Oven soldering
A Practical Approach

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ABSTRACT

A PRACTICAL GUIDE TO FURNACE BRAZING (OVEN SOLDERING)

This paper is intended to show that jewelry is a simple industry and the processes used should be kept as simple as possible. The paper touches on General theory of what is furnace brazing and will get into the Material, Equipment, and Labor needed to generate good product through the oven. There is no Black Magic involved in Furnace Brazing. This lecture is intended to show you how to get your oven working in your factory and to rid you of the fears and misconceptions associated with it. If you own an oven and don't think it is being used as it should, this lecture is for you.

KEYWORDS

Solder, Furnace, atmosphere, equipment, solder joint, fixture, heat zone, radiated heat, bombing, pickling, belt speed.

Oven brazing or soldering is a pretty straight forward process.
The solder is applied, it's put through the oven at a given temperature with adequate time in the heat. Ideally you want the solder to flow just before it leaves the heat zone.

Sounds easy....

Some basic soldering principles
General Theory

The process of "Soldering" (hard soldering, brazing), as we call it in the industry is a science as old as metal working itself.
It's the use of any fusible metal or alloy to effect the union of two metals by melting it into a joint. (Working with Precious Metals, Ernest A. Smith)

The process of oven soldering, or furnace brazing is not quite so old but has frustrated many individuals and organizations in it's relatively short life span. Furnace brazing is a process which uses a belt furnace to heat jewelry components to a specific temperature which will allow solder to flow into a joint, combining multiple pieces into a single part.
The process involves and is very dependant upon, clean parts to be joined, the most correct filler material (solder), time and temperature in the oven, and an oxygen reducing atmosphere to reduce or eliminate oxidation of the pieces.

Ideally, the idea is to use a solder (filler material) with a melting temperature as close to the melting temperature of the metals to be joined as possible.
You want the joint to come up to temperature, the solder to flow, and the part to cool leaving a smooth, structurally sound joint.
You don't want to dawdle in the heat. By leaving the joint in the heat too

long the solder flowing will seriously etch or melt the metals being joined compromising the integrity and appearance of the part.
I say ideally, but unfortunately we rarely have "ideal" conditions and certain compromises and adjustments will need to be made to ensure sound, esthetically pleasing joints solder joints.

Normally, components are inserted or loaded into some type of fixturing device such as a carbon board or wire wrapped, etc. The solder is applied to the joint area to be brazed and the fixture introduced into the beginning of the oven. The fixtured pieces will travel the length of the muffle (a metal tube running down the length of the furnace) arriving into the fire box, gaining temperature, soaking at temperature, and then returning to an ambient atmosphere in the cooling chamber. From the cooling chamber it exits the furnace.
The point of furnace brazing is to allow for multiple items to be soldered in a furnace environment, replacing single piece hand soldering operations. Real gains in productivity and quality can be made.
Getting good quality from your furnace brazing operations is not too difficult.

When at all possible use carbon or graphite fixturing for findings components like bails, posted items, basket settings with accents, etc. Have these fixtures made on a CNC mill, use a vendor that has furnace brazing capabilities to "try out" the fixtures and make sure they're correct. Have the vendor use the thinnest materials possible to cut down on the amount of mass the fixtures possess.
The fixture cavities need to have room built into them so that the pieces can expand without being trapped. If the pieces are confined too closely they will buckle and solder out of alignment.

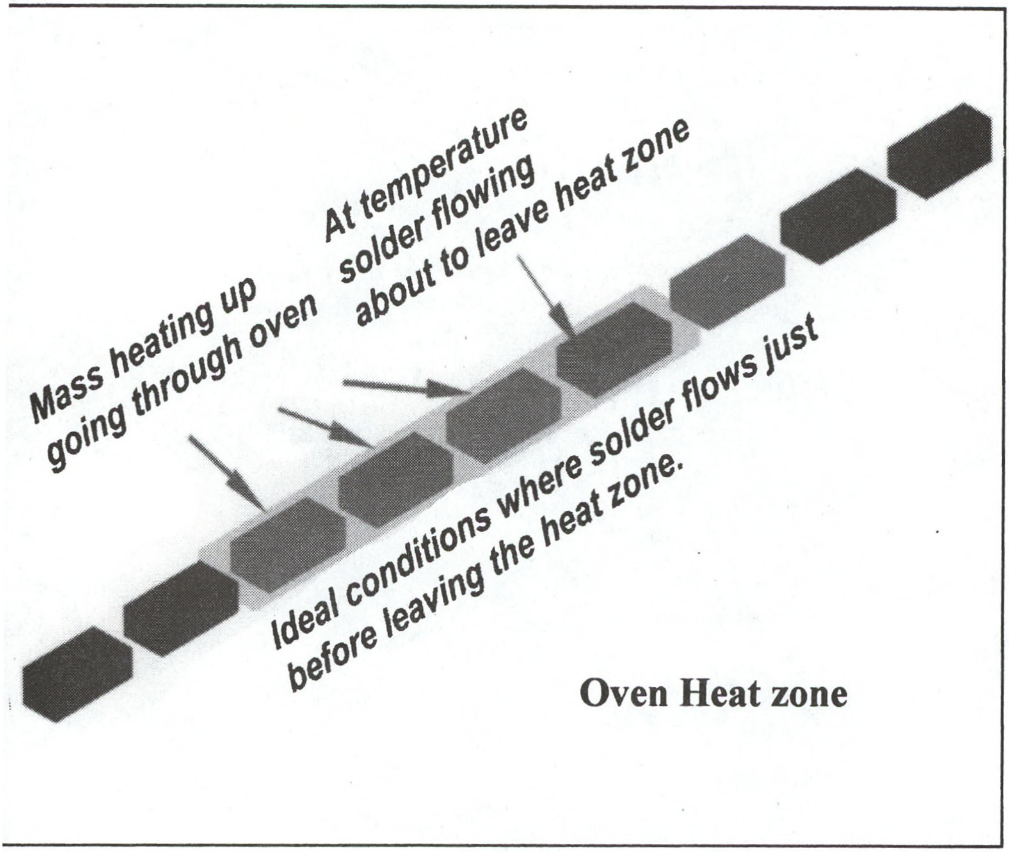
Once you have good quality fixtures, treat them well, keep them in good repair and replace them as they wear and begin to produce inferior quality.

Try to balance the amount of total mass running through the furnace and keep it consistent.
If you have a lot of work space it so that when the oven temperature drops due to the mass it stays as constant as possible. If there is a lull or gap in the amount of work to be run through the furnace, place empty fixtures on the belt and run those though. The point is to keep the temperature of the furnace constant by placing the same or close to the same amount of mass through the heat zone at all times.
If keeping a constant flow of mass through the furnace is not possible or practical, be sure you run a line of empty fixtures through the furnace just prior to running your product.
This will bring the furnace temperature down and stabilize it in preparation for the production to be run.
All the metals used in typical furnace brazing operations behave pretty much the same when introduced to intense heat and certain things must be taken into consideration.
Depending on the size of the muffle in your oven there will be some intense radiated heat applied to the pieces being soldered, particularly where these pieces are directly exposed to the inside walls of the muffle.

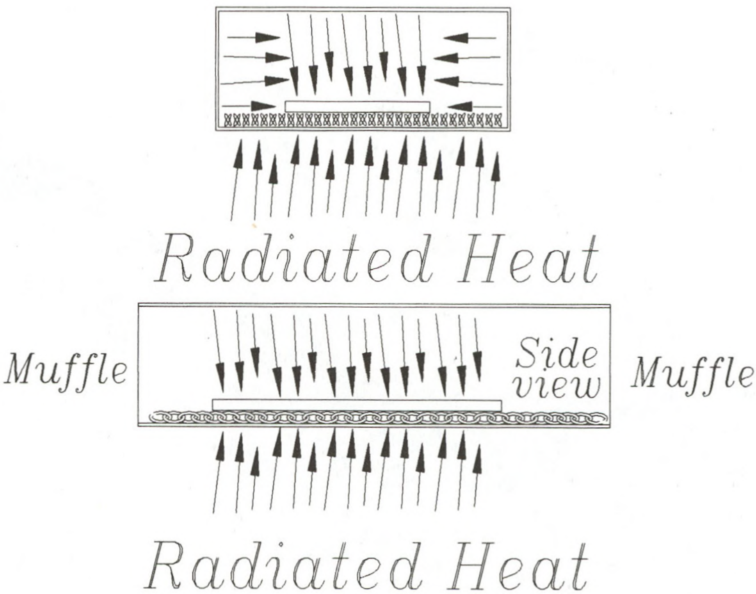
Gold pieces made up of a heat treatable alloy containing cobalt should be protected or covered so that the top or sides of the extremely hot muffle don't radiate heat directly on the unexposed pieces. These cobalt containing alloys tend to melt quickly, and without warning.
Even though you may be running other gold alloys in separate fixtures directly in front or behind these pieces, the exposed cobalt alloy parts being directly exposed to the radiated heat will have a detrimental effect on the parts.
Place a thin carbon cover (1/16" - 1/8" thick) on exposed metal surfaces within the fixture, this will protect the metal from direct exposure.

The same is true if running previously solder components fixtured with raw components through the brazing operation. Protect these pieces and

›e careful where you apply solder.
.f solder is applied in such a manner that it makes contact with the ›reviously soldered joints re-melting can occur and that can lead to ›omplete melting of the item. The solder flows, re-melts the previously ›oldered joint and consumes the remaining gold items in the fixture ›avity.



Protect the parts when running through the furnace.



Equipment

The equipment
1. Ovens
2. Dissociator
3. Solder application equipment
4. Lighting, etc.

The equipment needs to be in good repair.
You need to be able to depend on this equipment to give you reasonably consistent results.
Have a preventive maintenance program, regularly check the condition of your equipment, keep the house keeping up.

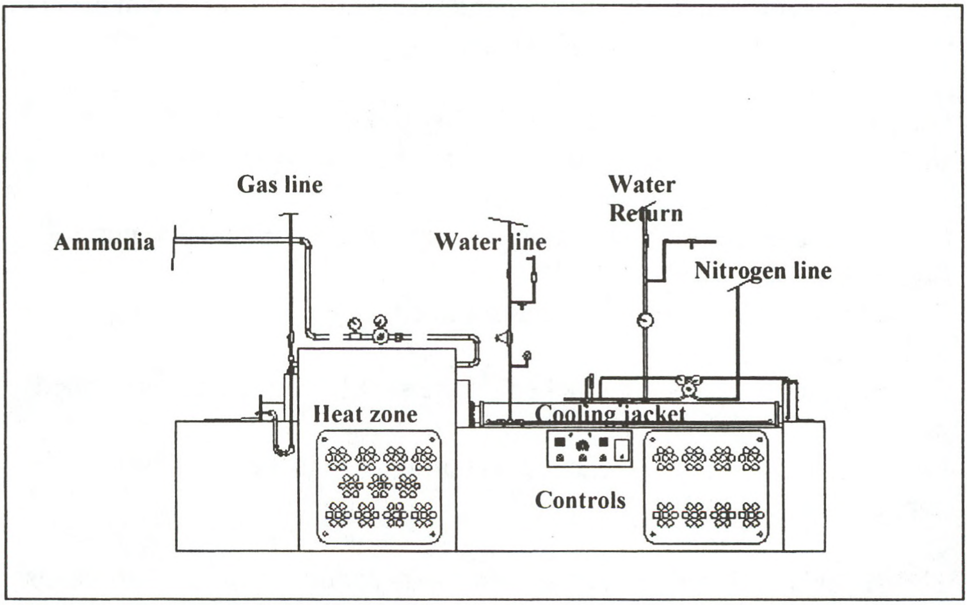
For your **oven**, check the belt speed every morning or every shift, use a stop watch and a tape measure. Verify the belt speed that produces acceptable quality and quantity, document it.
Check the actual oven temperature against what the old analog controller says.
If you have a temperature probe use it to check the corresponding temperature within the fixture.
Be sure your muffle is not cracked. Make sure the muffle is not warped radically.
Periodically flush out and clean the cooling jackets, keep the water temperature reasonable.

The **dissociator** is very important, check its condition and its output. Use the highest quality ammonia you can find.
If your using small tanks, don't try to drain them, have them replaced or topped off regularly.
Your atmosphere depends on it!

Use adequate **lighting** in solder application areas and oven areas, your people shouldn't have to strain to see what they're doing.

It's easy to apply too much solder, or too little. Be sure your air actuated solder application equipment is in top condition. Use traps in the air lines, clean them.

Give the applications people illuminated magnifying glasses.
Be receptive to the needs of the applications people, give them the tools they feel they need to do a better job.



Understanding the oven "Atmosphere"

The belt feed ovens that you operate daily have no air in the heat box or cooling jackets.

Instead, these ovens use what is called an atmosphere in the heat box and cooling jackets.
This atmosphere is made up of two different gases, one is Hydrogen and one is Nitrogen.
There is 75% hydrogen and 25% nitrogen produced with good quality anhydrous ammonia.
Anhydrous Ammonia is purchased and stored in a large tank, this ammonia is piped to what is called a **dissociator**. In the oven room the most obvious dissociator is against the back wall next to the double doors.

The dissociator is nothing more than a special oven used to heat the ammonia to 1500-1850F. Once the ammonia is heated and subjected to certain other chemicals within the dissociator, hydrogen and nitrogen are produced. The ammonia is said to be "cracked".
You may hear someone say something about "cracked ammonia", if you do this is what they're talking about.
These gases are piped directly into the oven through the flow meter that you see on the oven.
The flow meter shows you in relative terms, how much of the gases are flowing through the oven.
These gases are important, and need to be used in this type of operation because they evacuate, or push out all the air and oxygen within the oven chamber. At the heats we use within the ovens, any residue on the pieces, the solder on the pieces, or any foreign material in the oven would burn and permanently tarnish the gold if there were air in the heat chamber.

Have you ever wondered why you see no flames coming off the boards, or the solder when they're in the heat zone?
The reason is that if there is no oxygen in the heat zone, there is no flame,

no burning.
That equals no tarnishing or discoloration.
Another benefit to a hydrogen/nitrogen atmosphere is that the hydrogen actually helps clean the gold as it runs through the oven. That's why parts usually come out so bright and clean. (Or so they should). If the parts are dirty the solder won't flow or bond properly, don't depend on the hydrogen to fully clean the parts.
You can understand now how this atmosphere makes it possible for us to actually do the soldering so easily.

Nitrogen is an inert gas, which means it doesn't really react with other materials, it won't burn etc.
Hydrogen is very, very flammable!!
The flames you see coming out of the oven are made by burning off the hydrogen as it rolls out of the oven using the gas pilots.
Always be sure that the hydrogen is being burned off!!!
Never stick your hands or any object into the curtain at the exit side of the oven, if air enters the oven in any substantial quantities a violent explosion could take place.
The gauges behind the blue oven are ammonia gauges, they show us how much ammonia is being piped into the dissociator under the blue oven.
The blue oven has it's own dissociator.
Those gauges should never be tampered with.

Part Cleanliness

Clean parts are essential for top quality and good yields.

Solder tends to wick to areas where clean materials are in close proximity. Machine oil, dust, dirt, cookie crumbs, oil from potato chips, facial oils. All these things and more can contaminate a potentially good solder joint.

People don't need to eat and handle parts to be soldered at the same time. Even with the introduction and use of cadmium free solders its not a healthy idea to be handling food and solder together.
Be sure all previous operations have kept the parts as clean as possible, and be absolutely sure that just prior to soldering the pieces are bombed or cleaned adequately and kept clean while fixturing.
Thin white cotton gloves worn by the people loading the fixtures is not unreasonable.

Solder paste

The solder you use can make or break you operation.
So much has been written about solder, that I don't think I can add much.
Purchase your solder from a reputable dealer, <u>one that will be sensitive to your needs</u>.
A good working relationship with your vendor can reap many rewards.
Look for a consistent mix from tube to tube, ideally the solder should flow from the needle easily at an air pressure of from 5 to 10 psi. If your finished solder joints look rough or grainy make sure they're not cold joints. If your sure you have adequate heat and good flow but the joints still look grainy, get with your vendor and try to remedy the problem. If you don't have any luck don't be afraid to try another brand of solder. Not

all solders are created equal. Run tests, be sure of your results.
Experiment with solders that have different flow characteristics and compositions.
If you're using a particular brand of solder and not having the kind of success you expect, get with the manufacturer and find out what else is available or go to another manufacturer.
The viscosity of the solder is not terribly important as long as its consistent within a tube.
Consistency of mix is quite important, if the solder separates from the binder inconsistent metal application will result, and solder joints wont be consistent or acceptable.
Age and storage is a tough one. You keep a tube of solder tightly closed at room temperature and it can last quite a while. I've used solder that I know was three months old without a problem.
Don't buy cut rate solder, buy quality, you get what you pay for.

Fixturing

As stated previously when at all possible use carbon or graphite fixturing for findings components like bails, posted items, basket settings with accents, etc. Have these fixtures made on a CNC mill, use a vendor that has furnace brazing capabilities to “try out” the fixtures and make sure they’re correct.
Have the vendor use the thinnest materials possible to cut down on the amount of mass the fixtures possess.
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Once you have good quality fixtures, treat them well, keep them in good repair and replace them as they wear and begin to produce inferior quality.

Quality fixtures are very important for quality finished parts.
These fixtures help determine joint gap spacing and proper loading is essential.
If the fixtures are made properly there will be a little extra room for metal expansion within each cavity.
Load all the components carefully and be sure every joint area is tight and contact is made where necessary. When applying the solder be careful not to move the components out of alignment, and don’t apply too much solder.
Once the solder is applied and a cover is required, make sure not to push a cover on the pieces.
Pushing or sliding a cover on the parts will move the pieces out of alignment and smear solder where it is not needed or wanted. Place the cover down on the parts carefully and “don’t mess with it”!!
Perhaps I’m nit picking but a little extra care is worth the time.

Solder application

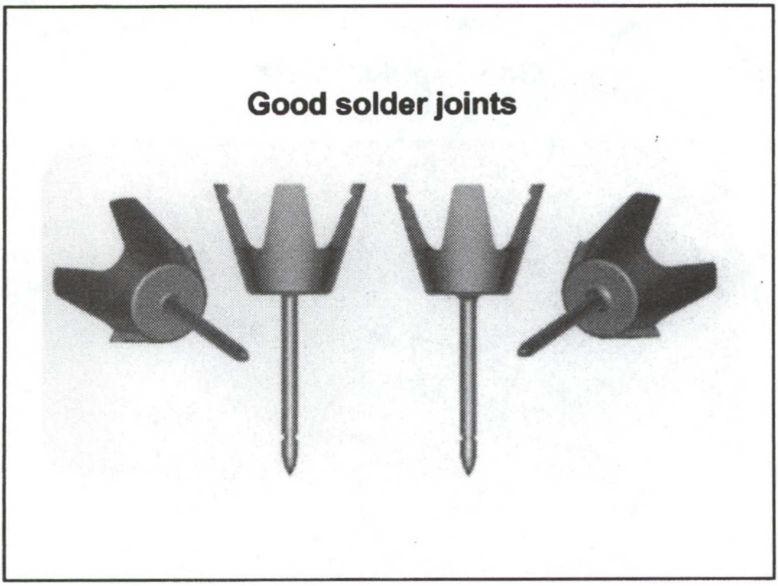
Once your pieces have been fixtured you need to apply the solder.
Not a real trick, just look at the pieces, figure about how much you need to apply to each joint and cut that in half.
Solder paste is great stuff, you don't need much, when conditions are correct it flows just right.
In most cases just use the smallest needle practical, apply a little air pressure and put a small dot on the joint. You may need to experiment with the placement, sometimes the side of the joint, sometimes the top, and sometimes the end of the joint will give you the most consistent results. When you can and the fixture allows, let gravity work for you. Let the solder flow down and into a joint.
When applying the solder be careful not to move the components out of alignment, and don't apply too much solder.
There are no real tricks to applying solder paste, just different techniques for different parts, you learn these as you go along, based on your product.

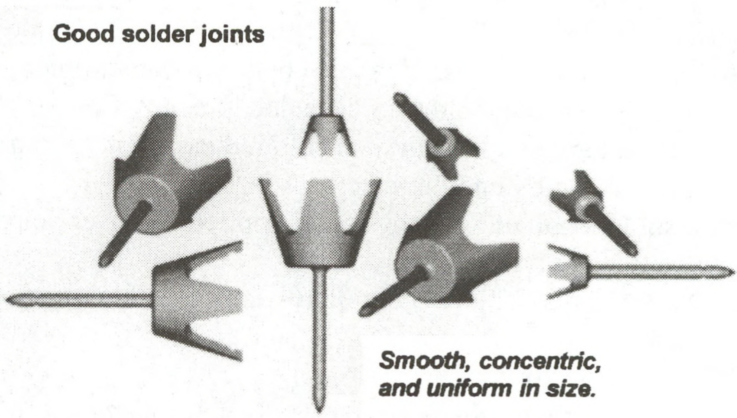
Joint strength and appearance

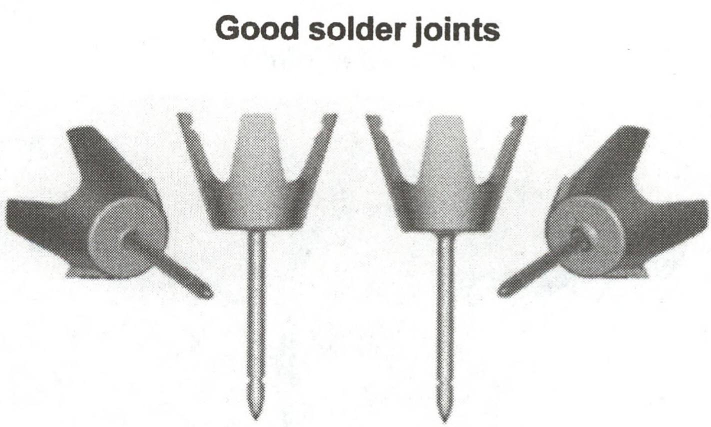
Joint strength is what?
Well, you certainly don't want the posts falling off your stud earrings, it's not good advertising.
So you need to apply an adequate amount of solder, know it's going to flow properly and bond into a strong joint.
As we said before, you don't need to apply a lot of solder, when conditions are correct it will flow and bond. So what do you do?
Apply the amount you feel is necessary, run the parts through the furnace and immediatly check your work. Take a couple of pair of needle nose pliers and aggressively attempt to remove the post or ring or whatever. If after testing 10 parts out of 100 you find nothing coming apart your in the chips. Just continue to check every batch.

If on the other hand you find 2, 3, or 5 parts becoming detached after aggressively bending and twisting you need to look at the process and make adjustments.
Look at the joint, is there excess clearance between the mating pieces, does the finished joint look cold (did the solder actually flow or just get cooked enough to harden up). If they're cold reduce the mass running through the furnace an try another batch.
Was enough solder applied, was any solder applied. Go over your process and adjust one thing at a time.
You may determine that 2, 3, or 5 out of 100 is acceptable, it's your choice.

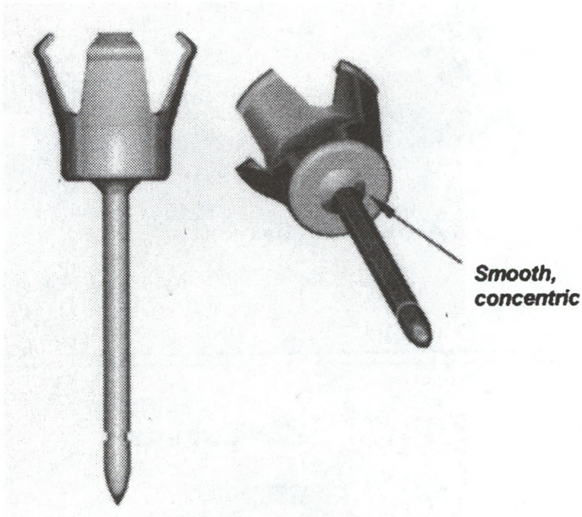
Joint appearance is pretty subjective, but we look for a smooth, consistent equal or concentric joint right out of the furnace. It saves time on downstream secondary or finishing operations.

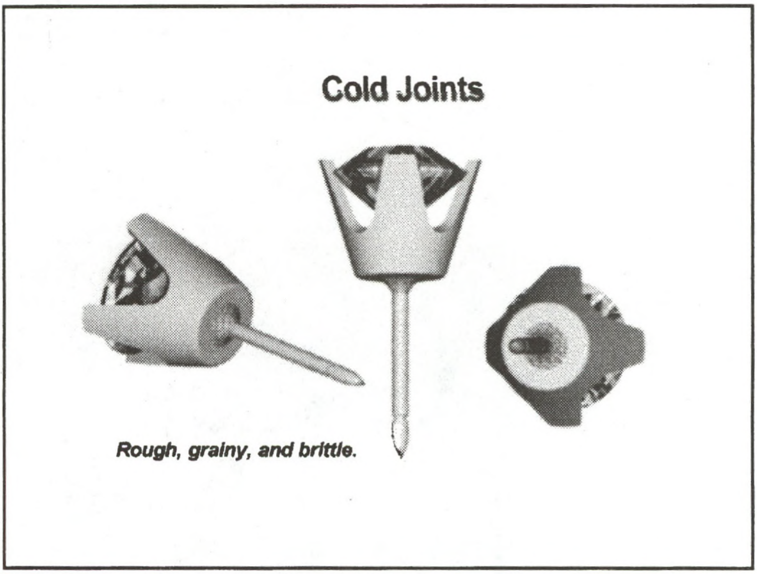


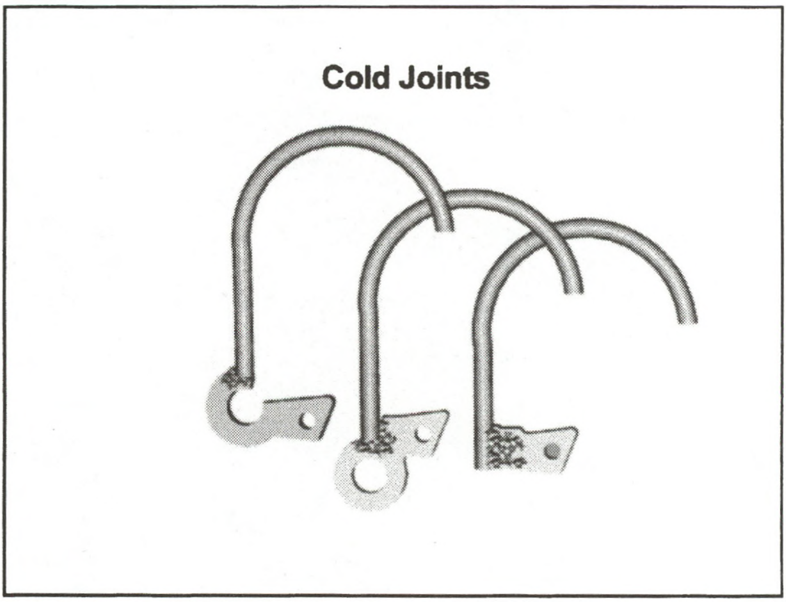

Good solder joints
Smooth, concentric, and uniform in size.


Good solder joints

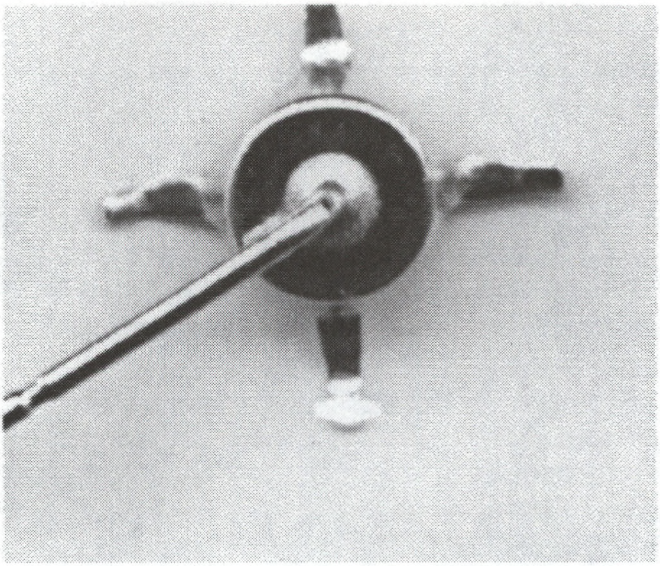
Good fillet, smooth and concentric with base and post.



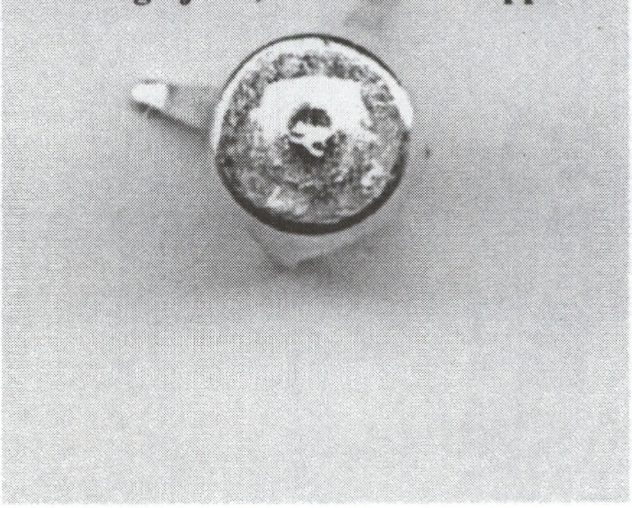

Cold Joints
Rough, grainy, and brittle.


Cold Joints

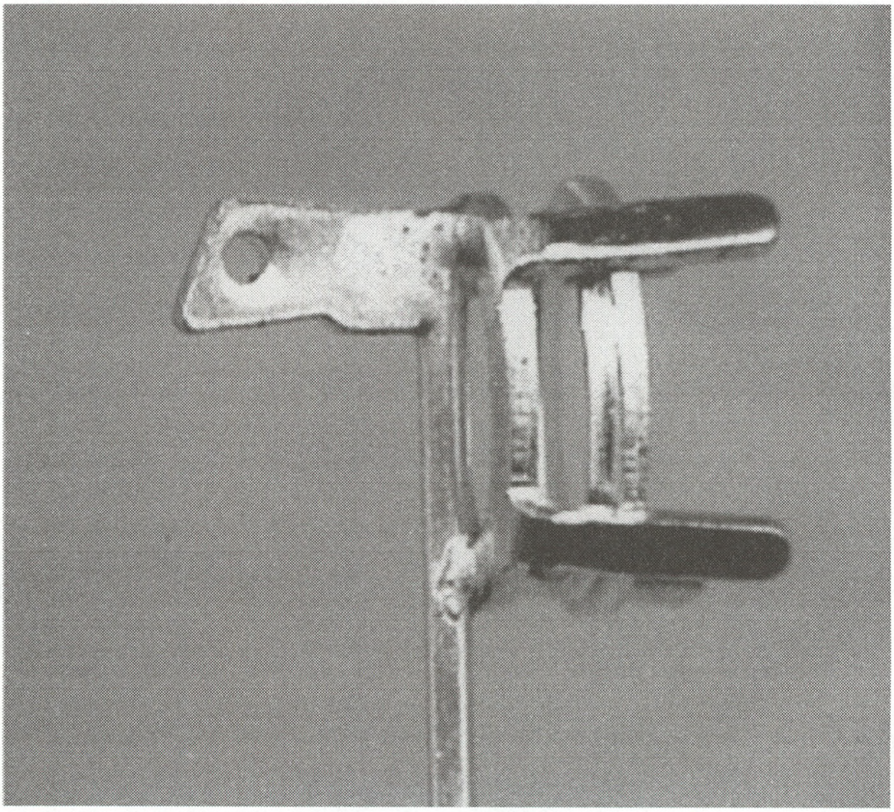
Good smooth joint, but a little large



Rough joint, excess solder applied.



Excess solder applied.



Real time process control:

The muffle (tunnel) running through the oven is considerably smaller than the muffle on the older oven.
The belt speed on the new oven needs to be set slightly slower because of a lower set operating temperature, (1575' F - 1584'F).
The maximum allowable mass to be run through the new oven needs to be less than the older oven because of the smaller muffle, lower operating temperature, shorter heat zone, and slightly slower belt speed.
Personnel responsible for the loading and unloading of the oven also play a major role in the quality of the finished solder joint.
Personnel responsible for the loading and unloading must pay special attention to the established loading procedures. These personnel must check as much product as possible as it exits the oven checking to insure that all solder joints have flowed properly.

In a line of production boards initial inspection will reveal the quality of solder joints. A particular board that can contain items/components with solder joints that are cold, rough, and grainy should be inspected further. These quality defects lead to the individual components falling apart immediately or in subsequent operations.
That particular board should be run right back through the oven again with mass adjustments, (less mass), made for that particular board alone.

The reasoning behind adjusting the mass for that board alone is that if major "mass" subtractions or additions are made for all boards running through the oven to compensate for one board, the oven temperature will be lowered or increased creating solder joint quality problems with the previously well soldered items/components. These problems won't show up immediately because of the time it takes for boards to move through the oven, and because of the time it takes for the oven to recover and stabilize.
If inspection reveals over heated items/components to a particular board

then adjustments (more mass or a re-arrangement of mass for that board need to be made. A re-arrangement of mass can be as simple as placing a thin board on top of the production board instead of on the bottom. Minor changes in mass can have profound effects on the quality of the solder joints.
Oven loaders need to be able to quickly inspect and identify quality problems in real-time and make immediate adjustments to the process.

Conditions of excess solder, insufficient solder, and no solder should be noted and communicated to the lead person as it is identified. Conditions such as "Cold joints", melted or eroded pieces should be identified and adjustments to the process made by the loader to correct the problem on an individual basis.

Joint and fixture design

This is simply to give you a broader understanding of the soldering process and the variables associated with it.
Quality solder joints are very dependent on good joint design and good fixture design and manufacture.

There are two basic solder joint designs used here:
One is called a Butt joint, the other is a Lap joint.

Butt Joint
When a Butt joint is used the two or more pieces to be soldered are simply butted up against each other. The butt joint is necessary when the overlapping of pieces is not attractive or allowed.
The butt joint can be a strong joint provided there is enough surface area on the pieces.

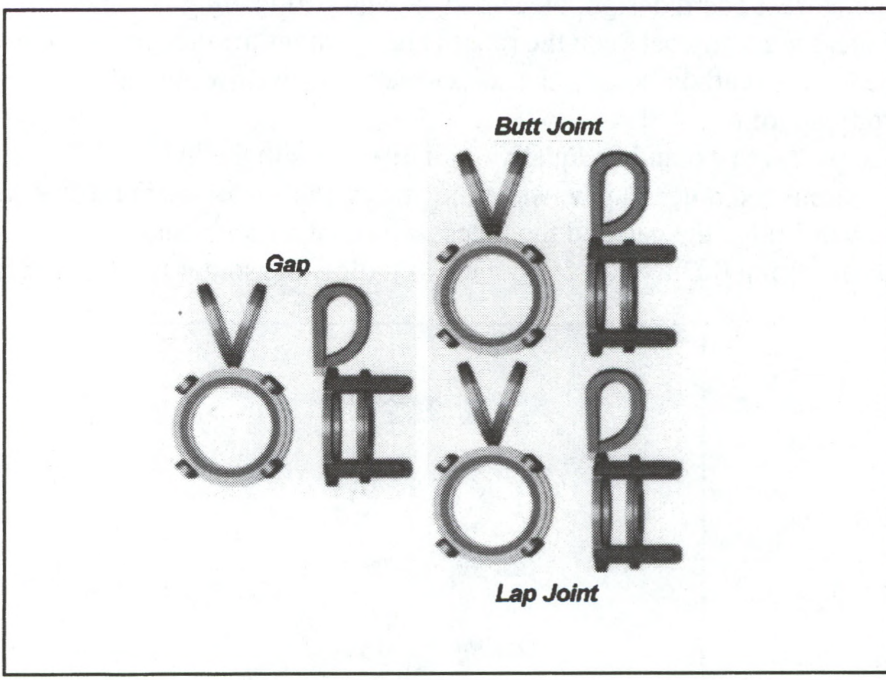
Lap Joint

When a lap joint is used the two or more pieces are on top of or underneath each other.

The joint is used where strength is the primary concern and the appearance is acceptable.

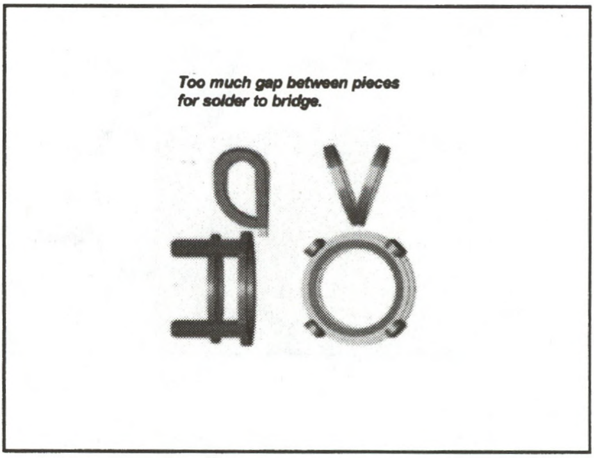
When we talk about surface area, that's the amount of material the two pieces have that is in contact with each other.

Normally there will be more material in contact with each other in a lap joint than in a but joint.

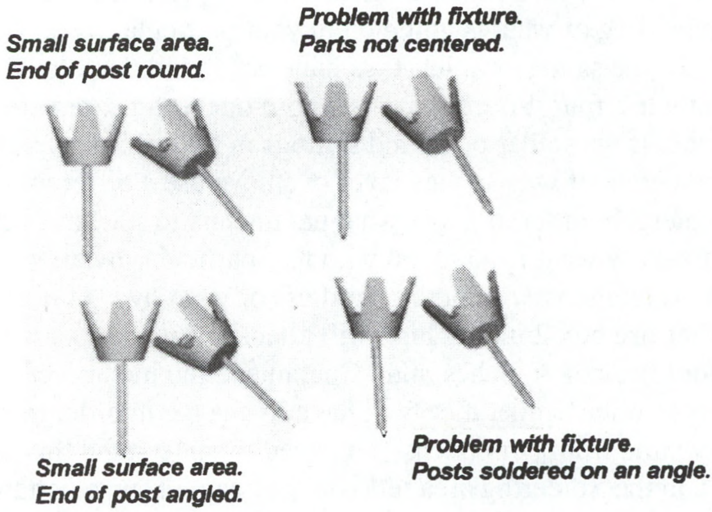


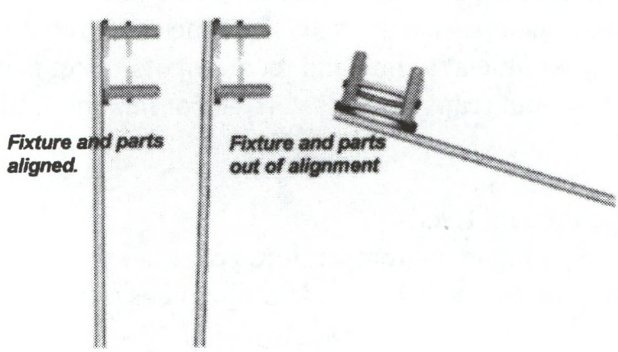
Joint and fixture design

With both types of joint an important consideration is the size of the gap between the pieces being soldered.
This gap is largely dependant on the fixture design (solder board).
Even without the help of gravity, flowing solder tends to wick to areas where clean materials are in close proximity. The idea is to position the materials so that a very small gap is produced. This will coax the solder to wick into that area. The solder will try to bridge any small gap present between materials. Large gaps will prevent solder flow, and the solder will spread out or puddle up on one of the materials.
The correct board design, piece part fit, and part loading are important.
If there is no gap between the pieces and no room for the parts to move in the fixture (carbon board), the solder may tend to flow around and away from the joint.
The pieces to expand unequally in all directions in the heat.
If there is too much gap between the pieces, the solder won't be able to flow or bridge the gap and the pieces won't solder together.
Ideally from .003 to .008 of an inch will allow the solder to flow and fill.



Problem areas with parts and fixtures





Creating a Process

Before you have any luck in the Oven soldering, you need to have an understanding of what is going on in your particular oven. No two ovens are the same, or at least we have not found them to be. We currently use four different ovens whose operating parameters are not the same. If we solder posts and settings in a Mini Six, we use one set of parameters, if we use the Hayes oven, we use a different set of parameters. In order to know what parameters to start out with, we need to know what is going on with that particular oven. An inch per minute is an inch per minute regardless of what oven you use but, a four foot fire box 2 inches high will attack the work differently than a four foot fire box 6 inches high. Guaranteed the inches per minute, or oven controller temperature will have to change in order to effect quality parts from both ovens. You need to understand this in case people in the Soldering area tell you they cannot run a certain part in a certain oven. One of the best ways to figure out what happens in a specific oven is to probe the curve from the beginning of the oven to when the temperature reaches a low enough area to no longer have an effect on the parts being soldered. If you record all this data, which can be time consuming, you will have a good idea of how to set the oven to run a particular item. The time spent recording the changing of one variable at a time and recording its effect is necessary, often not done, but reaps rewards you cannot fathom until you have the data.

Testing Equipment Used

1. 15' to 20' long metal temperature probe.
2. Digital thermometer which the probe plugs into

We purchased our probe from a local heat treating company in Attleboro MA but it can be purchased from almost any heat treating company.

We purchased out digital thermometer from catalog sales outfit in Warwick, RI but it can be purchased from almost any testing equipment company.

The first thing which needs to be established is the rate of travel on your belt through the oven. Simply set the dial until the belt is at full stop. Turn the dial until the belt begins to move and measure the rate of travel in inches. Record it for later reference and comparison. Continue this until you have established the rate of travel for any of the major points on the dial.

1. Make out a paper with which you can record the temperature of the oven, and the belt speed.
2. Set the oven to a specific belt speed and temperature.
3. Using a watch, allow the tip of the probe to stay on the belt and travel into the muffle.
4. Every minute, record the change in temperature of the probe.
5. When the temperature of the probe has risen and fallen to a point that solder would no longer flow, you have developed a set of points which can be plotted on a graph.
6. Increasing the belt speed but not the temperature, repeat the process to record the change in speed as it affects the probe temperature.
7. Keep repeating the process until you have recorded all the belt curves for that specific oven temperature.
8. Change the oven temperature upwards 50 and again record the curves by changing only the belt speed.
9. Keep doing this until you have covered all the relevant oven temperatures and their belt curves.

10. Plot all the curves for a specific temperature and you will see the relationship between changing the belt speed and its effect on the temperature of the probe.
11. Plug in the flow point of a specific solder and you should be able to make an educated guess as to what temperatures at which belt speeds will flow the solder.

You wouldn't have to do anything else if solder were just put on a belt and sent through an oven. The fact is, the solder is normally applied to items and the items themselves loaded into a fixture of sorts and then run through the oven. All this mass will change the temperature curves you have recorded so it becomes necessary to recreate another set of curves with the probe anchored in the fixture and then again with the probe anchored in the fixture and the fixture loaded with work. If you take the patience and time to develop these curves, you will find that your trial and error problems will go down greatly.

It becomes much easier to record the mass curves because you will already know which curves never even flowed the solder in the first place. If it couldn't flow solder on a belt, it is never going to do it with mass in the oven so don't bother testing those belt speeds.

You will find that if you develop all the curves, there are many settings which will give the correct conditions to flow solder. Although this is true, which one would be the best to start with? As we said earlier, ideally, the solder should flow just before it leaves the fire box so it is in its molten state as little as possible. If you look at your curves, and the time it took to reach temperature, you can figure out how far in the fire box this happened since you know the rate of the belt at that time. Choose the curves which satisfy this and chances you won't be picking little gold balls out of your oven.

If you have more than one oven and you develop a set of curves for each, lay the curves on top of one another for the same belt speed and temperature to see why no two ovens work the same.

To oven solder effectively, there are a few things which should be done before you even begin to have an understanding of what is going on. If you test the limits and behavior of your equipment, material, and properly train your employees, you should find the benefits of plugging the oven in and using it far outweigh the advantages of owning it and being afraid of it. There are not many things the combination of equipment, material, and fixtures, can't solder. Assume the item can be soldered and then choose the closest set of parameters. Whatever you do, whether the item comes out good or bad, document what you did so you have the parameters available to you and for posterity.

Once you have figured out the best parameters to run an item, chances are that many items you make will run under the same parameters or parameters very close. You may find, as we have found, that most items will fall into certain processes negating the need to develop the process for each item, but simply attaching a "template process" to the item.

Not everything we know or every process control we use could be jammed into one paper. We merely wanted to stress the importance of paying attention to what is going on and the rest will follow. Both Dana Castle and John Gavin are available to discuss any problems you might encounter with your process. What we know, we will impart free of charge in the spirit of this symposium. You might have to pay for the phone call but that is it.

There are a number of variables that can affect the process to one degree or another.
Here are a few:

1. Oven parameters:
(Belt speed, actual oven temperature, temperature within the fixture)

2. Oven condition:
(Have a preventive maintenance program, regularly check the condition of your equipment, keep the house keeping up.)

3. Solder paste quality:
(Viscosity, consistency of mix, age and storage, cut rate paste)

4. Solder paste composition:
(percentage and composition of metal, binders, and fillers.)

5. Poor fixturing:
(Worn fixtures, new incorrectly designed fixtures which are too snug for the parts once they are heated to temperature and expand, incorrect fixtures for the job. Re-think fixture design, minimize mass.)

6. Out of tolerance parts:
(Quality requires consistent part to part and part to fixture compatibility as it relates to joint design.)

7. Joint design:
(Solder won't flow across an eighth of an inch gap. To insure consistently well soldered and attractive joints, keep the joint design within the norms. .008 or less gap.)

8. Material/part composition:

(Casting alloys will vary in composition, some alloys may contain some silicon which is a real no-no for quality solder joints.)

9. Dirty parts/fixtures:
(Oils, films, oxides, water spots, carbon dust, carbon impregnation in material, dirt impregnation in material)

10. Training:
(Train the people doing the job in the identification of a poor solder paste mix when applied to the parts, in the identification of a poor or acceptable solder joint, identification of a poor fit in the fixture, and train them in the basics of good joint design. Give the people documented process instructions as a guideline, draw them pictures, take photographs, etc. Keep them informed.)

11. Human error:
(Incorrect piece part fixturing, inconsistent solder application, incorrect solder application, wrong solder.)

Guidelines for solder problems

Problem	Possible cause	Possible cure(s)
Components falling apart	Insufficient solder	Apply more solder.
	Cold joint.	Reduce or rearrange mass.
	Improper fixturing.	Correct fixture for job.
	Excess clearance between parts.	New fixture.
	Wrong components.	Correct components.
	Components loaded improperly.	Check Loading procedure.
	Out of tolerance components.	In tolerance components.
	Cast component alloy	Aggressive tubbing.
	Dirty/contaminated components.	Bombing, pickling.
Excess solder	Excess solder application	Apply less solder.
	Pre-soldered component re-flow	Apply less solder, rearrange mass, protect item from radiated heat.
	Solder smeared while oven loading	Extra care when oven loading
	Careless solder application	Extra care when applying.
Melted items	Insufficient mass	Increase mass.
	Pre-soldered component re-flow	Apply less solder, rearrange mass, protect item from radiated heat.
Cold joint	Excess mass	Reduce or rearrange mass.
Discolored items	Dirty/contaminated components	Bombing, pickling.
	Oven atmosphere incorrect	See supervisor

Board and Solder Conditions

Board

Excellent - All pieces of board complete and available for use, close fitting pins, nuts, and screws, 90% of cavities sharp, clean, and available for use.

Good - All pieces of board complete and available for use, good fitting pins, nuts, and screws, cavities somewhat worn, 80% available for use.

Poor - Boards not complete, parts missing not readily available for use, loose fitting pins and or covers, very worn loose fitting cavities, cavities crumbled, broken cavities, many cavities not available for use.

Solder

Excellent - Clean, new tube, easy consistent flow, good solder mix, no excess moisture seeping from tube, needle stays clean and free of blockages.

Good - Good reasonably consistent flow, good solder mix, needle needs occasional cleaning.

Poor - Poor flow, poor solder mix, excess moisture seeping form needle, needle needs constant cleaning.

The main requirements for furnace brazing are:
The furnace
The reducing atmosphere
The fixtures
The solder
The components
The operator

From a practical standpoint there *are* a things you can do:

1. Document everything!!
2. Look your oven over, make sure the muffle is in decent shape with no outrageous warps, hills, or valleys.
3. Get a good digital temperature controller.
4. Make sure you have thermocouples that are in good shape, you want accurate feedback to your controller.
5. Be as sure as you can that your ammonia supply is the best quality you can afford, if you're using smaller tanks don't try to run them right down to empty, you'll contaminate your atmosphere.
6. Experiment with solders that have different flow characteristics and compositions.
   If you're using a particular brand of solder and not having the kind of success you expect, get with the manufacturer and find out what else is available.
7. Experiment with some of the low carat solder pastes available, they melt at a lower temperature and do an excellent job. ((Be very careful with low karat solders, assay regularly to insure proper karat in the finished pieces. If your gold regularly assay's on the low side of the tolerance be very, very careful with low carat solder paste.)) EXPERIMENT AT YOUR OWN RISK.
8. Experiment with mass, belt speeds, oven temperatures, joint design, and solder application. But experiment with one variable at a time and document, document, document!

Failure identification diagram instruction sheet

When failures begin to occur we all need to have immediate feedback from the process where the possible problem area is. You need to have a means of identifying that problem area and quickly adapting the process to compensate.
You are the ones on the front lines, you see the failures first. By using this sheet you will have an extra tool for graphically identifying problems with board spacing, cleanliness, oven heat distribution, or a combination of any of these problems.

Periodically you should take boards from the oven and check the pieces individually by picking them out of the board and visually inspecting them. When you find failures of the solder joint on individual pieces mark the board diagram with an "X" at the cavity where the failure occurred.
Describe the failure in terms everyone can understand, be specific and clear.

If the solder joint is very **grainy**, it is a cold joint and may not stand up to quality standards, the joint may not hold and the item fall apart. This is just a descriptive example.

After inspecting the pieces in the board and marking the diagram, notice where on the board the failures are located.

If the majority of the failures are at the **front** and or **back** of the board then board spacing is probably the problem. Increasing the space between the boards with allow more heat to work on the solder and help the solder flow properly.

If the majority of the failures are on the **left** or **right** sides of the board then perhaps we have a problem with heat distribution, or equilibrium in the oven itself.

If the majority of the failures are **scattered** throughout the board we may have a problem with cleanliness of the parts or separation of the solder.

As you very well know, there are many variables at work when soldering pieces through the oven but we can help eliminate some of the variables by checking everything we do, keeping the parts as clean as we can, and using the tools we have to adapt the process to the changing conditions. We need to explore all the possibilities, use our imagination, get immediate feedback from the process, and constantly be alert for any potential problem.

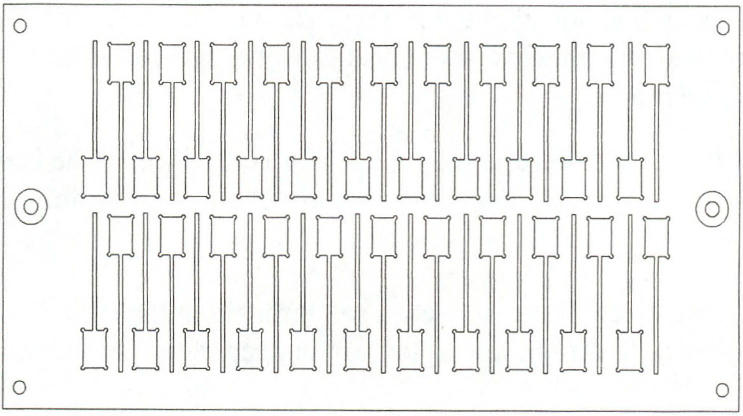
Keep filling out the process sheets, be as specific as you can, keep the comments and information coming. Everything you do and say is very important!

Failure identification diagram for carbon board items

Do not dump the board, take the pieces out individually and check for defects.
Identify where on the carbon board the failures occurred and mark each cavity with an "X".

Item #
Failure description(s) be specific and clear:

Solder process:



Solder paste and Viscosity (Dana)

From what we can observe, and determine by our observations, solder paste viscosity generally does not appear to have any great detrimental effect on the finished solder joint.
Based on what I'm reading in the board solder process sheets the solder we are presently using appears to vary a great deal in viscosity within an individual tube, and not just from tube to tube or day to day.
Sheets from various people are showing that the pressures required to apply the paste from an
individual tube vary from 18 psi to 70 psi during the course of a shift or production order.
More close observations are needed to confirm this but I believe oven temp, part cleanliness, board cavity to individual piece fit and accuracy, and board spacing have more of an influence on the finished solder joint.
The biggest problem with the varying viscosities is the amount of solder applied, sometimes far to much because of a thin viscosity area within the tube and high air pressure applied.

Solder paste separation on the other hand can have a very detrimental effect on the finished solder joint.
A bad mixture, too small an amount of metal particles in the application, and a solder joint is no good. Because of the way we apply the solder, the pressures we use can separate the solder paste components and make the solder akin to a two part epoxy. (liquid coming out of the needle with a very thin line or mix of metal particles in it is separated solder paste).
When you think about it a few things come to mind that can increase the pressures required to apply the solder to the parts and increase solder paste separation:

1. If the solder tubes are not capped shut when people are finished using them, or if the tubes are stored uncapped then the solder paste closest to the applicator tip will dry and harden enough to require extra pressure to force the paste through the needle.

2. If the tube is almost empty, then the solder paste has obviously been under constant pressure and use. Perhaps the moisture content has been reduced making the solder paste more difficult to move through the needle.

3. Dried, caked solder paste within the needle can further restrict the diameter of the needle making application more difficult and requiring more pressure which adds to the solder separation problem. Even cleaning the needle with wire won't completely restore the needles inside diameter.

These three possible problem areas can be addressed quite easily and at least eliminate a few more variables in the system.
We can keep the tubes capped at all times when not in use.
We can observe whether or not an almost empty tube is giving us problems, and if it is use if need be a much larger needle with very little air pressure to finish off the solder. Or get a new tube.

Oven Soldering

There are certain characteristics and factors required for a "Quality" solder joint.

A quality solder joint is more than adhesion or pieces just sticking together.
A fusion of all the materials takes place and a permanent bond, a solid new material is created where the separate pieces used to be. Everything melts together and when it solidifies it's one piece.

As you perform your job, and after reading and understanding this relatively brief booklet you will know what is required for a "Quality" solder joint, but you will also wonder how you can possibly control all the factors required.
The answer is that you can not control all the factors or variables, but you can control the majority of them.

More important to you are things like the strength of the joint and fluidity of the solder.
Mass in the oven, time and oven temperature, and cooling jacket water temperature.
Strength and fluidity are things you will see once the parts are soldered together.
As you inspect the parts, you will determine the strength of the joint based on how much solder was applied, how the board was loaded, and how well the solder flowed while in the oven.

The temperature at which the solder flows or becomes fluid should be below the temperature at which the base metal (parts) melt. The solder needs to be able to spend just enough time in the heat to flow and run into the joint to be soldered. Any extra time in the heat will tend

to make the solder flow more than it needs to and you will see what appears to be a case of excess solder.
If the solder doesn't spend enough time in the result will be a cold joint.
A rule of thumb says: "The higher the melting point of the solder, the stronger the joint."

Solder flow characteristics are determined by a number of factors:

1. The type of solder - restricted flow like Okai's RB or more free flowing like Krohns 14KYS.
2. Flux used if any.
3. Cleanliness of the parts before they enter the oven.
4. Oven atmosphere - we use a high hydrogen atmosphere, 75% hydrogen and
   25% nitrogen. This atmosphere <u>helps</u> clean the parts and promote solder flow.
5. Oven belt speed.
6. Oven temperature.
7. The solder joint clearances, the distance between the pieces to be soldered.
8. Even the time of the year, the relative climatic conditions can have some effect.

Conditions will vary from day to day. These conditions probably won't vary dramatically, but they will vary enough for you to have to modify certain process conditions like board spacing, mass, and even temperature and belt speed on some occasions depending on the product.

Some of things that you can do to help yourself will become obvious as time goes on.

1. When you start your job at the beginning of a shift take the time to check the belt speed so that you know exactly what speed your running. This only takes 60 seconds.
   To do this:
   Mark a line on the oven next to the belt where you load your work.
   Place a dummy board on the belt, when the trailing edge of the board passes the line marked on the oven start the stop watch.
   Time that board for sixty (60) seconds and mark on the oven where the end of the board is at sixty seconds.
   Use the tape measure or the yard stick and measure the distance between both marks. This will tell you the speed in inches per min.
   If it's not correct adjust the speed and time it again.
2. Check the oven temperature.
3. Check the dissociator temperature.
4. Check the hydrogen flow meter, make sure it's where it's supposed to be.
5. Check the water valves.

Visually check the entire process and equipment, if you find something that you feel is not correct, do not adjust at this time but let me know or let your supervisor know as soon as possible and we'll walk you through the adjustment process.

Once you know that all the parts of the process are correct you can start using the guidelines and checking the parts.

A few of rules you can live by are:

1. Too much mass in an oven will create problems you can't overcome.
2. Use tractor boards periodically to insure the boards don't get stuck behind the exit curtain.
3. Be flexible, be adaptable, conditions will vary.

Some terms to remember

(Oven Solder)

Ammonia (NH_3): a soluble gas. When dissolved in water, ammonia forms an alkaline, pungent solution, ammonium hydroxide (NH_4OH).

Atmosphere: A controlled brazing or soldering environment achieved by excluding oxygen and replacing it with one or a mixture of other gases. Most often associated with furnace brazing. (Our atmosphere is "cracked Ammonia", 75% hydrogen, 25% nitrogen)

Base metal: The alloy or pure metal which is being joined by soldering or brazing. (Not base metals)

Base metals: Metals that are not noble. Characteristically these metals will tarnish or oxidize in the presence of oxygen, heat and moisture. Brass, copper, steel, etc.

Binder: Binder is added to solder paste to keep the powdered metal in suspension and aid flow characteristics.

Board soldering: Use of carbon boards to fixture individual parts that make up a piece of jewelry, for soldering in the oven.

Brazing: A joining process where a non ferrous (no iron) filler metal is heated to melting temperature and distributed between two or more close fitting parts by capillary attraction. The filler metal reacts with and melts a thin layer of base metal to form a strong joint after cooling.

Capillary attraction: A natural force of adhesion governed by the relative attraction of liquid molecules for each other and for those of two or more adjoining solids.
In soldering it is the process by which the molten liquid solder is transported along the length of a close fitting joint.

Dew point: A method for determining the amount of water vapor (oxygen) in a controlled atmosphere. The Dew point is the temperature at which water vapor will begin to condense and become liquid.

Dissociator: The dissociator is an oven used to heat the ammonia to 1500-1850F. Once the ammonia is heated and subjected to certain other chemicals within the dissociator, hydrogen and nitrogen are produced. The ammonia is said to be "cracked". You may hear someone say something about "cracked ammonia", if you do this is what they're talking about.

Dummy board: Carbon boards of various thickness used to adjust the amount of heat a production board will absorb during the process of going through the oven.

Filler metal: An alloy or pure metal which, when heated, liquifies to flow into the space between two close fitting parts creating a joint.

Fillet: A clearly defined bead of solder which forms on and around the completed joint. Hopefully smooth and clean.

Some terms to remember

Flux: A material which when heated serves to remove and exclude surface oxides from the base metal.

Joint clearance: The distance between the two or more pieces to be soldered. Although requirements vary the optimum clearance should be from .002 - .008.

Muffle: The metal tube that runs the length of the oven heat chamber, it can be of various shapes depending on the oven heat chamber size and manufacture.

Oxidation: A chemical reaction promoted by oxygen and moisture in the air. On steel or iron based materials it presents itself as rust. For our purposes it is a film on the surface of the base metal that inhibits or stops solder flow.

Radiated heat: In the oven heat zone the radiated heat is generated by the elements through the muffle from all sides and transferred to the carbon fixture. The intensity of this radiant heat is determined by the oven temperature and the relative size of the muffle.

Re-flow: The application of sufficient heat to bring on flowing of solder previously applied and solidified. Pre-soldered items being solder in an assembly can re-flow inadvertently if fresh solder is applied on or too closely to these previously soldered joints..

Slump: The relative tendency of paste solder to flow with gravity and away from a joint if placed on an angle or in the vertical position.

Soldering: A joining process where a non ferrous (no iron) filler metal is heated to melting temperature and distributed between two or more close fitting parts by capillary attraction. The filler metal reacts with and melts a thin layer of base metal to form a strong joint after cooling.

Solder paste: A fusible metal alloy of gold, binders, and filler materials in a paste form used for joining individual pieces together to form a finished piece of jewelry.

Wetting agent: A substance used to lower the surface tension of a fluid (flux).

Solder training

Solder Initial

New employees:

1.

<u>Initial overview</u>	<u>Terminology</u>	<u>Quick Concept</u>
What they will be doing.	Glossary	Soldering, brazing,
How.	Common terms in solder,	What happens, Why.
What's expected.	in general, and industry	
	wide.	

2. Two weeks later.
(Will have some acclimation to the job, will have questions and will understand more of what is being taught.) For old timers too.

Solder Types: Yellow, White, Silver
10k, 14k, 18k, Sterling.
Conditions that can have adverse effects on solder paste.

Solder training

Metal types:	Yellow, White, Silver 10k, 14k, 18k, and heat treatable alloys Their differences, and how solders can affect them.
Castings:	Yellow, White, Silver 10k, 14k, 18k, Sterling. Their differences, the potential problems in soldering, how solder can affect the castings.
Tools:	Needles, syringes, air gauges, air pressure, fixtures, carbon boards. How to use these tools, how to care for them, how to identify problems with tools, using the right tools for the job.
Department hygiene:	Why no eating on the line, the importance of clean tools, benches and clean parts in the soldering process.

Solder training

Soldering concepts: Developing a broader understanding.
A more in depth and thorough instruction on the soldering process, and how they affect it.

What's important:

Attention to detail.
Reporting anything unusual.
Clean parts.
Good solder mix applied.
Time and temperature.
Excess and insufficient solder.
Joint types, the differences, the pluses and minuses of each type.
Joint gap size and it's effect on joint quality.
Fixture and carbon board importance, how to identify potential problems with solder joint gap size and worn boards.

Name:______________________________

Score:______________________________

Exam:
Oven soldering and monitoring.

Instructor:

All the questions can be answered from readings in the booklet assigned to you and job related experience.
This exam will help us all to understand where we have to concentrate our efforts in training you for this position.

Instructions:

The questions are set up as both multiple choice and compositional, in some cases a single question uses both formats.

Some questions may have more than one correct answer, choose the most appropriate.

Circle the appropriate answer on all multiple choice questions.
When a written answer or explanation is required, write the most appropriate answer or explanation within the lines.
If more room is needed, turn the page over, identify the question and finish the answer.

If you feel you would rather answer these questions orally, please let me know.

Relax, take your time, and use your best judgement.

Solder/oven operations

1. Yellow gold parts running a 3 inch spacing at 1575F comes out with pieces melted. What do you do?

    a. Slow the belt speed.
    b. Increase the belt speed
    c. Reduce the mass for all boards.
    d. Reduce the mass on that individual board.
    e. Increase the mass on that individual board.
    f. None of the above.

Why:

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2. White gold parts running a 5 inch spacing at 1575F comes out with the joints cold . What do you do?

    a. Slow the belt speed.
    b. Increase the mass on that individual board.
    c. Reduce the mass for all boards.
    d. Reduce the mass on that individual board.
    e. Increase the belt speed.
    f. Decrease the spacing.

Why:

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3. What is re-flow?

   a. A negative pressure through the oven.
   b. The addition of solder paste to an item by solderers.
   c. The sign of a cold solder joint
   d. An already soldered joint that re-melts and flows again.

4. What is a cold joint, how is it identified?

   e. A soldered joint that has been left in the open air.
   f. A grainy solder joint.
   g. A smooth well bonded solder joint.
   h. A solder joint that has not been exposed to enough time in the heat to flow properly.

How is it identified, what does it look like?

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4. What do you look for in the pieces when you feel pieces are running too hot?

   a. A clean, shiny appearance.
   b. A clean dull appearance.
   c. A frosted, crystalized appearance.

5. What is the purpose of dummy boards in the oven?

   a. To give the appearance of a full oven load of work.
   b. To keep the oven temperature down below what the thermostat is set for.
   c. To keep the oven temperature as steady as possible.
   d. To help clean the oven.

Describe any other reason you may have.

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6. How do you control the flow of water in the cooling jackets?

   a. Adding or subtracting dummy boards through the oven.
   b. By using tractor boards.
   c. By adjusting the water flow control valves on the oven.
   d. By putting paper towels on the cooling jacket.

7. Are there any special precautions you should take with pre-soldered items or items made of pinton gold?
   If so, what are they.

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8. What is the purpose of the "tractor" boards.

   a. Tractor boards are used to adjust mass running through the oven.
   b. They are used to keep the solder flowing in the boards.
   c. They are used to push the production boards through the exit curtain.
   d. They are used when regular dummy boards are not enough.

How often should they be used? ______________________________

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9. If conditions were ideal, when should solder flow?

   a. As soon as it gets into the heat zone.
   b. Just after it gets into the cooling jacket.
   c. Just before it gets into the cooling jacket.
   d. Just before it exits the oven.

10. Describe what happens as soldered pieces run through the oven and into the cooling jacket.

11. What temperature difference should you feel from one end of the cooling jacket to the other?

a. Ice cold near the heat box and cool by the exit curtain.
b. Too hot to touch by the heat box and ice cold by the exit curtain.
c. Warm from the heat box to the exit curtain.
d. Warm by the heat box and progressively cooler towards the exit curtain.

12. What could cause solder to appear smeared on leverarms?

    a. Cold joints.
    b. Insufficient solder.
    c. Incorrect board spacing.
    d. A board cover for that item that has shifted.

13. When first coming on shift or when first starting in the oven room, what should you do besides checking the oven and dissociator temperatures?

    a. Check the floor for broken boards.
    b. Make sure all the windows are open.
    c. Check the belt speed.

Can you think of anything else?

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14. How important is good communications between operators and shifts?

    a. Not very important.
    b. Kind of important.
    c. Very important.

15. Why is there spacing between boards?

    a. To take up enough time to get more boards to put in the oven.
    b. To adjust the mass running through the oven and insure quality joints.
    c. The boards are expensive, we need to use them all.

Why does it sometimes vary?

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16. What is the proper thickness for the dummy boards used in the blue oven?

    a. One quarter inch.
    b. Three eights inch
    c. One eighth inch.

18. What is the standard belt speed on the blue oven?

    a. 3 inches per minute.
    b. 10 inches per minute.
    c. 6 inches per minute.
    d. 7-1/4 inches per minute.

Is there any other standard belt speeds used on the blue oven?

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19. Where is the emergency stop for the belt on the blue oven?

    a. In the gold room.
    b. outside the oven room door.
    c. On the panel in front of the green oven.
    d. By the exit screen on the blue oven.

20. How often should you check solder joint quality?

    a. Once a day.
    a. Three times a week.
    b. As often as possible.
    c. Only if the solderers don't check.

21. Write your reasons for checking solder joint quality.

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22. Where should new information about board spacing, or mass through the oven be posted?

    a On a sheet of paper left on the oven.
    b On the chalk board.
    c In your locker for use the next day.