

Week 6. Experimental Smelt Preparations

This week's homework.

This week's homework has two components, in addition to the assigned readings for next week.

First – due before next week's class meeting – write up the results of your practicum and submit it (as a group) before next week's class. You may submit it as a word document or pdf onto the group page of the course wiki (1 copy per group, please).

Second – also due before class next week – everyone must submit a brief self-evaluation of you and your group to date. This need not be longer than 200 words, but should be a summary of what roles you've played in group activities to date (doesn't necessarily need to be an itemized list). This evaluation should also your honest feedback about how well (or not) you think your group is functioning as a whole. Are there any problems with communication or equitable distribution of labor? How do you feel about your group's composition overall? Are there any other types of students who you would like to work with in a group this semester? Or, would you like to keep the same groups for the Ceramics portion of the course?

Please note: This is not meant to be a device for attacking other students, although we are looking to alleviate any intra-group conflicts at this stage. The primary purpose is to give credit where it's due, and this can be hard to do in group situations, so the more detailed you are about your roles, the better.

Please SUBMIT SELF EVALUATIONS TO ALEX either by email or in person before the next class. Do not post them on the wiki!

Next week in class.

We will map out step-by-step instructions for our experimental mini-smelt. These will be based upon your groupwork results from this week. You may find it useful to skim the other groups' results ahead of time.

Team Bloomery Builders (A) **Max, Morgan, Zoe, Peter**

Team Bloomery Builders (B) **Hiu, Julieta, Matthew, Nick**

Bloomery teams are tasked with building the teeny-tiny bloomeries as discussed last week.

You should probably start by re-drawing the bloomery plans on the board.

To Do:

1. Appoint one member of the team to be the record-keeper. This person should keep detailed notes of every step of the construction process, and justification for design decisions that are made along the way. Notes can and should include rough sketches, information about timing (e.g. how long it takes to prepare the clay), and proportions (e.g. how much clay is being used, quantity and mixture of materials that are included into clay, etc.).
2. Carefully examine other small, experimental bloomery designs and (in discussion with the other bloomery team) decide on the precise dimensions of the bloomeries you'll be designing, as well as their design components. Record these on the board so that the other teams can use the data for their calculations.

Things to measure or carefully estimate measurements of include (but are not limited to): bloomery furnace height, width, diameter of inside (at top and bottom), diameter of exterior (at top and bottom), placement, size and angle of tuyere hole, placement and size of tap hole, angle of "ramp" coming from tap hole, placement and size of viewing port (if any), etc.

3. Identify what techniques will be used to construct the bloomery furnace. Will you do it in parts or all at once? Will you use clay coils or slab construction (or a combo), etc. Will you use water, etc.
4. Begin building the bloomery furnace. You may incorporate materials into the clay as per the groups' decisions. You should pre-process the clay (kneading with wedge technique).
5. Carefully measure and record each component of the bloomery furnace after it is constructed. You may also photograph it.
6. Include a sketch of the final product in your write-up.

Team Air / Supply - Seekay, Alicia, Jeremy, Kevin

In Part I your team is tasked with designing the tuyeres and air supply mechanisms for the two bloomery furnaces.

Part I. Air

What form, material, and size will the tuyeres take? How many will you need? Will you need back-ups?

What will be their length and width?

At what angle will they be inserted into the furnace?

How will air be supplied to the tuyere and furnace? Identify and describe the air supply mechanism as clearly as possible. Can you estimate the pressure or amount of air that bellow actions have the potential to supply?

Sketch a design of the tuyere and air supply mechanism that you devise, to be included in your write-up, and on the board.

Part II. Supplies

In Part II your team task is to consult with the other teams and create a thorough inventory of all supplies that we'll need to carry out the tiny bloomery smelts. This list should include the supply, a description of it, quantities needed, where to get it, and cost of materials.

Each team should already have an idea of their needs, so you don't have to do this alone. If you need to go over to Barus and Holley to access the internet, you may.

Team Special Ops - Susan, Ian, Anya

Part I.

In Part I you will determine the **type of** fuel and ore sources needed for the operation of the teeny tiny bloomeries. It might be worth looking to see what types of ores are available first.

Then you will determine the **quantity** needed of each. This will have much to do with the size of the bloomery furnaces – you should consult with the Bloomery Teams in deciding.

Next, identify how the fuel and ore should be processed before the experimental smelt. How do you expect these fuel sources and ore(s) to perform in the bloomery (based on their composition and properties, and based on the expected furnace conditions and air supply)?

Then, devise step-by-step instructions for the fuel and ore's pre-treatment, as well as a recommendation for how far in advance this should be done.

In the process, you should also identify places to **procure** these materials. You may find it helpful to consult with "Team Air/Supply".

Part II.

One of the most important components of the entire experiment will be the record-keeping process during it. Based on examples that you find from the Rockbridge Bloomery group and other experimental groups, your task is to design a spreadsheet that identifies particular variables to record.

This spreadsheet will be what we enter data into as we conduct the experimental smelt. The data will provide the basis for assessing where, how and why our experiments are successful (or not).

Topics should include (but are not limited to): when ore is added and how much (same for charcoal), when air is pumped, time information, weight of materials added, qualitative observations at particular times, slag removed, etc.

The Teeny-Tiny Bloomery

This is my first step toward developing a tiny bloomery that can be used as a teaching tool in a small academic laboratory, or with some improvement and a lot of experience, it should be suitable for assaying unknown ores. A Little Information about the Design.

Starting with all of the usual measurements from the Coated-Tyle furnace, I built the tiny furnace from kaolin and cellulose but reduced most of the measurements to 1/6th of the normal cross section. The diameter of the round stack was 5 inches compared to the 11 inch square tile. The shaft of the bloomery was approximately 12 inches tall. The tuyere diameter was 3/8 of an inch at the small end. The charcoal burn rate is equally reduced to about 4 lbs. per hour. This may be a great waste of time if you want to make big iron but this is a great way to test a bunch of ideas about how shaft height, tuyere materials, etc., effect the operation of a bloomery. The sloped clay box on the right of the stack is an air chamber, the idea being adopted while watching Michael McCarthy build a Japanese Kodai. The air chamber is fed from a blower in the back. It houses the tuyere, and has a removable clear Plexiglas top through which I can watch for slagging and also rod-out the tuyere. The round holes visible in the air box are plugged with clay bits to adjust the air rate. I think the total bloomery weighed only 12 lbs. The tiny bloomery, I call it the Ocarina, kicked butt. From only 1.5 lb of ore we made a bloom of 1.5 lb. OK there was a bunch of wall stuck to the bloom but the crazy thing was that the bloom looked pretty much like a regular (big) bloom except that it was tiny. Is it iron on top, slag on the bottom, just like it should be. The picture to the right shows the bloom with an indication of the direction that the tuyere was blowing.

The bloom turned out to be not as good as it looks though. After knocking off the slaggy bits we were left with just a crown of iron, just blobs and foils really. I should tell you a little about how I prepared the bottom of the furnace bowl because this might be useful someday. Normally we pack the bottom of the furnace with charcoal fines and allow the slag to create its own bottom by running through the fines and freezing wherever the temperature is low enough for solidification. Since we are working with such a tiny amount of ore, I thought that it would be good to choose a depth below the tuyere where the slag could go no farther. Figuring that about one inch below the center of the tuyere would do the trick, the furnace was preheated to dry it, and then I added fines to fill up bottom space and then put in a layer of ashes from the wood stove, packed it all down with a stick and let her rip. Whether by intent, or by luck, the bottom of the bloom still had the shape of the ash bed when we pulled it out. This technique culled from Biringuccio and Evenstad will probably become important when we start playing with liquid iron products, but who knows, choosing a place for the bloom to grow in front of the tuyere might be important for controlling carbon content or bloom quality and yield in a full size bloomery also.

Here is the tiny bar that Lee forged up from the bloom. It weighs only 2 ounces (60 grams)! Just enough to make a smallish pen knife and a good first try with the Teeny-Tiny Bloomery. With some luck this tiny smelter will become useful for quick demos and maybe assaying. We'll see.

Skip Williams

The Rockbridge Bloomery

The Rockbridge Bloomery –The Little Princess Bloomery

A Preliminary Report

Skip Williams - May 2, 2006

Construction. The Little Princess is built with a mixture of new, reused, and recycled materials that are now familiar to everyone who has ever built a bloomery before. To build the shaft you will need:-The remains of a previously fired bloomery, crushed to sand and grit sized particles. This is the grog. If this is your first furnace you can use sand as your grog material.-An equal volume of charcoal fines. Screened through a ¼" mesh.-A 50 lb bag of ball clay. Mix the grog, charcoal, and half of the clay while dry. Add water and more ball clay as needed to make a stiff plastic mixture. The shaft is built up around an internal form (wood or sheet metal) which is removed at the end of construction. At the bottom of the furnace the wall is approximately 5" and tapers to 2" thick at the top. When you have completed building the shaft carve a small air inlet near the bottom where the tap arch will be, and start a fire burning. The shaft will be bone dry and ready to use in about 5 hours. DimensionsInternal Diameter 25cm (10in.)Total Height 90cmTuyere to Top 70cmTuyere to Tap Arch 10cm OperationThis furnace is run in the same manner as the [Coated-Tyler furnace mentioned above.](#)

Experiment 83

Charge Interval 8 minutesTotal ore 45 lbs.4 hours 20 minutes from first ore charge to bloom removal. Bloom weight 13 lbs.Bar Weight 11 lbs.



Teeny-Tiny bloomery



Little Princess bloomery

Coated Tyle Bloomery

Here's a way to smelt your own iron, in a bloomery furnace built of cheap and readily available materials.

Furnace Materials: 7 or so 10" cinder blocks 2' section of 12" square flue tile about 50 lbs. dried, ground clay (any clay will work here, but the stickier the better).
8 lbs. Cellulose building insulation 5' of 2'wide chicken wire fan - high pressure/high volume, e.g. shop vac pipe fittings and hose ¼" thick copper for tuyere

Smelting Materials: (for @ 20 lbs of bloom) @70 lbs roasted ore @ 200 lbs wood charcoal (not briquettes!) scrap wood for preheat`

Preparing the ore and charcoal: Finding your ore is, of course, a major project in itself, which we don't have time and space to go into here. But when you find it, you first need to roast it. Heat the ore to a bright red color, in a wood or gas fire, and hold it at that temperature long enough to make sure it's heated through. Quench the ore in water while it's still hot. Your ore should now easily break up into small pieces. In this furnace you want the ore bits to be about the size of a sunflower seed. Breaking it up this small will also produce a lot of dust and fines, which is ok- we'll smelt it all. Pick out any obvious impurities.

Procuring your charcoal is also a major project. Break up your charcoal until the pieces are about 1", and sift out the fines through a ¼" mesh. Save the fines for the furnace base.

Forge a Tuyere: Using ¼" or thicker copper plate, roll up a tube of ¾" or 1" interior diameter, about a foot long. If you flare one end it will make it easier to attach to your air supply. Although we will be operating at temperatures way above the melting point of copper, it will conduct away the heat to the outside of the furnace rapidly enough to keep it from melting.

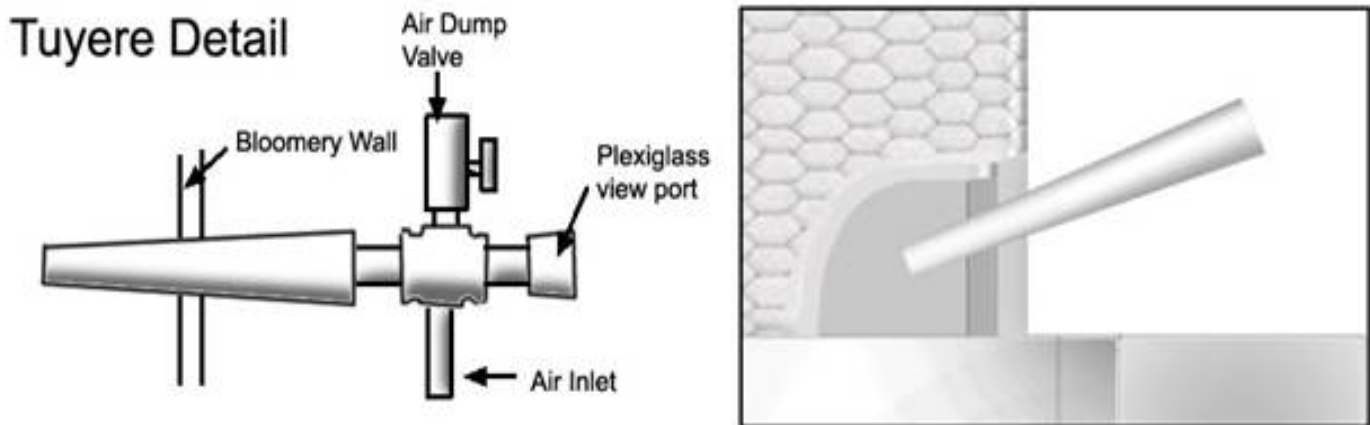
Building the furnace: First, you need a dry, elevated base for your furnace. Stack the cinder blocks into a rough square, leaving a space open in front, like so (plan view)

Fill and pack the center of the hearth you've created with charcoal fines, level to the top of the cinder blocks. Next, you need to build the furnace shaft itself. On one side of your flue, drill a hole large enough for your tuyere 6" or 7" from the bottom, centered right to left. Make sure it's large enough to allow the tuyere to protrude inside the tile 2 ½", and angling downwards 22-25 degrees. On an adjacent side of the tile cut a slag tapping arch out of the bottom edge, about 3" tall and 6" wide. The best way to cut these tiles seems to be to drill a series of small holes with a hammer drill, then chip out the piece you want to remove. If the tile cracks a bit, it's no big deal, as it's going to crack as soon as you light a fire in it anyway. Set the tile on top of your charcoal base. Now, to sheath the furnace with clay. This will hold the whole thing together. Weigh out your cellulose, and thoroughly shred the clumps. Mix in the clay, coating all the cellulose with clay. Next add water, and knead it to the consistency of cold gooey oatmeal. For 50 lbs of dry clay, this may require almost 50 lbs of water. Plaster the outside of the flue tile with the clay mixture ¾" or 1" thick. Wrap the furnace with the chicken wire, and twist the loops of the wire to tighten the whole thing up. Use the leftover clay to buttress out the bottom foot of the shaft where it rests on the base, and use some clay to lute the tuyere into place. Save a little clay for patching and emergency repairs.

Coated Tyle Bloomery (cont'd)

Now hook up your air supply to your **tuyere**. The following schematic gives you the basic idea. You may put a valve in the hose before the T; we prefer a dump valve on the T opposite the hose. Or you may use a variable speed fan. What's important here is that the sight glass is removable for clearing the tuyere during smelting, and that all connections are reasonably stable and airtight.

The tuyere protrudes approximately 2.5" into the furnace and dips down at an angle of 22 degrees.



Now to Smelt!

Light a gentle wood fire, with natural draft through the tap arch, to dry and preheat the clay. On the first run of the furnace, this will take well over an hour. Poke any bubbles forming under the clay to let the steam escape. When the clay is mostly dry, fill the furnace with charcoal, block the slag arch with a brick, and turn on the air. From now on, you will keep the furnace full to the brim at all times. Set your air rate so you burn 4 lbs of charcoal every 10 minutes. This 4 lb charcoal charge will be your basic unit of measurement throughout the smelt. When you see a really nice bright white heat through the tuyere, and maintain that temperature for maybe half an hour, you may begin to charge ore.

Sprinkle the ore evenly on top of the charcoal bed. At first, add only a half pound of ore to every 4 lbs. of charcoal burned, gradually increasing it until you are adding 3 or 4 lbs of ore for every 4 lbs of charcoal burned. It should take you 3 or 4 hours to work up to this charging rate. If you add it too fast, the furnace will start to cool, indicating you should back off on your ore charges. Your burn rate can increase to 7 or 8 minutes for 4 lbs charcoal.

Monitor your fire through the sight glass. Use a rod to clear slag from the tuyere if necessary. After you've charged 60 or 70 lbs of ore, remove the block from the arch. Poke in there gently and see what's going on. Your goal is to keep the lower part of the furnace full of slag. The slag is not just impurities to be removed- it is a vital part of the reduction process. If the slag rises high enough to start blocking the tuyere, poke in and let some run out. Cool it in water, break it up, and return it to the top of the furnace. Any slag that is black and freely running, indicating a high iron content, can be recharged onto the furnace. Only discard slag if it is thick and gooey, indicating a low iron content. Tapping and recycling slag ensures a constant flow of iron rich material through and around the bloom, this is what makes it nice and solid. When the slag begins to get thick and gooey, you'll know it's about time to finish. 7 or 8 hrs after your first charge, you'll be ready to remove your bloom. Scoop charcoal fines from under the base of the furnace. Using a rod from above, knock the bloom out the bottom of the furnace.