**Response to**
**Request for additional information**

From

**Richard Struckmeyer**

Dated Feb. 14, 2012

Prepared by

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**Ideal Source Quality Assurance**

Numbering corresponds to numbering in Struckmeyer letter.

1) You are correct in your interpretation that neutron irradiated topaz can be distinguished from electron irradiated topaz (with electron energy below about 15 MeV), by the complete absence of activation products in the latter material. The neutrons that produce the color centers in topaz have high energies (above 1 MeV) and the activation of impurities that occur with these neutron energies, (such as Mn-54), is inevitable, as long as the parent (in this case Fe) is present as an impurity. Since all topaz studied contains these impurities (although at varying levels depending on origin), activation is always encountered. With sufficient decay times these decrease to below the exempt limits, but it remains possible to observe these decay products in a well shielded NaI(Tl) counting system. On the other hand, the electron energy of 15 MeV is below the activation threshold for all but a few isotopes (of light elements), all of which have very short half-lives (a few days at most), and consequently are not seen in electron irradiated gemstones, including topaz.

   We are not, however, proposing to modify, in any way, the procedures used for testing topaz for exempt release, inasmuch as stones that allegedly were treated with electrons only have occasionally been found to show evidence of neutron irradiation. The present system for testing topaz does not distinguish between the two types of irradiation, and will not be modified, since the present system has proven satisfactory (with the exception of the anomalously low exempt limit for Na-22).

   On the other hand, we are proposing the use this distinction for the exempt release of diamonds, in the sense that we will (at the present time) reject any irradiated diamonds that show evidence for neutron irradiation, by the presence of activation products. <u>The only diamonds that we propose to release are those the show no evidence of activation.</u> In the case of topaz we know the by-products that appear

after neutron irradiation and can, thus, perform meaningful sum-of-ratio calculations. Since the isotope by-product profile for diamonds is not presently known, such calculations cannot be reliably performed using the statistical methods employed in our license. While we can safely assume that electron irradiated diamonds will fulfill the zero activation criteria, such an assumption may or may not apply to neutron irradiated diamonds. We may, at a later date, attempt to characterize neutron irradiated diamonds and further amend the license to encompass them: this is not the subject of the present amendment request.

2) The sensitivity of the NaI(Tl) detection system was extensively discussed in the original license submission to the NRC, in which we showed that 30 second counts on 10 gm samples was sufficient to reliably identify samples that contained outliers (those exceeding twice the exempt limit). This has been repeatedly tested by using single stone counting to find (and exclude) those stones found in the "flagged" samples. The program, used for testing and sorting, calculates the probability of an outlier, and single stone sorting (at the Maria reactor) has confirmed that these calculations are reliable, i.e. the number of outliers removed corresponds to the calculated probability. It should be noted that the removal of outiers at the Maria reactor uses the same detectors and configuration as at ISQA, and the same basic software. In that case, the program does the statistical analysis as the entire parcel (in 10 gm samples) is tested, but sample cups are maintained in a numbered rack until the entire parcel is tested. Sample cups that contain potential outliers are flagged by the program and those are sorted to identify and remove the outliers. These sorted parcels are then included in the shipment, from which 5% are selected, at random, for retesting in the ISQA facility.

   I apologize for the lack of precision in the description of sample size. A 10 gm sample has been designated as "standard" in the original license, and that remains true in practice. Inasmuch as the quantities of diamonds for testing remains unclear, I propose that 120 second counts be considered as standard for 10 gm diamond samples (which would be the largest employed to avoid self-shielding) and that the times be adjusted proportionately, should it become necessary to test smaller samples. This would enable us to observe any by-products, should they be present.

3) The use of modified software including the matrix calculations was described in at least one of the material transfer reports, and may have been discussed in brief in emails with Anthony Kirkwood. It is worth reiterating the method here to remove any ambiguity. The Genie2K software provided by Canberra uses a peak fitting method to identify isotopes and activities. The peak position (gamma energy) is used to identify the isotope and the area is used to calculate the activity (after, of course, suitable energy and efficiency calibrations and background subtraction). Unfortunately we found that for very low activities, the fitting procedure was not reliable, and isotopes were frequently misidentified. We have replaced this part of the software with a method better suited to the low activities normally seen. 10 energy windows, corresponding to the positions of gamma

emissions from the principle impurities in topaz are employed. The net area in these windows (even when no peak is visible) is calculated by subtracting the background (determined by a measurement of at least 1800 sec.) from the measured data. The areas in these windows are subjected to a cross correlation matrix calculation to identify the isotopes and their activities. For example, two isotopes might have similar gamma energies and the Genie2K software could incorrectly label the peak if the peak was not sharp due to low statistics. If, however, one of these isotopes had a second gamma, the cross correlation will more reliably identify the isotope present by the presence or absence of area in other windows. The software employed has been rigorously tested and compared with the results of HPGe measurements on the same samples. The agreement is consistently better, both in isotope identification and activity. The Genie2K software remains in use to identify peaks not associated with the principle isotopes in topaz, such as Cs-136, which are occasionally encountered. When encountered, these activities are included in the sum-of-ratios calculation.

4) Your interpretation of figure 1 is essentially correct, although there is an extension of the lead wall on the right side of the cave, viewed from the front. All measurements, including background, are performed in this configuration, with the front of the cave open. However, the detector face is depressed about 3 mm from the surface of the table (with the weigh stage table immediately above it). The solid angle viewed by the detector through the open cave is small. Our experience, as indicated by the data in figs. 3-5 shows that the system can readily identify activities of 1 bq/gm in 30 second counts, using our analysis method. This is well below the exempt limit for the commonly occurring topaz impurities, for which 14 Bq/g for Ta-182 is permitted as are higher limits for the other isotopes, Sc-46, Mn-54 and Co-58. This sensitivity is not possible with the original Canberra software for the reason described in 3) above. Potentially active materials (such as samples awaiting testing) are always kept out of the direct view of the opening and shielded by at least one 2" lead brick. Failure to do so could lead to **spuriously high** readings and to potential failure of the tests. This is, of course, a conservative safety position; it is better to reject stones that might be close to the limit than to accept them. In practice, though, tested stones are, on average, significantly below NRC limits and the more difficult challenge is to identify and remove (prior to ISQA testing) the outliers above twice the NRC limits.