The Effects of Ball Burnishing on Silver Castings: Phase II

Steve Alviti
President
Bel Air Finishing Supply
Warwick, RI, USA

Introduction

There has long been a great deal of misunderstanding as to the effects of steel ball burnishing on the surface quality of "as-cast" gold and silver jewelry. This presentation is a second phase of experimentation that will explore, in detail, the use of four types of finishing equipment (vibratory, disc finishers, magnetic pin, and roll burnishers). It will also focus on the resulting smoothness and hardness, as well as visual perception of finish, resulting from the use of these systems on silver castings only.

There will be an in-depth review of how the surface finish is affected when "as-cast" pieces are prepared utilizing vibratory, disc finishing, magnetic pin, or roll burnishing equipment for the ball burnishing process. Finally, this paper will touch on the benefits, as well as the drawbacks, of using a burnishing procedure prior to disc finishing operations and final hand buffing.

Burnishing Definition

Steel media has been used by manufacturers for many years for brightening metal surfaces. Jewelry producers have used steel media to produce a shiny, bright finish on earrings, pendants, chain, etc., to enhance their visual appeal to consumers.

Generally speaking, a wrought or cast piece of jewelry has a dull appearance when first formed. The process of rubbing, rolling or hammering a jewelry piece with a highly polished, hardened metal ball will reduce the average height of the microscopic peaks of the metal's surface. This provides a surface that is far more reflective of light and far brighter to the eye. Brightness, however, should not be confused with smoothness. A smooth (level) and bright surface is far more appealing than a surface that is simply bright. Brightness achieved by ball burnishing usually has an overall "orange peel" surface profile. For that reason, manufacturers have decreased their use of this method for finishing high-end jewelry and replaced it with hand-polishing, or wet and dry mass-finishing. The research, detailed in this presentation, explores a side benefit of steel ball burnishing that has been used on the industrial side of surface finishing.

Steel media weighing about 300 pounds per cubic foot (about three times heavier than any other media) impinges on the surface of the work piece, imparting a compressive stress that work-hardens the surface. This compression and hardening of the surface may be beneficial in mechanically reducing surface porosity and imperfections by compressing the grain structure of the surface of the metal. Subsequent mass-finishing and/or hand-polishing with the proper abrasives may produce a better finish with less metal removed.

Findings from Phase I

As we review the experimentation conducted in Phase I, we gather the results for pieces that were cast in silver alloy. The quality of the Phase I sample castings was far inferior to that of Phase II, so we will have a variation in surfaces as one would expect in the real world of jewelry manufacturing.

The surface profile of the Phase I samples was reduced by an average of 60% by ball burnishing, and the surface hardness was increased by an average of 12%.

Figure 1 *Sample casting from Phase I*

Objective of Phase II

A new set of samples was cast and prepared to be processed from raw casting stage through to hand-polished surface finish. We will investigate the depth of hardness that results from different methods of burnishing (disc, vibratory, pin, and roll burnishing), and the amount of reduction of the surface profile. Once these measurements are recorded, the samples will be processed through the hand-polishing operation without regard to the method of pre-finishing, and once again, be evaluated for surface profile and total weight loss. We will try to determine the advantages, if any, of ball burnishing on the final weight of the piece.

Procedure

The test specimen for Phase II is an infinity shaped earring that has a relatively narrow cross-section and a slightly convexed front surface (Figure 2).

Figure 2 *Phase II test specimen*

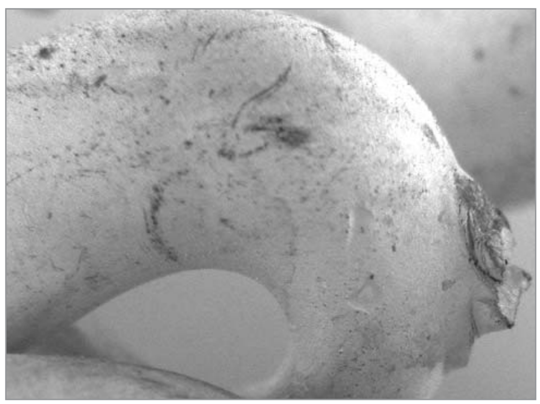

Figure 3 *Close up of "as-cast" surface of test specimen*

Nine lots of samples, each lot consisting of eight pieces, were cast and then laser engraved with a lot number on the back of each piece. Four types of burnishing machines were used. Lots numbered 1 and 5 were burnished in a centrifugal disc finisher. Lots numbered 2 and 6 were burnished in a roll burnisher. Lots numbered 3 and 7 were burnished in a vibratory bowl. Lots numbered 4 and 8 were burnished in a magnetic pin finisher. Lot number 9 was not burnished. The first group of castings, which included lots numbered 1, 2, 3 and 4, were ball burnished, then disc finshed in a wet-cut and dry-cut stage, and then hand polished. The second group of castings, made up of lots numbered 5, 6, 7 and 8, was ball burnished only and then hand polished. The last group of castings, lot number 9, was hand polished only. The lots were processed as shown in Figure 4:

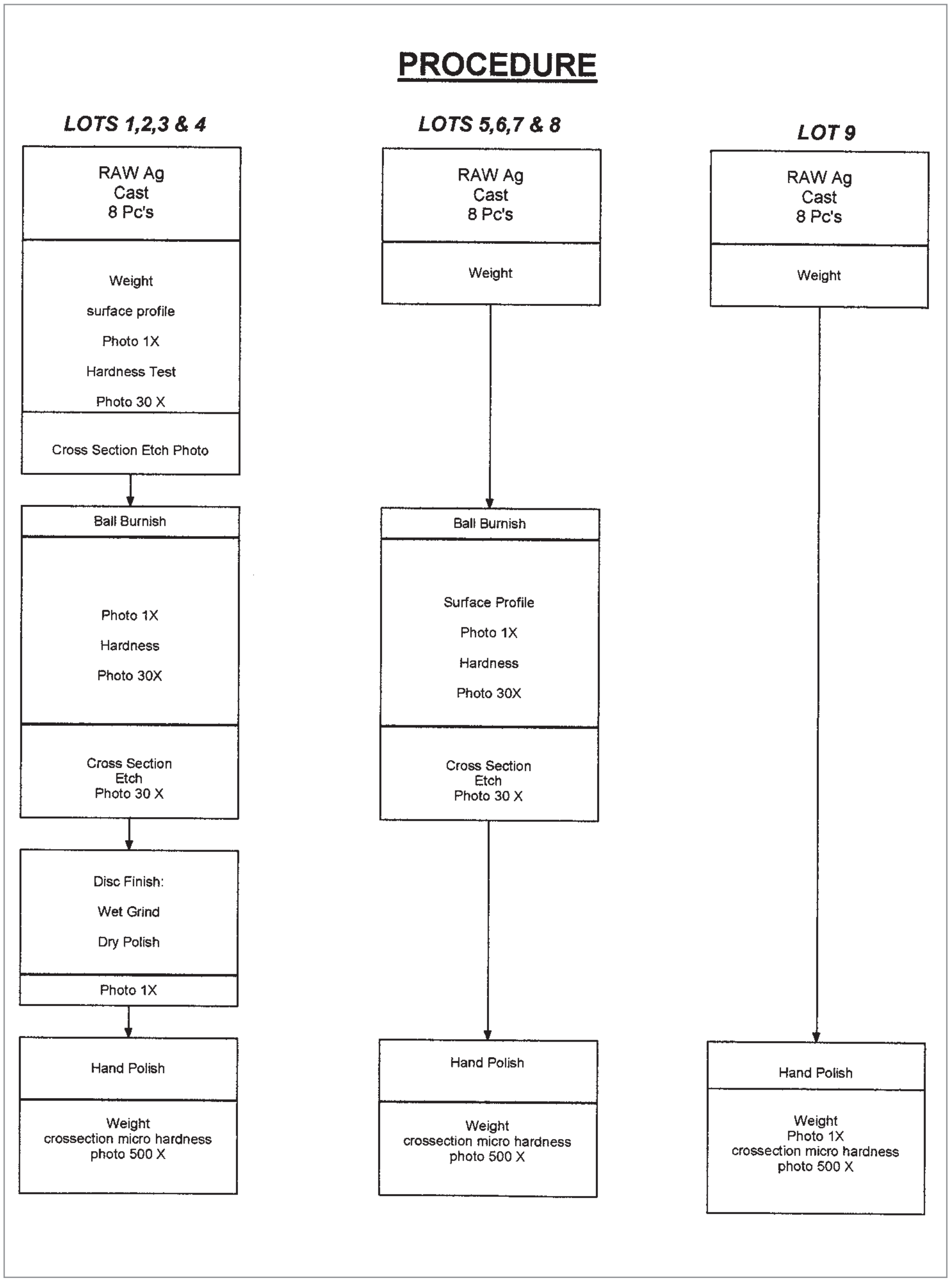

Figure 4 *Test procedure for Phase II*

Visual Inspection

As we expected, these photographs show the great improvement in reflectivity of the surface once burnishing was completed. In addition, we see that the surface appearance of the pieces utilizing vibratory and roll burnishing methods exceeds the surface appearance that resulted from utilizing magnetic pin finishing and disc finishing. We also notice that it is now very easy to see the surface defects and to what degree preliminary grinding is needed to prepare the pieces for subsequent finishing.

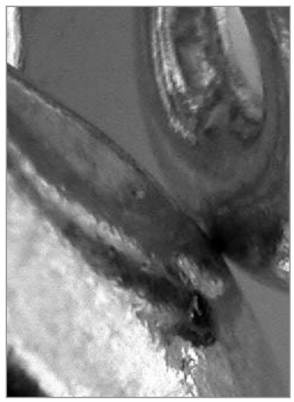

Figure 5 *Lot 5, burnished in disc finisher*

Figure 6 *Lot 6, burnished in roll burnisher*

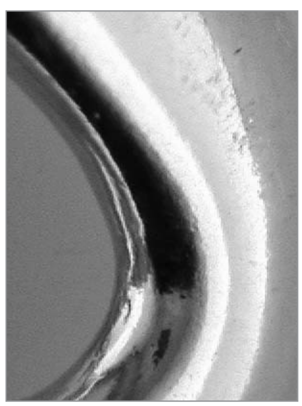

Figure 7 *Lot 7, burnished in vibratory finisher*

Figure 8 *Lot 8, burnished in magnetic pin burnisher*

Figure 9 Lot 9, "as cast"

Surface Profile Inspection

The Mitutoyo Surftest SV-400 surface profile tester was used to measure the surface of the castings before and after burnishing. The stylus was run over a course of 600 microns at a crest point of the castings. The speed of the stylus was .5mm/second. Visual inspection of the script charts is the easiest way to identify the reduction of peaks and valleys of the surface. We used the Ra factor of the surface tester to quantify the surface roughness shown in the following charts (Figures 10 through 13):

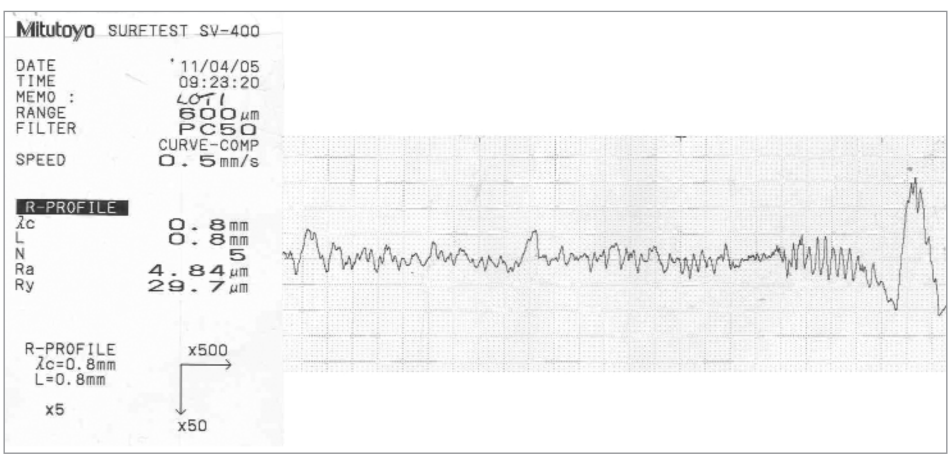

Figure 10 Surface profile chart, before burnishing

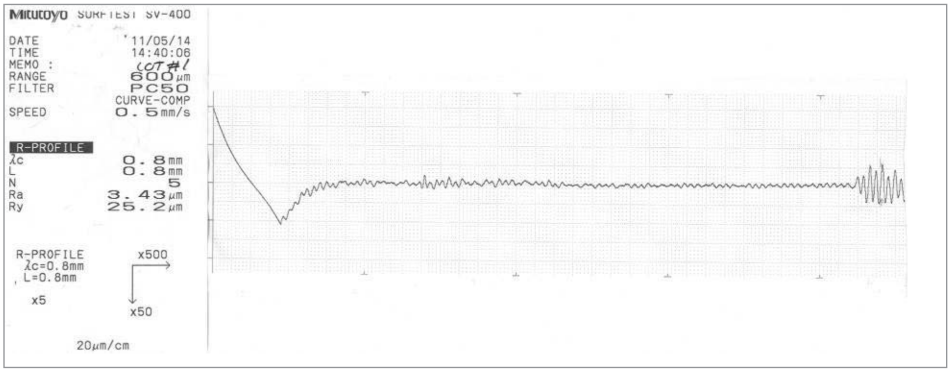

Figure 11 *Surface profile chart, after burnishing*

Before Burnishing

SAMPLE LOT#

TEST#	LOT#1	LOT#2	LOT#3	LOT#4	LOT#5	LOT#6	LOT#7	LOT#8	LOT#9
1	3.81	4.07	4.35	6.59	4.05	5.24	4.79	4.54	3.88
2	3.7	5.15	3.39	5.01	4.45	4.18	5.16	4.29	3.47
3	4.84	6.2	2.72	4.66	4.06	4.01	4.49	4.34	2.49
X BAR	4.117	5.14	3.487	5.42	4.187	4.477	4.813	4.39	3.28
RANGE	1.14	2.13	1.63	1.93	0.04	1.23	0.67	0.25	1.39

AVERAGE OF ALL LOTS 4.368

R BAR 1.197

Figure 12 *Surface profile readings, before burnishing*

SURFACE PROFILE READINGS
After burnishing

	SAMPLE LOT#								
TEST#	LOT#1	LOT#2	LOT#3	LOT#4	LOT#5	LOT#6	LOT#7	LOT#8	LOT#9
1					5.07	3.92	4.59	4.5	2.74
2					4.75	3.99	4.34	4.48	4
3					4.5	3.94	5.75	2.4	
X BAR					4.77	3.95	4.89	3.79	3.37
RANGE									

AVERAGE OF ALL LOTS 4.154

Figure 13 *Surface profile readings, after burnishing*

Surface Hardness Tests

Using a Rockwell surface hardness tester in Phase I of this research, we found that the surface hardness was increased an average of 12%. The data was relatively reliable and was not duplicated in this second phase of experimentation. The results are shown in figure 14 below:

PHASE I SURFACE HARDNESS

Ag	Meas. 1	Meas. 2	Meas. 3	Meas. 4	Average
1 as cast		26.9	28.4		**27.7**
2 vibe		37.4	32.9		**35.2**
3 roll		31.5	39.4		**35.5**
4 disc	29	34.6			**31.8**
5 mag	35.8	35.1			**35.5**

Figure 14 *Phase I surface hardness*

Cross-section Hardness Tests

Two random samples were chosen from each of the nine lots that were processed. These samples were sliced, mounted and had their surfaces polished. Note in Figure 15 shows the position of the slices taken prior to mounting for the hardness tests. Section "A" is through the center of the casting, which is the largest cross-section. Section "B" is through the yoke, which represents the smallest cross-section of the casting. The photograph shows the relative surfaces tested.

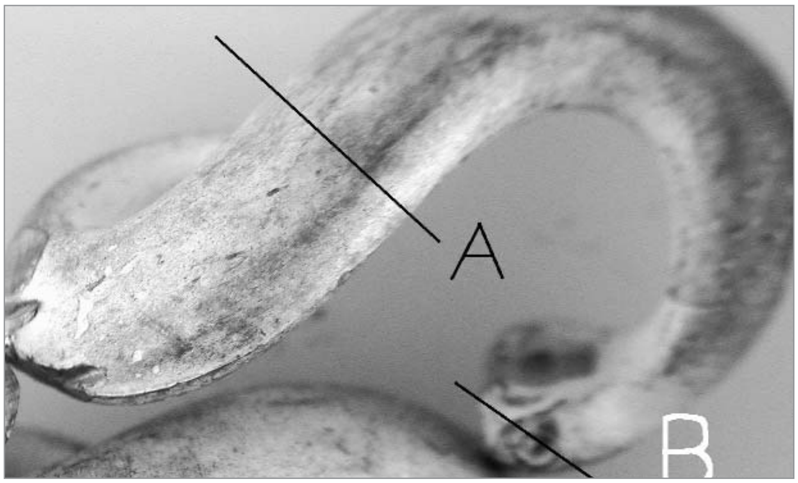

Figure 15 *Cross-sections for hardness measurements*

A Wilson Tukon 2100 Knoop hardness tester with a 500 gram load and diamond point with an impression width of .0015 inches was used on the cross-section. The first reading was taken at a distance of .002 inches from the surface and indexed .002 inches to the depth of .008 inches. The next reading was taken at the center of the large cross-section, and subsequently at the earring yoke, which is the smallest cross-section of the part.

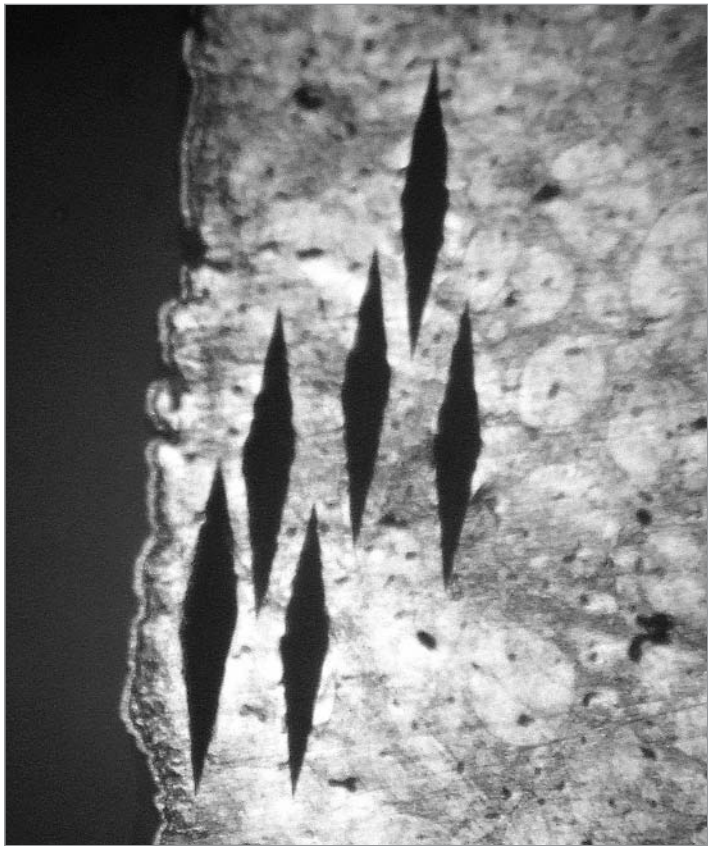

Figure 16 *Cross-section hardness test*

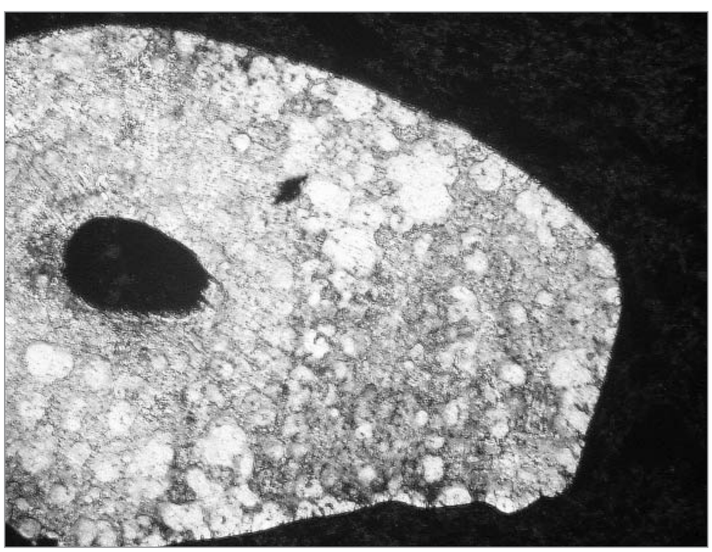

Figure 17 *Yoke cross section*

The cross-section hardness tests reveal several interesting points. We do not recognize any substantial increase in hardness at the surface and, as a matter of fact, in most cases, we had the same or slightly softer readings at the surface of each specimen. This can be explained by referring back to Figure 16. This photograph shows a slight bulging on the surface of the casting at the first measurement, which was taken approximately .002 inches from the surface of the casting. Evidently, this reading was taken too close to the surface for this type of hardness testing. Another interesting point is that the hardness varies a great deal within the same casting. Note in the following Figure 18, that the center of the yoke section (the smallest cross-section) is much harder that the rest of the casting. Also, we had a variation in the range of hardness of the test sample castings that all came from the same tree. We can only assume that, perhaps, such hardness variation on pieces throughout a tree is due to their relative position on the tree.

Cross-section Hardness Test

	0.002	0.004	0.006	0.008	0.01	0.012	0.014	Mean	Std dev	center	yoke
As Cast	51	67	65	71	69	72		65.8	7.7	68	124
Lot 9	86	91	92	96	92	95	91			78	68
After Burnish											
Lot 4	63	64	65	67				64.8	2.5		
Lot 5	96	90	84	76				83.6	8.1		
Lot 6	56	59	60	63				61.7	4.3	72	106
Lot 7	81	74	73	73				74	4	70	117
After Polish											
Lot 1	84	79	74	72				77.7	4.3	76	117
Lot 2	65	71	76	74				71.4	4.2	71	102
Lot 3	69	71	72	72				69.2	4.7	72	135
Lot 4	60	61	70	67				65.7	5.2	71	127
Lot 5	83	82	70	77						67	111
Lot 6	64	77	68	72						76	107
Lot 7	76	77	80	77						97	111
Lot 8	69	68	82	71				73.6	5.8	77	132
Lot 9	63	62	64	68				68.1	9.1	84	120
Phase I											
Star 1	53	62	69	67	68	71				65	
Star 3	67	71	75	74	71	71				68	
Star 4	58	64	63	65	69	66				70	

disc=1&5 roll=2&6 vibe=3&7 mag=4&8

Figure 18 *Cross-section hardness test*

We do know, however, that we did have a substantial increase in surface hardness from our Phase I testing. This prompted us to look at some 500X photographs of the hardness cross-sections. We found that a visible, thin layer "skin" appears on the surface of the burnished castings as shown in Figures 19 and 20. We measured this skin by comparison methods on the hardness tester. The skin is approximately .0002 of an inch in depth. It was not large enough to measure on the cross-section, but it was hard enough to influence our surface measurements.

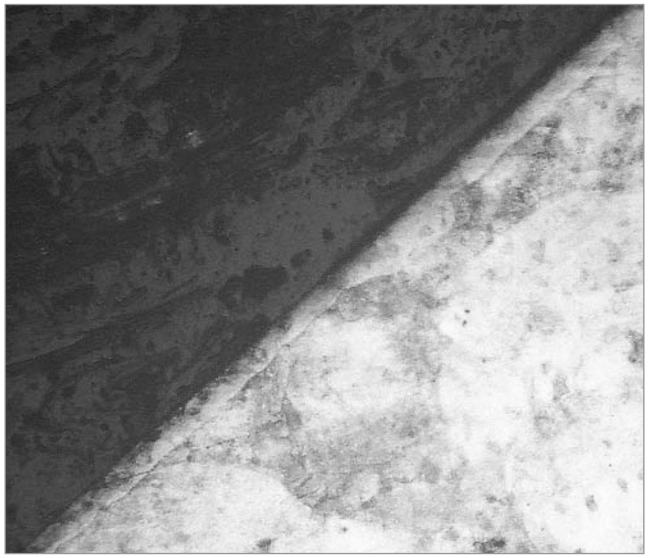

Figure 19 *Hardness skin from burnishing*

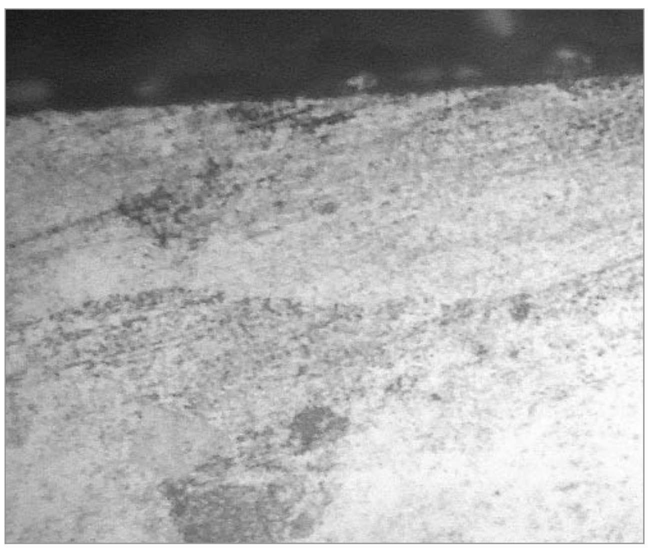

Figure 20 *Close up of hardness skin*

Weight Loss Comparison

Total combined weights were taken of the nine original lots of cast pieces, including the unground section of the feeder sprues. A final weight reading was taken after removal of the feeder sprue and hand finishing. The following chart (Figure 21) reflects the average percentage loss of material from the castings, from the start of processing, to the finish of each lot.

	Method	Begin Weight, ea	End Weight, ea	% Material Loss
WEIGHT LOSS COMPARISON before and after burnishing				
Burnish,Disc finish, & Hand Polish				
Lot 1	DISC	3.75	3.6	**4**
Lot 2	ROLL	3.775	3.67	**2.9**
Lot 3	VIBE	3.575	3.5	**2.1**
Lot 4	MAG	3.75	3.57	**4.9**
Burnish & Hand Polish				
Lot 5	DISC	3.775	3.73	**1.2**
Lot 6	ROLL	3.75	3.6	**4**
Lot 7	VIBE	3.585	3.53	**1.5**
Lot 8	MAG	3.74	3.63	**2.9**
Hand Polish Only				
Lot 9	HAND	3.78	3.6	**4.8**

Figure 21 *Weight loss comparison*

Conclusion

Phase II research establishes the following points of interest:

- Ball burnishing visually improves the "as-cast" surface, which in turn highlights surface defects for easier identification.
- Roll burnishing and vibratory finishing produce the smoothest finish.
- Ball burnishing greatly reduces the surface profile of castings.
- Hardness, as a result of ball burnishing, appears to affect the surface of the casting to a depth of about .0002 of an inch.
- The hardness skin is removed during mass finishing, and/or hand polishing.
- Ball burnishing does not appear to affect the cross-section of the casting.
- The size of the cross-section of cast pieces, and location of the piece on the tree seem to influence cross-section hardness to a great degree.
- Weight loss, from start to finish, was less for ball burnished pieces than it was for pieces not burnished.

The final hand polishing procedure of this phase was performed by a skilled hand polisher at the Tiffany and Company facility in Cumberland, Rhode Island. In many instances in the past, I have heard the same comment relative to finishing from many hand polishers. The general statement was that once cast pieces are burnished, they become too hard to polish. If the finishing is performed correctly, according to the Tiffany polisher, the final hand polishing moves much faster and easier. Defects on the surface are more easily identified. The back surface of many cast items are almost completely finished during the burnishing process. This study also reveals that when initial burnishing methods are used in the finishing procedure, it can result in as much as 3.6% reduction in the weight loss of the final jewelry piece.

Acknowledgements

I wish to gratefully acknowledge the efforts of my good friend, Tino Volpe of Tiffany and Company, for his invaluable assistance in all of the metallurgical experimentation and photography.