GENERAL ATOMICS

Rec'd 9/16/88
NMSS

September 14, 1988
GEN-1270

U.S. Nuclear Regulatory Commission
Medical, Academic, and Commercial Use
Safety Branch (Mail Stop OWFN-6H3)
ATTN: Mr. Michael Lamastra
Washington, D.C. 20555

Subject: Control No. 019643; Submittal of an Expanded Appendix 5.0 to General Atomics' Application for License to Distribute Irradiated Topaz

Reference: Keith E. Asmussen letter GEN-1266 to U.S. NRC Medical, Academic, and Commercial Use Safety Branch, ATTN: Mr. Michael Lamastra, dated September 9, 1988

Dear Mr. Lamastra:

As you know, General Atomics (GA) recently submitted the referenced application for a license authorizing the distribution of irradiated topaz to persons exempt from regulation. While we were finalizing that submittal, we were also nearing the completion of a test run of our system for assaying large samples of gemstones. This system was described in Appendix 5.0 to our application. Important results from this test run have just become available.

In order to make the information contained in our application as complete as possible, we have expanded Appendix 5.0 to include a summary and discussion of these results. The Appendix 5.0 submitted with our referenced application should be replaced by the complete expanded version which is enclosed.

We apologize for the inconvenience caused by this late change to Appendix 5.0.

If you should have any questions or need any additional information, please do not hesitate to contact me at (619) 455-2823 or Drs. Whittemore or Razvi at (619) 455-3277.

Very truly yours,

Keith E. Asmussen

Keith E. Asmussen, Manager
Licensing, Safety and
Nuclear Compliance

KEA/mk
Enclosure

8810240291

9pp.

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APPENDIX 5.0

Assay of Large Samples of Gemstones Using High Resolution Semiconductor Detector

The Ge(Li) [or equivalent HpGe] high resolution detector used in the determination of radionuclide concentrations in irradiated gemstones is mounted on a vertical cryostat. The available detectors have gamma sensitivities ranging between 5 and 20 percent. The diameters of the outer container will vary between 2.75 inches and 3.0 inches.

The design of a holder for the assay of a large number of gemstones in Step K1 (Figure 1 of Application) (eg., ~50 1-gram stones) is based on experimental measurements made with a specially assembled source containing approximately 0.08 μCi Cs-13.7 (662 keV) and 0.13 μCi Co-60 (1173, 1333 keV). The source holder for these measurements was a small polyethylene cap with inside diameter of about 8 mm and about one-half millimeter thickness between the source and the gemstone holder. A survey was made in four quadrants and at various heights to arrive at the curvature shown in Figure 1.

The relative sensitivity as a function of position is 44% of the sensitivity for a single stone placed in the usual location used for measurements on a single stone. The value (44%) is an average at each location of the sensitivities for the gamma rays from cesium and cobalt.

A test run for 44 gemstones weighing about 50 grams was made using the large sample holder. Tables 1 and 2 present the pertinent Ge(Li) data. In addition to the routine isotope callouts (Table 1) the spectroscopist provided results of his inspection and additional calculations that also identified weak Co-60 and Zn-65 components (Table 2). The absence of additional gamma lines for Eu-154 and Se-75 allowed the spectroscopist to line out these possibilities. A summary of the results was derived by the spectroscopist from Tables 1 and 2 and is given below:

Nuclide	nCi/g	10 CFR30.70 Limits (nCi/g)	Ratios
Ta-182	50×10^{-3}	0.40	0.125
Sc-46	2.7×10^{-3}	0.40	0.0068
Mn-54	3.5×10^{-3}	1.0	0.0035
Co-60	0.7×10^{-3}	0.50	0.0014
Zn-65	1.7×10^{-3}	1.0	0.0017
Cs-134	2.3×10^{-3}	0.09	0.026
Na-22	2.7×10^{-3}	(1.0)*	0.0027

*See discussion below.

$$\Sigma = 64 \times 10^{-3} \frac{nCi}{g} \qquad \Sigma = 0.167 \ll 1.00$$

These data demonstrate that for this batch, the "sum of ratios" is less than unity, with a total specific activity of 0.064 nCi/g. It is also apparent that stones with this same distribution of radioactive components could have specific activity as large as 0.383 nCi/g and still satisfy the release criteria - i.e.,

$$\frac{1.00}{0.167} \times 0.064 = \underline{0.383 \text{ nCi/g}}$$

This maximum specific activity is called L_{max} as used in Equations 5 and 6 on page 27 of the Application.

The assay methodology using a large holder with approximately 50-gram samples of gemstones for the Ge(Li) count (Step K1) has improved the sensitivity of detection level for the minor radioactive components in the

stones. Simultaneously, this has increased the possibility of identifying isotopes (at these very low levels of concentrations) not previously found in assays of one-gram samples. Furthermore, this increases the likelihood of finding an occasional isotope not included in Schedule A of 10CFR30.70. The "catchall" level of 10^{-6} μCi/gram is considered inappropriate for this application because it is arbitrarily small. Consider the case of Na-22 which is an isotope not listed in Schedule A and found at a level of 2.7 picocurie/gram in the reported data. In the following we illustrate a suitable approach for handling this and similar cases that may arise in the future.

In the particular case of Na-22, it is omitted from Schedule A even though it can be produced by nuclear reactors. This is well known to workers experienced with sodium cooled reactors. Its threshold for (n, 2n) production is about 12.5 Mev with the cross section as a function of neutron energy given in BNL-325 (1). The fraction of all fast neutrons from a reactor fueled with U-235 above about 13 Mev is 1.103×10^{-4} (2). Since the fast flux at the location of the gemstone irradiation is about 10^{12} nv, the portion of this fast flux suitable for this (n, 2n) reaction is about

$$\phi \ (E > 13 \text{ Mev}) = 1.1 \times 10^{8} \text{ n}\cdot$$

An activation of 2.7×10^{-3} nCi/grams corresponds to an activation of ~ 5.0 dps for the 50 gram sample of stones:

$$\text{Act} = (N\sigma)\ \phi \left[1-e^{0.693t/T_{1/2}}\right] \quad \ldots\ldots\ldots\ (1)$$

where Act = activation of Na-23 to produce Na-22,
$(N\sigma)$ is the number of atoms of Na-23 in the 50 gram sample of stones, and σ is the effective (n, 2n) cross section,

σ = 1.1×10^8 nv, and

t = 4 weeks or 0.077 yr.

$T_{1/2}$ = 2.6 yr.

From equation (1) we see that

$$(N\sigma) = 2.24 \times 10^{-6} \text{ cm}^{-2}.$$

If the average cross section above 12.5 Mev were as small as 1 millibarn, then $N = 2.24 \times 10^{21}$ atoms of Na-23 (~ 90 milligrams). A more reasonable average cross section might be as large as 10 millibarns, for which the mass of Na-23 would be only 9 milligrams. To find such a small admixture of Na-23 (9-90 milligrams) in a 50 gram sample of stones cannot be considered unreasonable, although it is unusual from all past experience.

The question now arises on how to arrive at a reasonable 10CFR30.70 limit for the Na-22 isotope. As demonstrated above, Na-22 can be produced by reactors from Na-23 and therefore, should be listed in Schedule A. To arrive at a suitable limit for this application, we have compared its gamma and beta radiation with other isotopes present and which may have similar half lives and/or emissions. These are compared in the following listing:

Isotope	$T_{1/2}$	γ Energies (keV)	β_{max} (Mev)	30.70 Limits nCi/g
Ta-182	0.32 yr	59, 67, 1121 1189, 1221	0.522	0.40
Sb-125	2.8 yr	176, 428, 601, 636	0.612	1.0
Zn-65	243.8d	1116	β^+ 0.325	1.0
Sc-46	83.3d	889, 1120	0.357	0.4
Na-22	2.6 yr	511, 1275	β^+ 0.545	---

For the case of Na-22 we first note that it cannot be ingested or inhaled because it resides within the completely insoluble topaz crystal. Next, we note from the above listing that on the basis of half life, Na-22 most nearly matches Sb-125 with a release limit of 1.0. We also note that the 1275 keV line of Na-22 matches the 1116 keV line of Zn-65 which also has a release limit of 1.0. Further, the range for positrons with E_{max} of 545 keV that are emitted by Na-22 is very much the same as the betas from the far more prevalent isotope, Ta-182, as well as Sb-125. In other words, even the smallest stones are infinitely thick for the Na-22 positrons. Because of the similarities in the half lives and emitted radiations between Na-22 and Sb-125, we believe a reasonable release limit for this minor component can be taken as that for Sb-125, i.e., 1.0 nCi/g.

References:

1. Neutron Cross Sections, BNL-325, Vol. 1, Suppl. 2, Second Edition (May, 1964).
2. H. Etherington, Ed., Nuclear Engineering Handbook, First Edition (1958), p. 7-91.

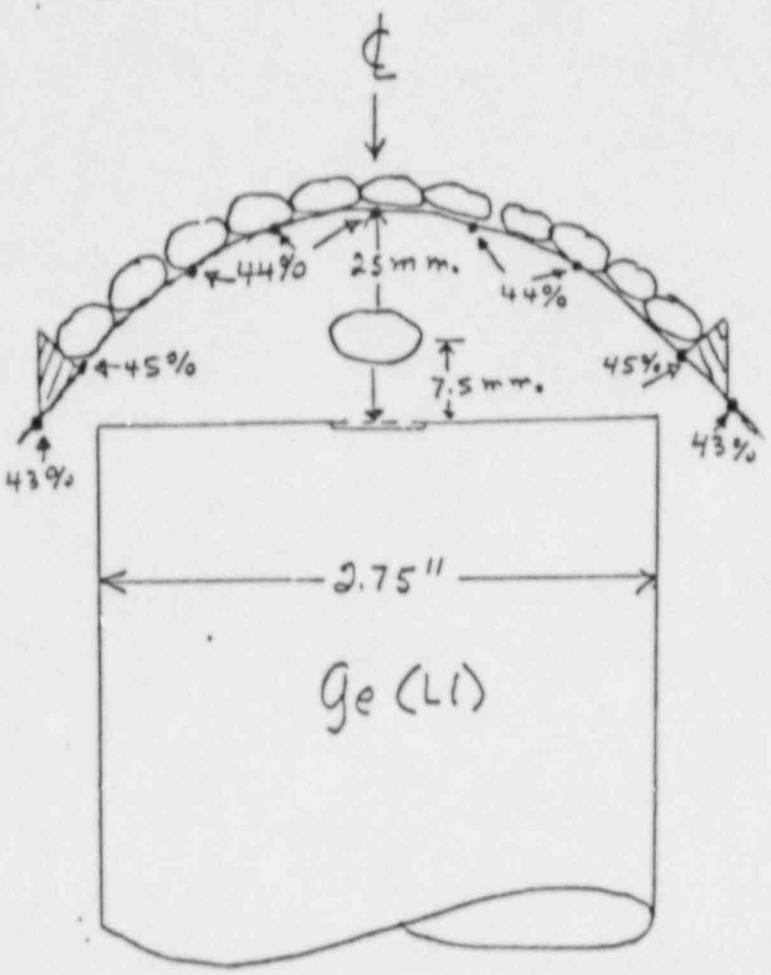

Fig. 1. Sketch roughly to scale showing dome shaped holder. This surface of revolution accommodates about 50 1 gram stones. For this holder the detector has about 44% of the sensitivity for a single stone placed at the usual (7.5 mm) position. Measured sensitivies are shown.

TABLE 1

GAMMA RAY SPECTRAL ANALYSIS

PROGRAM VERSION: GAIT-109 (4-22-88) DETECTOR: GE(LI)#2

SAMPLE: TRIGA STONES IN PLASTIC HOLDER

REQUESTOR'S NAME:	M. WHITTEMORE	SPECTRUM FILE:	SPEC.B4091
SAMPLE GEOMETRY:	STONE HOLDER	REQUEST NUMBER:	1590
COUNT DATE:	9/ 3/88	START TIME:	8:41:14
GAIN (KEV/CH):	0.1248927	INTERCEPT (KEV):	-0.646
LIVE TIME (MIN):	119.867	REAL TIME (MIN):	120.000
SENSITIVITY:	3.5	TOTAL CPM:	1060.
CALCULATION MODE:	AI	LIBRARY SEARCH:	4
CHANNEL RANGE:	90 - 8192	# OF PEAKS FOUND:	23

PEAK INTEGRATION DATA

NUCLIDE		PEAK CHANNEL	ENERGY KEV	CPM	SIGMA %	HM KEV	TW/HM	ERROR KEV
TA-182		177.44	98.78	7.119	9.95	2.47	1.82	-0.51
TA-182		203.11	87.41	27.739	1.91	1.68	2.25	-0.14
TA-182		257.89	84.18	2.981	19.72	1.76	1.80	-0.16
TA-182		299.99	96.81	15.642	5.18	1.61	1.75	-0.29
TA-182		340.41	111.19	1.937	21.17	1.37	1.82	-0.31
TA-182		452.71	152.09	9.045	6.66	1.42	1.79	-0.13
TA-182		469.78	156.15	2.669	13.40	1.55	1.79	-0.32
TA-182		527.12	179.24	4.177	11.56	1.72	2.25	-0.18
TA-182		591.63	199.16	2.549	15.66	2.22	1.70	-0.19
~~TA-182~~	*	593.42	199.16	2.549	15.66	2.22	1.70	-0.44
TA-182		654.76	221.39	7.626	7.22	1.67	1.86	-0.12
TA-182		656.74	222.14	1.291	12.66	1.81	1.75	0.02
TA-182		729.46	264.87	2.967	12.24	1.70	1.87	0.00
~~TA-182~~	*	730.46	264.87	2.967	12.24	1.70	1.87	-0.58
B-511		1527.88	511.01	7.419	5.39	2.22	1.89	0.01
CS-134		1807.72	604.75	1.747	19.19	1.70	1.96	0.09
CS-134		2377.18	795.52	1.543	11.75	2.51	1.61	-0.24
MN-54		2495.27	835.04	2.289	10.38	2.49	1.72	0.21
SC-46		2657.10	889.20	1.697	15.58	2.26	1.77	-0.05
SC-46		3349.97	1121.24	8.936	4.72	2.26	1.91	0.72
TA-182	*	3349.97	1121.24	8.936	4.72	2.26	1.91	-0.01
TA-182		3551.76	1189.15	1.679	6.22	2.52	2.15	0.12
TA-182		3648.94	1221.16	5.946	3.56	2.24	2.01	-0.02
TA-182		3679.57	1231.39	2.169	9.41	2.43	1.64	0.10
NA-22		3698.11	1274.54	1.209	11.72	2.62	1.49	0.19
~~TA-182~~	*	3698.11	1274.54	1.209	11.72	2.62	1.49	0.05
BKG		4169.29	1461.25	1.814	6.12	2.44	1.84	0.00

DPM COMPUTATION DATA

LIBRARY FILE: ABS.LOMN EFFICIENCY FILE: EFF.STONES

DIVISOR = 5.060000E 01 GRAM

DAYS DECAYED = 15.3620 9/22/88 12:00:00

NUCLIDE	ENERGY	HALF LIFE	MICROCI PER GRAM	2 SIGMA ERROR	DPM PER GRAM	2 SIGMA ERROR
B-511	511.03	>9999.00 Y	6.819E-06	9.13E-07	1.518E 01	1.32E 00
NA-22	1274.54	2.60 Y	2.679E-06	6.23E-07	5.947E 00	1.40E 00
SC-46	889.20	83.78 D	2.677E-06	9.51E-07	5.94IE 00	2.09E 00
SC-46	1121.24	83.78 D	1.947E-06	1.94E-06	4.322E 01	4.09E 00
MN-54	835.04	312.14 D	2.479E-06	7.64E-07	7.724E 00	1.70E 00
~~TA-182~~	198.16	115.0 D	7.419E-05	2.92E-05	1.647E 02	6.48E 01
~~TA-182~~	264.07	115.42 D	2.677E-06	7.15E-07	5.941E 00	1.59E 00
CS-134	604.75	2.06 Y	1.963E-06	6.36E-07	4.362E 00	1.41E 00
CS-134	795.52	2.06 Y	2.569E-06	7.06E-07	5.701E 00	1.57E 00
~~CS-134~~	1274.74	2.50 Y	7.481E-06	1.76E-06	1.661E 01	3.90E 00
TA-182	59.78	114.97 D	4.554E-05	9.06E-06	1.011E 02	2.01E 01
TA-182	67.41	114.97 D	3.782E-05	2.65E-06	9.396E 01	5.89E 00
TA-182	84.68	114.97 D	4.272E-05	1.68E-05	9.484E 01	3.73E 01
TA-182	99.81	114.97 D	3.716E-05	3.95E-06	8.249E 01	8.77E 00
TA-182	113.36	114.97 D	2.527E-05	1.57E-05	5.610E 01	3.50E 01
TA-182	152.30	114.97 D	4.257E-05	5.67E-06	9.451E 01	1.26E 01
TA-182	156.25	114.97 D	3.347E-05	1.22E-05	7.431E 01	2.74E 01
TA-182	179.24	114.97 D	5.211E-05	1.41E-05	1.157E 02	3.14E 01
TA-182	198.16	114.97 D	6.851E-05	1.63E-05	1.521E 02	3.63E 01
TA-182	221.38	114.97 D	4.614E-05	6.79E-06	1.024E 02	1.51E 01
TA-182	229.34	114.97 D	4.411E-05	1.19E-05	9.791E 01	2.66E 01
TA-182	264.07	114.97 D	4.257E-05	1.14E-05	9.450E 01	2.53E 01
TA-182	1121.24	114.97 D	5.250E-05	5.07E-06	1.139E 02	1.13E 01
TA-182	1189.15	114.97 D	5.075E-05	2.20E-06	1.126E 02	4.90E 00
TA-182	1221.16	114.97 D	4.995E-05	4.53E-06	9.995E 01	1.01E 01
TA-182	1231.39	114.97 D	4.179E-05	9.24E-06	9.272E 01	1.93E 01

TABLE 2

PEAK INTEGRATION DATA

NUCLIDE	PEAK CHANNEL	ENERGY KEV	CPM	SIGMA %	HW KEV	TW/HW	ERROR KEV
ZN-65	1112.00	1115.22	0.418	17.46	1.47	1.15	-0.10
CO-60	2505.00	1173.16	0.250	20.62	0.11	10.00	-0.05
CO-60	2999.00	1332.21	0.267	22.75	0.65	1.05	-0.24

DPM COMPUTATION DATA

LIBRARY FILE: APS.LONG EFFICIENCY FILE: EFF.STONES
DIVISOR = 5.000000E-01 GRAM
DAYS DECAYED = 15.8420 8/22/88 12:00:00

NUCLIDE	ENERGY	HALF LIFE	MICROCI PER GRAM	2 SIGMA ERROR	DPM PER GRAM	2 SIGMA ERROR
CO-60	1173.16	5.27 Y	7.112E-07	2.34E-07	1.585E 00	6.54E-01
CO-60	1332.21	5.27 Y	6.113E-07	2.79E-07	1.362E 00	6.20E-01
ZN-65	1115.22	243.94 D	1.744E-06	6.09E-07	3.871E 00	1.35E 00

NRC Form 374
(5-84)

U.S. NUCLEAR REGULATORY COMMISSION

MATERIALS LICENSE

Pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974 (Public Law 93-438), and Title 10, Code of Federal Regulations, Chapter I, Parts 30, 31, 32, 33, 34, 35, 40 and 70, and in reliance on statements and representations heretofore made by the licensee, a license is hereby issued authorizing the licensee to receive, acquire, possess, and transfer byproduct, source, and special nuclear material designated below; to use such material for the purpose(s) and at the place(s) designated below; to deliver or transfer such material to persons authorized to receive it in accordance with the regulations of the applicable Part(s). This license shall be deemed to contain the conditions specified in Section 183 of the Atomic Energy Act of 1954, as amended, and is subject to all applicable rules, regulations and orders of the Nuclear Regulatory Commission now or hereafter in effect and to any conditions specified below.

Licensee		
1. General Atomics P. O. Box 85608 San Diego, California 92138	3. License number	04-14395-02E
2.	4. Expiration date	October 31, 1993
	5. Docket or Reference No.	030-29179

6. Byproduct, source, and/or special nuclear material	7. Chemical and/or physical form	8. Maximum amount that licensee may possess at any one time under this license
A. Any byproduct material with atomic numbers between 1-83	A. Irradiated processed topaz	A. Not applicable

9. Authorized use

A. In accordance with Section 32.11, 10 CFR Part 32, distribution of processed topaz containing byproduct material to persons exempt from licensing pursuant to Section 30.14, 10 CFR Part 30 or equivalent regulations of any Agreement State.

CONDITIONS

10. Licensed material shall be distributed only from the licensee's facilities located at 10955 John Jay Hopkins Drive, San Diego, California.

11. Licensed material shall be distributed by, or under the supervision of Dr. Junaid Razvi or Dr. William Whittemore.

12. This license does not authorize possession or use of licensed material.

13. A. The licensee shall file periodic reports as specified in Section 32.12, 10 CFR Part 32.

B. The licensee shall file a report by November 1, 1989 and a new report at intervals not to exceed 14 months, listing the names and license numbers of all specific licensees to which the licensee has transferred irradiated gems pursuant to Section 30.41 of 10 CFR Part 30.

a/9

MATERIALS LICENSE
SUPPLEMENTARY SHEET

License number
04-14395-02E

Docket or Reference number
030-29179

CONDITIONS

14. Notwithstanding the requirements of Section 32.11(c) of 10 CFR Part 32, the licensee may use the approach described in Appendix 5.0 "Assay of Large Samples of Gemstones, Using High Resolution Semiconductor Detector" contained in its September 14, 1988 letter, to assign maximum concentration values for isotopes not included in Schedule A of 10 CFR 30.70, except for Na-22 which shall be 0.4 nanocurie per gram.

15. Notwithstanding the requirements of Section 32.11(c) of 10 CFR Part 32, the licensee may distribute processed topaz for the purpose of being worn by human beings.

16. Except as specifically provided otherwise in this license, the licensee shall conduct its program in accordance with the statements, representations, and procedures contained in the documents including any enclosures, listed below. The Nuclear Regulatory Commission's regulations shall govern unless the statements, representations, and procedures in the licensee's application and correspondence are more restrictive than the regulations.

A. Application dated September 9, 1988.
B. Letter dated September 14, 1988.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

DATE OCT 12 1988

BY _____
Medical, Academic, and Commercial Use
Safety Branch
Division of Industrial and Medical
Nuclear Safety, NMSS
Washington, D. C. 20555

3