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# Instruction Manual for Hadar's Clay™


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# Instruction Manual for Hadar's Clay™

## Storage and Shelf Life of the Clay

The powder clay does not require special storage. As long as it has not been mixed with water, it has an indefinite shelf life. Mixed clay should be refrigerated, wrapped with plastic food wrap inside a closed plastic box. It has been shown to last at least a few months when properly kept. If you don't intend to use the clay for a long period of time, it's best to freeze it.

The shelf life of **unfired** pieces is very long. There is no need to fire them right away.

## Toxicity

None of the ingredients of Hadar's Clay™ is toxic. It may be unhealthy to inhale any powder of any kind. Use a protective mask and goggles when handling the powder, as well as when handling carbon.

## Mixing Instructions

Also available as a video clip at www.youtube.com/artinsilver – select the video entitled "Hadar's Clay™ – Mixing."

**What you need:**

- ❑ Small metal bowl or soup bowl
- ❑ Kitchen knife or any other mixing tool
- ❑ Distilled or filtered water in a spray bottle
- ❑ Olive oil in a spray bottle

**Mixing the clay (just like cookie dough)**

1. Shake the metal clay powder container.
2. Pour the desired amount of powder into the bowl.
3. Spray small amounts of water into the powder and mix with the knife. The powder will gradually form into crumbs.
4. Keep spraying and mixing until the crumbs separate from the walls of the bowl. Don't over-wet! If you accidentally over-wet, add more powder.
5. When the crumbs have consolidated into one mass, oil your palms and knead it a little.

## Consistency of the Clay

The mixed clay is soft, pliable, does not crack when bent, and sticks well to itself.

The photo on the right shows how readily the clay drapes without cracking when mixed to the right consistency.

## Lubrication

The clay does not stick to the hands. As a release agent from texture plates use olive oil only (not from a spray can!). Other lubricants may contain ingredients that could react with the clay and damage its consistency.

## Drying

Dry pieces directly on a heating pan at 220-250°F (95-120°C). Flat pieces of Traditional (Flex) clay powder and all types of steel except for Low Shrinkage Steel *XT* tend to warp while drying. Once they start warping, keep flipping them over until they stay flat. Quick-fire copper, bronze, Rose Bronze, and White Bronze don't usually warp while drying.

If warping does occur with thin pieces, cool them in the refrigerator. They will become somewhat flexible. Gently flatten them down. You can leave them under a heavy book overnight.

## Reconstituting

You can reconstitute solid pieces that have not been fired. Always use distilled or filtered water to reconstitute clay. It can be reconstituted by grinding the dry piece in a dedicated coffee grinder and repeating the mixing process as described above. it is not recommended to reconstitute clay powder that is derived from sanding and filing.

If the clay dries, roll it with a rolling pin into a thin layer, spray it with water, fold it a few times and roll it again to work the moisture in. Repeat until you are satisfied with the consistency.

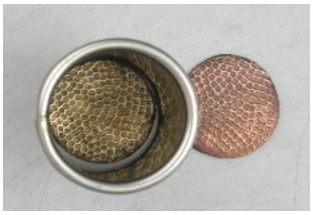
## Flexibility and Strength of Dried Clay

The surface of dried clay lends itself to carving, and is best sanded with 150-grit sandpaper or a fine-grit sponge sanding pad (do not use medium grit!). Cooling the dried clay in the refrigerator for 5 minutes will make it more flexible.

Traditional (Flex) clays and steel clays are a little tougher to carve and sand.

## Shrinkage

Quick-fire copper, bronze, White Bronze, Rose Bronze, and Low-shrinkage Steel *XT* clay shrink by less than 10% by volume. All other steels and Bronze *XT* shrink by 28%. Traditional (Flex) copper, bronze, Rose Bronze, shrink by about 25%. Traditional (Flex) Pearl Grey Steel *XT* shrinks by 28%.



## Firing with Core Material

It is possible to fire with core material – including cork clay. When firing the first phase with core materials in a kiln, it is recommended to hold for up to 2:00 hours at 1000°F/538°C in a top loader brick kiln or 1100°F/593°C in a front loader muffle kiln before continuing to the final hold temperature (see firing schedules below).

Some core materials, such as pasta and cardboard, will not burn off inside carbon, even with 2 hours' hold at the first phase.

## Flexible (Traditional/Flex) Clay

Mixing Traditional (Flex) copper, bronze, Rose Bronze, Quick-fire Steel XT and Pearl Grey Steel XT clay with glycerin makes clay that stay flexible after it has been dried. Flexible clay allows you to weave, fold, and knot with dried clay. See instructions for making and using flexible clay in my book: *The Handbook of Metal Clay: Textures and Forms,* 2nd edition. To see a demo video clip, go to youtube.com/artinsilver, select the Videos tab, and click on the video entitled *Hadar's Clay™ - Mixing Instructions*.

In this case, too, if firing the first phase in a kiln, it is recommended to hold for up to 2 hours at 1000°F/538°C in a top loader brick kiln or 1100°F/593°C in a front loader muffle kiln. It is recommended, however, to follow the shortened firing schedule (pp. 10-11).

Shrinkage: Flex copper, bronze, and Rose Bronze, 25%, Pearl Grey Steel *XT*. , 28%.

Tip: Let the flexible sheet or wires dry in the air and store them in the refrigerator.

## Repair

After firing, pieces can be repaired and re-fired. Unlike silver clay, base metal clays **cannot** be repaired with a torch. Repairing with small amounts of fresh clay does not require repeating the first phases of firing.

## Firing with Activated Carbon

Precious metals such as pure silver and gold can be fired in the air. They don't react with the oxygen under high temperature, and the oxygen ensures complete removal of the binder.

Base metal clays such as copper, bronze, White bronze, Rose Bronze, Bronze *XT*, and steels do react with oxygen under high temperature to create oxides, which prevent proper sintering (the final bonding of the particles together). To help prevent this, they should be fired buried in activated carbon, which reduces the amount of oxygen in the kiln and inhibits this reaction. However, most organic binders used in metal clays need oxygen in order to burn off. If there is not enough oxygen (because it has been reduced by the carbon), the binder will not burn off and proper sintering will not be achieved. This problem can be solved by using a proper firing schedule.

For an extended discussion of the firing process see my article **Understanding Metal Clay and the Firing Process** on p. 24.

## The Carbon

Use coconut shell-based carbon, acid-washed, size 12 x 40.

**Important note:** The same type of carbon may differ from one manufacturer to another. If sintering is not achieved using the firing schedules suggested below, try carbon with the same specifications from a different manufacturer.

**Good carbon for sintering purposes does not produce a lot of ash and does not stay hot a long time after firing.**

## The Firing Box

The carbon can be contained in a stainless steel mixing bowl or a pet dish, a box made out of fiver, fiber blanket, or ceramics. Each has its advantages and disadvantages. A round bowl is best for heat circulation.

**Stainless Steel Mixing Bowl or Pet Dish**

The big advantages of the mixing bowl and pet dish is that its shapes allows for better distribution of heat, and that it cools down very quickly between firing phases. It is also stable when taken in and out of the kiln, and pieces are less likely to break between phases. However, it oxidizes and flakes and covers the kiln floor with black dust (often mistaken for carbon). It is recommended to line the floor of the kiln with kiln liner or a lava cloth (available from glass fusing suppliers) and vacuum the kiln after firing.

## The Firing Set-up

1. Line the inside of the box with a ½" layer of carbon.

2. The challenge in firing with carbon is to achieve even heat distribution. In kiln chambers that measure 8"x 8"x 6" or more, arrange your pieces on the carbon as follows:

   - In one layer only
   - With ½" carbon underneath and 1"-2" above them
   - Horizontally
   - With ½" space between them, more for thick or big pieces
   - Avoid the center. If you have a front loader kiln, avoid the front as well. (In a circular mixing bowl there is a good chance that pieces in the front will sinter just fine).

3. Place the box on the four 2" posts. Make sure there is space for air flow between the top of the box and the top of the kiln chamber.

4. Do not use a lid. The carbon will stay contained in the box. If there is black dust inside the kiln chamber after firing, it is because the metal container has oxidized and flaked.

5. A top venting hole can be closed or open. It should be left open if both phases of firing are performed in the kiln.

6. If you perform the first phase in a kiln, always start the second phase with a cold kiln.

7. Use a 2-phase firing schedule (see firing schedules below).

8. If you perform the first phase in a kiln**, cool the box and the kiln before proceeding to the second phase.** You can take the box out while hot, wearing heat protective gloves, and let it cool outside the kiln (preferably outdoors, if weather permits).
9. When the first phase in the kiln is over, the carbon **should not** be on fire. If it is, next time lower the suggested temperature for the first phase by 50°F/30°C.

10. Some of the carbon will have turned into ash. To discard the ash after the first phase of firing, blow it away with a straw or a mini-fan.

11. When the carbon and kiln ares cool enough to touch, add some carbon and proceed to the second phase.

12. To discard the ash after the second phase of firing, pour the content of the box, from high above, through a large-hole sieve into a metal container (a large mixing bowl) placed on a heatproof surface. Be sure to wear a mask. Most of the ash will blow in the air. The fired pieces will stay in the sieve and the leftover carbon can be re-used.

## Test Firing

Each kiln fires a little differently, even kilns that are identical in model and age. There is no single firing schedule that will apply to all kilns. Whatever kiln you have, you need to do some test firing before firing actual pieces. By doing this simple test, you will make your kiln work for you.

Make a few pieces, as many as you would normally fit in your kiln (see p. 7-8). The pieces should be made from both quick-fire copper and bronze(not *XT*), non-textured. Here is how to make them:

- Roll a layer of copper clay at least 6 cards thick. Place a little ball of bronze on the layer.

- remove the cards, and roll the ball flush with he copper layer.

Make a few pieces with copper as the base and a few with bronze as the base.

Dry the pieces, and fire according to the following schedule:

| **Phase 1** | **Phase 2** |
|---|---|
| Pre-fire on a stove top (see instruction below), or use a kiln:<br><br>Ramp at 1800°F/1000°C to:<br><br>1000°F/538°C (brick kiln); 1100°F/593°C (muffle kiln)<br><br>Hold for 2:00 hours<br><br>This is the temperature at which the binder burns. The more binder in the kiln, the longer it will take it to burn out.<br><br>Cool the box down to room temperature. | Ramp at 1800°F/1000°C to:<br><br>1470°F/800°C (brick kiln)<br>1520°F/827°C (muffle kiln)<br><br>Hold for 2 hours. |

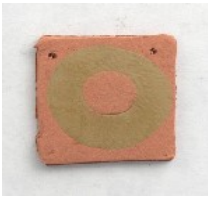
Check the results for over-firing or under-firing:

**Over-firing**

If the mixed pieces are curled, or a relief shows on pieces that were flush before firing, or the copper part has disappeared (photos B and D), the temperature was too high. Make new test pieces, and in the second phase fire them at a temperature lowered by 10°F/5°C. If you get a similar result, make new test pieces and lower the temperature by another 10°F/5°C. Repeat until the fired copper and bronze are flush as they were before firing. Photos C and E show the desired result ("married metals"). Photo F shows the same piece after patina was applied to highlight the contrast between the married metals.

**Under-firing**

Sand the copper part of the piece with 220-grit sandpaper. If the piece is fully sintered, the surface will look more metallic as you keep sanding. If you keep sanding and the copper becomes more pitted and dark (photo G) instead of becoming shiny metallic (photo H), then it was under-fired. Make new test pieces and fire again at a temperature that is 10°F/5°C higher.



A Before

B Over-fired

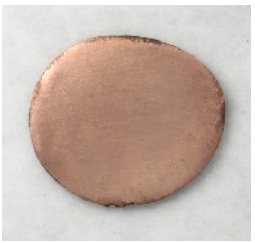
C Flush

D Over-fired

E Flush

F With patina

Under-fired



Fully sintered

**Note:** it is important to fire new test pieces at a higher temperature. If you fire the same pieces, they may sinter only because you fired them twice.(Re-firing is actually a good way of repairing under-fired pieces.)

**Testing White Bronze**

In the second phase, fire test pieces at 1250°F/676°C (brick) ,1325°F/718°C (muffle). If there is no sintering, raise the temperature by 10°F/5°C at a time. If the pieces melt, lower the temperature by 10°F/5°C at a time.

**Testing Bronze *XT***

In the second phase, fire test pieces at 1700°F/926°C (brick) 1780°F/971°C muffle). If pieces blister, lower the temperature by 10°F/5°C at a time.

## Pre-firing (Phase 1)

Perform the first phase of firing on a stove top (propane camping stove or a kitchen stove. To see a demo video clip, go to youtube.com/artinsilver, select the Videos tab, and click on the video entitled *Shortening the Firing Time for Base Metal Clay.*

Pour a 1" layer of carbon into a stainless steel bowl. Place your pieces on top of it without covering them in carbon. Put the bowl on the stove.

Cover the bowl. You can use a fiber board, or a piece of fiber blanket (fiber blanket is not recommended in a kitchen stove). It is possible to fire without a cover; the cover only speeds up the initial heating.

In each of these lids drill a pencil-size hole. To do this in a fiber board or the fiber box you can use a screwdriver. Just twist it in; the fiber is very soft. With the fiber blanket just stick in a pencil to make the hole.

Turn the flame on to full capacity. It will take 3-5 minutes for carbon to heat up. After a few minutes you will smell and see the smoke coming out of the holes in the lids. This is the binder burning. It is important that the binder burns slowly, without catching fire, or pieces will crack. If pieces catch fire, lower the flame. If you are not sure there is smoke, you can lift the lid with a glove or tweezers and look inside.

After about 10 minutes the smoke will stop. Remove the lid with a glove and peek inside. The pieces should look black.

Pour more carbon into the bowl to cover the pieces and put them in the kiln for the **second phase** of firing. The whole process takes about 2:30 from beginning to end.

Note: at high altitude the stove-top firing will last longer. In general, there is no harm in firing on a stove top for up to 40 minutes.

**All clays can be pre-fired on a stove top except for White Bronze.**

After pre-firing on a stove top, there is no need to cool down the box before continuing to second phase. However, there is no need to hurry. The second phase can wait.

## Firing Schedules

The following firing schedules include instructions for firing the first phase in a kiln. They apply to two popular types of kilns, both 8"x8"x6":
brick kiln (top and front loader), and front-loader muffle kiln. Use them as a starting point for testing your kilns.

**These firing schedules have been shown to work with all currently existing brands of base metal clay.**

## Mid-Fire Schedule

### Traditional (Flex) Bronze; Quick-fire Bronze; Combination of Quick-fire Copper, Bronze, and small amount of Quick-fire Steels

**Phase 1**

Pre-fire on stove top, or:

Ramp at 1800°F/1000°C to:

1000°F/538°C ( brick kiln)
1100°F/593°C (muffle kiln)

Hold between 2:00 hours

Cool the box and the kiln down to room temperature.

Bronze

Mixed copper, bronze, and steels (in small ampounts)

**Phase 2**

Ramp at 1800°F/1000°C to:
1470°F/800°C (brick kiln)
1520°F/827°C ( muffle kiln)

Hold for 2 hours.

Mixed copper and bronze

## High-fire Schedule

### Copper, Bronze *XT*, Rose Bronze, Steels, Combination of Bronze *XT*, Copper, and Large Amounts of Steels

**Phase 1**

Pre-fire on stove top, or:

Ramp at 1800°F/1000°C to:

1000°F/538°C (brick kiln)
1100°F/593°C (muffle kiln)

Copper

Copper, steel, and Bronze XT

Hold for 2:00 hours

**Be careful when you take the box out of the kiln, or pieces can break!**

**Cool down to room temperature.**

Rose Bronze

Quich-fire steel XT

**Phase 2**

Ramp at 1800°F/1000°C to:

1700°F/926°C (brick kiln)
1780°F/971°C ( muffle kiln)

Hold for 2:00 hours.

Copper and Rose Bronze can be also fired on their own as low as:

1470°F/800°C (brick kiln)
1520°F/827°C (muffle kiln)

However, they will not be as strong, and will not reach their maximal shrinkage.

## Low-fire Schedule

### White Bronze on its Own and Combined with Other Clays

**Phase 1**

**(Pre-firing on stove top is not recommended)**

Ramp at 1800°F/1000°C to:

1000°F/538°C (brick kiln);
1100°F/593°C (muffle kiln)

Hold for 2:00 hours.

Cool to room temperature (optional).

**Phase 2**

Ramp at 1800°F/1000°C speed to:

1250°F/677°C (brick kiln)
1325°F/718°C (muffle kiln)

Hold for 2:00 hours.

White Bronze has a narrow sintering range. It can quickly go from not sintering at all to melting or deforming. Therefore**, it is necessary to make test pieces before you begin firing actual pieces!** Use schedule C as your starting point.

## Post-firing

To delay tarnish and corrosion it is recommended to soak all types of fired clay in oil (preferably scented oil) for an hour or so. Due to the porosity of the clay, pieces will hold the oil inside them and defy humidity.

Pieces can also be coated with long-lasting lacquer (such as Permalac) or wax. No form of sealing is permanent.

### Copper and Bronzes

To highlight the contrast between copper and bronze in mixed, non-textured pieces, sand the pieces smooth, apply Baldwin's Patina, and rinse with warm water. See the video clip on YouTube (go to youtube.com, click on the Videos tab, and select the clip entitled *Baldwin's Patina on Metal Clay*) and my books: *Mixed Metal Jewelry from Metal Clay*, and *Patterns of Color in Metal Clay*.

Baldwin's Patina is not meant to add color but to highlight the contrast between the married metals.

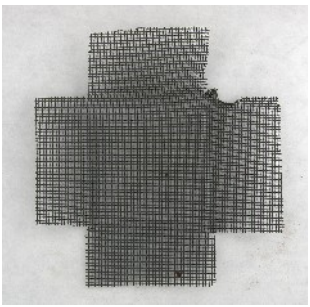
### Steels

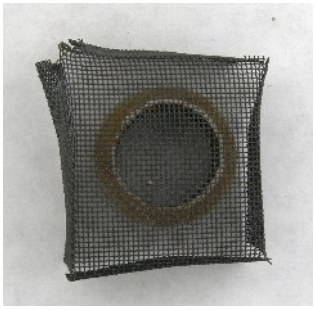
All types of steel clays have a pearl gray, silvery color after firing. They are very strong when used on their own. Pearl Grey Steel *XT* and Quick-fire Steel *XT* shrink 28% by volume. Pearl Grey Steel shrinks less and is preferred for gradient surfaces. It is not recommended to fire it on its own. Low Shrinkage Steel *XT* shrinks about 10%. Quick-fire Steel *XT* (both low- and high shrinkage) is malleable and can be hammered into shape after firing. When combined with other metals (except for Bronze *XT*) in one piece they should be used in small amounts and fired at mid-fire schedule. When combined with Bronze XT they can be fired at high-fire schedule. All are magnetic!

Because of most steel clays' high shrinkage rate, when fired on their own (not in combination with other metals), inside carbon, cracks and distortions may occur. This is caused mainly because of friction with the carbon. The more complex the piece is, the more chance that distortion will happen. This is especially the case with rings. To avoid this, you can fire inside a cage.

**Firing inside a cage**

To make a cage, use stainless steel or brass screen, fine enough for the carbon not to filter through.





1. Using scissors, cut a square that matches the size of your piece. Cut 4 small squares, one at each corner of the square.

2. Fold the flaps down. It doesn't have to be at a right angle.

3. Place a piece of fiber paper or another flat piece of screen on top of the carbon. Sprinkle some carbon on top of it and place your piece on top of that carbon. This will allow the piece to slide while shrinking.

4. Place the cage on top of the piece. This will isolate the piece from the rest of the carbon. You can fire the first phase on a stove top this way, then add carbon to cover the cage, and go on to the second phase. If you fire the first phase in the kiln, cover the cage with carbon.

   The fact that air is trapped inside the cage does not affect the firing results. There is no oxidation.

**Coloring Steel**

There are many ways to blue steel and and a continuing debate as to which way is best. Suggested here are two processes for bluing. If performed prior to sealing, both contribute to the sealing quality.

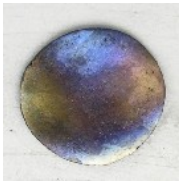
**Cold Bluing**

Blue color can be achieved by applying a little bit of Birchwood Casey Super Blue. After bluing, sealing should be done with or wax as described above.

**Hot Bluing (also called tempering)**

Heat the piece with a torch. When the desired color appears, immediately dip in cold water. Repeat a few times until you reach the desired color. Polish by rubbing the piece with steel wool.

This rock was held by the wire and heated gradually with a torch until it turned dark blue. After quenching it looked like hematite.



**Baldwin's Patina will darken steels when mixed with other metals in one piece. It will not darken them if they are fired in combination with Bronze *XT*.**

The earring on the right was fired with Quick-fire bronze. The earring on the left was fired with Bronze *XT*.

## White Bronze

White Bronze is a copper alloy powder which, after firing, yields a metal with a color very similar to that of silver. It is not to be confused with nickel silver (also known as German silver or alpaca). It contains no nickel.

Fully sintered pieces are hard, strong, and easy to sand. However, they are not flexible. **Do not try to bend them with pliers or to hammer them, or they will break!** Be sure to do all your fabrication before firing. White Bronze is most suitable for combining with other metals in one piece. Thin pieces are brittle, but thick pieces of White Bronze and pieces from combinations of White Bronze are not.

White Bronze does not tarnish as readily as silver. It also reacts well to liver of sulfur and other patinas. It does not react to Baldwin's Patina, which makes it possible to highlight the contrast between White Bronze, copper, and steels in mixed pieces.

## Mixing Different Metals in one Piece

When different metals are fired in one piece, the firing schedule is determined by the lowest firing clay in the mix: any mix containing white Bronze has to be fired at the low-fire schedule; any mix containing bronze (not *XT*) and no White Bronze, has to be fired at the mid-fire schedule. Any mix of high-fire clays can be fired a high-firing schedule. For further details, please see my presentation *Introduction to Mixed Metal Clay,* which can be downloaded from the right-hand pane of my blog at hadarjacobson.com/blog .

A mix of copper, bronze, and steel that uses Quick-fire Bronze has to be fired at mid-fire schedule and allows only small amounts of steel to be included.

A mix of copper, bronze, and steel that uses Quick-fire Bronze *XT* can be fired at high-fire schedule and allows large amounts of steel to be included.

The following chart shows different possible mixes together with their firing schedules.

## Compatibility Chart

### Part 1. Which metal clays can be fired together in the same piece, in one firing, and at what schedule?

All clays are compatible with each other and will bond to each other if fired in one piece.

1. Traditional (Flex) copper and bronze
   Mid-fire schedule


2. Quick-fire copper and bronze
   Mid-fire schedule

3. Quick-fire copper and steels
   High-fire schedule

   The bronze color in the photo on the far right is a result of alloying between the steel and copper at the contact point.


4. Rose Bronze and Steels
   Mid-fire schedule

   Although both clays can be fired at the high-fire schedule, a better contrast is achieved at a lower temperature

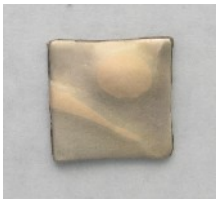
5. Quick-fire Bronze and Pearl Grey Steel
   Mid-fire schedule

6. Quick-fire Copper, bronze, and steels
   Mid-fire schedule

7. Quick fire Copper, steels, and Bronze *XT*
   High-fire schedule

Bladwin's Patina will not blacken steel when Bronze *XT* is used in combination of copper and steel or just steel.

8. Bronze *XT* and Quick-fire Steel *XT*
   High-fire schedule



9. Bronze and White Bronze
   Low-fire schedule

10. Copper and White Bronze
    Low-fire schedule
    (may require repeating the second phase of firing for full sintering of the copper part)

    The bronze color is created by the reaction between copper and White Bronze.


11. Copper, bronze and White Bronze
    Low-fire schedule
    (may require repeating the second phase of firing for full sintering of the copper part)


12. White Bronze and Pearl Grey Steel
    Low-fire Schedule (Schedule C);
    (may require repeating the second phase of firing for full sintering of the steel part)

13. Quick-fire copper, bronze, White Bronze, and steels
    Low-fire schedule ((Schedule C);
    (may require repeating the second phase of firing for full sintering of the copper part*


14. Quick-fire copper and low-shrinkage silver clay
    Low-fire Schedule (Schedule C)

* For canes, gradients, mokume-gane and striped designs as in the examples above, see my book: *Patterns of Color in Metal Clay: Canes, Gradients, Mokume-Gane.*

## Part 2. Which metal clays can be fired together in the same piece, in more than one firing, and at what schedule?

1. Fire copper first (High-fire Schedule) and add silver by torch-firing. Silver does not stick to copper, so a mechanical connection is required.*


2. Fire copper first (High-fire Schedule) and add White Bronze in the second firing (Low-fire schedule - C). White Bronze sticks to copper, so no mechanical connection is required. This type of inlay will not work with silver since the silver will shrink and fall out, while the White Bronze will stick to the copper.


3. Fire copper and bronze first (Mid-fire schedule) and add White Bronze in the second firing (Low-fire schedule). This will not work with silver – both because silver does not stick to copper and because of the reaction between silver and bronze**.



4. Fire steel first (High-fire schedule) and add silver (torch), or bronze (mid-fire schedule), or White Bronze (low-fire schedule) at second firing.


5. Fire steel and copper first (high-fire schedule), and add bronze (mid-fire schedule), or White Bronze (low-fire low-fire schedule) at second firing.


* For mechanical connections see my book: *Mixed Metal Jewelry from Metal Clay.*

** For combining silver and bronze see my book: *Silver and Bronze Clay: Movement and Mechanisms.*

# How to Talk to Your Kiln
# Programming Your Kiln

With 2-phase firing schedule

## Demonstrated on Firing Schedule A

**Phase I**

On the control panel, press the left button until you reach a program that is not pre-set. If the kiln is not pre-set, press the "up" button until you reach PrO1 (Program 1). On pre-set kilns it may be program 6.


Press the left button again. The kiln will say: "Idle."

Translation: "I am doing nothing. Tell me what to do."


Press the left button again.
Translation: You are telling your kiln "Start asking."

The kiln says:
"rA 1" (ramp 1).

Translation: "How quickly would you like me to reach the desired temperature the first time around?"
(1 means the first time around)


Your answer is "Full speed," which means "Ramp up as quickly as you can." (In most kilns this means 1800°F/1000°C per hour.) Press the up and down arrows until the display says "Full."

**Note: 1800°F/1000°C <u>per hour</u> is only the rate ("speed") at which the temperature will rise. The kiln is not actually going to reach this temperature.**


In some kilns, the speed is determined by time, not by temperature. For those kilns, ask the kiln to ramp in 1:00 hour.

Press the left button again.
Translation: You ask "What's your next question?"
The kiln says: "°F 1."

Translation: "What temperature would you like me to reach the first time around?"


Using the up and down arrows answer: "1000 (538°C)."

In a muffle kiln answer: 1100 (593°C).

In a very small kiln answer "1000 (538°C)."

Press the left button again.


The kiln asks: "HLd1" (hold 1).

Translation: "How long should I *hold* (stay) at that temperature?"


Your answer: "30 minutes" to "2:00 hours". (To say this, press the up and down arrows until the display reads 00:30 or 2:00, or anything in between).


Press the left button again.

Now the kiln asks: "rA 2" (ramp 2).

Translation: "How quickly would you like me to get to the desired temperature the second time around?"
(2 means the second time around).


Your answer is: "0 "

Traslation: "I don't want a second time around."

If the kiln keeps asking questions keep pressing 0 until the kiln says “Strt” (Start).

Press the left button again. The kiln will say: “On.”


**Phase II**

Press the “up” arrow to PrO2 (Program 2). If your kiln is pre-set, you will have to use program 6 again. Just press the left button, and change only the temperature and time as noted below.



As before, prompt the kiln for the next question by pressing the left button after each of your answers.

Kiln: “Ramp 1”?

You: “Full speed.”


Kiln: “°F 1”?

You: “1470°F (800°C).”

In a muffle kiln the answer is 1520°F (827°C).


In a very small kiln the answer is 1463°F (795°C).


Kiln: Hold 1?

You: “2 hours.”

If the kiln asks “Ramp 2” answer “0”.
Press the left button until it says “On.”

# Checklist

| Question | Correct Answer |
|---|---|
| ❑ Did I shake the jar before mixing the clay? | Yes |
| ❑ Did I use distilled water when mixing the clay? | Yes |
| ❑ Did I use any lubricant other than olive oil? | No |
| ❑ Did I use core material or glycerin? | If you did, hold 1:00-2:00 hours in the 1st phase |
| ❑ Does the thermocouple stick into the chamber? | Yes |
| ❑ Is the thermocouple older than 3 years? Could it be rusty? | No |
| ❑ Did I use a box other than a stainless steel mixing bowl? | Adjustment of the temperature may be required |
| ❑ Did I elevate the box to the top of the kiln? | Yes |
| ❑ Did I use a lid? | No |
| ❑ Did I leave enough space around the box for heat flow? | Yes |
| ❑ Did I leave the venting hole open? | Yes |
| ❑ In a front loader, did I remember to lay the pieces along the side and the back walls, avoiding the center and front? | Yes |
| ❑ In a top loader, did I lay the pieces along all 4 walls of the kiln avoiding the center? | Yes |
| ❑ Did I overcrowd the box? | No |
| ❑ Did I leave ½" space between pieces? | Yes |
| ❑ Did I leave more than ½" for thicker or bigger pieces? | Yes |
| ❑ Did I cool the kiln and the box after the 1st phase of firing? | Yes |
| ❑ Was there silver in the box? | No |
| ❑ Did I mix different brands of copper and bronze clay? | No |
| ❑ Did I fire test pieces before firing actual pieces? | Yes |
| ❑ Did I confuse bronze with White Bronze? | No |
| ❑ Did I confuse bronze with Bronze *XT*? | No |
| ❑ Did I start with a cold kin after doing phase 1 in a kiln? | Yes |
| ❑ Was the carbon on fire at the end of the first phase? | No |
| ❑ Was there a lot of ash in the box at the end of each phase? | No |
| ❑ Did the carbon and/or kiln stay hot long after firing? | No |

# Understanding Metal Clay and the Firing Process

When I started this blog, I predicted that within a year many brands of metal clay would be available. This has become true, and it seems to create a lot of confusion – different instructions, different firing schedules, etc. Different teachers use different brands and may not be fully aware of how to handle other brands.

To help clear up this confusion, I thought it might be best not necessarily to clarify the differences between the brands, but to establish what they have in common. Perhaps understanding the process of sintering metal powder will help individual users to find their own optimal firing schedule.

I am by no means a scientist, and all I am about to say is based on a lot of reading and experimentation. Reading material about the theory of sintering is not necessarily helpful, since practice rarely goes hand in hand with theory. However, things that I have read gave me ideas about what may be worth trying, and through trial and error I arrived at a certain level of understanding. That is what I have to share.

**Sintering** means the bonding of the loose metal particles together well below their melting point. The term sintering applies not only to metal powder but also to ceramics.

A metaphor that may be helpful in understanding the sintering process is ice cubes. Ice melts at 32°F/0°C. The temperature in the freezer is far below that. What happens if we raise this temperature without reaching the melting point? The ice cubes will start sticking to each other until we are able to pick them up as one solid unit. However, since they don't touch each other at every point of their surface, there are spaces between them and this whole mass is porous. If the metal is brought above its melting point it becomes liquid which flows and fills the pores.

The sintering process consists of 2 main phases:

1. Removal of the binder
2. Densification of the particles

**Removal of the Binder**

The role of the binder is to give the metal powder the consistency of clay, so we can shape it or press it into molds. For the clay to turn into pure metal, the binder needs to be removed completely before the sintering process begins. If it is not

completely removed, whatever is left of it prevents the metal particles from adhering to each other.

If the binder is completely removed, it does not matter what type it is. The type may affect the working condition of the clay, but not the sintering results.

**Densification**

Once the binder is removed, the particles are allowed to get closer and closer. As the temperature rises, their contact areas grow, but since they don't reach their melting point and turn into liquid, they cannot flow and entirely fill the spaces between them.

Here is a link to a short video clip that I linked a while ago on my blog. About halfway through the clip, you can see a good illustration of densification.

www.hadarjacobson.com/blog/2009/03/08/powder-metallurgy/

Also see: "The Sintering Bracelet Project":
www.hadarjacobson.com/blog/2010/04/28/the-sintering-bracelet-project/

And: *Introduction to Mixed Metal Clay* (Presentation), accessible from the right-hand pane of my blog at hadarjacobson.com/blog.

**What needs to happen in order for us to have successful firing?**

Precious metals such as pure silver and gold are fired exposed to air. They don't react with the oxygen in the air, and the oxygen ensures the complete removal of the binder.

Base metal clays such as copper, bronze, and steel, when fired exposed to air, react with oxygen to create oxides, a third material which, like the residue of the binder, prevent the particles from bonding. Pure copper can be fired exposed to air for a very short time before it oxidizes internally. However, longer or repeated exposure to heat and air will enhance the oxidation and eventually the copper will disintegrate. This is true not only for copper clay but also for solid copper, such as plumbing parts and sheets.

Bronze, White Bronze, Rose Bronze, and steels cannot be fired exposed to air. If they are, a large chunk of them will come off, taking with it the texture and details.

Therefore, base metals are fired buried in activated carbon, which reduces the amount of oxygen in the kiln and inhibits this reaction. Gold granulation is done this way, since it involves the use of copper. The carbon creates a "reducing atmosphere"; when heated, carbon monoxide fumes are generated, which bond

with the oxygen present in the kiln. Carbon monoxide fumes can be also generated by burning gas such as propane or natural gas.

However, most organic binders used in metal clays need oxygen in order to burn off. If there is not enough oxygen (because it has been reduced by the carbon), the binder will not burn off completely. If the binder is not completely removed, there will be no proper sintering.

So in a way, the activated carbon is both a blessing and a curse. On the one hand it enables sintering; on the other it interferes with the removal of the binder. In industry, vacuum or gases are used to create a reducing atmosphere.

It is therefore recommended to burn off the binder outside the carbon. The easiest way to do this is on a stove top. The pieces to be fired are laid on a a layer of carbon inside a round steel bowl, so they can easily be transferred to the kiln after the binder burns off. It is important that they don't catch fire or they may crack. When there is no more smoke and the pieces turn black, they are covered with another layer of carbon and carefully moved to a kiln for sintering.

The process may last between 10 to 40 minutes. No internal oxidation occurs during that period, and the thin outer layer of oxide can be easily removed after sintering.

If you choose to burn the binder inside carbon, it is important to burn it *before* the carbon catches fire.

From my experience, the binder burns at around 1000°F/538°C in a brick kiln or 1100°F/593°C in a muffle kiln. (I refer to the most popular kilns, that are about 8"x 8"x 6".) At this temperature the carbon does not burn yet. Some brands of clay have more binder in them than others and may need to stay at this temperature longer in order for the binder to burn off completely.

No matter which brand of clay you use, it is always a good idea to hold at this temperature about 2:00 hours before going on to the goal temperature. Then the firing should be **s**topped. Let the pieces cool down to room temperature, then ramp to the sintering temperature.

To make sure the carbon is not on fire in the first phase, open the kiln at the end of the cycle. If the carbon is on fire, lower the temperature next time.

See the section about firing high- and low-firing clays together in one piece in my presentation *Introduction to Mixed Metal Clay,* which can be downloaded from the right-hand pane of my blog at hadarjacobson.com/blog .

# Firing Schedules – Quick Reference Table

## Mid-Fire Schedule

Traditional (Flex) and Quick-fire Bronze; Combinations of Quick-fire copper, bronze, and small amount of steels

**Pre-fire on stove top**, or,

Ramp at 1800°F/1000°C to:

1000°F/538°C (brick)
1100°F/593°C (muffle)

Hold 2:00 hours.

Cool down to room temperature.

Ramp at 1800°F/1000°C to:

1470°F/800°C (brick)
1520°F/827°C (muffle)

Hold for 2:00 hours.

The second phase of this schedule applies to silver clay as well.

## High-Fire Schedule

Copper, Rose Bronze, Steels, and Bronze XT

**Pre-fire on stove top**, or,

Ramp at 1800°F/1000°C to:

1000°F/538°C (brick)
1100°F/593°C (muffle)

Hold 2:00 hours.

Cool down to room temperature.

Ramp at 1800°F/1000°C to:

1700°F/926°C (brick)
1780°F/971°C muffle)

Hold for 2:00 hours.

## Low-Fire Schedule

White Bronze on its own, and combined with other clays

**Pre-firing on stove top not recommended**

Ramp at 1800°F/1000°C to:

1000°F/538°C (brick)
1100°F/593°C (muffle)

Hold 2:00 hours.

Cool down to room temperature (optional).

This schedule applies to combination of Quick-fire copper and silver clay.

Ramp at 1800°F/1000°C to:

1250°F/676°C (brick)
1325°F/718°C (muffle)

Hold for 2:00 hours.