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Session Two:

Electronic Weighing – Gold and Silver – A Refiner's Experience

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I. Introduction

I am here to talk to you about a heavy subject – weighing. This is electronic weighing from a refiner's perspective. I am here to discuss different approaches to weighing gold and silver bars: to share our experience with weighing with electronic balances for 400 troy ounce gold bars, and share with you briefly some of the experiences we have had with the 1,000 troy ounce silver bars. I also want to review the gold giveaway: how that changes depending on how you do your data calculations from the same set of data. It is a bit of mathematical playing, but it is very interesting to see how that plays out in terms of real-world giveaway.

II. Electronic Weighing – Gold and Silver Bars

As we are aware, the bank vaults in London have gradually begun to switch to electronic weighing systems from beam balance. A wide range of weighing devices is available: there are many manufacturers out there and not all have the same capabilities in terms of capacity or precision. Overall there are low to moderate costs. You can then go to a mass comparator, which gives you extra precision; these are used by mass meteorologists to certify weights, and they are used for a narrow range of comparison between a check weight – or a known artefact weight – and your unknown weight. These have been used to weigh gold; there must be a trained operator to use them, and they are very expensive: they are about three to four times more than a normal electronic balance that would be used for weighing gold. There has also been a beam balance that has been fitted with a load cell on one end – there have been reports of that. These are custom built and they are very high cost; of course, because they are beam balance, you still have to maintain the knife edge for the weighing device. It is kind of a hybrid between two worlds, but it does cost more and is more costly to maintain.

III. Mass Measurement at the Royal Canadian Mint

In the Ottawa facility we have 104 electronic balances in operation. They range from micrograms for our assay balances, to thousands of kilogram floor scales. We have an annual electronic balance calibration done by the vendors that we have for our ISO 9001/2008 requirements. However, check weights are at each balance – or for most of them – and they are required to be used on a daily basis.

We also have a Mass Meteorology Lab within the Mint, and we have primary waste mass calibration standards that were done at the National Research Council Canada's national lab; these are about as close to the national kilogram that you can get. Our weight uncertainties are therefore very low and all check weights are calibrated by the Mass Lab. All calibrated mass values are traceable to the international kilogram, and our technicians have gained a lot of experience in repairing balances before calling in a service technician. This gives us a lot of up-time for our balances.

IV. Gold Bar Weighing Technology RCM

When the Mint started in 1908 to about 1976 – slightly before my time – we used the beam balance to weigh gold. Then from 1976 to 1995 we used one of the first electronic balances, a Mettler-Toledo PK60. In 1995 this got changed to an upgraded Mettler-Toledo, but we had to have a service module installed so we could get an extra decimal place displayed on it. This worked very well. This was ending its life just as Sartorius Gold Bullion Balance came out, and it seemed like an opportune time to buy a Sartorius Gold Balance in 2011.

This is what it looks like. We have two of these balances: the one on the left has a gold bar on it, and it is resting on what looks like two hockey pucks – sorry, Canadian reference to hockey, cannot get away from it. The one on the left has a 400 troy ounce check weight that we use on a daily basis. Above that we have the wires leading up to a computer which automatically catches the data.

You will also notice we have a guard rail in front; we found this to be very important because there are always big trucks of gold being run around. The last thing you want to do is have the table knocked repeatedly, which we did have initially until we put the guard rail there. That has saved a lot of balance time, from not having to re-level it, and things like that. That is what our physical system looks like.

V. Approaches to Weighing

If we take a look at our approaches to weighing, you can do it one of two ways. You can have a single balance, which is simpler to operate, requires less space and lower cost, but the downside is you may have to do your check weighing more frequently to make sure the balance is operating in the required fashion. We have gone to a two balance system, where you have two independent checks: replica weighing determinations for the bars. This gives you an automatic verification for the gold bar weight because it is unlikely that both balances will be out of whack at the same time, and if one is down you can still operate, and weigh bars, but you just have to verify your check weight more frequently. It is higher cost and takes up more space, but overall we feel it is quite worthwhile.

VI. Sartorius GBB Gold Balance

In terms the Sartorius Gold Balance, this reports mass in troy ounce, and you can have the choice of recording it to 0.01 grams or 0.001 troy ounces. For a 400 troy ounce gold bar, you can either have it reported in troy ounces with six significant figures or in grams with seven. We prefer to operate in grams, and it gives us an extra significant figure to operate in.

There is supposed to be minimal interference from air, with that hockey puck-like design to rest the balance on it. However, it is not interference free: you do have to be wary about air movement in your room. If you consider the air density is about one kilogram per cubic metre of air, the mass of air in our weighing room is about 178 kilograms, so if you get the ventilation system moving air around that room, you have 178 kilograms of air moving around the room. It is not insignificant. We had to change the ventilation fins a bit so it diverted air away from the balance. You can still have air circulating; you just do not want to have air flowing onto that balance, even though it is a minimal footprint.

VII. Balance Performance Test

We did a performance test over 40 days, where we would come in, warm up the balance – put on a check weight five times but not record the weight – then measure a stainless steel 400 troy ounce check weight in grams, and then record that information and convert to troy ounces. We would do that measurement, and then do a third step: we perform an internal calibration, and then re-measure the stainless steel weight. We repeat steps one to four for 40 working days. If possible I tried to do this at different times.

The results for a 400 troy ounce stainless steel check weight in grams are summarised. The first column is just doing the warm up only, on the left and on the right we have the internal calibration. You can see the averages are very close to each other: the big difference is in the standard deviation of 40 replicate measurements. When you just do a warm up only, you have a plus or minus 0.05 standard deviation; if you do an internal calibration and then put on the check weight, you get much more precise data: lower standard deviation of plus or minus 0.02. The third row gives you the mass certificate value for the check weight in grams. For those of you that are not conversant in grams – being in Canada we are used to doing things bilingually – we have also done it in troy ounces. This is our mass weight in grams. The difference is very slight: 0.01 grams difference when we did the internal calibration. Practically speaking this is not a measurable difference in troy ounce: if you were to do a confidence interval with a coverage factor of two on your standard deviation, 95% of the results would land between plus or minus 0.1 gram or plus or minus 0.04, depending on whether you did a warm up only or used an internal calibration.

That gives you a sense of what the long-term performances of these balances are. We are quite happy with that, and it does point out that the internal calibration is quite useful.

This is the same data just converted to troy ounces. I have included in brackets an extra decimal place, or four, because we can go to seven significant figures in grams. Standard deviation is very low in troy ounces; the difference from our certificate weight, once we convert to troy ounce, is there is no difference to three decimal places, and the confidence interval in troy ounces is very small. Nevertheless there is some variation, which you can expect in any measurement system.

VIII. Comments on Performance

In general terms, the internal calibration is useful: you have improved precision and lower standard deviation when you do that. There is no real change in accuracy. The short-term precision specification is then observed at plus or minus 0.02 grams or plus or minus 0.006 troy ounces over the entire mass range. Then, based on this long-term data, you can set your internal check weight limits to either plus or minus 0.002, or 0.004, depending on whether or not you are using internal calibration. What was interesting is we have always heard that the manufacturers say you should be using internal calibration; I wanted to verify it myself, and I am pleased to see that what I observed and what the vendors were saying was the same thing.

IX. Experiment II: Weight Calculations and Rounding

1. Overview

We did another experiment: we wanted to review the weight calculations and rounding for a number of gold bars. We took 16 - 400 troy ounce bars, measured them in grams on two different gold balances to seven significant figures, and then we repeated the experiment and weighed them in troy ounces to six significant figures. We wanted to compare the gold giveaway from the different calculation methods, which I will speak to in a minute.

There are some notes on the bottom of the slides that indicate, in red italics, the gold giveaway. If I put a grey box around it that means that the gold value that I display is lower than my first method.

2. Gold Bar Weighing – Single Balance

In this next slide we have the gold weighing presented here where we just do a single weight in grams. We convert the grams to troy ounces; we apply the rounding – take 0.002 off as per the LBMA calculations – and then we do the rounding to the lower quartile and get a giveaway based on taking the average full weight and subtracting the rounded weight. That is our difference in red: 0.297, for 16 bars.

3. Gold Bar Calculation Variations

That is a very standard calculation. What I tried to do is compare five different methods; this is mathematical play-time. Let us see what happens if we do these different things:

- In the first case, this is straight out of the LBMA manual, where we weigh in grams. We take the average of two weights, subtract 0.002 and then do the quartile rounding.
- The second method is to take the average of the weight captured in troy ounces, take 0.002 troy ounces off of that, and then do the quartile rounding.
- If you want to be a little bit more conservative and not risk over-reporting you can take 0.003 off instead of 0.002. What will happen? You would expect the giveaway to go up.
- If you really want to be conservative, you take 0.005 off.
- In method five, you take the lower of the two weights and you take 0.005 off – if you really want to be conservative and not worry about over-reporting. This minimises the possibility of over-reporting, but it will probably increase your giveaway.

4. Gold Bar Weighing – Two Balances

Let us consider the first case – method one – where we take two weightings in grams, weight one and weight two. We take the average of that and then we convert to troy ounces as an average, take the 0.002 off, and then do the rounding. Lo and behold, if we compare the average weight to the rounded weight there is a difference of 0.272, which is actually lower than when we did it solely in troy ounces.

5. Gold Bar Weight Calculation

Rather than going through these ad nauseum, we try to summarise this in this slide, and it is somewhat busy, but the thing I want you to focus on is really the lowest giveaway row.

Method one is our standard method, where we take the average of two grams to troy ounces and take off 0.002. That is our comparison point. If we go to method two where we just convert everything to troy ounces – or do all the measurements in troy ounces – and take off 0.002, we find a slightly higher giveaway of 0.297. Method three, where we are taking off 0.003, as you would expect, our giveaway is a bit higher, but only on one bar. If we go to methods four and five where we are even more conservative we see a few more bars that are showing a higher giveaway – or a lower rounding – and you can see at the bottom the giveaway is 0.372 in those two cases.

6. Comments on Various Calculation Methods

It was a little bit of a play time to see, if we are going to have a bad giveaway, how bad would it be – so we know. In terms of comments that we take away from this, different gold giveaways were observed for 16 bars; single versus average of two weights: that gave different giveaways. If we weigh in grams, average, and then convert to troy ounces, we are going to get a lower giveaway than if we just do everything in troy ounces. As the value to swing the bar increases, the giveaway increases of course; increasing the value taken off the original weight, your risk of over-reporting is decreased, your gold giveaway increases, and the vaults may have to re-evaluate the weight of your bar, because they will not be using the same calculation if you use something other than 0.002. From discussions I have had with vault managers, they do not like that because it creates more work for them if they have to re-evaluate the bar; they will weigh it on an electronic balance first, and if there is a discrepancy, then they will take it to a beam balance to weigh. That creates a lot more work for them.

X. Silver Bar Balance Workstation

In terms of silver bars, because they are heavier we used a slightly different weighing method: we are using a Mettler Toledo X64001L balance, which has just under a 2,000 troy ounce capacity, and resolutions to 0.001 troy ounces. Because the bars are a lot heavier to deal with we put them on roller tops and roll the bars on to the balance. We found this to be very useful: it is easier on the balance and easier on everybody's backs.

We took a look at a 1,000 troy ounce check weight over 24 days and we compared the two balances that we had. We had a standard deviation of 0.009 for the RCM143, which is an older balance, and the newer, 174, we had a little bit tighter tolerance. If we compare it to the certified mass of the check weight, we find there is very little difference between them: not anywhere near what we would consider significant. The Good Delivery Rules state that readability has to be at least 0.1 troy ounces, the repeatability has to be at least 0.02 troy ounces and the calibration uncertainty has to be within 0.05 troy ounces; we met all those criteria.

XI. Observations: Gold Bar Weighing

In terms of confidence intervals, generally for 100 troy ounce bars, we can say it is somewhere around 0.01-0.02 for a 95% confidence interval and a 0.02-0.03 for a 99% confidence interval. Precision and accuracy do meet the Good Delivery Rules. High volume of weighing material on these electronic balances may cause them to fail or fall out of tolerance for gold and silver sooner than you would expect: generally within three to five years. Our older RCM143 in the previous slide had a higher tolerance, or standard deviation, than the newer one at 0.006.

XII. Conclusions

For gold bar weighing, measuring in grams and then converting to troy ounces is preferred: it gives you more significant figures. Two independent weightings have advantages. It may be worthwhile to review the weight calculations within your institution to make sure that your giveaway is meeting your requirements. In general it is good practice to monitor the check weight results and repair frequency, and be prepared to replace the balances more frequently after three to five years of use. It may be within the manufacturer’s tolerance requirements, but it may not meet your tolerance requirements.

With that, I would like to thank the Royal Canadian Mint for their support in this, the various refiners and vaults for informal discussions, and the LBMA for the invitation to speak. I would like to thank you for your attention.