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ROUGH DRAFT

PUREX PULSE COLUMN DESIGNS FOR CAPACITY FACTOR OF 3.0 to 3.5

CHEMICAL ENGINEERING DEVELOPMENT UNIT
SEPARATIONS TECHNOLOGY SECTION
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HANFORD ATOMIC PRODUCTS OPERATION

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PUREX PULSE COLUMN DESIGNS
FOR CAPACITY FACTOR OF 3.0 to 3.5

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INTRODUCTION

This memorandum indicates the Purex-Plant pulse-column and pulse-generator revisions which would be required to assure an instantaneous capacity of 25 tons U/day with a 20% capacity safety margin under Purex HW #3 Flowsheet conditions. (The use of the Purex HW #4 Flowsheet⁽⁶⁾ with the revised columns would be expected to increase the capacity to 29 or 30 tons U/day.) The indicated design changes are recorded here for study and for possible reference if need for increased production capacity should arise. No recommendation for adoption at this time is made.

In case of later adoption of these designs, it would be desirable to review and -- if advisable -- modify them in the light of semiworks and plant experience accumulated after this writing. For example, the results of forthcoming Hot Semiworks studies, back-mixing, and liquid-liquid-disengagement investigations, and initial Purex-Plant experience should be taken into account.

The Purex Plant as originally scoped was intended to process 8.33 tons U/day, although the estimated capacity of the Plant as designed, was 14 tons U/day, limited by the IBX Column capacity. However, relatively minor process modifications (Purex HW #4, in lieu of HW #3, Flowsheet⁽⁶⁾), in conjunction with only minor equipment changes, described in Reference 8, would increase the capacity of the Plant to 23 tons U/day. The possibility of attaining a 25-ton/day capacity (capacity factor of 3.0) with some additional relatively minor equipment changes has been discussed in Reference 5.

SUMMARY

Revised specifications of the Purex Plant EA, IA, 2D, HC, IC, 2E, ILX, 2A, IO, and 2O Columns to permit a capacity increase to 25 tons U/day with a 20% safety margin are presented in Table I and Figures 1 through 12, attached. The overall heights remain unchanged from the presently adopted design, and the changes in other dimensions are believed to be sufficiently small to permit the installation of the revised columns in the Purex Plant cells with a minimum of cell piping changes.

Specific changes from previous specifications are summarized below and explained in more detail in the following Discussion and in the table and figures.

- (a) The internal diameters of the A-type-column extraction and scrub sections are increased from 24 and 32 in., respectively, to 27 and 36 in., respectively; the IBX Column diameter is increased from 27 to 38 in.; and the 2A Column diameter is increased from 7 to 8 in.
- (b) The C-type and O-type column fluorothene plate cartridges are replaced by stainless-steel "nozzle" plates.
- (c) The disengagement section volumes of the A-type, C-type, and IBX Columns are increased to increase the effluent holdup times to ca. 10 min. at 25 tons U/day.

- (d) Because of the change in disengagement volumes, the heights of the A-type column extraction and scrub section sieve-plate cartridges are reduced from 13.5 and 13.3 ft., respectively, to 12 ft. each; and the heights of the C-type column cartridges are reduced from 18 to 15 ft. The cartridge efficiencies are sufficiently great so that the waste losses and decontamination performance with these height reductions will still be satisfactory (U waste loss per column less than 0.1% of the feed).
- (e) The pulse frequency limit for the A-type columns is increased from 110 to 120 cyc./min., and the present IBX Column pulse generator is paralleled with a second 485-cu.in. pulse generator (necessary only if processing rates less than 12 to 15 tons U/day are anticipated).

Minor changes include replacing the influent distributors on all columns but the IBS, 2B, and 20 Columns with new distributors providing a linear flow velocity of 2.4 ft./sec. maximum at 25 tons U/day and redesign of the louver plates, cartridge-support-rod pattern, and 2A Column Raschig ring grids for the new column diameters.

An alternate IO Column design is provided which allows ca. 20 min. organic holdup time in the plate section at 25 tons U/day. This design is not recommended unless Plant experience should show that the additional holdup time is required for satisfactory fission product clean-up.

The Purex HW #3 Flowsheet is the basis for the 25-ton U/day Purex Plant, with the IBS stream flow reduced to 40% of the nominal flowsheet value to eliminate the necessity of a IBS Column diameter or cartridge change. Use of the Purex HW #4 Flowsheet will provide still greater capacity; however, some of the proposed items in this flowsheet are still under development.

DISCUSSION

A general discussion of the design specifications for new Purex process pulse columns capable of processing 25 tons U/day with an adequate safety margin appears below in support of the dimensions on Table I and the sketches on Figures 1 through 12. The Purex HW #3 Flowsheet is the basis used unless otherwise noted.

Cascade Height

The over-all column heights and the cascade arrangement have not been changed.

Column Diameter Changes

The diameters of the A-type columns, the IBX Column, and the 2A Column have been increased as indicated in the table below to provide an assured processing capacity of 25 tons U/day in these columns without changing the cartridge or packing geometry.

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Column	Diameter, In.		Estimated Processing Capacity, Tons U/Day ^(a)	
	Old	New	Old	New
A-Type Extn.	24	27 ^(b)	≥ 28	≥ 35
A-Type Scrub	32	36	24	30
IBX	27	38	13	26
2A	7	8	21	28

Notes: (a) After allowing a 20% safety margin, HW #3 Flowsheet.
(b) Diameter change recommended to reconcile pulse requirements with those of 36-in.-diameter scrub section.

The 8-in.-diameter 2A Column is no longer infinitely safe from a slow-neutron chain reaction; however, the arguments used to justify the use of an 8-in.-diameter IBX Column will apply to the 2A Column also (i.e., reliance for nuclear safety is placed on the diluteness of the plutonium and on the unlikely probability of sufficient undetected plutonium accumulating in the column to reach the minimum potentially critical mass). With this increase in diameter, the 2A Column can no longer be used with the proposed 2A-2B reflux flowsheet.

Revised louver-plate and Raschig-ring-grate designs for the enlarged-diameter columns are shown in Figures 5, 6, 7, and 8. The free areas provided in these designs are essentially the same as those specified for the present Plant columns.

Cartridge Design Changes

The fluorothene plate cartridges of the C-type and O-type columns have been replaced by stainless-steel nozzle-plate cartridges. The nozzle plates, spaced 4-in. apart, are sieve plates with the 1/8-in.-diameter perforations (10% free area) indented by punching to form nozzles extending 0.05 in. below the bottom surface of the plates:

The new nozzle-plate cartridges are expected to improve both the capacity and efficiency of the C-type and O-type columns, enabling the assured attainment of 25 tons U/day in the present 34-in.-diameter columns without increasing losses or impairing solvent clean-up (except for the possible second-order effect of the O-type column holdup time on solvent clean-up, as mentioned above).

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Cartridge Height Changes

The cartridge heights of the A-type and C-type columns have been reduced, as indicated in the table below, to permit the enlargement of the top and bottom disengagement sections (discussed later in this report).

Column	Cartridge Height, Ft.	
	Old	New
A-Type Extn.	13.5	12
A-Type Scrub	13.3	12
C-Type	18.0	15

Though these height reductions will increase uranium and plutonium losses slightly, the high efficiencies of the "standard cartridge" in the A-type columns and the new nozzle-plate cartridge in the C-type columns should still normally maintain the waste losses from each column well below 0.1% of the feed. The scrubbing effectiveness of the A-column scrub sections should also remain adequate since above about 12 ft. the D.F. obtainable is essentially independent of height.

Cartridge Support Rods

The following table gives the recommended spacing and number of support rods for all plate cartridges requiring changes. Although the spacing and number of the C-type and O-type support rods for the present fluorothene plate cartridges are adequate for the new cartridges, new and simpler specifications for these columns are included to take advantage of the rigidity of the stainless-steel plates.

<u>Column</u>	<u>Column Diameter, In.</u>	<u>No. of Tie Rods</u>	<u>Circle Diameter, In.</u>	<u>No. of Tie Rods on Circle</u>
A-Type Extn.	27	21	0	1
			10	4
			18	8
			24	8
A-Type Scrub	36	21	0	1
			14	4
			24	8
			32	8
C-Type	34	21	0	1
O-Type			13	4
			22	8
			31	8

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<u>Column</u>	<u>Column Diameter, In.</u>	<u>No. of Tie Rods</u>	<u>Circle Diameter, In.</u>	<u>No. of Tie Rods on Circle</u>
IBX	38	21	0	1
			15	4
			25	8
			34	8
IO (Alternate)	48	33	0	1
			19	8
			31	8
			42	16

Possible spacer arrangements for the A-type and IBX Columns are indicated in the louver-plate drawings, Figures 6, 7, and 8. Only the 9 rods passing through the center lines of the plate need be tied to the support spiders; the remaining rods may be bolted to the top and bottom plates (using spacers to keep the nuts away from the plate).

The new cartridges would be installed in such a way that they can be removed by contact maintenance, as in the present Purex Plant columns.

Disengaging Sections

The disengaging sections of the A-type, C-type, and IBX Columns were re-designed to increase the holdup time of the effluent streams to about 10 min. at 25 tons U/day (6 min. for IBU, 4 min. for IOO). The new end-section designs for these columns are shown in Figures 9 through 11. The bottom end-sections of all uranium (large-diameter) columns are vertical cylinders capable of withstanding the working pressure and providing minimum pulse pressure-wave distortion. Box-type disengaging sections are specified for the top. The following table indicates the volumes and holdup times of all disengaging sections:

<u>Disengaging Section</u>	<u>Disengagement Volume, Gal. (a)</u>	<u>Flow Rate of Disengaged Stream, Gal./Min. (b)</u>	<u>Holdup Time, Min. (b)</u>
HA, IA, 2D Top	490	49.0	10
HA, IA, 2D Top (Alternate)(c)	460	49.0	9.4
HA, IA, 2D Bottom	190	20.2	9.6
HC, 2E Top	520	47.4	11
HC, 2E Top (Alternate)(c)	500	47.4	11
IC Top	520	52.3	10
IC Top (Alternate)(c)	500	52.3	9.6
HC, IC, 2E Bottom	860	87.6	9.8
IBX Top	340	54.0	6.2
IBX Bottom	79	4.2	19

Notes: See following page.

Disengaging Section	Disengagement Volume, Gal. (a)	Flow Rate of Disengaged Stream, Gal./Min. (b)	Holdup Time, Min. (b)
IBS Top	41	3.2	13
IBS Bottom	24	4.1	5.8
2A Top	18	1.9	9.7
2A Bottom	24	8.4	2.9
2B Top	14	1.9	7.6
2B Bottom	12	0.93	13
IO Top	400	99.7	4.0
IO Bottom	310	33.3	9.2
IO (Alternate) Bottom (d)	540	33.3	16
20 Top	400	47.4	8.4
20 Bottom	310	47.4	6.4

Notes: (a) Defined as volume of liquid in disengaging section between the influent distributor and the column outlet, or between the normal interface position and the column outlet when the interface is located in the disengaging section.

(b) At 25 tons U/day, modified Purex HW #3 Flowsheet (see text).

(c) Using the alternate box width of 38 in. instead of 40 in.

(d) Using the 48-in.-diameter column design (Figure 12).

The bottom-end section of the present IBS, 2A and 20 Columns fail to meet the 10 min. holdup time desideratum. Of the three, only the 2A Column may present a problem; modification of the present disengagement section would involve either considerable cell rearrangement or relaxation of nuclear-safety geometry requirements. Solvent entrainment in the 2AW, however, even if appreciable, would represent only a small economic loss because of the small relative volume of the 2AW (ca. 40% of the HAW). "Cold" pilot-plant tests have indicated that entrainment in the 2AW with a 3-min. holdup time in the disengagement section will normally be less than 0.1% (possibly as low as 0.01%) of the 2AW. Entrainment of solvent in the IBP and 20W streams would not present a problem since these streams are not discarded (the IBP going to the 2A Column, the 20W recycling as 20S).

The top end sections of the IBX, 2B and IO Columns also fail to meet the 10-minute holdup time requirement. The IBX column, however, is not required to provide any decontamination, so entrainment of fission products in the IBU stream is normally not objectionable. The 2BW stream is recycled to the IBX column and also presents no entrainment problem. Any aqueous (and fission-product) entrainment in the IOO stream is removed in the solvent centrifuge.

Alternate designs for the A-type and C-type column top end sections are provided which at a small sacrifice in holdup time permit the use of the same horizontal cross-section as used in the present columns. These alternate designs would be used in the event that the new designs would require excessive cell-piping rearrangement.

Influent Stream Distributors

Detailed specifications for the influent stream distributors to be used in the revised columns are shown in Figures 1, 2, 3 and 4. These distributors are sized to give a maximum flow velocity of 1.5 ft./sec. from the nozzles at 25 tons U/day with the exception of the jet-mixer distributors for the A-type-column feed streams which have a flow velocity of 2.4 ft./sec. at 25 tons U/day.

Although specifications are given for 20 Column distributors, the present distributors are adequate; and no change need be made unless such a change is desired to make the 20 Column identical to the IO Column.

The orientation of the distributors in the columns is either indicated in Figures 9 through 12 or remains unchanged.

Pulsers

No pulser changes need be made for the A-type, C-type, IBS, 2A, 2B, and O-type columns; although for advantageous operating flexibility it is desirable to increase the maximum pulse frequency to ca. 120 cyc./min. on the A-type column pulsers.

The present IBX pulser is adequate for the new column for processing rates of 20 to 30 tons U/day; an increase in the frequency range to ca. 150 cyc./min. (by changing gear ratios in the drive or motor) will suffice if the minimum capacity to be used in the column is about 12 tons U/day. If still lower processing rates are anticipated it is advisable to install two 485-cu.in. pulse generators in parallel to achieve the desired range of pulse energies. Two 485-cu.in. pulse generators in parallel are also recommended for the IO Column if the alternate design (48-in. diameter) is installed.

IO Column (Solvent-Cleanup)

Although simply replacing the fluorothene-plate cartridge of the IO Column by a nozzle-plate cartridge, as discussed above, will provide over 25 tons U/day processing capacity, some laboratory data indicate that it may be desirable to provide a 20 to 30-min. organic holdup in the solvent cleanup columns to achieve good decontamination of the solvent. This 20-min. holdup time at 25 tons U/day can be obtained by increasing the IO Column diameter to 48 in. (doubling the cross-sectional area).

A redesigned IO Column, designated as IO Column (Alternate) is shown in Figure 11.

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Revised pulser requirements, cartridge-support rod geometry and influent distributors are indicated in the appropriate sections of this report. In addition, an enlarged bottom disengagement section has been designed and included in the figure and in the table of disengagement or holdup times.

Flowsheet

The Purex HW #3 Flowsheet is the design basis for the new columns; however, to enable the present 8-in. IBS Column to operate satisfactorily at an assured 25 tons U/day processing rate, it is necessary to reduce the IBS stream flow, as suggested in the HW #3 Flowsheet (HW-31373), to about 40% of the indicated flowsheet rate. This reduction in IBS flow will also reduce slightly the volume flow rates of the IBXF, ICF, IOF, and IOS streams, providing an additional small safety margin in their designed capacities.

The following table indicates the approximate capacity increases obtainable in the columns modified as discussed above by using the Purex HW #4 Flowsheet.

Estimated Processing Capacity, Tons U/Day^(a)

<u>Column</u>	<u>HW #3 Flowsheet</u>	<u>HW #4 Flowsheet</u>
HA	30	31
HC	27	33
IA	30	33
IBX	26	29
IBS	27 ^(b)	31
IC	26	33
2A	28	33
2B	25	36
2D	30	33
2E	27	36
IO	25	26
2O	30	33

- Notes: (a) With a 20% safety margin.
(b) IBS flow = 24% of HAF flow (40% of HW #3 Flowsheet flow rate).

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REFERENCES

- (1) HW-29688 Revised Specifications of Purex-Plant Solvent-Extraction Columns Excluding IBS, 2A, and 2B. R. E. Smith. 10-20-53.
- (2) HW-30109 Revised Specifications for Purex Plant IB Scrub, 2A, and 2B Columns. R. E. Smith. 12-1-53.
- (3) HW-31373 Purex Chemical Flowsheet HW #3. R. E. Smith. 4-6-54.
- (4) HW-33297 Progress Report - Chemical Development Unit, September 1954. F. W. Woodfield. 9-30-54.
- (5) HW-33825 Estimated Capacities of the Purex-Plant Pulse Columns. G. Sege. 11-16-54.
- (6) HW-35225 Purex Chemical Flowsheet HW #4 - Increased Purex Plant Capacity. R. E. Smith. 3-4-55.
- (7) R. E. Smith to F. A. Hollenbach: "Purex HC Column-Nozzle Plate Cartridge Specifications. 2-25-55.
- (8) R. E. Smith to W. M. Harty: "Purex IBX and IO Columns. HW #4 Flowsheet Cartridge Specifications. 3-10-55.

SPECIFICATIONS FOR PUREX PUL

<u>Column</u>	<u>Over-All Height, Ft. (a)</u>	<u>Cartridge or Packed Height, Ft. (b)</u>	<u>Plate or Packed Section I.D., In.</u>	<u>Sieve Plate or Packing Type</u>	<u>Fig. No. for Louver Plate Design</u>	<u>Ampl., In. (c)</u>
HA	33	12 Extr. 12 Scrub	27 Extr. 36 Scrub	(f)	6 Extr. 7 Scrub	0.8 Extr 0.5 Scrub
HC	27	15	34	(g)	—	0.5
IA	←————— Same as H					
IBX	33	28	38	(f)	8	0.4 0.4 0.8
IBS	19	13.3	8	(f)	—	0.8
IC	27	15	34	(g)	—	0.5
2A	40	20.9 Extr. 9.8 Scrub	8	(h)	—	0.8
2B	30	21	7	(f)	—	1.1
2D	33	12 Extr. 12 Scrub	27 Extr. 36 Scrub	(f)	6 Extr. 7 Scrub	0.8 Extr 0.5 Scrub
2E	27	15	34	(g)	—	0.5
IO	33.4	26.3	34	(g)	—	0.5
IO Alternate (m)	33.4	26	48	(g)	—	0.5
20	33.4	26.3	34	(g)	—	0.5

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Notes:

- (a) Distance between bottom surface of bottom disengaging section and the top surface of
- (b) The cartridge height is the distance from the bottom plate to the top plate and does packing support and hold-down grates.
- (c) Measured from one extreme position to the other.
- (d) At 25 ton U/day operating capacity, based on influent stream volumes.
- (e) Estimated range of H.T.U. values (over-all raffinate-film basis) for plant-size column
- (f) Stainless-steel plates (14 to 16 gage) with 1/8-in. perforations on 1/4-in. equilateral of the HA, IA, IBX, IBS, and 2D Columns as indicated in the figures or, for the IBS C
- (g) Stainless-steel plates (14 to 16 gage) with 1/8-in. perforations on 3/8-in. centers (spaced 4-in. apart.
- (h) Fluorothene Raschig rings, 1-in.-diameter by 1-in.-long with continuous 1/16-in.-thick
- (i) Number of transfer units required to reduce U concentration in IBP to 0.1% U in Pu at
- (j) Frequency range required if U processing capacity is to be 20 tons/day or greater.
- (k) Frequency range required if U processing capacity is to be 12 tons/day or greater.
- (l) Pulse volume (amplitude) required for processing rates below 12 tons U/day.
- (m) Alternate IO Column design will provide ca. 20 min. organic holdup time at 25 tons U/

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TABLE I

COLUMNS CAPABLE OF PROCESSING 25 TONS U/DAY

Pulse Volume Cu. In. (c)	Freq. Range, Cyc./Min.	Pulsed Phase	Continuous Phase	Volume Velocity, GPH/Sq. Ft., Sum of Flows (d)		H.T.U., Ft. (e)	No. of Transfer Units Req'd for 0.1% U or Pu Loss
				HW #3 Flowsheet	HW #4 Flowsheet		
485	35-120	Organic	Aqueous	1040 Extr. 490 Scrub	1010 Extr. 480 Scrub	0.7 to 1.2 Extr.	7 for U 7 for Pu } Extr.
485	35-110	Aqueous	Organic	1140	1040	0.8 to 1.4	8 for U 7 for Pu
Column				950 Extr. 450 Scrub	Same as HA Column		
485	35-110(j)	Organic	Aqueous	440	400	1.3 to 3.0	11
485 970(1)	35-150(k) 35-110						
44	25-100	Aqueous	Aqueous	1260	1100	0.8 to 1.3	11(1)
485	35-110	Aqueous	Organic	1330	1040	0.3 to 1.4	8
44	25-100	Aqueous	Organic	1760	1490	1.3 to 2.2 Extr.	8 Extr.
44	25-100	Aqueous	Aqueous	620	420	1.2 to 2.0	7
485	35-120	Organic	Aqueous	1040 Extr. 490 Scrub	950 Extr. 450 Scrub	0.7 to 1.2 Extr.	7 Extr.
485	35-110	Aqueous	Organic	1140	950	0.8 to 1.4	8
485	35-110	Aqueous	Organic	1270	1200	—	—
970	35-110	Aqueous	Organic	630	600	—	—
485	35-110	Aqueous	Organic	900	820	—	—

top disengaging section.

include cartridge supports. The packed height of the 2A Column is the distance between sawtoeth of the

at optimum pulse frequency at processing rates corresponding to about 5 to 25 tons U/day.

triangle centers giving 23% free area, spaced 2 in. apart. Louver plates are inserted in the cartridges

man, in HW-30109.

free area) indented a minimum of 0.05 in. by punching to form nozzles pointing down. The plates are

all.

0 g. Pu/ton U in HAF (5.8×10^{-5} % U loss) with IBS flow equal to 40% of Purex HW #3 Flowsheet value.

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FIGURE 1

HAF, IAF AND 2DF JET-MIXER
FEED DISTRIBUTORS

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	Distributor		
	HAS, 2DC	IAS	IBX
Ring Diameter, In.	24	24	25
Ring Pipe Size, In.	3	3	2
Hole Diameter, In.	3/8	3/8	1/4
Discharge Velocity at 25 Tons U/Day, Ft./Sec.	0.4	0.8	0.8

FIGURE 2

THIRTY-TWO HOLE RING DISTRIBUTORS
HA, IA, 2D AND IBX COLUMNS

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	Distributor								
	HAX, IAX, 2DX	HCX, ICX, 2CX	ECF, 2EX	ICF	IBXF	IOF	IOS	IOF (Alt.)	IOS (Alt.)
Ring Diameter, In.	18	23	23	23	26	23	23	32	32
Nozzle Pipe Size, In.	1 $\frac{1}{4}$	1 $\frac{1}{2}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	1 $\frac{1}{4}$	2	1 $\frac{1}{4}$	2	1 $\frac{1}{4}$
Discharge Velocity at 25 Tons U/day, Ft./Sec.	1.1	1.5	1.2	1.3	1.3	1.1	0.8	0.5	1.1

FIGURE 3NINE-NOZZLE RING DISTRIBUTORSHA, IA, 2D, HC, IC, 2E, IBX, IO AND 20 COLUMN

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Number of Nozzles
Doughnut Diameter, In.
Discharge Circle Diam., In.
Nozzle Pipe Size, In.
Position of Doughnut
(Above or Below Nozzles)
Discharge Vel. at
25 T. U/Day, Ft./Sec.

HAIS, (IAIS), 2DIS	Distributor		
	2A7	2AS(2AIS)	2AX
4	3	3	3
48	$\geq 2\frac{1}{4}$	$\geq 2\frac{1}{4}$	$\geq 2\frac{1}{4}$
30	6	6	6
3/4	1	3/4	3/4
Below	Below	Below	Above
0.6	0.9	0.2	0.4

FIGURE 4

"DOUGHNUT"-TYPE DISTRIBUTORS
HA, IA, 2D, 1BS, 2A AND 2B COLUMNS

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FIGURE 5

2A COLUMN RASCHIG RING GRATES

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FIGURE 6.
15 % FREE AREA LOUVER PLATE
FOR THE A-TYPE COLUMN EXTRACTION SECTION

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FIGURE 7

18% FREE AREA LOUVER PLATE
FOR THE A-TYPE COLUMN SCRUB SECTIONS

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SECTION "A-A"

FIGURE 8

18 % FREE AREA LOUVER PLATE
FOR THE IBX COLUMN

SCHEMATIC DIAGRAM OF HA (A-TYPE) PUREX COLUMN

FIGURE 9

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FIGURE 11
SCHEMATIC DIAGRAM OF IBX COLUMN

FIGURE 12
SCHEMATIC DIAGRAM OF IO COLUMN
(ALTERNATE)

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