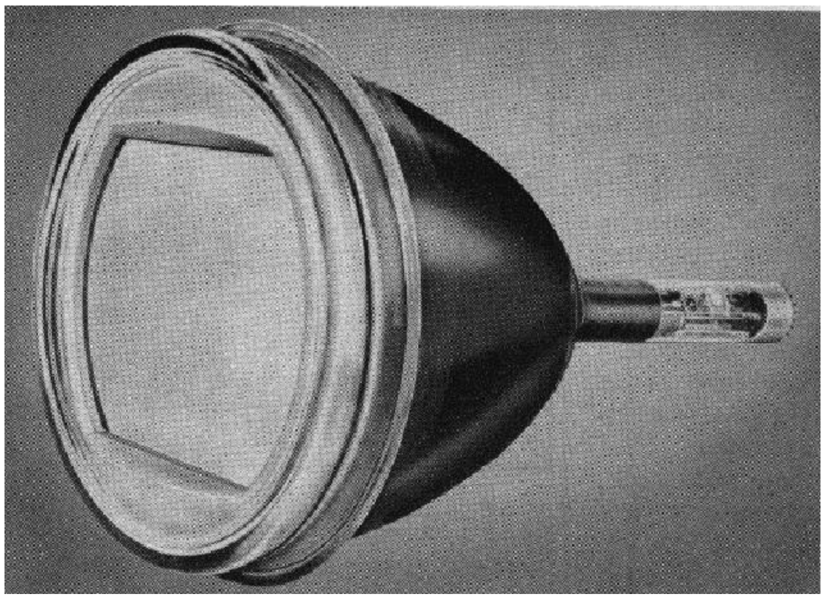
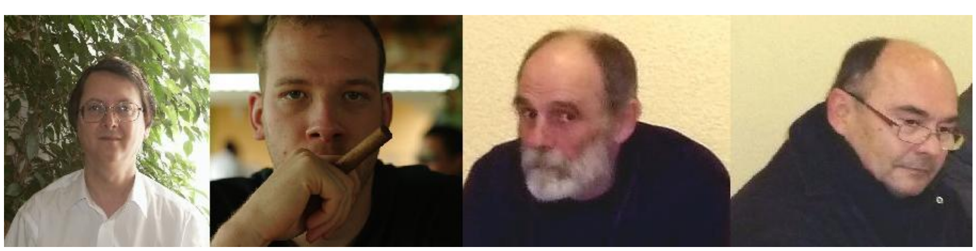
Picture Tube Rebuilding



A detailed report of information learned on-site at the RACS facility in France from 18-22 and 25-29 July 2012, courtesy of Jerome Halphen, Nick Williams, Philippe & François Raedersdorff.



Forward

First allow me to express my sincere thanks to Jerome Halphen. Without his kindness and willingness to put his own personal treasure on the line to continue the vintage CRT rebuilding effort, much of this information would be lost forever. It is his leadership which brings 30 years of CRT rebuilding experience from the Raedersdorff brothers to you, everyone involved in the repair and restoration of vintage television sets owe him a debt of gratitude.

Next, let me say that I have no idea where the idea to have me learn CRT rebuilding came from. Perhaps it grew out of the fact that at 30 I am one of the younger collectors out there, and the unfortunate fact is that I simply will be around longer than most other collectors. Or maybe this was all Jerome's idea, and he took it upon himself to ensure that this invaluable information is still around for the future. However it came about, I am being entrusted with knowledge that can be used to keep our sets glowing far into the current millennium and I take it very seriously. You can rest assured that no matter what happens, either I or someone I personally train will be able to renew your picture tubes at some point in the near future.

A lot about what will happen in the coming years hinges on a multitude of factors, but there are a few specific requisites that must be fulfilled if this is going to happen. Things like what will become of the equipment at the ETF Museum in Hilliard and the RACS gear when they eventually close their doors, where I will be in my life after 8 years' time and I'm retired from active duty, the availability of spare parts, and the continued willingness of the collecting community to come together as a team to make it all come to fruition. A few people cannot make this happen on our own; we need the involvement of everyone if we earnestly believe that this is possible, and I believe that it is.

It seems to me that the hobby stands to gain quite a bit by having the capability to rebuild CRT's available, so the future looks as bright as ever. 8 years seems like a lot of time to wait, but the reality is that it will fly by. Before you know it I'll be sitting in front of a vertical lathe, rebuilding your tubes. So stay tuned in, and don't let the fear of a dim future get you down. There are many people actively working to see this through to the end, and we all have a vested interest in getting an operation set up.

Nick Williams

Neck Glass Cutting

These are the steps required in order to remove the old electron gun, or to trim excess amounts of glass from the neck of the tube.

First you must make sure the entire outside of the bulb is clean and free from debris, which will avoid contamination of the tube at later steps in the process. This includes removal of any old dag coating and/or dust or filth that may tend to foul the welding process or the evacuation oven, since debris constitutes a glass fracturing risk. Hand must also be clean when welding, since finger oils may lead to incomplete or failed welds if the oil gets between the glass.

Take your clean bulb and score the neck with a file or sharp pointed object about a ½" from the base. You want to create a scratch about a ¼" long perpendicular to the axis of the tube, which forms the line around which a crack will propagate upon application of heat from the hot wire tool.

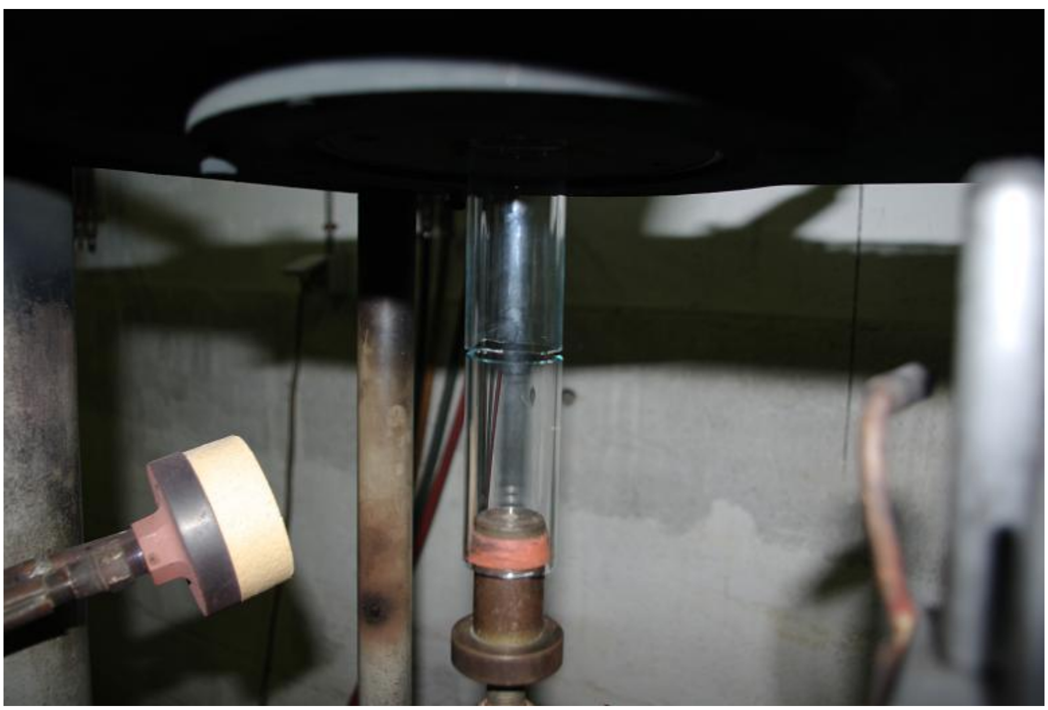
Wipe excess glass away from the scratch with a moistened fingertip.

Next position the hot wire around the neck in line with the score in the glass, being mindful that the tips of the tool are to be on either side of the scored line. Turn on the tool, and allow it to heat up. You will hear the glass fracture after about 10-15 seconds, at which point you should remove power from the tool and allow it to cool. The neck should now be fractured all the way around, and you can remove the tool from the neck.

Visually inspect that the fracture has gone all the way around the neck. You should now be able to carefully grasp the base, and twist it slightly so that air begins to enter the tube. Don't go too fast, or the phosphor may get blown off the screen or the tube may implode. After the tube is up to atmospheric pressure, the gun may be withdrawn from the neck. All old getter material must be removed from the neck by cleaning with distilled water at this point, or it will contaminate the tube after it is rebuilt and possibly cause arcing of the gun from its conductive properties. Clean new cuts with isopropyl alcohol, to remove finger oils.

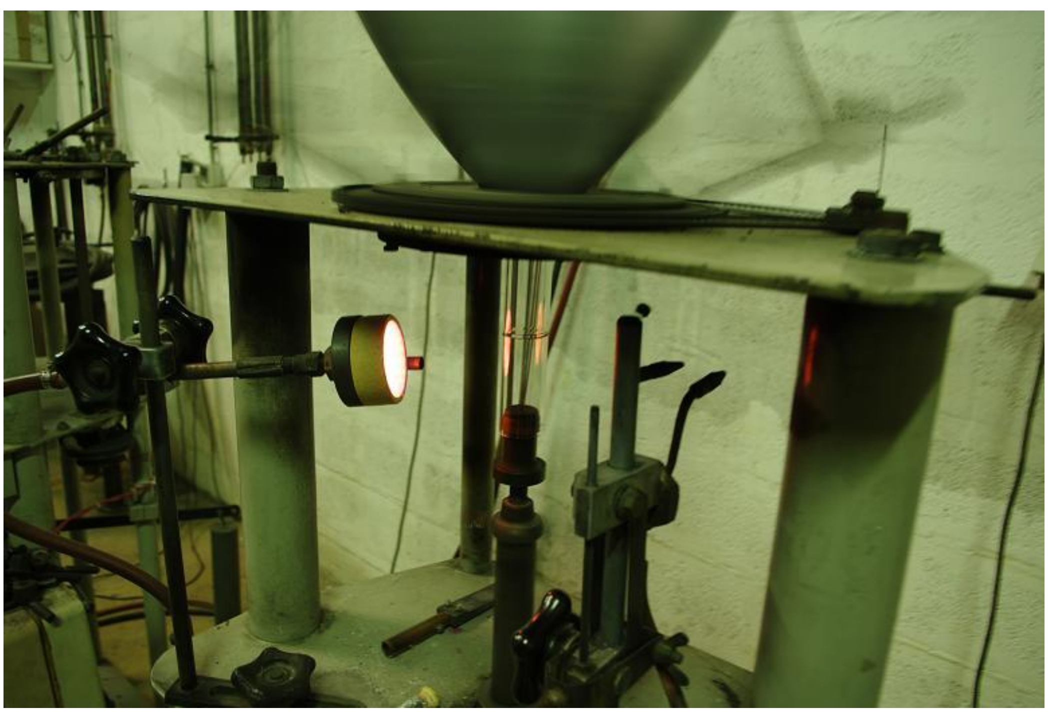
Neck Glass Welding

Neck welding is accomplished on a vertical lathe, employing both a natural gas or propane fueled infrared burner, and two or more hydrogen/oxygen torches. The natural gas fueled burner serves to warm up the glass prior to application of the higher temperature hydrogen flame, and to slowly cool the glass once a bond is achieved so it does not fracture. Mount the bulb in the lathe, making sure that it is perfectly aligned with the axis of the chuck at the bottom. Then mount a section of neck glass is the bottom chuck, and align it perfectly to the glass from the bulb at the top. Take care to ensure that any irregularities in either glass part are aligned with each other- in other words, high spots in the new glass section should align with any low spots in the neck of the bulb. This will help make sure that the gap between the two pieces is as uniform as possible as the parts rotate, and facilitate the joining of the two pieces upon application of heat. The gap should be about 1/16" to 1/8".



Turn on the natural gas burner, keeping it at distance from the glass for the time being.

Adjust both gas and shop air supply for a ¾" protrusion of the flame from the front face of the burner, and allow it to warm up. Once the burner has achieved a nice red appearance on the inside ceramic insulator, the burner is ready.



Start the rotating motor on the lathe, and progressively (over a period of about 3 minutes) move the burner into position near the glass. The front part of the burner should end up approximately 3” from the surface of the glass, and under no circumstance should the flame be allowed to touch the glass at this point or it may fracture. The goal is to have the infrared heat from the burner heating the glass, not the flame directly. After the glass has warmed for a period of approximately 2-3 minutes, it is ready for application of the hydrogen flame.

CAUTION!

Working with oxygen is dangerous! Flash points and auto-ignition points of many materials are greatly lowered in oxygen enriched atmospheres, make double sure that all connections are tight and free from leaks. Additionally, NEVER allow the hydrogen source to be turned off before the oxygen source. The result will be a supersonic backfire that may travel back to the regulator or tank, causing an impressive and very destructive explosion.

Light the hydrogen torch by holding a flame in front of it (or simply facing it towards the existing natural gas flame from the other burner), and slowly opening the hydrogen valve. Once on, add oxygen until a 4” blue flame emanates from the torch. Simultaneously remove the natural gas burner and move the hydrogen flame into position, so that both sections of glass receive heat right at their edge.

You want the flames to hit both sections of glass equally, so they heat up at the same rate. If the flame heats one section more than the other, the result will be a bad joint because one piece was cooler than the other. After a few seconds the glass will be at the correct temperature, and the lower chuck should be slowly raised so the 2 pieces meet plus an additional 1mm or so to allow the glass to 'mix'.

Pull back the glass on the bottom chuck a slight amount while blowing air into the tube so the glass creates a slight bulge on the outside, then use a preheated graphite paddle to smooth the joint. Take care not to apply too much pressure with the paddle, as 'scarring' of the glass will result.

Remove the hydrogen flame, and apply the natural gas burner again. After about 30 seconds, anneal the joint with a medium flame from the natural gas burner. This may be accomplished by reducing the amount of shop air supplied to the burner, or by increasing the supply of natural gas. Anneal the area of the joint for approximately 30 seconds, then bring the burner back to infrared heat.

Reduce heat applied to the glass by progressively pulling the burner away over a period of 3 minutes. After that, the flame may be extinguished. The glass will still be quite hot at this point, and subject to thermal shock if it comes into contact with overly cool air or liquids. Therefore the tube should be placed in an environment with as little moving air as possible, and allowed to cool to room temperature on its own.

Phosphor Screening, Dag Coating and Aluminization

The phosphor screening process is the most involved portion of tube rebuilding, most of the other procedures being automated by machine. Screening is a bit of chemistry, a bit of manual dexterity, and a bit of luck. As always, cleanliness is what you seek when you begin. The overview of steps is as follows:

1. Removal of any inside contaminates via hydrofluoric acid
2. Bulb washing, with demineralized water
3. Phosphor deposition, removal of liquids
4. Silicate 'cutting' via water jet to clean bulb
5. Drying
6. Phosphor wetting
7. Lacquer coating
8. Lacquer 'cutting' via water jet
9. Drying
10. Graphite neck coating
11. Drying
12. Aluminization
13. Baking, to remove lacquer
14. Short time on drying machine, to remove residual lacquer vapors
15. Tube is ready for gun

First the inside of the glass bulb must be cleaned with hydrofluoric acid, then purged with demineralized water.

The chemical screening recipe for each tube depends on the size of the bulb and type of phosphor, different mixtures are calculated from the master list for odd sizes. In general the mixture in the tube will contain silicate, phosphor, barium oxide and demineralized water.

The bulb is filled with the predetermined amount of demineralized water, then the mixture of barium and water is poured in through a fine mesh sieve and funnel. Next the phosphor/silicate is introduced through a fine mesh sieve and funnel (having radial dispersing holes in the tip) into the tube and left to settle on the face for a period of not less than 30 minutes.

A plastic tube is inserted touching what will be the top of the bulb above the water level, and plastic tape placed onto the neck so that the liquid will not run down the bulb but into the collection trough. The plastic tube lets air into the bulb so that bubbles do not occur as the bulb is slowly tilted, in order for the liquid portion of the mixture to drain off.

After all the fluid has left the tube, the excess silicate must be 'cut' away from the lower portion of the bulb with a water jet.

Then it is placed on a heated air drying rack, so the coating can solidify and attach itself properly to the tube face.

Once all the moisture has been purged, the glass will be quite warm. Allow it to return to room temperature for the next step, lacquer coating.

Oddly, the inside of the tube is first wetted with a low speed water jet. This may seem counter intuitive, but the water forms a barrier between the phosphor and lacquer coating. The water is only at 2 meters of pressure, stored in overhead bins.

Next lacquer is sprayed for 1 second at low pressure at the tube face, rotating at 90 RPM, running down towards the neck. The tube continues to rotate after spraying for a couple of minutes, to ensure an even coating.

The lacquer is ‘cut’ with a water jet for several minutes at a predetermined point below the phosphor coating, which removes excess lacquer so the aluminum can bond properly with the glass during aluminization.

The tube is again sent to the drying rack to remove moisture- there is now a thin coating of lacquer and phosphor, separated by the space formerly occupied by the removed water.

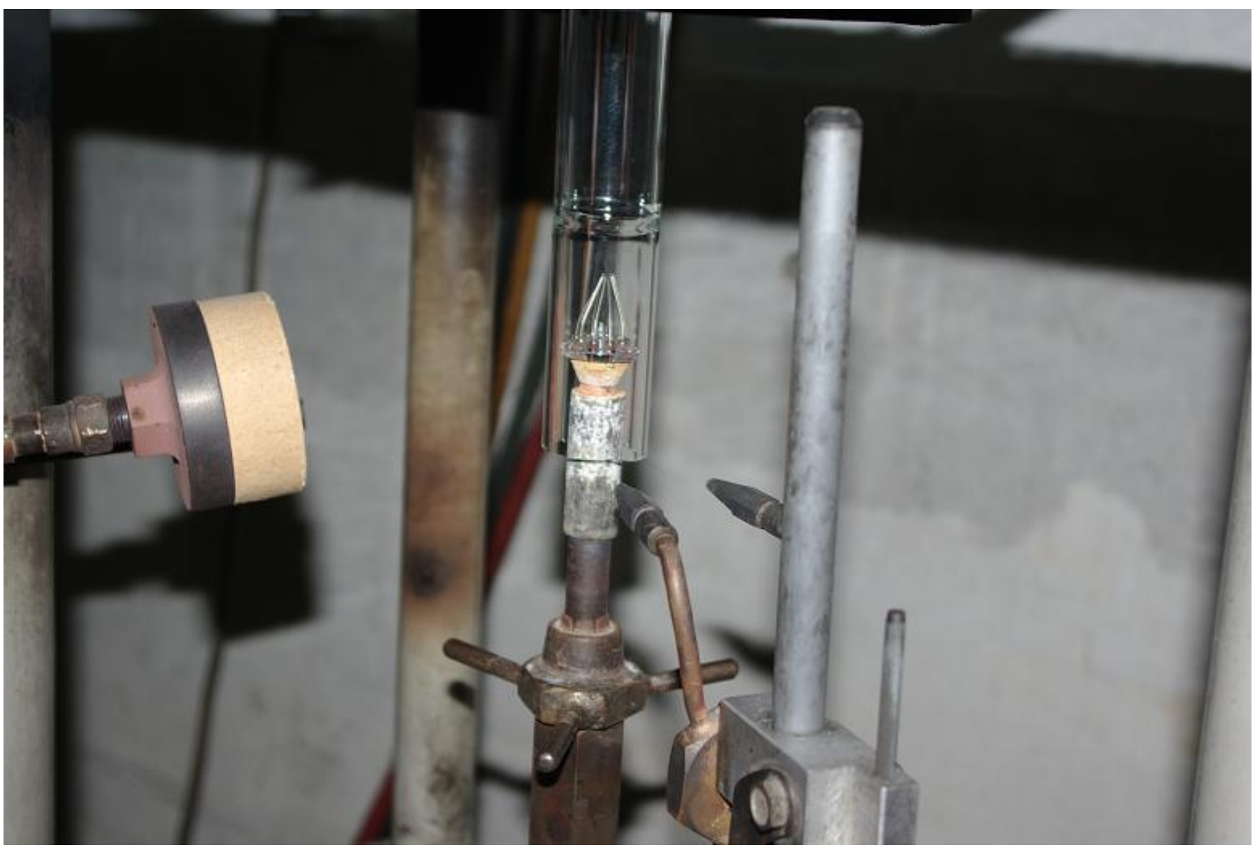
The next step is to apply a coating of dag on the inside of the tube. This dag coating, which is colloidal graphite or iron oxide, forms a conductive path that will take high voltage from the anode button and carry it to the electron gun. The tube is placed in a rotating fixture, which holds the tube at a downward angle. A small brush is dipped in dag and inserted into the neck of the tube while it rotates, coating the inside. Make sure the dag is liberally applied around the anode button before coating the rest of the inside, if it doesn't make contact it will arc internally and the tube will be useless. After dag coating dry the tube on the drying rack, then it's time to aluminize.

Aluminization is more or less an automated process; you simply make sure you have the machine loaded correctly, pull a vacuum on the tube and vaporize the pellet. You must make sure to use the appropriate size of pellet for the tube you are coating, too much and you must start over from the beginning. Only 99% pure aluminum will do, anything else will only cause contamination. Heating elements may only be used a few times, as the remaining aluminum deposits can short out turns on the element which will cause it not to function correctly.

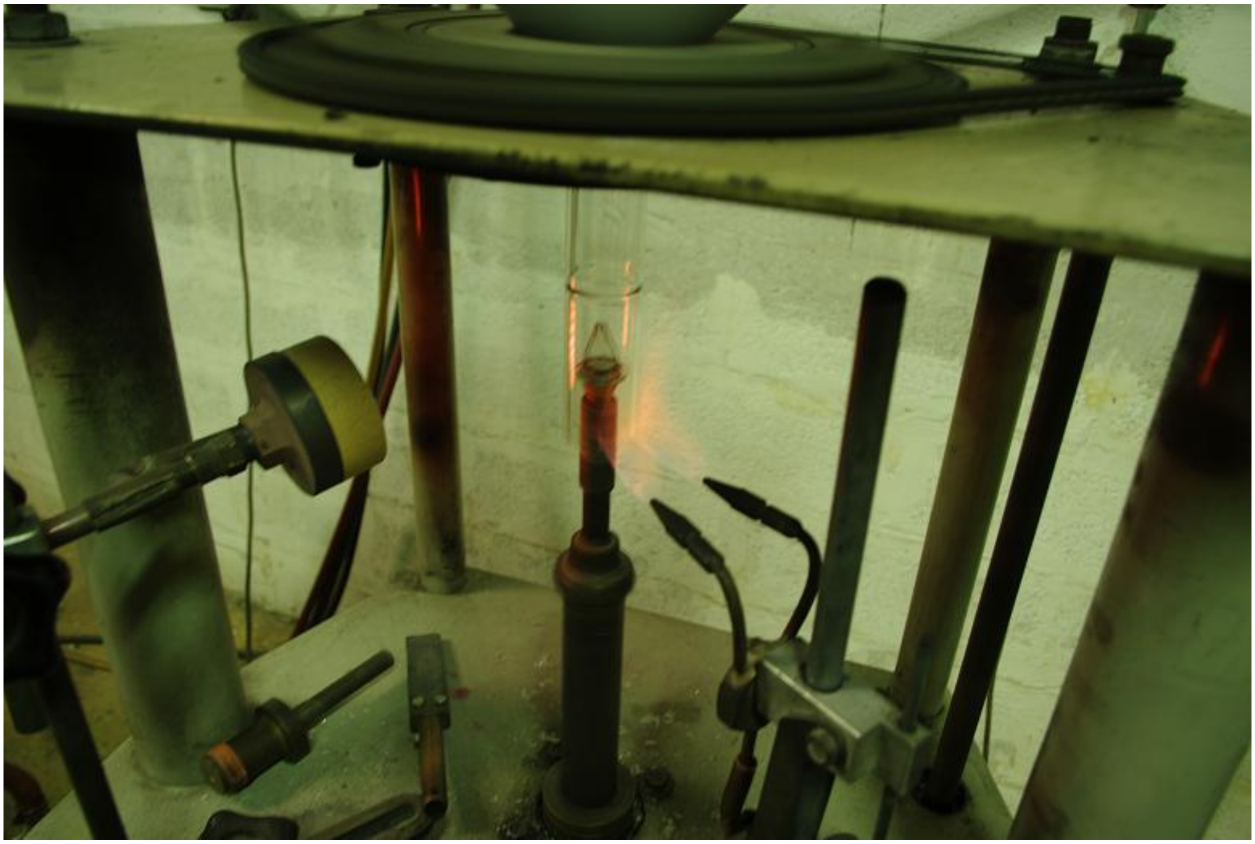

After the coating has been applied, the tube goes into the oven at 410*C to bake out the remaining lacquer. There is now a thin coating of phosphor and aluminum on the bulb face, separated by the space formerly taken up by the lacquer. A picture tube layer cake! After baking out the lacquer, blow out the fumes on the drying rack. Tube is now gun ready.

Button Sealing

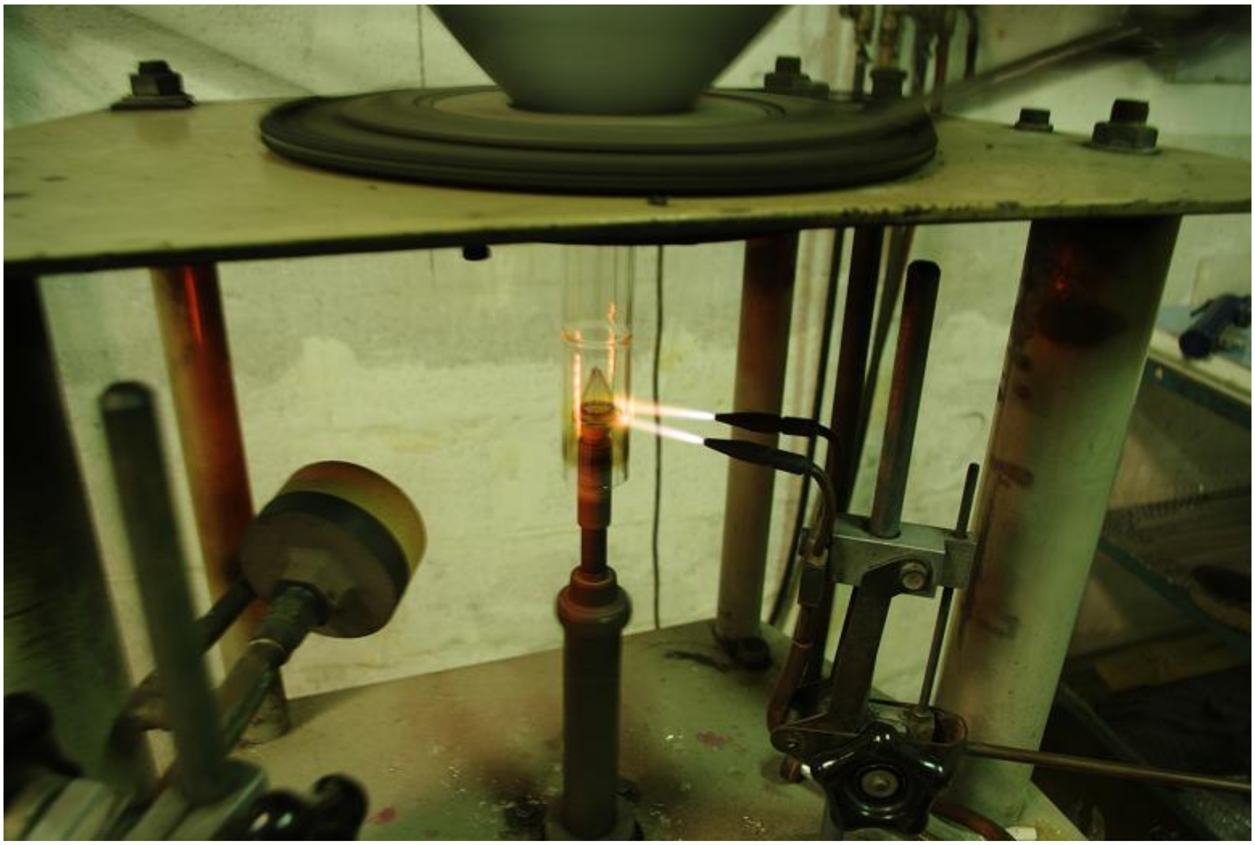
Sealing the gun into the neck of the tube follows basically the same rules as neck glass welding, with a few important exceptions. Ensure the gun is perfectly clean, use isopropyl alcohol on glass parts and blow the rest clean with filtered shop air. Mount the tube in the vertical lathe as before, only this time use the gun mounting chuck. Position the gun into the neck, and preheat the metal chuck with an oxy/hydrogen flame until it achieves a dull red color. This preheats the stem, so it will not crack. The chuck has also been covered with chalk, to prevent the falling glass from adhering to it in its molten state. Prepare the natural gas burner as before, it will be used twice during this operation.



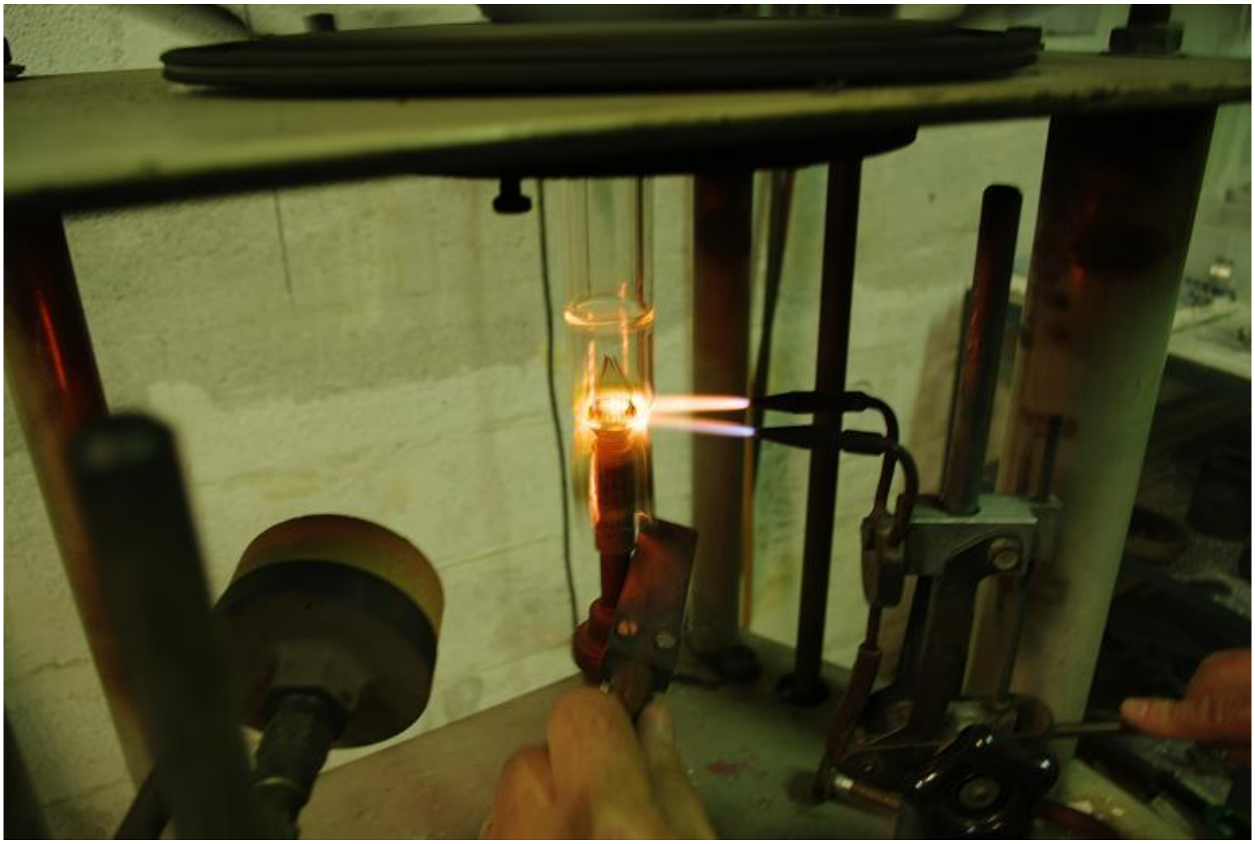
Now heat the neck glass below the button using only a hydrogen flame. Upon application of the flame to the glass, moisture will form on the neck; heat the glass briefly with the natural gas flame to boil it off, then point the flame away but leaving it on for its next use. Once the glass turns black, it is ready for sealing. The black color of the glass is merely a result of the interaction of the hydrogen with the glass, I suspect that Francois only uses it as a convenient timer to know when the glass is ready since it takes about 3 minutes.



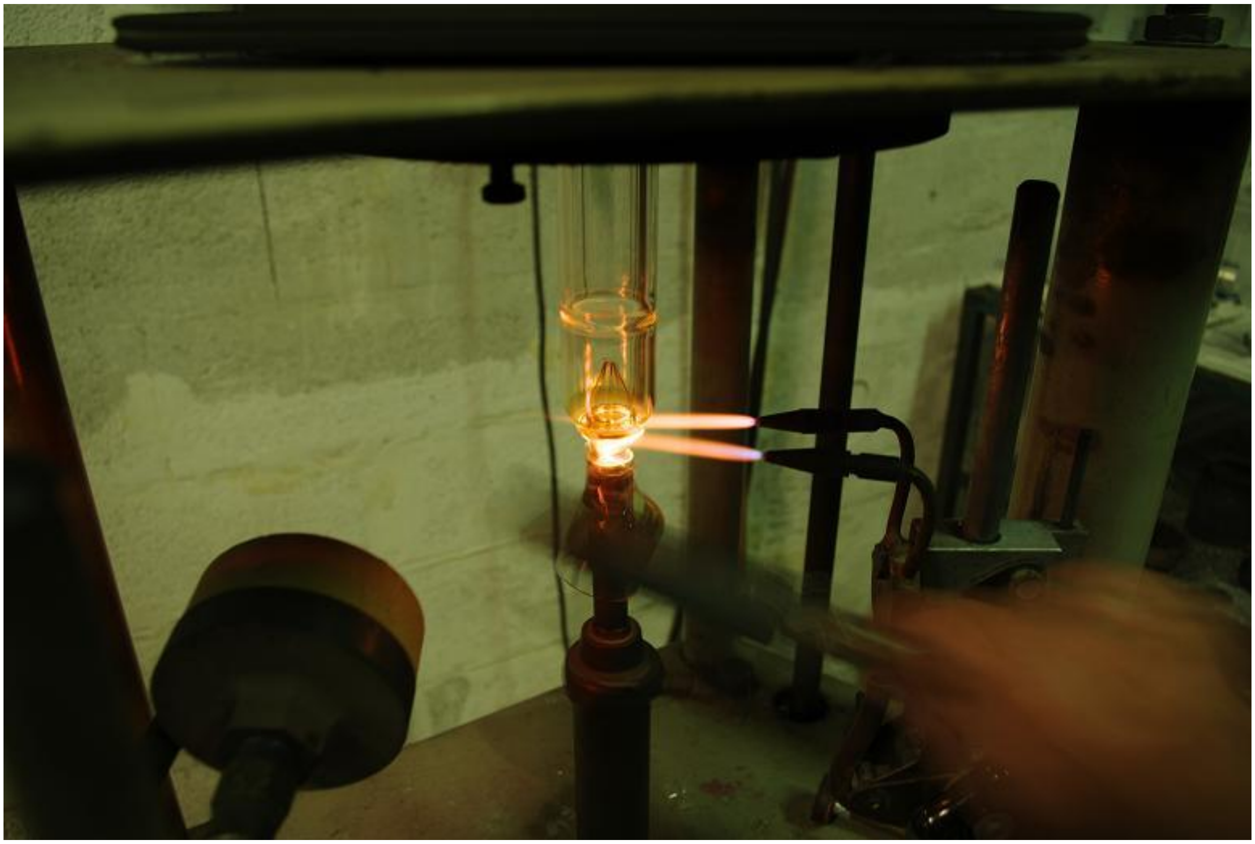
Once the black ring appears around the neck glass, add oxygen to the flame and move in on the button. Positioning of the flame is critical, it should be pointing at the upper edge of the button. If you aim too high, the glass will stretch out too much as it falls, making the joint weak and prone to cracking. Aim too low and the glass won't even touch the button when it falls, then you'll have no choice but to affix a new section of glass and try again.



When you notice that the glass has started to melt, follow it on its downward path with the flame. You want to stop it from falling with the graphite paddle, about 1-2” of fall is appropriate.



Use the flame to cut the glass off just below the button, and focus the flames at the new joint for a moment to ensure that the glass has fused. Once fused, position the natural gas burner on the new joint for approximately 30 seconds. Anneal with a small blue flame for 20 seconds, then slowly cool the joint by progressively pulling the burner away. Secure all gas, and let the whole thing cool as previously described back to room temperature in the enclosed space.



The sealed tube is now ready for bake out.

Bake Out Procedures

The successful bake out and pinch off of a tube depends completely upon careful control of the ramp up and ramp down temperatures inside the oven, failure to keep consistent temperatures will result in the glass fracturing. Because of this, high quality very accurate temperature control devices are a must to regulate the oven. RACS uses a computer controlled master panel to regulate all oven stations on the 5-tube large ovens at the same time, while the smaller single bay unit is done manually with a temperature knob just like you have on your stove. Monitoring on this single bay unit was done by digital thermocouple on a multimeter, with its probe tip positioned right at the height of the tube face. There are several holes in the side of the oven to permit the probe entering at the correct height. This is because the temperature increases at higher points in the oven, as much as 15*C difference can be seen in as little as 12”. Make sure to read the hottest temperature that the tube will experience, if you measure below the tube face the top of the glass may reach a higher temperature and actually melt in on itself. During bake out the tube is heated to just below the point where the glass will soften, so be careful! Normally a B&W tube is done at around 390-400*C, at 425*C you have gone too far and the glass will cave in. That’s how close things get.

Monochrome tubes differ greatly in their processing vs a color tube. Generally speaking a B&W tube is much more resilient than color with respect to temperature ramps, because there are no parts inside it which are susceptible to breakage such as phosphor dot plates (15GP22), shadow masks, frit sealed panels, ect. Because of this nearly all B&W tubes have only a ramp up cycle, on the way back down the oven is simply switched off and cools via convection. By contrast, color tubes may need as slow as 10*C every 10 minutes to avoid failure. During bake out, gasses are removed from the tube by a 2-stage pumping process. This involves a diffusion pump, backed by a high vacuum mechanical pump (itself being 2-stages). The tube is brought up to its bake out temp and held there for 30 minutes, then the temperature will be brought back down, pinch off will occur at 100*C, and the tube will cool to room temperature.

The quality of vacuum achieved is directly related to the state of the pumps used, so it is essential that the pumping devices are regularly maintained. Diffusion pump oil in particular can oxidize, after which it will become useless. Care must also be taken to avoid moisture accumulation in the mechanical high vacuum pump, or corrosion is the result. The end goal after an oven cycle is to end up with a tube that is at 10 to the -5 millibar, any residual gasses will be taken care of by the getter when it’s flashed.

Note that RACS does not ascribe itself to the ‘traditional’ bake out procedure of bombarding the gun, or activating the cathode during an oven cycle. Francois has told me that no ill effects have been noticed by them over the years by not doing so, thus I must assume they have a good reason for it. I suspect that glass failures have happened right near the end of a cycle, where cathode activation would have rendered the gun useless. By not activating the cathode, the gun can be cut out and reused in another tube after mounting it on a new stem. Some have asked if activating the cathode introduces gas into the tube, and after seeing it for myself all I can say is that if it does, it's not enough to ruin the tube. The 10" one I built while I was there was done in this way, and it produced a nice bright, sharp picture upon testing.

I will not go into detail about specific temperatures or ramp profiles here, because that information is still proprietary to RACS until they close. It will come to us via Jerome, after he has finished translating the master cookbook.

Post Bake Out

After the tube has been successfully pumped down, pinched off and is back to room temperature, the next step is flashing the getter. This is a simple procedure, you just turn the thing cherry red with an induction heater. You should be left with a nice silvery looking deposit on the inner surface of the glass; anything dull, brown or hazy looking indicates contamination and the tube will have to be pumped again after a new gun is installed. Then comes spark knocking, where a high potential (up to 30kv) is applied to all pins on the gun to clean off any conductive debris. If this is not done, arcing might occur which can destroy the gun or chassis circuitry. Only now is the cathode activated, a base attached and the tube is tested on a bench.