HOW CAN ONE DISTINGUISH REAL FROM FAKE GOLD IN A NON-DESTRUCTIVE MANNER?

Recent interested in gold and silver due to a potential demise of paper currencies worldwide has brought to the forefront the question of how pure are those gold bars being held by ETFs , international banks, and at Ft.Knox . Rumors have been spreading (possibly initiated by short sellers) concerning some of the commonly traded 400oz gold bars being just cladded tungsten. How can one tell? There are several ways, some simple others more elaborate and expensive.

The first and oldest approach for testing the purity of gold in a non-destructive manner is the fluid immersion test first proposed and used by Archimedes. The story goes that Hiero , the ruler of the Greek colony at Syracuse, Sicily had a crown of gold made by a local goldsmith using a given weight of gold supplied to the goldsmith by the king. On receiving the finished crown Hiero was suspicious that the crown may not have contained all of the original gold but rather made with a mixture of gold and less expensive silver. The weight of the crown just matched the weight of gold he gave the goldsmith so he could not directly prove that the goldsmith had kept part of the gold. To the resolve this problem the king called on his scientific advisor Archimedes. Archimedes thought about the problem for awhile and while taking a bath suddenly had a "eureka" moment. He realized that a body immersed in a fluid is buoyed up by the weight of the displaced fluid. This information allowed him to first weigh the crown in air and then in water knowing the difference equals the weight of the displaced fluid. This information allowed him to deduce the density of the crown without needing to know the crown's volume. Mathematically one has the crown density equals-

$$\rho_{crown}=\rho_{water}/[1-(W_{water}/W_{air})]$$

where W is the weight using any convenient weight system. So if the crown weighed 9lbs under water and 9.5lbs in air, the density of the crown would be $\rho_{crown}=1/[1-9/9.5)]=19\text{gm/cm}^3$ which is essentially the density of gold and everything would be found to be ok. Another version of the story is that the weight ratio was found to be 9/9.7 yielding a density of $\rho_{crown}=13.85$ indicating that the crown contained more silver than gold. Now applying such a test to a fake gold bars made of a tungsten core surrounded by a thin layer of gold plating **would probably not give a definitive answer since the density of gold and tungsten are almost identical.** The handbooks give $\rho_{Au}=19.32\text{gm/cm}^3$ and $\rho_W=19.25\text{gm/cm}^3$. This leads us to a second approach involving acoustics.

It is known that the speed of sound in a material goes as the square root of the bulk modulus divided by its density. For gold the speed of sound is 3240 m/s while one has a value of 4620m/s for annealed tungsten. This wide difference in sound speed will lead to a large reflection coefficient R at a tungsten gold interface equal to-

$$R=[(1-\gamma)/(1+\gamma)]^2 \quad \text{with} \quad \gamma=\text{impedance ratio}=[(\rho c)_W/(\rho c)_{Au}]=1.421..$$

(See our MATHFUNC.htm page for a derivation of this formula). The value of R in this case will be 0.0302 so that a full three percent of the incident acoustic energy will be reflected at the gold-tungsten interface. This will be easy to detect using an ultrasonic acoustic machine such as used in the medical arena. It is only necessary that a good acoustic seal is provided at the surface of the gold bar and that the ultrasonic pulses sent into the bar have a frequency f greater than c_{Au}/δ, where c_{Au} is the speed of sound in gold and δ the thickness of the gold cladding. An additional benefit is that one will be able to determine the cladding thickness from the return echo. For detecting a 3mm thick gold cladding the pulse frequency should be above 1 megahertz.

A third (and least high tech) way to detect fake gold bars with tungsten cores involves tapping the bar with a hammer and listening to the resultant sound. The acoustic response should be detectible by a trained ear and could be automated using stored signals for solid gold bars of equal dimensions. This last method is essentially equivalent to the practice of testing gold coins by dropping them on a flat surface and listening for the sound.

Other methods such as electrical resistance measurements, heat transfer measurements, and magnetic response measurements should also work but not as efficiently and inexpensively as the acoustic approach. **Our recommendation would be to first weigh a gold bar, then perform an Archimedes test, and finally apply the above described ultrasonic test on all larger gold bars held by banks and individuals. A foreign metal such as copper and silver mixed with the gold would be quickly detected by the Archimedes approach. A homogeneous mixture of gold and tungsten would be detected by the acoustic method by noting the higher sound speed in the mixture.** It is very likely that one will find only a very small number of fakes but it will help put investors' minds at ease. At today's gold price of $1292 per troy ounce, the standard 400oz (=12.441kg) gold bar is worth $516,800. Gold jewelry of 18k and 14k contain only 18/24=75% and 14/24=58.3% gold, respectively.