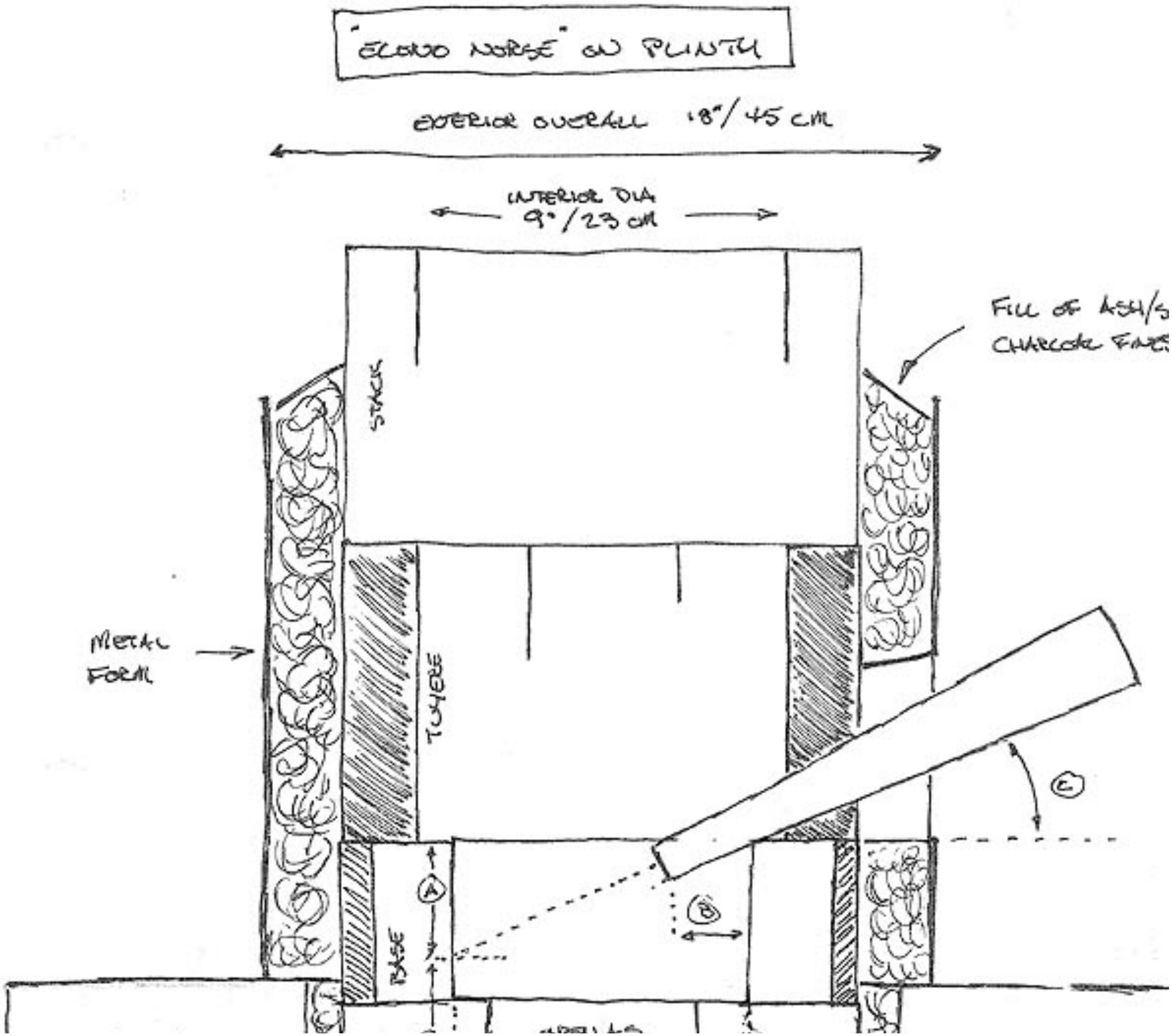
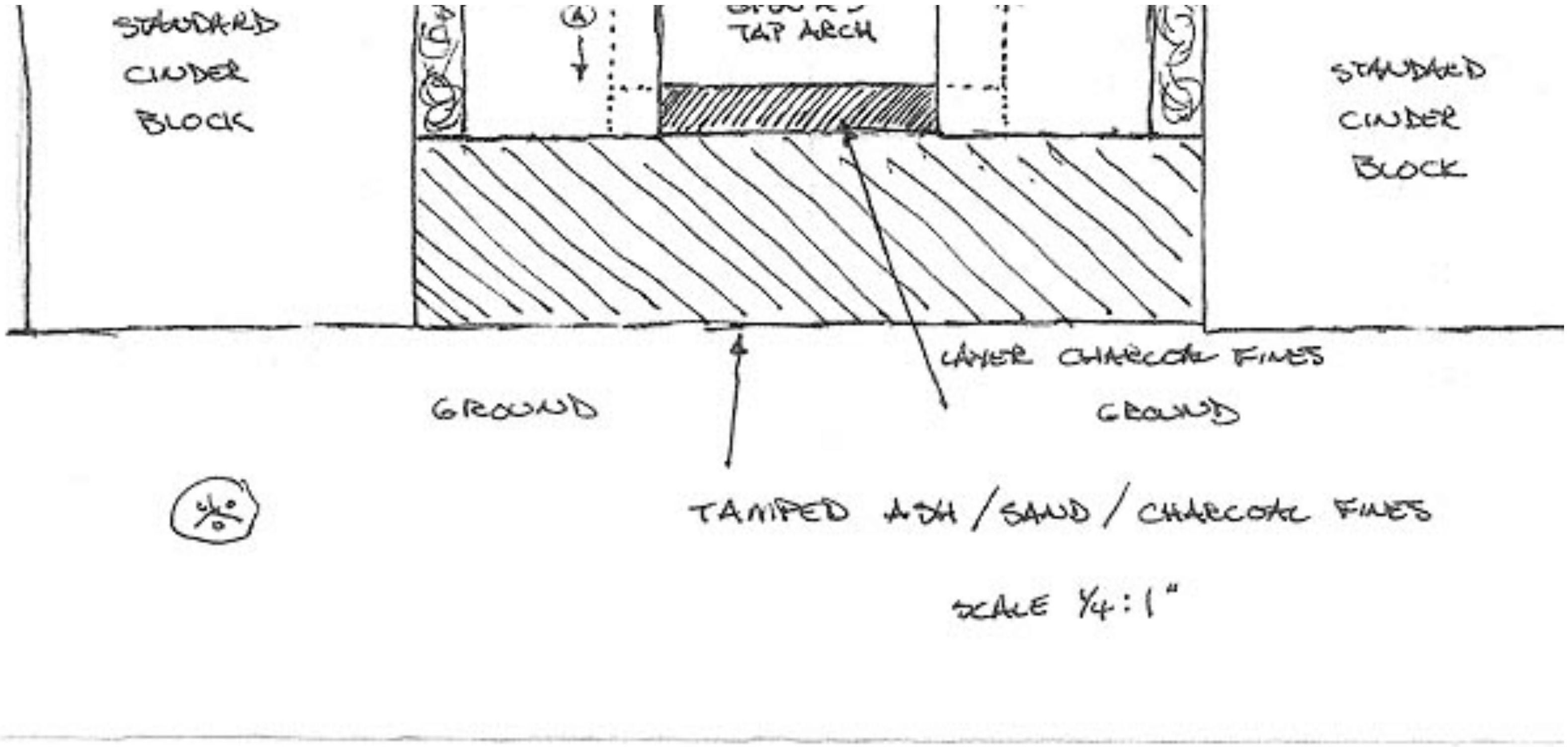
The EconoNorse Iron Smelter





Note: This handout was prepared earlier, and describes the simpler 'EconoNorse' (brick) direct process bloomery iron smelting furnace. Although the construction is different than the more historically accurate clay or clay cobb furnaces, the basic physical measurements & layout plus the actual operation sequence are similar.

The EconoNorse is a small, quick to build iron furnace, made from easy to acquire materials. It takes its rough size and general operating characteristics from a blend of Viking Age archaeology and modern practical experience. The rough form was developed in Fall of 2004 by members of the Dark Ages Re-Creation Company, with further refinements made in February of 2005 with guidance from Sauder / Williams / McCarthy.

A direct bloomery furnace works by reducing iron oxide ores (Fe_2O_3 or Fe_3O_4) as they fall and react through a column of super heated carbon monoxide gas produced by burning charcoal. The resulting metallic iron does not melt, but is at the 'sticky' stage, just below welding temperatures. The particles sinter into a bloom mass, collecting inside a pool of liquid glass slag just below the tuyere. The objective of this process is to produce a dense mass of low carbon iron. Despite what some claim, fine control of carbon content is dependant on a HUGE number of variables, most importantly the skill and experience of the supervision iron master.

Past experience has shown that the smelter team ideally should consist of at least THREE individuals, with an additional person as record keeper. Charcoal and ore should be prepared before the actual smelt.

The basic structure is made up of three circles of standard fire bricks set above one another, with eight fire bricks standing on end making each layer (for a total of 24). This gives an internal size roughly 25 cm in diameter and about 60 cm high. The bricks are contained inside a support structure made of a cylinder of sheet metal (or leaning stone slabs) about 60 cm in diameter. The gap between these two is filled with a loose mix of 50/50 wood ash and sand (or other insulating material).

The internal floor of the smelter should be built up to a depth at least 5 cm deep with a tamped down mixture of wood ash and charcoal dust. A gap in the first layer of bricks should be constructed about the size of a single brick laying horizontal to form at tap arch. If the whole structure is constructed on plinth of bricks containing a built up layer of sand / ash / charcoal fines, the slag tapping process is made easier.

The tuyere (air inlet) can be made of a simple length of 2 - 3 cm OD schedule 40 (or standard black threaded) steel pipe. Ideal is a ceramic kiln support tube, available at pottery suppliers. The tuyere is placed on top of the first layer of bricks, in a small gap in the second layer - at 90 degrees to the tap arch. Above the tuyere, this gap should be filled with part bricks and sealed with clay. The tuyere should protrude about 5 cm inside the smelter wall (B). It should be positioned on a slight down angle of roughly 20 - 25 degrees (C), and stabilized with spare bricks or wood blocks. The shape and quality of the bloom is greatly effected by the position of the tuyere.

Air flow can be provided by a old vacuum cleaner blower or great bellows. If an electric blower is used, it should be equipped with either a sliding plate air valve or adjustable motor speed control. The air volumes required are considerable, and must be delivered both constantly and consistently over the entire smelt. The pressure of the blast determines the effective 'hot spot' inisde the furnace. Too little pressure and the iron produced will be lacy or fragmented. (A hand cranked forge blower is not a suitalbe air supply.) Air volume required is a variable related to smelter diameter, and for this size will be approximately 600 - 800 l/min. (Ideal is 1.2-1.5 litre per cm2 area at tuyere level.)

Expect to consume from 50 - 75 kg of hardwood charcoal per smelt. This should be broken up and then screened so that no pieces are larger than 2.5 cm dia. (walnut) or smaller than 1 cm (pea). The fines are used as insulating material.

Iron ore may be natural rock, primary bog ore, industrial taconite or haematite blasting grit.'Spanish Red' potter's oxide is best prepared by mixing with 10% white silica sand and 10% whole wheat flour into a dough, then allowed to dry. The key is the ore needs to contain at least 50% Fe content. Rock or taconite ores should be roasted - heated to critical temperature. This assists the breaking process. The ore should be broken to between pea and rice (1 to .2 cm) size, retaining the dust.

The smelter should be preheated, starting with softwood splits and no air blast. The fire size plus air blast will be increased over about a one hour period. Then the furnace is filled with rough charcoal, with graded fuel used after. At correct operating temperature, the smelter consumes a standard galvanized pail (roughly 1.75 kg) every 8 - 10 minutes. Charcoal should heap up over the top of the smelter and be added whenever the level drops to even with the top edge. At 6 minutes per charge, the furnace is to hot, and cast iron may be the result. Over 12 minutes per charge and the furnace is too cold, and the metallic iron may not sinter correctly. Correct operating temperature can be modified by adjusting air flow.

After about 30 minutes, the combustion zone should be observed just below the top level of the furnace and the first . 5 kg charge of ore is added. Ore should be sprinkled evenly over the top, and distributed through each bucket of charcoal (not added as a single slab). It is suggested that a standard sized long handled scoop be used for this. Note that various ore types will have different volumes to achieve this weight.

About one hour into the smelt, the smelter should 'take off' with consumption rates rapidly increasing (marking the formation of the lower slag bowl. The consumption rate is stabilized by increasing the amount of ore added per fuel charge to maintain the time interval, typically increasing by .25 kg amounts. Normally the ore additions will peak in the range of 1.75 - 3 kg added per standard charcoal charge.

The rate and volume of slag created will vary due to ore type, but a balance must be made between maintaining a bowl of liquid slag, and not 'drowning' the tuyere. Tapping is done by removing the brick blocking the tap arch, then digging away the loose material to expose the bottom of the slag bowl. Typically a rod is used to pierce the solid bowl through to the liquid slag above. Returning tapped slag to the top of the smelter effectively recycles iron still embedded in the slag into the growing bloom. If there is a large volume of slag, but it is too viscous to easily run, a small amount of forge scale can be added with the charges. The first slag produced is light green, viscous and full of bubbles. As the smelt progresses this should change to a dark black, fluid, sold, iron rich slag which taps off easily.

How long the sequence of adding ore charges should continue will depend on just how large a metallic bloom is desired. The EconoNorse Smelter has successfully produced blooms as small as 3 kg, but with careful management of the slag bowl, monster blooms of 10 - 20 kg are possible. Generally, at a point ranging from 5 to 6 hours into the smelt, addition of ore charges should be stopped. A further 2 - 3 fuel charges should be added to allow the final ore charges to reduce, and drop to sinter to the bloom. These last charges are allowed to burn down to close to tuyere level, reducing air volume all the while.

With the EconoNorse, extraction begins with removing the metal sheeting containing the brick core of the furnace (also spilling the hot insulating material). Then the top most layer of bricks can be removed. At this point it should prove possible to pry loose the bloom mass from the slag bowl. Fire resistant clothing, gloves and full face shields absolutely required!

Primary consolidation of the bloom can be undertaken using the residual heat of smelting. The ideal surface is the top of a hardwood stump. If care is taken with dismantling the smelter, it now can be operated as a large forge for further compression of the bloom mass. Typically the original foot ball shape of the bloom is hammered into a hockey puck, then hot cut with an axe - a shape found with artifact blooms.

Exact yield dependent on ore purity (from 25 - 35% expected)
Exact carbon content of the resulting metal is related to a large number of variables over the smelting sequence!

"Smelting iron is extremely dangerous. It involves very high levels of heat and potentially toxic materials. Do NOT attempt this without suitable precautions."

For Further Information:

Darrell Markewitz at **the Wareham Forge**
www.warehamforge.ca/ironsmelting

Lee Sauder & Skip Williams at the Rockbridge Bloomery
http://iron.wlu.edu/