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THERMAL DIFFUSION DEVELOPMENT DESIGN OF MAIN EQUIPMENT

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by

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DESIGN OF MAIN EQUIPMENT

INTRODUCTION

This paper presents a scope design of two coaxial type thermal diffusion columns. These experimental columns are proposed to meet the requirements of the research and development program given in Part II of this report series. They would rearrange the isotopes of xenon from the Case II product of the Purex Gas Separations Facility to yield a product with a composite neutron absorption cross section of less than one barn. The theoretical basis for the design is given in Part I. The auxiliary equipment necessary for the operation and control of the columns is described in Part IV.

Major components of the columns and their functions are described in this part. The proposals for the materials of construction and the heating systems are not conclusive. Several possibilities for these requirements, however, are included.

SUMMARY

The design of two experimental thermal diffusion columns is given to meet the needs of a proposed research and development program for rearranging the isotopes of xenon. The proposed columns are six meters in length and have a maximum diameter of about five inches. They could be built at Hanford for an estimated cost of \$10,000.

DISCUSSION

Theoretical calculations show that a coaxial thermal diffusion column as short as 5.4 meters can rearrange the isotopes of xenon as required in the proposed Purex Gas Separations Facility. (See Part I.) It is noted, however, that the operating pressure must be 0.4 atmosphere if a column as short as this is to be used. This column with an inner tube having outside diameter of 3.41 cm and an outer tube having inside diameter of 4.68 cm should generate the desired 1 gm/day of product. A length of six meters is recommended for experimental columns. The additional 0.6 meter provides a margin of "safety" in output and greater experimental flexibility.

The second column is identical in design with the first except for a factor of three in the mean circumference of the gas chamber. This larger column would provide a means for determining whether the production rate of these columns can be increased by enlarging the cross section of the gas chamber. If such a determination is positive the construction of columns of plant scale would be simplified. To obtain this effect, however, appears to be contrary to the basic theory of thermal diffusion but some evidence in its favor has been given. (See Section II.)

The dimensions of the proposed experimental columns are:

	<u>Column I</u>		<u>Column II</u>	
	<u>Centimeters</u>	<u>Inches</u>	<u>Centimeters</u>	<u>Inches</u>
Length	600	236.4	600	236.4
Inner Tube OD	3.41	1.34	11.49	4.52
Outer Tube ID	4.68	1.84	12.76	5.02

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HW-60333 Part III of IV
Page 3

Column Operation. A separating column is usually required to produce, with greatest economy of materials and energy, a product gas mixture enriched in one, or more, of its components. For this purpose, a column may be used in one of two ways. In discontinuous operation, the mixture is allowed to separate for a time to approach equilibrium. Thereafter, a fixed quantity of gas is drawn off intermittently. In continuous operation gas is removed at a low constant rate so that maximum separation cannot be attained. The latter type operation is, of course, a compromise; but it appears to be more practical for a large scale operation.

Apparatus. A coaxial tube type column is a theoretically simple device. The stringent requirements of dimensional precision, i.e., straightness, 0.0010-inch per foot; ovality, 1 percent of nominal diameter, indicate that the fabrication will be difficult.

The main equipment shown in Fig. 1 comprises the gas chamber, made up of the concentric inner and outer tubes, having a heater to give the outer surface of the inner tube a non-longitudinally variant temperature in the range of 750 C to 900 C; a manifold on the gas feed inlet to the column as a means for changing the point of entry of the gas to the column; and a cooling system to provide the inner surface of the outer tube with a uniform temperature of about 27 C. A valving arrangement is incorporated in the two proposed columns allowing their effective lengths to be changed and, thus, eliminating the need for fabricating additional equipment to study the length parameter. When the feed is introduced below the top of the column, the part of the column above the feed point is the scrubbing section and the part below it is the enriching section. (See flowsheet Fig. 2.)

The proposed columns consist of upper and lower sub-assembly which may be separated from one another by the removal of fastening devices on the top plate of the column. (See Fig. 3.) This arrangement simplifies fabrication and maintenance.

Upper Sub-Assembly. The upper sub-assembly is made up of the heater, centering tube, inner tube, upper plate, and lower guide plate. These parts are shown in Fig. 3.

Heater. The heater should afford a dependable, economical means of heating the outer surface of the inner tube to any specified temperature in the range of 750 to 900 C, and maintaining it for an indefinite period. Three methods of heating merit consideration.

- (1) An electrical resistance element(s) contained within a centering tube. The element is supported and centered by rings of ceramic material (e.g., lavite) placed at 0.75 meter intervals throughout the centering tube. The element could be of silicon carbide (e.g., Kanthal) or a special Nichrome, or similar, alloy. The transfer of heat from heater to inner tube is mainly through radiation. The calculated heating requirements of the columns are:

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	<u>Column I</u>	<u>Column II</u>
Radiation to cold wall (KW)	11.8	40.0
Conduction of Xenon gas (KW)	0.24	0.73

This technique of heating has proved successful in other somewhat similar circumstances* but at a very much lower temperature range. It is not known whether such elements can provide sustained uniform heating without frequent burn out.

- (2) The use of the inner tube as a resistor in an electric circuit. This method eliminates the need of transferring energy from a heater to the tube surface. It would simplify the fabrication of the upper sub-assembly. Questions yet unanswered are: (a) Is the use of specialized electrical circuits on a large scale practical? (b) Can a uniform temperature be achieved over the full length of the tube surface?
- (3) The use of a molten material heated by electrical immersion elements. This method transfers heat by conduction, rather than by radiation. As a consequence, the heating elements will operate at near wall temperatures and may be less subject to burn out than in method (1). Any longitudinal non-uniformity in temperature introduced by the heating element would probably be eliminated by liquid convection. A disadvantage derives from the corrosive and erosive nature (to metals) of the molten material. A special metal alloy, if an adequate one exists, would probably be required to contain the melt at the high operating temperatures. Charging and discharging the melt from the heater may introduce a design problem.

Centering Tube. The centering tube is less than one inch in diameter and composed of the same material as the inner tube. It houses the heater (type No. 1 above). It is concentric to the inner tube and welded to the bottom guide. The centering tube moves freely through a center hole in the top plate and serves to keep the inner tube vertical and concentric with the outer tube.

Inner Tube. The inner tube forms the inside wall of the gas chamber and provides it with a uniformly hot surface. If the heater type sub-assembly is used, type 310 stainless steel is a good choice for its material. Austenitic steel would probably be non-flaking in the xenon gas atmosphere and should maintain its tensile and compressive strength at the high temperatures. Its polished surface would be expected to be retained, which is necessary to give low emissivity and a consequent low radiant heat loss. If the direct or melt method of heating is used, a metal of requisite electrical or corrosion-resistant properties may be used. The inner tube is welded to the top plate and the bottom guide plate to assure concentricity with the centering tube. To assure precise spacing in the gas chamber, spacer cylinders of lavite or similar material are used (see Fig. 4). These are mounted on three small

*Watson, W. W., et.al., Review of Scien. Instruments 20 (1949). and Nier, A. O., Phys. Rev. 57 (1940).

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steel pins welded to the outer surface of the tube at equal intervals along the periphery. This arrangement occurs every 1.5 m. along the column length. The pins are not long enough to touch the outer tube and, thus, avoid causing hot spots on the cold surface. The cylinders are about 1/4 inch in diameter.

Upper Plate. The upper plate is a thin disk composed of the same material as the inner tube. A center hole provides a guide for the centering tube, to permit movement resulting from a temperature difference between the centering and inner tubes. The inner tube is welded to the upper plate. The latter is provided with a gas seal and a means of fastening the upper and lower sub-assemblies together.

Lower Guide Plate. The lower guide plate keeps the inner tube concentric with the centering tube. It also keeps the upper and lower sub-assemblies concentric and vertical. A vertical member slides through a cylindrical opening in the bottom plate. It is penetrated by the heating element which may be used as a temperature indicator to supplement the thermocouples. (See bottom plate description below.)

Lower Sub-Assembly. The lower sub-assembly consists of the outer tube, water jacket, gas manifold, and bottom plate.

Outer Tube. The outer tube forms the outer wall of the gas chamber. It must, therefore, provide a uniform low temperature on its inner surface. Its outer wall forms the inner surface of the water jacket. Its material should, therefore, be a good conductor of heat. It should be resistant to water corrosion. A low emissivity is desirable for conserving the radiant energy from the inner tube. Brass appears to be the best choice for this tube. Copper and aluminum also may be considered. The outer tube is brazed at its lower end to the bottom plate. Its upper end provides a flange for fastening the upper plate. The arrangement is made gas-tight by an O-ring.

Water Jacket. The water jacket provides a path for the cooling water, which maintains the inner surface of the outer tube close to the ambient temperature of the cooling water. It may be provided with several entry and exit lines to give a shorter residence time to the cooling water thereby minimizing the temperature rise. The water jacket should be of the same material as that of the outer tube.

Gas Manifold. A gas manifold introduces the gas uniformly into the gas chamber around the outer tube at both the upper and lower ends of the column. The perforations in the outer tube should be no larger than 1 mm. The inner surface of the tube should, of course, be left as smooth as possible. The valves are placed in the 1/4-inch copper tube manifold to permit the entry of gas at any one of the four levels spaced at 0.5 meter at the top of the column.

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Bottom Plate. The bottom plate is a flange of the same material as the outer tube. Its cylindrical opening acts as a guide for the lower guide plate, which moves through it as the inner tube changes its length with temperature change. A transparent housing is fused to the bottom plate. It provides a gas-tight seal for the gas chamber. It may be calibrated against the movement of the heating element extension for measuring the temperature of the inner tube.

EQUIPMENT PROCUREMENT AND COST

Manpower and facilities in the 300 Area are competent and available to fabricate the projected equipment. The non-standard inner and outer tubing for the gas chambers can be supplied within ten weeks*. No other special items are required. It is noted that the use of a single material throughout the main equipment, e.g., type-310 stainless steel, instead of two different materials - as brass and stainless steel - as suggested, may facilitate the ease of fabrication. The estimated unit cost of only one thermal diffusion column is:

Labor (350 hr. at \$7/hr.)	\$2,450
Material	1,000
Contingency	<u>1,550</u>
Total Unit Cost	\$5,000
Cost for two columns	\$10,000

*Quotation letter Western Pneumatic Tube Co. to General Electric Co.;
March 27, 1959.

THERMAL DIFFUSION
COLUMN CROSS-SECTION

FIG. 1

PRESSURE RANGE
 1.0 TO 0.1 ATMOS ABS.
 859°C TO 750°C FOR TC.

THERMAL DIFFUSION APPARATUS
EQUIPMENT FLOW DIAGRAM

FIG. 2

THERMAL DIFFUSION COLUMN
UPPER & LOWER SUB-ASSY.

FIG. 3

GAS CHAMBER SPACER ARRANGEMENT
SECTION (AT 1.5 m INTERVALS)

FIG. 4

THERMAL DIFFUSION COLUMN
GAS MANIFOLD & VALVING ARRANGMENT

FIG. 5

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