

~~SECRET~~

UNCLASSIFIED

DPSP 55-25-30

~~This document consists of
22 pages. No. 1 of
28 copies, Series A.~~

Classification Changed to
UNCLASSIFIED by Authority of

W H Emslie
DOE SR

By *CTS* Date *6-23-81*

TRITIUM ATTENUATION BY DISTILLATION

o o o o o o o o o o o o o o o

N. E. Wittman

July 5, 1955

Restricted Data

This document contains Restricted Data as defined in the Atomic Energy Act of 1954. Its transmittal or the disclosure in any manner of its contents to an unauthorized person is prohibited.

E. I. du Pont de Nemours and Company
Explosives Department - Atomic Energy Division
Savannah River Plant

UNCLASSIFIED

This document was prepared in conjunction with work accomplished under Contract No. AT(07-2)-1 with the U.S. Department of Energy.

DISCLAIMER

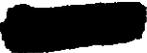
This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available for sale to the public, in paper, from: U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, phone: (800) 553-6847, fax: (703) 605-6900, email: orders@ntis.fedworld.gov online ordering: <http://www.ntis.gov/ordering.htm>

Available electronically at <http://www.doe.gov/bridge>

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from: U.S. Department of Energy, Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831-0062, phone: (865) 576-8401, fax: (865) 576-5728, email: reports@adonis.osti.gov

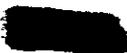

DistributionWilmington

- 1 J. B. Tinker
- 2 H. W. Bellas
- 3 D. F. Babcock
- 4 W File

Savannah River Plant

- | | |
|-------------------|------------------------------|
| 5 J. D. Ellett | 15 N. E. Wittman |
| 6 W. P. Overbeck | 16 W. J. Jacober |
| 7 M. H. Wahl | 17 S. M. Katz |
| 8 W. S. Church | 18 A. A. Johnson |
| 9 K. W. French | 19 P. S. Shane |
| 10 C. W. J. Wende | 22 RT File |
| 11 P. A. Dahlen | 23 TIS File |
| 12 F. E. Kruesi | 24 TPO File |
| 13 R. C. Holmes | 25-27 PRD File, Extra Copies |
| 14 E. C. Bertsche | 28 PRD File, Record Copy |

Atomic Energy Commission, SROO

- 20 R. C. Blair
 - 21 W. Davis
- 

Contents

| | |
|---|----|
| INTRODUCTION | 4 |
| SUMMARY | 4 |
| RECOMMENDATIONS | 5 |
| DISCUSSION | 5 |
| Background and Objective | 5 |
| Theory | 6 |
| Attenuator Evaluation | 7 |
| Light Water Production Capacity | 11 |
| Equipment | 14 |
| CONCLUSIONS | 15 |
| FIGURES | 17 |
| REFERENCES | 22 |

ABSTRACT

Tritium in the degraded moderator distilled from the 100 Area reactor system will exceed the 400 Area rework capacity late in 1955. A theoretical evaluation shows that redistillation of the degraded moderator in a 100 Area distillation system will reduce the tritium quantity for the next 9.5 years to a tolerable level. A plant test of this tritium attenuator concept is recommended.

Introduction

Tritium content of the circulating moderator in the 100 Area reactor systems and in the distillation overheads draw-off will continue to increase. Based on the tritium concentration reduction of 2.5 to 3 experienced in R and P Area distillation columns, the overheads production will exceed the 400 Area tritium product specification during the latter part of 1955. The reconcentration of this diluted moderator will therefore require either improved operation of existing equipment or installation of additional equipment.

The objective of this study was to determine how a 100 Area distillation system could be used to reduce to a satisfactory low value the tritium content of the dilute moderator produced in the 100 Area stills, and whether such a tritium attenuator would have sufficient capacity to process all this material before it is sent to the 400 Area for reprocessing.

Summary

The design evaluation, based on operating four 100 Area distillation systems to remove light water from the reactor moderator and the fifth distillation system as a tritium attenuator, showed that such an attenuator would have sufficient capacity to process all degraded moderator produced by the four normal distillation systems. The tritium attenuator would consist of a standard distillation system isolated from the reactor system and operated with a 500-gallon bottoms working inventory circulating continuously through the A rundown tank and the A column reboiler.

Re-distillation of the normal distillation overheads product in this attenuator will simultaneously reduce the tritium concentration, the total amount of tritium, and the volume of dilute moderator which is returned to the 400 Area. Reduction in tritium quantity will accrue from distilling the feed moderator into a low tritium overheads (32 mol % D_2O) containing 90% of the feed H_2O and a high tritium bottoms (98 mol % D_2O) containing 97% of the feed tritium.

Tritium flow to the 400 Area will be reduced by a factor of 30 when the moderator in the reactor systems averages 99.8 mol % D_2O or less. This reduction will enable the 400 Area to maintain the desired low tritium specification in their product for at least 9.5 years, while reconcentrating the entire projected 100 Area production of degraded moderator. The total projected normal distillation overheads draw-off from four 100 Areas of 75,000 pounds (85 mol % D_2O) per year can be reduced in the attenuator to 16,500 pounds (32 mol % D_2O) per year. In 1960, the tritium content of this 16,500 pounds of moderator will be 1680 curies per year compared to the 400 Area rework capacity of 1730 curies per year.

Recommendations

- The tritium attenuator proposed in this report should be evaluated by actual operation.
- The L Area distillation system should be operated as a tritium attenuator during initial operation.
- Provided the theoretical evaluation is substantiated by actual operation of the L Area distillation system as an attenuator, all dilute moderator requiring reconcentration should be processed through a tritium attenuator prior to shipment to the 400 Area.

Discussion

Background and Objective

Moderator Purity. The isotopic purity of the moderator in a reactor must be kept high to maintain high productivity and neutron efficiency. Distillation systems have been provided in each of the 100 Areas to remove the undesirable light water from the reactor moderator. The overheads product from these stills is the main source of degraded moderator. A small amount of degraded moderator resulting from minor leaks is fed to the distillation columns as an intermediate or secondary feed.

Heavy water concentration of the distillation overheads varies between 80 and 95 mol % depending on the reactor moderator concentration and the distillation draw-off rate. No equipment is available in the 100 Areas to upgrade dilute moderator to a concentration suitable for use in the 100 Area reactors (over 99.75 mol % D_2O). Upgrading has to be done in the 400 Area. Since degraded moderator may contain a substantial amount of tritium (200 to 5000 $\mu\text{c}/\text{ml}$), only a limited amount can be concentrated by the 400 Area without exceeding their product tritium activity specifications of 5 $\mu\text{c}/\text{ml}$.¹ The 400 Area would also have to take the special precautions required to handle the radiation hazard presented by higher amounts of radioactive tritium. Late in 1955, the quantity of degraded water produced in the 100 Areas will contain more tritium than the 400 Area can handle without exceeding their tritium specifications.

¹ DPSTS 421-1.03.

Tritium In Moderator. Tritium is produced in the reactor moderator by neutron capture at a rate of 0.0038 $\mu\text{c}/\text{ml}/\text{mwd}$. Ninety percent of the maximum concentration will be approached in 41 years if the reactor operates at a constant power level. For example at 600 mw constant power, the maximum tritium concentration in the reactor moderator will be 14,500 $\mu\text{c}/\text{ml}$ and 1500 mw, 36,300 $\mu\text{c}/\text{ml}$.² As the tritium content of the reactor moderator increases, the distillation overheads tritium content will increase correspondingly from its present value of 280 $\mu\text{c}/\text{ml}$ to a maximum value of about 580 $\mu\text{c}/\text{ml}$ at 600 mw, and about 15,000 $\mu\text{c}/\text{ml}$ at 1500 mw.

The tritium activity in the overheads from the 100 Area distillation systems has proved to be higher than predicted by design. (During the design period no reliable information was available on the vapor pressure of tritium oxide.) Design was based on the assumption that the ratio of the vapor pressures of tritium oxide to deuterium oxide was the same as that for deuterium oxide to light water. From these figures design tritium attenuation was calculated to be between 50 and 100. Recent unpublished information has indicated that the vapor pressure of tritium is only slightly lower than that of heavy water and would produce a tritium attenuation in a 100 Area still system between 2 and 5. This is in agreement with the attenuation of 2.5 actually obtained in the R and P Area distillation systems.

When all of the distillation systems are producing degraded moderator containing substantial amounts of tritium, the problem of concentrating this degraded moderator will become more acute. One possible method of solving this problem would be to use one 100 Area distillation system as a tritium attenuator.

The objective of this report was to evaluate the potentialities of the tritium attenuator principle and to determine its limitations.

Theory

The proportion of a volatile component removed in a distillation column is dependent on the vapor pressure of the components, the draw-off rate, the number of actual plates in the column, and the plate efficiency. At the optimum conditions of operation in the existing distillation system at total reflux and with a bottoms composition of 99.75 mol % D_2O , the tritium concentration of the overheads can only be decreased to 33% of the feed concentration (or to 40% at the normal draw-off rate of 1.5 lb/hr). Thus, the existing equipment can not be modified nor operated to produce the desired 10 to 30 fold decrease in tritium concentration.

² The current concentration in R and P Areas is about 710 $\mu\text{c}/\text{ml}$.

An additional distillation would reduce the tritium mass flow rate since: (a) redistilling the overheads from the normally operated distillation system decreases the overhead tritium concentration at least an additional 40% and further concentrates the light water in the overheads, thus reducing the gross amount of degraded moderator sent to the 400 Area, and (b) this increase in light water concentration between the top and bottom of the system further decreases the overheads tritium concentration.

Since the reactor systems of four 100 Areas have experienced no great dilution to date it was reasonable to assume that a distillation system in one area could be isolated from its reactor moderator system and used to reduce the quantity of tritium sent to the 400 Area.

Attenuator Evaluation

The tritium attenuator concept was evaluated using theoretical vapor pressure data, and actual operating data from the 100 Area stills and the 400 Area DW system. Concentrations and flow rates of the feed, overhead, and bottom streams were calculated from material balance equations.

Batch Size. The production capacity of a batch-still is determined by the holdups in the top and bottom of the still. The capacity of the existing 100 Area still systems was limited by a reboiler capacity of only 100 gallons. By connecting the A rundown tank to the reboiler (as described later), operating with 400 gallons in A rundown tank, and circulating moderator through both units, the bottoms capacity could be increased to 500 gallons. Thus, the total charge size would be 1600 gallons, which could be stored in the two 800-gallon rundown tanks if, for any reason, the columns had to be emptied.

A charge size of 1600 gallons (1200 gallons in the columns and 400 gallons in A rundown tank) was therefore chosen for use in evaluating a 100 Area distillation system as a tritium attenuator.

Light Water Concentration Gradient. The equilibrium concentrations of light water in the overheads and bottoms of the still for the initial charge were calculated by trial and error material balances using calculated system holdups and past experimental concentration data. The initial charge was assumed to be 1600 gallons with a tritium content of 1000 $\mu\text{c}/\text{ml}$ and a heavy water content of 87.5 mol % D_2O . (This total charge of 748 mols was, therefore, composed of 93.5 mols of H_2O and 654.5 mols of D_2O .) An assumed concentration gradient was then selected for the attenuator based on 100 Area and 400 Area Distillation experience. The light water inventory in the attenuator was then calculated for this assumed gradient and compared to the light water content of the feed. Based on the difference between these two figures, the assumed concentration

gradient was then changed and the above inventory calculation repeated until satisfactory agreement was reached between these two figures. The final calculation (see table 1 below) showed that the light water inventory calculated from the assumed concentration gradient was 92.2 mols compared to the actual value of 93.5 mols.

Table 1. Light Water Concentration Gradient and Inventory

| <u>Location</u> | <u>Mol Fraction H₂O</u> | <u>Inventory, total mols</u> | <u>Inventory, mols H₂O</u> |
|-----------------|--|----------------------------------|---|
| A Rundown Tank | 0.01 | 182 | 1.8 |
| A Reboiler | .01 | 100 | 1.0 |
| A Column | .035 | 196 | 6.9 |
| B Reboiler | .08 | 27.5 | 2.2 |
| B Column | .29 | 200 | 58.0 |
| B Condenser | .5 | 42.5 | 21.3 |
| Calculated | | 748 | 92.2 |
| Charged | 0.125 | 748 | 93.5 |

The above calculation is confirmed by the fact that a gradient of 0.99 (bottom) to 0.92 mol fraction D₂O (top) was observed during the operation of A column in R Area startup total reflux operation, and a gradient of 0.92 (bottom) to 0.50 (top) mol fraction D₂O was observed during total reflux operation of the last stage of the 400 Area DW system. (The last stage in 400 Area is similar to the B column in a 100 Area, so a similar concentration gradient is to be expected.)

The assumed light water gradient shown in table 1 was deemed satisfactory and was used in the further calculations.

Tritium Concentration Gradient. Tritium concentrations at the extremes of A and B columns were calculated by the following equation (see DPSPN 309, p 150) using the D₂O concentrations previously determined and a series of trial and error material balances.

$$CA = \frac{X_b}{X_t} = \alpha \text{ avg}^{90e} \quad (1)$$

where $\frac{X_b}{X_t}$ = ratio of tritium concentration in bottom of a column to that in top of a column is defined as column attenuation (CA)

$\alpha \text{ avg}$ = average separation factor in each column (assuming the moderator to be a mixture of TDO and THO) which will be dependent on the vapor pressure of the constituents and may be estimated by averaging the α 's at the column extremes obtained from figure 1.

X_b = tritium concentration at bottom of an individual column

X_t = tritium concentration at top of an individual column

90 = number of sieve plates in each column

e = plate efficiency or efficiency of separation, assumed to be 0.6.

The results of this calculation are presented in table 2.

Table 2. Tritium Separation Factors and Concentration Gradient

| <u>Location</u> | <u>H₂O Mol Fraction</u> | <u>α</u> | <u>α avg</u> | <u>CA</u> | <u>Tritium, μc/ml</u> |
|-----------------|------------------------------------|----------------------------|--------------------------------|-----------|--------------------------------------|
| A Bottoms | 0.01 | 1.0085 | | | 1450 |
| A Column | 0.01 to 0.08 | | 1.010 | 1.72 | |
| A Overhead- | | | | | |
| B Bottom | 0.08 | 1.012 | | | 845 |
| B Column | 0.08 to 0.50 | | 1.025 | 3.5 | |
| B Overhead | 0.50 | 1.033 | | | 240 |
| Over-all | 0.01 to 0.50 | | | 6.0 | |

The overall system attenuation of 6.0 is the product of the A column attenuation of 1.72 times the B column attenuation of 3.5.

Using the data from table 2, a set of tritium material balances was calculated assuming various values for the average tritium content of each column. The final calculation is shown in table 3.

Table 3. Tritium Concentrations and Material Balance

| <u>Location</u> | <u>Moderator Inventory, total moles</u> | <u>Tritium Content, μc/ml</u> | <u>Tritium Inventory, mole-μc/ml</u> |
|------------------|---|--|---|
| A Rundown Tank | 182 | 1450 | 264,000 |
| A Reboiler | 100 | 1450 | 145,000 |
| A Column | 196 | 1150 | 225,000 |
| B Reboiler | 27.5 | 845 | 23,200 |
| B Column | 200 | 540 | 108,000 |
| B Condenser | <u>42.5</u> | <u>240</u> | <u>10,200</u> |
| Total Calculated | 748 | | 775,400 |
| Total Charged | 748 | 1000 | 748,000 |

The calculated tritium inventory in the system (775,400 mole- μ c/ml) and the tritium content of the initial charge (748,000 mole- μ c/ml) differed by less than 4% and were considered to be in substantial agreement.

The assumed tritium concentration gradient shown in table 3 was, therefore, used in further calculations.

Cycle Time. The capacity of the attenuator is dependent on the time required to charge and discharge moderator from the system and on the operating time required for the attenuator to reach the desired concentration gradient. In this evaluation an allowance of one day was made for charging and discharging. The time required to attain the desired final A bottoms concentration was determined to be 7 days by the following reasoning.

When the attenuator is operated at total reflux, the light water concentration in the bottoms will increased according to the equation. (See DPSPN 309, pp 158 and 159).

$$Y_1 = Y_0 e^{-0.0149t} \quad (2)$$

where t = time attenuator has operated at total reflux in hours
 Y_0 = mol fraction H_2O in bottoms at start of distillation (0.125)
 Y_1 = mol fraction H_2O in bottoms at time, t .

This relation is plotted in figure 4 which shows that approximately 7 days will be required to attain the desired A bottoms concentration of 0.01 mol fraction H_2O , assuming a feed concentration of 0.125 mol fraction H_2O .

The over-all cycle time of 10 days, used for further calculation, included an allowance of 2 days for inaccuracies in vapor pressure data and for other contingencies.

Results, First Starting Cycle. The proposed tritium attenuator can process a charge of moderator during a 10-day cycle to achieve an attenuation of 6.0 resulting in the following separation.

Table 4. Tritium Attenuator, First Cycle

| | <u>Charge</u> | <u>A Rundown Tank</u> | <u>A Bottoms</u> | <u>B Bottoms</u> | <u>B Overhead</u> |
|-----------------------------|---------------|-------------------------------|----------------------|----------------------|-----------------------|
| Total Quantity, mols | 748 | 182 | 100 | 27.5 | 42.5 |
| gal | 1600 | | | | |
| Heavy Water Content, mol % | 87.5 | 99.0 | 99.0 | 92.0 | 50.0 |
| Tritium Content, $\mu c/ml$ | 1000 | 1450 | 1450 | 845 | 240 |

Preliminary calculations (see DPSP 55-25-8) had indicated that the tritium concentration of the moderator which was to be shipped back to the 400 Area for reconcentration, should not be greater than 200 $\mu c/ml$. It was therefore decided: (1) not to withdraw any overheads at this time, (2) to replace the moderator in the rundown tank with fresh material (87.5 mol % D_2O and 1000 $\mu c/ml$ of tritium), (3) to operate the attenuator at total reflux until a satisfactory concentration gradient was achieved, and (4) to calculate the tritium and light water concentrations at the top and bottom of the attenuator at these conditions.

Results, Second Cycle. The light water and tritium concentration gradients shown in table 5 for this second cycle were determined by material balances in the same manner as described above for the first cycle, assuming the same batch size and cycle time. The overall column attenuation was 8.0.

Table 5. Tritium Attenuator, Second Cycle

| | Moderator Charge | | | Final Conditions | | | | |
|-----------------------------------|------------------|---------|---------|------------------|---------|--------|-----------|--------|
| | Removed | Charged | Total | A | | | | |
| | From | to | Charge | Bottoms | A | B | A | B |
| First | Second | Second | and | | | | | |
| Cycle | Cycle | Cycle | Rundown | Column | Bottoms | Column | Overheads | |
| | | | Tank | | | | | |
| Total Quantity, mols | 182 | 182 | 748 | 282 | 196 | 27.5 | 200 | 42.5 |
| Heavy Water Content, mol % | 99.0 | 87.5 | 84.7 | 98.8 | - | 91.0 | - | 35.0 |
| Tritium Content, $\mu\text{c/ml}$ | 1450 | 1000 | 890 | 1310 | - | 730 | - | 164 |
| Separation Factor, α | - | - | - | 1.0085 | 1.011 | 1.0125 | 1.028 | 1.0405 |
| Column Attenuation | - | - | - | - | 1.80 | - | 4.45 | - |

The overheads product from the second cycle of the attenuator satisfied the desired goal, that the tritium content of the moderator, which was to be reconcentrated in the 400 Area, should be less than 200 $\mu\text{c/ml}$. Thus, after the first two startup cycles of attenuator operation, the desired end conditions had been achieved and normal operation could be started.

Normal Operation. Normal operation of the attenuator was assumed to consist of a series of batch distillations. At the start of each batch, 182 mols, (400 gallons) of degraded moderator (75 to 85 mol % D_2O) will be charged to the previously emptied rundown tank. The attenuator will then be operated at total reflux for about 7 to 9 days until the entire charge (748 mols) has come to equilibrium. Overheads product (36 mols of 25 to 35 mols % D_2O) and bottoms product (146 mols of 98 to 99 mol % D_2O) will then be removed and the attenuator will be ready for the next charge.

Light Water Production Capacity

The amount of light water that can not only be removed from the 100 Area reactor system (in the form of dilute moderator), but also satisfactorily reconcentrated depends on: (1) capacity of the 400 Area for reconcentrating moderator containing tritium, (2) H_2O production capacity of the 100 Area normal distillation units, and (3) H_2O production capacity of the tritium attenuator.

In the discussion of these factors, it is assumed that: (1) the reactor moderator tritium concentration is 15 times larger than that in the moderator sent to the 400 Area (ie, an attenuation of 2.5 in the normal distillation system and 6.0 in the attenuator, or an overall attenuation of 15.0), and (2) the isotopic purity of the moderator sent to the 400 Area is constant at 30 mol % D_2O .

Moderator Reconcentration Capacity - 400 Area. The capacity of the 400 Area for reconcentrating degraded moderator is limited by the tritium content of that moderator since the tritium content of the heavy water produced in the 400 Area electrolytic plant is specified to be below 5 $\mu\text{c}/\text{ml}$. (A trial specification according to DPSTS 421-1.03 is "No more than 11 microcuries per pound of D_2 produced by the 400 Area Deuterium Gas Plant"; this is equivalent to 5.6 $\mu\text{c}/\text{ml}$ of D_2O .) Degraded moderator from the 100 Areas is upgraded in the 400 Area distillation and electrolytic plants, in which 70,000 pounds per month of D_2O from river water is simultaneously being concentrated.

The amount of 100 Area degraded moderator which can be upgraded by the 400 Area may be determined in the following manner.

Assuming steady state operation with all tritium entering 400 Area via 100 Area degraded moderator leaving in the 400 Area product moderator.

$$\text{Input} = \text{Output} \quad (3)$$

$$\text{NP} \times \text{Zero Activity} + \text{RA} = (\text{NP} + \text{RP}) 5 \mu\text{c}/\text{ml} \quad (4)$$

where

NP = normal production from the 400 Area,
70,000 pounds per month

R = permissible rework rate of degraded
moderator from 100 Areas, gross pounds
per month

P = average isotopic purity of degraded
moderator, weight fraction D_2O

A = average activity of 100 Area degraded
moderator, $\mu\text{c}/\text{ml}$

This becomes

$$R = \frac{350,000}{A} \text{ lb/mo} \times \text{Ac/ml} = \frac{144 \text{ c/mo}}{A} \quad (5)$$

since the product $\text{RP} \ll 70,000$.

This equation can be rewritten as:

$$S = \frac{3,550,000}{B} \text{ lb/mo} \times \mu\text{c/ml} \quad (6)$$

where

S = maximum weight of light water (shipped to 400 Area in the form of 30 mol % D₂O) that the 400 Area can rework in a month

B = average reactor tritium concentration.

Equation 6 is shown graphically in figure 2 as the 400 Area Maximum Capacity Curve. The ordinate represents the 400 Area reconcentrating capacity for 30 mol % moderator in pounds of light water, while the abscissa represents: (1) the tritium content of the reactor moderator before distillation or attenuation, and (2) the time when the average tritium content of the moderator in all areas will have the indicated value.

Distillation Systems. The capacity of the distillation system for removing light water from the reactor moderator is dependent on the isotopic purity of the moderator, and on the draw-off rate from the stills. A series of Reactor Isotopic Purity curves are shown in figure 2, together with Draw-off Rate curves for 1.5 and 4.0 lb/hr draw-off. The ordinate of the intersection of these curves for the desired isotopic purity and draw-off is the instantaneous monthly average amount of light water that will be removed from the moderator in all the four areas in which the distillation columns are assumed to be operating. (The system in the fifth area is assumed to be operating as a tritium attenuator.)

If the amount of light water removed from a system is greater than the inleakage experienced at that time, the reactor isotopic purity will increase. The maximum equilibrium purity which can be obtained at any light water production rate (or inleakage at equilibrium) is the value (mol % D₂O) of the Reactor Isotopic Purity curve which crosses the 400 Area Maximum Capacity Curve at the equilibrium light water production rate.

The 100 Area production of degraded moderator will exceed the attenuator capacity if the intersection of the Reactor Isotopic Purity curve and Draw-off Rate curve is to the right of the 400 Area Maximum Capacity curve. Therefore, operation in this area is undesirable.

Tritium Attenuator. The maximum attenuator light water production capacity depends only on the isotopic purity of the feed if a constant cycle time (10 days), charge size (500 gallons), overhead purity (30 mol % D₂O), and bottoms purity (98.5 mol % D₂O) are assumed. The Attenuator Capacity is therefore given in figure 2 as a function of the horizontal Attenuator Feed lines. These lines

are not affected by tritium concentration, since the tritium attenuation depends only on the isotopic purity of the moderator in the top and bottom of the attenuator.

The isotopic purity of the overheads for a normal distillation system can be found in figure 2 by drawing a line from the origin through the intersection of the pertinent Reactor Isotopic Purity curve and the Draw-off Rate curve, and extending this line until it intersects the 400 Area Maximum Capacity curve. The Attenuator Feed Composition at this point is also the average isotopic purity of the normal distillation overheads for the assumed conditions.

Equipment

Each existing 100 Area distillation system consists of two 90-sieve-plate distillation columns operated in series and designed for continuous operation (see figure 3). Moderator which has been processed through the purification deionizer and filters is fed into the base of A column and vaporized. After passing up the column, the moderator is totally condensed, flows into B reboiler, and after vaporization and mixing with the B column reflux is pumped back to A column for use as A column reflux. A small amount of B column condensate (normally between 0.5 and 4 lb/hr) is drawn off as overhead product, and the remaining condensate is pumped back to the top of B column reflux.

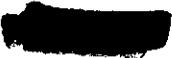
Instrumentation is provided to control the vacuum at each condenser (by exhausting the noncondensable vapors with a vacuum pump), the steam flow rate to each reboiler, the process water level in each reboiler and condenser, and the process water flow rate to the A reboiler.

Piping has been incorporated in the L, K, C distillation systems to provide a means of circulating the A column bottom moderator through the bottoms cooler, the flow measuring instruments, and the proposed specific gravity measuring instrument. The circulation of moderator through this equipment is necessary prior to connecting the distillation system to the reactor moderator system to provide a convenient means of determining the isotopic purity of the moderator and of observing possible instrument difficulties.

The above described moderator circulation system in L, K and C Areas includes the A rundown tank. The A bottom holdup, which is too small (100 gallons) for efficient batch operation, may easily be increased by using the A rundown tank as a reservoir and charging it with additional moderator.

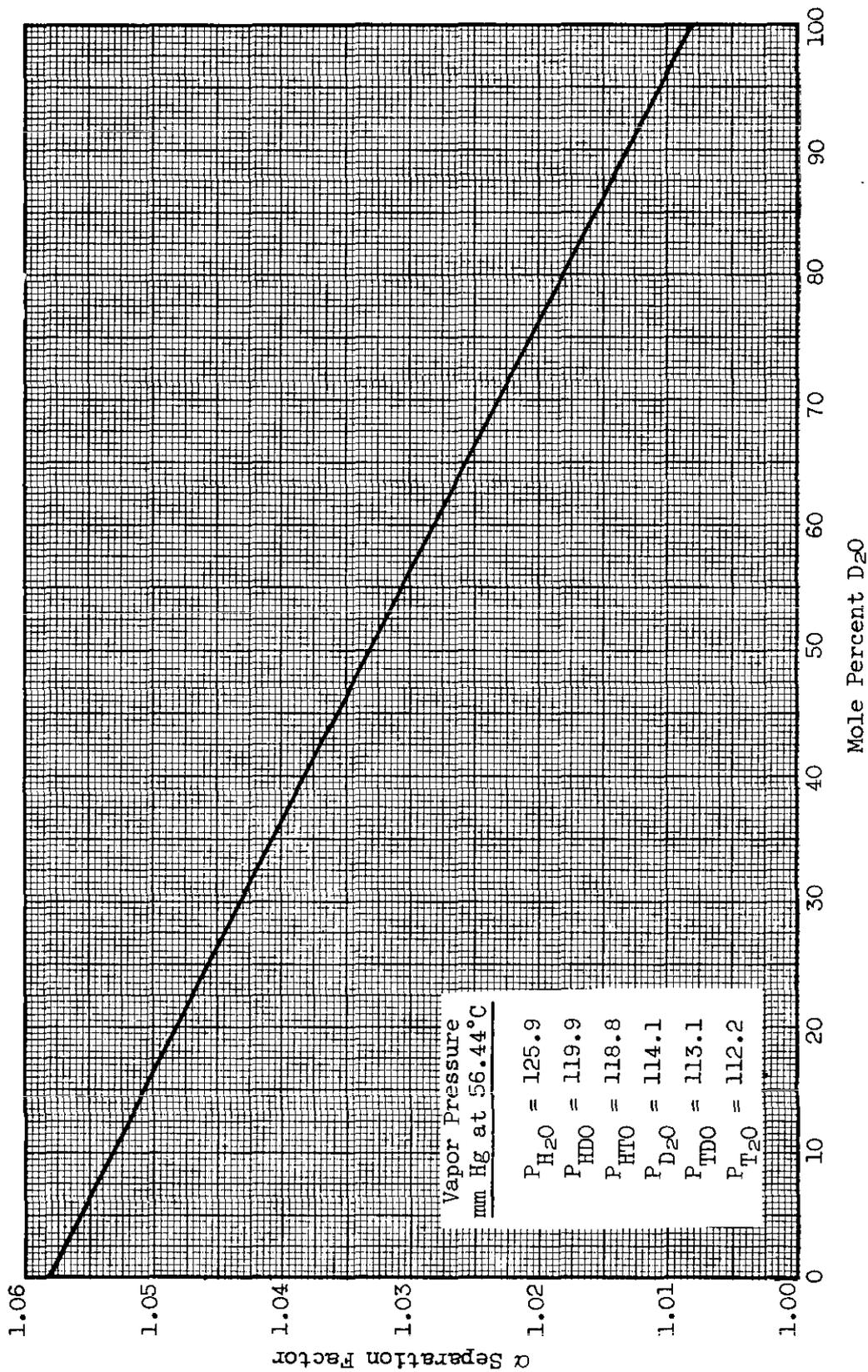
Conclusions

1. The use of one 100 Area distillation system as a tritium attenuator for processing the distillation overheads product from the other four 100 Areas has been calculated to be technically feasible by a theoretical evaluation. This evaluation was based on an estimated of the separation factor of TDO and THO versus HDO, D₂O and H₂O systems (see figure 1) based on the available tritium oxide-heavy water vapor pressure information which was very limited in scope.
2. When the isotopic purity of the reactor moderator is 99.80 mol % D₂O, the mass flow rate of tritium to the 400 Area can be reduced by a factor of 30, since the overheads product from the attenuator will have a tritium content one-sixth of that of the feed, and a weight one-fifth that of the feed.
3. This 30 fold reduction in tritium mass flow will be sufficient to enable the 400 Area to upgrade the isotopic purity of the moderator produced from the distillation columns in the other 4 areas without exceeding the 400 Area tritium specification under the following conditions:
 - a. For 9.5 years at a 4 lb/hr draw-off in each of 4 areas with an average reactor moderator concentration of 99.80 mol % D₂O. See figure 2.
 - b. Indefinitely at any moderator purity and even at the maximum tritium content expected in the moderator at 600 mw (1500 mw), if the draw-off from all stills does not exceed 2.5 (1.0) pounds per hour.
4. Use of the distillation system in one area as a tritium attenuator assumes that there would always be one area where the light water inleakage rate was negligible and did not require the use of a distillation system to increase the isotopic purity of the moderator. Performance of the 100 Area reactor system for the last 18 months indicates that such an area will be available.
5. A summary of the results of this theoretical evaluation is shown in graphical form in figure 2 which presents the following relationships:
 - a. Between tritium content of the reactor moderator and the maximum amount of H₂O in the moderator that can be upgraded in the 400 Area without exceeding 400 Area tritium specification.

- 
- b. Between the draw-off rate of the 4 distillation systems (operated to improve the isotopic purity of the reactor moderator) at a given isotopic purity of the reactor moderator, the production rate and overheads isotopic purity of these distillation systems, and the maximum capacity of the attenuator when operated on the overheads product from those distillation systems.
 6. The speed of the separation of the degraded water has been calculated to be about 7 to 9 days. This time factor will determine the maximum handling rate of the attenuator, and can be best established experimentally.
 7. An experimental evaluation of this proposed tritium attenuator is desirable since the present theoretical evaluation is based on available tritium oxide vapor pressure information which is incomplete, limited in scope, and of unknown accuracy.
- 

FiguresFigure

| | | |
|---|---|----|
| 1 | Simplified Tritium Vapor Pressure Curve for 3-Component System | 18 |
| 2 | Light Water Production Curves | 19 |
| 3 | 100 Area Distillation System | 20 |
| 4 | Attenuator Equilibrium Curve | 21 |



Vapor Pressure
mm Hg at 56.44°C

| | |
|------------|---------|
| P_{H_2O} | = 125.9 |
| P_{HDO} | = 119.9 |
| P_{HTO} | = 118.8 |
| P_{D_2O} | = 114.1 |
| P_{TDO} | = 113.1 |
| P_{T_2O} | = 112.2 |

Figure 1. Simplified Tritium Vapor Pressure Curve for 3-Component System

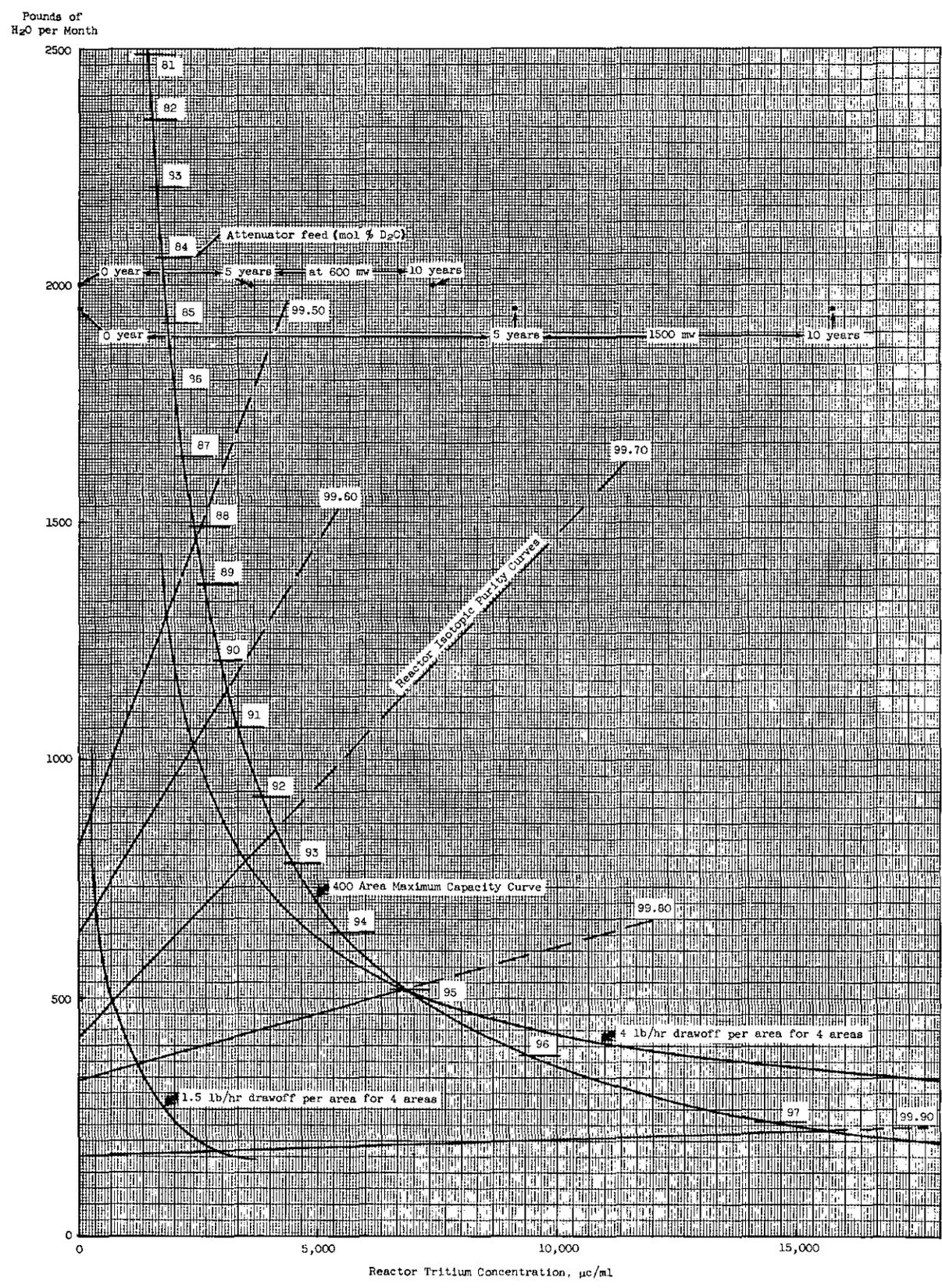


Figure 2. Light Water Production Curves

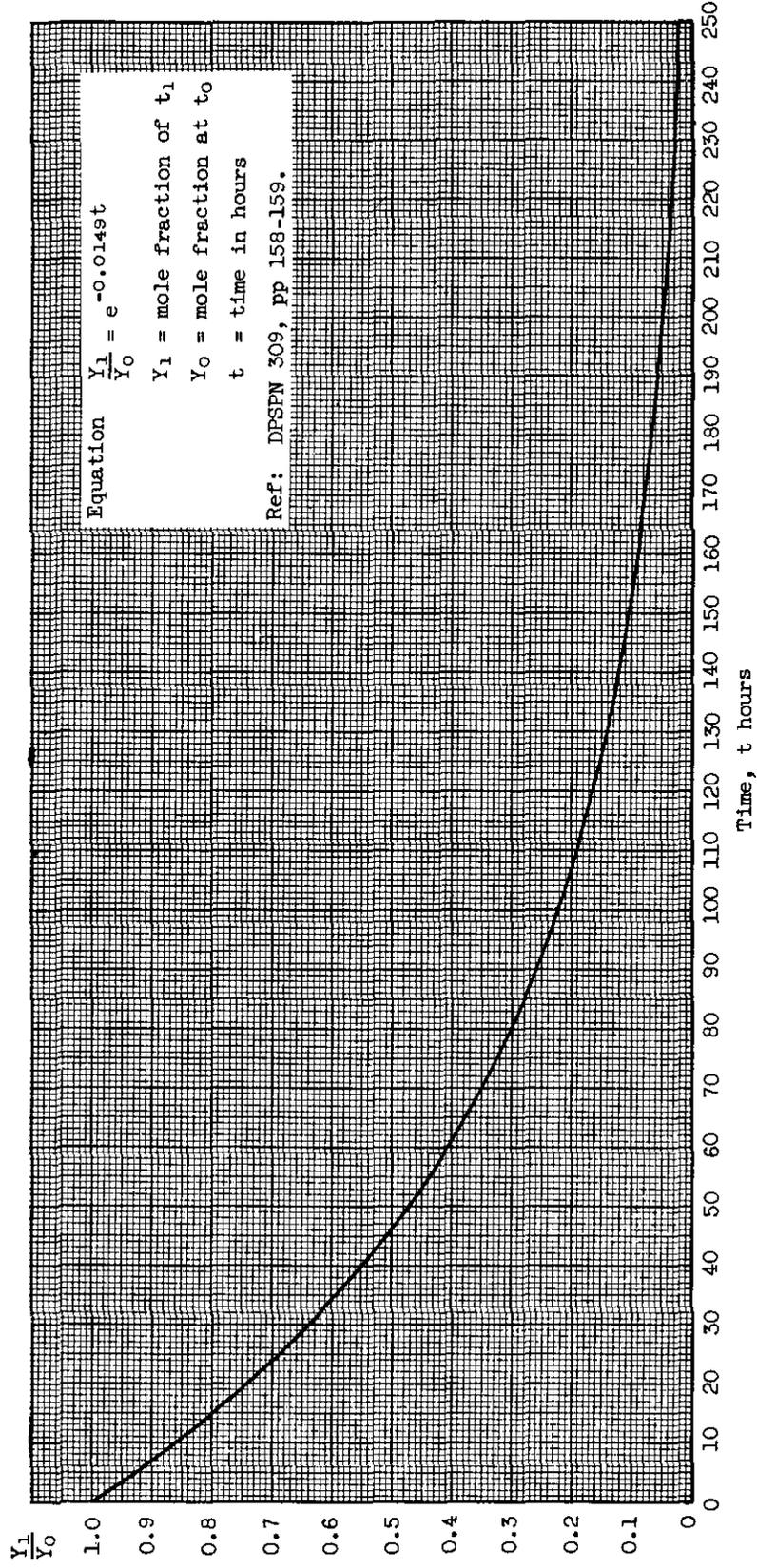


Figure 4. Attenuator Equilibrium Curve

References

Hartshorn, W. R., Memoranda to A. A. Johnson, "Isotopic Distillation, TA 1-119", Report No. 1, August 11, 1954; Report No. 2, August 20, 1954; Report No. 3, September 15, 1954; and Report No. 4, September 23, 1954.

Ingham, R. R., Memorandum to A. A. Johnson, "Isotopic Distillation, TA 1-119", Report No. 5, December 13, 1954; Report No. 6, January 28, 1955; and Report No. 7, March 14, 1955.

Thayer, V. R., and J. P. Hood, Technical Standard, "400 Area - E Process", DPSTS 421-1.03, Rev 2, July 20, 1954.

Wittman, N. E., Notebook Reference on Tritium Attenuation, DPSPN-309, pp 140 to to 181, July 11, 1955.

~~SECRET~~

UNCLASSIFIED

UNCLASSIFIED

~~SECRET~~

AB6530-1018-93-001

N60-03-07

10560