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Instruction Manual for Hadar's Clay™

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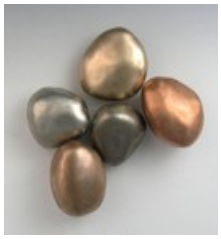

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Instruction Manual for Hadar's Clay™

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 an airtight plastic box. It has been shown to last at least a few months when properly stored. If you don't intend to use the clay for a long period of time, it's best to freeze it.

The color of the powders may vary or change over time. However, this has no impact on the color of the fired metal.

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 Instructions."

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. When the crumbs have consolidated into one mass, oil your palms and knead the clay a little. Rolling the clay as shown in the video is optional but not necessary.

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 affect its consistency.

Drying

Dry pieces in the air or directly on a heating pan at 220-250°F (95-120°C). Flat pieces of Traditional (Flex) clay powder and all types of steel tend to warp while drying, even when dried in the air. Once they start warping, keep flipping them over until they stay flat. This takes only a couple of minutes (watch the video entitled "How to Dry Hadar's Clay™ Steel" online at www.youtube.com/artinsilver). Quick-fire copper, bronze, Brilliant Bronze, Rose Bronze, and White Bronze don't usually warp as much while drying, but flipping them is recommended.

If warping does occur with thin pieces, cool them in the refrigerator. They will become somewhat flexible. Gently flatten them down. You can also spray them with water and once they are soft, flatten them; then wrap them with a paper towel and 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 breaking the piece into small chunks, grinding them 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 3M™ sponge sanding pad. (Do not use medium grit!) Cooling the dried clay in the refrigerator for 5 minutes will make it more flexible.

Shrinkage

The shrinkage of each clay depends on the firing schedule. At low-fire schedule, White Bronze shrinks by 10%. At mid-fire schedule, copper and Rose Bronze shrink by 10%, bronze and Bronze *XT* shrink by 15%, and Brilliant Bronze shrinks by 23.5%. At high-fire schedule, copper, Rose Bronze, Bronze *XT* and Low Shrinkage Steel *XT* shrink by 28%. See the document entitled "Shrinkage Chart for Hadar's Clay™," linked on the right-hand pane of my blog.

Please note: shrinkage rates cited here are based on tests conducted on flat pieces of a certain size and thickness. The shrinkage of actual pieces depends on their thickness, size, and whether they are 3D or hollow.

Firing with Core Material

It is possible to fire with core material – including cork clay and paper clay. When firing the first phase (pre-firing), it is important to make sure that the core material has burnt off.

Some core materials, such as pasta, cardboard, and certain types of paper clay, will not burn off inside carbon.

Flexible (Traditional/Flex) Clay

Traditional/Flex clays have a specialized application and are not recommended for beginners. Mixing them with glycerin makes clay that stays 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."

Shrinkage: Flex copper, bronze, Brilliant Bronze and Rose Bronze – 25% at mid-fire schedule. Pearl Grey Steel *XT* – 28% at high-fire schedule.
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 indefinitely. Unlike silver clay, base metal clays **cannot** be repaired with a torch.

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, Smart Bronze, Brilliant 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). To help prevent this, base metal clays should be fired buried in activated carbon, which reduces the amount of oxygen in the kiln and inhibits this reaction.

For an extended discussion of the firing process see my article **Understanding Metal Clay and the Firing Process** on p. 30.

The Carbon

Use coconut shell-based carbon, acid-washed, size 12x40.

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 is best contained in a round stainless steel mixing bowl, a pet dish, or a silica crucible. Round vessels circulate the heat better than square ones.

Stainless Steel Mixing Bowl, Pet Dish, and Silica Crucible

The advantage of the mixing bowl and pet dish is that the circular shape allows for better distribution of heat. However, they oxidize and flake and cover the kiln floor with black dust (often mistaken for carbon). You can line the floor of the kiln with a lava cloth (available from glass fusing suppliers) and vacuum the kiln after firing. Silica crucibles are resistant, do not suffer from thermal shock like ceramics, and do not flake.

The Firing Set-up

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

2. Arrange your pieces on the carbon horizontally, in one layer only. (Hollow forms are better fired on their narrow side to avoid slumping).
3. Cover the pieces with at least 2" of carbon.
4. 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.
5. 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.

6. After firing, some of the carbon will have turned into ash. To discard the ash, blow it away with a straw. Pour the contents 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.

Classification of the Clays According to Their "Native" Firing Schedules

Each clay has a "native" firing schedule with which it is most typically used when fired alone. However, it may need to be fired at a different schedule when fired in combination with other metals. This is explained below in further detail.

- White Bronze – low-fire schedule (1-phase firing)
- Smart Bronze – between low- and mid-fire schedule (1-phase firing)
- Bronze, Brilliant Bronze, Traditional/Flex bronze and Traditional/Flex Brilliant Bronze – mid-fire schedule (2-phase firing)
- Steels – high fire schedule (1-phase firing)

- Bronze *XT*, Rose Bronze, copper, Traditional/Flex Rose Bronze and Traditional/Flex copper – high-fire schedule (2-phase firing)

Firing Schedules for Single-metal Pieces

The following firing schedules apply to two popular types of kilns, both 8"x8"x6": Brick kiln (top and front loader), and front-loader muffle kiln. Use these schedules as a starting point for testing your kilns.

Note: The initial S in the schedule number stands for Single-metal.

S1. Low-fire Schedule

White Bronze – 1-phase firing

Brick kiln

Ramp at 1800°F/1000°C per hour to:
1275°F/690°C
Hold for 2:00 hours.

Muffle kiln

Ramp at 1400°F/778°C per hour to:
1325°F/718°C
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! (See **Test Firing**, p. 14.) Use low-fire schedule as your starting point.

S2. Smart Bronze Firing Schedule

Smart Bronze – 1-phase firing

Brick kiln

Ramp at 1800°F/1000°C per hour to:
1420°F/771°C
Hold for 2:00 hours.

Muffle kiln

Ramp at 1400°F/778°C per hour to:
1470°F/799°C
Hold for 2:00 hours

S3. Mid-Fire Schedule – 2-phase firing

Brilliant Bronze, Quick-fire Bronze,
Traditional/Flex Bronze,
Traditional/Flex Brilliant Bronze

Brick kiln

Phase 1

Ramp at 1800°F/1000°C per hour to:
1000°F/538°C
Hold for **1:00** hour.

Muffle kiln

Phase 1

Ramp at 1400°F/778°C per hour to:
1100/593°C
Hold for **1:00** hour.

Cool to 450°F/230°C or to room temperature.

Phase 2

Ramp at 1800°F/1000°C per hour to:
1460°F/793°C
Hold for **2:00** hours.

Phase 2

Ramp at 1400°F/778°C per hour to:
1510°F/821°C
Hold for **2:00** hours.

See **Options for Shortening the Firing Time**, p. 17-18.

S4. High-fire Schedule – 1-phase firing

Low-shrinkage Steel *XT* and Pearl Grey Steel *XT*

Brick kiln

Ramp at 1800°F/1000°C per hour to:
1750°F/955°C
Hold for 2:00 hours.

Muffle kiln

Ramp at 1400°F/778°C per hour to:
1830°F/999°C
Hold for 2:00 hours.

S5. High-fire Schedule – 2-phase firing

Bronze *XT*, Copper, Rose Bronze,
Traditional/Flex Rose Bronze, Traditional/Flex Copper

Brick kiln

Phase 1

Ramp at 1800°F/1000°C per hour to:
1000°F/538°C
Hold for **1:00** hour.

Muffle kiln

Phase 1

Ramp at 1400°F/778°C per hour to:
1100/593°C
Hold for **1:00** hour.

Cool to 450°F/230°C or to room temperature.

Phase 2

Ramp at 1800°F/1000°C per hour to:
1700°F/927°C
Hold for **2:00** hours.

Phase 2

Ramp at 1400°F/778°C per hour to:
1780°F/971°C
Hold for **2:00** hours.

Copper and Rose Bronze (including Traditional/Flex) can be also fired at schedule S3 (mid-fire schedule, 2-phase firing). However, they will not be as strong, and will not reach their maximal shrinkage.

For best strength, copper (including Traditional/Flex) can be also fired at schedule S4 – 1750°F/955°C (brick) or 1830°F/999°C (muffle) – *but with 2-phase firing*.

See **Options for Shortening the Firing Time**, p. 17-18.

Firing Schedules for Mixed-metal Pieces

When firing a mixed metal piece, the firing temperature is determined by the lowest firing clay in the mix.

Note: The initial M in the schedule number stands for Mixed-metal. The mixed-metal schedule numbers correspond to their single-metal counterparts.

M1. Low-fire Schedule – 2-phase Firing

Any mixed metal piece that contains White Bronze

Brick kiln

Phase 1

Ramp at 1800°F/1000°C speed to:
1000°F/538°C
Hold for **1:00** hour.

Muffle kiln

Phase 1

Ramp at 1400°F/778°C to:
1100/593°C
Hold for **1:00** hour.

Cool to 450°F/230°C or to room temperature.

Phase 2

Ramp at 1800°F/1000°C speed to:
1275°F/691°C
Hold for **2:00** hours.

Phase 2

Ramp at 1400°F/778°C to:
1325°F/718°C
Hold for **2:00** hours.

Note: There is no M2 schedule, because Smart Bronze is not meant to be mixed with other metals.

M3. Mid-fire Schedule – 2-phase Firing

Any mixed metal piece that contains bronze and/or Brilliant Bronze, as well as copper and/or small amounts of steel (but no White Bronze)

Brick kiln

Phase 1

Ramp at 1800°F/1000°C per hour to:
1000°F/538°C
Hold for **1:00** hour.

Muffle kiln

Phase 1

Ramp at 1400°F/778°C per hour to:
1100/593°C
Hold for **1:00** hour.

Cool to 450°F/230°C or to room temperature.

Phase 2

Ramp at 1800°F/1000°C per hour to:
1460°F/793°C
Hold for **2:00** hours.

Phase 2

Ramp at 1400°F/778°C per hour to:
1510°F/821°C
Hold for **2:00** hours.

See **Options for Shortening the Firing Time**, p. 17-18.

M4. High-fire Schedule – 2-phase Firing

Any mixed metal piece that contains copper and Low-shrinkage Steel *XT*

Brick kiln

Phase 1

Ramp at 1800°F/1000°C per hour to:
1000°F/538°C
Hold for **1:00** hour.

Muffle kiln

Phase 1

Ramp at 1400°F/778°C per hour to:
1100/593°C
Hold for **1:00** hour.

Cool to 450°F/230°C or to room temperature.

Phase 2

Ramp at 1800°F/1000°C per hour to:
1750°F/955°C
Hold for **2:00** hours.

Phase 2

Ramp at 1400°F/778°C per hour to:
1830°F/999°C
Hold for **2:00** hours.

M5. High-fire Schedule – 2-phase Firing

Any mixed metal piece that contains Bronze *XT* as well as copper, Rose Bronze and/or steels (but not Quick-fire bronze, Brilliant Bronze or White Bronze)

Brick kiln

Phase 1

Ramp at 1800°F/1000°C per hour to:
1000°F/538°C
Hold for **1:00** hour.

Muffle kiln

Phase 1

Ramp at 1400°F/778°C per hour to:
1100/593°C
Hold for **1:00** hour.

Cool to 450°F/230°C or to room temperature.

Phase 2

Ramp at 1800°F/1000°C per hour to:
1700°F/927°C
Hold for **2:00** hours.

Phase 2

Ramp at 1400°F/778°C per hour to:
1780°F/971°C
Hold for **2:00** hours.

See **Options for Shortening the Firing Time**, p. 17-18.

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.

Testing the kiln for low-fire schedule (S1)

Fire a few test pieces of White Bronze, 6-, 8-, and 10-cards thick. After firing, sand the pieces on both sides with 220-grit sandpaper.

If the surface becomes all metallic, with no powdery spots, the temperature is correct.

If you see powdery spots and the piece crumbles, the temperature is not high enough (pieces are under-fired). Make new test pieces and raise the temperature by 5ºF/3ºC. If this happens again, continue raising the temperature by 5ºF/3ºC at a time.

If the surface shows bubbles or blisters or melts altogether, the temperature is too high (pieces are over-fired). Make new test pieces and lower the temperature by 5ºF/3ºC. If this happens again, continue lowering the temperature by 5ºF/3ºC at a time.

Do not repeat the firing with the same pieces. If White Bronze has not sintered at the first firing, it is not likely to sinter at the second. Always start with new pieces!

Testing the kiln for Smart Bronze (S2)

Fire a few test pieces of Smart Bronze using the 1-phase firing schedule. As with the low-fire schedule (directly above), check for powder or bubbles on the surface. Change the temperature accordingly, until you reach the correct temperature.

Testing the kiln for mid-fire schedule (S3)

Fire a few pieces of Brilliant Bronze, 6 cards thick. If pieces are under-fired, raise the temperature by 10ºF/5ºC at a time. If pieces are over-fired, lower the temperature by 10ºF/5ºC at a time.

Testing the kiln for high-fire schedule (S4)

Fire a few pieces of copper and Low-shrinkage Steel *XT*, 6 cards thick. They are not likely to be under-fired. If they are over-fired, lower the temperature by 10°F/5°C at a time.

Testing the kiln for mid-fire schedule (S5)

Fire a few test pieces of Bronze *XT*, 6 cards thick. They are not likely to be under-fired. If they are over-fired, lower the temperature by 10°F/5°C at a time.

Testing the kiln for low-fire schedule (M1)

No need to test. Fire at the temperature you established for S1.

Testing the kiln for mid-fire schedule (M3)

Make a few pieces from both Quick-fire copper and bronze (regular or Brilliant, not Smart Bronze or Bronze *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 the copper layer.

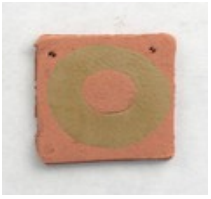
Make a few pieces with copper as the base and a few with bronze as the base.

Dry the pieces, and fire according to M3 firing schedule.

Here is how to check 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 10°F/5°C lower than before. 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.

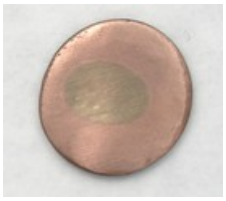


A Before

B Over-fired

C Flush

D Over-fired



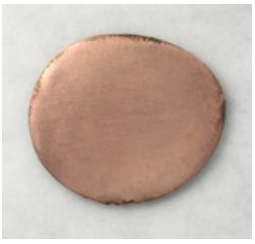
E Flush

F With patina

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 10°F/5°C higher than before.

G Under-fired



H Fully sintered

Note: When firing again at a higher temperature, it is important to use new test pieces. 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 the kiln for High-fire schedule (M4 and M5)

If you tested for S4 and S5, there is no need to test.

Options for Shortening the Firing Time
1. Pre-firing

The advantage of pre-firing this way is saving time. The disadvantage is a higher risk of pieces cracking during the pre-firing and getting damaged when handled and moved between firings. Pre-firing is not recommended for big pieces and hollow forms!

Firing time for 2-phase firing schedules can be shortened by performing phase 1 in a different manner (pre-firing). This has its advantages and disadvantages.

Phase 1 (pre-firing) can be done on a stove top or in the kiln. In both cases the pieces rest on a layer of carbon but not covered by it.

Stove-top Pre-firing (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 without covering them in carbon. Put the bowl on the stove.

If you pre-fire outdoors, cover the bowl to keep the heat in. You can use a fiber board, the SpeedFire Metal Clay PreFire Cone from www.metalclaysupply.com, or Fiber Firing Container from www.pmcconnection.com.

Poke a pencil-size hole in the fiber board and the fiber container. To do this you can use a screwdriver. Just twist it in; the fiber is very soft.

Turn the flame on to full capacity. 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 the smoke stops, remove the lid with a glove and peek inside. The pieces should look black. Using a spoon, carefully turn the pieces over.

Cover the pieces with carbon and put them in the kiln for the **second phase** of firing.

Kiln Pre-firing: Set the kiln to the desired firing schedule. When the kiln reaches 800°F/430°C in a brick kiln, or 1200°F/650°C in a muffle kiln, open the kiln to check on the pieces. If they are all black and the smoke is gone, turn them over with a spoon, cover them with carbon, and close the door. The kiln will continue its cycle.

Kiln pre-firing is easier and more successful in a brick kiln. In a muffle kiln, be sure to ramp at 1400°F/778°C per hour.

All clays can be pre-fired except for White Bronze. Smart Bronze and Low-shrinkage Steel* XT *do not require pre-firing but will not be damaged if pre-fired.

After pre-firing you can move on directly to phase 2. However, there is no need to hurry. The second phase can wait.

2. Firing Two Phases in One Uninterrupted Session

The advantage of firing this way not having to handle the kiln between phases. You can program your kiln to fire two phases without your intervention. This also saves a lot of time for teachers who fire in a 2-3 day workshops, since both phases can be fired overnight.

See instructions for programing the kiln for this firings schedule on p. 35.

Post-firing

See the document entitled "Finishing Fired Metal Clay" on the right-hand pane of my blog.

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). White Bronze 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 are stronger. White Bronze paste can be painted on fired pieces (except for steel), and re-fired at low-fire schedule (S1).

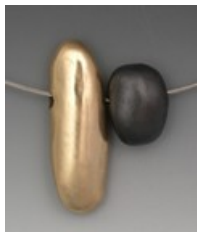
White Bronze does not tarnish as readily as silver. It does not react to Baldwin's Patina, which makes it possible to highlight the contrast between White Bronze, copper, and steels in mixed pieces.

Copper and Quick-fire Bronze/ Brilliant Bronze

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.

Brilliant Bronze and Smart Bronze can be polished to look like shiny gold. See the document entitled "Finishing Fired Metal Clay," linked on the right-hand pane of my blog.



Bronze *XT*

Bronze *XT* is darker than Quick-fire bronze. It is best used as a third color at high-fire schedule (M4) in combination with Low-shrinkage Steel *XT* and copper. Combining only copper and Bronze *XT* at high-fire schedule may result in alloying.

Rose Bronze

Rose bronze has a pinkish color, lighter than copper. It is best fired on its own at high-fire schedule (S5) or in combination with small amounts of steel at high-fire schedule (S5).

Steels

All types of steel clays have a pearl gray, silvery color after firing. Low-Shrinkage Steel *XT* shrinks about 28% and is best used as the main, structural part of a piece. It is malleable and can be hammered into shape after firing. Other steels, especially Pearl Grey Steel *XT* are best used in combination with other metals or as accents. Pearl Grey Steel *XT* is preferred for gradient surfaces. All steels clays are magnetic!

Coloring Steel

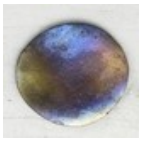
There are many ways to blue steel and a continuing debate as to which way is best. Suggested here are two processes for bluing. If performed prior to sealing, both contribute to the sealing quality.

Cold Bluing

Blue color can be achieved by applying a little bit of Birchwood Casey Super Blue™.

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 at mid-fire schedule. It will not darken them if they are fired at high-fire schedule.

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

To prevent steel from rusting, it is recommended to seal it with a water-resistant acrylic sealer such as PYM II.

The following compatibility 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 or Brilliant Bronze
   Mid-fire schedule – M3


2. Quick-fire copper and bronze or Brilliant Bronze
   Mid-fire schedule – M3

3. Quick-fire copper and steels
   High-fire schedule – M5
   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 – M3
   Although both clays can be fired at the high-fire schedule, a better contrast is achieved at a lower temperature.

5. Quick-fire Bronze or Brilliant Bronze and Steel
   Mid-fire schedule – M3

6. Quick-fire copper, bronze or Brilliant Bronze, and steels
   Mid-fire schedule – M3

7. Quick fire copper, steels, and Bronze *XT*
   High-fire schedule – M5

Baldwin's Patina will not blacken steel when fired with Bronze *XT* and copper at high-fire schedule.

8. Bronze *XT* and Quick-fire Steel *XT*
   High-fire schedule – M5

9. Bronze or Brilliant Bronze and White Bronze
   Low-fire schedule – M1

10. Copper and White Bronze
    Low-fire schedule – M1

11. Copper, bronze, or Brilliant bronze and White Bronze
    Low-fire schedule – M1


12. White Bronze and Pearl Grey Steel
    Low-fire Schedule – M1

13. Quick-fire copper, bronze, or Brilliant Bronze, White Bronze, and steels*
    Low-fire schedule – M1



14. Low-shrinkage Steel *XT*, Bronze *XT* and copper
    High-fire schedule – M4

15. Quick-fire Copper and low-shrinkage silver clay
    Low-fire Schedule – M1

* 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 – S4) 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 – S4) and add White Bronze in the second firing (Low-fire schedule – S1). 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 or Brilliant Bronze first (Mid-fire schedule – M3) and add White Bronze in the second firing (Low-fire schedule – S1). 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 – S4) and add silver (torch), or bronze (mid-fire schedule – M3), or White Bronze (low-fire schedule – S1) in the second firing.


5. Fire steel and copper first (high-fire schedule - S4), and add bronze or Brilliant Bronze (mid-fire schedule - M3), or White Bronze (low-fire schedule - M1) at second firing.

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

How to Talk to Your Kiln

Programming Your Kiln

With 2-phase firing schedule

(Demonstrated on mid-fire schedule)

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.

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:
"1460°F/793°C"
In a muffle kiln answer: "1510°F/821°C "

Press the left button again.

The kiln asks: "HLd1" (hold 1).
Translation: "How long should I *hold* (stay) at that temperature?"

Your answer: "1:00 hour". (To say this, press the up and down arrows until the display reads 1:00)

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 "
Translation: "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: "1460°F (793°C)."
In a muffle kiln answer "1510°F (821°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 (when not using the whole jar)?	Yes
❑	Did I use distilled/filtered water when mixing the clay?	Yes
❑	Did I use any lubricant other than olive oil?	No
❑	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 round stainless steel bowl?	Adjustment of the temp. may be required
❑	Did I use a square box?	No
❑	Did I fire 2 phases when required?	Yes
❑	Did the piece catch fire while pre-firing on top of carbon?	No
❑	Were the pieces black and the smoke gone at the end of the pre-firing on top of carbon?	Yes
❑	In 2-phase firing, did I cover the pieces with carbon for the first phase?	Yes
❑	In 2-phase firing, did I cover the pieces with carbon for the second phase?	Yes
❑	Did I cover the pieces with at least 2" of carbon?	Yes
❑	Did I use the right kind of carbon?	Yes
❑	Did I elevate the box to the high part of the kiln?	Yes
❑	Did I cover the bowl with a lid?	No
❑	Did I leave enough space around the box for heat flow?	Yes
❑	Did I overcrowd the box?	Lower the temperature° by 20°F/10°C and hold for 2:30 hours
❑	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 or Smart Bronze?	No
❑	Did I confuse bronze with Bronze *XT*?	No
❑	Did I use Pearl Grey Steel *XT* for gradients and mokume-gane?	Yes
❑	Did I use Low-Shrinkage Steel *XT* for structural purposes?	Yes
❑	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
❑	Did part of the pieces show through the carbon at the end of the firing?	No

Understanding Metal Clay and the Firing Process

When I started making my own clay, 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.

The example of ice cubes may be helpful. 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, the contact areas grow, but since the particles don't reach their melting point and turn into liquid, they cannot flow and entirely fill the spaces between them.

Back in 2008, I posted a link on my blog to a video clip about powder metallurgy. From my blog, enter **Powder Metallurgy** in the search box, click **Go**, and then click on the title of the article appearing in the Search Results column. About halfway through the clip, you can see a good illustration of densification.

Also see my blog entry entitled "The Sintering Bracelet Project," originally posted on April 28, 2010. (From my blog, enter **The Sintering Bracelet Project** in the search box, click **Go**, and then click on the title of the article appearing in the Search Results column.)

And: *Introduction to Mixed Metal Clay* (Presentation), accessible from the right-hand pane of my 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 when heated, 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. Bronzes 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.

The carbon reduces the amount of oxygen in the kiln but does not eliminate it. For some clays, such as White Bronze, Smart Bronze, and Low-Shrinkage Steel *XT,* the amount of oxygen present inside the carbon is enough to burn the binder, if enough time is allowed for it. For the rest of the clay varieties, no amount of time is enough; firing longer hours or slowing the ramp does not help burn off the binder. For these clays, sintering can be achieved in one of two ways: firing twice, or burning the binder outside the carbon.

Firing twice: fire once for one hour, and a second time for 2 hours, cooling to room temperature between firings. In both firings the pieces are fully covered with carbon.

Burning the binder outside carbon: this can be done on a stove top or inside the kiln. The pieces are laid on top of a layer of carbon inside a round steel bowl, so they can easily be transferred to the kiln after the binder burns off. They are not covered with carbon. It is important that they not 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 and 40 minutes. No internal oxidation occurs during that period, and the thin outer layer of oxide can be easily removed after sintering.

Firing Schedules for Brick Kilns - Single Metals

Clay	Firing schedule	Phases	Ramp	1st phase (1hr)	2nd phase (2 hrs)
White Bronze	S1, p. 9	1	1800°F/1000°C		1275°F/690°C
Smart Bronze	S2, p. 9	1	1800°F/1000°C		1420°F/771°C
Brilliant Bronze Quick-fire bronze	S3, p. 19	2	1800°F/1000°C	1000°F/538°C	1460°F/793°C
Low-Shrinkage Steel *XT*	S4, p. 10	1	1800°F/1000°C		1750°**F**/955°C
Bronze XT, Rose Bronze XT, copper	S5, p. 11	2	1800°F/1000°C	1000°F/538°C	1700°F/927°C

Firing Schedules for Brick Kilns - Mixed Metals

Clay	Firing schedule	Phases	Ramp	1st phase (1hr)	2nd phase (2 hrs)
White Bronze with other metals	M1, p. 12	2	1800°F/1000°C	1000°F/538°C	1275°F/690°C
Smart Bronze	N/A	N/A	N/A	N/A	N/A
Brilliant Bronze/ Quick-fire bronze with copper and steel in small amounts	M3, p. 12	2	1800°F/1000°C	1000°F/538°C	1460°F/793°C
Low-Shrinkage Steel *XT* and copper	M4, p. 13	2	1800°F/1000°C	1000°F/538°C	1750°**F**/955°C
Bronze XT, copper and steels	M5, p. 13	2	1800°F/1000°C	1000°F/538°C	1700°F/927°C

Firing Schedules for Muffle Kilns - Single Metals

Clay	Firing schedule	Phases	Ramp	1st phase (1 hr)	2nd phase (2 hrs)
White Bronze	S1, p. 9	1	1400°F/778°C		1325°F/718°C
Smart Bronze	S2, p. 9	1	1400°F/778°C		1470°F/799°C
Brilliant Bronze Quick-fire bronze	S3, p. 10	2	1400°F/778°C	1000°F/538°C	1510°F/821°C
Low-Shrinkage Steel *XT*	S4, p. 10	1	1400°F/778°C		1830°F/999°C
Bronze XT, Rose Bronze XT, copper	S5, p. 11	2	1400°F/778°C	1000°F/538°C	1780°F/971°C

Firing Schedules for Muffle Kilns - Mixed Metals

Clay	Firing schedule	Phases	Ramp	1st phase (1 hr)	2nd phase (2 hrs)
White Bronze and other metals	M1, p. 12	2	1400°F/778°C	1000°F/538°C	1325°F/718°C
Smart Bronze	N/A	N/A	N/A	N/A	N/A
Brilliant Bronze/Quick-fire bronze with copper and steel in small amounts	M3, p. 12	2	1400°F/778°C	1000°F/538°C	1510°F/821°C
Low-Shrinkage Steel *XT* and copper	M4, p. 13	2	1400°F/778°C	1000°F/538°C	1830°F/999°C
Bronze XT, Rose Bronze, copper	M5, p. 13	2	1400°F/778°C	1000°F/538°C	1780°F/971°C

Firing Two Phases in One Uninterrupted Schedule

Short Version

Ramp at 1800°F/1000°C (brick); 1400°F/778°C (muffle) to 1000°F/538°C (brick); 1100°F/593°C (muffle)

Hold 1:00 hour

Ramp at 1800°F/1000°C to 450°F/232°C (both types of kilns)

Hold 0:00 hours

Ramp at 1800°F/1000°C to 1460°F/793°C (brick); 1510°F/821°C (muffle)

Hold 2:00 hours

Programing Instructions
Demonstrated on mid-fire schedule

Muffle kilns and Brick Kilns with Sentry Xpress Controller

Display	What to Do
dELA/0:00	Press the left button. The controller will display:
PrO	Choose a program that is not pre-set. In many muffle kilns it is Program 6 or USER. With the up button choose 6. The controller will display:
PrO6	Press the left button. The controller will display:
rA1	With the arrow buttons choose either Full (for brick kilns) or 1400 (for muffle kilns). The controller will display:
rA1/FULL	Press the left button. The controller will display:
°F1	With the arrow buttons choose 1000 (for brick kilns); 1100 (for muffle kilns). The controller will display:
°F1/1000	Press the left button. The controller will display:
HLD1	With the arrow buttons choose 1:00. The controller will display:

HLD1/1:00	Press the left button. The controller will display:
rA2	Choose Full. The controller will display:
rA2/Full	Press the left button. The controller will display:
°F2	With the arrow button choose 450. The controller will display:
°F2/450	Press the left button. The controller will display:
HLD2	With the arrow buttons choose 0:00. The controller will display:
HLD2/0:00	Press the left button. The controller will display:
rA3	Choose full or 1400, depending on the kiln. The controller will display:
rA3/FULL	Press the left button. The controller will display:
°F3	With the arrow buttons choose 1460 (brick kiln) or 1510 (muffle kiln). The controller says:
°F3/1460	Press the left button. The controller will display:
HLD3	Choose 2 hours. The controller will display:
HLD3/2:00	Press the left button. The controller will display:
rA4	Choose 0:00. The controller will display:
ON	The kiln will start its cycle.

Bartlett Controller

Display	What to Do
dELA/0.00	Press the left button. The controller will display:
USr	Choose a program that is not pre-set. With the up button choose a number, for example: 1. The controller will display:
USr1	Press the left button. The controller will display:
SEG	With the arrow buttons choose 3. The controller will display:
SEG3	Press the left button. The controller will display:
rA1	With the arrow buttons choose 1800.
rA1/1800	Press the left button. The controller will display:
°F1	With the arrow buttons choose 1000 (brick kiln); 1100 (muffle kiln). The controller will display:
°F1/1000	Press the left button. The controller will display:

HLD1	With the arrow buttons choose 1:00. The controller will display:
HLD1/1:00	Press the left button. The controller will display:
rA2	Choose Full. The controller will display:
rA2/Full	Press the left button. The controller will display:
°F2	With the arrow button choose 450. The controller will display:
°F2/450	Press the left button. The controller will display:
HLD2	With the arrow buttons choose 0:00. The controller will display:
HLD2/0:00	Press the left button. The controller will display:
rA3	Choose full or 1400, depending on the kiln. The controller will display:
rA3/FULL	Press the left button. The controller will display:
°F3	With the arrow buttons choose 1460 (brick kilns) or 1510 (muffle kilns). The controller s display:
°F3/1460	Press the left button. The controller will display:
HLD3	Choose 2 hours. The controller will display:
HLD3/2:00	Keep pressing the left button until it displays:
END	Press the left button again. The kiln will start its cycle.