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RADIOACTIVITIES OF INTERNAL COMPONENTS OF SOME SNO-CANDIDATE PHOTOMULTIPLIER TUBES

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Gamma-spectrometric analysis of photomultiplier tube (PMT) parts from different manufacturers is an ongoing effort at the LBL Low Background Facilities in support of design and construction of the Solar Neutrino Observatory (SNO) detector. Results from the last several months work are summarized here.

"Parts" from several different PMT types/manufacturers were analysed. A number of sets of internal PMT parts were provided, as indicated below. Samples analysed by the NaI system were counted for intervals ranging from 500 to 5000 minutes. Ge-detector system analyses employed counting times ranging from 1 to 7 days.

Manufacturer/Type		Parts Sets	Ge Spectra	NaI Spectra
Hamamatsu	20-inch	5	11	17
Hamamatsu	8-inch	6		5
Burle	8-inch	3	2	10
EMI	9350	4	1	3
Phillips		3		1

The nuclides of particular interest include: the U-series, the Th-series, potassium, and Co-60. Radiometric quantities are reported in terms of the activities in pCi expected from the amounts of these materials in a single tube, as follows:

U-series	Ra-226 pCi (U-238 pCi, if different from Ra-226)
Th-series	Th-228 pCi (Ra-228 pCi, if different from Th-228)
Potassium	K in grams of natural K
Co-60	Co-60 pCi.

Disequilibrium in the U-series and Th-series can be obtained only from Ge-detector data, and is noted when observed (as in several ceramics samples).

The radioactivity measurements are summarized in the following tables, and where feasible have been grouped according to the categories: ceramics, glasses, plastics, and metals. The HAM-20" parts were examined in greatest detail, and in conjunction with the other analyses, provide some insight into the range of activities that can be expected from a class of items, such as ceramics or glasses.

COBALT-60 in PMT Metal Parts

		Weight grams	Co-60 pCi	Detector
HAM-20"	Largest flange with tabs	408	1.22	NaI
	Large 2-step flange (7 1/2" dia)	327	0.11	Ge
	Large 1-step flange (7 1/2" dia)	280	0.20	Ge
	Grids, Venetian blind (4" dia)	206	0.23	NaI
	Grids, Fine-mesh (4" dia)	43	< 0.001	Ge
	Grids, Square frame (1 1/2" square)	14	N.D.	Ge
	Straps (6" length)	180	0.072	Ge
	Threaded posts (3" length)	54	2.9	Ge
	Discs with Grids (4" dia)	48	0.05	NaI
	Wires, getters, small parts	33	0.46	NaI
	Getters	5	N.D.	Ge
	TOTAL		5.24	
BURLE-8"	Large metal flange	539	0.11	NaI
	Large KOVAR flange	460	1.7	NaI
	Misc. parts, grids	255	N.D.	NaI
	TOTAL		1.81	
HAM-8"	Grids	23	N.D.	NaI
	Other internal parts	28	0.05	NaI
	TOTAL		0.05	
EMI 9350	Small parts	66	< 0.02	NaI
	Internal "assembly" parts	22	N.D.	NaI
	TOTAL		< 0.02	

HAM-20" getters also contain: Ra-226 0.10 pCi
K 0.020 grams

Natural (primordial) Radionuclides in PMT Non-metallic Parts

		Weight grams	Ra-226 pCi	Ra-228 pCi	Potassium grams	Detector
HAM-20" Ceramics	Large rings (4" dia)	56	*0.8 (9.5)	0.8	0.002	Ge
	Short standoffs & washers	35	*15. (21)	3.4	0.007	Ge
	Long standoffs (1" length)	15	18.	4.0	0.002	Ge
	Insulators with wires (3" length)	14	19	4.5	≤ 0.001	Ge
	TOTAL		52.8	12.7	0.011	
BURLE-8" Ceramics	Standoffs (off-white)	62	21.	15.	0.050	Ge
	Wafers (white and green-surface)	124	*7.9 (21)	4.0	0.029	Ge
	Misc. ceramics, small metal parts	50	7.2	5.2	0.044	NaI
	Misc. ceramics, crushed metal parts	255	16.2	5.8	0.053	NaI
	TOTAL		52.3	29.0	0.136	
HAM-8" Ceramics	All small parts	25	9.5	4.0	0.003	NaI
EMI 9350 Ceramics	All small parts	25	7.1	8.8	0.040	NaI
	"Assembly" parts, some ceramics	22	0.6	0.3	0.007	NaI
	TOTAL		7.7	9.1	0.047	
PHILLIPS Ceramics	Small metal parts, ceramics	50	2.3	2.2	0.26	NaI

Natural (primordial) Radionuclides in PMT Non-metallic Parts

		Weight grams	Ra-226 pCi	Ra-228 pCi	Potassium grams	Detector
HAM-20" Glass	Milk glass rings	22	10.	1.7	0.34	NaI
	Bases with pins	45	22.	2.9	1.0	NaI
	Bases with feedthroughs	30	21.	2.6	0.60	NaI
	TOTAL		53.	7.2	1.94	
BURLE-8" Glass	Pin assemblies (2 rings & wires)	87	20.	2.5	0.91	NaI
	Bases with pins	37	12.	23.	0.019	NaI
	TOTAL		32.	25.5	0.93	
HAM-20"	Tube bases with pins	37	12.	22.	0.029	NaI
HAM-20"	Total, non-metallic parts		118.	42.	1.98	
BURLE-8"	Total, non-metallic parts		84.	54.	1.06	
HAM-8"	Total, non-metallic parts		9.5	4.0	0.003	
EMI 9350	Total, non-metallic parts		7.7	9.1	0.047	
PHILLIPS	Total, non-metallic parts		2.3	2.2	0.26	

Several general conclusions can be drawn from these results:

1) Co-60 is present in some metal parts, probably stainless steels and Kovar; U,TH,K are not present in these metals in significant amounts;

2) U and Th are present in significant quantities in both ceramics and glasses (and in filled plastics);

3) Potassium is a significant activity only in the glasses.

The Co-60 content of the metals is explainable in either of two contexts:

1) in stainless steel, it is fixed by the manufacturing process through dissolution of furnace liner "monitor" sources;

2) in Kovar, about 15% cobalt, it is variable according to the ambient slow neutron fluxes and the time of exposure to these neutrons (the cosmic-ray neutron flux is significant in this situation).

The BURLE tube Co-60 content is mainly (we believe) due to slow neutron capture in cobalt in the large amount of Kovar used in this type tube. The large amount of Co-60 in the HAM-20" threaded posts is believed to be a caprice of manufacture, and surely could be avoided by radiometric screening of potential stock material.

Radioactivities in ceramics and glasses, on the other hand, may be much more difficult to minimize - - given that certain mechanical and/or electrical properties are required of these materials. We note that the large-ring ceramic (HAM-20") has much lower activity (except for excess U-238) than almost all other measured ceramics - - and offers the potential of substantial activity reduction if used for all other ceramic parts. However, finding a low-activity "soft" glass (for PMT pin feedthroughs) may be a very difficult task.

The last entries of the table on page 4 give summations for activities in the non-metallic components for each type tube. It is these values that should be compared to the activities expected from the glass PMT envelopes, in order to put our present results in the proper perspective. The question is: do we need cleaner materials for these "internal" PMT parts, or does the glass envelope activity dominate? We must know approximate weights for the different PMT envelopes in order to make the relevant judgements. For example, the Schott type 8246 glass has been measured to contain as little as:

U = 0.020 ppm or 0.007 pCi/gram
Th = 0.020 ppm or 0.002 pCi/gram.

One kilogram of this glass would contain:

U = 7 pCi
Th = 2 pCi.

This example suggests we may well need to find lower activity internal PMT ceramic and glass parts.