Annals of Nuclear Energy 111 (2018) 676–682

Contents lists available at ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/anucene

Fuel conditioning facility inert gas filled reprocessing hot cell leak rate measurement

Chad L. Pope [a,*], Charles W. Solbrig [b], Jason P. Andrus [b]

[a] Idaho State University, 921S. 8th Avenue, Pocatello, ID 83209-8060, United States
[b] Battelle Energy Alliance, Idaho National Laboratory, P.O. Box 2528, Idaho Falls, ID 83404, United States

ARTICLE INFO

Article history:
Received 8 June 2017
Accepted 25 August 2017
Available online 7 October 2017

Keywords:
Pyro-processing
Hot cell
Leak measurement

ABSTRACT

The Idaho National Laboratory Fuel Conditioning Facility conducts treatment of U.S. Department of Energy owned metallic fast reactor spent fuel using pyro-processing. Certain steps in pyro-processing generate pyrophoric metal laden with radioactive material. Therefore, the process is conducted within an inert atmosphere to prevent ignition. The Fuel Conditioning Facility uses a 60,000 ft^3 (1700 m^3) shielded hot cell environment with a purified argon gas atmosphere. Significant leakage of air into the hot cell can raise the oxygen concentration to the point where exposed pyrophoric metal will burn, which can subsequently result in release of radioactive material through the air in-leakage point. Additionally, limited air in-leakage can cause exposed metal to oxidize, rendering it unfit for pyro-processing. To ensure hot cell confinement boundary integrity, the Fuel Conditioning Facility executes periodic surveillance of the confinement boundary leak rate. This paper describes the leak rate surveillance techniques associated with this large inert-gas-filled hot cell.

Two methods have been developed to determine the cell leak rate. One method uses the cell atmosphere oxygen concentration change over time. The other method uses the cell pressure and temperature change over time. The oxygen rate increase method is a very accurate method of determining the air leak rate during many types of operating conditions. However, the data observation period must be sufficiently long to obtain an accurate value. The pressure-temperature method is not as time consuming but is significantly less accurate than the oxygen concentration method.

The cell leak rate is extremely small, less than 0.01 cfm, given the very large cell size. The oxygen concentration method is accurate to approximately ±0.002 cfm. The pressure-temperature method is accurate to about ±1 cfm. The pressure-temperature leak rate method can be used as a confirmation of the oxygen method results or as a backup if the oxygen monitors are not working.

1. Introduction

The Idaho National Laboratory Fuel Conditioning Facility, shown in Fig. 1, conducts treatment of U.S. Department of Energy owned metallic fast reactor spent fuel using pyro-processing. The process involves chopping spent nuclear fuel elements; high temperature molten salt electrorefining to separate uranium from fission products and transuranic elements; high temperature distillation to separate recovered uranium metal from entrained salt; and uranium ingot casting Till and Chang (2011).

Since certain steps in pyro-processing generate pyrophoric metal laden with radioactive material, the process is conducted within an inert atmosphere to prevent ignition. Additionally, given the intense radiation associated with spent nuclear fuel, pyro-processing must be conducted within a heavily shielded environment. The Fuel Conditioning Facility uses a 60,000 ft^3 (1700 m^3) shielded hot cell environment with a purified argon gas atmosphere.

Significant leakage of air into the hot cell can raise the oxygen concentration to the point where exposed pyrophoric metal will burn (~4%), which can subsequently result in release of radioactive material through the air in-leakage point (Solbrig et al. 2014). Additionally, limited air in-leakage can cause exposed metal to oxidize, rendering it unfit for pyro-processing. To ensure hot cell confinement boundary integrity, the Fuel Conditioning Facility executes periodic surveillance of the confinement boundary leak rate. This paper describes the leak rate surveillance techniques associated with this large, inert-gas-filled hot cell.

* Corresponding author.
E-mail address: popechad@isu.edu (C.L. Pope).

https://doi.org/10.1016/j.anucene.2017.08.058
0306-4549/

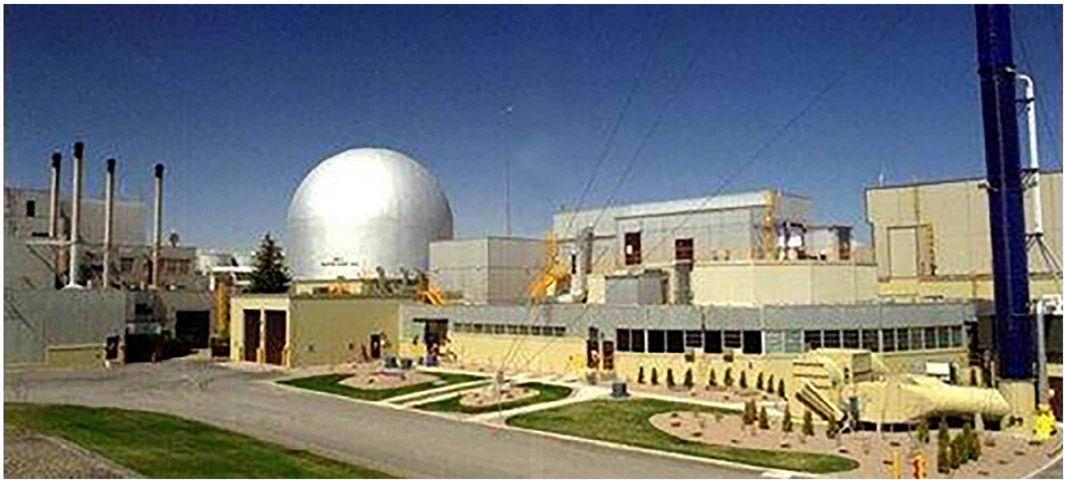

Fig. 1. Fuel Conditioning Facility.

2. Facility description

The Fuel Conditioning Facility hot cell arrangement is shown in Fig. 2. The rectangular portion of the cell arrangement contains an air atmosphere and is used for preprocessing activities as well as spent fuel and product storage. The annular portion of the hot cell contains an argon atmosphere and is used for all processing steps potentially producing pyrophoric material. The argon atmosphere cell is a hexadecagon-shaped, reinforced concrete structure with a central observation room. The annulus of the argon cell has an outer nominal diameter of 62 ft (18.9 m), an inner nominal diameter of 30 ft (9.1 m), and an inside nominal height of 22.5 ft (6.9 m). The cell walls are 5-ft (1.5-m)-thick, high-density concrete. The cell is lined with a seal-welded steel liner 0.375 in. (9.5 mm) thick on the walls and ceiling and 0.5 in. (12.7 mm) thick on the floor.

There are 15 viewing windows located in the outer wall of the argon-filled cell and four windows in the central observation room. Items are transferred into and out of the cell using either the small transfer lock or the equipment transfer lock. No other entrances or exits exist. The small transfer lock is embedded in the wall between the rectangular air-filled cell and annular argon-filled cell. The equipment transfer lock is embedded in the floor between the argon-filled cell and a transfer tunnel connected to the rectangular air cell. Air has several potential paths for entry into the argon-filled cell, including utility penetration seals, windows seals, transfer locks, and various argon gas cooling and purification piping.

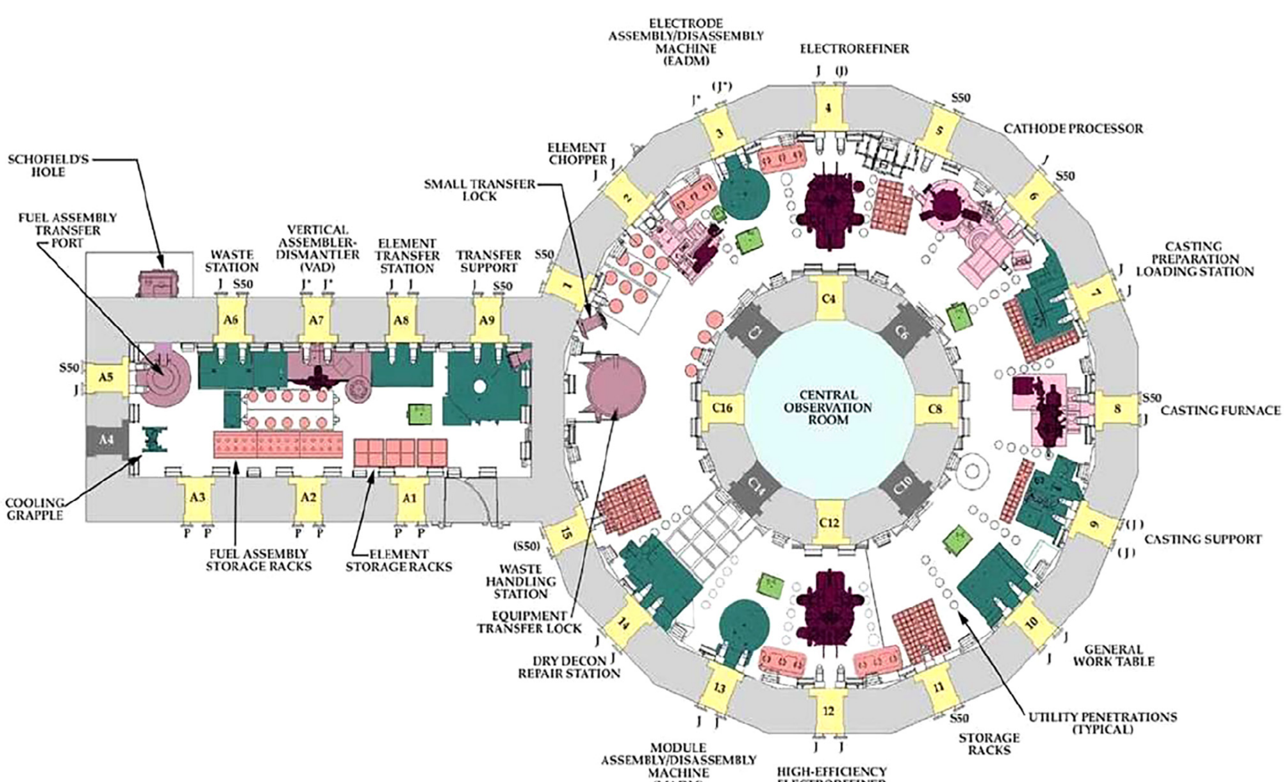

Fig. 2. Fuel Conditioning Facility hot cell plan view.