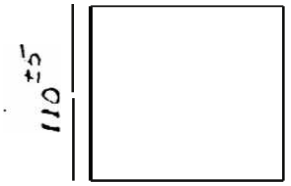

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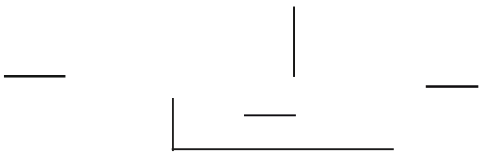

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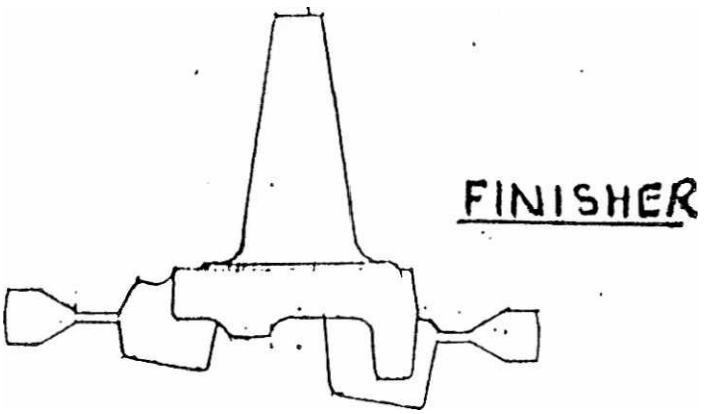

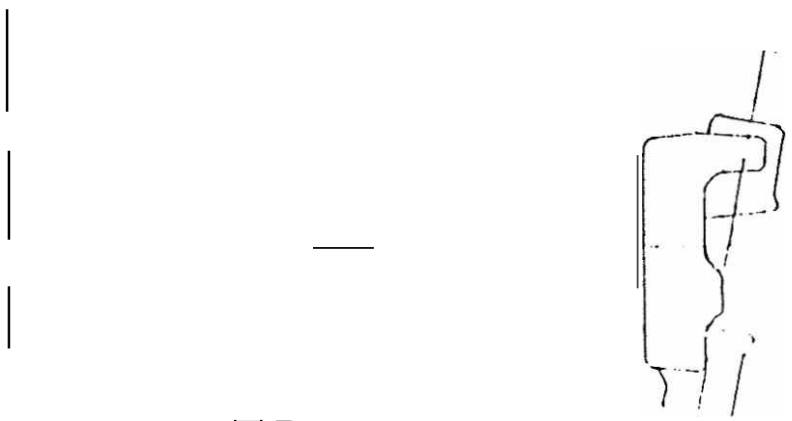

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FIG.24

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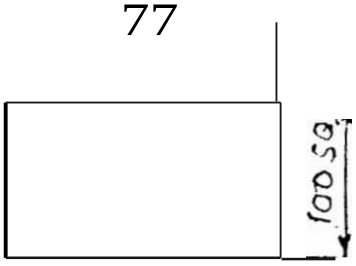

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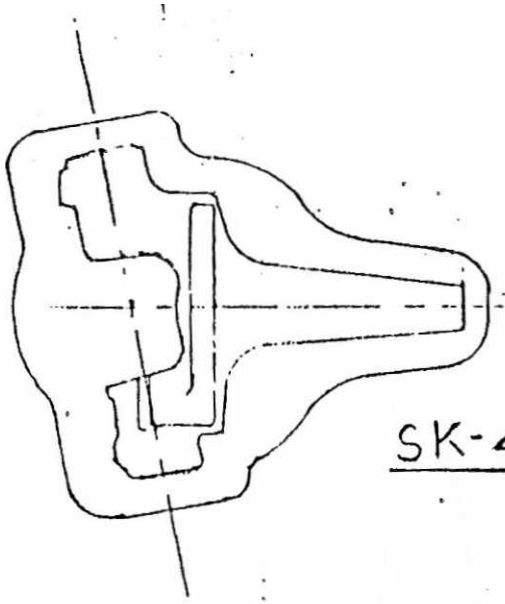

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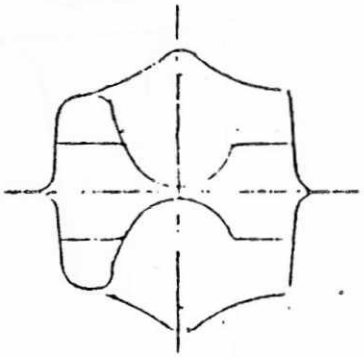

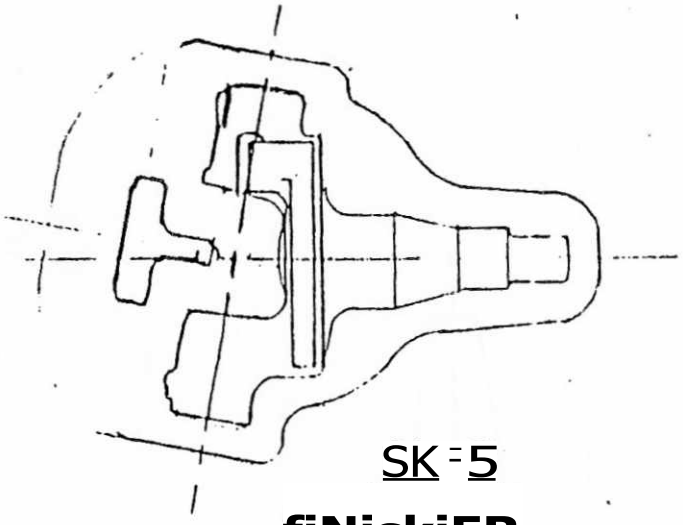

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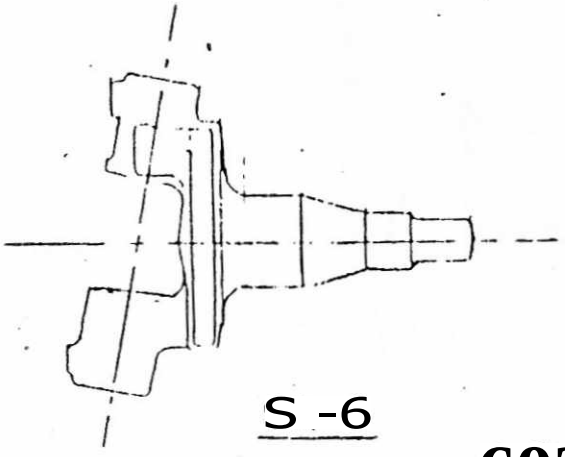

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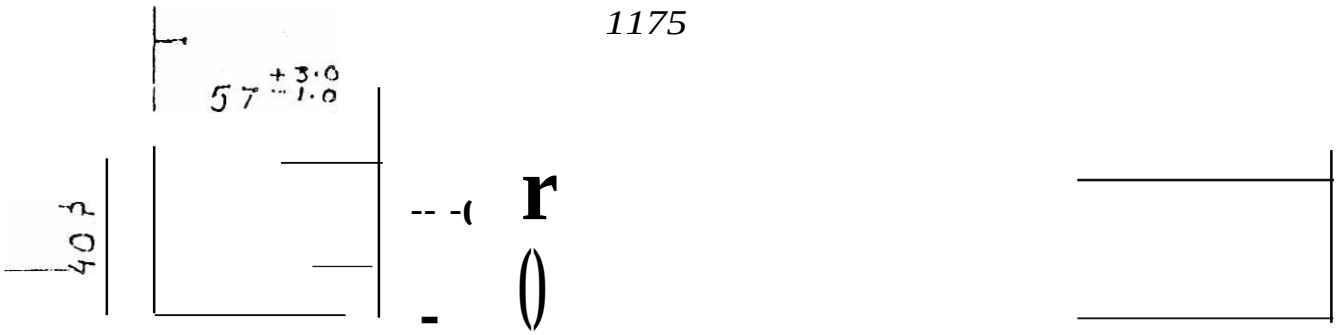

SPLINE END UPSETTING

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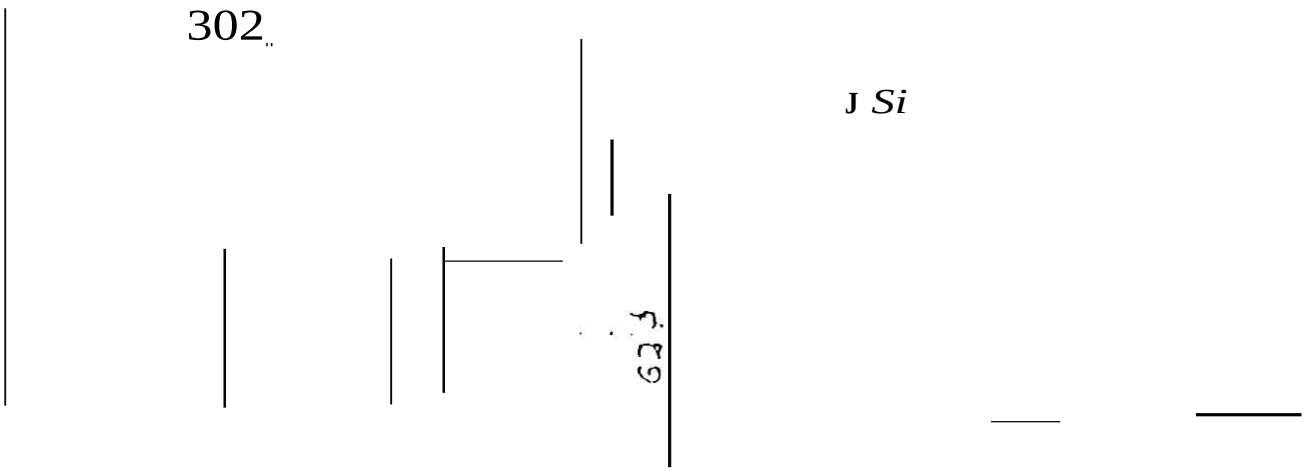

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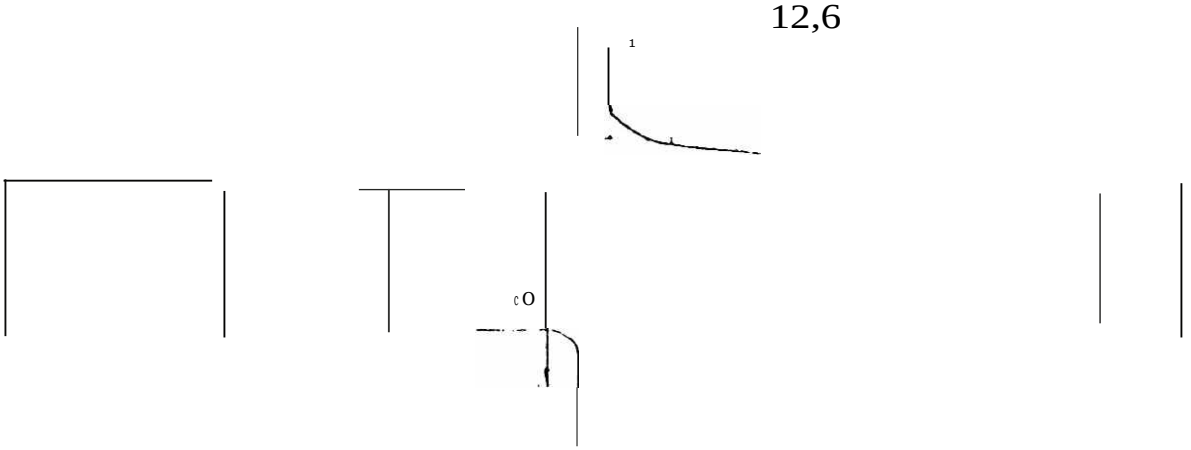

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FIG.25 2

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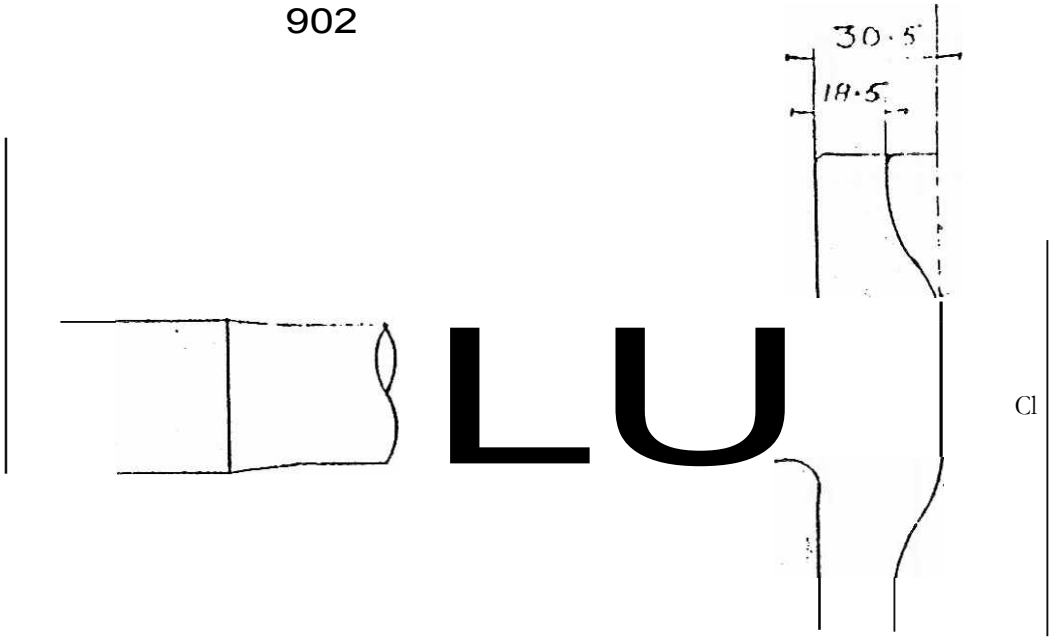

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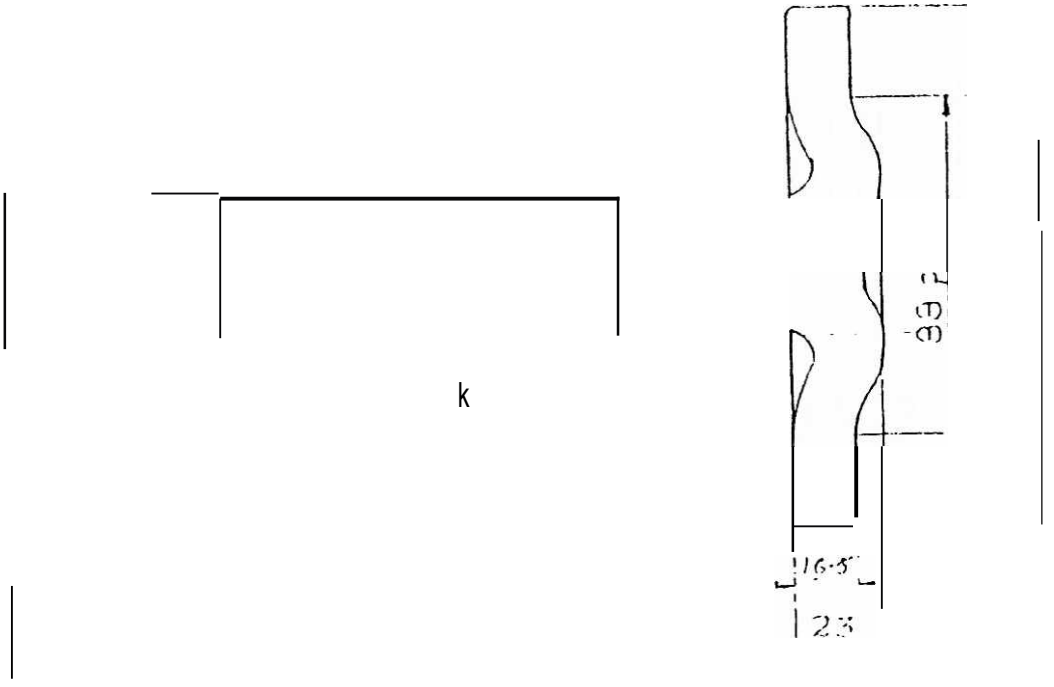

FINAL PASS **25** (CONTD.)