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TUBE WALL THICKNESS
ISOTOPE PRODUCTION TUBES

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ISOTOPE PRODUCTION TUBES

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TUBE WALL THICKNESS
ISOTOPE PRODUCTION TUBES

INTRODUCTION

Irradiation of process tubes containing appropriate parent materials has been proposed by Manufacturing as a method for obtaining new products from the Hanford Reactors. The process tubes would be removed at appropriate intervals and shipped to separations plants for recovery of the products. The tube residence in the reactor could be determined by the optimum irradiation period for isotope production rather than by the period required to corrode tubes of current design to the minimum permissible wall thickness at replacement.

This paper presents an analysis to determine the benefits from reducing the initial wall thickness of the process tubes below the current 65 mils when the desired residence for isotope production is shorter than the residence based on maximum permissible internal corrosion for tubes of current design.

SUMMARY AND CONCLUSIONS

Reduction of the process tube wall thickness at installation would provide benefits of either (1) increased total production or (2) reduced operating costs while maintaining constant production. Increased production could be realized either from a higher conversion ratio from using larger fuel elements or from a higher reactor power level as a result of increased coolant flow. Reduced operating costs could result from using larger fuel elements and then reducing reactor power level in proportion to the increased conversion ratio. The cost savings would result primarily from reduction of the quantity of uranium used to obtain the same quantity of plutonium that would have been produced if isotope production tubes had not been irradiated. The metal cost would be reduced approximately in proportion to the increase in conversion ratio.

Reduction of the process tube wall thickness would reduce the maximum permissible tube residence based on internal corrosion. The relationships of tube residence and reactor conversion ratio to initial tube wall thickness for 1100-H18 alloy tubes are as follows:

Table I
Effects of Reduced Tube Wall Thickness

<u>Case</u>	<u>Initial Process Tube Wall Thickness (Mils)</u>	<u>Relative Reactor Conversion Ratio</u>	<u>Relative Average Tube Residence Because of Internal Corrosion</u>
I	65*	1.000	1.00
II	60	1.005	0.95
III	55	1.009	0.88
IV	50	1.013	0.77
V	45	1.017	0.62

* Current process tubes

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The wall thickness selected for isotope production tubes and the resultant benefit will depend primarily on the number of isotope production tubes, the desired irradiation time, and the alloy in the isotope tubes. If the number were relatively small (less than 1000 tubes), the extra fabrication cost for a small number of special size fuel elements could make larger fuel elements uneconomical and flow unbalances could make increased flow in isotope tubes undesirable. If all tubes in the central zone of a reactor were isotope tubes, a significant reactor power level increase (e.g., ten percent) would be possible if the necessary additional coolant were available from the water plants. If the irradiation time is relatively long, the wall thickness would have to be sufficient to prevent failure by internal corrosion prior to the end of the desired irradiation. If the irradiation period were relatively short and the alloy used had the same strength as 1100-H18 alloy, 50 mils would be the minimum permissible thickness to prevent a significant probability of Van Stone flange failures and burst failures in the front quarter of the tubes when significant scratching (10 to 20 mils penetration) occurs during installation. This 50 mil minimum permissible thickness and the residence periods for the various wall thicknesses will change if the alloy used in the isotope tubes has a different strength and corrosion rate than has 1100-H18 alloy.

Selection of the wall thickness for isotope production tubes must await receipt of information concerning the number of tubes needed, the irradiation time, and the strength and corrosion rate of the isotope tubes.

The advantages shown above for isotope production tubes may also be realized for regular production tubes. After the process tube corrosion rate with 6.6 pH process water is known, a study should be made to determine the optimum wall thickness for the regular production tubes.

DISCUSSION

The average initial wall thickness of a process tube is selected by making an economic balance involving the following significant variable factors:

1. Reactor conversion ratio.
2. Reactor power level (i.e., coolant flow and temperatures).
3. Process tube burst strength.
4. Probability of Van Stone flange failures.
5. Tube replacement cost.
6. Fuel cost.
7. Process water cost.

In addition, if isotope production tubes of different than current tube design are used, there are the additional factors of extra charge-discharge time and possible metal handling errors because of use of additional fuel element designs which are not noticeably different than the current designs.

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The following discussion is based on the assumption that the irradiation time for isotope production tubes is less than the residence time for a 65 mil wall tube as determined by internal corrosion. Selection of the process tube wall thickness then becomes an economic balance of all factors listed above except the tube replacement cost. It is assumed that the extra value of the special isotopes produced will repay the additional costs of the necessary extra tube replacements and enrichment to support the parent materials added to the process tubes.

As the wall thickness of the tubes is decreased, one has a choice of (1) increasing the diameter of the fuel elements and consequently the reactor conversion ratio and/or (2) increasing the reactor coolant flow and the reactor power level.

The permissible coolant flow increase is dependent on the availability of coolant and on the number of isotope tubes in a reactor. If less than half of the tubes are isotope tubes, increased flow and power levels might not be practical because of flow and temperature unbalances. The reactor power level might have to be reduced in order to keep the tube outlet temperatures within the process standard limits. If all central tubes were isotope tubes with thinner than current wall thickness, substantial power level increases (up to ten percent) are possible. The maximum increase would be determined by the tube wall thickness, the availability of coolant, and the occurrence of other power level limits (e.g., graphite temperature).

If the reactor coolant flow is held constant and the fuel diameter is increased as the tube wall thickness is decreased, a production gain of up to two percent could be realized from increased conversion ratio (see Table I). The reactor enrichment requirements decrease as the fuel diameter increases (see Table II). This results in a negligible increase in fuel costs and a small increase in time operating efficiency because less outage time is required for charge-discharge of natural metal than for the same number of tubes of enriched metal (less than 0.1 TOE units gain for a 50 mil tube wall thickness). Increasing the fuel diameter might not be desirable if less than half the tubes in a reactor are isotope tubes. The extra costs for fabricating a small number of special size fuel elements might exceed the benefits from a small increase in conversion ratio.

In general, it can be concluded that decreasing the tube wall thickness and increasing the fuel diameter are increasingly favorable for isotope tubes until there is a significant probability of tube failure because of Van Stone flange failures or tube bursting because the tube cannot withstand the process water front header pressure. The minimum permissible wall thickness of an 1100-H18 alloy tube appears to be about fifty mils.

An 1100-H18 alloy tube with a fifty mil wall thickness has a burst pressure of 1200 to 1500 psi. Since the front header pressures are approximately 600 psi, the safety factor would be only two with no tube scratching during installation and less than two if scratching occurs. A burst failure could result in flooding of the reactor and could cause significant fuel damage.

The frequency of Van Stone flange failures would be expected to increase rapidly as the tube wall thickness is decreased below fifty mils. The yield strength of a 50 mil flange is only 4300 pounds. The strength would decrease in proportion to any decrease in wall thickness below 50 mils.

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The above analysis is for a tube with strength and corrosion rates equal to those of 1100-H18 alloy. If the alloy of the isotope tubes has a different strength or corrosion rate, the analysis and conclusions must be modified accordingly.

Also, it is assumed that the isotope tubes will be made of a homogeneous material. If the tubes are bimetallic, the total wall thickness of the two materials must equal the wall thicknesses of Table I if the conversion ratios shown are to be realized. The average tube residence would be as shown in Table I only if the metal layers penetrated by internal corrosion have the same corrosion rate as 1100 aluminum.

Because the best tube wall thickness for isotope production tubes is dependent on such factors as the desirable irradiation time, the tube alloy and the number of tubes, selection of the wall thickness must await receipt of such information when the desired product and quantity are known.

The cost reductions and production gains described above for isotope production tubes also may be realized for regular production tubes. At present, a study to determine the optimum wall thickness for regular production tubes cannot be made with accuracy because the process tube corrosion rate with 6.6 pH process water is not known. Enough corrosion data should be available to permit an accurate study early in CY-1964.

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Table II
Economic Analysis of Increased Fuel Diameter
Basis: One 100-B Design Reactor

<u>Case</u>	<u>Tube Wall (Inches)</u>	<u>Tube ID (Inches)</u>	<u>Canned Fuel OD (Inches)</u>	<u>Bare Fuel OD (Inches)</u>	<u>Relative Tube Life (Years)</u>
I	0.065	1.598	1.444	1.356	1.00
II	0.060	1.608	1.454	1.366	0.95
III	0.055	1.618	1.464	1.376	0.88
IV	0.050	1.628	1.474	1.386	0.76
V	0.045	1.638	1.484	1.396	0.62

<u>Case</u>	<u>Conversion Ratios</u>		
	<u>Natural</u>	<u>Enriched</u>	<u>Total</u>
I	(0.892)(0.875) +	(0.769)(0.125)	= 0.781 + 0.096 = 0.877
II	(0.895)(0.884) +	(0.772)(0.116)	= 0.791 + 0.090 = 0.881
III	(0.898)(0.891) +	(0.775)(0.109)	= 0.800 + 0.085 = 0.885
IV	(0.901)(0.897) +	(0.778)(0.103)	= 0.808 + 0.080 = 0.888
V	(0.904)(0.904) +	(0.781)(0.096)	= 0.817 + 0.075 = 0.892

<u>Case</u>	<u>Tubes E Metal</u>	<u>Tons E Metal Per Year</u>	<u>Annual E Metal Incremental Cost</u>	<u>Annual Incremental Cost of Natural Metal Used in These 208 Tubes</u>	<u>Increased Annual Metal Cost</u>	
					<u>Per Reactor</u>	<u>Per Central Tube</u>
I	208	75.8	265,000	0	0	0
II	193	70.3	246,000	21,200	2,200	1
III	182	66.3	232,000	36,700	3,700	2
IV	172	62.6	219,000	50,900	4,900	3
V	160	58.3	204,000	67,800	6,800	4

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Table III
Basic Assumptions and Data for Calculations

1. The effect on reactor economics of the quantity of aluminum in a tube is negligible.
2. Fuel diameter data (650 MWD/T):

<u>Fuel Diameter</u>	<u>Gms. Pu/MWD</u>		<u>Fraction of E Metal</u>
	<u>Natural</u>	<u>Enriched</u>	
1.356	0.892	0.769	0.125
1.366	0.895	0.772	0.116
1.376	0.898	0.775	0.109
1.386	0.901	0.778	0.103
1.396	0.904	0.781	0.096

Source: Personal communication, W. A. Blyckert, June, 1963

3. Corrosion Data:

Tube Corrosion Rate

<u>Fraction of Tube Life</u>	<u>Mils Corrosion of Bottom</u>
0.2	2
0.4	5
0.6	9
0.8	17
1.0	30

4. Burst data for process tubes (HW-72037):

<u>Wall Thickness - Mils</u>	<u>Burst Pressure - psi</u>
65	1550 to 1950
50	1200 to 1500
40	950 to 1200

5. The incremental cost of E metal is \$3,500/ton.
6. The incremental cost of natural metal is \$3,000/ton.
7. Four metal cycles/year.
8. An E metal charge contains 1/10.97 tons metal.
9. A natural metal charge contains 1/8.49 tons metal.
10. The average E metal tube has a factor of 1.2.

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