ALUMINUM-BRONZE ALLOY COINAGE:
BASIC DATA AND HISTORY

compiled and edited by: Mr. Gary S. Dykes
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The aluminum-bronze alloy is a modern introduction. The combination of copper and aluminum first took place in the mid 1800s. It was very expensive to produce and consequently, other than being an object of investigation for metallurgists, was not much used. In the early 21st century the U.S., Mint evaluated various metals and alloys to replace the copper coinage in circulation. However, not evaluated were the aluminum-bronze types, probably because they also contain large amounts of copper. As for pure aluminum coins, these are first seen in 1907. [East Africa 1/2 cent].

In the 1865 *Annual of the National Academy of Sciences*, the U.S. Mint assayer (J. P. Eckfeldt) evaluated aluminum-bronze alloy for the production of coins. He determined that an aluminum-bronze coin alloy was unfavorable (his tests alloys were generally, nine parts of Cu to one part of Al): unacceptable as the coins tarnished quickly in the closed hand. [data from the 1865 Annual, tests were done in June 8, 1864, pages 139-142, Appendix C of the 1865 Annual]. [NOTE: Eckfeldt had heat treated and shaped the metal before testing, which probably accounts for the tarnish he observed]. Modern methods and alloy improvements, provide aluminum-bronze ingots/coins with no tarnish problems.

P. H. G. Durville of France has a patent (US 1007548A) involving the making of aluminum bronze alloys via the addition of the proper amounts of manganese for reducing the aluminum oxides occurring during the making of the alloy. This patent was filed in 1910, and granted in 1911. He recommended the addition of .5% to 5% of manganese to the aluminum-copper alloy. This solved a problem seen in early aluminum-bronze alloys, it removed the oxides and air/gas pockets in the metals which caused cracks and other problems. Durville also shortly afterward, patented a process for tilted pouring of molten metals so as to avoid bubbles and slag, and air pockets. Both patents paved the way for the production of aluminum-bronze coinage. Durville's own France led the way, as we see aluminum-bronze coinage first appearing there in 1920, with the one Franc coin and other denominations. Interestingly, we also see early aluminum-bronze coins in Brazil in 1922, the 500 and 1000 Reis coins. Many nations soon followed France, including Russia, Germany, Denmark, Finland, Greenland, Guatemala and Portugal, et cetera. The United States has yet to mint an aluminum-bronze coin. Below an announcement concerning the new (1921) French coins:

NEW BRONZE-ALUMINUM COINAGE.

[From bullion letter of Samuel Montagu & Co., September 8, 1921.]

* * * The pieces are struck from an alloy of bronze-aluminum, the correct proportions having been found only after much research. The coins are of an attractive golden color, and at present are being struck at the rate of 10,000,000 francs per month. We are informed that the small output is owing to the deteriorating effect of the new alloy, which is very hard, upon the machinery used in coining.

As concerns copper Cu, we note that the world's principal copper mining areas are around the Pacific Rim and Central Africa. In Europe, the main copper mining countries are Russia, Poland, Portugal, Spain and Sweden. As for the production of aluminum-bronze coins, one other element is of course required, aluminum. Aluminum is the most abundant metallic element in the earth's crust. Bauxite, the ore most commonly used as a source of aluminum, is found primarily in the less industrialized areas of the world. The leading world producer of bauxite in 1971 was Jamaica where 1.8 million short tons were produced. The wear-corrosion characteristics of aluminum compare very favorably with 95 percent copper - 5 percent zinc coins. So the limiting factors as concerns the minting of aluminum-bronze coins are: availability of copper, and the technology and foundries needed. Hence most industrialized nations can and do mint aluminum-bronze coins.

Types of Aluminum Bronze

In many cases of aluminum-bronze coins, the tin component of true bronze is largely replaced by aluminum. Hence it is not a regular "tin-bronze" but aluminum-bronze, aluminum and copper. There are also different kinds of standard bronze alloys and these bronze alloys often contain 88% copper and 12% tin. Alpha bronze consists of the alpha solid solution of tin in copper. Some alpha bronze alloys which contain 4-5% tin are used to make coins, springs, turbines and blades.
The copper-aluminum alloys commonly known in English-speaking countries as "aluminum bronzes" contain approximately 5% to 11% aluminum, some having additions of iron, nickel, manganese or silicon. It is assumed that coin alloys have some of the following characteristics:

The following table lists the most common standard aluminium bronze wrought alloy compositions, composition of the alloy by weight. Copper is the remainder by weight and is not listed:

Alloy	Aluminium	Iron	Nickel	Manganese	Zinc	Arsenic
CuAl5	4.0–6.5%	0.5% max.	0.8% max.	0.5% max.	0.5% max.	0.4% max.
CuAl8	7.0–9.0%	0.5% max.	0.8% max.	0.5% max.	0.5% max.	
CuAl8Fe3	6.5–8.5%	1.5–3.5%	1.0% max.	0.8% max.	0.5% max.	
CuAl9Mn2	8.0–10.0%	1.5% max.	0.8% max.	1.5–3.0%	0.5% max.	
CuAl10Fe3	8.5–11.0%	2.0–4.0%	1.0% max.	2.0% max.	0.5% max.	
CuAl10Fe5Ni5	8.5–11.5%	2.0–6.0%	4.0–6.0%	2.0% max.	0.5% max.	

Alloys similar to the above aluminum-bronzes are used in making coins: for example the 20, 200 and 500 Italian Lire, the one and two dollar coins of Australian and New Zealand currency produced by the Royal Australian Mint, some Mexican coins and the Nordic gold used for some Euro coins.
The Canadian two dollar coin, produced by the Royal Canadian Mint and circulated since 1996, is a bi-metallic piece with an outer ring of nickel-plated steel and an inner core of aluminum-bronze composed of 92% copper, 6% Aluminum, and 2% nickel (also known as Bronzital). [chart (modified) and this paragraph - courtesy of Wikipedia]. Paragraph below is from the Encyclopedia Britannica's article:

Aluminum bronze, any of a group of strong, corrosion-resistant alloys of copper containing from 4 to 15 percent aluminum and small amounts of other metals, used to make many machine parts and tools. Because of their golden color and high tarnish resistance, the alloys are also used for jewelry and in architecture. Their resistance to oxidation at high temperatures and to corrosion, particularly by dilute acids, makes them useful for pickling equipment and other service involving exposure to dilute sulfuric, hydrochloric, and hydrofluoric acids. They have strength comparable to that of mild steel and are used for such machinery as paper-making machines, brush holders and clamps for welding machines in the electrical industry, heavy-duty gear wheels, worm wheels, metal-forming dies, machine guides, non-sparking tools, and nonmagnetic chains and anchors. Aluminum bronzes can be welded by the metallic arc process and can be brazed (soldered with certain alloys) with special fluxes.

Alloys with up to about 8 percent of aluminum can be cold-rolled into sheet or drawn into tubes for use in chemical plants and oil refineries for pressure vessels and heat exchangers. Alloys with more than 8 percent of aluminum may also contain iron and manganese; they are capable of limited cold-working but can be hot-rolled, extruded, or forged. The strongest and most corrosion-resistant of the group contains nickel; it has been used for gas-turbine compressor blades. Alloys containing approximately 10 percent aluminum are fabricated by sand casting and gravity die-casting into strong objects, including ship propellers. [courtesy of: Encyclopedia Britannica]

In 1969-1971 for example, the 20 Paise aluminum-bronze coins of India were alloyed as follows: 92% Copper + 2%Nickel + 6%Aluminum. These coins were probably harder than the two below.

Below, are two coins of Brazil:

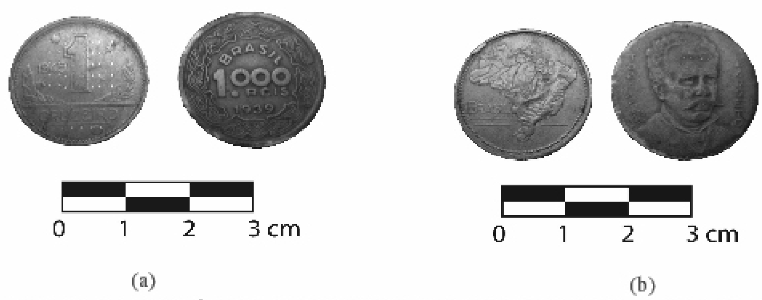

Fig. 2: Brasilian coins 1945 One "Cruzeiro" and 1939 Thousand "Reis", (a) averse (b) reverse of coins.

Table 1: Elemental Coins Composition defined by Edict –law.

Coin	Cu (%)	Al (%)	Zn (%)
1939's Thousand "Réis	90.0 (20)	8.0 (10)	2.5 (10)
1945's One "Cruzeiro"	90.0 (20)	8.0 (10)	2.0 (20)

These two coins were then tested as per below, following the published article title:

Laser Induced Breakdown Spectroscopy (LIBS) applied to stratigrafic elemental analysis and Optical Coherence Tomography (OCT) to damage determination of cultural heritage Brazilian coins.

Nuclear and Energy Research Institute, IPEN / CNEN – SP, A
v. Prof. Lineu Prestes, 2242,
São Paulo, SP, BR 05508-900

National Institute of Metrology, Standardization and Industrial Quality
INMETRO, Av. N. Sra.
Das Graças, 50 –Duque de Caxias – RJ , BR – ZIP: 25250-020

THE RESULTS (layer by layer, in microns)

Table 3: Elemental Concentration of coins constituents of 1945's One "Cruzeiro" on analyzed layers, after non-thermal ionization fraction correction.

Element	Concentration (%)					
	40μm	80 μm	120 μm	160 μm	200 μm	400 μm
Cu	89.0 (11)	86,5 (5)	86,5 (6)	90,9 (8)	88,8 (8)	89,0 (17)
Al	8.08 (12)	9,85 (7)	10,88 (9)	7,09 (18)	9,1 (10)	8 (4)
Zn	1.09 (17)	2.00 (12)	1.74 (12)	1.82 (16)	1.9 (6)	2.5 (5)
Ca	0.129 (3)	0.0852 (19)	0.030 (4)	0.0107 (22)	0.0082 (15)	-
Na	0.651 (5)	0.1307 (16)	0.1614 (28)	-	-	-
Mg	0.309 (6)	0.1922 (19)	0.0730 (10)	0.0277 (8)	0.0172 (7)	-
Fe	0.71 (7)	0.59 (6)	0.22 (10)	-	-	-
Ti	-	0.23 (5)	0.16 (3)	0.13 (5)	0.14 (8)	-
Mn	0.0098 (16)	-	0.0200 (19)	-	-	-
Si	0.0138 (13)	0.46 (9)	0.19 (4)	-	-	-

The two charts above, demonstrate the composition of two aluminum-bronze Brazilian coins: the top shows the published alloy composition of the coins, and the second shows a laboratory analysis. As the testing went deeper into the coin, we note that it shows that the core elements are: 89% Cu, 8% Al, and 2.5% Zn, which matches the typical stated composition, seen above. Most of the trace elements are seen on the coin's surface. Some of the trace elements result from the intentional alloy as well as: (1) the casting/molding environments and (2) contamination of the planchets as they were being extruded and rolled. Additionally, I have read that 100% pure aluminum is difficult to produce, it usually contains some minute trace elements.

This family of aluminum-bronze alloys have compositions between 3 and 15% of aluminum with additions of iron, manganese and nickel, as mentioned. The alloys with less than 8% Al are known as single phase; those with more than 9% Al are known as two phase and capable of being quench hardened to give a martensitic micro-structure. The addition of Sn (tin) to Cu, 7% Al in presence of 1% Fe and 1% Mn increases the corrosion resistance in HCl, H2SO4, NaCl and Sea Water. BUT...tin addition in the absence of Fe and Mn causes embrittlement of the Cu, 7% Al alloy. Thus one can see that much experimentation and time was involved in just perfecting this one composition, utilizing Sn.

Collectors who want to identify the type of aluminum-bronze coin in question, have only three reasonable options: color, dry weight, and specific gravity. A lighter, pale color indicates higher amounts of Al, or the addition of Sn or Ni. Darker reddish colors suggest the addition of Mn or higher levels of Cu, and perhaps Fe. Lighter (weight-wise) coins suggest more Al or Mg. Zinc can at times darken the overall color. Note the Kroner below, it has streaks revealing its alloyed nature. The darker streaks may be copper or but being umber in color are probably streaks of manganese! They are seen on both the reverse and obverse sides of the coin..

Above a 2 kroner coin of Denmark, showing alloying streaks.

Concerning the current standard Euro coins, we note these compositions:

10, 20 and 50 cent	CuAl5Zn5Sn1
1 and 2 euro	CuNi25
1 and 2 euro	CuZn20Ni5

As you can see, each mint or nation can and does utilize various compositions of aluminum-bronze alloys. These can be differentiated by careful specific gravity tests. None respond to any types of magnets that I know of, even with small amounts of Ni or Fe. So for the average collector, one must rely upon the color, the weight of the coin and its specific gravity to gain some idea of its possible composition, as mentioned. For the collector with deep pockets I can suggest the following metal testing equipment, which is non-destructive:

XRF (X-ray fluorescence spectrometry) is a non-destructive analytical technique used to identify and determine the concentrations of elements present in solid, powdered and liquid samples. XRF is capable of measuring elements from Beryllium (Be) to Uranium (U) and beyond at trace levels and up to 100%. An X-ray fluorescence spectrometer measures the individual component wavelengths of the fluorescent emission produced by a sample when irradiated with X-rays. An X-ray fluorescence spectrometer often includes special electronics and software modules to take care that all radiation is properly analyzed in the detector. A hand-held model can be had for about 23,000 dollars - below:

The SPECTRO xSORT hand-held XRF analyzer is designed for high-throughput elemental testing and spectrochemical analysis of a wide range of metals and other materials in the field. Its speed, accuracy and ease of use set new benchmarks for hand-held XRF spectrometric performance. When it comes to positive material identification equipment, SPECTRO'S hand-held XRF analyzer is the ideal solution. It is also ideal for use as an environmental analyzer and for applications such as XRF RoHS testing, recycling of alloys including aluminum, precious metal analysis, plus mining and compliance screening. For many jobs, such as material verification, the SPECTRO xSORT hand-held XRF analyzer delivers highly reliable analyzes in two seconds. And, for more complex matrices such as in environmental screening, SPECTRO xSORT achieves very low detection limits without the need for complex sample preparation. Do note that other bench-top type models of XRF analyzers can cost less than $2,000 and work quite well.

Cleaning most aluminum-bronze coins is not difficult. When dipped in Ezest coin dip (for example) most aluminum-bronze coins come out cleaner and brighter. Aluminum-bronze coins are almost impervious to most acids, chlorides and salts. However, very dirty and worn coins may not do well in ammonia, as it can alter the color of the coins. Tarn-X, is useful to "freshen up" nice BU and proof aluminum-bronze coins. Acetone is the standard solvent used to remove glues, oils, plastics, gums and fresh fingerprints.

As to melt-values, it is said that in Argentina, many coins are melted for their metal content, including aluminum-bronze coins. In fact a severe shortage is occurring there, a lack of coins!

All aluminum-bronze coins have good corrosion resistance but they vary in this respect according to their metallurgical structure which in turn depends upon the composition of the material and its manufacturing history - especially the thermal treatment to which they have been subjected. In reality, each nations' aluminum-bronze coins are in some ways quite unique, [as demonstrated above] especially as to their metallic composition when all of the actual elements are analyzed and revealed!

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