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THE PALMOLIVE CYCLE AT HANFORD

July 10, 1959

by

L. J. Beard

and

B. F. Judson

Advance Process Development
Research and Engineering
Chemical Processing Department
HANFORD ATOMIC PRODUCTION OPERATION

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THE PALMOLIVE CYCLE AT HANFORD

I. INTRODUCTION

The Palmolive program is directed toward the recovery of neptunium-237 and production of plutonium-238. The neptunium is recovered during the chemical processing of irradiated uranium and is purified and fabricated into target elements. The target elements are irradiated to produce plutonium-238 by neutron capture of neptunium-237 and are processed to provide plutonium for shipment to the final customer and neptunium for recycle within the system.

The production of plutonium-238 in this manner is currently in progress on an interim basis as an integrated effort between the Hanford and Savannah River Plants. Hanford's contribution to the interim phase of the program is the recovery of neptunium from the Purex Plant and subsequent purification and fabrication of the neptunium in laboratory facilities to provide suitable target elements. The target elements are irradiated in the production reactors at the Savannah River Plant and then processed to the final products at the Savannah River Laboratory in special interim facilities. Long-term manufacturing facilities will be installed as part of the Palmolive program following accumulation of a large neptunium inventory and adoption of long-range production goals.

The production goals of the Palmolive program have recently been reduced from a long-range capability of 8 to 10 kilograms of plutonium-238 per year to a FY 1962 capability of about 2 kilograms per year.(1)(2) Relaxation of these goals has affected the magnitude of construction effort and the various program schedules previously estimated for meeting the high plutonium-238 demands. Scope design of a project for installing long-term neptunium recovery and purification facilities in the Purex Plant has therefore been temporarily suspended to permit further engineering studies.(13) Similarly, the bases for the pre-design studies previously made for long-term fabrication and reprocessing of target elements have been revised with attendant effects on the capital and operating costs estimated for undertaking the Palmolive target cycle at Hanford.

The following report summarizes a preliminary engineering study of the technical and economic factors involved in installing long-term Palmolive manufacturing facilities at Hanford to meet the reduced production goals. Prime emphasis is placed on the process technology and plant equipment requirements for fabricating and reprocessing neptunium target elements on a production basis. The relationships of these phases of the target cycle to the recovery and purification of virgin neptunium in the Purex Plant and irradiation of target elements in the Hanford reactors are reviewed in the light of the reduced plutonium-238 demands.

II. SUMMARY

Target cycle manufacturing facilities capable of meeting the 2 kilogram per year plutonium-238 production goals of the Palmolive program could be installed at

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an estimated capital cost of approximately $2,000,000. An integrated chemical processing facility is available at Hanford for conversion to a neptunium fabrication and reprocessing system. This facility was formerly employed as a Hot Semi-Works for piloting the Redox and Purex processes with full-level irradiated fuel elements. The area therefore contains a fully-shielded solvent extraction process building, an aqueous make-up building, a solvent treatment building, ventilation and stack facilities, waste disposal and cribbing systems, maintenance shops, a change house, and an office building all within a separate exclusion area. It is proposed that the former solvent treatment building be modified as a wet chemistry and fabrication plant and that the solvent extraction building be modified to permit reprocessing and purification of neptunium-237 and plutonium-238.

Improved process technology coupled with the reduced program goals would permit production-scale processing for the Palmolive target cycle at Hanford at a capital cost lower than that previously estimated. Fabrication of the neptunium target elements, for example, would be based on the co-extrusion process successfully developed at Hanford for the interim program. In addition, the behavior of neptunium in solvent extraction and anion exchange systems has been extensively studied in support of the Hanford neptunium recovery and purification operations. The reduced program goals would involve much lower fabrication and reprocessing throughputs than previous goals so that operations in the various steps of the target cycle can be closely integrated. Preliminary estimates of building modification costs to provide a wet chemistry and fabrication line and a reprocessing system are thus $900,000 and $1,100,000 respectively, totalling $2,000,000 and thus approaching the more optimistic estimates made previously.

The capabilities of the proposed Hanford manufacturing facilities could probably be expanded by at least 100 per cent beyond the current goal of 2 kilograms per year plutonium-238 with essentially no further capital investment. The system could be readily employed for fabricating and reprocessing target elements associated with an irradiation program in either the Hanford or the Savannah River reactors. In addition the facility could reasonably be employed for the purification and concentration of virgin Palm recovered in the Purex plant, thereby potentially reducing the capital investment needed for long-term recovery at Purex by as much as $200,000.

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The production phase of the Palmolive program could be initiated at Hanford during the fourth quarter FY 1960 by preparation of target elements for charging into the Hanford reactors. Assuming authorization of design funds early in the second quarter FY 1960, the reprocessing building modifications could be completed during fourth quarter FY 1961 (19-21 months for beneficial use) to permit receiving irradiated target elements. The building revisions for the wet chemistry and fabrication system could be completed during the second quarter FY 1962 (24-26 months) thereby relieving laboratory facilities of their target element preparation load. A standard time cycle of 12 months for irradiation, three months for cooling, and six months for reprocessing and fabrication could probably be initiated with the second reactor charge. If the demands for Olive should exceed the capabilities of the Hanford reactors for a given inventory of Palm, the proposed fabrication and reprocessing system could be readily operated in conjunction with the Savannah River reactors until a sufficiently large inventory of Palm can be accumulated through the recovery program at Purex.

III. STUDY BASES

The reduction of the production goals for plutonium-238 has correspondingly reduced the neptunium throughput requirements for the over-all target cycle. In addition, improved process technology has become available that permits reducing the capital investment needs for a Palmolive program at Hanford. Thus in a reduced demand program the bases chosen for a preliminary engineering study of fabrication and reprocessing systems can be less conservative in terms of throughput assumptions and more optimistic in terms of process and plant equipment assumptions.

A. Throughputs for Fabrication and Reprocessing

The yields and costs of plutonium-238 from neptunium irradiation are dependent upon: 1) the neptunium content of the element, 2) the neutron flux to which the elements are exposed, and 3) the length of time the target elements are irradiated. The over-all magnitude of these effects has been discussed previously for Hanford-type reactors.(2)(3) To achieve maximum production of plutonium-238, a low neptunium content, a short tube loading and low reactor residence times would be employed, resulting in a high throughput rate for the fabrication and reprocessing systems. To minimize over-all unit costs with reduced program goals, however, a high neptunium content, full tube loadings and a high reactor residence time would be employed, resulting in lower throughput rates for the fabrication and reprocessing systems.

The study bases chosen for the production of 2 kilograms per year plutonium-238 were: a target element 20 per cent by weight in neptunium, full reactor tube loadings, and a reactor residence time of one year. The calculated yields for Hanford K-type reactors would be 107 grams of plutonium-238 produced per kilogram of neptunium-237 based on a tube power of 1.4 megawatts for enriched uranium, a time operating efficiency of 75 per cent, and a uranium integrated exposure of 800 MWD/T. Thus the throughput rates for the fabrication and reprocessing systems would be approximately 20 kilograms of neptunium-237 per year. Assuming target elements 1.4 inches in outside diameter by 12 inches long, each containing 130 to 135 grams of neptunium, approximately 150 elements would be fabricated and reprocessed each year. This throughput rate contrasts sharply with the 2,000 - 4,000 target elements per year needed to process 50 - 100 kilograms per year neptunium as 5 per cent weight alloys as assumed for the high demand goals of earlier studies.(4)(5)

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B. Integrated Facilities for Fabrication and Reprocessing

Close integration of the target element fabrication and reprocessing operations were assumed for study purposes. Earlier studies indicated that in a long-range continuing program new facilities should be installed for fabrication of target elements rather than campaign use of laboratory facilities.(4) In addition, order-of-magnitude cost estimates indicated an incentive to use oxide target elements rather than alloy-type cores. These studies were based on installation of enough shielding (1/2" - 5/8" of lead equivalent) to permit operation with equilibrium levels of protactinium-233, the gamma-emitting daughter of neptunium-237. Rapid processing of the neptunium after purification from the protactinium would minimize shielding requirements to the levels required for miscellaneous accumulated powders. The present study for fabricating reduced numbers of target elements is based on the use of an oxide-type element to minimize capital investment and close integration of the fabrication operation with the purification system to minimize shielding requirements.

The most attractive alternate for reprocessing the neptunium target elements was previously found to be modification of the Hot Semi-Works solvent extraction facility.(5)(6) This approach was again employed with suitable revisions in process and equipment requirements to account for the reduced throughput rate, the close integration with fabrication operations, and newly developed process technology. The irradiation of 20 kilograms per year of neptunium as 20 per cent by weight neptunium target elements represents approximately four tube loadings in a K-type reactor. Reprocessing rates were therefore assumed to be two tube loadings or a 10-kilogram batch every six months. Separation and purification of the plutonium-238 were assumed to be performed relatively rapidly. The neptunium, however, was assumed to be stored as a solution and purified in approximately 1-kilogram batch sizes immediately prior to fabrication so that hood shielding in the fabrication system could be minimized. Maximum utilization of equipment currently available in the Hot Semi-Works Plant was assumed within the limits set by compatibility with operating, maintenance, and process technology needs.

IV. PROCESS TECHNOLOGY

A. Target Preparation

Neptunium target elements suitable for pile irradiation could be prepared at Hanford by a number of process and design alternatives. Processing methods chosen for laboratory evaluation and pre-design cost estimating studies include: 1) the preparation of a neptunium-oxide aluminum powder element by blending and co-extrusion, 2) the preparation of a neptunium-aluminum alloy element by cryolite reduction and vacuum casting, and 3) the preparation of a mixed neptunium-oxide magnesium-oxide element by blending and swaging.(4) The co-extrusion process was successfully developed at Hanford and employed in the fabrication of target elements for irradiation in the Savannah River reactors.(7) The basic steps in the cryolite process have also been demonstrated in a laboratory program at Hanford.(8) In addition, swaging of

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plutonium-containing oxides is planned for the plutonium recycle program. The co-extrusion process, however, was chosen for preliminary engineering studies since it represents the advantages of a minimum capital investment as compared to alloy processes and a minimum surface contamination control problem as compared to swaging processes.

A tentative flowsheet for preparing neptunium target elements by co-extrusion process is presented in Figure 1. Neptunium-oxide, prepared by calcination of neptunium-oxalate, is weighed and blended with aluminum powder (approximately 100 mesh). A large diameter, thick-walled aluminum billet with a conical nose and an open end is cleaned and painted with a strippable coating (for ease in subsequent decontamination). The billet is loaded with a layer of aluminum oxide - aluminum powder mixture that is tamped and pressed (at 25,000 psi) into the nose end. The inert layer is followed by layers of the neptunium oxide and aluminum powder mixture similarly compacted into place and topped with a second layer of aluminum oxide - aluminum powder at the end. The billet is closed with a welded cap and decontaminated by removing the surface coating. The pressed mixture is outgassed at 550 to 600°C for 15 to 20 hours. The hot billet is then extruded to the desired diameter in a large press (150 tons). The can wall thickness resulting from the extrusion process is 80 to 100 mils (as compared to 30 mils for present fabrication cans). The neptunium is located within the extruded piece by radiography and the ends of the piece sawed off to leave 1/4" to 1/2" aluminum oxide - aluminum powder as an integral end closure. The ends are then counter-bored and an aluminum cap welded in place to provide an all-aluminum surface.

The feasibility of the co-extrusion process has been demonstrated by the successful development program at Hanford and the interim fabrication effort for the Savannah River Plant. Adaptation to the Hanford reactors may involve preparing a longer element to prevent chattering in the process tubes and spot-welding bumpers on the element for self-support in ribless tubes.(9) In addition, the welded cap end closure assumed in the flowsheet may be substituted for the integral end closure now employed at Savannah River Plant. Future laboratory development efforts may be directed toward different end closures (both integral and cap closures), different can alloys, closer control of can wall thickness, and general procedural improvements (better lubricants, improved temperature and pressure control).

B. Target Reprocessing

A number of potential process alternatives are available for the reprocessing of neptunium target elements due to the chemical similarity of plutonium, uranium, and neptunium. Many alternatives have been studied at Hanford in conjunction with reprocessing plutonium and uranium for the plutonium production program, reprocessing plutonium for the plutonium recycle program, and recovering neptunium from the Purex Plant. Thus, the behavior of plutonium and neptunium in a TBP solvent extraction system has been studied in support of Purex Plant operations. Anion exchange methods have been developed at Hanford for neptunium purification(10)(11) and at Savannah River for neptunium-237, plutonium-238 reprocessing.(12)(13) Liquid amine extraction methods

using tri-n-octyl and tri-n-lauryl amines are believed to be feasible based on preliminary laboratory tests.(14) Solvent extraction, however, presents some major advantages over the other process methods. Process technology and plant operating techniques, for example, are more highly developed for solvent extraction methods. Based on today's technology the problems associated with controlling solids in the process system and maintaining the desired plutonium-238 valence state (due to alpha bombardment) can be met more readily in a solvent extraction system than in an anion exchange system. In addition, the relative equipment sizes, contact maintenance requirements, and essential material needs all favor use of a solvent extraction process. These factors, plus the availability of solvent extraction equipment of appropriate size, led to the choice of solvent extraction methods for co-decontamination, partition, and plutonium-238 decontamination steps for the target reprocessing system. Anion exchange was chosen for neptunium purification since the technology has been well developed, highly efficient separations are practical, and the batch size (and therefore the equipment size) was intended to be small.

Tentative flowsheets are presented in Figure 2 through 6 for dissolution of the irradiated target elements and preparation of feed solution, co-decontamination and partition of the neptunium and plutonium, decontamination and concentration of the plutonium-238 product, and purification and concentration of the neptunium. The target elements are dissolved in nitric acid with mercuric ion present as a catalyst. The dissolver solution is diluted with acid (recycled from the solvent extraction system) and an oxidant (such as dichromate ion) to provide a feed solution approximately 4 molar nitric acid and 0.2 molar aluminum nitrate. The solution is diluted to a large enough volume to insure satisfactory column operation and neptunium-plutonium partition. The neptunium and plutonium are co-decontaminated in the 1A Column by co-extraction into a 30 per cent TBP solvent phase. The plutonium is partitioned in the 1BX Column by reduction to plutonium III and back-extraction into the aqueous phase. The 1BS Column serves to scrub out residual neptunium and some fission products from the first-cycle plutonium product stream. The neptunium is stripped from the solvent in the 1C Column and stored for subsequent purification by anion exchange.

The plutonium from the partition system is decontaminated and concentrated by "reflux spinning" in a 2A and 2B Column system where the plutonium is extracted, scrubbed and stripped and then recycled to the 2A feed point for re-extraction, scrubbing and stripping. After decontamination, the plutonium is concentrated by a factor of 30 to 50 in a titanium evaporator for load-out as 90 g/l product. Since chemical impurities should not be introduced into the product with such a large concentration factor, the final solvent stripping in the 2B Column is performed with nitric acid and distilled water. A back-up 1F stripping column is provided to insure minimum plutonium losses to the solvent.

The neptunium is purified in 1-kilogram batches as compared to the 10-kilogram solvent extraction runs. The product solution from the 1C Column is adjusted to 6 molar nitric acid and the neptunium reduced to the four valence state by ferrous ion and hydrazine. The neptunium is loaded onto the anion exchange column at 10 mg/min/cm^2. Plutonium is washed from the resin by a stabilized

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reducing agent in 6 molar nitric acid. Fission products are removed with an 8 molar nitric acid wash containing .01 molar fluoride ion and hydrazine. The neptunium is eluted from the column with dilute acid and concentrated for transfer to wet chemistry operations. Neptunium-oxide is prepared by precipitation of neptunium-oxalate from 3 molar nitric acid solution. The precipitate is filtered, dried, and calcined to the oxide for fabrication operations.

A major portion of the process steps has been demonstrated as part of the interim Palmolive program. Thus, extraction and stripping of neptunium for solvent extraction have been accomplished in the Purex Plant as part of neptunium recovery operations.(15) The concept of decontaminating a given amount of product by "reflux spinning" in the 2A - 2B system has been demonstrated in the Purex Plant with recovered neptunium. Purification and concentration of neptunium in kilogram amounts have been successfully accomplished in the interim program as have the neptunium precipitation and calcination steps.(10)(11) Areas of potential difficulties include solids control (for which an organic continuous 1A Column may be adequate), partition control (for which further dilution may be required), plutonium-238 valence control (to which a solvent extraction system should be less susceptible than an anion exchange), solvent degradation (for which the back-up 1F Column is provided and a Purex-type solvent treatment flowsheet with an alkaline-permanganate-treating turbo-mixer, the acid 1C Column, and a carbonate-treating turbo-mixer may be required). To provide a firm flowsheet, research and development is also required in the areas of dissolution (to determine target dissolution and hydrogen evolution rates), decontamination (to determine a suitable oxidant and optimum column conditions), partition (to establish adequate reducing conditions), and plutonium-238 chemistry and extraction (to determine valence change kinetics and solvent degradation). Alternative process methods should also be evaluated for potential long-range application such as use of amines for extraction and possible pyrochemical methods.

V. PLANT EQUIPMENT AND OPERATION

An integrated chemical processing facility is available at Hanford for fabrication and reprocessing of neptunium target elements. As shown in Figure 7, the Hot Semi-Works area contains a three-cell shielded building for processing full-level irradiated fuel elements (201-C), a plant control and aqueous make-up building (271-C), a solvent treatment building (276-C), ventilation and stack facilities (291-C), waste disposal (241-C) and cribbing (216-C) systems, inert gas (215-C) and demineralized water (217-C) systems, hot maintenance shop, cold maintenance shops (272-C & 2707-C), a change house (2707-C) and an office building (2704-C), all within a separate exclusion area. It is proposed that the 276-C Building be modified as a wet chemistry and fabrication building and that the 201-C Building be modified to permit reprocessing and purification of neptunium-237 and plutonium-238.

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A. Wet Chemistry and Fabrication

The 276-C Building proposed for use as the Palmolive wet chemistry and fabrication facility is a multi-storied, unshielded structure formerly employed for treatment and storage of solvent. The ground floor has an area of about 900 sq. feet and each of the three above ground floors has an area of about 450 sq. feet. The equipment on the ground floor and the second floor would be removed while the remaining equipment would be retained for use in the Palmolive program. The existing 7,000 cfm ventilation system would be supplemented by an exhaust filtration system installed on the first floor roof level with the second floor. The dock area along the length of the building would be enclosed with insulated steel siding to provide solution transfer and storage facilities.

As shown in Figure 8, the bulk of the process equipment would be installed on the first floor with the remainder on the second floor. Approximately 70 feet of work stations would be required with roughly 75 per cent in sealed hoods and the remainder in open-face hoods or open work areas. The neptunium would be loaded into the system in transfer cans as concentrated nitrate solution from the 201-C reprocessing building or from the Purex recovery and purification system. The solution would be transferred from the receiver tank to a precipitator tank for precipitation of the oxalate. The slurry would then be filtered in a boat station with the supernatant solution accumulated for recycle to the 201-C purification system. The filter cake would be dried and calcined in a furnace. The resulting neptunium oxide would be weighed, blended with aluminum powder and pressed into an aluminum billet. The billet would be decontaminated, out-gassed, and extruded. The final steps would include radiographing, sawing, counterboring, and welding the end caps. The finished elements would be stored in shielded units. Hood sizes and equipment pieces assumed for cost estimating purposes are summarized in Table I.

The process operations in the 276-C Building would be closely integrated with those in the 201-C to minimize shielding requirements. The feed material received into the system would thus be free of the gamma-emitting protactinium-233 and would be processed rapidly to minimize the amount formed while handling the elements. Time cycle studies based on the interim fabrication program indicates that such a scheme is feasible.(16) One kilogram of separated neptunium could be fabricated into seven elements within two days so that the increase in protactinium-233 would be less than 5 per cent of the equilibrium level. Some hood shielding should be provided due to the probable accumulation of aged powders. The hoods could therefore be constructed of stainless steel sheet with thin lead glass windows rather than plastic siding. The final storage system would be shielded for equilibrium levels of protactinium-233 -- 1/2" to 5/8" lead equivalent.

B. Neptunium Reprocessing

The 201-C Building proposed for use as the Palmolive reprocessing facility is a heavily-shielded, three-cell structure formerly employed for piloting the Redox and Purex processes with full-level irradiated fuel elements. The A and C cells contain 880 sq. feet of process area each and the B cell 720 sq.

feet. The shielding walls are three to five feet thick. The building contains equipment suitable, with minimum modifications, for dissolution, co-decontamination, partition, and purification of the neptunium and plutonium. The hot maintenance shop would be modified to provide improved solution transfer facilities and an expanded work space. A new crib would be provided for disposal of wastes and a new 5,000 gallon underground tank would be installed for temporary storage of recycle solutions.

As shown in Figure 9 the high-level feed and waste tanks are contained in A cell, the solvent extraction columns in B cell and the intermediate and low-level tanks in C cell. A new charging machine would be required to load the long elements into the dissolver. Dissolution and feed preparation would be carried out in existing equipment. The extraction and stripping columns in the co-decontamination and plutonium purification cycles would be replaced with new columns of similar size but with improved column internals. The existing columns would be employed for the partition and solvent treatment steps. The piping between existing tanks would be rerouted to provide intercycle feed and receiver systems. A new receiver would be provided for the first-cycle waste and a new tube bundle for the neutralizer and utility concentrator. Wastes would be transferred to existing underground storage tanks. Two existing tanks would be provided with turbo-mixers for solvent treatment. The plutonium-238 product would be concentrated in a new titanium evaporator for load-out. The neptunium-237 would be purified in a new anion exchange column using existing equipment for feed and waste tanks. Final evaporation of the neptunium for transfer to 276-C Building would be accomplished in an existing concentrator. The equipment requirements assumed for cost estimation purposes are summarized in Table I.

The 201-C Building was designed as a remotely-operated, contact-maintained plant and could not be employed otherwise without a major capital expense. The experience gained in operation of the plant as a semi-works unit, however, coupled with the low operating efficiency needed to meet the Palmolive goals, should permit operation of the plant as a manufacturing facility within reasonable personnel exposure and maintenance cost limits. A number of specific recommendations for equipment revisions have been made by Hot Semi-Works personnel for raising the on-stream efficiency of the plant from approximately 35 per cent to an estimated 60 or 70 per cent.(17)(18) These revisions include installation of stainless steel floors in the cells, spot-shielding of critical tanks and sumps, welding of process and sampler lines (rather than use of fittings), compartmentalization of high-level equipment pieces, locating critical equipment for rapid access and replacement, providing certain equipment pieces with remotely-replaceable parts. A major fraction of the revisions were made upon shutdown of the Semi-Works operations. The others are assumed to be required prior to start-up for cost estimating purposes. In addition, further revisions may be desired for operation of the plant as a manufacturing unit including cleaning and painting of cell walls, installation of hoods around the Olive samplers, identification of lines in the cells, replacement of certain instruments and pumps, expansion of the cell lighting system, and provision of an outside solution storage tank. Such revisions have also been assumed for cost estimating purposes.

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In addition to adoption of equipment revisions for increased maintenance efficiency, use of the 201-C Building as a manufacturing plant is believed to be made practical by the low operating efficiency needed to meet the Palmolive production goals. Processing the 10 kilograms of neptunium associated with two reactor tubes should involve about one week processing time every six months. Thus the solvent extraction system could be operated on a campaign basis probably with personnel borrowed from the main chemical processing plants. Such infrequent operating campaigns would require planned start-up maintenance and cold run-in programs. The processing schedules and personnel needs assumed for cost estimating purposes are summarized in Table II. Each 10 kilograms of processing campaign would be preceded by a two to three week period of start-up maintenance and calibration work performed by the skeleton operating crew normally assigned to the plant, supplemented by a campaign maintenance crew. There would then be one week of cold solvent extraction runs performed by the normal operating crew. The skeleton crew supplemented by the campaign operating crew would operate the system with cold and reject elements for about a week and then with hot elements for a second week. The plant would be shut down and the B cell decontaminated during the following three to four weeks by the skeleton crew (extensive non-routine decontamination is assumed to be required once a year). Neptunium purification runs would then be started in B cell with each batch processed on through the element fabrication prior to starting the next batch. The normal crew would perform the purification, wet chemistry, and fabrication operations for 16 to 18 weeks until start-up of campaign operations was again necessary. Such a schedule permits extensive decontamination and maintenance work between campaigns if it should be required. The high maintenance costs associated with such decontamination programs, however, should be minimized by the equipment revisions assumed as plant modification costs.

VI. COST ESTIMATES

Modification of the Hot Semi-Works Area to provide an integrated manufacturing facility for Palmolive fabrication and reprocessing is estimated to involve a capital cost of about $2,000,000. As shown in Table III approximately 0.9 million dollars would be required for modification of the 276-C Building to a wet chemistry and fabrication facility and 1.1 million for modification of the 201-C Building for reprocessing the target elements and installation of underground storage tanks, a waste crib and the hot shop expansion. The estimated capital cost is less than the conservative value of $3,000,000 previously estimated and approaches the previously optimistic value of $1,800,000.(2)(4)(6) The reduction in estimated capital costs results from reduced program goals and the existence of a firmer technical basis, especially with respect to target element fabrication. The capabilities of the proposed manufacturing facilities could probably be expanded by at least 100 per cent beyond the current goal of 2 kilograms per year plutonium-238 with essentially no further capital investment.

Activation of the Hot Semi-Works facility for the Palmolive program would involve transfer of the building and equipment capitalized value to the Palmolive account. The net book value of the facility as of April 30, 1959 was

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approximately $3,100,000. Of the total, $800,000 represents buildings and $2,300,000 represents other structures and equipment.

The estimated annual operating costs for fabricating and reprocessing 20 kilograms of neptunium per year at the modified Palmolive facility are summarized in Table IV.

The total annual charges for the Palmolive fabrication and reprocessing program would be dependent upon the rate of depreciation assumed for existing and new buildings and equipment. Assuming a depreciation rate of 2.5 per cent per year for buildings and 5 per cent per year for equipment (approximately the current rates), annual depreciation charges would be $200,000 per year for the transferred capital and approximately $100,000 per year for the construction capital costs. Total annual charges would thus be $870,000 to $1,120,000 and the corresponding incremental annual charges would be $450,000 to $650,000.

VII. SCHEDULING

The production phase of the Palmolive program could be initiated at Hanford during the fourth quarter FY 1960; final integration of all the manufacturing facilities associated with the program could be completed by the end of the second quarter FY 1962. A possible design and construction schedule for modification of the 201-C Building to a reprocessing facility and the 276-C Building to a fabrication line is presented in Figure 10. The schedule is based on the availability of research and development amounts of plutonium-238 at Hanford prior to August, 1959 (recent cancellation of an MTR target irradiation test has prevented obtaining plutonium-238 and thus hindered flowsheet development). If design funds are authorized early in the second quarter FY 1960, the 201-C Building modifications could be completed on an expedited basis during fourth

quarter FY 1961 (19-21 months for beneficial use) and the 276-C Building modification during the second quarter FY 1962 (24 to 26 months). Fabrication of the target element for two reactor tubes (76 elements) could be performed during the fourth quarter FY 1960 and first quarter FY 1961 in existing laboratory facilities at Hanford. The elements could then be charged into the Hanford reactors during first quarter FY 1961, irradiated for approximately six months or more, and cooled for approximately six months prior to reprocessing in the 201-C Building. The recovery goals at the Purex Plant are 11 kilograms of neptunium during FY 1959 and FY 1960 which would be adequate. A standard over-all time cycle of 12 months for irradiation, three months for cooling, and six months for reprocessing and fabrication could probably be initiated with the second two-tube reactor charge. If the demand for plutonium-238 should exceed the capabilities of the Hanford reactors for a given inventory of neptunium, the proposed fabrication and reprocessing system could be readily operated in conjunction with the Savannah River reactors until a sufficiently large inventory of neptunium can be accumulated through the recovery program at Purex.

VIII. ACKNOWLEDGEMENT

The preliminary engineering study was based on the direct and indirect efforts of many groups within HAPO. Major direct contirubtors included: C. R. Cooley, E. A. Coppinger, W. S. Hartnett, J. R. LaRiviere, R. L. Lysher, E. T. Merrill, and R. J. Pence.

IX. REFERENCES

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13) Letter, A. T. Gifford from W. K. MacCready, "Palmolive Program", dated April 15, 1959.

14) Geneva 1958, "Tertiary Amine Extraction of Plutonium from Nitric Acid Solutions", AS Wilson, June, 1958.

15) HW-58236, "Palm Recovery - Purex Reflux Considerations" by WH Swift, November 20, 1958.

16) W. S. Hartnett, Personal Communication

17) Geneva 1958, "Operating Experience in a 'Hot' Solvent Extraction Pilot Plant", GC Oberg and RJ Sloat, June, 1958.

18) C. R. Cooley, Personal Communication.

TABLE I

WORK SHEET
TENTATIVE SEMI-WORKS HOT PROCESS EQUIPMENT REQUIREMENTS
FOR PALMOLIVE PROCESSING

201-C A Cell

Vessel Number	Size-Gallons	Function	Revisions
1	140	Dissolver	None
2	110	Back cycle acid add tank	New piping to TK3 and from TK82
3	270	Feed adjustment	New piping from TK2
5	275	Dissolver off gas scrubber	None
6	255	Feed storage	None
G-6	9	Feed centrifuge	Not used
7	170	1AF	None
8	300	Condensate catch tank	None
54	805	Condensate storage	None
55	700	Neutralizer & utility concentrator	Modify vessel with remotable tube bundle; gilmont
64	65	1AW catch tank	None
67	55	2WW catch tank	New piping to TK82, TK57 and TK2
69	470	1AW storage	Replace existing TK69 with existing TK22. Modify as required to take agitator and connect to vent system.
73	180	2AW concentrator	New piping to condenser 67. New piping to TK 67.
82*	5000	Back cycle acid storage	New

*In new vault adjacent to A Cell

TABLE I (CONTINUED)

201-C B Cell

Vessel Number	Size-Gallons	Function	Revisions
75	265	XAF	New piping to TK12 and XA Column. New piping from weigh tank 42.
81	345	XAW	New piping to TK55 and TK12.
1A Column	3 inches by 25 feet	Co-decontamination	New, sieve plate column
1C Column	3 inches by 15 feet	Co-decontamination	New, sieve plate column
1BX Column	4 inches by 18 feet	Partition	New piping for pulse leakage. Weld flanges.
1BS Column	1 inch by 12 feet	Partition	New piping for pulse leakage. Weld flanges.
2A Column	5 inches by 25 feet	Pu decontamination	New packed column
2B Column	2 inches by 21 feet	Pu decontamination	New sieve plate column
1F Column	4 inches by 38 feet	2BW - strip	New piping to TK11. Weld flanges.
10 Column	5 inches by 16 feet	Solvent Recovery	New piping from TK52
XA Column	8 inches by 5 feet	Np decontamination	New

TABLE I (CONTINUED)

201-C C Cell

Vessel Number	Size-Gallons	Function	Revisions
9	60	None	None
10	370	Condensate catch tank	New piping from E-17 condenser
11	805	10F turbomixer	New piping to TKS 55, 21, 10 Column and from AMU. Modify tank to function as a turbomixer.
12	410	1CN catch tank	Relocate TK13 pump to TK12 and provide piping to TKS 75 and 7.
13	1800	1CN storage tank	None
14	295	1BXF	None
15	370	1CW catch tank	None
16	805	100	New piping from TK78
17	95	Np product concentrator	New piping from E-17 condenser to TK10. New piping from TK17 to TK12.
18	130	10R	None
19	25	Np product catch tank	New piping to load out station
20	130	None	None
21	1430	10C turbomixer	New piping to TK78 and from AMU. Modify tank to function as a turbomixer.
57	90	2AF	New piping from 1F & 2B Columns
76	180	None	None
78	210	Decanter	None
83	80	Pu product concentrator	New
84	25	Pu product catch tank	New

TABLE I (CONTINUED)

201-C Hot Shop

Hood	Equipment
Neptunium product load out	Scale, hoist, vacuum transfer system, decontamination station.
Plutonium product load out	Scale, hoist, vacuum transfer system, decontamination station.
Recycle load-in	Hoist, receiver tank, vacuum transfer system, decontamination station

AMU Building

Present chemical add tanks	Activate for use; install vent system.
Resin add tank	New
Distilled water supply	New

TABLE I (CONTINUED)

Hood	Approximate Size Feet	Equipment
276-C 1st Floor		
Load in	6 x 2.5 x 4	Hoist, 20 gal. receiver, vacuum transfer system, decontamination station.
Wet chemistry	12 x 2.5 x 4	20 gal. precipitator, agitator, filter station, 3-2 liter filter boats, 20 gal. supernatant tank, 5 gal. vacuum trap.
Dry chemistry	8 x 2.5 x 4	Calcination furnace (600°C), 5 gal. acid catch pot.
Powder preparation	6 x 2.5 x 4	Balance and ball-mill
Compacting	4 x 3.5 x 4	25,000 psi press
Billet preparation	8 x 2.5 x 4	5 gal. catch pot, 580°C outgassing furnace, vacuum pump, welding machine.
Extrusion	8 x 3.5 x 4	150 Ton extrusion press
276-C 2nd Floor		
Open face finishing hood	16 x 3 x 4	X-Ray machine, saw, lathe, welding machine
Chemical makeup		Existing tanks

NOTE: All hoods are of stainless steel construction with lead glass viewing ports. Glove ports are shielded and equipped with leaded rubber gloves. Surfaces are smooth finish and water-tight to permit ease in decontamination.

TABLE II

WORK SHEET

PRELIMINARY ESTIMATES OF PERSONNEL NEEDS & SCHEDULES

	Minimal Operating Crews		Full Complement Crews	
	Normal Skeleton Crew	Supplementary Campaign Crew	Full Complement Crew	Supplementary Campaign Crews
Personnel Needs	Manpower	Manpower	Manpower	Manpower
Chemical operations	2	4	6	-
Utility operations	2	2	4	-
Radiation monitoring	1	5	6	-
Mech. maintenance	2	2	2	2
Elect. maintenance	1	1	1	1
Instr. maintenance	1	2	1	2
Direct	9	16	20	5
Process technology	1	2	1	2
Supervision	1	2	3	-
Duties & Schedules	Direct Manweeks/year	Direct Manweeks/year	Direct Manweeks/year	Direct Manweeks/year
Start-up maintenance (4 wks/yr)	36	24	80	20
Start-up calibration (2 wks/yr)	18	-	40	-
Cold solvent extraction runs (2 wks/yr)	18	-	40	-
Cold and reject runs (2 wks/yr)	18	30	40	8
Hot runs (2 wks/yr)	18	30	40	8
B Cell decontamination (3 wks/yr)	27	-	60	-
A&C Cell decontamination (5 wks/yr)	45	55	100	-
Purification, wet chemistry and fabrication (32 wks)	288	-	640	-
	468	139	1040	36

TABLE III

WORK SHEET

PRELIMINARY ESTIMATES OF HOT SEMI-WORKS MODIFICATION COSTS

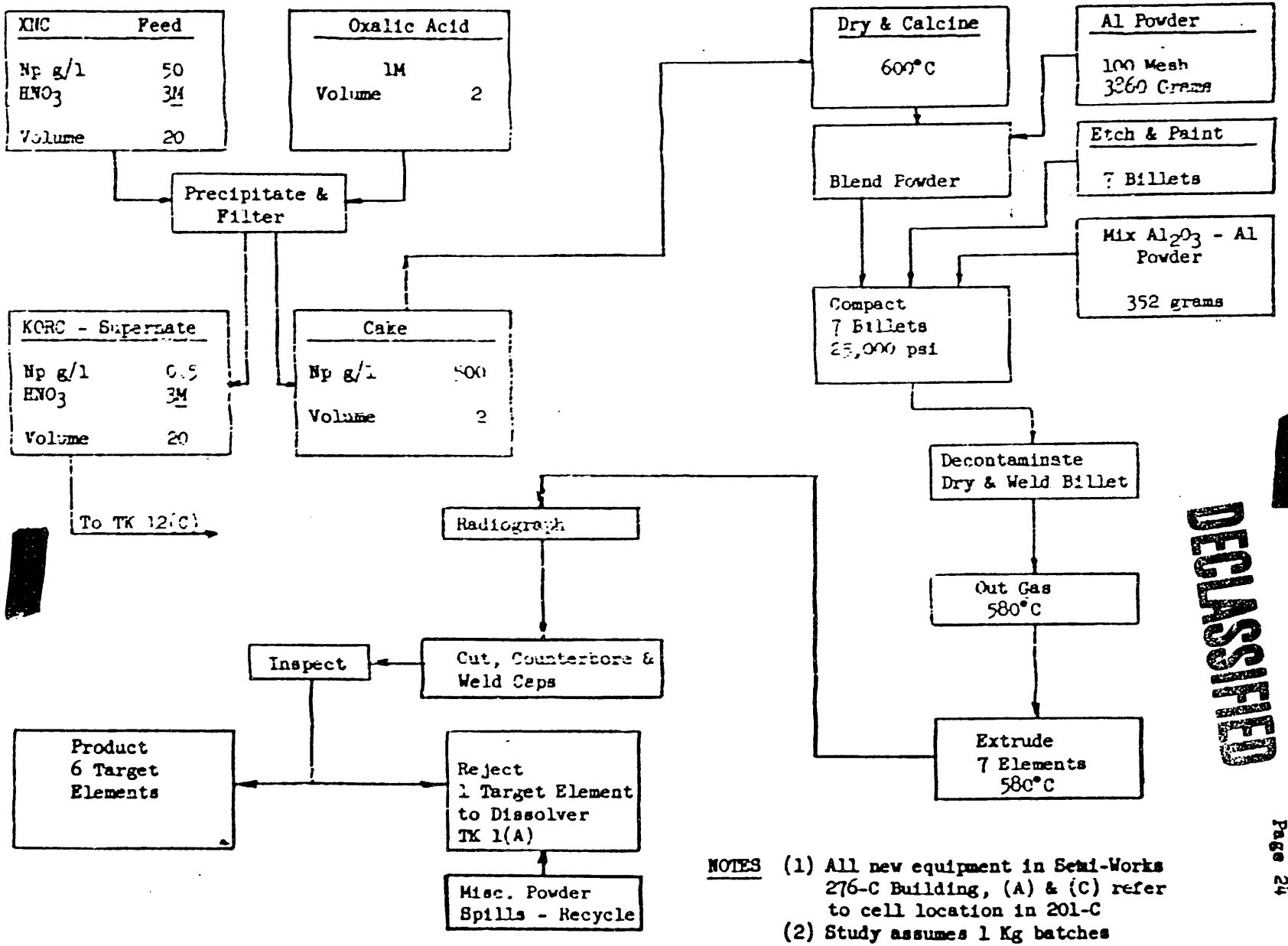
	Reprocessing Modifications (201-C)	Fabrication Modification (276-C)	Total
Building Modifications			
Temporary Construction	$ 7,000	$ 8,000	$ 15,000
Area Activation	38,000	15,000	53,000
Building & Structure	-	18,000	18,000
Hoods & Shielding	35,000	48,000	83,000
Process Equipment	238,000	316,000	554,000
Instrument & Electrical	92,000	59,000	151,000
Direct Costs	$ 410,000	$ 464,000	$ 874,000
Contractor Indirect	130,000	91,000	221,000
	$ 540,000	$ 555,000	$ 1,095,000
Fixed Price Contracts			
Hot Shop Expansion	$ 48,000	-	$ 48,000
Underground Storage	46,000	-	46,000
New Crib System	6,000	-	6,000
	$ 100,000		$ 100,000
Supervision of Construction (5%)	$ 30,000	$ 28,000	$ 58,000
Project Start-up (5%)	30,000	28,000	58,000
Contingency & Escalation (30%)	205,000	180,000	385,000
General Overhead (5%)	45,000	39,000	84,000
Management Services	40,000	32,000	72,000
Design Services	110,000	53,000	163,000
TOTAL ESTIMATED MODIFICATION COST	$ 1,100,000	$ 900,000	$ 2,000,000

Table IV

WORK SHEET
TENTATIVE ESTIMATES OF ANNUAL OPERATING COSTS

FIGURE 1

TENTATIVE NEPTUNIUM WET CHEMISTRY & TARGET ELEMENT FABRICATION FLOWSHEET



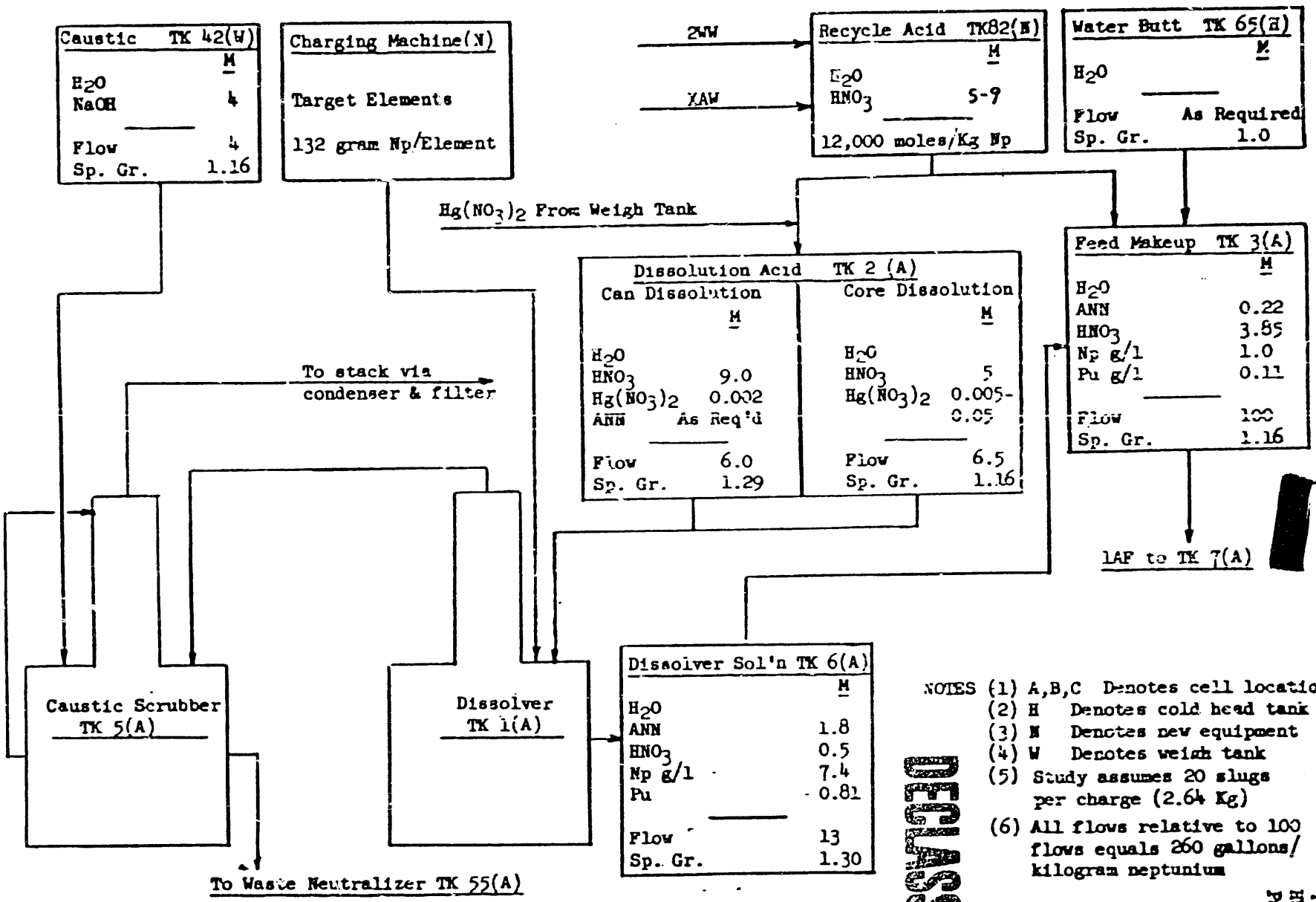
NOTES (1) All new equipment in Semi-Works 276-C Building, (A) & (C) refer to cell location in 201-C

(2) Study assumes 1 Kg batches

(3) All volumes in liters

FIGURE 2

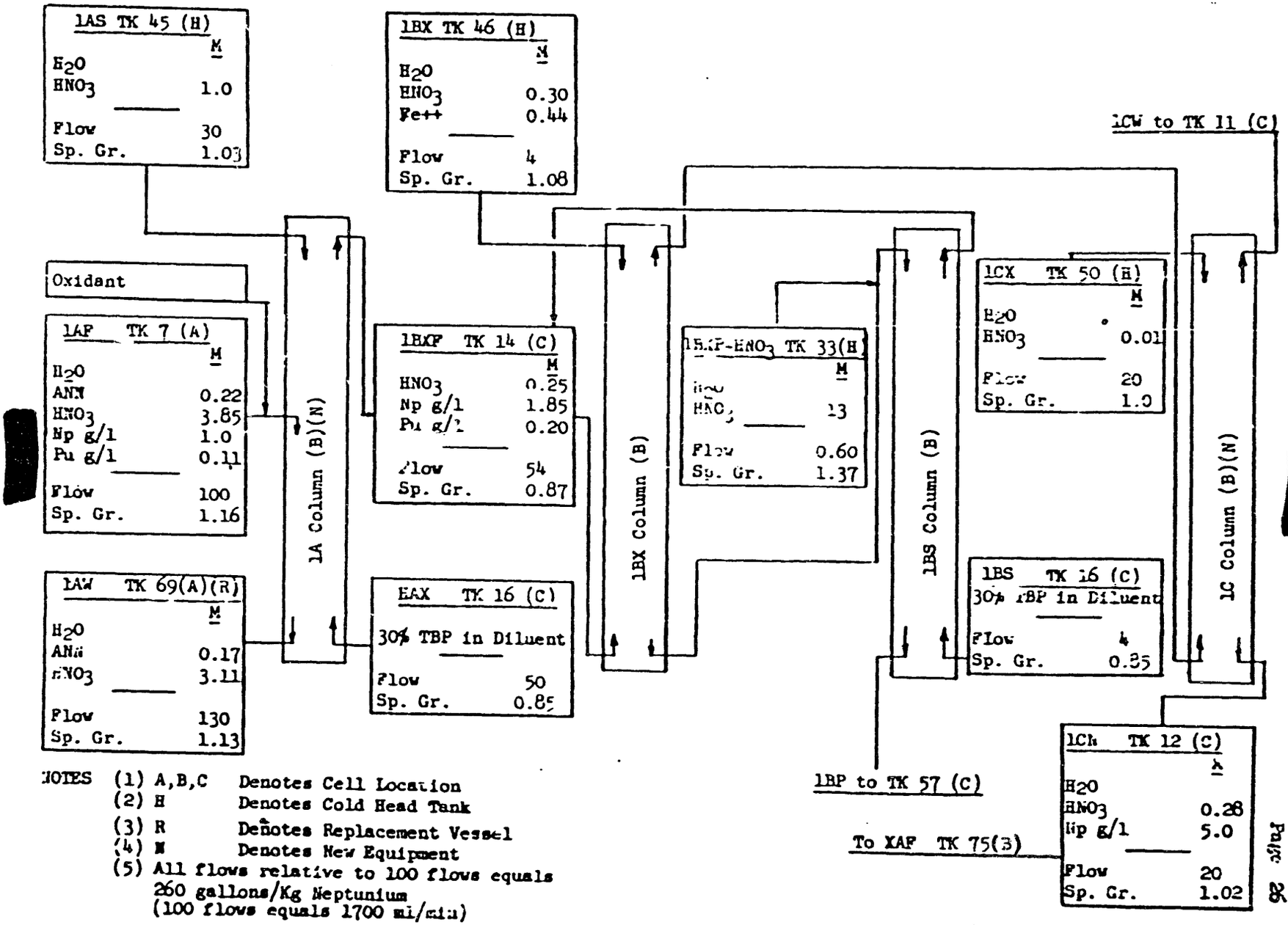
TENTATIVE TARGET ELEMENT DISSOLUTION FLOWSHEET



NOTES (1) A,B,C Denotes cell location
(2) H Denotes cold head tank
(3) N Denotes new equipment
(4) W Denotes weigh tank
(5) Study assumes 20 slugs per charge (2.64 Kg)
(6) All flows relative to 100 flows equals 260 gallons/kilogram neptunium

FIGURE 3

TENTATIVE FIRST CYCLE CODECONTAMINATION AND PARTITION FLOWSHEET



NOTES (1) A,B,C Denotes Cell Location
(2) H Denotes Cold Head Tank
(3) R Denotes Replacement Vessel
(4) N Denotes New Equipment
(5) All flows relative to 100 flows equals 260 gallons/Kg Neptunium (100 flows equals 1700 ml/min)

FIGURE 4

TENTATIVE PLUTONIUM DECONTAMINATION FLOWSHEET

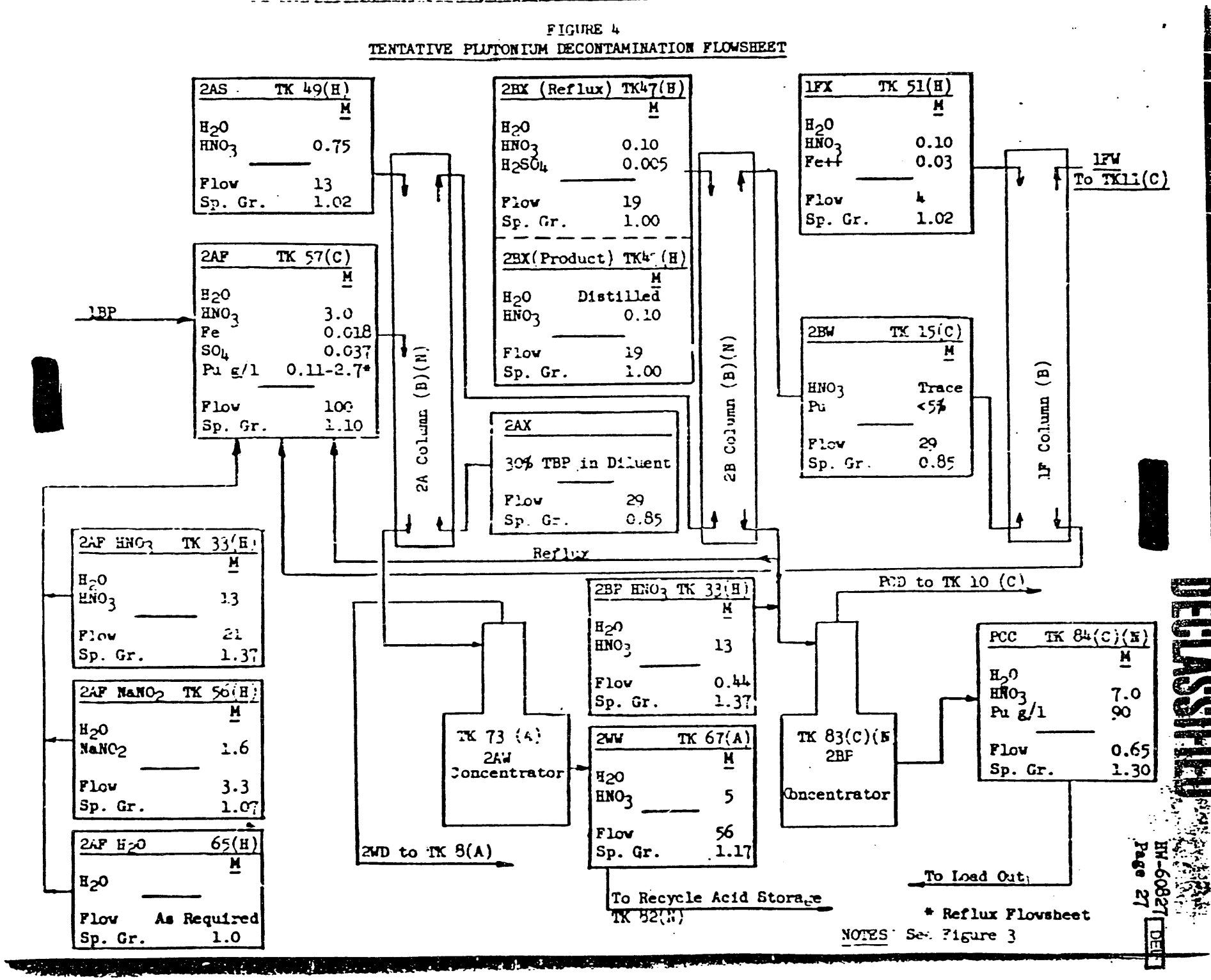
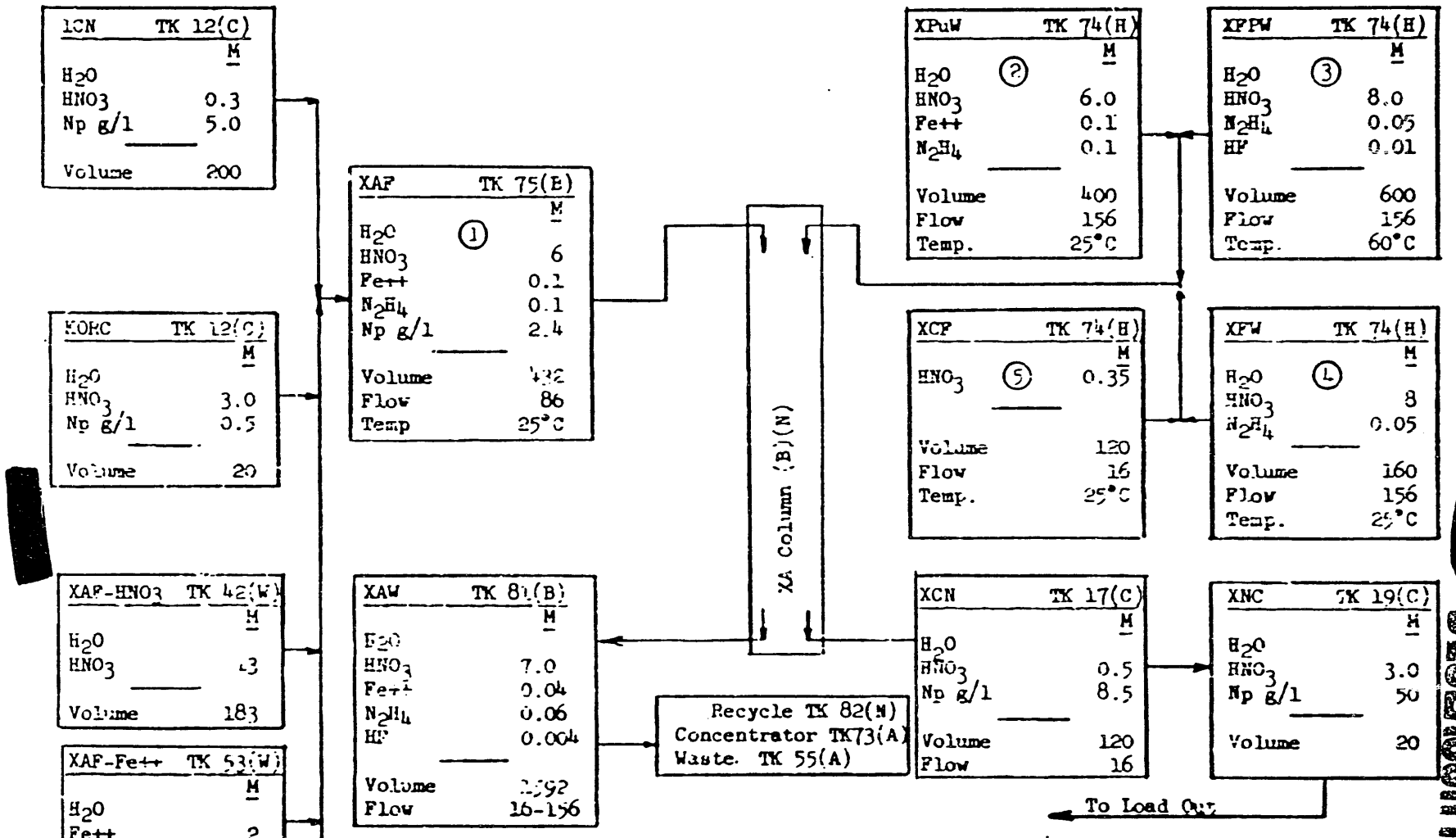


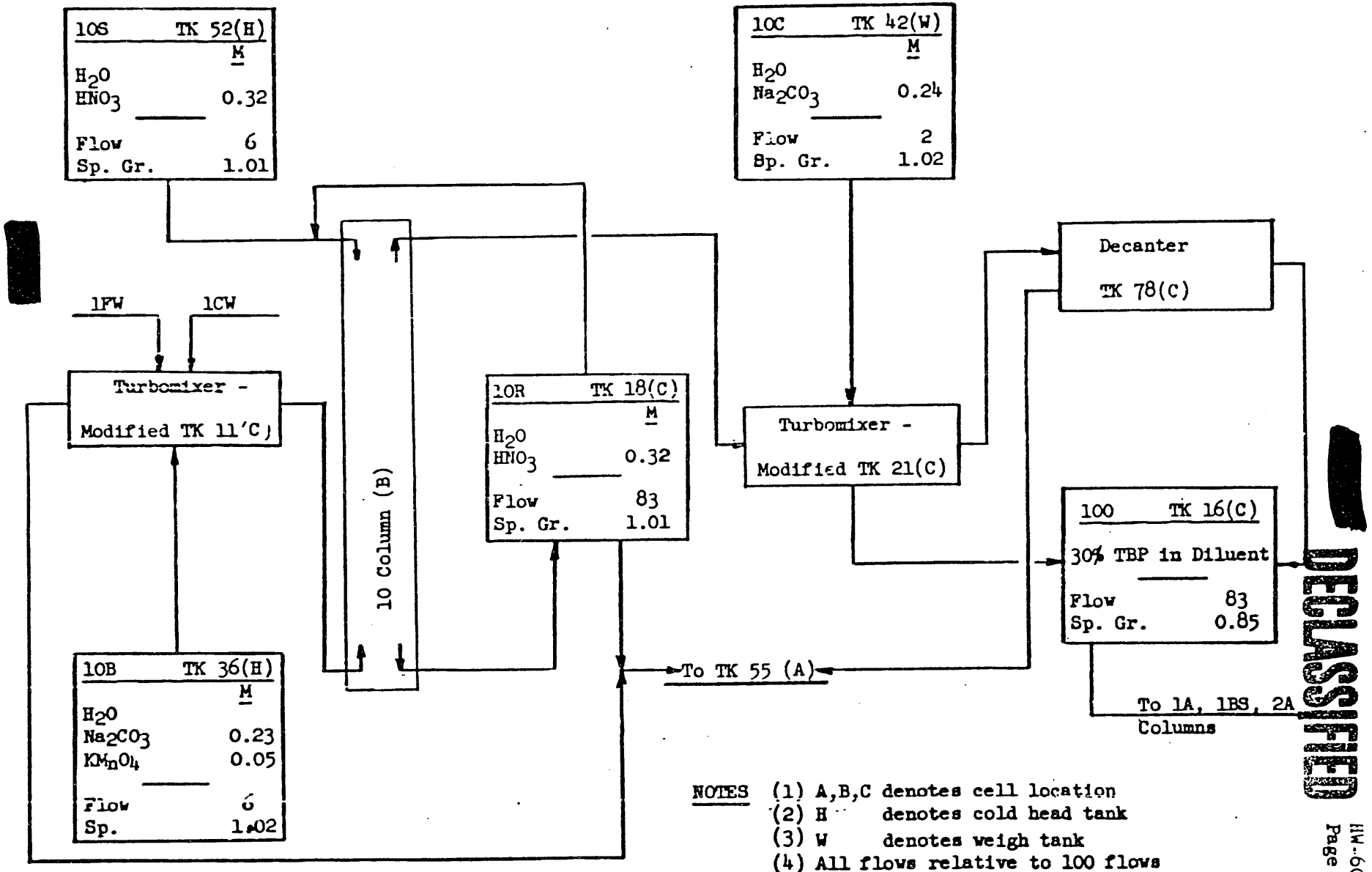
FIGURE 5

TENTATIVE NEPTUNIUM DECONTAMINATION FLOWSHEET



NOTES (1) A,B,C Denotes cell location
(2) H Denotes cold head tank
(3) W Denotes weigh tank
(4) N Denotes new equipment
(5) Study assumes 1 Kg batches with all flows relative to 100 flows equals 260 gallons/Kg Np (100 flows equal 1700 ml/min)
(6) All volumes in liters
(7) Sequence of operations (1) (2) (3) (4) (5)

FIGURE 6
TENTATIVE SOLVENT TREATMENT FLOWSHEET



NOTES (1) A,B,C denotes cell location
(2) H denotes cold head tank
(3) W denotes weigh tank
(4) All flows relative to 100 flows equals 260 gallons/Kg neptunium (100 flows equals 1700 ml/min)

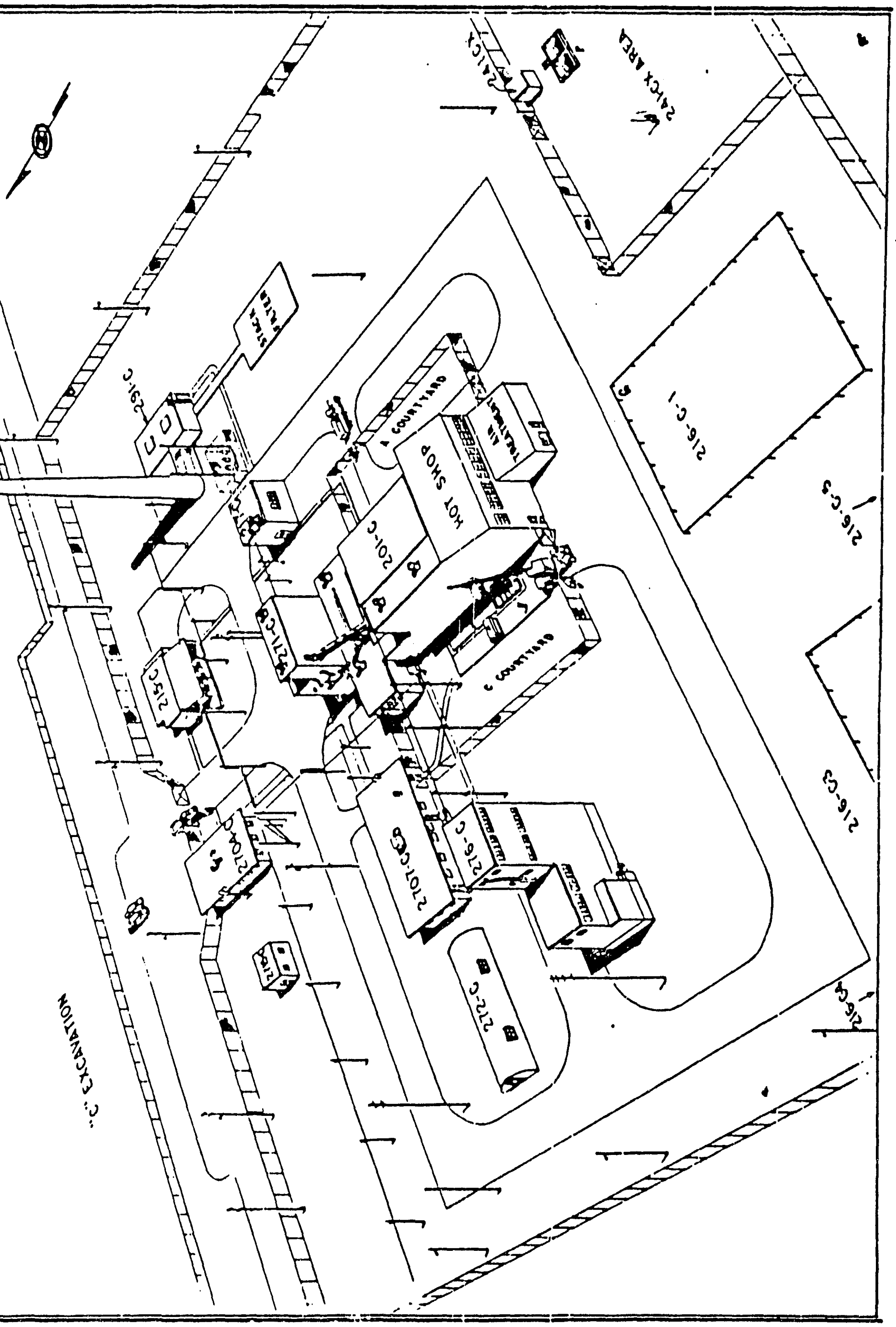


FIGURE 7

AVAILABLE CHEMICAL PROCESSING FACILITY

FIGURE 8

TENTATIVE EQUIPMENT LAYOUT - WET CHEMISTRY & TARGET ELEMENT FABRICATION - 276-C BUILDING

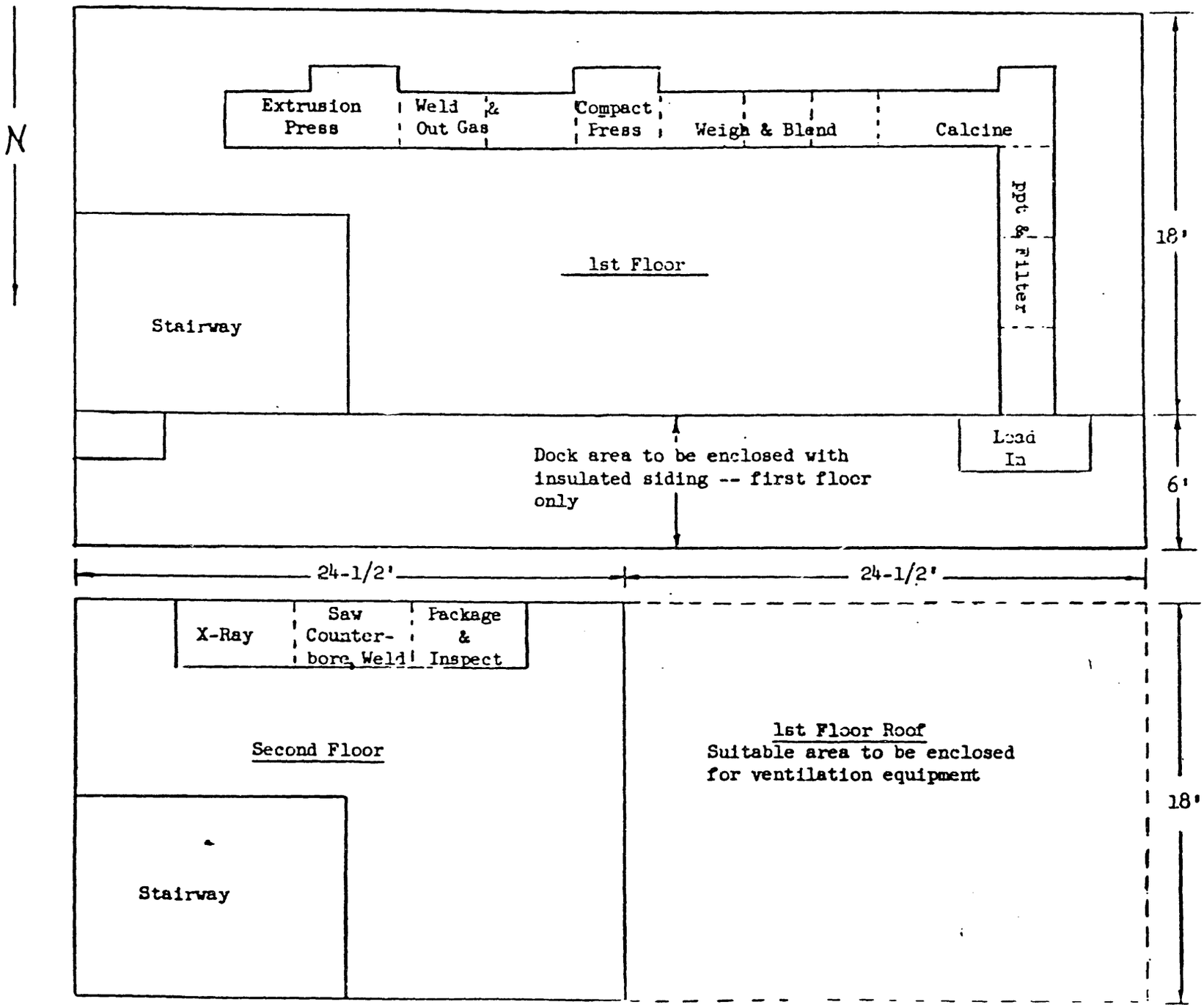
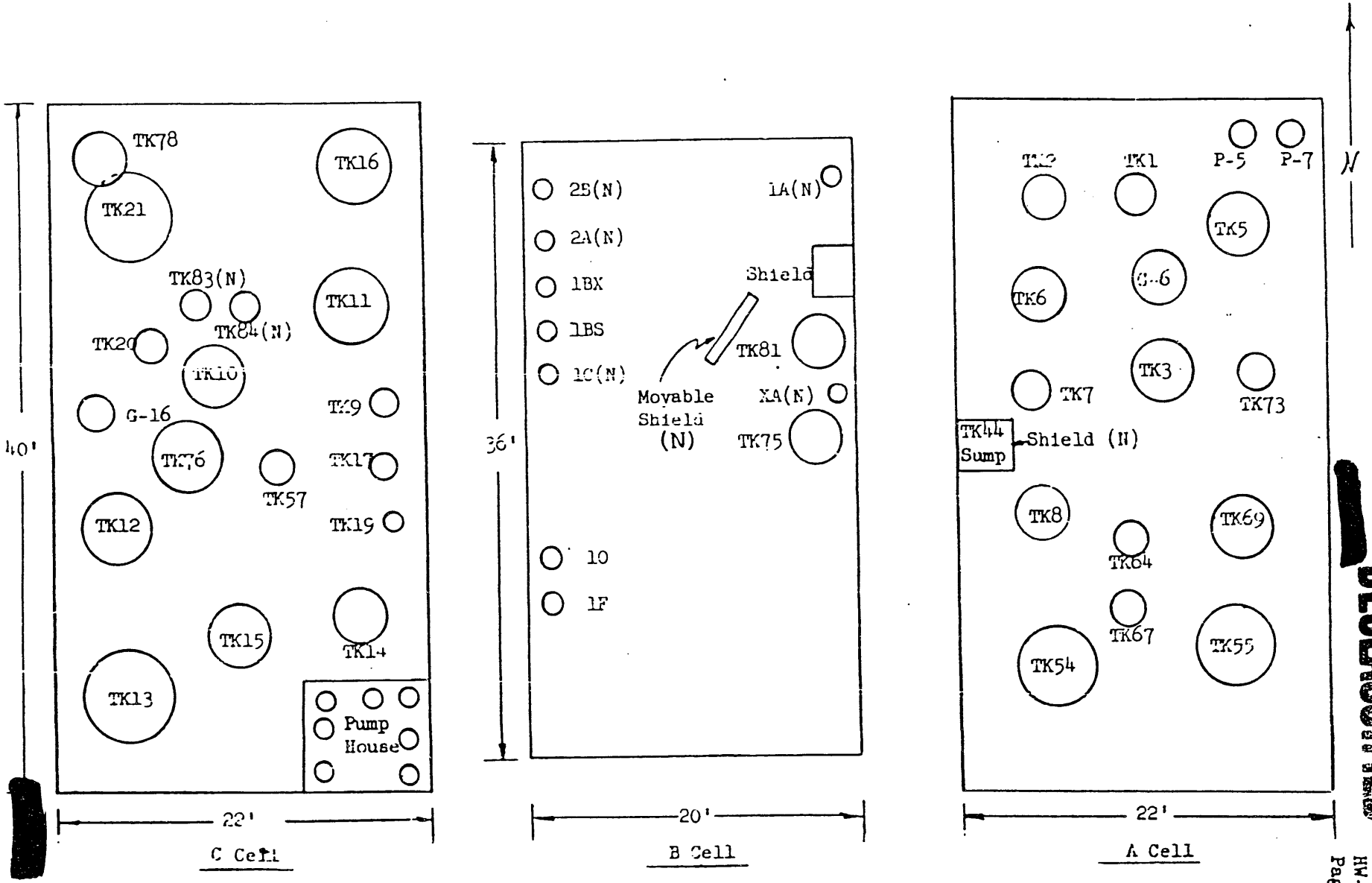


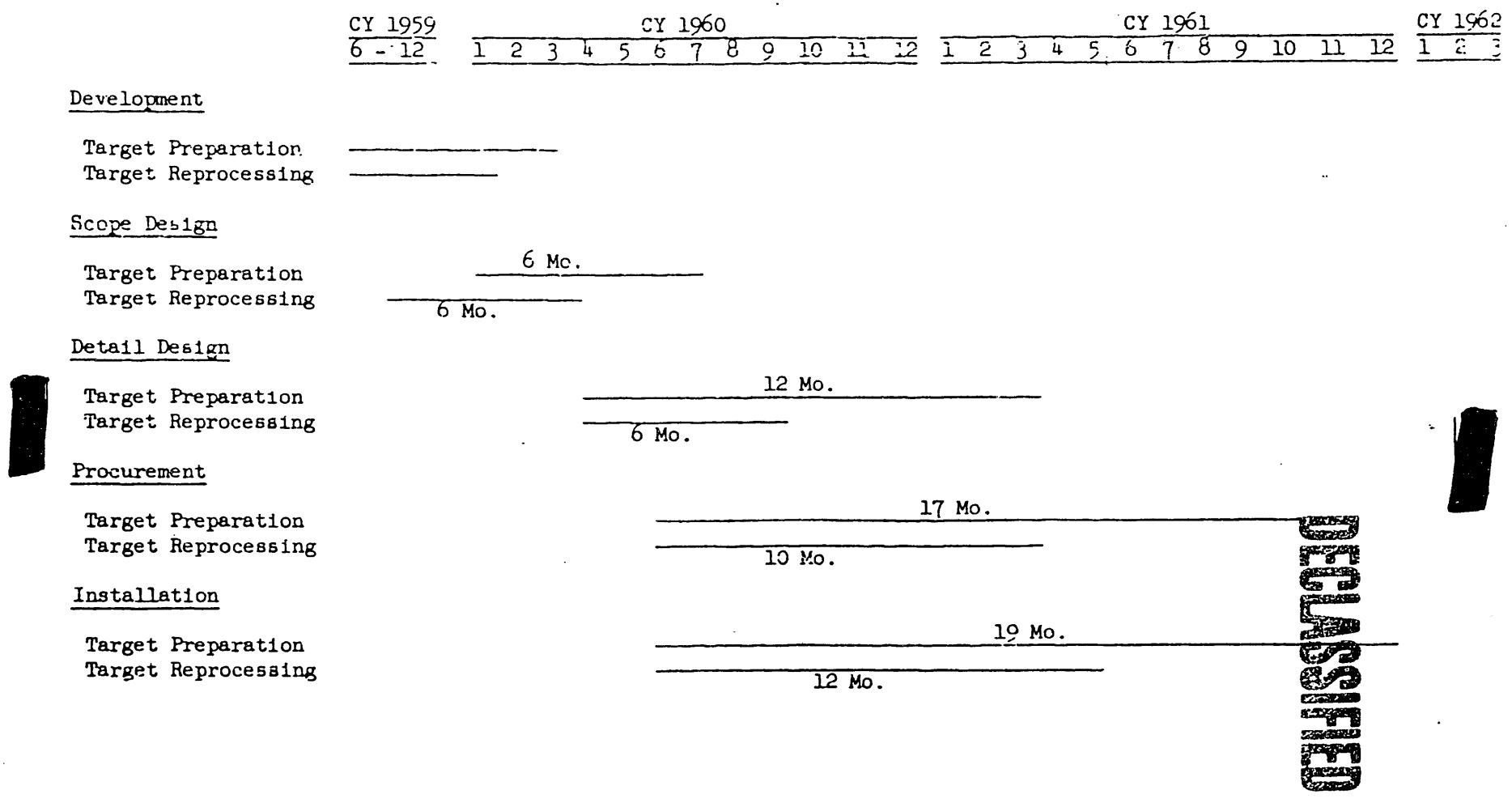
FIGURE 9
TENTATIVE A, B, C, CELL EQUIPMENT LAYOUT



NOTE (1) N denotes new equipment
(2) P denotes remotable pump

FIGURE 10

TENTATIVE SCHEDULES FOR PALMOLIVE PROCESSING



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