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NEUTRON POISONED
ION EXCHANGE EQUIPMENT

by

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U.S. ATOMIC ENERGY COMMISSION
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A B S T R A C T

A neutron poisoned ion exchange column was built for use in the purification of plutonium nitrate solutions. The column was poisoned by stainless steel grids containing boron-10. The column performed satisfactorily but was found to be uneconomical.

An improved design utilizing boron carbide tubes instead of grids was developed. This design would overcome most of the difficulties of the grid column but would offer little economic advantage over non-poisoned ion exchange equipment.

S U M M A R Y

A 4-foot high, 18-in. diameter ion exchange column was built for use in plutonium purification. The column was made safe by the insertion of boron-10 stainless steel grids in to the resin bed. A control program was developed to assure the continued integrity of the grid material.

The column was run through 14 complete cycles to establish operating characteristics. The ion exchange in the grid column accomplished good decontamination of the plutonium nitrate feed material. Major difficulty was encountered in loading the column to a satisfactory level without breakthrough. This problem was solved to the extent that the column could be operated in a satisfactory manner. However, a portion of the problem appears to be in the column design.

A design for a tube poisoned column was developed. The design would eliminate corrosion of the neutron poison and would be cheaper to fabricate than the grid design. However, the cost of developing the tubular array column would have been quite high.

An economic analysis of poisoned ion exchange showed there is little economic advantage from large, poisoned equipment. The advantage was not sufficient to justify completing the necessary development work. Therefore, the grid poisoned column was scrapped and work on the tube poisoned column discontinued. In the future, ion exchange at Rocky Flats will be carried out in critical-safe, 6-in. diameter equipment which is designed to be operated automatically.

INTRODUCTION

The diameter of plutonium ion exchange equipment used at Rocky Flats is limited by nuclear safety considerations to 6 inches. This limitation restricts the volume of resin which a column can hold and therefore limits the processing capacity of the column.

In 1960 work was begun at Rocky Flats Plant on a design which makes it possible to increase the size of ion exchangers by intermixing a neutron poison with the resin. A neutron poison is a material which has the ability to capture thermal neutrons, thus preventing neutron multiplication. The quantity of fissile material required for a critical mass increases with the concentration of the poison.

The poison proposed for use in ion exchange equipment was boron-10. The boron-10 has one of the highest neutron capture cross sections of all isotopes. Preliminary calculations indicated that the ion exchange column diameter could be expanded to 18 in. by the use of such a poison.

The first design considered involved the use of boron-stainless steel plate grids. A production scale grid poisoned column was built and tested for nuclear safety in 1962. Development of a more advanced poison design was also carried out. This design utilized boron carbide tubes instead of grids. Design and operation of the grid column and design of the tube column are described in this report.

DISCUSSION

DESCRIPTION AND OPERATION OF THE GRID COLUMN

Stainless steel (Type-304L) ingots containing approximately one weight percent boron were fabricated to order by the Universal-Cyclops Steel Company. The boron-10 isotope made up about 90 percent of the total boron. This material was rolled to 0.165-in. plate and fabricated into an egg-crate shaped gridwork. This gridwork consisted of a set of vertical plates spaced 2 in. apart with a second set of plates perpendicular to and welded to the first. The grids extended from the top to the bottom of each segment of the column.

Figure 1 shows a plan view of one segment of the grid poisoned column. Each segment was 18-in. diameter and 12-in. high. Grids divided the plan view of each segment into 2-in. by 2-in. square void spaces. The nine squares at the center of the column were plugged

with polyethylene blocks for nuclear safety purposes. The remaining squares were filled with Dowex-1 anion exchange resin. The resin was supported in the segment by a 100-mesh screen which was supported by an 18-gage expanded metal screen.

Figure 1. SEGMENT OF THE GRID COLUMN

Figure 2 shows a flow diagram of the grid column system. Feed, elutriant, wash and reconditioning liquids were introduced into the system by way of a hot water heater which raised the temperature to $50^{\circ} \pm 5^{\circ}\text{C}$. The liquid was then filtered through a porous stainless steel filter element which removed essentially all suspended solids greater than 20 microns. The rate of flow was then measured by use of a 0 to 10 liters per minute rotameter.

The grid column consisted of four of the segment-types shown in Figure 1. The process liquid could be fed either to the top or bottom of the column. The material leaving the column passed through an alpha radiation detection cell which sensed the activity of the flowing stream. Finally, the material passed to a storage tank.

Each cycle of operation of the grid column consisted of the following steps:

- a. Loading — Adsorption of plutonium hexanitrate anions from solution in $7N \text{ HNO}_3$. Flow direction: bottom to top.

Figure 2. FLOW DIAGRAM OF THE GRID COLUMN SYSTEM

- b. Washing — Removal of non-adsorbed material from the loaded resin by flushing with $7N$ HNO_3 . Flow direction: bottom to top.
- c. Elution — Desorption of purified plutonium from resin into solution in $0.35N$ HNO_3 . Flow Direction: top to bottom.
- d. Reconditioning — Filling of column with $7N$ HNO_3 in preparation for next cycle. Flow direction: top to bottom.

The ion exchange resin was charged to each column segment as a water slurry. The water was drawn through the bottom support screen to a storage tank, thus packing the resin in the grid squares. When the resin became sufficiently degraded to be no longer usable, it was totally eluted and removed from the column. The removal was accomplished by mechanically lifting the segments, one at a time, to a vacant portion of the glovebox and dumping the resin into large plastic bags. The resin was then sampled and discarded.

Associated with the system were six storage tanks. One tank of 280 liters capacity was used for eluate. Two tanks of 500 liters capacity were used for effluent storage. Three tanks of 420 liters capacity were used for feed storage. The tanks were filled with 1-1/2 in. diameter glass Raschig rings containing 12 percent B_2O_3 (unenriched). The rings served to poison the tanks.

The column was built to be operated in a semiautomatic manner. The alpha cells were the key to the automatic feature. The alpha radiation of the liquid leaving the column was read out on a logarithmic ratemeter and recorded on a strip chart recorder. A programmer provided the following capabilities:

- To switch the cycle from load to wash when the alpha radiation indicated that breakthrough had occurred.
- To switch from wash to elution on signal from a timer. The timer was set by the operator to give a wash of the desired volume.
- To switch from elution to reconditioning when the alpha count indicated that most of the plutonium was eluted.
- To switch from reconditioning to loading on signal from a timer.

An interlock panel provided a safety shutdown feature. The system was shutdown if the feed pump ran dry, if a storage tank overfilled, if the column feed temperature was too high, or if there was acid in the hot-water heating system. A pH cell was placed in the hot-water system to detect the presence of nitric acid which would indicate a radioactive material leak.

Figure 3 shows a photograph of the grid column glovebox prior to installation of the windows and gloves. The alpha cells and piping may be seen at the right hand side

Figure 3. GRID COLUMN AND AUXILIARY EQUIPMENT. Part (A) Resin Removal Area, (B) Storage Tank, (C) Grid Column, (D) Alpha Cells, and (E) Storage Tank.

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of the box. The grid column is immediately to the left of the cells. The resin removal area is at the left side of the photograph. Storage tanks for the process liquids are seen in the background.

NUCLEAR SAFETY

Early calculations by the Nuclear Safety Group indicated that the gridwork described in this report (Description and Operation section) contained sufficient boron-10 to make the column safe. It was decided to experimentally check the validity of these calculations.

A column was built which contained grids of only 0.090-in. thickness. Thin grids were tested in order to allow for corrosion of the 0.165-in. grids actually used. Large quantities of plutonium peroxide cake were dissolved in nitric acid, yielding solution concentrations of about 300 g/l in plutonium and 2.6N to 9.0N in nitric acid. The

solution was drawn into the test column by vacuum, and neutron fluxes were determined for various volumes of liquid in the column. From these data, the neutron multiplication factors (M) were calculated by taking the ratio of neutron flux at any volume to the background flux.

Results of three of the more important tests are reported in Figure 4. The inverse of the neutron multiplication factor is plotted against volume of liquid in the column. The solid portions of the curves connect experimentally obtained points. The dashed curves show the expected extrapolation beyond the data. Intersections of the curves with the abscissa are the points at which the system was expected to be critical. Two vertical lines are drawn on Figure 4 at 187 and 136 liters/column volume. The larger volume corresponds to the grid column as-built. The smaller volume corresponds to the column with the nine center grids plugged by polyethylene blocks. The purpose for the grid plugging is described as follows:

Figure 4. NEUTRON MULTIPLICATION TEST CURVES

Two of the three tests were run with the grid column as-built and one with the nine center grids plugged with polyethylene blocks. The two runs made with no blocks and approximately the same plutonium concentration show the effect which nitrate ion has on critical mass. Nitrate ion is seen to be an effective neutron poison. The curve for 9N nitric acid is subcritical to a point above 1000 liters. The 3.1N nitric acid curve, however, is critical at 247 liters which is uncomfortably close to the actual volume of the column, 187 liters. In operation of the column, elution takes place with 0.35N nitric acid. This normality would be expected to yield an even lower critical mass. For this reason the Nuclear Safety Group requested that the center grids be plugged.

The test which was run on the blocked column showed that the critical volume was again over 1000 liters even with the low nitrate concentration. The grid column was henceforth operated with nine blocked grids.

The design of the grid column was quite conservative. In practice, plutonium concentrations of 300 g/l are never approached. This, coupled with the low neutron multi-

plication factors shown in Figure 4, proves that no nuclear hazard existed, provided that the boron neutron poison remained intact.

Because the grids were in contact with nitric acid, a control program was instituted to insure that the grids retained their integrity. This program is described in detail elsewhere.¹ It was found that the thickness of the grids was not a good indication of the boron remaining in the grids. The quantities of boron lost from the grids by leaching and by thickness reduction are shown graphically in Figure 5. The removal of boron from the grids is seen to be mostly a result of selective leaching of boron from the base material.

At the rate that the boron was lost from the grids, it was calculated that the gridwork would have lasted approximately 4 years before being reduced in thickness to 0.090 inch.

¹Irwin, D. S., *Corrosion of Boron-Stainless Steel*, The Dow Chemical Company, Rocky Flats Division, March 29, 1966, RFP-781.

Figure 5. LOSS OF BORON FROM BORON-STAINLESS STEEL COUPONS

PERFORMANCE OF THE GRID COLUMN

PRODUCT QUALITY

The separation of cationic impurities from plutonium by use of the grid column was satisfactory. See Table I for the average impurity levels determined for the various process streams by emission spectroscopy. Analyses are presented for the feed, the wash stream immediately prior to elution, the eluate stream and the reconditioning stream at the end of the cycle. Only the major metallic impurities are listed in Table I. Satisfactory decontamination of the plutonium stream was achieved in every case. These results were obtained using a wash amounting to only 1.5 column volumes. Better decontamination could undoubtedly have been obtained if a more thorough wash had been employed.

The decontamination factors for anions were not determined.

THROUGHPUT CAPACITY

There were three major problems encountered in operation of the grid column. Each problem contributed to inefficiency of operation and, therefore, low throughput capacity. The problems were:

- Lack of satisfactory in-line analysis for plutonium in the effluent stream.
- Lack of sufficient tankage for efficient operation.
- Channeling of the flow through the column resulting in low total loads.

The effluent, eluate and other streams leaving the grid column were analyzed by an alpha radiation counter. In order for this method to work satisfactorily, plutonium must be the major alpha emitter present in the stream. At the time of design of the grid column, plutonium did account for essentially all of the alpha count. Later, however, the americium-241 content of the feed streams became significant; as high as 0.01 g/l. Because a unit mass of americium-241 emits approximately 53 times as much alpha radiation as does a unit mass of plutonium-239, this analytical method did not work for low plutonium streams such as the effluent.

Part of the automatic control of the grid column depended on the ability of the alpha instrument to sense the breakthrough point. Breakthrough is here defined as the point beyond which the effluent leaving the column was no longer below the plant discard limit of 0.023 g plutonium/liter. Because the alpha counter could not determine the breakthrough point, time consuming laboratory analyses

TABLE I
ANALYSIS OF GRID COLUMN PROCESS STREAMS

Process Stream	Elemental Analysis (mg/l)											
	Al	B	Ca	Cr	Cu	Fe	K	Mg	Mn	Mo	Ni	Pb
Feed	2	<1	50	25	20	600	800	20	10	5	15	35
End of Wash	1	-	5	<20	<1	5	10	<2	<1	<2.5	<2	<1
Eluate	<1	<1	2	<20	<1	20	5	3	<1	<2.5	<2	1
7N Reconditioning Acid, at end of cycle	<1	<1	<1	<20	<1	5	<1/2	<2	<1	<2.5	<2	<1

were used instead. If a reliable low level plutonium detector had been available, the grid column could have been operated considerably more efficiently.

The 6-in. diameter ion columns which the grid column was designed to replace are not so dependent on plutonium analysis. The reason is that the small columns are usually operated two in series, and a medium level plutonium detector placed between the columns can determine gross breakthrough of the first column while the second column keeps the effluent below the discard limit.

The operation of the grid column was also hampered by the lack of sufficient storage capacity. This resulted in excessive downtime while waiting for analytical results, excessive time spent in batching of feeds and in shutdown of equipment upstream from ion exchange. Six tanks containing 1200 liters of capacity were available. An additional 3000 liters was needed for efficient operation.

The most serious of the problems encountered was the tendency for channeling to occur in the resin bed. This resulted in heavy loading of portions of the resin and little or no loading in other parts.

The distribution of loaded and non-loaded resin in the column was determined by visual inspection. The color of new Dowex-1 anion resin in the nitrate form is yellow. When the resin is loaded with plutonium it becomes green. Highly loaded resin approaches a black color.

The first time the column was loaded, breakthrough occurred at 2.1 kg of plutonium for an average load of 15.5 g/l of resin. Rocky Flats experience in operating 6-in. diameter ion columns indicates that 50 g/l is a typical resin loading. It was observed that the northwest quadrant of the grid column loaded far more heavily than any of the others.

Numerous improvements were made in the construction and operation of the column over a period of several months. The major improvements included:

- a. Vertical Alignment of Column – The column was found to tilt from the vertical about 1/2-in./ft in a northwesterly direction. The tilt was corrected.
- b. Improved Distribution of Feed Liquids – The column, as constructed, was piped so that entering and leaving liquids encountered unequal resistances in flowing to and from various quadrants of the column. This undoubtedly contributed to the greater loading of the northwest quadrant. The piping was revised to correct this inequality. See Figure 6 for a diagram of the piping before and after revision.

Valves were installed in the distributor pipes for use in correcting the maldistribution. It was found that completely closing the north and west valves resulted in the most desirable flow distribution as determined by high g/l resin loadings and by visual inspection. It is not known why the channeling occurred in the northwest quadrant, but the described measures, for the most part, corrected this tendency.

One other effort was made to improve flow distribution through the column. Top and bottom distributor plates were designed in such a manner as to provide equal flows through 0.035-in. diameter orifices.² The use of the distributor plates failed to improve the flow distribution. Further, the plates tended to plug with resin due to the small orifice size. They were, therefore, eliminated from the system.

²Richardson, D. R., "How to Design Fluid-Flow Distributors", *Chemical Engineering*, May 1, 1961, pp 83-86.

Figure 6. DISTRIBUTOR PIPE CONFIGURATIONS

c. Elimination of Short Circuiting – As discussed in this report previously (Nuclear Safety section), polyethylene blocks were installed to make the column critically safe. It was found that short circuiting of the feed occurred between the blocks and grid walls. This allowed plutonium-containing feed to leave the column as effluent. This was corrected by the installation of fluoroelastomer gaskets across the blocks to stop the flow.

In Table II the feed rate and breakthrough results for six selected cycles of operation of the grid column are listed. Cycles 1, 2 and 3 were run before the described improvements were made in the column or in the operation. Therefore, they represent the worst performance of the grid column. Cycles 11, 13 and 14 were run using all the improvements discussed above.

They were the only three cycles made under the best known conditions. These results show that, for similar rates of mass and volumetric loading, the last three cycles yielded loads which were more than twice as great as those of the first three cycles.

The results in Table II show that feed rate is inversely proportional to breakthrough level. It was not determined whether mass or volumetric rate was the controlling factor. Others have found that mass rate is controlling and that volumetric rate contributes little to the plutonium loading in a cylindrical anion column. It is assumed that this was also the case in the grid column.

Even though the column loading was greatly improved, it still fell below the performance obtained using 6-in. diameter equipment. The loads on the column during cycles 11, 13 and 14 ranged from about 50 g to 80 g of plutonium/liter of resin. The Rocky Flats production

TABLE II
LOADS AND LOADING RATES FOR GRID COLUMN

Cycle No.	Plutonium Mass Loading Rate (g/m)	Liquid Flow Rate (l/m)	Feed Concentration (g/l)	Breakthrough Point (kg)
1	36.2	3.2	11.3	2.1
2	7.7	2.4	3.2	3.7
3	4.4	1.5	2.9	6.4
11	3.5	1.5	2.3	11.0
13	9.4	2.7	3.5	8.7
14	35.0	4.4	8.0	6.4

columns are able to load to the same levels while loading at three times the rate. For instance, the loading rate during cycle 14 was 0.012 g of plutonium/cm²/min of column cross section. Comparable capacities are obtained in 6-in. equipment while loading at 0.036 g/cm²/min. Since capacity at breakthrough is an inverse function of mass loading rate, it is obvious that the grid column was not as efficient as small scale equipment.

The cause of this inefficiency was probably the irregular column geometry and the high wall-surface-area-to-volume ratio. The wall-area-to-volume ratio in 6-in. cylinders is 0.67. The average ratio for the grid column is about 2.0; three times that of the 6-in. cylinder. From inspection of Figure 1 it may be seen that the surface-area-to-volume ratio near the circumference of the grid column is greater than that near the center. The presence of the vertical surfaces made it impossible to completely pack the bed uniformly. The packing density approached zero at the grid wall. The area near the grid wall, therefore, offered less resistance to flow and, consequently, a path for channeling.³ This mode of channeling was accentuated by the tendency of the resin bed to shrink as it loaded and thus pull away from the walls. Wall effects, therefore, must be considered as major factors in design of poisoned ion exchangers.

From this analysis it would be expected that the resin near the grid walls would have been more thoroughly loaded than the resin at the grid center. Further, it would be expected that the outside portions of the column would have been loaded more than the areas near the center due to the higher surface-to-volume ratio. Observations of the green-yellow resin distribution in the column confirmed that this was generally true.

It is concluded that most of the gross flow maldistribution problems were solved. It appears that the local flow problems due to wall effects accounted for the low resin loadings experienced in the grid column. Therefore, since the wall effects are inherent in the column design, no significant improvements could have been made in the resin loadings above those experienced in cycles 11, 13 and 14.

OPERATION OF GRID COLUMN UNDER PRODUCTION CONDITIONS

Data obtained during grid column development were used to predict average column performance for an operating cycle under production conditions. The performance is

described in Table III. Included is information on chemical separations, operating time requirements and reagent requirements. The times required are calculated on the basis of one man operating the column each shift. It is assumed that sufficient storage space is available for the process liquids. The periodic shutdown times are 3-month averages because the resin must be changed once each quarter as a result of degradation by radiation and acid. The data in Table III would differ if the operating conditions were changed.

TABLE III

EXPECTED LONG TERM PERFORMANCE OF GRID COLUMN SYSTEM

Operating Conditions for Typical Cycle

Feed concentration	3 g/l
Flow rate	3 l/m
Mass rate	9 g/m

Concentrations of Plutonium in Process Streams

Feed	3.0 g/l
Effluent discarded	0.01 g/l
Eluate	25-30 g/l

Column Loading

Total load at breakthrough	8.6 kg
Heel left in resin	0.9 kg
Plutonium eluted	7.7 kg

Times Required to Operate One Column Through One Cycle

Actual loading time	14.3 hr
Downtime during loading	4.8 hr
Time for washing, elution, reconditioning and minor maintenance	19.2 hr
Total time required per cycle	38.3 hr

Reagents Required Per Cycle

Washing column	200 L, 7N HNO ₃
Eluting column	
Pre-eluate	60 L, 0.35N HNO ₃
Elute	300 L, 0.35N HNO ₃
Reconditioning column	150 L, 7N HNO ₃

Times Allotted for Periodic Shutdown, Shifts Per Quarter

Inspection of neutron poison	6 shifts
Inventory	9 shifts
Resin change	5 shifts
Major maintenance	4 shifts
Total	24 shifts per quarter or 8 shifts per month

³Schwartz, C. E., and Smith, J. M., "Flow Distribution in Packed Beds", *Industrial and Engineering Chemistry*, 45, pp 1209-1218.

THE TUBULAR ARRAY COLUMN

The major drawback of the grid column was that neutron poison was in direct contact with the corrosive process solutions. This resulted in chemical attack of the poison and, consequently, reduction of the nuclear safety factor (see Nuclear Safety section).

A design was developed which eliminated this serious objection to the grid column. The new design involved the placement of stainless steel encased boron carbide tubes horizontally in the resin bed. A prototype of this design was built to be used in nuclear safety tests.

The tests, however, were never carried out.

The tubes were fabricated from boron-carbide powder by use of an epoxy binder formulation. The tubes were 18-in. long, 3/4-in. outside diameter and 1/2-in. inside diameter. The composition was about 50 percent boron by weight. The boron was of natural composition, containing 18.8 percent boron-10. The bulk density of the tubes was found to be 1.77 g/cm³.

Figure 7 is a photograph of one of the segments of the prototype column. It is seen that the column is square in cross section rather than round. This was done for ease of fabrication. There were 70 stainless steel tubes welded into each section of the column. A boron-carbide tube was slipped into each stainless steel tube. The tubes were placed on 1-3/4 in. centers. The end of the tube bundle could be enclosed so that hot water could be circulated through the tubes, or it could be blocked with transparent plastic as was done in the prototype. A column of this design would be operated in the same manner as the grid column and be of about the same maximum dimensions and resin volume. Therefore, a tube column could be installed in place of a grid column with little additional expense.

The major advantages of the tubular design are:

- a. Degree of Nuclear Safety — The degree of nuclear safety would be greater due to the isolation of the poisoning material from the process stream.
- b. Tube Poisoned Equipment Life — The tube poisoned equipment life would last much longer than the grid column because the poison could not be damaged.
- c. Tube Column Cost — The tube column cost would be considerably cheaper to build because boron-carbide is much cheaper than boron-stainless steel. The price of the metal used was \$25,000 as versus \$5,000 for boron-carbide.

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Figure 7. TUBULAR ARRAY COLUMN TEST DEVICE

The major disadvantages of the tubular design are:

- a. Cost of Development of the Column — The cost of development of the column would be high. The largest single cost would be a test of the nuclear safety characteristics of the design. This test would involve the holdup of about 40 kg of concentrated high purity plutonium solution. It is estimated that an expenditure of \$50,000 would be required to fully develop the column.
- b. Fluid Flow Characteristics — The fluid flow characteristics of the tubular array design are doubtful. The presence of the tube bundle in the resin bed could cause poor distribution of feed over the column cross section, resulting in a low-average resin loading figure.
- c. Introduction of the Ion Exchange Resin — The introduction of the ion exchange resin into the column as an evenly packed bed with a minimum of void pockets would probably be a major problem.

ECONOMIC CONSIDERATIONS

The major purpose in development of poisoned ion exchange was to obtain a system capable of being operated more economically than the 6-in. diameter column system in operation at that time. The existing system consisted of two widely separated sets of columns with insufficient liquid storage capacity and little instrumentation or automatic control.

An economic analysis was made of grid poisoned and tube poisoned systems and of a 6-in. diameter non-poisoned column system of new, improved design. All three systems were considered to have ample storage capacity for process solutions, a high degree of automatic operation and to be designed out in an efficient manner. The analysis included estimated cost figures for construction of the various units based on the availability of the necessary floor space and services. The total cost of each system, excluding design engineering cost, is presented in Table IV. The costs are calculated for systems capable of processing 10 kg of 3 g/l plutonium nitrate feed each full day of operation. The engineering costs are omitted because they are not representative of design costs at other sites. The grid and tube poisoned systems each consisted of two 18-in. diameter columns. The non-poisoned system consisted of six 6-in. diameter columns.

Also included in Table IV are the estimated operating and maintenance costs. These figures are presented as differentials based on the low-cost tube poisoned system. The cost figures cited in Table IV were obtained from Rocky Flats cost history and from estimates made by the Rocky Flats Facilities Engineering Department.

All three systems evaluated were found to be more economical, from the standpoint of operating costs, than the system in use at that time. The tube poisoned system is seen to be the most economical, from the standpoint of investment cost and operating cost, of the three systems. It must be remembered, however, that a sizeable development project must be undertaken before the tube poisoned system could be built. The cost of such a project is estimated to be \$50,000. The operating cost savings to be realized from the tube poisoned system over the non-poisoned system would be very small in comparison to the total capital investment. Therefore, the decision was made to discontinue development of poisoned ion exchange equipment.

As a result of this evaluation, a new non-poisoned ion exchange system was constructed and is in operation. It is expected that this system will economically satisfy the Rocky Flats anion exchange requirements.

TABLE IV
COSTS OF ION EXCHANGE SYSTEMS

Type of System	Grid Poisoned	Tube Poisoned	Non-Poisoned
Construction cost, dollars	225,000	185,000	215,000
Differential operating and maintenance costs, dollars per year	15,000	0	2,000