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Problem: Detect density changes in ThO_2 slurry

Solution to be considered: Gamma ray detection

Conditions:

1. Gamma source located on the opposite side of a 3-inch schedule 160 pipe from a gamma detector.
2. Gamma detector has a $3/8$ -inch diameter, 2-inch long collimator attached to it. These dimensions were chosen because they are the dimensions of the present experimental set-up.
3. Assume the worst condition for the Th present; namely, that all its decay products have reached equilibrium.
4. Require 40,000 counts/min by the detector which counts only $1/4$ of the gammas reaching it. Based on present set-up.
5. Wish to detect a change in ThO_2 slurry density of ± 100 gm/liter. ThO_2 initially in slurry is 1000 gm/liter.
6. Maximum source strength to be $10^6 - 10^7$ disintegration per second.
7. Present study based on slurry loop experiment, not on reactor use.
8. Detector will discriminate to ± 0.1 Mev.
9. B_1^{212} in the Th decay chain has a gamma energy spectrum of 0.04 - 2.2 Mev. For these calculations if the contemplated gamma source energy fell within this range, it was assumed that the entire B_1^{212} disintegrations were of this energy.
10. Gammas from the Th decay series of higher energy than the source gammas were not considered. Conceivably these gammas could be scattered into the detector at an energy corresponding to the source gammas. It is assumed to be a small effect.

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Summary:

1. This gamma-ray detection system appears to be feasible.
2. The 1.33 Mev gamma from Co^{60} seems to be a suitable source provided a 7 - 9% count rate change in source gammas is sufficient for detecting the $\pm 100 \text{ gm/liter}$ change in the ThO_2 slurry density. A source strength of about $5.18 \times 10^7 \frac{\text{d}}{\text{sec}}$ is required.
3. The background counts due to the Th decay chain appears to be about 1% of the total counts for a Co^{60} source. This is based on a highly approximate calculation but in any event does not appear to contribute significantly to the total count rate. The greatest effect would probably be obtained if Th of a different "age" were introduced into the system during the experiment.
4. At the end of one month the Co^{60} source strength will have changed by about 1%. At the end of a year this change will be about 12%.
5. Low energy gammas require too large a source strength with the present set-up.
6. The collimator size has not been optimized. Since the background counts from the Th decay chain seem to be rather small, a reduction in source strength might be obtained by either increasing the collimator diameter or decreasing its length, or both.
7. One possible improvement would be to reduce the diameter of the pipe or split the flow into two smaller pipes in the section where the measurements are to be made. This reduces the effect of the Th decay chain (maybe), reduces the source strength necessary (decreases the

amount of material a gamma ray must traverse and increases the source gammas which are "aimed" at the detector). This would, however, increase the effect of the iron pipe (percentage-wise).

8. Table 1 gives an indication of the ability of this gamma ray detection system and a comparison of various sources.

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TABLE I

Source	E Mev	$T_{1/2}$	% Change in source strength		Attenuation of γ 's across pipe and 1000 gm/liter ThO ₂ slurry	Count rate change with ThO ₂ density changes -100 g/l +100 g/l		Collimated source needed to get 40,000 c/sec	Source needed based on 3/8" dia., 2" long collimator d/sec	Effect of Thorium decay series based on 3/8" dia., 2" long collimator			Count rate change with ThO ₂ density change due to Th decay series -100 g/l c/m
			1 mo.	1 yr.		c/m	-c/m			I_0	AI_0	I	
-	0.5	-	-	-	.032 I_0	10 ⁴	7520	5.0 x 10 ⁶	2.06 x 10 ⁸	-	-	-	-
						25%	19%						
Cs ¹³⁷	0.669	37 y.	-	2%	.067 I_0	5960	5360	2.39 x 10 ⁶	1.37 x 10 ⁸	208,080	.258 I_0	456	-14
						14.9%	13.4%					~1.1% ⁴	
Na ²²	1.28	2.8 y.	~2%	22%	.171 I_0	3508	3508	9.6 x 10 ⁵	5.36 x 10 ⁷	69,360	.413 I_0	244	-15
						8.77%	8.77%					~0.6% ⁴	
Se ⁷⁵	0.4	127 d.	~15%	-	.015 I_0	11,468	8000	1.07 x 10 ⁷	6.1 x 10 ⁸	208,080	.122 I_0	216	+9
						28.7%	20%					~0.5% ⁴	
Co ⁶⁰	1.33	5.3 y.	~1%	12.2%	.177 I_0	2920	3840	9.04 x 10 ⁵	5.18 x 10 ⁷	69,360	.422 I_0	249	-14
						7.3%	9.6%					0.6% ⁴	

1. Intensity of decay gammas in the pipe which interfere with the source - disintegrations/cc - min.

2. Attenuation of collimated decay gammas across the slurry and pipe wall.

3. Actual effect of the decay gammas - counts/min.

4. Based on 40,000 c/m.

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