Ethno-archaeometallurgy of Iron in India

(With Special reference to Chhota Nagpur & Bastar)

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CHAPTER – V

ETHNIC-SMELTING OF IRON IN CHHOTANAGPUR AND BASTAR REGIONS

Iron was extracted from its ores by methods which were fairly effective, though the whole procedure may look primitive now. Furnaces made for the purpose were, apparently, crude yet what they produced was admirable. This was because of the cumulative experience gained through generations of the primitive workers working in the same field.

One of the most systematic description of primitive iron smelting process in India may be found in John Percy's *'Metallurgy: Iron and Steel'*, published in 1864 from London. Percy isolates three basic types of primitive iron smelting furnaces in India.

The first was the simplest and also the most common. Circular in form, its height varied from two to four feet. At the bottom on across the hearth, the width was from ten to fifteen inches, and at the top from six to twelve inches. It was made entirely of carefully tempered clay. The lower part tended to wear away rapidly and was constantly repaired with living of fresh clay. There were two openings towards the bottom of the furnace-One for removing the cinder, and the other for drawing out the smelted product, or spong-iron. Though in the second opening two earthen pipes, or tuyeres, connected with a pair of bellows were inserted. Both the openings were covered with clay before the furnace was lit. The opening for the under was generally at the side, that for the sponge iron and the tayeres was in front.

The tuyeres, some twelve inches long and an inch in internal diameter, were placed side by side, projecting two to three inches into the furnace, three to four inches from its bottom.

If the furnace was newly built, it was first dried by keeping a fire going in it for several hours. The tuyers were then placed in the positions mentioned above, and the openings both at the side and front stopped with clay. The furnace was half-filled with charcoal and lighted and then filled upto the top. The bellows were applied at this stage. When then charcoal at the top had partly subsided, alternate change of ore and charcoal were applied till the requisite amount of ore had been introduced. The blast from the bellows was then increased to the maximum and kept there till the operation was complete. This took at least four to six hours, during which the cinder was removed from time to time with the help of a small rod or bar through the opening devised for that purpose. But still the greater part of the cinder remained in the furnace and was removed with the spong-iron, which was taken out at the end of the operation, taking off the front cover. If sufficiently hot, the spong-iron was immediately hammered into a tolerably sound bloom, and it came out cold for the purpose, it was repeated and hammered.

The second type of furnace was a cavity made in a bank of clay which was well-tempered. The cavity was cylinderical, fifteen to eighteen inches in diameter, and some two and a half feet deep or high. At the bottom were two opening facing each other, though one of which the tuyeres were inserted. A row of such furnaces could be made at convenient distances from each other in a bank of clay - a distinct advantage the type offered. The furnace was filled with charcoal and lit in the manner previously described. Alternate charges of ore or charcoal were applied and the bellows kept going at full blast. When the cinder reached a certain height in the furnace, it was tapped with an iron bar introduced from above, then taken out with tongs through the top again. After the ball was removed the cinder was also completely removed by tapping through the front opening. The furnace was then ready for the next charge of ore and charcoal. The lower part of the furnace did not have to be (indeed, could not be) removed for a fresh charge, which saved time and was an improvement upon the first type of furnace. As per Percy information this was in fact a small catalan furnace.

The third type of furnace have also a cavity scooped out in the side of a clay mound. Its height on the outside was eight to ten feet but inside the furnace was only six to seven feet high, the bottom being two to three feet above the ground level. The internal diameter, top to bottom, was eighteen inches square, but a variation of fifteen by twenty one inches was also known. The front wall was only five to six inches thick and could be removed at pleasure. When it was removed the furnace presented the appearance of a vertical trench cut in a mound of clay. The base of the furnace was provided with a perforated tile of dried clay placed at an angle of 45° to the back of the furnace.

The base tile or plate was first positioned and cawdung deposited upto a height of twelve inches - four or five inches above the upper edge of the plate. Above this bed of cowdung two earthen tuyeres, at least eighteen inches long, were introduced, almost touching the back of the furnace. The furnace was then partly filled with charcoal, lighted and then filled up to the top. The blast was applied from the front and the man working the bellows sat upon a sort of scaffold two to three feet from the ground. Ore and charcoal were then alternately introduced and the whole operation took twelve to sixteen hours regularly. A considerable quantity of cinder was tapped at intervals during the operation with an iron bar passed through the perforations in the base plate, beginning with the lower holes and then proceeding to the upper ones. The holes through which the cinder had been drawn were stopped with clay as the iron accumulated at the bottom and would otherwise escape. When the iron ores at the level of the tuyers and the tuyers were burnt away, the smelting was considered complete. The base plate was then removed with an iron bar and the mass of cinder and iron allowed to fall to the ground. This lump of iron weighed a hundred and fifty to two hundred kgms, and was thus too large to be hammered whole. It was therefore, cut by means of sharp-edged sledge, so that when cold it could be broken into four pieces. It consisted of mixture of malleable iron and natural steel, and their proportion depended on the nature of the ore. Therefore, from the above description it is clear that the third type of furnace was thus obviously used to make better grade iron and natural steel.

Iron Smelting Furnace in Chhotanagpur Plateau

On the area of Chhotanagpur the kols generally understand the smelting of iron, because their country is pretty rich in that mineral but it is the widder clanis, the mountain Kharrias, the Birhors; and in Lohardaga or Palamau, the Asurs and Agarihas, that chiefly utilized it, the people who devote themselves to it regularly paying no attention to the cultivation of soil.

A close study of ethno records from different parts of the India reveals that there were regional variations in each of the aforesaid three types of furnaces. However, in 1963, H.F. Cleeve the then Assistant Secretary of the Iron and Steel Institute of U.K.; reported two types which do not seem to have been reported before. A demonstration of primitive Indian iron-making was staged at the National Metallurgical Laboratory, Jamshedpur, in February that year, and Cleeve saw three types of furnaces in operation there. This demonstration, held during a symposium on recent development in iron and steel making with special reference to Indian context, was organised by Moni Ghosh of the Tata Iron and Steel Company, who is said to have studied these primitive furnaces and their aborigioned operators for many years these furnaces were called after the three villages of Chhotanagpur Plateau associated with them, the Kamar Joda furnace, the single Becha furnace and the Jiragoran furnace. The last conforms to the first type described by Percy.

The Kamar Joda furnace near Joda mines of Jharkhand consisted of a shallow bowl, about a foot in diameter and six inches deep, excavated in the earth and lived with clay. A mound some eighteen inches high was erected above the bowl, extending two feet or so behind it. A shaft, three to four inches in diameter, was made immediately above the centre of the bowl, the front of which was open. The structure was entirely of puddled clay mixed with chopped straw or husk, It was dried in the sun and the cracks were lined with fresh clay. When the furnace was ready for operation, the bowl was filled with charcoal and the next step was to close the open front with damp sand, probably bonded with a little puddled clay. A tuyere was inserted through twin foot-operated bellows. Some of thirty kgms. of ore were charged with an forty kgms of charcoal. When the charge had been used up, the sand-wall was broken open and the bloom, a mass of slag and iron with much adhering unreduced ore and charcoal, dragged out with tougs and quenched with water. The bloom was then battered with a hammer and the small fragments of metal picked up by hand. These bits of iron were then repeated and forged together. Cleeve points out that in this type of furnace temperature did not exceed approximately 1100 degrees centigrade and the metal was never molten during this process. As the ore was reduced to metal it became plastic and very slowly travelled down the furnace, forming globules of varying sizes. There was almost no accretion of carbon at the low temperatures encountered, and the charcoal used as fuel did not introduce sulphur or phosphorus in the metal. So the result was a very pure iron. An ingot of two kgms approximately, was obtained from thirty kgms of ore. The Kamar Joda furnace, has been described as a furnace of the most primitive type, because it had no provision for tapping of slag. The metal tended therefore to scatter in small discrete partices throughout the slag matrix, which had to be broken open to obtain the metal.

The first step in building the single Becha type of furnace was to dig a pit, some four square and three feet deep with steps leading down to it. A bowl, a foot in diameter and nine inches deep was then dug in the floor of the pit, the bowl extending in part beyond one of the side-walls. The next step was to dig a shaft, three to four inches in diameter, immediately over the centre of the bowl. For tapping the molten slag a pit was dug out of the bowl, sloping downwards. This slag pit lay inside the main pit. Hearth shaft and slag-pit were lined with puddled clay mixed with chopped straw or husk and sundried the cracks filled later with fresh clay. When the furnace was in operation, the operator probed the hearth at intervals through the tuyere with an iron rod. When the end of the rod showed slag the said-wall blocking the slag pit was puddled down and the slag allowed to run out and collect in the pit, where it was quenched with water before being thrown out. This was done a number of times till the end of the operation. The spongy mass of iron was then taken out and after hammering off the adhering slag it was repeated or forged. The major advantage of this furnace over the kumar Joda furnace was that the tapping of the slag made for a greater coherency of the iron, and consequently less difficulty in forging and shaping.

The Jiragora furnace in the Karaput area shows a shaft which is about two and a half to three feet high with an internal section tapering from one foot at the base to three to four inches at the top. On the opposite side of the tuyere aperture a platform supported on bamboo poles is built on the top of the furnace. This is meant to carry the change before it is fed gradually into the top of the furnace. Everything is built in clay. The front arch is closed with sand and the two belows operating through single tuyere supply the blast. Slag is removed at intervals by breaking open the sand front and the slag is allowed to collect in a pit nearby. Cleeve describes this furnace as an above-ground version of the single Becha furnace.

It would now seem that more than the three basic types of furnaces were employed in primitive Indian iron-smelting. The parallels of the Kumar Joda furnace and the single Becha furnace of Chhotanagpur Plateau, have also been explored by the author from Baster District of Chhattisgarh.

Chemical Analysis of Raw Material and Products From Chhotanagpur Plateau

Smelting Site

Chemical Material	Jiragora	Kamarjoda
Iron Ore Fe%	63.4	20.00
SiO_2%	2.44	1.27
Al_2O_3%	1.86	2.13
CaO%	0.5	—
MgO%	0.23	0.27
CO%	—	0.28
P%	0.008	—

Charcoal Analysis

	Jiragora	Kamarjoda
Ash%	3.2%	6.7%
VM	21.0%	
Fixed carbon	75.8%	76.43%
Metal Produced	Non Refined	Refined
	Fe = 44%	Fe = 95.25%
	FeO = 20.38%	S = 0.19%
	Fe_2O_3 = 3.29%	Mn = 0.03%
	SiO_2 = 20.27%	C = 3.4%
	Al_2O_3 = 8.02%	Al_2O_3 = 0.013%
	CaO = 1.4%	P = 0.032%
	MgO = 0.72%	
Slag Analysis		
	SiO_2 = 27.88%	—
	Al_2O_3 = 6.72%	—
	FeO = 53.34%	—

Fe_2O_3 =	1.14%
Fe metallic =	16.00%
Fe Total = 46.00%	—
MnO = 1.026%	—
CaO = 5.0%	—
MgO = 1.16%	—
SO_2 = 0.075%	—

Their smelting furnaces, though rude in appearance, are nevertheless very exact in their interior proportions, and it has after surprised me to see men who are unquestionably ignorant of their principle, construct them with precision, in so simple a manner; their unit of measure is the breadth of a middle sized man's finger; 24 of which constitute their large and 20 their small cubit; thus there is a constant ratio of 6 to 5 prevailing throughout these furnaces, nor is it of the least consequence, that their dimensions are larger or smaller, so long as all the parts are in the same proportion; the length of these measures is on an aver,age 19.20 inches for the large cubit, and 16 inches for the small one.

As they have no standard measure their fingers, their span, and their arm are substituted by which a piece of stick is measured which they use in practice; neither is the division of the cubit necessary though the large one is spposed to be divided into six parts and the small one into five, of four fingers each-as the measurement is invariably ascertained by their fingers; the length of these parts is on an average 3.20 inches.

Geometrical Construction of the Furnace

To construct the outlines of the furnace geometrically (Plate I fig 1 and 2) rule and indefinite line A.B. which suppose equal to a large cubit of 24 digits or 19.20 inches, and divide it into 6 parts; at C erect a perpendicular, then from C to E set off 6 parts and it will mark the centeral point of the greatest bluge, and consequently the point of greatest heat; next, from E to F set off 6 more points, and it will mark the point of cremation; then again from F to G, 6 parts more, will mark the line, where it is necessary to recharge the furnace, after the burden has sunk thus low, and from G to D-two parts more; will give the perpendicular height of the furnace, in 20 parts equal to 5 feet 4 inches measure. To complete the figure, rule lines parrallel to the base, through the points E, F, G, and D, and from D, fig 1 set off three parts to the left hand for the top; bisect it at J, bisect also the bottom at H, draw H, J, right angled at K, and it will be the oblique axis of the furnace (fig 1. K-J) bisecting all the parallels AB six parts,-E six parts, F five parts, and D three parts; rule lines through all these points, and the geometrical outline will be complete the sum of the parallels in parts, corresponding with those of the perpendicular.

Practical Construction of the Furnace

To construct it practically-dig a fosse 3 feet deep in the annexed form (Plate III, fig2) the semicircular part of which contains the furnace B, the walls CCC being composed of unburnt bricks of large dimensions; the first structure is rude, preserving only an approximation to the required form, the interior being afterwards cut away; a large stone capable of containing heat is placed at the bottom; and in this state it is suffered to remain until thoroughly dry; the next operation is performed by a more skillful artist who cuts away the inteior. And plasters it with clay, using the measures above described to adjust its dimensions; he first finishes the top, and from the centre of the back part of it, he drops a plummet, to ascertain the sport where the centre of the front part of the stone is to rest; this pulmmet line corresponds with the perpendicular CD of the geometrical figures I and 2- and thus he obtains not only the required obliquity of the furnace but the points most essential for the adjustment of all the rest.

When the furnace is thus far prepared it is again suffered to dry, and in the mean-time other appendages called by the smelters Gudaria, Pachar, Garrairi, and Akaira (names which have no synonymies in the English language), are constructed; the Akaira in particular is a most extraordinary implement, (Plate I, figs 4 and 5; and Plate II fig 1 and 3); externally viewed it is a clumsy mass of clay enveloping the wind tubes (Plate I, fig. 9) but when it is considered that the complete fusion of this mass, and the perfect completion of the smelting process must be simultaneous results, the implement becomes the most important of all the appendages; thus for instance if it is too small, or too large, its effect will immediately be perceived; in the former case the masset of crude iron will be full of impurity and in the latter the iron will be consumed, and if it cracks during the operation of smelting, there is no remedy for such an ancient-short of dismantling the furnace and commencing the work again.

I found after numerous experiments that its mean length should be 4/2 parts, its mean breadth 3 parts, and its mean thickness I $^{1}/_{2}$ part and it is somewhat remarkable that the product of these dimensions, should exactly equal a twentieth part of the cubic contents of the furnace when fitted for use; this coincidence may, arise from the peculiar nature of the clay of Lohardaga[1] the ingredients of which are well assorted, but the rule will nevertheless apply generally-because clay by admixture is susceptible of being rendered amenable to rule; and therefore, this implement will be found in all Indian furnaces to have (or by tempering the clay may be made to have) the same corresponding dimensions.

The Guddaira[2] is a wedge of clay used to adjust the vertical position of the Akaira when placed in the furnace; and the pachar is an oblong plate of clay, used in walling up the orifice after the Akaira is placed, and adjusted; these figures and dimension are given in Plate I-fig7 & 8; the Gurairy (Plate I, fig. 6) is a convex plate of clay; perforated with holes and used as grate-through which the scoria are drawn off

When the appendages are ready, and the furnace thoroughly dry, it is prepared for use in the following manner. The front part is walled up from the top to the line S- Akaira to the top (Plage I fig 1 & 3) which line is ascertained by the small cubit; one end being placed at C, the other will measure CB and CS (fig. 1)-the grate is next put in, its lower edge resting upon the edge of the stone; and space is filled-with a mixture of pulversied cow dung and kodo straw-up the dotted line (Plate I fig l) upon which is placed the Akaira3; its sides being every where 1 1/2 parts distance from the walls of the furnace-as represented in (Plate I-fig. 4 and Plate II-fig. 1/+; where a, b, c, d) are the walls of the furnace, fig: 5 and 1 the Akaira; the Gudaira4 or wedge, is next introduced in order to adjust its vertical angle (Plate I fig l) and this begin placed satisfactorily, the Pachar is inserted and the whole has then appearance represented in Plate I, fig 3, where No 5, 6, 7 and 8 are the, Akaira, Gudaira, Pachar, and Garrairi; nothing now remain but to jute the whole with clay, leaving the ends of the wind tube open to receive the bellows.

Bellows

The bellows are as singular in their construction as the Akaira, and are worked by the hand; they are made of a single goat skin, the dimensions of which ought to be 7 parts in breadth when doubled, and 8 parts in length;

such proportions being required for circular bellows of 5 parts diameter, and which when worked by a man of ordinary strength will rise 6 parts in height-having $11^1/_4$ circular folds; the wooden nozzle through which the blast IS conveyed into the furnace surfaces the Akaira in its complex nature, and so little is its principle understood-that the art of making it was once lost at Purbhi Singhbhm and was again restored by the smelters of Lohardaga.

Construction of the Nozzle of the Bellows

To construct its figure geometrically, rule a line AB equal 3 parts (Plate II fig 2) divide it into four, giving one of those divisions to each of the legs, and two for the space in the centre; set off a perpendicular from C to D equal 3 parts; bisect it and the middle point will mark the apex of the central angle; then through the point D rule a line parallel to AB and from it as a centre set off each way $^3/_4$ of a part making together $1^1/_2$ parts; divide it also into four, giving one each to the legs, and two for the space in the centre as before; and then by ruling lines to connect all these points, the outline will be complete; the exterior; of the implement is plain but the interior is complex and cannot be described except by a reference to Plate II: fig 3 which represent it, divided in the middle, to shew its internal structure.

This curious appendage is fastened to the bellows by leather thongs, and the blast is forced through it at an angle of 24° degrees but when it is luted to the wind tubes of the Akaira, the blast enters the furnace at an angle of 12° degrees, both vertically and horizontally - because those tubes are placed so as to reduce that angle; plate II fig. I represents the whole apparatus luted together and placed in the furnace the walls of which are marked by a. b. c. d, and it exhibits at one view, the whole of the mechanism of this complex machinery; the furnace when closed up with clay, and the bellows luted in, is represented entire in Plate III and IV, the dotted lines shewing the chimney-A the outer walls, B, a mound of earth to strengthen the walls, C an upper chimny of moveable briks, D planks laid across the trench to support the bellows and the man who works them, E a stone supporting one end of the plank, F forked branches supporting an iron bar on which the other end of the planks rests, and G a simple apparatus for preventing the bellows from rising from the planks when they are worked.

The above description is not founded on theoretical conclusions; the measurements given are derived from taking the mean of several and the results were proved in furnaces under my own supervision; the coincidence of the several parts are very striking, thus for instance, the perpendicular and paralled lines of the geometrical outline are equal in quantity (Plate I, fig 2); and the top bluge and bottom being 3, 6 and 41/2 parts respectively, shew that the furnace is exactly constructed and that is corresponds well enough with the most regular furnaces of Bastar (Plate I, fig 1); it is also curious, though perhaps of no importance to observe, that the mean of those numbers, being squared and multiplied by the terms of the perpendicular or axis, give cubic area of the furnace, and shew that it is twenty times larger than the cubic content, of the Akaira; the angle of the blast is also worthy of notice, as well as the simplicity by which both it and the obliquity of the furnace is obtained; all these serve to shew that the original plan of this singular furnace must have been the work of advanced intelligence, and that its geometrical proportions have been preserved by simple measures; hence though its original form may be changed by caprice or ignorance, its principle never can be lost so long as hands and fingers remain.

Refineries

The refinery is as rude is its appearance, and as novel in its construction as the furnace, to which it seems to have been purposely adapted: two refineries being required for one smelting furnace; to construct it they use the small cubit of 20 digits, or what is still more available, the space or distance between the tips of the thumb and little finger of a middle sized man when extended without force, two spans being considered equal to the cubit; the first process is to arrange a number of square unburnt bricks, as in the ground plan (Plate V fig 1) in which a. a. a. a. are the walls-A is the chimny-B the refining furnace, C the seat of the refiner, and D the anvil; see also (fig 2) for a side view of it-divided in the middle for the purpose of shewing the interior structure, in which E is a piece of crude iron under the process of decarbonization; the dimensions of the chimney are not material, but it is usually about one cubit broad, one deep and six in length; the oval part where the operator sits is altogether a fanciful appendage, being merely a mound of earth in which a long of wood is inserted for receiving the anvil and its elevation serves the further purpose of giving the workmen a purchase in using the hammer; when the walls of the chimney are finished, the top is covered with unburnt bricks of an oval shape, flat below and convex above and these are luted together by a plastering of clay-fig. 3 is a front view-shewing the opening of the furnace and Plate VI exhibits the refinery complete, with the refiner at work on his seat, the bellows-man playing the bellows, and various implements saying about the outside of the chimney-B a mound of earth to strengthen its wall-C the refining furnace-D a piece of crude iron undergoing the process of decarbonization (in dotted lines)-E the bellowsman playing the bellows-F the refiner with an iron spike in hand regulating the operation (the dotted lines shewing the interior of the furnace)-G a thick plate of iron placed at the bottom of the refinery (in dotted lines)-H a fosse for the hammerman-I the anvil-K implements, and L a heap of charcoal.

The furnace of the refinery is the only part which requires skill in its construction, and this is usually done by the operator himself; its geometrical outline is represented (Plate V fig 4) and its construction is as follows. Rule a-line AB equal five parts, divided it into six-set off four of these divisions for the top-let fall a perpendicular from the center-rule a line through D-parallel to AB and make it two division, now the rule outline-bisect the perpendicular and the center parallel will be equal to three divisions. Some error in this poing; the usual measure for the former is the span above mentioned applied both longitudinally and transversely as in Plate V fig 1, B where a ground plane of the furnace is exhibited-the inner circle of which corresponds with the centre parallel of fig 4-this measure never differ much from 8 inches, and that quantity may be assumed as a fair average;-the outer circle b of the same figure is indefinite-the space between the two-being merely a slope, chamfering from the inner edge, and gradually expanding, until it is lost in the sides of the furnace, so that in fact it is reverberatory; with regard to the blast, it is absolutely necessary that it should be directed, at an angle of about 12° degrees, upon the opposite edge of the inner circle or to the poing c fig 1, B; the natives have no instruments to enable them to do this exactly but the working of the furnace soon tells them where there its an error and they know well enough how to correct it;-the bellows resemble those of the smelting furnace, but instead of the wooden nozzle, they are furnished with long iron tubes-as in Plate V fig 5 which are so placed, that the angle of the blast thrown through them is 24° degrees, the same as that the wooden nozzle.

Smelting Furnace

Plate VII: fig 1 and 2 represent the front and back view of a small circular smelting furnace, which is very common in Chhattisgarh area-its measurement may be taken form the scale of the Plate either in parts or inches; the bellows are the same as fig 5: Plate V and the form of the interior or chimney is exhibited by dottd lines; fig 3 and 4 of the same Plate shew another description of refinery used chiefly for decarbonizing large masses for the manufacture of anvils & worked by two pairs of bellows-this refinery might be more extensively applied; such as for the manufacture adletrees or other heavy work[4]. Fig. 5 of Plate VII is a small field black-smith's forge, constructed of the same kind of oval bricks, as those which are used for covering in the refinery, and luted together by clay; used in the refinery to preserve the ends of the bellows-fig 7 is a tube of the same kind used in the small circular furnaces.

Mode of Smelting and Refining

In the process of their manufacture the endogenous smelters use charcoal only; the ore is broken into pieces about the size of a walnut, but it is not washed nor is it roasted although it is known to contain a large quantity of sulphur which might be dissipated by that method; they commence by filling the chimney of the furnace with charcoal which they suffer to burn until all moisture is expelled; they then throw in a small basket of ore, and upon it a larger one of charcoal, after which the burden is allowed to sink as low as the line G (Plate I: fig 1 and 2) when it is again charged- and afterwards ore and charcoal are alternately given in the same proportions until the operation is complete; the scoria begin to flow within the space of an hour, and that by time; it is know whether the furnace will work well or ill-the scoria being a sure indication; it is let out by piercing the grate with an iron spike, and the orifice is again closed with clay as soon as it is drawn off; the bellows are worked by three men-who take it by turns; and they should be kept constantly playing until the process is completed; the time of which is ascertained by introducing a hooked piece of iron through the wind tubes, into the furnace, which shews how much of the Akaira remains; for as I have shewn before, it is indispensably necessary that this appendage should be totally fused before the operation is complete, and when this is the case, it would be useless to continue longer, because the furnace would cease to work properly; it usually continues 12 hours but much depends on the bellows-man, and also on the working of the furnace.

The metal is never completely melted by this process-the heterogeneous mixture of the ore alone is fused and thrown off in scoria, and the iron being freed from it falls by its superior gravity to the bottom of the furnace and there coagulates into a mass or masset; it is very highly carbonized and sometimes it is partially malleable even in its crude state; when the process is finished, the bellows are removed; the front part of the furnace demolished; and the red hot masset dragged out and divided by large ades before it has time to cool, hence it happens that the parts of the furnace thus broken up, require daily renewal.

This completes the business of the smelting furnace - the process of decarbonization being performed in the refinery, and plate VII, fig. 6 D represents half a masset- properly placed in a refinery and undergoing that operation; as it becomes decarbonized, it drops into the hollow of the furnace upon the plate of iron G - and when a sufficient quantity has accumulated, it is taken out and hammered into more circular lumps which are seen in every bazar; the charcoal used in the operation is always of hard wood, such as teak *(tectona grandis)*, mowa *(fanalatifolia)* or bamboo; this is the part of the manufacture in which the Indian manufactures play tricks; for in the first place they do not allow time for the crude mass to become properly decarbonized and then again they have a most pernicious practice of knocking off corners and small pieces from the masset in its crude state into the decarbonizing fluid, and instead of waiting patiently until the whole of the masset is decarbonized they often throw in large lumps at the end of the process, mixing all these crude pieces with the other so that the cheat cannot be detected except on trial; thus they not only shorten the time of the operation, and thereby use less fuel, but contrive by this nefarious practice to sell a large portion of their crude iron at the same price as the malleable; they are also very sparing in their hammering lest they should force out too much of the Vitreous Oxide and thereby reduce the weight; so that upon the whole there seem to be causes which have justly affected the reputation of Indian iron but as they are repairable errors, they ought rather to be placed to the account of the perversity of local habits than arrayed against that fair repute to which the Indian metal under different management might lay claim.

PRODUCE

The produce of the ore of Chhotanagpur varied from 36 to 40 per cent-but as it was upon the whole nearer to 40 than 36. I am quite safe in fixing the average at 38 per cent; I tried by roasting the ore to obtain a greater quantity but without effect, neither was I satisfied with its result in another point of view, as will be shown hereafter; with regard to charcoal the consumption varied according to its quality or, in accordance with the working of the furnace. The following diary contains a statement of the daily produce of four smelting furnaces, from which I assumed a mean, as a fair proof of their power of production. They were under my own superintendence from the 30th May to 6th June 1998 which is beyond all question the most unfavourable portion of the year for smelting iron, and the result therefore is the more enhanced in value.

From this statement it appears that each furnace yielded upon an average about 18l/2 Panchseri, and that every hundred sers of crude metal yielded 63 sers of malleable iron; the total of the produce therefore is as follows: the ore yielded 38 per cent - the crude metal 63 per cent-and the malleable iron yielded 56 per cent.

Iron Smelting Furnace in Bastar District

Primitive tribes dwelling in the interior forests of Madhya Pradesh and Orissa have continued to live in their traditional way and were preparing iron on ancient methods. Their techniques could be an index of the ancient practice of making iron as all the rituals and ceremonies with their songs and sacrifices were carried out. The Government of India has released a documentary film on the manufacture of iron by the tribals of the Khoraput District in Orissa. But in the case of Bastar District of Chhattisgarh no attempt has yet to be made either by the government of India or by Government of Madhya Pradesh (now Chhattisgarh) certain group of skilled and professional artisous migrated from one place to another this spreading their craft. Although it can be said that Mundid and Halbi tribes of Bastar were well versed with the iron making technology and they were capable of producing together iron from their tiny furnace. The region of Bastar could not be surveyed and included in the primitive Agaria belt of iron smelting because of inaccessibility of that region due to the traditional self cantonments of these tribes. Further it has also been suggested that a certain group of skilled and professional artisans migrated from one place to another which help in spreading their craft. It is obvious, that the local communities, in course of time and space modified the process, utilizing the local available raw materials and facilities. In the absence of written records of this region[5], it can be inferred from the raw materials available in the regions, the composition of the slag and other furnaces remains like bricks, refractories, old tools etc. as to the methods followed by iron smelters. Even Dr. F. Buchanan in his description of 1807, he had used the term 'Laterite' for the first time on a species of iron clay very prevalent in India, had did not shows the existence of any iron technology in the District of Bastar. Recently while working on Ethnoarchaeology of Iron making technology in the District of Bastar in 1999 by the author, two tribes Mundia and Malbi are identified, who were still living in their traditional way and extract iron from locally available ores. They have been making iron by the traditional method to prepare arrow-heads, axes and hoe which form a part of their routine life. At Bailadila mines a village named kameli is situated about 20 km towards Dantevade-sukma road where traditional iron melting was performed by local tribes. In this village we were shown a forge shop operated in the ancient manner and we contacted a young lohar (blacksmith) who agreed to bring us in contact with his relations who operated iron making furnace. With this guide we could go by jeep into a village 'Mokhpal' near 'Nakulunar' another journey of about 30 km. towards south on the Dantevade-Sukma Road. At Mokhpal with great difficulty we could get some information regarding the existence of such furnace in 'Loharpura' we had to pass through 5 or 6 villages and find our way by walking through about 6 km. of forest area to reach 'Loharpura'[6] village. The local tribals were very reluctant to show us the furnace and only after great persuasion they agreed to show the furnace and explain the process. We could see large pieces of slag and semifused mass lying around the furnace and collected by me for our further chemical analysis.

Description of the Furnace

The furnace used by these people was essentially of the same type as used in the Chiglabecha area of Koraput in Chhotanagpur Plateau. The furnace was made by digging a hole in ore of the vertical (same of the pit). This part of the furnace formed only the 75% of the furnace was made by layering shift mud and two bamboo layers having 5 to l0mm inner diameter were filled in the bowl of the furnace. The furnace had a total height of about 800mm and the diameter of the furnace at the throat 200mm. The shaft of the furnace was 600mm in depth and had a tapered wall. It ended into a bowl shaped length having about 240mm maximum diameter and 1,000 mm depth. A hole was provided in the bowl to tap out slag. The furnace was made below the ground level to cut down the access of inner wall and was coated with a layer of refractory clay. During the operation of the furnace about 50 to 70mm thick layer of earth surrounding the furnace got baked to cherry red colour.

At the mouth of the furnace a tapered plateform was built from green wood sticks and mud to preheat the ore and charcoal and to push the material inside the furnace. The top of the plateform was about 800 to 1000mm high and the surface was laid with 100mm thick layer of mud. This platform served three purposes:

1. Preignition of the charcoal
2. Drying and preheating the ore
3. Platform to push the hot material inside the furnace.

Supply of the Blast

The air blast to the furnace was supplied by a pair of foot operated bellows known as Bhati, 280mm in diameter and 100mm in height. The bellow (bhati) was made from two wooden circular frames covered with a deer or 'wild buffalo' skin. The top cover of the bellow had a 100mm hole fitted with an inside flap of leather. The leather flap acted as an one wag value. A pair of these bellows were connected to the furnace through hollow bamboo tuyers having a hole of 5 to 10 mm diameter and 300mm length. The pair of bellows were operated by a single person by standing on them and pressing them downwards alternately. The upward motion of the bellows top surface was achieved by attaching to it a green bamboo pole through a leather cord. The other end of the pole was securely fixed in the cartle at some distance and it could bend down wards with the bellows motion and then spring back when the leg pressure was released. The bamboo holes also served as a support to the tribal man working the bellows the bhati's were many a times operated by the women or children of the local blacksmith's family.

Collection of Raw Material

The iron ore for the furnace smelting was brought from a near by available ore deposit in 'Lphar Gano Village' very soft pieces of ore cherry red in colour were hard picked and brought in big bamboo baskets. This expedition was supposed to be a very sacred one and womenflor used to sing sacred songs wishing great success. The charcoal was made from the local wood by piling it up in the open and firing when the ward got charred it was quenched with water to get charcoal. The chemical analysis of charcoal and slag samples collected from this site is given below, but one thing must be clear that there is no indication was found here of using any flux to control the slag properly.

Analysis of Charcoal collected from Loharpura

Moisture	9.0%
Ash	29.5%
V.M.	13.7%
Fixed carbon	47.8%

Analysis of slag collected from Koharpura

SiO_2	1 5.4%
Fe_2O_3	33.0%
Total Fe	54.4%
C	5.5%

Preparation and Operation of the Furnace

After making all the preparations first a puja of the furnace was performed wishing success in producing good iron and then the furnace was dried and preheated to red hot temperature by burning charcoal inside the furnace. At the same time the charcoal was ignited on the platform the coal burnt in the nature air draft and when it become red hot it was pushed inside the furnace. Thus the red hot charcoal and preheated ore were charged in alternate layer till the furnace become fall and about 15 to 20kg of the charges to that coal, The blast to the furnace was supplied by working the bellow. The tribal women took part in all the activities and operation of the Bhathi was their prime responsibility. The air, blowing rate was adjusted to maintain a temperature around 1115°C.

As the furnace blowing progressive the iron ore got reduced and its gangue formed a high ferrous oxide slag with the charcoal ash. This first got collected in bottom of the furnace and fommed a hot solid bottom. The blowing rate of the furnace was controlled by the heat operator and it was increased in the last phase to increase the furnace temperature and separate the slag from the sponge iron. The whole operation took about 8 to 9 hours after which the bellows were removed and the furnace bowl was opened by breaking the front wall. This semifused mass of spong iron block mixed with slag and was taken out and separated from the solidified bottom change. The sponge iron block was forged on an anvil to flat it and squeeze out the slag. The forging characteristics of the sponge gave an idea of its iron content and it indicate the success of the operation. This after around 6 hours of operation about one kg of iron was obtained.

The qualities of iron thus produced was not consistent and many a times the carbon contant was so high that the iron became brittle. The spong obtained from the furnace was further heated on a forge hearth alongwith SiO_2 and hammered till a 25mm square rod was sprinkled over the iron bar so that it could react with the Ferrous oxide slag and make it fluid enough the squeeze out altering forging. The iron bar thus obtained was sold in the market and brought by the other lohars (blacksmiths) to shape them into arrow heads, hoe and axes.

The chemical analysis of the axes and an iron piece obtained from Lohargano in the District of Bastar is given bellow which conform the high quality of iron produced by them. Chemical analysis of Iron samples prepared at Loharpura

	Sample No. 1	Sample No. 2
C%	0.59	0.45
Si	11.00	—
A1	17.06	84
S	20.02	—
Ca	51.00	170
Ti	11.23	<70
Cr	<3	<5
Mn	41	18.7
CO	183	47
Ni	353	—
Cu	340	59
Fe	Rest	Rest

Evidence of Iron Smelting from Konta in Bastar

Nearly the whole area of Konta is an indulating forest Plateau, about 698 meter high and over this plateau there are disconnected chians of hills. Therefore, it is an isolated village covering about 0.5km2 in area with 0.01% of the total rural population of the Bastar District as per 1991 census record of India7. An interesting picture about the smelting process of iron was seen by the author during his field work of the District in 1998.

Preparation and Operation of the Furnace

Iron was found partly from the haematite, which is found in the rainy season in channels of many of the stream and mountain torrents in the country and partly from the lumpy float ore from the iron ore quarries. In order to separate the earth from the iron, it was washed in flowing water so that the clay was leached away leaving behind clean iron, the lumpy ore was crushed, and the quartz and other gauge materials were separated by winnowing the hard picking.

The smelting furnace was generally a cylindrical vertical, pear shaped shaft built of tempered clay with a stone fore-hearth the height, diameters, at the top and the bottom, as well as the thickness of the wall varied from locality to locality but the general outline and basic features were 45 cms to 610 cms and the top opening was 20 cms to 25 cms. The thickness of the wall which tapered from the bottom to top varied from 20cms to 7 cms. The height varied from 900 cms to 2500 cms. Some of the furnaces were rectangular in section. In some designs the front portion could be broken open and rebuilt for each new smelting operation. At the bottom of the shaft there were two openings, one of which was used for inserting the muzzles, of the bellows and the other, which was larger was for the removal of ash, slag and semi- molten mass of iron.

Supply of the Blast

There were usually two bellows and their outlets were jointed to a common pipe, the muzzle of which coated with a thick layer of clay was inserted into the furnace hearth.

The bellows were made from buffalo's. skin removed without cutting it lengthwise. At the neck it was sewn up so as to have a small opening for a wooden muzzle. The wider part of the hide was slit vertically and ore side made to lie over the other. In the middle of the outerside was tastened a ring of leather, through which the workman passed his arm and seized the upper angle of the skin, which served as a handle when he drew back his arm, the opening in the inner part was dilated and admitted the air and when forced his arm forward, the opening was closed and the air was forced through the muzzle. In some parts of Orissa, the bellows were two circular box like devices made of goat skin with rigid tops. A person by pressing his foot on the box and raising it, could keep a steady stream of pressurised air.

There were two such bellows, which were worked alternatively by continuously pressing one after the other by of each of the worker's feet. There were springs Blacksmith's workshop made of bent bamboos, which help in easing the laborious work.

Smelting

The manner of smelting the ore and rendering it fit for the blacksmith had followed particularly the some, rule of thumb method, handed down through generation. The practice appears to have been almost universal, including Africa, South America and Europe. The lumpy iron ores mostly heamatite or magnetite was beaten up to the size of coarse sand and was cleaned to separate the gangue. The fuel used was charcoal made by the artisans themselves from hard forest wood available locally. The use of flux was not a common practice, although in few cases calcareous stone was also charged.

The furnace was filled with a basket or two of charcoal and this was ignited to burn freely. After a sufficiently high temperature was reached (700°C) basket of dry iron ore was put in and over it a layer of charcoal, so that several such alternate layers were progressively built up while the blast was maintained continuously. After 6 to 7 hours by which time, the entire mass has been smelted, the slag or scoria was removed. The lump of semi molten and pasty mass of iron which was mixed with slag was the pulled out by a pair of tougs and then beaten by hammers on a stone slab by two or three workers. The lump of iron was further cut into smaller pieces and the heating of the pieces and hammering was continued till the iron was free from the slag.

The iron so made was generally akin to wrought iron. It was low in carbon and sulphur and the phosphorous content depended on the kind of ore used. The absence of manganese is a distinct feature of this local iron. An analysis of iron and slag taken from konta village have been given bellow:

Chemical analysis of iron lump from Konta

Fe	98 to 99.5%
Si	0.01 to 0.04%
S	trace
P	0.013 to 0.3%
Mn	Nil
C (Graphite)	Nil
C (Combined)	0.01 to 0.3%

Chemical analysis of slage fr Konta

SiO_2	10.33%
Fe_2O_3	1.85%
Al_2O_3	8.13%
FeO	73.95% to 63.21%
MnO	0.23%
S	0.03%
P_2O_5	0.035%
Charcoal & coke	1.57%

Therefore, the aforesaid analysis shows that the distribution of carbon content would vary within a lump of iron on account of the heterogeneous nature of the smelted product and the reduction is not being uniforms. Since the temperature in the furnace was not high (100°C) enough to bring the charge in a molten or liquid state, the composition was not uniform. As mentioned earlier the iron was low in combined carbon corresponding to the present day wrought iron. It could be forged readily and did not harden when quenched in water. The structure was mostly ferrite with areas of pearlite.

Certain general features may be observed at this stage. Ore, before being put in the furnace, was carefully sifted and reduced to the size of small peas. In some case ore was roasted to increase its ferrous content. Charcoal of sal (*Shorea robusta*) wood was considered the best but sometimes even bamboo charcoal was used. It is pertinent to point out here that Bastar have dense forest of sal tree along with iron ore.

Bellows were of different types but usually conformed to the simple bellows that ore can see in operation among Indian blacksmith even today. The large furnaces might use a pair of bellows made of bullockhids but for the smaller ones bellows made of goatskins were enough. Some bellows were worked by hard but in some others one or two persons stood with one foot on each bellows, transferring their weight alternately from one with other. Tuyeres were usually made of clay but sometimes bamboo poles were used. The bellows which were worked by feet more or less conformed to the following type. First, a drem was made from a hallowed-out section of a free trunk. Then a leather diaphragm with a hole about two inches in diameter in the centre was secured by the cord around the drum. A nozzle of hallowed bamboo was fixed into the side of the drum with pitch. A wooden toggle was fitted inside the hole in the centre of the diaphragm. A cord was tied to this toggle at one end and at the other it was fixed to a bamboo pole planted firmly in the ground. A pair of bellows like this was placed with their bamboo nozzles to keep them in place. The bamboo poles acted as return springs to keep the diaphragms raised. The operator stood facing the furnace and kept his toes on the drums above the nozzle. He closed the hole in the diaphragm and forced it downwards by lowering his heel, means by raising it had caused the diaphragm to rise, drawn up by the bamboo spring. By raising and lowering the heels alternately a steady blast could easily be maintained. A common type of bellows, which can be operated by seating on the ground, has been described by Percy[8].

In areas where the first type (i.e. of percy's types) of furnace was used the whole enterprise was a family business with hardly any division of labour. The smelter very often used to wander around, collecting ores locally, and catered to the needs of the villages of the region. Furnaces of the second and third types were usually found in villages inhabited primarily by iron-smelters, and their miners, charcoal-burners, smelters and blacksmiths formed distinct occupational classes.

It is very difficult to obtain iron production statistics from the aforesaid furnaces, but even using the first type of furnace it was possible to obtain ten to fifteen kgm. of iron in a working day. We are indebted to percy again for some of these details. In southern India, about 1844, the lumps obtained straight from the furnaces weighed about eleven lb. each were sometimes sold for 02 annas or 03 pencle each. Generally, each of these lumps yields after forging about three lb. of iron, the best lumps yielded six lb. The expense of forging crude lumps of iron into rough bars by hand-hammers was estimated to be 40 rupees or 04 pounds. The total expense of the bar-iron was about 80 rupees per ton in 1884, which a few years ago, when the above statement appeared, was less than the market price at Madras of the cheapert English bar-iron. Four men-one master three labourers- were required to work a furnace about 4 ft. high, and they could make only 3 lumps in 12 hours[9]. At Arnce in Madras Presidency 100 lb of ore (in this case washed iron-sand) yielded 33.75 of crude iron and 100 Ib. of crude iron yielded after forging 33.25 of bar iron. In North Canara about 200 lb of crude iron were obtained from each furnace at open smelting. The price was about 50 rupees per ton. In Malabar the annual out turn was estimated to be 475 tons, the selling price being about 60 rupees per ton. To produce lb of crude iron, 6 to 7 lb of charcoal and 04 to 05 lb of ore were required. The estimated profit to the smelter the cost of a furnace varied from 4 annas to 2 rupees and these furnaces were capable of containing 15 to 18 lb. of ore. This area was stated to be the principal seat of steel manufacturing in south India. In Nagpur a furnace did not cost more than a rupee and the monthly yield per furnace was about 1 mound of bar-iron derived from 1.74 maund of crude iron. Through Kumaun, Garhwal in northern India and Bengal Presidency the average price of charcoal delivered within 4 miles of the forest was about 3 annas for 30 seers (60 lb.) In Kumaun 930 seers of ore produced 327.5 of crude iron or bloom metal, which in tum produced 81.75 seers of bar-iron. For 930 seers of ore, one needed 327 seers of charcoal, therefore the ratio between ore and charcoal must be in 3 :1.

J.H. Blackwell, *'Mineral Viewer for Bombay'* published in 1857 a report of the examination of 'mineral districts' of the Narmada valley. According to him the town of Tendukhera was entirely engaged in iron-making. It is interesting to note that no flux was used in smelting at Tendukhera. But it is, however, reported that in the Waziri hills limestone was used as flux. A graphic account of the economic condition of the Agaria iron smelters of the Chotanagpur plateau comes from Valentine Ball, writing in 1880. The spong-iron, before being hammered into a bloom, was locally called giri. Occasionally the Agaries themselves produced the bloom and fashioned agricultural implements and other products, but quite often they sold the giri to blacksmiths who then made the bloom and manufactured implements.

References

1. It may here be observed the nature of the clay is a material point with regard to this implement, and at Lohardaga it is well adapted, being not the great trap-range, the trap family; in all probability therefore it contains a small portion of lime; a few small grains of wake may also be observed in it and in addition to these *Kodo* straw being mixed with it the potash derived from these materials facilities the fusion of its silex, whilst the lime renders it a fusible compound, the ingredients of which are well assorted, and seem to be well adapted for use. The native smelters once deserted these mines on account of some pique, but the quality of the clay brought them back again.
2. The broad end $3^1/_2$ the narrow end $2^1/_2$, the mean of which is 3 parts. These dimensions do not greatly differ from those of the native smelters, on the contrary they are founded on the mean of all the measures I could procure and the difference consists in their being regular and fixed while those of the natives are irregular and often governed by caprice.
3. The vertical angle is obtained by means of the wedge the thickness of which is adapted to the angle of 12 degrees, and the horizontal angle is obtained by keeping the ends of the wind tubes a certain number of fingers breadth as under when imbedded in the Akaira. These quantities never differ much.
4. The refinery is convertible into a blacksmith's forge by taking out the iron plate and building up a wall in the middle so as to destroy the reverberating effect.
5. Major James Franklin of Bengal Army, F.R.S., M.R.A.S. had in his description of *'The Mode of Manufacturing Iron in Central India in 1829'* describe the traditional Iron smelting centers in the Districts of Jabalpur, Panna, Katola, Sagar, but he did not includes the District of Bastar. His description is available in the record of Royal Society, London (manuscript No. A.P. 5/22).
6. The village of blacksmith
7. Census of *India 1991 (Series 3)* Part II-A, 228.
8. Percy J. *'Metallurgy . Iron and Steel '* (London, 1864) p. 255.
9. On the account given by Captain Campbell who was Assistant Surveyor General of Madras Establishment (A.D. 1842).

PLATE NO. I

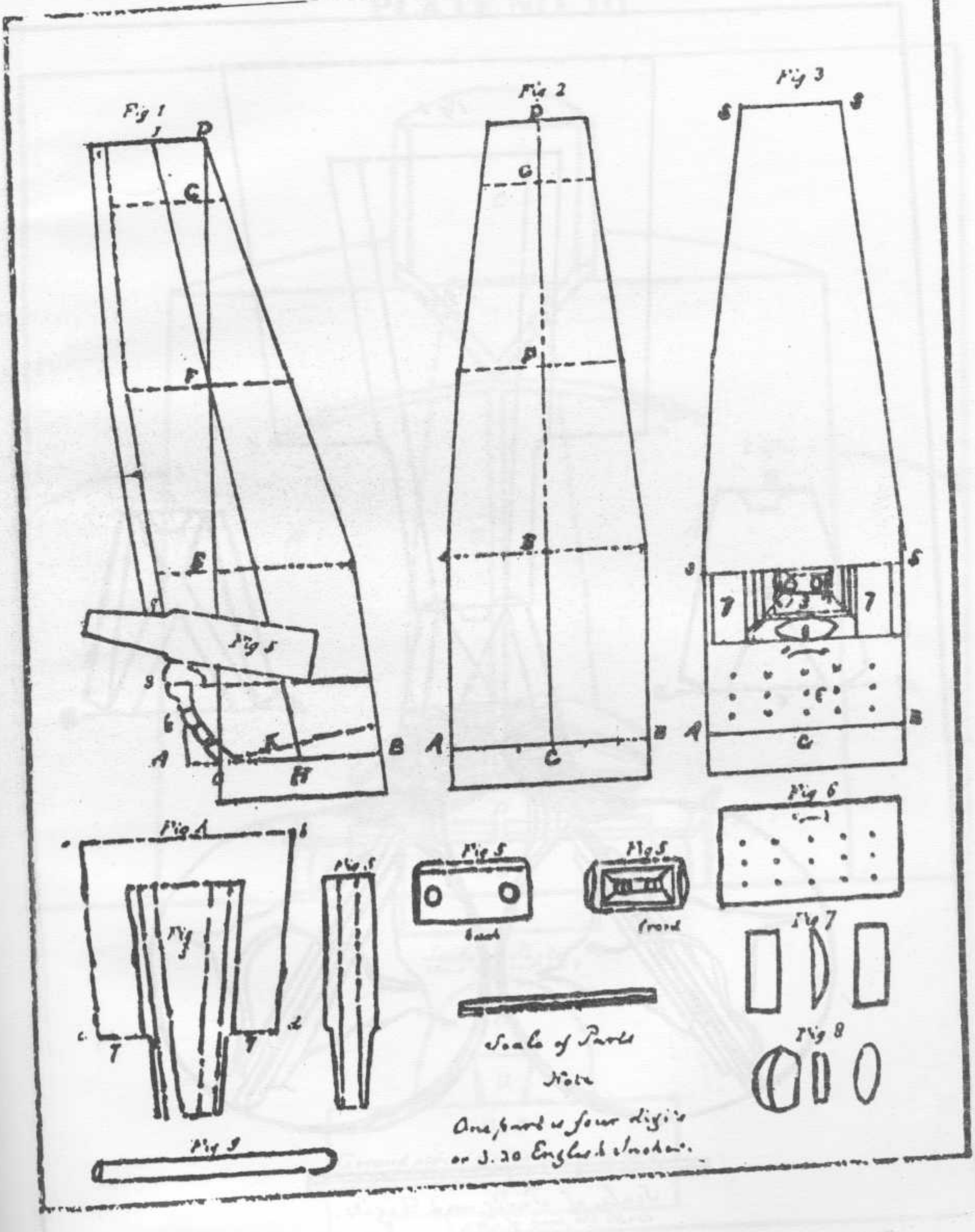
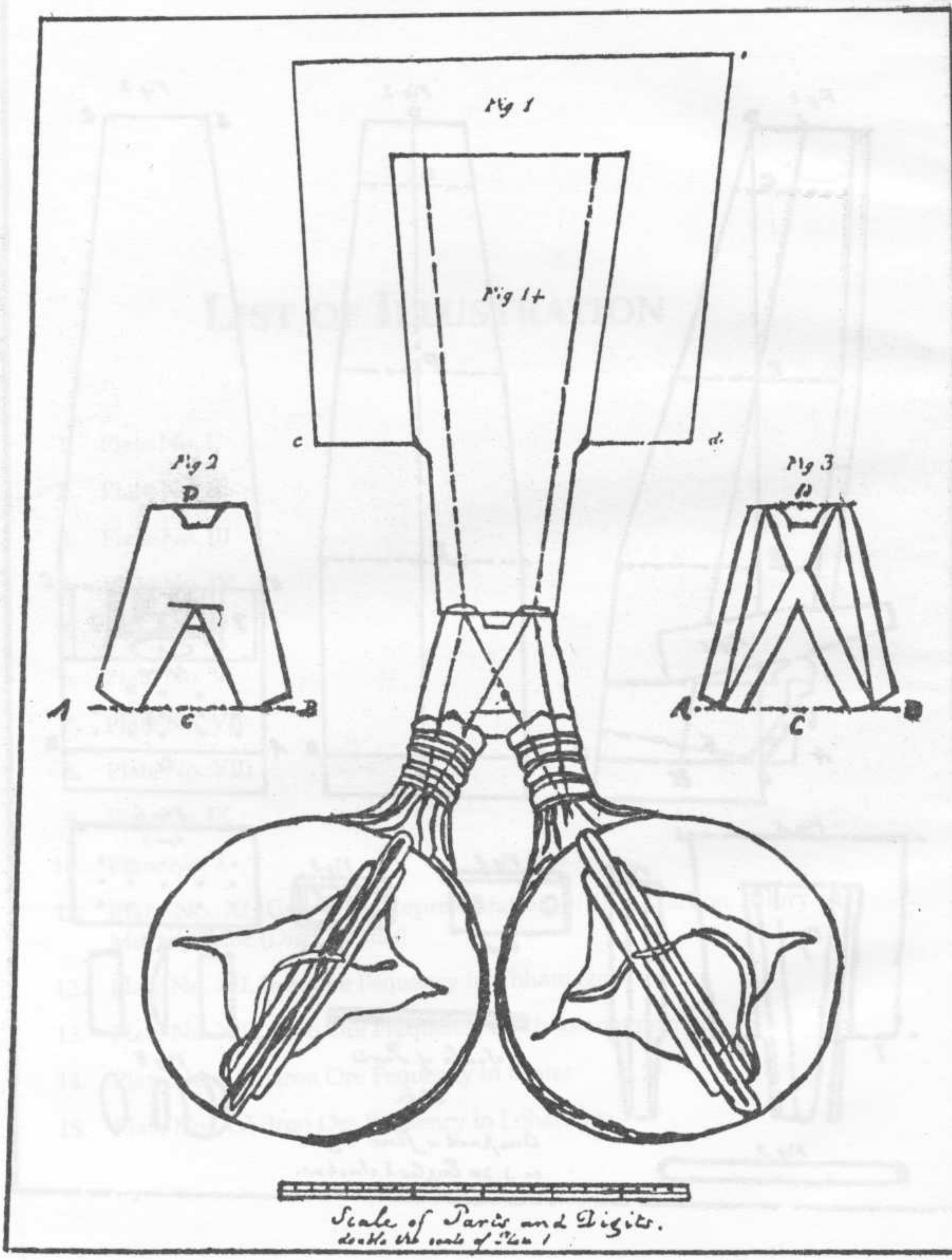


Fig 1
Fig 2
Fig 3
Fig 6
Fig 7
Fig 8
Fig 9
Scale of Parts
Note
One part is four digits
or 3.20 English Inches

PLATE NO. II



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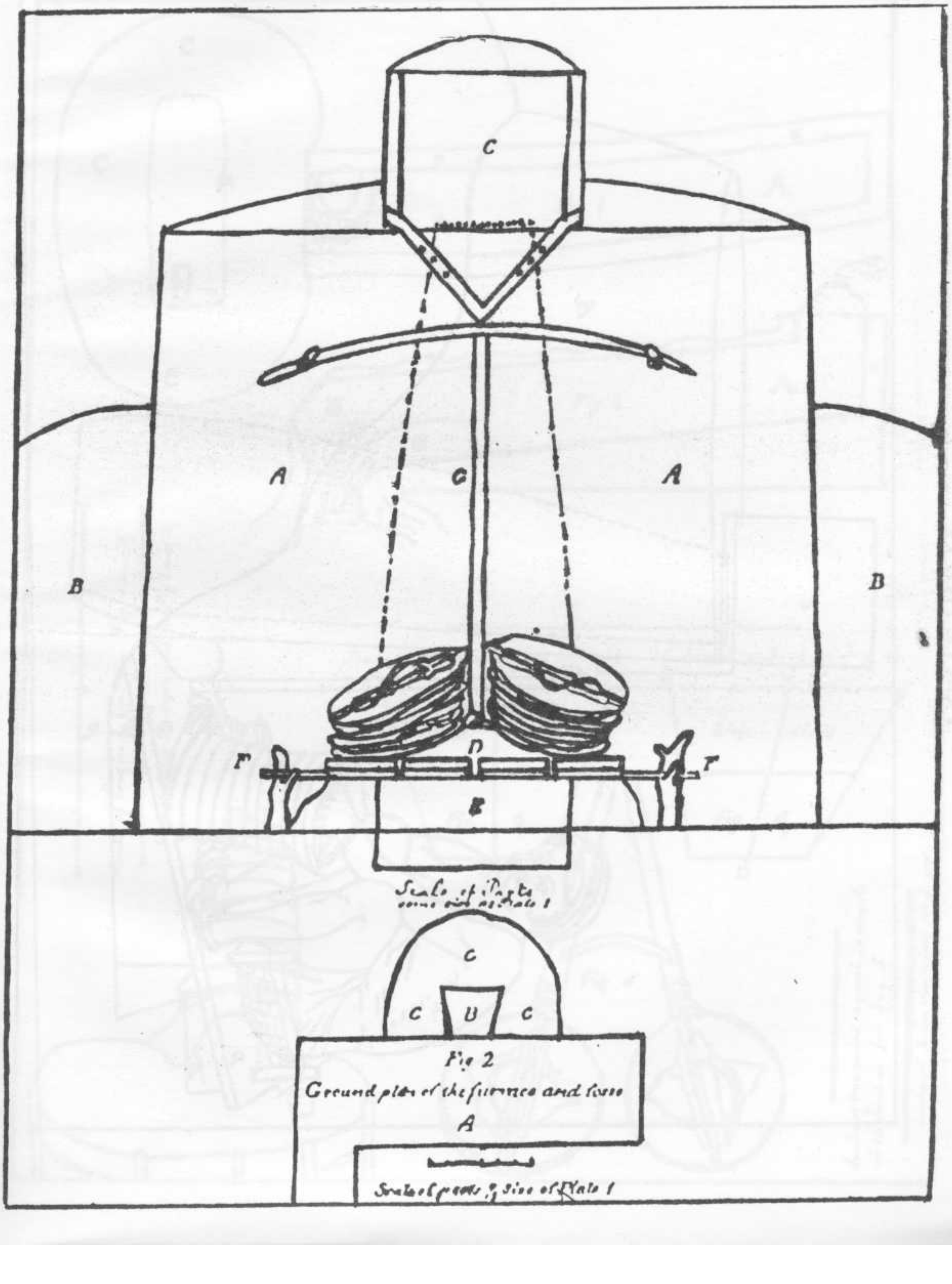

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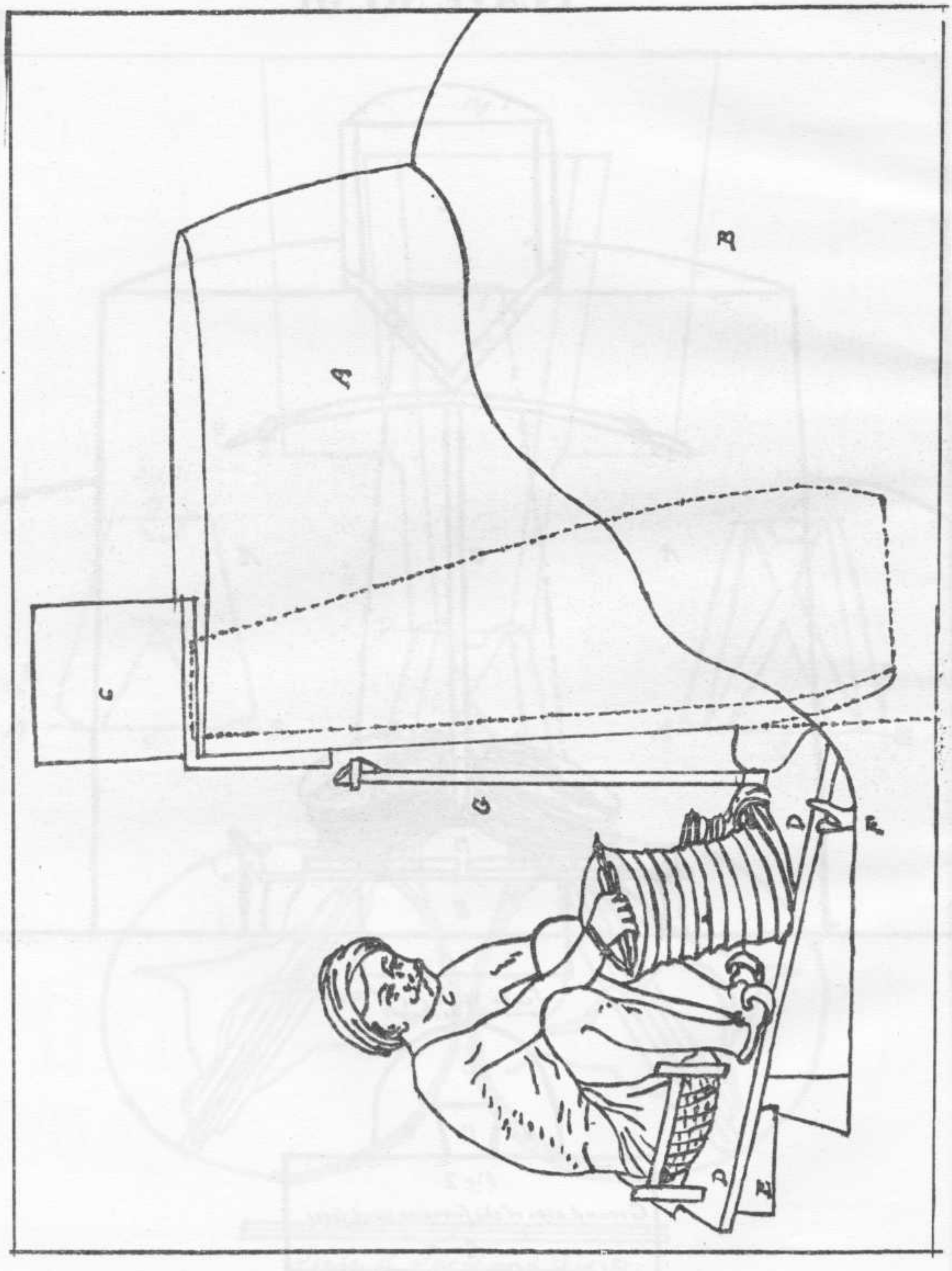

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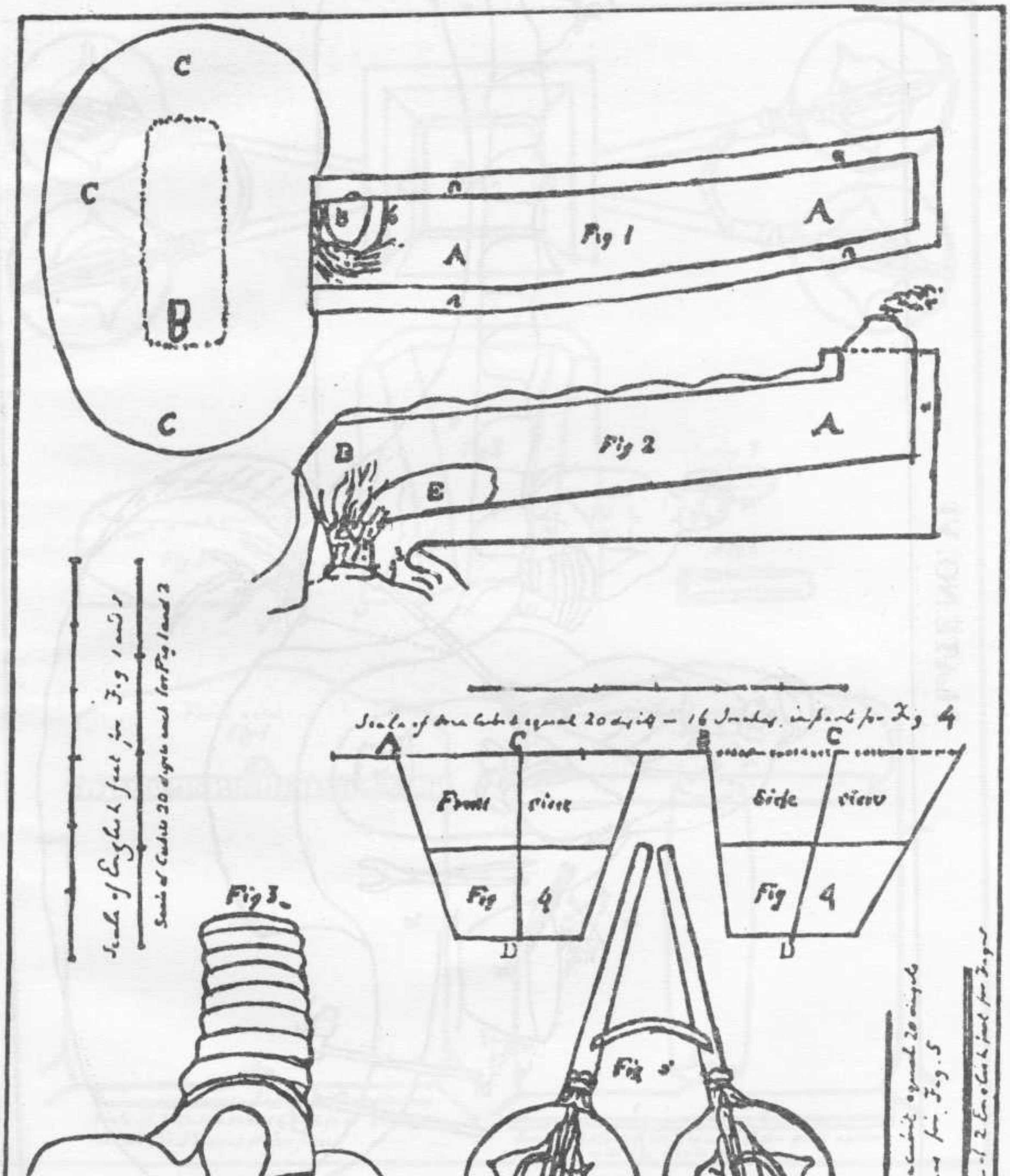

C
C
C
D
A
A
Fig 1
Fig 2
A
B
E
Scale of English feet for Fig 1 and 2
Scale of Cubits 20 digits each for Fig 1 and 2
Fig 3
Front view
Side view
Fig 4
Fig 4
D
D
Fig 5

PLATE NO. VI

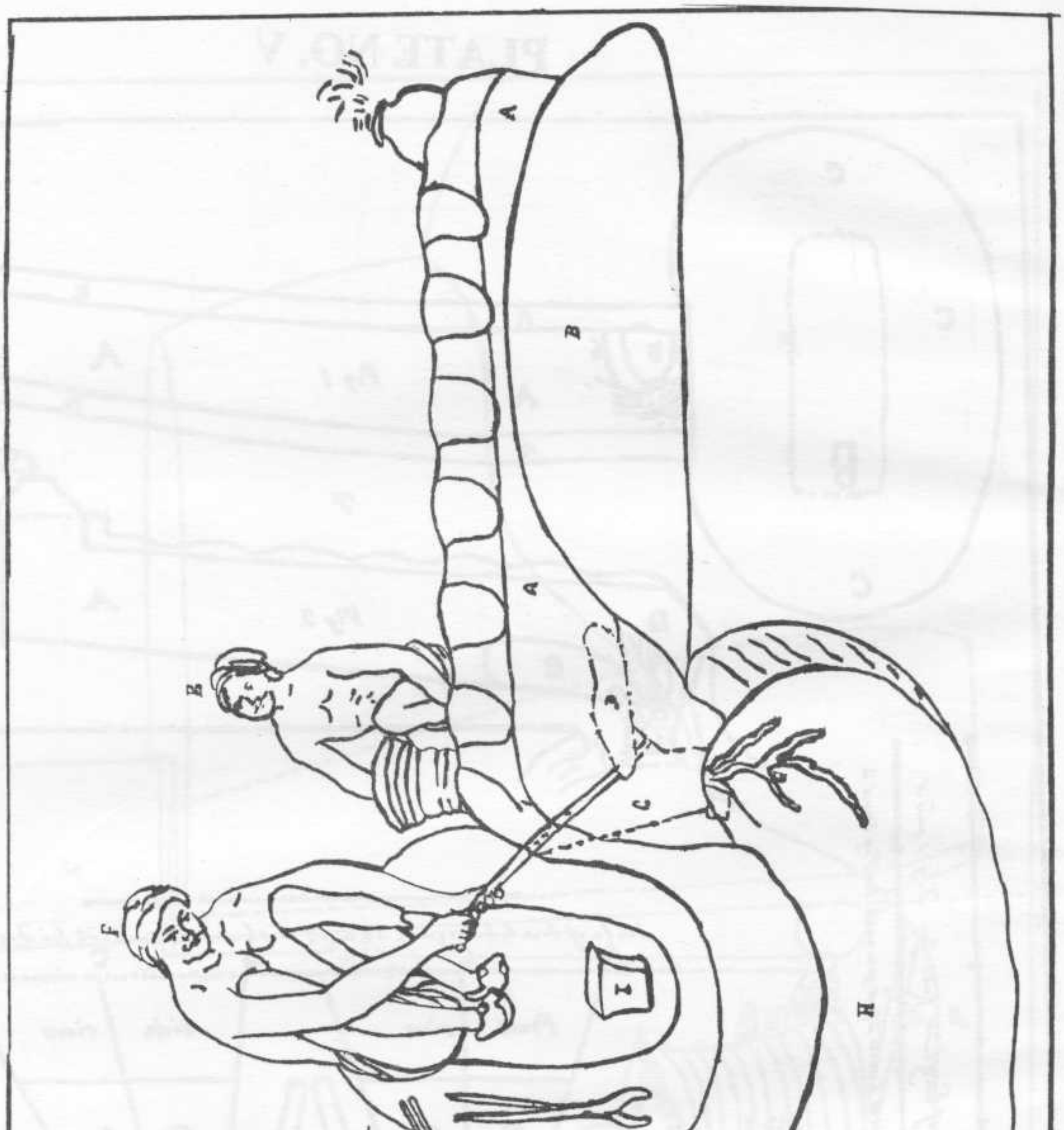


PLATE NO. VII

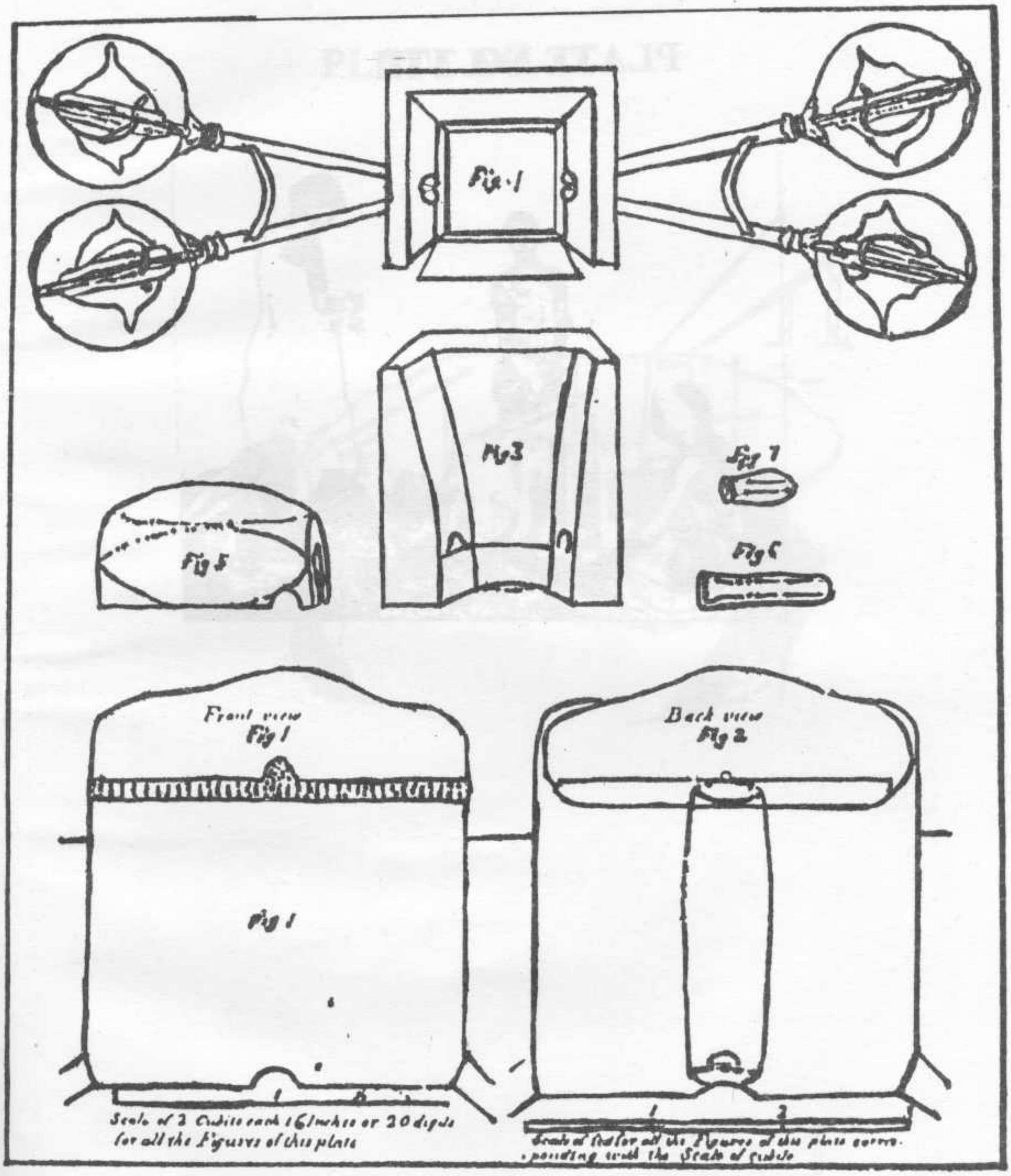
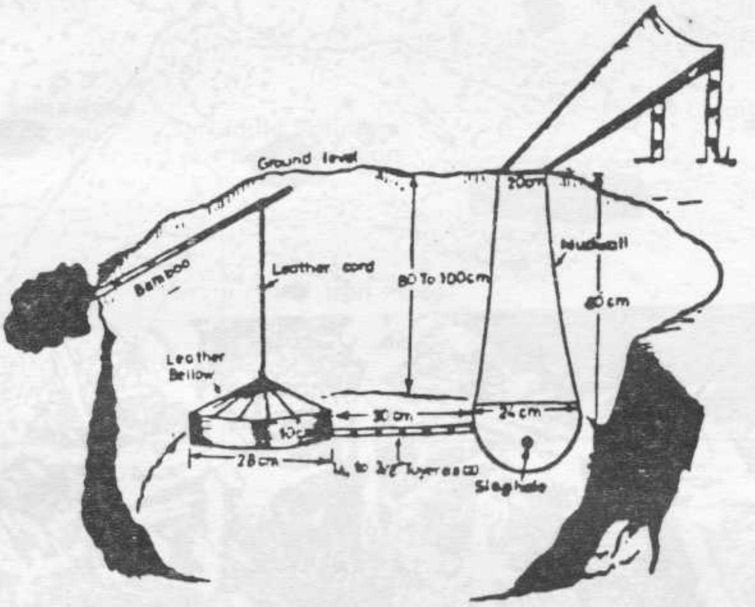


Fig. 1
Fig 3
Fig 7
Fig 5
Fig 6
Front view
Fig 1
Fig 1
Back view
Fig 2
Scale of 2 Cubits each 16 Inches or 20 digits
for all the Figures of this plate

PLATE NO. VIII

PLATE NO. IX


Ground level
Bamboo
Leather cord
80 To 100cm
20cm
Mudwall
60cm
Leather Bellow
30 cm
24 cm
28cm
Slaghole