Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

LiDAR Inspection of GPS Denied Hazardous Environment Exhaust Tunnel

William Willie Wells,* Jean R. Plummer*, Jane M. Carter†

*Savannah River National Laboratory, Savannah River Nuclear Solutions LLC, Building 781-A, Aiken SC, 29808, William.Wells@srnl.doe.gov, Jean.Plummer@srnl.doe.gov
† Savannah River Nuclear Solutions, Savannah River Nuclear Solutions LLC, Building 704-2H, Aiken SC, 29808, Jane.Carter@srs.gov

INTRODUCTION

At the Savannah River Site the H-Canyon Exhaust Tunnel (H-CAEX) structure, Fig 1, is periodically inspected to confirm conditions can perform their credited safety function and provide assurance that corrective actions can be performed before the safety function is compromised if evidence of degradation is detected. Prior to November 2019 inspections were performed using cameras situated either on tethered unmanned ground vehicles or poles. The United States Department of Energy - Environmental Management (DOE-EM) Office of Technology Development sponsored the evaluation of enhanced inspection methods.

Fig. 1. H-Canyon Facility with tunnel locations noted.

An advanced technology demonstration using a Light Detection and Ranging (LiDAR) system was deployed on a pole via a pitot tube, Fig 2, in the H-CAEX on November 4, 2019 [1]. The H-CAEX is an under-ground tunnel. The H-CAEX pitot tube diameter is 154 mm. Nitric acid vapors, high humidity, radioactivity up to 10 mSv, and air flow between 11.176 and 13.411 m/s are the environmental hazards of the H-CAEX. The H-CAEX environment is a GPS denied environment. These design challenges limited sensor selection for the inspection.

A Leica BLK360 LiDAR, which includes 3 aligned spaced embedded cameras, an internal Inertial Measurement Unit (IMU) and a LiDAR was selected

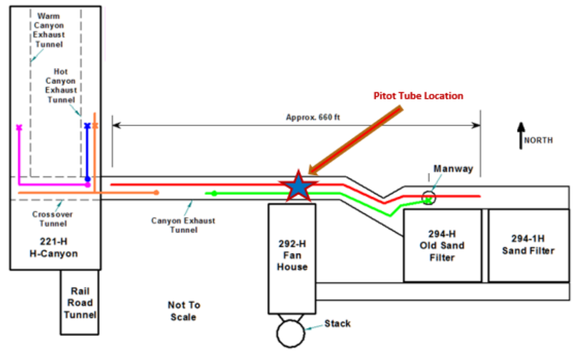

Fig 2. H-CAEX pitot tube location.

as the inspection sensor. Four evenly spaced Banner HLS27 LED strip lights placed near the BLK360 provide lighting for the embedded cameras. The BLK360 is designed to use a battery. The battery was replaced with tethered power. Cable management for the rotating BLK360 was provided by a Moog AC6438 slip ring. Two wired Ubiquiti NanoStation LocoM2s are used to relay the wireless signal from the BLK360 to a remote above ground iPad.

At this date, two inspections have been completed, 8 months apart, using the LiDAR system. After the first day of the initial two-day scheduled inspection in November 2019, the BLK360 became inoperable due to excessive stress on the rotation axis possibly caused by the tethered setup and/or extensive dwell time in the hazardous environment. The second deployment occurred on June 10, 2020. The LiDAR system was modified for the second deployment.

A new BLK360 was procured from Leica for the second inspection. Battery power was used with the new BLK360 for the second inspection. The slip ring was rendered inoperable. Each BLK360 emits a unique wireless local area network. The two NanoStations used in the first deployment were replaced with new units that were configured with the Service Set Identifier and password of the new BLK360.

RESULTS

A high point density scan from each of three scan elevations, Fig 3, was merged into a single point cloud for analysis. This merger was performed on the data for both inspections. The point clouds from both inspections were aligned and comparisons were performed both to determine the viability of using this enhanced inspection technique as well as to determine the tunnel surface erosion rate between the two inspections. Nine high point density scans were taken three at each designated elevation during the first deployment. Three medium point density and 1 high point density scan were taken at the lowest elevation while 2 high point density scans were taken at the two remaining elevations due to battery life and human heat stress considerations.

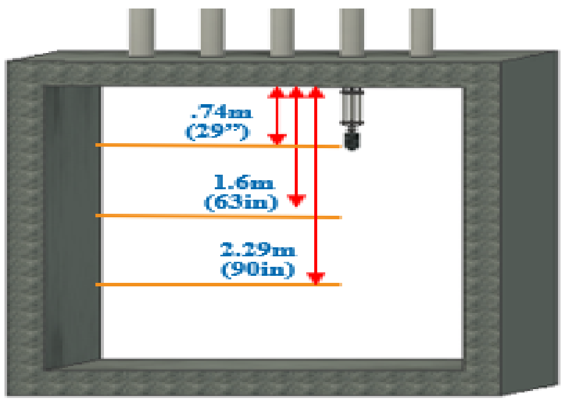

Fig 3. Three scan elevations employed to reduce shadowing in results.

Autodesk Recap Pro Mobile was used to collect the data from the BLK360. Autodesk Recap Pro was used to transfer the data off the iPad and to perform initial axis alignment corrections. Open source CloudCompare was used to generate contour maps depicting surface distance comparisons.

Although, more than three scans were performed during each inspection only three were merged due to point cloud comparison processing time considerations. Leica states that point clouds generated by the BLK360 have a 6 mm accuracy within 10 m of the scanner location. Thus, an area spanning [-9.292, 9.203] m along the tunnel, Fig 4, from the scanner location was analyzed.

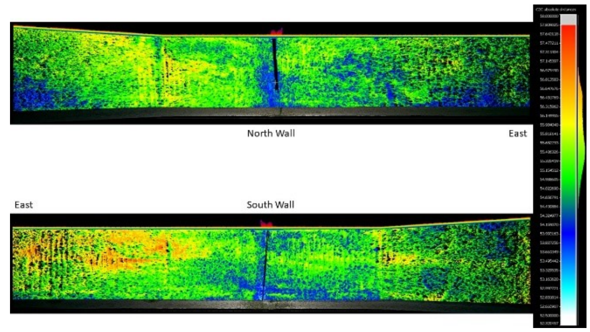

Fig 4. HCAEX wall to artificial plane comparison method.

Analysis of the region indicated in Fig 4 revealed uneven erosion on North and South walls as well as areas of interest that have eroded further than their surroundings. Features identified in previous camera inspections were validated as correct. These results establish the baseline from which surface change measurements from future deployments can be monitored. Previous visual inspections were taken at approximate 10' to 20' intervals based on the camera resolution and location making it difficult to accurately establish feature location within the tunnel. The LiDAR provides a more complete view of tunnel conditions especially with the identification of physical locations of those areas of interest along the inspection route.

Application of a LiDAR system for inspection in a dark, hazardous, GPS denied environment promises to be a viable option for future inspections. Not only is quantitative data obtained but erosion rates between inspections may be observed using a LiDAR system as an additional inspection method. The identification of erosion rates reduces uncertainty in safety function service life expectancy and allows for corrective actions to be implemented well in advance of any degradation that would compromise the facility safety function. Investment in a LiDAR system integrated on a tethered unmanned ground vehicle for tunnel inspections will yield similar results along the tunnel for the entire trip of the vehicle not just a localized tunnel segment obtained from these first two deployments.

REFERENCES

1. J. Plummer et al., “Savannah River Site H-Canyon Advancing Technologies for Remote Inspections,” *Waste Management Conference 2020*, Phoenix, Arizona, March 8-12, 2020.