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THE H-MODIFIED PROCESS

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INTRODUCTION

Construction of the H-Area canyon separation facility was completed in the early 1950's. Processing of irradiated depleted Uranium fuel using the Purex flowsheet began in July 1955. The introduction of enriched uranium fuels into Savannah River reactor operations was to produce a greater variety of products. This required the development of a modified flowsheet to ensure criticality safety during recovery of unburned uranium from spent enriched uranium fuels. This H-modified (HM) process was introduced in H-canyon in May 1959. The process was modified in 1963 to permit recovery of neptunium as well as enriched uranium. In addition to SRP fuels, offsite fuels from research and test reactors can be dissolved and processed using HM flowsheet. An electrolytic dissolver, used for processing fuels clad in stainless steel and other metals resistant to nitric acid attack, was installed in 1969. Normal throughput of uranium is in the range of 400-500 kg per month.

SUMMARY

Plutonium-239 and tritium are produced by irradiating depleted uranium and lithium-aluminum targets, respectively, with neutrons in SRS reactors. The source of the neutrons are driver assemblies consisting of enriched uranium fabricated in long tubes; the two assemblies currently in use are Mark 16B and Mark 22. After irradiation for a certain length of time, usually several months, the enriched uranium fuel assemblies are discharged from the reactor, stored about 200 days in a water basin, bundled, and sent in heavily shielded cask cars via railroad to H-canyon for recovery of enriched uranium and neptunium. Enriched uranium is recovered in a dilute aqueous stream and converted to an oxide in the Uranium Solidification Facility and transported to the Y-12 plant at Oak Ridge, Tennessee for conversion to metal. Uranium metal is returned to the plant for the fabrication of fuel assemblies.

Neptunium is also recovered by solvent extraction in a dilute aqueous stream. Neptunium-237 is transferred to HB-Line for conversion to an oxide, shipped to 235-F for production of billets, then sent to the 300 Area for the fabrication of Np-237 targets for the production of Plutonium-238. The complete fuel cycle is shown in figure 1.

Major operations in the HM-process are shown schematically in figure 2. Irradiated fuel from either plant or offsite reactors is dissolved in boiling nitric acid catalyzed with mercuric nitrate. The resulting solution contains a mixture of uranium, plutonium, neptunium, aluminum, and fission products. During normal operation the solution is first evaporated. Then MnO_2 and gelatin are added to remove fission products and silica, respectively. The solution is then clarified through the use of a centrifuge. The treated solution is adjusted with water or nitric acid, then fed to the first cycle of solvent extraction.

Uranium and neptunium are extracted into a 7-1/2% TBP-n paraffin solvent phase in mixer-settler 1A. The plutonium, aluminum and greater than 99% of the fission products are not extracted, and are carried out in the 1AW waste stream. The solvent flows to mixer-settler 1B where neptunium and uranium are partitioned by stripping out the neptunium with 1.55M nitric acid; about 95% of the Np is removed. The uranium remains in the solvent and flows to mixer-settler 1C where it is stripped from the solvent into dilute nitric acid.

The neptunium, which exits the 1B bank in the 1BP, is adjusted with nitric acid and ferrous sulfamate (to reduce valence to the plus 4 state) and fed to second neptunium cycle. The Neptunium is extracted into a 30% TBP-n paraffin solvent phase in mixer-settler 2A, then stripped into the aqueous dilute nitric acid phase in mixer-settler 2B. Fission products and any residual plutonium are rejected in the 2AW waste stream to low activity waste.

The aqueous uranium stream (1CU) from mixer-settler 1C is concentrated in a batch evaporator to approximately 6 g U/l, adjusted with nitric acid and fed to second uranium cycle mixer-settler 1D. The uranium is extracted into the 7-1/2% TBP-n paraffin solvent, and about 3% of the neptunium originally present in the first cycle feed leaves in the 1D aqueous waste stream (1DW). This solution goes to low activity waste or may be concentrated and blended with

neptunium from mixer-settler 1B. The uranium passes to mixer-settler 1E in the solvent, where it is stripped into a dilute nitric acid aqueous stream resulting in a product of about 8 g U/l. This uranium product stream is transferred to a tank in 211-H where it is stored and eventually sent to Uranium Solidification Facility.

processing?

Irradiated fuel elements are normally cooled several months before reproducing begins to allow fission products to decay. The fuel elements are shipped in casks on railroad cars to Building 221-H for processing. SRS elements are in open frameworks aluminum bundles that hold the fuel assemblies in a line; for Mark 16B and Mark 22 assemblies, four assemblies are bundled together. Offsite fuels are bundled as the special shape and dimensions require, normally in 5-inch diameter general purpose aluminum tubes. HFIR are not bundled; they are disassembled into an inner element and an outer element that are charged to the dissolver on special aluminum carriers.

Elements are charged vertically into an insert dissolver. Three inserts are commonly used: the Mark XII insert in the plant fuel dissolver, and the HFIR and ten-well inserts in the offsite fuel dissolver.

The Mark XII insert can accommodate four bundles of elements; the bundles are confined in two rectangular, parallel slots that have space for two bundles each. A partition in the middle of each slot divides the slot into two bundles compartments or quadrants. The slots are perforated on the bottom and the sides to allow solution to flow around the tubes.

The ten-well insert can accommodate one fuel bundle of fuel in each of ten spaced, parallel, cylindrical wells. The wells are in a rectangular 2 x 5 array and are perforated to allow free flow of dissolvent.

The HFIR insert can accommodate one HFIR core or assembly, consisting of an inner element and outer element, in two parallel cylindrical wells. HFIR fuel must be dissolved in the HFIR insert only.

Nuclear Safety considerations often limit the number of bundles that can be charged to the available space in an insert. When all four quadrants of the Mark XII or all ten wells of the ten-well insert cannot be used for nuclear safety reasons, unused quadrants or wells must be blocked by plugs to prevent overcharging.

The maximum number of elements allowable in any dissolver insert is determined by the largest whole number of elements that contain less than 50.6 kg ^{235}U (6.4D larger dissolver) or 25.3 kg ^{235}U (6.1D smaller dissolver). These limits are based on the maximum safe concentration of 11.5 g ^{235}U/liter and the minimum volumes (for accidental evaporation to 4400 and 2200 liters, respectively).

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DISSOLVING

A) SRS Fuels

Spent Uranium (1.1-93.5% ^{235}U) fuel elements (bundles) with aluminum cladding are shipped by railroad, in shielded casks from SRS reactor areas, to Building 221-H for chemical dissolution in dissolver 6.4D (figures 3 & 4). The uranium is present in the form of U-Al alloy. Chemical dissolution is accomplished by boiling the fuel elements in HNO_3 (about 4M initially and 0.6M finally) for approximately 22 hours. A small amount (0.0002M) of mercuric nitrate is added to catalyze aluminum dissolution by destroying the passive aluminum oxide surface on the fuel. Completeness of dissolution is verified by physically "probing" the dissolver to ensure that no fuel fragments remain. The dissolver solution contains about 0.9M Al and 3 g U/l.

All types of dissolution produce an off-gas containing nitrogen oxides, gaseous fission products, and traces of hydrogen. Off-gas from dissolver 6.4D passes through first a reactor (7.1R) packed with silver nitrate-coated Burl saddles to trap iodine (figure 5), then through a glass wool filter (7.1F) to remove any particulate matter (figure 6), before being exhausted to 200-ft. high stack.

B) Offsite Fuels (Aluminum Clad)

Offsite Fuels from various sources (e.g. University test reactors) stored at the Receiving Basin for Offsite Fuels (RBOF) that can be dissolved chemically are charged to dissolver 6.1D. The dissolving recipes and off-gas handling are almost identical to those of the plant fuel (the catalyst concentration is 0.0035M), although the offsite fuel dissolver does have its own iodine reactor (6.2R) and off-gas filter (6.2F).

C) Offsite Fuels (Stainless Steel Clad)

Some offsite fuels, such as certain test reactor fuels, cannot be dissolved chemically because the stainless steel or zircaloy cladding is resistant to attack by nitric acid. These fuels must be dissolved electrolytically (figure 7) due to the passive metal oxide films; dissolution is accomplished by increasing the electrochemical potential at the metal-solution interface by applying an external source of electrical energy. Current flows from cathode through the fuel to the platinum anode. The fuel is contained in a ceramic fuel basket. Acidity in the dissolver pot is maintained above 6.5M HNO_3 to prevent embrittlement of the electrodes; a dissolving temperature of 60-80°C is maintained to minimize corrosion. The concentration of the uranium-235 in the dissolver solution is maintained at a safe level (4.6 g ^{235}U/l) and is the primary nuclear safety control. In addition, the dissolver solution contains 2.5 g/l boron in the form of boric acid solution as a secondary nuclear safety control. Typical operating conditions for the electrolytic dissolver are 7500 ampere at 40 volts (dc). The off-gas from the dissolver is connected to the off-gas system of dissolver 6.4D or 6.1D.

HEAD END

In head end operations, the dissolver solution is clarified and adjusted as required for feed to the first cycle of solvent extraction. The type of head end treatment is determined by gamma activity in routine SRS fuel solution or by chromium content in the electrolytic dissolver solution.

A) Combined Strike -

For fuel containing no chromium, dissolver solution is moved batchwise from accountability tank 8.3 through evaporator feed tank 11.2 to evaporator 11.3E. The solution is evaporated until the aluminum concentration is about 1.5-2.0M, then transferred to "strike" tank 10.2. Solutions containing significant chromium are not evaporated to avoid excessive corrosion of the evaporator by chromic acid.

A combined strike is the simultaneous precipitation of silica-gelatin polymer and manganese dioxide by the addition of manganous nitrate, gelatin, and potassium permanganate, in that order. The order is important to maintain a reducing environment which avoids volatilization of fission product ruthenium as RuO_4. The gelatin reacts with the silica (present from impurities in aluminum and the transmutation of aluminum) to form an insoluble polymer. The manganese dioxide removes some of the zirconium and niobium fission products. The "struck" solution is simmered for one hour at 75°C and fed continuously to centrifuge (10.3C) to remove the solids before transfer for adjustment for feeding the first cycle of solvent extraction. The combined strike flowsheet is shown in figure 8.

B) Dilute or "Double" Strike -

Dissolver solution that is high in gamma activity may require a dilute or "double" strike to enhance removal of zirconium and niobium fission products. The struck solution is centrifuged (figure 9), evaporated, and then treated with gelatin to remove silica. The struck solution is again centrifuged before adjustment for feeding first solvent extraction cycle. The dilute strike flowsheet is shown in figure 10.

FIRST CYCLE

First cycle processes dissolved irradiated fuel to recover uranium and neptunium and decontaminate them from fission products and impurities by solvent extraction. The cycle uses three multistage mixer-settlers which are commonly called banks (figure 11). In the A bank, uranium and neptunium are extracted into an organic solvent (7-1/2% TBP, with the remainder being n-paraffin), thereby separating them from fission products and chemical impurities. In the B bank, neptunium and uranium are separated from each other by stripping neptunium in to a 1.55M HNO_3 aqueous product stream (1BP) while uranium remains in the solvent. In the 1C bank, uranium is stripped from the solvent into a very dilute nitric acid product stream (1CU). The A and B banks have 16 stages each while the C bank has 12 stages. The organic solvent used is tri-n-butyl phosphate (TBP) diluted to 7.5 vol. % with n-parrafin (a C-12 to C-14 straight chain hydrocarbon). Uranium and neptunium are extracted by the solvent when the concentration of the salting agent (aluminum nitrate and/or nitric acid) in the aqueous is high (3.8M to 5.8M), and are stripped from the solvent when the total nitrate concentration is low. Since neptunium is less extractable than uranium, the two can be separated by using an intermediate total nitrate concentration. Aqueous and solvent flows are concurrent in an individual stage, and countercurrent between adjacent stages of the mixer-settlers. Solvent exits at stage 1, while aqueous exits at the opposite end of the bank, stage 12 or 16 depending on the bank.

Feed for first cycle is received from head end into adjustment tank 12.2. After adjusting the aluminum nitrate and nitric acid concentrations, the feed (1AF) is transferred to feed tank 12.3 and fed to stage 8 of the A bank. Solvent (1AX) is fed to stage 16 and extracts uranium and neptunium from the 1AF in stages 8 through 16. Extracted or entrained fission products and impurities are scrubbed from the solvent in stages 1 through 7 by an aqueous scrub stream (1AS) fed to stage 1. Ferrous sulfamate in the 1AS reduces the valence of neptunium in the aqueous phase to to extractable (IV), and reduces the valence of plutonium to unextractable (III). Thus neptunium is extracted by the solvent but plutonium is rejected to the waste stream (1AW). The uranium valence does not change, and it remains extractable (VI).

The solvent stream (1AU) with extracted uranium and neptunium exits the A bank at stage 1 and gravity fed to stage 8 of the 1B bank. An aqueous stream of intermediate acid strength (1BX, 1.55M HNO_3) is fed to stage 1 to extract neptunium from the solvent. The aqueous neptunium product stream (1BP) exits the 1B bank at stage 16 and subsequently goes into the second neptunium cycle solvent extraction for further decontamination. A clean solvent stream (1BS) is fed to stage 16 to scrub any uranium from the neptunium product stream.

The uranium bearing solvent stream (1BU) exits the 1B bank at stage 1 and flows by gravity to the C bank at stage 12. A very dilute (0.01M HNO_3) acid stream (1CX) is fed to stage 1 and strips the uranium from the solvent. Spent solvent (1CW) exits at stage 1 and is transferred to solvent recovery. The aqueous uranium product stream (1CU) exits the bank at stage 12. The aqueous product stream passes through the 14.2 decanter to 1CU hold tank 18.4. The 1CU product is then transferred to the second uranium cycle for further decontamination. First cycle tankage and flow sheet are shown in figures 12 and 13.

Nuclear safety is maintained by limiting organic-to-aqueous flow ratios and salting agent concentrations, to maintain the concentrations of uranium in the mixer-settler, to less than the feed concentration. All cold streams are equipped with dual flow measurement instrumentation for enhanced reliability. In addition, several nuclear safety control instruments are located in-line. The 1CU conductivity meter ensures that the acidity of the 1CX is low enough to prohibit uranium refluxing in the 1C bank. The 1CU colorimeter measures uranium concentration in the product stream. Also, each mixer-settler (1A, 1B, and 1C) are equipped with two neutron monitors to detect increases in fissile material concentration in the mixer-settlers.

SECOND URANIUM CYCLE

Second uranium cycle provides additional decontamination for the uranium product stream from first cycle. Uranium leaves the first cycle solvent extraction process in the 1CU stream and is concentrated by batch evaporation to about 6 grams total U/liter for feed to the second uranium cycle. Uranium is decontaminated in mixer-settlers 1D and 1E and transferred to outside facilities for storage and solidification by USF.

The aqueous exit stream (1CU) from first cycle is transferred from 1CU hold tank 18.4 to the evaporator feed tank 18.7 and is fed to the 1CU batch evaporator 17.6E. The 1CU solution is evaporated, nitric acid is added and evaporated again to adjust the feed concentration. The concentrate is transferred to feed adjustment tank 17.5 where further acid adjustment is made if necessary. The adjusted feed (1DF) is sampled for uranium and acid in tank 17.5 to determine the proper flow rates of the feed and cold streams. The second uranium cycle feed is transferred from tank 17.5 to feed tank 16.8 from which it is continuously fed by pump or jet to stage 8 of mixer-settler 1D.

Uranium is extracted from the aqueous feed solution into solvent fed to stage 16 (1DX), and scrubbed with nitric acid fed to stage 1 (1DS), and a small amount of ferrous sulfamate fed to stage 4 (1DS′). The ferrous sulfamate is added to ensure that any plutonium present will remain in the unextractable trivalent state and exit the mixer-settler in the waste stream. The acidity of the scrub and the flow ratio of extractant to scrub streams are adjusted to reject neptunium (IV) to the waste stream. Neptunium, plutonium, and fission products exit mixer-settler 1D in the aqueous 1DW stream. 1DW may be evaporated then transferred to the second neptunium cycle for recovery of neptunium or may be discarded to low activity waste (LAW). The solvent containing the uranium (1DU) flows from mixer-settler 1D into stage 12 of mixer-settler 1E.

In mixer-settler 1E, uranium is stripped from the solvent into a low acid aqueous stream fed to stage 1 (1EX). It exits the mixer-settler as the 1EU stream. The solvent stream (1EW) flows from stage 1 to solvent washer 14.8. The 1EU flows to decanter 15.7 to remove entrained solvent. From decanter 15.7, the 1EU is transferred to hold tank 14.5 and sampled to verify it is within specifications before transfer to 211-H for storage. Second uranium cycle tankage and flow sheets are shown in figures 14, 15, and 16.

SECOND NEPTUNIUM SOLVENT EXTRACTION CYCLE

A) Reducing flowsheet

The neptunium stream from first cycle (1BP) and solvent washes are processed in the second neptunium cycle, along with plutonium-free wastes from HB-Line. The 1BP (1.5M HNO_3), received from the 1BP run tank 14.7 is adjusted with HNO_3 in the feed adjustment tank 12.7 to give a resulting feed solution (2AF) to 4.0M HNO_3. HB-Line wastes are received in tanks 9.6 and 8.8, and are blended in 12.7 as necessary. The neptunium stream from second uranium cycle (1DW) can be processed through the second neptunium cycle to recover neptunium rather than being processed through Low Activity Waste (LAW). In this case, the 1DW is evaporated in 17.6E from 3.5M HNO_3 to about 7.6M HNO_3 and combined in batches with 1BP in 12.7 to give a resulting feed solution of 4.3M HNO_3. Adjusted feed batches are transferred to tank 12.5 for continuous feeding to stage 8 of the 2A mixer-settler. The neptunium is extracted into the organic phase (30 vol % TBP, 2AX); fission products, plutonium, and other salts are scrubbed into the aqueous phase by the 0.88M HNO_3 2AS scrub stream, and leaves the 2a mixer-settler in the aqueous stream (2AW). Ferrous sulfamate in the 2AS reduces the valence of neptunium in the aqueous phase to extractable state (IV), and reduces the valence of plutonium into unextractable state (III). The organic stream containing neptunium flows by gravity to stage 16 of the 2B mixer-settler, where the neptunium is stripped from the organic phase into the 0.01M HNO_3 aqueous stream (2BX). The aqueous product stream (2BP) exits into the 10.8 decanter where entrained solvent is separated from the 2BP and returned to the 2B mixer-settler. The 2BP is transferred to tank 18.5 for feeding to the 17.8E evaporator, where the neptunium solution is evaporated and allowed to accumulate. When sufficient neptunium has accumulated in 17.8E, the 2BP concentrate is transferred back to 12.7 for a recycle pass through the mixer-settler for additional decontamination before transfer to HB-Line. In the recycle run, the 2BP "heart cut" is transferred to tank 9.8 from decanter 10.8, and the remainder returned to the evaporator. Tank 9.8 is then simmered to increase the neptunium concentration, and transferred to HB-Line.

Aqueous waste (2AW) leaves the 2A mixer-settler and flows to tank 11.7. The 2AW solution is then transferred to Low Activity Waste (LAW) hold tank 11.8 for subsequent processing through LAW.

Since the cycle does not separate neptunium from any uranium present, a uranium purge is performed periodically to reduce the uranium-235 inventory of the system. Uranium accumulates in the second neptunium cycle because uranium fed to the cycle (from 1BP and 1DW streams) is returned to the system from HB-Line following a recycle run. The uranium purge is performed by extracting the uranium into the organic 2AX stream, stripping it back into the aqueous 2BX stream, and sending the resultant 2BP solution to the head end to be combined with dissolver solution in the 11.3E head end evaporator.

Typical compositions and flows for streams in the reducing flowsheet are shown in figure 17 and 18. Also shown are the type A mixer-settler bank, a standard canyon tank, a batch evaporator, and a tank decanter (figure 20-23).

B) Oxidizing Flowsheet

The reducing flowsheet described above for neptunium recovery and purification does not separate neptunium from thorium. If significant thorium contamination is present in the neptunium, an oxidizing solvent extraction flowsheet is used. Generally, significant thorium contamination is not a problem; however, the flowsheet is available for use if needed. The 2AF feed is adjusted to 1.5M HNO_3, and ceric ammonium nitrate is added to about 0.01M to oxidize neptunium to its most extractable valence state, Np(VI). The 2AF is fed continuously to stage 8 of the 2A mixer-settler, where the 2AF and 2AX flow rates are adjusted to extract neptunium into the organic phase; thorium remains in the aqueous (2AW) stream. In the scrub section the 2AS scrub stream (0.5M HNO_3) removes residual thorium and fission products. The neptunium is stripped from the organic phase into the slightly acidified (0.01M HNO_3) 2BX stream in the 2B mixer-settler. Cerium is extracted and follows neptunium into the 2BP. The product 2BP solution must be recycled using the reducing flowsheet to remove cerium. The 2BP solution from the recycle run is then simmered before transfer to HB-Line as described in the reducing flowsheet.

SECOND PLUTONIUM CYCLE

The second plutonium cycle, which normally provides additional decontamination for the neptunium recovered from high-enriched uranium fuel, is also used to process plutonium. The plutonium originates from processing low-enriched uranium fuel, scrap dissolved in HB-Line, or occasionally, targets made of plutonium or americium and curium.

The plutonium is partitioned to the 1BP in mixer-settler 1B and transferred from tank 13.3 to tank 14.7. Plutonium solution is then processed through second plutonium cycle. The feed solution (2AF) is received in tank 14.7 and moved to tank 12.7 where it is acid adjusted to 4.5M HNO_3. Sodium nitrite is added and then the tank is sampled for excess sodium nitrite. The presence of excess sodium nitrite verifies any ferrous sulfamate that was present has decomposed and the plutonium is stabilized in the extractable IV valence. The solution is then transferred to the second plutonium cycle feed tank 12.5 to stage 8 of the 2A mixer-settler. The plutonium is extracted into the organic phase (30 vol % TBP, 2AX), fission products and other salts are scrubbed in to the aqueous phase by the 0.90M HNO_3 2AS scrub stream, and leaves the 2A mixer-settler in the aqueous stream (2AW). The organic stream containing plutonium flows by gravity to stage 16 of the 2B mixer-settler, where the plutonium is reduced to the unextractable III valence by Hydroxly Amine Nitrate (HAN) in the 2BX and stripped from the organic phase into the 0.01 HNO_3 and 0.056M HAN aqueous stream (2BX). The aqueous product stream (2BP) exits into the 10.8 decanter where entrained solvent is separated from the 2BP and returned to the 2B mixer-settler. The 2BP can be transferred to HB-Line via tank 9.8, or transferred to tank 8.5 for storage.

Aqueous waste (2AW) leaves the 2A mixer-settler and flows to tank 11.7. The 2AW solution is then transferred to the low activity waste (LAW) hold tank, 11.8 for subsequent processing through LAW. The stripped organic stream, 2BW flows to tank 10.5, and then is processed through the solvent recovery system. Second plutonium cycle tankage is shown in figure 19.

RERUN

Rerun's principal function is to receive and process leaks, spills, and floor flushing solutions from canyon cells. Uranium, if present, is recovered by batch extraction, transferred to head end, and combined with dissolver solution.

Solutions collected in the canyon sumps are transferred and received in sump collection tanks 18.2 (hot canyon) and 16.6 (warm canyon). The solutions are sampled to determine if they contain recoverable amounts of uranium, and transferred to hold tank 17.1. If there is not enough uranium to justify recovery, the solutions are transferred from tank 17.1 to either the high activity waste or frame waste evaporators for disposal. If there are recoverable amounts of uranium, the solutions are transferred from tank 17.1 to tank 15.2 for storage. Solution is stored in tank 15.2 until enough uranium has accumulated for a batch extraction. The volume of solution is periodically reduced by evaporation in the frame waste evaporator, adjusted to 5M HNO_3, and returned to tank 15.2.

Uranium is recovered by batch extraction in tank 15.3 using 5% TBP in an n-parrafin dilutent. The raffinate is decanted through decanter 16.1-1S to tank 16.2 and disposed of through frame waste evaporation. Uranium is stripped from the solvent with two process water strips. The strips are decanted and transferred through tank 16.2 to tank 18.1. In tank 18.1, the strips are washed with n-parrafin to remove any entrained degraded solvent. From tank 18.1, the uranium is transferred to head end and combined with routine dissolver solutions. Rerun tankage is shown in figure 24.

SOLVENT RECOVERY

Each of the three solvent extraction cycles has a separate solvent recovery system. The solvent recovery system removes radioactive fission products and solvent degradation products, maintains acceptable solvent quality, and returns washed solvent to the respective cycle. Operating experience has shown that an efficient washing cycle is an alkaline wash (0.35N to 0.49N Na_2CO_3) followed by an acid (0.03N to 0.12N HNO_3) wash. Carbonate is used to minimize the possibility of precipitating uranium in the washes. First cycle and second uranium cycle both have solvent compositions of 7.5 vol % tri-n-butyl phosphate (TBP) and 92.5 vol % n-parrafins (normally C_{12}-C_{14}), with a density of about 0.80 g/ml. Second neptunium cycle solvent is 30 vol % TBP and 70 vol % n-parrafins, with a density of about 0.82 g/ml.

The first cycle solvent system is located in the hot canyon and behind shielded walls in Building 211-H, Outside Facilities. (Shielding is necessary due to the higher radioactivity of the first cycle solvent.)

Solvent from the 1C mixer-settler (1CW) flows by gravity to the 15.1 solvent run tank. It is then pumped to the first stage alkaline washer, 12.6, where it is washed with about 15,000 pounds of sodium carbonate solution. After gravity separation from the wash solution, the solvent flows over a weir into the 12.6 blister tank where it is pumped to the second stage alkaline washer, 12.8. In 12.8, the solvent is washed as in 12.6, and is pumped outside the canyon to 211-H to the tank 903 acid washer. The solvent is washed with about 20,000 pounds of dilute nitric acid, then flows by gravity to the 904 washed solvent hold tank.

Solvent is pumped from tank 904 to the canyon third level head tanks for feeding to first cycle as the 1AX and 1BS streams. When first cycle is down, solvent is normally circulated at all times to maintain quality by pumping solvent from tank 904 directly to 15.1, bypassing the mixer-settlers.

Solvent recovery facilities for the second uranium cycle are located in the warm canyon and 211-H. Unwashed solvent is received directly from the 1E bank as the 1EW stream, and flows by gravity to the alkaline washer 14.8. The solvent is washed with about 10,000 pounds of carbonate solution. The solvent separates by gravity and flows over a weir into the 14.8 blister tank where it is pumped to the 901 acid washer in building 211-H. The solvent is washed with about 20,000 pounds of dilute nitric acid, and flows to washed solvent hold tank, 902. Solvent is pumped from 211-H to the canyon third level tanks for feeding to the 1D mixer-settler as the 1DX stream.

The solvent recovery system for the second neptunium cycle is also located in the warm canyon and in building 211-H. Solvent leaves the 2B mixer-settler as the 2BW stream, and flows by gravity to the solvent run tank, 10.5. Solvent is pumped to the alkaline washer, 14.6, where it is washed with about 10,000 pounds of carbonate solution, separates by gravity, and flows over a weir into the 14.6 blister tank. From there, solvent is pumped to the acid washer 905, in 211-H where it is washed with about 20,000 pounds of dilute nitric acid. The solvent the flows by gravity to the washed solvent hold tank, 906. Solvent normally is transferred from 211-H to the 2A mixer-settler as the 2AX stream via a pressurized header; however, canyon third level head tanks are available if necessary. When the cycle is down, solvent can be recirculated from tank 906 to tank 10.5 to maintain solvent quality. Solvent recovery tankage is shown in figures 25, 26, and 27.

Aqueous wash solutions are changed at regular intervals. In first cycle, alkaline washes are decanted to wash hold tank, 13.5, then transferred through box decanter, 13.6-2S, to aqueous run tank 13.7 for eventual processing through LAW. Alkaline washes are changed on the basis of operating time, gamma activity, or alkalinity. Acid washes from tank 903 are decanted to 501 skimmer in 211-H for processing through the general purpose (GP) evaporator. Acid washes are changed on the basis of acidity or activity.

In both second cycles, aqueous washes are treated in the same manner as in first cycle washes, except that alkaline washes are decanted to the solvent wash hold tank, 13.8, and decanted through box decanter, 13.6-1S, to tank 13.7. Second uranium solvent washes are treated in the same manner as first cycle washes, but second neptunium washes are transferred from tank 13.7 or 905 to tank 18.5 if recoverable amounts of neptunium are present; otherwise they are treated in the same manner as first cycle washes.

The acid and alkaline continuous washers, and a box decanter are shown in figures 28, 29, and 30.

LOW ACTIVITY WASTE

Low activity waste is received in tank 11.8 from the following sources: (1) 2AW aqueous waste received from tank 11.7 (from the second neptunium cycle), (2) 1DW aqueous waste received from tank 16.7 (from the second uranium cycle), and (3) solvent washes and evaporator overheads received from tank 13.7. Solvent washes that have not been acidified are received into acidic 2AW (about 2 pounds of wash to 1 pound of 2AW). Evaporator overheads are received into tank 11.8 and are generally transferred directly to decanter 9.7.

Transfers are made through decanter 9.7 (to remove solvent present) to LAW evaporator feed tank 8.7 where waste streams from other sources are received. These sources include B-Line waste from tank 9.6, water from the dissolver fuel storage cells, sump solutions from tank 805 (Building 211-H), and various decontamination solutions from the swimming pool, hot shop, and the decontamination cells. Solutions of high specific gravity are received first into tank 8.7, and are diluted to a sp. gr. between 1.035 and 1.040 using water or low specific gravity waste (805 waste or dissolver fuel storage cell water). LAW waste from decanter 9.7 will require dilution and the addition of sodium nitrite ($NaNO_2$) for ammonia control. B-Line waste is normally received adjusted with $NaNO_2$, and only requires dilution. Decontamination solutions, depending on their composition may require dilution with water or low specific gravity waste, blending with dilute 2AW waste to acidity, or addition of $NaNO_2$. Evaporator overheads, received unblended from 13.7, do not require dilution but do require $NaNO_2$ adjustment, either through $NaNO_2$ addition or receiving the overheads into a waste heel of adjusted ($NaNO_2$) waste in tank 8.7.

LAW evaporators, 6.8E, 7.6E, and 7.7E are arranged in parallel, and may be fed individually or in any combination from tank 8.7. Evaporators are operated initially by continuously feeding waste during evaporation to maintain a level of 35 to 38 inches in the pot. If feed becomes depleted, the evaporator is shut down. Evaporation continues at a constant level until the specific gravity reaches 1.23 at a level of 38 inches.

The second LAW stage is called acid stripping. This will recover additional Nitric acid from the waste. Acid stripping is initiated by evaporation at constant specific gravity while continuously feeding process water to the evaporator from tank 8.7 or from third level head tank 11B. Stripping continues for 12 hours, or until the liquid level decreases to 28 wt ftr at a sp. gr. of 1.23. The evaporator is then shut down and cooled.

Overheads from evaporations and acid stripping are collected from all three evaporators in evaporator overheads condensate tank 7.5, and transferred as necessary to basin transfer tank B1-2 (Building 211-H) for subsequent processing through the acid recovery unit.

LAW concentrate (evaporator bottoms) is transferred to LAW neutralizing tank 8.6. The scrubber jumper is operated to prevent NH_3 from entering the Process Vessel Vent system during neutralization. 1.2M excess NaOH is added to neutralize the waste. Neutralization is confirmed by a pH sample. After neutralization, dilution water is added, if necessary to adjust the solution to a sp. gr. of 1.25 or less to prevent pluggage of the waste header. The neutralized concentrate is transferred to the waste storage tanks (Building 241-H). The dissolved solids content of the concentrate is about 33% at an excess hydroxide of about 1.2M.

The 2AW from thorium decontamination runs contains ceric ammonium nitrate and is not evaporated. This solution goes directly to tank 8.6 and is neutralized. Low activity waste tankage is shown in figure 31.

HIGH ACTIVITY WASTE

The main feed source for high activity waste (HAW) is the first cycle waste 1AW, received from the 1AW hold tank 9.4. HAW also processes: (1) rerun solutions from tanks 18.2 or 16.6 (sump solution from the hot and warm canyons) if they do not contain recoverable amounts of uranium, (2) sump solutions from tank 805 in Building 211-H (Outside Facilities), (3) vessel vent system solutions from tank 7.4 and, (4) various decontamination solutions from the swimming pool, hot shop, and the decontamination cells. HAW feed solutions are received in tank 8.1 where sodium nitrite ($NaNO_2$) is added to 1AW for ammonia control and/or gamma control in the overhead condensate solutions. Dilution water is added to rerun solutions to lower the specific gravity below 1.05.

If the 1AW solution contains chromium from dissolved fuels containing stainless steel, evaporation is omitted due to the potential for evaporator corrosion. Such waste is neutralized directly and sent to waste storage (Building 241-H).

HAW waste is fed continuously from tank 8.1 to the first stage evaporator 9.1E to maintain a constant level during evaporation. Overheads from 9.1E flow continuously by gravity to the second stage evaporator, 9.2E. Overheads from the head end evaporator tank 11.4 along with overheads from tank 17.3 are also evaporated in 9.2E. Solutions received from 11.4 are already adjusted with $NaNO_2$. 9.1E is evaporated to a temperature endpoint of 119°C (a specific gravity of approximately 1.40 hot) and cooled.

The HAW concentrate is transferred to tank 8.4 for neutralization. Approximately 3000 pounds of 9.2E bottoms are recycled to 9.1E, and evaporation is continued, feeding from tank 8.1. If the sp. gr. of the 9.2E bottoms exceeds 1.18 or the activity in the overheads condensate tank 9.3 exceeds 2.5×10^5 d/m/ml, all of the 9.2E bottoms are transferred to 9.1E and evaporation continued. Periodically, tank 9.3 overheads are transferred to basin tank B2-1 (211-H) for eventual processing in the acid recovery unit (ARU). If the tank 9.3 gamma activity is excessively high, they are recycled for processing in low activity waste (LAW).

HAW concentrate from 9.1E bottoms are received along with head end cakes from 10.3C (head end centrifuge) into tank 8.4 for neutralization with 50% sodium hydroxide (NaOH). Some dilution water is added before neutralization, and during neutralization the ammonia scrubber jumper is operated to minimize ammonia entering the process vessel vent system. NaOH is added at a controlled rate to minimize localized heating and subsequent overflow of the vessel. Additional process water is added if necessary to dilute the solution to a sp. gr. of 1.25 or less so the waste header does not get plugged. The vessel contents are simmered at 80°C to 85°C to insure complete dissolution of aluminum hydroxide precipitate as sodium aluminate. A sample aisle pH sample is requested to verify neutralization. After the neutralized concentrate has cooled to 65°C, or if evaporator 9.1E is ready to dump, the neutralized concentrate is transferred to 241-H. The dissolved solids content after neutralization is approximately 36% with an excess hydroxide molarity of about 1.2M. High activity waste tankage is shown in figure 32.

FRAME WASTE EVAPORATION

In the frame waste recovery (FWR) system, frame wastes from the primary columns are processed to recover neptunium or plutonium present. Column raffinates from the FWR system are processed through the frames waste evaporator for recovery of acid. Column raffinate is received from the frame waste column raffinate tank 16.3 into hold tank 16.2, if recycle of the column raffinate to recover additional neptunium or plutonium is not needed. Frame waste solution is then received into the rerun/FWR evaporator feed tank 15.4 and is diluted with process water. Flow rates are maintained at a rate to dilute the waste solution to a sp. gr. of 1.035. Approximately 6 pounds of water per pound of frame waste is required for dilution. Sodium nitrite ($NaNO_2$) is then added to the dilute waste from third level head tank 11A for ammonia and gamma activity control. Evaporator 17.2E is fed continuously to maintain a level of 30 to 36 inches in the pot. Evaporation continues until: (1) 40,000 pounds of undiluted frame waste (received into 15.4 from 16.2) has been fed to 17.2E, (2) a hot sp. gr. of 1.32 at a level of 30 to 36 inches has been reached, or (3) the pot temperature reaches 117°C at 30 to 36 inches. The evaporator is then shut down and cooled.

The evaporator bottoms are dumped to the neutralization tank 16.1 for the following reasons: (1) the evaporator has reached one of the endpoints described above, (2) when required for nuclear safety control (a maximum of 560 grams of ^{235}U equivalent may be present in 15.4 and 17.2E system) or, (3) excessive solid buildup is present in the evaporator. In the first case, 4,000 pounds of concentrate are transferred to 16.1, in the second and third cases, the entire contents of 17.2E are transferred (in two batches if necessary). To begin neutralization, dilution water is added to the concentrate, and a sample aisle pH is requested to verify acidity. The ammonia scrubber jumper is operated and sodium hydroxide (NaOH) is added to neutralize the concentrate. If necessary, additional dilution water is added. A sample aisle pH is requested to verify neutralization. The neutralized concentrate is then transferred to waste storage (Building 241-H). FWR evaporation tankage is shown in figure 33.

ACID RECOVERY UNIT

Acidic condensate from the high and low activity waste evaporators, the 1CU evaporator, the 2BP evaporator, the rerun and frame waste evaporators are transferred to the basin tanks (B2-1, B1-2, B4-2, and B4-1 respectively) in Building 211-H and subsequently to tank 601. The condensate normally contains 0 to 5% HNO_3, less than 10,000 d/m/ml gamma acitivity, and less than 500 d/m/ml alpha activity. The condensate is processed in the acid recovery unit (ARU) to increase the acid strength to 48-52% HNO_3 for reuse in the HM-process. Reuse of acid reduces the amount of fresh acid consumed and waste produced.

Dilute acid is fed through a pre-heater to the distillation column. The column contains ten bubble-cap trays and is operated under a partial vacuum maintained by a steam jet. 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 may be recycled to the process as recycle water resulting in a reduction in waste volume and radioactivity released to the Effluent Treatment Facility (ETF). The excess overheads solution is monitored for gamma and alpha activity and transferred to the ETF for disposal. Acid concentrates in the bottom of the column and in the reboiler which maintains the concentrate at boiling. Acid concentrate is continually drawn from the bottom of the column and transferred through a cooler to tanks 606 and 607. This acid is adjusted with either 64% acid or process water as required to make 48-52% and stored in tank 608 for use in the HM-process. Acid Recovery Unit tankage is shown in figure 34.

GENERAL PURPOSE (GP) EVAPORATOR

Low activity waste is received in the waste storage tanks 716 and 717. Material from the waste storage tanks is pumped to feed tank 701 and adjusted with caustic to a pH of 8 or greater. Feed from tank 701 and liquid from the bottom of GP evaporator 703 is pumped through a steam header (702-1) into the evaporator where the superheated liquid flashes; overheads condensate is collected in hold tanks 706 and 707. Both the evaporator and the condenser are maintained under a vacuum by a steam jet. When the evaporator concentrate reaches a solids content of about 35% (specific gravity of about 1.25), the evaporator is shut down for transfer of the bottoms to concentrated hold tank 710. The bottoms are then transferred to the waste tank farm. Overhead condensate is pumped from the hold tanks to the Effluent Treatment Facility (ETF) if activity is less than 100 d/m/ml alpha and 5000 d/m/ml beta-gamma. GP evaporator tankage is shown in figure 35.

WATER HANDLING

There are two water systems maintained: process water and recycle water. Process water uses demineralized water from the powerhouse as makeup. The incoming stream passes through an in-line mixer where 50% nitric acid is added via a metering pump, and into process water storage tanks 507 or 508. The acid concentration is maintained at about 0.012%.

The recycle water system receives overhead condensate from Building 211-H acid recovery unit tanks 614 and 615. This material is received in the 505 skimmer. The aqueous stream flows to waste water storage tank 506; the skimmed solvent flows to tank 511. The waste water in 506 is recycled back to the canyon process. Recycling the waste water reduces the waste volume and radioactivity transferred to ETF. Any remaining waste water is transferred to the ETF if the activity is less than 100 d/m/ml alpha and 5000 d/m/ml beta-gamma. Waste water from the decant sump, the segregated solvent sump, Building 221-H acid drain, and the basic drain tank 183 flows through skimmer 501. The aqueous flows to tank 503 and is processed in the general purpose evaporator; skimmed solvent is stored in tank 511.

HM PRODUCT STORAGE AND SHIPMENT

Uranyl nitrate solution is the product from the H-Canyon HM-process. Uranyl nitrate solution at a concentration of 4-8 g U/l flows from the warm canyon tank 14.5 to basin tank B3-1. It is then pumped to storage tanks F1-5, E4-2, E1-1 and EUS. The uranyl nitrate solution will then be converted to a solid oxide in the Uranium Solidification Facility (USF) for shipment to the Oak Ridge Y-12 plant. Product storage facility are shown in figure 36.

VENTILATION SYSTEM

The 211-H ventilation system is designed to prevent spread of airborne radioactive contamination from contaminated areas to clean areas. This is done by maintaining a slight vacuum in areas of high contamination potential, atmospheric pressure in areas of low contamination potential, and a positive pressure in clean areas. Canyon air flow and air exhaust systems are shown in figure 37 and 38.

CENTER SECTION SYSTEM

Filtered outside air is supplied by fans to the first and fourth levels of the center section of the canyon building. Air flows from the first level, to the second level, to the third level, and from the fourth level to the third level. From the third level the air flows into the sample aisles and exhausts at the south end to the center section exhaust tunnel. Outside air is supplied to the gang valve corridors and exhausts at the south end to the center section tunnel. The center section air tunnel leads to Building 211-H where exhaust fans pull the air through High Efficiency Particulate Air (HEPA) filters in 292-H and discharge it to the 291-H stack.

CANYON AIR SYSTEM

Filtered outside air is supplied to the canyon by fans. Air enters the canyons through registers along the craneways and exits to the canyon air exhaust tunnel through registers near the bottom of each cell. The downward flow of air helps keep contamination inside the cell. Exhaust fans in Building 292-H pull the air through the sand filters, Building 294-H and 294-1H, and discharge it to the stack. The sand filters are made of layers of progressively smaller aggregate, starting with course stone on the bottom and ending with fine sand on top. Flow of air is from the bottom to top. The two sand filters operating in parallel remove about 99.98% of the particulate radioactivity from the air, equivalent to HEPA filters.

B-LINE AIR SYSTEM

B-Line air is supplied by the center section supply fans. Air is exhausted from rooms and process cabinets by fans in Building 292-H and discharged into the canyon air tunnel upstream of the sand filter.

PROCESS VESSEL VENT

All canyon vessels, except dissolvers 6.1D, 6.3D, and 6.4D are connected to the process vessel vent system. About 50 cfm of air is pulled through each vessel by the vent system to prevent chemical fumes, steam, and radioactivity from escaping from the vessel into the canyons. The air pulled into the vessel vent system is filtered to remove particulate radioactivity and is then exhausted into the canyon air exhaust tunnel.

The process vessel vent system has two 28-inch vent headers, one located in the hot canyon air exhaust tunnel, the other in the warm canyon air exhaust tunnel. Each canyon cell module has a wall nozzle connected to vent header. Pipe jumpers connect the equipment to be vented to the wall nozzle. The hot canyon vent header connects to scrubber 7.3, where the air is scrubbed with water and heated, and then connects to fiberglass filter 7.2F. Scrubber solution is pumped from tank 7.4 through the scrubber, and returns to tank 7.4. The warm canyon vent header connects to a heat exchanger and then to fiberglass filter 5.7F. Both hot and warm vent headers enter section 5 of the warm canyon where they join and connect to the vessel vent exhausters. One exhauster runs and the other is on standby. The exhausters vent to the warm canyon air exhaust tunnel which leads to the sand filter and stack. The vessel vent system is shown schematically in figure 39.

COOLING WATER SYSTEM

Cooling water used in the canyon and outside facilities leaves the cooling towers in a 36-inch header. The 36-inch header branches into two headers, the 24-inch normal supply header and the 20-inch independent supply header. If the system loses water pressure for any reason, the segregation valve in the normal supply header closes and diverts all available water to the independent supply header.

Most equipment is supplied with cooling water from the normal supply header, however, equipment needed for safe emergency shutdown of the process is supplied from the independent supply header. The independent supply is also used to supply a constant small flow of water to coils which are not equipped with an air pressurization system to maintain a static head inside the coil greater than the static head of process solution outside the coil. Both coil pressurization systems, static head and air pressurization, prevent or at least minimize activity entering the cooling water in the event of a hole corroded in the coil.

Cooling water, used in equipment supplied with cooling water only, is discharged to the circulated cooling water return header and is pumped back to the cooling towers for reuse. Cooling water and steam condensate from equipment supplied with both cooling water and steam are discharged to segregated water header. The segregated water is sampled and if within release limits is discharged to Four Mile Creek.

Both systems have facilities for detecting radioactivity and diverting the contaminated water to the retention basin. These facilities include alpha and gamma activity monitors, delaying basins to give response time, and diversion valves. The canyon can operate while the low flow segregated water is being diverted, but diversion of the high flow circulated water causes canyon shutdown, because the cooling tower basin would be depleted in about 30 minutes at normal cooling water flow. The H-Area cooling water system is shown schematically in figure 40.

CONDENSATE HANDLING

Condensate and ground water inleakage which collects in the sand filter sumps, air tunnel sumps, and stack sumps are transferred to tank 805 for subsequent processing in canyon waste evaporators.

DECONTAMINATION AND REPAIR OF EQUIPMENT

Facilities are provided in the canyons for decontamination and repair of highly radioactive process equipment. The facilities consist of the following:

- Hot Canyon Decontamination Cell
- Hot Canyon Decontamination Facility (commonly called the swimming pool)
- Hot Canyon Shop
- Warm Canyon Shop
- Warm Canyon Decontamination Cell (now used as second warm canyon shop)

Examples of repairs performed after decontamination are:

- Replacement of leaking coils in tanks and evaporators
- Replacement of motors on pumps and agitators
- Overhaul of agitator gearboxes
- Overhaul of centrifuges

Equipment to be decontaminated is placed in the hot decontamination cell where a series of alternate full volume flushes are made with HNO_3/MnO_4 (or $NaOH/KMnO_4$) solution and oxalic acid solution. The solutions are heated with a steam splarge. Spent decontamination solutions are processed through either HAW or LAW evaporation for disposal. Personnel do not enter the hot decontamination cell.

After a series of flushes, the equipment is placed in the hot shop for a radiation survey. Personnel can enter the hot shop. If the working radiation rate is acceptable, the equipment is moved to the swimming pool, otherwise it is returned to the decontamination cell for further cleaning. Some minor repairs such as regasketing of jumpers are made in the hot shop if radiation levels permit, but the hot shop is normally used for radiation surveys and preliminary inspections.

In the swimming pool, decontamination is continued by spraying the equipment inside and out with a manipulator controlled lance. The manipulator is controlled by an operator from a shielded, elevated work area from which he can see the equipment through windows. Decontamination agents used are the $HNO_3/KMnO_4$ (or $NaOH/KMnO_4$) and oxalic acid solutions, steam, hot water, and hot detergent solutions. Full volume flushes can be made in the swimming pool if the decontamination cell is occupied by other equipment.

After the radiation level is further reduced in the swimming pool, the equipment is moved to one of the two warm canyon shops for final decontamination and repair. To move from the hot canyon to the warm canyon, the equipment is loaded by the hot crane into a box on a rail car in then removed from the box by the warm canyon crane in the warm canyon truckwell. Final decontamination before repair is done by hand in the warm canyon shops. Lead shielding is used when necessary to cover "hot" spots to reduce body exposure rates. The arrangement of the canyon decontamination and repair facility is shown schematically in figure 41.

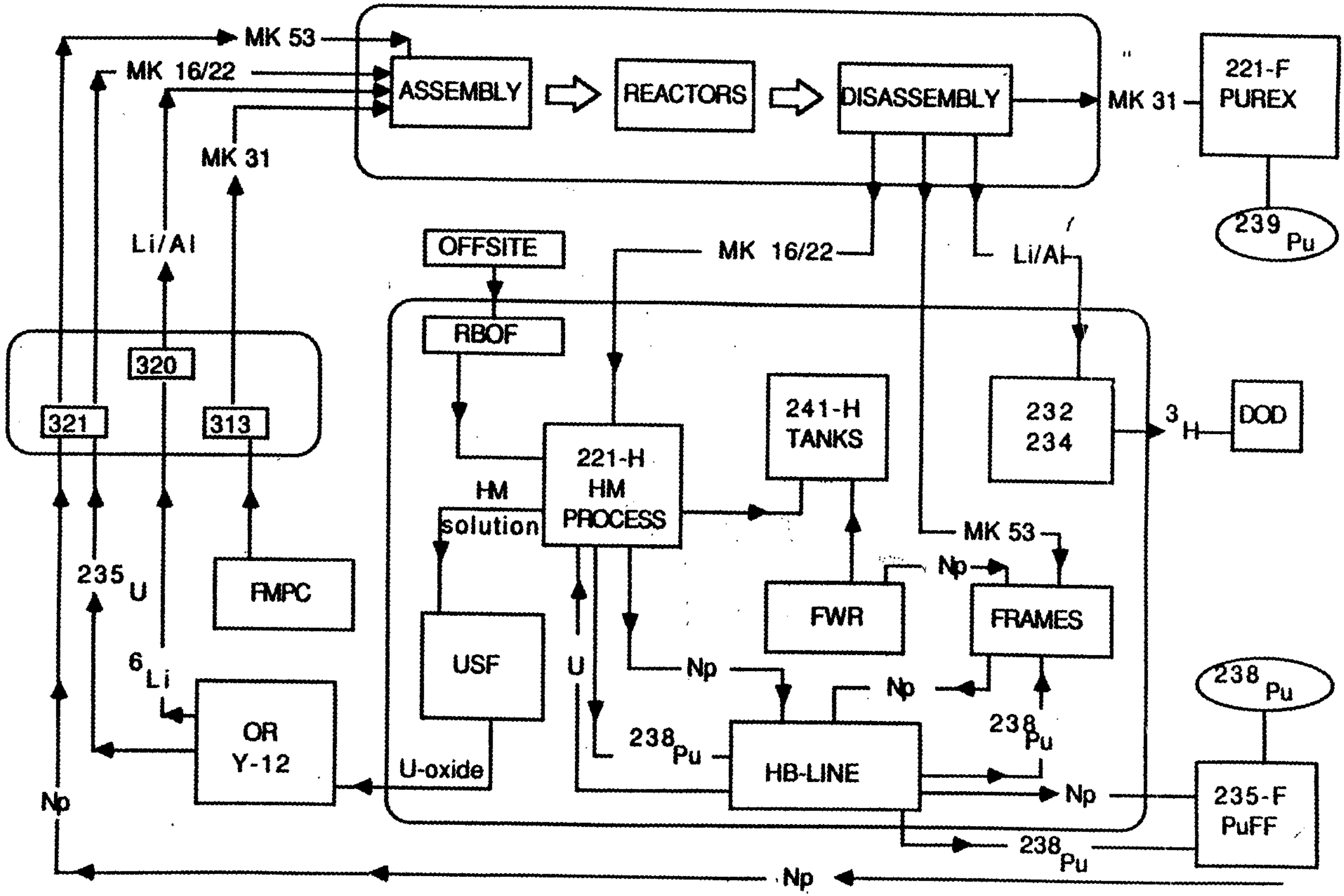


FIGURE 1. SRP FUEL CYCLE

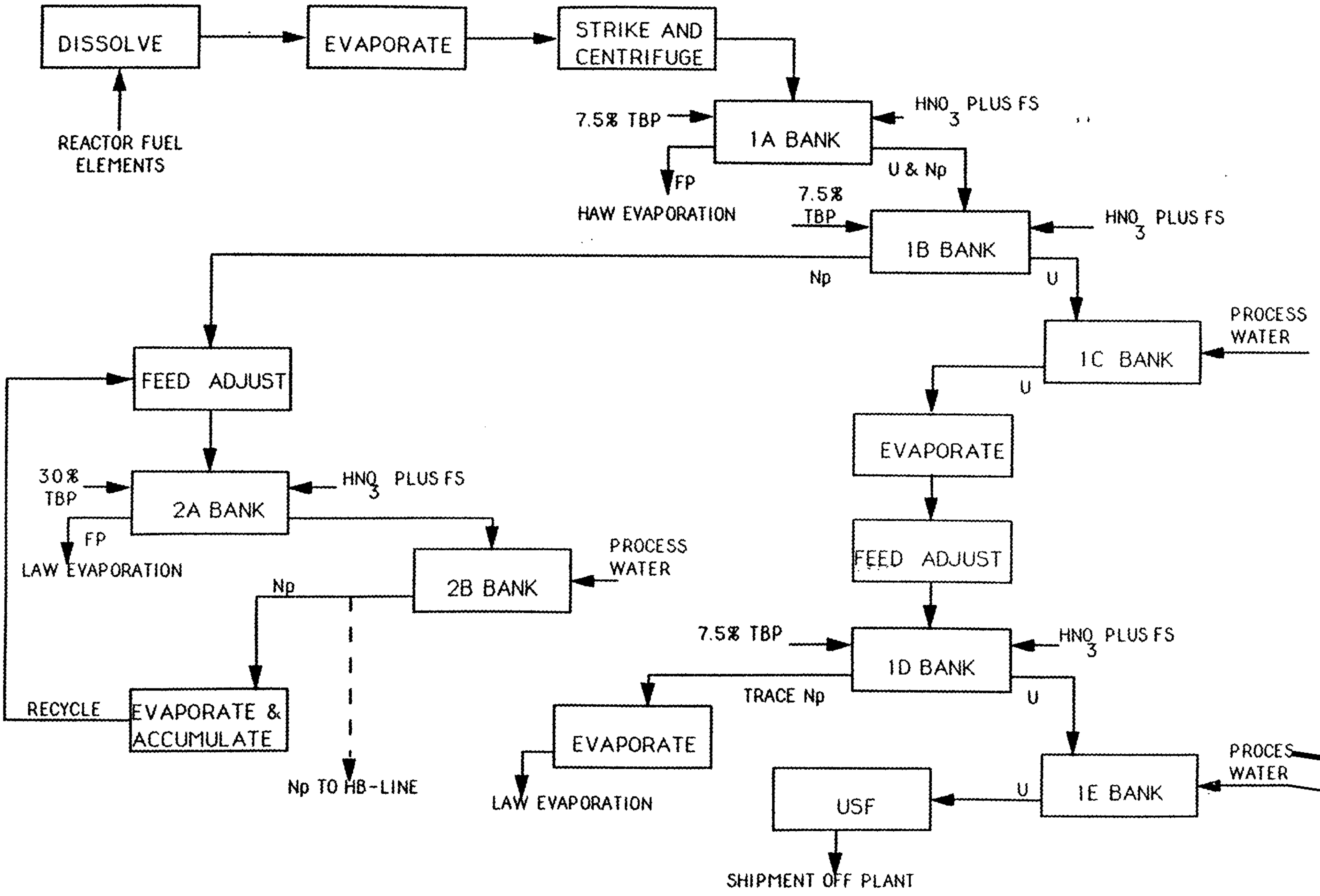


FIGURE 2. HM PROCESS FLOWSHEET

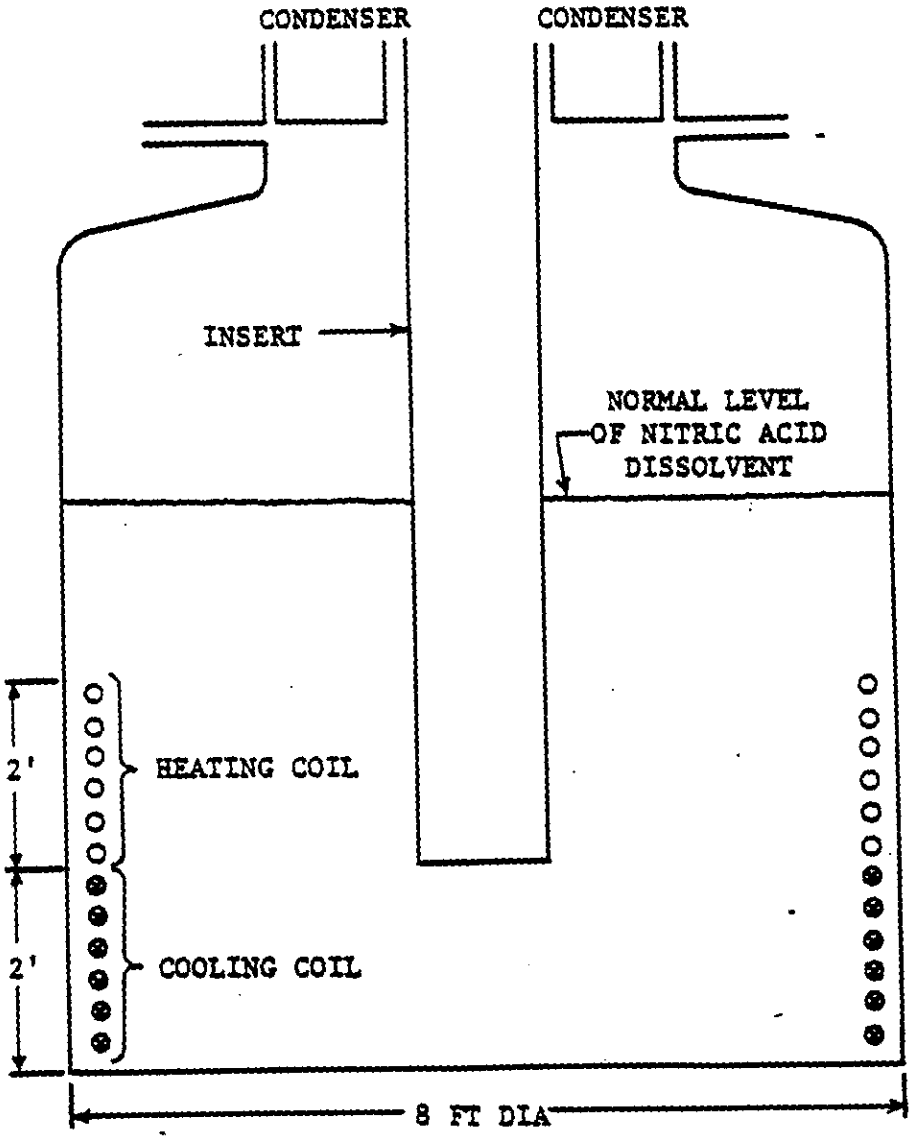


FIGURE 3. HM DISSOLVER

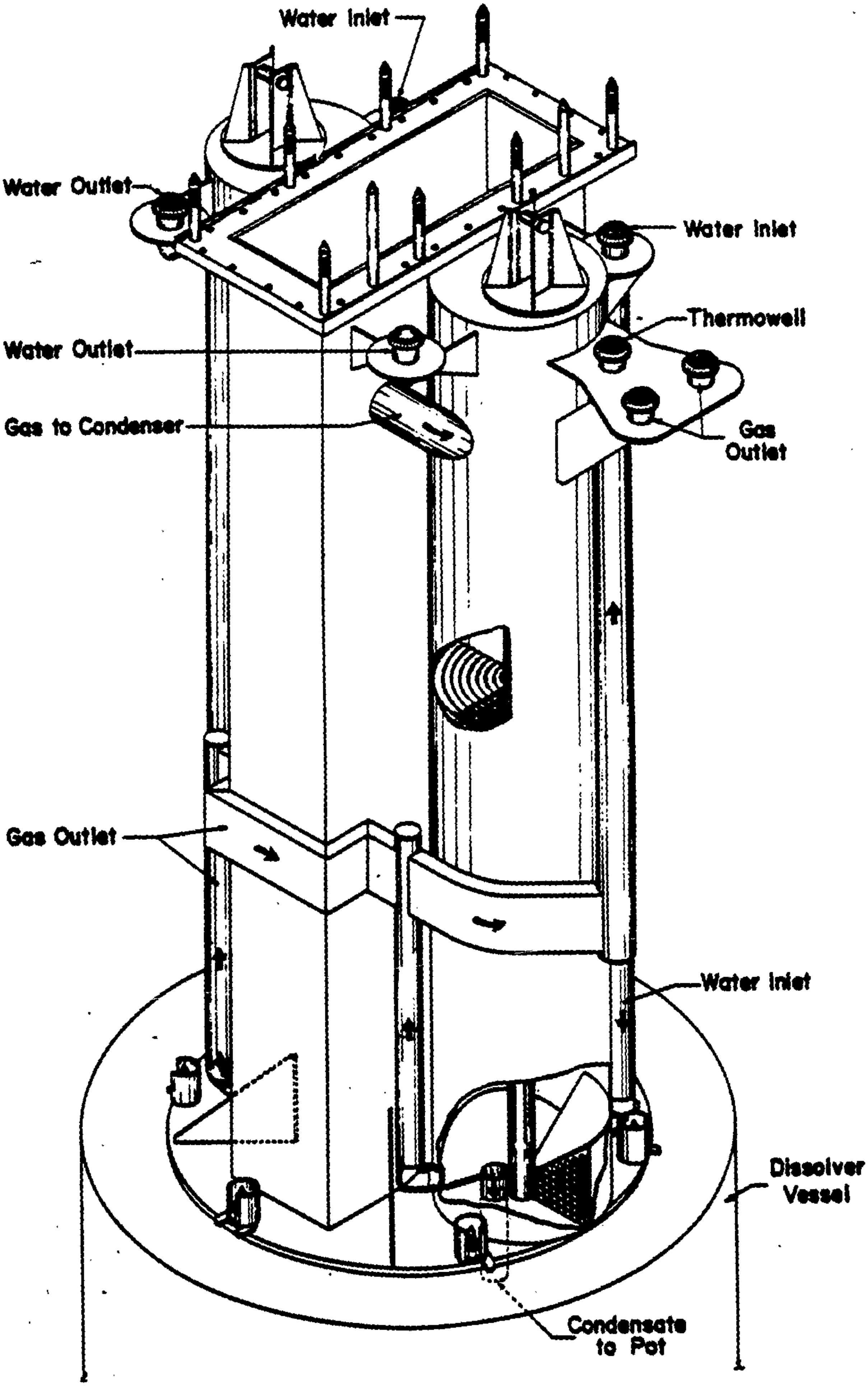
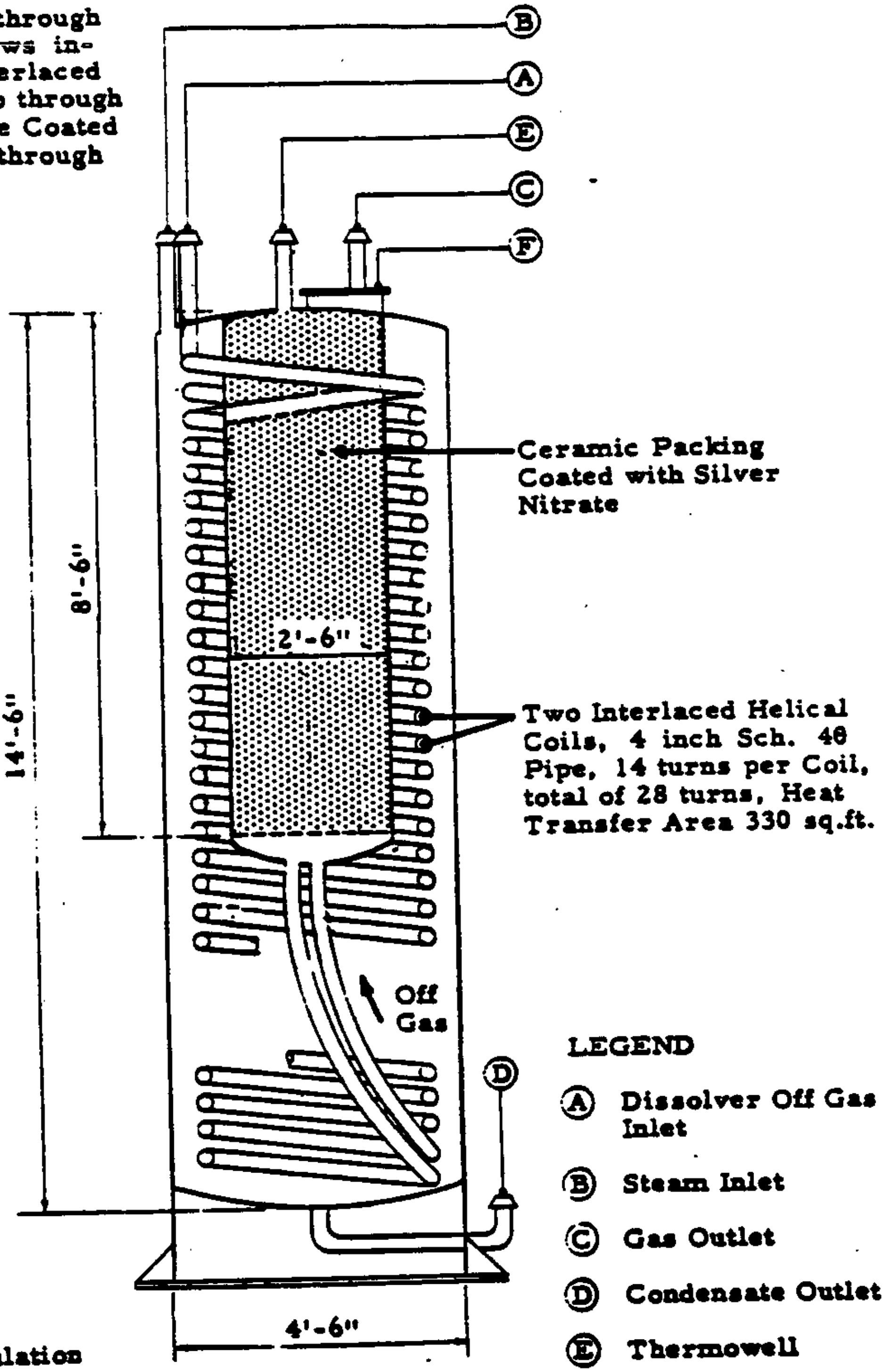


FIGURE 4. DISSOLVER COLUMN

Off Gas enters through Nozzles (A), flows inside the two interlaced Helical Coils, up through the Silver Nitrate Coated Packing and out through Nozzles (C).

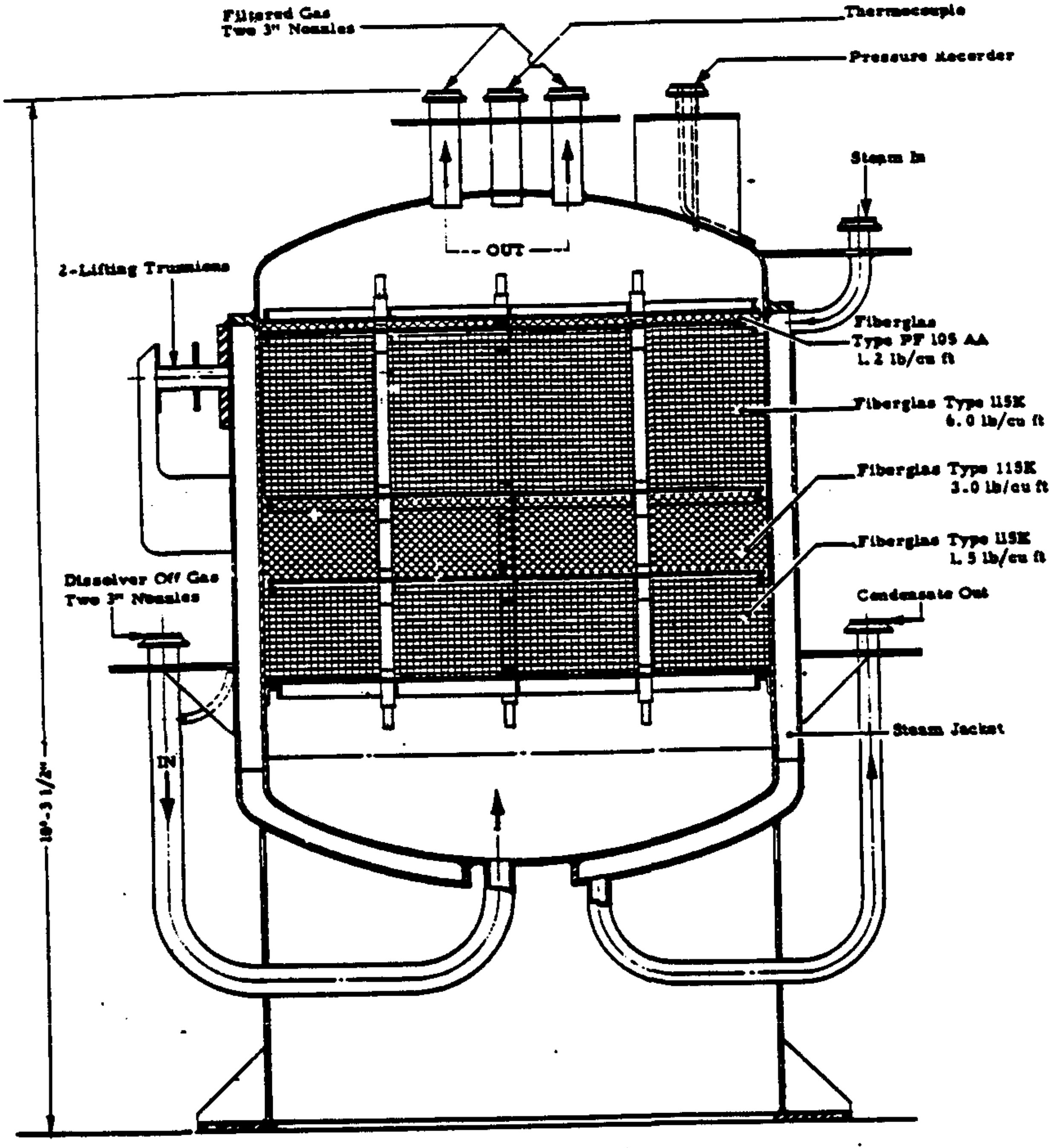


LEGEND

- Ⓐ Dissolver Off Gas Inlet
- Ⓑ Steam Inlet
- Ⓒ Gas Outlet
- Ⓓ Condensate Outlet
- Ⓔ Thermowell
- Ⓕ Access Hatch for installing Packing

Equipment Insulation Not Shown

FIGURE 5. DISSOLVER OFF-GAS HEATER AND IODINE REACTOR



Principal Dimensions
Diameter of Bed 4'-11"
Depth of Bed 3'-7"

FIGURE 6. DISSOLVER OFF-GAS FILTER

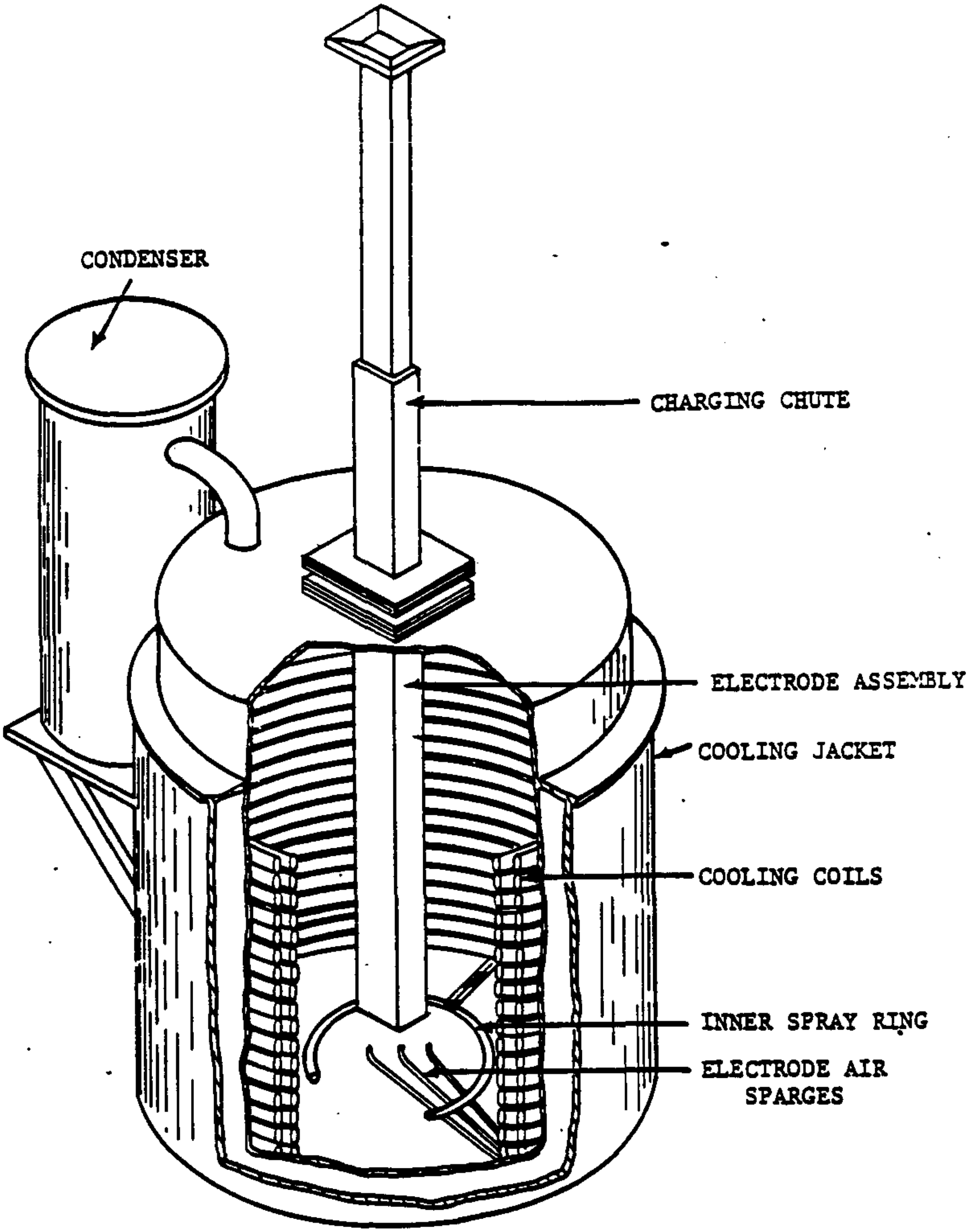
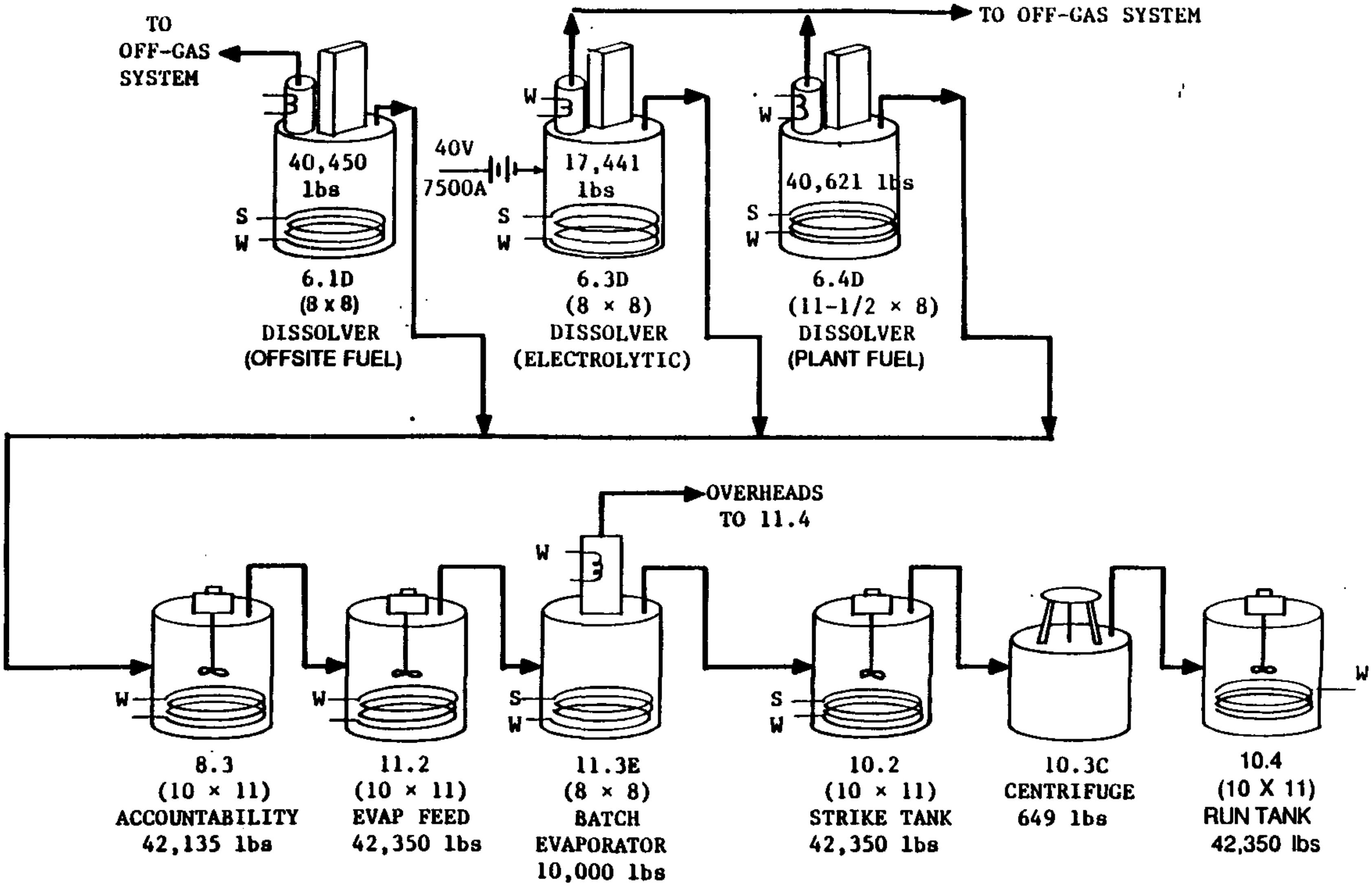


FIGURE 7. ELECTROLYTIC DISSOLVER



[NOTE: TANK CAPACITIES ARE WORKING VOLUMES IN LBS @ sp gr = 1.0]

FIGURE 8. DISSOLVING & HEAD END (COMBINED STRIKE)

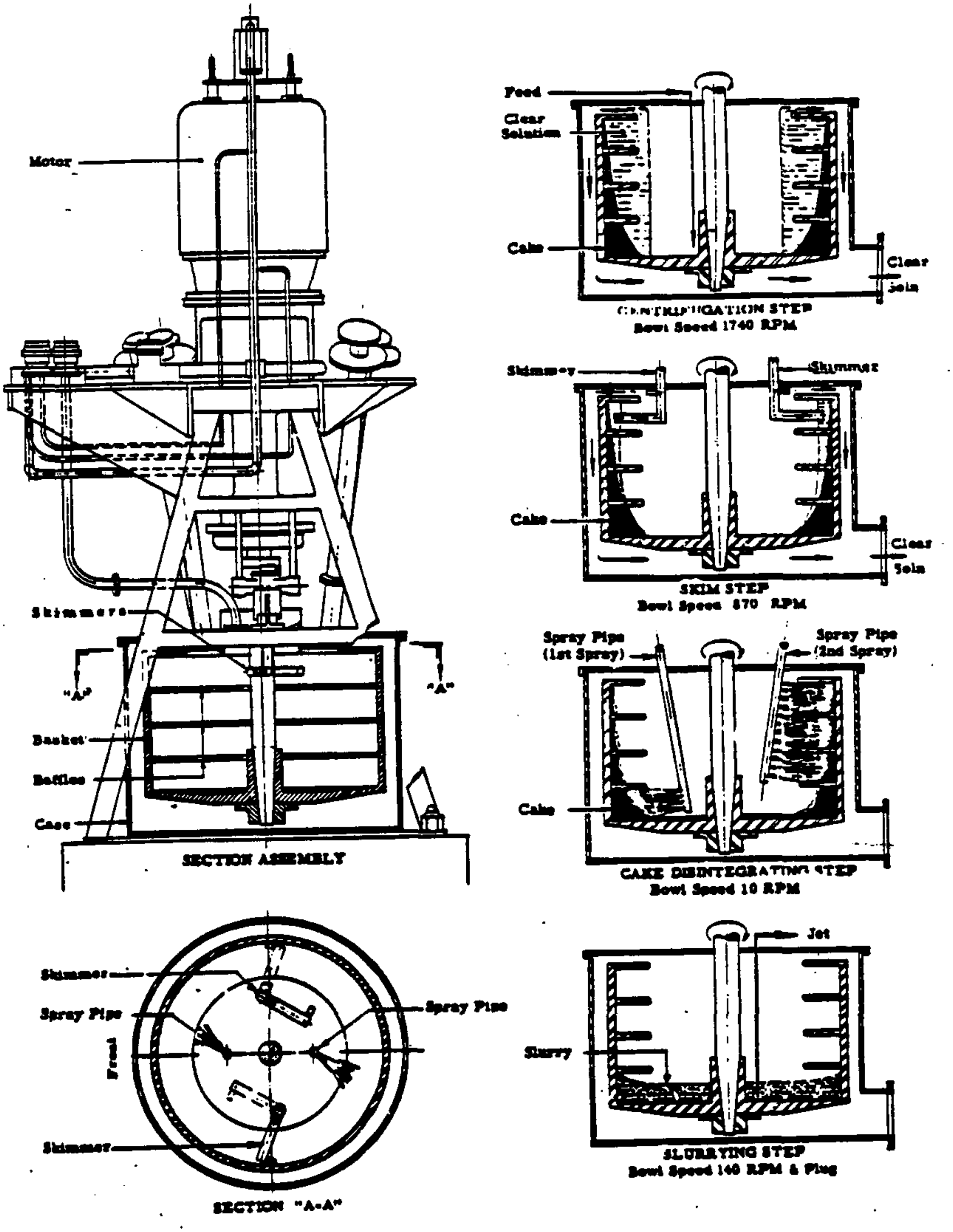
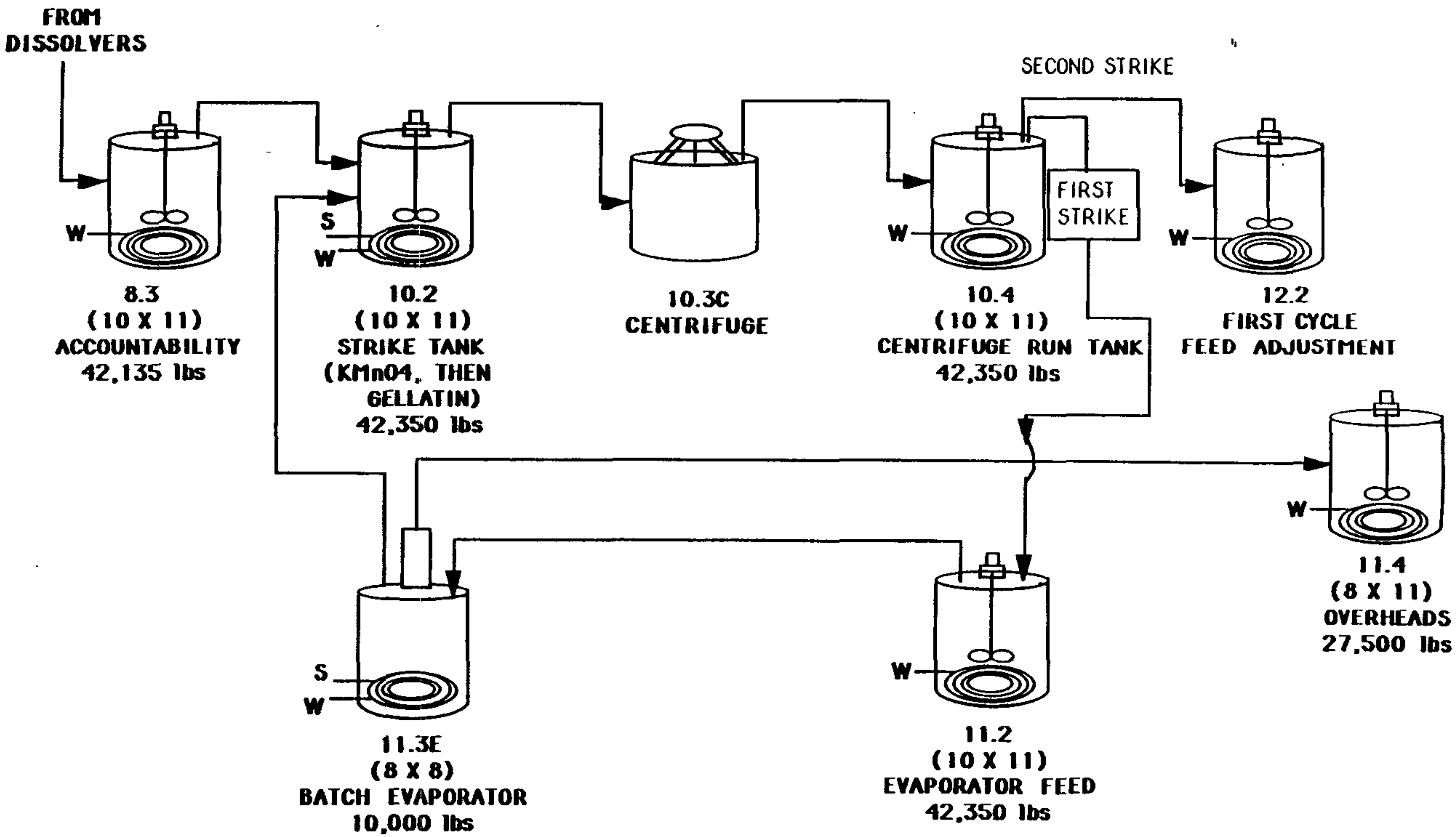


FIGURE 9. CENTRIFUGE



[NOTE: TANK CAPACITIES ARE WORKING VOLUMES IN H20 @ sp gr = 1.0]

FIGURE 10. HEAD END (DILUTE OR DOUBLE STRIKE)

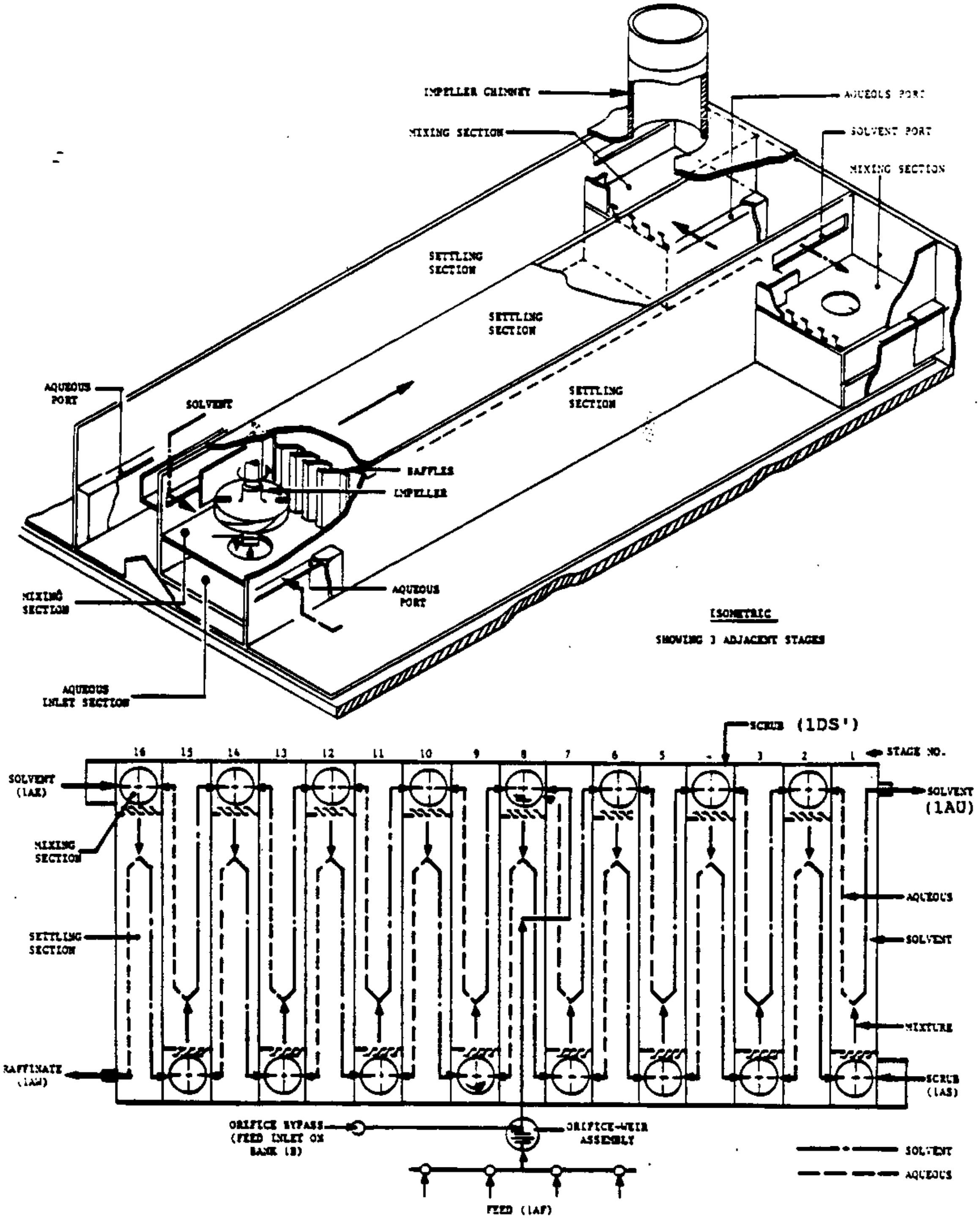


FIGURE 11. MIXER-SETTLER STAGE DETAILS

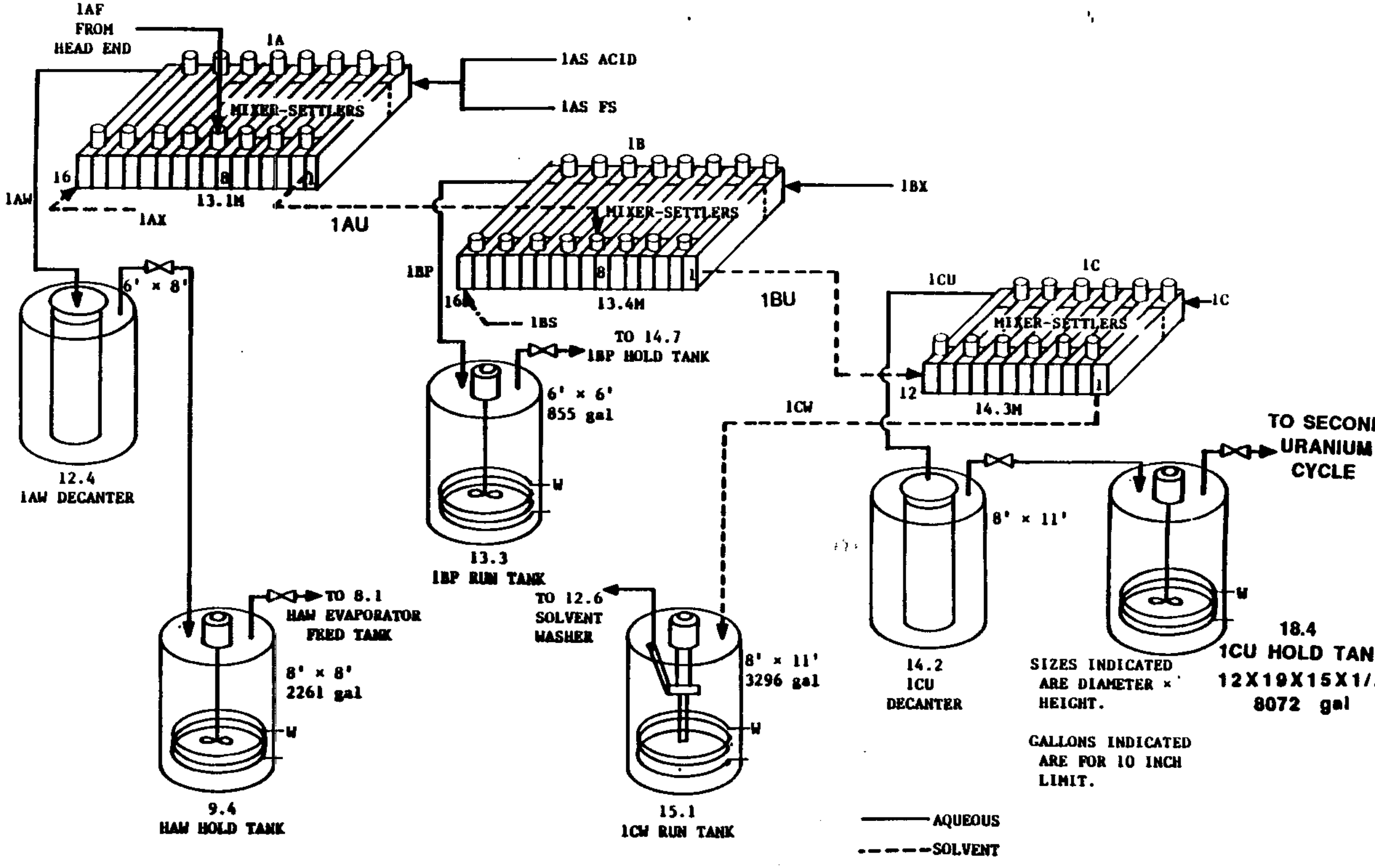
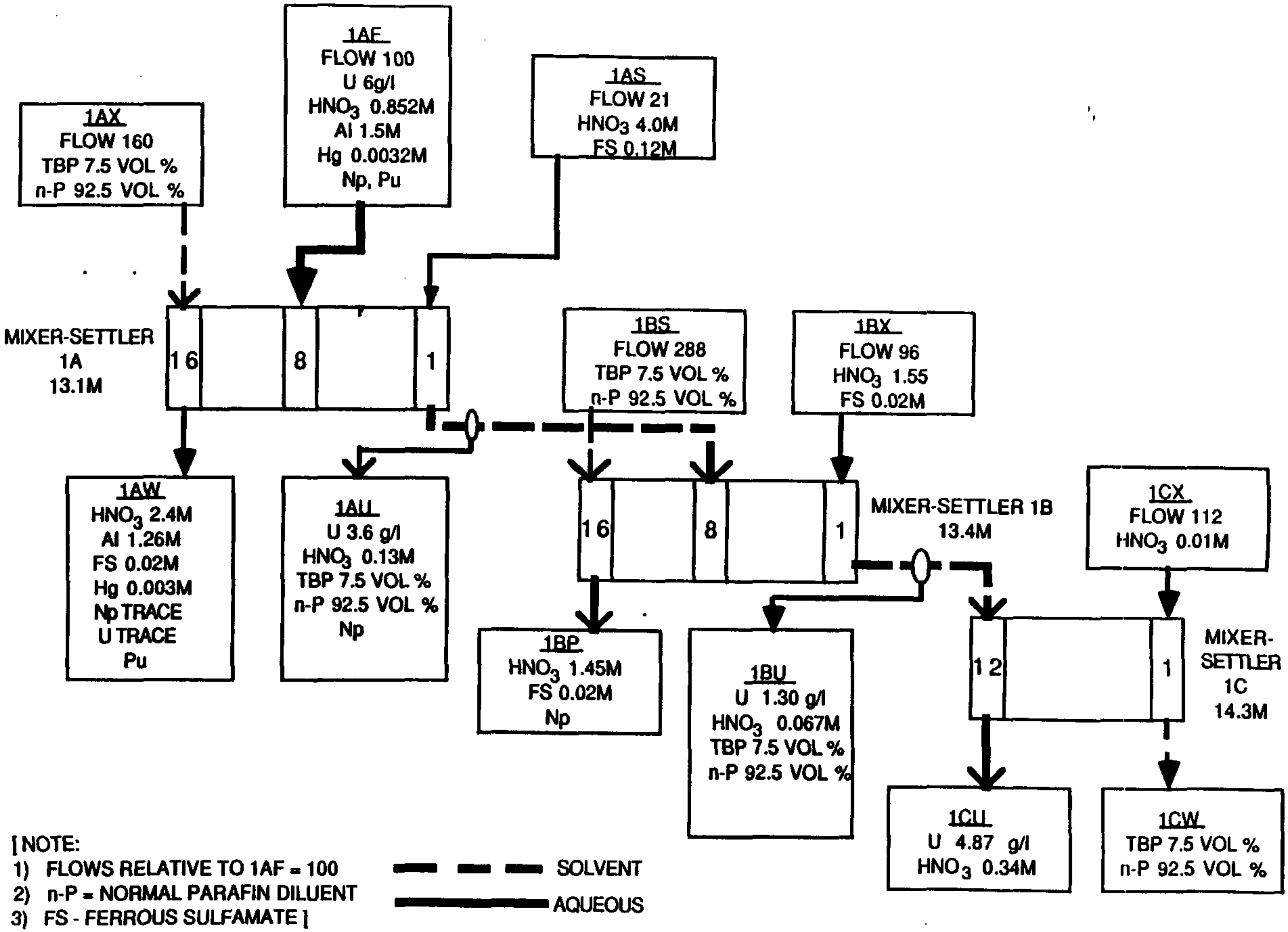


FIGURE 12. FIRST CYCLE SOLVENT EXTRACTION



[NOTE:
1) FLOWS RELATIVE TO 1AF = 100
2) n-P = NORMAL PARAFIN DILUENT
3) FS - FERROUS SULFAMATE]

FIGURE 13. FIRST CYCLE FLOWSHEET DATA

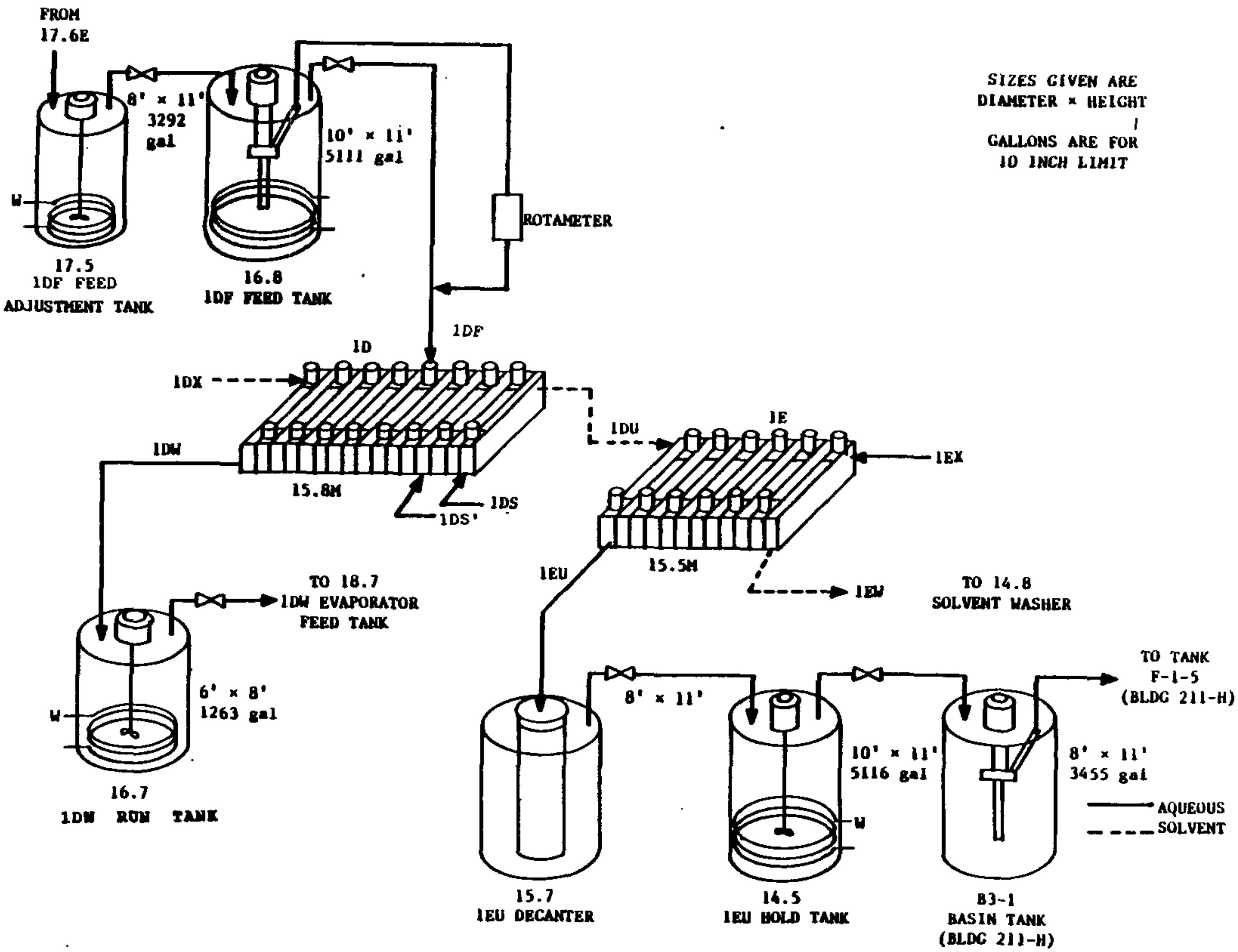


FIGURE 14. SECOND URANIUM CYCLE SOLVENT EXTRACTION

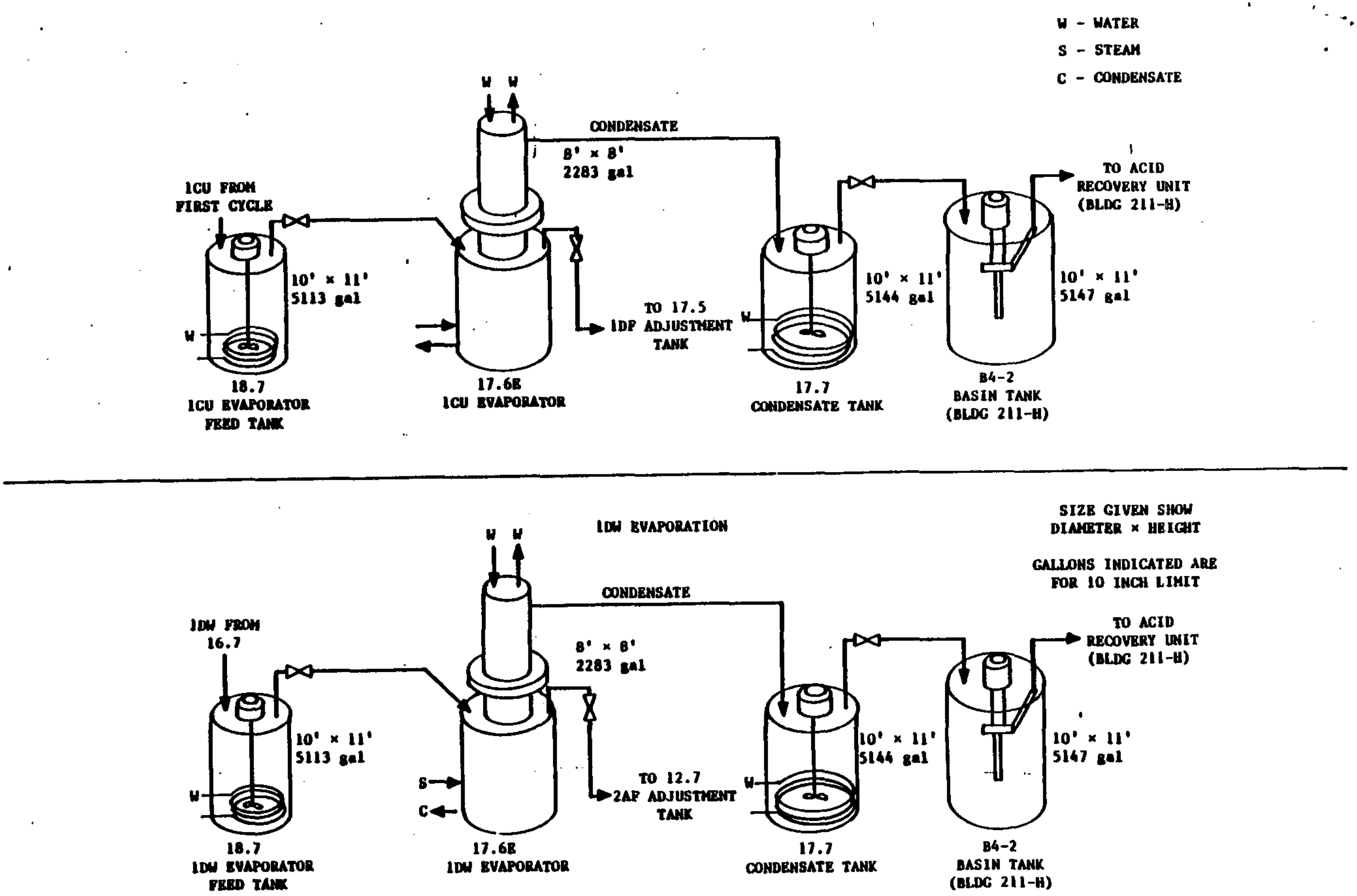
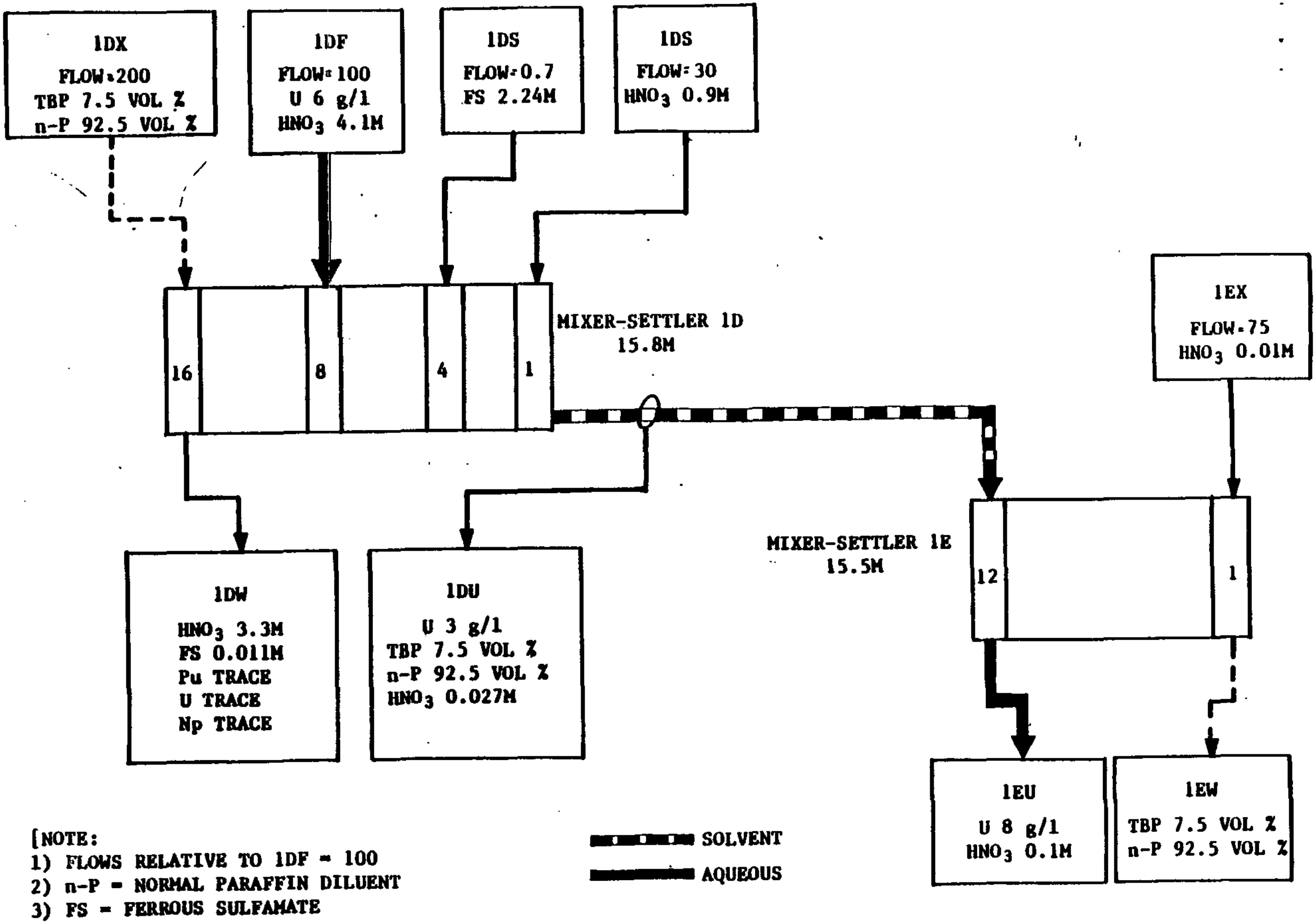


FIGURE 15. 1CU EVAPORATION



[NOTE:
1) FLOWS RELATIVE TO 1DF = 100
2) n-P = NORMAL PARAFFIN DILUENT
3) FS = FERROUS SULFAMATE

FIGURE 16. SECOND URANIUM CYCLE FLOWSHEET DATA

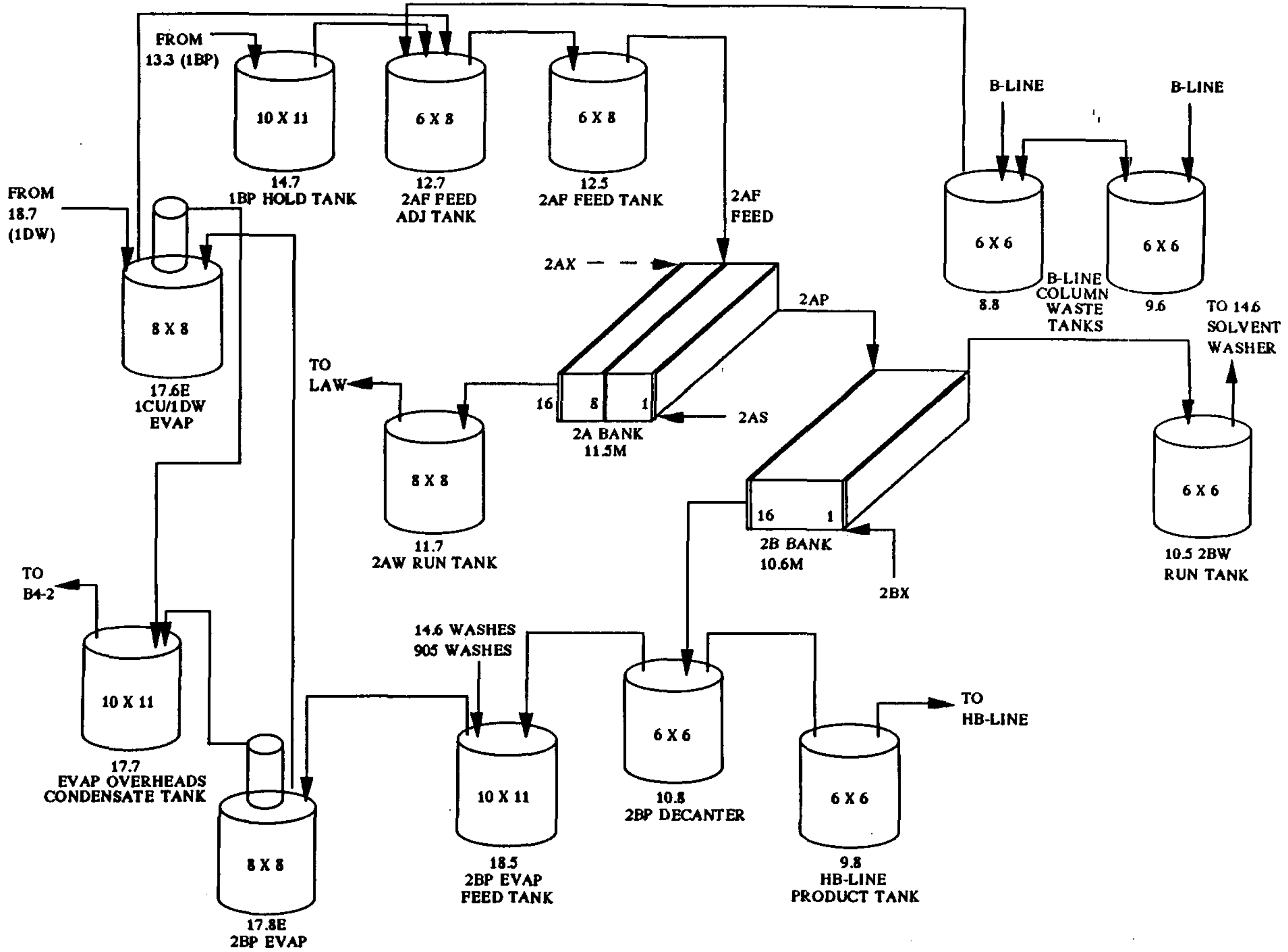


FIGURE 17. SECOND NEPTUNIUM SOLVENT EXTRACTION CYCLE

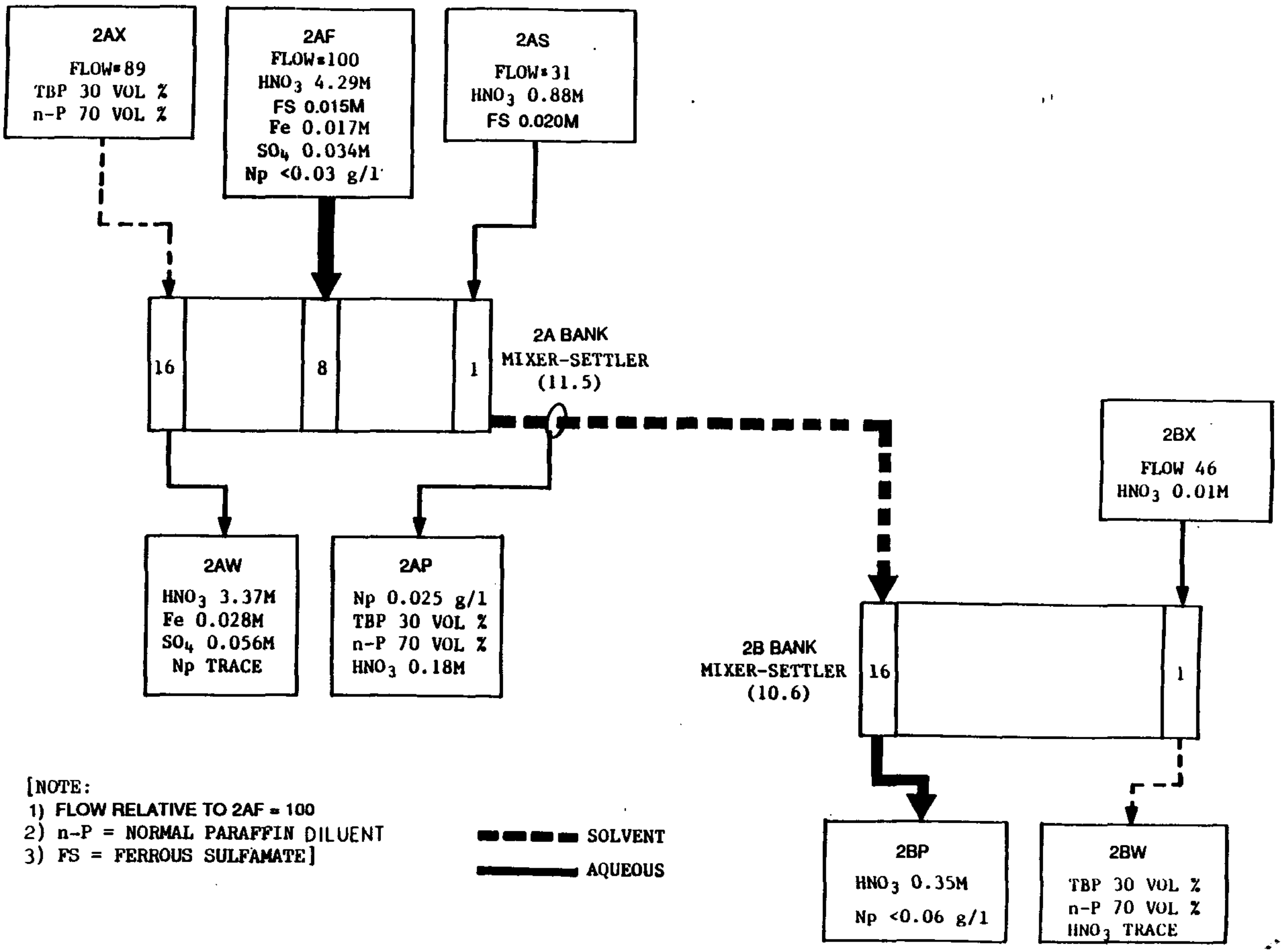


FIGURE 18. SECOND NEPTUNIUM SOLVENT EXTRACTION CYCLE

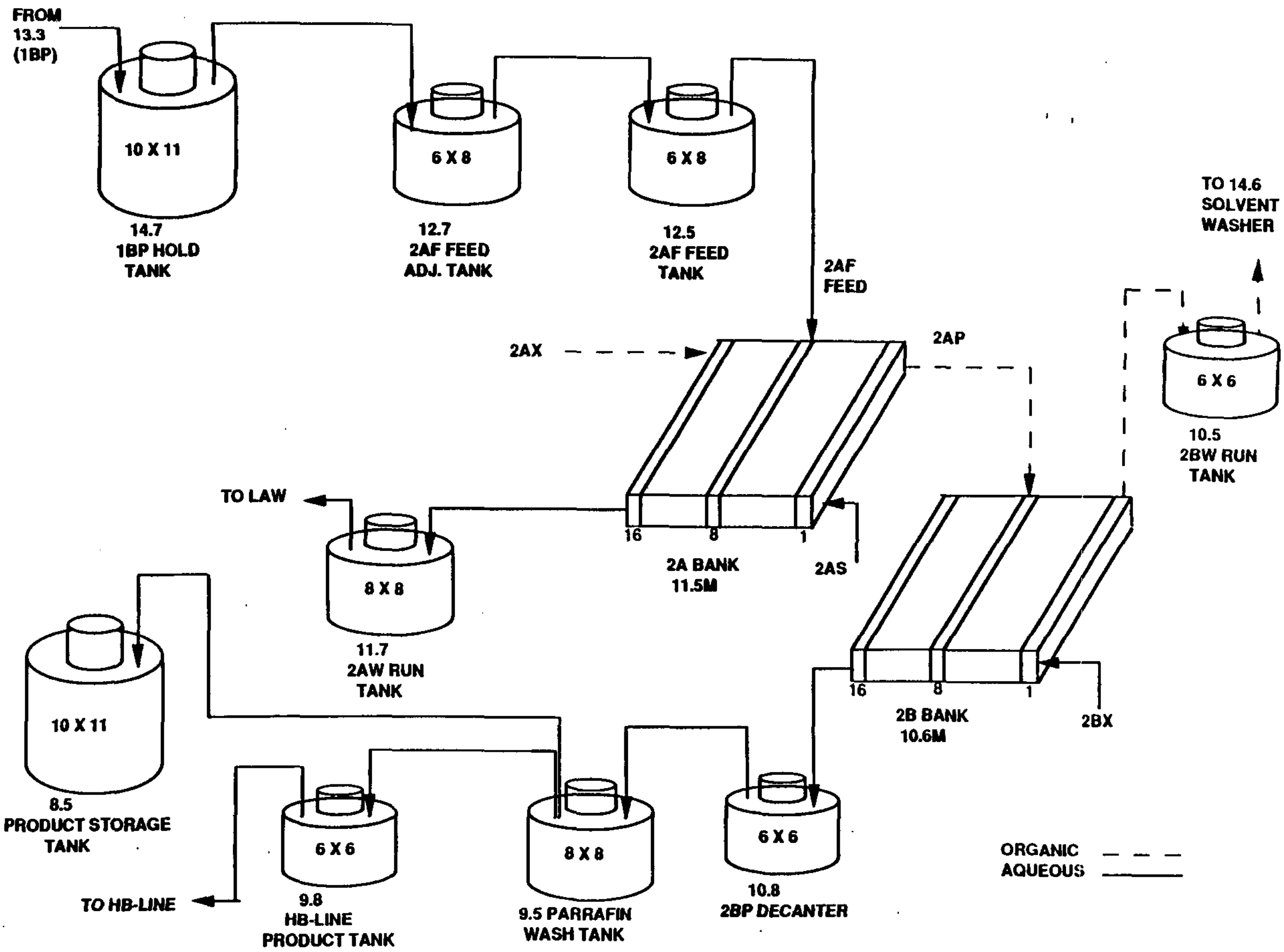


FIGURE 19. SECOND PLUTONIUM SOLVENT EXTRACTION CYCLE

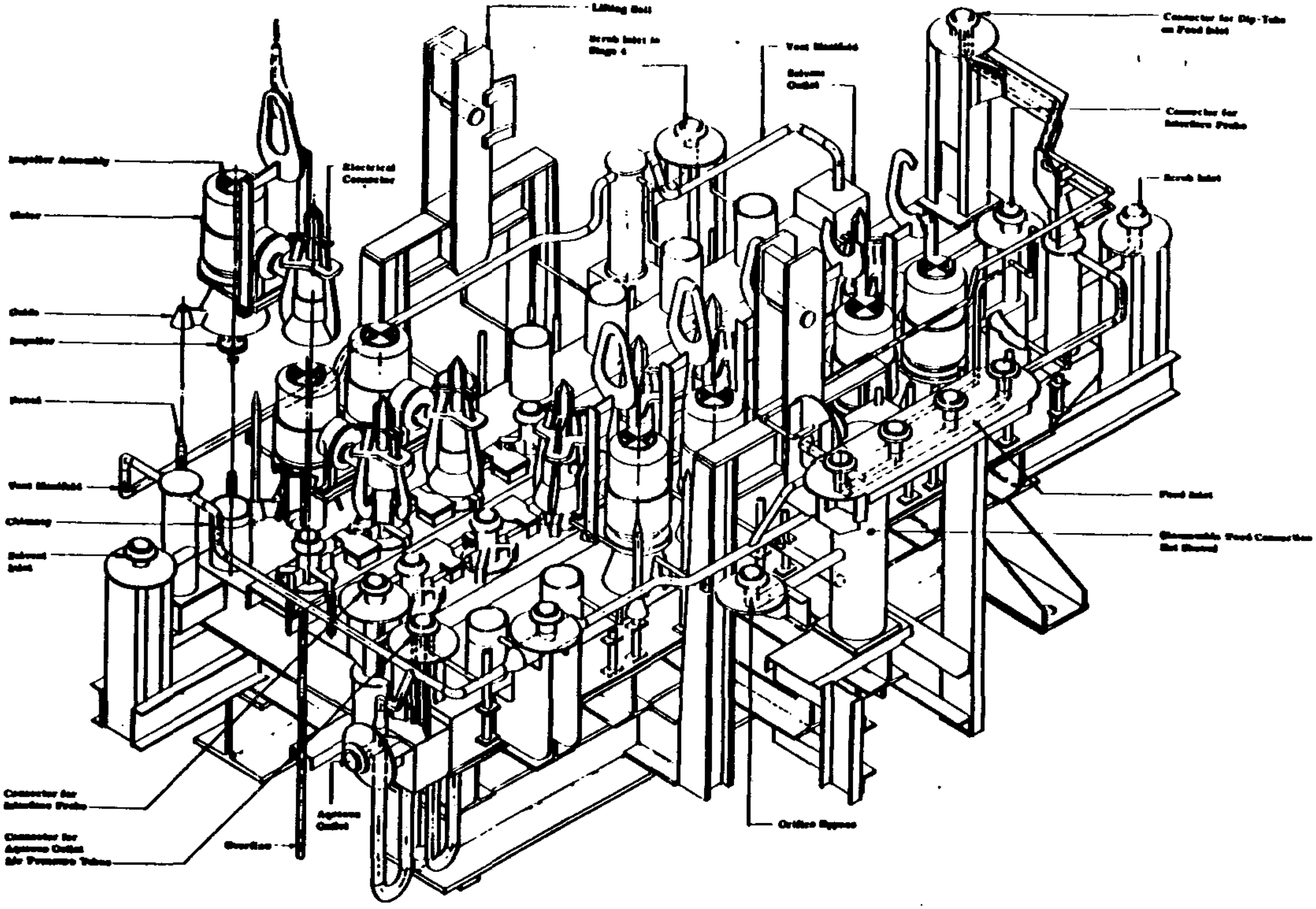


FIGURE 20. TYPE A (2B) MIXER-SETTLER

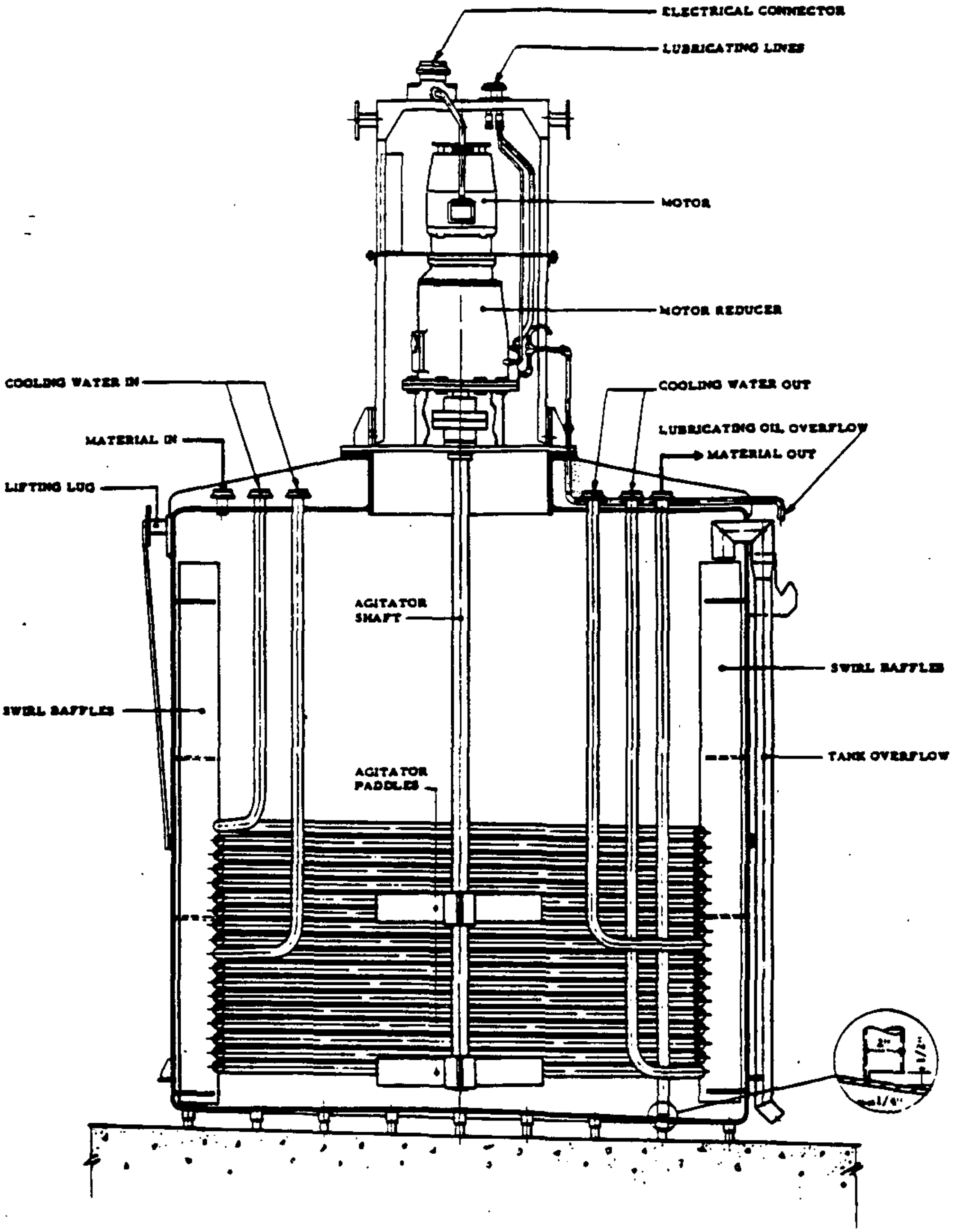


FIGURE 21. STANDARD CANYON TANK

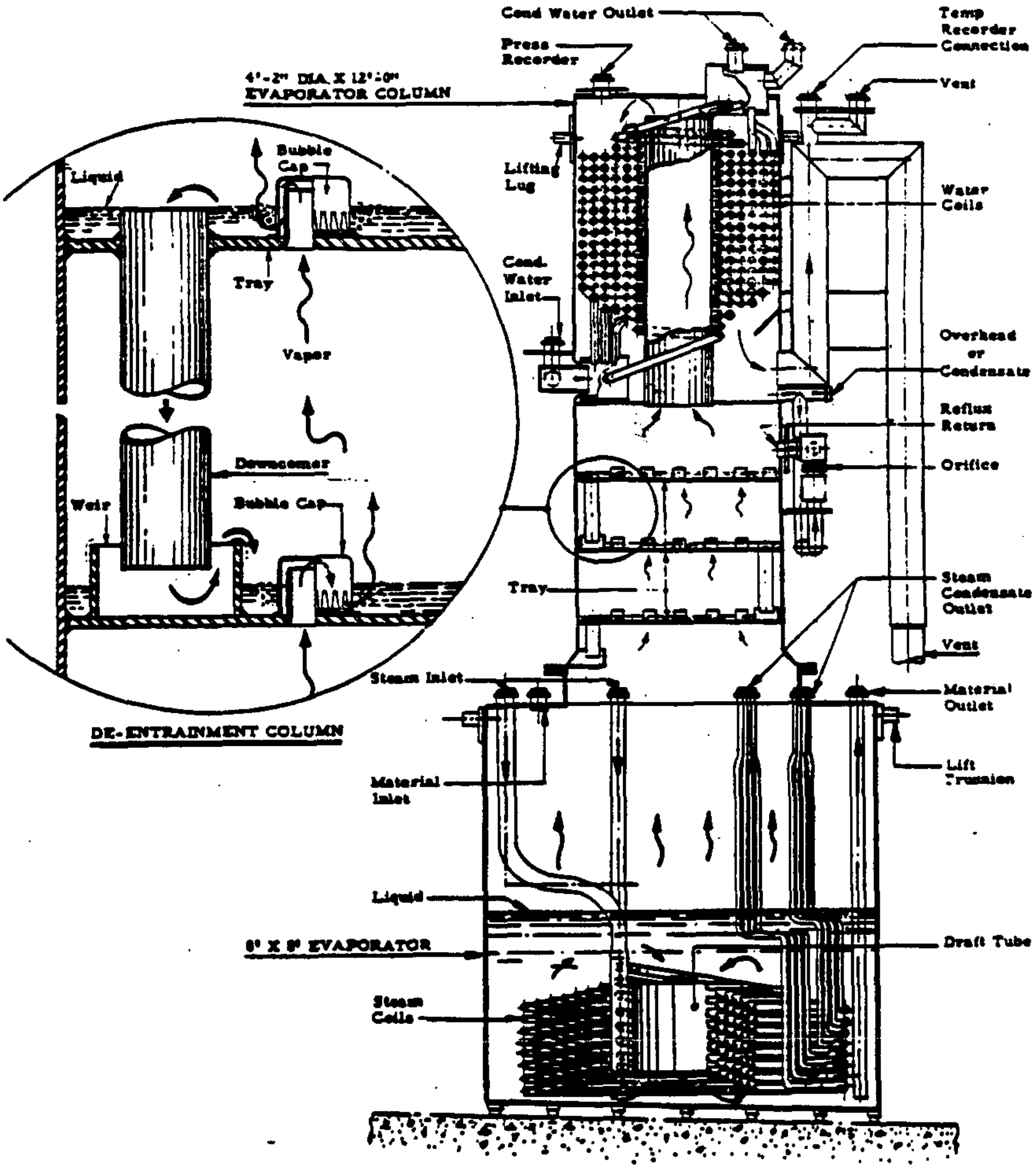


FIGURE 22. BATCH EVAPORATOR AND COLUMN

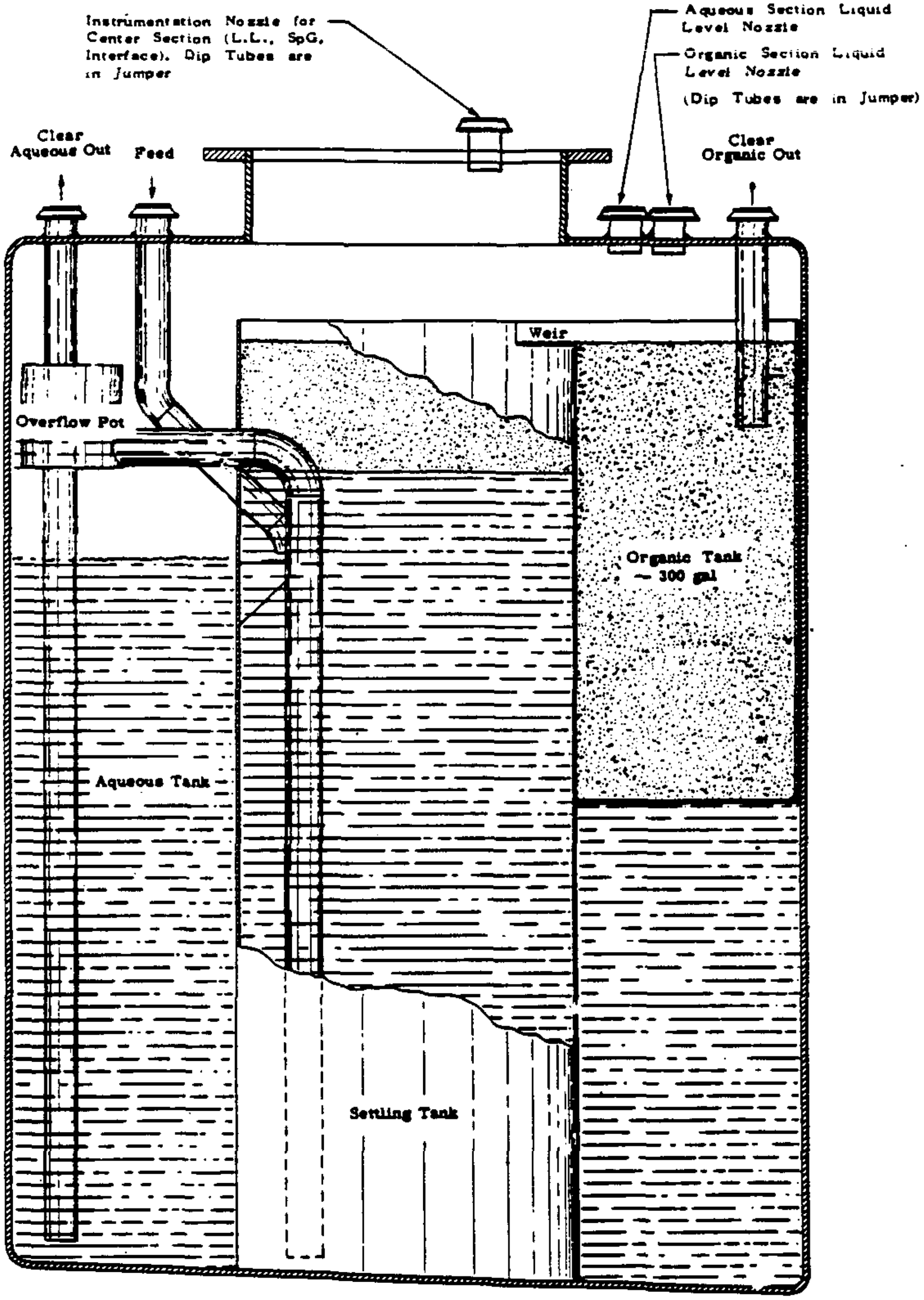


FIGURE 23. TANK DECANTER

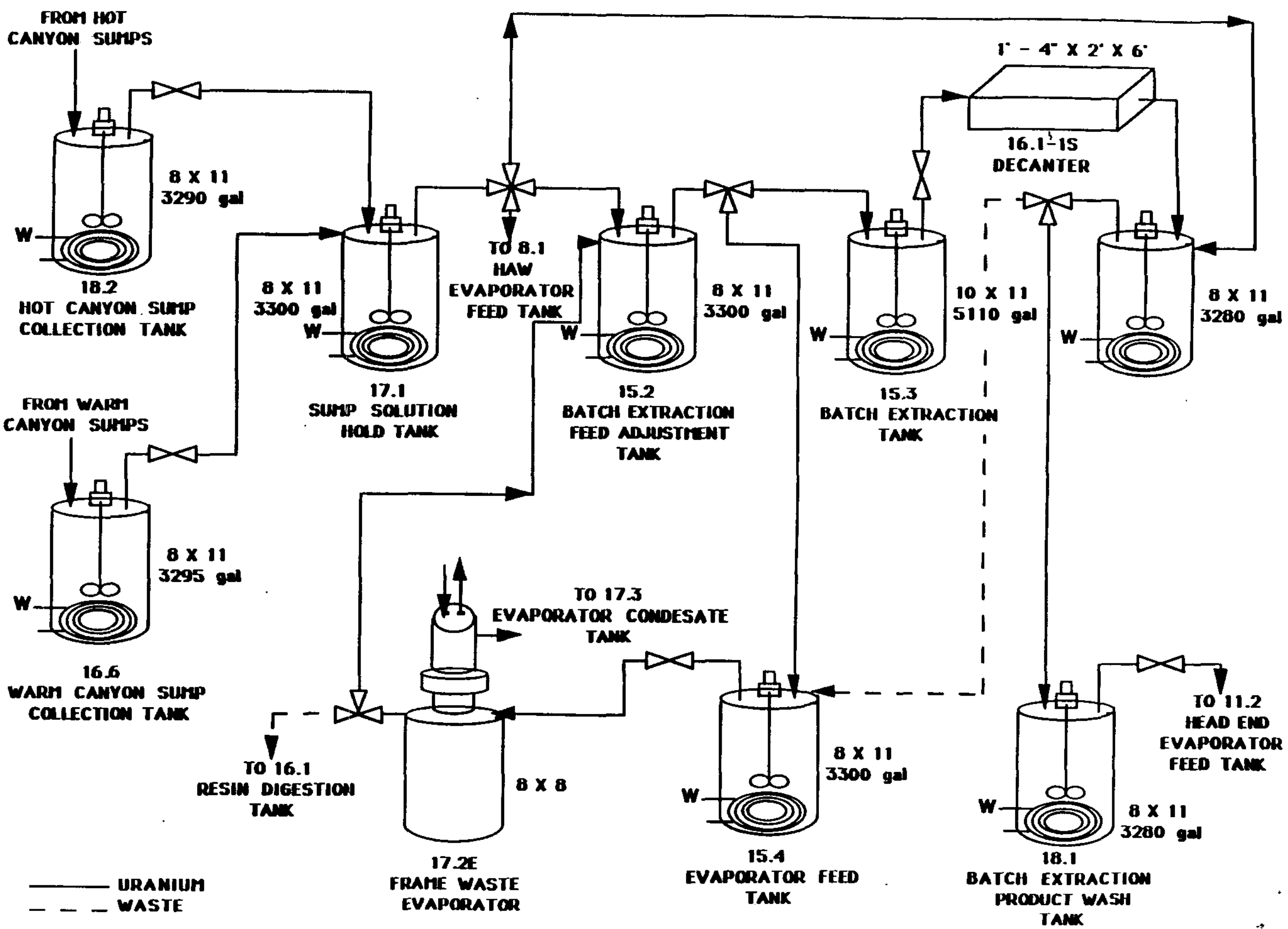


FIGURE 24. RERUN

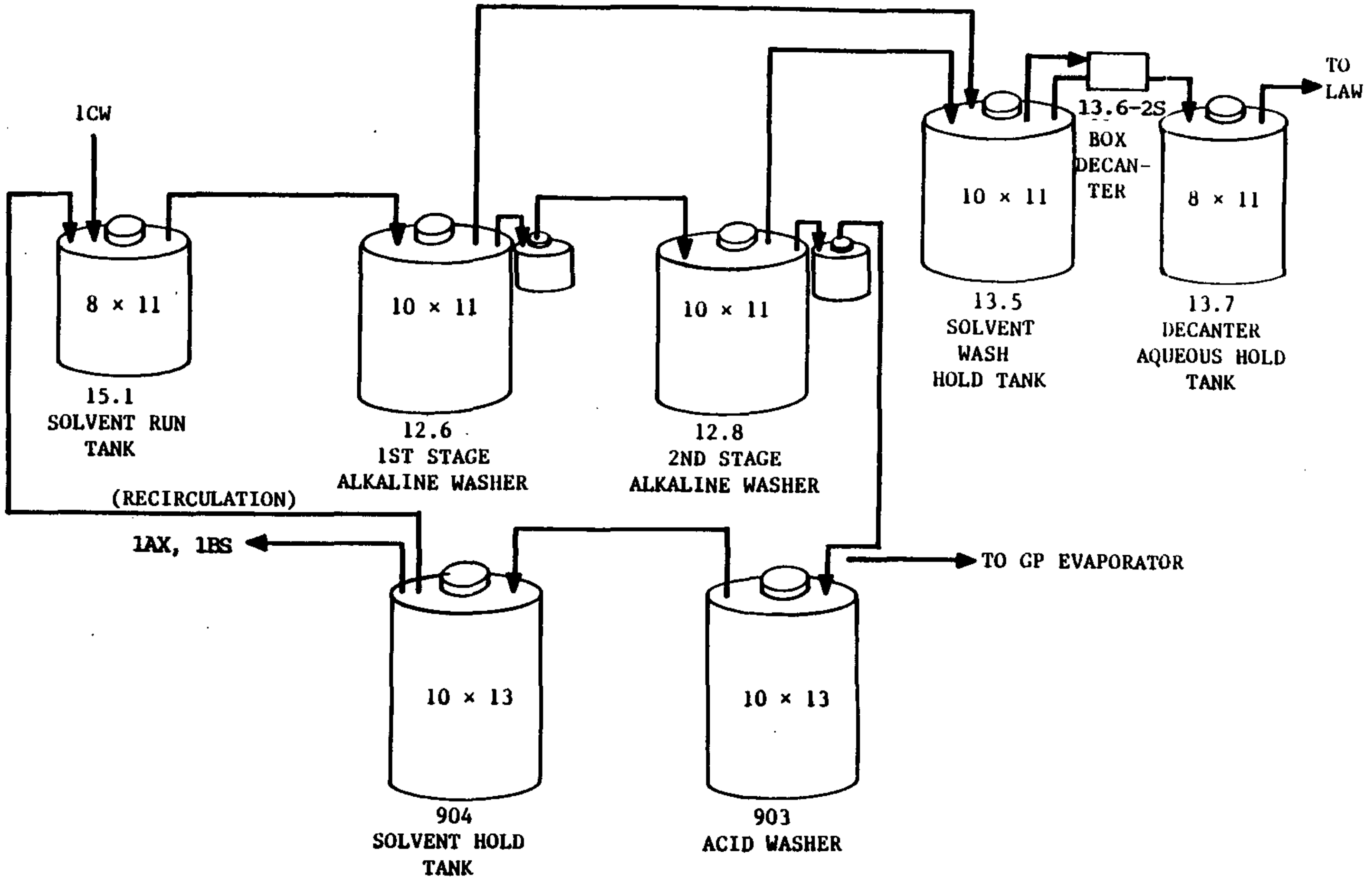


FIGURE 25. FIRST CYCLE SOLVENT RECOVERY SYSTEM

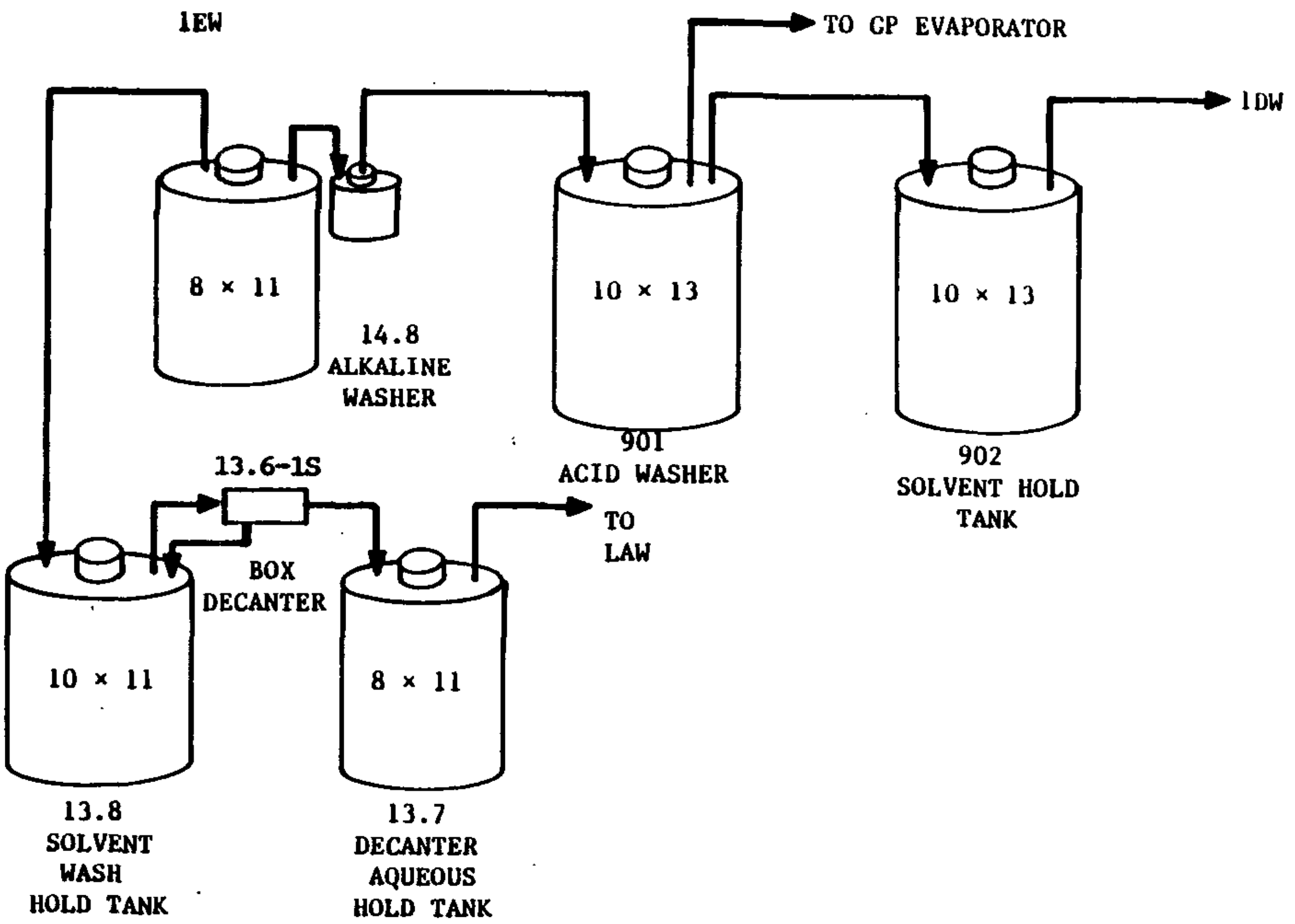


FIGURE 26. SECOND URANIUM CYCLE SOLVENT RECOVERY SYSTEM

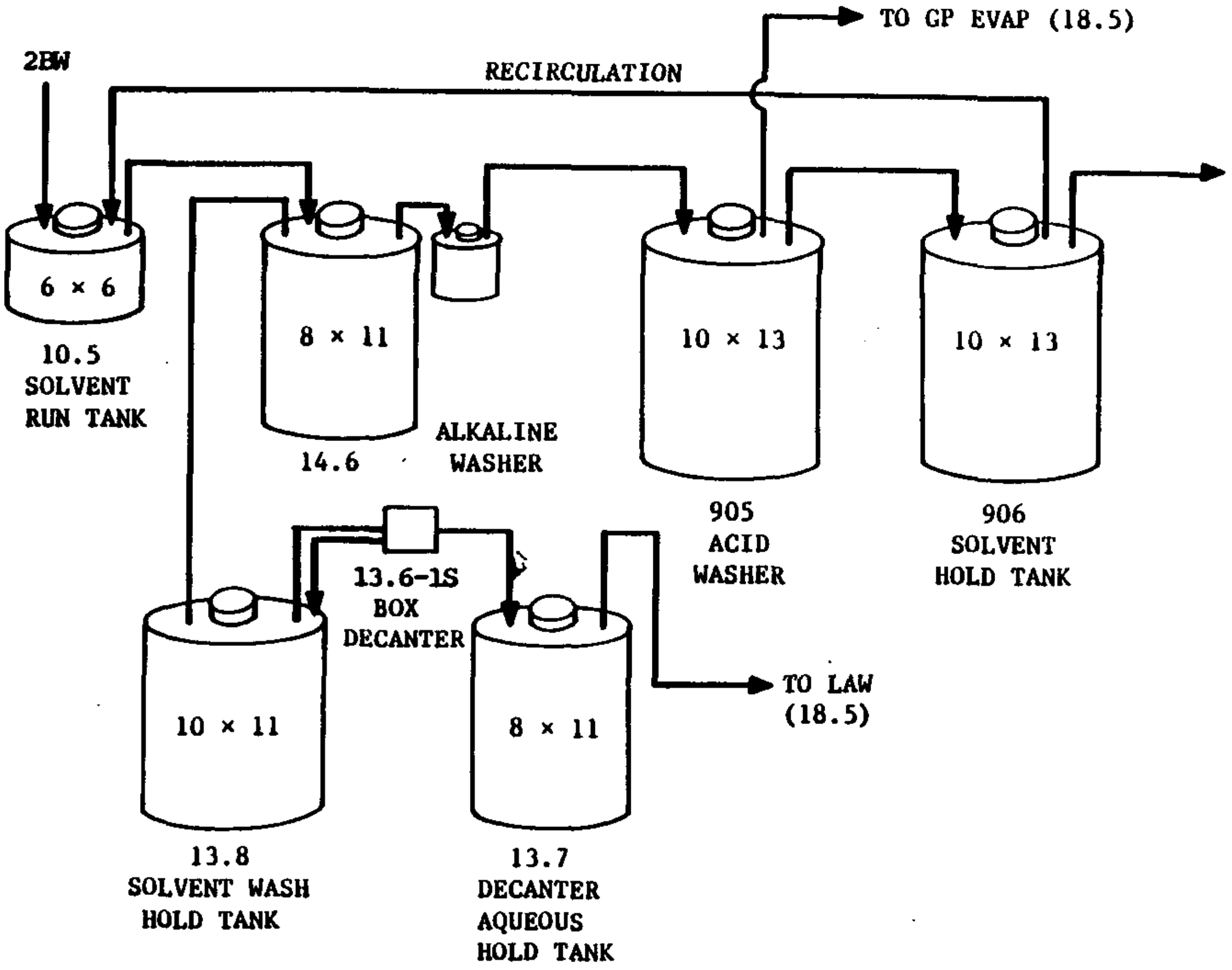


FIGURE 27 SECOND NEPTUNIUM CYCLE SOLVENT RECOVERY SYSTEM

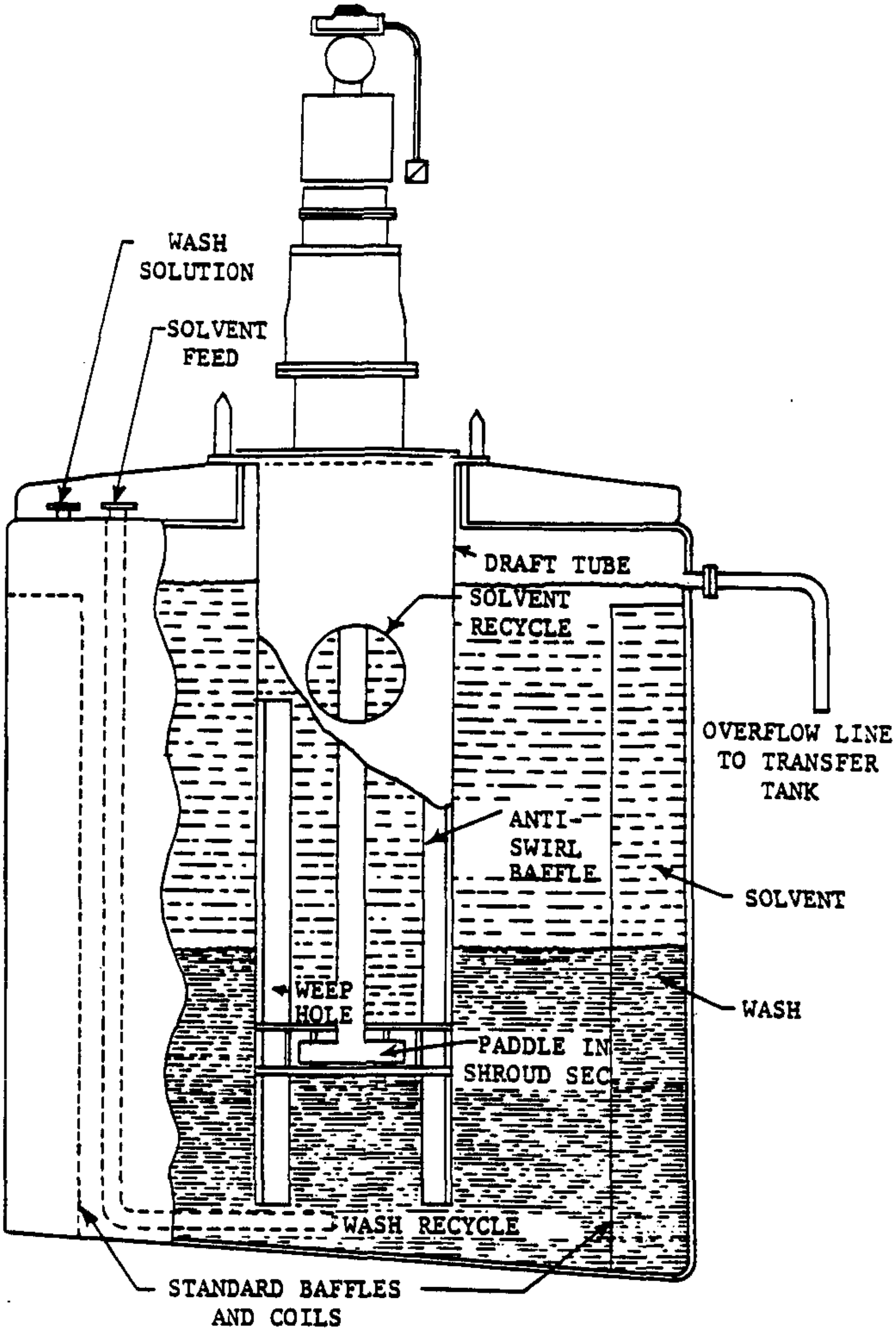


FIGURE 28. CONTINUOUS SOLVENT WASHER (ACID)

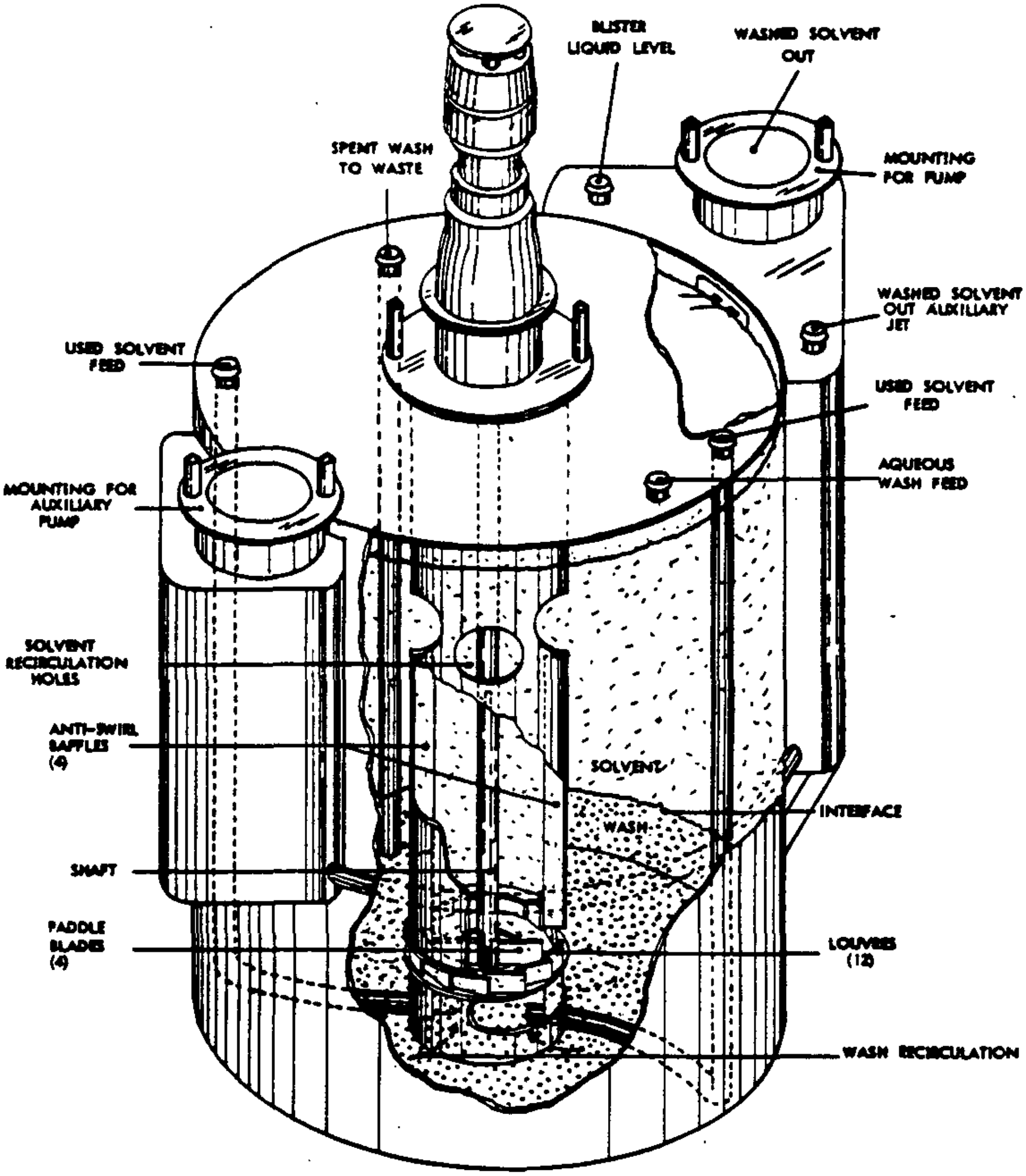


FIGURE 29. CONTINUOUS SOLVENT WASHER (CARBONATE)

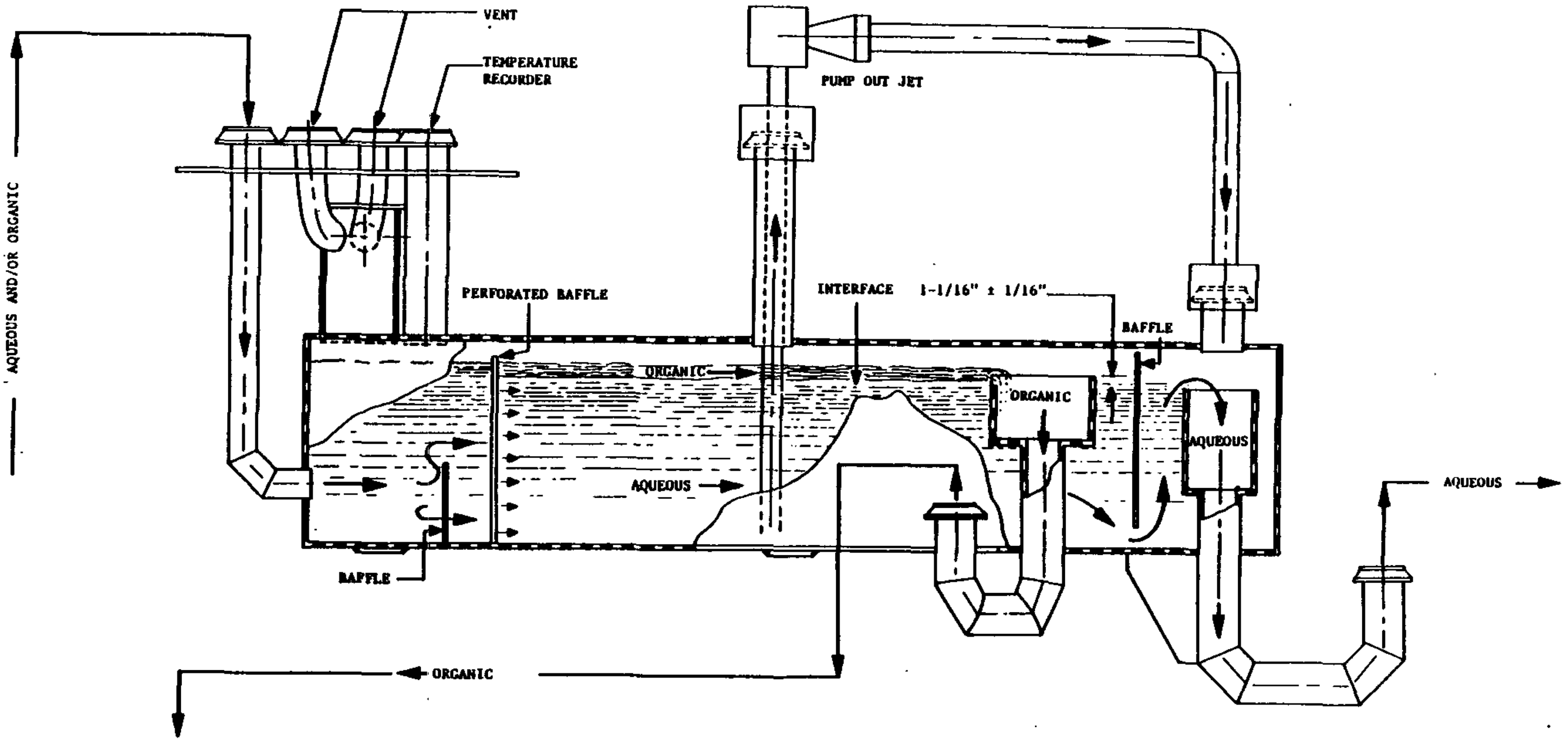


FIGURE 30. BOX DECANTER

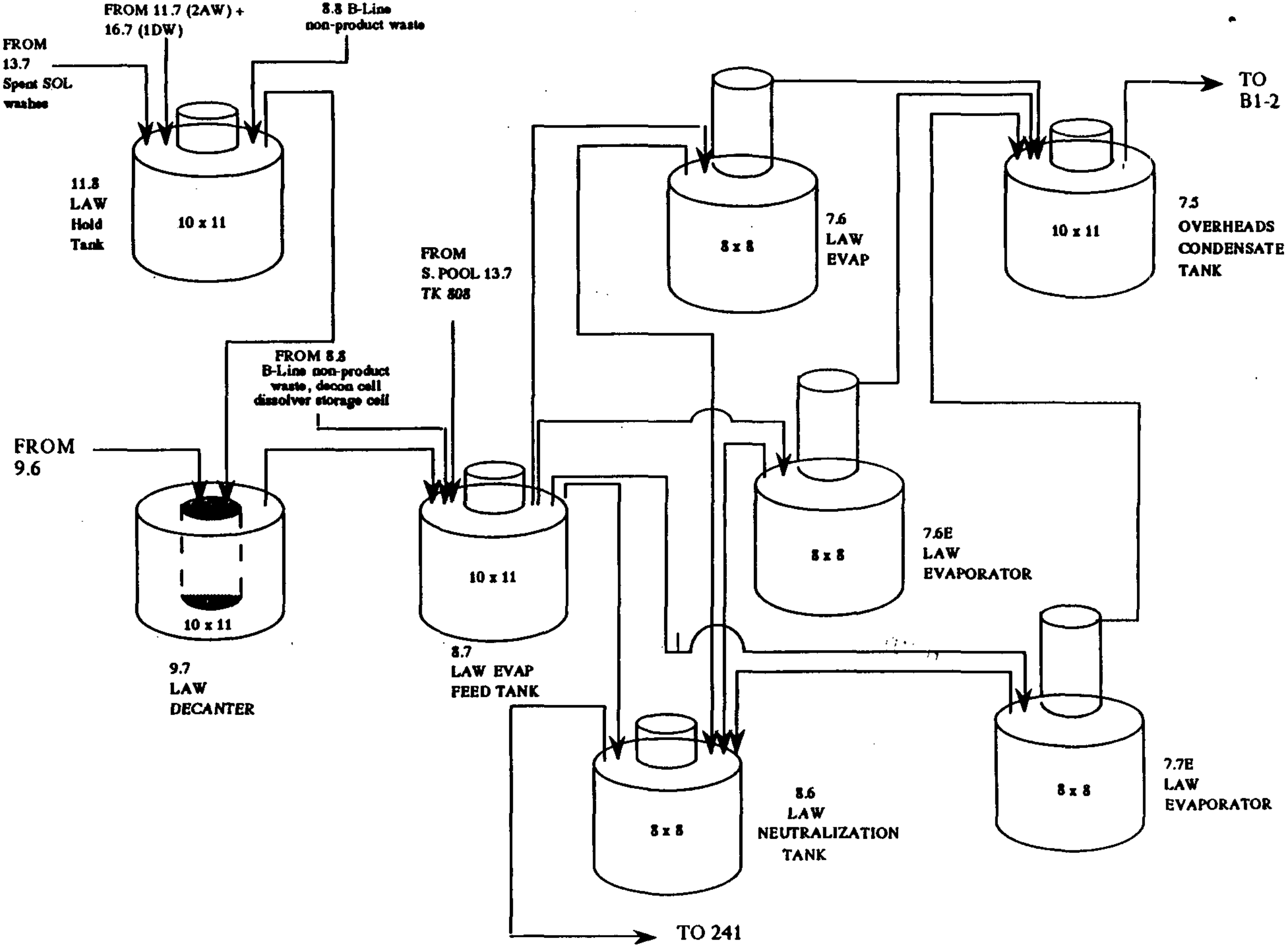


FIGURE 31. LOW ACTIVITY WASTE

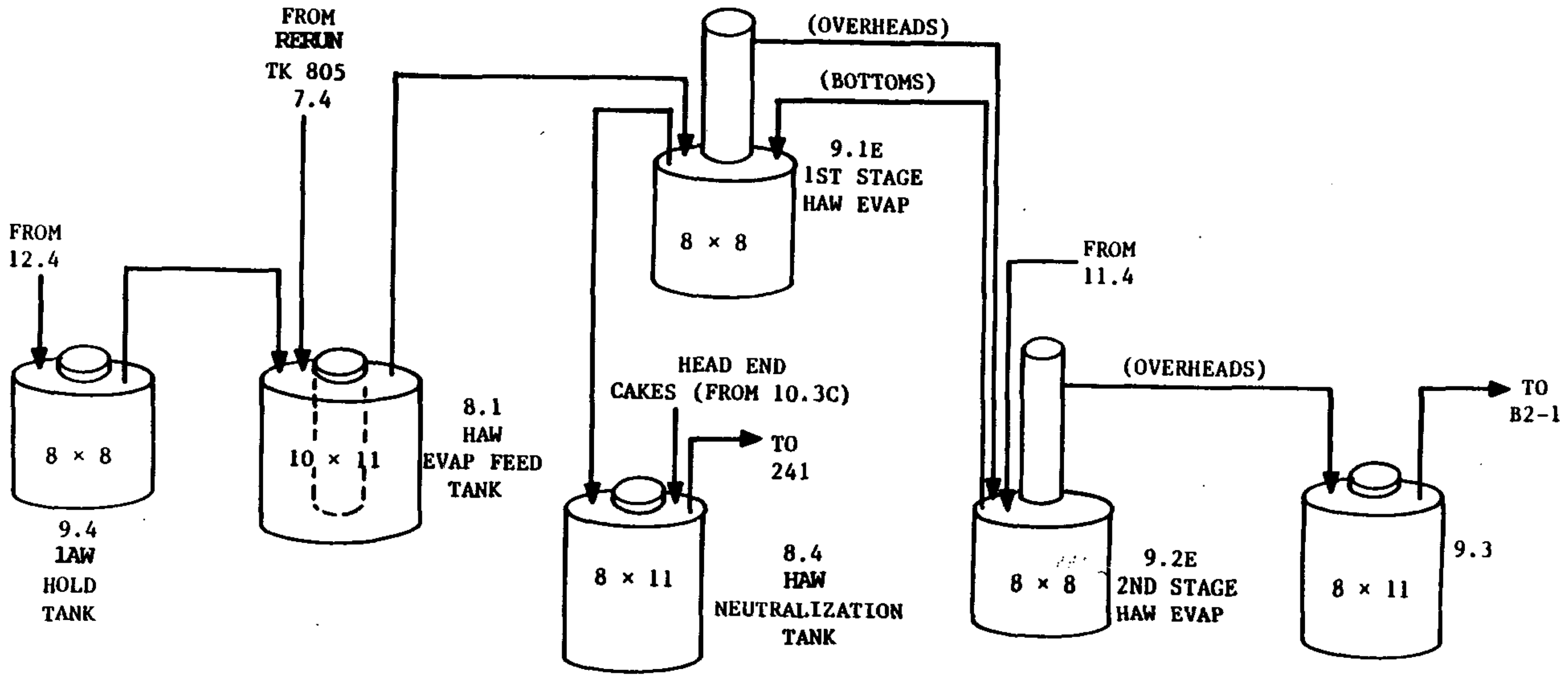


FIGURE 32. HIGH ACTIVITY WASTE

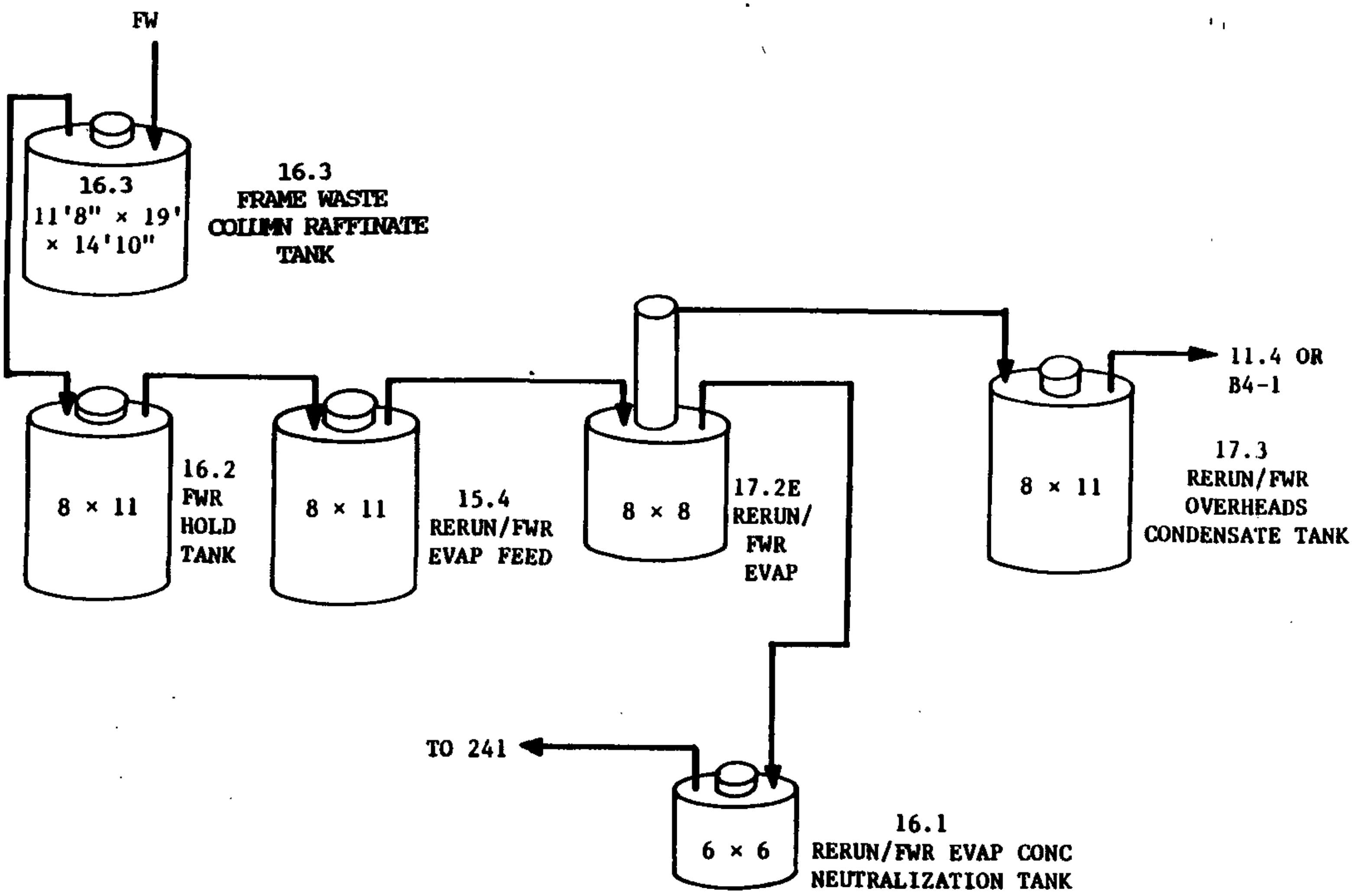
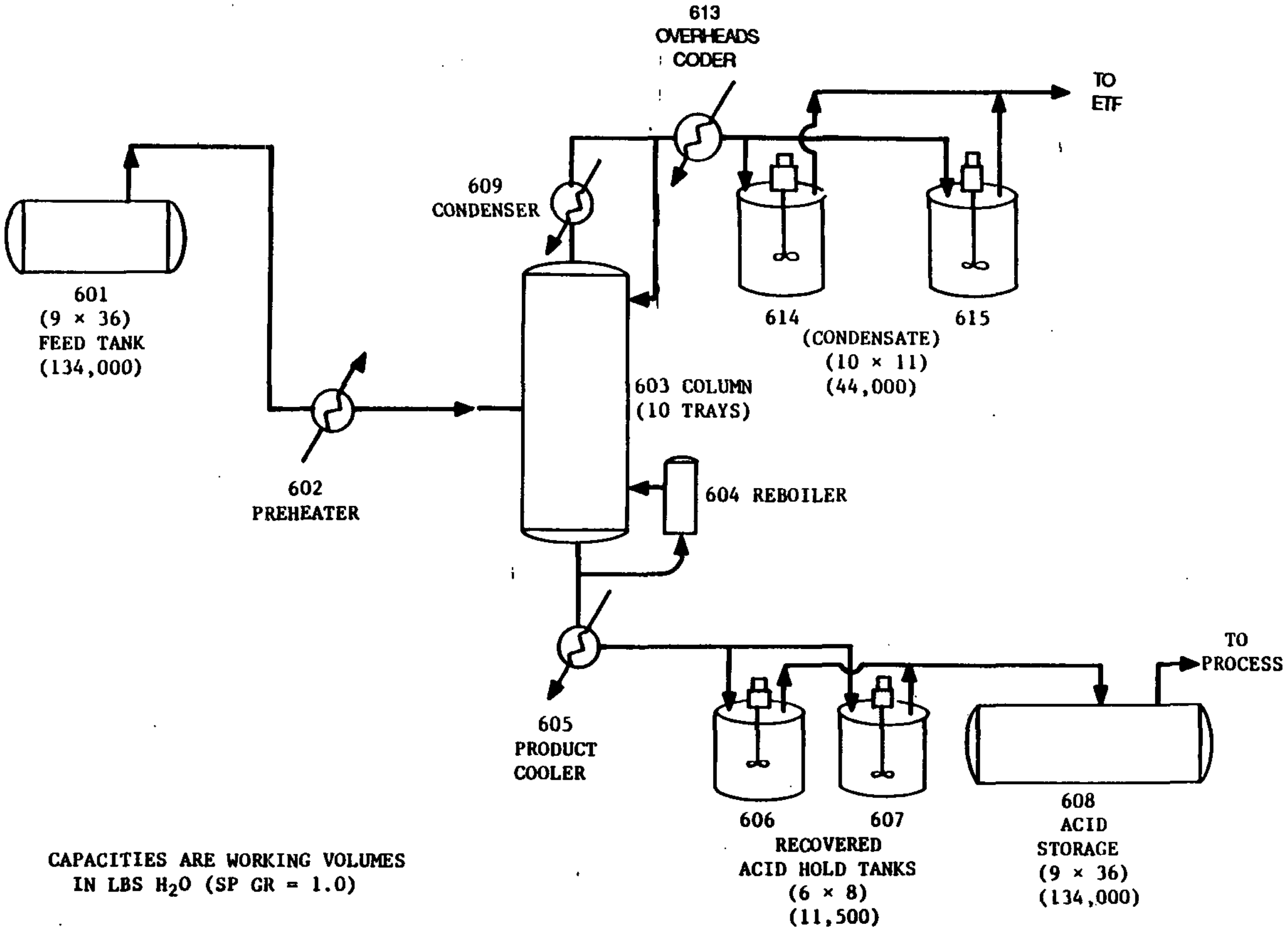
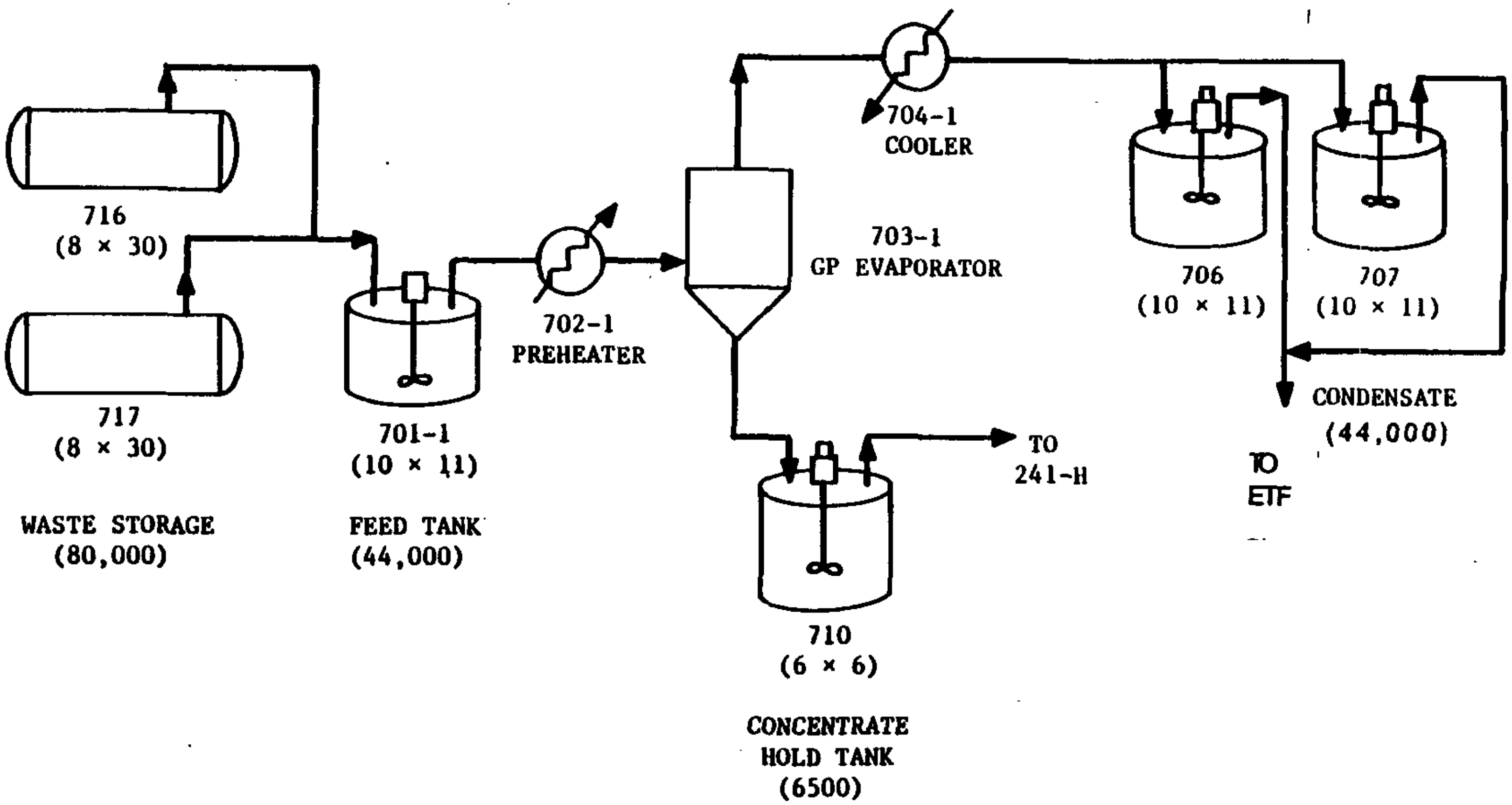


FIGURE 33. FRAME WASTE EVAPORATION



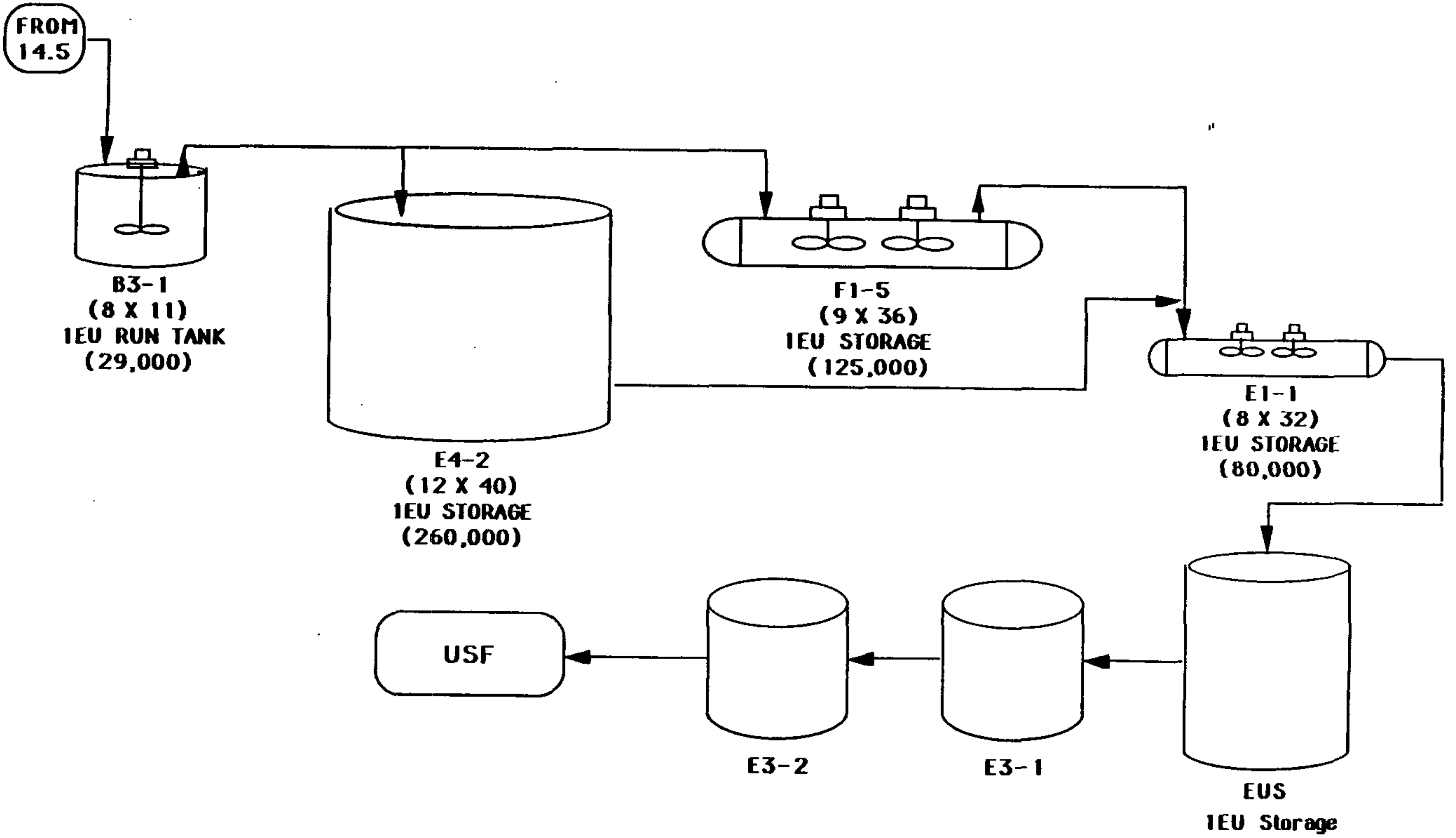
CAPACITIES ARE WORKING VOLUMES
IN LBS H_2O (SP GR = 1.0)

FIGURE 34. ACID RECOVERY UNIT



[NOTE: CAPACITIES ARE WORKING VOLUMES IN LBS H_2O (sp gr 1.0)]

FIGURE 35. GP EVAPORATOR



CAPACITIES ARE WORKING VOLUMES IN lbs H_2O (sp gr = 1.0)

FIGURE 36. PRODUCT STORAGE

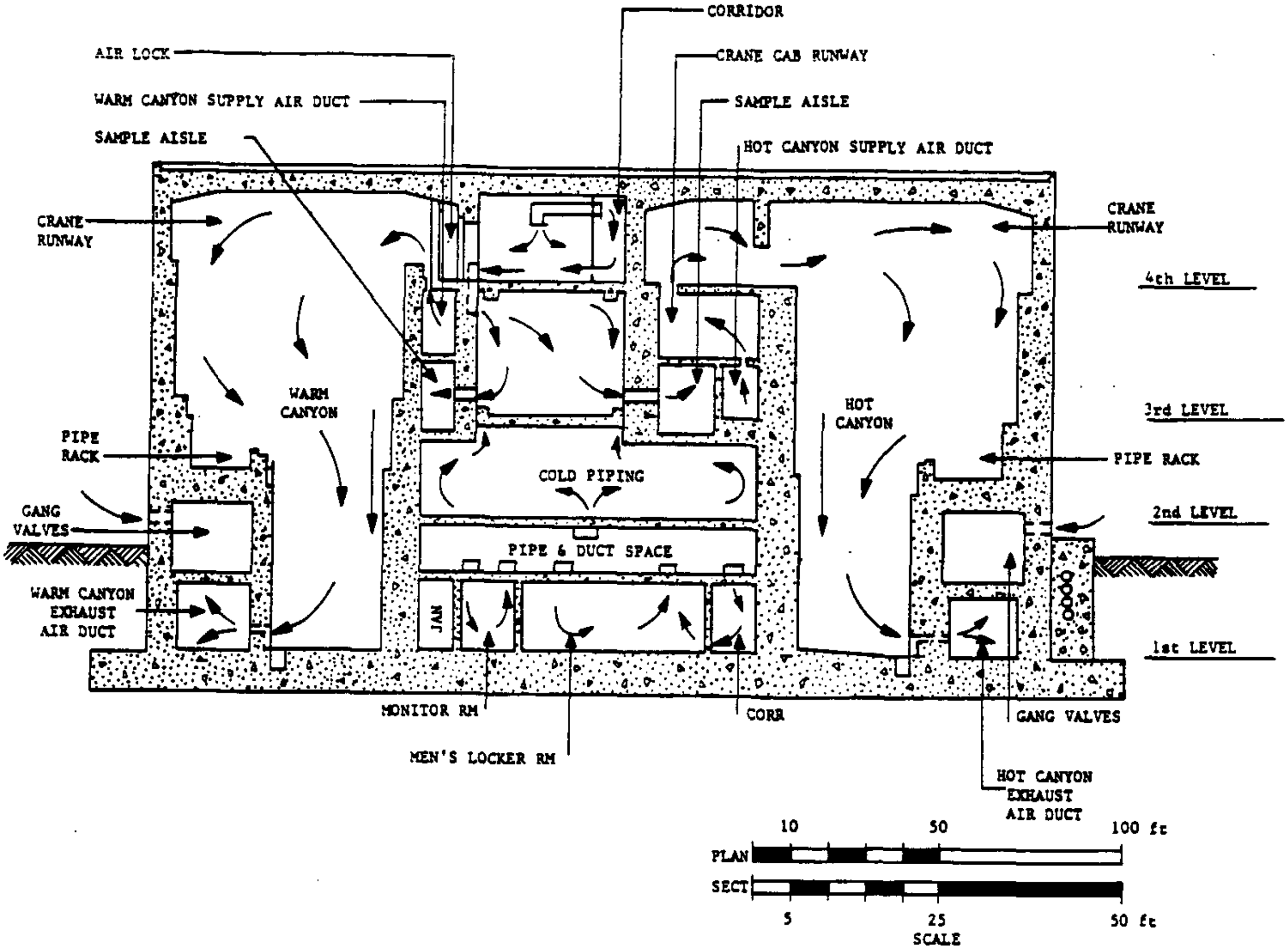


FIGURE 37. VENTILATION AIR FLOW, 221-H

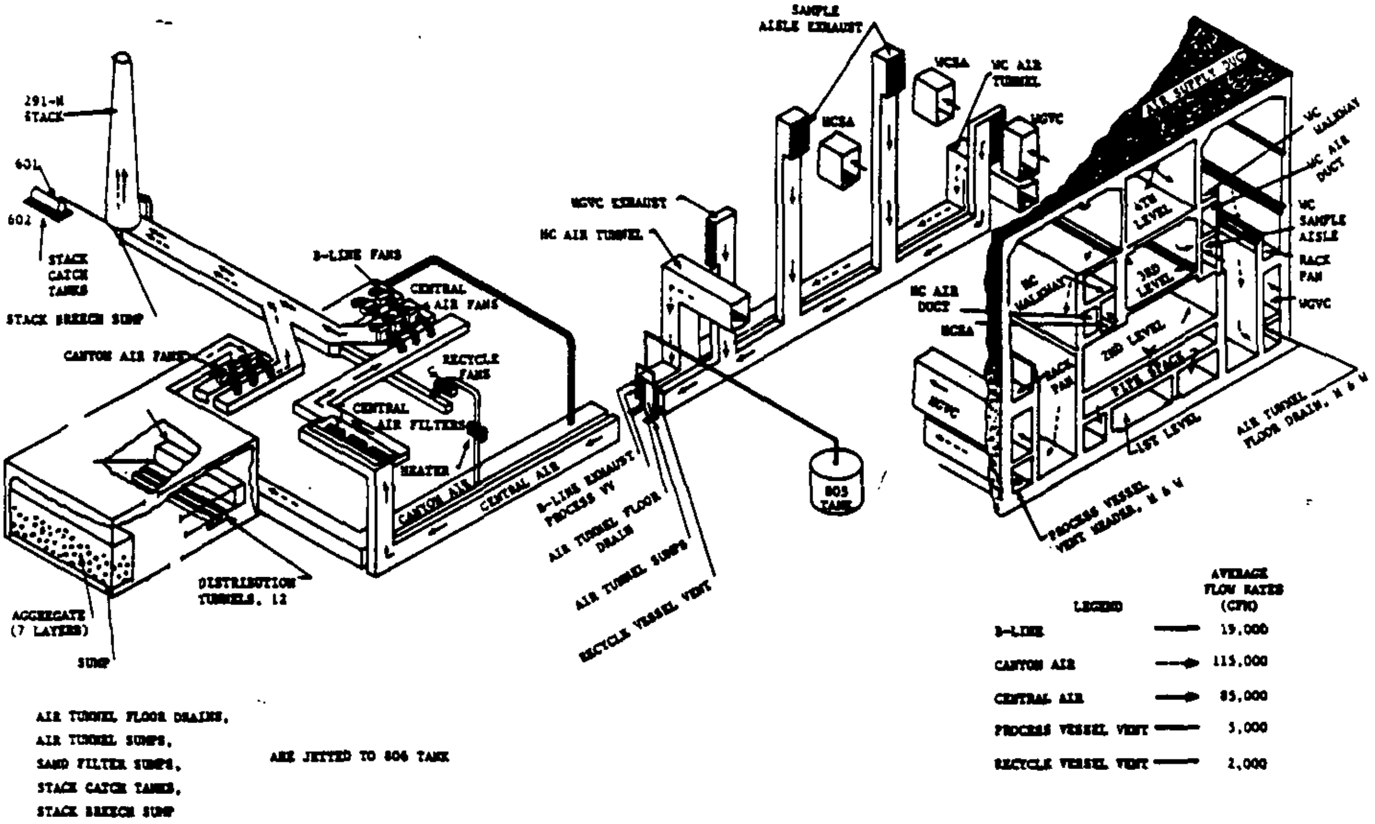


FIGURE 38. CANYON AIR EXHAUST TUNNELS

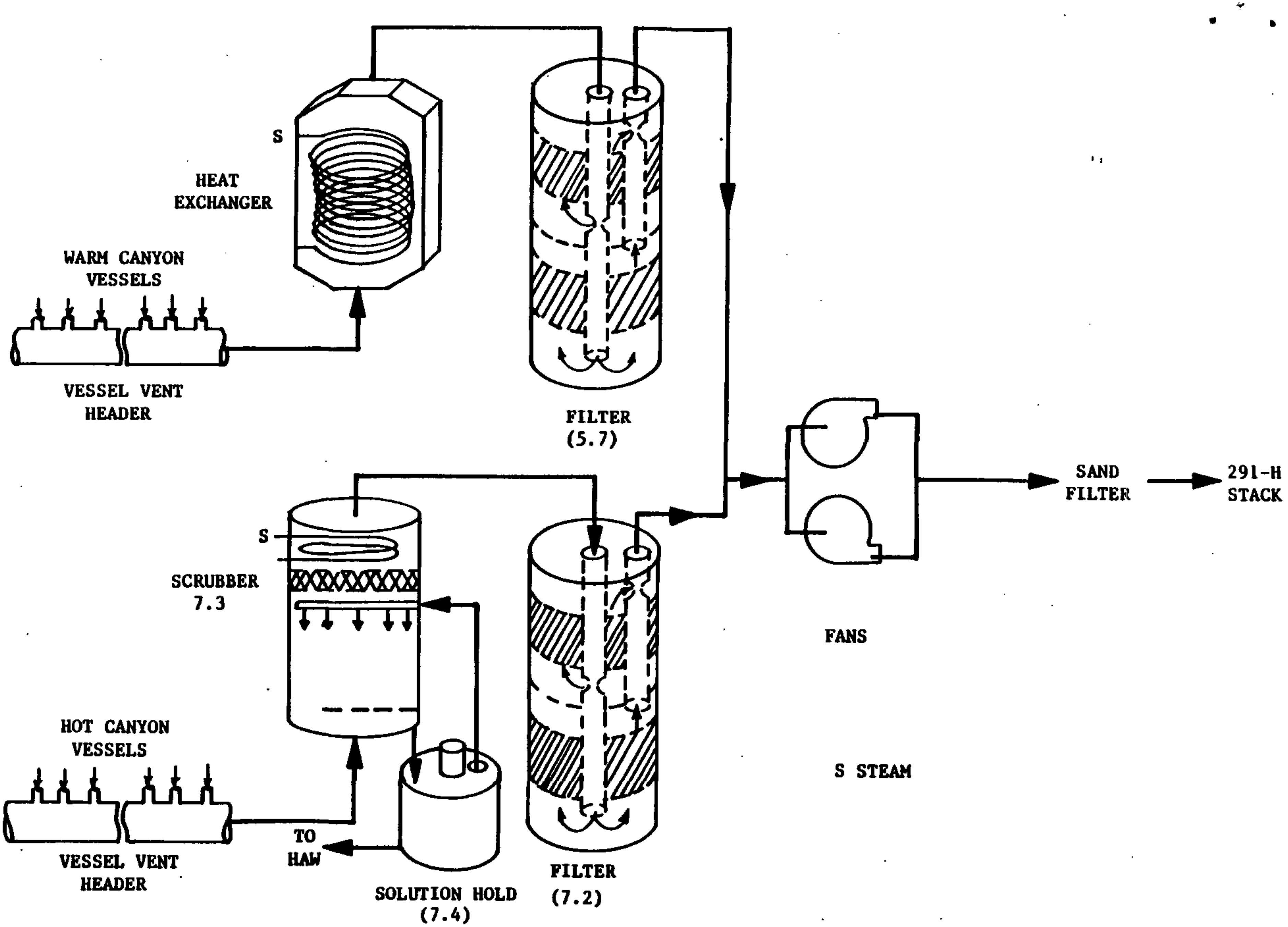


FIGURE 39. VESSEL VENT SYSTEM

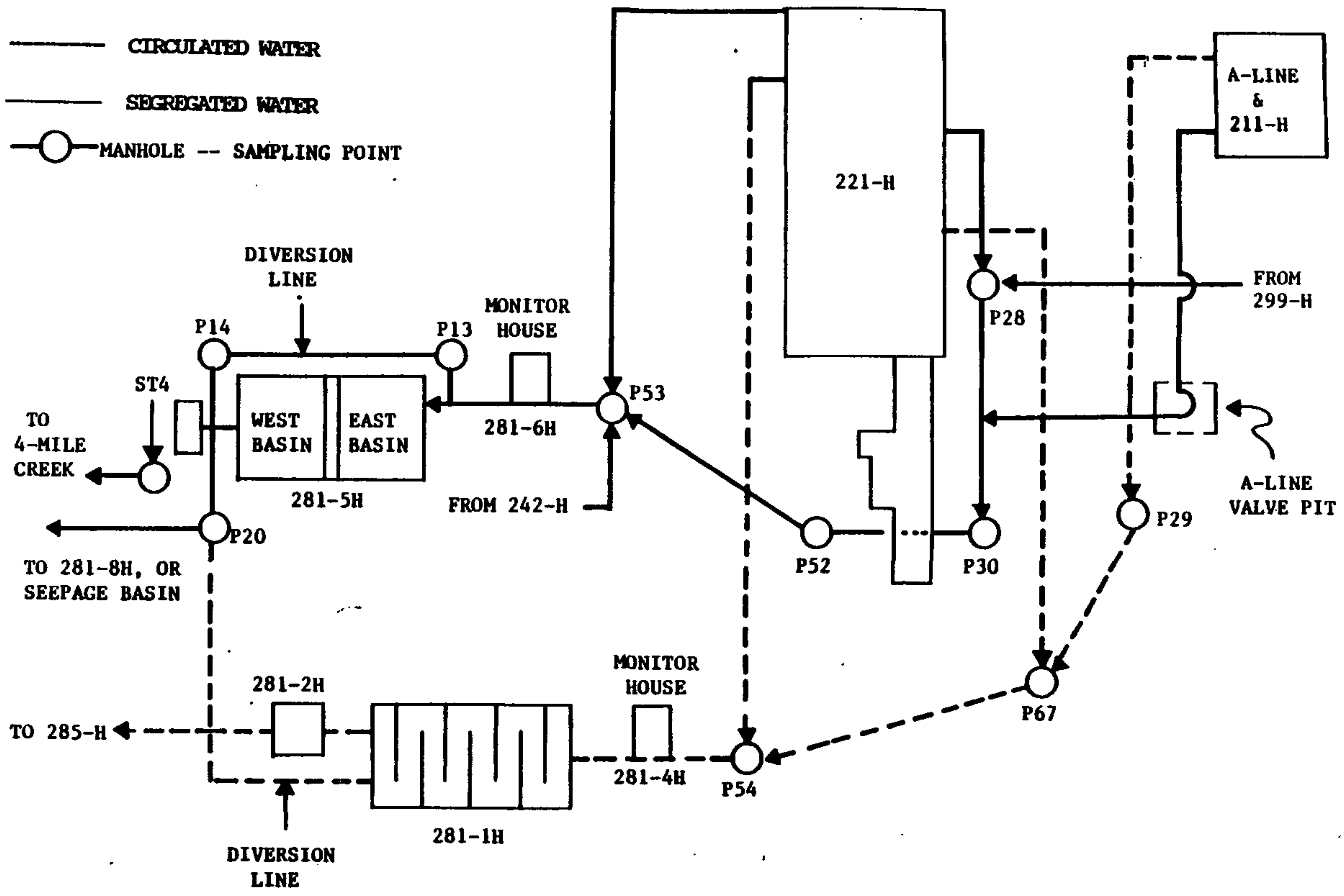


FIGURE 40. H-AREA COOLING WATER SYSTEM

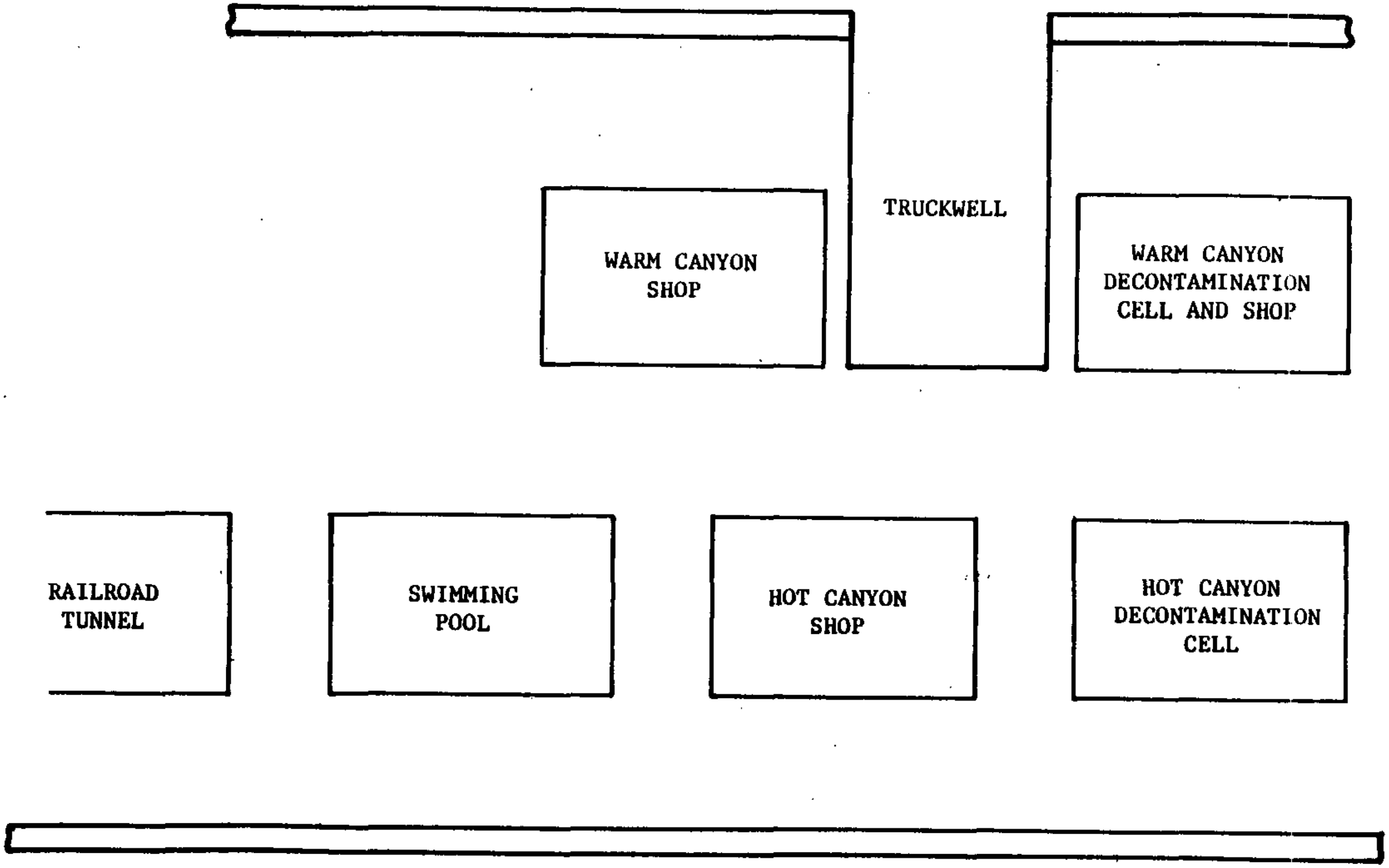


FIGURE 41. ARRANGEMENT OF DECONTAMINATION AND REPAIR FACILITIES