potteries. This called for quantities of little rolls of clay called wads, which were made with a wadmill. Such a mill was just a vertical pug with a multiple wad die on the end instead of a mouth cone. As the new handcraft interest was very much based on a desire for something small, this was an obvious answer, so wadmills were sold to these people and were renamed. For wad making the design is well suited, but for simple clay preparation it has some limitations. The first drawback arises when safety inspectors start demanding a grill to protect the operator's hands. Such a grill makes feeding very difficult without a force-feed device, but the grill itself makes it impossible to fit this. A force-feeding device can, however, be very easily fitted to a horizontal pug, with or without a safety grill. The second disadvantage arises from the difficulty of combining a cut-off table with the vertical delivery of the clay. Even to make a clean wire cut to remove the column of clay is difficult because the operator needs two hands to receive it. The column, therefore, has to be torn off leaving an end that is so mauled that it cannot be used on a lump cutting device. A column of clay flowing out horizontally is more easily controlled, and the cutting-off is simple.

A DE-AIRING PUG MILL

A photo of the de-airing pug mill described below is shown in Fig. 7.1. This was the second machine built to this design using the methods described here. A number of changes have been made since, notably regarding the breather plate in Fig. 7.14C which now has no moving parts. In the photo it shows a spring-loaded moving part on the ground which used to open and close once every revolution of the blade shaft. The lid of the vacuum chamber also shows wing nuts holding it down which were soon found to be unnecessary. Note the pair of shredding screens in the foreground. These are illustrated in Figs 7.14F and G.

Fig. 7.2 is of an exploded view of all the twenty-four non-moving parts in the outer casing. This exploded breakdown of the assembly is referred to repeatedly in the figures and text that follow.

Fig. 7.4 is the assembled machine seen both from above and from the side, together with the screen slot cover.

Fig. 7.5 deals with the blades and helices in detail and indicates the direction of rotation. In B and C of this figure, the end plates of one possible version of a gearbox are shown, together with a layout for two sets of 4:1 spur wheels in B.

The order of procedure for making the machine follows. In order to follow the steps more easily, look again at the exploded drawing of the twenty-four parts of the pug mill casing in Fig. 7.2. These parts will be welded together into four separate units of the finished pug mill as follows. The four circular flanges *d*, *k*, *m* and *n* will all be welded to the part on which they are mounted and bolted to the neighbouring part. In other words, *d* is welded to *e*, *k* and *m* are welded to *l* and *n* is welded to *o*. Other parts are also welded together in groups as follows: *a*, *b* and *c* are welded together to form a single unit; *d*, *e*, *f*, *g1*, *g2*, *h*, *i* and *j* are all welded together to form one unit; *k*, *l* and *m* make another unit; and finally *n*, *o* and *p* are welded together to form the mouth cone.

The whole structure behind plate *a*, and the size of *a* itself, depends on what

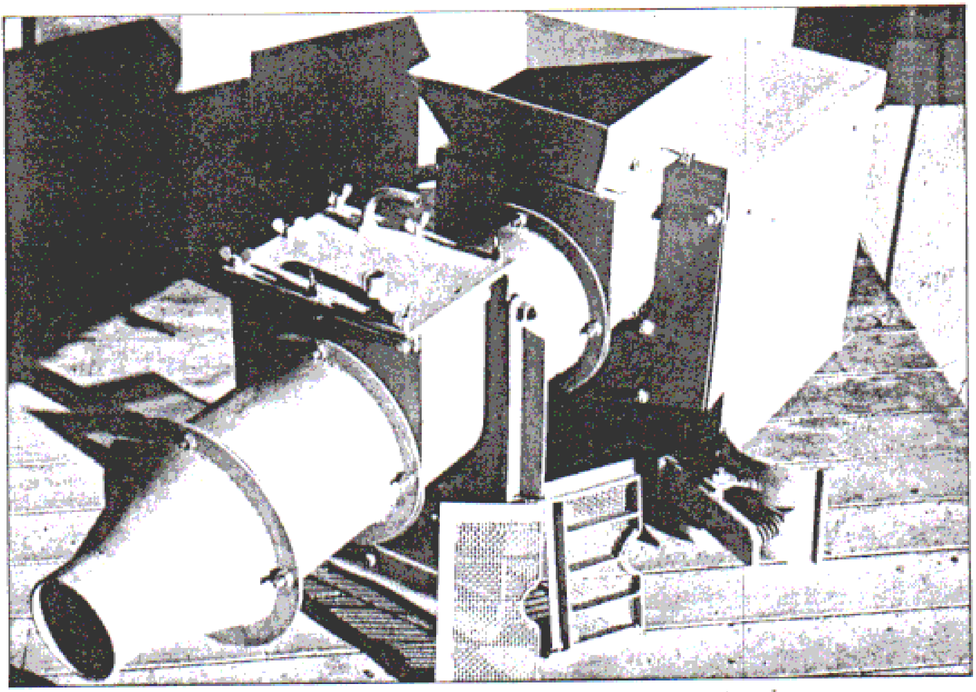


Fig. 7.1 The de-airing pug mill built for the Peru project using the alternative techniques described in Part II. In the foreground are the two shredding screens seen in Figs 7.14F and G. To the right is the breather valve later abandoned in favour of the simpler unit in Fig. 7.14C

type of gearbox is used. The layout shown in Fig. 7.4 was based on two sets of 4:1 spur wheels I happened to have at the time the machine was built. Other combinations of ratios would dictate a different layout, and a self-contained industrial gearbox would dictate yet another and require a chain and sprocket link instead of the spur wheels. Basically the problem can be resolved by anything that will bridge the gap between 1450 rpm at the motor (or whatever speed the prime mover has) and 15 to 30 rpm at the blade shaft of the pug.

SUGGESTIONS FOR MATERIALS

The specification list consists of small pieces of metal but not always as small as they may finally have to be. Whether one seeks out oddments of steel in a scrapyard or orders the list from a firm willing to cut them to order, there is an advantage in getting units that will yield several smaller ones, as this often makes further work on the pieces much easier. Very accurate and clean cutting can be done by the trepanning technique, but this can be difficult on large sheets, especially if one is working alone. Very small units, however, are difficult to hold. That is why it is better to buy one piece of steel 10½ in (263 mm) × 42 in (1050 mm), rather than four pieces 10½ in (263 mm) × 10½ in (263 mm) square, such as are needed to make the four flanges *d*, *k*, *m* and *n*. To take advantage of scrap steel prices one often has to be willing to accept pieces larger than one strictly needs, but even so the savings can be huge. Equally, it is often not possible to buy less than whole sheets or full length bars of flat-stock from a supplier of new steel. This can mean that one is forced to buy much more than one needs and the prices will be much higher. If oddments of scrap are not available one must shop around to find a firm that is willing to cut to order.

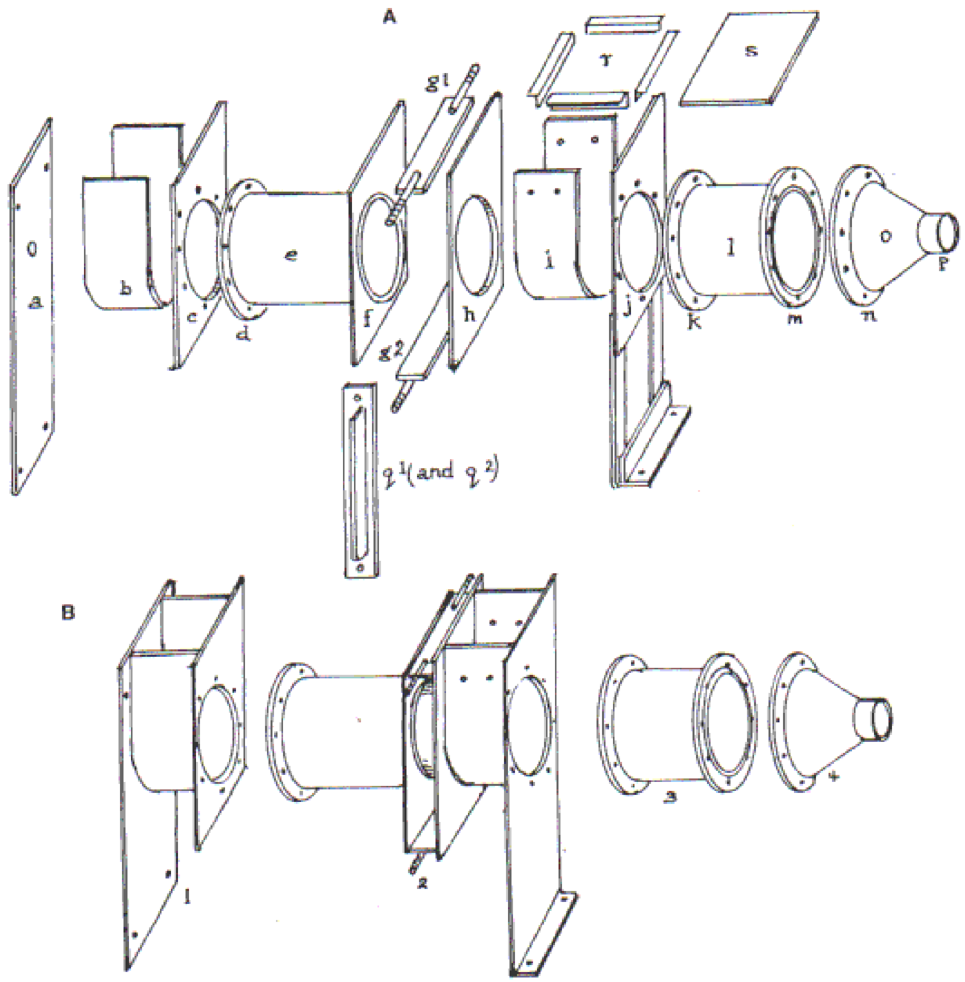


Fig. 7.2 The 24 parts of the pug mill casing

A *An exploded drawing of the parts of the casing. These parts are welded together forming four units shown in B below. The four pieces of angle iron marked r will also be welded to unit 2 in B but q and s remain as separate accessories*

B *The four assembled units after welding. They are grouped as follows: (1) a, b and c; (2) d, e, f, g1, g2, h, i and j; (3) k, l, and m; (4) n, o and p. Unit j is drawn here with the alternative design suggested in Fig. 7.3 marked j*

The blades can be taken from the 8¼ in (206 mm) discs which result when the flanges *d*, *k*, *m* and *n* are taken from the 10½ in (263 mm) × 10½ in (263 mm) squares (see below). These should be of 3/16 in (5 mm) plate and the flanges also need to be of heavier metal than the walls of the various chambers. One disc will yield three blades so three discs will give nine blades, leaving only one to be taken from the fourth. This calls for a single strip of plate 10½ in (263 mm) × 42 in (1050 mm).

A thickness of ⅛ in (3 mm) is adequate for those parts shaped by rolling; that is to say, *b*, *e*, *i*, *l* and *o*. The units *g1* and *g2* must be 3/16 in (5mm) in thickness by ⅞ in (22 mm) wide. It is essential to have *f*, *g1*, *g2* and *h* all exactly 10½ in (263 mm) wide. The flat vertical units *c*, *f*, *h* and *j* can also be of ⅛ in (3 mm) plate. Unit *a* is an integral part of the gearbox and rather large in area. I have used 3/16 in (5 mm) or even ¼ in (6 mm) for this. However, it could also be done in the ⅛ in (3 mm) plate and reinforced with some angle iron at the vertical edges and with some flat-stock where the pillow block bearing is attached. This depends on what gear wheels (spur wheels) are being used to make up the gearbox.

When in use the two *q* units are bolted on over rubber gaskets to guarantee an airtight seal. It is important, therefore, that they should have no flexibility. A 1¼ in (30 mm) width is needed to give slight overlap on *f* and *h* and the same would be suitable for the stiffening fin, using ¼ in (6 mm) thickness for both; *p* can be a 2 in (50 mm) length of 4 in (100 mm) pipe, or be rolled from a 12½ in (313 mm) length of 2 in (50 mm) flat-stock, ⅛ in (3 mm) or 3/16 in (5 mm) thick; and *r* consists of four pieces of ¾ in (19 mm) angle iron to form a rim for the vacuum chamber. This is seen in Fig. 7.14E and again at the top of Fig. 7.14B with a rubber seal and the cover plate *s* on top of that. Note that this rim and its lid are narrower than the unit *j* to which they are attached. Unit *j* has to be the standard 10½ in (263 mm) to accommodate the flanges. Fig. 7.14B shows two ways in which rim *r* can be adapted to unit *j*. Below is a list of sizes of materials required for the components shown in Fig. 7.2.

SPECIFICATIONS

- *a* — 22½ in (565 mm) × 10½ in (263 mm) of ¼ in (6 mm) plate or lighter if strengthened
- *b* and *i* — each 26¼ in (656 mm) × 6 in (150 mm) of ⅛ in (3 mm) plate
- *c* — 13 in (325 mm) × 10½ in (263 mm) of ⅛ in (3 mm) plate
- *d*, *k*, *m* and *n* — each ¼ in (6 mm) plate 10½ in (263 mm) × 10½ in (263 mm)
- *e* and *l* — each 25 in (625 mm) × 8 in (200 mm) of ⅛ in (3 mm) plate
- *f* — 10½ in (263 mm) × 10½ in (263 mm) of ⅛ in (3 mm) plate
- *g1* and *g2* — ⅞ in (22 mm) × 3/16 in (5 mm) of flat-stock 10½ in (263 mm) each
- *h* — 13 in (325 mm) × 10½ in (263 mm) of ⅛ in (3 mm) plate
- *j* — 13 in (325 mm) × 10½ in (263 mm) of ⅛ in (3 mm) plate plus 10½ in (263 mm) length of angle iron for the foot and two legs 9 in (225 mm) × 1½ in (38 mm) × 3/16 in (5 mm)
- *o* — one piece of ⅛ in (3 mm) plate 24 in (600 mm) × 11 in (275 mm) (see Part II chapter 19, Fig. 19.4 for details of how this size was arrived at)
- *p* — one piece of 4 in (100 mm) pipe 2 in (50 mm) long or a piece of 3/16 in (5 mm) × 2 in (50 mm) flat-stock to roll

q — the screen entry covers: two 12½ in (312 mm) lengths of 1¼ in (31 mm) × ¼ in (6 mm) flat-stock and two lengths of the same 10⅜ in (263 mm) long

r — 32 in (800 mm) of ¾ in (19 mm) × ¾ in (19 mm) angle iron for the rim of the vacuum chamber

s — one piece of ¼ in (6 mm) plate 10 in (250 mm) × 8 in (200 mm) for the vacuum chamber cover and a piece of flat smooth rubber the same size for the seal

In addition the following items are also needed.

Screen frames:	— 36 in (900 mm) of ¾ in (19 mm) × ¾ in (19 mm) angle iron
	— 40 in (1000 mm) of ¾ in (19 mm) × ⅛ in (3 mm) mild steel flat-stock for the fins that support the screen
	— $\frac{3}{16}$ in (5 mm) mesh in stainless steel 9 in (225 mm) × 9 in (225 mm) square
Half helices:	— 4 pieces 8⅝ in (219 mm) × 3¾ in (94 mm) of $\frac{3}{16}$ in (5 mm) plate or 1 sheet 8⅝ in (219 mm) × 15 in (375 mm) of the same
Blade shaft:	— 45 in (1143 mm) of 1½ in (38 mm) steel shaft
For the unit shown in Fig. 7.12B:	— 4 × 15¼ in (388 mm) lengths of 2 in (50 mm) angle iron
One plate for the end of the gearbox:	— shown in Fig. 7.5B. The size cannot be finalised until the gearing system has been settled. It can be of ⅛ in (3 mm) plate with suitable angle iron stiffeners (especially crosswise where the thrust bearing is situated) or it can be a single piece of heavier plate of ¼ in (6 mm) or ⅜ in (9 mm) thickness.

Two shafts and four bearings in the gearbox shown in Fig. 7.4B are not included in this list because of the options that may present themselves. However, if a reduction gearbox and chain drive is not used, four ball bearings of the type shown in Part II, chapter 17, Fig. 17.3D, together with housings, either of the type shown or made up with wood and angle iron, as shown in Fig. 7.9, will be needed. As the shafts are short, everything could be smaller than indicated in Fig. 7.4B, including the diameter of the shafts (though less than 1 in (25 mm) would not be advisable). The pillow block bearing and thrust bearing on the blade shaft will need to be acquired also, used or new.

CUTTING-OUT PROCEDURE

Fig. 7.2 indicates the 24 pieces that have to be shaped and later assembled and welded into four final units. Fig. 7.3 shows what these pieces look like at the start. All start as rectangles and acquire their special shape by trepanning and rolling.

Fig. 7.3B gives an idea how the pieces might be cut from half a standard sheet of ⅛ in (3 mm) steel plate. This involves 16 sq. ft (1.5 sq. m) but they could be cut from several oddments of that thickness from a used steel scrapyard. To buy new metal would cost a great deal more and one would be obliged to buy a full 8 ft (2400 mm) × 4 ft (1200 mm) sheet. If one cannot find a scrapyard one would have to find a workshop where cutting to order is acceptable. In that case it might be worthwhile having the 24 pieces cut to size.

Cutting with the straight trepanner: If the alternative technology described in Part II, chapter 18 is used, most of the cutting would be done with the trepanning tools in Figs 18.9 and 18.10. Some of the narrower strips, and the shorter cuts across them, could be done to advantage with the cutting disc, illustrated in Fig. 21.9. If this tool is used, allowance must be made for the greater thickness of the cut which can be as much as ⅛ in (3 mm). To do this, as shown in Fig. 21.9 presupposes that the guide on the saw bench offers 10½ in (263 mm) between the disc and the guide. However, with a number of cuts to make, it would be worthwhile making up the frame shown in Fig. 21.10E. With this almost all the incisions across longish strips could be done much more quickly; but if this is intended, a loss of ⅛ in (3 mm) of metal with each cut must be allowed for in marking out the original pieces. In any case one of the straight trepanning tools would have to be used to separate the longer strips indicated in Fig. 7.3. For instance, if one were to commence with the unit *o* and trepan its curves with the pilot hole in the waste bit alongside, the strip containing *a* and *j* could be removed by trepanning and fatiguing along the line *p–q*. Then *o* could be removed by working on the *y–z* line. This would leave the line *u–r* free for trepanning and separation. With units *f*, *h* and *c* out of the way the line *s–t* could be tackled leaving only the units *i*, *l* and *e* to be separated from each other. Unit *b* could be separated by trepanning *w–x*. All the small waste bits left attached to these various pieces could be quickly removed with the cutting disc by the method shown in Part II, chapter 21, Fig. 21.9.

Turning now to Fig. 7.3B, we see that an oddment of 3/16 in (5 mm) or ¼ in (6 mm) plate 36½ in (913 mm) × 22½ in (563 mm) suffices for almost all the rest of the casing, plus the blades and the half helices. The obvious first thing to do with this sheet is to divide it down the middle, but as with the strip on the other sheet, containing units *f*, *h* and *c*, the cross incisions may be made (both sides of course) without separating the units from each other until the circular trepanning has been done. Note again that the ½ in (13 mm) pilot holes for trepanning the four half helices have been arranged to fall in a waste strip.

Circular trepanning: In Fig. 7.3 14 pieces need to have circles trepanned. Units *a*, *j*, *h* and *c* have their circles with the centre 7 in (175 mm) from one end. Units *d*, *k*, *m*, *n*, and *f* have their centres marked where the diagonal lines cross. Start by carefully marking the centres of these 9 parts and punching deeply with a centre punch. They can then be drilled with the standard ½ in (13 mm) pilot hole. In the case of *o* the location for its centre lies in waste metal and must be derived using the technique referred to in Part II, chapter 19, Fig. 19.4. See also the text that follows on the mouth cone. In the case of the four half helices, the technique for locating their centres (also in waste metal) is discussed further under the section headed 'The Helices' below.

The small trepanner shown in Part II Fig. 18.1 together with the beam drill in

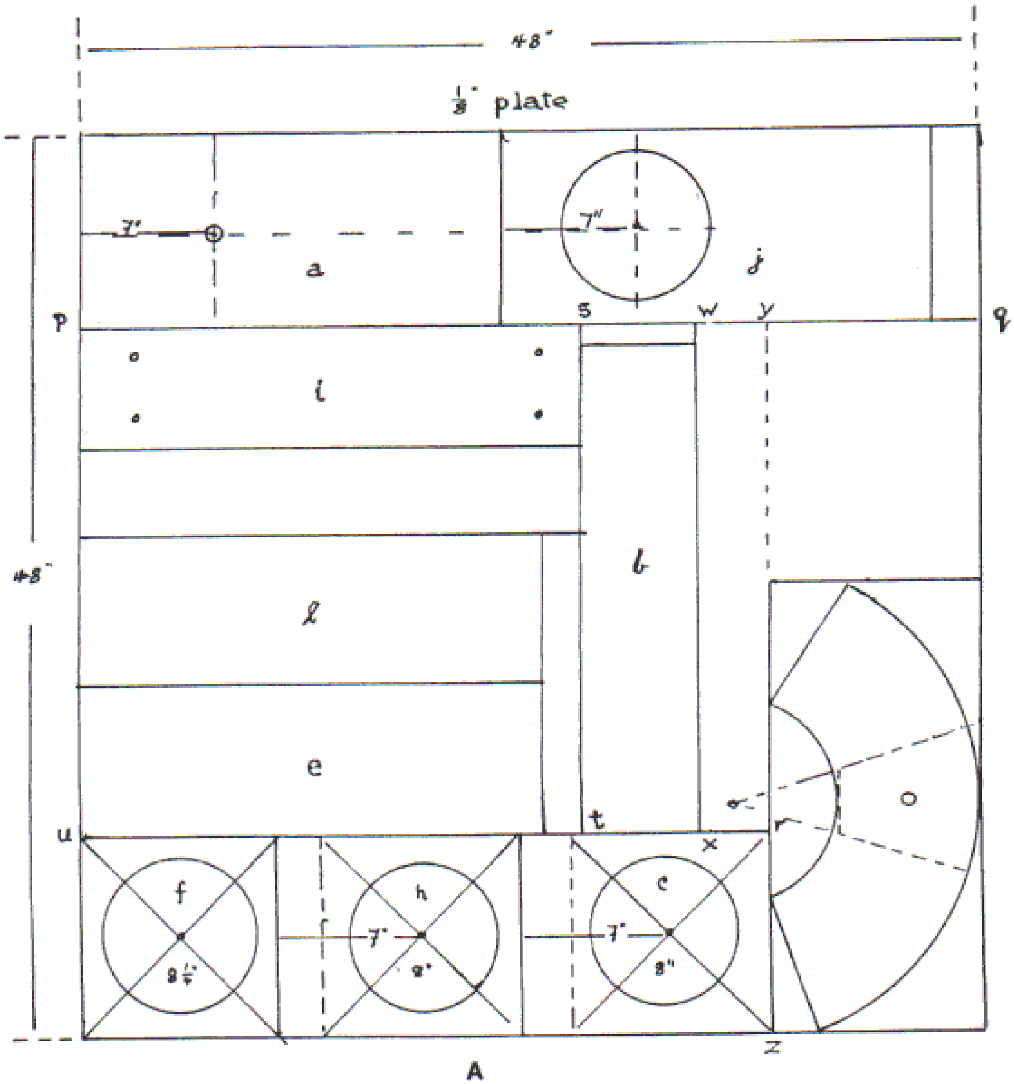


Fig. 20.2, should be used for the $1\frac{11}{16}$ in (42 mm) circles in *d*, *k*, *m* and *n*, for the $1\frac{1}{2}$ in (38 mm) hole in *a* and for the inner curve of the helices. A further circle in *d*, *k*, *m* and *n* should be very lightly scratched measuring $1\frac{1}{2}$ in (38 mm). This is not a proper trepanning incision but merely serves to draw the straight sides of the blades later by drawing lines tangentially from this circle (see Fig. 7.6).

The large trepanner should then be used for the big circles in *j*, *f*, *h*, *c*, *d*, *k*, *m* and *n*. The blades will later be taken out of the spare discs left from cutting the flanges *d*, *k*, *m* and *n*. As these discs are slightly too large ($8\frac{1}{4}$ in [206 mm]) for the blades a further circle should be lightly trepanned in each of *d*, *k*, *m* and *n* having a diameter of $7\frac{3}{4}$ in (194 mm). This circle will then form the outside edge of the blades seen in Fig. 7.6.

Nothing should be done about fatiguing out these discs and rings as yet. First, the centre holes for *o* and for the four half helices have to be located, punched, and a $\frac{1}{2}$ in (13 mm) pilot hole drilled. Then the mouth cone *o* should have its two large

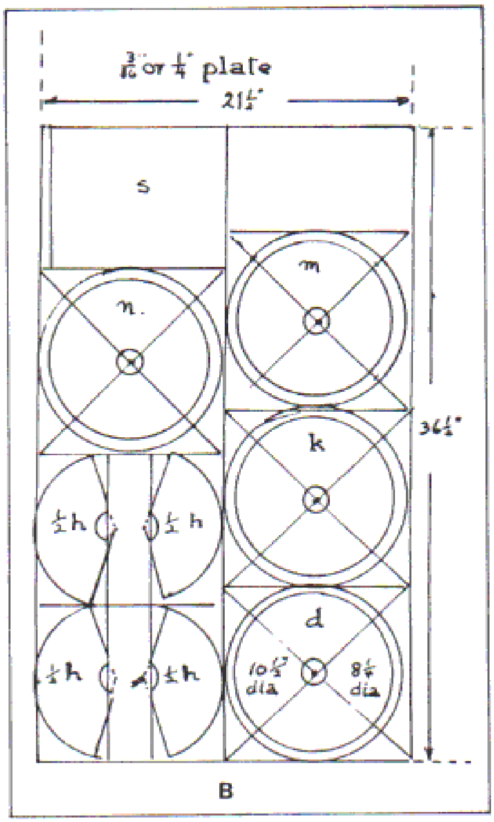


Fig. 7.3 Cutting out the parts

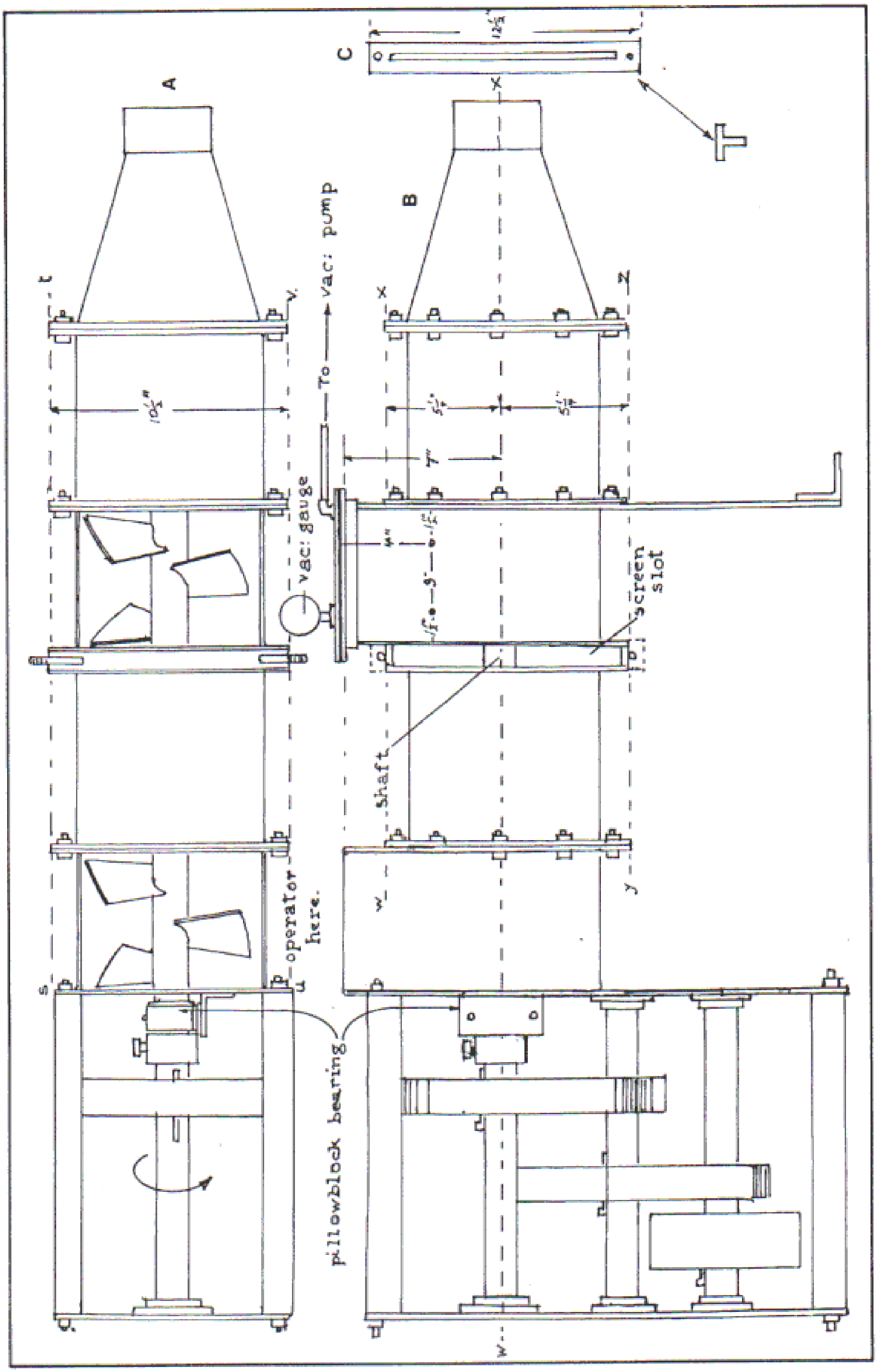
A A suggested layout for cutting up a 48 in (1200 mm) × 48 in (1200 mm) sheet of 1/8 in (3 mm) steel sheet to the best advantage. For details on the correct order to remove the pieces see the text

B A suggested way of dividing an oddment of 3/16 in (5 mm) sheet steel to yield four flanges and four discs (for blades), four half helices and a lid for the vacuum chamber

semi-circles incised with the large trepanner and the half helices should have their outer circles similarly incised.

When all this is done, all the discs and rings can be fatigued out as described below. The hole in unit *a* is the only exception; it should be punched out using the technique described in Part II, chapter 18, Fig. 18.7.

Rolling: Rolling is discussed in Part II, chapter 19, and is only needed on units *b*, *i*, *e*, *l* and *o*, plus *p*, unless a piece of 4 in (100 mm) pipe is used for the end of the mouth cone. Note that unit *i* requires four 3/8 in (9 mm) holes for attaching the breather plate, to be drilled before rolling. This is the moment to drill them, and their positions are shown on the $x-y$ line in Figs 7.14B and H. Units *i* and *b* have to be rolled to a semicircle at their centres. The rolling is started at the halfway point and continued back and forth until the U-form has been achieved. Units *e*, *l* and *o* are cases of simple full circle rolling. See Part II, chapter 19.


A
B
C
To vac: pump
vac: gauge
screen slot
shaft
operator here.
pillowblock bearing