INL/MIS-21-62348-Revision-0

Engineering Evaluation of an Integrated Off-gas System for a UNF Processing Facility

April 2021

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Changing the World's Energy Future

Idaho National Laboratory

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Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

Engineering Evaluation of an Integrated Off-gas System for a UNF Processing Facility

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UK/US Off-Gas Technical Exchange
April 19, 2021

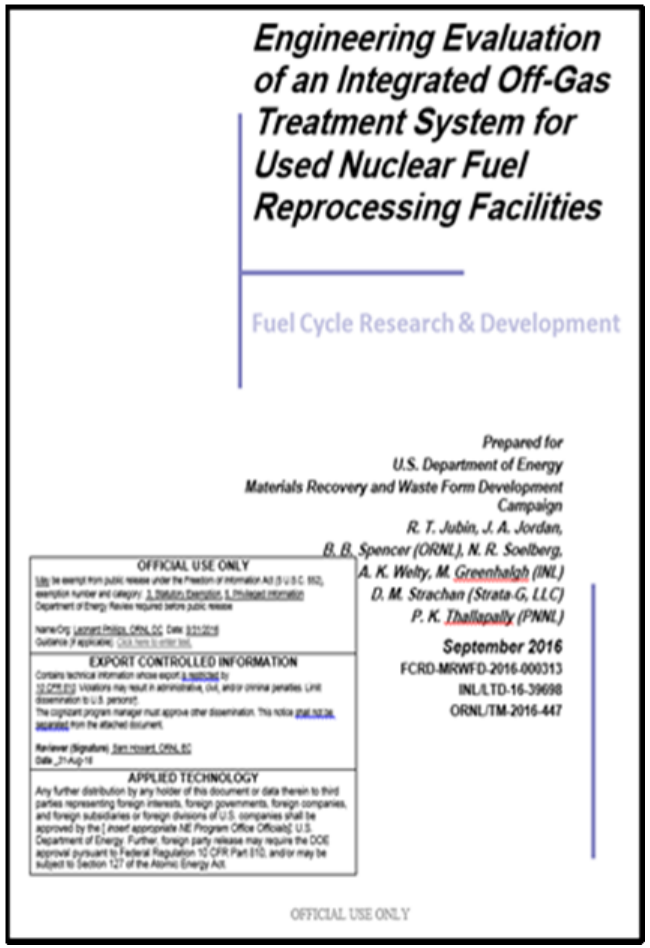
U.S. DEPARTMENT OF ENERGY

Outline

- Scope
- Motivation
- Assumptions
- Key Findings
- Follow-on Analysis

Overarching aims of evaluation

- This analysis is an initial engineering evaluation and design of the off-gas abatement systems required for future used nuclear fuel (UNF) reprocessing facilities.
- This engineering study is conceptual and not tied to a specific UNF processing facility.
  - Intended to assess the complexity and sizes of the required systems.
- It evaluates:
  - (1) relative equipment sizes,
  - (2) energy requirements,
  - (3) key instrumentation requirements, and
  - (4) the extent to which key design data are, or are not, available for the off-gas systems.
- Only addresses the designs of the head-end off-gas (HOG), dissolver off-gas (DOG), and vessel off-gas (VOG) systems.
  - HOG and DOG systems are considered with and without tritium pretreatment.


Engineering Evaluation of an Integrated Off-Gas Treatment System for Used Nuclear Fuel Reprocessing Facilities

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Materials Recovery and Waste Form Development Campaign

R. T. Jubin, J. A. Jordan,
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September 2016
FCRD-MRWFD-2016-000313
INL/LTD-16-39698
ORNL/TM-2016-447

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APPLIED TECHNOLOGY

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Major Assumptions

- The basis of the facility design
  - Aqueous processing of UNF
  - Throughput = 1000 t/year
  - Plant operating time = 200 days/year.
  - Off-gas systems operate 365 days/year.
  - Fuel cooling time = 5 years
  - Fuel type = UOX (UO_2-based fuel), 60 GWd/tIHM burnup
  - Steady state conditions.
  - Halogens other than iodine from the UNF and process chemicals are included for sizing the DOG iodine beds.
  - Maximum decontamination factors (DFs):
    - ^{3}H, ^{14}C, ^{85}Kr, and ^{129}I are those found in Jubin et al. (2012).
    - Ruthenium DF is found in Jubin et al. (2014).

Target DFs used in analysis

Table 1. Maximum DF values for the isotopes considered in this study	
Isotope	**DF**
^{3}H	200
^{14}C	10
^{85}Kr	50
^{129}I	3000
^{106}Ru	3.0×10^{7}

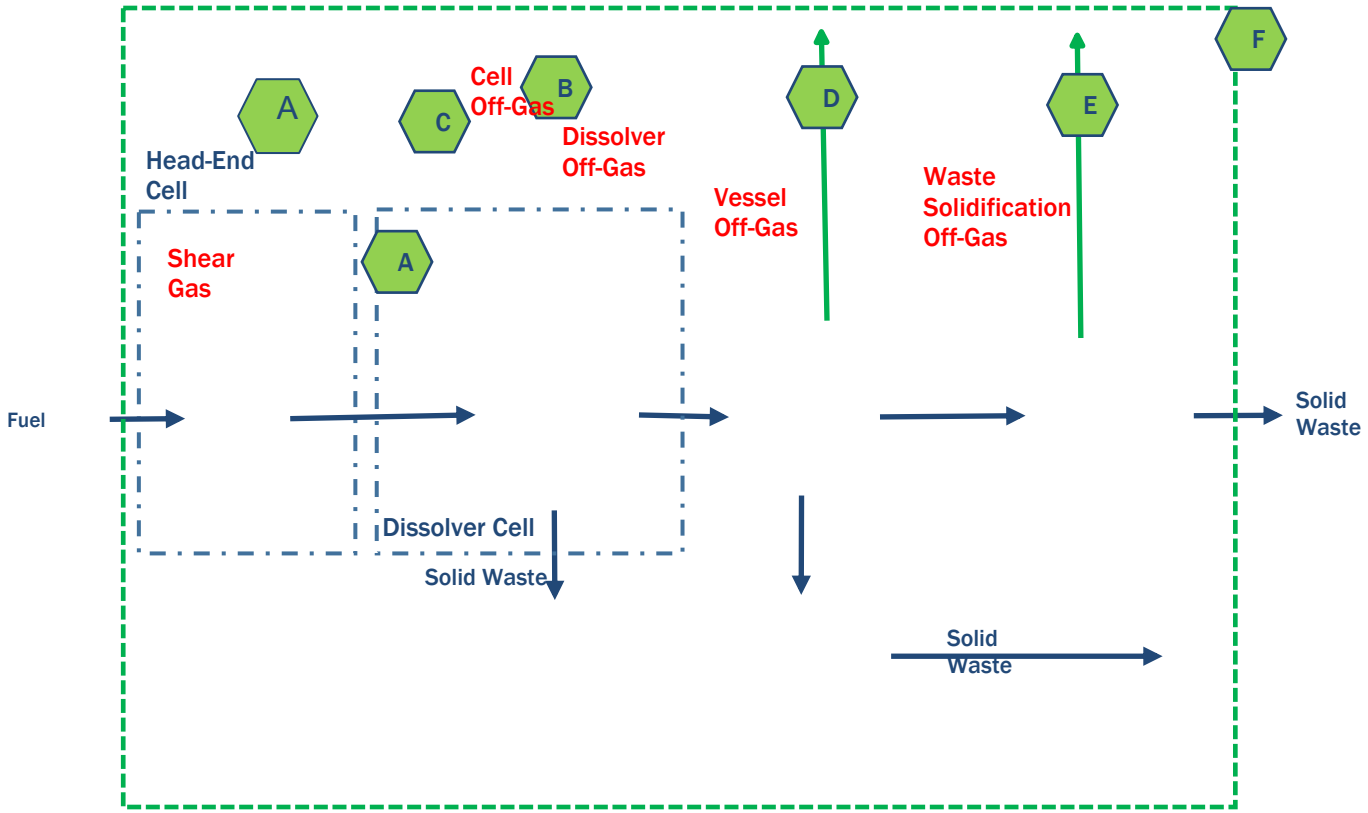
Process design assumptions

- Tritium capture system based on two primary operating flowsheets.
  - Case 1: Base case UNF dissolution.
  - Case 2: Adds air tritium pretreatment (TPT).
    - A NO_x-based TPT, being studied because it may be more efficient, is addressed in a separate report.
- Iodine capture analysis addresses iodine distribution throughout the facility and iodine speciation.
  - Silver mordenite (AgZ)
  - Silver-functionalized silica-aerogel (Ag-Aerogel) (Matyáš et al. 2011)
- Removal of NO_x is based on acid/water scrubbing.

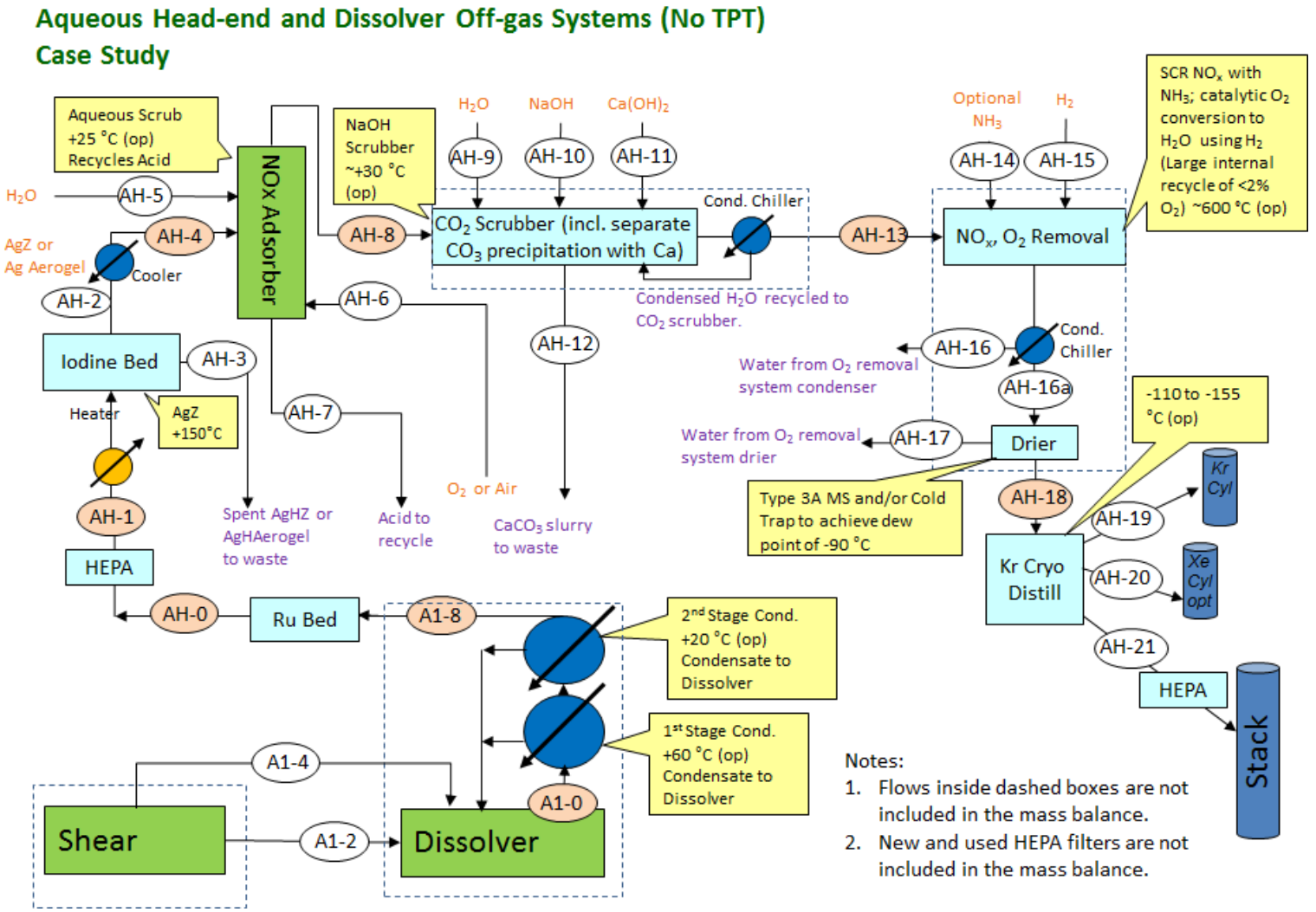
Process design assumptions

- Caustic scrubbing is used for the removal of ^{14}C (e.g., $^{14}CO_2$).
- Both cryogenic and sorbent-based capture systems for noble gas capture are evaluated.
- Tramp species are included.
  - Halogens (fluorine, chlorine, etc) from process chemicals.
  - Water vapor and CO_2 in the plant air.
- The effects of extended operations on equipment size and design are considered.
  - Where possible, sorbent beds are designed for greater than a 6 month operating lifetime.

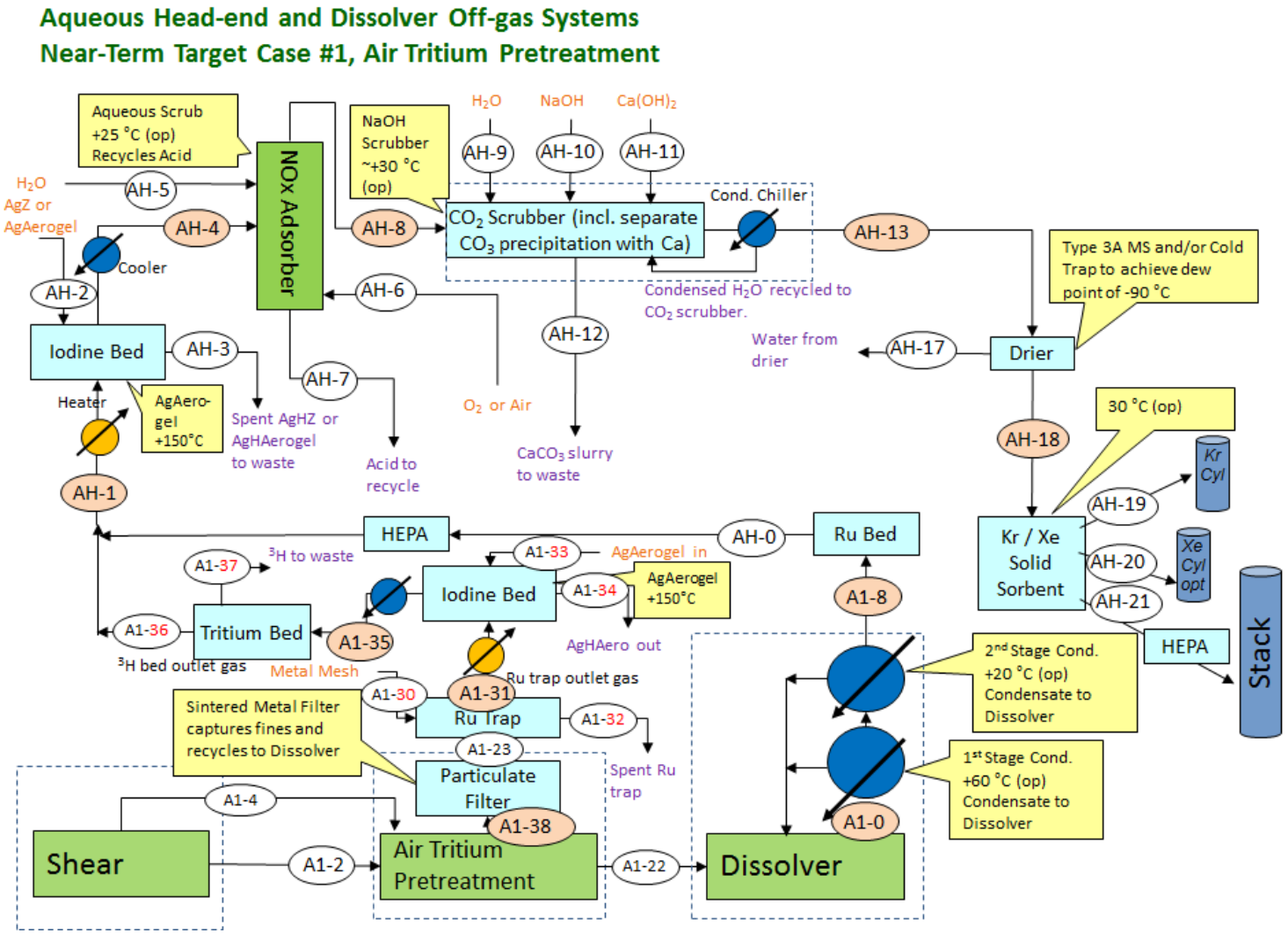
Process streams considered



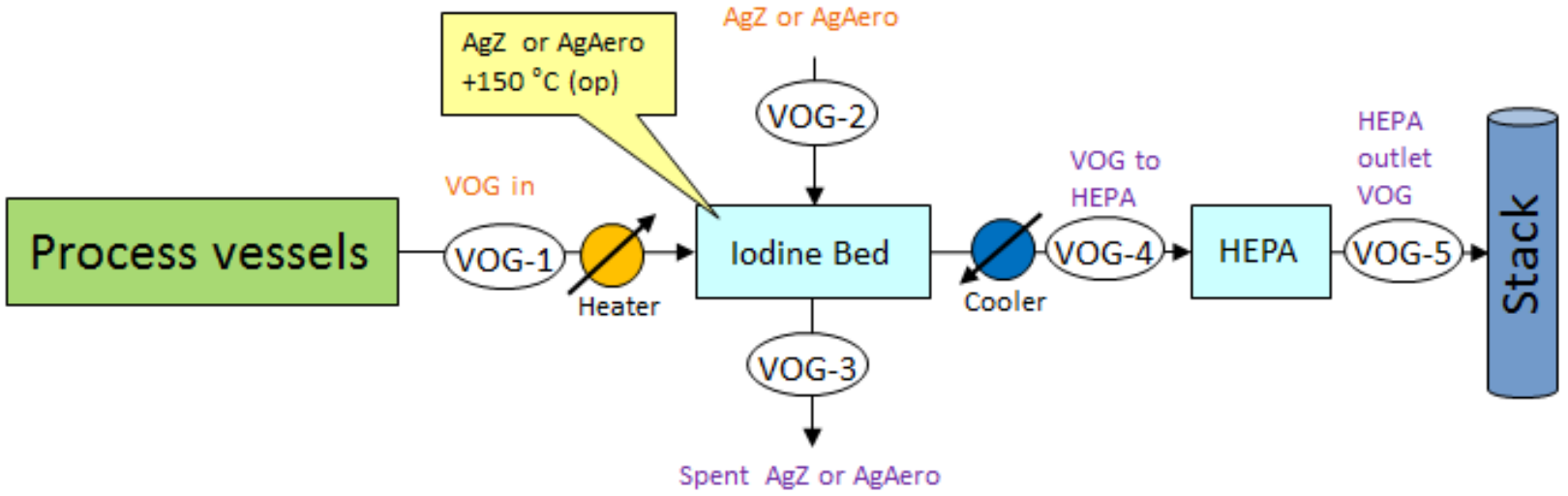
Aqueous head-end and DOG Base Case



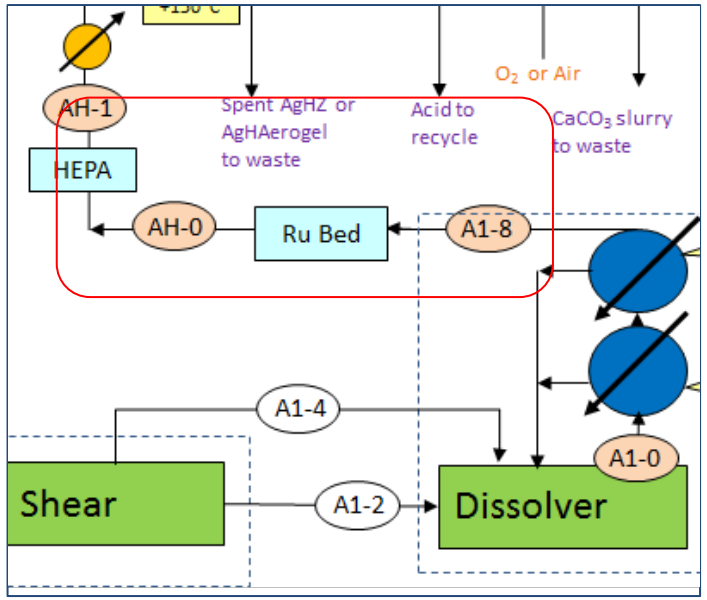
Aqueous head-end and DOG with air tritium pretreatment

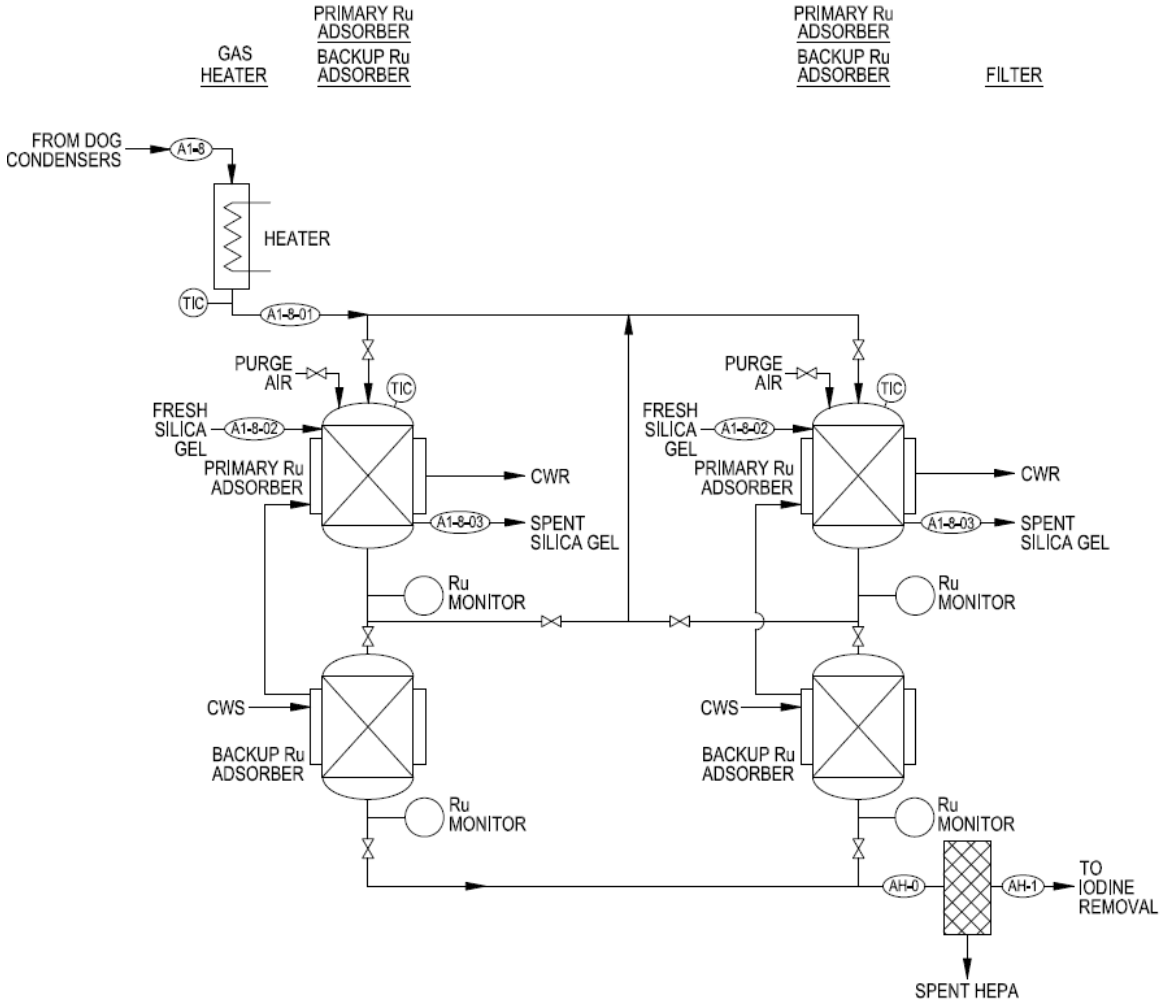


Vessel off-gas system



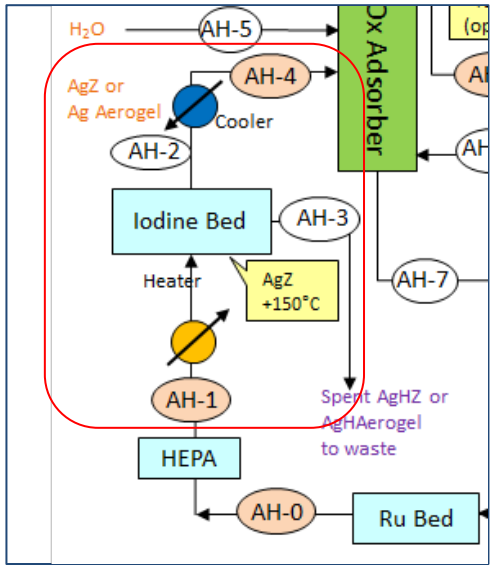
Ruthenium removal





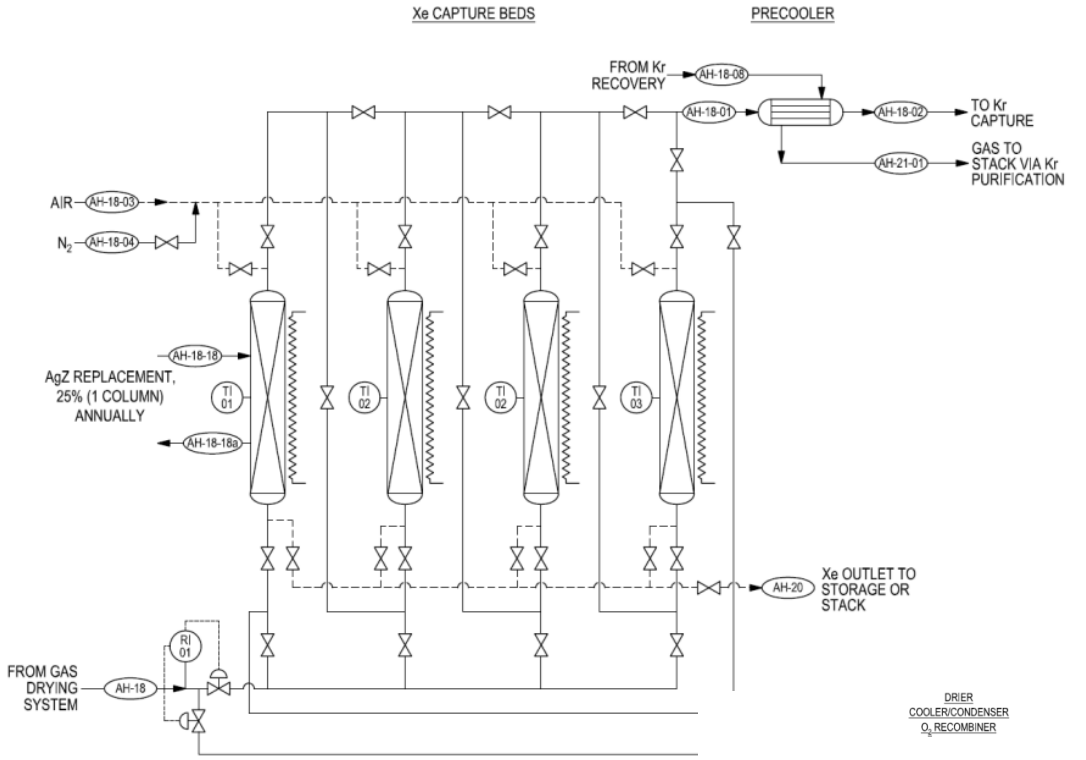
RUTHENIUM REMOVAL DISSOLVER OFF-GAS

DOG iodine removal

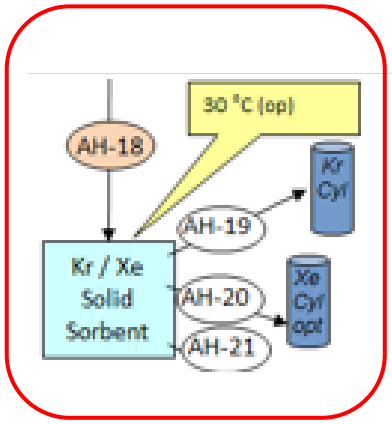


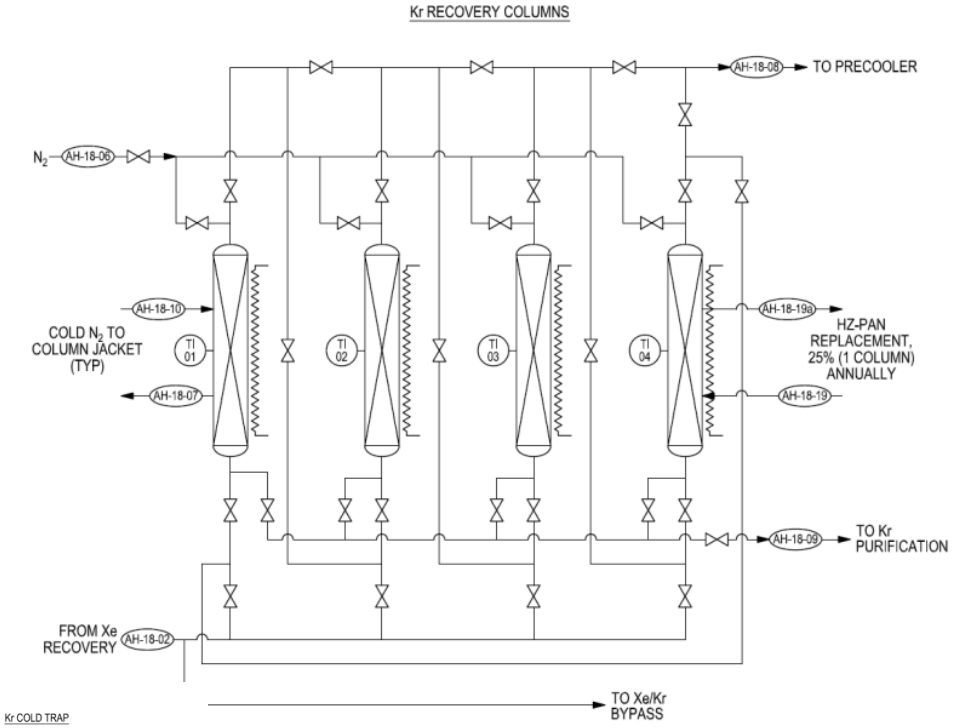
IODINE REMOVAL

Kr/Xe removal

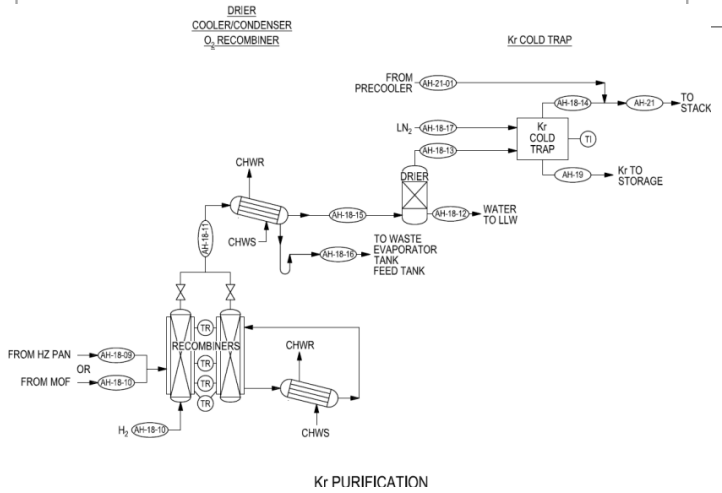


Xe CAPTURE (AgZ-PAN)



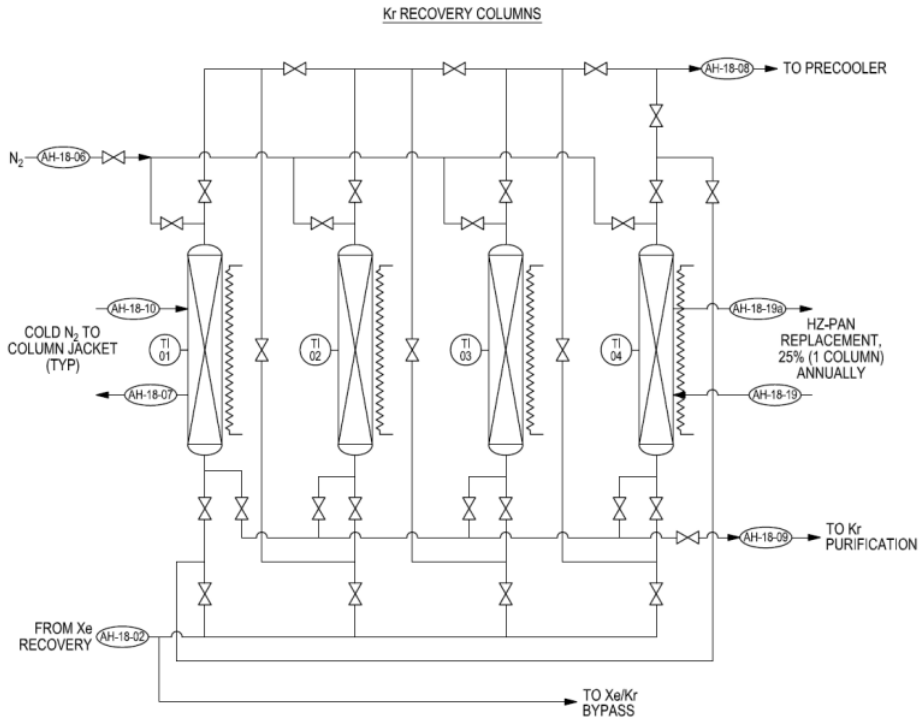


Kr CAPTURE (HZ-PAN)

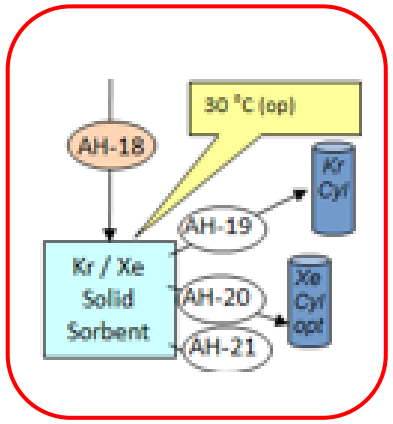


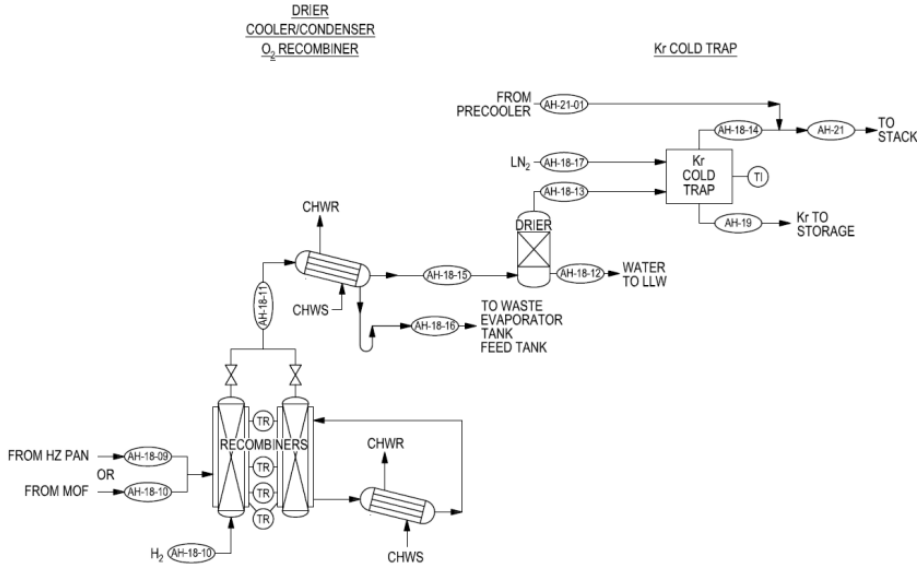
Kr PURIFICATION

Kr/Xe removal



Kr CAPTURE (HZ-PAN)





Kr PURIFICATION

Additional

- Energy balance and recovery were not evaluated.
- Gas and water cycle/recycle were not evaluated.
- The possibility of installing by-passes around equipment for use when there is insufficient volatile radioactive species present to warrant treatment should be investigated.
- Subsequent studies should add similar assessments for the cell off-gas (COG) and melter off-gas (MOG) systems.

Questions/Comments