AmBe source certification procedure

Based on the EXO-200 source certification procedure by C.Grant, R.MacLellan, A.Piepke

I. PRE-CLEANING OF LAB SUPPLIES

Five 5 mL polyethylene counting bottles, and a pair of plastic tweezers will be used either to handle the source or in the process of preparing a control soak sample. One bottle will be used to clean the source; one will be used to soak the source; and one will be used as a control. Fourth counting bottle will be used to store the control and the last one will be used to count the source soak. The tweezers will be used to manipulate the source throughout this procedure.

150 mL of 0.3M HNO_3 will be prepared in one 200 mL glass beaker. This solution will be used to clean the source. 300 mL of 0.3M HNO_3 solution will be prepared in two 200 mL glass beakers for rinsing the source, soaking the source and the control bottles, and counting.

150 mL of 1M HNO_3 will be prepared in one 200 mL glass beaker. This solution will be used to rinse the five 5 mL polyethylene counting bottles, and the plastic tweezers.

TABLE I. Apparatus

5 ml Poly bottles		200 ml glass beakers	
1	Clean Source	1	250 ml of 1 M HNO_3 for cleaning apparatus
2	Soak Source	2	150 X 2=300 ml 0.3 M HNO_3 for rinsing the source, soaking the source, control and counting bottle
3	Control	3	
4	Store Control	4	100 ml 0.3 M HNO_3 Cleaning the source
5	Count the sorce	5	For Sonication

The cleaning procedure for all of the above equipment will be as follows.

1. rinse with acetone
2. rinse with alcohol
3. soak with 1M HNO_3 for 1 day
4. rinse with deionized water three times
5. optionally rinse with alcohol to expedite drying

After cleaning all supplies will be covered with plastic wrap to prevent any possible external contamination.

II. CRYOSTRESSING THE SOURCE

The source will be cooled down to mimic the conditions during the EXO-200 calibration source deployment. A plastic standoff will be placed inside a Styrofoam container such that the top's surface of the standoff is a few inches above the bottom of the container. A thermocouple will be attached to the standoff's top surface. The Styrofoam container will be partially filled with liquid nitrogen such that the standoff's top surface remains free of liquid. Once the thermocouple will indicate the standoff's top surface reached temperature below -100 °C, the source will be placed on the top of the standoff. The source will remain at the temperature at least -100 °C or colder for an hour and then allowed to warm up to room temperature. If no cracks or other visible signs of the source's encapsulation failure will be observed, the cryostress cycle will be repeated three more times.

III. CLEANING OF THE SOURCE

The following procedure will be used to initially clean the source.

1. sonicate in acetone for 1 h
2. sonicate in alcohol for 1 h
3. soak in 0.3M HNO_3 for 1 d at 50 °C
4. rinse with deionized water
5. immerse in fresh 0.3M HNO_3 and sonicate at 60 °C for 1 h (repeat sonication 2 times)
6. sonicate in deionized water for 5 min (repeat two times with fresh water)
7. optionally rinse with alcohol to expedite drying

IV. SOURCE CERTIFICATION

A. Leak sensitivity goal

To established the maximum tolerable amount of radioactive contamination from the source in EXO-200 we assume that if the source is leaking inside the guide tube, only gamma radiation from ^{241}Am is relevant, not the neutron radiation. This is reasonable, as americium is not alloyed with

beryllium. We further assume that the leaked activity will remain inside the solid copper guide tube. ^{241}Am gamma rays pose little risk to EXO-200 due to their low energy and branching ratios. The most prominent gamma rays (intensities) are: 59.5 keV (36%), 662 keV ($3.6{\cdot}10^{-4}$%), and 722 keV ($1.96{\cdot}10^{-4}$%). These gamma rays pose no risk to the neutrinoless double beta decay search. Moreover, only the 722 keV gamma rays are (barely) above the threshold of the two-neutrino double beta decay analysis. A reasonable requirement is to expect that the leaked activity contributes no more than 1% of the observed two-neutrino double beta decay rate, which we take here to be 145 events/day after all analysis cuts, including the energy range cut [1]. The efficiency of passing all cuts for the EXO-200 gamma calibration sources (^{137}Cs, ^{60}Co, ^{226}Ra, ^{228}Th) located in the guide tube are in 1-5% range [2]. We conservatively assume 10% efficiency of passing all cuts for 722 keV gamma rays of ^{241}Am in the guide tube. In that case, an 80 Bq leak of ^{241}Am in the guide tube is required in order to contribute 1.5 events/day in the two-neutrino double beta decay energy range. Due to the large value of americium activity tolerable by EXO-200, let's apply an additional safety factor of 10. We therefore establish the certification sensitivity goal of less than 8 Bq of ^{241}Am.

B. Certification procedure

The two 5 mL polyethylene counting bottles and two soak bottles, one containing the source, will be dried in an oven for 1 h at 60 °C. The masses of these will then be recorded.

The source will be given one final rinse with 0.3M HNO_3 for 1 h in a soak bottle. The source and bottle will be rinsed with deionized water then soaked in 0.3M HNO_3. The control soak bottle will be also filled with 0.3M HNO_3. The soak bottles will then be alternately sonicated, at 60 °C, for 1 h each. This will be repeated 2 times.

The masses of the bottles, and contents, will be recorded. The acid solution from each bottle will be used to fill the two 5 mL polyethylene counting bottles respectively. The masses of the beakers will be recorded along with the masses of the full counting bottles.

The source will be sonicated in fresh deionized water 2 times for 5 min each. The source will then be stored inside two ziplock bags.

The two counting bottles will be placed inside ziplock bags. The source soak will be counted first for three days on the high resolution germanium detector (GeIII). The first day or so will be rejected to reduce radon emanation backgrounds not associated with the soak itself. The resulting spectra will be analyzed for leached ^{241}Am. If the sensitivity is not immediately realized, or if a positive signal is seen, after counting the source soak, the control soak sample will be counted in

the same manner.

If the sensitivity goal is achieved for the EXO-200 source soak, we will consider the source sealed and acceptable for deployment.

[1] J. B. Albert *et al.* (EXO), Phys. Rev. C **89**, 015502 (2014).

[2] I. Ostrovskiy (private communication),.