

1 Some ironfounding cupola furnaces in Asia and Europe

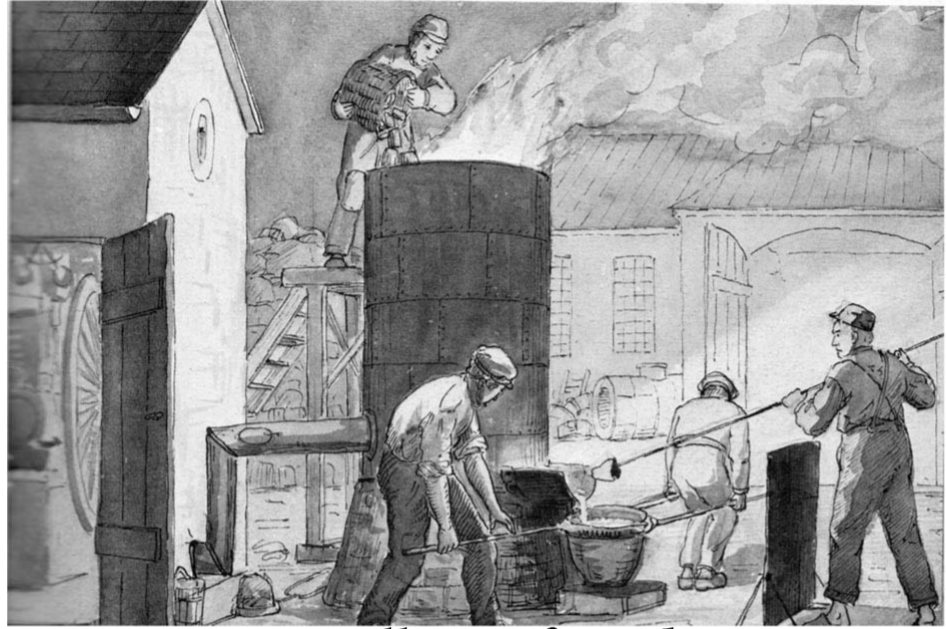
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The cupola furnace was the usual furnace for casting iron from ancient times to the middle of the 20th century. This sheet shows some early modern cupolas.



Torben Witt, Aalborg og Fabrikkerne, 1980, p. 21

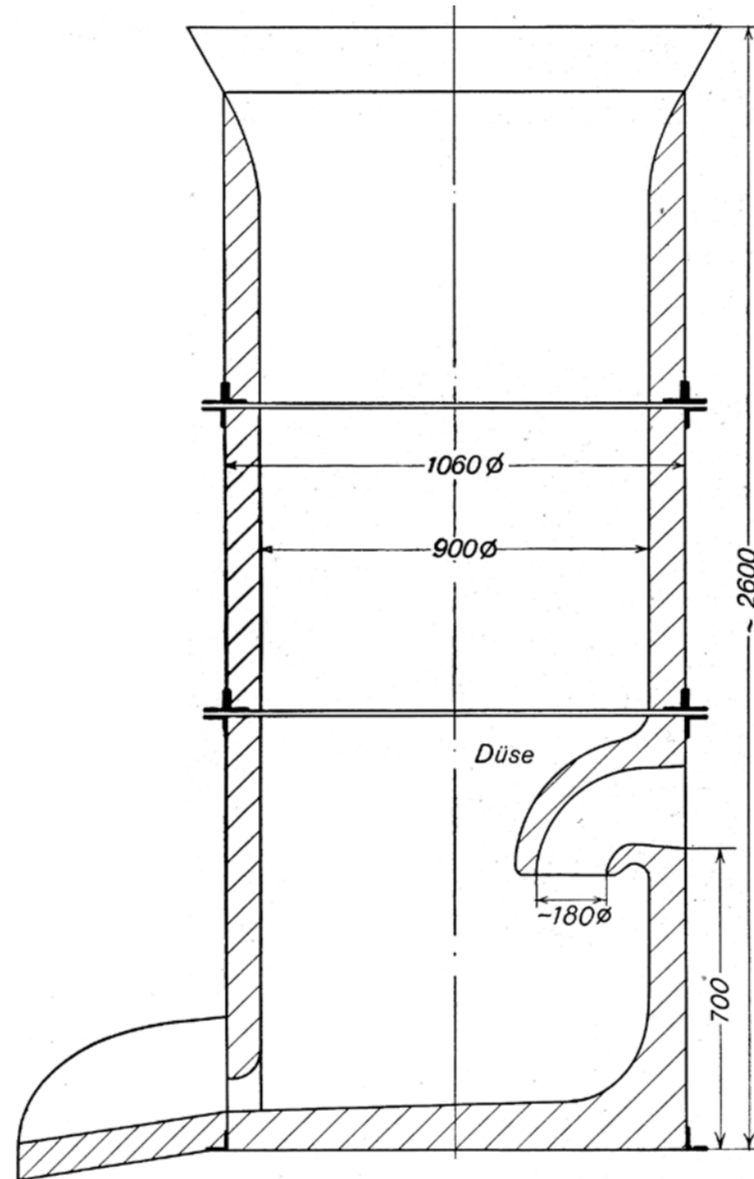
Here is a small iron foundry in Denmark in 1890. The cupola is a shaft furnace. Iron and fuel (in this case coke) are charged in the top, and air is blown in near the bottom. There is a steam engine inside the building at the left.

The fuel burns in contact with the iron, the iron melts, and molten iron is tapped out at the bottom.

Notice the workers. The one whose job is to open and close the taphole is protected by a screen from the high radiant heat from the molten iron.



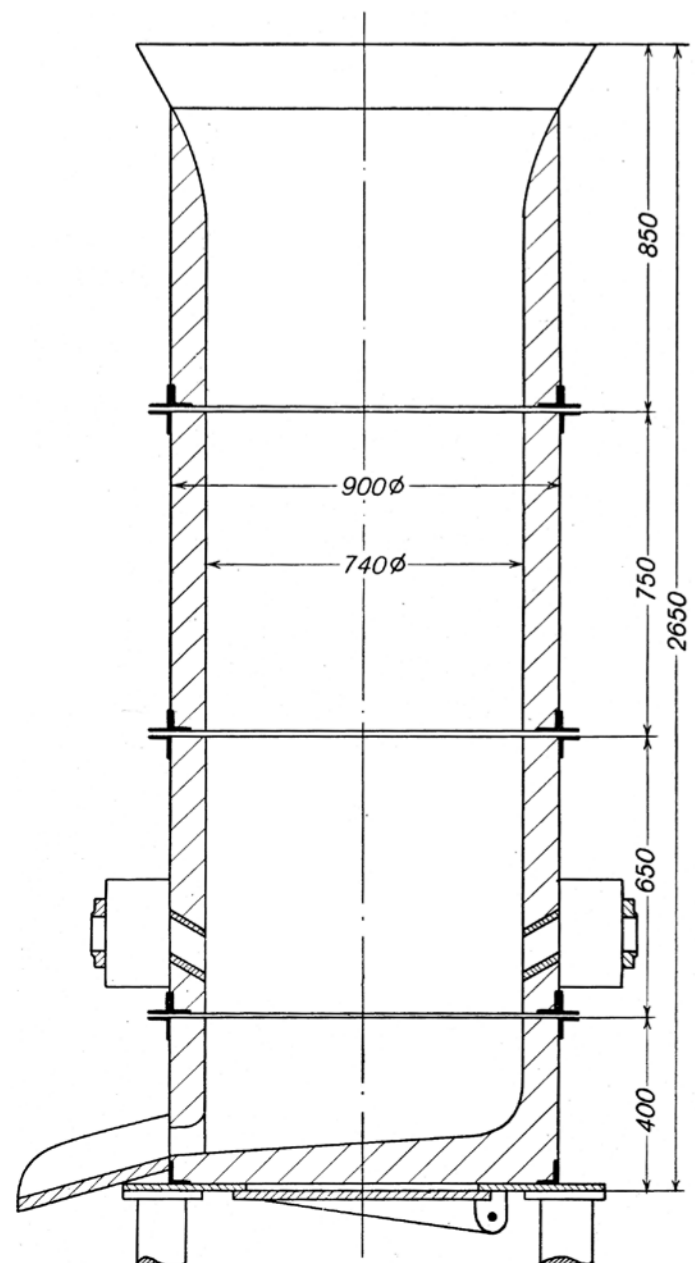
Archives of the Needham Research Institute, Cambridge



Gottwald, Technische Mitteilungen Krupp, 1938, 6.4, p.110

Diagram of a traditional Chinese cupola furnace, probably in Shanghai. Dimensions in mm.

Operation of a cupola furnace in Chengdu, Sichuan, photographed by Joseph Needham in 1943.



Gottwald, Technische Mitteilungen Krupp, 1938, 6.4, pp.110-111

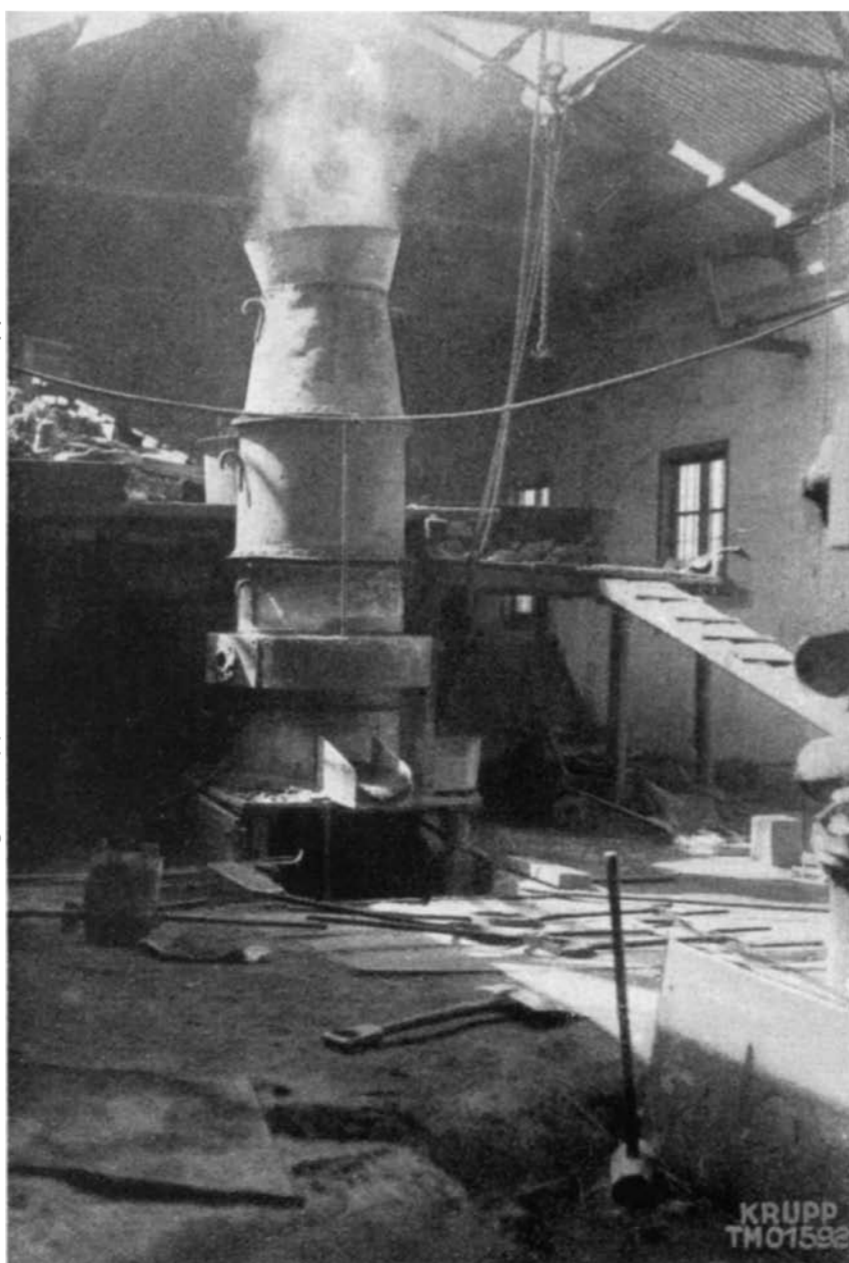
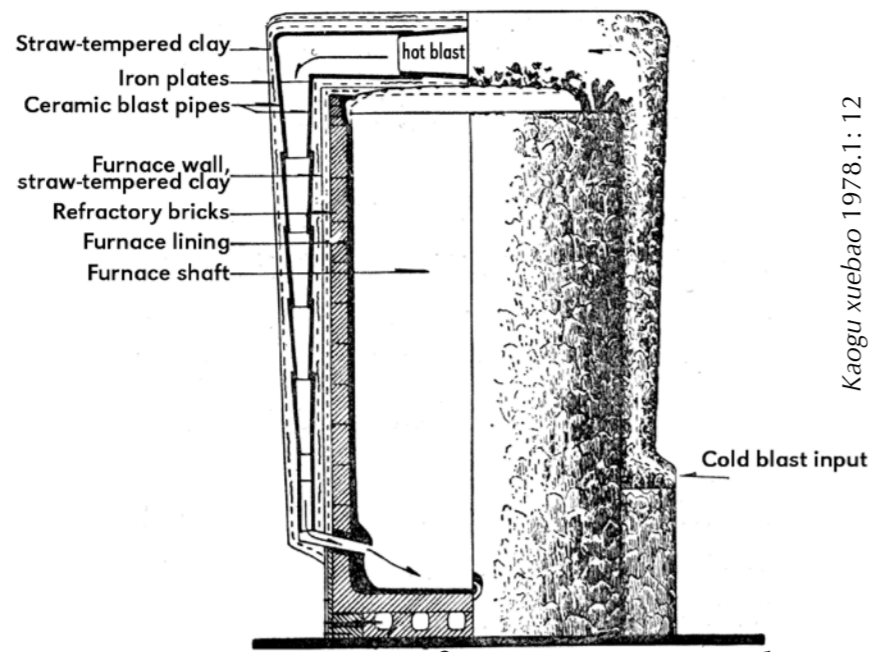


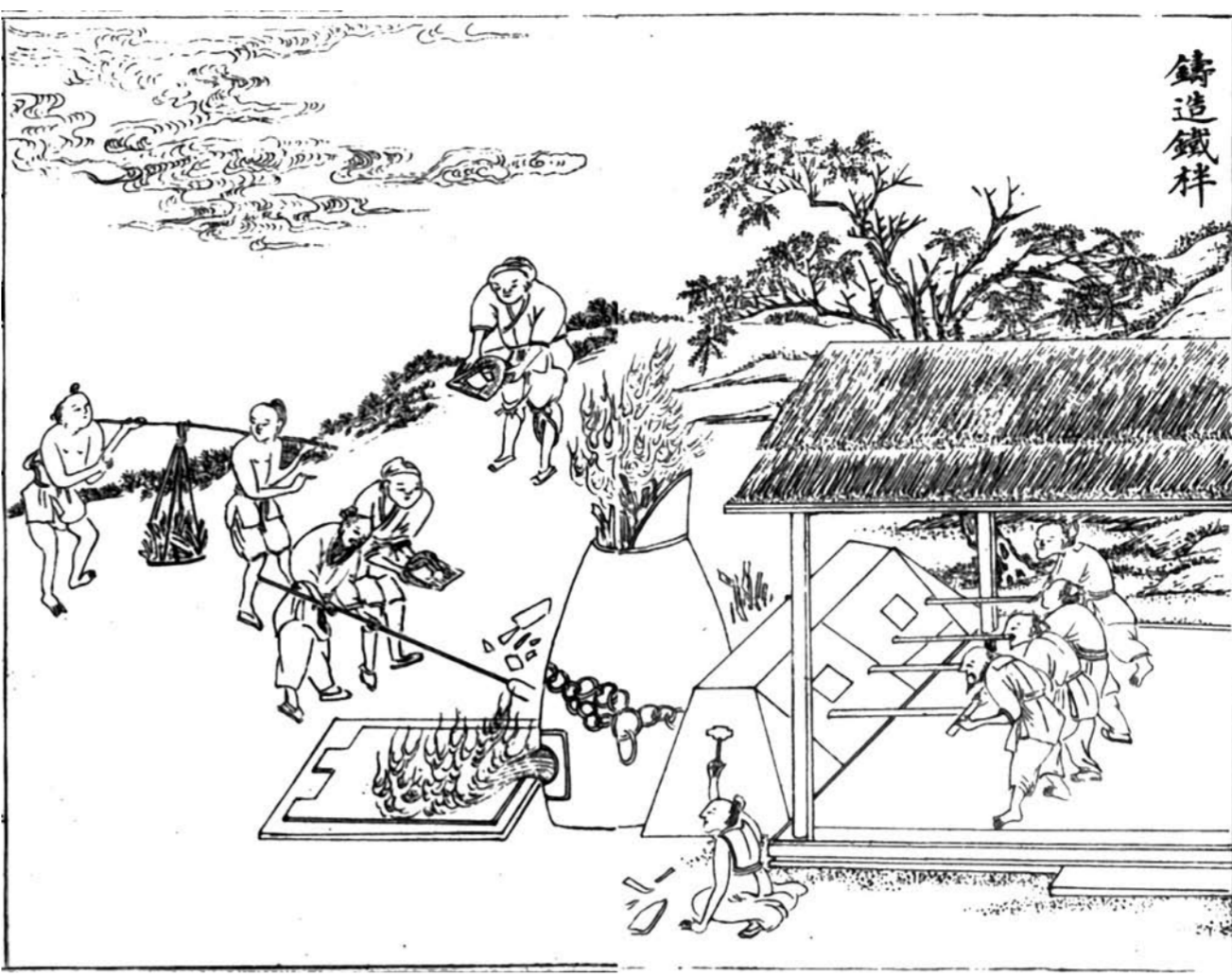
Diagram and photographs of a 'Chinese cupola furnace with European influence', probably in Shanghai. European influence is seen in the use of multiple tuyères and the bottom drop-plate for maintenance.

Here are a couple of ancient Chinese ironfounding cupola furnaces.



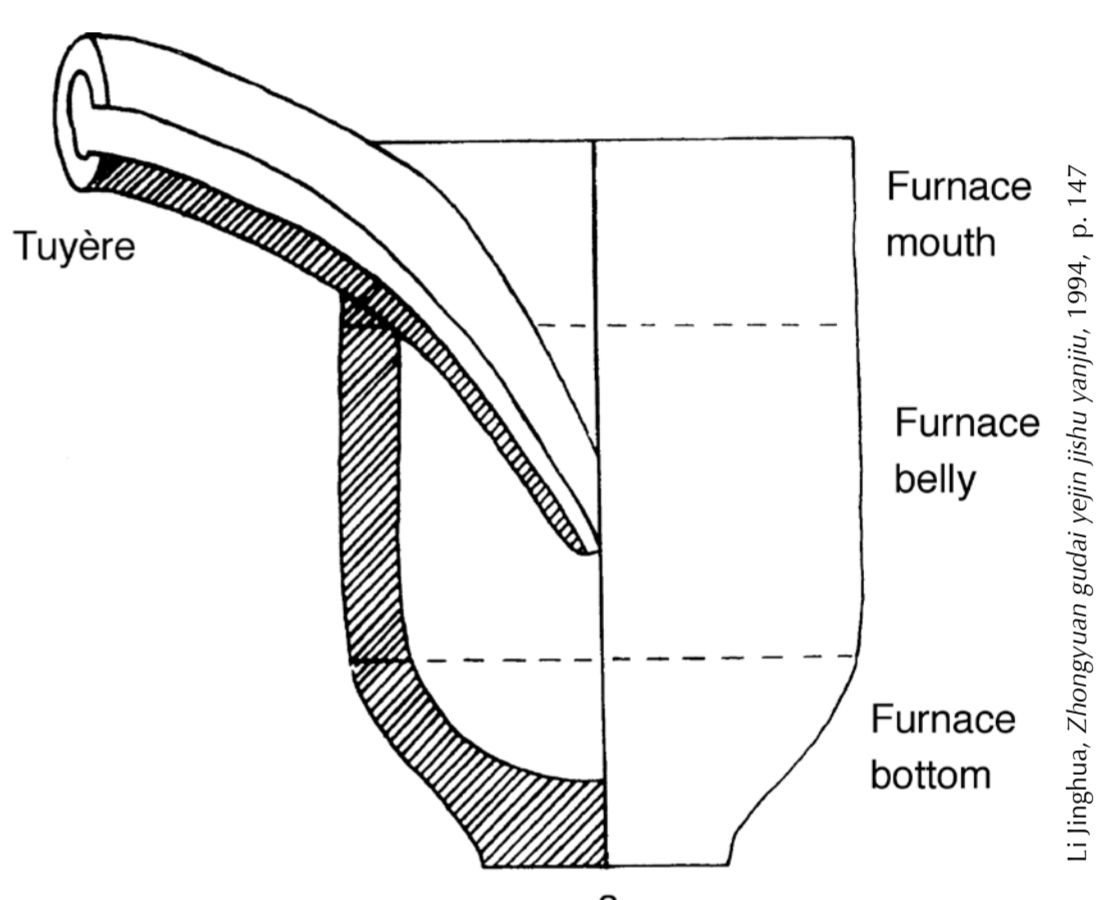
Kaogu xuebao 1978.1: 12

Reconstruction of a Han-period (2nd cent. BC – 2nd cent. AD) cupola furnace excavated in Henan, China. Note that the blast-pipe runs over the mouth of the furnace, pre-heating the blast to some extent.



A Yuan-period cupola furnace, casting a large salt-boiling cauldron. 18th-century copy of a drawing dated AD 1332.

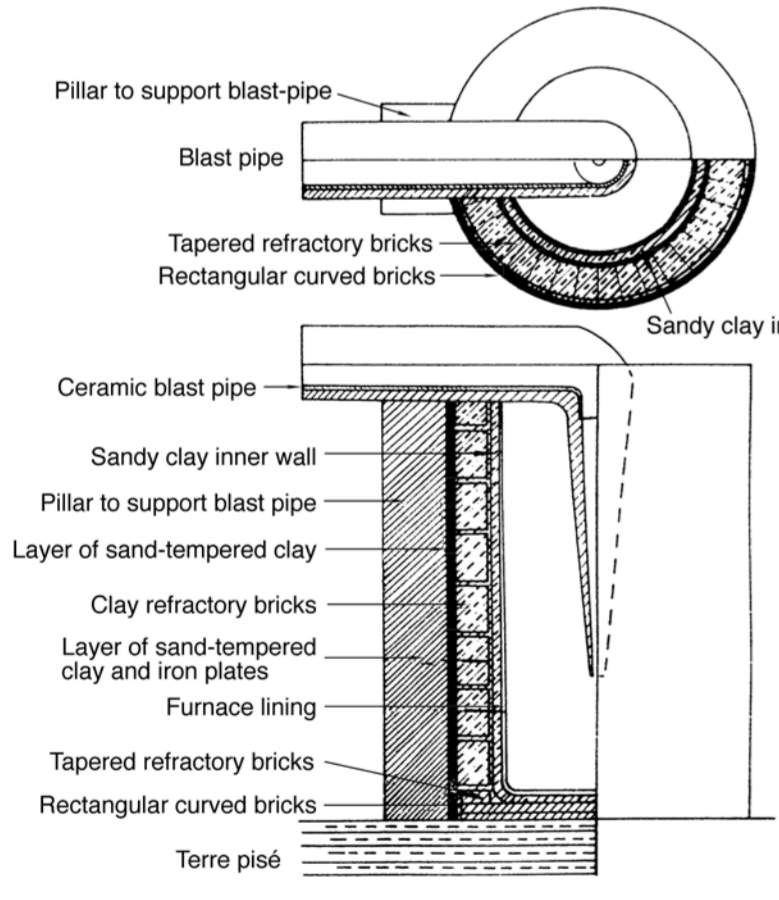
The two holes through the wall of a modern cupola furnace – for the blast and for tapping – are parts where troubles can occur. The blast hole can become clogged, and there can be difficulties opening the taphole when necessary. In pre-modern cupola furnaces there were at least three strategies sometimes used to reduce these difficulties. (1) The tuyère could be inserted through the mouth of the furnace. (2) The taphole could be left open, and the furnace tilted for tapping. (3) The furnace could be built in sections, with the bottom section functioning as a crucible when the upper sections are removed.



Li Jinghua, Zhongyuan gudai yejin jishu yanjiu, 1994, p. 147

Reconstruction of a type of bronze-melting furnace found at many foundry sites of the Spring and Autumn period (770–476 BC).

Here are three cupolas with the tuyère inserted through the mouth.



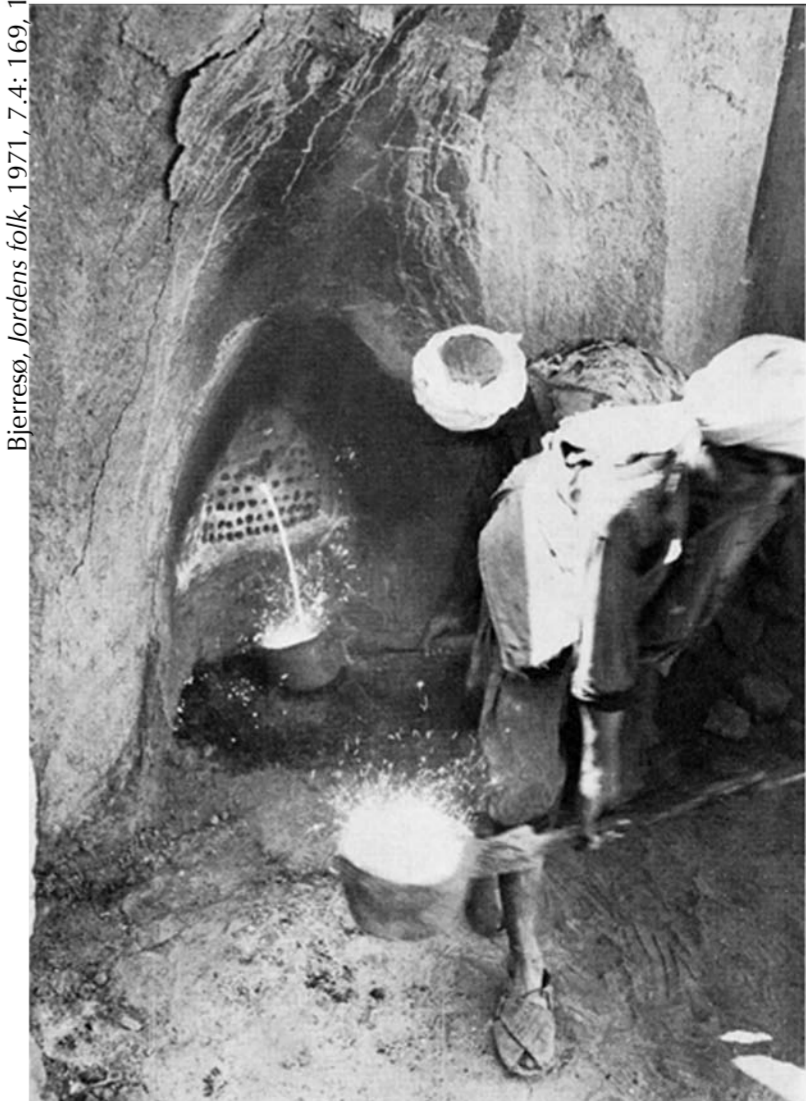
Reconstruction of a type of iron-melting furnace of the Warring States period (475–221 BC).



Chinese gouache painting, Guangzhou (Canton), 19th century. It is not clear what is happening here, but I suspect that iron is being melted in a crucible with the tuyère inserted into the mouth.

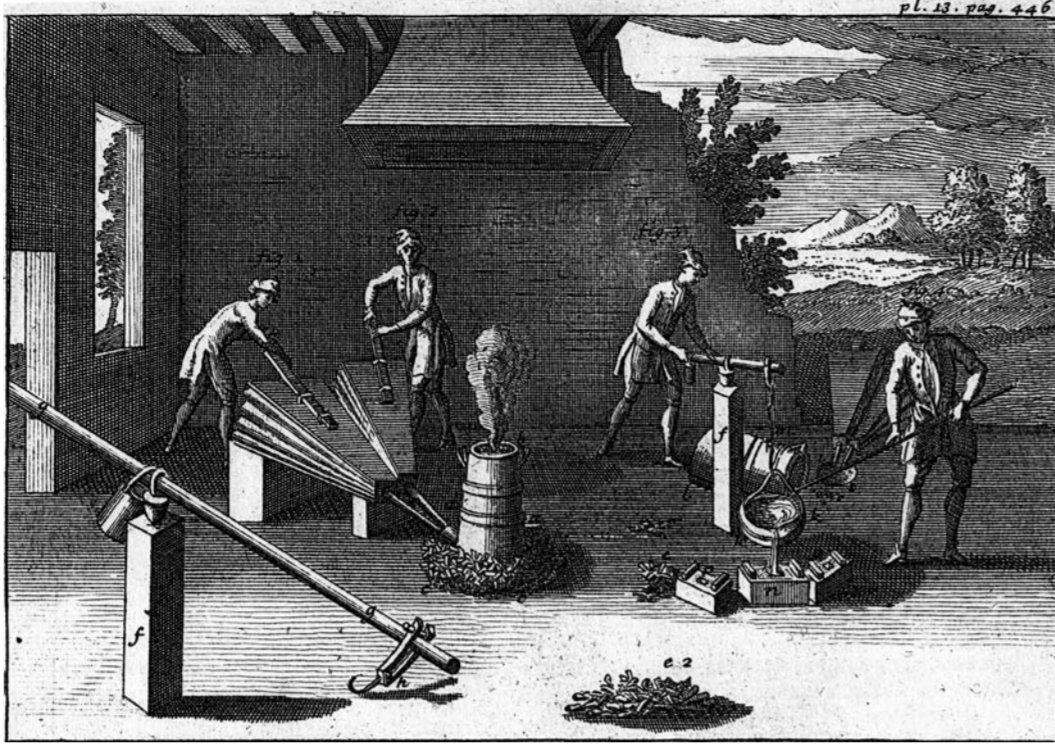


Iron cupola in Herat, Afghanistan, 1960's.



Bjerrnes, Jordens folk, 1971, 7.4: 169, 171

Here are some iron cupolas built with a bottom section functioning as a crucible.



One kind of furnace used by Gypsy ironfounders in Europe. The illustration is from the 18th century. This is a cupola furnace in three parts. When the iron has melted, the upper sections are removed and the iron is poured from the bottom section.



Photographed by Rewi Alley in Anhui, 1958.

A Gypsy ironfoundry, 19th century

The Gypsy method of smelting iron, for sole-clout for ploughs, and smoothing-irons, is also simple, rude, and primitive. The tribe erect, on the open field, a small circle, built of stone, turf, and clay, for a furnace, about three feet in height, and eighteen inches in diameter, and plastered, closely round on the outside, up to the top, with mortar made of clay. The circle is deepened by part of the earth being scooped out from the inside. It is then filled with coal or charred peat; and the iron to be smelted is placed in small pieces upon the top. Below the fuel an aperture is left open, on one side, for admitting a large iron ladle, lined inside with clay. The materials in the furnace are powerfully heated, by the blasts of a large hand-bellows, (generally wrought by females,) admitted at a small hole, a little from the ground. When the metal comes to a state of fusion, it finds its way down to the ladle, and after being skimmed of its cinders, is poured into the different sand moulds ready to receive it.

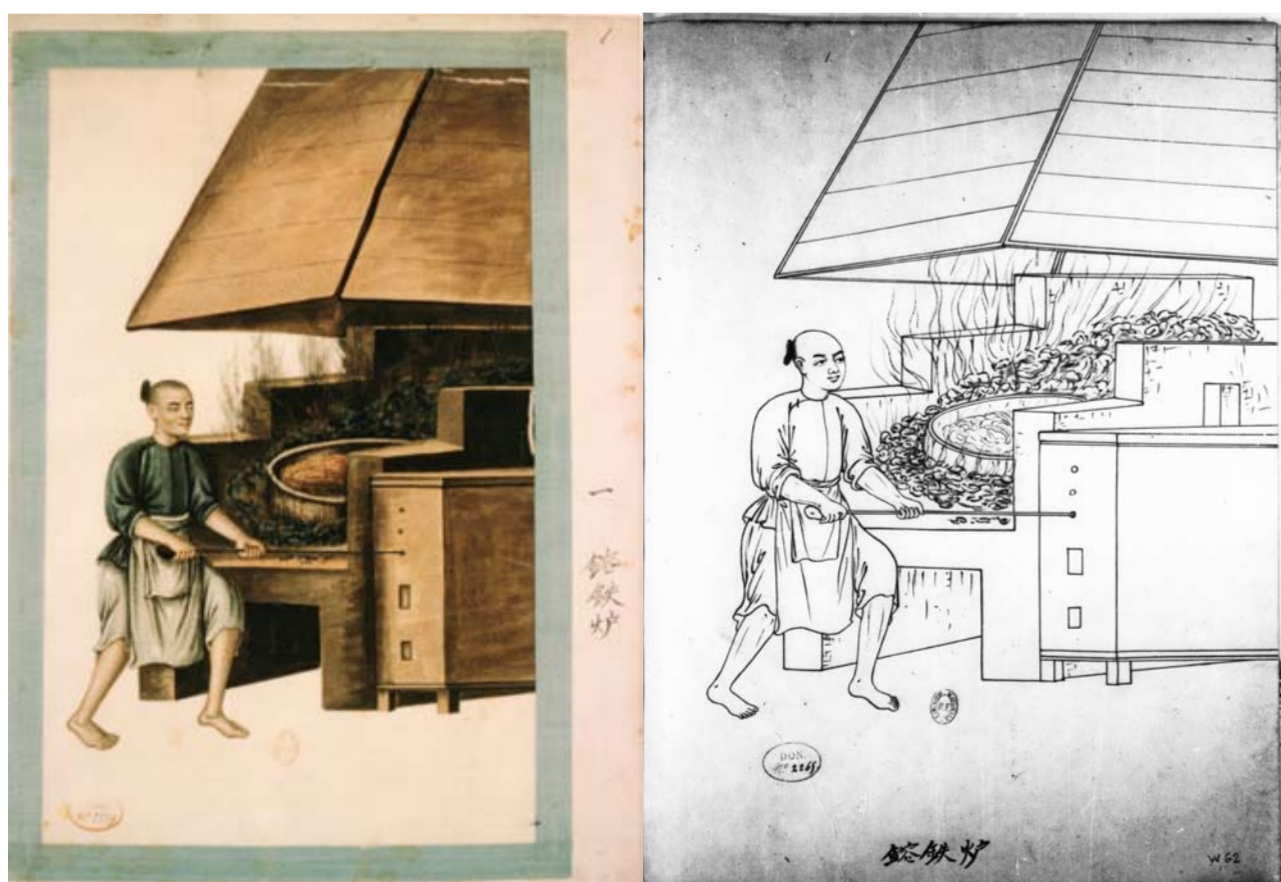
(Simson, *A history of the gipsies*, 1865, pp. 234–235)

Iron Casting in Guangdong, ca. 1899

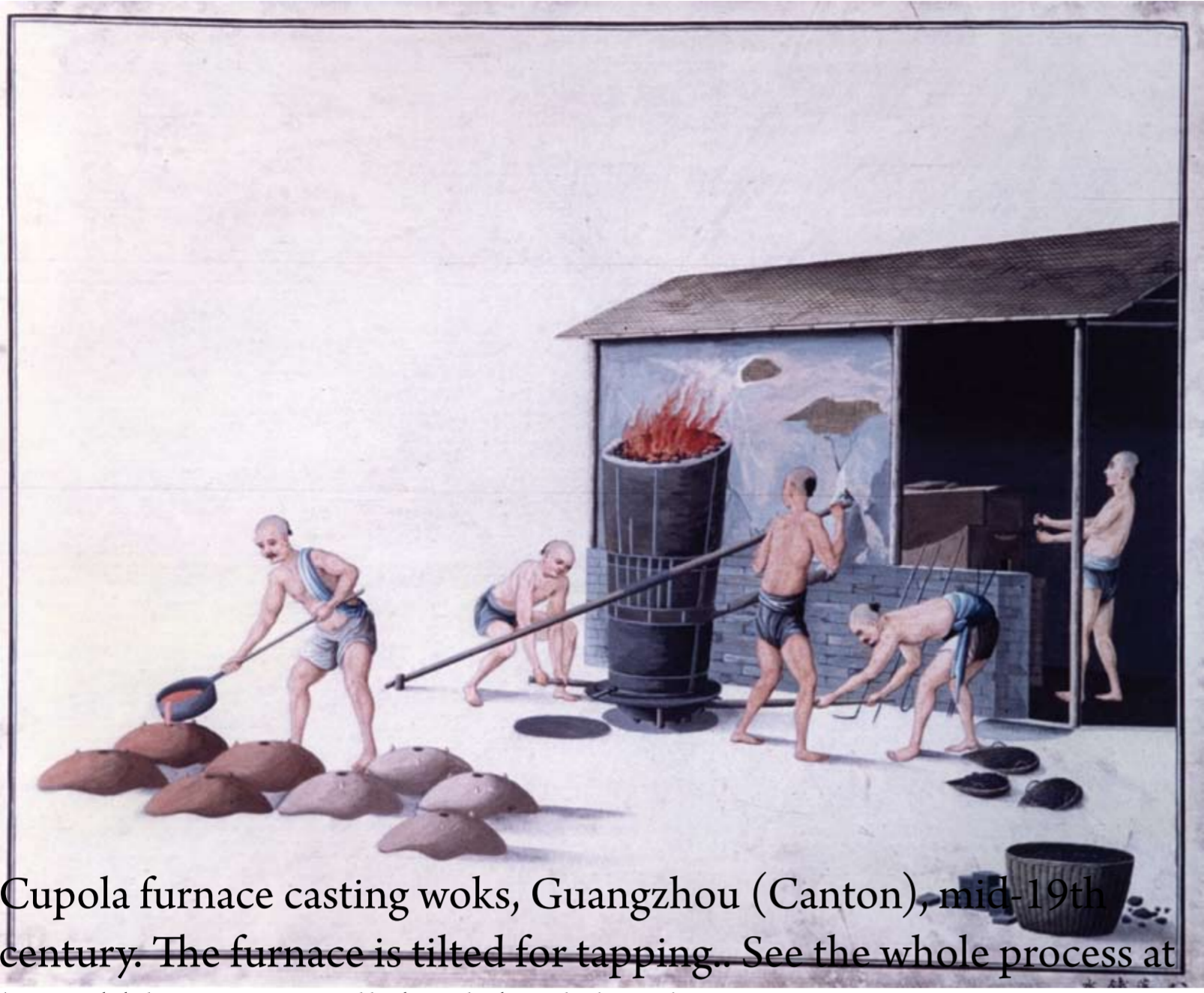
Description of the operation of an iron foundry, probably somewhere near Guangzhou (Canton), in 1899, reproduced from an anonymous article in *American Manufacturer*, 1899, 64: 125, where it is quoted from 'The Celestial Empire of November 21'.

At Huangkiao we witnessed the operations of a Chinese iron foundry. The furnace was very simple in construction, being made of clay in three sections. The lowermost was what might be called the crucible, and was the receptacle for the molten metal, being about a cubic foot [28 litres] in capacity. The middle section was a ring of the same diameter as the lower section, and about eight inches [20 cm] in height. In this was a hole to receive the blast pipe, the blast being supplied by a native 'box' bellows of the usual type. The upper section was another ring about a foot [30 cm] high. I was not fortunate enough to see the putting together of the furnace; when I saw it, the operation was begun, and a man was piling on the last of the charge - scrap cast iron and coke. One man was then pumping the blast; I waited till I saw the yellow flame begin to show above the piled up iron, which gradually sank down as that below melted. By and by two men pumped the blast. As the process went on, a still stronger blast was needed, so a third man helped at the bellows, and the pumping grew fast and furious, while one workman, wearing an old broad-brimmed straw hat to protect his head and face from the shower of sparks, stirred the glowing mass with an iron rod. In due time the melting was finished, the molten iron having fallen through to the bottom section of the furnace. The blast was stopped, the bellows disconnected, and the upper and middle sections of the furnace taken off and laid aside. **The surface of the molten iron being skimmed of its slag, it was well covered with rice husk ashes. This protected the face of the man who next had to handle it from the intense heat that would otherwise have radiated from the molten iron. This man's duty was to clasp the crucible in his arms, literally hugging it to himself, and to fill the molds arranged around.** In this he was assisted by a woman, who raked back the ashes where the iron was to run out. On this occasion plowshares were the result of the operation, the one charge being sufficient to cast about 20. Almost immediately following this man was another, who took the molds apart and removed their contents. No sooner were the molds empty, than the workmen set about repairing their inner surface with a black paste, ready for another casting. Upon inquiry I was told that about 50 catties [30 kg] of iron and 20 catties [12 kg] of fuel constituted one charge for the furnace, and that four meltings were effected in a day's work.

a *Feng xiang* 風箱 or double-action piston bellows.



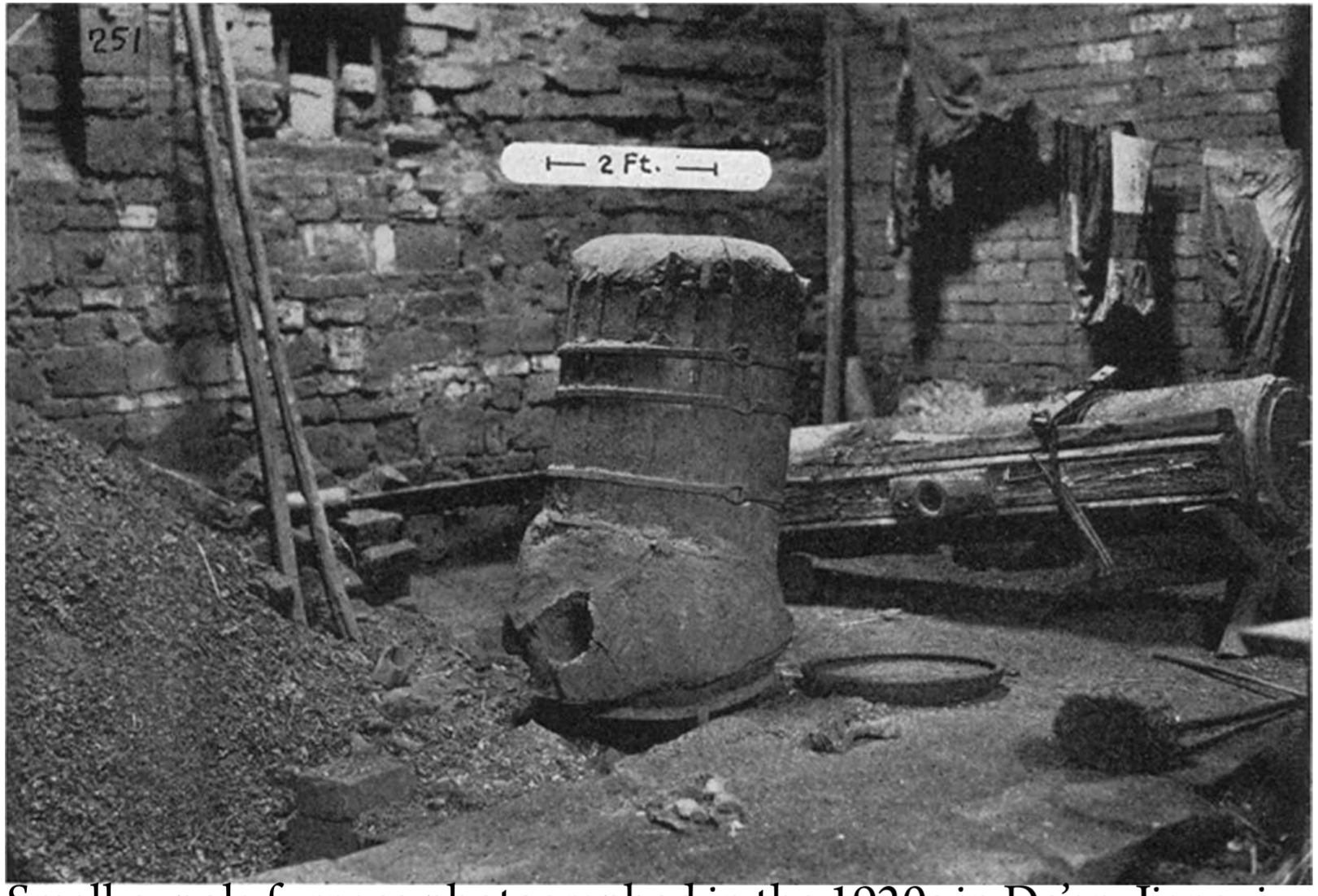
Gouache painting and line drawing by anonymous Chinese artists in Guangzhou (Canton), mid-19th century. The title of each is 'Furnace for melting iron', but it is difficult to understand what is going on here. It seems likely that the original artist has misunderstood what he saw. Perhaps the crucible visible here was the bottom section of a sectional cupola.



Cupola furnace casting woks, Guangzhou (Canton), mid-19th century. The furnace is tilted for tapping. See the whole process at <http://donwagner.dk/wok/wok.html>

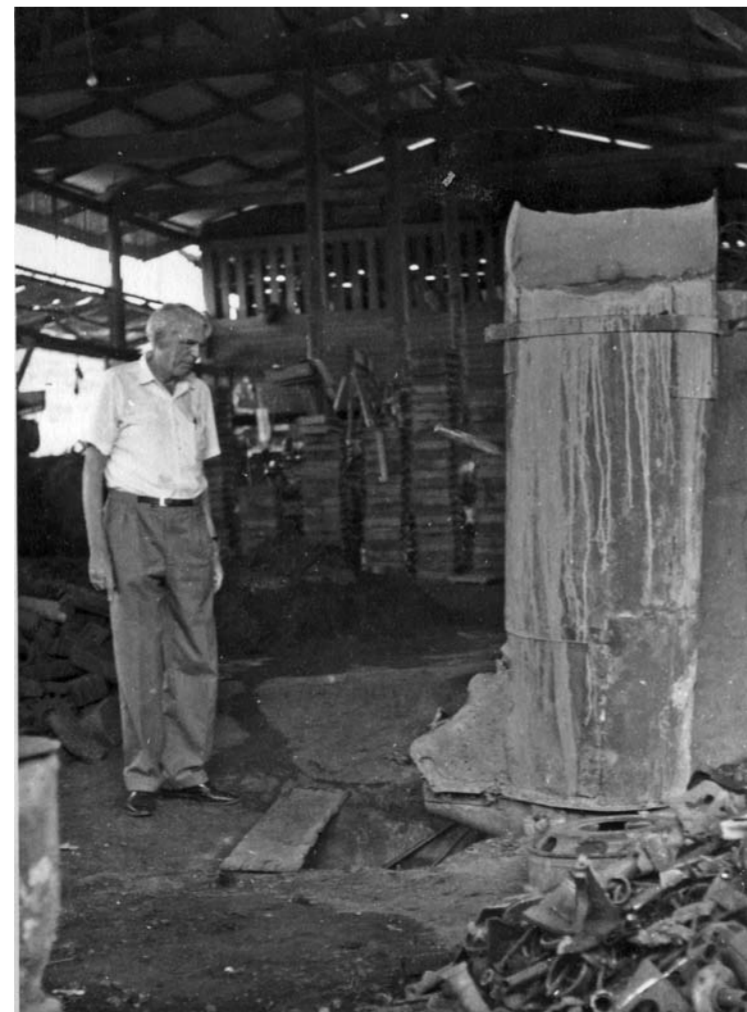


An ironfoundry in Huize 会泽, Yunnan, 2008. Taken from a film by Yang Ruidong 杨瑞栋 and used with his permission. A 50-second clip from the film can be seen here: donwagner.dk/cice/Yunnan-cupola-clip.html



Small cupola furnace photographed in the 1920s in De'an, Jiangxi, China. Tapped by tilting the entire furnace.

Hommel, *China at work*, 1937, p. 27



Robert Thomsen, *Støberiet*, 1970, 12



Iron foundry in Nakhorn Sawan, Thailand, Photographed by Robert Thomsen ca. 1970. The cupola furnace is tilted to tap out the iron.