OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

ORNL-TM-699
COPY NO. - 4
DATE - October 9, 1963

MERCURY COSTS IN HERMEX PROCESS

O. C. Dean

NOTICE

Mr. S. A. Lawroski, of Argonne National Laboratory, raised the question of the cost of mercury holdup and replacement in the Hermex process. He thought a low limiting concentration of <1 wt % uranium in mercury would make the cost of mercury inventory prohibitive. This seemed to be an important consideration, therefore I determined the cost per pound of uranium for mercury inventory and annual mercury process loss. Certain assumptions were made for fuel geometry in order to calculate dissolving surface available. Dissolution to 0.5 wt % U was assumed to take advantage of the fast initial rate (straight line portion of dissolving curve). The ratio of mercury to uranium in the dissolver was calculated from the rate equation to determine whether or not the geometry of the dissolver would be reasonable.

The calculations follow:

Hermex Dissolver Design Information

A. Assumptions Made in the Hermex Process

1. Continuous processing through washing and drying.
2. Dissolution to 0.5 wt % uranium.
3. No mercury holdup on hot filter.
4. Diameter of declad fuel elements, 0.15 in.
5. Ten percent of the mercury inventory per year will be lost in process.
6. The mercury inventory is three times holdup.
7. Interest charges, 4% per annum.

B. Hermex Dissolver Design

Fuel, declad uranium rods 0.15 in. dia.

Cross section of rods, $cm^2 = (0.15 \times 2.54)^2 \left(\frac{\pi}{4}\right) = 0.114\ cm^2$.

Density of U = 18.7 g/cm^3.

Weight of rod per cm length = (0.114)(18.7) = 2.13 g.

Length of rod per pound U = 453.6/2.13 = 213 cm.

Approximate surface of 1 pound of rods (not counting ends) = (3.1416)(0.381)(213) = 255 cm^2/lb U.

The optimum time holdup in the dissolver is 30 min. To determine whether or not the dissolver pot would have a reasonable geometry with this holdup, use is made of the dissolution rate equation, $dC/dt = ks/m\ (C_s - C)$, where C is the molal concentration of U in Hg at time t; C_s is the molal concentration at saturation (0.047 m); k is the specific rate constant, g·Hg/cm^2/min; s is the U surface, cm^2; m is the mass of mercury used in the dissolution, g; and t is the time, min. Integrated between C = 0 at t = 0 and C_s, it becomes $\log\ (1 - \frac{C}{C}) = \frac{-ks}{m}\ t$. At 0.5 wt % U in Hg C is 0.021 m; k = 2.2 g Hg/cm^2 U/min; t = 30 min; C/C_s = 0.448; 1 - C/C_s = 0.552. Solving, s/m = 0.009 cm^2 U/g Hg. For the U shapes assumed the mercury to uranium mass ratio in the dissolver is 255 cm^2/lb U/0.009 = 24,800 g = 62.5 lb Hg/lb U.

The uranium which will be dissolved by 62.5 lb Hg in 30 min at 0.5 wt % U is 142 g. The mercury required to dissolve 1 lb U in such a dissolver is 200 lb, and the dissolver uranium heel, 3.2 lb/lb U/hr. The mercury feed rate would be 200 lb/hr.

The flowsheet and mercury holdup analysis is shown in Fig. 1.

C. Calculation of Mercury Holdup Per Pound Uranium

From the flowsheet (Fig. 1)

200 lb Hg/lb U/hr for 3/4 hr = 150 lb Hg/hr.
33 lb Hg/lb U/hr for 1 1/4 hr = 41 lb Hg/hr.
Average Hg holdup/lb U/hr = 191 lb
Mercury inventory (3 x holdup) = 573 lb Hg/lb U/hr.
Mercury investment ($3/lb Hg) = $1720/lb U/hr.
Interest for 1 hr at 4% per annum = 1720 x .04/6000 hr/yr = 1.15¢/lb U.
Mercury losses (10% of inventory)/yr = 573 x .10 = 57.3 lb Hg/lb U/hr/yr.

Replacement cost = 57.3 x 3/6000 = 2.87¢/lb U.
Total mercury cost = 2.87 + 1.15 = 4.0¢/lb U.

O. C. Dean

O. C. Dean

OCD/jr

UNCLASSIFIED
ORNL-LR-Dwg #25409

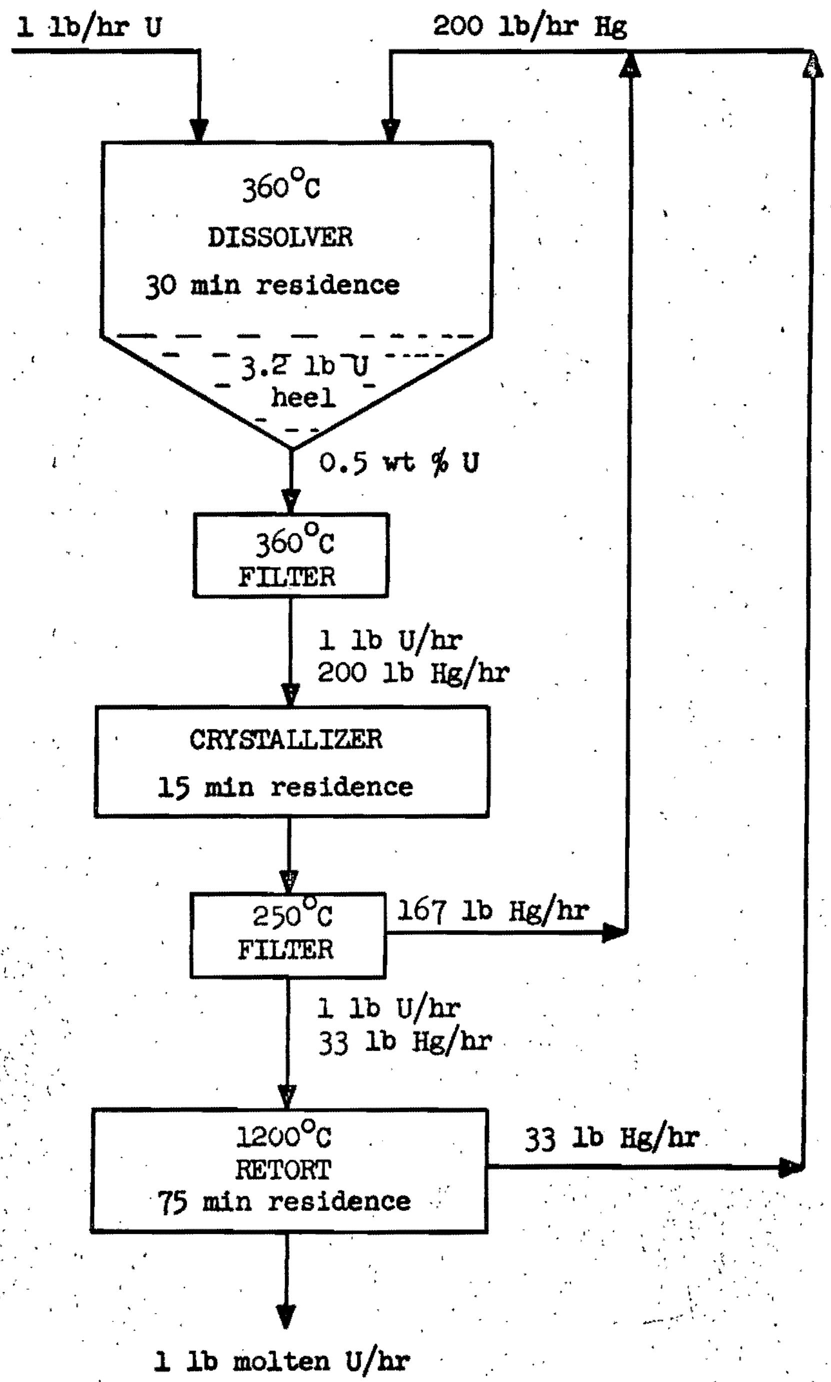

Fig. 1. HERMEX FLOWSHEET AND MERCURY HOLDUP ANALYSIS

Distribution

1-2. DTIE, AEC
3. M. J. Skinner
4. Central Research Library
5. Document Reference Section