SNO-STR-91-C1C

CRL Acrylic Radioactivity work September 1990 - January 1991

February 18. 1991

Abstract

This file contains a summary of CRL work on acrylic radioactivity, three CRL monthly reports (Oct. '90, Nov. '90 and Jan '91), a report on trace element analysis in acrylic and a draft on planned acrylic Q.C. program

1 Summary

Alpha-spectrometry : A review of the acrylic radioactivity disequilibrium measurements during the past three years has been made. This technique is reliable to better than a factor of 2. In 6 out of 8 acrylic samples the ^{228}Th to ^{232}Th ratio was within 40% of unity for the Th chain. The recovery of ^{226}Ra is not yet as reliable but measurements suggest no disequilibrium in the U chain.

TIMS : Vaporisation and mass spectrometry analysis indicate Th levels between 5 and 12 ppt for 8 out of 11 Polycast acrylic samples (the others were at 16, 27 and 32ppt), between 1 and 4 ppt for 4 Polycast monomer

samples and between 5 and 11 ppt for all but one Rohm acrylic (7 samples, one was measured at 24 ppt). Six LANL spiked (at 134 ppb) samples were also analysed and the mean recovery was found to be 88% +- 10%.

NAA : The Ge-counting system has been upgraded to allow detection of about 1 ppt Th levels in 30g. samples. There is good evidence that Polycast monomer is low in Th. 7 out of 12 monomer samples contained Th levels of or below 3 ppt, 4 others have been measured between 5 and 8 ppt. Previous evidence of an inhomogeneous Th distribution is confirmed by three new results on core (all between 3 and 5 ppt) compared to Th concentrations of 9, 10, 16 and 43 ppt on four surface samples.

The apparent discrepancy between NAA results at Guelph and CRL data (mass spectrometry and NAA) is being vigourously investigated by many cross-check studies (standard verifications, measurements of spiked samples, intersite measurements of the same samples). The factor of about 3 between the two sets of data is still not yet understood. It is noted that the discrepancy is between upper limits set by the Guelph group and values measured at CRL.

An evidence of a correlation between trace element concentrations and Th levels in Polycast material (monomer, core, surface, acrylic) has been found. The correlation is strongest for Cr and Fe. Many trace elements are also inhomogenously distributed inside the acrylic, the surface layer containing higher concentrations than those observed in the core. Monomer samples contain only a small fraction of the trace concentrations measured in acrylic.

Alpha-spectrometry, mass spectrometry and neutron activation analysis at CRL give compatible results and reinforce our confidence in their reliability. The acrylic Q.C. program to be implemented during the acrylic production will however rely principally on mass spectrometry, mainly because this technique provides results more efficiently.

All results on Th concentrations in acrylic obtained at CRL since September 1990 with the three techniques available there are summarized on Figure 1. and measurements on spiked acrylic are presented on Figure 2.

Figure 1.

Summary of Th measurements in acrylic

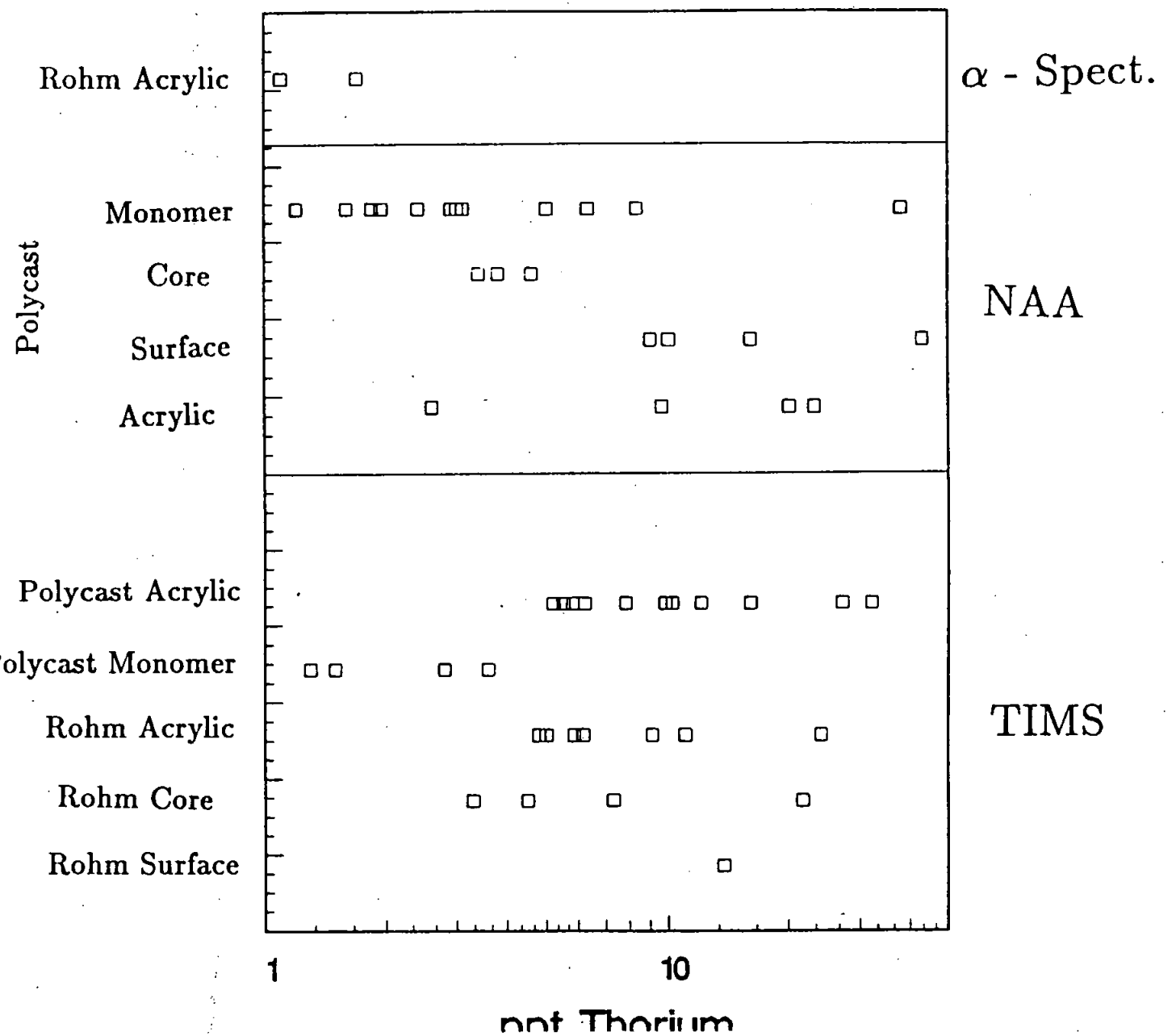
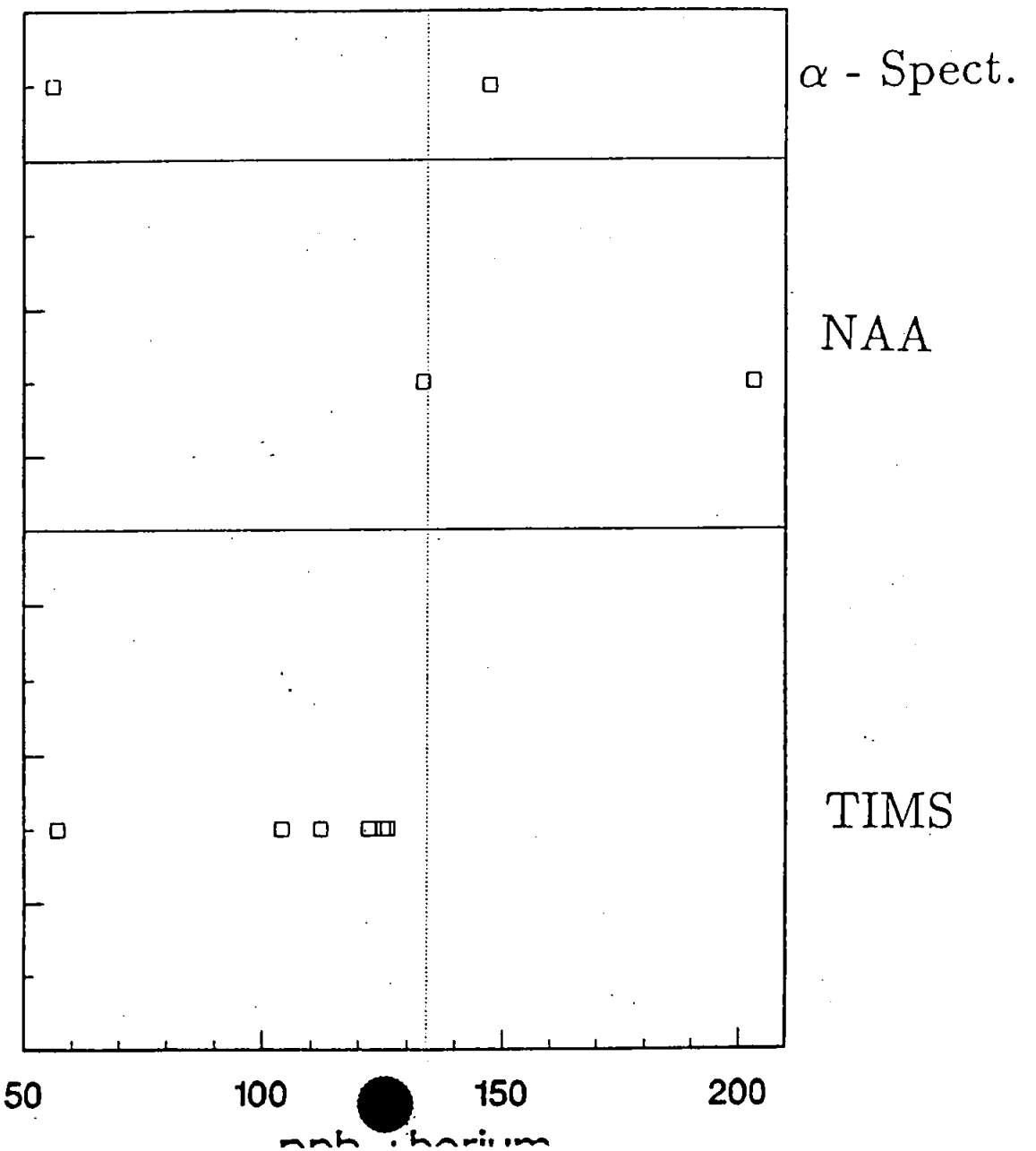


Figure 2.

Results on spiked acrylic



Acrylic Radioactivity Report
Edited by Earle,
Nov 1, 1990

Summary:

At Guelph, measurements have been made on a number of rope samples and on the Polycast "candle" material (samples taken from the core of the sheets).

At LANL, acrylic samples spiked with 232Th have been made. They have confirmed their high recovery efficiencies and precise Th determination by NAA. Spiked samples have been distributed to CRL and eventually to Guelph (via CRL) for verification of their procedures.

At CRL, the confidence in the reliability of the TIMS results continues to be high and our confidence in the NAA results has much improved during the last period. There is now good evidence that the Polycast monomer and acrylic sheet cores are low in Th (3 ppt). The high values observed in many samples over the years may be due to Th concentrated on or near the surfaces of the sheets. The Th in the kevlar rope is higher than we would like it to be if it is to be used to support the vessel.

LANL Acrylic Report.
(Edited by Earle from bitnets received)

Abstract:

Samples of acrylic spiked with Th have been made for distribution to the collaboration for checks on their measuing techniques. The uniformity of the spike and the measuring techniques at LANL have been verified.

Text:

We (Jerry at LANL) have assayed by NAA Th spiked acrylic made at LANL by Mac. We took four different samples from the first rod Mac cast. Each sample was about 3.5 gm. The total rod weighed 303.55 gm and Mac added 40.6 micrograms of 232Th. (i.e. 134 ng/gm). After irradiating for one hour we counted the 233Pa to determine the 232Th concentration. We used our well counter and counted each sample in one direction and then rotated it 180 degrees and counted it the other way (this checks for nonuniformity of the Th distributions - with previous commercial sources of acrylic we would often see detection rates vary by a substantial amount when this rotation was performed - thus indicating non homogenaities in the sample). The results were:

sample	irrad port	orient. 1	orient. 2
3010	R-4	133 +/- 1.20	136 +/- 1.18
3020	R-4	134 1.18	135 1.19
3030	R-5	127 1.14	127 1.14
3040	R-4	136 1.18	136 1.20

As you can see all of the samples gave good agreement with the additive amount and showed no significant inhomogenaities. The sample 3030 was irradiated in a different port than the other three and gave a somewhat low value. We did not have a specific flux monitor in the irradiation. With previous flux tests we had reproduced the reactors claimed fluence (9.7e12 n/cm2-sec) in both ports and therefore do not regularily check the value. The reactor had been shut down for a long maintainence perior and we have not used it recently. However, one of my colleagues claims that his samples done in the R-5 port were consistenly giving a 5% lower value than the other port. If we would scale the 3030 sample up by this 5% factor then it would be in excellent agreement with the others. The bottom line is that we are quite confident we have a very well calibrated sample containing 134 ng/gm of 232Th.

One of these irradiated samples has been shipped to CRL where it will be counted with their well shaped Ge detector. Mac has made another acrylic rod spiked with Th and that also has been shipped to CRL together with a small portion of the first rod, a portion that had not been irradiated. CRL plans to count the small irradiated piece immediately upon arrival and do NAA and vaporization followed by TIMS and alpha counting) on the unirradiated samples. Samples should also be sent to Guelph.

One other item of information. We took one of our irradiated samples (#3010) and added some 231Pa tracer (as we have done in all of our previous measurements of commercial acrylic) and then volatilized the mixture using our standard technique. We did this as a method of certifying that the spike behaved in the same manner as the bulk acrylic. The results were:

233Pa from acrylic = 86.0 +/- 0.6% recovery
231Pa from spike = 84.1 +/- 1.8% recovery

This is very gratifying in that it shows (as we have always assumed) that the tracer behaves the same as the bulk material.

CRL Monthly Report on Acrylic Radioactivity.
Bonvin, Earle, Deal, Hurteau, Martin, Millar, & Milton

a) Alpha Spectrometry Section: (contact Milton)

Since the CRL Sept meeting 8 kg of Rohm material have been vaporized and separation of the Th, U and Ra isotopes are about to begin. It was noted that the Ra spectrum from one of the samples reported at the Sept meeting contained a 224Ra peak indicating concentrations of this short lived isotope much higher than would have been expected from the 228Th concentration measured in the Th spectrum. This could not be due to disequilibrium but must be from 232U contamination, 232U is used in the laboratory as a tracer and it must have gotten into the Ra stream but not the Th stream. The conclusions of the report tabled at the Sept meeting are unchanged.

b) Vaporization and TIMS Section: (contact Earle)

i) Kevlar Rope - 380 ppt Th
A 58 g sample of kevlar rope was vaporized and analysed by mass spectroscopy. Due to the large quantities of other solids in the sample the solution following the vaporization was passed through an anion exchange column to isolate the Th and U. The level of Th and U was found to be 380 ppt and 210 ppt respectively and is consistent with NAA measurements at Guelph.

ii) Guelph Shop Acrylic - 11.6 ppt Th
A 400 g sample of shop acrylic measured at Guelph by NAA to contain less than 2 ppt Th (see SNO6 in the report at the CRL Sept meeting) was vaporized and measured by TIMS to contain 11.6 ppt Th. Recently Guelph has found that with better statistics these 68% confidence limit numbers may be misleading. Samples initially considered to be less than 2 ppt are in fact more like 5 ppt. In addition, the yield from their Al standard appears to depend on its location with respect to the acrylic. (See the Guelph section of this report). Cross checking of samples will continue.

iii) Polycast "candle" - 10, 16, 27, 32 ppt Th
Four samples of Polycast acrylic taken from the "candle" distributed by Peter Doe have been measured and shown to contain 10, 16, 27 and 32 ppt Th. In all cases the U level was about 25% of this concentration. These Th levels are significantly higher than the 5 ppt Th reported by Guelph from an adjacent piece of the same sheet.

iv) Rohm for alpha counting - 4.8 ppt Th
A quantity of Rohm material has been vaporized for disequilibrium measurements. The 232Th concentration by TIMS is 4.8 ppt.

v) Polycast Monomer - 1.3, 1.5, 3.6, and 2.8 ppt Th
Quantities of inhibited liquid Polycast monomer (around 0.8 litre) have been evaporated and the Th and U in the residue measured by TIMS. The levels of Th may depend on the plant location of the sample. Samples taken from the delivery truck (2.8 ppt Th), the underground storage tank (3.6 ppt) and the mixing vat (1.5 & 1.3 ppt) have been measured.

c) Neutron Activation Section (contact Bonvin)

Results:
Reactor operations at CRL release a few times a week high levels of Ar-41, and therefore dramatically alter the sensitivity of the Ge-well detector measuring neutron activated acrylic samples. A standard ambiant radiation monitor has been installed and is being used to automatically stop data collection when Ar-41 is detected. Accordingly the background in the 312 KeV region has been reduced to 1.2 counts/hour/kev.

Data on Polycast material (12 samples), irradiated during September 1990 are presented in Table 1. For comparison mass spec results on Polycast material (described in another section of this report) are also presented. The monomer samples for NAA were uninhibited 30g samples taken from various locations in the Polycast plant. The acrylic samples were from the large sheet of Polycast "candle" material distributed by Peter Doe and measured by the GST (Guelph Sno Team) to have 5 ppt. The core and the surface samples were from earlier Polycast material on hand at CRL and were prepared by laser cutting at NRC.

	N.A.A.		Mass. Spec.
	ppt Th	ppt Th	ppt Th
momoner (truck)	1.9 (0.8)	6.3 (1.2)	2.8
monomer (tank)	2.4 (0.8)	38. (4.)	3.6
monomer (mix-room)	3. (1.)	1.9 (0.8)	1.5, 1.3
acrylic, "candle"	20. (8.)	23. (6.)	32, 27, 16, 10
core	4.6 (1.3)	3.4 (1.1)	
surface	16. (3.)	10. (4.)	

Table 1.
Th levels (stat. error) in Polycast samples measured by NAA or Mass Spec.

These NAA results are preliminary since we are still studying the reliability of the Th monitors used during the irradiations (cf. "the Guelph depletion effect") and we would like to get better confidence in the fitting routines used to determine the net peak area.

Observations:

1. The sensitivity of NAA is now around 1 ppt thanks to the lower background.

2. Four out of six monomer samples show a low Th level (2-3 ppt). The higher values for the two other samples may be due to external contamination.

3. Th levels in core acrylic and in monomer are similar.

4. The levels of Th in the surface and core components of the acrylic are different in agreement with previous evidence (see September 90 report) of an inhomogeneous distribution of Th.

5. Th measurements by NAA and by Mass Spec. give compatible results.

Discussion:

1. The good agreement between Mass Spec. and NAA data as well as recent results from Los Alamos on spiked acrylic (high recovery efficiency after vaporisation and precise Th determination by NAA) reinforce our confidence that both methods are adequate to determine ppt levels of Th in acrylic samples.

2. The following scenario may describe the observed Th levels in Polycast acrylic:

* The monomer and the core of acrylic samples have 2-4 ppt of Th.
* Random contamination during either the manufacturing of acrylic and/or the handling prior to measurements contribute (in a major way) to the higher Th concentrations observed in acrylic. This contamination is randomly distributed on or near the surface.

CRL Acrylic Radioactivity Report for Nov.
Summarized by Earle

Abstract: Levels of Th in the several rope samples checked are higher than we would like for vessel support. New measurements on the monomer increase our confidence that clean acrylic raw materials can be obtained for SNO. Intersite comparisons of results suggest inconsistencies which have not been resolved.

a) Spiked samples from LANL have been vaporized and the Th content measured by TIMS. LANL claims that the spike was 134 ppt and they measured 134 +-2 ppt by NAA. We have measured 104 & 112 ppt (suggesting about 80% recovery). We plan to increase the data set.

b) Last month we reported that the vaporization and TIMS gave 380 ppt Th for kevlar rope (cf 360 +-200 from Guelph). We have now measured 880 ppt for the spectra rope (cf 250 +-100 from Guelph). We must try to get better rope.

c) The data set on NAA on monomer has been increased. Three more samples have been measured for Th.
Truck <1.5 ppt, UG tank 3+-0.7 ppt and mixing room 7+-1.5 ppt. The mixing room sample also showed significant levels of Cr, Zn and Fe.

d) Irradiated acrylic from Guelph, shaped as 400 g Marinelli beakers, have been vaporized and the residue both gamma counted (two samples) and TIMS (four samples).

Guelph ID	Guelph Th ppt (gammas)	CRL Th gammas	CRL Th mass spec.	CRL U mass spec.
J03	approx 4.5+-1.8		5.6	3.8
J04	" 4.5+-1.8		7.8	8.6
J11	< 1.4	1.6+-0.3	5.6	3.4
J12	4.3+-4.0	<0.6	5.3	1.8

This material is the Polycast candle which last month was reported by CRL to be around 20 ppt by both NAA and TIMS. The surface to volume ratio is probably lower for the Marinelli beakers than for the CRL material which might explain the 20 ppt as compared to 5 ppt. The differences between the TIMS and NAA numbers are disconcerting. The NAA values depend on the correctness of the Al monitor (the monitor is required for both the Guelph and CRL gamma results) which is being examined at Guelph and at CRL.

CRL Acrylic Radioactivity Report
Feb 1, 1991

Alpha Spectroscopy.

A review of the acrylic radioactivity disequilibrium measurements during the past three years has been made. Over this period of time about a dozen measurements have been made on acrylic from various sources and the following conclusions can be made.

a) The technique for checking the Th chain compares the 232Th to 228Th ratio and this technique is reliable to better than a factor of 2. In 6 out of 8
examples the ratio was within 20% of unity, in the other two it was 0.4 and 1.7 but the levels of Th were low in both these cases. Also in all eight cases the value for 232Th for a portion of the residue as measured by mass spectroscopy agreed with the alpha spectroscopy values to better than 50% giving confidence to the absolute reliability of both techniques for Th.

b) The same confidence has not been obtained for the U chain. In this chain we have compared the 238U to 230Th concentrations and also the 238U to 226Ra concentrations. From a SNO point of view the 226Ra value is the important one and reliable recovery efficiencies have not yet been obtained for this element. The 238U/230Th ratio is less interesting and for 7 examples this ratio is less than unity six times (typically it is about 0.5 but in one case it was 2). In the five cases where 226Ra was recovered and measured no evidence of disequilibrium to within a factor of two was reported but we must caution that there are large uncertainties in the recovery efficiencies assumed. A comparison of the 238U concentrations with those measured by mass spectroscopy for the same residue agree to within a factor of two for eight cases. This is poorer agreement than for the Th comparison but adequate.

c) At this point we recommend that the quality control program for acrylic concentrate on measuring the Th disequilibrium and not worry about disequilibrium in the U chain. This recommendation is made because the U concentrations are always lower than the Th and the importance of U as compared to Th is 1/4 as far as SNO backgrounds are concerned. Only if we can attain significantly more confidence in the Ra recovery techniques for trace quantities of this element should this recommendation be reconsidered.

Mass Spectroscopy.

Vaporization followed by mass spectroscopy has been selected as the main method for checking for Th and U in acrylic and measurements on acrylic and rope has continued at CRL.

a) Four more pieces of acrylic spiked with 134 ppt Th at LANL have been measured, in addition to the two reported previously. The six values obtained are 112, 104, 126, 126, 119, & 57 ppt. We have no explanation for the low value of 57 ppt. The two at 126 ppt were slow burns as distinct from our usual rate of vaporization. It would appear that we are losing about 10% of the Th during the vaporization and an additional 5% during the sample preparation for mass spectroscopy. You may recall that in May 090 we reported on recoveries for Th and U from acrylic spiked with nitric acid containing Th and U at CRL. The recoveries after vaporization and mass spect. at that time were 95 +-3% for three samples. We can conclude that our Th recovery by this method is about 85 +-5% for Th in acrylic.

b) Mass spectroscopy of Rohm material comparing surface vs core of the same sheet may be inconclusive. The optical surfaces removed with a band saw contained 13.7 ppt whereas the core was measured to contain 7.3, 4.5,

3.3, and 21.6 ppt (average 7.5 ppt, obtained by adding weights). This is program should be continued.

c) Other measurements on miscellaneous acrylic samples.

Rohm candl	- 11, 6, 6, 5 ppt Th
Rohm piece shipped after Aug visit	- 9.1 ppt
" " " " " "	- 24 ppt
Polycast piece shipped with monomer	- 10, 12 ppt.
Stanley monomer containing c her junk	- 1.3 ppt
Spectra rope	- 481, 880 ppt

d) Samples irradiated and counted at Guelph have been shipped to CRL for measurements. The results are reported with the NAA results in the next section.

Neutron Activation Analysis

a) New samples of Polycast material have been neutron activated and counted. The following results agree with measurements previously reported :

Polycast monomer (truck)	:	1.2 +- 0.4 ppt Th	(< 1.5 ppt in Nov)
monomer (truck)	:	< 1.6 ppt Th	
monomer (tank)	:	3.0 +- 0.7 ppt Th	
monomer (tank)	:	8.3 +- 1.0 ppt Th	
monomer (mix-room)	:	5.0 +- 1.4 ppt Th	
Polycast core (laser cut)	:	3.8 +- 1.2 ppt Th	
sides (")	:	43. +- 5. ppt Th	
optical sides (")	:	9.0 +- 2.0 ppt Th	

b) Material from other suppliers (4 acrylic samples from Rohm, 1 acrylic sample from Stanley, 1 sample of acrylic additives from Sweedlow) have also been irradiated. However since they all contain a significant amount of phosphorous, the pure beta emitter P-32 (half-life of 14.3 days, Q-value of 1.7 MeV) is also detected by the Ge-counter and lowers the Th sensitivity to ppb levels. NAA is therefore not suitable to analyse samples from those suppliers. An alternative would be a chemical separation of the irradiated samples but this procedure, as we have experienced, may introduce other uncertainties.

c) Two LANL spiked (Th concentration 134 ppb) acrylic samples have also been analysed:

LANL sample 01	:	133 +- 3 ppb Th
LANL sample 02	:	203 +- 4 ppb Th

The second result is puzzling but an examination of the tiny quartz tube containing the monitor during the irradiation showed it to be improperly sealed.

d) The consistency of 45 monitors used for NAA during the last 6 months was analysed and an indication of careless monitor preparation detected. The dispersion in counting rates observed between these 45 monitors was 28%, which is unacceptable large. The neutron activation at CRL is always performed at the same location in the reactor and therefore a neutron flux proportional to reactor power can be assumed. Normalizing the monitor counting rates to the reactor power during the irradiation did not change the observed dispersion. Even monitors irradiated in the same container presented a similar dispersion. We therefore believe that the problem was ocurring during the monitor preparation.

Since this analysis ten monitors have been prepared with greater care and irradiated simultaneously. The dispersion observed after Ge-counting these ten monitors was only 5%.

e) 0.4 kg samples irradiated and counted at Guelph have been shipped to CRL for counting, for NAA and for mass spectroscopy. Some of these results have been reported previously and indicate a Guelph/CRL discrepancy. A recent summary of results from Guelph are different from earlier reported information (see Nov report) but the discrepancy is confirmed. A complete table of results are as follows in ppt of Th and includes information reported in Nov.

Sample ID	Guelph NAA 0.4kg	CRL Vap 0.4kg gamma	CRL NAA 30g gamma	CRL Vap 0.4kg Mass Spect.
J3	<1.1		9.6 +-2	7.8
J4	<0.75		2.6 +-1.1	5.6
(later)	4.5+-2			
J11	<1.4	1.6 +-0.3		5.6
J12	4.3+-4	<0.6		5.3
J14	<2.6	<0.7		6.2
J15	<1.8	-		
J16	<3.2	<0.4		116

Col. 1 is the sample identification. Col. 2 is from gamma counting the Pa after neutron activation at Guelph (note two measurements for J4). Col. 3 is gamma counting the Pa after the sample was shipped to CRL from Guelph, vaporized at CRL and the residue collected for mass spectroscopy. Col. 4 is for NAA of a small portion of the 0.4 kg when the remainder was vaporized for mass spect. Col. 5 is from mass spect. for all or most of the sample.

Comments:

i) The large value of 116 ppt for J16 is from contamination introduced during rinsing at CRL and is understood.

ii) The gamma ray backgrounds during counting of the vaporized sample J11 at CRL where four times those of J12. Yet Guelph was able to put their best limit on J11 whereas J12 was their worse sample. A mix up in labeling might expand this discrepancy.

iii) The CRL gamma counting of samples irradiated at Guelph is consistent with the Guelph gamma counting.
The NAA and gamma counting at CRL is consistent with the mass spect. at CRL.
The reported Th in identical samples is consistently higher at CRL than at Guelph by about a factor of 3.

Correlation between trace element concentrations and Th levels in Polycast materials

E. Bonvin

February 18. 1991

The trace elements of twenty three 25gr. samples of Polycast materials (12 monomer, 3 core acrylic, 4 surface acrylic and 4 acrylic) have been analysed. An evidence of a correlation between the concentrations of some of these elements and the Th concentration has been found.

The observed count rates (per unit weight , corrected for decay to the irradiation day) of neutron activated isotopes of nine trace elements (^{141}Ce, ^{203}Hg, ^{51}Cr, ^{198}Au, ^{122}Sb, ^{46}Sc, ^{59}Fe, ^{65}Zn and ^{60}Co) are presented in Table 1. together with the measured Th concentrations. Since this analysis has been initiated after the sample irradiations, no effort has been made to present the data in absolute concentrations. This step would have required simultaneous irradiation of known standards for each of the elements. The normalised count rates presented here are simply proportional to the absolute concentrations since the irradiation conditions (6 hours irradiation at the same position in the NRU reactor with a monitored reactor power stable to within 5% during the irradiation time) were similar. However small (about 3g.) Shop acrylic samples have been reported by the Guelph group at the Chalk River collaboration meeting in September '90 to have concentrations of about 0.5ppm for Fe, 0.1ppm for Zn, 20ppb for Cr, 1ppb for Co and 30ppt for Sb.

The average of the Th levels in those samples was about 35ppt. No evidence of a correlation between the Th levels and the levels of other elements was observed by the Guelph group.

The normalised count rates of neutron activated isotopes of specific traces are shown in Figures 1. to 9. as a function of the Th levels measured in the samples. A correlation is clearly evident for some trace elements (i.e. ^{51}Cr with a correlation factor r=0.83 and ^{59}Fe with r=0.58), while almost non-existent for some others (e.g.^{203}Hg with r=0.23).

Core and surface acrylic samples exhibit quite different count rates for some of the n-activated trace isotopes analysed, confirming the evidence of an inhomogeneous distribution of impurities (and also of Th) in the acrylic.

Focussing on the monomer data set (12 samples), it appears that all samples with Th levels above 3 ppt contain much larger concentrations of especially Cr (and also Fe and Zn), which may be understood as a leaching contamination for SS containers (delivery trucks, piping, etc.) since Cr is known to migrate to the SS surface. However the Th and the other trace elements levels observed in monomer are a small fraction of the concentrations observed in finished acrylic, therefore priority should be given to identifying and avoiding (or at least reducing) the contaminations occuring after the mix-room.

The observed correlations between Th and trace element concentrations may be used either to identified the sources of Th contamination (as mentionned in the case of the monomer samples) and/or to select low Th materials on the basis of their trace concentrations. For example, a requirement of a ^{51}Cr count rate not exceeding 500 counts/day·gr. (represented by an arrow on Fig. 3.) would select all but one samples with a Th level below 5 ppt and reject all samples above that concentration. Other trace elements (like Fe, usually present at about 0.5ppm in acrylic) may also be suitable for similar selection procedures.

sample ID	Th (ppt)	Ce141	Hg203	Cr51	Au198	Sb122	Sc46	Fe59	Zn65	Co60
		Count rate (Counts per day and per gr. of sample)								
Monomer:										
29	1.2	23	100	118	600	800	2	32	60	3
33	<1.6	10	186	178	2242	1031	4	34	43	2
16	1.9	16	74	331	1974	2647	4	26	149	5
24	1.9	16	57	315	2541	2559	6	35	156	19
25	2.4	40	45	608	2641	1417	8	64	117	4
13	3.0	–	117	229	1262	960	13	50	144	26
27	3.0	–	77	87	1800	325	4	34	43	
30	3.0	59	111	151	3077	1600	4	76	97	3
31	5.0	22	213	853	8692	4767	6	68	139	6
23	6.3	63	308	1257	2758	–	14	254	400	17
28	7.0	62	162	1524	3401	1659	35	848	66	9
32	8.3	117	140	598	4643	3470	34	181	176	8
17	38.0	102	248	2807	4189	7445	49	5935	215	64
Core acrylic:										
21	3.4	22	449	349	1333	809	4	35	733	4
48	3.8	12	58	276	1078	440	2	61	166	11
20	4.6	60	171	297	2486	7553	9	33	690	18
Surface acrylic:										
46	9.0	60	209	2162	9426	4952	16	418	1470	71
19	10.0	58	169	1684	30267	–	43	250	970	67
18	16.0	57	565	615	4609	3818	22	102	343	18
47	43.0	146	202	3625	12550	4570	28	376	1258	96
Acrylic:										
35	2.6	83	146	356	30589	1556	9	162	381	12
34	9.6	158	81	676	14113	6500	15	430	567	13
14	20.0	38	18	593	9890	–	20	109	513	9
15	23.0	39	193	1315	6528	1149	19	133	135	11

Table 1.

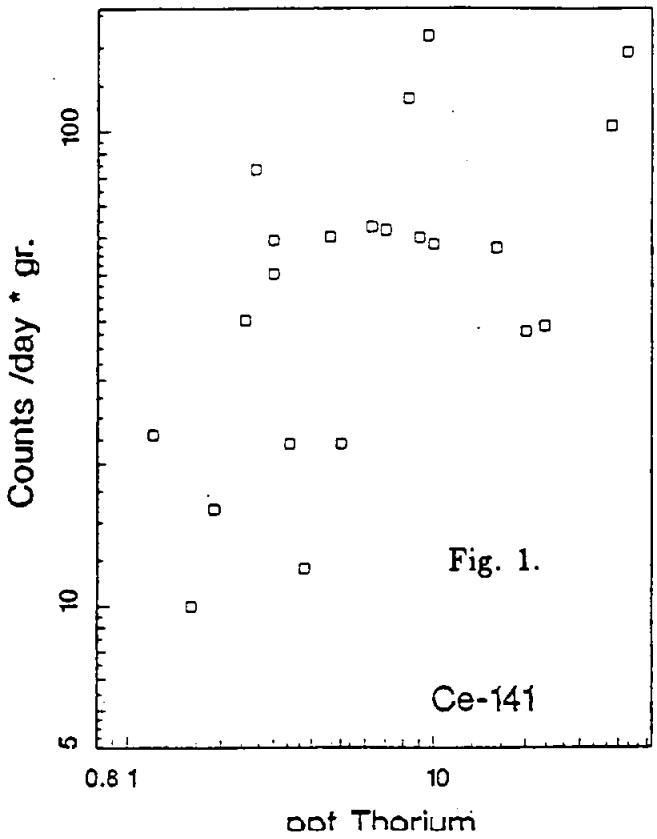


Fig. 1.

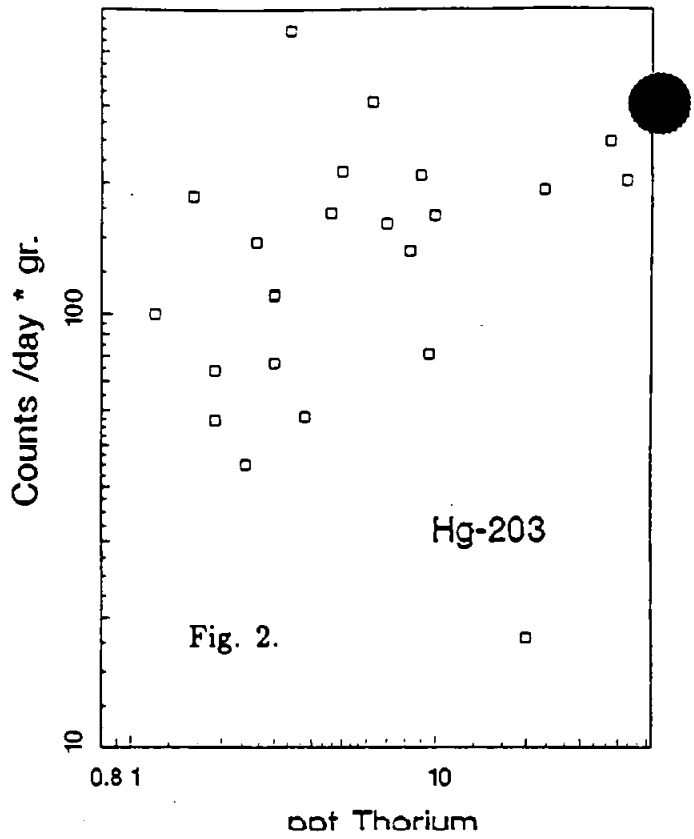


Fig. 2.

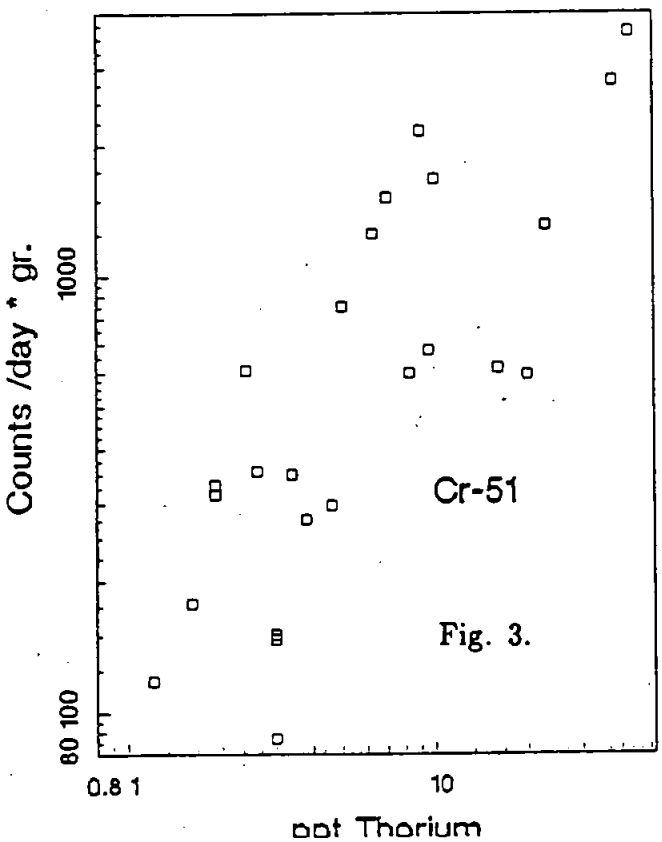
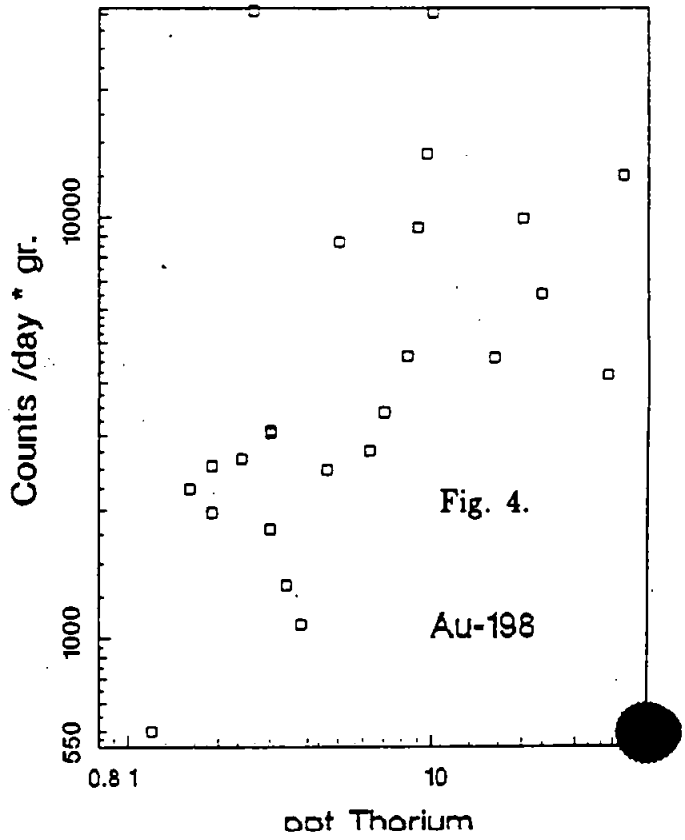


Fig. 3.



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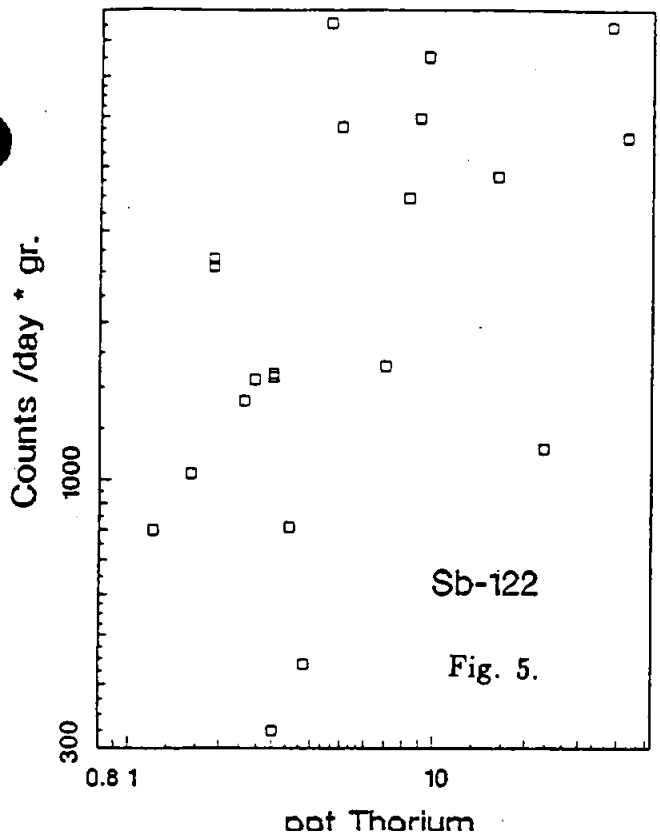

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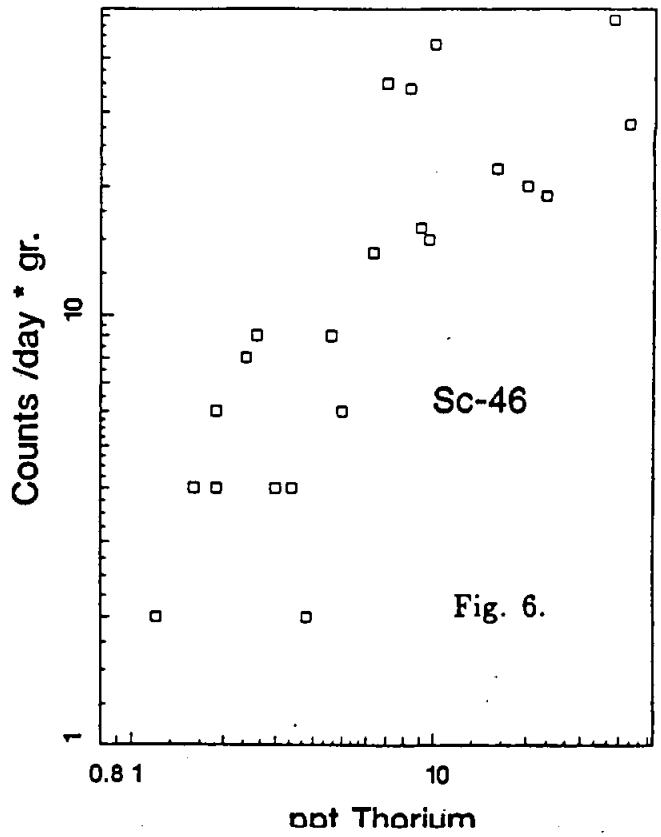
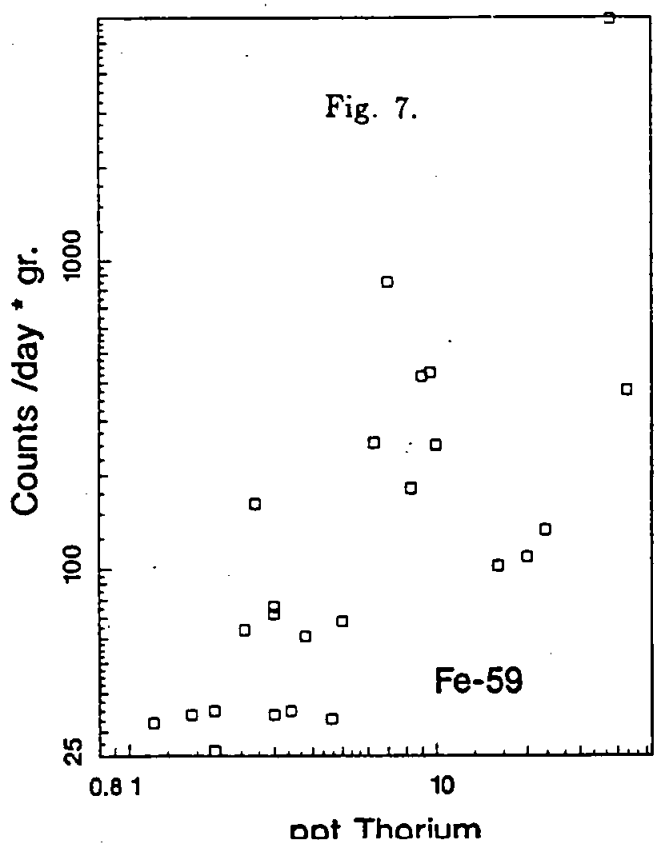


Fig. 6.

Fig. 7.



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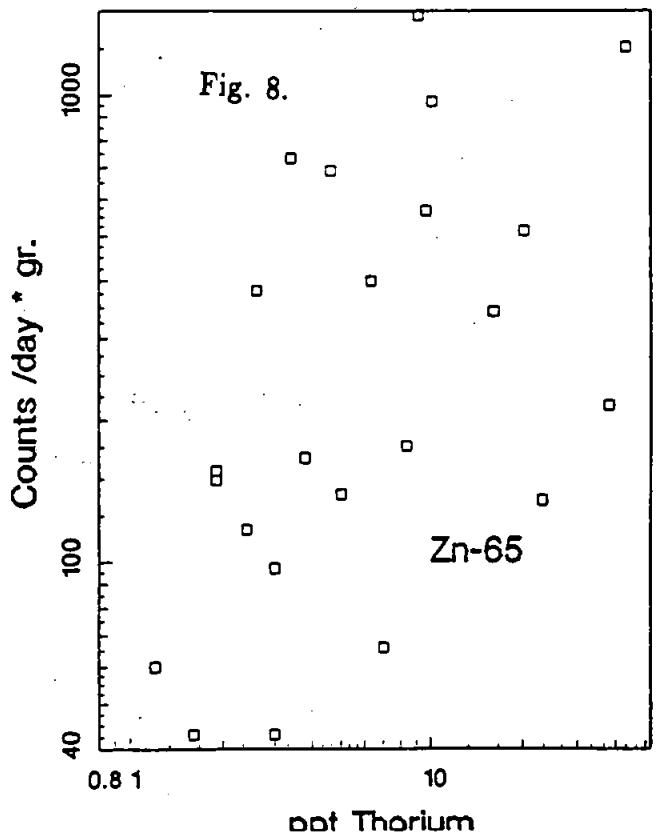

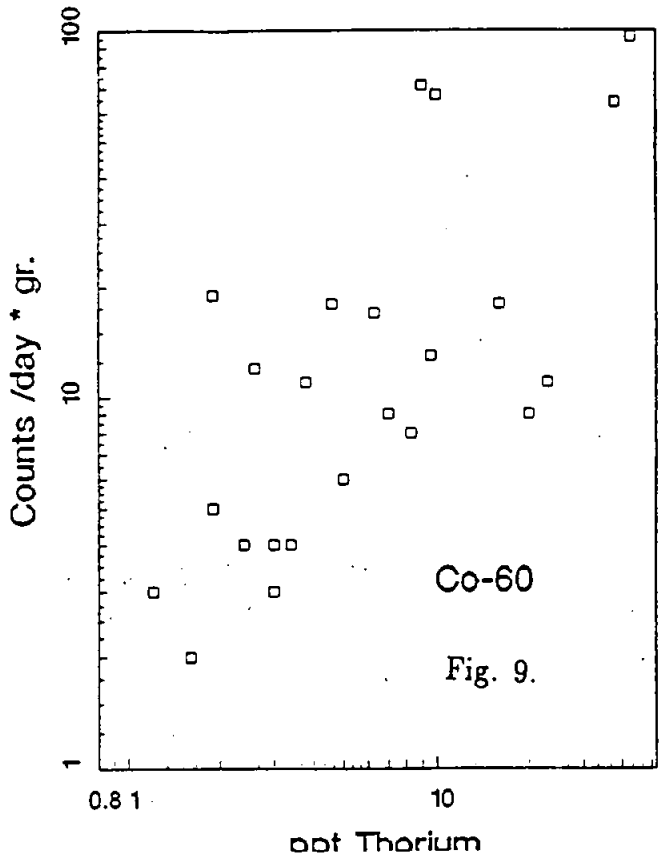

Fig. 9.

Acrylic Vessel Quality Control.
1st Draft by Earle
Valentine's Day 1991

Introduction:

There will be many steps in this procedure. This note is only meant to act as a begining in defining what will be required. QC will be required on the raw materials i.e. the sheets, bonding agents and castable components and on aspects of the finished vessel.

Raw Materials:

QC of the sheets was discussed at length during the 1989 visit to Polycast, one of the potential suppliers of sheet material and was documented at that time. Excerpts from that report follow:

Reynolds will need 160 1"x6'x8' sheets, 45 3"x4'x8' sheets and 37 2"x4'x8' sheets. Polycast has 29 machines each of which can make up to 28 sheets of 1" material at a time and each can be configered to make a number of sheets of various thicknesses. A possible running scenario might be to use four machines at a time, 2 making 25 1" sheets each, 1 making 12 3" sheets and 1 making 12 2" sheets. This scenario would be repeated up to four times to get the entire job done and would take about 6 weeks. They make about 30 t of acrylic, or the SNO vessel, a day.

Roger would like to have for each sheet, the batch, sheet and monomer lot numbers. The spectral scan, the tolerences in thicknesses and the results of a visual inspection. All this Polycast routinely provides to customers that ask for it. We would have to do the Th and U checks and any other confirmation checks that we wanted to do on their measurements. We will have to determine the specifications that we need. Roger was concerned about the thickness uncertainties which seem to be about 10%.

Once we have a routine for checking for Th and U set up, Lee will supply us with 1 litre of the monomer from the truck, 1 litre from the underground tank, 4-1 kg pieces from 1 sheet and 4-1 kg pieces from four other sheets all from the same batch and we will do this three times. Le will do the light transmission on the 24 pieces and CRNL will do the Th and U measurements.

If the tests proposed in the previous paragraph show batch consistency then we will check the production runs the same way. Since we will not be able to keep up with the production (Polycast can make all our sheets in two months) we will probably have to make our material in two one month periods. The amount of material ordered in the second production run will depend on the success of the first production run. If the firm can use the rejected material in some other application we may be able to get a rebate since I doubt that they will be prepared to quarrente the Th levels to our satisfaction.

The firm will do their usual QC, including optical transmission measurements. We will cross check the optical QC in some cases only. The Th and U checks will be as described above for each batch or more detailed than that if necessary. The Th and U will be measured by mass spectroscopy at CRL where about five samples per week could be processed. (Double that rate if it was required). Tests on the strength of the material will have been performed prior to ordering and it may be assumed that the sheet material will have adequate strength.

Similar radioactivity checks will have to be done on the bonding materials chosen by the vessel fabricator and on separate test samples made from time to time by the fabricator.

Bonded Vessel:

Test samples of the bond joints made during vessel assembly will have to be checked for Th and U in a similar way to the sheet tests and, in addition, the samples will have to be mechanically tested (see Peter Doe for this section). Optical checks on the bonded joints of test samples and the vessel can be visual.

There will also have to be a series of acceptance tests performed on the completed vessel. (Add text here, if possible).

Samples will also be made during erection and left in the water for future ageing checks. This program must also be detailed.