STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

Mock- Up Scrubber System

DOE-FIU SCIENCE & TECHNOLOGY
WORKFORCE DEVELOPMENT PROGRAM

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ABSTRACT

During the summer of 2015, DOE Fellow Jesse Viera performed a 10-week long internship at Idaho National Laboratory (INL). INL is an 890 square mile nuclear facilities complex in eastern Idaho. Some of the projects carried out at INL are Next Generation Nuclear Plants Development, Fuel Cycle Research and Development, Light- Water Reactor Sustainability, and Nuclear Waste Management. Under the mentorship of Rick Demmer (Chemist) and Stephen Reese (Mechanical Engineer) both and Jesse were tasked with the design, assembly, and testing of a mock-up ruthenium scrubber system intended to support development of a scrubber system needed at Rokkasho Nuclear Fuels Reprocessing Facility in Japan. The interns conducted all of the design, assembly, and testing in INL's Energy Innovation Laboratory.

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1. INTRODUCTION

1.1 Problem Set

The International Atomic Energy Agency (IAEA) and Idaho National Laboratory (INL) have been tasked with developing a ruthenium scrubber which efficiently extracts ^{106}Ru from the off-gas sy stem at the Rokkasho Nuclear Fuel Reprocessing Facility. Furthermore, our team was assigned to design, assemble and test a mock-up, bench scale system.

1.1 Background

The Rokkasho Nuclear Fuel Reprocessing Facility (RNFRF) is a nuclear reprocessing plant in northern Japan with an annual reprocessing capability of 800 tons of uranium or 8 tons of plutonium from commercial power reactors. Reprocessing of nuclear fuel has become a favorable and effective way to extract fissile materials for recycling and to reduce the volume of high-level waste for disposal. Roughly 96% of nuclear fuel which has reached the end of its life is recyclable material for both uranium and plutonium. The remaining 4% is non-recyclable. The current mechanical and chemical processes for reprocessing used fuel yield off-gas streams containing volatile fission products. This aggressive process introduces nitric acid which oxides and creates an environmental hazard. The radioactive isotope of highest interest for extraction is ruthenium, which is present in the gas phase in the form of RuO_4. In the Rokkasho facility, the need for a ruthenium scrubber which can efficiently extract ruthenium from off-gas is imperative before nuclear reprocessing begins again. RNFRF contacted the IAEA with their need for a ruthenium scrubber system. Given INL's past experience with scrubber development the IAEA reached out to INL for assistance on the research and development of the needed scrubber system. Our team was tasked with the development stage in which we had to design, assemble, and test a bench-scale mock-up of a ruthenium scrubber, with silica gel serving as the scrubber medium. Figure 1 shows the INL Advanced Test Reactor and Figure 2 the INL Energy Innovative Laboratory.

Figure 1. INL Advanced Test Reactor.

Figure 2. INL Energy Innovation Laboratory.

2. EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Initiative, an innovative program developed by the US Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2015, DOE Fellow intern Jesse Viera spent 10 weeks doing a summer internship at Idaho National Laboratory under the supervision and guidance of Stephen Reese, Mechanical Engineer. The intern's project was initiated on June 1, 2014, and continued through August 6, 2014 with the objective of researching and developing a mock-up ruthenium scrubber system.

3. RESEARCH DESCRIPTION

3.1 Design

The design consists of three main components; 1) A vacuum to create negative pressure within the system, 2) the scrubber assembly and 3) Tygon tubing to complete the system. The scrubber body was created out of modified braided vinyl while polyvinyl chloride (PVC) bushings served as scrubber caps. Commercial silica gel was used to fill the scrubber. All other small components and bushing were made manufactured out of brass. Two sets of differential pressure gauges were used to collect pressure data.

The mock- up scrubber was designed based on the following requirements:

- Efficiently trap water vapors passing through.
- 2016 in^3 volume assembly restriction.
- **S**crubber must hold at least 1 liter of silica gel.
- Cost effective

Figure 3. Scubber components.

Figure 3 shows the scrubber components. All materials and equipment were purchased off the shelf and modified at INL facilities during the assembly process. The materials included:

- Vinyl tubing (7/8” O.D. x 5/8” I.D)
- Braided Vinyl (2 ½” OD x 2”ID x 8”)
- Stainless Steel Clamp
- Brass Adapter (¼” x ¼”)
- Brass Hex Bushing (½ x ¼)
- Brass Adapter Barb (3/16” x1/4’)
- 5/8” Barb X ½” MIP Adapter
- ½” Red Brass Tee
- ½” x closed brass pipe nipple MIP
- 5/16” x 3/16” x 10’ pre-cut poly hose
- Aluminum filter kit
- PVC Bushing

- Pressure Gauge (psi)
- Pressure gauge (in. H_2O)

The cost of all materials for the manufacturing and assembling of the mock- up scrubber system totaled to a cost of $65.50. Figure 4 shows Mr. Viera working on assembling the scrubber and Figure 5 shows the silica gel used for testing effectiveness of the scrubber assembly.

Figure 4. Scubber assembly (Jesse Viera).

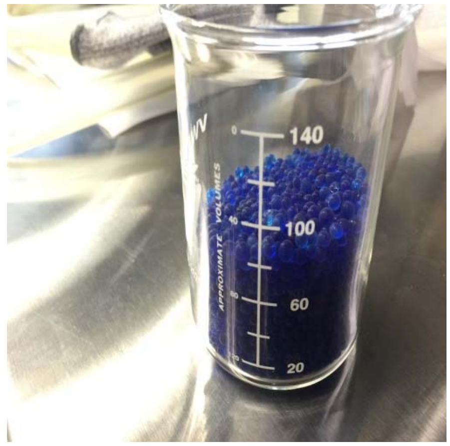

Figure 5. Silica gel.

3.2 Testing Procedures

Before testing, the scrubber system was positioned on the designated testing bench with all main components secured and connected to a fume hood vacuum source. For testing purposes, 100 grams of silica gel was held as a constant for each trial to evaluate the effectiveness of the scrubber. Each trial was conducted until all of the water was vaporized. Overall, this took about 45 min- 1 hour. After full vaporization of water the silica gel was immediately removed from the scrubber, weighed, and documented.

3.4 Future Design

For the final scrubber design the system will be manufactured out of stainless steel. Stainless steel is a material that is able to handle high radioactive environments. The final assembly will be capable of holding 111 in^3 of silica gel which meet the requirement needed by RNFRF. The CAD drawings shown in Figures 6, 7, and 8 were designed and developed using AutoDesk Inventor.

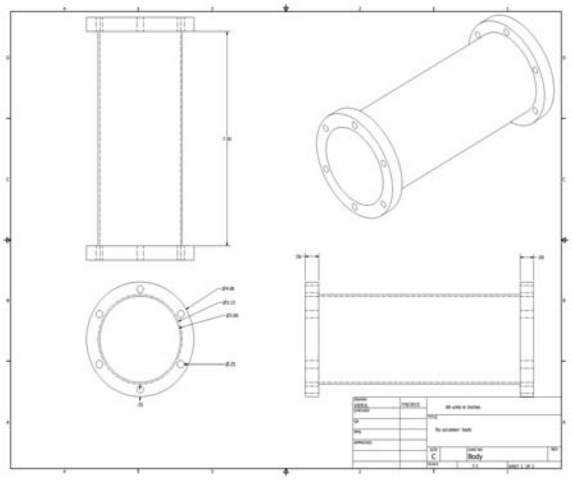

Figure 6. Scrubber body.

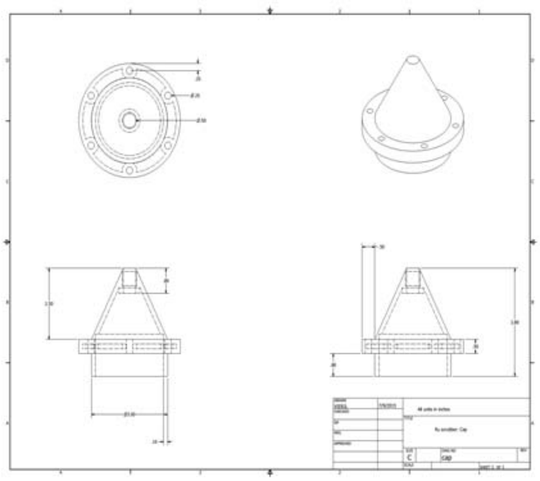

Figure 7. Scrubber cap.

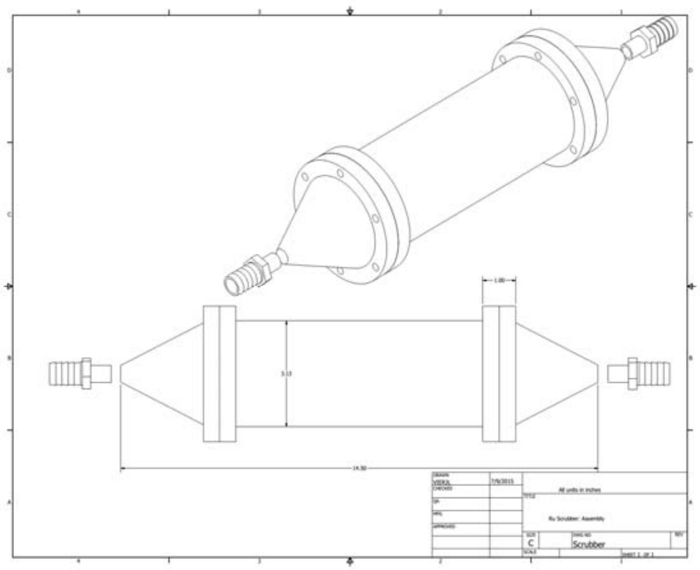

Figure 8. Scrubber assembly.

4. RESULTS AND ANALYSIS

For testing purposes, water was boiled and the steam served as a surrogate gas to evaluate the effectiveness and functionality of the system. The following conditions were held constant:

- 100 grams of silica gel inside the scrubber
- Water held at boiling temperature
- Constant volumetric flow

The following is data collected during the vaporization trails using the mock-up scrubber system.

4.1 Results

Table 1. Silica Gel Performance

Scrubber System Mock-Up Test				
Test	Original Weight of Silica Gel (g)	Volume of Water (mL)	Weight of Silica Gel After Run (g)	Water Absorbed by Silica Gel (g)
1	100	300	118.26	18.26
2	100	300	118.30	18.30
3	100	9.0	105.50	5.05
4	100	20.0	107.00	7.00
5	100	60.0	119.00	19.00

All trials were run until all water was vaporized from the beaker. Trial one made sure all necessary adjustments were made to expedite the heating process and ensure all components functioned. During the first trial, a weight of 18.26 grams was absorbed by silica gel. Using the density of water (1.0 g/ml), we are able to obtain an absorption percentage of 6.09 %. For trails 2, 3, 4, and 5, we obtained an absorption percentage of 6.1%, 56.1%, 35%, 31.6%, respectively.

4.2 Analysis

The data show that the silica gel was successful in absorbing moisture passing through the scrubber system during all trials. In addition, the data supports the idea that the silica gel may have a moisture retention threshold. This may be an area of interest for future research and development.

5. CONCLUSION

The mock- up scrubber system proved to accomplish its mission of providing passage for water vapor into the scrubber where it was absorbed. No leaks were found which indicates that the mock-up scrubber assembly was properly secured and assembled. The cost of this project was minimal for a laboratory and nuclear reprocessing facility budget. With this mock- up testing and data acquired INL will further the development of a ruthenium scrubber which can operate in a highly radioactive environment while effectively extracting ruthenium from nuclear fuels reprocessing off-gas.

Figure 9. Mock-up scrubber system.

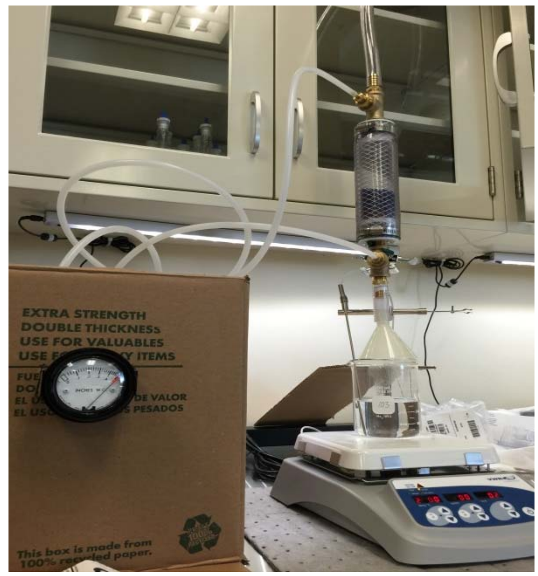

Figure 10. Mock-up scrubber system (2).

6. REFERENCES

1) "INL." *INL*. N.p., n.d. Web. 1 Sept. 2015.

2) "International Atomic Energy Agency | Atoms For Peace." *International Atomic Energy Agency (IAEA)*. N.p., n.d. Web. 9 Sept. 2015.