A Review of Cast Platinum Jewelry Fabrication Methods

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Platinum alloys were commonly used in U.S. jewelry markets until platinum became reserved for strategic uses in 1942. During the following years, the use of platinum in the U.S. jewelry markets declined and platinum manufacturing skills and experience were lost to many jewelry manufacturers. Renewed consumer interest in platinum jewelry has put a strain on the ability of manufacturers to satisfy increased demand for new platinum products. Stuller Settings is committed to delivering the best quality products on very short shipment schedules and products are manufactured in a wide range of alloys. Under these operating conditions, it is imperative that the best alloys are selected for a particular manufacturing and product application.

Platinum-Ruthenium and Platinum-Iridium alloys have been commonly used in jewelry applications for many years while Platinum-Cobalt alloys are relatively new to the United States. Trials were undertaken to critically compare and contrast the behavior of a Pt-Co alloy with the behavior of Pt-Ir and Pt-Ru alloys in jewelry casting and finishing operations so that the best alloy could be selected for achieving Stuller's quality and customer service goals.

Metallurgy

In recent years, engineering alloys have become classified according to the processes that are used to fabricate finished parts. For example, stainless steel compositions that are classified in the traditional "300 series" for sheet, wire, bar, etc., have equivalent, but slightly different, compositions for products that are produced by investment casting. This requirement for differences in composition is a result of efforts to create alloys that develop the best properties and demonstrate optimum behavior in different types of manufacturing operations.

With the exception of a need for a deoxidizing addition to investment casting alloys, most precious metal alloys were not developed for investment casting versus cold forming applications. As a result, a manufacturer may be left to struggle to cast an alloy that was originally designed for use as sheet, rod, or wire. In 1978, Ainsley, Bourne, and Rushforth[1] evaluated a series of platinum alloys for their performance in investment casting applications. As a result of their trials, Pt-4.5% Cobalt alloys were determined to be superior for cast products over a wide range of product applications. This development effort was undertaken to supply an alloy for platinum jewelry distributed in Japan.[2]

Most platinum alloys consist of pure platinum alloyed with only one other element. These other alloying elements include iridium, ruthenium or palladium, which are also in the platinum group of metals. In contrast to this simplicity, karat golds might typically contain up to four elements, some of which are not in the category of precious metals. In metallurgical terms, platinum alloys are simple binary alloys. Many karat golds are complex, quaternary alloys.

Melting temperature and freezing range are important characteristics of alloys and must be considered in any manufacturing processes. Melting points and melting ranges of the platinum alloys used in this investigation are presented in Table 1.

The most important information in the table is the fact that the entire liquidus solidus melting range of Pt-Ir and Pt-Ru alloys is greater than the melting point of pure platinum. This is uncommon behavior for alloys. The melting point of most metal systems decreases as the concentrations of alloying elements is increased. Platinum cobalt alloys have melting points and freezing ranges that are less than the melting point of pure platinum.

Alloy	Solidus C	Liquidus C	Melting Range C
Pure Platinum	1773	1773	0
Platinum 10% Ir.	1780	1800	20
Platinum 5% Ru	1780	1795	15
Platinum 5% Co	1750	1765	15

Table 1: Melting Points and Melting Range of Platinum Alloy [3]

Fig. 1: Shrinkage in Pt-Ir alloy "marquise" setting at intersection of baguette prongs and galleries

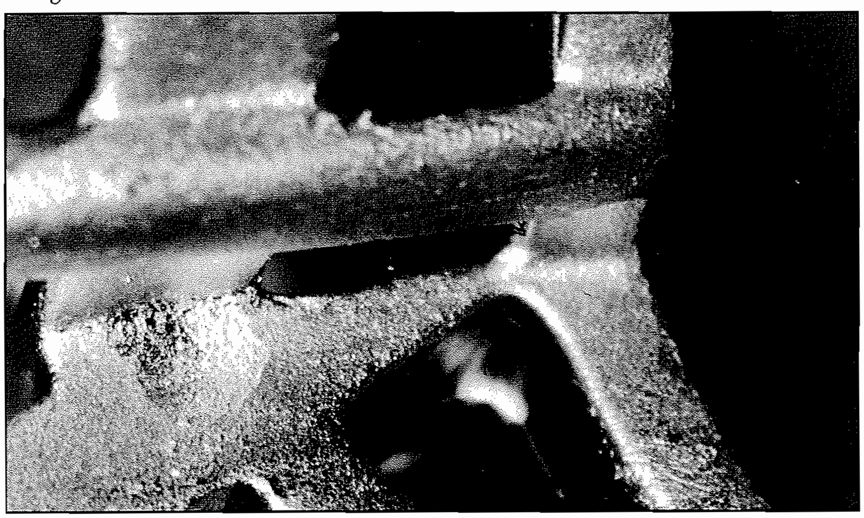

Fig. 2: Shrinkage in Pt-Ru alloy "marquise" setting at intersection of baguette prongs and galleries

Fig. 3: Shrinkage in Pt-Co alloy "marquise" setting at intersection of baguette prongs and galleries

Platinum and its alloys can be fabricated by the same basic methods that are used to fabricate karat gold alloys. Of course, consideration must be given to the much higher melting points of platinum alloys.

Investment Casting

Because platinum alloys melt at such high temperatures, special refractories must be used for molds and crucibles. In spite of a great deal of development effort, it appears that the most useful crucible and mold refractories will continue to be based on silica, SiO_2. The melting point of pure SiO_2 is 1710°C, mixtures of SiO_2 and Al_2O_3, alumina, start to melt at approximately 1825°C. Pure alumina will melt at approximately 2050°C.
The point of reviewing these melting points is to demonstrate that molds and crucibles used for holding molten platinum that is cast at temperatures in the neighborhood of 1900°C are being pushed to extreme limits of performance. Molds and crucibles used for casting platinum and its alloys are always on the ragged edge of failure. Any reduction in metal casting temperatures or increases in melting temperatures of mold and crucible materials are benefits for the platinum caster and represent opportunities to improve and increase process reliability.

Manufacturers worldwide are now using 95 Platinum-5 Cobalt alloy for investment casting. Cobalt is reported to improve platinum's fluidity, and thus leads to greater filling of the east piece.[3] The alloy is reported to be hard enough to make polishing an easier process and is reported to be the most popular European platinum casting alloy.[3] Platinum-5% Cobalt alloy is described as useful for casting a whole range of patterns from fine filigree to heavy section items and is more forgiving to changes in cross-section, thus reducing the chances for shrinkage and consistently producing quality castings regardless of part size. Table 1, indicates that Pt-5% Cobalt has a slightly lower temperature. This can allow the use of slightly lower temperature conditions during casting and retard reactions between crucible and mold materials. All these factors make Platinum-5% Cobalt a logical choice for casting operations.

Evaluation Trials

Two different styles of jewelry mountings were cast under the same conditions in the three platinum alloys that have been used at Stuller Settings. The alloys were Pt-10% Ir, Pt-5% Ru, and Pt-5% Co. Castings were finished with the same manufacturing processes to compare finishing characteristics. Both styles of jewelry selected for these trials were of two-piece construction. One style included a stone setting with V-prongs and side prongs for a large marquis stone and additional prongs for two adjacent baguettes. With its stone setting prongs, gallery, and thin, open shank construction, this piece was considered to be very typical of many popular jewelry styles. The other test piece was of two-piece construction, which required two different types of castings to be produced. The shank of the mounting was a smooth circular band with a rectangular cross section. The associated setting was a five stone, scalloped "fishtail." This test piece had heavier sections with their own particular casting process issues. The two-piece construction of

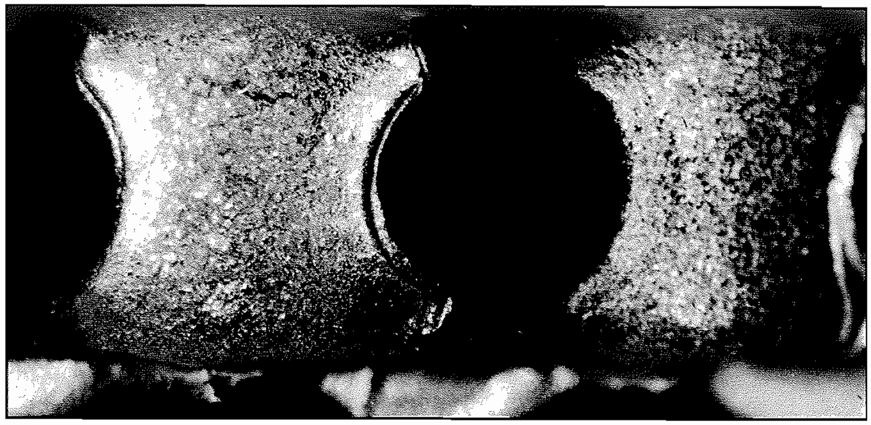

Fig. 4: Porosity in "fishtail" setting cast in Pt-Ir alloy

Fig. 5: Porosity in "fishtail" setting cast in Pt-Ru sprue post

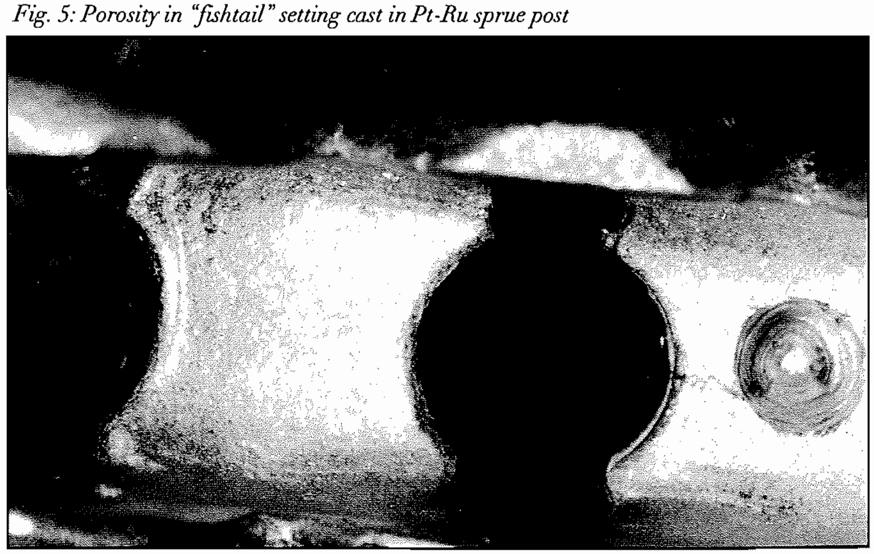

Fig. 6: Porosity of "fishtail" setting cast in Pt-Co alloy

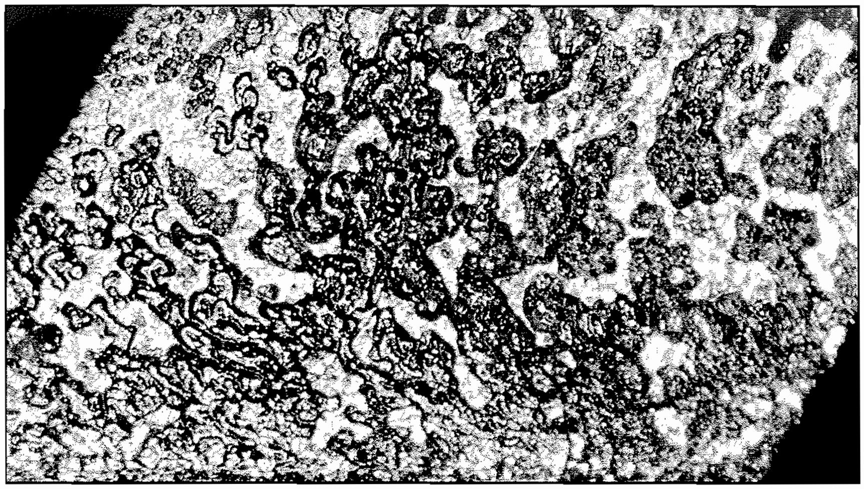

Fig. 7: As-cast surface of Pt-Ir sprue post

Fig. 8: As-cast surface of Pt-Ru sprue post.

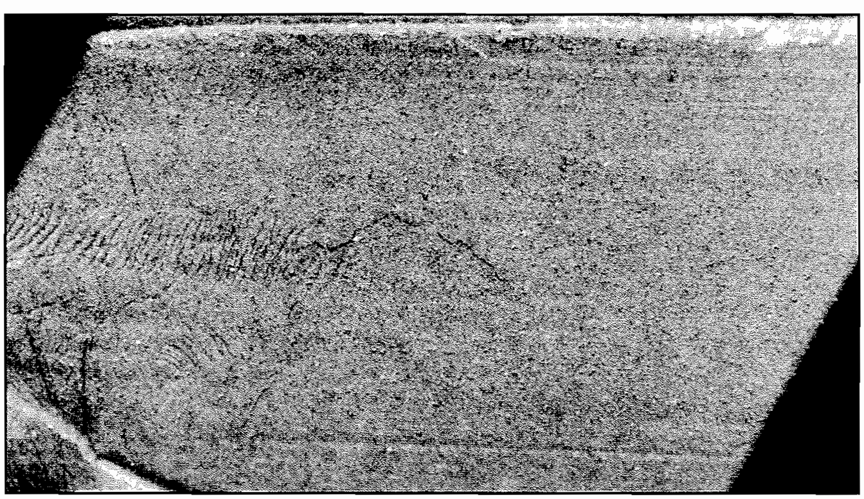

Fig.9: As-cast surface of Pt-Co sprue post

both styles created opportunities to evaluate soldering procedures.

Casting Operations

Pieces were set-up on hexagonal, tapered sprue posts and invested with a two-part phosphate bonded silica investment. The molds required for each alloy were prepared from the same investment mix. Molds were burned out with the standard schedule used for all platinum casting molds at Stuller:

1 hour at 300°F
3 hour ramp to 1400°F
1 hour at mold casting temperature

Molds were cast in a vacuum centrifugal casting machine at the same conditions used for production parts. Mold temperature was 1650°F and metal temperature was 1850°C, (3662°F). Metal temperatures were measured with an optical pyrometer to determine the proper moment to start the casting machine.

Assembly Operations

Stone settings and mountings were assembled by methods that are routinely used in Stuller's manufacturing operations. Surfaces of pieces were prepared by abrasive cleaning with files or buff sticks and tightly fitted to one another. A coating of zirconium dioxide was used on "fishtail" settings to prevent solder migration. 1500°C solder was used for all the alloys that were assembled in this investigation. A 70-30 Gold-Palladium solder formulated by Stuller was used. Natural gas and oxygen were used as torch fuel. After soldering, pieces were pickled in hot "Safety Pickle" and steamed, if necessary.

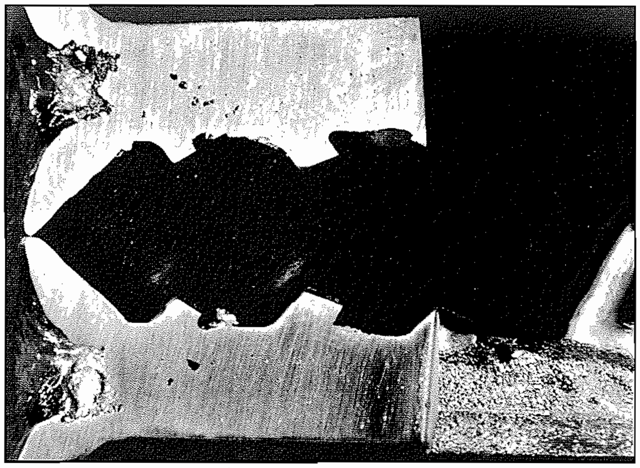

Fig. 10: Internal shrinkage in Pt-Ir sprue post

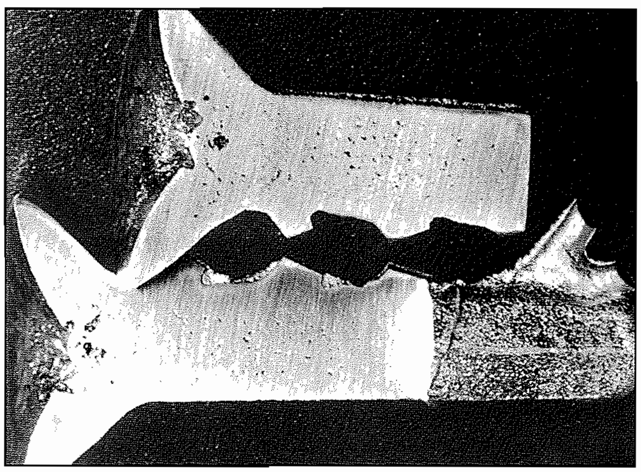

Fig. 11: Internal shrinkage in Pt-Ru sprue post

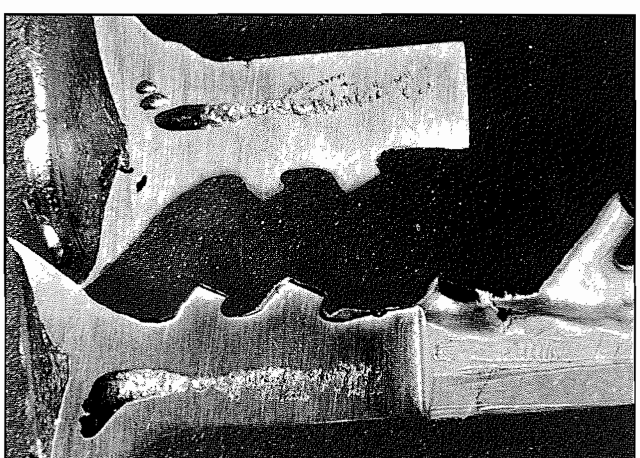

Fig. 12: Internal shrinkage in Pt-Co sprue post

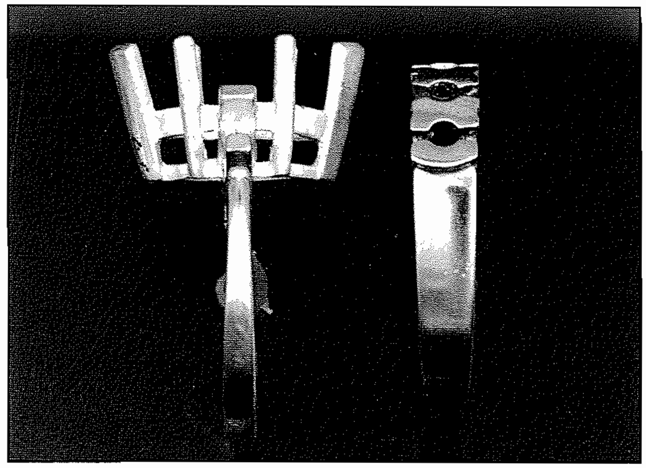

Fig. 13: Assembled Pt-Ir alloy pieces after soldering and prior to cleaning

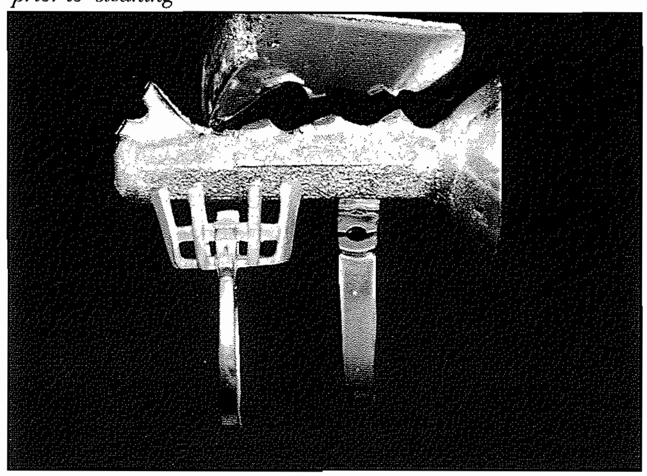

Fig. 14: Assembled Pt-Ru alloy pieces after soldering and prior to cleaning

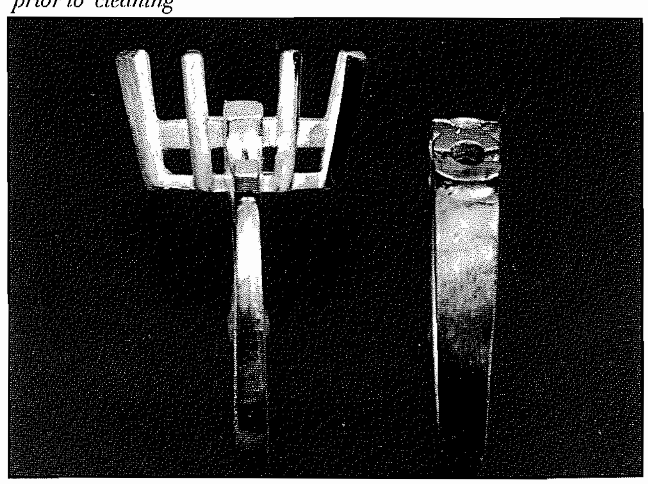

Fig. 15: Assembled Pt-Co alloy pieces after soldering and prior to cleaning

Pre-Finishing

Pieces were cut down in centrifugal disc-finishing machine in two stages. Initial tumbling was done with abrasive-filled plastic media. A 50/50 blend of media was used. One fraction of the media was rated to produce a 10-microinch finish and the balance was rated to produce a 3-microinch finish. Pieces were tumbled for half an hour. Vibratory tumbling in stainless steel media for four hours completed pre-finishing.

Resizing

Each assembled piece was resized to evaluate the results of inserting a piece of sizing stock into the palm-side of the ring shank as if the finger size were being increased. Pt-Co sizing stock was used with the Pt-Co shank. Pt-Ir sizing stock was used with both the Pt-Ir and Pt-Ru alloy shanks.

Different joining methods were used at the two joints on each ring. One joint was soldered using 1700°C seamless solder, and the other joint was completed by fusion welding. Fusion was done with a thin shim of metal that was clipped from casting sprue post. The clipping was hammered to final thickness and wedged in the joint between the sizing stock and ring shank.

Final Finishing

Rings were prepared for final polishing by filing, buff-sticking and rubber wheeling operations with traditional jewelry finishing tools and supplies. The rings were then lapped and buffed with Gray Star buffing compound, followed with White 6000 and 8000. Separate hard felt laps and stitched muslin buffs were used alternately with each grade of polishing compound to develop the final finish.

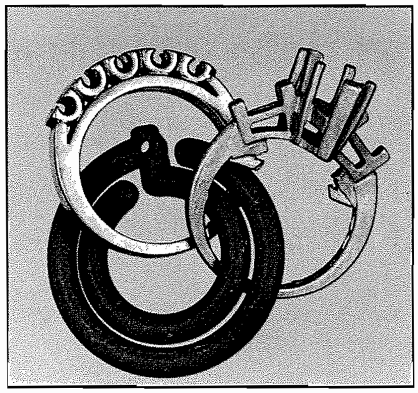

Fig. 16: Pt-Ir alloy after centifugal tumbling in abrasive media

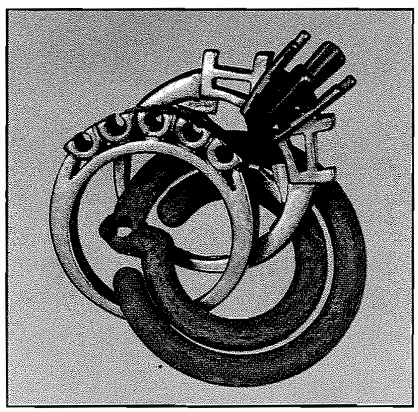

Fig. 17: Pt-Ru alloy after centrifugal tumbling in abrasive media

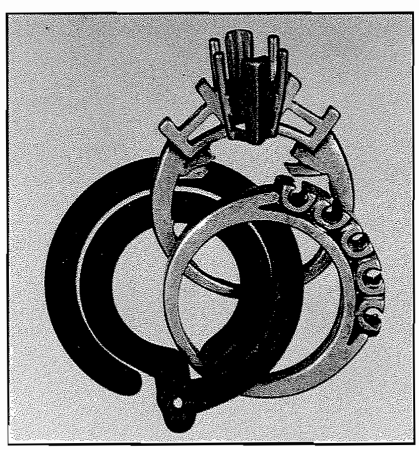

Fig. 18: Pt-Co alloy after centrifugal tumbling in abrasive media

Stone Setting

Rings that were to be stone-set were polished to their final finish before stone setting. Stone seats were cut with a high-speed bur and generous amounts of lubricant to prevent the platinum from galling and sticking to the burr. Stones were set into final position and prongs were pushed over the stone girdle.

Results and Discussion Casting Operations

Molds were broken out, trees were water blasted and pickled. Final pickling was done in 48% hydrofluoric acid to remove final traces of investment. After casting and cleaning, the Pt-Co had a duller surface. The Pt-Ru alloy was brighter but slightly rougher. The Pt-Ir alloy was brightest but contained visible shrinkage on close inspection. The Pt-Ir gave evidence of being the most unforgiving with regard to shrinkage in designs with isolated heavy sections or drastic changes in cross sectional area.

In the "marquise" setting, a location where baguette prongs intersected the top and bottom galleries was susceptible to visible shrinkage. Figure 1 is an example of the shrinkage that was observed in Pt-Ir alloys at the prong/galley intersection. Similarly, Figures 2 and 3 illustrate shrinkage conditions at the same location in the Pt-Ru and Pt-Co alloys, respectively. Shrinkage was not grossly evident in the Pt-Co alloy castings.

The underside of "fishtail" settings demonstrated tendencies to exhibit surface porosity. Figures 4, 5 and 6 illustrate surface porosity conditions in Pt-Ir, Pt-Ru, and Pt-Co alloys, respectively. Settings that were cast in Pt-Co alloy demonstrated the lowest levels of surface porosity on the undersides of "fishtail" settings.

The condition of the sprue post was used to evaluate the general surface quality of castings and was taken to be an indicator of tendencies for reactions between metal and investment material. The surface of the Pt-Ru sprue was the roughest, Figure 8, indicating a strong driving force for metal-mold reactions. This is confirmed by Johnson Mathey's rating of Pt-Ru alloys as being "very poor in the relative quality of heavy jewelry." The Pt-Ir sprue post was also quite rough, Figure 7. The Pt-Co alloy sprue post was the smoothest of all, Figure 9. Sprue posts were sectioned lengthwise along their centerlines by wire EDM methods to evaluate the internal soundness and general structure of the sprue. Abrasive polishing to remove burned metal, Figure 10-12, finished the EDM surface.

The Pt-Co sprue, Figure 12, contained a well-formed shrinkage pipe along its centerline extending down into the interior of the cast tree. There was limited evidence of micro-porosity in the metal walls surrounding the shrinkage pipe. In contrast, both the Pt-Ru and Pt-Ir alloy sprues, Figures 11 and 10, did not contain a massive shrinkage pipe. In each alloy, the sprue post was riddled with micro porosity from the centerline of the sprue post to the chill zone at the surface of the post.

Assembly Operations

Pieces were assembled by the methods previously described. The Pt-Co alloy developed a light oxide film during soldering, Figure 15, as a result of some slight oxidation of the cobalt in the alloy.

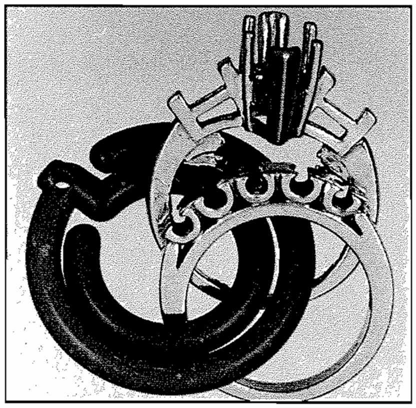

Fig. 19: Pt-Ir alloy after vibratory tumbling in stainless steel media

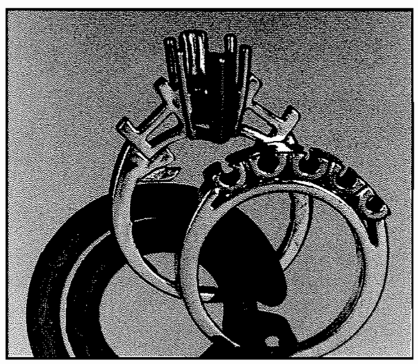

Fig. 20: Pt-Ru alloy after vibratory tumbling in stainless steel media

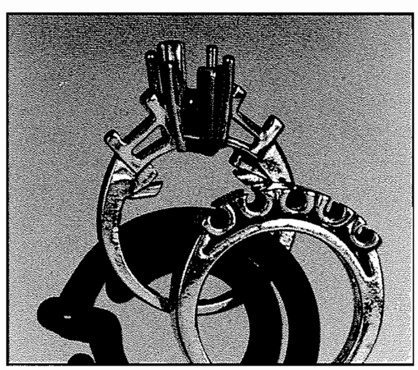

Fig. 21: Pt-Co alloy after vibratory tumbling in stainless steel media

The results of soldering the Pt-Ir and Pt-Ru alloy pieces are presented in Figure 13 and 14; the degree of tarnishing in the Pt-Co alloy assembly can be estimated by comparing the three figures.

Pre-Finishing Operations

Pieces were pre-finished by the methods previously described. Results are presented in Figures 16 and 21. The three different alloys seemed to have similar responses to abrasive and stainless steel media.

Re-Sizing Operations

Unfinished joints formed during soldering and fusion welding re-size operations are illustrated in Figures 22-24. It is interesting to note that the fusion joint in the Pt-Co alloy, Figure 24, appears to want to have a small, confined sink from solidification of the fusion zone of the weld. This behavior seems to mirror the general solidification behavior of the alloy observed in investment casting.

Final Polishing and Stone Setting

Pieces were polished and stone set by the methods previously described. All three metals behaved in the same way during these operations; photographs of completed rings are presented in Figures 25 and 26. The appearances of the pieces in these photographs speak for themselves. No obvious differences in color or quality could be readily observed.

Samples of each type of alloy were submitted to an outside laboratory to determine if significant differences in color could be measured. The CIELAB color coordinates were measured for each alloy as well as pure platinum and results are listed in Table II. Values for color differences, DE, were calculated based on methods outlined in Reference 4 and are also listed. Pure platinum was used as a reference standard for color difference calculations.

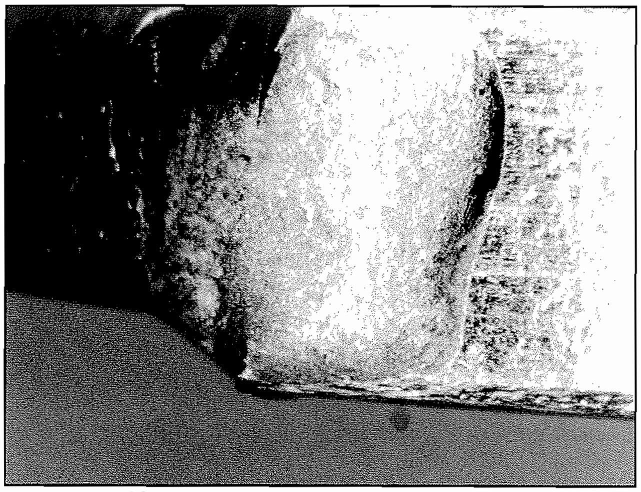
Fig. 22a: Solder joint in resized Pt-Ir alloy

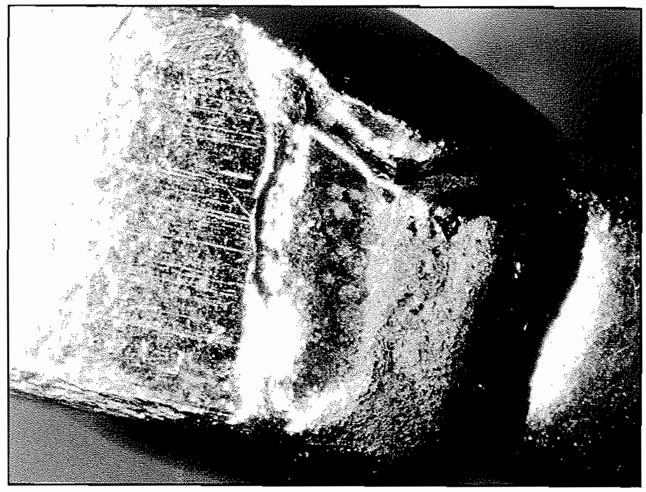
Fig. 22b: Fusion weld in resized Pt-Ir alloy

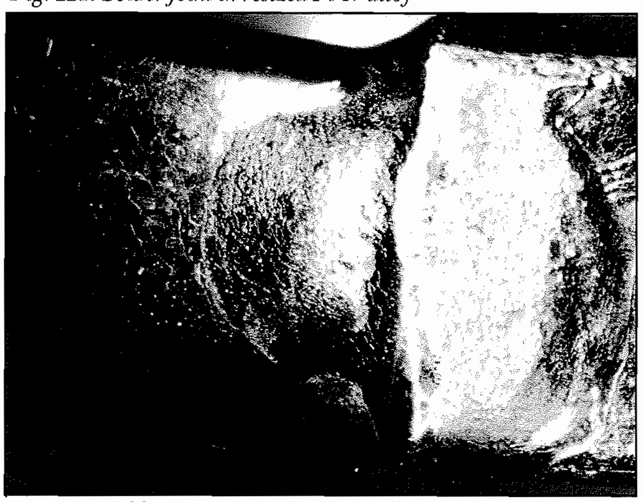
Fig. 23a: Solder joint in resized Pt-Ru alloy

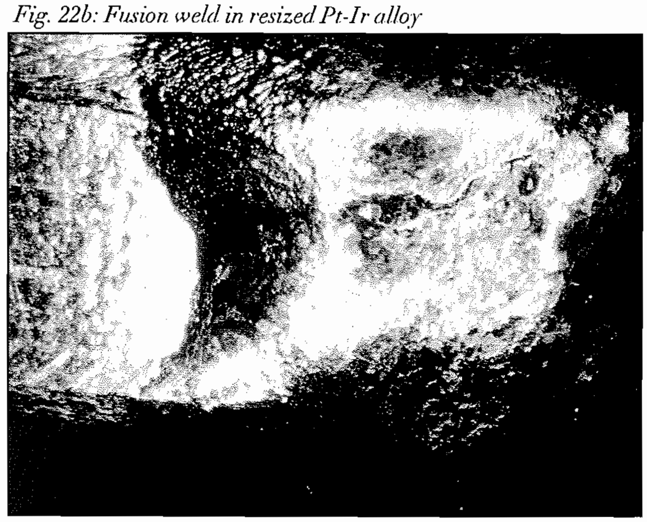
Fig. 23b: Fusion weld in resized Pt-Ru alloy

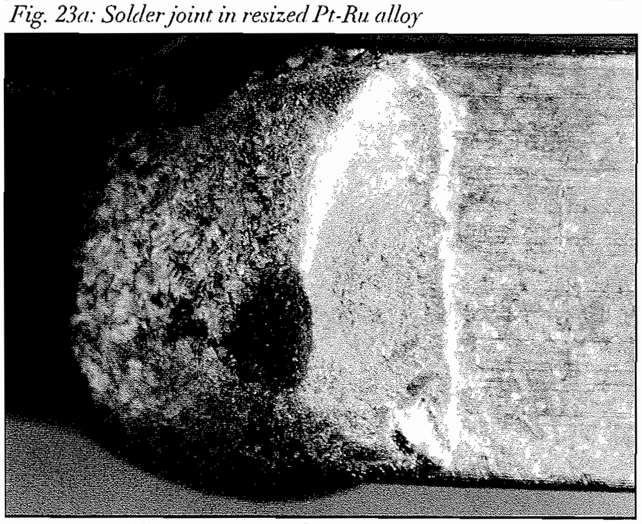
Fig. 24a: Solder joint in resized Pt-Co alloy

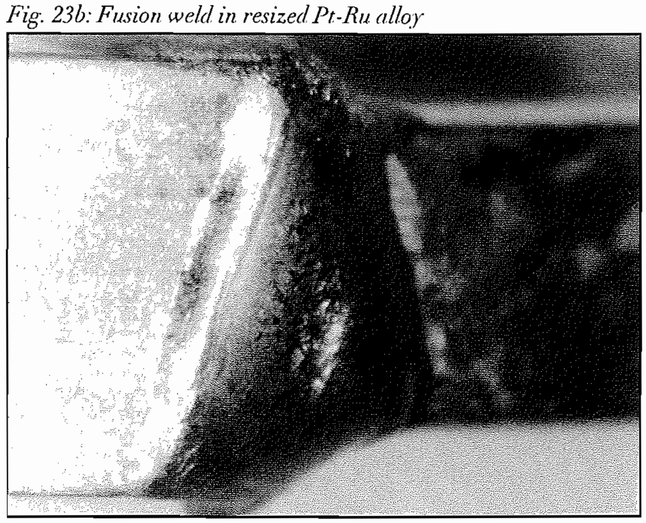
Fig. 24b: Fusion weld in resized Pt-Co alloy

The laboratory report of CIELAB color coordinate measurements concludes that the slight differences in L*, a*, and b* are not discernible to a normal human eye. Values for color difference, DE, are all less than one. It is generally accepted that color differences with numerical values of (1) or less can not be readily distinguished.

Conclusions

Careful monitoring at each stage of investment casting and finishing processes indicated that Platinum-5% Co alloys tended to perform better than alloys of Pt-5% Ru and Pt-10% Ir. Raw castings were superior when cast in the Pt-Co alloy because of their smoother surfaces and reduced amounts of shrinkage and porosity. Assembly operations were easily accomplished in spite of a tendency by the Pt-Co alloy to develop a light film of cobalt oxide. This film was easily removed in subsequent finishing and polishing operations. Pt-Co alloys are slightly magnetic but this feature did not interfere in any way with jewelry manufacturing operations. Finally, the CIELAB color coordinates of Pt-5% Co, Pt-5% Ru and Pt-10% Ir alloy were measured in a polished and finished condition. The numerical values for the color coordinates indicate that these alloys are indistinguishable from one another when observed by a normal human eye.

Acknowledgments

The authors wish to express their appreciation to all the employees at Stuller Settings who participated in the production of the pieces used in this project. Special thanks to John McCloskey, Executive Director of Metals, for his guidance and support.

Alloy	Brightness, L*	Red/Green, a*	Yellow, b*	Color Difference, DE
Platinum	85.5	-0.1	4.8	-
Pt-5%Ru	85.5	-0.2	4.6	.22
Pt-5%Co	85	-0.2	4.3	.71
Pt-10%Ir	85.5	-0.1	4.7	.10

Table 2: CIELAB color coordinates of Platinum alloys

Fig. 25: (Left to right) Finished "fishtail" ring mountings in Pt-Co, Pt-Ru, and Pt-Ir alloys

Fig. 26: (Left to right) Finished "fishtail" ring mountings in Pt-Co, Pt-Ru, and Pt-Ir alloys

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