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PROPOSAL OF SOLID TITANIUM SHIM AND CONTROL RODS

BY

OSCAR D. SEAWELL

February 1, 1950

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PROPOSAL OF SOLID TITANIUM SHIM AND CONTROL RODS

Recent consideration has been given to using a pattern of 49 hollow steel rods of 3-inch diameter alloyed with neutron absorbers, for the G Pile control system. These would include 24 shim and control rods, for which gadolinium would probably be the absorber.

A study of cost, absorption, burnout and heating leads me to recommend serious consideration of solid 2-inch diameter titanium rods, in place of gadolinium-steel, for shim and control. This change would require an increase in number of about 50% for shim and control rods. Safety rods would still probably be 3-inch hollow boron-steel, as previously considered.

The accompanying diagram (page 5), entitled "Suggested 'G' Control Arrangement", shows a pattern of 35 solid titanium shim and control rods, plus 24 hollow boron-steel safety rods. These rods are placed symmetrically, except for a shift of one-half block toward the rear face in order to have each rod centered in $4 - 3/16$ by $4 - 3/16$ inch block unit.

With a cross-section of 5.5 barns per atom of titanium, a 2-inch solid rod has 80% blackness to thermal neutrons. Shim and control design for the "G" pile has been based on a minimum of 70% blackness, so there is a slight excess in the 2-inch rods on that basis. A length of 48 feet gives a weight of 295 pounds, which is slightly less than the weight for which rod driving mechanisms are being designed. In order to cut material cost, the use of only 33 feet length of titanium within the pile plus the top 15 feet of steel would increase the weight to 365 pounds, which is not excessive from the rod drive standpoint.

It might be noted here that a 2-inch diameter stainless steel rod has 70% blackness to thermal neutrons. However, the weight of an all-steel rod

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would be 520 pounds, and other disadvantages are that the modulus of elasticity of steel is twice that of titanium, and the radiation saturation level for steel is greater than for titanium. Advantages to steel are availability and comparatively low cost.

Using an estimated unit (per pound) price of \$7 for titanium, \$1.40 for stainless steel, and \$1000 for gadolinium, Table I (page 6) is established showing a cost comparison of possible shim and control rod materials.

The estimated costs given in Table I do not include any consideration of the increased cost of a 35-rod over a 24-rod shim and control system, due to more instrumentation, additional rod drive mechanisms, and possibly heavier reinforcing in the shield because of more holes; nor do they show the decreased cost due to easier fabrication and machining of solid 2-inch rods than of hollow 3-inch rods. These and other factors should be completely studied, and balanced against the estimated saving in cost of materials, amounting to about \$92,000, from the use of 2-inch solid titanium rods (with steel top section) instead of the 3-inch hollow gadolinium-steel rods which have been under consideration.

For gadolinium alloyed in titanium or steel, the neutron absorption in the base metal is neglected for the computation of the alloy requirements shown in Table I, because of the thin wall of such alloys. In the near future a study of intermediate thicknesses will be made to seek an optimum for cost, weight, flexibility and burnout, considering the absorption of both the base metal and gadolinium in combination.

The number of control rod replacements shown in Table I is determined by the time required for gadolinium burnout to reach 70% blackness to thermal neutrons, in the manner shown in my report HDC-1572, "Alloys of High Cross-Section Absorbers for Sheet Rods".

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Burnout may be neglected for either titanium or steel used as the neutron absorber. In 33 feet length of 2-inch round titanium rod there are 1.2×10^{27} atoms. With a continuous 50 inhours absorbed at 800 megawatts, only 2×10^{24} neutrons would be captured each year, which is negligible compared to the number of atoms available and the ability of most titanium or steel atoms to capture more than a single neutron. This slow burnout is an important advantage over the rapid burnout of the very expensive gadolinium. The longer a rod is used the more advantageous it would be to make it of solid titanium or steel. Furthermore, shim and control rods are interchangeable when burnout is not a factor.

The possibility of a hollow 3-inch titanium rod, with titanium as the only absorber, is also presented in Table I. This rod would have a 3/4-inch wall thickness to give 70% blackness. It could be used in the pattern set for 3-inch rods, but would have much greater weight and lesser flexibility than a thin-walled gadolinium alloy.

The low radiation saturation level of titanium makes it a desirable control rod material. Radiation resulting from neutron capture is mostly gamma rays, which are transmitted to the surrounding graphite. The use of 2-inch in place of 3-inch rods would cause less localized heating in the graphite with the greater number of 2-inch rods distributing the heat more uniformly.

The use of solid rather than hollow rods cuts leakage of neutrons through the shield. Further, a 2-inch rod leaves ample space for balls of the 3X safety system, without cutting a larger hole than that of a 4 - 3/16 by 4 - 3/16 inch graphite block size.

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A possible disadvantage to the use of titanium is its corrosion with carbon dioxide. If helium can be used for gas cooling this difficulty will be eliminated.

Oscar D. Seawell

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REACTOR DIVISION

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SUGGESTED "G" CONTROL ARRANGEMENT

107x80 GRAPHITE BLOCKS, EACH $4\frac{3}{4} \times 4\frac{3}{4}$ (= SQUARE)

Rear Face

4x blocks

SYMMETRICAL ABOUT $\left(\begin{array}{c} \text{---} \\ \text{---} \end{array} \right)$

X X X X X X

X X X X X X

X X X X X X

X X X X X X

X X X X X X

X X X X X X

X X X X X X

X X X X X X

X X X X X X

15x blocks

Front Face

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35 SOLID 2" TI SHIM & CONTROL RODS

X 24 HOLLOW 3" BORON-STEEL SAFETY RODS

59 TOTAL

Cecilia D. Sauer
January 20, 1950

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Control Rods						Total Shim & Control		
Single Rod Weight	% Alloy	Single Rod Cost	No. of rods Orig. Repl.		20 Yr. Cost	No. of Rods	Weight	Cost
shim rods.			5	0	\$10,000	35	10,300#	\$73,000
shim rods.			5	0	8,000	35	12,800	58,000
shim rods.			5	0	4,000	35	18,200	26,000
shim rods.			4	0	14,000	24	11,900	84,000
shim rods.			4	0	11,000	24	14,600	67,000
210#	3.0%	\$6,700	4	8	80,000	24	4,800	150,000
185	3.0	4,600	4	14	83,000	24	4,400	153,000
shim rods.			4	24	98,000	24	4,400	168,000
200	4.0	7,800	4	7	86,000	24	2,900	168,000
shim rods.			4	23	111,000	24	2,500	193,000
250	4.0	7,500	4	7	82,000	24	3,600	160,000
shim rods.			4	23	105,000	24	3,100	183,000