CSE LICENSE ANNEX

SOLVENT EXTRACTION

CSE LICENSE ANNEX

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TABLE OF CONTENTS

CSE LICENSE ANNEX

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REVISION RECORD

REVISION NUMBER	DATE OF REVISION	PAGES REVISED	REVISION RECORD

CSE LICENSE ANNEX

SOLVENT EXTRACTION

Process Summary

The Columbia plant generates contaminated uranium from production upsets, equipment cleanouts, combustible trash incineration, off-stream material accumulation, general housekeeping, and miscellaneous processing. All of the materials are converted to contaminated uranyl nitrate solution via oxidation and dissolution in nitric acid in other equipment. The contaminated uranyl nitrate solution is delivered to the Solvent Extraction Area through piping for the Conversion Scrap Area, the C4 Dissolver Area, or the UN Storage Tank Area. The objective of Solvent Extraction is to separate the uranium from the contaminants present, recover it as clean uranyl nitrate solution and deliver it to storage tanks so that it may be converted back to usable product UO_2.

The Solvent Extraction System comprises two sets of glass extraction columns, a primary set to recover the majority of the uranium and a secondary set to scavenge the last of the uranium from the raffinate prior to its discharge as a free-release waste stream. Each set of columns features an extraction column, where a solvent mixture containing tributyl phosphate (TBP) extracts uranium from a high-acid content uranium-bearing feed; and a stripping column, where the uranium is removed from the solvent with clean water forming a purified uranyl nitrate solution. All the columns are pulsed with large diaphram pumps to facilitate movement of the solvent through perforated plates that are installed in the columns to provide a mechanism for breaking the solvent into small droplets as it passes through each column.

The primary and secondary systems both have steam-heated product concentrators to increase the uranium solution strength of the product coming off the stripping columns in order to satisfy subsequent processing requirements for the product nitrate solution. Additional ancillary equipment, vessels, and pumps are utilized to contain and supply the solvents, water, and acid components necessary for the process. The entire system features automatic flow controls for liquid and steam requirements and a central control computer to control the process parameters.

Pertinent Operating Procedures and Process and Instrument Drawings are as follows:

OPERATING PROCEDURES

PROCEDURE NO.	TITLE
COP-830109	Solvent Extraction - Feed Concentrator
COP-830110	Solvent Extraction Columns & UN Evaporator - Startup & Operation
COP-830111	Solvent Extraction & UN Evaporator System II - Startup & Operation
COP-830114	Pumpout of Solvent Extraction Clean Product
COP-830116	Solvent Extraction & UN Evaporator System I - Shutdown
COP-830117	Solvent Extraction & UN Evaporator System II - Shutdown
COP-830120	Solvent Extraction Kerosene Wash Change
COP-830124	Solvent Extraction Emergency Shutdown - Trouble Shooting
COP-830128	Adjusting and Making UP Solvent Extraction

SYSTEM DRAWINGS

DRAWING NO.	SHEET NO	DRAWING TITLE
301F01PI01	1	Solvent Extraction/UN Purification Process Nitric Acid & Water
301F01PI01	2	Solvent Extraction/UN Purification Solx I Feed Vessels
301F01PI01	3	Solvent Extraction/UN Purification Solvent Extraction System I
301F01PI02	1	Solvent Extraction/UN Purification Solvent Extraction System II
301F01PI03	1	Solvent Extraction/UN Purification Aqueous Waste System
301F02PI01	1	Solvent Extraction/UN Product Concentrator - Systems I & II
301F02PI02	1	Solvent Extraction/UN Product Concentration Holding Vessels V-1087A Thru V-1087D
301F02PI02	2	Solvent Extraction/UN Product Concentration Holding Vessels V-1487A & V-1487B

Environmental Protection and Radiation Safety Controls

To be provided in a future Integrated Safety Assessment

Nuclear Criticality Safety (NCS) Controls and Fault Trees

Controlled Parameters and Criticality Safety Limits:

Controlled Parameters - individual units

- Concentration
- Geometry

Controlled Parameters - array

- Spacing
- Concentration
- Geometry

Criticality Safety Limits

- Single Unit: See Table 0-1

Bounding Assumptions:

- Homogeneous uranyl nitrate
- Optimum H_2O Moderation
- Partial Reflection sides and top
- 14 inches Concrete below

Controls

Safety Significant Controls

Passive engineered controls (PEC)

Passive engineered controls are described in the License and in Regulatory Affairs-108. The requirements for functional verification are determined from this evaluation.

- None

Active engineered controls (AEC)

Active Engineered Controls are defined in the License and in Regulatory Affairs Procedure RA-108. They are also called safety significant interlocks The requirements for functional verification are defined in RA-108 and/or area operating procedures.

- None

Administrative controls with computer or alarm assist (AC)

Administrative controls with computer or alarm assist (AC) typically consist of operator actions that are prompted or assisted by computer output. The requirements for functional verification are determined by this evaluation.

- None

Administrative controls

Safety Significant administrative controls are required operator actions that usually occur without prompting from a computer/control panel alarm or indication. These controls may require documentation via Control Form or some other record. Functional verification is not normally required.

- None

Safety Margin Improvement Controls

Safety Margin Improvement Controls consist of all types of controls: passive, active, process, administrative with computer assist, and wholly administrative. These controls do not require periodic functional verification. They are primarily process controls but contribute to the system's margin of safety. They typically are identified in the Fault Tree.

Control Function/Failure Condition/Action
Favorable geometry for nitrate (< 15.4 inch diameter cylinder) vessels used in system/ Non-favorable geometry vessels used in system/ Prevent non-favorable geometry vessels in system via procedure TA-500 requirements for Regulatory review.
Prevent decrease in spacing of the vessels in system/ Spacing of vessels in system reduced to lose neutron-interaction isolation/ Prevent re-arranging vessels in system via procedure TA-500 requirements for Regulatory review.
No unauthorized NFG vessels allowed in area/ Nitrate-bearing portable NFG vessel brought into area / Prevent unauthorized portable NFG vessel in area via procedure RCOP-843002
Prevent High Concentration in SOLX-I Loop/ RE-1084 fails to function or operators disregard indications/ Operators monitor RI-1084 indications to control SOLX-I nitrate concentration to $\leq 5.0\ g^{235}U/\ell$
Prevent High Concentration in SOLX-II Loop/ RI-1081 fails to function or operators disregard indications/ Operators monitor RI-1081 indications to ensure SOLX-II feed (SOLX-I aqueous) $\leq 0.05\ g^{235}U/\ell$
Prevent High Concentration in Feed Concentrator Loop/ RE-1095 fails to function or operators disregard indications/ Operators monitor RE-1095 indications to control Feed Concentrator nitrate concentration to ≤ 5.0 g—$^{235}U/\ell$

Margin of Safety

The nuclear criticality margin of safety for the Solvent Extraction System is evaluated to be very strong. Analysis shows that the 95/95 keff ≤ 0.95 for all normal operating conditions. Further, for any credible process upset, the 95/95 keff < 0.98.

Double Contingency Protection has been demonstrated for SOLX for both single unit criticality and neutron interaction among units in a fixed array. The controlled parameters that directly affect neutron multiplication for the single unit criticality are geometry and ^{235}U concentration. The controlled parameters that directly affect neutron multiplication for neutron interaction among units in an array are ^{235}U concentration and spacing.

Single unit criticality could be possible given the following conditions:

- cylinder diameter greater than or equal to 15.4 inches, fills with uranyl nitrate with uranium concentration of 50 g-$^{235}U/\ell$, and becomes fully reflected.

Criticality resulting from neutron interaction among units could be possible given the following conditions:

- numerous cylinders each containing uranyl nitrate with uranium concentration of 50 g-$^{235}U/\ell$ are positioned close enough to each other such that the resulting configuration behaves like a single nonfavorable geometry cylinder, with full water reflection.

Table 0-1:
Nuclear Criticality Safety Limits for k_{eff} 0.90, 0.95, and Delayed Critical for a Typical Favorable Geometry Solvent Extraction Vessel

PARAMETER	NORMAL OPERATING CONDITIONS	BOUNDING ASSUMPTION	≤ 0.91 LIMIT	LICENSE LIMIT ≤ 0.95	CRITICALITY SAFETY LIMIT Delayed Critical
^{235}U MASS	See Concentration		Unrestricted	Unrestricted	Unrestricted
MODERATOR/ CONCENTRATION	≤ 5 g ^{235}U/l	50 g ^{235}U/l	50 g ^{235}U/l	50 g ^{235}U/l	50 g ^{235}U/l
GEOMETRY	FG cylinder (≤ 10.75" OD)		FG cylinder (12.5" ID)	FG cylinder (13.6" ID)	NFG Diameter (15.4" ID)
SPACING	N/A	N/A			
DENSITY	Uranyl Nitrate Solution	Uranyl Nitrate Solution			
ABSORBERS	None	None			
ENRICHMENT	≤ 5.0 wt%	5.0 wt %			
REFLECTION	Partial Water	Partial Water		Full Water reflection in KENO Model	Full Water reflection in KENO Model

Chemical Safety and Fire Safety Controls

To be provided in a future Integrated Safety Assessment.