FURNACE BRAZING: A PRACTICLE OVERVIEW OF PRODUCTION

by

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Abstract

Tips and techniques for improving the efficiency and lowering the cost of jewelry assembly through furnace brazing. From fixtures and solder selection, to product design and furnace settings, this paper will discuss the necessary steps for producing high quality, high volume gold jewelry items in an atmospheric belt furnace.

Introduction

Today's manufacturing environment requires products to be delivered with low cost and high quality. Furnace brazing, or more commonly known within the industry as oven soldering , is one method of achieving these goals, by lowering labor costs, lowering product weights, minimizing defects, and producing high volume within a short manufacturing cycle. The production efficiency of furnace brazing is well documented, and the potential cost savings are substantial.

The average carbon fixture is five inches wide be six inches long, holding about 50, 6x8 millimeter findings. These fixtures can hold as many as 250, 4 millimeter ball and posts, or as few as eight bracelets. Running one board of findings through a furnace every two minutes, soldering some 50-75 pieces per board, will produce 1500-2250 pieces per hour, utilizing one oven and five to seven lightly trained people.

The basic principle behind the atmospheric furnace is to replace the ambient air inside the heating chamber with an inert gas, providing an oxygen free soldering environment. Most atmospheric furnaces utilize “cracked ammonia” to generate the inert atmosphere. Gaseous ammonia (NH_4) is broken down into its component parts of nitrogen (N) and hydrogen (H) through the use of a dissociator. The nitrogen, being heavier than the ambient air, forces the lighter gases up and out of the heating chamber, while the hydrogen combines with free oxygen, leaving a relatively oxygen free atmosphere. Soldering within an inert atmosphere produces bright, tarnish free results, minimizing or eliminating the need for cleaning and polishing after assembly.

Furnace settings

Before introducing material into an oven, basic parameters must be set. This seemingly simple step is the major cause of defects when furnace brazing. A proper balance between temperature and belt speed is essential for defect free soldering. As a benchmark, the oven temperature should be set at 100 degrees Fahrenheit above the flow temperature of the solder.

When using carbon fixtures, a superheat of 150^{o} F should be used. Although the characteristics will vary from oven to oven, a good starting belt speed is about 10 inches per minute, beginning with 8 inches per minute when using carbon fixtures.

The weight and cross section of the piece to be soldered need to be considered when setting the belt speed. Pieces with large cross sections require more time in the heating chamber and therefore a slower belt speed is needed. Proper solder flow requires both the solder and the finding to be at the flow temperature of the solder. Failure to fully heat the finding to this temperature will prevent the solder from "wetting" or adhering to the piece. The most common example of this is when two pieces of unequal weight are being joined and the solder flows on only one side of the joint. Inefficient heating time allows the solder and the lighter side of the finding to reach flow temperature, while the heavier side remains below the critical flow temperature, causing the solder to adhere to only the hot of the joint.

Longer heating cycles are also necessary when using fixtures. Fixturing materials draw heat from the furnace, slowing the heating cycle. Therefore lower belt speeds and somewhat higher furnace temperatures are required.

When belt speeds are too slow, the surface of the finding can become matte. In the case of thin walled hollow findings, the piece can distort or collapse from the excess heating caused by a slow belt. Slow speeds can also cause solder to boil, producing "pitted" joints, scarred pieces, and excess solder flow. These subjects and their remedies will be addressed later in this paper.

Utilizing the initial settings, belt speeds are adjusted after reviewing the results of a first trial pass. Remember, always send an empty carbon board or two into the furnace before beginning any sequence of boards. This allows the furnace to compensate for the heat loss caused by the fixture. If the solder fails to flow completely, simply slow the belt speed and run another trial. Repeat as necessary. If the solder flows on the first run, test continually faster speeds until the solder fails to flow, returning the speed to the last successful setting. This method identifies the fastest most efficient speed, and reduces the negative effects of over heating.

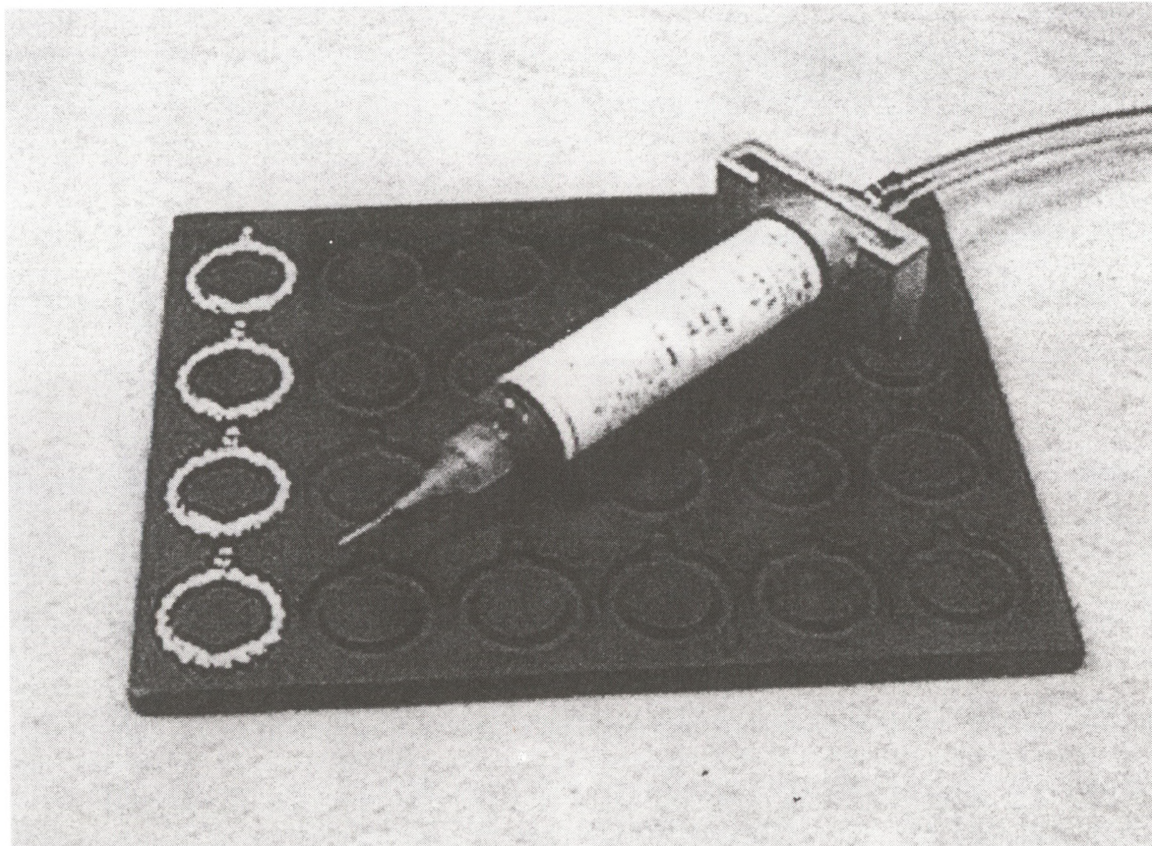
Fixtures

The first challenge, when furnace brazing, is keeping intimate contact between the pieces being joined, while allowing them to expand during the heating cycle. To help compensate for expansion, and hold the items together while in the furnace, a number of methods are employed. Each of these methods has its own advantages and disadvantages.

Bailing wire is the simplest method, and is predominantly used to hold stamped hollow shells together. To begin, the two halves are formed and faced off, smoothing and leveling the edges and insuring intimate contact along the entire seam. Paste solder is dotted along the inside edge of the upper shell and the pieces are bailed in place using a length of copper wire. The wire allows three dimensional thermal expansion of the piece, while holding the seams intact. Unfortunately, the wire is often soldered to the piece requiring it to be cut away and the remaining wire buffed off, adding excess labor and finishing costs.

To avoid adhering the wire to the piece, steel clips may be employed. The clips hold the hollow shells together, while avoiding contact with the seams. Therefore the risk of joining itself to the piece is eliminated. The clips are simple to use and, unlike the bailing wire, are reusable. The clips however, must perfectly conform to the piece, keeping even pressure across the seam. Many different clips may need to be designed to allow the soldering of different sized and shaped findings. In addition, clips need to be stamped and formed. This requires custom tooling, making them less practical for low volume items.

Another method which may be used is tack welding. Tack welding has been well covered in past symposiums, and it too has its applications in oven soldering. It is best suited for holding heavier findings together during the heating process. One disadvantage this method is that each different configuration will need its own unique settings. Tacking can also



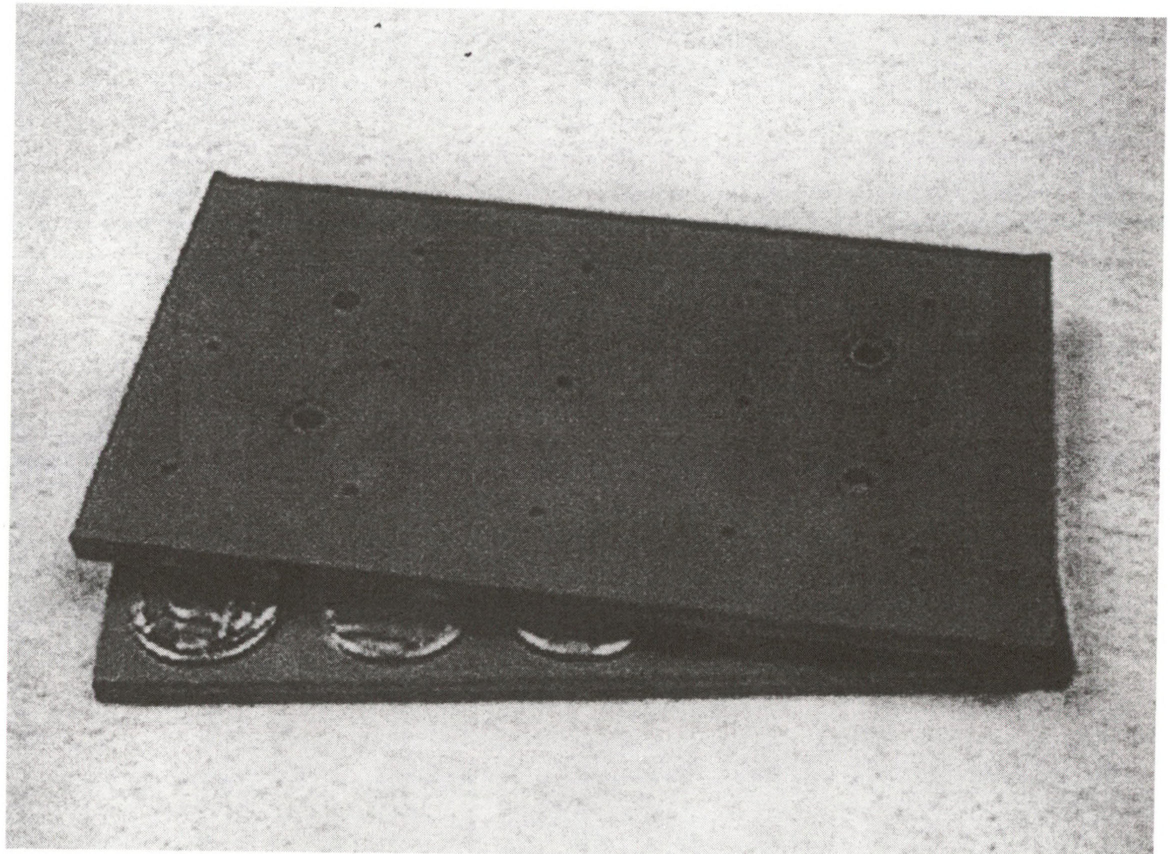
A CNC machined carbon board and paste solder.

scar the piece, making additional finishing necessary, and there is always the potential of melting the piece beyond repair. In addition, because the operation of the welder is technical tacking requires extra training and higher skilled labor. Fixturing boards however, such as carbon boards, require little training to use and produce excellent results.

There are two types of fixturing boards, soft and hard. The soft fixturing boards come in three main types dry, dry hardened, and wet. Soft boards allow the use of custom fixtures with very little setup time and low cost. Impressions are pressed into dry boards and they're ready to use. This allows furnace trials of prototypes, short run jobs, and one of a kind pieces to be oven soldered with little preparation, expense, or preplanning. However the extreme softness of these boards limits their reusability because the tolerance of the impression decreases with every use, quickly rendering the board obsolete as a fixture.

Hardened dry fixturing material solves the problem of the rapid loss of tolerance. These materials accept an impression like the dry boards, but can be hardened with the application of a liquid. The extra rigidity keeps the impressions intact for hundreds of re-uses when properly handled. These boards are more expensive than their dry counterparts, but can be extremely cost effective through re-use.

Three dimensional CNC machined carbon is best when tight tolerances are necessary and longevity of the fixture is required. A properly designed carbon board is the ideal fixture for mass production. The versatility of three dimensionally machined carbon boards allows many extra options the soft boards cannot. They allow for two dimensional heat expansion, double decker applications for right angle soldering, and multi-joint soldering, in a single pass through the furnace. Machined carbon fixtures are expensive to manufacture and require time to produce, yet are cost beneficial in high volume operations.



A double decker carbon fixture with post holes in top.

Solder Selection

Solder selection is perhaps the most important part of furnace soldering. Pre-soldered material, such as solder flush sheet and solder cored wire, offer the advantage of simplicity and ease of use, along with reduced assembly steps. However the burdens of using solder bonded material outweigh the benefits. The cost savings of labor reduction are lost to the increased refining costs and increased inventory requirements associated with the inability to recycle these materials in house.

The most flexible combination of solder and material is the use of standard karat gold and paste solder. When karat gold stock is used, stamping scrap from the forming operation can be re-melted with fresh metal to produce additional sheet to feed the stamping line. This reduces refining costs. Paste solder increases the speed and efficiency of solder application. The paste solder clings to the joint, staying in place in the oven and flowing into and along the seam forming cleaner neater joints. When necessary, paste solder can also contain flux, delivering the chemical directly where it is needed, in one simple step.

Far too often when selecting a solder, “easy” solders are assumed to be the best or “easiest” to use in assembly, when in fact this is often not the case. Easy flow solders may offer low melt temperatures, but often have wide melt flow gaps and less flow control than harder, or higher melting, solders with narrower melt-flow temperature gaps. Moreover, it is often incorrectly assumed that lower karat solders have lower melt temperatures and this assumption can lead to karat problems, especially in light weight items where the solder to finding weight ratios are high.

Where solder control is necessary, restricted flow solders are most desirable. The ability to keep the solder within the joint or seam reduces or eliminates the finishing time required. It also relies less upon a color match between the solder and the piece. Choosing a solder with a small melt-flow gap will help control the flow of the solder by reducing the time a solder must be kept above its melt temperature. This may lead to the use of a solder with a somewhat higher melt temperature, but can often solder a piece utilizing faster belt speeds and boosting production, while increasing the quality and lowering finishing costs.

Soft solders are necessary when step brazing is employed. However, step brazing can often be avoided through carbon jig design, allowing multi-joint soldering in one step. Avoiding extra production time is always desirable. When step brazing, a hard solder is employed in the first soldering operation followed with a softer or lower temperature solder in the second assembly step. This allows the soft solder to flow, while keeping the integrity of the first solder joint intact. During the second soldering operation it is necessary to lower the furnace temperature and in many cases, slow the belt speed. Far too often, step soldering is attempted with the same furnace parameters for each step. This causes excess solder flow in the second assembly step, re-flow of previously soldered joints, and failed pieces. In most cases this failure is attributed to "bad" solder, and not contributed to poor planning or improper furnace parameters.

The gap between melt and flow temperature must always be considered. Wide melt-flow gaps can cause serious problems during furnace brazing operations. During the time necessary to heat the solder from its melt temperature, or solidous, to its flow temperature, or liquidous, the solder may start dissolving the finding. This scars the piece requiring polishing out or possibly scrapping the piece altogether. Small gaps flow the solder shortly after melting, reducing the chance of scaring and effecting greater control of solder flow within the joint.

When planning a soldering operation for a belt furnace, the temperature limits of the oven must also be considered. The standard oven has a maximum operating temperature of about 1800 degrees Fahrenheit, limiting the solders to about 1650^{O}F. This is why platinum soldering cannot be performed in an oven.

When positioning the paste solder on a piece, care should be taken to use only enough solder to fill the joint. Excess solder adds extra weight and expense while increasing the risk of overflow and additional finishing. Solder should be placed in recesses when possible and, in a best case scenario, solder recesses should be designed into the piece during the design phase. When two hollows are soldered one atop another, the solder should be positioned under the top piece, ensuring a good bond and a hidden joint. Small solder recesses are frequently designed into the receiving piece to facilitate the solder charge.

When solder flow needs to be strictly controlled, for example, chains, bracelets, and moving charms, restricted flow paste solder systems are used and a stop flow may also be necessary. When the chance of "freezing" a moving joint is possible, extra care must be taken. Unlike bench soldering, there is no way to "eye" the joint and remove the heat at the exact moment the solder flows, preventing it from flowing into unwanted areas and freezing the pieces designed to move. Therefore, a stop flow agent may be necessary to keep the solder confined to the areas it is intended. There are many such commercially available agents, however I have found milk of magnesia to work well as a stop flow agent, rinsing off with simple warm water leaving no visible marks on the soldered piece.

When trapped air or an imperfect atmosphere prevents a solder from flowing the use of a flux may be necessary. A good indication of the presence of oxygen in an oven is when a paste solder turns to powder or forms a crust in the oven. This is often accompanied by a dark oxide layer or tarnish around the solder. As a first step, before resorting to a flux, check the dissociator settings because the use of fluxes in an oven can be a double edged sword. Atmospheric furnaces are not designed to be used with fluxes. The chemicals, being reactive by nature, can cause irreversible damage to its internal parts. This undesirable side effect can shorten the life span of the heating elements causing extra maintenance, expense, and increased down time.

Fluxes are a necessary component in soldering operations where trapped air cannot be expelled by the furnace and therefore must be chemically removed. Examples of this include large domed pieces, and capping a tube. Some commercially available paste solders require fluxes to flow, eliminating the no-flux option regardless of the soldering operation. These solders should never be used when a flux is not required to eliminate oxygen, avoiding unnecessary wear to the furnace. In addition to the danger flux may pose to the internal workings of an oven, the flux can ball up after soldering and remain within a hollow piece causing a rattle, or in some extreme cases add enough excess weight to lower the overall karat of the piece.

Design

Trapped air can also distort a piece. Expanding when heated, the trapped air causes excess pressure within a hollow, and distort the finding while searching for a way out. One option for eliminating the trapped air without the use of a flux is to design a small hole in the dome, allowing the air to rise from the hollow. The hole is placed in a position where a finding, such as a clasp or pin will be later soldered to the piece covering the hole.

Summary

Furnace brazing, when performed with a well designed fixture and the appropriate paste solder, can substantially reduce the assembly and finishing costs of many jewelry items. The reduced need for skilled labor and lower man-hours, coupled with the cost savings of higher quality finish and reduced finishing costs, greatly improves the efficiency and productivity of jewelry assembly operations. Producing higher quality jewelry and findings with greater throughput and lower cost.

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