Hardware Around the Making of Metals and Their Proper Names

There are a lot of words for all those implements needed for metal making. Most of these words are known to everybody - but not necessarily in the proper context of of present-day or ancient metal making.

- I will discuss this in English and German - it's educational! I will also give the etymology (ancestry) of some words. Some are very old and go back to the proto-Indo-European language that is at the core of most European languages.

Some Like It Hot

Basics

Hearth [1)] (*German:* ***Herd***)
"*Am stillen Herd in Winterszeit, wann Burg und Hof mir eingeschneit*", sings **Walter von Stolzing** in the "**Meistersinger**". There are no English or American operas worth mentioning (first educational fact), so I must fall back to Wagner to illustrate that the *hearth* / *Herd* was the central and most important feature of a home. The *Herd* in ye olde homestead is more or less a synonym for *Heimat* and *Gemütlichkeit* (homeplace and coziness; English just isn't quite up to this).
In old times, the fire in some hearths was holy and guarded by goddesses (Hestia for the Greeks, Vesta for the Romans). The original French "foyer" is the German *Feuer* (=fire) and denoted the central place of a building.
That's all very learned and heartwarming but the smiths' throughout the millennia worked with a hearth too, and that was neither cozy nor heartwarming but hot, dangerous and backbreaking.
So, what exactly is a hearth?

- A hearth in its simplest form is a fireplace with a low perimeter wall, made by lining a hole in the ground or a more advanced contraption with stones or bricks. Your fireplace / "chimney" is technically a hearth. In any case you have an "open" fire.

Remains of very old hearth and attached oven, and the "standard" inside hearth as used for millennia

- A smith's hearth (***Esse*** [10)]) is different. It needs a good chimney and in particular a source of air. This has been a hand (or foot) operated bellows for millennia. Here are some pictures:

A smith hearth with an (invisible) electric blower and a (big) bellows [7)]

- A smith's hearth might also be called a **forge**[3)] in English. The same word also describes the whole ensemble like the German translations "*Schmiede*", except that the German word means *only* the whole set-up of hearth, anvil, tools, building. A *smith* (one who smites), is a "*Schmied*".
  This just serves to show that translating a few times back and force will definitely produce confusion; witness the *melting* / *smelting* (from old German "schmelzen"=melting) confusion. Smelting, by the way is *verhütten* in German, no way to mix that up with *schmelzen*=melting. It's only one consonant away from verhüten (=to put a hood on something=preventing pregnancy).
- All things considered, a *hearth* is an open fire place into which you can hold things (from marshmallows to pieces of steel to be forged), either to just heat them up or to change them by typically burning (=oxidation) / annealing / chemical reactions. You also can hang a cauldron over it for cooking stew or your underwear, or put a pot / crucible right into it.
  Moreover, you can use the fire in your hearth to heat your:

Oven [2)] (***Ofen***)

An oven in a strict sense is a more or less closed chamber, thermally well insulated, for exposing things to not-so-high temperatures - but usually *without* a fire in there. The thermal energy needed to make things hot must come from an attached heat source, typically a fire (in a hearth) under or next to the oven.
The term "oven" is often reserved for contraptions with temperatures below about 250 °C (482 °F), or temperatures usually sufficient for the processing or even decomposition of organic stuff like food. Anything working at higher temperatures is some kind of "furnace" or "kiln"; see below.

- The oven in your modern kitchen may have some electric heaters at top and bottom, or burning gas heating the the bottom / walls. Otherwise it was the wood / coal fire in the hearth of your kitchen stove or range cooker.
  In slightly older times, you used the big communal oven for baking big loaves of bread. Then you first ignited a wood fire *in* the oven that heated up the bricked inside. After the proper temperature was reached (controlled by completely burning a defined amount of wood) you scraped the ash out of the oven and inserted the loafs of bread into the hot inside. I helped my mother doing that many times when I was a kid. What you got was bread that was about 1 million times better than what you buy today.

Baking ovens. The communal kind my mother used, and a reconstruction of a Roman army oven

Wood / coal fired kitchen cooking range
Remove the rings on top of the hearth and you have an open fire.

It goes almost without saying that the German *Ofen* is almost but not quite the same thing as an oven. It could also mean "**stove**", something exclusively used for heating rooms or for cooking:

American (Lincoln) stove and German "Ofen"

Cast iron part of Baroque stove in the Schmalkalden (Germany) Castle.

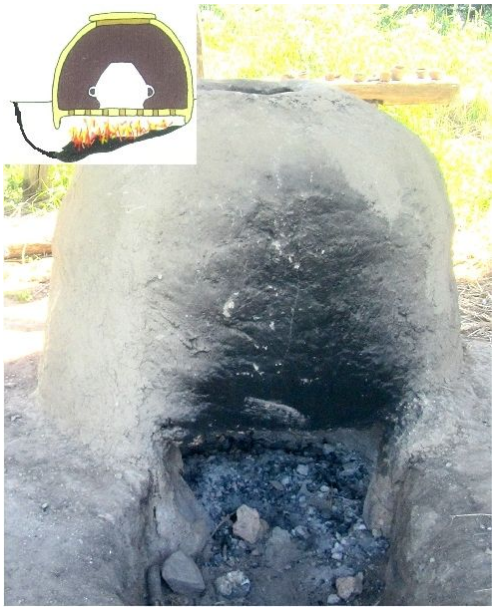
Isn't the picture above cool (for a stove)? You have *cast iron*, a *stove*, a *good story* from an unassailable source (Cain murdering Abel because his hearth didn't work so well) and Abel's well-working *hearth* in the background. But enough about bread baking and getting cozy. Let's make pottery or metals! For that we need high temperatures and thus kilns or furnaces.

Kiln [8)] (***Brennofen***)
An kiln is typically a closed chamber, possibly rather large, for exposing things to temperatures high enough to finish some process - but without a fire in there. The thermal energy needed typically comes from an attached heat source (sometimes called a "fire box") and is often hot air. What one does in kilns includes:

- Heating people (then it's called Sauna).
- Drying lumber / wood.
- Drying tobacco leaves, malted barley and hops for brewing beer, corn, wheat and other cereals before storage.
- Making glass soft and fusing it with other stuff (e.g. making email).
- Producing quicklime (or Portland cement) by heating limestone (plus clay).
- Making bricks of all kinds (including the ones needed for lining kilns).
- Making pottery in general and China in particular.
- Melting metals and stuff.
- Heating crucibles for making crucible steel
- Producing charcoal by pyrolysis.
- Treating garbage by pyrolysis.

The last two examples are a bit special because in these cases you have the heat source (wood, garbage) *inside* the kiln.
The temperature inside those kilns varies a lot. Saunas and brewery kilns operate at reasonable temperatures in the 100 ^{0}C (212 ^{0}F) range. For making cement you need 1450 ^{0}C (2640 ^{0}F), while for making pottery you should at least have 1000 ^{0}C (1830 ^{0}F). If you want to melt tungsten, osmium or just carbon, you must go above 3000 ^{0}C (5430 ^{0}F).
For temperatures above, say, 800 ^{0}C (1470 ^{0}F) you must give some thought to your kiln design and the (electric) heat source; above, say, 2000 ^{0}C (3630 ^{0}F) you must be prepared to spend real money.
As long as you only have wood or charcoal for generating heat, you must actually give a *lot* of thought to your kiln design if you want to get high temperatures.

The basic idea behind high-temperature kilns (and furnaces) is that the thermal energy created by burning something always dissipates rapidly. For making things really hot you need to put a lot of thermal energy into the materials. If most of the energy created escapes into the air and the surroundings, you won't get far. So contain the energy in an enclosure made from materials with bad heat conductivity that do not easily transmit thermal energy and allow to focus the energy flow on the things you want to get hot.



Reconstructed kiln from way back and cross-section

Furnace [4)] (***Hochofen, Brennofen, Schmelzofen, ...***)
A furnace is a rather ill-defined contraption. The first association that comes to mind in the USA is that thing in the basement that is essential for central heating and warm water in the house. The British beg to differ. That thing is a heater or boiler; a furnace in England is an *industrial* piece of hardware used for smelting, distillation, or whatever is done outside the house. It might be synonymous with *kiln*.
Hell also uses furnaces, as described in Matthew 13:42 ("*They will throw them into the blazing furnace, where there will be weeping and gnashing of teeth*"). I guess that the processing of sinners (including all non-Christians by definition) needs to be done on an industrial scale, considering the numbers.
German has no directly corresponding word but uses specialized terms.
Since we are only interested in the smelting bit, we need to look at important variants of (industrial) **smelting**

furnaces:

- **Bloomery furnace** (*Rennofen*) or just bloomery for short.
  The oldest kind but with all the ingredients of a smelting furnace:

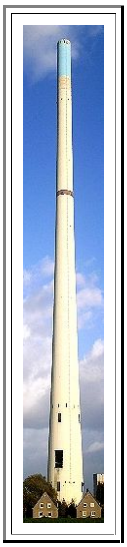
  - Heat source inside (burning charcoal / coke).
  - Air supply at the bottom by tuyères. Either self-made by chimney effect ("*air furnace*") or forced by bellows / blasters.
  - Materials (charcoal, coke, ore, fluxes, ...) added through opening at top; in batches or continuously.
  - Reducing agent (typically carbon monoxide (CO)) produced in-situ.
  - Metal produced collects at bottom (if liquid), otherwise as "bloom" in lower part.
  - Slag collects as liquid at the bottom (but on top of the denser liquid metal) and "runs out" (*rennen*) when the furnace is tapped (hence "*Rennofen*").

  A bloomery produces solid wrought iron or steel intermingled with slag, ashes, unburned charcoal and so on - a hot brightly glowing lump called a **bloom**. It is charged intermittently and operates in a one-way fashion and the whole contraption may need to be destroyed to get the bloom out.
  Not much has changed in the *general* smelting furnace design and working over the millennia (hahah). *Details*, however, changed a lot. The major improvements were in the air supply. Forcing the air in with the help of human or water-wheel operated bellows helps some; forcing a hell of a lot of air in with big blowers run by steam-engines / huge motors helps a lot. Pre-heating the air forced in gets up the temperature (with lots of cold air you effectively cool your fire). Using the heat of the hot air and smoke coming out in large quantities of your furnace (the **flue gases**) to pre-heat the air you blow in makes the process economical.
  There you are. 3 500 years of iron / steel production technology condensed in 5 sentences!
- **Blast furnace** (*Hochofen*)
  A furnace where the air is blown (blasted) in. Well - no. While that is the literal meaning of the term, by now it is reserved for furnaces smelting *iron* with a continuous supply of fuel, ore, and flux through the top, and plenty of hot air at the bottom. This leads to a kind of steady-state inside, allowing continuous operation. Blast furnaces produce only liquid or cast iron. The liquid metal and the liquid slag on top of the (denser) liquid metal accumulate at the very bottom and are removed in a discontinuous fashion.The name, purportedly, comes from the noise all this blasting makes
- **Reverberatory furnace**
  Reverberatory means: reflected, resounding, repercussive, and in a *reverberatory furnace*" the heat is "reflected" from the top or ceiling of the furnace onto the material to be processed. It is a kind of advanced development of a kiln, always made for rather high temperatures, typically fueled by wood, and used for metal melting and glass processing. Here is a drawing of an advanced reverberatory furnace.
  This type of furnace was of some importance in iron processing in the 19th century and before, in particular if the combustion products contained "evil" stuff, like sulphur from burning coal, that should not get into contact with the metal. It might have been used in antiquity, too.
- **Open hearth furnaces**
  You guessed it. Not used for primary smelting but for "cleaning". You could clean your (already condensed and pre-cleaned bloom) in an open hearth furnace by "melting out" the slag still in there, or the liquid pig iron from an early blast furnace by exposing it to the oxygen from the air. You could also make steel by "puddling" or stirring the carbon-rich liquid cast iron, burning out the carbon more efficiently. Open-hearth furnaces are usually of the reverberatoy type; in the form of the "Siemens-Martin furnace" it was *the* furnace for producing steel from about 1890 to1970. I will come to that.
- There are plenty of *modern furnaces*: electric arc furnace, electric induction furnace, vacuum furnace, plasma furnace, ... Look it up yourself.

Tuyère [11] (***Luftdüse, Blasdüse***)
A tuyère is the tube through which air is blown into a (smith's) hearth or furnace. In the very old days you just had some guys blowing through hollow reeds (with clay re-enforced ends, of course). Then you called it a **blow pipe**.
A tuyère is something tricky. Seen by itself it is a rather simple thing and archeologists often find (broken) remains in quantities. Proper use of tuyères, however, is absolutely crucial to smelting.

- Your tuyère must be able to take the heat; it ends right at the hottest part of the furnace. It better not break or gets clogged up or your smelting is unsuccessfully finished. Its diameter and length must be just right to transport the optimal amount of air for the pressure differential (how hard you can blow) at your disposal. Where exactly it enters the furnace and how far you stick it in is essential.
  How did the ancients make suitable hollow tubes 8 000 years ago? Hollow reeds with some clay lining (that burns to hard stuff in the heat) will only only get you so far. Making a fully ceramic tuyère isn't so easy - how do you fire such a long contraption?
  I actually don't know either but you see once more that "doing some smelting" isn't quite as easy as it might appear at first.

Chimney, Stack (***Kamin, Schornstein***)



All fires produce hot air that needs to go somewhere. Since its density is smaller than that of cold air it has a ***natural buoyancy*** and thus moves upwards; witness hot-air balloons. A chimney or stack is a longish tube into which the hot air is funneled, moves upwards, and then is released through the **flue**. The term "flue", nowadays reserved for whatever is on top of a chimney where the hot air plus combustion products are released, was used synonymous to chimney in older times.

- Make a fire in the hearth in your living room without a chimney and you know why it was a great invention. It keeps the smoke, soot and whatever else is produced in your fire besides the hot air, from killing you prematurely. And it does so because a chimney creates a considerable draft by the "**stack effect**". It is easy to see why. The hot air raises up and thus cold air has to be sucked in at the bottom opening lest a vacuum (or low pressure) will be created.

The draft produced by a chimney, measured for example in how many cubic meter of air will flow through the chimney per second, is proportional to the square root of the length of the chimney times the temperature difference.
Now you know why there are tall smoke stacks out there. They generate substantial drafts and you might get enough airflow through your furnace in this way, saving you a blower. Here is an example.

- Of course, the very tall chimneys of old factories and power plants also served another purpose: blow all the dirt and poisons contained in your exhaust fumes high up into the clean air, so when it comes down again it is diluted enough not to kill people and other things right away.
  That's why those chimneys are better called **smoke stacks**. The picture shows the 300 m tall smoke stack of the coal-fired Westerholt power plant in Germany, built around 1960 and demolished in 2003. The idea was to distribute the bad stuff over a large area (Wiki commons).

Handling Hot Stuff

Very few liquid metals will do well in a hollowed-out sun-dried gourd, the skull of your former foe, a sewed-up goat skin, or whatever else Çrockü and Mrs. Nölüdyæ used some 10 000 years ago to contain their booze (probably only water, poor suckers). What you need to have if you want to work with hot or even liquid metals are things like:

Crucible [6] (German: ***Tiegel, Schmelztiegel***)

A crucible is a (usually not very large) container that can withstand high temperatures and does not react (very much) with the hot stuff it contains. This is a tough nut to crack! If you want to melt copper at "only" 1 084 ^{0}C (1 982 ^{0}F), you need a "pot" that was fired at the same or preferably higher temperature. Otherwise the probability that your pot / crucible will not survive is quite large. If you want to melt iron at 1 535 ^{0}C (2 795^{0}F), you need materials that are not all that easy to get.
The Siemens - Martin process revolutionized steel production around 1860, and the major contribution of Émile Martin und Pierre-Émile Martin (father and son) was to come up with "bricks" that could take the heat!

- A vessel made from some good clay and fired at a temperature above 1 000 ^{0}C (1 830 ^{0}F) might have been good enough for melting copper, gold or silver. It would not have survived liquid iron or steel, however. Not that this mattered much in the first 2 000 years or so of iron and steel technology; nobody could produce the high temperatures anyway. Wootz steel, however, was molten at least once, and being able to produce special crucibles that could take the heat was a decisive part of Wootz technology. I'll get to that.

Crucible from Yarýkkaya, North Central Anatolia. Late Chalcoliticum
About (4 x 11) cm

Source: U.-D. Schoop: "Das anatolische Chalkolithikum" A chronological study on pre-bronzeage cultural sequence in north central Anatolia and the surroundings. Urgeschichtliche Studien, Vol. 1 (2005).

- The crucible shown looks like it still gas some metal clinging to it. It's not specified but if it looked like that after some 6 000 years, it can only be gold.

Tongs, **hammers** and **anvil**.
You need to hold and to bang your very hot objects. For the banging you need something we call a hammer, and the banging takes place on an anvil. In old times both were simply stones. They may not last very long but there are plenty around.
"Modern" hammers and anvils came rather late, and you know what they look like.

Stone hammers from Camlibel Tarlasi, Anatolia, ≈ 4 000 BC

Source: U.-D. Schoop: "Çamlibel Tarlasi, ein metallverarbeitender Fundplatz des vierten Jahrtausends v. Chr. im nördlichen Zentralanatolien", p. 53, in "Anatolian Metal V", Hrsgb. Ünsal Yalcin, 2011. With permission.

- Tongs are much trickier. They are best made from iron that has a not-so-good heat conductivity. Cooper tongs, conducting heat much better, tend to get hot quickly, not too mention that they are soft, not allowing a good grip. A modern smith, working with iron, could make his own tongs, and he has many kinds for specific jobs, see below.

Tongs in a standard smithy (before 1 000 - 1960 and beyond)

Old (Roman or so) tongs.
They look pretty much the same as modern ones

Source: Photographed in the Archeological Museum Copenhagen

- The pre-iron smiths from about 10 000 BC - 1 500 BC had a problem. You can use that split wood stick for a while, but it neither lasts very long nor does it allow precise manipulation of the hot object.
  How the early smiths did their thing in this respect, I simply don't know.

Molds [9)] (spelled "*moulds*" in British English)
If you cast something like lead, bronze copper, silver or gold, you need a mold. There are many ways to make molds, the major distinctions are

- Single use (mold is destroyed by use) vs. multiple uses.
- One-piece or open mold, two-piece or **"bivalve" mold**, or composite mold (three pieces or more).

- Obviously, open molds are easiest but don't give final shapes. It's only good for simple geometries and the cast object needs some shaping after casting. Permanent molds needed to survive the heat and the thermal shock, and thus had to be made with care.
  In all cases, making thin-walled objects by casting required precise mold making - and that is not so easy to do with stone tools. Here is one of the the reasons why hammering metals into thin sheets, and then forming the desired objects from the sheets, was done parallel to casting for quite some time, especially if the metal was rare like gold. Witness the Varna gold and copper artifacts.

Open (?) stone mold for bronze castings
Negative picture

Source: Photographed in the Archeological Museum Copenhagen

I'm not exactly sure what you get when casting into this mold.

Miscellaneous.
Making metals is hot and hard work, so one needs good food, beer, and some entertainment during the free time. The first two items could be gotten by trading the stuff one made, the third one might have posted some problems. However, a really good smith simply made the necessary stress-relieve equipment himself.

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1) *Hearth*: Old English heorð "hearth, fire", in transferred use "house, home", from West Germanic hertho "burning place". The deepest root is the Proto-Indo-European (PIE) kerta-, from ker- "heat, fire". The word carbon has its source here, too

2) *Oven*: Old English ofen "furnace, oven", from Proto-Germanic *ukhnaz, from PIE *aukw- "cooking pot" (cf. Sanskrit ukhah "pot, cooking pot", Latin aulla "pot", Greek ipnos), originally, perhaps, "something hollowed out".

3) *Forge*: late 14century. "a smithy", from Old French forge (12c.) "forge, smithy", earlier faverge, from Latin fabrica "workshop", from faber (genitive fabri) "workman in hard materials, smith" (see fabric). As the heating apparatus itself, from late 15c.

4) *Furnace*: Early 13c., from Old French fornaise "oven, furnace" (12c.), from Latin fornacem (nominative fornax) "an oven, kiln", related to fornus, furnus "oven", and to formus "warm", from PIE root *ghwer- "warm" (cf. Greek thermos, Old English wearm; see warm (adj.)).

5) *Smith*: Old English smið "one who works in metal" (jewelers as well as blacksmiths), from Proto-Germanic *smithaz "skilled worker", from PIE root *smei- "to carve, cut" (cf. Greek smile "knife, chisel"). Attested as a surname since at least c.975.

6) *Crucible*: Early 15c., from Medieval Latin crucibulum "melting pot for metals", originally "night lamp". First element might be Middle High German kruse "earthen pot". Or perhaps it is from Latin crux on some fancied resemblance to a cross.

7) *Bellows*: ca.1200, belwes, literally "bags", plural of belu, belw, northern form of beli, from late Old English belg "bag, purse, leathern bottle" (see belly (n.)). Reduced from blæstbælg, literally "blowing bag". Used exclusively in plural since 15c., probably due to the two handles.

8) *Kiln*: Old English cyln, cylen "kiln, oven," from Latin culina "kitchen, cooking stove," unexplained variant of coquere "to cook".

9) *Mold*: Also mould, "hollow shape," c.1200, originally "fashion, form; nature, native constitution, character," metathesized from Old French modle "model, plan, copy; way, manner", from Latin modulum (nominative modulus) "measure, model," diminutive of modus "manner" (see mode (1)). From c.1300 as "pattern or model by which something is shaped or made."

10) The German "Esse" has an "as" root, like Asche=ash and connotations to burning, glowing.

11) Middle French tuyère, going back to "tuyau"=pipe. First known use in English in 1781.