BI-METAL CASTING TECHNIQUES FOR JEWELRY APPLICATIONS

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Abstract

The casting of one metal onto another (bi-metal casting) is not a new technique. It has been successfully used in the dental industry for over 30 years. As there are different alloy systems being used for dental castings, the technique and results are only partially applicable to jewelry manufacturing.

This paper addresses the pro's and con's of bi-metal castings, discusses the best alloys for this techniques and provides practical advise, which will give you the ability to successfully employ these techniques in jewelry manufacturing.

Keywords

Casting, technique, soldering, sintering, puddeling, bi-metal casting, alloys, understanding, industry, design jewelry, annealing, manufacturing, metallurgy, investment, burn-out, oxidation, de-vesting, newly developed, advantages, practical advise

Introduction

The manufacturing jewelry industry is constantly searching for new ways and methods to manufacture or fabricate creative jewelry. It is especially favored among designers to combine different metals or alloys together in the creation of jewelry.

To do this, several techniques are employed. Besides the mechanical connections, such as rivets, screws, pins etc. more permanent connections are used, such as soldering, brazing, welding, puddeling and sintering techniques. Exotic methods, such as mokume gama are highly labor-intensive and are useful only for small productions and single, one-of-a-kind pieces.

Today, creative metal stock, such as two and three color sheet stock are made available in strips and pallets through the gold- and silver refinery.

As these newly created materials allow for new and creative design possibilities, one is also bound by the basic design of this material and thus limited. A "new" technique to bring different metals together could be bi-metal casting. Having been used sparingly in the industry, this technique has not been proven to be as successful as could be hoped. However the reasons for this are not economical, but a knowledge deficit in metallurgical and technical understanding.

The fact that bi-metal casting can be used very successfully, is proven by the dental industry. Here this technique has been employed for years with great success in the creation of dentures and other prosthetic construction elements. In this industry, soldering and bi-metal casting are in direct competition. The technician can decide which technique to employ.

In the industrial area, bi-metal casting is used to create strong multi-metal materials for specific applications. It is possible to combine the different characteristics such as durability, heat-conductivity and corrosion resistance of the two metals and create a useful and special material.

With this paper I will explain the fundamental metallurgical events and discuss the problems and solutions as they apply to bi-metal casting.

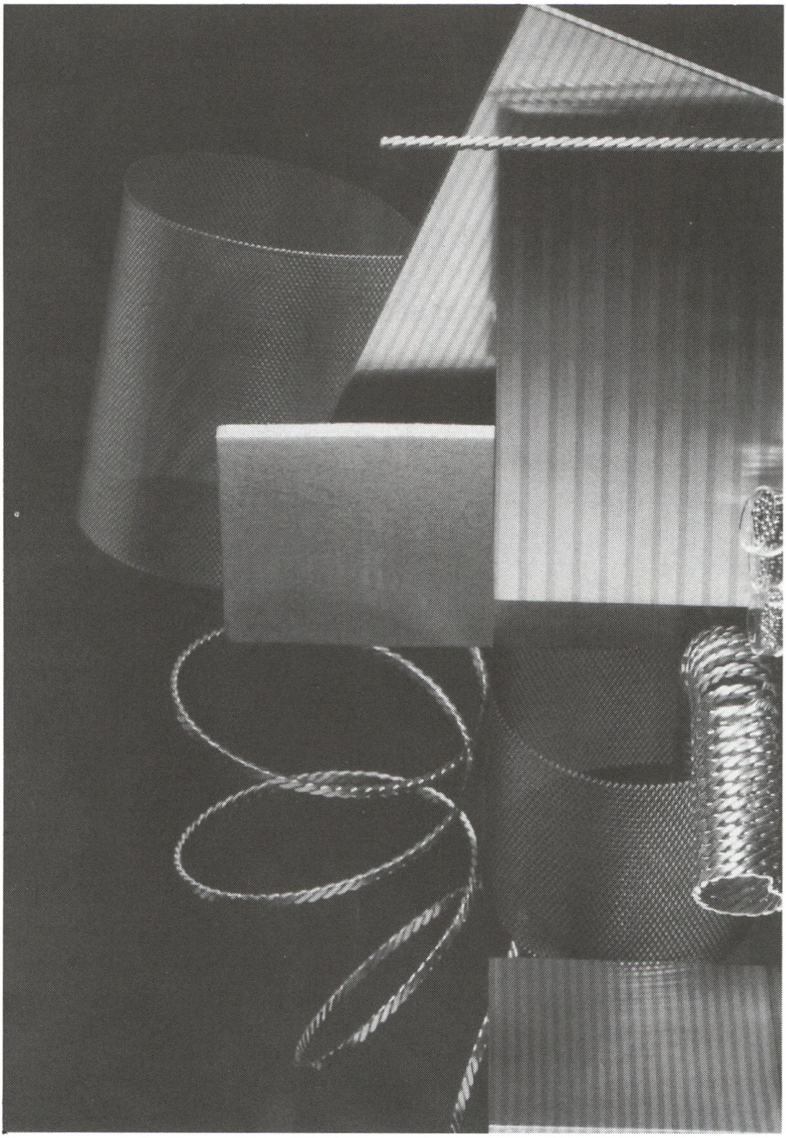


figure 1: creative semi-finished products

Consideration of permanent connections

Method	Advantages	Disadvantages
soldering	• Simple gold smithing technique • Can be done in any workshop • No investment in expensive equipment required • Any combinations of alloys • Any size part can be soldered	• Visible, often porous seam • Seam subject to corrosion and/ or oxidation • A limited number of parts can be soldered • May need to be plated • Long seams require Cd solder (toxic) • Solder seams without Cd tend to come undone • Not permanent
puddeling	• Simple gold smithing technique • Can be done in any work-shop • No investment in expensive equipment required • No visible seam • Permanent connection	• Not all shapes can be realized • Partial drilled or burred areas fill • Not all alloy combinations can be used (YG/RG-WG possible)
sintering	• All alloys possible • Any desired shape possible • No visible seam	• Time intense preparation • Expensive machine required • Permanent connection
bi-metal casting	• Small and large parts possible • Any desired shape possible • No visible seam • No plating required	• Technique requires effort • Casting „know-how" required • Not all alloys can be used (W in Y or R) • Large effort to determine castability

figure 2: advantages and disadvantages of version of procedure

Soldering and puddeling are the most commonly used connecting methods. These techniques can be done by the jeweler without the expense of complicated equipment.

Sintering, a relatively new technique, requires more effort. Investing in machines costing several thousand Dollars is necessary. The calibration and set-up for sintering machines requires more time, as does the preparation of the pieces to be sintered. It does however give the manufacturer a broad range of design options.

The advantages of bi-metal casting can be described in the following sentence:

The uniqueness of this technique is that one adds metals with a high melting point to a base of white, red or yellow gold. This can be done in almost any desired shape, without the creation of a visible seam, that may tarnish or oxidize, to create a permanent bond.

Any jewelry manufacturer with access to casting has the capability to learn and use this technique. Bi-metal casting may also be an attractive specialty for casting houses serving the trade

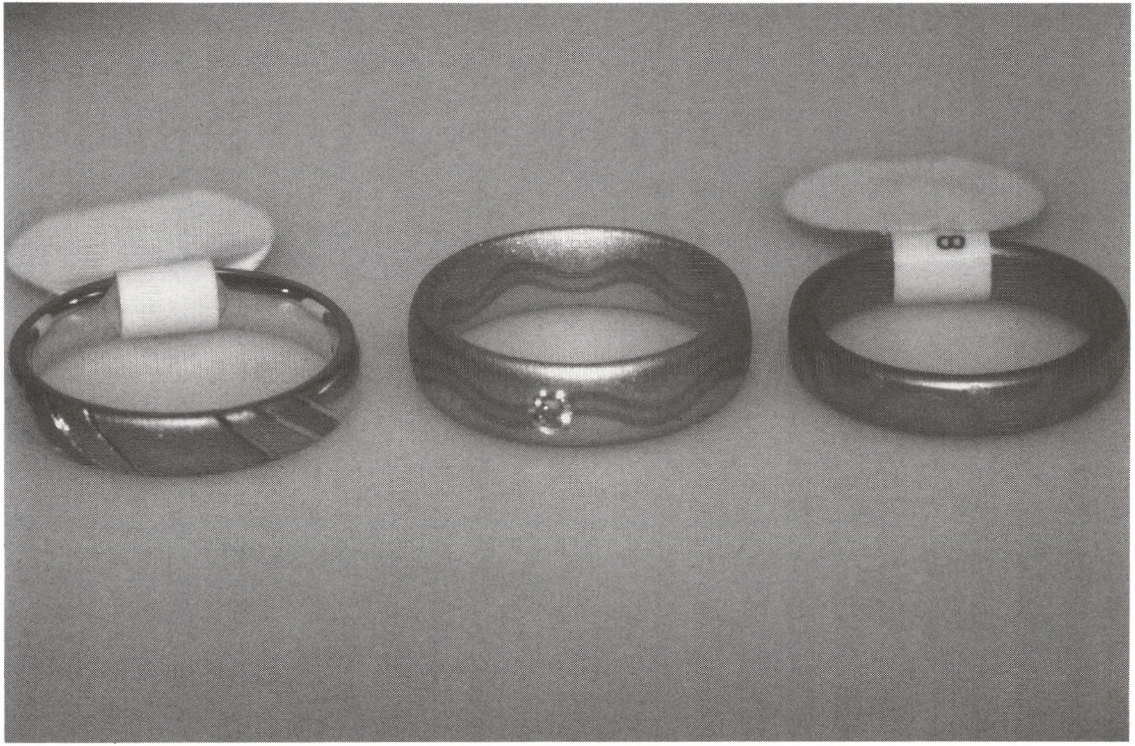


figure 3: samples of different connection technique, from left to right: soldering technique, sintering technique, puddeling technique

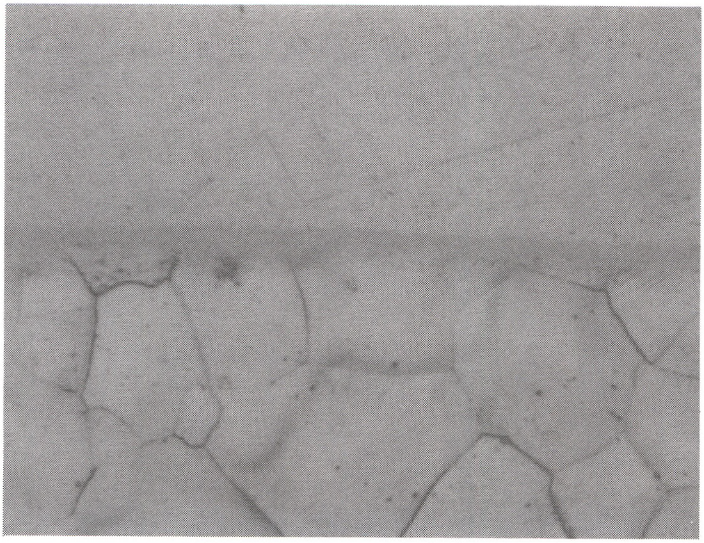
Basic metallurgical requirements

In bi-metal casting one is dealing with a surface reaction between a solid and a liquid phase. As the liquid meets the solid under the proper conditions, a permanent metallurgical bond is created.

1. It is necessary that a direct contact is created between the two metals. To accomplish that, both, the solid body as well as the liquid counterpart must be free of non-metallic layers, oxidation in particular.

2. The alloys used must be compatible or capable of creating an inner metallic compound. The thermal relationship should be such, that a good wetting of the metal structure takes place and an alloying takes place at the joining area.

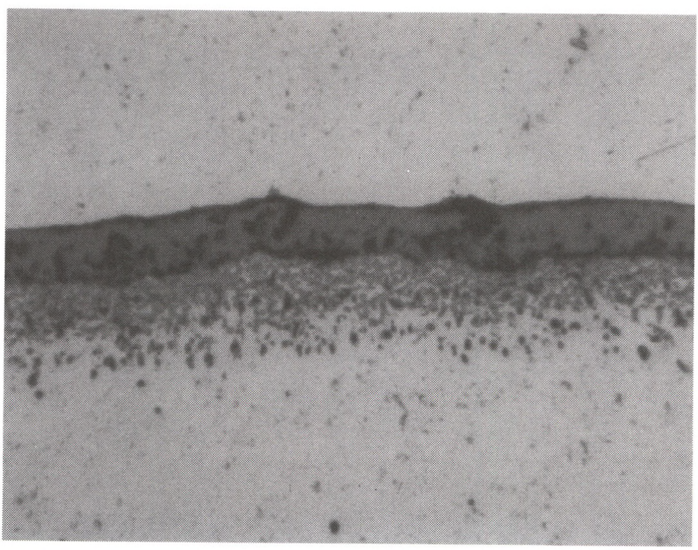
3. As to not make a spotty connection, the metal should not freeze immediately at contact, but stay in a liquid state for a short time. If additional force is applied by centrifugal or pressure casting, that time will shorten accordingly.



platinum

redgold

figure 4: (200:1) cross section of a good connection, between platinum/ copper and 18kt redgold



yellowgold

redgold

figure 5: (200:2) cross section of a bad connection, oxid layer between 14kt redgold and 14kt yellowgold

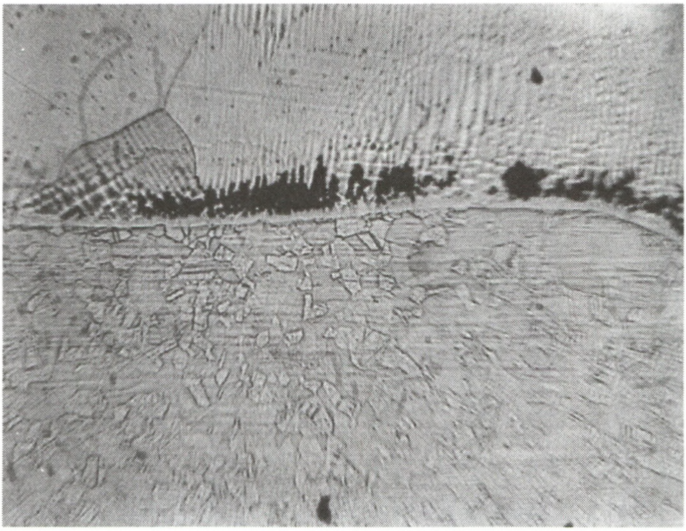


figure 6: (100:1) cross section, connection with porosity between 14kt whitegold and 14kt yellowgold

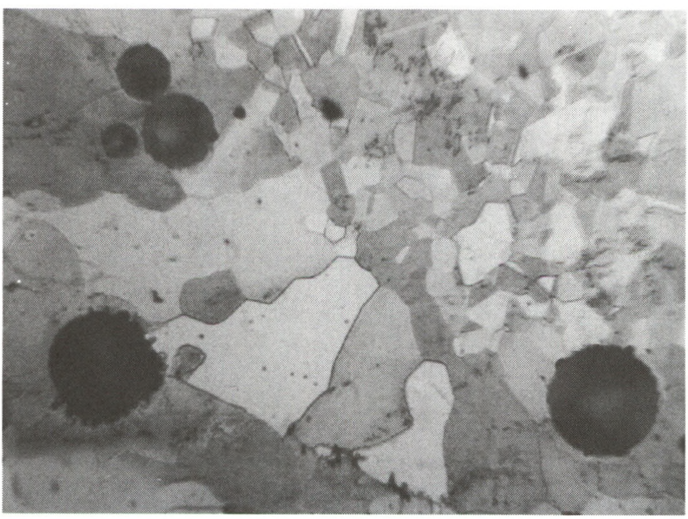


figure 7: (200:1) cross section, connection with gas porosity between 14kt yellow- and redgold

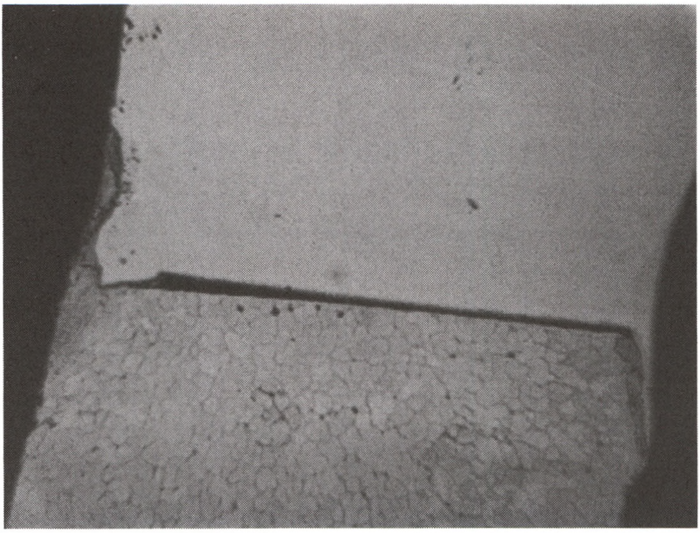


figure 8: (40:1) cross section of a bad connection, shrinkage crack between platinum/ copper and 22kt yellowgold

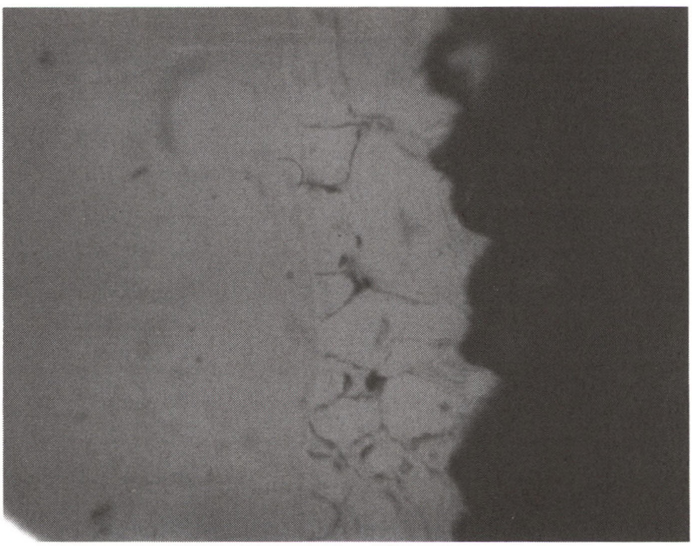


figure 9: (200:1) cross section of a failure surface, fracture in the cast metal

To fulfill the requirements for a clean surface, one can employ gaseous or liquid media. It is important to mention the surface coating with a flux that operates at a certain temperature range. Paste flux, based on borax (boric acid with fluoride additives) have been especially useful. There is also the option to galvanically coat the connecting surface. Useful are gold or silver plating's with a minimum coating thickness of 10-20μ . Additional help for the reduction of oxidation is a pre-heating of the flask under cover gas. Often this is not an option, as many casters do not have burn-out kiln that offer atmosphere control. If the bi-metal casting is done with a vacuum or pressure casting machine, the possibility to flush the already hot flask with a cover gas is given. This too will result in a reduction of oxidation at the contact surface.

One of the most important tasks in bi-metal casting , is to create and set a timely and localized, accurate temperature field at the connecting surface of the invested metal part. This will realize requirement two and three. The thermal parameters, such as the pre-heat temperature of the invested metal section as well as the casting temperature of the casting alloy, depend on the geometry of the piece to be made. The determining factor is the relationship: Mass/ casting metal of the piece (not the casting tree) versus the contact surface of the invested metal. During the casting process, the temperature of the contact surface of the invested metal has to increase to a point slightly above the solidus temperature of the casting alloys.

When there is a wet metal connection at the connecting surface, a good interface is possible. If the metals chosen are such, that there are problems with reaching this required liquid state, it is possible to overcome this problem by coating the connecting surface with a lower melting solder. This will then create the wet surface and makes a bond possible, using a far lower temperature.

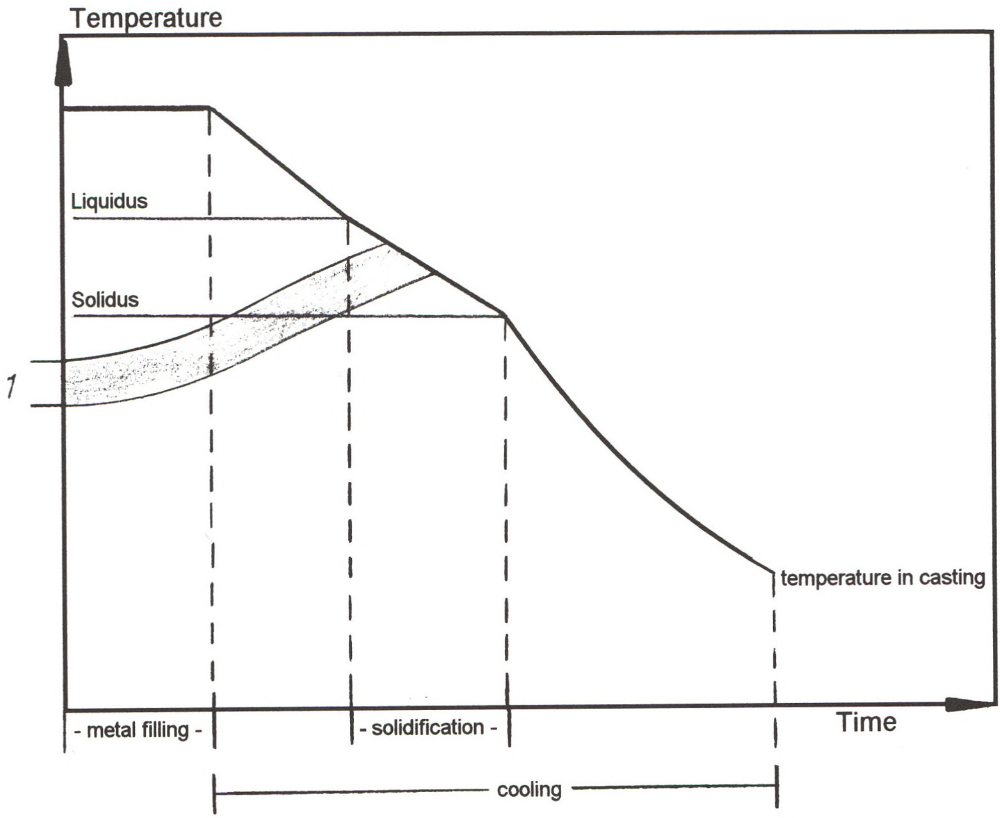


figure 10: showing temperature cyclus, starting with flask temperature (point 1) up to temperature over solidus

There are of course many other complex influences on the connecting surface, such as structure, stress, expansions and cooling considerations, which may influence the outcome. These areas, however, are not addressed in this paper.

Selecting the alloy combination

When selecting a suitable alloy for bi-metal casting, several points must be considered.

1. The alloys have to be able to blend together.
2. Jewelry alloys with low copper content are preferred. If a red/ pink gold is required, then the contact surface has to be plated for protection of oxidation.
3. The solidus temperature of the invested section has to be at least 50 - 100°C above the liquidus point of the casting metal.
4. Use casting alloys that have no complex characteristics.
5. Use alloys with similar expansion coefficient.
6. Use cold formed parts made of sheet, wire, tube for investing.
7. Alloys that absorb and release a lot of gas should not be used.

Technical information regarding each alloy should be obtained from your metal supplier.

Alloys containing silicon develop a lot less oxidation and are preferred. The oxidation that does occur is very thin, transparent and thus invisible. It is however capable to protect the alloy from a heavier oxidation. The thin oxide layer that is developing will be flushed away when the metals contact.

Platinum is ideal for bi-metal casting. Most platinum alloys do not oxidize and the flask temperature can be varied in a broad range because of the high melting point of Platinum. This is the reason why Platinum is the metal of choice for bi-metal casting.

Alloys that are absorbing and thus releasing a lot of gases during the cooling process are the source of many problems. When cooling, the casting metal releases gas. If the atmospheric pressure is less than the gas pressure, a bubble forms. During a normal casting, this gas will be carried through the investment and dissipate. Not so at the interface surface of a bimetal casting. Here the danger of a gas build-up can lead to gas porosity. This can lead to a weakening of the connecting area which can cause breakage down the line.

If points one through seven are fulfilled the bases for a successful bi-metal casting has been created. It is possible to cast precious metal alloys together with other precious metals as well as base metals.
It is always a good decision to do a test casting for compatibility.

Alloy	Melting range °c	Cu-content %	Expansion coefficient µm/m K (25-600°C)	Precipitation hardening yes/ no
14kt yellow	min.❶ 780 max.❷ 915	5 - 30	~ 20	yes
14kt red	min. 880 max. 940	35 - 40	~ 20,5	yes
14kt white	min. 960 max. 1270	1 - 10	~ 18	no
18kt yellow	min. 870 max. 920	8 - 13	~ 18	yes
18kt red	min. 870 max. 920	20 - 23	~ 18,5	yes
18kt white	min. 950 max. 1280	1 - 5	~ 16	no
Pd 950	1400 - 1300	2,5	~ 13	no
Pt 950 Cu	1745 - 1730	5	~ 10,5	no
fineplatinum	1770	-	9,6	no
finegold	1060	-	15,5	no

❶ the lowest solidus ❷ the higest liquidus

figure 11: alloys with an average of technical dates, based on alloys of C. Hafner, Comp.

Metal part	Melt
redgold	yellowgold
whitegold	yellow- and redgold
palladium	yellow-, red- and whitegold
platinum	yellow-, red-, whitegold and palladium

figure 12: alloy combinations proven successful for bi-metal casting

Planing a bi-metal casting

Important for the successful creation of a bi-metal casting is the proper planing and communication at several levels. It starts with the designer, the model-maker the caster and finally the bench jeweler in assembly. They all need a thorough understanding of the process and its dynamics.

The designer must be able to design a piece that is castable. For bi-metal casting, this means that the connecting surfaces should be as simple as possible. Simple geometric forms are better to realize than complicated ones. The caster, and not the jeweler should determine how to sprue the item.

Preparing the metal/ wax parts and tree

To ready a wax tree for investing, the pieces to be cast need to be prepared. The wax part and the metal part for the bi-metal casting need to be combined. This can be done in several ways. Just as one

does in casting stones in place, the metal sections can be simply pressed into the wax. Another method is to create a holding device inside a rubber mold, insert the metal into the mold and then inject the wax around it. The third possibility is to model the wax to the metal section by hand. With all three methods , it is important to remember to let the metal protrude 2-3/10th of a millimeter over the wax. This will guarantee that the metal is held in place by the investment after burn-out.

Of disadvantage are metal section which block or interfere with sprueing. In that case the use of hollow stock, such as tube sections, can be of help. The casting alloy will flow through the tube, which will heat it evenly, without interference of the filling process. This flow-through or flow-over as the case may be , has the positive effect of removing all non metallic particles and thus leaving a clean surface. It is possible in special cases to roughen the surface of the metal insert or install mechanical connectors to make the casting alloy adhere.

It is important to be clean and exact in connecting the metal to the wax and the entire unit to the wax tree. When the investment is poured, there can be no wax between metal and investment, as this may cause the metal to come lose during burn-out.

To create the proper thermal conditions it is helpful to place same or similar pieces on the wax tree.
Waxing the parts too close together is not advisable, as the heat radiating from the metal sections can negatively influence the piece too close. It is desired to have each piece at the same thermal conditions. This is difficult to do when one creates a complex tree. Best results are obtained when the unit is waxed to the tree at a 45° angle. The placement should be such, that the contact area wax/metal is 90° to the flow of the metal at casting. This will help with metalostatic as well as centrifugal forces during casting.

The attaching of the sprues to the tree should be done with care and the use of a hollow core center.
This will create a turbulence free filling during casting.

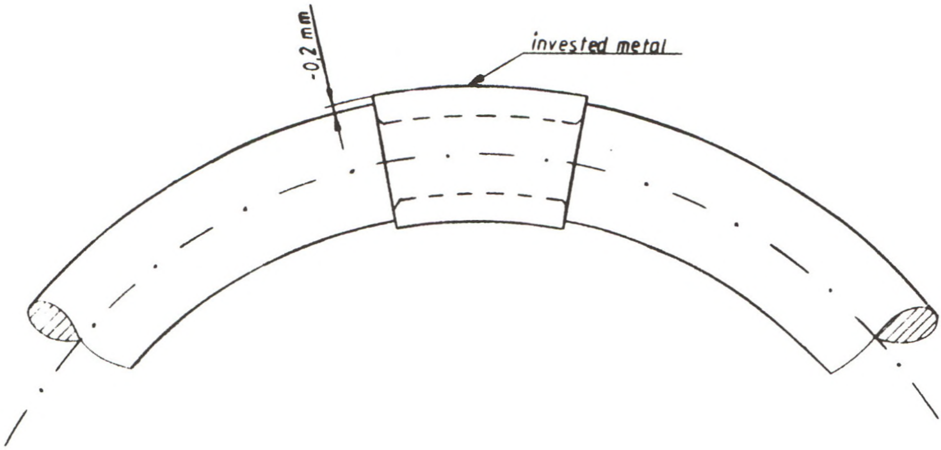


figure 13: ring sector with invested metal (tube form)

Investing and burn-out

To invest the wax tree for bi-metal casting, the regularly used gypsum or phosphate based investment powders can be used. When using a gypsum based investment, a 11 - 13 hr burn-out cycle is necessary. Phosphate investments can be burned out in 5 - 6 hours. These long burn-out cycles can be detrimental to the metal that is inside the flask. In the last few years in the Dental industry, so called "High Speed" investments were developed. These investments make it possible to cast in as little as 1 - 2 hours.

As regular investments are always burned out from room temperatures, these new investments start with a kiln temperature of about 900°C. This will then be cooled to the casting temperature in about 30 minutes and cast. The advantages of these systems that the inserted metal sections are not damaged by too long of an heat exposure. The disadvantage is, that only metals with a solidus point truly over 900°C can be used. A danger to consider is to not open the kiln door during the burn-out phase, as the wax vapors inside the kiln can ignite.

Investment powder	Advantage	Disadvantage
gypsum bonded	• reasonable in price • easy handling • in each foundry in stock • easy de-vesting	• longest burn-out cycle • max. temperature 730°C • not for Platinum, Palladium an White-gold with high melting range
phosphate bonded	• shorter burn-out cycle • temperatures over 730°C possible	• more raised price • harder, difficult de-vesting
speed investment	• shortest burn-out cycle • temperatures over 730°C possible • also possible to work under normal conditions	• raised price • cooling down to room temperature • very hard, difficult de-vesting

figure 14: comparison of different investment types

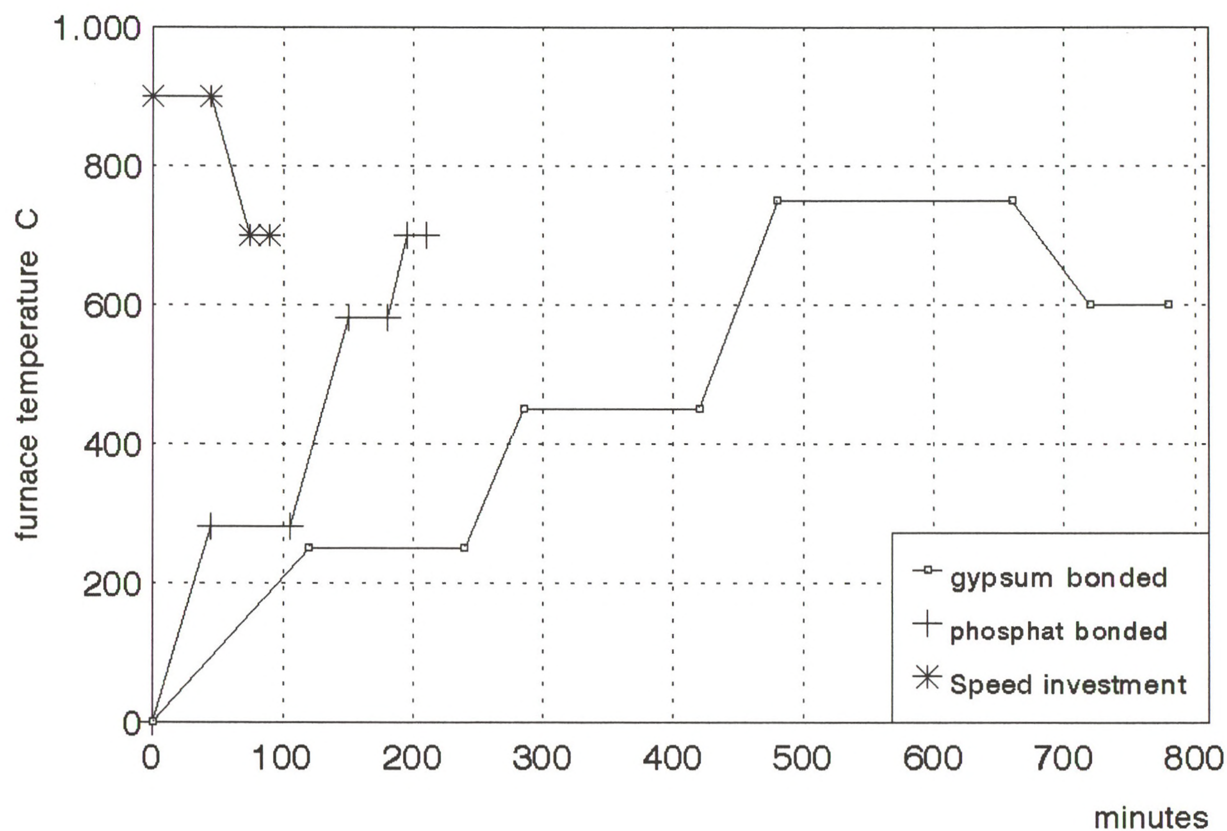


figure 15: flask burnout cycle

To reach the proper temperature requirements for bi-metal casting, it is very important to chose the proper flask temperature. This can be determined by experimentation. If the proper temperature has been determined for a particular piece, that information can then be used to estimate temperatures for different situations. For this, the following rules apply:

Metal part in relation to test casting	**Pre-heat temp**
Metal/ wax same, contact surface larger	=
Metal/ wax same, contact surface smaller	↑
Metal/ wax smaller, contact surface same	= / ↓
Metal/ wax smaller, contact surface larger	↓
Metal/ wax smaller, contact surface smaller	=
Metal/ wax larger, contact surface same	↑
Metal/ wax larger, contact surface larger	= / ↑
Metal/ wax larger, contact surface smaller	↑

Casting

To assure a controlled casting, a machine with a temperature measuring device is required to accurately determine the casting temperature. It is an additional advantage if the machine is capable to bring external force, such as centrifugal force or pressure to do the casting. Atmosphere control such as vacuum or cover gas are an additional advantage. The use of casting techniques without such controls, such as torch casting, is not recommended.

techniques without such controls, such as torch casting, is not recommended.

For bi-metal casting it is absolutely required to control all parameters exactly. For each alloy combination and volumes, the exact flask and casting temperatures should be logged and used exactly every time a casting is done.

If the casting temperatures are not exactly adhered to, it is possible to experience casting failure and the entire tree may be lost. If the casting temperature is too low, it is possible that the connecting surfaces do not bond. If the temperature is too high, the metal can create too big an interface area, or worse, be dissolving the metal that was to be joined.

The time the flask rests in the cradle in the casting machine before casting should also be constant. If these times vary greatly, the thermal conditions at the connecting surface will vary too. As the flask temperature has the greatest influence on the quality of bi-metal casting it is not advisable to leave this area uncontrolled. As I mentioned before, the main difference between casting and bi-metal casting, is that in case of failure in bi-metal casting the entire tree may be ruined. This is why it is imperative to use precise process control for this process.

Cooling and de-vesting

The cooling of a flask is a critical process. Three different materials, two different metals as well as the investment material, are cooling at the same time. This can lead to stress in the jewelry as well as cracking at the interface of the two metals.

After casting, the flask must cool to room temperature. Quenching can crack the metals at the interface and should therefore be avoided (thermal shock cracking). After cooling the investment is carefully removed. Hitting the button with a hammer should be avoided. The pieces are now sand blasted and cleaned. With a loupe or a microscope the interface surface is checked for cracks. This is important, as the cracks are usually hairline cracks and cannot be seen without magnification.

Additional treatments and finishing

If there are no cracks present, it is advisable to anneal the piece. This can be done with a torch or in a kiln. The annealing removed the build-up stresses within the piece, that may have been created during the casting process.

The casting can now be finished as usual at the bench. Any excess metal can be filed away and the pieces can be finished and polished as usual. If the colors are to expectation, additional plating is not required.

Economic considerations

The fact that casting is economical is without doubt. The advantages of bi-metal casting are being shown by comparison. Analytical testing of is only of value if all parameters are considered. These are:

- unlimited design possibilities
- economical manufacturing - the small additional cost for preparation is offset, as traditional fastening techniques are not required
- galvanic treatment is not required
- less material than assembled jewelry
- large quantities possible

Here is a typical work process for bi-metal casting. Each manufacturer can use this information to calculate their own and compare to traditional fastening methods.

work process for bi-metal casting

- fabricating the metal part by casting, die-striking, piercing etc.
- injecting the wax portion
- contact surfaces plating (if) needed, fluxing contact surface
- attaching the metal piece to the wax
- invest, burn-out,
- cast
- de-vest
- anneal
- finish, (sand blast, file, sand, polish etc.

Conclusion

If one considers the advantages that bi-metal casting offers, it is surprising that we don't see more manufacturers using this technique. This paper offered an insight into the metallurgical and technical requirements basics, that will help to simplify this process and practical application.
As it is a "know-how" intense process, each manufacturer needs to use their own experience to accomplish it. One should, however, not let a failure stop further experimenting, but an analysis of the failure should serve to increase the know how and be viewed as a learning experience. As we all know, even a routine regular casting is not always guaranteed to be perfect. It is hoped that this symposium as well as this paper are helpful tools in the combining of metallurgical theory and casting practice, and can be used to solve some of the problems that casting in general and bi-metal casting in particular represent.

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