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The construction, installation and operation of an improved
pit-kiln for charcoal production

By: A.R. Paddon

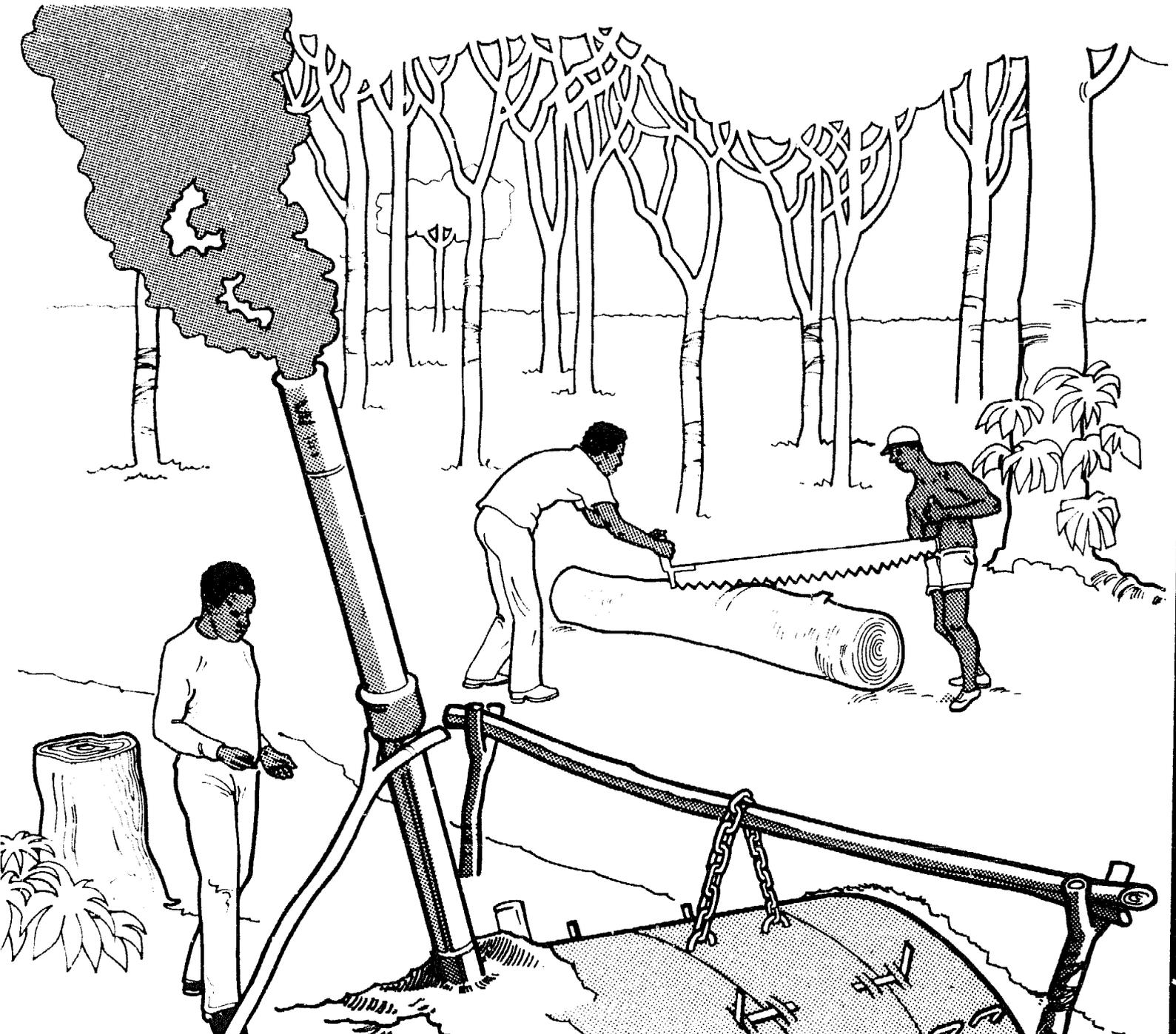
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The construction, installation and operation of an improved pit-kiln for charcoal production



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A R Paddon

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Introduction

This guide describes how to construct, install and operate a charcoal kiln by digging a pit and using a cover made with metal sheets. The kiln is particularly suitable for operations in rural areas where local charcoal makers have only a small amount of capital to invest and where a plentiful supply of wood is available near the kiln. It will produce charcoal more quickly and efficiently than the traditional pit and earth clamp methods.

The kiln should only be used in areas where there is sufficient wood for at least 2 months' continuous operation in order to justify the effort of digging the pit. The method should not be used in rocky areas where digging the pit would be both difficult and excessively time consuming. Under these conditions and where the extra capital investment can be arranged, the Tropical Development and Research Institute recommends the use of a transportable metal kiln. Instructions for the construction and operation of the TDRI transportable metal kiln are given in Rural Technology Guides 12 and 13.

Description of the kiln

The kiln holds around 8 cubic metres of stacked wood, most of which is contained in a rectangular pit dug in the ground to a depth of about 1.8 metres. It will produce up to 1 tonne of charcoal during its 5–6 day operation.

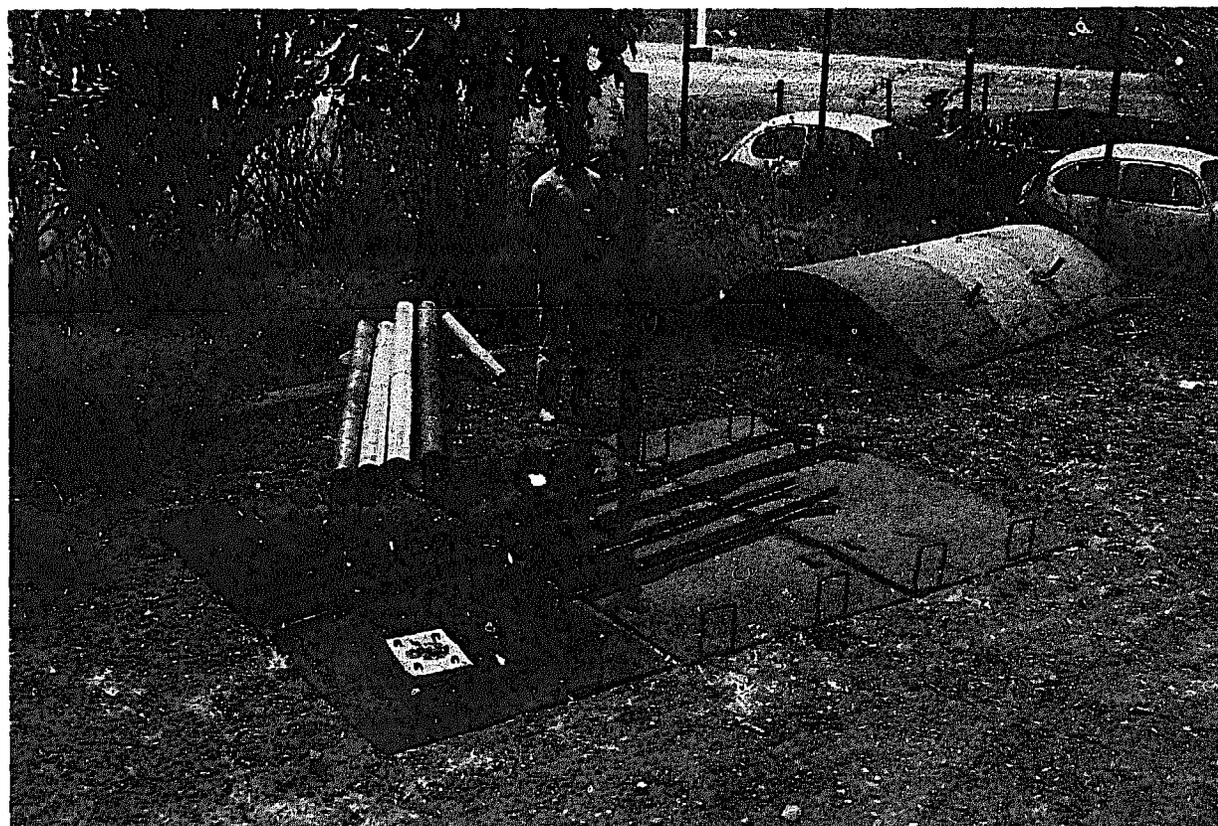
The cover of the kiln is formed using three overlapping stock-sized mild-steel sheets, sprung into an angle-iron framework surrounding the top edges of the pit. The open ends of the cover are blocked up with mud.

Metal tubes are set into the walls of the pit to provide 3 air inlets, 1 smoke outlet, and a steam-release vent to assist lighting. A constructional drawing of the kiln is shown in Figure 1 (enclosed in the back cover).



List of materials required for the construction of the metal cover and inlet/outlet tubes

Material	Size	Quantity
Angle-iron for frame	40 × 40 × 5 mm	12.2 m
Mild-steel covering sheets	2 440 × 1 220 × 1.5 mm	3
Flat mild-steel or galvanised steel sheet for making tubes and plugs	2 440 × 1 220 × 1.0 mm	2
Flat mild-steel bar for making slide bolts and slots to secure metal covering sheets and for clips to secure angle-iron framework	40 × 4 mm	3 m
Round mild-steel bar for making handles and hooks for metal covering sheets	12 mm diameter	3 m
Mild-steel bolts or short pieces of rod for assembly of angle-iron frame and for welding on to the upper lip of the framework to retain the sprung metal sheets	30 × 12 mm diameter	20
Steel chain to support central metal sheet	2 m	1



Making the frame

The rectangular angle-iron frame is used to keep the metal sheets of the cover in position.

Make up the frame with two pieces of 40 mm steel angle each 3 660 mm long, and two pieces each 2 120 mm long. Weld 150 mm lengths of angle, arranged at 90° to each end of the two longest sides so that the angle-iron framework can be firmly clipped together when used. Provide an arrangement of studs and holes at each corner to ensure a secure assembly. Code-mark the joints so that the frame will always be reassembled in the correct way.

Place the assembled frame on level ground and insert a metal stake into the ground halfway along the outside edge of each of the two longest sides of the rectangle. This will prevent distortion of the frame when the mild-steel sheets are sprung into place.

Making the metal cover

Insert the first mild-steel sheet into the frame halfway along its length. Locate the remaining two sheets at each end of the framework allowing the inner edges of each end sheet to overlap the centre sheet by 50 mm.

Weld a set of two handles on both ends of each sheet and weld on the 4 slide-bolt assemblies used to clip the sheets firmly together as shown in Figure 1. Make the slots large enough to ensure that the bolts can slide easily in and out, allowing for the formation of rust with prolonged use.

To prevent the metal sheets from springing out of the angle-iron frame, weld six metal bolts or short pieces of rod (30 mm long × 12 mm diameter) to the top edges of each of the longest sides of the frame. Weld corresponding reference marks on the top faces of the metal sheets so that when re-assembled the correct positioning can be assured.



Finally, weld two brackets onto the middle of the centre sheet so that a length of chain may be attached to support the centre of the metal cover during the operation of the kiln.

Making the air inlet/ smoke outlet tubes and plugs

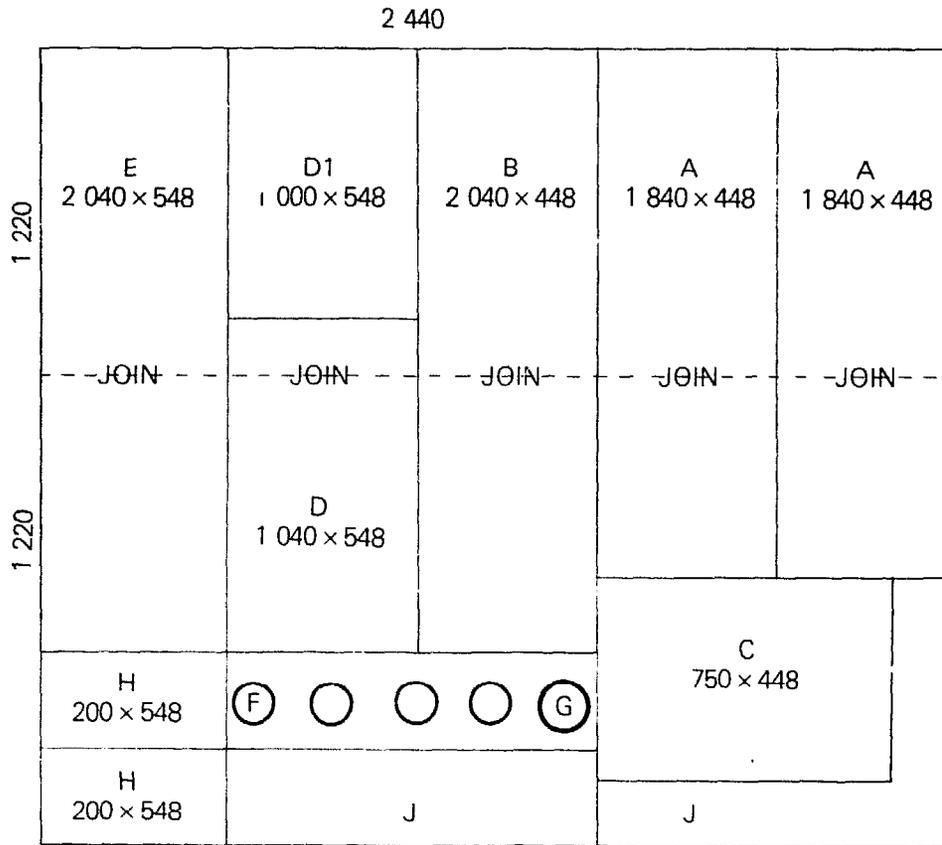
Make the tubes and plugs from two stock-size 2 440 mm x 1 220 mm x 1.0 mm thick steel sheets as shown in the cutting plan on p. 5. If available, flat galvanised steel sheets may be used. Do not weld galvanised steel as the fumes produced are hazardous to health. Always use hammered seams or bolts and rivets for joining this material.

The three air inlet tubes and the short steam release tube are all 130 mm diameter and are formed from 448 mm wide strips of metal sheet by carefully hammering them into shape around a suitable former (e.g. a scrap drive shaft from a truck or a straight wooden pole). The seams along the length of the tubes are welded or suitably flanged by bending and interlocking the edges of the metal sheet and hammering tightly as shown in Figure 1. The smoke outlet tube and the two extension tubes which form the chimney are all 160 mm diameter. These are formed from 548 mm wide strips of metal sheet. Join shorter lengths of tubes together to obtain the required lengths.

Weld bolt or rivet a 200 mm wide strip of metal sheet around the outside of one end of the smoke outlet tube and also at the end of one of the chimney extension tubes. This provides a means of joining these tubes together to form the complete chimney assembly during the operation of the kiln.

To make the plugs, cut out 4 discs each 120 mm in diameter and one 150 mm diameter disc. On the top surface of each of these discs secure three metal strips 20 mm wide and 120 mm long at equal distances around the circumference. Shape the metal strips to enable the discs to be suspended inside the top ends of the inlet/outlet tubes to support the mud used to seal the ends of the tubes during the operation of the kiln.

Cutting plan



(All dimensions include an extra 40 mm where necessary for forming seams)

Reference	No. off	Description and size
A	2	Air inlet tube approximately 1 800 mm long x 130 diameter
B	1	Air inlet tube approximately 2 000 mm long x 130 diameter
C	1	Steam release tube approximately 750 mm long x 130 diameter
D	2	Chimney extension tube approximately 1 000 mm long x 160 diameter
E	1	Smoke outlet tube approximately 2 000 mm long x 160 diameter
F	4	Insert plugs 120 mm diameter
G	1	Insert plug 150 mm diameter
H	2	Connector collars for references D1 and E
J	—	Spare material for other requirements.

Kiln installation

Selecting the kiln site

Choose an area with deep firm soil as close as possible to a plentiful supply of timber. At least 70 stacked cubic metres of useable wood should be available at each kiln site to justify the installation.

On sloping ground, arrange for the chimney end of the kiln to be at the highest point. A supply of water is required at the site for mixing the mud used in the kiln's construction and for quenching any small fires which may occur whilst unloading the charcoal.

To avoid flooding make sure that the maximum height of the water table at the site is below the proposed level of the bottom of the pit.

Digging the pit

Clear surface growth and forest debris from an

Inserting the metal tubes

Dig out the four recess channels half-way along each of the four walls of the pit. Remove sufficient soil so that the metal tubes can be inserted into the channels with the base of the tubes in line with the bottom perimeter of the pit and the top of the tubes protruding above ground level at a point about 30 cm outside the angle-iron framework.



With the four metal tubes in position, fill in the channels with a mud plaster until the original line of the pit wall is retained.



Repair any damage to the perimeter of the top of the pit with mud, and insert a firm layer of soil underneath the angle-iron framework to support the frame about 3-4 cm above ground level.



Building the end walls

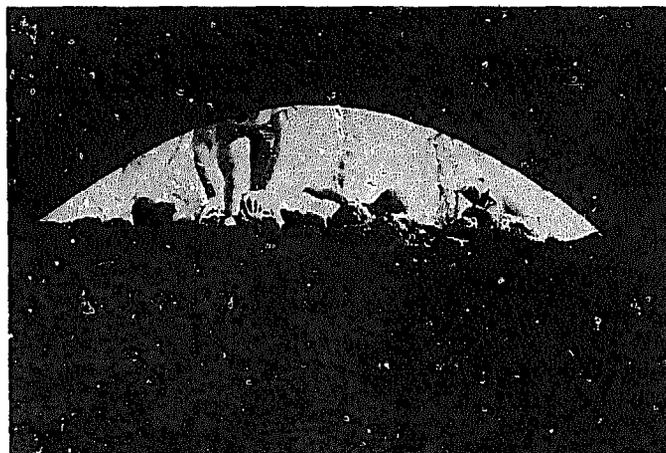
Insert the two metal end sheets into position within the angle-iron framework.



Build up the two end walls with mud and rock to fill in the spaces between ground level and the curved ends of the sheets. Insert the short steam-release tube when building the mud wall at the chimney end of the kiln. The outer edges of the end sheets must overlap the mud walls by at least 10 cm.



The final construction of the end walls of the kiln is achieved by the builder plastering with mud from inside the kiln.



Allow the kiln to dry out before use. Any cracks in the mud plaster which appear during this period should be plastered over.

Dig sufficient drainage channels around the kiln to prevent surface water from entering the kiln during periods of heavy rain.

Keep the metal sheets on the kiln when the unit is not being used.



Tools required for kiln operation

Item	Quantity	Purpose
Chainsaw and spares	1	Timber preparation
Cross-cut saw*	1	Timber preparation
Bow saw*	1	Timber preparation
Axe*	2	Timber preparation
Machete	2	Timber preparation
Wedge	2	Splitting oversize timber
Sledgehammer	1	Splitting oversize timber
Shovel	2	Unloading charcoal
Spade	2	Digging pit
Pickaxe	1	Digging pit
Bucket	2	Carrying water for mixing mud and quenching hot spots
Sieve	2	Separating larger pieces of charcoal from dust and fines
Flat file	1	For sharpening wood preparation tools

*When cutting wood by hand

Kiln operation

Preparation of the wood

Experience has shown that the size of timber used in the pit kiln affects the performance of the process. The following instructions should be used as a guide to the size of the feedstock needed to give the best results. Larger sizes than those suggested will result in prolonging the carbonisation time and could affect the quality of the product.

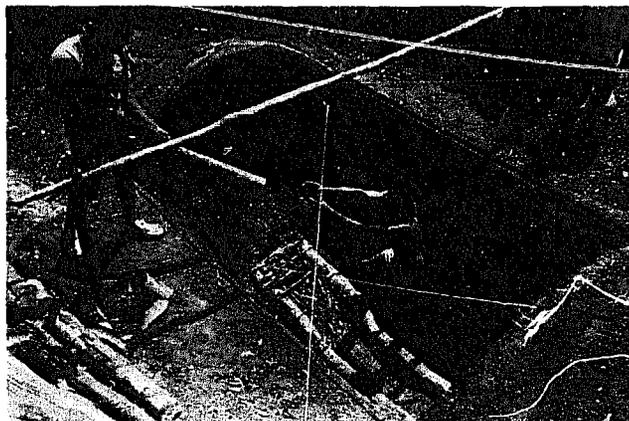
The timber should be cut to a maximum length of 1.5 m. Wood with a diameter greater than 15 cm should not exceed 1 m in length. Wood with a diameter greater than 25 cm should be less than 0.5 m long, and billets more than 30 cm in diameter should be split.

If possible stack and air-dry freshly felled wood for at least 6 weeks before use. This will reduce the burning period and increase the yield.

Loading the kiln

Lay two lines of 'stringers' – medium diameter (15 cm) lengths of wood laid end to end – along the floor of the kiln to support the charge and allow the free flow of gases underneath the wood. Take care that the bottoms of the 4 metal tubes are completely free from obstruction.

Using easily ignitable material, lay kindling for a fire around the base of the pipe opposite the chimney end of the kiln. This will be lit by dropping hot coals down the inlet pipe after the kiln has been loaded.



Lay small-to-medium diameter wood across the stringers to form the first layer of the charge.



Load the remainder of the wood making sure that the larger diameter billets are placed in the centre of the kiln. Fill in the sides of the kiln and any holes between the larger billets with smaller wood so that the maximum amount of wood is packed in.



When the kiln is filled to ground level, place the metal sheet nearest the chimney end in position and pack the space underneath with small-diameter wood.



Next, place the centre sheet in position and fill the space beneath with wood.

Finally, fill with wood the space below where the third sheet will fit and place the third sheet in position. Do not distort the cover by forcing the sheet down on any protruding billets of wood. Make sure that the centre sheet is positioned underneath the edges of the two end sheets with an overlap of 5 cm.

Support the centre sheet by hanging it from a wooden pole arranged across the centre of the kiln with a length of chain.

Secure the 3 metal sheets to each other using the sliding metal bolts.



Lighting the kiln

Open all the inlet and outlet tubes. Feed hot coals down the air inlet tube opposite the chimney end of the kiln to light the kindling material. The smoke produced will escape to the outside through the short steam-release tube in the mud wall at the top of the opposite end of the kiln.

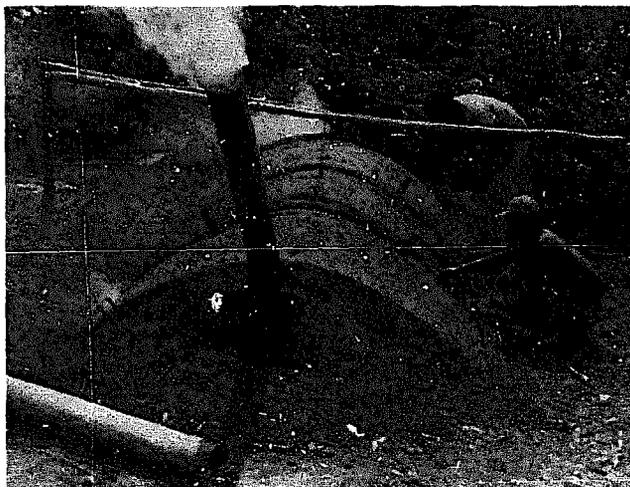


During the lighting stage, seal the edges of the overlapping joints of the metal cover with soil. Apply soil also to the edges of the metal sheets overlapping the mud walls at each end of the kiln and along the sides of the kiln where the cover is held in place by the angle-iron framework.

In wet conditions, or when a strong wind is blowing, place one of the chimney extension tubes over the end of the steam release tube to assist the 'draw' of smoke out of the kiln.



After a period of 1 or 2 hours, the end of the kiln opposite the chimney should be well alight. A drop of water applied to the cover in that area will evaporate with a hissing noise. Thick smoke and steam will leave the kiln through the steam-release tube at considerable pressure.



When this stage is reached, assemble the two extension tubes onto the chimney and seal the steam-release tube with one of the plugs provided. The smoke will be forced to the bottom of the kiln and up through the chimney assembly.



Carbonising the wood

Carbonisation is usually completed in about 48 hours. The amount of air entering each of the 3 inlet tubes during this period can be regulated by partially covering the ends of the tubes with the metal sealing plugs. If there is a strong prevailing wind, it may be necessary to reduce the amount of air entering the windward side of the kiln. Any cracks or joints releasing smoke during the carbonisation period should be sealed with mud or soil.

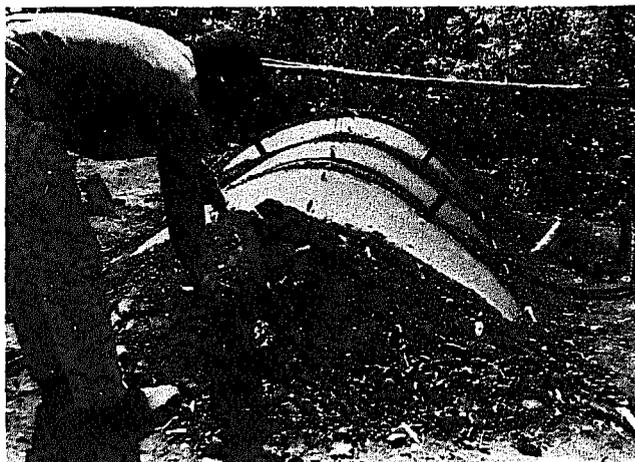
The fire in the charge will move steadily from the lighting end of the kiln towards the chimney.

Seal the air-inlet tube opposite the chimney end (i.e. the lighting tube) when fire can be seen through the air-inlet tubes situated half-way along the kiln's length. This prevents further air entering that area of the kiln where the charcoal has already been produced.

At the end of the carbonisation period the smoke leaving the kiln will be very hot, so that drops of water applied to the surface of the chimney extension tubes will evaporate with a hissing noise. The smoke will also become thin and almost transparent, with a bluish colour. This indicates that all the wood in the kiln has been converted to charcoal.



At this stage, remove the chimney extension tubes using a pair of heat-proof gloves, and seal the kiln completely.



Sealing and cooling the kiln

Seal all the metal inlet and outlet tubes by inserting the metal plugs and filling the tops of the tubes with wet mud. Cover all seams and joints with fine soil to prevent leaks. Check also the area around the edge of the kiln for leaks and seal any cracks or holes with mud and fine soil.

When the air supply to the kiln is cut off, the charcoal will cool rapidly by releasing its heat through the metal cover of the kiln. The rate of cooling may be increased by humidifying the atmosphere inside the kiln. This is done preferably on the day after the kiln is first sealed. It is achieved by pouring about a quarter of a bucketful of water down each of the air inlet tubes and quickly resealing the tubes with mud.

After 3 days, the contents of the kiln should be cold, providing that it has been sealed properly. This can be checked by feeling the metal cover with a bare hand early in the morning before the heat from the sun exceeds and obscures any heat remaining in the kiln.

If the kiln has not cooled after 3 days, then efficient sealing has not been achieved. The kiln should then be checked once more for leaks and a further cooling period given.

Before breaking the seal of the kiln, make sure that the contents are cold and that all tools, sacks and labour are at hand. Once the kiln is opened, the charcoal must be removed quickly, as there is a small chance of fire. Any hot-spots must be isolated and quenched with water before the fire spreads.



Unloading the kiln

To open the kiln clear all mud and soil from the surface of the metal cover and withdraw the slide bolts securing the metal sheets. Dismantle the length of chain and wooden pole used to support the centre sheet.

Remove the metal sheets at each end of the kiln first and then the centre sheet. Carry the sheets well clear of the kiln area to avoid accidental damage by people walking on them during the unloading operation.

If fire is seen in the kiln when the cover is removed, replace the metal sheets immediately and re-seal the kiln for a further cooling period.



After carbonisation, the contents of the kiln will have shrunk to about two-thirds of the original volume. There is usually a fairly deep hole in the charcoal at the lighting point where the operator can descend to commence unloading into sacks.

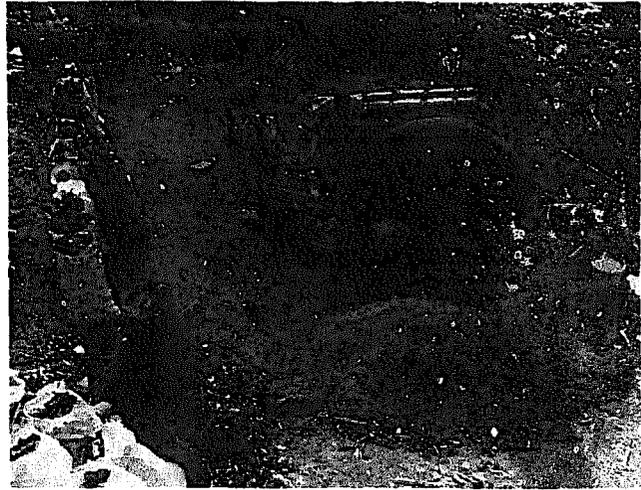
Unload the kiln from this point forward towards the chimney end of the kiln. Use the wooden support pole located over the centre of the kiln to suspend a rope and basket to assist the unloading process.

When unloading the kiln do not stand directly on the charcoal as this will break it into small pieces. Place a piece of flat board over the charcoal before standing on the product.



When the kiln is nearly empty, a certain amount of dust and small pieces of charcoal will have accumulated on the kiln floor. Recover the larger pieces of charcoal by shovelling this material out onto a 10 mm mesh sieve placed on the ground near the pit. The design of a suitable sieve is shown in Figure 2.

Finally, before re-loading the kiln with wood, remove all loose dust and soil from the bottom of the pit and clear all metal tubes of obstructions.



Storing the charcoal

As a precaution against fire, keep freshly-made charcoal separate from the other stocks for at least 24 hours. When exposed to atmosphere, fresh charcoal absorbs oxygen from the air with an associated rise in temperature. There is an associated risk of spontaneous combustion.

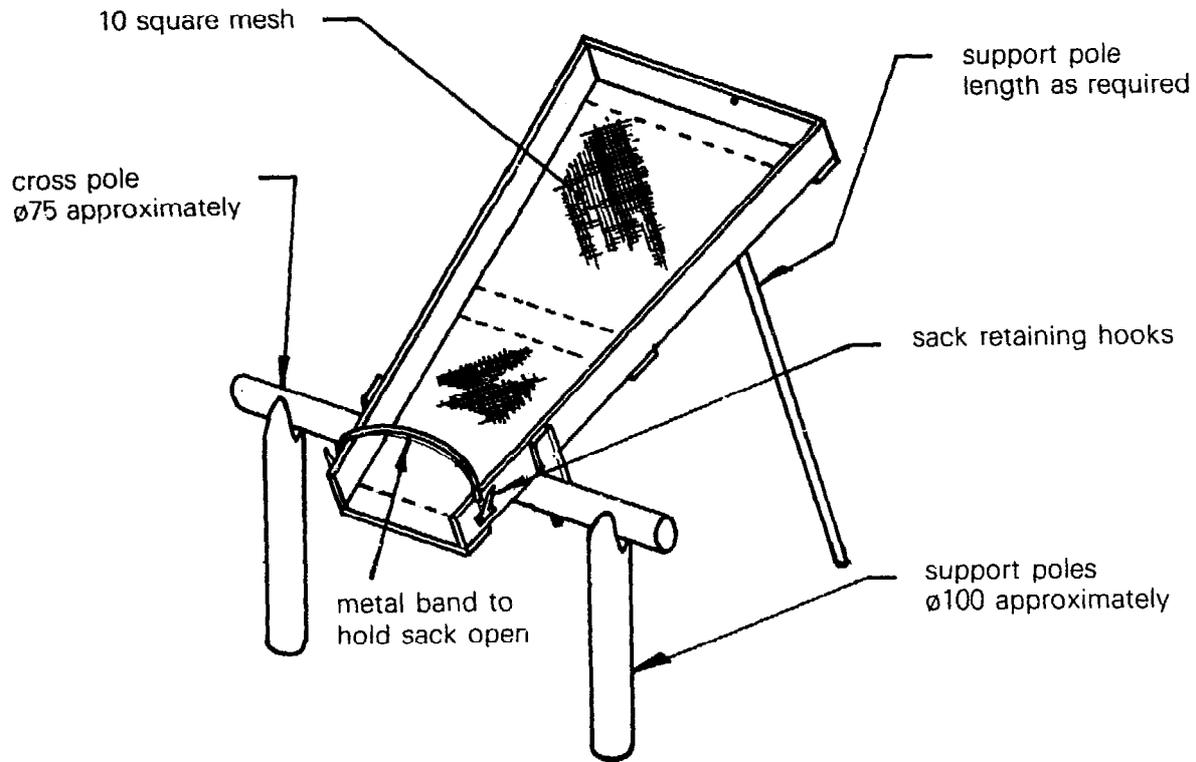
Operation schedule for two pit kilns

Day	Kiln 1	Kiln 2
1	Remove cover, unload charcoal and tie up sacks Clean kiln	Kiln cooling
2	Place stringers and kindling Load timber and light kiln	Kiln cooling
3	Control charring	Remove cover, unload charcoal and tie up sacks Clean kiln
4	Close down kiln Seal all tubes, joints and cracks with mud and soil	Place stringers and kindling Load timber and light kiln
5	Kiln cooling Humidify by pouring water down inlet tubes and reseal kiln	Control charring
6	Kiln cooling	Close down kiln Seal all tubes, joints and cracks with mud and soil
7	Kiln cooling	Kiln cooling Humidify by pouring water down inlet tubes and reseal kiln

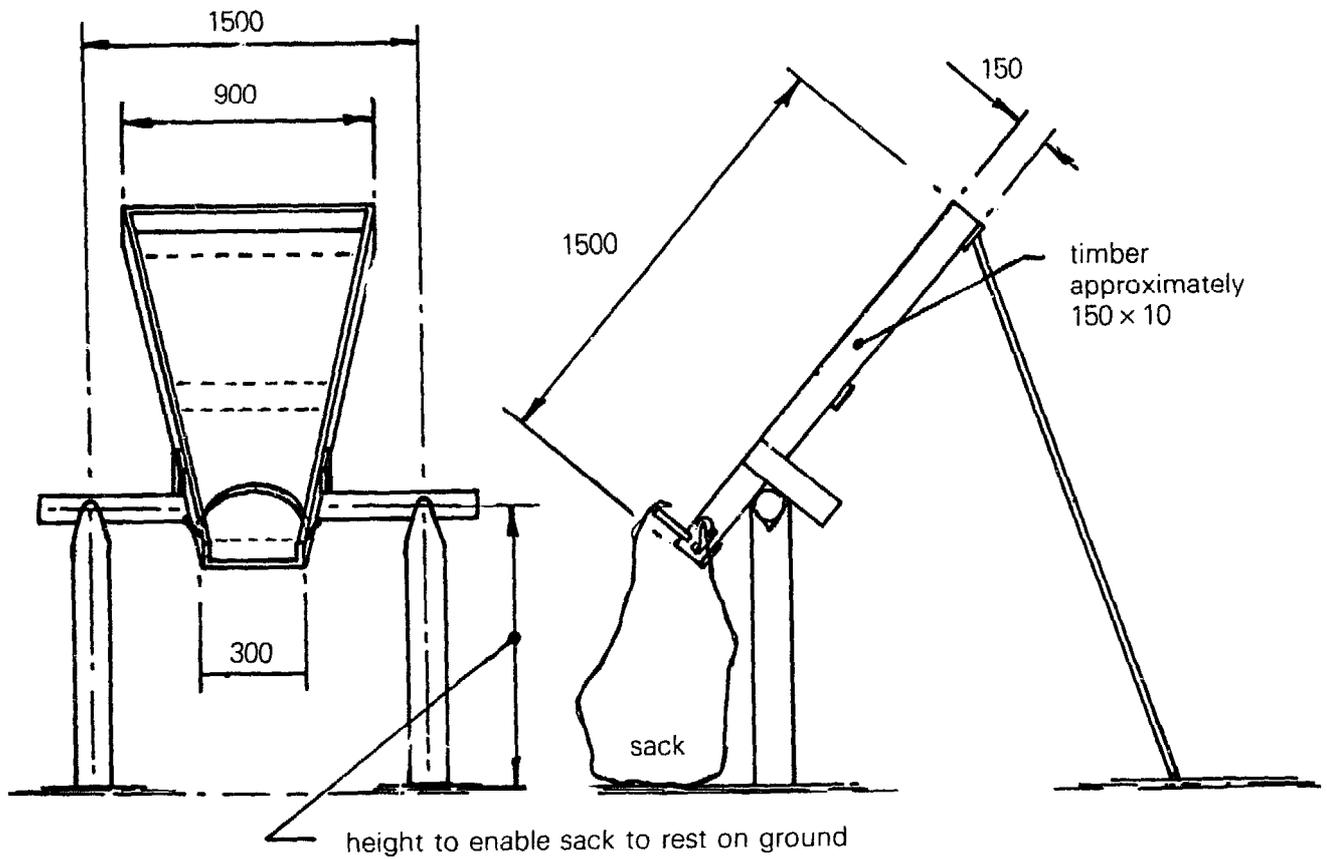
Labour input for two kilns

- 1 Labourer/Chainsaw operator
- 1 Kiln operator
- 1 Kiln assistant

Figure 2
Sieve-chute



All dimensions in mm



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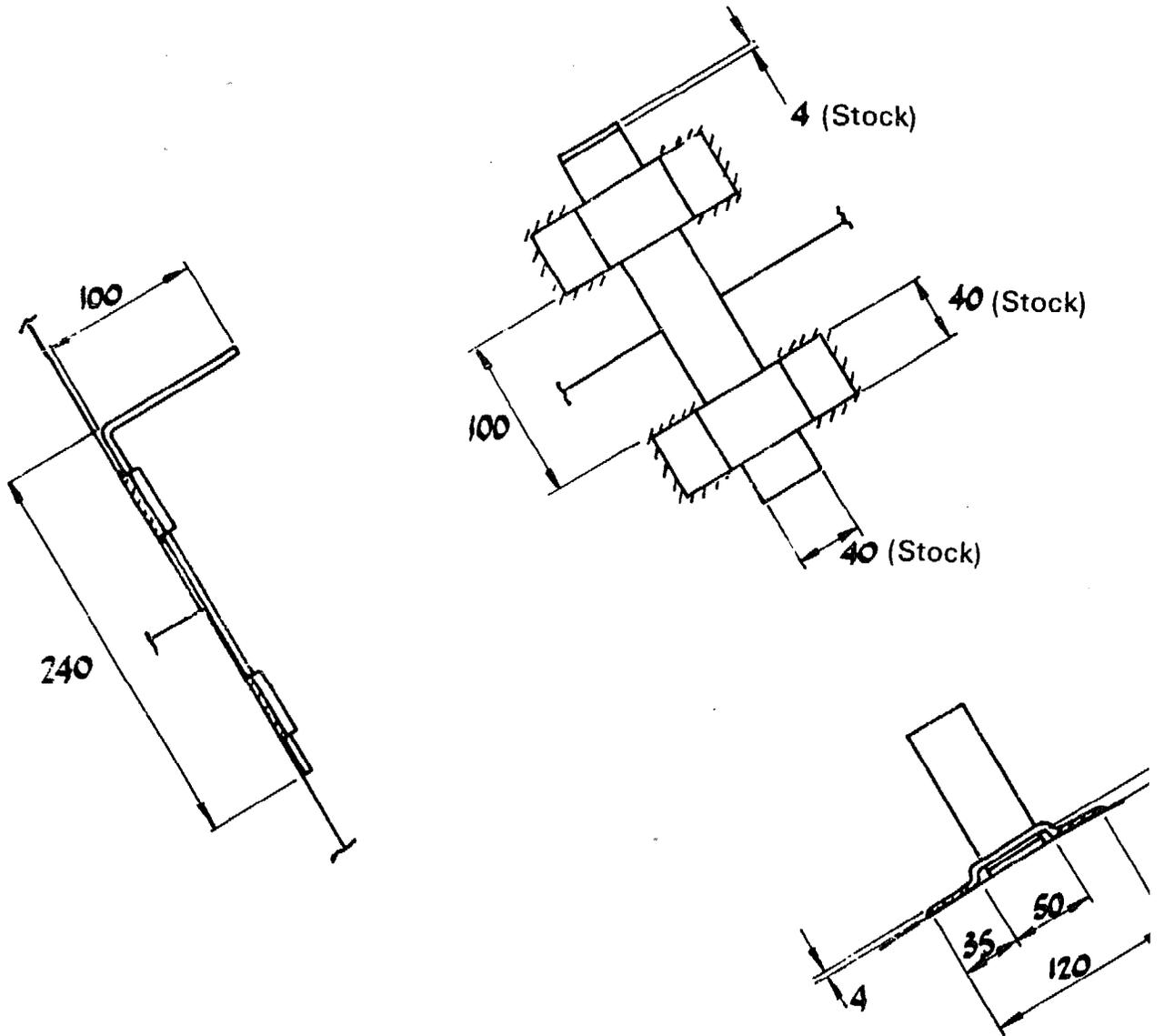
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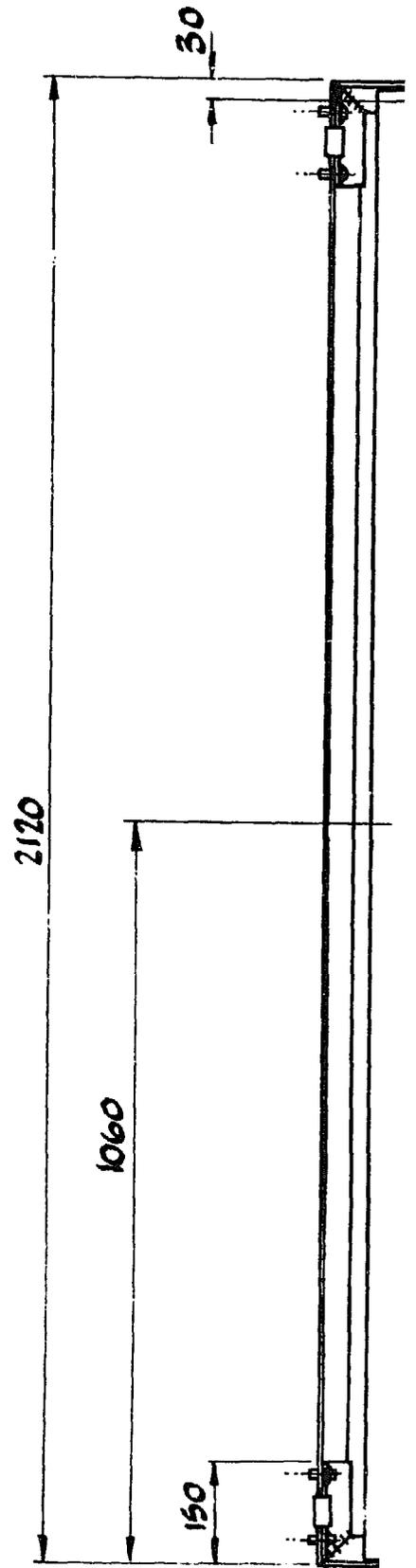
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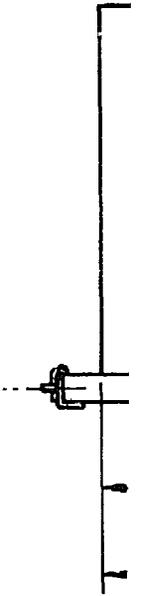
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Figure 1 - Improved charcoal pit-kiln - constru

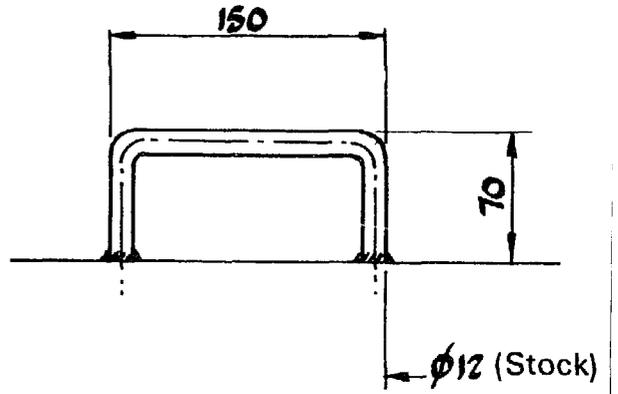


DETAIL ON 'B'
SCALE:- ¼ Full Size

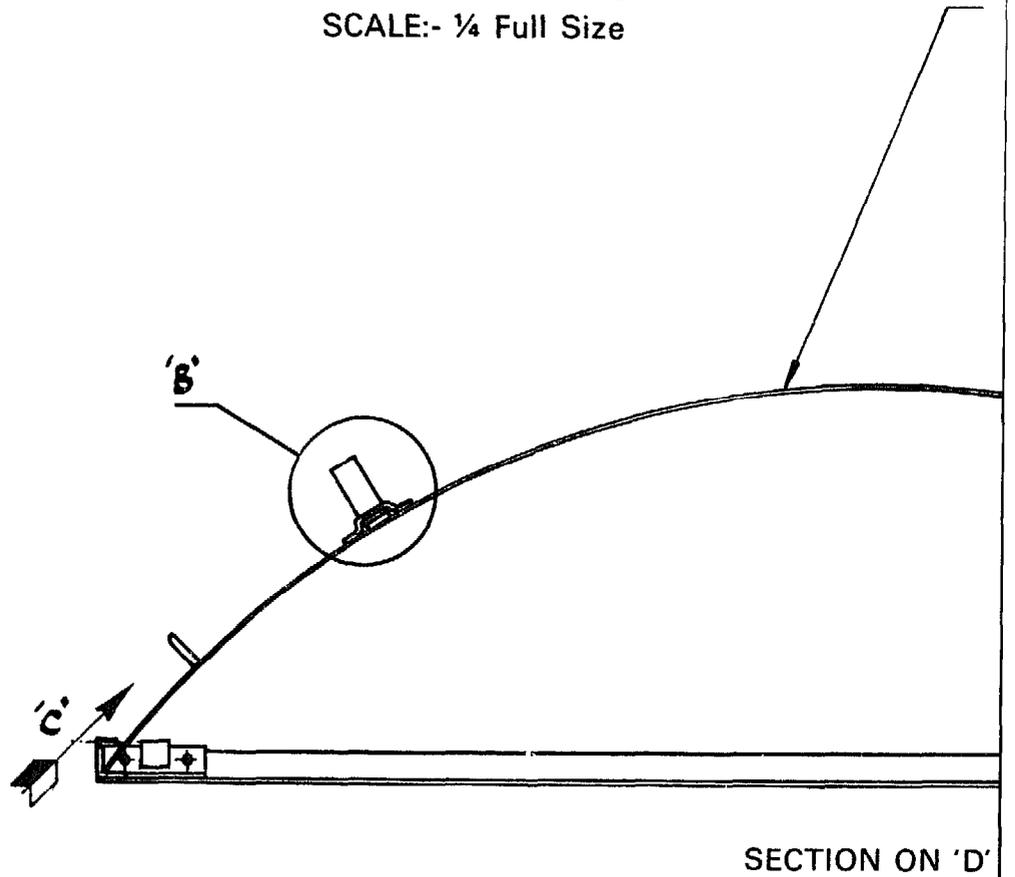


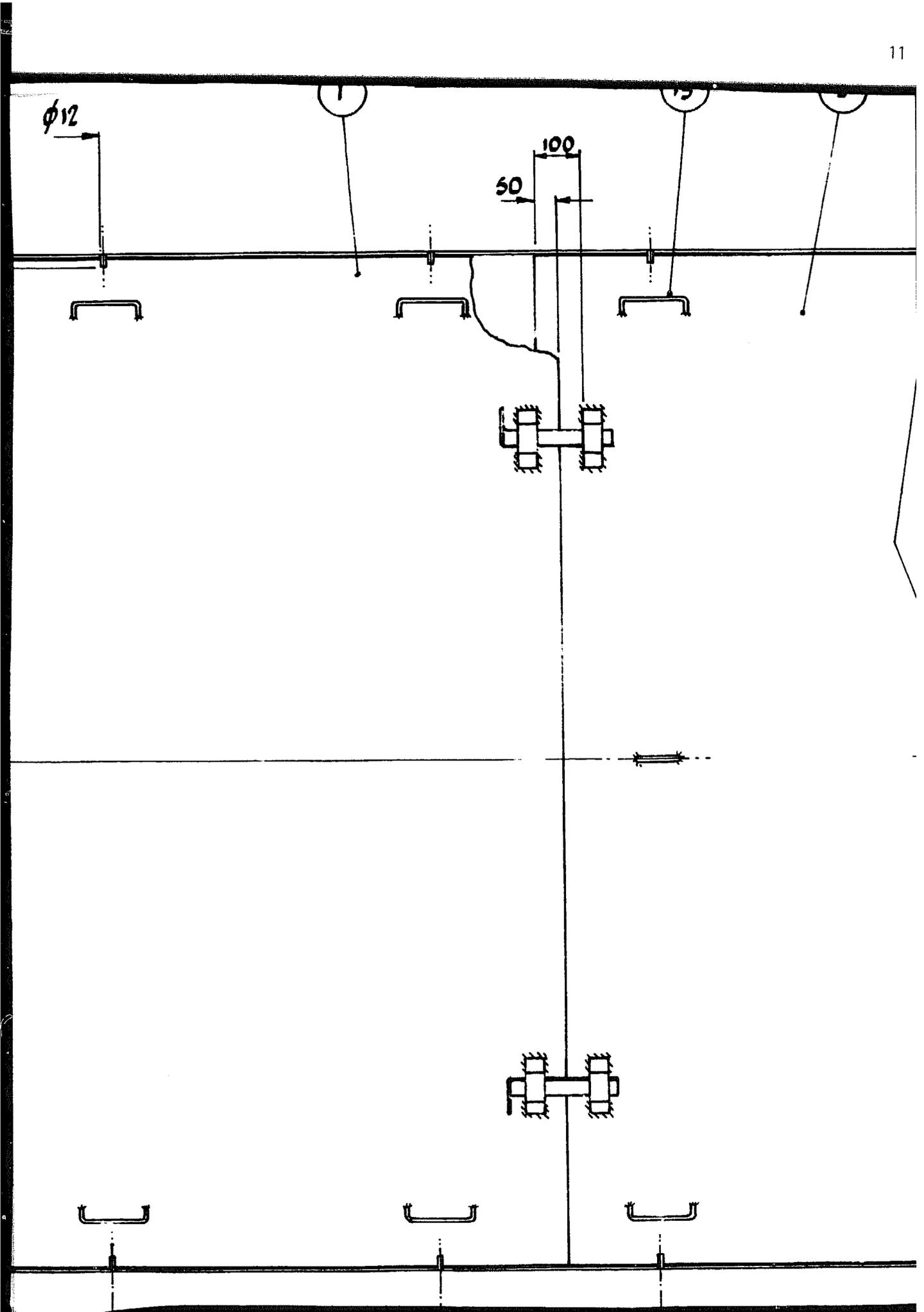


Sectional drawing



VIEW ON ARROW 'C'
SCALE:- $\frac{1}{4}$ Full Size





10

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1480

2

3660

910

210

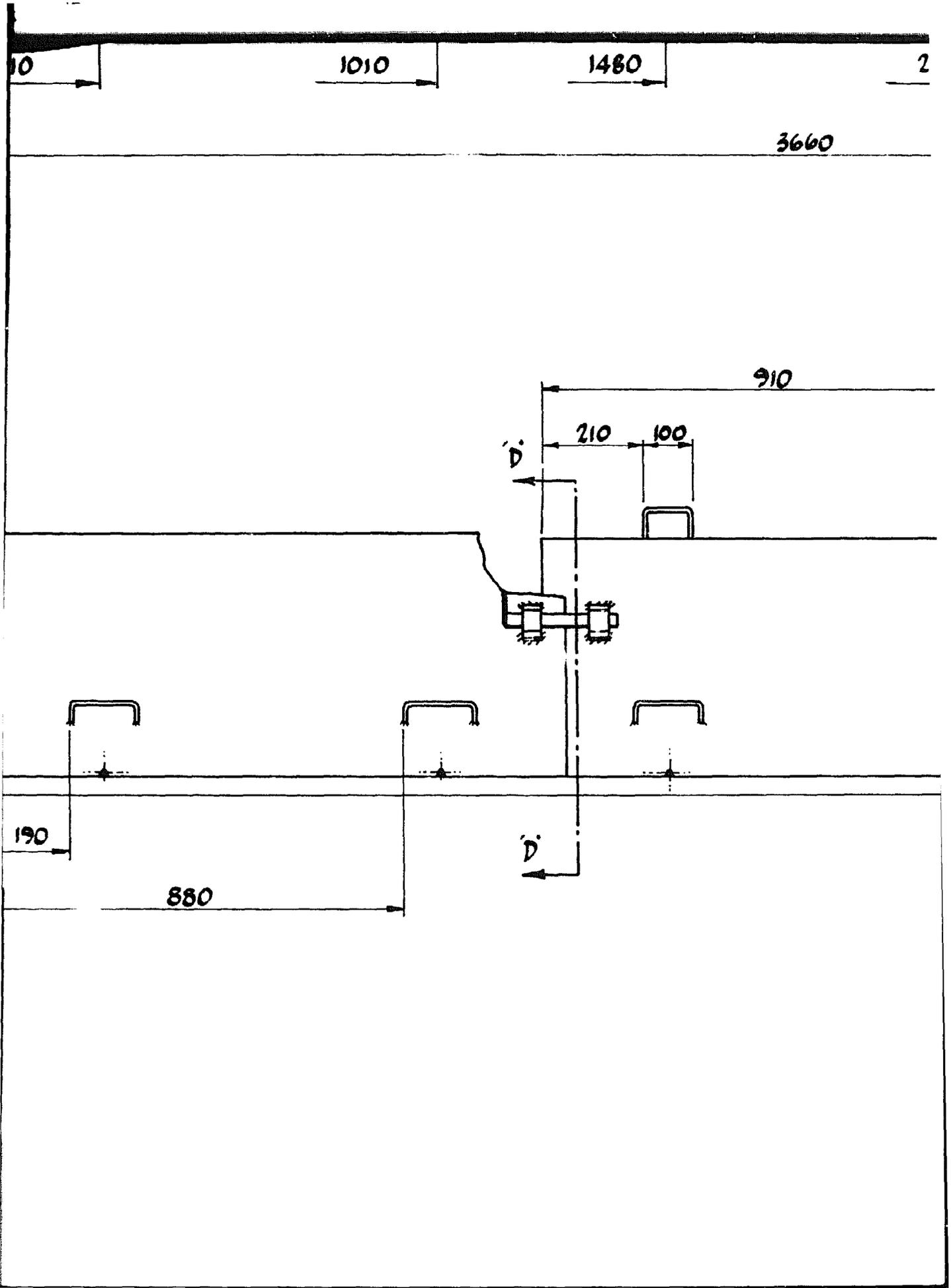
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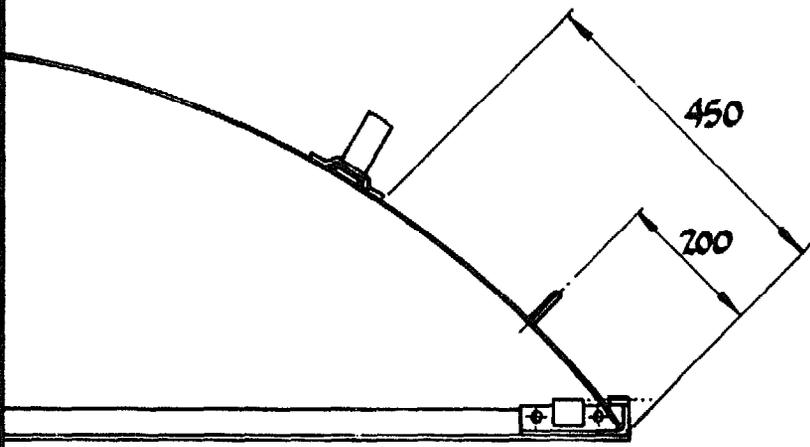
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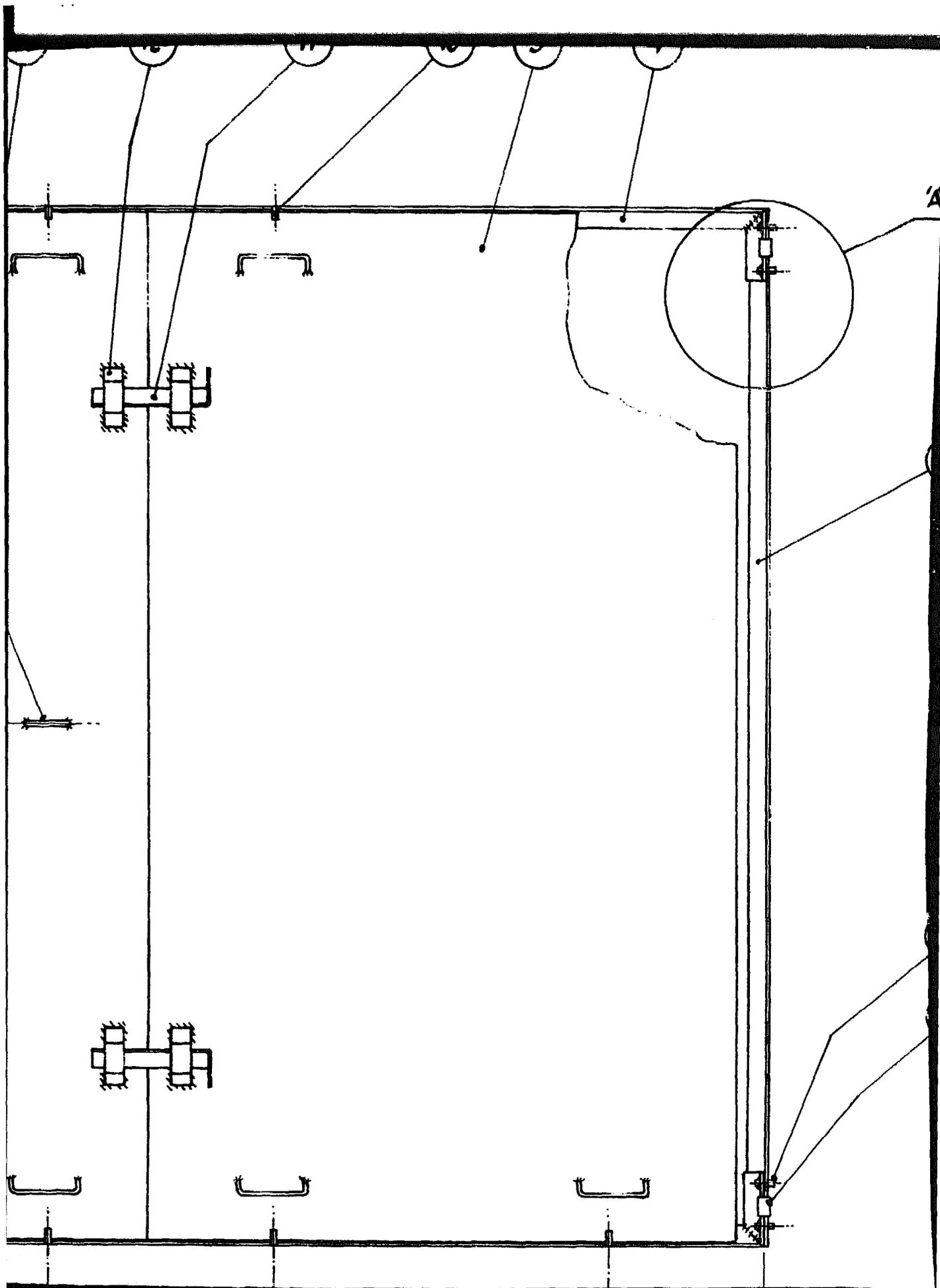
40 x 40 x 5 mild s
angle.

Items ① ② and ③ are to be 2440 long. When fitted
between items ④ (2120 wide) they "bow" to the
shape shown. Item ⑱ (which is welded to item ④)
will stop them springing out. Note items ① ②
and ③ NOT to be welded to items ④



D'





Items (7) are to be 130 O/D x
the tubes are to be made from
steel sheet and rolled to the giv
See view on arrow 'F' for joint
(See Note 1)

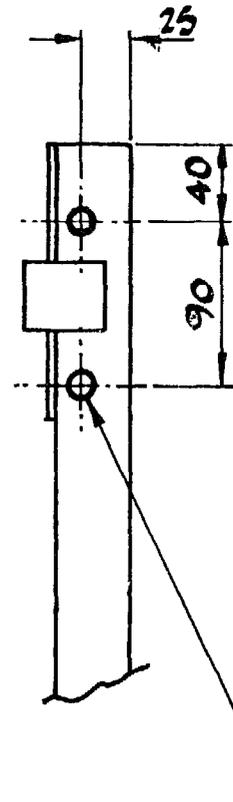
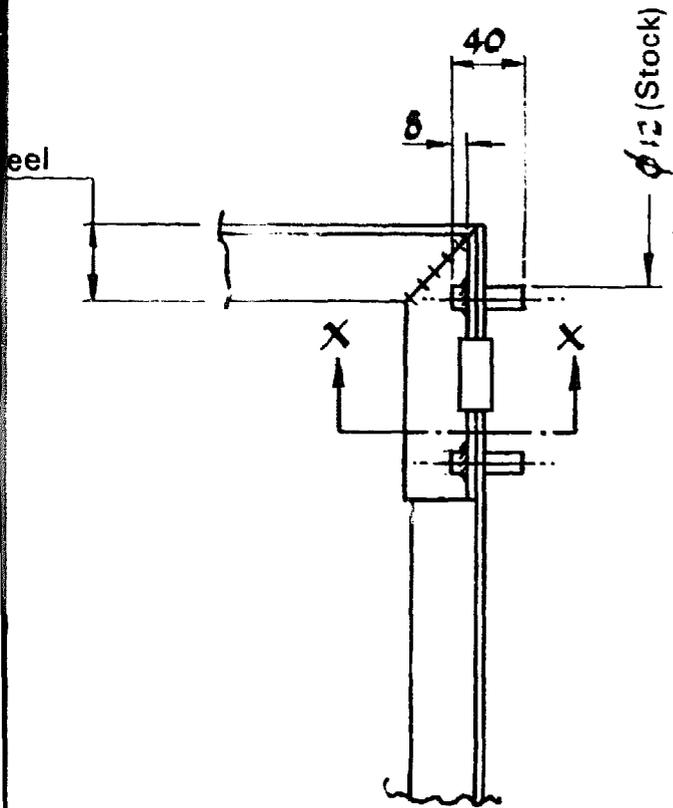
$\phi 12$ (Stock)

70

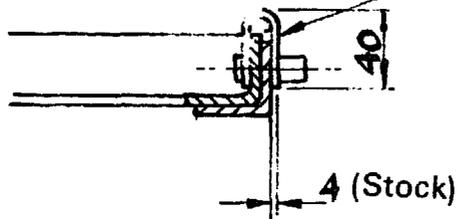
Item (19)
bolted or w
item (10)
assembly is
removable

Earth to fill the gap ✓
between item (10) and
top of the tube (to
ensure an airtight seal)

Item (10) to be cut so —
that it will fit inside
the tube (See Note 1)



DETAIL OF 'A'
SCALE:- 1/4 Full Size



Item ①⑥ is to be folded so that a tight fit is obtained when fitted over items ①④ and ①⑤ as shown

SECTION ON X - X

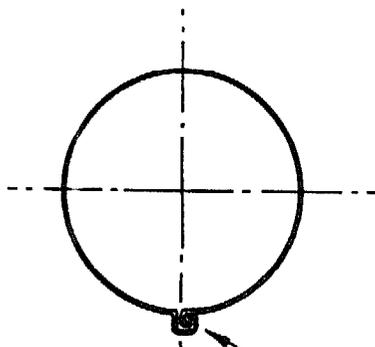
Mark the joints as shown so that items ④ and ⑤, on reassembly always go back together the same way.

Weld the numbers 1, 2 and 3 on the sheets as shown.

⑤

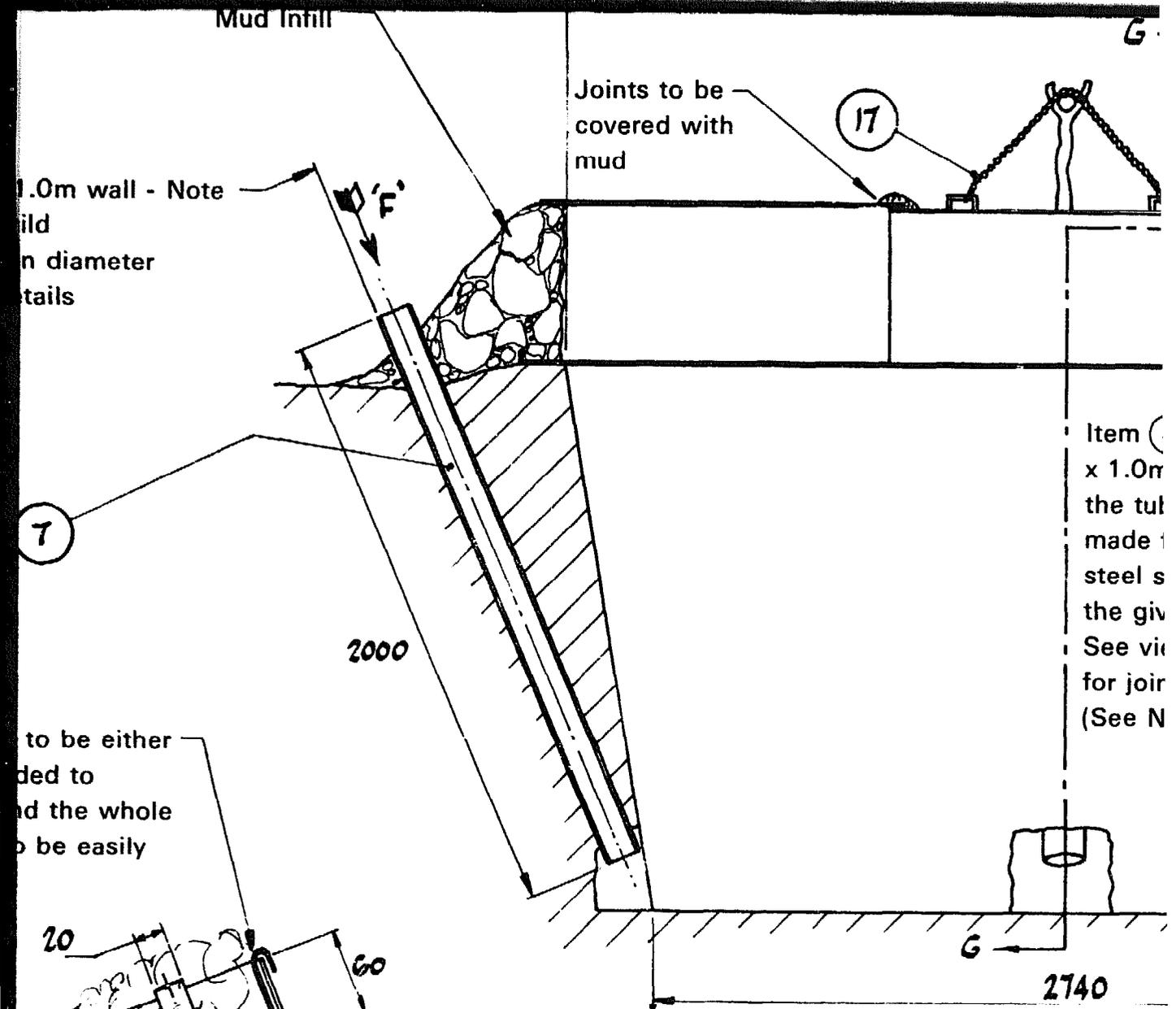
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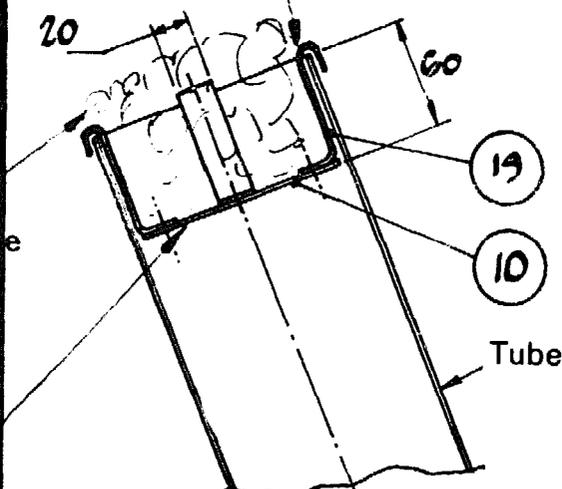
VIEW ON ARROW 'F'
SCALE:- ¼ Full Size

.The joint may either be welded or suitably flanged, bent over and hammered tight as shown.
(Typical all joints - See Note 1)



Item ()
 x 1.0m
 the tub
 made
 steel s
 the giv
 See vic
 for join
 (See N

to be either
 ded to
 and the whole
 to be easily



See Note 1

DETAIL ON 'E'
 (TYPICAL ALL TUBES)
 SCALE:- 1/4 Full Size

SECTION ON H - H

drill items (4) and (5) ϕ 12.5. Item (15) is to be welded to items (4) and the holes in item (5) may be enlarged to suit on final assembly



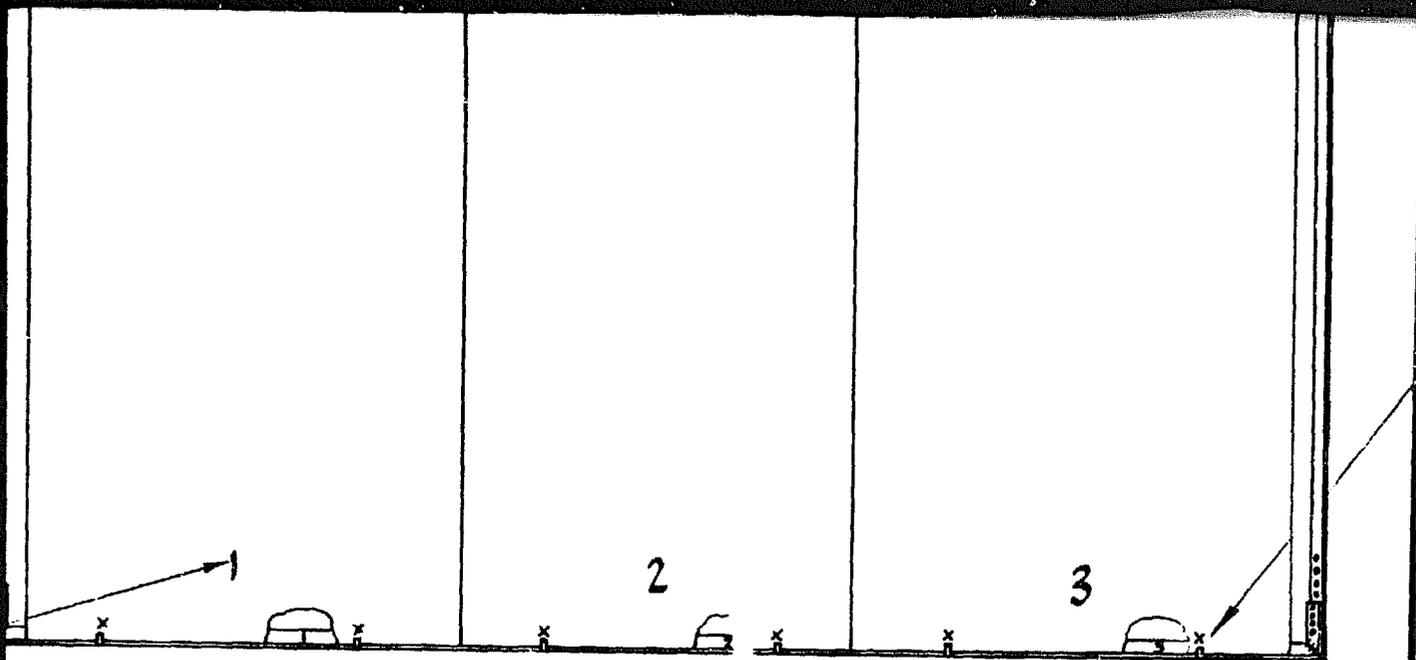
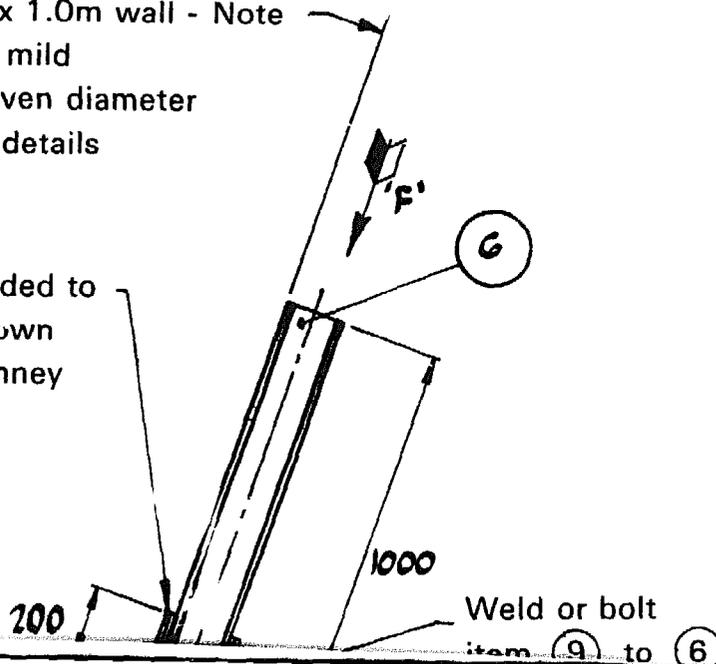


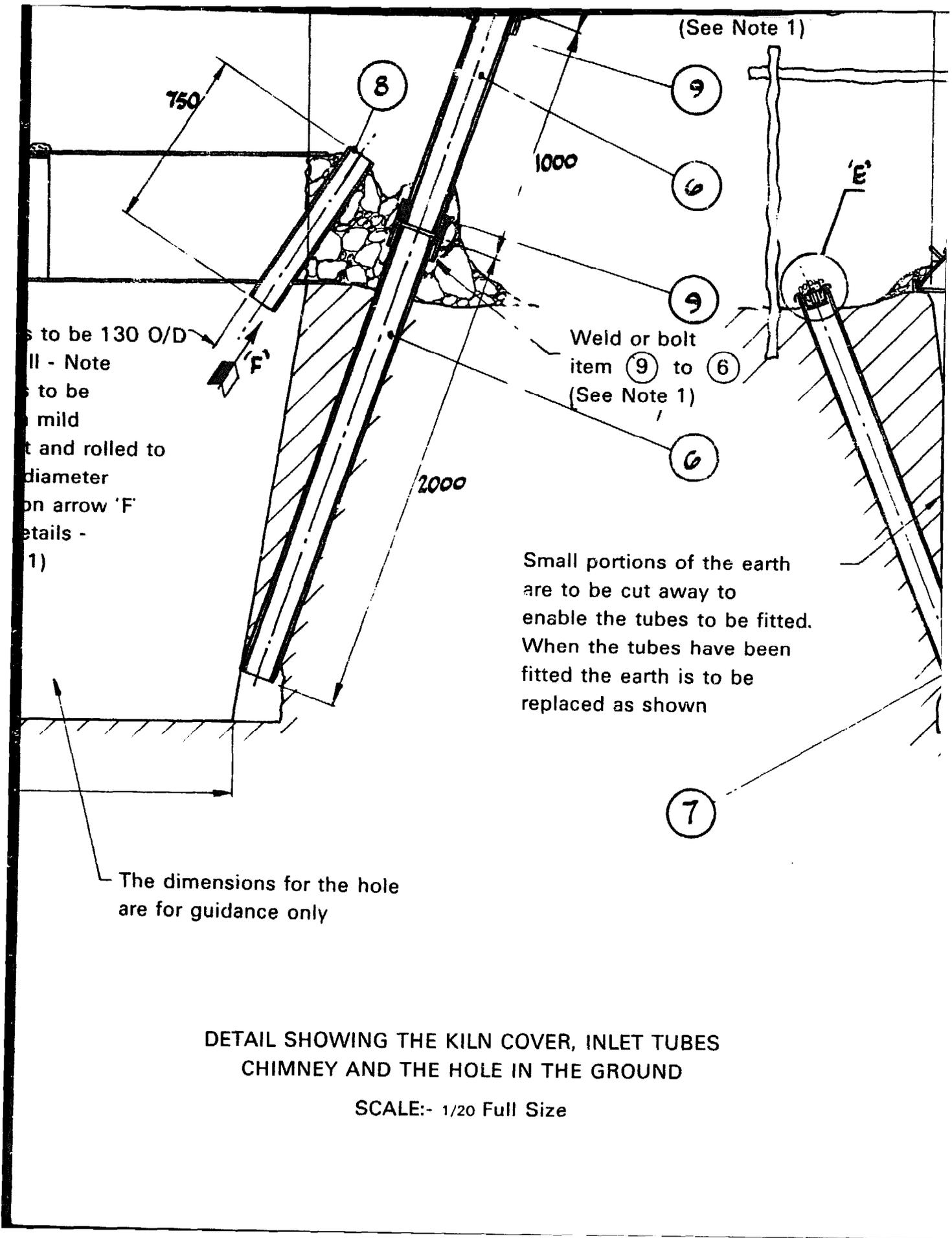
DIAGRAM SHOWING A METHOD OF MARKING THE VARIOUS COMPONENTS, SO THAT ON REASSEMBLY THEY ALWAYS FIT BACK TOGETHER THE SAME WAY

SCALE:- 1/20 Full Size

Items (6) are to be 160 O/D x 1.0m wall - Note the tubes are to be made from mild steel sheet and rolled to the given diameter See view on arrow 'F' for joint details (See Note 1)

Item (9) is to be bolted or welded to one of the chimney tubes as shown and made so that the other chimney tube can easily slide into it (See Note 1)





s to be 130 O/D
 ll - Note
 s to be
 mild
 t and rolled to
 diameter
 on arrow 'F'
 details -
 1)

The dimensions for the hole are for guidance only

DETAIL SHOWING THE KILN COVER, INLET TUBES CHIMNEY AND THE HOLE IN THE GROUND

SCALE:- 1/20 Full Size

ITEM No	DESCRIPTION DRAWING No.	No. OFF	REMARKS
1	Left Hand Cover	1	2440 x 1220 x 1.5 Mild Steel Sheet
2	Central Cover	1	2440 x 1220 x 1.5 Mild Steel Sheet
3	Right Hand Cover	1	2440 x 1220 x 1.5 Mild Steel Sheet
4	Long Arm	2	40 x 40 x 5 Mild Steel Angle
5	Cross Beam	2	40 x 40 x 5 Mild Steel Angle
6	Chimney	3	Mild Steel Tube, 1.0mm thick wall
7	Air Inlet Tube	3	Mild Steel Tube, 1.0mm thick wall
8	Steam Release Tube	1	Mild Steel Tube, 1.0mm thick wall
9	Chimney Connector	2	Mild Steel Tube, 1.0mm thick wall
10	Plug	4	Mild Steel Sheet 1.0mm thick
11	Slide Bolt	4	40 x 4 thick Mild Steel Bar
12	Slide Bolt Retainer	8	40 x 4 thick Mild Steel Bar
13	Handle	12	Ø12 Stock Steel Bar
14	Central Support Bracket	2	Ø12 Stock Steel Bar
15	Locating Pin	8	Ø12 Stock Steel Bar
16	Clamping Peg	4	40 x 4 thick Mild Steel Bar
17	Chain	1	Steel
18	Holding Stud	12	Ø12 Stock Steel Bar
19	Plug Support Bracket	16	Mild Steel Sheet 1.0mm thick
20			

Notes

1. Galvanised mild steel may be used to make items (6) , (7) , (8) , (9) , (10) and (19) but the joints are to be made with bolts, screws rivets or similar. Galvanised mild steel is not to be welded.

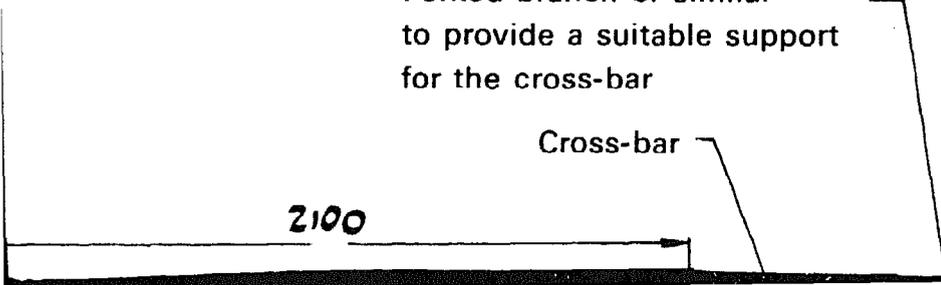
Position sheets 1 and 3 so that they have a 50mm overlap with sheet 2. Mark an 'X' opposite item (18) as shown (as long as the sheets are reassembled with the 'X' opposite items (18) they will always have the required amount of overlap)

Weld No. 1 on item (4) under sheet No. 1
Weld No. 2 on item (4) under sheet No. 2
Weld No. 3 on item (4) under sheet No. 3
As shown (so that the sheets when reassembled always fit back in their original positions)

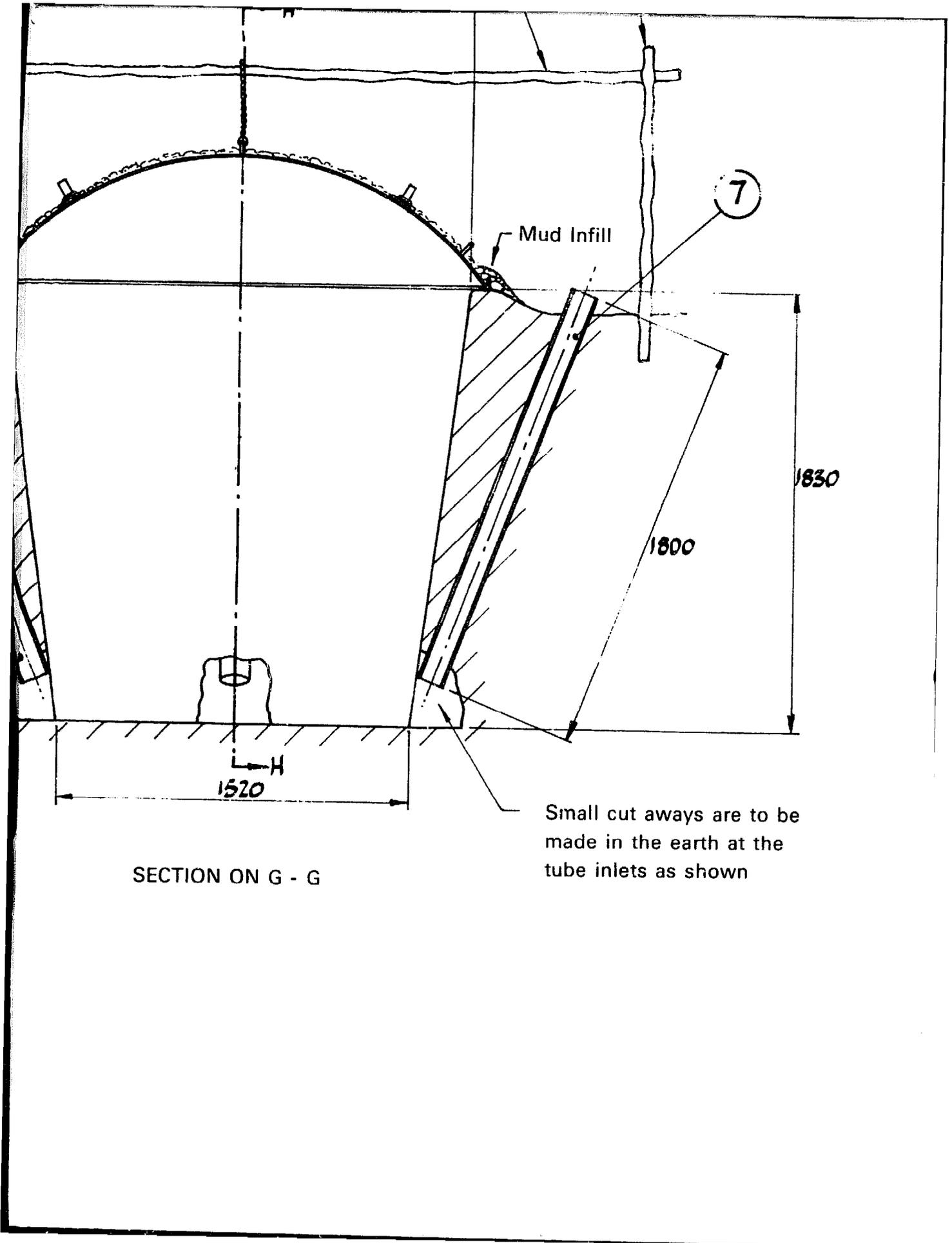
Forked branch or similar
to provide a suitable support
for the cross-bar

Cross-bar

2100



The diagram shows a horizontal line representing a cross-bar. A dimension line below it is labeled '2100'. To the right, a vertical line rises and then splits into two diagonal lines forming a 'Y' shape, representing a forked branch or support. A label 'Cross-bar' points to the horizontal line, and another label 'Forked branch or similar to provide a suitable support for the cross-bar' points to the Y-shaped structure.



SECTION ON G - G

Small cut aways are to be made in the earth at the tube inlets as shown