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THE PUREX PROCESS

A Training Lecture by
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1. INTRODUCTION

Construction of the F-Area Purex facilities was completed in the early 1950's, and irradiated fuel processing started in November 1954. Processing facilities were shut down from March 1957 to March 1959 for modification and for installation of larger equipment, primarily jumbo mixer-settlers and continuous evaporators, to increase throughput by a factor of about three. Uranium throughput is normally in the range of 10 to 13 metric tons per operating day.

2. DESCRIPTION

A. Summary

[1][1] Major operations in the Purex process are shown schematically. Irradiated target or fuel slugs are received from the reactor areas, charged to the dissolvers, and dissolved in nitric acid. The resulting solution contains primarly uranium-238 with smaller amounts of uranium-235, plutonium, and fission products. Dissolver solution is processed through head end to remove silica solids. The clarified solution is chemically adjusted and fed to the first solvent extraction cycle. Uranium and plutonium are extracted into solvent in centrifugal contactor 1A. About 95% of the fission products remain in the aqueous phase and are transferred to high activity waste. Plutonium is separated from uranium in mixer-settler 1B by stripping it from the solvent, and it is then transferred to the second plutonium solvent extraction cycle. In this cycle, plutonium is further decontaminated and concentrated by extracting it from the aqueous feed into solvent in mixer-settler 2A. Plutonium is stripped from the solvent in mixer-settler 2B. The resulting aqueous stream is transferred to JB-Line where the plutonium is precipitated and reduced by reaction with calcium to produce plutonium metal as a disk or button.

Uranium, which remained in the solvent in mixer-settler 1B, is stripped from the solvent in mixer-settler 1C. The aqueous uranium stream is concentrated in a continuous evaporator prior to being fed to the second uranium solvent extraction cycle. The concentrate is chemically adjusted and the uranium is further decontaminated by extracting it into solvent in mixer-settler 1D and stripping it from the solvent in mixer-settler 1E. The aqueous stream leaving mixer-settler 1E is transferred to A-Line (outside facilities) where uranium is processed to uranium trioxide.

Each of the three solvent extraction cycles has a separate solvent system. Solvent leaving each cycle is washed alternately with 2.5% sodium carbonate and dilute nitric acid to remove fission products and solvent degradation products before reuse.

The aqueous waste stream from centrifugal contactor 1A contains most of the fission products; it is transferred to high activity waste (HAW) and evaporated to reduce waste volume and recover nitric acid. In 1960, additional equipment was installed in the canyons and flowsheet changes were made to permit recovery of Pu and byproduct Np from high activity waste. High activity waste is processed

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[1] Bracketed numbers (originally slide numbers) refer to the numbers in the lower left corner of the figure pages.

through the primary recovery column (PRC) where Pu and Np are recovered on anion resin. The waste is neutralized and transferred to underground storage tanks. Fission products are removed from the Pu and Np which are then stripped from the PRC and transferred to special ion exchange equipment in the warm canyon for further decontamination, separation of Pu from Np, and recovery of the Np. The plutonium is transferred to the second Pu solvent extraction cycle for recovery and the Np is shipped to HB-Line.

B. Dissolving – Head End

[2] Typical Purex feed consists of target or fuel slugs with a core of depleted or natural uranium metal and aluminum cladding. The slugs are shipped in buckets from one of the reactor areas (P, K, or C) in a shielded railroad car called a cask car. The slugs are charged to annular dissolver 6.4. The aluminum cladding, or coating, is dissolved by metering in 50% NaOH in the presence of $NaNO_3$. The $NaNO_3$ suppresses the formation and evolution of hydrogen during the dissolving of the aluminum. The alkaline solution of aluminum, called coating waste, is transferred to tank 5.3. A portion of this coating waste solution is recycled to the dissolver for the next aluminum dissolution to get maximum use of the sodium hydroxide and to decrease waste volume. After a portion of the solution is recycled, the remaining solution is transferred to tank 5.2, combined with B-Line waste, and transferred to waste storage.

The uranium is dissolved in two separate cuts with 50% HNO_3 and the raw metal or dissolver solution is transferred to tank 8.1 for analyses which are the bases for uranium and plutonium accountability. The dissolver solution is processed through head end in batches. A batch is transferred to tank 12.2 and struck by adding gelatin and simmering; this removes silica by forming a gelatin-silica polymer. Silica is removed to prevent formation of solids which cause emulsions in solvent extraction equipment during later processing. The digested solution is transferred to tank 10.4, then to centrifuge 11.1C where the polymer and any other solids are removed. The solids are washed to remove uranium and plutonium, then slurried to high activity waste neutralization tank 12.1. In tank 12.1 the solids are combined with high activity waste, neutralized, and transferred to waste storage.

Clarified dissolver solution is received in tank 11.2 and adjusted for first (solvent extraction) cycle feed. Tanks 10.2 and 10.3 are used to store plutonium received from JB-Line scrap recovery operations. This plutonium is usually blended with first cycle feed to increase the Pu to U ratio in the feed and to adjust the Pu isotopic composition to meet product specifications. The adjusted feed is transferred to tank 13.1 from which it is fed to first cycle.

Dissolver 6.1, a small pot-type, is used for materials in special campaigns, it is not used in normal Purex operation. It is equipped with an insert which makes it possible to receive fuels with higher fissile contents than those normally processed. Dissolver solution can be transferred to a large tank (8.1) or a smaller head end tank (12.2) for analysis and further processing.

C. First Solvent Extraction Cycle

[3] First cycle has two functions: (1) to provide decontamination of the Pu and U from fission products and chemical impurities, and (2) to separate Pu and U into individual streams for futher processing. First cycle consists of centrifugal

contactor 1A, jumbo mixer-settlers 1B and 1C, decanters, and process tanks. Centrifugal contactors are used in bank 1A because they minimize radiation to the solvent. Adjusted first cycle feed (1AF) enters centrifugal contactor 1A at stage 10. The plutonium in the feed is in the extractable (IV) valence state. Plutonium and uranium are extracted into the solvent (1AX) which is 30 vol % tributyl phosphate (TBP) in an n-paraffin diluent. The solvent containing the products (Pu and U) is scrubbed with 3M HNO_3 (1AS) before it exits bank 1A as the 1AP stream. The aqueous solution containing most of the fission products and chemical impurities leaves bank 1A as the 1AW stream and is transferred through the 1AW decanter to high activity waste. A small stream of $NaNO_2$ (1AN) is fed into stage 17 to provide enough nitrite to oxidize Np(IV) to Np(V) and thus divert most of the Np to the 1AW stream for subsequent recovery on the PRC.

The solvent stream (1AP) containing the Pu and U is transferred from the contactor to stage 11 of mixer-settler 1B. Aqueous 1BX, containing ferrous sulfamate, is fed into stage 1. Ferrous sulfamate reduces plutonium from Pu(IV) to Pu(III), stripping it from the solvent into the aqueous phase. The aqueous stream containing the plutonium is scrubbed with fresh solvent (1BS) to ensure adequate separation of the U from the Pu. It then exits the bank and is transferred to tank 12.6 in the warm canyon for further processing in the second plutonium solvent extraction cycle. The solvent stream containing the uranium (1BU) flows by gravity from mixer-settler 1B to stage 12 of mixer-settler 1C. A low-acid aqeuous stream (1CX) is fed to stage 1 to strip uranium from the solvent. Solvent leaving mixer-settler 1C (1CW) is transferred to solvent recovery. The aqueous stream containing the uranium (1CU) is transferred to evaporator feed tank 18.5 in the warm canyon.

The 1AW and 1CU aqueous decanters separate entrained solvent and return it to the centrifugal contactor and mixer-settler 1C. The 1CW organic decanter separates entrained aqueous material and returns it to mixer-settler 1C. The 1AP, 1BP, and 1BU decanters are bypassed and are not now in use. The decanters are located beneath the contactors and mixer-settlers.

[4] The compositions and relative flows of all streams in the first solvent extraction cycle are shown for typical operating conditions.

[5] The 18 stages of centrifugal contactor 1A are fabricated in units; each unit consists of 6 stages, and is commonly called a six-pack. A six-pack is shown prior to installation in the hot canyon. The motor and seal assembly and the electrical power supply harness for each stage can be replaced remotely. If a failure should occur in the contactors or associated piping, the six-pack would need to be removed and repaired or replaced.

[6] Centrifugal contactor 1A is shown in Building 717-F before it was installed in the hot canyon. The eighteen stages are contained in three six-packs. The 1AP and 1AW decanters are located beneath the six-packs and are the supporting base for the contactors and associated equipment. The tank that is shown is the 1AF tank located in the 13.1 position in the hot canyon. In some respects, what the hot crane operator sees when working on the contactors is shown in this photograph. The 1AW and 1AX pumps and the Hackman hats for the 1AX and 1AF streams are not installed.

[7] Top, side, and end views of the type of jumbo mixer-settler used as the 1B, 1C, 1D, and 1E banks are shown. The motor-impeller assemblies and transfer pumps are not shown. Note the mixer-settler stages in the side view. Aqueous and organic decanters are located underneath the mixer-settlers and may be used or bypassed. Aqueous solution leaves the last stage and enters a large duct leading

to the back section of the aqueous decanter. The aqueous solution then flows to the opposite end, underneath a weir, then over an overflow weir into a tank where it is pumped out. Entrained organic material collects in a separate section of the aqueous decanter and is airlifted back to the end stage of the mixer-settler. The organic stream enters a large duct leading to the back section of the organic decanter. The organic stream then flows to the opposite end and over a weir to a tank where it is pumped out. Entrained aqueous material collects in a separate section of the organic decanter and is airlifted back to the end stage of the mixer-settler.

The mixer-settler, the two decanters, and the two pump tanks are all fabricated as a single unit.

D. Second Plutonium Solvent Extraction Cycle

[8] Plutonium that was separated from uranium in the first cycle is further decontaminated and concentrated in the second plutonium (solvent extraction) cycle, then transferred to B-Line for eventual reduction to metal. 1BP plutonium solution is received continuously from first cycle into tank 12.6 and then transferred in batches for feed adjustment in tank 12.5. Plutonium recovered in Frame II-F is combined in tank 12.6 with 1BP solution for processing. B-Line plutonium solutions are also transferred to tank 12.5. In tank 12.5, plutonium valence is adjusted by oxidizing from Pu(III) to extractable Pu(IV) by adding excess sodium nitrite, after which the acidity is adjusted to 4M. The adjusted feed is transferred to tank 11.8 for continuous feeding to mixer-settler 2A. Plutonium is extracted from the aqueous solution into the solvent and is scrubbed to remove fission products and chemicals in mixer-settler 2A. Solvent containing the plutonium leaves mixer-settler 2A as the 2AP stream and enters mixer-settler 2B where plutonium is stripped from the solvent into an aqueous solution by a chemical reducing agent, hydroxylamine nitrate, which changes the plutonium valence from Pu(IV) to inextractable Pu(III). The 2BP aqueous stream exits into a decanter where entrained solvent is separated and returned to the mixer-settler. The 2BP solution is transferred to tank 9.5 and subsequently to tank 9.8 when space is available. The 2BP in tank 9.8 is analyzed and, if the fission product content and U/Pu ratio are within operating guides, the solution is transferred in batches to B-Line.

Aqueous waste leaves mixer-settler 2A as the 2AW stream and flows to decanter 11.7 where entrained solvent is separated and returned to the mixer-settler. The 2AW solution is transferred to the low activity waste (LAW) evaporator feed tank. (The solvent system for the second plutonium cycle is reviewed later.)

[9] Typical compositions and flows for streams in the second plutonium cycle are shown.

[10] A small mixer-settler of the type used as the second plutonium cycle 2A and 2B banks is shown. It is fabricated as a single unit and installed on a stand in the warm canyon. Only the motor-impeller assemblies and feed Hackman hat can be removed remotely. Separate decanters are used for the exit streams from the small mixer-settlers.

E. Second Uranium Solvent Extraction Cycle

[11] Uranium leaves first cycle in the 1CU stream, is concentrated to 425 g U/1 for feed to the second uranium (solvent extraction) cycle, decontaminated further in jumbo mixer-settlers 1D and 1E, and transferred to A-Line for denitrating to UO_3.

The aqueous 1CU stream, containing about 70 g U/1, is received in evaporator feed tank 18.5 and fed to 1CU continuous evaporator 17.7. Uranium is concentrated to 425 g/1 and the concentrate overflows to bottoms tank 17.7B. The concentrate is transferred to 1DF tank 16.7 where traces of Pu are reduced by the addition of ferrous sulfamate (FS) to prevent Pu from extracting. The solution is fed continuously to mixer-settler 1D where uranium is extracted from the aqueous solution into the solvent (1DX) and scrubbed with acid (1DS´) and water (1DS) to remove fission products and excess acid. The solvent containing the uranium exits mixer-settler 1D as the 1DU stream and enters mixer-settler 1E.

In mixer-settler 1E, uranium is stripped from the solvent into low acid aqueous (1EX) which exits the mixer-settler as the 1EU stream. The 1EU passes through a solvent decanter to tank B3-1 located in a concrete basin outside Building 221-F. From tank B3-1 the solution is automatically transferred to A-Line tank E1-3.

The aqueous 1DW stream contains small quantities of Pu and Np and is transferred to HAW to recover the products on the PRC.

[12] Typical compositions and flows for streams in the second uranium cycle are shown.

F. Solvent Recovery Systems

[13] Each of the three solvent extraction cycles has a separate and continuous solvent system. The solvent recovery system removes radioactivity and solvent degradation products, maintains acceptable quality, and returns washed solvent to the respective extraction cycle. Operating experience has shown that the most efficient washing cycle is alternating alkaline (0.19 to 0.47N Na_2CO_3) and acid (0.03 to 0.12N HNO_3) washes. All solvent is 30 vol % TBP and 70 vol % n-paraffins (normally dodecane), with a density of about 0.8 g/cc.

The first cycle solvent system is contained completely within the hot and warm canyons because of gamma radiation in the unwashed solvent and aqueous wash solutions. Unwashed solvent leaves mixer-settler 1C and flows to first stage washer 14.5-1 where it is washed with sodium carbonate. After gravity separation from the wash solution, it flows to second stage washer 14.5-2, is washed with dilute nitric acid, separated, and pumped to third stage washer 14.8. In this stage, the solvent is washed a second time with sodium carbonate and transferred to feed tank 14.7.

Solvent is fed to first cycle as 1AX and 1BS streams and exits the cycle as the 1CW stream returning to first stage washer 14.5-1. When first cycle is down, the solvent may be circulated to maintain quality by transferring from tank 14.7 to first stage washer 14.5-1.

Solvent recovery facilities for the second uranium cycle are located behind shielded walls in Building 211-F (outside facilities). (Radioactivity in the unwashed solvent from second uranium cycle is low enough to make this practical.)

Unwashed solvent from the second uranium cycle leaves mixer-settler 1E as the 1EW stream and is transferred continuously to first stage alkaline washer 901. Solvent is washed, separated, and transferred to second stage acid washer 903 where it is again washed, separated, and transferred to tank 904. From tank 904 it is fed to mixer-settler 1D as the 1DX stream. The solvent leaves mixer-settler 1D as the 1DU stream and goes to mixer-settler 1E.

The solvent recovery system for the second plutonium cycle is partially located in Building 221-F warm canyon and partially behind shielded walls in Building 211-F (outside facilities). Solvent leaves the cycle as the 2BW stream. After it flows through decanter 10.5 for removal of entrained aqueous solution, it is transferred continuously to first stage alkaline washer 12.8 located in the warm canyon. (This

washer is located inside Building 221-F because plutonium from a process upset could be present in the 2BW. Under these conditions, plutonium could accumulate in the alkaline washer and result in high levels of alpha activity and possibly a nuclear safety hazard.) After it is washed and separated in first stage alkaline washer 12.8, the solvent is transferred to second stage acid washer 905, located in Building 211-F, where it is again washed and separated. It is then received in tank 906 and fed to second plutonium cycle as the 2AX stream. When the cycle is down, the solvent may be circulated to maintain quality by transferring from tank 906 to first stage washer 12.8.

The aqueous wash solutions in all solvent washers are replaced at regular intervals.

[14] Bicell tank 14.5, which contains washers 14.5-1 and 14.5-2 used for first cycle, is shown. All other solvent washers are single-stage units of similar design. Solvent enters the first stage washer and is routed underneath the agitator shroud. Aqueous wash solution, the incoming solvent, and solvent recirculated through the upper ports is drawn to the agitator paddles, mixed, and propelled outside the shroud into the settling area. Wash solution settles to the bottom and solvent floats to the top where it overflows into the second stage washer. The washing action is repeated and solvent entering the pump tank is transferred to third stage washer 14.8.

G. High Activity Waste — Primary Recovery Column

[15] Waste streams contain high radioactivity and usually contain some Np and Pu. The Np and Pu are recovered on an anion exchange resin column (the PRC) before the waste is neutralized for underground storage.

The main feed sources for high activity waste (HAW) are first cycle waste 1AW, second uranium cycle waste 1DW, decontamination solution from the PRC, and overheads from acid stripping evaporator 11.3. HAW also processes: (1) bottoms recycled from HAW second stage evaporator 9.1, (2) solutions from Frame II-F tank 6.6, (3) canyon sump solutions from tank 820 that are transferred through tank 16.4, (4) vessel vent dehumidifier condensate from tank 7.4, and (5) sump solution from tank 805 in Building 211-F (outside facilities). All feeds are received in tank 8.3 and diluted with process water as required to maintain a feed acid concentration of 6 to 8% before the material is fed to first stage evaporator 9.3.

Dissolved solids are fed into the first stage evaporator where they concentrate and overflow continuously into the bottoms tank to maintain a constant specific gravity (sp gr) in the evaporator.

Concentrate from the first stage evaporator is chemically adjusted to about 8M nitrate with 64% HNO_3 and fed in batches to the PRC; a separate FS stream is also used. The Pu and Np in PRC feed exist as anionic nitrate complexes that absorb on anion resin. Pu and Np absorbed on the PRC resin are washed with 8M HNO_3 to remove gamma activity. The acid decontamination solution goes to tank 10.1 and then to tank 8.3 for evaporation and acid recovery. The Pu and Np on the column are eluted to tank 10.1-2, sampled, and then transferred to tank 6.5 in the warm canyon for later processing in Frame II-F.

The raffinate, or feed solution remaining after the products are absorbed, passes through the PRC into tank 10.1. After feeding is complete, the raffinate is transferred to batch evaporator 11.3 where most of the free acid is removed by steam stripping to reduce waste volume when it is neutralized. The overheads from acid stripping flow into tank 11.4 and, since they contain high gamma activity, they are

transferred to tank 8.3 for recovery of the acid. The stripped raffinate from evaporator 11.3 is transferred to tank 12.1 for neutralization and then to underground waste storage tanks in Building 241-F.

The overheads from HAW first stage evaporator 9.3 are fed to second stage evaporator 9.1. The overheads from the second stage are transferred to Building 211-F (outside facilities) for processing in the acid recovery unit (ARU). Decontamination factors of 10^8 to 10^9 are obtained across the 2-stage evaporation. Acid concentrated in the second stage evaporator accumulates activity and is periodically overflowed to the bottoms tank and transferred back to feed tank 8.3.

[16] A continuous canyon evaporator, overheads condenser, and reboiler are shown. Each of these pieces can be replaced remotely. A continuous evaporator can boil 12,000 to 20,000 lb/hr, compared to 2,000 to 3,000 lb/hr for a batch evaporator. Feed flow into the evaporator is continuous; a given sp gr is reached and maintained in the evaporator. As dissolved solids are fed in, concentrate overflows the outlet weir to the bottoms tank, thus maintaining the sp gr. Solution flows down to the bottom of the reboiler, up through the reboiler tubes, partly flashes to steam and passes into the de-entrainment column where steam and liquid separate. New feed enters the Hackman hat and flows to the bottom of the reboiler. Steam and acid vapors rise through the bubble-cap trays into a downdraft condenser where they are cooled and condensed and flow either to a second stage evaporator or to a pump tank. A total gamma decontamination factor about 10^4 is obtained from feed to overheads. The evaporator can be emptied by a jet.

[17] A canyon batch evaporator and its column are shown. Batch evaporators are used to steam-strip acid from waste concentrate to: (1) reduce waste volume by decreasing the amount of caustic required for neutralization, (2) recover nitric acid for recycle to the process, and (3) concentrate some waste streams such as solvent wash solutions to reduce waste volume. Acidic waste concentrate is transferred into the evaporator and brought to boiling. Water is fed to the evaporator while a prescribed sp gr is maintained. Most of the free acid is carried out by the overheads. Dilute waste solutions can also be fed continuously until a designated specific gravity for a given volume of concentrate is reached; then the evaporator is cooled and emptied. The evaporator is fabricated in two pieces — the column which contains three trays of bubble caps and the overheads condenser, and the pot which contains the steam coils.

H. Frame II-F

[18] In Frame II-F, Pu and Np that were recovered on the PRC are decontaminated and separated. The Pu is transferred to second plutonium cycle for recovery and the Np is shipped to HB-Line.

The Frame II-F facility consists of three 25-liter resin columns and associated tanks assembled within a modular frame structure located in section 5 of the warm canyon. Tanks 6.5 and 6.6 store and transfer the feed and waste solutions in support of Frame II-F operations.

The PRC eluate, containing Pu and Np, is received in tank 6.5 and concentrated by simmering to increase Frame II-F throughput. A batch of feed is transferred from tank 6.5 to tank 5.8-1 and adjusted and fed to anion resin column 2K. Batch size is dependent on either the Pu concentration (for nuclear safety of column loading) or (if the Pu concentration is low) the volume that can be adjusted in tank 5.8-1. The Pu and Np are absorbed on column 2K as anionic nitrate complexes on anion resin.

The raffinate is routed to tank 5.8-3. Decontamination solution is fed through the column to tank 5.8-3 to remove gamma-emitting impurities. Raffinate and decontamination solutions are transferred to waste tank 6.6 and later to HAW feed tank 8.3. Pu is partitioned from the Np with 5.8N nitric acid and routed to tank 5.8-3. It is analyzed and transferred to second plutonium cycle for recovery. Np is eluted from the resin with weak acid to tank 5.8-4. The Np solution is then adjusted and absorbed again on anion resin column 5K. The raffinate goes to tank 5.8-3, along with more decontamination solution. The raffinate and decontamination solutions are transferred to tank 6.6 and later to HAW. Np is eluted from column 5K to tank 5.8-6 with 0.4N nitric acid. Elution solutions from two column 5K runs are combined in tank 5.8-6 and simmered to minimize the volume of product solution shipped to HB-Line following a column 7K run. Concentrated Np solution in tank 5.8-6 is then adjusted and fed to cation resin column 7K to absorb and remove thorium. The effluent from the column goes to product tank 5.8-8. A weak acid flush is made through column 7K to displace Np solution from the column; the flush solution is combined with the product in tank 5.8-8.

The traces of thorium must be removed from the Np because its high energy gamma would produce radiation exposure to personnel in HB-Line. Column 7K is reconditioned occasionally to remove thorium from the resin; the solution is routed to HAW.

The Np product solution is loaded from tank 5.8-8 into containers called doghouses and shipped to HB-Line.

I. Low Activity Waste

[19] The low activity waste (LAW) system is located in the warm canyon. LAW strips and recovers nitric acid from low activity waste streams and concentrates, neutralizes, and transfers the waste to underground storage. LAW evaporation equipment consists of continuous evaporator 8.5 and acid-stripping batch evaporators 7.6 and 7.7. Waste streams received into bicell tank 8.7 for feed to continuous evaporator 8.5 are second plutonium cycle 2AW stream transferred from decanter 11.7, B-Line waste transferred from tank 9.7, overheads from batch evaporators 7.6 and 7.7 transferred from tank 7.5, and condensate from the warm canyon vessel vent dehumidifier transferred from tank 5.5.

Process water is added to the material in tank 8.7 as required to adjust the acid concentration to 6 to 8%; the material is then fed to evaporator 8.5. Overheads from the evaporator are transferred to the acid recovery unit in Building 211-F (outside facilities). Evaporator 8.5 is operated to maintain a sp gr and, as dissolved solids are fed in, concentrate overflows to bottoms tank 8.5B. When a batch is accumulated in the bottoms tank, it is transferred to tank 7.8 and analyzed. If the Pu and U contents are within disposable limits, it is transferred to evaporators 7.6 and 7.7, one-half to each. There it is steam-stripped for 16 hours by feeding water and maintaining a constant sp gr in the evaporators. This distills most of the free acid to the overheads which are received in tank 7.5 and transferred to tank 8.7. These overheads are recycled to evaporator 8.5 because of high gamma activity. After steam stripping is complete, solvent wash solution in tank 13.7 is transferred to tank 7.8 and fed to the batch evaporators, combining with the acid concentrate. Some of the remaining acid in the concentrate is neutralized by the alkaline solvent wash solution, thus reducing waste volume by decreasing the amount of caustic required for neutralization. The acidic concentrate is transferred to tank 6.8, analyzed, then neutralized with sodium hydroxide. The neutralized waste is transferred to Building 241-F waste storage tanks.

J. Laboratory Waste Evaporation

[20] Waste solutions are received into underground tank 809 from Building 772-F laboratory and truck shipments from SRL. Alkaline wash solution from the second uranium cycle solvent washer is received into tank 902, and on occasion rerun evaporator overheads are received in canyon tank 16.2. Materials from these sources are processed as an alkaline solution in batch evaporator 18.6, located in the warm canyon. Batches of feed are transferred into tank 18.7, analyzed, and neutralized. The neutralized waste is concentrated to a prescribed sp gr in the evaporator before it is transferred to Building 241-F waste storage tanks. Overheads from the evaporator are accumulated in tank 18.8 and analyzed for alpha and gamma activity. If the activity is low enough, the overheads are transferred to the seepage basin. If the activity is high, they are recycled to the evaporator.

K. Vessel Vent System

[21] All vessels in the canyons are connected to the vessel vent system. Fans pull an air purge of about 50 cfm through each of the vessels to prevent chemical fumes and radioactivity from escaping into the canyons. This air purge is routed into a header located within the air tunnel for each of the canyons. These headers connect to dehumidifiers 5.6H in the warm canyon and 7.3H in the hot canyon, then to fiberglass filters 5.7F in the warm canyon and 7.2F in the hot canyon. The individual headers join a main header in the Building 221-F exit air tunnel which connects to the vessel vent fans. Air is discharged from the fans to the sand filter and subsequently to the stack. Condensate from warm canyon dehumidifier 5.6H is collected in tank 5.5 and transferred through tank 7.5 to LAW tank 8.7 for disposal. Condensate from hot canyon dehumidifier 7.3H is collected in tank 7.4 and transferred to HAW tank 8.3 for disposal. The vessel vent fans are located in an underground shielded facility in Building ~~211-F~~ 292-1F.

L. A-Line

[22] Product solution from the second uranium cycle (1EU), containing about 90 g U/l, is transferred out of the warm canyon through a small box decanter into basin transfer tank B3-1. The solution is pumped automatically to silo tank E1-3 in A-Line. Entrained solvent may be removed in the box decanter to a small solvent hold tank if separation is rapid enough or it will float to the surface of tanks B3-1 and E1-3. These tanks are not agitated, and they are operated with large solution heels to give adequate time for the entrained solvent to separate and be removed. 1EU solution is fed from tank E1-3 to EU continuous evaporator E2-2. Uranium is concentrated from 90 g U/l to 450 g U/l, then the solution is transferred to tank S1-1. A small amount of solvent is always present in the feed solution. Most of the n-paraffin in the solvent distills to the overheads and is transferred to the seepage basin. The remaining TBP is concentrated to 90 to 95 vol % of the organic material. Off-specification evaporator concentrate, flush solutions, and other miscellaneous solutions are routed to tank E1-2 for analysis and later fed to the EU evaporator. EU concentrate in tank S1-1 is transferred alternately to tanks S1-8 and S1-9. These tanks are filled with EU concentrate, isolated, then analyzed. The concentrate must be above minimum limits for density and uranium concentration, and below the maximum limit for organic material, before it can be processed to the hydrate evaporators. Batches of solution are transferred through tank C1-1 to tank C1-2 and into a hydrate evaporator, where they are concentrated to molten

uranyl nitrate hexahydrate (UNH), at about 1200 g U/l. Then it flows by gravity to denitrators while it is still hot. The denitrators are heated by propane furnaces and convert the molten UNH to UO_3. The UO_3 is conveyed pneumatically into drums and stored. (Silica gel columns are available but are not being used at the present time. These columns can provide additional Zr-Nb decontamination, if required, to meet product specifications and reduce personnel radiation exposure.)

M. Airflow and Filtration

[23] General building ventilation air (called central air) and air flowing through certain process areas in Building 221-F is transferred through tunnels, or headers, and through filters to the Building 291-F stack for release to the atmosphere. In addition, air from noncanyon vessels and cold feed tanks in Building 221-F and from process vessels in A-Line is routed to the recycle vessel vent header, and subsequently to the 195-ft stack.

Air from the hot and warm canyons and filtered air from the vessel vent header flow through the sand filters before it is exhausted through the stack. The sand filters contain aggregate of several different sizes in layers starting with larger material on the bottom to the smallest (sand) on the top. A new and larger sand filter was constructed next to the original sand filter and is in service in parallel with the original sand filter. The new filter was built because pressure drop across the original filter had increased, indicating partial pluggage, and because on two occasions portions of the support gratings collapsed and required emergency repairs.

The sand filters remove about 99.98% of the radioactivity contained in air entering the filters; this is equivalent to removal by high efficiency particulate air (HEPA) filters. Air enters from lateral distribution tunnels beneath the bed, passes upward through the aggregate, and exhausts from the filter to the stack.

Central air leaving from the hot and warm gang valve corridors and from the hot and warm sample aisles, passes through banks of HEPA filters and is exhausted directly to the stack without going through the sand filter. B-Line air is HEPA filtered and exhausted to the stack. Recycle vessel vent air passes through a glass fiber filter and then out the stack.

Liquid collected in the sumps and catch tanks is transferred to tank 805 for subsequent processing in Building 221-F waste evaporators.

N. Acid Recovery Unit

[24] Acidic condensate from the high activity waste and low activity waste continuous evaporators in Building 221-F is transferred to basin tank B2-1 in Building 211-F (outside facilities) and subsequently to tank 601. The condensate normally contains 6 to 8% HNO_3, less than 10,000 d/m/ml gamma activity, and essentially no alpha activity. The condensate is processed in the acid recovery unit (ARU) to increase the acid strength to 50% HNO_3 for reuse in the Purex process. Reuse of acid reduces the amount of acid and radioactivity transferred to the seepage basin in the overheads.

Dilute acid is fed through a preheater to the distillation column. The column contains ten bubble-cap trays and is operated under a partial vacuum maintained by a steam evactor. Operating under vacuum decreases the corrosion rate by lowering the boiling point of solution in the reboiler and column. Water is distilled from the acid solution and collected in tanks 614 and 615. The overheads solution is monitored for gamma activity and transferred to the seepage basin for disposal. A composite sample of overheads is accumulated each day and analyzed for gamma

activity and acid content. Acid concentrates in the bottom of the column and in the reboiler which maintains the concentrate at boiling. Hot vapor rises upward from the boiling solution through the distillation section, removing water as overheads and refluxing acid to the bottom of the column. Acid concentrate is continually drawn from the bottom of the column and transferred through a cooler to tanks 606 and 607. The acid is adjusted with 64% HNO_3 or process water as required to make 50% HNO_3 which is stored in tank 608. Recovered acid contains some gamma activity and is transferred to the Purex process in Building 221-F through a separate header. This acid is also used to make 3.0M HNO_3 for process use, primarily in the 1AS stream.

O. Fume Recovery

[25] Large quantities of oxides of nitrogen (NO_x) are routinely emitted from canyon dissolvers 6.1 and 6.4 and the six denitrators in A-Line. These gases are routed through the acid absorber column, converting most of the NO_x to 40 to 50% HNO_3 which is reused in the process.

Dissolver fumes generated during coating removal (aluminum dissolution with caustic) contain ammonia and are routed direct to the stack using off-gas jets. Fumes from uranium dissolution are routed through off-gas coolers F9-4 and -5 to Nash exhausters F7-3 and -4. The exhausters discharge the fumes into the bottom of the acid absorber column.

Denitrator fumes flow to separators F1-1 and -6 where entrained uranium solids are removed, through coolers F9-1 and -6 to Nash exhausters F7-1, -2, and -5. The fumes leave the exhausters and enter the bottom of the acid absorber column with fumes from the dissolvers. Uranium solids accumulated in the separators are dissolved with nitric acid and transferred to the denitrators for processing.

The acid absorber column consists of 44 bubble-cap trays. Process water enters at the top of the column and flows countercurrent to the fumes. The water absorbs most of the fumes, making nitric acid which is collected in tanks F1-3 and -4. Seals are maintained in the exhausters with a flow of process water which absorbs fumes and generates acid. This acidic seal liquid overflows from tank F1-2 to either tank F1-3 or -4.

High strength acid accumulated in tanks F1-3 and -4 is adjusted with 64% HNO_3 or process water as required to make 50% HNO_3 which is transferred to storage tank F1-5. Low strength acid is recycled to the lower section of the column to increase the acid concentration prior to adjustment.

Absorber acid (50% HNO_3) in tank F1-5 contains some uranium, usually 2-10 g/l, and consequently is used only for dissolving and first cycle feed adjustment.

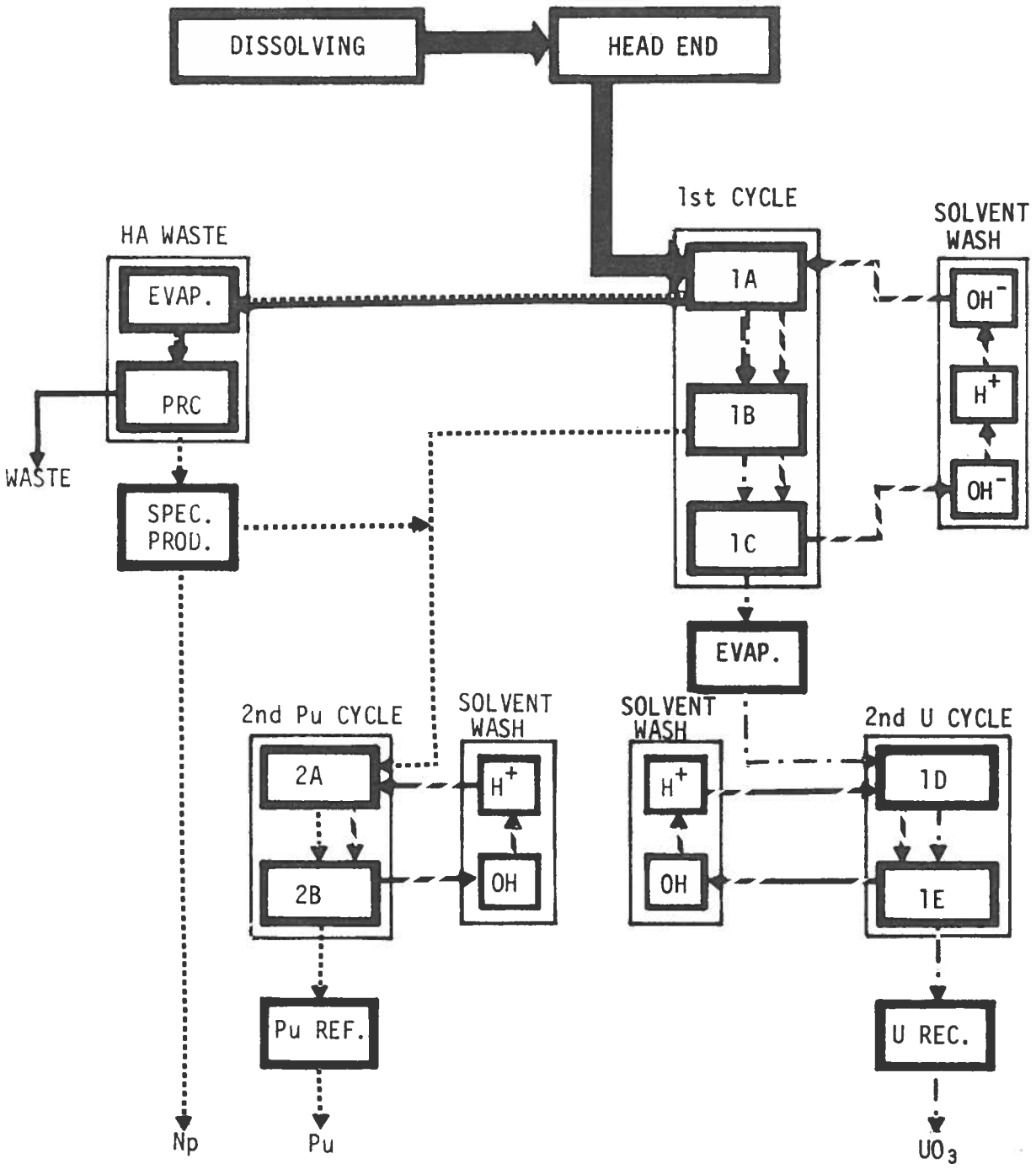
If the denitrator off-gas system loses vacuum because of pluggage or equipment malfunction, an off-gas jet will start automatically and transfer the fumes directly to the stack and restore denitrator vacuum.

P. Discharges to Seepage Basin

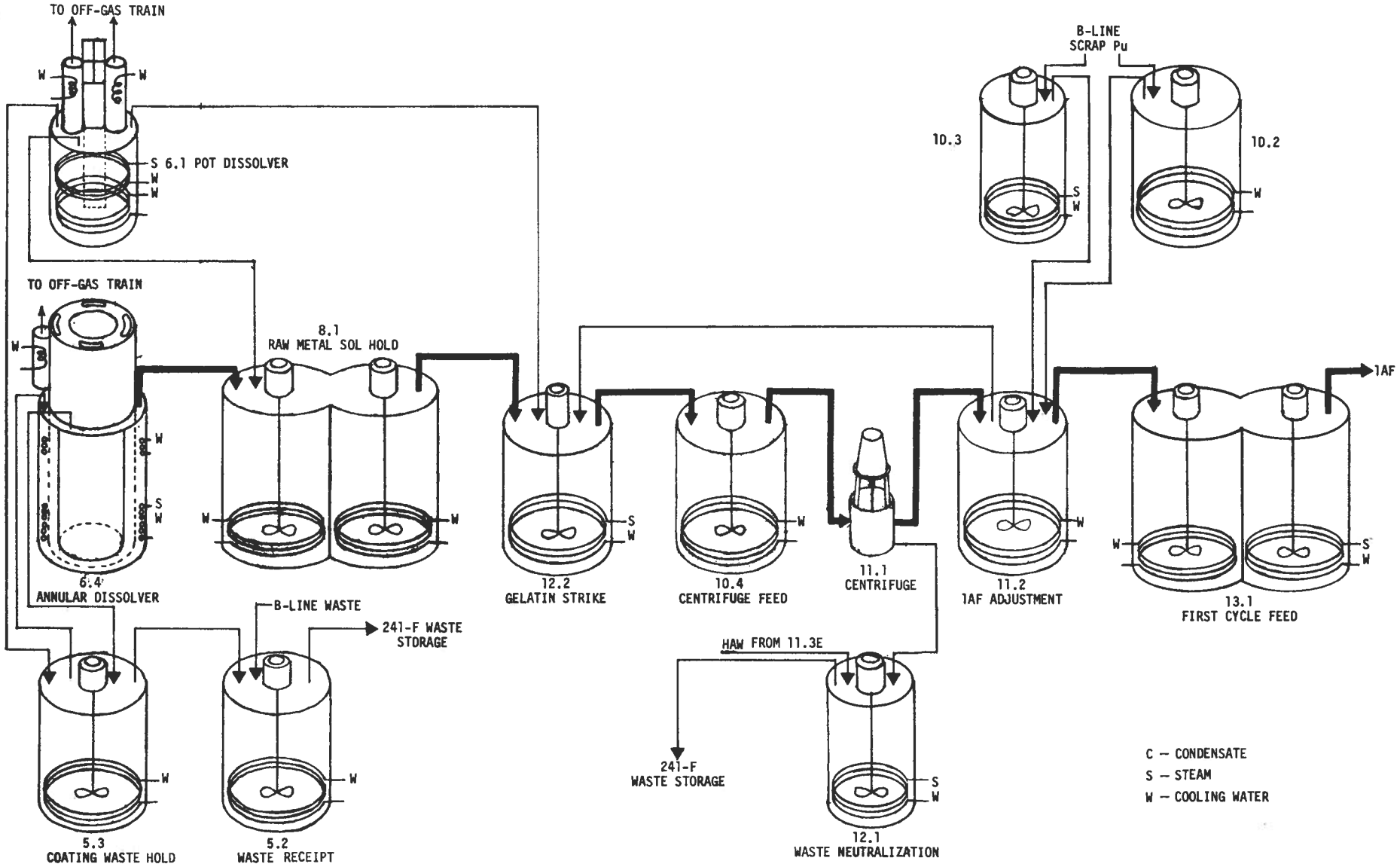
[26] The F-Area seepage basin receives 150,000 gallons of overheads each day when all Purex facilities are operating at normal throughput. The acid recovery unit in Building 211-F contributes about 62,000 gal/day or 41.4% of the total. These overheads from the ARU, plus those from the 1CU continuous evaporator in the warm canyon and the EU continuous evaporator in A-Line, account for 131,200 gal/day or 87.6% of the total. Overheads from the alkaline waste evaporator in Building

242-F contribute 9250 gal/day or 6.2% of the total when the evaporator is operating. Overheads from the hydrate evaporators in A-Line, the general purpose evaporators in Building 211-F, and the laboratory waste evaporator in the warm canyon contribute 8275 gal/day or 5.6% of the total. Only laboratory waste evaporator overheads within seepage basin discard limits are routed to tank 802 and subsequently to the seepage basin. Overheads containing high alpha or gamma activity are routed to the general purpose evaporator for further processing. Miscellaneous solutions are transferred to tank 503 in Building 211-F. This solution is transferred to either the general purpose evaporator or to the seepage basin, depending on its alpha and gamma activity.

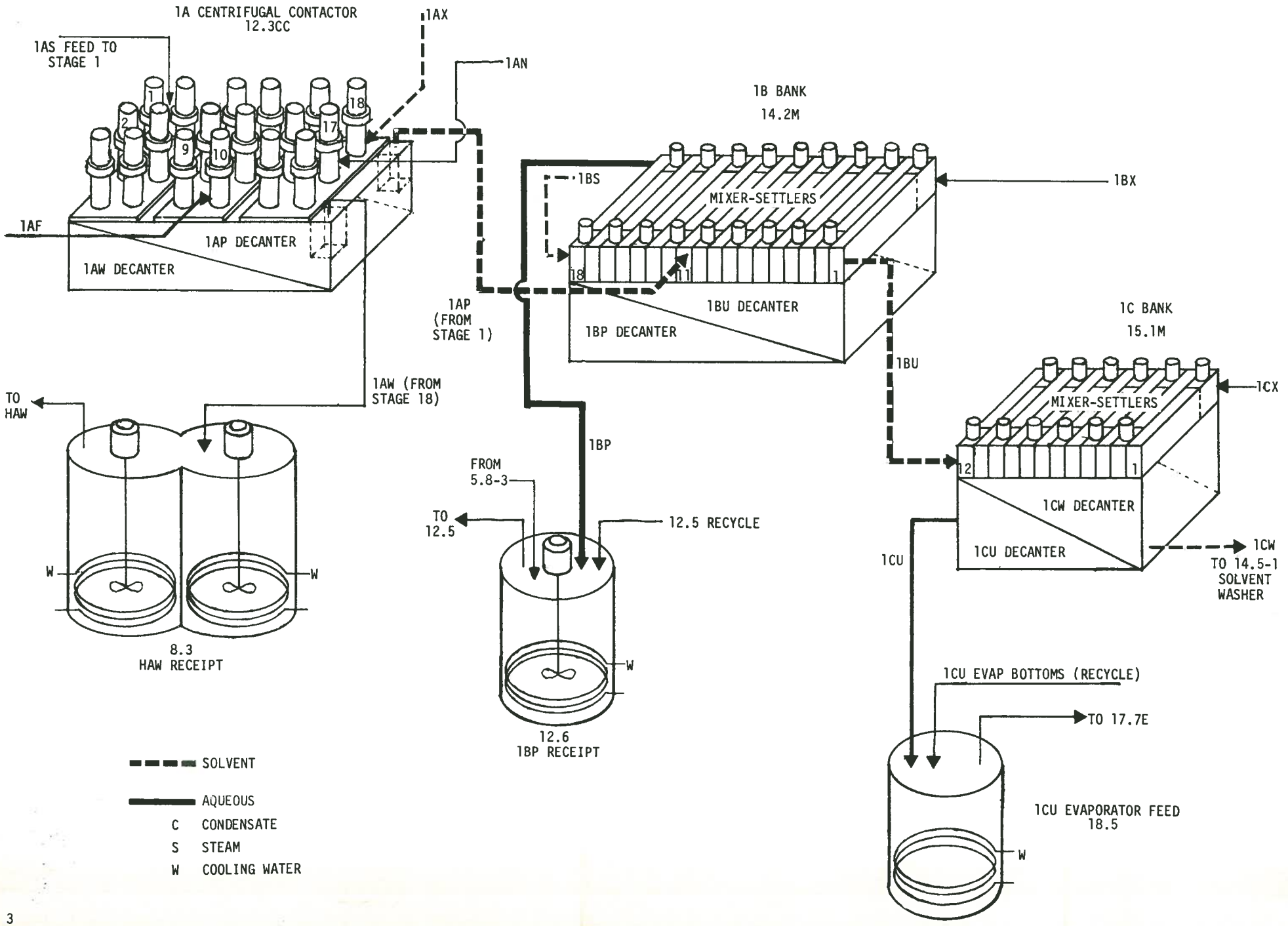
PUREX PROCESS



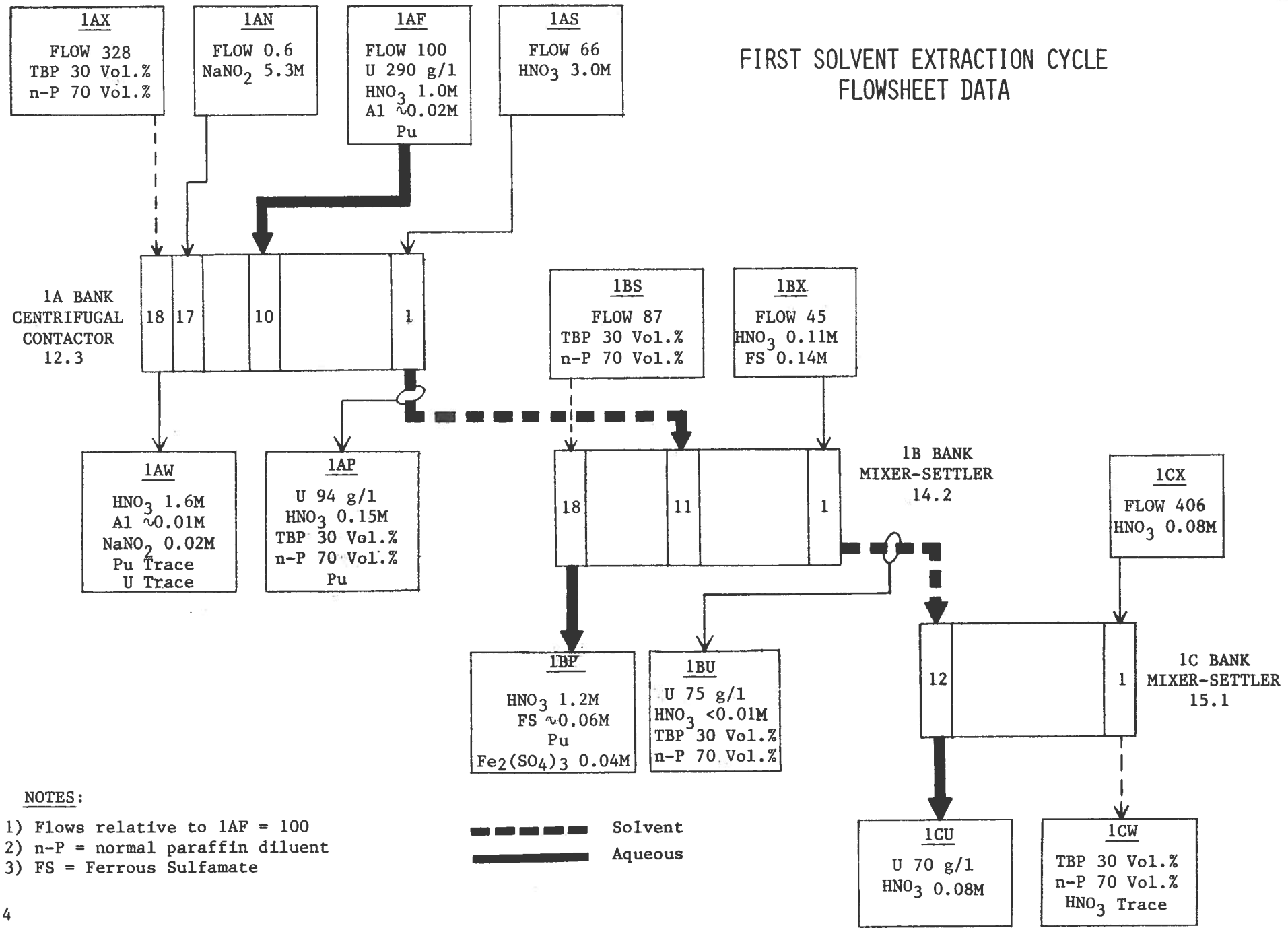
DISSOLVING – HEAD END



FIRST SOLVENT EXTRACTION CYCLE

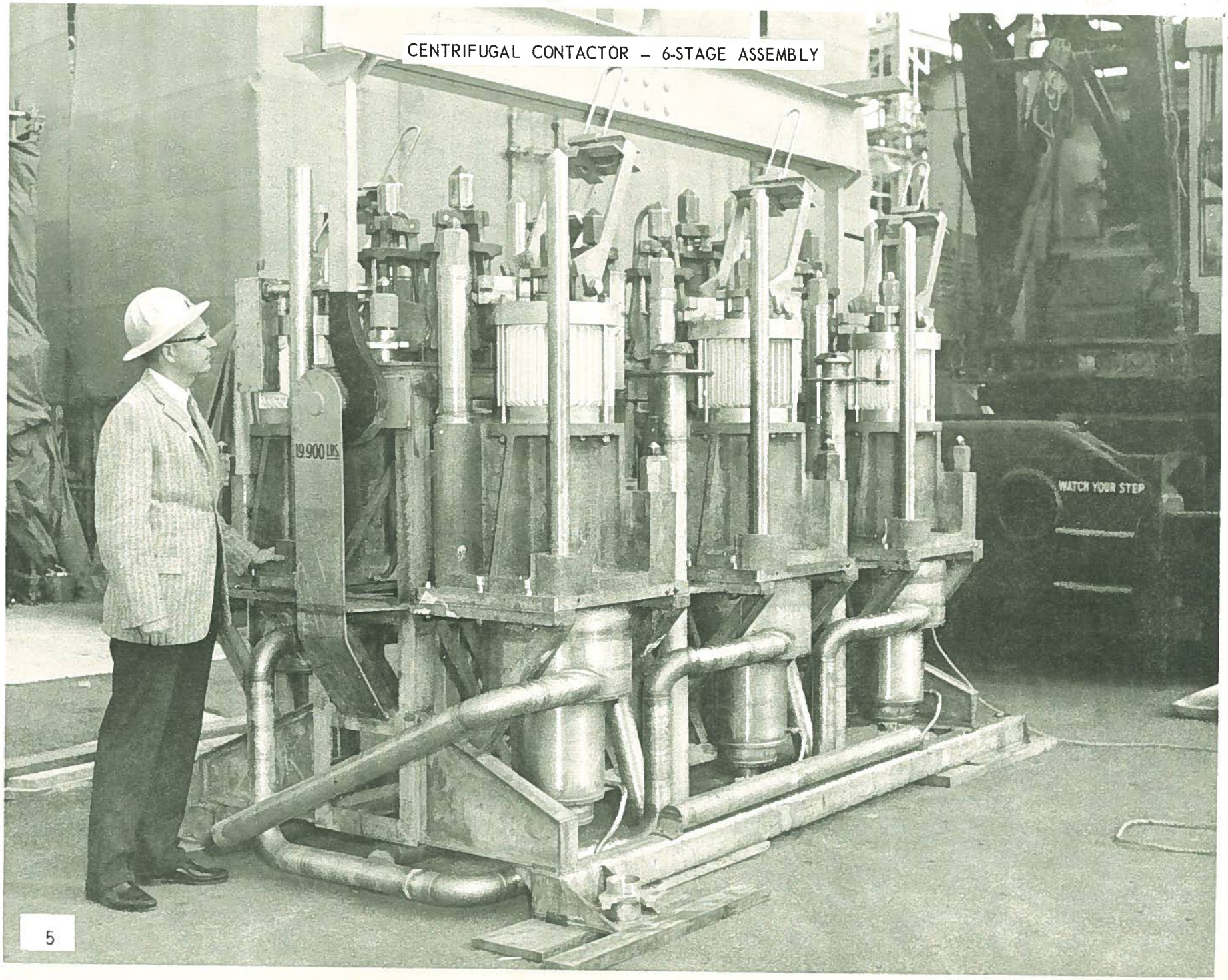


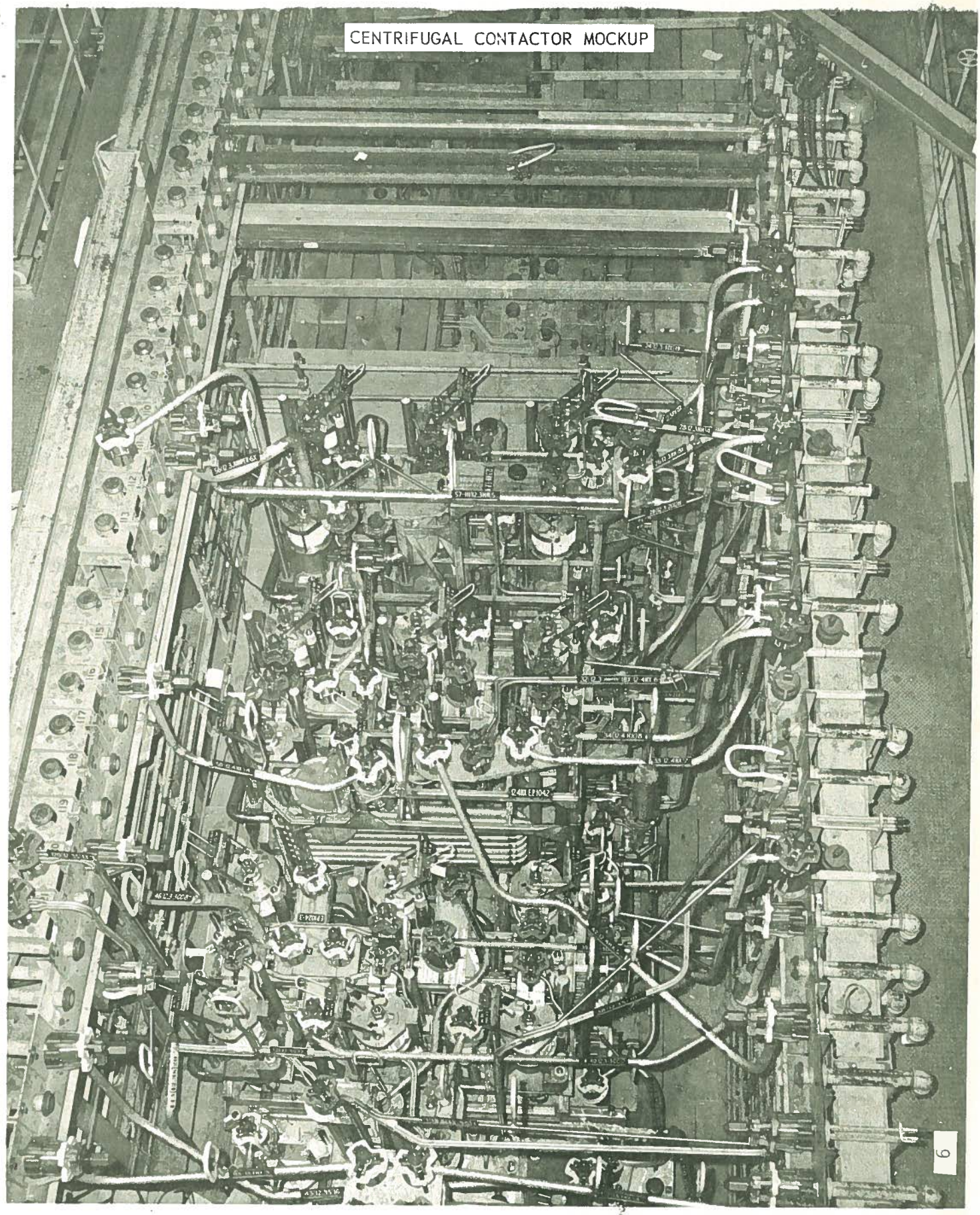
FIRST SOLVENT EXTRACTION CYCLE FLOWSHEET DATA



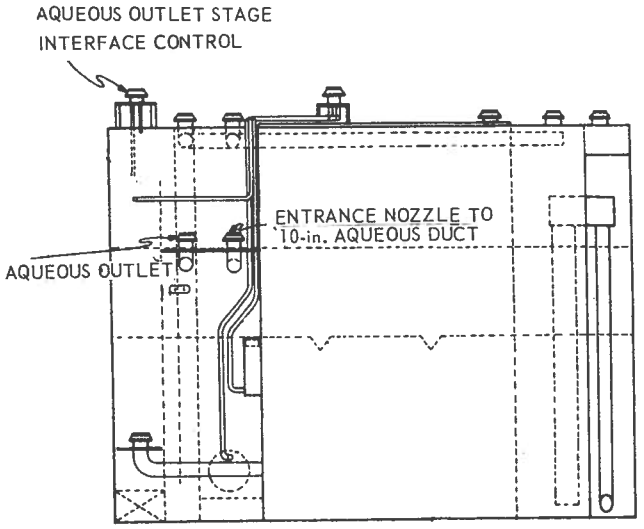
NOTES:

1) Flows relative to 1AF = 100
2) n-P = normal paraffin diluent
3) FS = Ferrous Sulfamate

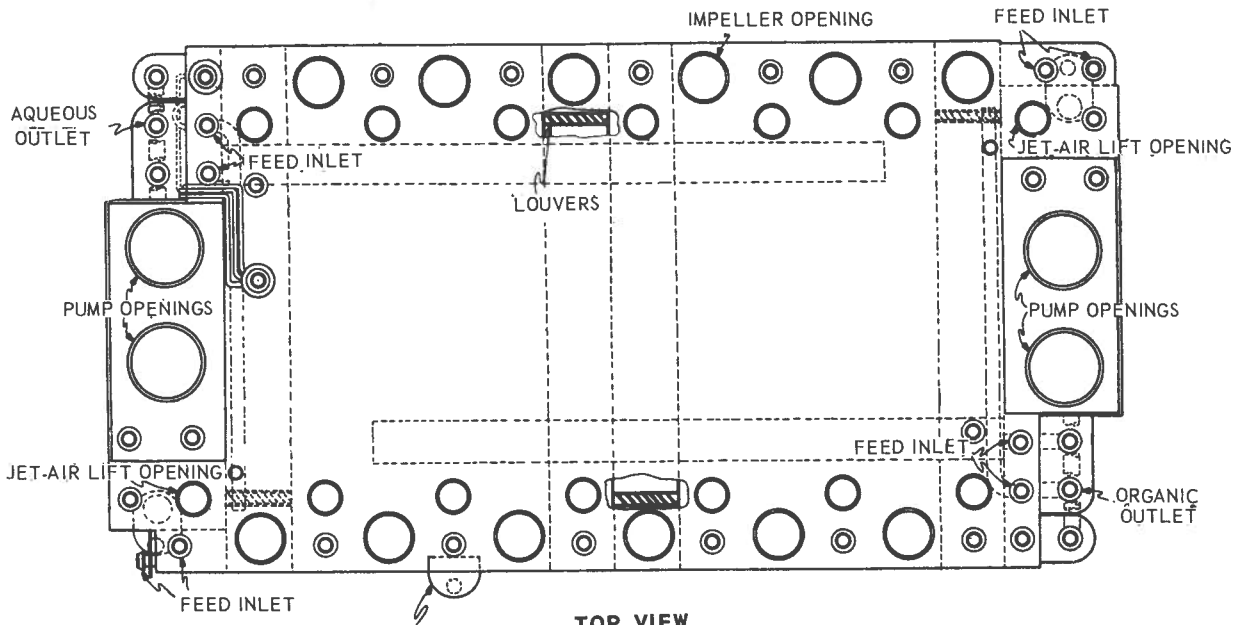

CENTRIFUGAL CONTACTOR – 6-STAGE ASSEMBLY
19,900 LBS.
WATCH YOUR STEP
5


CENTRIFUGAL CONTACTOR MOCKUP

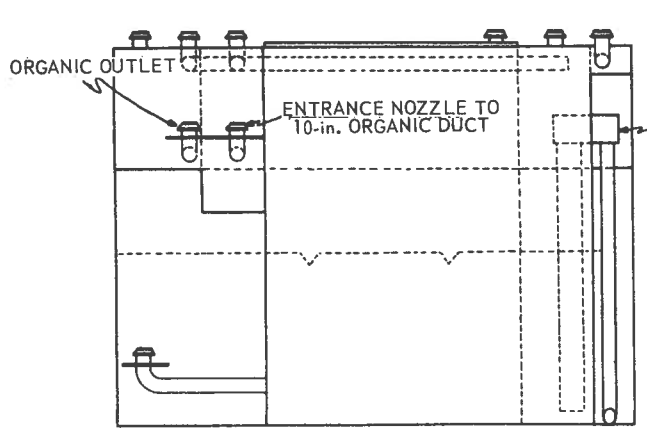
JUMBO MIXER-SETTLER



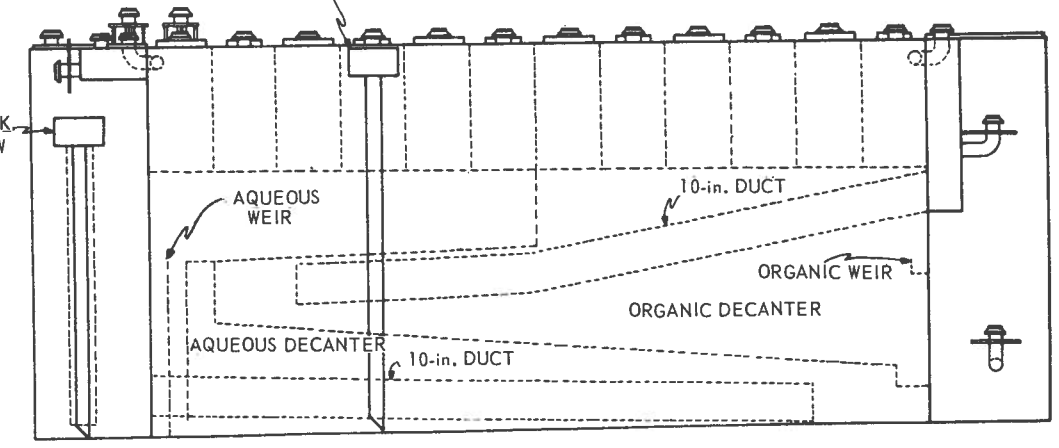
AQUEOUS OUTLET END



TOP VIEW

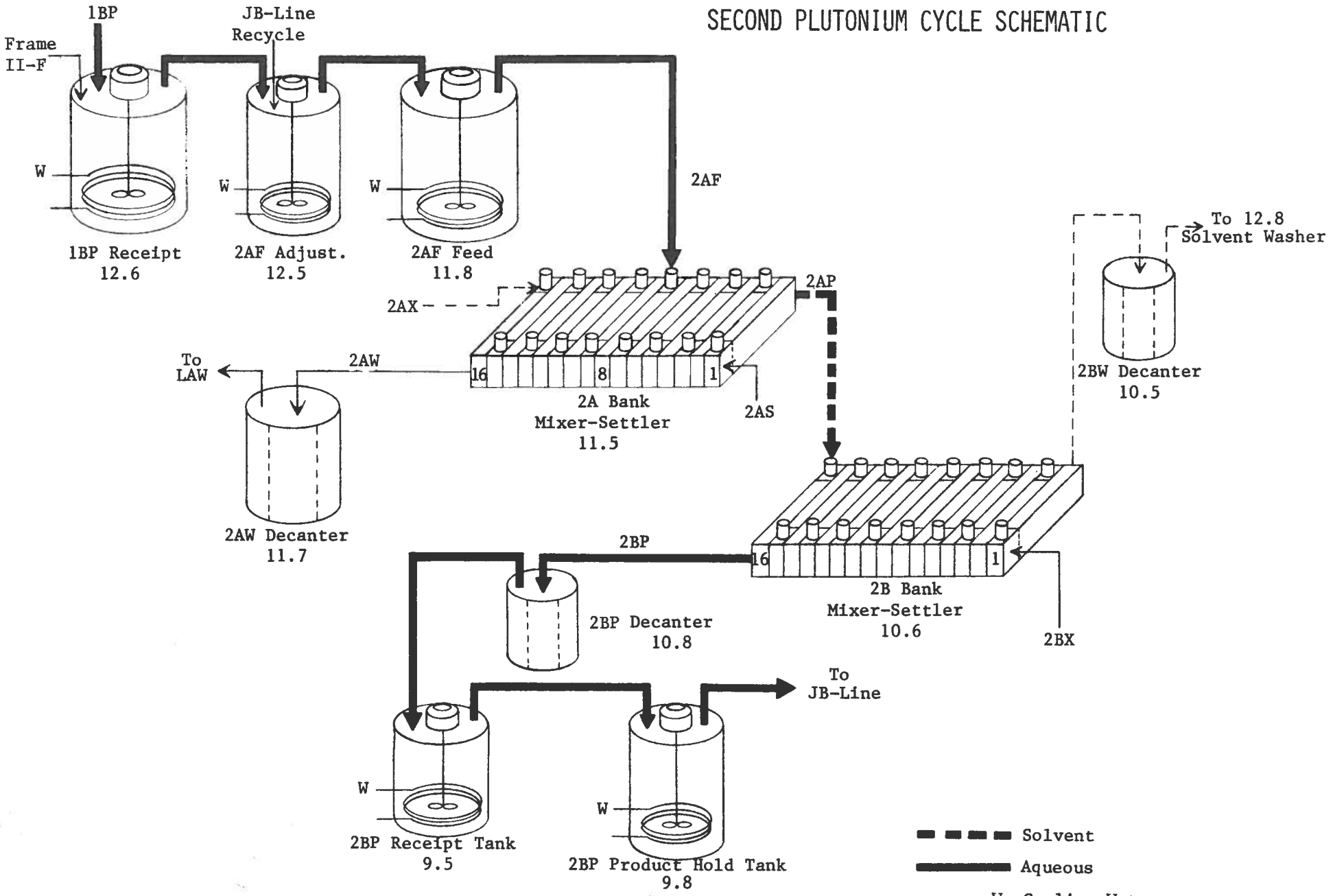


ORGANIC OUTLET END

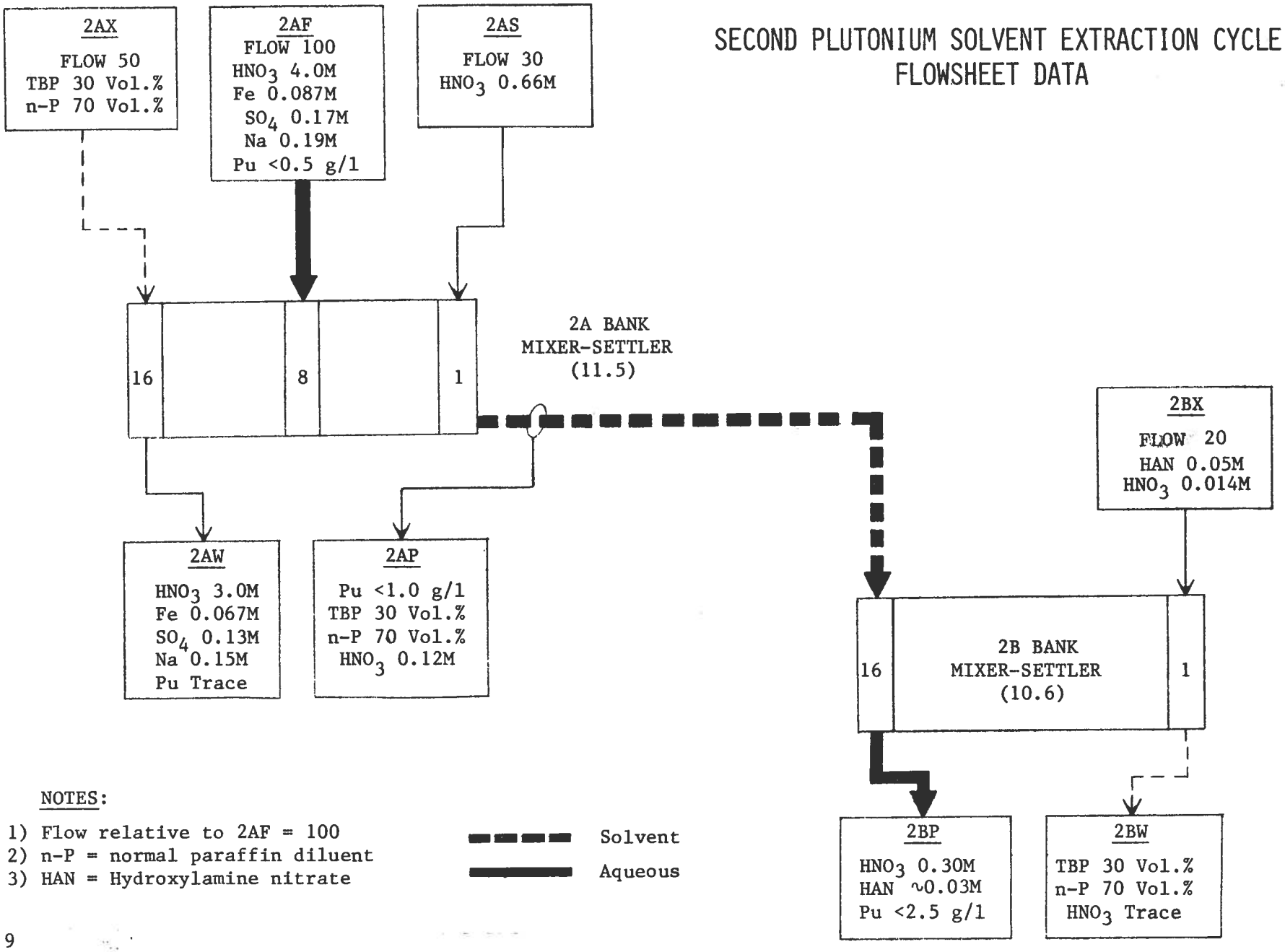


SIDE VIEW

SECOND PLUTONIUM CYCLE SCHEMATIC



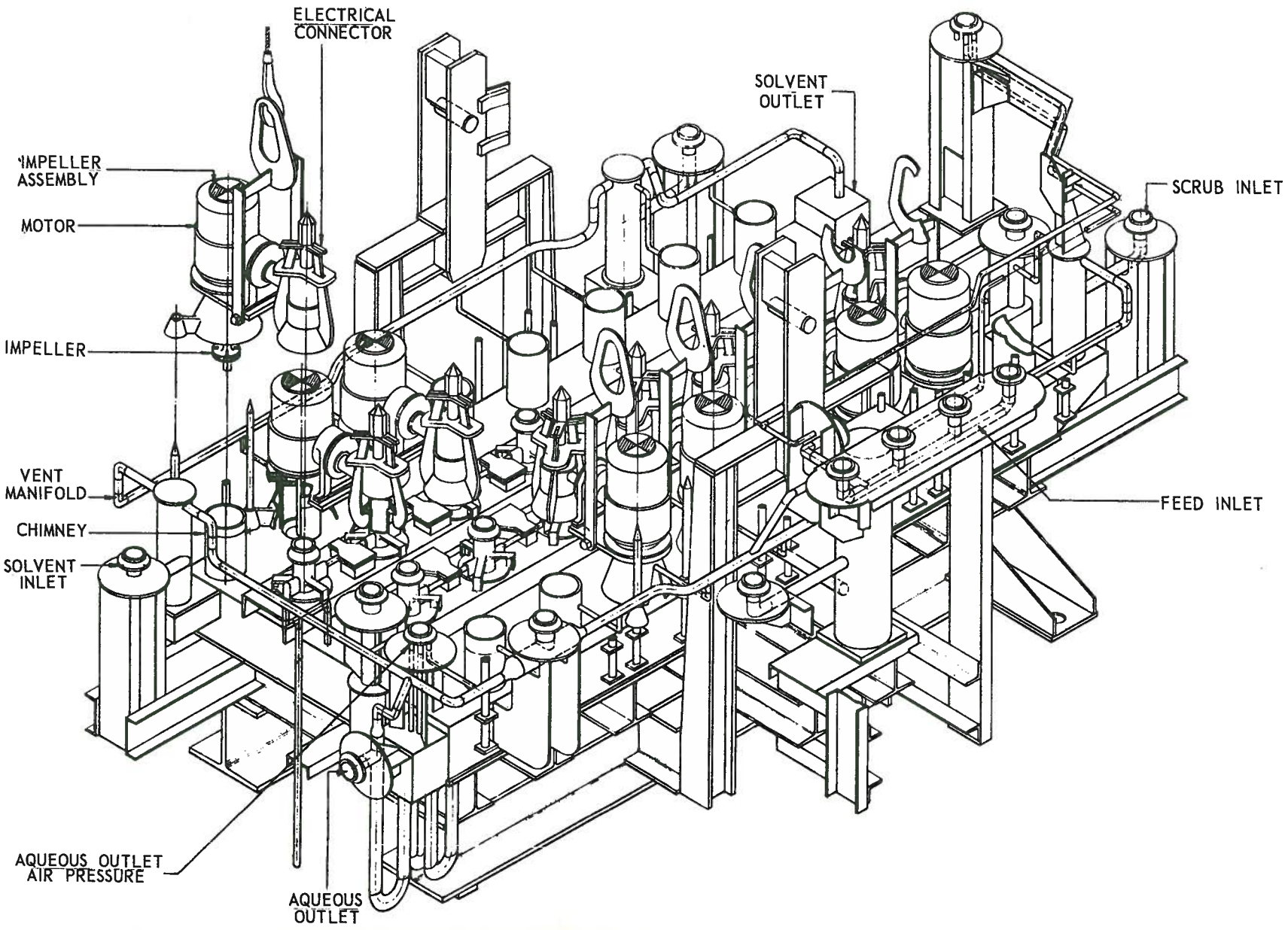
SECOND PLUTONIUM SOLVENT EXTRACTION CYCLE FLOWSHEET DATA



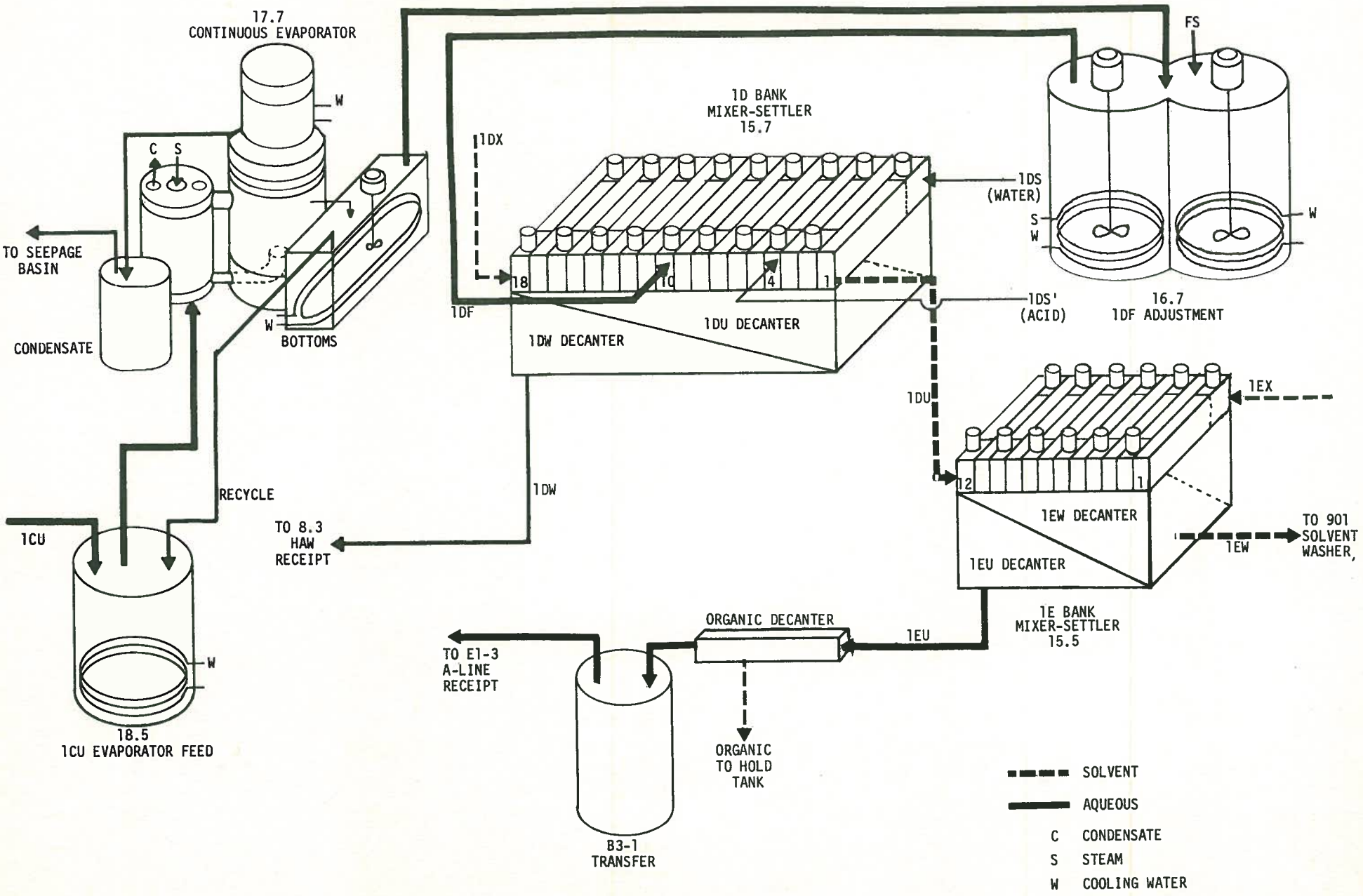
NOTES:

1) Flow relative to 2AF = 100
2) n-P = normal paraffin diluent
3) HAN = Hydroxylamine nitrate

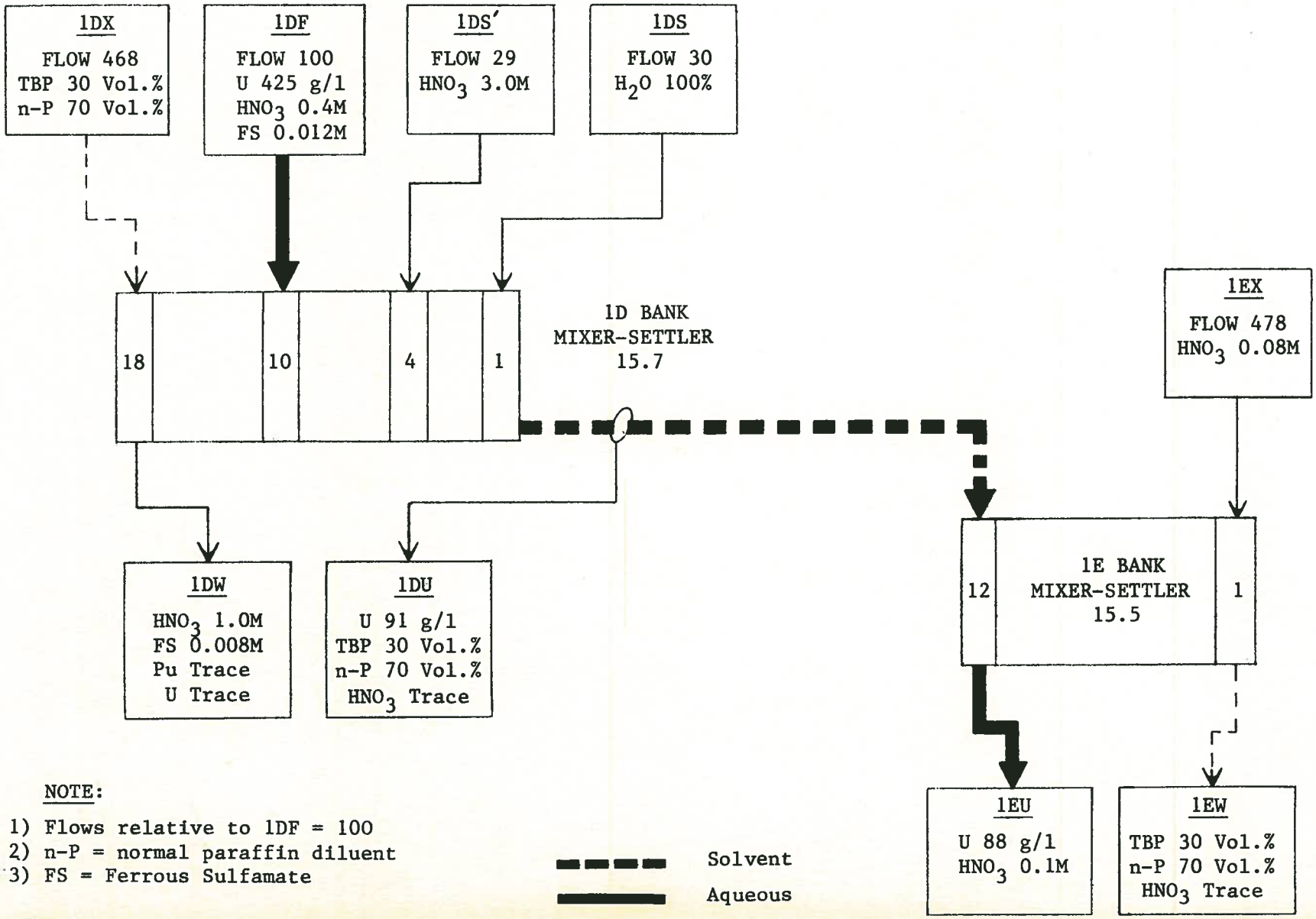
TYPE A (2B) MIXER-SETTLER



SECOND URANIUM SOLVENT EXTRACTION CYCLE



SECOND URANIUM SOLVENT EXTRACTION CYCLE
FLOWSHEET DATA

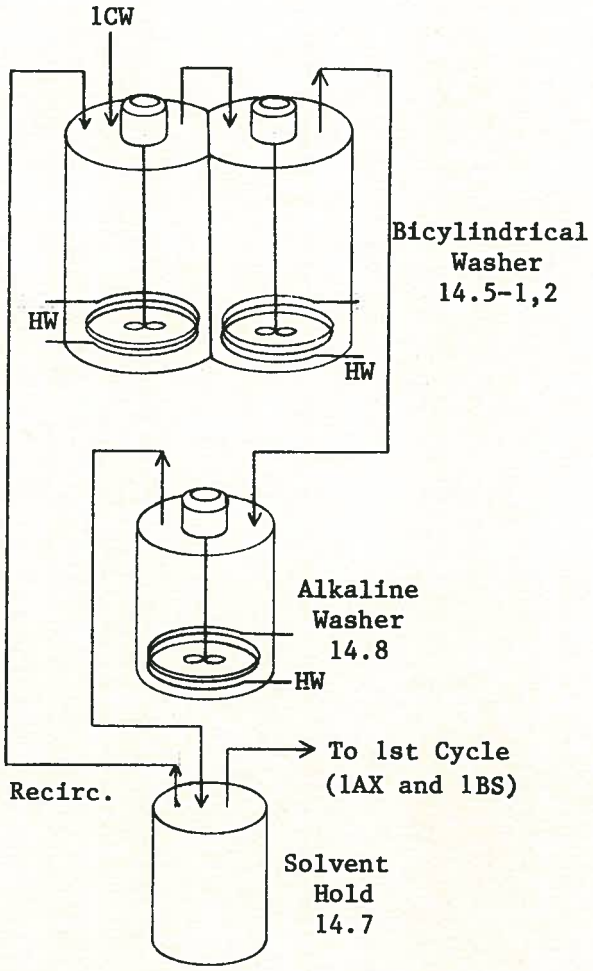


NOTE:

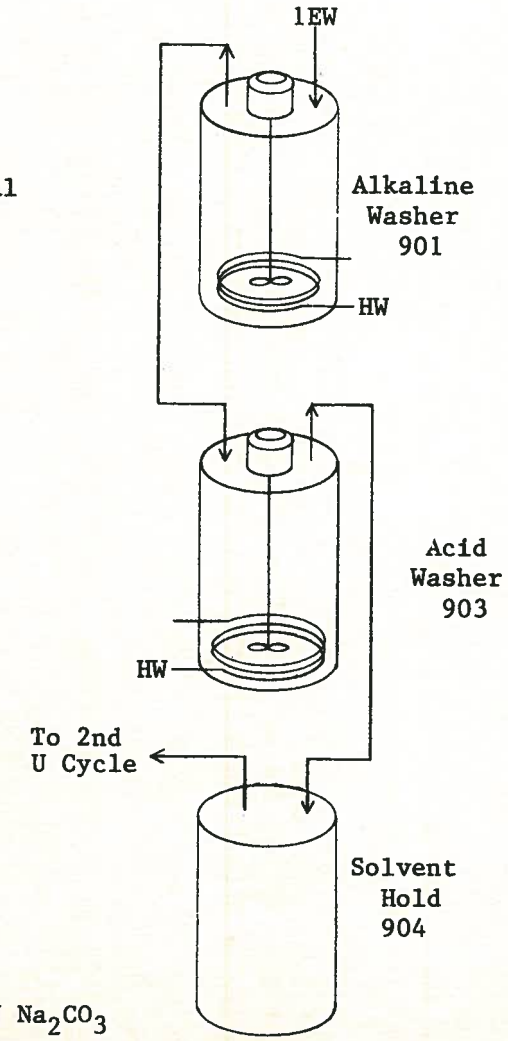
1) Flows relative to 1DF = 100
2) n-P = normal paraffin diluent
3) FS = Ferrous Sulfamate

SOLVENT RECOVERY SYSTEMS

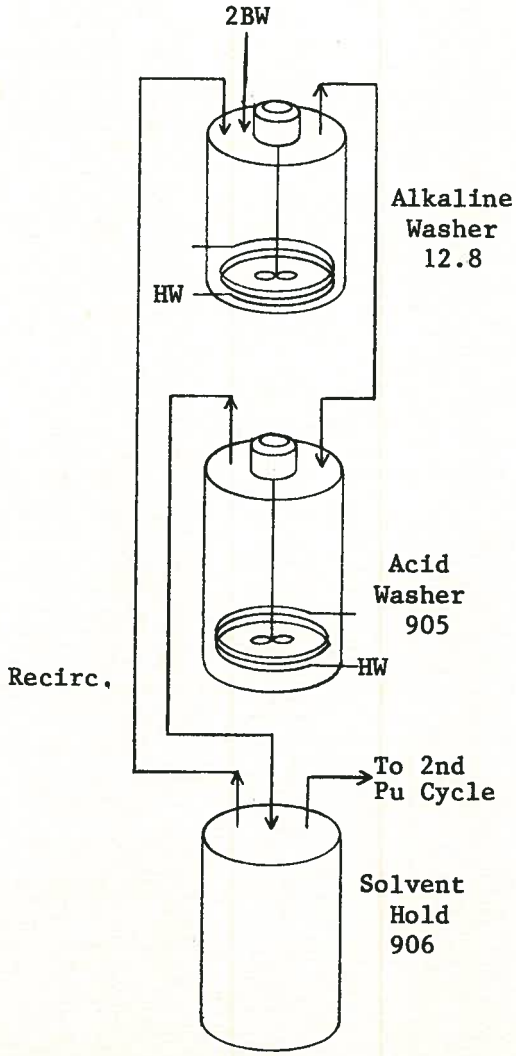
1ST CYCLE



2ND U CYCLE

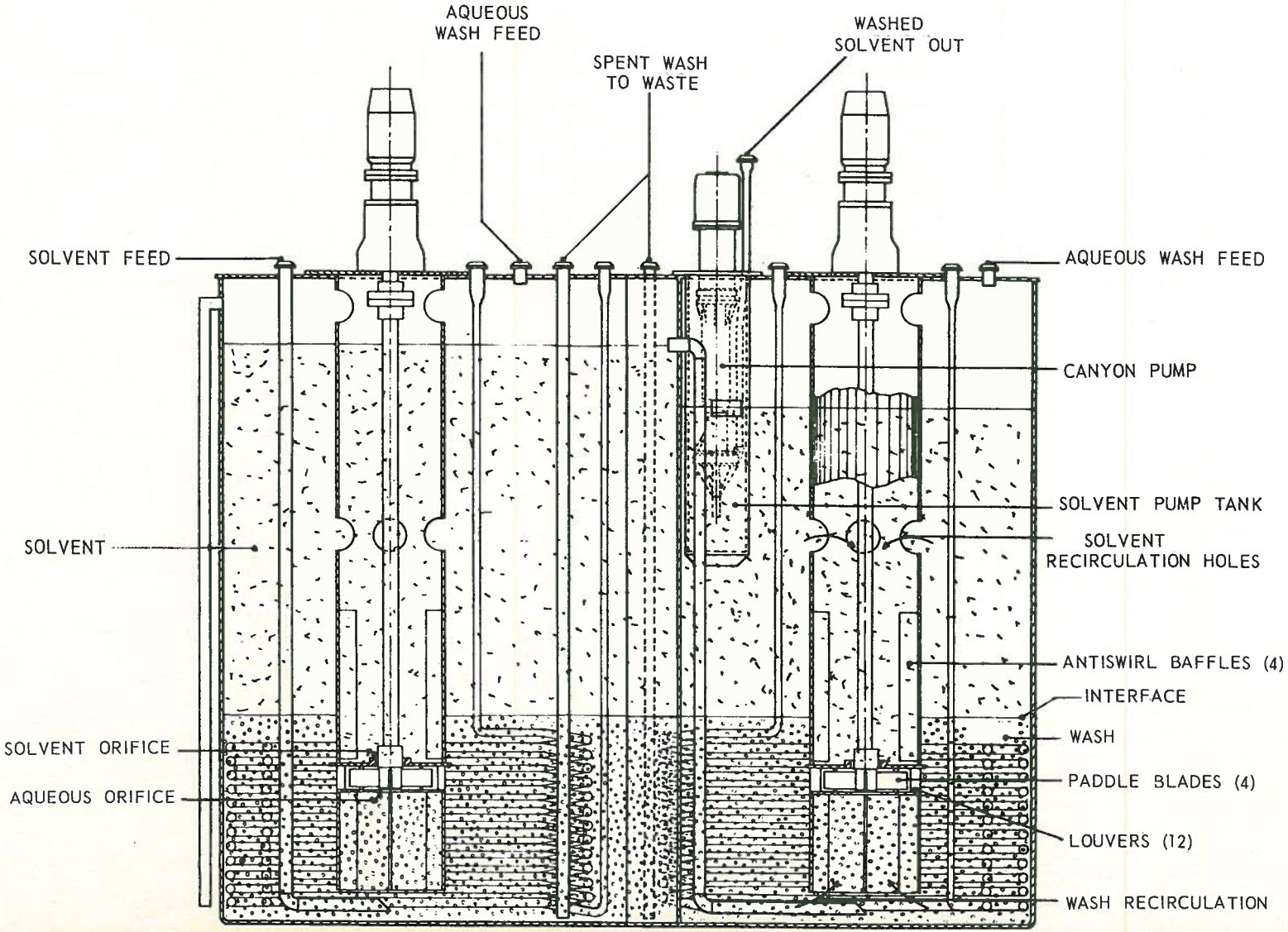


2ND PU CYCLE

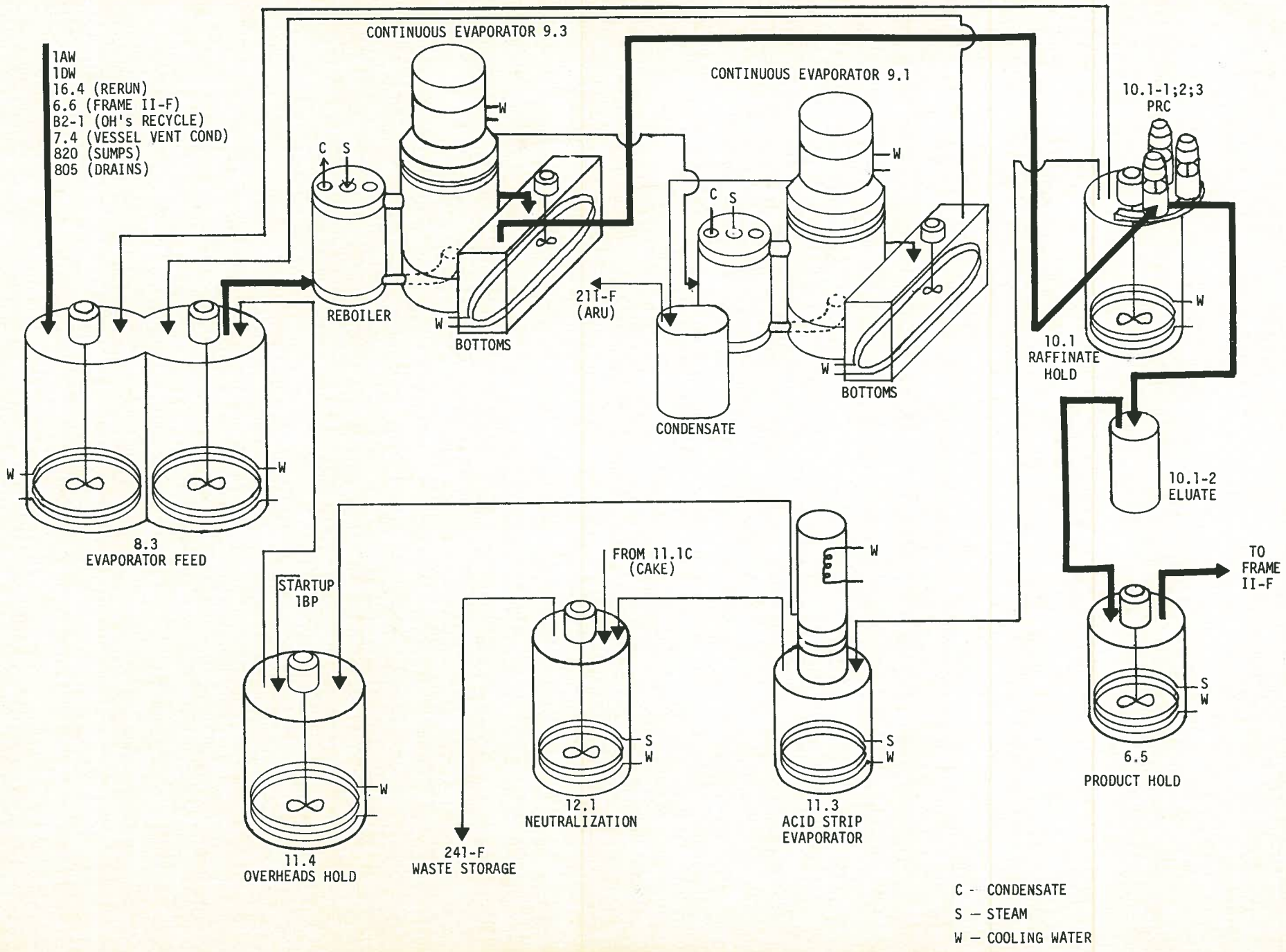


Note:
Alkaline = 0.19-0.47N Na_2CO_3
Acid = 0.03-0.12N HNO_3
HW = Hot Water

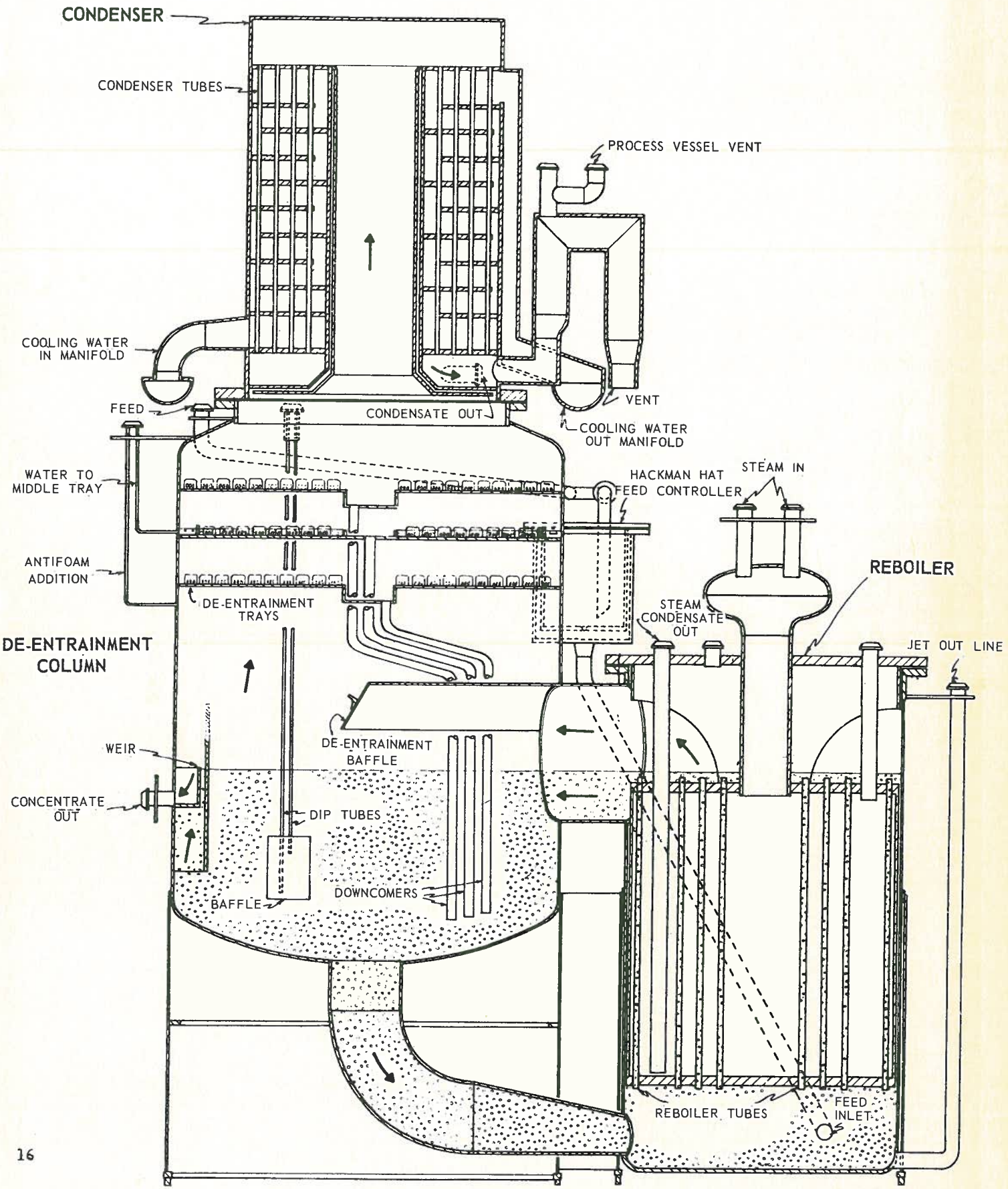
TWO-STAGE BICYLINDRICAL WASHER



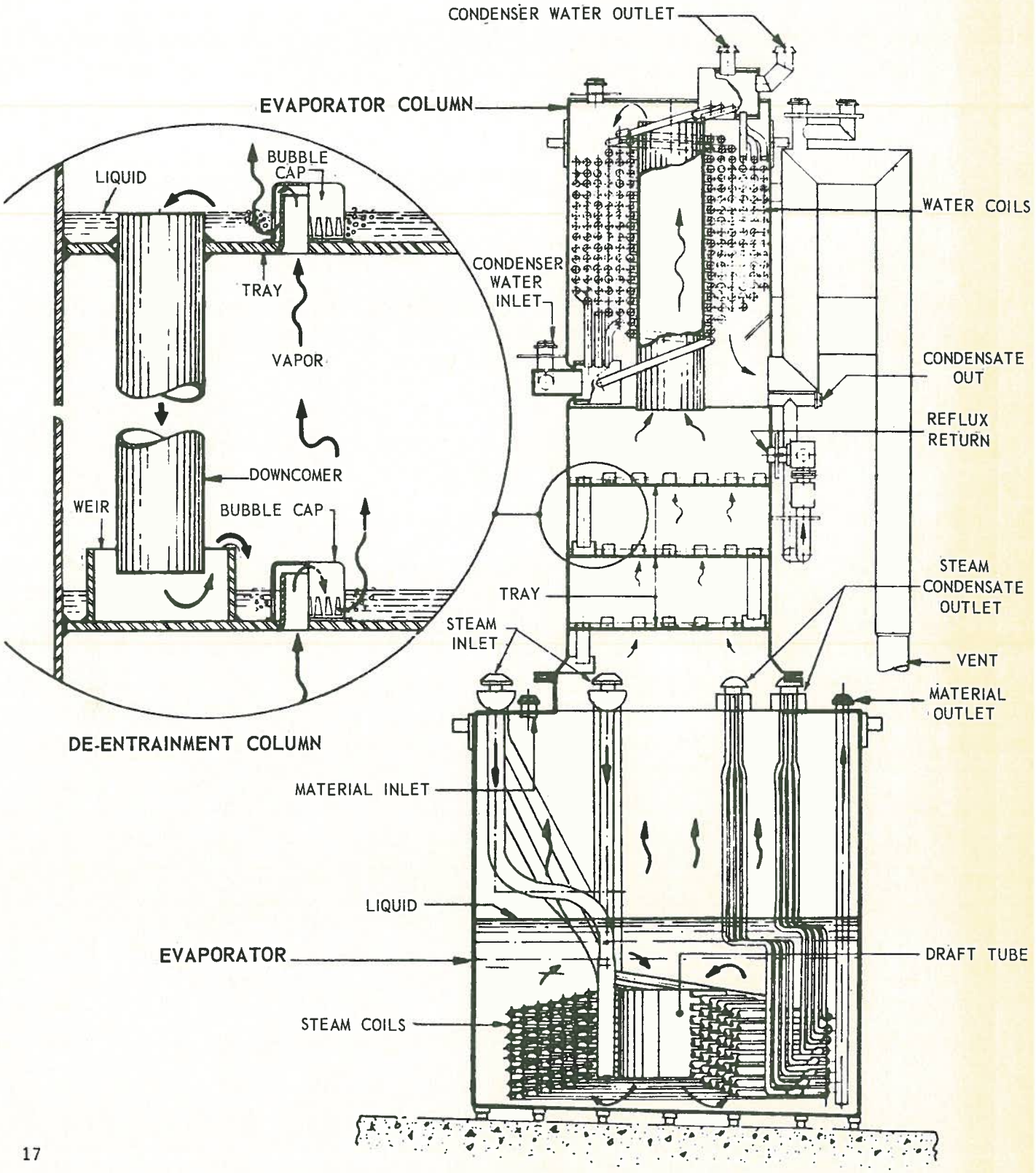
HIGH ACTIVITY WAST PRIMARY RECOVERY COLUMN



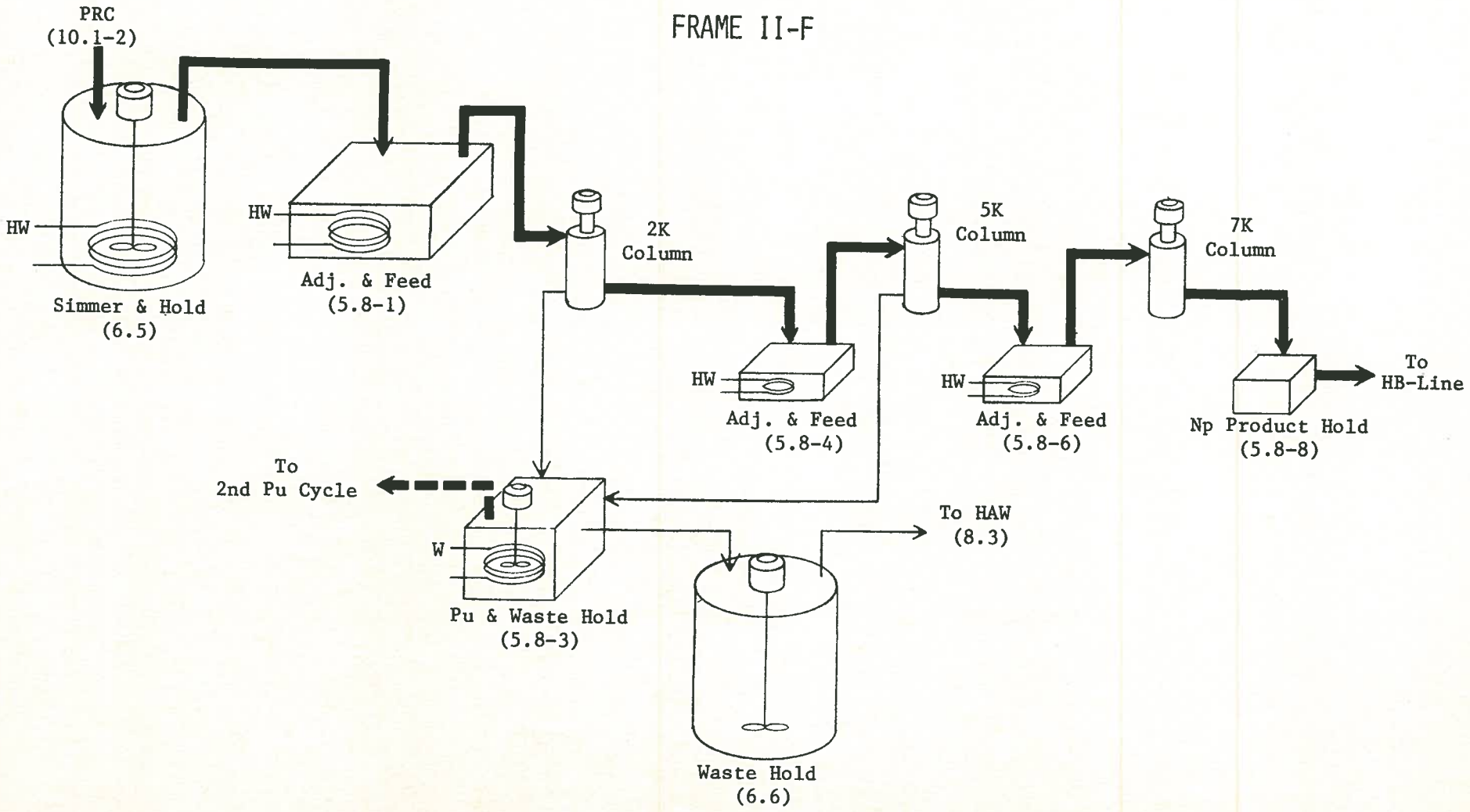
CONTINUOUS EVAPORATOR



BATCH EVAPORATOR AND COLUMN

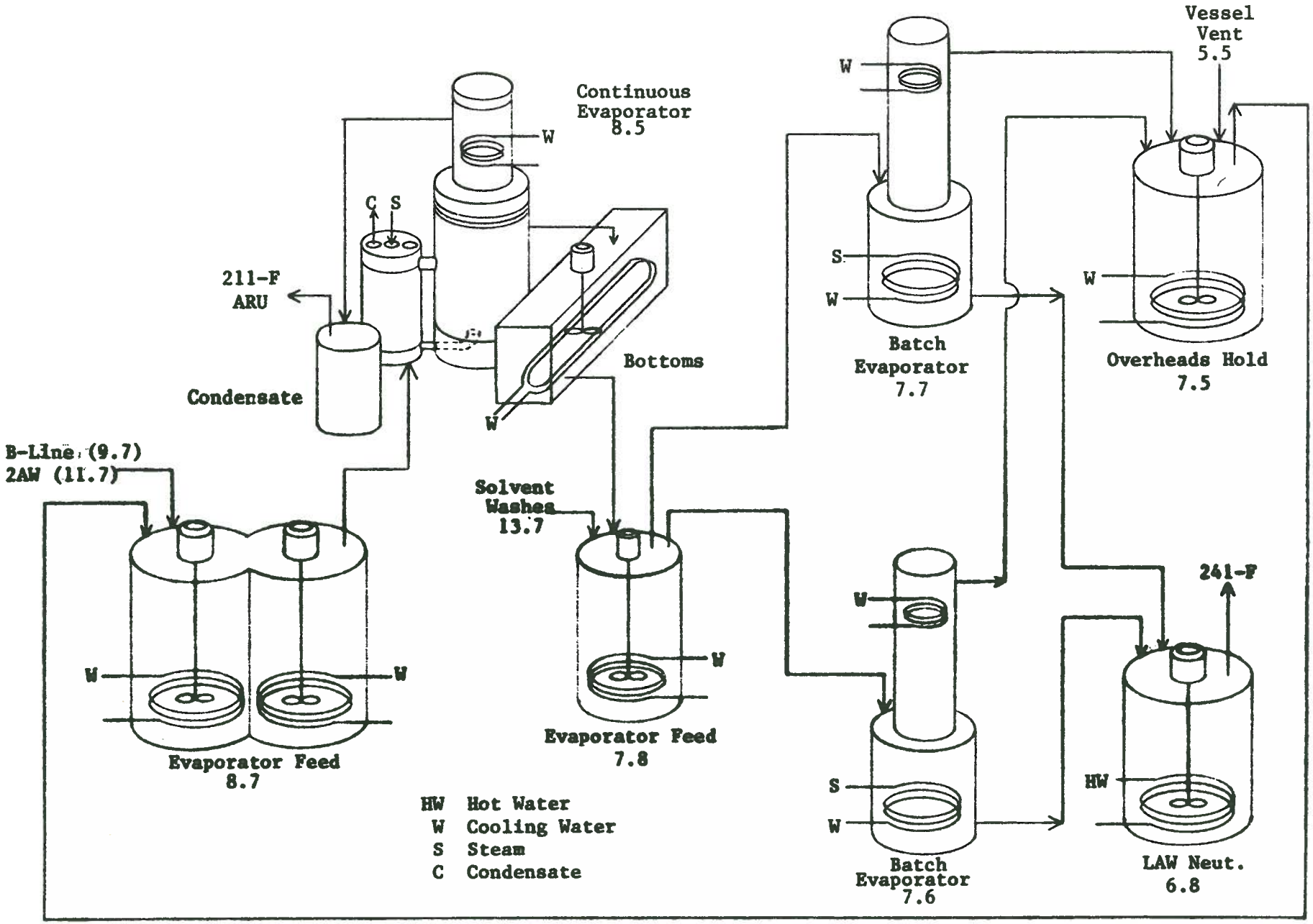


FRAME II-F

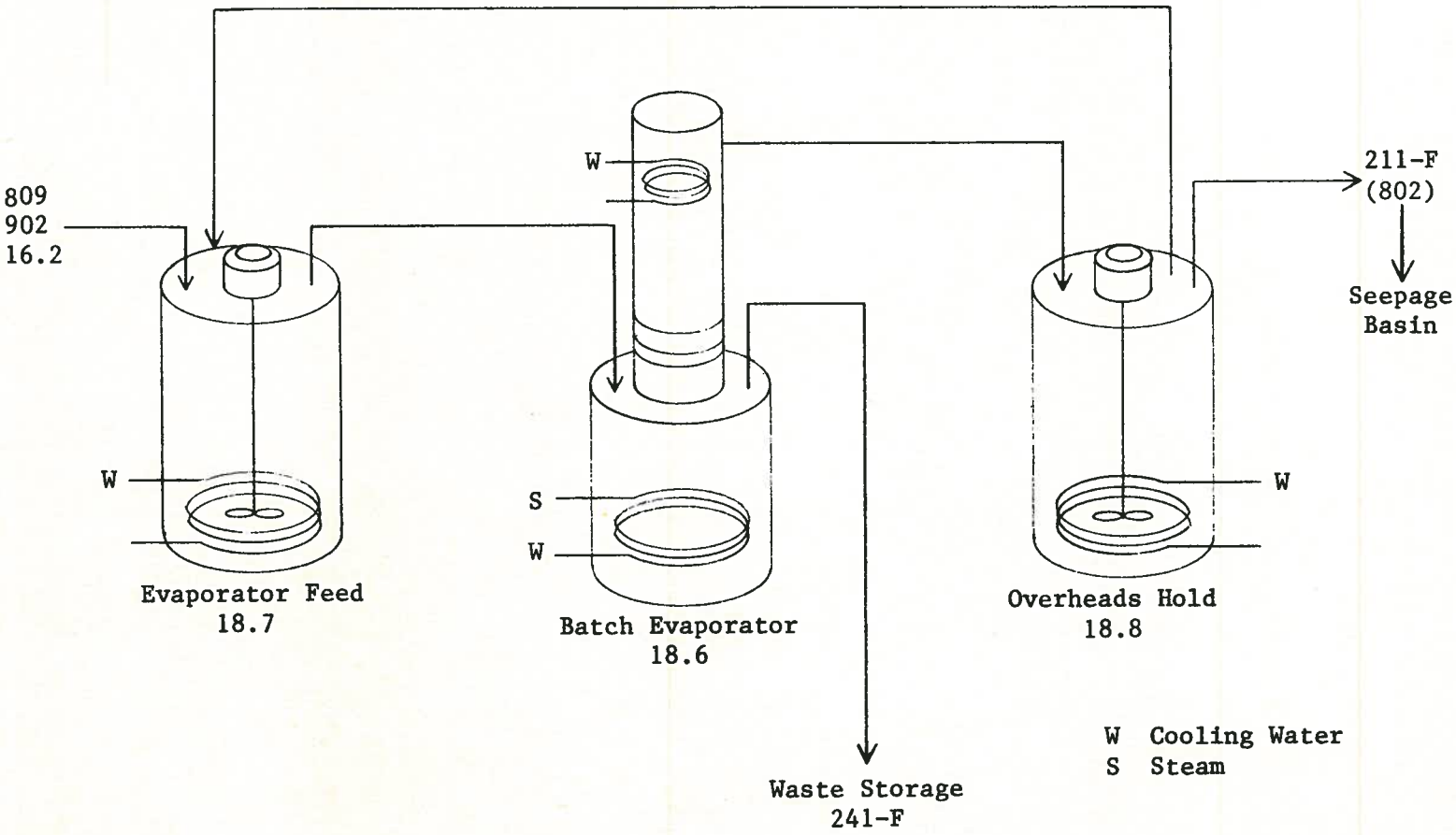


HW Hot Water
W Cooling Water

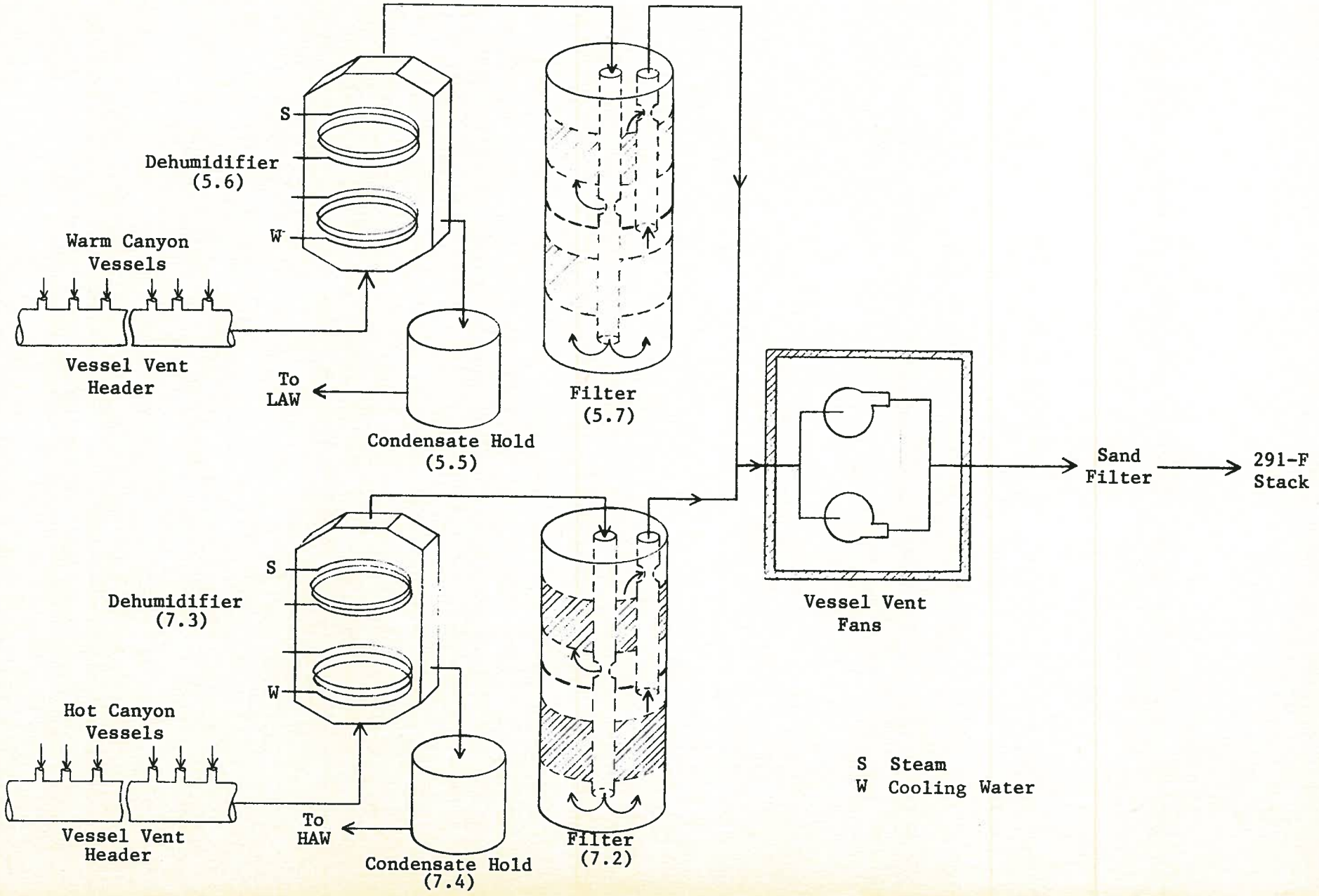
LOW ACTIVITY WASTE



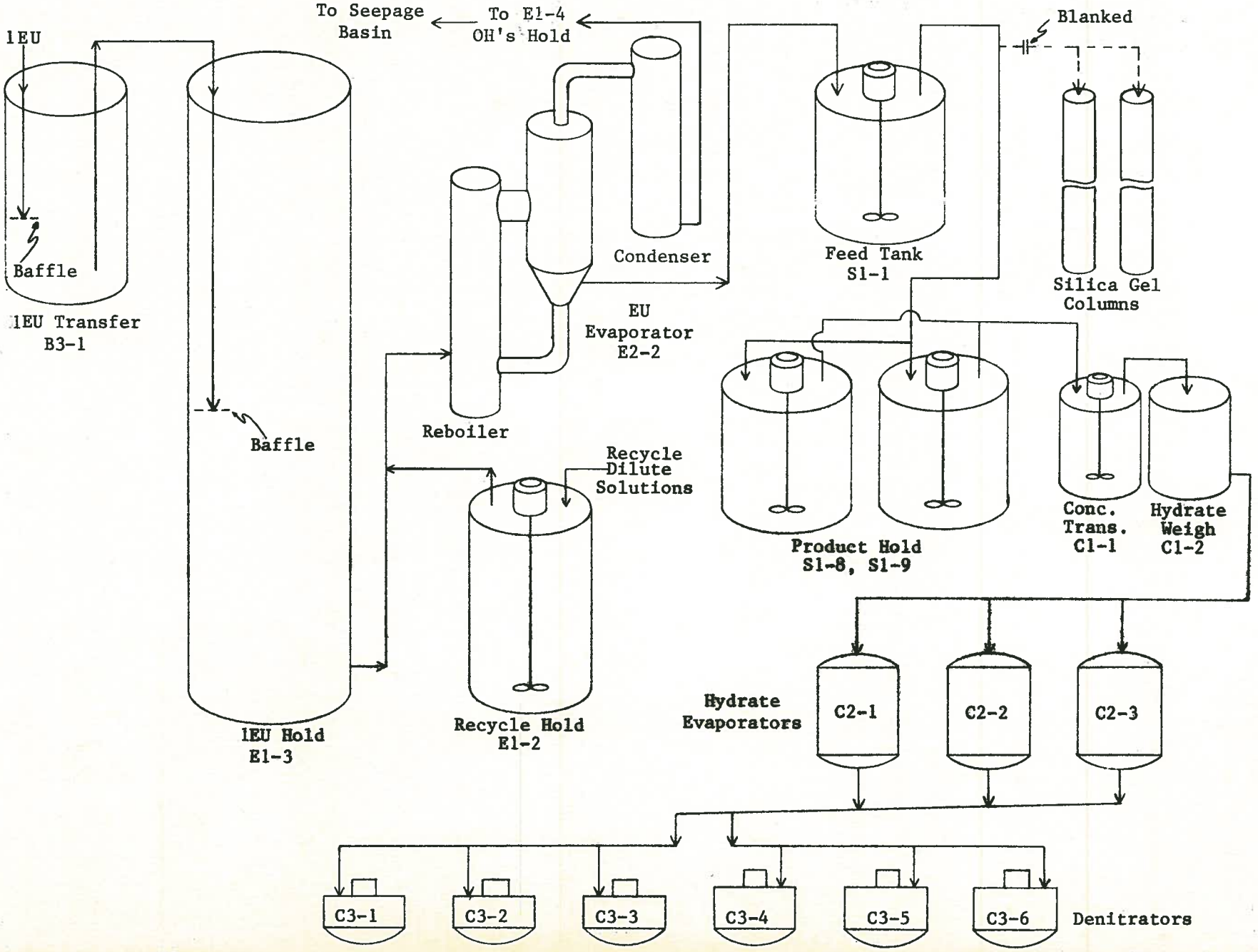
LAB WASTE EVAPORATION

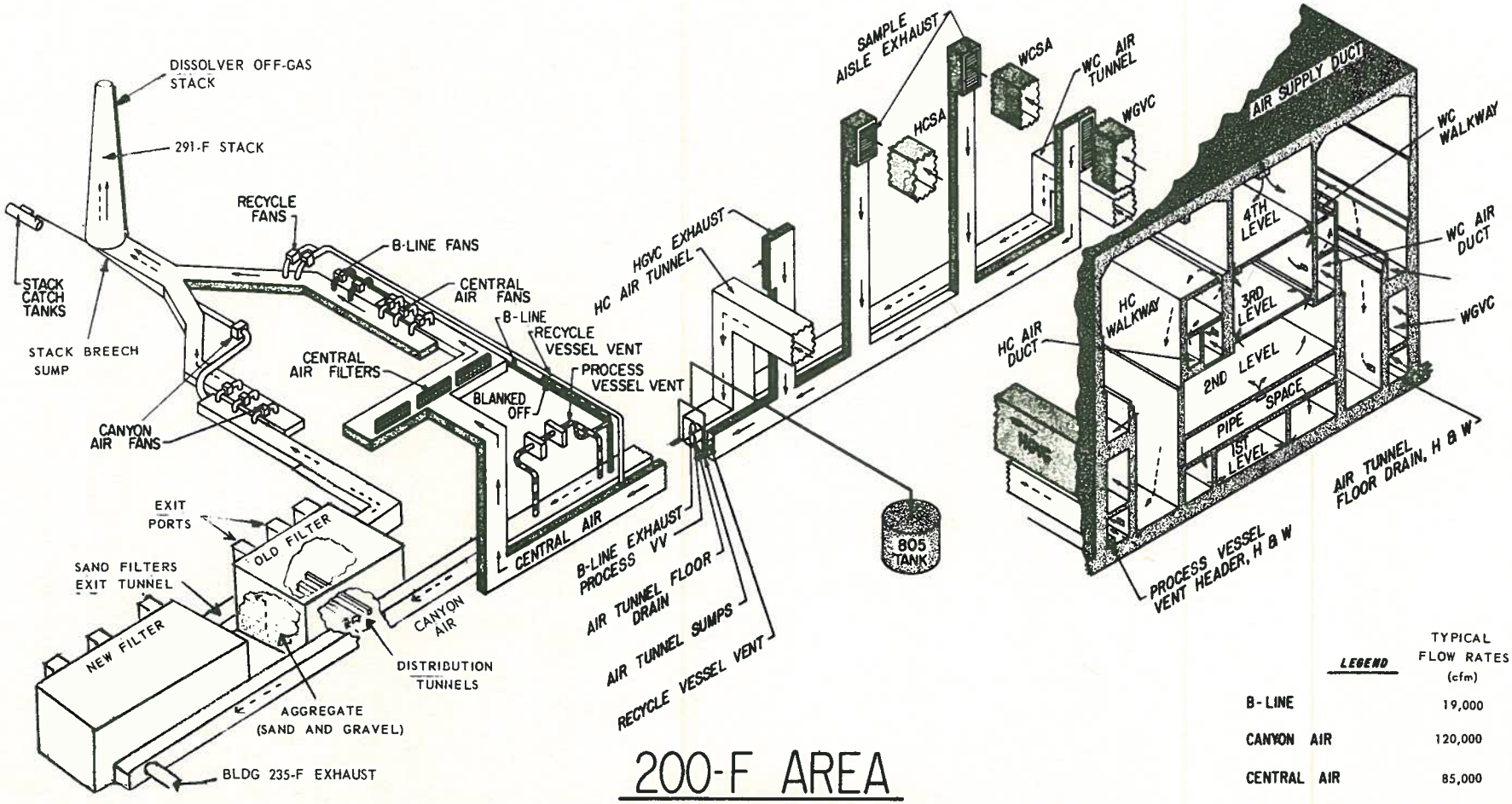


VESSEL VENT SYSTEM



A-LINE


1EU
Baffle
1EU Transfer
B3-1
Baffle
1EU Hold
E1-3
To Seepage
Basin
To E1-4
OH's Hold
Condenser
EU
Evaporator
E2-2
Reboiler
Recycle
Dilute
Solutions
Recycle Hold
E1-2
Feed Tank
S1-1
Blanked
Silica Gel
Columns
Product Hold
S1-8, S1-9
Conc.
Trans.
C1-1
Hydrate
Weigh
C1-2
Hydrate
Evaporators
C2-1
C2-2
C2-3
C3-1
C3-2
C3-3
C3-4
C3-5
C3-6
Denitrators

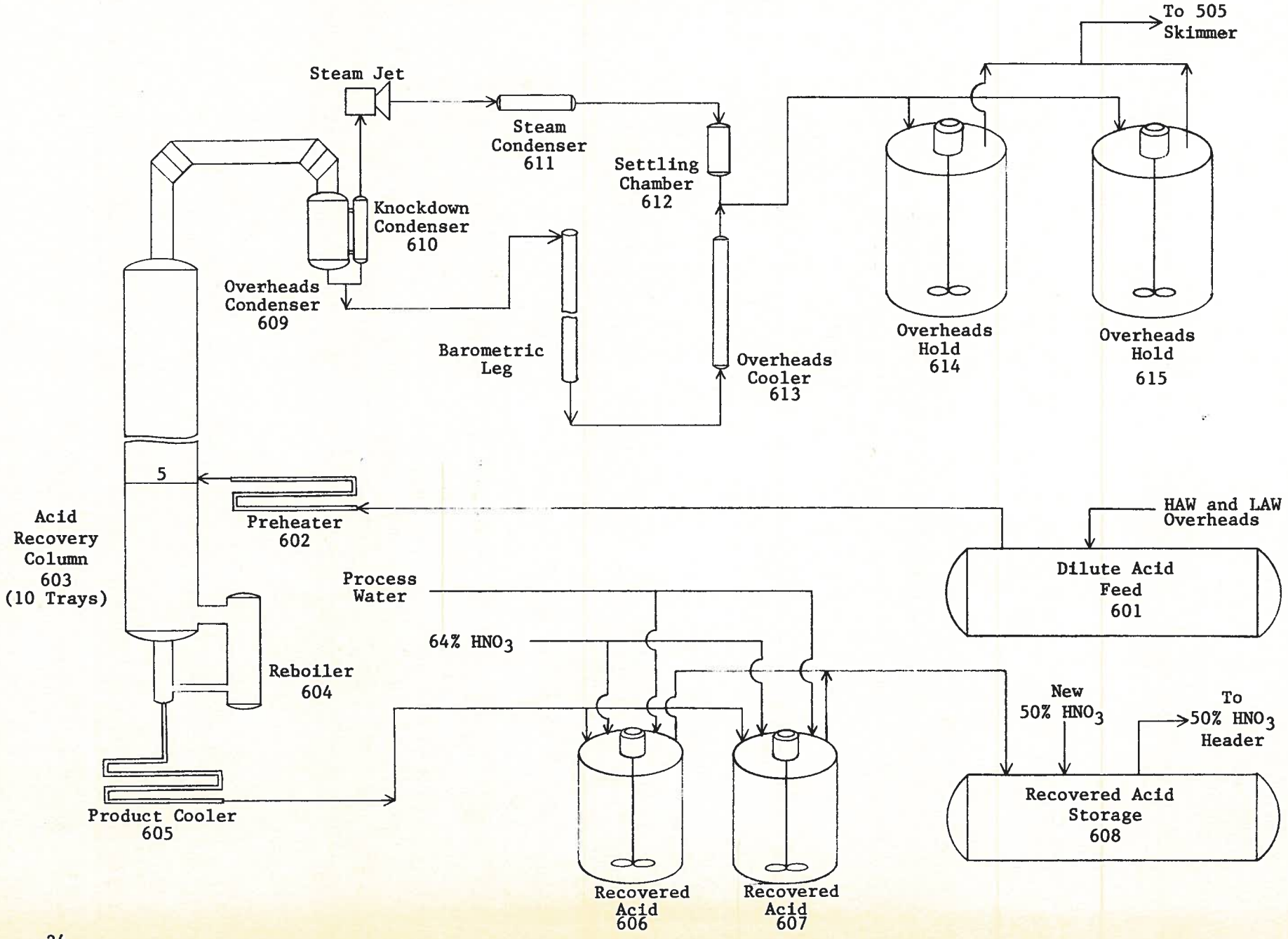


200-F AREA
AIR EXHAUST TUNNELS

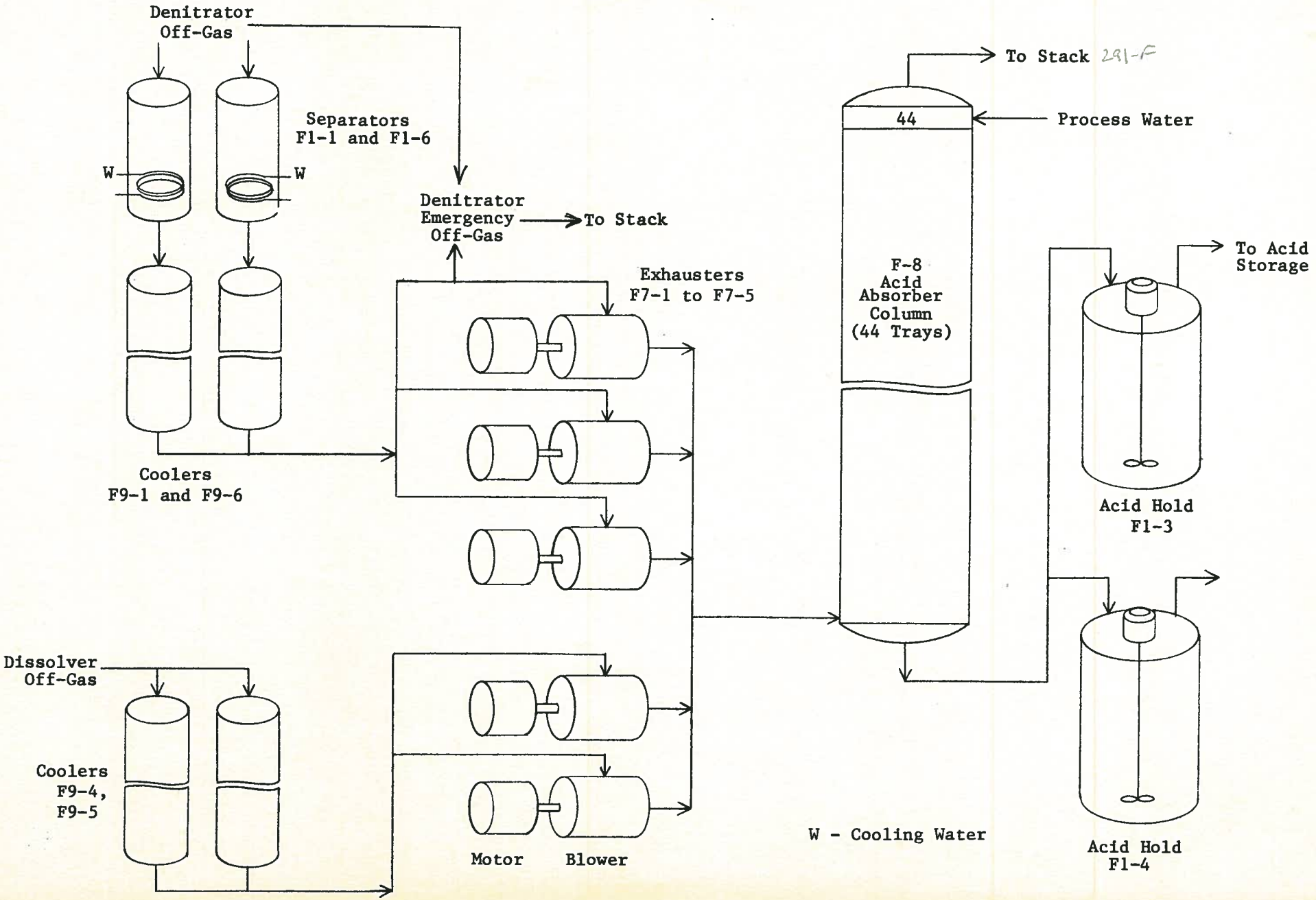
LEGEND	TYPICAL FLOW RATES (cfm)
B-LINE	19,000
CANYON AIR	120,000
CENTRAL AIR	85,000
PROCESS VESSEL VENT	15,000
RECYCLE VESSEL VENT	2,000
BLDG 235	30,000
TOTAL STACK FLOW	261,000

AIR TUNNEL FLOOR DRAINS
AIR TUNNEL SUMPS
SAND FILTER SUMPS
STACK CATCH TANKS
STACK BREECH SUMP
} JETTED TO 805 TANK

ACID RECOVERY UNIT



FUME RECOVERY



SOURCES OF SEEPAGE BASIN RECEIPTS

SOLUTION	TRANSFER TANK	VOLUME, GAL/DAY	% OF TOTAL
ARU O. H.'S	614/615	62,010	41.4
1CU EVAP. O. H.'S	17.7	41,910	28.0
1EU EVAP. O. H.'S	E1-4	27,300	18.2
242-F EVAP. O. H.'S	3N/3S	9,250	6.2
HYD. EVAP. O. H.'S	C1-3/C1-8	4,125	2.8
G. P. EVAP. O. H.'S	706-1, 706-2 707-1, 707-2	2,800	1.9
LAB. EVAP. O. H.'S	802	1,350	0.9
221-F DRAINS	503	930	0.6
		149,675	100.0