PLATED ZINC MATERIALS PROVIDE ENHANCED SECURITY WITH PROVEN TECHNOLOGIES

By:
CARL DELSORBO, M.S.
JARDEN ZINC PRODUCTS, LLC
TENNESSEE, USA

AND

MARK BLIZARD
JARDEN ZINC PRODUCTS, LLC
TENNESSEE, USA

ABSTRACT

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Central Banks and Mints continue to stress the need for more secure and lower cost coins. Plated coinage has met the cost challenge and has partially addressed the security challenge. However, most of these technologies have been focused on the plating layers and less on finding new and uniquely secure, cost-effective substrates.

This paper addresses the introduction of a new zinc alloy series, ZincSecure™, which provides a spectrum of alternative base metal electromagnetic signatures (EMS). These signatures can be outside the through alloy and plated coinage materials commonly used. Additionally, these alloys are available with white, yellow, and red finishes using commonly accepted plating practices. Additionally this paper describes the associated conductivity and EMS testing of this alloy series that demonstrates its alternative values in comparison to typical materials in this market segment. This paper also illustrates the high performance of these alloys coupled with plating layers by presenting comparative EMS, wear resistance, hardness and corrosion resistance testing.

With these new technologies, an electromagnetically secure blank can be delivered to the Central Banks and Mints at a reasonable cost. This is achieved while maintaining a known outer plating layer that is well tested in the market place, exhibiting high wear and corrosion resistance with an attractive luster. The result represents the security of a through alloy coin at plated coin prices.

I. INTRODUCTION

Central Banks and Mints continue to stress the need for more secure and lower cost coins. Plated coinage has met the cost challenge and has partially addressed the security challenge. However, most of these technologies have been focused on the plating layers and less on finding new and uniquely secure, cost-effective substrates.

This paper addresses the introduction of a new zinc alloy series, ZincSecure™, which provides a spectrum of alternative base metal electro-magnetic signatures (EMS). These signatures can be outside the through alloy and plated coinage materials commonly used, with the added feature that zinc is non-magnetic. Additionally, these alloys are available with white, yellow, and red finishes using commonly accepted plating practices. Additionally this paper describes the associated conductivity and EMS testing of this alloy series that demonstrates its alternative values in comparison to typical materials in this market segment. This paper also illustrates the high performance of these alloys, coupled with plating layers, by presenting comparative EMS, wear resistance, coinability and corrosion resistance testing.

Further, zinc based coinage, in general, has many attributes that make it a good candidate for higher denomination coins that require increased security, but continue to have increasing cost pressures due to rising metal costs. These attributes include:

- Cost effectiveness
  - Metal cost advantages over copper and nickel,
  - Density gain (8% to 12% over commonly used materials),
  - Improved coining die life – longer production runs / less cost of dies,
  - Scrap advantages – evidenced reduced coining production scrap and good value on scrapped or reclaimed material,
  - Ease of recyclability of the scrapped or reclaimed material,

- High performance
  - Capability of utilizing most of the common plating finishes in the market – nickel, copper, bronze,
  - Excellent corrosion and wear resistance,
  - Excellent coinability,
- With the introduction of ZincSecure™, increased covert security

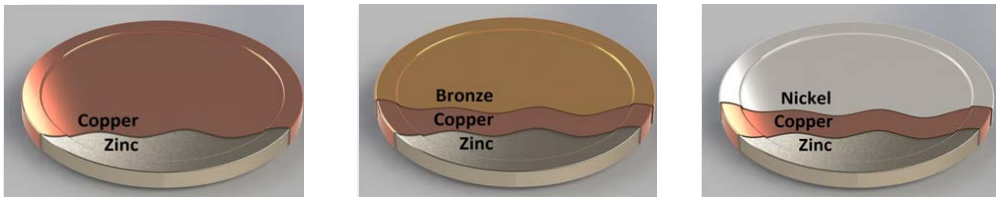
With these new technologies, an electro-magnetically secure blank can be delivered to the Central Banks and Mints at a reasonable cost. This is achieved while maintaining a known outer plating layer that is well tested in the market place, exhibiting high wear and corrosion resistance with an attractive luster. The result represents the security of a through alloy coin at plated coin prices.

Jarden Zinc Products, LLC, is based in Greeneville, Tennessee, United States of America. Jarden Zinc Products (JZP) is part of Jarden Corporation, a Fortune 500 company. Currently with over 300 billion plated blanks in circulation. Jarden Zinc Products has supplied the US Mint copper plated zinc coin blanks since 1981, brass and bronze plated products worldwide since 2004 on varying substrates, and nickel plated products since 2006 on varying substrates. Jarden Zinc Products is an independent supplier of plated blanks and is capable of supplying every plated coin blank technology offered in the world today.

II. DISCUSSION

The scope of this project was to introduce a newly developed zinc alloy series, ZincSecure™, coupled with multiple plating finishes (see Figure 1) common to the coinage market that provides a spectrum of alternative base metal electro-magnetic signatures (EMS). Also included in the scope was to demonstrate the viability of these products for higher denomination coins through various product performance testing.

Figure 1. ZincSecure™ Base Coupled With Standard Plated Finishes



Blanks and tokens were produced using both zinc and steel as substrates in a range of sizes and plating thicknesses, see Table 1. A few common through alloy materials were also selected and added to the test matrix.

Table 1. Materials used in the various test methodologies in this report

Type	Base Metal	Plating Layers	Target Plating Thick. (µm)	Size (Dia.) 19 mm
MultiPly	Steel	Ni/Cu/Ni	5 / 12 / 5	x
Mono-Ni	Steel	Ni	25	x
Bi-Ply	Steel	Cu/Ni	17 / 8	x
CuproNickel	Cupronickel	---	---	
ZincSecure™ NiCPZ	Zinc	Cu/Ni	10 / 5	x
			20 / 10	x
Mono-BrzPS	Steel	Bronze	25	x
Alum. Brz	Alum Brz.	---	---	
ZincSecure™ Mono-BrzPZ	Zinc	Bronze	15	x
ZincSecure™ BrzCPZ	Zinc	Cu/Brz	15 / 10	x
CPS	Steel	Cu	25	x
ZincSecure™ CPZ	Zinc	Cu	12	x

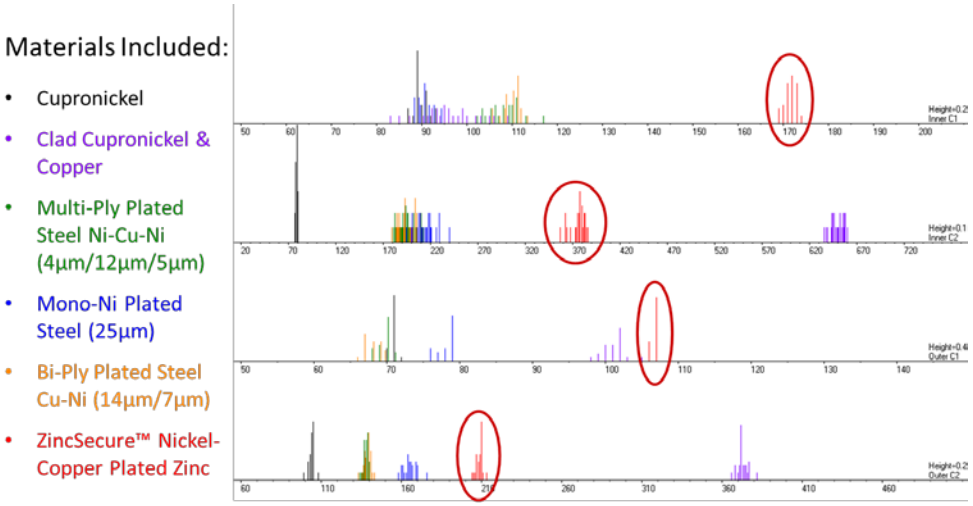
Electro-Magnetic Signature (EMS)

The main purpose of this paper is to highlight and demonstrate the covert security features of this product series and it is through EMS testing that this is accomplished.

The EMS of a product is one of the characteristics by which coins are validated, differentiated and discriminated in coin vending and

coin sorting technology. This is the characteristic by which coinage blanks contribute to the overall security of the final coin design. The ZincSecure™ nickel plated product was compared to general circulation coins made from other plated or through alloy construction common to the white finish coinage market using a ScanCoin 4000 model coin sorter (SC4000). As seen in Figure 4, the ZincSecure™ product has a unique signature in relation to these other products.

Figure 4. Zinc Based Coins Provide a Unique Signature as Compared to Typical White Coinage Products

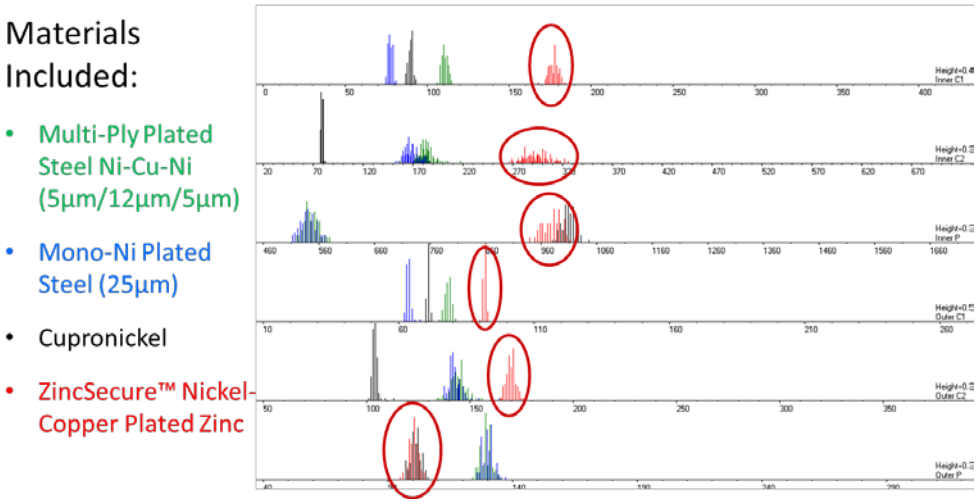


According to the 2012 Coin Design Handbook (CDH) by the European Vending Association, "The Coin's materials, dimensions, shape, construction method, manufacturing tolerances, rim height, embossing, etc. can all affect the EMS of a Coin."[1] For this reason, samples using the various common plating finish technologies were produced to the same size and coined in the same token die for a direct comparison. All sets were run through the SC4000 and the output data plotted (see Figure 5 and Figure 6).

The zinc based product provides an alternative signature as compared to the other white finish technologies with no differences in size or coin design, Figure 5. Also, the non-magnetic materials (zinc and

cupronickel) are distinctly different than the magnetic based material (steel) with regards to the Inner and Outer P component, which measures magnetic permeability of the coin or token.

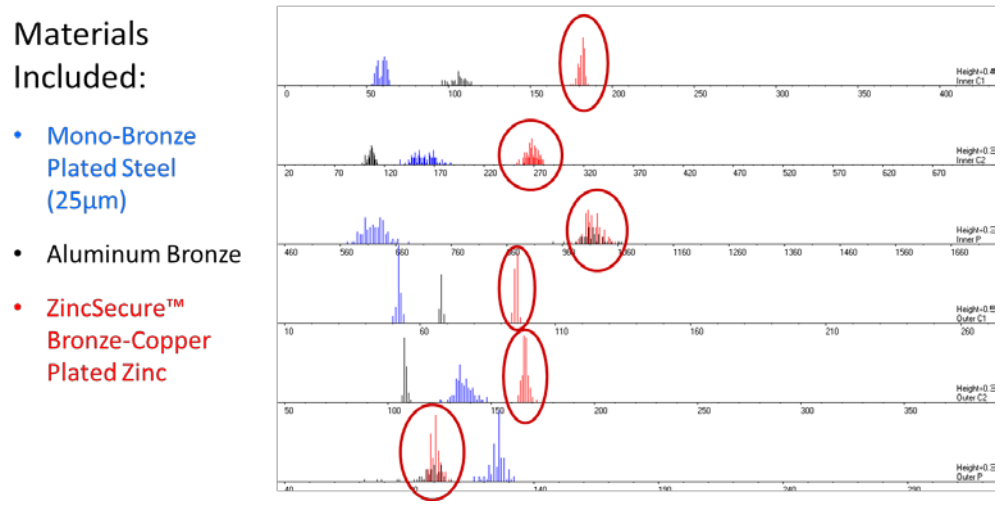
Figure 5. Zinc Based Coins Provide a Unique Signature as Compared to Typical White Coinage Products Using Same Size Blank and Token Die



Similarly, the zinc based product differentiates itself from plated steel and commonly used higher priced yellow products, such as aluminum bronze, Figure 6.

In the next example, it will be shown that just increasing the thickness of plating on a zinc-based product does not shift the signal significantly, unlike a steel based product. This is extremely important, because a major concern with plated steel product is that when the plating layer wears the signal drifts and a larger acceptance window is required to accommodate this drift, making the product “less secure”. This is not the case with zinc based product and is why the ZincSecure™ product can provide the security of a through alloy coin at plated coin prices.

Figure 6. Zinc Based Coins Provide a Unique Signature as Compared to Typical Yellow Coinage Products Using Same Size Blank and Token Die



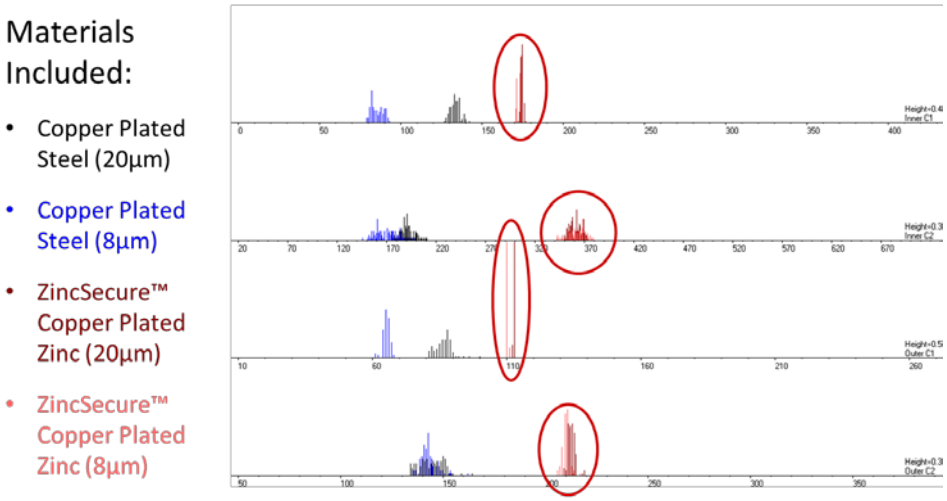
Copper plated steel product at two different plating thicknesses, 8 and 20 microns, were compared to ZincSecure™ copper plated zinc product at similar thicknesses using the same size token and die design. These samples were run through the SC4000 and the results shown in Figure 7.

At significantly different plating thicknesses the zinc based product signal does not drift. In contrast, there is significant drift in the steel based product with changes in plating thickness.

Furthermore, the overall variation in the signal is less with the zinc based product.

Both of these characteristics demonstrate that the ZincSecure™ base alloy is what drives the EMS signal, which allows for a tighter acceptance window, closer to that of through alloy. This increases the overall covert security of the coin.

Figure 7. Copper Plated Zinc Coins Provide a Unique Signature as Compared to Copper Plated Steel Product Using Same Size Blank and Token Die



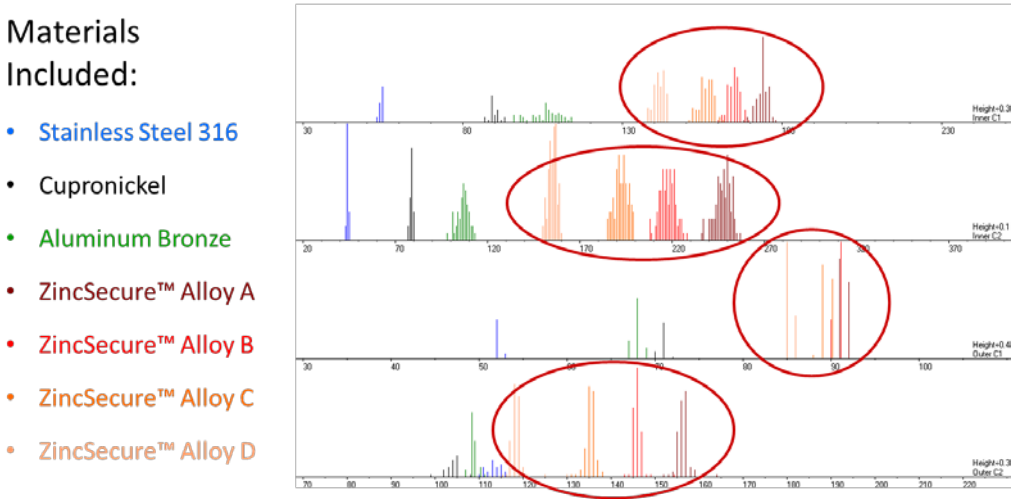
Zinc Alloys - EMS

Up to this point only one ZincSecure™ base alloy was used for simplicity of presentation. However, the key to the ZincSecure™ product is the ability to create multiple variations in the base alloy to arrive at several different, alternative electro-magnetic signatures emanating from the zinc base substrate and driving the overall EMS.

Blanks from different ZincSecure™ alloys were produced and coined using the same token die. These blanks were run through the SC4000 and the data compared to cupronickel, aluminum bronze and stainless steel material. The output data is shown in Figure 8.

As observed in Figure 8, JZP is able to produce base alloy variants that have a demonstrated shift in electro-magnetic signature. This means that when combined with different plating finishes, coin dimensions, coin designs, and coin constructions a myriad of electro-magnetically secure coins can be created.

Figure 8. Four ZincSecure™ Alloys Exhibit Significant Shifts in Electro-Magnetic Signature



Hardness & Micro-Hardness

Samples were tested for bulk hardness utilizing the Rockwell 15T scale and a 15 second dwell time. For micro-hardness, samples were tested at the NRCC (National Research Council of Canada) using a 25 gram load and a 10 second dwell time. The results are shown in Table 2.

These results show that the ZincSecure™ materials have an overall lower bulk hardness, which is an attribute that allows for increased coining die life, lower press tonnage and excellent die fill. Also, the ZincSecure™ plating layers were observed to have a higher overall Micro-hardness than comparable other plated materials or the surface condition of the through alloy material. A higher micro-hardness observed at the surface layer of the coin relates to a higher wear or abrasion resistance of that surface to scuffing or scratches.

Table 2. Relative Bulk Hardness and Vickers Micro-Hardness Measurement Results

Type	Bulk Hardness (Rockwell 15T)	Vickers Micro-Hardness
MultiPly	83.4	284
Mono-Ni	82.4	247
CuproNickel	76.6	181
ZincSecure™ NiCPZ (10/5)	55.5	319
ZincSecure™ NiCPZ (20/10)	55.8	
Mono-BrzPS	78.7	229
Alum. Brz	74.1	220
ZincSecure™ Mono-BrzPZ	58.2	308
ZincSecure™ BrzCPZ	62.4	
CPS	82.2	
ZincSecure™ CPZ	64.9	

Corrosion Testing

Fifty blanks of each type were coined with a common token die and immersed in a 2% sodium chloride solution for four hours. After four hours, the coined blanks were removed, rinsed, and left to air dry for one hour. The coined blanks were then examined for any evidence of "corrosion" (oxidation reaction with the substrate or intermediate layers).

In all testing the plated ZincSecure™ products exhibited acceptable results and an equal to or better corrosion resistance than any of the plated steel based products.

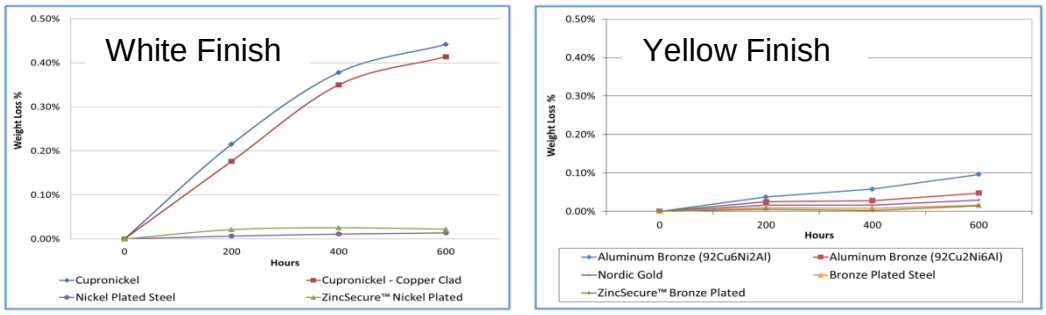
Wear Tests

The accelerated wear tests that are used to predict normal wear of coins in circulation are often one of the more debated topics in the coinage market. This is partly due to tests being constructed to attempt to predict wear for very different environments that a coin may see in circulation. These environments can vary greatly which has resulted in many different types of tests all categorized under one moniker of "wear".

However, the wear tests used in this report are consistent with wear testing practices used in the industry.[2]

The first wear test discussed is one that encompasses all three categories of wear (abrasion, impact and corrosive wear) and is, therefore, JZP's recommended procedure for wear testing. It is a tumble test conducted using containers filled with parts and various media (leather, cork and cotton). This test structure creates sliding abrasive wear between the parts and media as well as incorporates a "bump" design into the container to create part-on-part impact wear. Finally, it includes a specific amount of sweat solution to introduce a corrosive wear component. The tumbler is rotated for 1,000 hours stopping at 200 hour increments to weigh, measure and inspect the coins/tokens for condition. Through our extensive testing, this test has demonstrated more comparable results to normal wear characteristics observed in circulation.

Figure 2. Wear Results - Tumble Test with Media and Sweat Solution

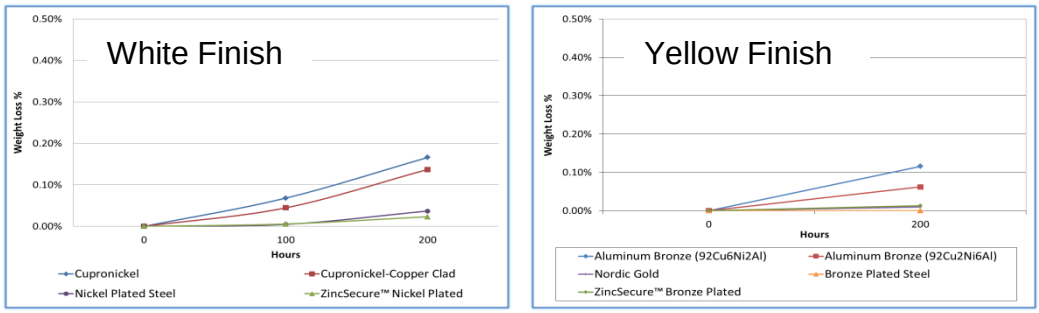


The resulting wear results for the white finish samples are illustrated in Figure 2. As can be seen, the wear results for all nickel plated product, whether zinc-based or steel-based are comparable and exceptionally lower than the through alloy cupronickel material.

A second internal wear test used is again a tumble test with a "bump", but with no media and no sweat solution. Tumbling in this manner allows part-on-part impact, and to some extent sliding abrasion. The tumbler is rotated at a set RPM for 200 hours, stopping at 100 hour increments to weigh, measure, and inspect the coins/tokens for condition.

There is little, if any, corrosive wear, even when different materials are present. In JZP's opinion based on studying multiple types of wear testing, this mode of testing unduly favors extremely hard deposits or base materials and has the propensity to deform parts in a manner not realized in normal circulation. However, this type of test is used by some prominent Mints, and therefore was included to present data in varying conditions. Note: Typically this test would be stopped at less than 100 hours and considered to be predictive.

Figure 3. Wear Results - Dry Tumble Test with no Media



Similar to the wear test in Figure 2, the wear results in this dry tumble test (Figure 3) demonstrate that for all nickel plated product, whether zinc-based or steel-based, the wear rates are comparable and exceptionally lower than the through alloy cupronickel or cupronickel-copper clad material.

The third type of wear test used was the pin-on-disc test. This test is a standardized abrasive wear test (ex., ASTM G99-04) used to quantify abrasive wear characteristics of materials in the general sense. It is not designed specifically for the coinage market or to address all the types of wear mechanisms observed in a circulation environment. However, since it is a standardized wear test and is known to be used as a qualification test for coinage materials by some groups in the coinage market[1], this wear testing was included in the analysis of the plated ZincSecure™ and plated steel products.

The pin-on-disc test was conducted by the NRCC, an internationally renowned materials laboratory. In summary, the NRCC concluded that, "The wear rates of the nickel plated products . . . are comparable or similar to the wear rate of the through alloy Cupronickel."[3] Also, in the same report, the NRCC concluded that, "The wear rates of the bronze plated products . . . are comparable to each other, and significantly lower than the wear rate of the through alloy Aluminum Bronze."[4]

III. CLOSING

Through the above testing, ZincSecure™ products have shown to meet or exceed the typical requirements to classify them as viable candidates for circulated coinage. ZincSecure™ products incorporate the well tested and heavily circulated copper plated zinc technology, that has been in circulation for over 30 years, and the well-established, validated plated finishes (nickel, bronze, copper) used in the plated coinage market today.

In addition, ZincSecure™ products have a range of zinc base alloys that provide alternative electro-magnetic signatures that when coupled with the various finishes, coin dimensions, coin constructions and coin designs, allow for a myriad of electro-magnetically secure coin combinations.

Zinc based plated products also deliver lower Mint costs through a lower purchase price than other secure metals, lower scrap costs, lower transportation costs, longer die life due to lower press tonnage requirements, and ease of recyclability.

All of these factors allow ZincSecure™ products to produce a reliable, secure, cost-effective coin with the feel of a through alloy without the expense.

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[1] European Vending Association. (2012). *The Coin Design Handbook, Version 2.* Brussels, Belgium. pg. 10

[2] McDaniel, Paul and Beets, Randy (2010). *Industry Guidelines for Electroplated Coinage.* Mint Director's Conference 2010 - Technical Committee Report. pg. 23

[3] Yang, Qi and McKellar, R.C. (2014). *Evaluation of Wear Resistance of Coin Blanks Using ASTM Standard Pin-on-Disc Testing Method for Jarden Zinc Products.* Ottawa, Canada: National Research Council Canada - Aerospace-SMM Laboratory. pg. 20

[4] Yang, Qi and McKellar, R.C. (2014). *Evaluation of Wear Resistance of Coin Blanks Using ASTM Standard Pin-on-Disc Testing Method for Jarden Zinc Products.* Ottawa, Canada: National Research Council Canada - Aerospace-SMM Laboratory. pgs. 20-21

Please refer questions to:

Mark Blizard
Vice President,
Coinage Sales and Business Development
Jarden Zinc Products
P.O. Box 1890
Greeneville, TN 37744-1890
+1.423.639.8111
+1.800.251.7506
sales@jardenzinc.com
www.jardenzinc.com