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DP-930

AEC RESEARCH AND DEVELOPMENT REPORT

RADIOCHEMICAL SEPARATIONS PLANT STUDY

LIMITED MAINTENANCE-CASE VII

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DU PONT

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DP-930

Chemical Separations Processes
for Plutonium and Uranium
(TID-4500, 32nd Ed.)

RADIOCHEMICAL SEPARATIONS PLANT STUDY
Limited Maintenance - Case VII

by

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ABSTRACT

A conceptual design and estimate for a "limited maintenance" radiochemical separations plant for processing irradiated nonproduction reactor fuels have been prepared to supplement the cases presented in Report DP-566.

CONTENTS

LIST OF EXHIBITS

RADIOCHEMICAL SEPARATIONS PLANT STUDY

Limited Maintenance - Case VII

I. SUMMARY

A. General

This work, requested in AEC Directive 28(AP), consisted of studies and an evaluation estimate for a 10-ton-per-day Radiochemical Separations Plant.

This study and estimate supplement the six previous Radiochemical Separations Plant Study cases requested by AEC Directive 7(AP) and reported in DP-566. The same labor and material indexes were used in preparation of all estimates so that they can be compared directly. The estimates contain no escalation allowances for labor and material.

The principal differences between this case and the Base Plant Case I are the features of "limited maintenance" and greater use of in-line instrumentation. Raw metal feed clarification was also eliminated as in the Case II - Contact Maintenance Plant.

The estimated cost for the total plant is $58,000,000, as compared to $60,000,000 for Case I, indicating a lower investment but at the expense of plant process flexibility and extended shutdown time in the event of major equipment failure.

The major portion of the investment savings was realized in the separations facilities, the cost for which was lower than Case I by about 7 or 8 per cent.

B. Conclusion

A lower plant investment is indicated for the Case VII; however, it is still within the range of accuracy of the Case I estimate. More extensive design and development would be necessary to firmly establish a cost differential.

The annual cost of operating the plant is expected to be about the same as the cost of operating the Contact Maintenance Plant (Case II), reported in DP-566 as being $6,380,000.

II. DISCUSSION

A. General

On May 14, 1959, the AEC by Directive 7(AP) requested the Du Pont Company to conduct engineering studies and prepare evaluation estimates for six different cases of Radiochemical Separations Plants for recovery of fissionable materials contained in irradiated fuel from power reactors.

A definition of these cases and results of the studies were reported in DP-566 issued in March 1961.

The collection of data from a plant featuring "limited maintenance"* resulted in the request by the AEC on November 11, 1962, by Directive 28(AP), to add a Case VII to the RSPS (Radiochemical Separations Plant Study), which would incorporate (1) major design features of the "limited maintenance" plant and (2) advances in U.S. technology developed since the RSPS report which were considered worthwhile from the standpoint of reduced plant investment.

This report covers the engineering study and evaluation estimate for only the first phase of this work associated with incorporating "limited maintenance" features. Incorporation of advanced U.S. technology would require further study.

B. Design Basis

All of the feed material, process flows and final product for this Case VII are the same as for the DP-566 Base Plant Case I. The aluminum element cladding is removed chemically with an NaOH solution and the uranium core is dissolved in HNO_3. The Purex process is used for separating uranium and plutonium from various impurities with the liquid-liquid extraction being performed in mixer-settlers.

*Limited Maintenance is taken to mean providing for the replacement of equipment with moving parts and some selected items without moving parts where susceptibility to failure from wear, pluggage, or other factors is significant. All other equipment items and piping are to be designed and built to specifications which would make them likely to last indefinitely in the intended service. No provisions are made in the design to facilitate their repair or replacement.

The plant is capable of processing, on a sustained basis, 10 tons* per day of irradiated uranium-aluminum reactor fuels, having a maximum reactor exposure of 5,000 MWD/ton and a minimum cooling period before processing of 180 days. The waste is stored underground in carbon steel tanks. The finished products leaving the plant consist of a 43 wt % solution of uranyl nitrate, and a plutonium nitrate solution containing 250 grams plutonium/liter.

The only variations in the design basis from the Base Plant Case I are those required by the substitution of the "limited maintenance" concept for remote maintenance and greater use of in-line instrumentation to reduce the requirement for process solution storage to obtain analytical results prior to further processing in the separations plant. A Plant Material Flow Diagram is shown in Exhibit 1 and a Simplified Process Flow Diagram with location of in-line instrumentation is shown in Exhibit 2. For comparison the Case I Simplified Process Flow Diagram is shown in Exhibit 3.

C. Design Procedure

The design procedure followed in arriving at a description of Case VII sufficient for estimating was to make maximum use of the Base Plant Case I and develop only those parts directly affected by the defined concept changes. This meant that no design work was necessary in areas such as the laboratory, sand filter, control room, change room, and office building.

In some cases building arrangement and equipment design were not developed in sufficient detail to establish compatibility with the base case ground rules, particularly with respect to ensuring at least 80% on-stream capability. It was assumed that such problems could be overcome in final design without major cost penalty.

III. DESCRIPTION OF FACILITY

A. General

The only facilities described herein are those which represent changes from Case I. Exhibits 4, 5, and 6 are taken from Case I and show the Plot Plan, building arrangement, and canyon equipment arrangement for Case I.

*The 10-ton-per-day is based on natural uranium. The plant can also process higher enrichment but at a reduced capacity. (DP-566).

Process Equipment Requirements

1. The raw metal adjustment tank, 2A feed tank, and the head end centrifuge were eliminated from the process. The first two are considered unnecessary as a result of more accurate in-line analysis and application of continuous solution adjustment. The centrifuge was eliminated as it was in the contact maintenance Case II. The penalty of scheduled shutdown for 1A mixer-settler flush-out of solids would therefore have to be accepted.

2. A third dissolver and off-gas filter were added as installed spares. This unit was considered necessary to guarantee an acceptable on-line time with the anticipated relatively high maintenance of dissolvers.

B. Process Equipment Design Concept

All process equipment, such as mixer-settlers and blending tanks that require mechanical devices for successful operation, is designed to permit easy removal of mechanical parts which, in turn, are driven by motors positioned outside canyon cell barriers.

Process equipment with heating elements, such as evaporators, is designed to operate under vacuum to reduce operating temperature and thereby to minimize corrosion. In addition, all hot walls of these vessels are fabricated of either heavy plate or extra heavy wall pipe.

The dissolver was designed to receive elements directly from shielding casks rather than being charged by a remotely operated crane.

The use of all welded permanent type connections as process and service lines to process vessels completely eliminates the need for fabrication to close tolerance. This reduces somewhat the cost of conventional equipment such as tanks; however, opposed to this, there is the need to design and fabricate the equipment to a higher quality.

C. Separations Building Arrangement

The general arrangement of the separations building is specifically adapted to the "limited maintenance" concept. Exhibits 7 to 10 show plans and sections of this building.

The principal part of the building is the canyon, which contains the main process equipment. This section is never entered during processing operations and is separated from all adjacent operating areas by a 5-foot concrete radiation shield or equivalent. Contamination is contained within the canyon by maintaining air pressure several inches of water below that of surrounding areas so that leaks or openings will result in air flow toward the canyon.

The canyon is subdivided into three dissolver cells, one cell containing mixer-settlers and other extraction equipment, and one cell containing evaporation equipment. The three dissolver cells contain two on-stream dissolvers and one operating spare. They are separated from one another by 5 feet of concrete shielding so that maintenance work can be performed on one unit without interrupting normal production in the others.

The extraction area is separated from the evaporation area mainly for economic reasons since in doing so the ventilation air quantities can be greatly reduced. High air flow for cooling would otherwise be needed to keep solvent temperatures below the flash point.

The equipment pieces in the canyon are spaced closer together than they would be in a Contact Maintenance Plant because only infrequent and minor repairs are provided for in this concept, and no provisions are made to facilitate the removal and replacement of major equipment units.

The area below the canyon is considered a limited access operating area and contains mainly that equipment associated with the flush-out of canyon equipment.

The areas above and to the sides of the canyon are normal operating areas and except for the bulges* this area is considered free of contamination.

All electrical drives for canyon equipment (Exhibit 11) are located on the canyon covers directly above the particular equipment served. The extended shafts pass through the concrete cover and directly to the process equipment, such as mixer-settlers and mix tanks. The shafts are provided with liquid seals to eliminate air flow through these points of entry.

*The bulges (Exhibit 11) are enclosures used to house selected small equipment items in radioactive service, such as jets, samplers, and instruments which are expected to require periodic maintenance. Their construction is such that, after decontamination of the equipment within them, the biological shield can be removed to permit essentially contact maintenance.

Agitator removal is accomplished by using the service crane to lift the drive and a shield plug. The contaminated shaft and agitator are decontaminated in place and sprayed during removal through the cell cover, and are lifted directly into a shielded shipping box for transfer to the maintenance shop.

The charging of dissolvers is performed by lowering elements directly into the dissolver from a shielded transfer cask. The cask is lifted from the element storage basin by the large charging crane and placed directly above the dissolver. Cask valves and dissolver cover valves are then opened and the element charged directly to the dissolver.

D. Services

Instrumentation

The basic premise for instrumentation to measure essential process variables is to provide equipment so designed and installed that all necessary functional tests can be made routinely without the need for access to the measuring assemblies, but with provisions for ready access under non-hazardous conditions when routine tests indicate need. Constant rate sample streams will be brought to measuring assemblies located in shielded instrument bulges and then returned to the main process stream. Functional testing facilities will be located just outside the bulges and means will be provided here for decontamination of equipment when maintenance access is required. Read-out signals only will be transmitted to a remote control center where alarm annunciators, recorders when required, and data logging equipment will be located. Only the remote control equipment required to make process adjustments will be located here. All manipulations for testing and maintenance of the measuring devices will be located at the intermediate instrument stations away from the control center.

This approach permits use of minimum panel space at the main control center leading to optimum concentration of canyon process control equipment. This will result in maximum operating labor effectiveness and savings to offset any additional investment costs which may be required due to this measurement and control concept. When equipment dependability has been established, further savings plus operating continuity advantages should be achievable through minimizing the necessity for routine sampling and laboratory analysis.

Exhibit 2 indicates various locations and types of measurements required to monitor the process for control purposes. Essentially all the devices indicated have been developed and can readily be adapted to the "limited maintenance" concept.

It is entirely possible that some additional operator labor savings can be achieved by bringing necessary intelligence and required operating facilities from process steps located outside the main separations area to the one main control center. This should be possible since the concentration of remote control gear permits an arrangement requiring relatively small control room area.

Heating and Ventilating

The only other major revision to service facilities from the Base Case is that associated with the reduced supply and exhausting of air from the canyon. The Case I flow diagram is shown in Exhibit 12. The canyon air flow was reduced by more than 50 per cent, thereby reducing in proportion the area of the sand filter and the diameter of the 400-foot exhaust stack.

E. Plot Plan

The rearrangement of buildings which resulted from the revised separations building concept is shown in Exhibit 13. In this rearrangement, the separation of regulated and non-regulated areas provided in earlier work was preserved but buildings were relocated to take better advantage of the smaller canyon building.

IV. ESTIMATE

The comparison of estimated cost is shown in Exhibit 14. These estimates were prepared on the following basis:

1. Construction would be performed by a competent and qualified contractor under commercial conditions.

2. The costs cover only those facilities located within the plant operating fence. That is, no allowance is included for facilities or maintenance of facilities located on land surrounding the operating area fence which may be owned or controlled by the plant operator.

3. The estimate is based upon the general site data given in DP-566.

4. No costs are included for the purchase of land either within or around the plant operating fence line.

5. No costs are included for bringing the service facilities and utilities to the operating area fence line.

6. An average weighted wage rate of $3.14 per hour has been assumed.

7. A Bureau of Labor Statistics Buildings Material Index of 135 has been assumed - 1947 to 1949 Index taken as 100.

8. A Bureau of Labor Statistics Metals and Metal Products Index of 155 has been assumed - 1947 to 1949 Index taken as 100.

9. No allowances have been included for premium time to complete construction on an accelerated schedule.

10. No allowance is included for advances in labor and materials costs.

11. Normal allowances are included for undeveloped design and for assistance to an operating group for placing the plant in operation.

12. No provision is included for prototyping or testing of special equipment.

13. Estimates on a conceptual design only. They are suitable for comparison and evaluation but not for authorization of construction.

V. COMPARISON OF CASES I AND II WITH CASE VII

A. Cases I and VII

The lower cost for Case VII results mainly from the reduced size of the canyon building and reduced canyon piping and equipment costs.

The lower piping cost results mainly from elimination of jumpers and their connector blocks and bailing which are a necessary part of the remote maintenance plant. Outside facilities such as filters, stacks, etc., were also reduced in cost because of reductions in canyon ventilating air quantities brought about by the smaller building and revised concept of air requirements.

Extra machinery costs are reduced since it is not necessary to provide as many spares when many pieces of equipment can be more easily repaired in place than removed and replaced.

Cost increases were noted in areas such as chemical storage, cold feed preparation and decontamination solution storage. These costs result from the additional facilities required to decontaminate process equipment in place and then safely store or dispose of the resultant contaminated solution.

As to the relative operating advantage of the separate plants, this depends largely on the intended service of the plant. It is to be expected that the "limited maintenance" plant would have far less day-to-day maintenance, particularly with elimination of the numerous canyon jumper connections. This same feature would be expected to greatly reduce the canyon contamination resulting from leaks. However, when a major equipment failure occurs the time required to replace or repair it and the resulting production outage could be a major item.

The "limited maintenance" plant also adapts itself better to a set process which is not expected to change for a long period of time. The remote maintenance plant can be more rapidly adapted to major process changes involving production rate changes and even product changes.

The greater use of in-line instrumentation and resulting equipment reduction would probably be a major advantage for the "limited maintenance" case.

B. Cases II and VII

These cases are similar in that they both represent plants which require direct contact with canyon process equipment for repair or replacement.

The major difference which shows up as a sizable cost differential is the ability of the contact maintenance Case II plant to continue to be operable even through periods of repair to major equipment.

To attain this objective, it was necessary in Case II to duplicate a large portion of the process equipment and to install this equipment in a large number of individual cells.

The wall effect of the multiple cells, the added space for the installed spare equipment, and the large space provided on both sides of the canyon for shielded access to equipment resulted in a canyon cubage nearly twice that for the "limited maintenance" Case VII.

The added canyon space also resulted in larger ventilating requirements and these together with the cost for extra process equipment constituted the major portion of the cost differential.

In both Cases II and VII, there was a savings over Case I in equipment piping by elimination of jumpers and an added cost allowed for storage of fresh and used contaminating solutions.

C. Operating Costs

The manpower requirements for the plant described herein will be essentially the same as those estimated for the contact maintenance plant (Case II) reported in DP-566, since the same services must be provided. While there might be some reduction in personnel assigned to the control laboratory because of the extensive use of in-line instrumentation, there must of necessity be an increase in the number of instrument mechanics and in the cost of decontaminating and repairing the instruments. The total personnel requirement would remain at about 285, and the annual cost at about $6,380,000. As stated in the original study, actual plant operating costs may vary ±20% with individual items being subject to even wider variation.

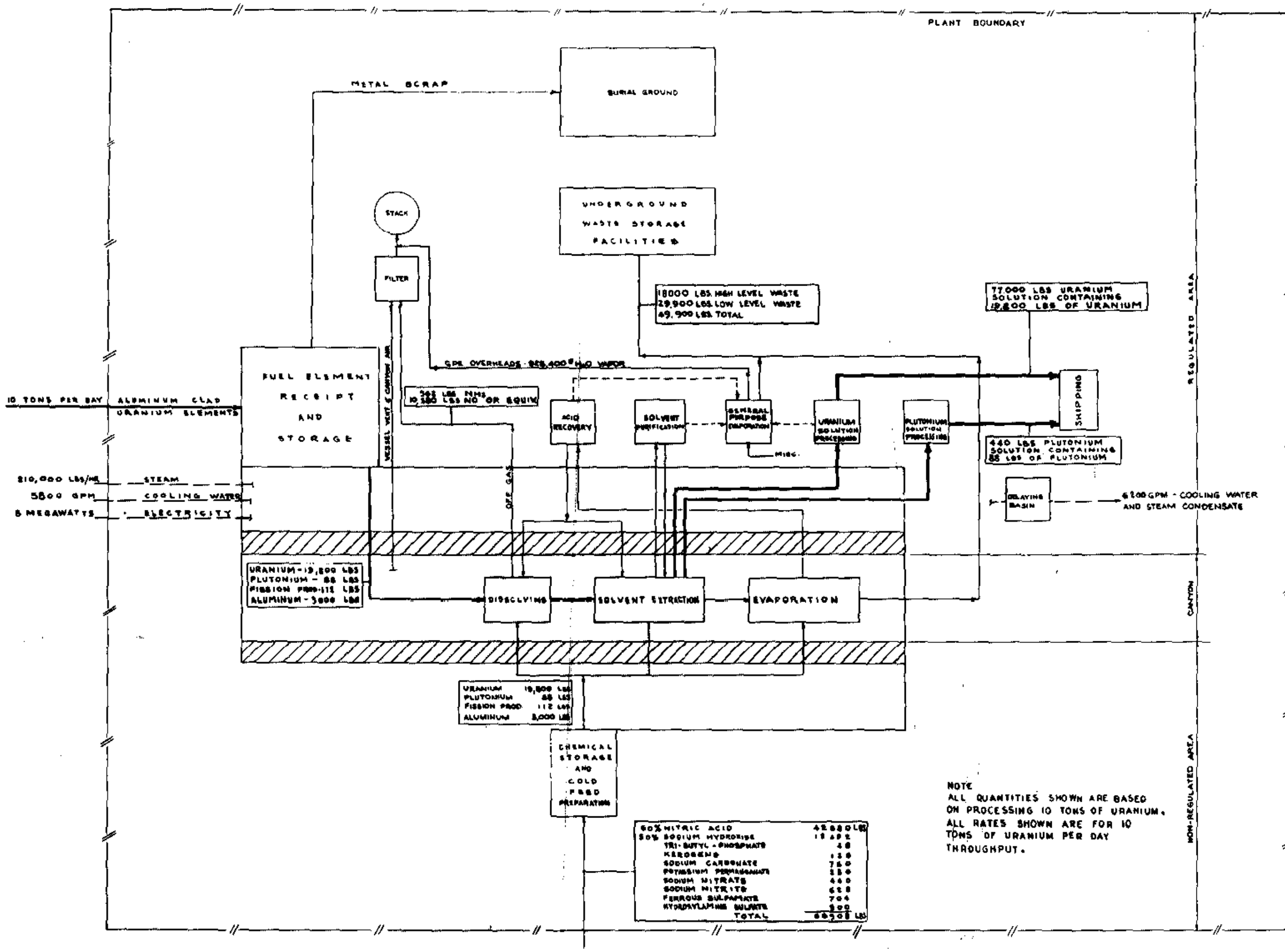


EXHIBIT 1 CASE VII - PLANT MATERIAL FLOW DIAGRAM

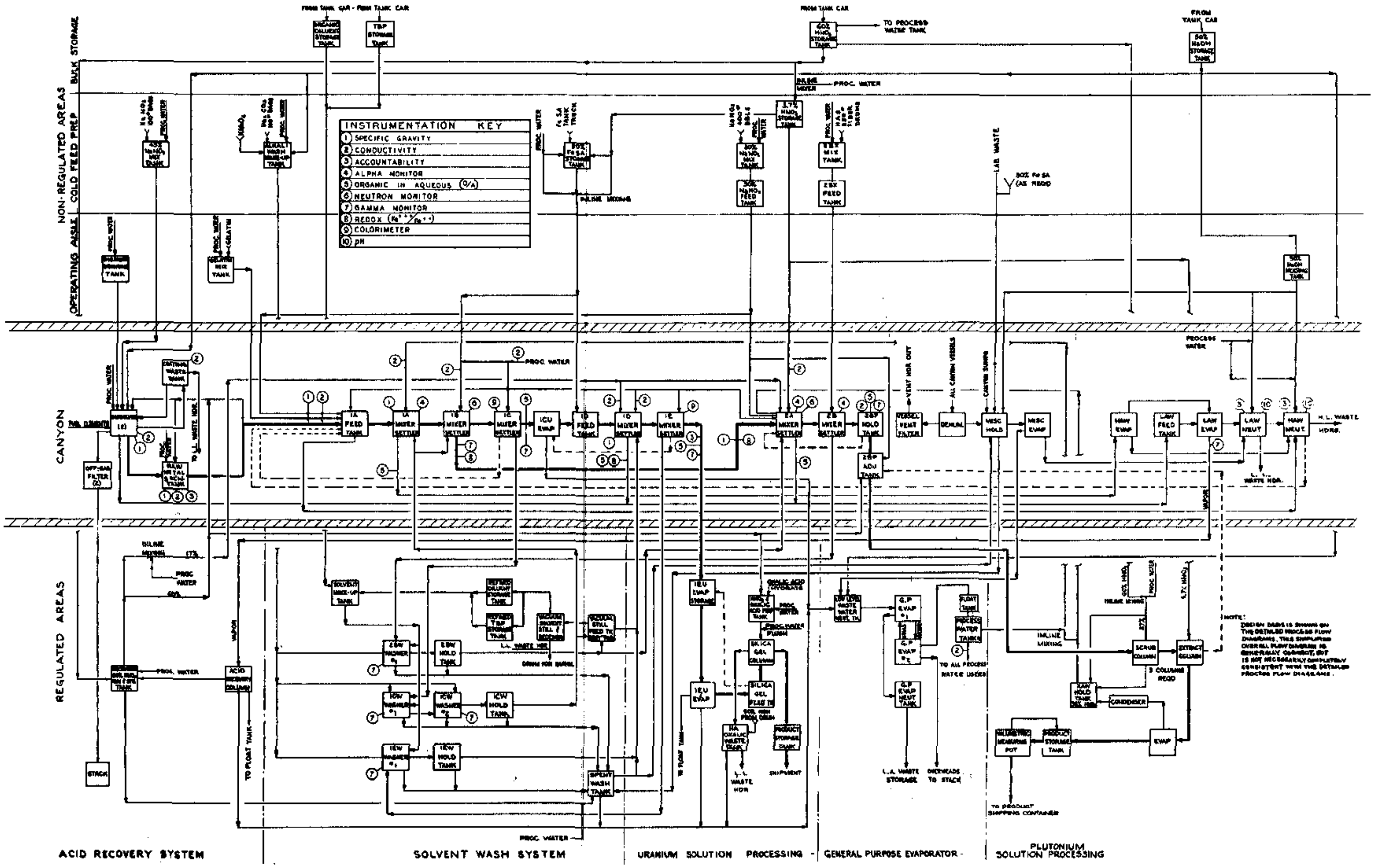


EXHIBIT 2 CASE VII - SIMPLIFIED PROCESS FLOW AND INSTRUMENT DIAGRAM

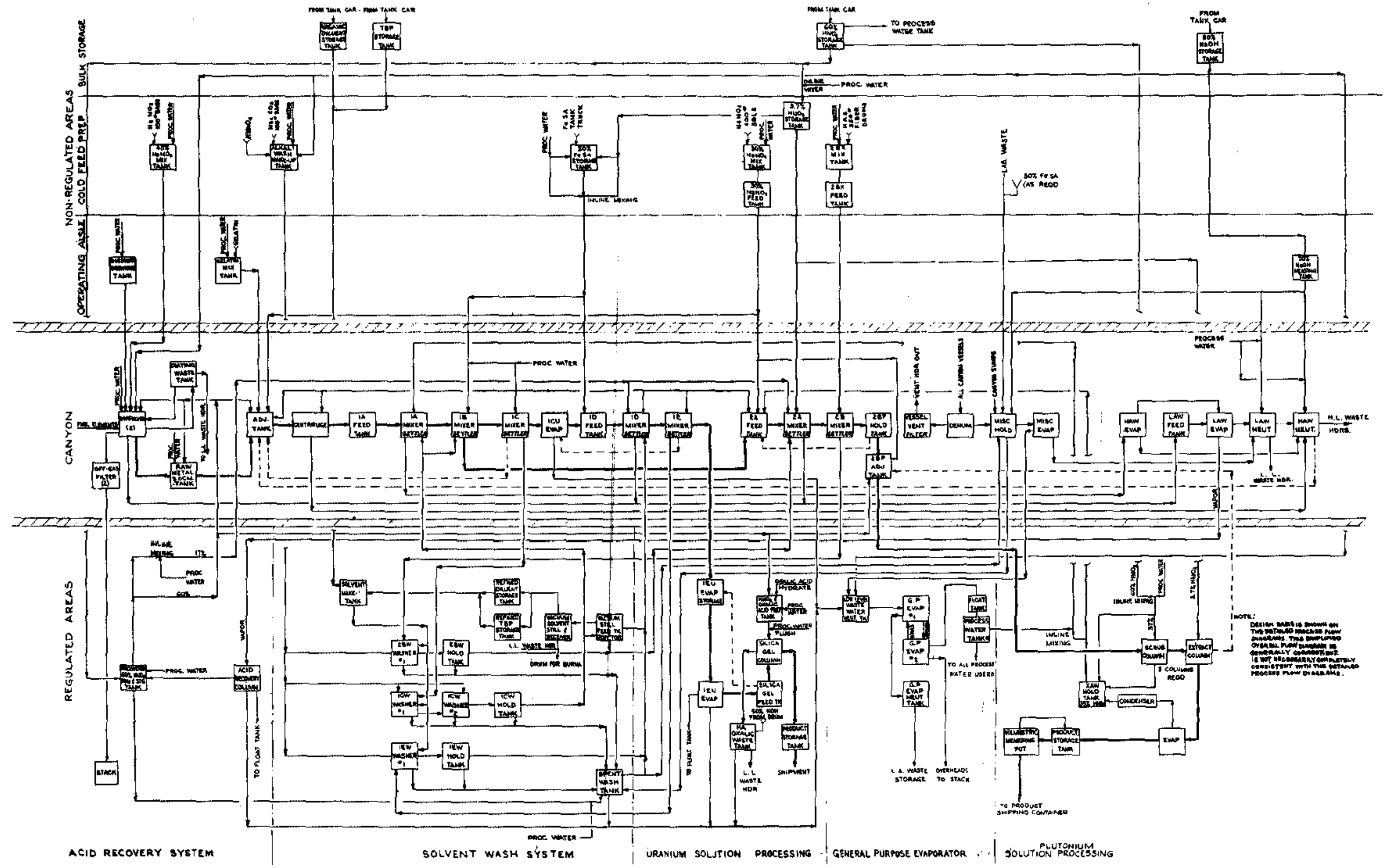
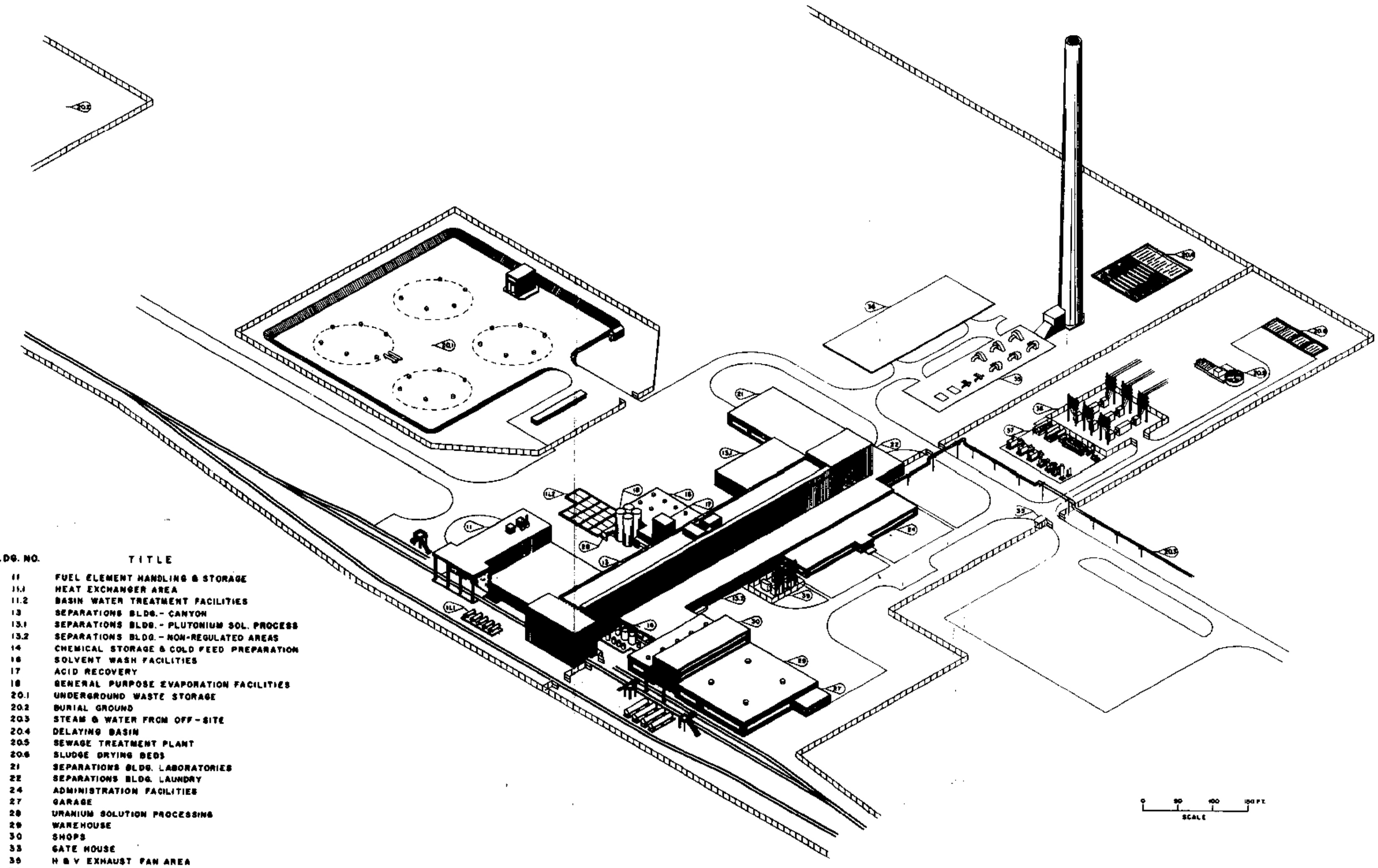


EXHIBIT 3 CASE I - SIMPLIFIED PROCESS FLOW DIAGRAM



BLDG. NO.	TITLE
11	FUEL ELEMENT HANDLING & STORAGE
11.1	HEAT EXCHANGER AREA
11.2	BASIN WATER TREATMENT FACILITIES
13	SEPARATIONS BLDG.- CANYON
13.1	SEPARATIONS BLDG.- PLUTONIUM SOL. PROCESS
13.2	SEPARATIONS BLDG.- NON-REGULATED AREAS
14	CHEMICAL STORAGE & COLD FEED PREPARATION
16	SOLVENT WASH FACILITIES
17	ACID RECOVERY
18	GENERAL PURPOSE EVAPORATION FACILITIES
20.1	UNDERGROUND WASTE STORAGE
20.2	BURIAL GROUND
20.3	STEAM & WATER FROM OFF-SITE
20.4	DELAYING BASIN
20.5	SEWAGE TREATMENT PLANT
20.6	SLUDGE DRYING BEDS
21	SEPARATIONS BLDG. LABORATORIES
22	SEPARATIONS BLDG. LAUNDRY
24	ADMINISTRATION FACILITIES
27	GARAGE
28	URANIUM SOLUTION PROCESSING
29	WAREHOUSE
30	SHOPS
33	GATE HOUSE
35	H & V EXHAUST FAN AREA
36	SAND FILTER
37	REFRIGERATION - COMPRESSED AIR & DIESEL ELECTRIC GENERATOR AREA
38	ELECTRICAL SUB STATION
39	ELECTRICAL SUB STATION

EXHIBIT 4 CASE I - ALL BUILDINGS - AREA ISOMETRIC PLOT PLAN

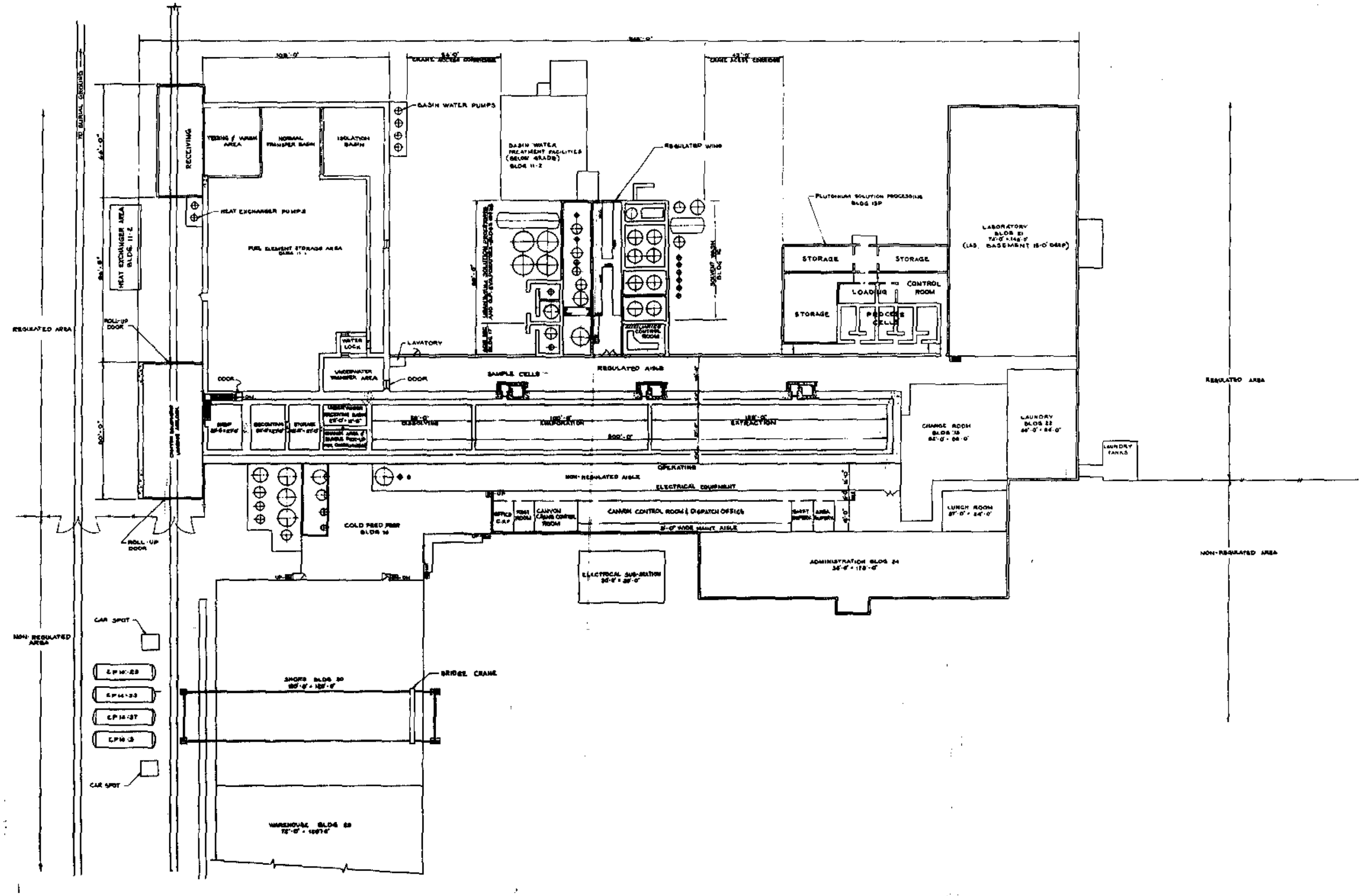


EXHIBIT 5 CASE I - ALL BUILDINGS - GENERAL ARRANGEMENT
PROCESS FACILITIES

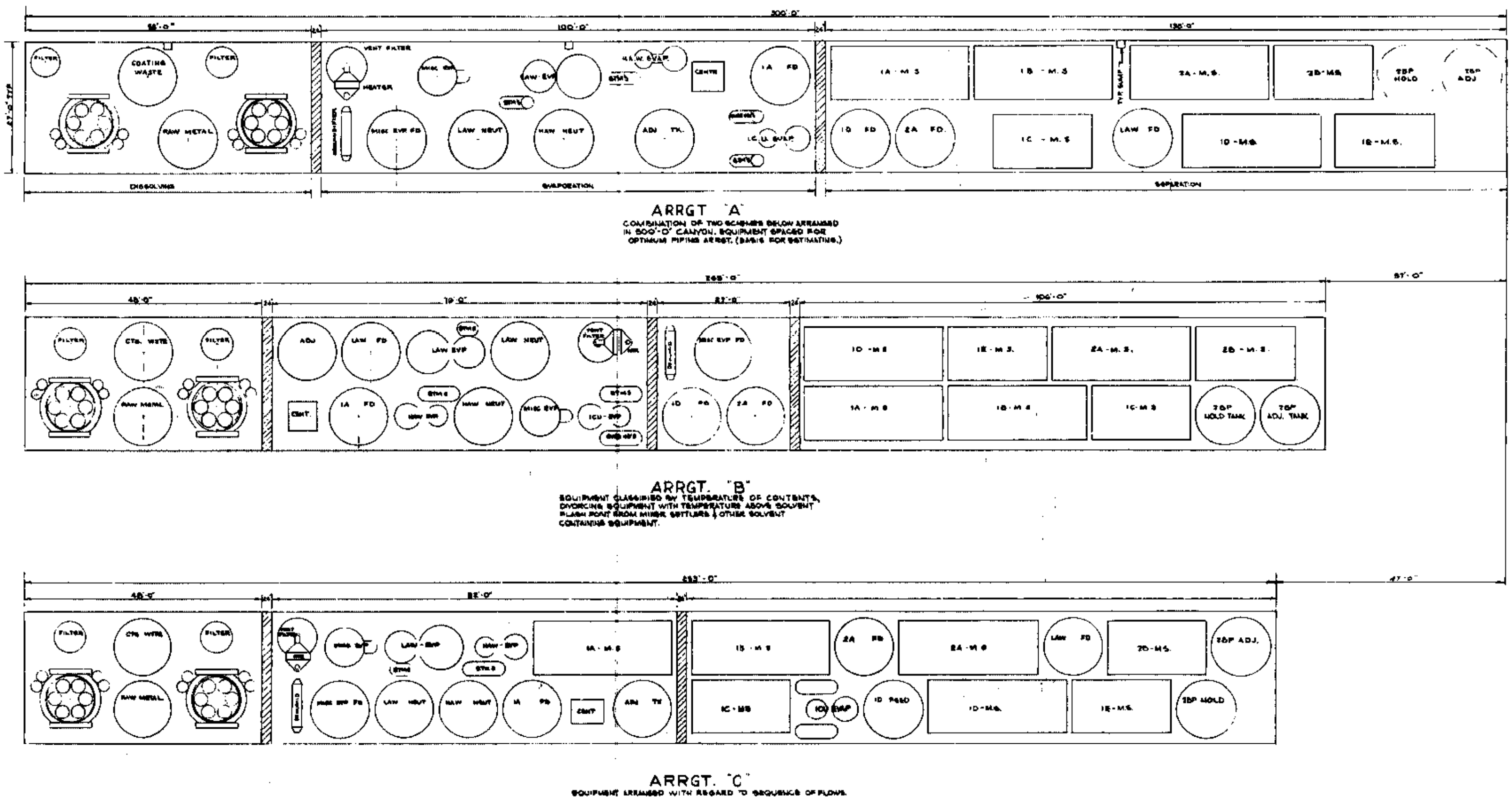


EXHIBIT 6 CASE I - BUILDING NO. 13 CANYON EQUIPMENT ARRANGEMENT

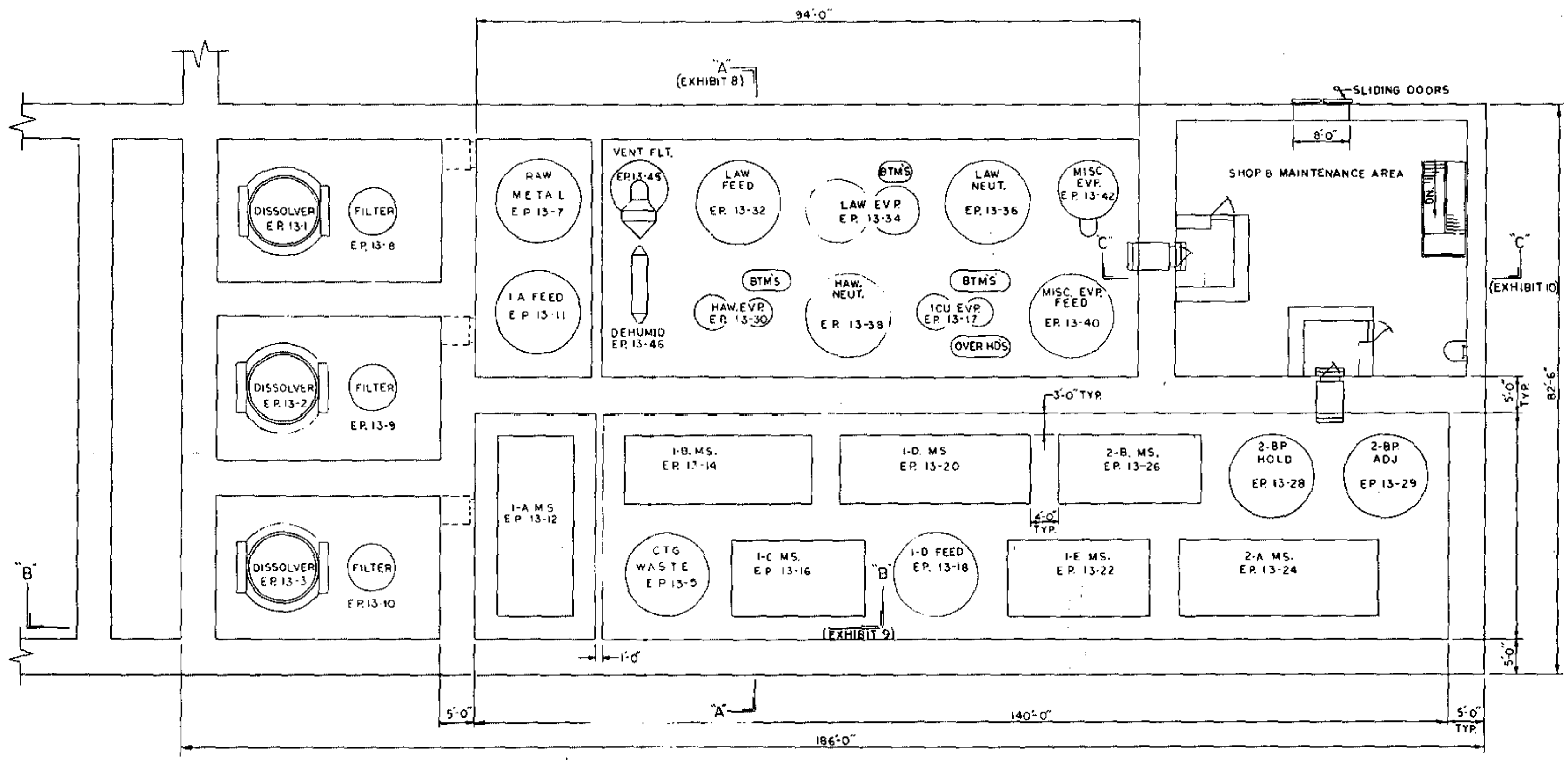


EXHIBIT 7 CASE VII - BUILDING NO. 13 CANYON ARRANGEMENT

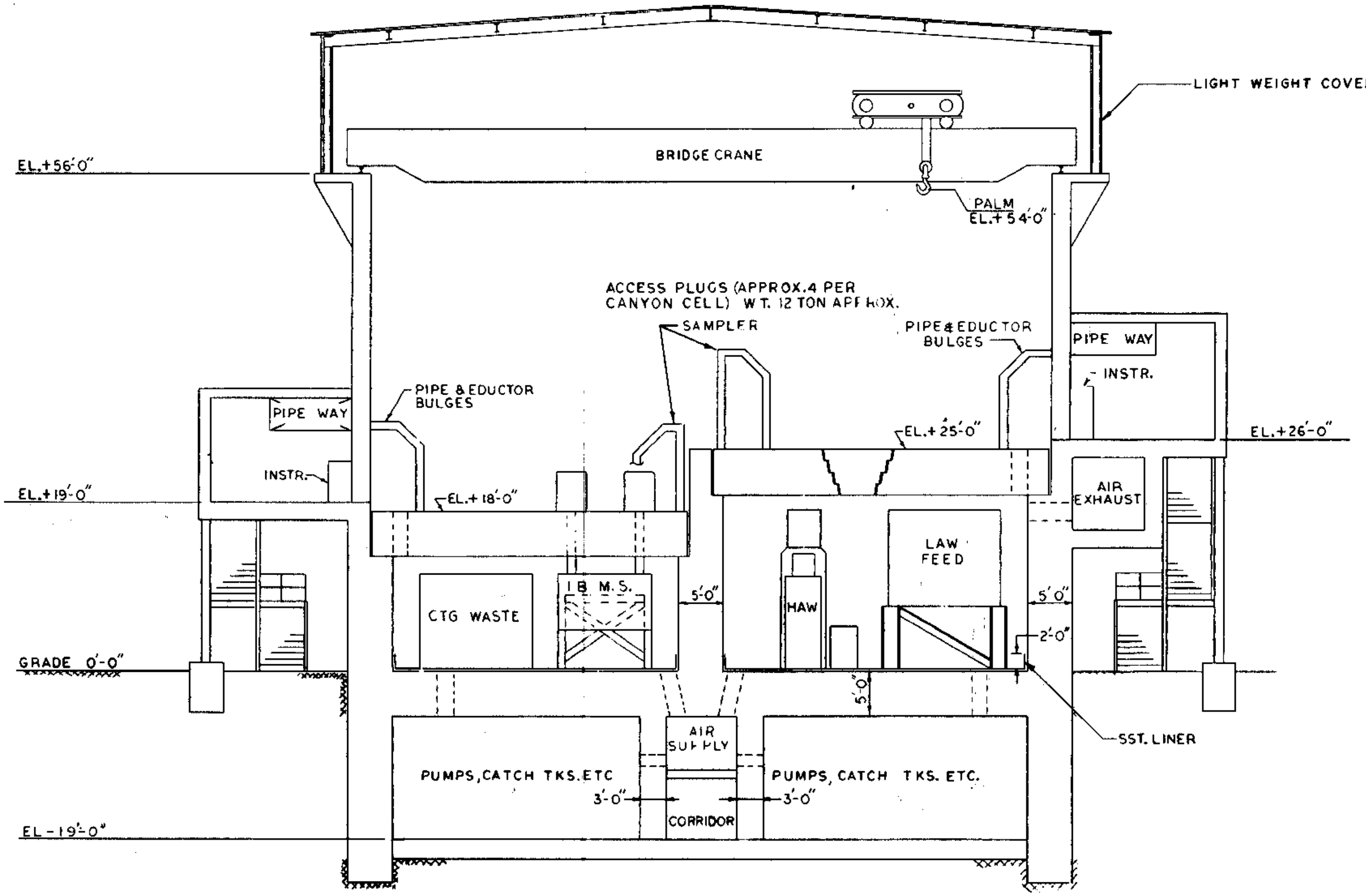


EXHIBIT 8 CASE VII - BUILDING NO. 13 SECTION - SHEET 1

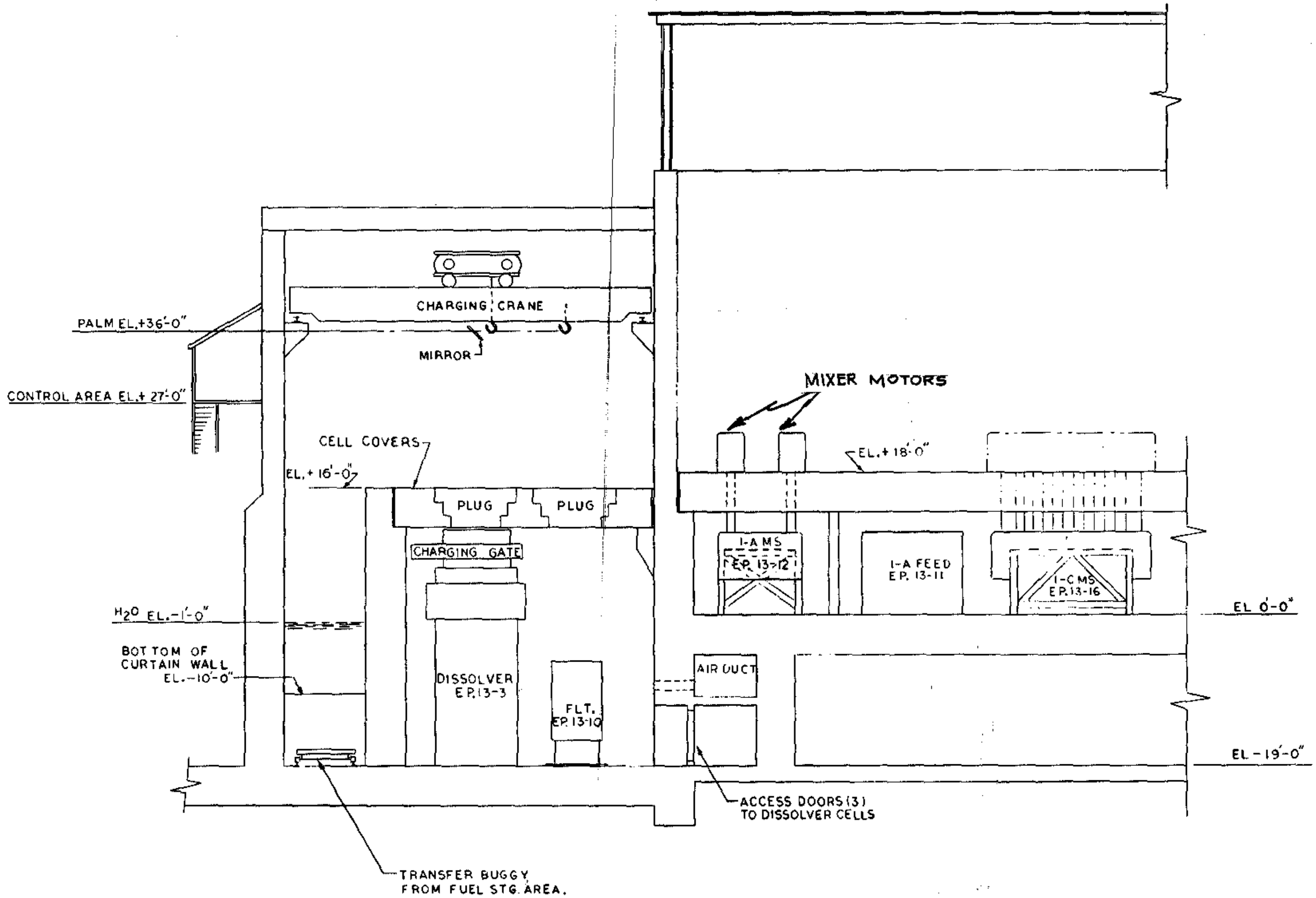


EXHIBIT 9 CASE VII - BUILDING NO. 13 SECTION - SHEET 2

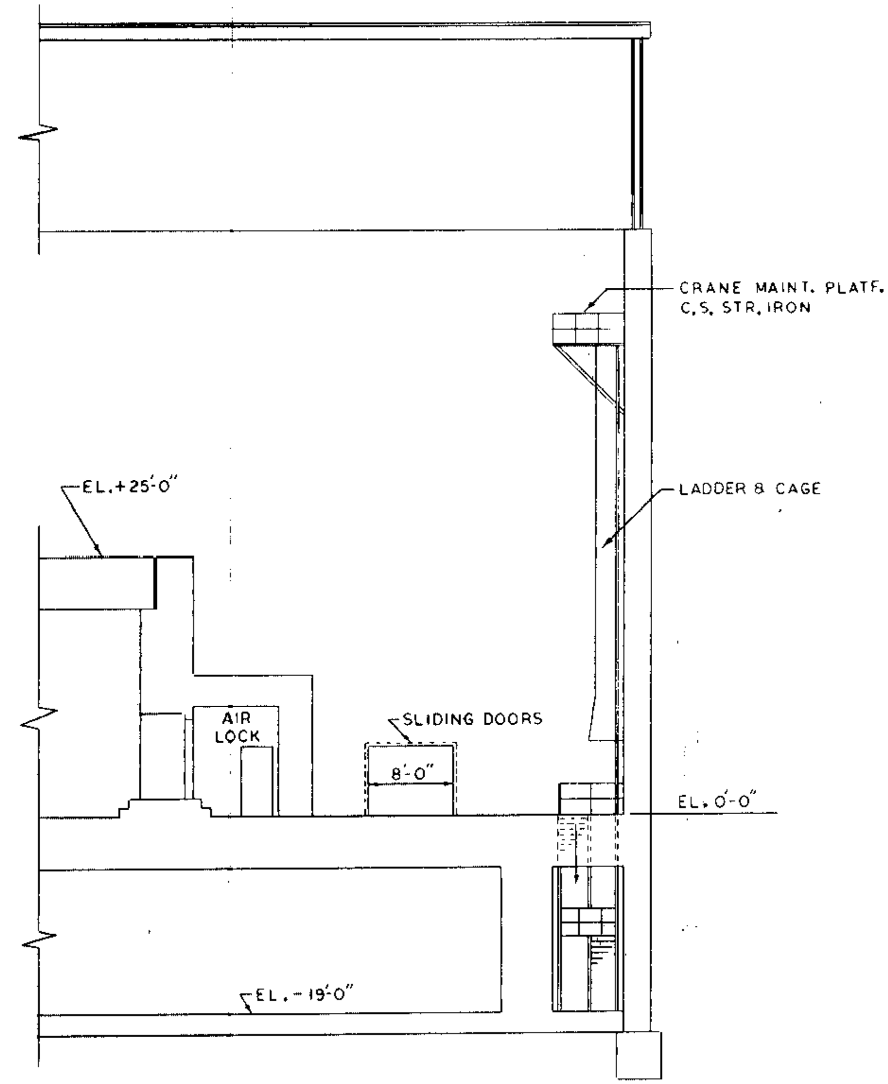
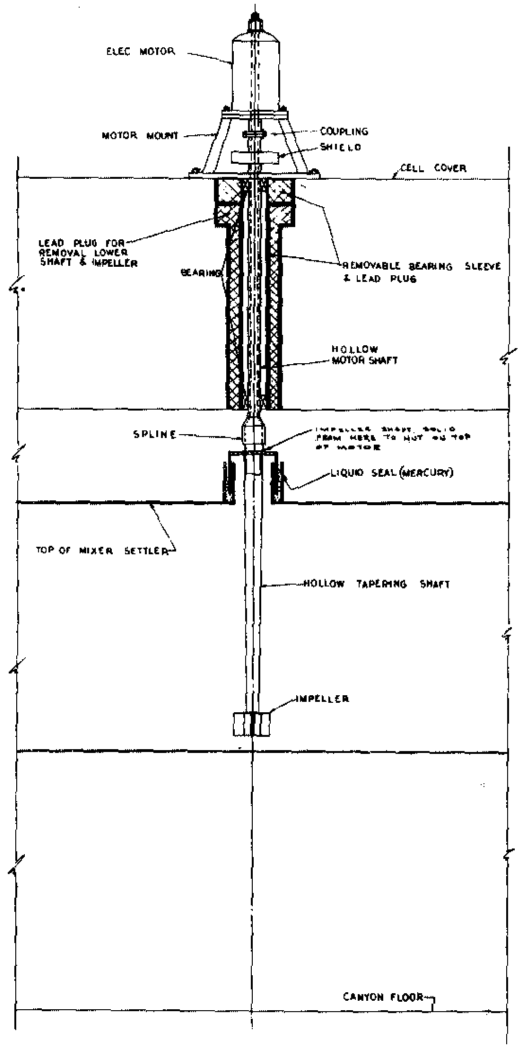
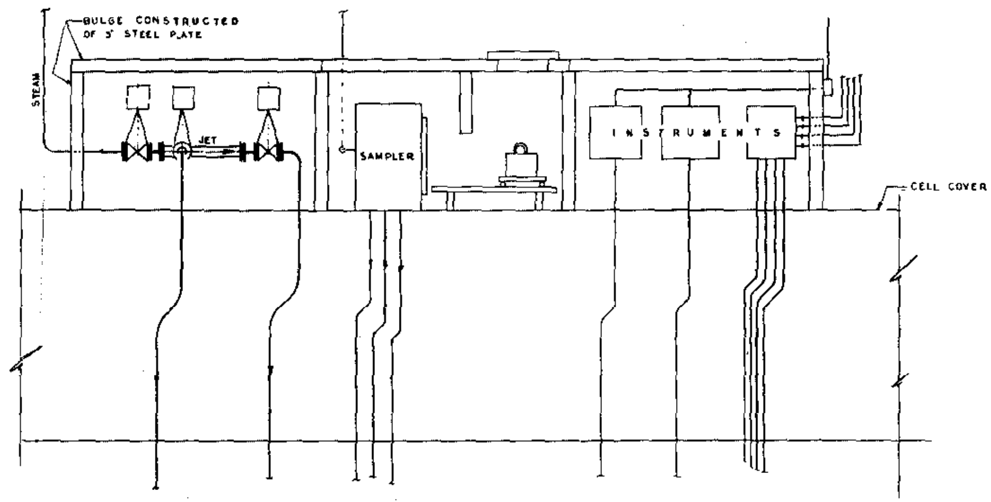


EXHIBIT 10 CASE VII - BUILDING NO. 13 SECTION - SHEET 3





TYPICAL LONGITUDINAL SECTION THRU BULGE

EXHIBIT 11 CASE VII - TYPICAL AGITATOR DRIVE AND BULGE ARRANGEMENT

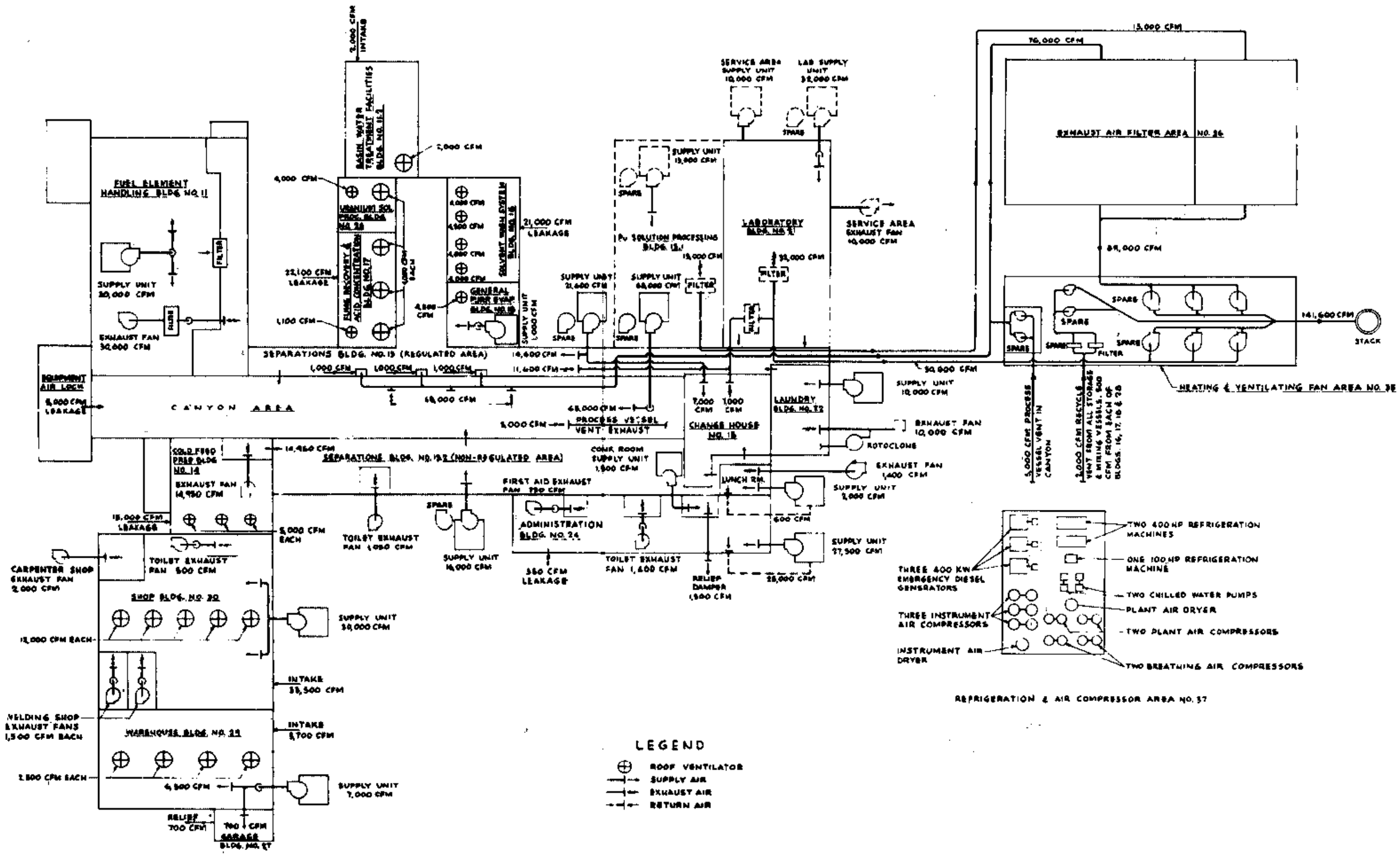


EXHIBIT 12 CASE I - ALL BUILDINGS - AIR FLOW DIAGRAM

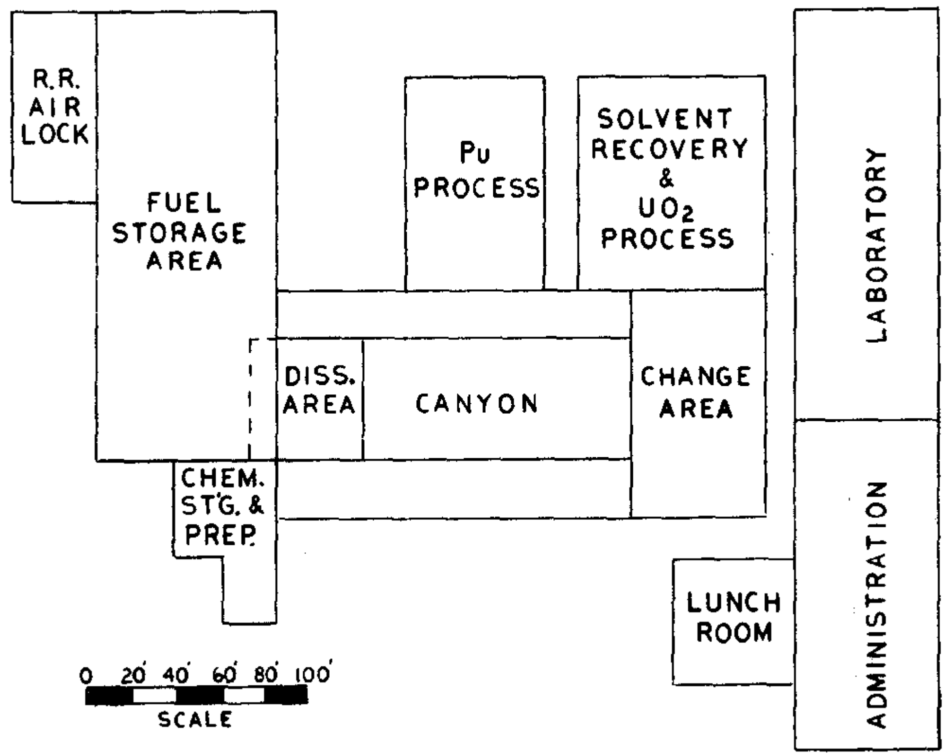


EXHIBIT 13 CASE VII - BUILDING NO. 13 - BUILDING ARRANGEMENT

	U/Al - 10 Tons/Day		
	CASE I "Remote" Maintenance	CASE II "Contact" Maintenance	CASE VII "Limited" Maintenance
1. Engineering Design & Inspection			
Design	5,100,000	5,900,000	4,950,000
Administrative Expense & Inspection	1,500,000	1,800,000	1,200,000
Total	6,600,000	7,700,000	6,150,000
2. Construction Costs			
A. Improvements to Land			
General Grading, Roads, Parking Area, Railroads, Fence, Walks, Burial Ground	400,000	400,000	400,000
B. Buildings			
Fuel Element Receipt & Storage	3,450,000	3,450,000	3,450,000
Fuel Element Basin Water Treatment	300,000	300,000	300,000
Separations	7,500,000	13,500,000	6,850,000
Plutonium Solution Processing	1,390,000	1,390,000	1,390,000
Laboratories	1,100,000	1,100,000	1,100,000
Decontamination Solution Storage		100,000	100,000
Chemical Storage & Cold Feed Prep.	250,000	250,000	250,000
Solvent Purif., Acid Recov., G.P. Evap. & U Soln. Proc.	980,000	980,000	980,000
Service Buildings - Administration Shop, Warehouse, Change House, Laundry, Garage, Guard House	980,000	980,000	980,000
Total - Buildings	15,950,000	21,650,000	15,400,000
C. Other Structures	None	None	None
D. Utilities			
Sewers, Culverts	200,000	200,000	200,000
Steam, Water, Air, Effluent, Delaying Basin Fire Protection	880,000	880,000	880,000
Electric Substations, Grounding	570,000	570,000	570,000
Total - Utilities	1,650,000	1,650,000	1,650,000
E. Equipment			
Fuel Element Receipt & Storage	1,500,000	1,500,000	1,500,000
Fuel Element Basin Water Treat.	1,280,000	1,280,000	1,280,000
Separations	11,600,000	13,600,000	10,900,000
Plutonium Solution Processing	1,500,000	1,500,000	1,500,000
Laboratories	2,260,000	2,260,000	2,260,000
Chemical Storage & Cold Feed Prep.	870,000	1,100,000	1,100,000
Decontamination Solution Storage		70,000	70,000
Solvent Wash. Acid Rec., G.P. Evap. & U Soln. Proc.	3,500,000	3,500,000	3,500,000
Service Buildings	1,040,000	1,040,000	1,040,000
Underground Waste Storage Facilities	4,150,000	4,150,000	4,150,000
O.S. Vent. Ducts, Fans, Sand Filter, Stack	3,500,000	3,900,000	2,900,000
Non-Operating Equipment	750,000	750,000	750,000
Extra Machinery	450,000	450,000	400,000
Total - Equipment	32,400,000	35,100,000	31,350,000
Total - Construction Costs	50,400,000	58,800,000	48,800,000
3. Contingencies	3,000,000	3,500,000	3,050,000
Total Project Cost	60,000,000	70,000,000	58,000,000

EXHIBIT 14 COMPARISON OF ESTIMATED COSTS