Practical Applications of Specific Gravity Determination to Platinum Jewelry Manufacturing

The uses and limitations of Archimedes Principle

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The manufacturing of jewelry using platinum usually entails greater sophistication and more precise control than does gold or silver. In addition, jewelry which combines platinum with other metals also requires special efforts to maintain control of the relative proportions of each metal. Such control may be especially difficult if the fabrication process involves operations which remove metal, such as faceting or polishing, subsequent to the assembly of the two metals.

In seeking to address this issue, the authors explored the applications of density data to the control of jewelry manufacturing processes and also investigated techniques for the accurate measurement of density. In particular, the utilization of modern analytical balances in conjunction with Archimedes Principle was analyzed for reliability and practicality. It was determined that, under controlled conditions, the procedure yields data which are both reliable and useful.

Recent growth of platinum jewelry

Since early in the decade of the 1990s, the North American jewelry industry has witnessed a dramatic resurgence in the use of platinum for jewelry applications. This significant growth has been accelerated in no small way by the extensive marketing efforts of the Platinum Guild International. Certain of platinum's inherent properties, such as intrinsic value, chemical inertness, color and luster, density, durability and formability, make it ideally suited for jewelry applications. Platinum has long been recognized as the premier material for setting diamonds, but is now also being widely employed for wedding bands, ring shanks and tops, and many other types of jewelry.

Platinum in combination with other metals

In addition to widespread use as a stand-alone jewelry metal, platinum has also been especially popular with jewelry designers who create products which combine platinum with other metals, particularly gold. By skillfully combining alloys of varying *color* and *texture*, designers have created a whole new world of beauty. In the past, these two-tone or multi-colored products generally utilized two or more differently colored gold alloys which were almost always of the *same karat or fineness*. Now, however, designers are focusing on jewelry items which *combine alloys of platinum and gold*. These two metals, together, do indeed create marvelously beautiful pieces of jewelry. *(Figure 1 and Figure 2)*. The rich, contrasting colors, and the unmistakable "feel" of platinum are very compelling!

The issue of metal content

A combination of significantly different metals such as platinum and gold, or, for that matter, a composite involving different alloys of silver, palladium or other metals, raises interesting issues for all facets of the jewelry trade. From the standpoint of the consumer, the value of a piece of jewelry is comprised primarily of factors such as: (1) artistry of design, (2) skill

Fig. 1: Gold over Platinum Wedding Band

Fig. 2: Gold between two Platinum Bands

and ingenuity of craftsmanship, (3) choice of materials, and (4) tasteful and appropriate presentation by the retail store. For the jewelry tradesman, however, the value of an item is more likely to be determined by the spread between cost and selling price. In this situation, the calculation of value will often require an accurate determination of the weight of each precious metal component. For jewelry constructed of a single, homogeneous precious metal alloy, this determination simply involves knowing the "fineness" of the alloy and the total weight of the piece. However, when the jewelry item involves a combination of materials, this determination can be considerably more complex.

Complexity of determining relative proportions

The most effective way to determine the relative proportion of each material in an assembled item of jewelry is to carefully weigh each component before assembly and then insure that no subsequent fabrication operation changes this proportion. If, however, the design of the item requires that the components be assembled in a semi-finished condition, and then entails subsequent cutting or finishing operations which remove metal, it may be very difficult to accurately determine just how much of each component remains in the finished jewelry.

An Issue through the Ages

A lesson from ancient history

Despite the venerable legacy of jewelry making for literally thousands of years, modern manufacturers are still faced with many of the same issues which concerned their ancient fellow craftsmen, Each facet of the jewelry trade has always been concerned with knowing the intrinsic value of the items which are produced and bought and sold. Let's examine this problem from an historical perspective.

King Hieron has a problem

The story of the king of the ancient Greek colony of Syracuse is a classic example. King Hieron wished to commission the creation of a sacred crown, which probably would have taken the form of a wreath. The king delivered to the selected craftsman a measured weight of pure gold and instructed that the entire amount was to be incorporated into the finished work.

Eventually, the craftsman completed the crown and delivered it to the king. The king was pleased with the beauty of the crown, but being somewhat skeptical, he instructed that the crown be weighed. Hieron was greatly relieved when it was found that the crown weight was reasonably equal to the original weight of the pure gold. Subsequently, however, the king became puzzled when it was pointed out that the color of the metal did not have the same hue and luster as the original gold. Could it be possible that some other metal, probably silver, had been substituted for a portion of the king's gold?

Archimedes develops a solution

King Hieron then summoned his trusted advisor, Archimedes, whose wisdom and ingenuity had been demonstrated many times, and asked him to test whether the crown did, indeed, contain all of the king's gold. Of course, since the crown was a sacred article, it could not be harmed or changed in any way!

According to the story, Archimedes was pondering the king's problem as he prepared to take his customary bath. When he entered the bathing pool, which was completely full, he noticed that the water overflowed the brim as it was displaced by his body *(Figure 3)*. Suddenly realizing that here, indeed, was the key to solving the riddle of the crown, he is said to have jumped from the bath and run naked through the streets crying "Eureka, I have found it!!" Archimedes took pieces of pure gold and of pure silver that had *weights identical to the weight of the wreath*. He then successively immersed the gold, the silver, and the wreath in a container filled to the brim with water and measured the volume of water that overflowed with each material. He found that the wreath displaced more water than the gold but less than the silver, thereby proving that the wreath contained some other metal which was less dense than gold.

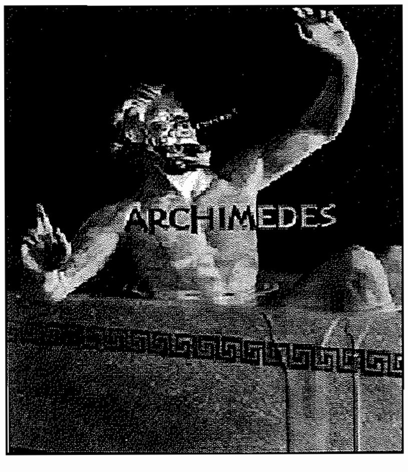

Fig. 3 : Archimedes takes a bath

Further, assuming that the substituted metal was silver, measuring the amounts of water displaced in the three cases allowed him to calculate the relative amounts of gold and silver which the wreath contained.

A bathtub alone won't do

Although Archimedes solved the problem at hand, if the above account is correct, he did not actually use the famous Principle that we wish to employ. He used the simpler concept that a body fully immersed in a liquid will displace a volume of liquid equal to the object's volume. Because of silver's lower density, the gold-plus-silver wreath had a greater volume than the same weight of pure gold; it therefore displaced more water, upon immersion, than an equal mass of pure gold. Unfortunately, the accuracy of volume measurement directly by fluid displacement is too low to be very useful.

Archimedes Principle

Archimedes Principle goes a step further and allows us to use an object's buoyancy in a liquid to arrive at a *much more precise* measure of its density, or specific gravity. This accuracy improvement is a consequence of the precision available by measuring *weight* using a modern analytical balance.

Calculating the ratio of Constituents

Fundamentally, the objective is to determine the ratio of constituents in an object fabricated as a composite of two or more known materials, for instance, a ring made from platinum and 18 karat gold (*Figure 4 and Figure 5*). If the density of each individual component alloy is known, and it the density of the composite object itself can be determined, then the ratio of materials can be calculated rather simply, as shown below.

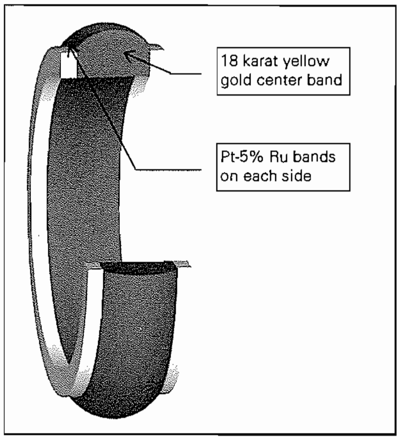

Fig 4: 18K Gold + Pt-5%Ru Wedding Band sample (A) configuration

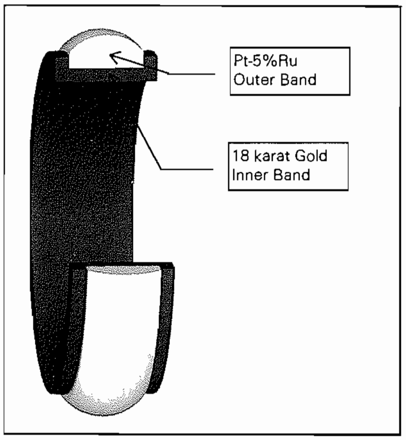

Fig 5: 18K Gold + Pt-5%Ru Wedding Band Sample (B) configuration

Define: For an object comprised of two alloys. A and B

F_A = weight fraction comprised of alloy A

D_A = density of alloy A

F_B = weight fraction comprised of alloy B

D_B = density of alloy B

D_C = density of the composite object

It then follows that the sum of the two weight fractions equals the whole:

$$F_A + F_B = 1$$

The density of the composite object is given by:

$$D_C = \frac{1}{\left(\frac{F_A}{D_A}\right) + \left(\frac{F_B}{D_B}\right)}$$

Substituting ($F_B = 1 - F_A$) and solving for F_A gives:

$$F_A = \left(\frac{D_A}{D_C}\right) + \left[\frac{(D_B - D_C)}{(D_B - D_A)}\right]$$

This equation now expresses the weight fraction of constituent A. The complementary weight fraction of constituent B is simply

$$1 - F_A$$

Obviously, the weight of either constituent, $W_{(X)}$, can now be easily calculated by simply multiplying the total weight of the object by the weight fraction of the desired constituent.

$$W_A = F_A \times W_C$$
and
$$W_B = F_B \times W_C$$

Calculating metal ratios requires determining density

Determining DENSITY is key to calculating METAL RATIOS:

Knowing the *density*, then, is the key to finding the ratio of constituents when using this methodology. This, in turn, requires an accurate means to determine both *weight* and *volume*. Fortunately, measuring *weight* is well understood and simply requires an accurate weighing balance. *Volume*, however, is usually considerably more difficult to measure accurately, as subsequently discussed.

Determining density requires knowing the volume

Determining VOLUME is key to calculating DENSITY:

There are several methods of finding volume. This paper will include only a brief discussion of each alternative method before focusing on the application of Archimedes Principle.

1. **Direct calculation using measured critical dimensions.** This method typically applies best when the object is a regular, geometric solid such as a sphere, a cylinder, or some type of regular prism. Since most items of jewelry involve complex geometry, this method is usually impractical. It is employed here only as a means to validate other methods.
2. **Measuring the volume of a displaced liquid.** Accuracy is the principal problem with this method. Except in the case of a specialized shape, such as a slender cylinder, it is very difficult to capture and directly measure the volume of a displaced liquid with a significant degree of precision.
3. **Direct numerical calculation,** This procedure requires specialized computer analysis, sometimes found in more sophisticated Computer Aided Design (CAD) software. The technique will probably become more important as the software becomes increasingly capable. However, it is only useful if the object of interest has been fully described within the mathematical model of the program. Jewelry whose manufacture involves hand work or finishing would not be accurately calculated.
4. **Employment of Archimedes Principle** by measuring the difference between an object's weight in air compared to its weight while submersed in a liquid of known density (water).

Determining volume using Archimedes Principle

Archimedes Principle states:
"A BODY WHOLLY OR PARTLY IMERSED IN A FLUID IS BUOYED UP BY A FORCE EQUAL TO THE WEIGHT OF THE FLUID DISPLACED" [CRC Handbook of Chemistry & Physics].

Given a working fluid of known density, measurement of this upward force, which is equivalent to the weight of the fluid displaced, leads to a determination of the volume displaced, which, in turn, equals the volume of the immersed body! In practical terms, one must first weigh the object of interest " in air" and then weigh the object a second time while it is fully immersed in a fluid, e.g. water. Given the **density of the water**, the difference between the object's *weight in air* and its *weight in water* is used to calculate the volume of the immersed object.

$$\text{VOLUME}_{\text{Displaced Fluid}} = \frac{\text{WEIGHT}_{\text{Air}}\text{-WEIGHT}_{\text{Water}}}{\text{DENSITY}_{\text{Water}}} = \text{VOLUME}_{\text{Object}}$$

The density of water, at any temperature, is well-established and has been defined to be equal to 1 gram per cubic centimeter at 40 Celsius. Table 1 shows water density for temperatures over a typical working range (room temperature).

DENSITY of WATER As a function of temperature	
Temp C	g/cc
20	0.99823
21	0.99802
22	0.99780
23	0.99756
24	0.99732
25	0.99707
26	0.99681
27	0.99654
28	0.99626
29	0.99597
30	0.99567

Table 1: Density of Water

The item's mass ("air weight") divided by this calculated volume is the item's density. Overall, then,

$$D = [\text{weight}_{\text{air}}/(\text{weight}_{\text{air}}\text{-weight}_{\text{water}})] \times D_o$$

where D is the density of the item, and D_o is the density of water at the measurement temperature.
A note on terminology: Since we are using water to determine the object's volume, technically we are also determining its specific gravity: "The ratio of the mass of a body to the mass of an equal volume of water." [CRC Handbook of Chemistry & Physics]

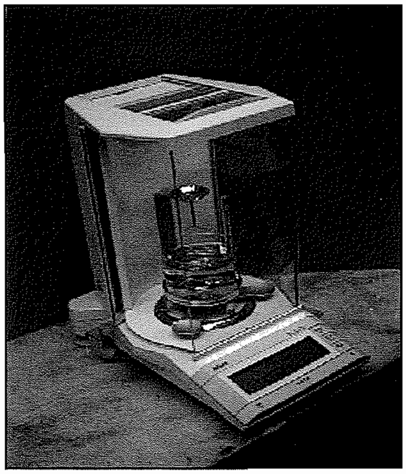

Fig. 6: Mettler AG245 Analytical Balance

Fig. 7: Specific Gravity Attachment

Practical Measurement of "Weight submersed in Water"

A modern digital analytical balance allows weight measurement, in grams, to 4 or 5 decimal places. The balance used for this research was a Mettler AG245, which operates in the 5-decimal mode up to 41 grams *(Figure 6)*. An accessory density determination kit *(Figure 7)* allows the weighing of objects immersed in water. It consists of a bracket (1) that replaces the weighing pan, from which one hangs a weighing basket (2). The basket is suspended in a beaker (3), filled with water, that sits upon a platform (4) that straddles the bracket. Also, an alcohol thermometer (5) that clips onto the beaker wall is provided for measuring the temperature of the water. The design of the kit allows air weighing without disassembling the water weighing apparatus; the bracket has two arms at the bottom for this purpose, and the basket has a weighing cup at the top.
The balance may be linked to a personal computer using software such as Mettler's BalanceLink to send the weight data directly to a spreadsheet. All calculations discussed above may be incorporated into the spreadsheet, which allows the weight and weight percent of each alloy to be calculated immediately upon transmission of weight data to the personal computer.

Reliability of the method

The practical usefulness of this procedure is highly dependent upon the degree of reliability of the measurements. Therefore, it was deemed necessary to examine all possible sources of error and to determine quantitatively the margin of error which would result. The measurement of "water weight" is the procedure most prone to error. The following factors were considered.

1. Inherent repeatability of weight measurements under ideal conditions: i.e. fundamental reliability from a statistical standpoint.
2. Sample cleanliness and surface finish.
3. Sample geometry: wettability and bubble entrapment factors
4. Homogeneity of sample: internal voids, microstructure, alloy segregation, etc.
5. Condition of working fluid (water): purity, air content, temperature, use of wetting agent.
6. Operator recognition of anomalies: balance levelness, vibration, spills, vapor condensation, air drafts, temperature fluctuations, bubbles adhering to sample, etc.

Testing of known reference materials

The most straightforward way to validate the reliability of the Archimedes Principle technique is to compare the results with data obtained from the published literature and by using alternative methods. Test samples were chosen carefully in order to permit the use of multiple techniques for obtaining density values. The selection of wrought cylinders of high purity metals (elements) gives the ability to compare density values using (a) geometric measurement, (b)Archimedes Principle and (c) published literature. The results showed a high degree of correlation as shown in Table 2.

Inherent statistical reliability

Understanding the statistical repeatability of the method is necessary in order to practically assess the usefulness of data from actual test applications. A program was established to ascertain a statistical standard deviation under carefully controlled condi-

Table 2: Comparison of Density values for pure metals

ID	Element Purity	Sample Form	Air Weight	Geometric Calculated Density	Measured Density	Published Density
2	Gold .99999	Ring	13.74164	-	19.294	19.32; 19.28
3	Aluminum .99999	Rod 3/8"	8.46633	2.698	2.999	2.6989
4	Zinc .99999	Rod 3/8"	21.08612	7.135	7.140	7.133
5	Copper .99999	Rod 3/8"	20.89011	8.939	8.939	8.96; 8.93
10	Diamond	.76 Ct. E.C.	0.15287	-	3.513	3.52±.01
39	Cubic Zirconia	6.25mm R.B.	0.33165	-	5.933	5.80±.20

Note: Density expressed as g/cc
Sources: American Society for Metals, Shackelford. GIA Gem Ref.1995

tions. At least thirty (30) identical tests must be performed in order to be statistically significant. The following conditions were established as procedural standards:

1. Use of an accurately calibrated balance situated in a clean, draft-free environment on a stable and level surface.
2. Use of boiled, distilled water at a known, stable temperature with the addition a small amounts of a wetting agent.
3. Selection of a homogeneous sample of simple geometry with a smooth surface to minimize bubble entrapment.
4. Selection of a sample whose weight is near the upper limit of the high accuracy weight range for the balance being used. (Approximately 20 grams for the Mettler AG245 with the density kit installed and using the 1/100 milligram range) This will minimize the significance of errors as a percentage of total sample weight.
5. Use of extreme care and attention to detail by the operator.

The results obtained would be expected to constitute a normal statistical distribution similar to that shown in *Figure 8.*

Data from this array of tests allows calculation of a standard deviation (σ) which is useful to assess the reliability, and therefore the usefulness, of actual density measurements. For this type of normal (Gaussian) distribution, the data may be expected to be grouped about the mean value as follows:

68.3% of data will lie within ±1σ
95.4% of data will lie within ±2σ
99.7% of data will lie within ±3σ

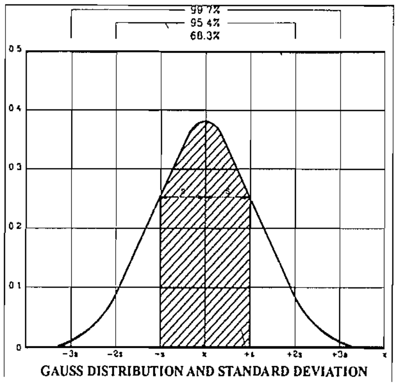

Fig 8: Normal (Gaussian) Distribution

Generally speaking, the true density value may be expected to lie within plus or minus three standard deviations of any single measurement. Performing multiple tests and taking the average value will obviously improve the reliability of the data.

Four different jewelry samples (wedding bands) were selected for statistical testing. These included bands of plain platinum and of plain gold and two types of composite platinum-gold bands. The results of these measurements are presented in Table 3. The standard deviation for the single metal samples averaged 0.006 grams/cc while the composite rings were two to three times greater at 0.013 and 0.022 g/cc.

These data can also be used to calculate the proportion of metal content in the composite wedding bands, as shown in Table 4.

Application of density measurement to jewelry manufacturing

This paper has thus far dealt with the theory and mechanics of density testing using Archimedes Principle and with the reliability of the results which may be expected. It is now possible to explore specific applications of this

Table 3: Statistical Reliability

ID	Sample Form	Nom. Wt.	Average Minus 3 Sigma	Measured Average Density	Average Plus 3 Sigma	Standard Deviation
1	Pt-5%Ru Ring Blank	21.1	20.682	20.699	20.716	0.0057
6	18K Y Ring Blank	11.5	15.176	15.195	15.214	0.0064
11	18K Y+Pt-5% Ru Mechanical Bonded Ring Assembly with Milgrain	12.7	17.189	17.227	17.266	0.0128
12	Pt-5%Ru + 18K Y Brazed Ring Blank	9.8	18.073	18.138	18.202	0.0216

Note: Density expressed as grams/cubic centimeter. Population = 30 tests

Table 4: Statistical Reliability: Determination of Metal Content

ID	Sample Form	Nom. Wt.	Average % Minus 3 Sigma	Calculated Average % Pt-5%Ru	Average % Plus 3 Sigma	Standard Deviation
1	Pt-5%Ru Ring Blank	21.1	-	-	-	-
6	18K Y Ring Blank	11.5	-	-	-	-
11	18K Y+Pt-5% Ru Mechanical Bonded Ring Assembly with Milgrain	12.7	43.78	44.52	45.26	0.2469
12	Pt-5%Ru + 18K Y Brazed Ring Blank	9.8	60.09	61.22	62.35	0.3758

Note: Density expressed as grams/cubic centimeter. Population = 30 tests

Table 5: Comparison of Density and Metal Ratio from individual vs. combined weighings

Condition	Parameter	Test #A
Air Weight of Pt-5%Ru Component	Sample Number	9
	Air Weight g	10.25945
Air Weight of 18K Gold Component	Sample Number	6
	Air Weight g	11.54504
Calculated Density of assembly derived from individual components	Sample Number	40
	Air Weight g	21.80449
	Density g/cc	17.360
	Pt-5%Ru Content	**47.05%**
Measured Density of Assembly	Sample Number	40
	Air Weight g	21.80449
	Water Weight g	20.55175
	Density g/cc	17.357
	Pt-5%Ru Content	**47.00%**
Calculated Weight (g) of Pt-5%Ru in assembly		10.247

Pt-5%Ru Density=20.674 18K Y Gold Density= 15.195 Density of Water=0.99720

testing to typical jewelry manufacturing situations. The following applications were investigated:

1. Determination of density for any given alloy.
2. Determination of relative proportions of materials in a composite product.
3. Evaluation of microstructure porosity.
4. Evaluation of voids within an assembly.
5. Approximate determination of fineness of a known alloy.

Using density data for any given alloy

The many different alloys utilized within the jewelry industry provide a great range of color, mechanical properties and precious metal fineness. Accurate knowledge of the density (ratio of weight to volume) of each alloy provides an important tool for control of manufacturing processes and of material costs. Some typical applications include:

1. Estimating the weight of a new product design.
2. Calculating the weight of an item produced from an alternative material; e.g. if the weight of an existing product in 14 karat gold is known, then its weight in platinum can be calculated by using the ratio of densities.
3. Finding the length or other dimensions of stock products (strip, wire, tube, etc.) given a known weight.
4. Checking the metal quality of a sample item.

Finding the relative proportions of materials in a composite product

Jewelry design may encompass an endless variety of combinations of materials. As previously described, two types of composite ring design were examined in this paper, as shown earlier in Figure 4 and Figure 5. In one case, three bands of metal are bonded together side-by-side, while in the other case, one band is mechanically constrained within a second band.

Evaluating theoretical product assemblies:

The potential accuracy of calculating metal ratios using density measurement can be demonstrated by using a simple two-component assembly. Each of the two components are first carefully weighed in air and then weighed together under water. This method eliminates any error due to the assembly process itself. The resulting "combined" density is then used to calculate a metal ratio which is compared to the ratio using weights alone. Table 5 shows the high correlation (within 0.05%) between the two results.

Evaluating actual product assemblies:

In actuality, the assembly process involves creating two or more components which are subsequently joined. Joining processes include mechanical assembly (Figure 9), diffusion bonding (Figure 10), brazing or welding. The integrity of the assembly is dependent upon the dimensional fit of the components and the quality of the joining process. Improper fit will typically result in a poor joint and often leaves voids or porosity within the as-

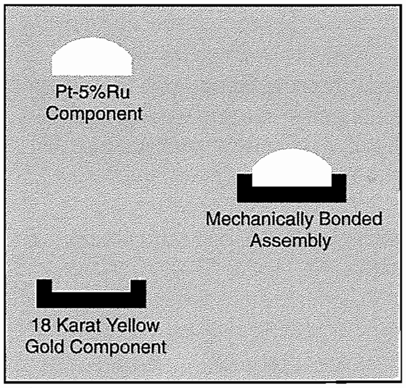

Fig. 9: Mechanically bonded ring assembly

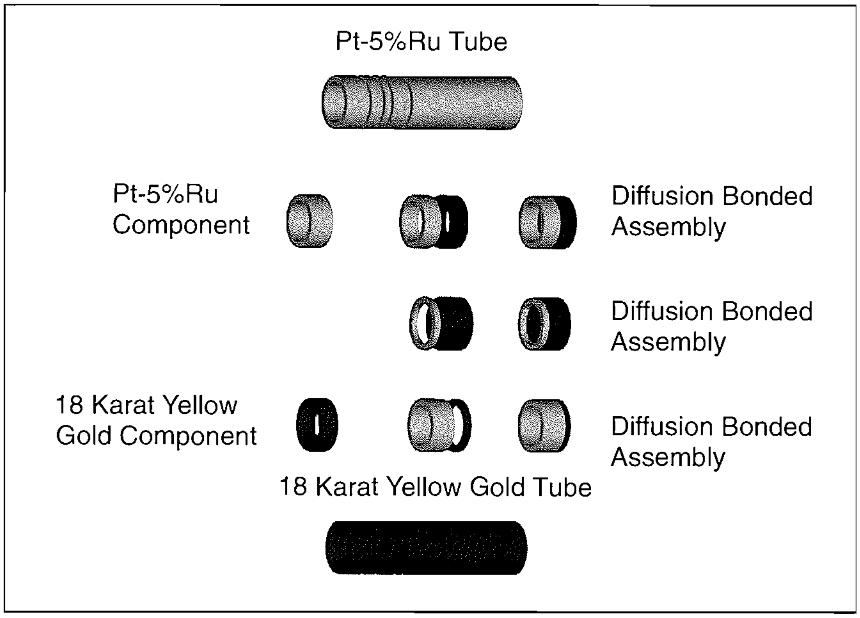

Fig. 10: Diffusion Bonded Ring Assembly

sembly. A schematic example of "fit" problems is shown in Figure 11. Figure 12 shows the presence of small voids which may occur in diffusion bonded joints. The presence of voids will affect the accuracy of the measured density. Table 6 and Table 7 show results from density measurements and calculations of metal content for two types of assembled rings.

Table 6 reports results for diffusion bonded rings of the type shown in Figure 4. Here, tests using three different metal distributions, illustrated in Figure 10, show an average difference in Pt-5%Ru content of only 0.2% between pre- and post-assembly products. Table 7 reports results for mechanically joined assemblies of the type shown in Figure 5. These results show a difference of 0.8% on average, suggesting poorer fit.

Table 6: Diffusion Bonded Ring Assemblies

Condition	Parameter	Test #A	Test #B	Test #C
Air Weight of	Sample Number	36	34	32
Pt-5%Ru Component	Air Weight g	12.23559	11.40571	13.17407
Air Weight of 18K	Sample Number	37	35	33
Gold Component	Air Weight g	9.29568	9.97181	8.65434
Calculated density	Sample Number	45	44	43
of assembly derived	Air Weight g	21.53127	21.37752	21.82841
from individual	Density g/cc	17.889	17.694	18.091
components	Pt-5%Ru Content	56.83%	53.35%	60.35%
	Sample Number	48	47	46
Measured Density	Air Weight g	21.53606	21.38119	21.83220
of	Water Weight g	20.33628	20.17787	20.62930
assembly	Density g/cc	17.895	17.714	18.094
	Pt-5%Ru Content	56.94%	53.71%	60.41%
Calculated weight (g) of Pt-5%Ru in assembly		12.262	11.483	13.190

Pt-5%Ru Density=20.717 18K Y Gold Density=15.164 Density of Water=0.99694

Evaluation of microstructural porosity

Variations within the microstructure of an alloy may affect the apparent density. Published density values for common metals typically assume a fully recrystallized grain structure. The dendritic microstructure typical of casting may often contain porosity from shrinkage, gas or other defects. Accurate measurement of density in both wrought and cast forms will allow an estimate of the relative amount of voiding. Figure 13 shows the normal wrought (as cold worked) structure of 18 karat yellow gold. Figure 14 and Figure 15 show the microstructure of 18 karat yellow gold in the as-cast condition, reflecting both good technique and poor technique. Careful density measurement gives an indication of relative porosity (Table 8).

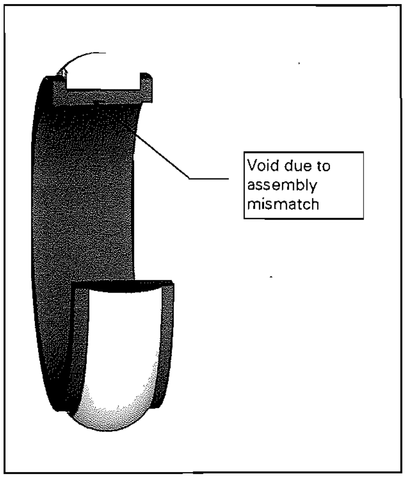

Fig. 11: Mismatch during Assembly (Mechanically Bonded Ring Assembly)

Table7: Mechanically Bonded Ring Assemblies

Condition	Parameter	Sample #A	Sample #B
Air Weight of	Sample Number	26	27
Pt-5%Ru Component	Air Weight g	5.53973	5.54580
Air Weight of 18K	Sample Number	24	25
Gold Component	Air Weight g	6.46215	6.44134
Calculated density	Sample Number	41	42
of assembly derived	Air Weight g	12.00188	11.98714
from individual	Density g/cc	**17.313**	**17.318**
components	Pt-5%Ru Content	**46.16%**	**46.26%**
	Sample Number	41	42
Measured Density	Air Weight g	12.00167	11.98694
of	Water Weight g	11.30834	11.29550
assembly	Density g/cc	**17.259**	**17.285**
	Pt-5%Ru Content	45.14%	**45.63%**
Calculated weight (g) of Pt-5%Ru in assembly		5.417	5.470

Pt-5%Ru Density=20.674   18K Y Gold Density=15.195   Density of Water=0.99707

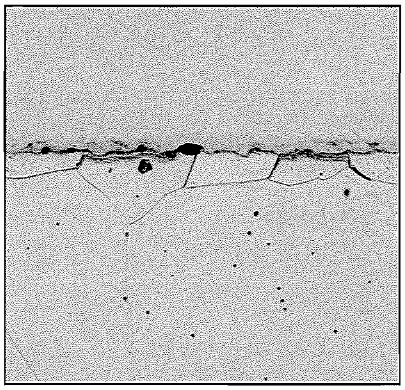

Fig. 12: Diffusion bonded interface between Pt-5%Ru (upper) and 18K YGold (lower) Original magnification 200X

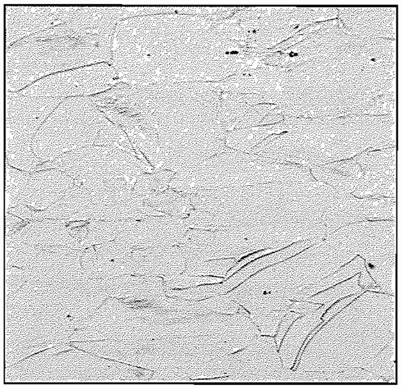

Fig. 13: Wrought 18K yellow gold. Microstructure shows cold worked grains and an absence of detectable porosity. Original magnification 200X

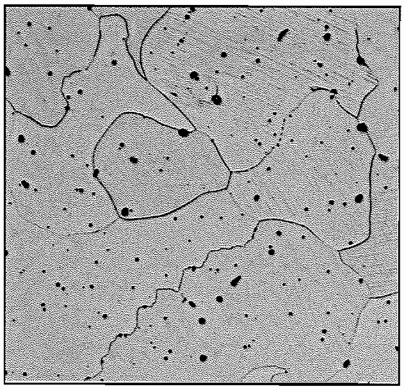

Fig. 14: 18 K yellow gold cast with good techniques. Microstructure shows large grains, dendritic substructure, and some porosity. (Dark spots) Original magnification 50X

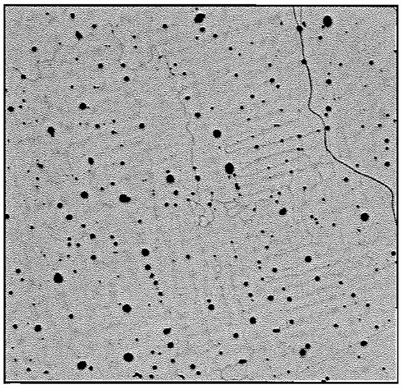

Fig. 15: 18 Karat yellow gold cast with intentionally poor technique. Microstructure shows increased porosity relative to Figure. 14. Original magnification 50X

Approximate determination of "fineness" for a known alloy

There are some circumstances where density measurement may be used to give an approximation of the relative quantity of precious metal in a known alloy. This application must be used with caution and can not generally be considered an adequate procedure for metal quality control in the modern manufacturing environment. The method does have the advantage of being relatively simple and is totally nondestructive.

The test requires that the composition of the alloy be known except for small variations of the precious metal constituent. The accuracy of the procedure can be greatly enhanced if a series of "standards" have been tested whose composition and density have been previously determined.

Table 9 shows the density difference associated with a fineness variation of 18 karat yellow gold. Test alloys were prepared with a gold content variation of ½karat (±2%) from normal 18 karat, with the balance of the composition adjusted proportionally. A fineness difference between the alloys is easily detectable through density measurements conducted under proper conditions.

Summary and Conclusions

The authors determined that density determination by Archimedes Principle using modern equipment yields accurate and reliable information which has a variety of useful applications for jewelry manufacturers. Under various controlled conditions, the

Table 8: Determination of Apparent Porosity

ID	Microstructure of 18K yellow gold Cast vs. Wrought	Sample Weight	Measured Average Density	Percent Porosity
13	As cast (Good technique)	10.40285	15.14900	0.16%
16	As cast (Poor technique)	9.85261	15.09100	0.55%
17	Wrought	17.73688	15.17400	N/A

Note: Density expressed as g/cc

Table 9: Effect of Fineness on Measured Density

ID	18 Karat Yellow Gold (sample form)	Nominal Karat	Gold Fineness	Percent Porosity
20	Wrought Ring	17.5K Y	0.7315	14.912
17	Wrought Ring	18K Y	0.7515	15.174
23	Wrought Ring	18.5K Y	0.7715	15.414

Note: Density expressed as g/cc

statistical reliability of these tests shows a standard deviation ranging from 0.006 to 0.022 grams per cubic centimeter. Taking the average, several tests will further improve the reliability. This process is particularly useful in determining the ratio of metal content for jewelry assembled from components of different alloys.

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