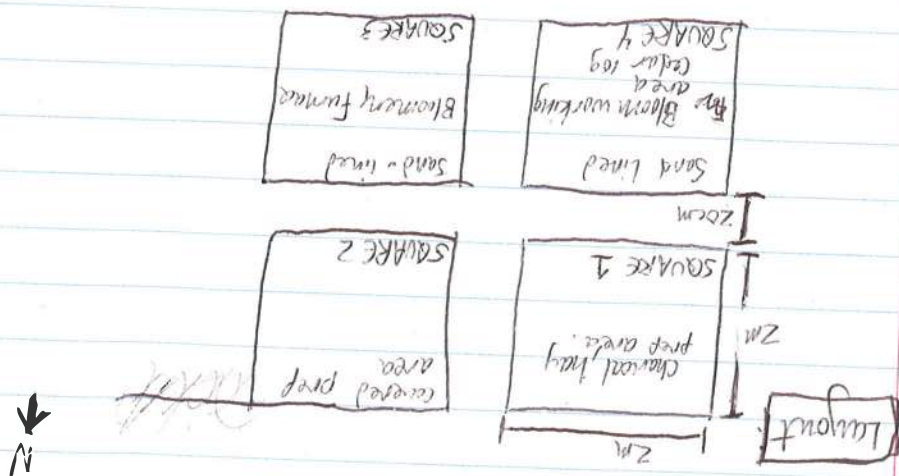


Daryl Markwitz - Experimental Setup

Setup of work area:
four 2x2m enclosed wood squares,
2 are tiled with sand.



Procedure

Square 1 - 9:00 AM - 9:40 AM
Hay chopping with axes. Two people (Kevin + slash)
cutting hay into 10cm lengths.
Hay to be mixed with clay for furnace.
1/2 bale to be cut.

Hay Cutting

Square 3 - 9:00 AM - 9:25 AM
Two people building frame for furnace -
Steel sheets - interior cylinder duct taped
+ covered w/ paper. Will be pulled out
after clay form is built
3 pieces of cut wire strung around

Furnace Frame

outer sheet of form, through pre-existing holes, then this outer layer also layered with brown paper.

FURNACE PLINTH SETUP

Figure 3

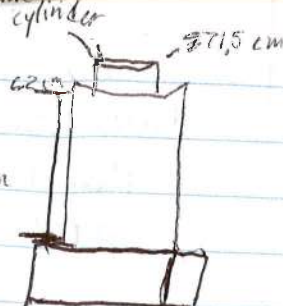
9:25 am - 9:44 am

- Underblocks laid on top of sand. Blocks were placed in layers of brown paper placed underneath as a test of how hot (or not) the furnace base becomes. Then underblocks filled with charcoal fines, and hole in middle of them, filled but not compacted. Slag will bury into this.
- Underblocks arranged in diamond shape with attention to where bloom will be extracted.
- Bloom extraction will be on west-facing side of furnace, so group can pull bloom back towards S.W. 4.5 ft more space open in that direction.
- A second piece of brown paper laid on top of plinth as a test. Expectation that this top layer will become perforated.
- Sheet metal cylinders placed on plinth interior cylinders fits within interior hole ~~and~~ within under blocks
- 3 people worked on this

Measurements of Frame

Need at least 15 cm beneath tapers

- From base of outer cylinder to top of outer = 62 cm
- From base of outer cylinder to top of inner = 71.5 cm



- Need a minimum outer height of 55 cm to run efficiently
- Extra height allows greater efficiency

9:45 -
10:04 am

Savage 3

Clay mixing for furnace walls

4 people involved

- 1/2 of chopped hay (dry hay)
- 28.6 kg of powder kaolin clay (Not measured)
- Composition info from clay bag photographed & included in records
- Importance of clay in the resulting slag
- Clay used = ~~28.6~~ 150 lb
 - 3/4 bag of kaolin
 - 1/3 bag of Hawthorn clay
- Water added in increments (unmeasured)
 - 'goal to achieve "bread-like" consistency
 - 'can add sand if too wet
- Goal - to make pieces about size of a softball to apply to furnace shaft
- no sand added this time, Sand would increase refractory value but also increase crumbly nature of clay
- Multiple batches made as needed

10:45 -
second batch

SQUARE 3

10:04 am

FURNACE BUILDING

4 people

↓
Stacking softball sized clay from base - up
2:30 pm between sheet metal forms. They are stacking
~~one~~ one level at a time, in 4
quadrants → opposite directions 12:00 + 6:00,
then 3:00 + 9:00.

- Use stick to pound clay balls together to make sure no air. But don't push too hard or balls won't adhere, and will form crack surface.

⊗ - @ 11:04 - inner cylinder removed
~~removed~~ because wall packed too
tight. Tool brought in to problem
solve. Nails to be trimmed
back. Interior wall. Then they
will hand build rest.

Trimming 10-12 in / 25-30 cm back
of internal diameter

11:30 - finished trimming, smoothing
inside and beginning to hand build

12:05 FINISHED second batch, break
time

12:45 pm

New group arrives

~~12:40~~ ~~off~~ ~~hole~~ ~~rest~~

- From 12:45 - 2:30 - furnace building
finished.
- Outside cylinder removed ~~to~~
- Large cracks + voids exposed, then were
patched up.

Furnace stack exterior then smoothed.

- @ 2:40
2:45
- Extraction hole cut. Trouble initially removing door, so cut it @ bottom too.
 - Door rolled in safely

@ 2:45

3:00

Tuyere Placement

- Ceramic tuyere - originally a spacer in porcelain kiln, can be heated up to 1150°C
- Tuyere hole measured 15cm from plinth, extends 5cm into furnace from interior wall
- All tuyere measurements taken from center of tuyere hole
- Shield of clay packed around tuyere
- Tuyere set at 22° - took 2 attempts to set the tuyere & cut hole correctly

Blooming Furnace

Sketch Dimensions

- Center of tyger to base: 16cm $\updownarrow$
- Internal diam @ tyger height: 27cm, 24cm, 25cm
- Extraction door:

21cm upper length / across	] furnace
25cm lower "	
- height of hole = 8.5cm
- height of piece 8.5cm
- 21cm upper
- 24cm lower
- piece

furnace height from plinth $\rightarrow$ h @ low = 64cm
 @ high = 68cm

tyger height above base = 16cm

External furnace diameter @ top 39cm

Tyger angle = 22.5°

Wall thickness = 8.5 - 9cm, 8.5cm @ top

Circumference = 1.24m $\rightarrow$ top

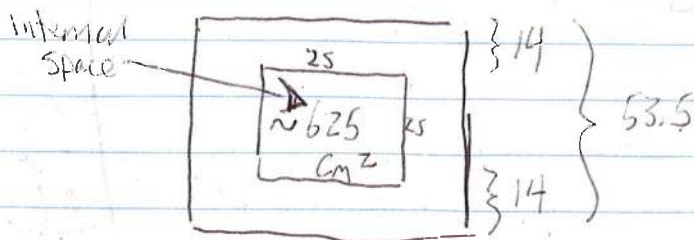
external 1.16m $\rightarrow$ middle

1.27m $\rightarrow$ tyger height

Internal Circumference = 1.14m @ top

Plinth = 53.5 cm²

dimensions of 1 plinth block 39cm Long x 14cm wide
 14cm = height



Light / Optical Holes

"Light Bright" Installation

Rick inserts small holes with

stakes every 10 cm on side of stack across from top hole

Furnace Heat Treatment - Pre-heating fire
Fire Building

Furnace Filled w/wood + paper
Flame @ top emits moisture, exposing cracks
on interior wall

Cre Crushing
- by 5pm moisture +
blower furnace & to drier
brown

~~Real hammer~~

hammering in a bowl-shaped container
to pea sized dust also kept
Hamato, pre-roasted so its brittle
- @ 4:39, sorting one through sifting
screen to extract larger chunks
of ore from rocks + charcoal
that are mixed in
finished @ 5pm → Durrell kept pre-heating blooming
until 9pm.

Blooming Temp Measurement Holes

0.1
0.2
0.3
0.4
0.5
0.6

3:00
3:05

lit @
3:15 pm

Prep Steps

Saturday, April 22

Swelt Prep
(Cont'd)

Charcoal Processing

8 bags of hardwood lump charcoal @ 20 lbs each

3-4 people

hammering on top of mesh table to break up charcoal. Broken charcoal falls through table to chute beneath. 1 person rakes charcoal and loads back into 50 lb bag for use during swelt

Start:
9:00 am

10:00 am

Baby Blooming

AKA Anstotle
remelting furnace

9:00 am

Alex + Geryl pre-heat treat baby mouse
blooming with small fire to dry out
structure of furnace

- By 10 am furnace exterior shows signs of
cracking but is otherwise structurally
OK

- Copper pipe lengths cut with electric
saw for tuyeres

- Clay slurry applied to exterior cracks
made of 50% clay, 50% sand

11:17 am

- Stopped adding wood to fire - letting
embers burn out over next hour

April 22

SATURDAY

Process of

~~9:00 am~~

Smelt Begins @ 9:30 am (for David) 12:00

Temperature Measurements taken every half hour

Jeremy on morning shift (see facing page)

Holes are 10cm apart

Time First Reading @ 10:50 AM 45 min after smelt start w/ thermocouple b/c needed replacement battery

Hole	1050	1120	1150	1220pm	1250	1:20
Top 1	270°C	810°	780°			
2	684°	985°	936°			
3	1080°	1035°	1070°			
4	1100°	1155°	1180°			
5	1200°	1356°	1160°			
6	1100°	985°				

Top	1:50	2:20	2:50	320	350	420
1						
2						
3						
4						
5						
6						

SMELT NOTES (2)

★ Translation from Darrell's smelt time clock to
 also am 50 & Darrell's in
 these notes in "real time", Darrell's in
 his time

9:00 AM Blowing fire restarted by loading wood + paper

- Viewing port + air flow monitor attached to furnace

- Overnight preheating caused cracking on exterior walls of furnace, but all is ok

SMELT START
 10:00 AM

- Wood split, gentle air fed to blowdown

- Now, heat gradually ramped up so that @ 11 AM can add all of charcoal

- Exterior cracks painted w/ slurry - 50% clay 50% sand

- Clay mix with higher sand quantity used to patch up door of top hole

- Base created with ash + packed charcoal

10:22 AM
 * Charcoal - all added
 2/3 rough charcoal
 1/3 graded charcoal
 air @ 800

lots of smoke = incomplete combustion
 Some air leakage @ bottom, will need to patch w/ clay

- Paper not burning at top = reduction fire, no oxygen

Tasks delineated. Record keeper, Charcoal + Ore,

1 bucket of charcoal @ a time added Charcoal
 should never be lower than top of furnace

11:23

11:16 AM

11 AM

SMEET NOTES (3)

10:35 AM - Smelting Ritual - Jiffy
Pop made over bloomery! Everyone eats it
for success

- Reduction flame continues - would look blue if it were dark out
- 10:40 AM - sand added to base to prevent air from escaping
- Ideal charcoal consumption rate per load (pre-ore) 8-10 min
- When ore addition, this will change. To achieve ~~maximum~~ minimum consumption of load

- 10:57 = 1 psi of air pressure

- Smells gassy

11 AM => Reactive column fully produced, meaning orange flame is all the way to top!

will now test rate of charcoal consumption by timing bucket of charcoal burn rate if in 8-10 min range, then can start ore addition

11:16 AM Plan put in lower Fe content ore to make slag bowl (8 kg)

- Then 11 kg of higher purity ore to make bloom

- Then pure lower Fe ore to make more slag-purity.

11:23 Adjusted air to 850

Sweet Notes (4)

11:22 - Added 1 scoop of ore ~ 300g
↳ poor quality looking like limonite.
Approx. 3 charges for ore to hit bottom of furnace.

11:32 Add scoop of ore.
- For every $\frac{1}{4}$ kilo of ore add $\frac{1}{4}$ bucket of charcoal

11:40 1 bucket + 1 kilo of ore
↳ 12 mins between because slower w/ add of ore but should come back up no charge to air
1 scoop ore + $\frac{1}{4}$ bucket added.

12:02 - 1 bucket + 1 kilo ore finished

12:04 - Probing through view port → drop in charcoal on top

↳ high silica content in ore produces a lot of slag → ensuring the slag is clear

12:11 Probing to tap slag through view port.

12:13 Added 1 bucket + 1 kilo ore 210 mins elapsed → temp being brought up / burning faster

→ increase charge to 1.5 kilo @ 1st charge because charcoal consumption too fast adding more ore to keep temp more constant

Smith Notes (3)

12:52 - probe through top to bottom of
slag bowl → look @ slag on
probe → dark ^{solid} w/ metallic finish = happy slag
also used to check height

12:53 height of slag too high tapping through
peep hole → cleaning taphole

12:58 - Removed slag tap ^{to check} → taphole broke pushed
back into slag off of air flow → Removed
air flow to clear taphole → tapped back
into far side of furnace

1:08 trying to remove the taphole with tongs.
The problem is that there is too much goo
on it to extract it from the hole.

1:09 Breaking into the furnace wall to remove the taphole.
extracted it that way.

★ We were confused what actually happened
was that slag had attached to the taphole
& while trying to break that off we pushed it off
into the furnace then needed to extract it.

1:13 part of the taphole is still stuck inside. Have
to call our losses. Patched the hole with clay, ^{Essex}
trying to increase the heat with air all the
way up. Also patching up the slag trap.
Max air. Over for prob II.

1815 - We think we actually have all of the tyger. Intend to replace it with a new one when temp increase again.

* prob that when we switch to a metal tyger the temp is too high for it starts melting it.

1817 adding sand around the furnace for structural support & insulation.

1821 The slag bowl is too high. Its above the tyger trying to pull out the slag door & remove stuff to shift the slag back down. See that we have had slag very gooey.

1822 Finished bucket

1824 Fixed things so that air is getting in again by shifting material

1825 Removing brick base & extracting lots of charcoal can see the slag bowl dropping down. Slipping down. Trying to get the bowl of slag to drop.

1828 - patching the hole around the tyger. Still have a massive hole still ~~at~~ the base where we pulled the brick out.

1830 Finished bucket

1833 adding a new type of ore higher quality

1839 remove checking the air Jamming a metal rod down to clear air flow

1840 adding wood blocks to create a buttress near the tuyer wall. covering it with sand for structural support.

1842 Finished

1845 patching another hole with clay mixture

1851 Finished bucket

2100 Finished bucket

2802 patching up the Furnace cracks with clay & sand

2:07 Checking air flow with the metal rod

1810 trying to clear the tuyer hole

1815 Started breaking into the slag formation to allow the slag to pool off onto the ground very liquid like.

1824 ended up getting a crush out of the bottom air with sparkles came out suggested that metal was being eaten at need a cushion

of slag to make sure our metal
doesn't get eaten up. To stop that filled
the slag area back in & added sand
to help against air.

2:33 Clearing fuge air flow

* New charge of ore 1.5 high quality ore
& 0.5 hematite

2:38 Finished bucket

* next charge 1 hematite & 1 high quality

2:44 Big drop in material out of the top

3:01 extracting more slag. Letting it stream
off

3:01 Finished a bucket

3:03 slag streaming a lot so we used
water & added sand to slow it down

3:13 Wood block caught on fire
had to use water & sand to put it
out

3:13 Finished bucket 2nd of low quality hematite
on to the last bucket of ore.

3:17 tapping slag from the bottom
- use a rod & tap with the hammer. Got a lot of slag out.

3:20 got enough slag out plugging the hole
back up.

3:22 Last of the ore added

3:32 tried to tap slag but nothing ran out
Filled back in.

3:35 tapping to clear air flow.

3:36 tapping for air flow. * Another crack by the
tuyere hole opened &
a lot of slag is coming off the rod
tap it off ^{on rod} after cooling it in the water bucket.
then put the rod back down the tuyere.

3:40 still clearing tuyere keeps filling up.

3:41 Shoveling the sand out of the way
digging deep below the furnace removing all
charcoal & sand out of the way ^{also}
clearing air out of the tuyere.

3:46 lots of slag coming off onto the rod
when clearing the tuyere.

3:50

everyone in place

~~test~~ & Ian Strickling Peter & Alex: Strickling
Ash: removing the bloom bottom, switch
It's going to remove from top

3:50

lots of fire coming out of the top of the bloom.

3:52

significant yellow deposit on charcoal on top
Odr. Looks like sulfur. Idea it might be
an impurity in the clay.

3:54

Still clearing the tuyers.

* Slag & ash is keeping the bloom from dropping

4:00

tapping the top of the mass trying to get
everything to settle to the bottom

4:05

Digging into the top & removing the burning
material into a bucket. Ian using a ladle
to do this. Removing charcoal & wasted
one that did not adhere to the bloom.

4:07

Darrel loosening up material with a rod
Ian cooled down the ladle in a bucket of water.

4:08

Back to removing material
more loosening with rod pick
Keep dipping tools in water both are red hot

4:10 Derrell & Ian using a big Rod to push the bloom down. D

4:11 Seems to be moving very little
use pick tool to try & loosen up & dig out

4:12 Bottom of the furnace is breaking open
from the pounding
wall came off.

4:13 Slash removes the top piece of material
with tongs

4:14 Moment of truth to see if this is a bloom
Slash holding with tongs
Peter & Alex pounding with hammers

4:15 Rotating hits from Derrell Alex & Peter
constant hits knocking off black material
rotating the mass to keep hitting it.

4:16 burning a hole in the black. Wood is catching
on fire.

4:17 Mass is getting to cold. Definitely a bloom.
though can tell its metallic when you hit it

Slash retrieved the big piece put the
other one back in

4:18 Derrell breaking it up easy to tell its all
slag. Easy to break it.

11/19

Everyone drink beer & cheer

Because of the problems in temp control
the Bloom is very irregular & "grumpy"
Not ideal.

- We should start with a wooden mallet
to work it, once it's down. Don't want
to shatter it.

Bloom final weight = ~2 kilos
(need to re-weigh in
lab though)

TIME	ELAPSED	EVENT	ADD T	ADD T	DATE
12:00	13 hr	WOOD SPLINTS + AIR			
12:41	9 min	Playsa tap arch			
1:05	8 min	Added bucket of gravelly material			
1:24	11 min	air added more @ 800			
1:36	12 min	Column to top			
1:43	7 min				
1:48	5 min				
1:53					
1:54		Adjusted air to 850			
2:04	10 minutes				
2:14	12 minutes				
2:33	17 minutes				
2:43	10 minutes				
3:12	14 min				

TIME	ELAPSED	EVENT	ADD	TT	ADD	
12:00		~~PREHEAT~~				
12:37	2.5 hr	WOOD SPLINTS + Ger + 4				
12:41		Plugged tap arch				
12:50	4 min	Added bucket of partially ^{com. prepared} charcoal				
12:55		air added may @ 800	2/3 rock			
1:03	8 min		1/3 grate			
1:04	11 min		1 bucket rock			
1:24	10 min		1 bucket rock			
			1 bucket rock			
		air to 900				
1:32		Column to top				
1:36	12 min		1 bucket			
1:43	7 mins		1 bucket			
1:48	5 min		1 bucket			
1:53						1 scoop
1:54		Adjusted air to 850				
2:04	16 minutes		1b		1 kilo	1
2:14	12 minutes		1b		1 kilo	2
2:33	17 minutes		1b		1 kilo	3
2:43	10 minutes		1b		1 kilo	4
2:58	5 min		1b		1 kilo	5
3:12	4 min		1b		1 kilo	6

TIME

3:33

3:35-45

ELAPSED

21 min

EVENT

lugs got pushed in,
try to take out with
tongs, break furnace
wall & later patched
up with muddy clay,
air blast not full, try
to get temp back up

CHARCOAL

ORE

1b

1.5kg

3:53

4:01

4:10

4:19

4:21

4:41

4:52

5:05

20 min

8 min

9 min

9:10 min

8 min

14 min

11 min

13 min

New ore

New ore

New ore

Mixed ore

1.5k-high quality, a hematite

13 min

1k low quality

1k hematite

All low quality

All low quality

All low quality

5:17

5:28

5:39

5:49

12 min

11 min

11 min

10

1b

1b

1b

1b

1b

1b

1b

1b

1b

1b

1b

1b

1b

1.5kg

1.5kg

1.5kg

1.5kg

1.5kg

1.5kg

2k

2k

2k

2k

2k

2k

2k

2.0kg

11k

12.5k

14k

15k

16.5

18.5

20.5

22.5

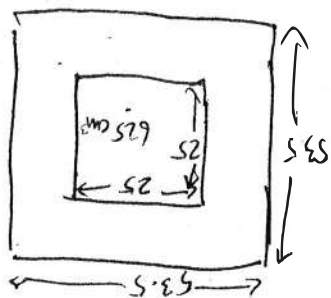
22.5

24.5

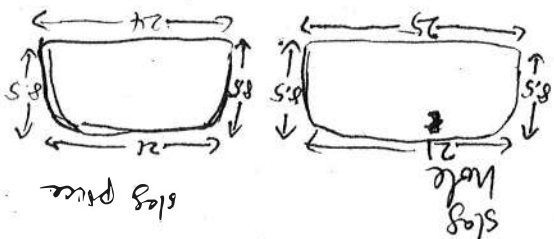
26.5

28.5

One plank 610 X 39 cm



internal hole : 13 cm
width : 8.5 cm



Circumference = 1.24 m
at tyre = 1.27 m
Internal Circumference = 1.24 m
at tyre = 1.27 m

