Testing of an Iodine and Tritium Removal System for Advanced Tritium Pretreatment Off-Gas

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SUMMARY

The reprocessing of used nuclear fuel would release volatile radionuclides into the off-gas of a processing plant, including ^{3}H, ^{14}C, ^{85}Kr, and ^{129}I. For a reprocessing plant sited within the United States and governed by US regulations, the abatement of some or all of these radionuclides from the plant off-gas would be required before discharge of that gas to the environment.

A potential simplification of the off-gas management system can be achieved through an efficient advanced tritium pretreatment (ATPT) step in which the UO_2 fuel is oxidized by NO_2 prior to dissolution. Oxidation of the UO_2 fuel matrix results in the release of tritium contained within. Up-front removal of tritium from the fuel in a pretreatment step, followed by the abatement of tritium from the advanced tritium pretreatment off-gas (ATPTOG) stream, can minimize or eliminate the distribution of tritium throughout the plant, also decreasing or eliminating the need for tritium capture on multiple off-gas streams. The use of NO_2 as the oxidant allows tritium pretreatment to be performed at lower temperatures and may result in the quantitative release of iodine from the fuel.

The ATPTOG will contain up to 75 vol% NO_2 gas. In a previous report, Spencer et al. (2017) identified the most promising iodine sorbent as silver nitrate–impregnated alumina (AgA) and the most promising tritium sorbents as 3A molecular sieve (3A MS) and silica gel for radionuclide capture from ATPTOG streams. Jubin et al. (2017) documented the preliminary testing of those sorbents for iodine and tritium removal from ATPTOG streams, while this report describes the results from both that testing and selected follow-on testing.

A total of five tests examined AgA as a potential iodine sorbent at an operating temperature of 150°C and both 3A MS and silica gel as potential tritium sorbents with an operating temperature of 40°C. 3A MS and silica gel are intended for use as regenerative sorbents, in which the adsorbed tritium (as tritiated water or tritiated nitric acid) is loaded onto the sorbent at operating temperature and then subsequently desorbed at high temperature into a small-volume gas stream for recovery and conversion to a waste form.

Analysis of the test materials showed that much of the tritium and iodine delivered during testing was not recovered on the solid sorbent test materials or liquid scrubbers used in test execution. The cause of this discrepancy was identified during system disassembly, in which a system component was found to be corroded. Analysis of the corroded component found that it contained both iodine and tritium. The loss of tritium and iodine to the test system negatively impacted the ability to draw quantitative conclusions regarding the adsorption of tritium by either silica gel or 3A MS in high NO_2 systems. Residual tritium was found on both the iodine and tritium sorbents at the end of each test.

The ability of AgA to adsorb iodine in the presence of high levels of NO_2 appears to be substantially reduced upon exposure of the sorbent to NO_2, with replicate testing showing variable iodine recoveries on the sorbent of 29.6% and <0.1%. Given the corrosion observed during testing, the performance of AgA should be reexamined with a more robust system. These initial tests, however, do indicate a failure of the sorbent to perform to the levels that would be required in an ATPTOG treatment system.

This testing leaves many fundamental questions regarding the ATPTOG iodine and tritium abatement systems unanswered. These include questions regarding sorbent capacity and sorbate desorption. Overall, this testing indicates that tritium and iodine abatement from an ATPTOG stream by solid sorbents is currently at a low stage of technological development and that deployment of such an abatement system would require substantial additional research and development.

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ACRONYMS

3A MS	3 angstrom molecular sieve
AgA	$AgNO_3$-impregnated alumina
ATPTOG	advanced tritium pretreatment off-gas
DOG	dissolver off-gas
ICP-MS	inductively coupled plasma–mass spectrometry
IP	iodine sorbent purge
LPM	liters per minute
LSC	liquid scintillation counting
MDA	minimum detectable activity
NAA	neutron activation analysis
ORNL	Oak Ridge National Laboratory
TC	tritium capture
TR	tritium sorbent regeneration
TPTOG	tritium pretreatment off-gas
TPT	tritium pretreatment

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TESTING OF AN IODINE AND TRITIUM REMOVAL SYSTEM FOR ADVANCED TRITIUM PRETREATMENT OFF-GAS

1. INTRODUCTION

The reprocessing of used nuclear fuel will release four volatile radionuclides into the off-gas of a processing plant. These radionuclides are ^{3}H, ^{14}C, ^{85}Kr, and ^{129}I. For a reprocessing plant sited within the United States and governed by US regulations, the abatement of some or all of these radionuclides from the plant off-gas will be required before discharge of that gas to the environment. In some cases, the level of abatement required is significant (Jubin et al., 2012).

Traditional aqueous reprocessing dissolves sheared used fuel in hot nitric acid solution. As the fuel dissolves, the volatile radionuclides contained within the fuel are evolved into the dissolver off-gas (DOG) stream. This off-gas contains, in addition to the volatile radionuclides, several volume percent of NO_x vapor and H_2O. There is also some proportion of the volatile radionuclides retained by the dissolver solution, and those radionuclides are transferred to subsequent processing steps and to the process off-gas generated by those processes. The distribution of the radionuclides into multiple liquid and gaseous streams results in the need to abate volatile radionuclides from multiple off-gas emission streams throughout the reprocessing plant.

A potential simplification of the off-gas management system can be achieved through an efficient tritium pretreatment (TPT) step in which the UO_2 in the used fuel is oxidized prior to dissolution. Oxidation of the UO_2 fuel matrix results in the release of tritium contained within. Traditional TPT is conducted by oxidizing the fuel with a dry O_2-bearing gas stream at high temperatures. Upfront removal of tritium from the fuel in a pretreatment step, followed by the abatement of tritium from the TPT off-gas stream, can minimize or eliminate the distribution of tritium throughout the plant, also decreasing or eliminating the need for tritium capture on multiple off-gas streams.

An advanced variant of the O_2-based TPT process utilizes NO_2, a stronger oxidant, as the gaseous reagent. The use of NO_2 allows TPT to be performed at lower temperatures and may result in the quantitative release of iodine from the fuel. Upfront removal and abatement of iodine and tritium could result in substantially further simplification of the off-gas treatment processes required in the United States. Oak Ridge National Laboratory (ORNL) has developed this technology at the kg-scale with unirradiated UO_2 and is prepared to demonstrate the technology with irradiated fuel in ORNL hot cells (Johnson and DelCul, 2016).

The advanced tritium pretreatment off-gas (ATPTOG) will contain up to 75 vol% NO_2 gas. Given the highly oxidizing, corrosive, and toxic nature of NO_2 gas, it is unknown how traditional iodine sorbents, such as silver-exchanged zeolites, and traditional tritium adsorbents, such as molecular sieves, will perform in the ATPTOG system.

A previous report (Spencer et al., 2017) identified the most promising iodine sorbent as silver nitrate–impregnated alumina (AgA) and the most promising tritium sorbents as 3A molecular sieve (3A MS) and silica gel for radionuclide capture from ATPTOG streams. The reaction between silver nitrate ($AgNO_3$) and I_2 to form AgI is thermodynamically favorable, and minerals impregnated with $AgNO_3$ have been used for I_2 removal from DOG streams at the La Hague fuel reprocessing plant in France. However, the DOG stream contains only ~2 vol% NO_x gaseous species, far below the levels expected in the ATPTOG stream. The preliminary testing of AgA, 3A MS, and silica gel for iodine and tritium removal from ATPTOG streams is documented in *Assembly and Testing of a Tritium and Iodine Removal System for Use with Advanced Tritium Pretreatment*, NTRD-MRWFD-2017-000157 (Jubin, et al. 2017). The intent of this report is to document the results of both the testing described by Jubin et al. (2017) and the results of selected follow-on testing.

2. TEST DESCRIPTIONS

A total of five tests were performed, and the details of each test are summarized in Table 1. Jubin et al. (2017) suggested an experimental test matrix that included a total of 10 tests. Because of a required relocation of the laboratory, only five of the selected tests from the proposed test matrix were completed. The test IDs provided in the initial report differ from the test IDs used here, and both test IDs are provided in Table 1 for ease of reference.

Table 1: Test descriptions.

Test ID	**Previous test Id** (2017)	**Iodine sorbent**	**Tritium sorbent**	**Tritium sorbent operating temperature (°C)**	**Iodine introduction**	**Tritium bed desorption temperature (°C)**	**Notes**
ATPTOG–1	ATPTOG–1	AgA	None	N/A	None	N/A	Establish tritium/ethylene glycol baseline
ATPTOG–2	ATPTOG–2	AgA	Silica gel	40 °C	Mid-Test	90 °C	
ATPTOG–3	ATPTOG–3	AgA	3A MS	40 °C	Mid-Test	250 °C	
ATPTOG–4	ATPTOG–6	AgA	None	N/A	None	N/A	Confirm tritium/ethylene glycol baseline
ATPTOG–5	ATPTOG–10	None	None	N/A	None	N/A	Determine whether AgA retains tritium

AgA was tested as a potential iodine sorbent at an operating temperature of 150°C, and both 3A MS and silica gel were tested as potential tritium sorbents with an operating temperature of 40°C. 3A MS and silica gel are intended for use as regenerative sorbents, in which the adsorbed tritium (as tritiated water or tritiated nitric acid) is loaded onto the sorbent at operating temperature and then subsequently desorbed at high temperature into a small-volume gas stream for recovery and conversion to a waste form. The manufacturer-recommended desorption temperatures for 3A MS and silica gel are >250°C and >90°C, respectively.

In the operation of the test system, the system is first charged with an NO_2/O_2 gas mixture, and the recirculation loop is established. Following establishment of the recirculation loop, tritium and iodine can be introduced. Tritium was introduced as tritiated liquid water, and iodine was introduced as solid iodine crystals. An isolation lock for component introduction was designed such that a test port was opened, the material was introduced into a small load chamber, and the test port was closed. A second port was then opened connecting the load chamber to the recirculation loop. As the recirculation loop was at sub-atmospheric pressure, and the load chamber was heated, it was expected that both the crystalline iodine and liquid tritiated water would transfer into the gas recirculation loop quickly and completely.

The details and timing of iodine release from the fuel during the advanced tritium pretreatment process are not well known. Jubin et al. (2017) proposed two types of testing—one in which the iodine was introduced immediately upon establishment of the recirculation loop and the other in which the iodine was introduced after the recirculation loop had been in contact with the sorbent for 2 hours. The effect of NO_2 on AgA sorbent is not well known, but previous tests have indicated that its iodine capture capacity decreases upon exposure to NO_2 (Jordan et al., 2017). Introduction of iodine after some exposure of the sorbent to NO_2 could provide an indication of AgA resistance to degradation by NO_2. For each of the tests described here, iodine was introduced at the mid-point of the test (2 hours after establishment of the recirculation loop). Tritium was introduced immediately after the establishment of the recirculation loop.

As was recommended by Spencer et al. (2017), the tritium bed was bypassed during iodine adsorption. At the conclusion of testing, the gas stream was passed through the tritium bed and discharged into a series of ethylene glycol and caustic scrubbers. This was intended to simulate operations in which the tritium is allowed to build up to a maximum concentration during fuel oxidation, potentially improving adsorption of tritium from the gas stream upon discharge through the tritium sorbent bed. The scrubbers were used to assess the amount of tritium passing through the tritium sorbent bed.

As is shown in Table 1, ATPTOG-1 and ATPTOG-4 are replicate tests designed to assess the expected baseline tritium recovery when no tritium sorbent is present and to be used for comparison with tests in which the tritium sorbent is present. ATPTOG-2 and ATPTOG-3 served to test each tritium sorbent and provided replicate testing of the AgA iodine sorbent. Finally, ATPTOG-5, with no tritium or iodine sorbent emplaced, was intended for comparison with ATPTOG-1 and ATPTOG-4 to determine whether the AgA sorbent retained tritium.

3. MATERIALS AND METHODS

The experimental methodology for the tests was reported previously in Jubin et al. (2017). The specific details of the experiments and any deviations from the proposed methodology are discussed below. Five tests were conducted utilizing the experimental setup shown in Figures 1 and 2 with conditions presented in Table 1.

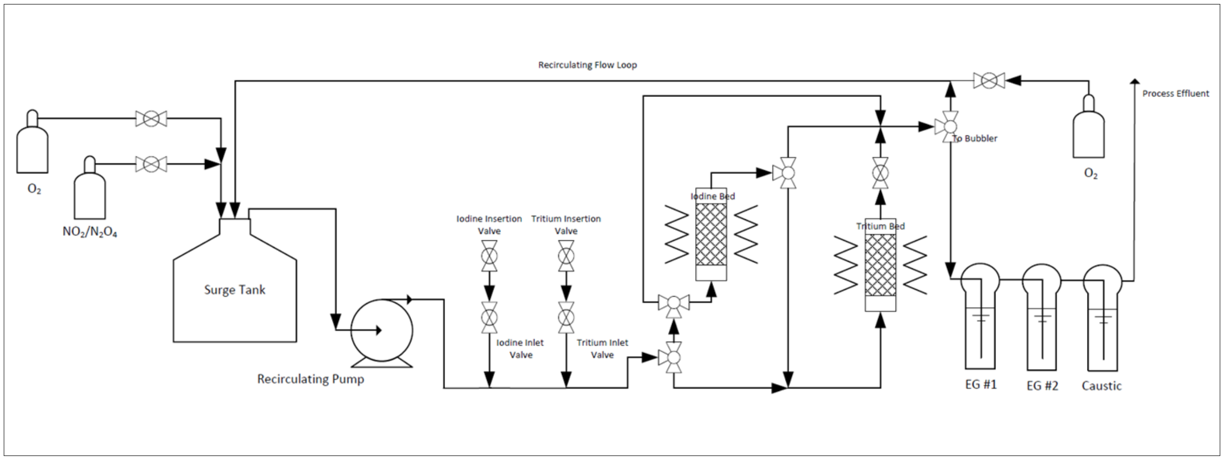

Figure 1: Schematic of iodine and tritium sorbent test system.

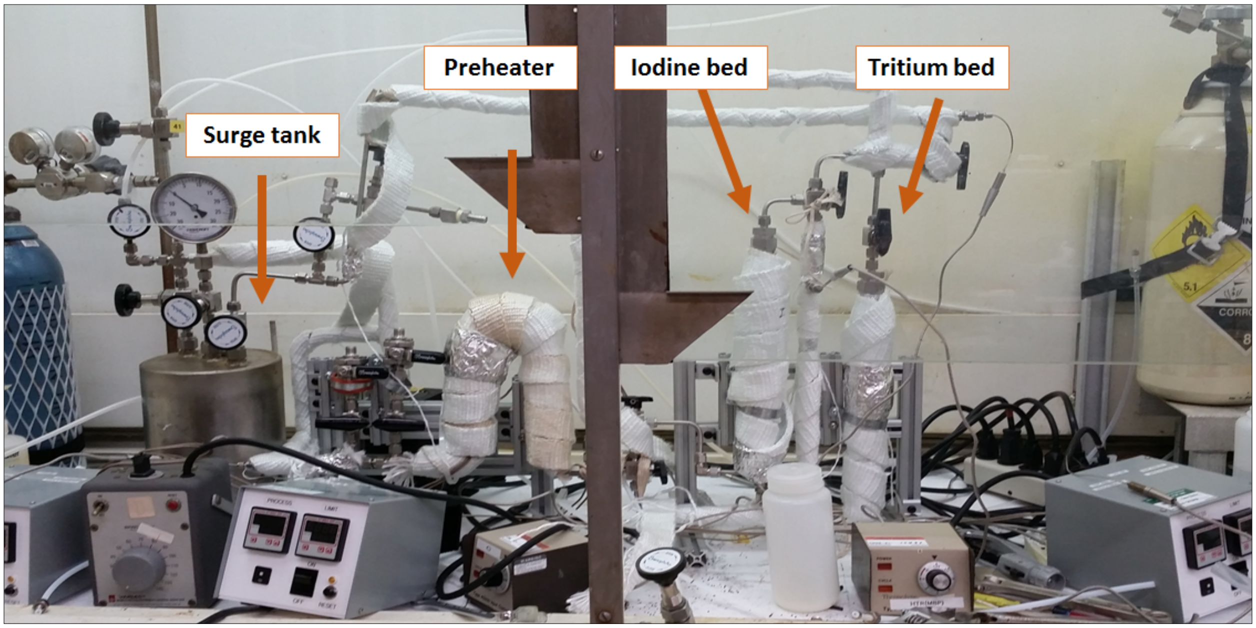

Figure 2: Photograph of iodine and tritium sorbent test system.

3.1 Materials

The system was primarily constructed of stainless steel components. The surge tank was legacy equipment and had previously been exposed to NO_2, O_2, inert gases, and some uranium. The NO_2 and O_2 feed lines were Teflon, and the discharge connection between the stainless test system and the liquid scrubbers was Teflon.

Prior to the start of each test, the iodine column was loaded with AgA prepared at ORNL. This material was prepared by combining 500 g of 1.18–1.40 mm diameter activated alumina desiccant spheres (Sorbent Technologies) with 380 mL of 1.936 *M* $AgNO_3$ solution. This solution was heated to a maximum temperature of 125°C for 9 hours under vacuum. After completion of this process, the alumina spheres weighed 653.3 g. The column is separated into discrete segments with layers of quartz wool between the segments. The length of the iodine bed is 10 cm. The tritium column contained silica gel or 3A MS, both approximately 6–12 mesh size, with a bed depth of 10 cm.

3.2 Establishment of Recirculation Loop and Iodine Capture Phase

The recirculation system was closed off to the environment, evacuated to an absolute pressure of 0.30 atm, and held to determine whether the system was leak tight. After determination of the leak rate (observably leak tight for the experimental durations), NO_2 was delivered to the system from a tank of liquid N_2O_4 until the system pressure was raised to ~0.83 atm and oxygen was added until the final pressure of the system was ~1.14 atm. This resulted in a total system NO_2 partial pressure of 0.53 atm and an NO_2 concentration of 47% in the gas phase.

After addition of the NO_2 and O_2, the recirculation pump was activated. The system flow path (Figure 3) was set so that gas flow would recirculate through the iodine bed (which contained ~30 g of AgA in all but test ATPTOG-5) and surge tank. The total pressure of the system dropped during the establishment of the recirculation loop such that the gas loop was at sub-atmospheric pressure prior to the introduction of iodine and tritium. This pressure drop may be due to the consumption of gaseous components by system materials or sorbent material.

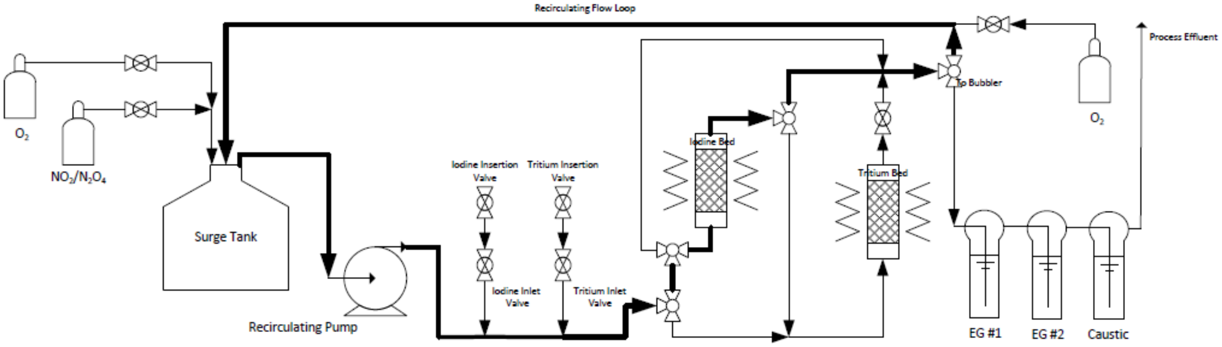

Figure 3: Gas flow path (bolded) during iodine capture phase.

The tritium bed was bypassed during recirculation. Heat tapes were placed on the main recirculation lines, the iodine bed, and the tritium bed; the surge tank was not heated. The heat tapes were activated after recirculation was initiated. There were three primary heating zones: a "hot zone" designed to simulate the reactor in an advanced TPT system with a setpoint of 300°C; the iodine bed with a setpoint of 150°C; and the process lines, which were heated to achieve temperatures >40°C. The gas was recirculated to allow heating and to expose the sorbent bed to the gas stream. During recirculation, the pressure of the system dropped by ~0.30 atm.

A short time after beginning recirculation (~10 min), 100 µL of tritiated water was added to the system, corresponding to a total activity of 100 µCi. About 2 hours after the addition of tritium, 0.13 g iodine was added (Tests 2 and 3 only). Recirculation continued for 2–4 hours.

3.3 Tritium Capture (TC) Phase

After iodine capture and recirculation, the heat tapes and recirculation pump were turned off and the tritium bed was heated to 40°C. The flow path was altered so that the gas stream would not pass through the iodine bed but would pass through the tritium bed and then pass out of the system through bubblers of ethylene glycol and/or sodium hydroxide (NaOH), as shown in Figure 4. To ensure that the tritium-bearing gas stream was fully discharged through the scrubbers, oxygen was added to the system to reach a pressure of 3.0 atm and bled down through the tritium bed and bubblers to ~1.1 atm. The system was successively pressurized and depressurized five times, resulting in a final nominal NO_2 concentration of ~0.34% from an initial nominal concentration of 47%. These pressurization/depressurization cycles should result in

>99% of the gas-phase tritium being discharged through the tritium bed and into the ethylene glycol and NaOH scrubbers. Any tritium adsorbed by the solid sorbents would remain in the system.

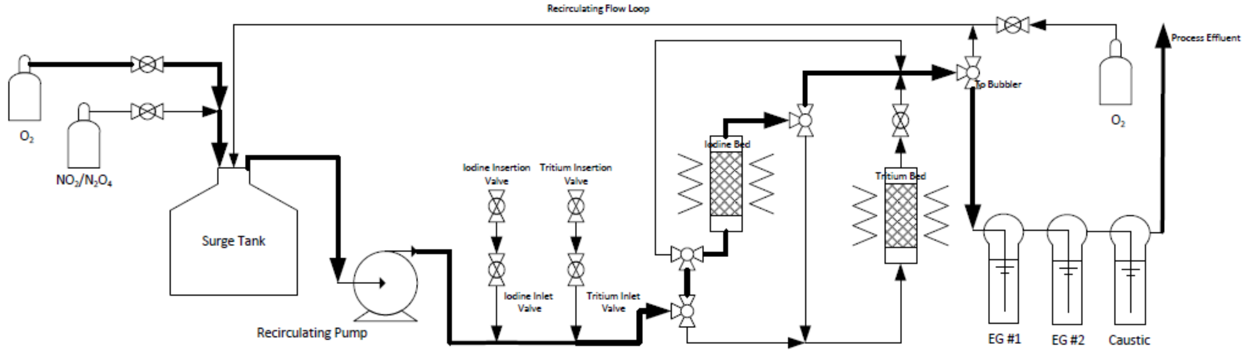

Figure 4: Gas flow path (bolded) during tritium capture phase.

3.4 Tritium Sorbent Regeneration (TR) Phase

The system was then sealed off, and the temperature of the tritium bed was raised to the selected regeneration temperature. After reaching the setpoint, the system was opened, and the bed was purged with oxygen at 0.5 liters per minute (LPM) for 2 hours. The effluent from the tritium column was flowed in series through two ethylene glycol scrubbers and one NaOH scrubber, with the scrubber solutions replaced between the TC and TR phases of testing. The flow path for the oxygen purge is shown in Figure 5.

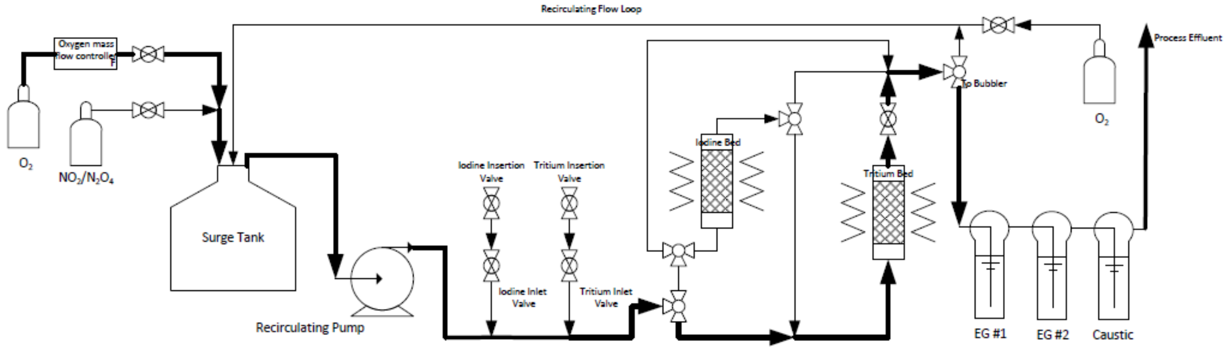

Figure 5: Gas flow path (bolded) during tritium regeneration phase.

3.5 Iodine Sorbent Purge (IP)

Upon completion of tritium regeneration, the system valving alignment was modified so that the tritium column was sealed from the rest of the system, and the iodine column was included in the flow path (Figure 6). The iodine column was held at 150°C and purged with oxygen at 0.5 LPM for 2 hours. The effluent was passed through one ethylene glycol and one NaOH scrubber, with the scrubber solutions replaced between the TR and IP phases of testing.

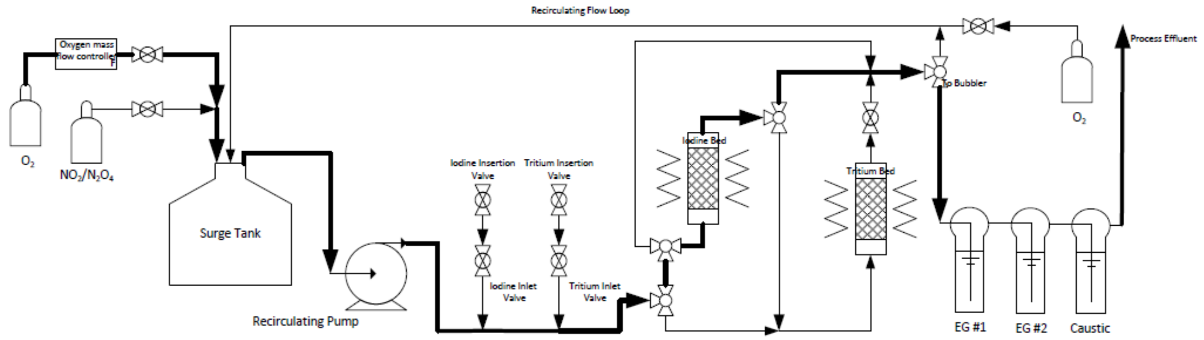

Figure 6: Gas flow path (bolded) during iodine sorbent purge phase.

3.6 Analysis

The tritium content of the ethylene glycol and NaOH scrubbers were determined by liquid scintillation counting (LSC). Tritium determination on both iodine and tritium solid sorbents was performed by placing ~1 g of the sorbent into a liquid scintillation cocktail and counting the resulting solution. The iodine content of each scrubber was determined by inductively coupled plasma–mass spectrometry (ICP-MS). The iodine content of the iodine and tritium sorbents was determined by neutron activation analysis (NAA) performed using ORNL's High Flux Isotope Reactor.

4. RESULTS

Five experiments were completed. The total tritium and iodine recoveries for each test are shown in Table 2. The iodine recovery is based on the total amount of iodine recovered in both the sorbent (analyzed by NAA) and the liquid scrubbers (analyzed by ICP-MS). The tritium recovery includes the amount of tritium found in the liquid scrubbers only. Both the tritium and iodine sorbents were counted upon conclusion of the experiment by LSC but given the potential for self-shielding of the weak beta emitter by the solids, these numbers can only be considered qualitative.

Table 2: Tritium and iodine recovered from ATPTOG test system.

Test #	Tritium sorbent	Iodine sorbent	Liquid scrubber tritium recovery (%)	Tritium on AgA	Tritium on silica or 3A MS	Total iodine recovery (%)
1	None	AgA	6.2	Yes	n/a	N/A
2	Silica gel	AgA	2.0	Yes	Yes	0.4%
3	3A MS	AgA	3.6	Yes	Yes	30.2%
4	None	AgA	5.4	Yes	n/a	N/A
5	None	None	3.8	n/a	n/a	N/A

4.1 Iodine Distribution

The AgA sorbent changed color during the course of testing, from an initial grey color to ivory or white upon test conclusion. Tests ATPTOG-2 and -3 displayed markedly different iodine recoveries, with only 0.4% of the ~0.13 g delivered recovered on the iodine sorbent or in the liquid scrubbers for Test -2, and 30.2% recovered in Test -3. The distribution of iodine in the bed segments is shown in Tables 3 and 4. Of the iodine recovered, the majority was found on the AgA sorbent, with <1 mg located in scrubbing liquids. The first AgA segment in Test 2 contained <0.02 mg I/g sorbent, with no other segments above the detection limit. In the case of Test 3, the recovered iodine was located on the first bed segment analyzed (5 mg/g sorbent), with subsequent segments displaying loadings of <1 mg/g sorbent.

Table 3: Iodine distribution between AgA bed segments and liquid scrubbers, Test 2

Sample ID	Bed segment mass (g)	Iodine (mg/g sorbent)	Uncertainty (mg/g sorbent)	Iodine recovered (%)
R2-AgA1	5.2643	0.0172	0.0001	< 0.1
R2-AgA2	5.0465	MDA	-	-
R2-AgA3	4.9000	MDA	-	-
R2-AgA4	5.2317	MDA	-	-
R2-AgA5	5.0229	MDA	-	-
Liquid scrubbers				0.4
MDA = below minimum detectable activity				

Table 4: Iodine distribution between AgA bed segments and liquid scrubbers, Test 3

Sample ID	Bed segment mass (g)	Iodine (mg/g sorbent)	Uncertainty (mg/g sorbent)	Iodine recovered (%)
R3-AgA1	6.3215	5.9400	0.0297	27.6
R3-AgA2	5.3908	0.5115	0.0026	2.0
R3-AgA3	5.4881	MDA	-	-
R3-AgA4	5.485	0.0087	0.0000	< 0.1
R3-AgA5	4.4879	MDA	-	
Liquid scrubbers				0.6
MDA = below minimum detectable activity				

4.2 Tritium Distribution

The distribution of tritium within the ethylene glycol and NaOH scrubbers is shown in Table 5. The designators TC, TR, and IP refer to the tritium capture, tritium sorbent regeneration, and iodine sorbent purge stages, respectively.

The maximum observed tritium recovery was 6.2% of the 100 mCi delivered to the system per test. There was observable tritium present on both the AgA and 3A MS/silica gel at the conclusion of each test, even following regeneration and/or purging of both sorbents.

Table 5: Tritium distribution in liquid scrubbers

Scrubber designation	Scrubber liquid		Total tritium recovery in scrubber (%)			
		Test 1	**Test 2**	**Test 3**	**Test 4**	**Test 5**
TC1	Ethylene glycol	0.114	0.1	0.132	0.292	3.803
TC2	Ethylene glycol	MDA	MDA	0.002	MDA	MDA
TC3	NaOH	*n/a*	*n/a*	0.005	MDA	0.003
TR1	Ethylene glycol	3.787	0.93	2.765	4.088	*n/a*
TR2	Ethylene glycol	MDA	MDA	MDA	MDA	
TR3	NaOH	*n/a*	MDA	MDA	0.005	
IP1	Ethylene glycol	2.256	0.91	0.737	0.828	
IP2	NaOH	*n/a*	0.07	MDA	0.142	
	SUM	**6.2%**	**2.0%**	**3.6%**	**5.4%**	**3.8%**
	MDA = below minimum detectable activity *n/a = scrubber not included in test*					

Given the low overall recoveries of tritium from the ATPTOG system, only limited conclusions can be made based on the tritium content of the scrubbers. The amount of tritium in the gaseous effluent during the tritium capture phase is of the same magnitude regardless of whether a tritium sorbent is present. However, the total amount of tritium released during the tritium regeneration phase is lower with a tritium sorbent present, and there is some residual tritium on the solid sorbents at the conclusion of each test. This indicates some interaction of tritium with the sorbent even in the presence of NO_2.

Given that residual tritium was located on AgA at the conclusion of each test, there is also indication that tritium is interacting with the iodine sorbent. The magnitude of this interaction was not quantified during testing, as tritium analysis of solids is analytically complex. Some of the tritium on the sorbent was desorbed during the iodine purge step, in which the column was held at 150°C, and dry gas was passed through the column for 2 hours. An unknown fraction was retained by the sorbent.

5. SYSTEM DISASSEMBLY

The low tritium and iodine recoveries, along with confirmation by pressure test that the system was leak tight, prompted a full system disassembly to assess whether there was holdup of tritium and iodine within the system. Smears were taken at multiple points in the system. It was found that the surge tank within the system was corroded and smeared positive for tritium at multiple locations. Several corroded fittings were removed from the surge tank, and both iodine and tritium were found in the corrosion products. No corrosion was observed at other visually inspected locations, and no other inspected locations smeared positive for tritium.

During system disassembly, substantial NO_2 holdup was found within the surge tank, as the tank off-gassed characteristic brown NO_2 gas for at least 2 weeks following system disassembly. The surge tank was not heated, and it is possible that there was some condensation of NO_2 gas within the tank.

The recirculation loop was structured such that the iodine-bearing gas stream encountered the alumina sorbent bed prior to the surge tank. System disassembly showed no corrosion in the portion of the system between the iodine introduction port and the iodine sorbent column. Given these details, it was concluded that the measured iodine content of the sorbent could be representative of a single-pass iodine sorbent column within a ATPTOG treatment system.

6. CONCLUSIONS

Given the extent of corrosion observed in the surge tank and the confirmed presence of iodine and tritium within the corrosion products, the low tritium and iodine recoveries observed during testing are unsurprising. Although the surge tank was constructed of stainless steel, which is considered to be compatible with NO_2 gas and N_2O_4 liquid, the materials of construction for an ATPTOG treatment system should be carefully reconsidered. Iodine is known to corrode stainless steel in the presence of water. A second possibility is that NO_2 itself contributed to the corrosion of the system, either as a liquid (N_2O_4) or a gas. The surge tank, which was the only visibly corroded component, was not heated during testing.

The low tritium recoveries prevented quantitative conclusions regarding the adsorption of tritium by either silica gel or 3A MS in high NO_2 systems. Tritium was observed on the sorbent at the conclusion of the tritium sorbent regeneration step. Tritium was found to interact with the iodine sorbent, AgA, to an unknown extent. Tritium was also found in the effluent of the AgA purge and on the solid sorbent following the completion of the sorbent purge.

Although the final iodine content of the AgA sorbent varied significantly during Runs 2 and 3, the ability of AgA to adsorb iodine in the presence of high levels of NO_2 appears to be substantially reduced upon exposure of the sorbent to NO_2. The sorbent was contacted with NO_2 for 2 hours prior to the introduction of iodine, and even this limited exposure resulted in an observable decrease in iodine capacity. The replicate testing showed iodine recoveries on the sorbent of <0.1% (Run 2) and 30.2% (Run 3). Given the difficulties observed regarding the materials of construction used for this testing and the difference in sorbent loading of Runs 2 and 3, the performance of the AgA should be reexamined with a more robust system. These initial tests, however, do indicate a failure of the sorbent to perform to the levels that would be required in a ATPTOG treatment system.

This testing leaves many fundamental questions regarding the ATPTOG iodine and tritium abatement systems unanswered. Some of the most critical include the following.

- What is the total iodine capture capacity of AgA if operated with a recirculating gas stream?
- To what extent does tritium co-adsorb on the AgA sorbent?
- To what extent can 3A MS and silica gel retain tritium from an ATPTOG bleed stream?
- Can the tritium retained on 3A MS and silica gel be desorbed quantitatively?

These questions, and others not listed, indicate that tritium and iodine abatement from an ATPTOG stream by solid sorbents is currently at a low stage of technological development and that deployment of such an abatement system would require substantial additional research and development. It is unknown what currently available solid sorbent technology is able to withstand degradation from high concentrations of corrosive NO_2 and I_2 gas.

7. REFERENCES

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