Robotic Pipe Inspection Tool utilized for the Department of Energy High Level Waste Project at the Hanford Site - Environmental Management

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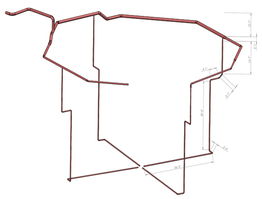
Pneumatic Pipe Crawler

The pneumatic pipe crawler is being designed to travel through the air supply lines, leading to the central plenum of AY-102, and provide live video feedback.

Requirements

The proposed inspection will be approximately 100 feet in length, requiring:

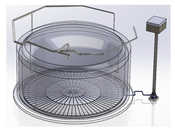
1. Crawling through pipes and fittings which are 3 and 4 inches in diameter
2. Climbing vertical runs
3. Providing live visual feedback
4. Tolerating elevated temperature (170 F)
5. Tolerating moderate radiation levels (85 rad/hr)
6. Providing a means for removal in the event of a malfunction



Proposed inspection

Design

The pneumatic pipe crawler is a worm type robot with a modular design, composed of interchangeable cylindrical modules connected with flexible links.

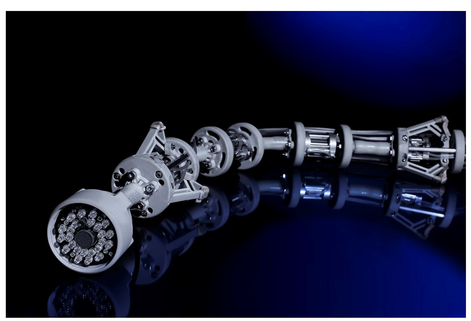


The design is an evolution of previous peristaltic crawlers developed at FIU, and utilizes pneumatic actuators to produce the contractions of the peristaltic motion, which does not require embedded electronics, with the exception of a camera.

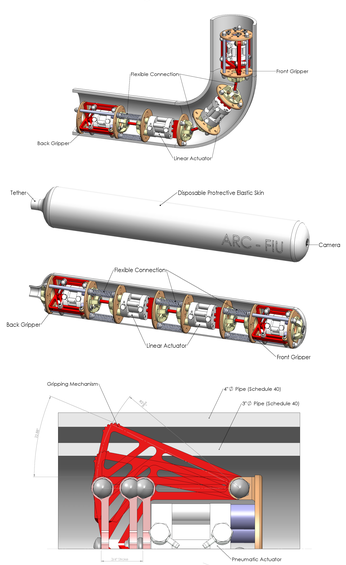
The primary advantage of using a peristaltic propelled crawler with this design is that the device can navigate inside a pipeline without using any external moving parts, such as wheels and continuous tracks. If needed, the device can be fully encapsulated with a disposable protective skin which is suitable for decontamination.

Another design advantage is associated with its modular design. With the addition of extra modules, it has the potential to be customizable for specific tasks, such as instrumentation, material sampling, and pipe repair.

Prototype



Conceptual design



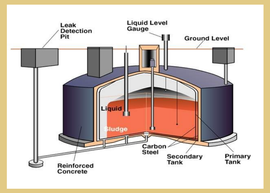
Path Forward

- Design and build real scale mockup test layout
- Develop delivery mechanism for easy deployment
- Provide feedback using other inspection parameters, such as
- temperature, humidity, and radiation level
- Design additional instrumentation modules for non-destructive pipeline inspection, such as magnetic flux leakage and ultrasound

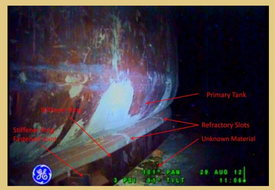
Background

The Hanford Site has 56 million gallons of radioactive waste left from the past production of weapons plutonium being held in underground tanks.

In August of 2012, radioactive waste was found in the annulus of the AY-102 double-shell tank at Hanford. This leak has prompted the need for inspection tools that can travel in confined radioactive areas and identify the location and potential cause of the leak.



Tank configuration

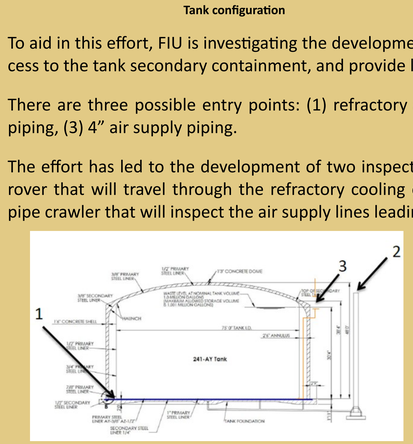


AY-102 leak

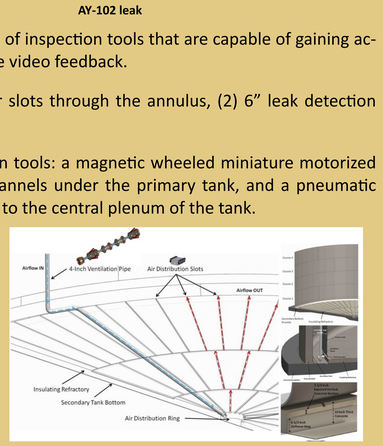
To aid in this effort, FIU is investigating the development of inspection tools that are capable of gaining access to the tank secondary containment, and provide live video feedback.

There are three possible entry points: (1) refractory air slots through the annulus, (2) 6" leak detection piping, (3) 4" air supply piping.

The effort has led to the development of two inspection tools: a magnetic wheeled miniature motorized rover that will travel through the refractory cooling channels under the primary tank, and a pneumatic pipe crawler that will inspect the air supply lines leading to the central plenum of the tank.



Tank entry points



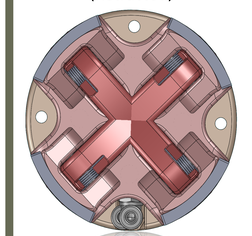
Inspection tool entry points

Acknowledgments

This research is sponsored by the U.S. Department of Energy Office of Environmental Management under cooperative agreement # DE-EM0000598, along with the FIU-DOE Science & Technology Workforce Development Program. Special thanks to DOE fellow mentor Anthony Abrahao.

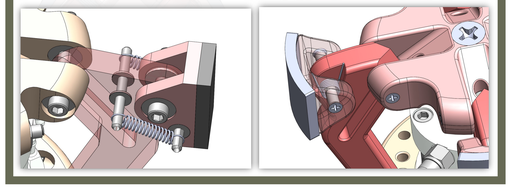
Gripping Module (Retracted)

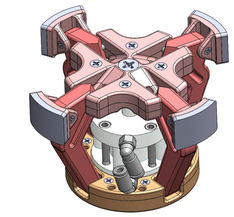
Gripping Module (Expanded)

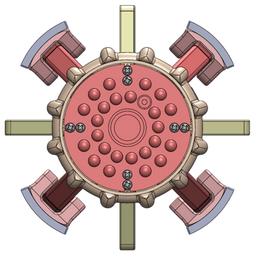


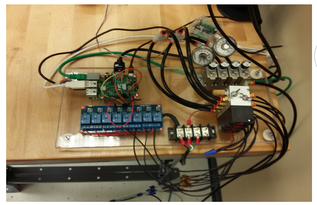
Old Grip Hinge

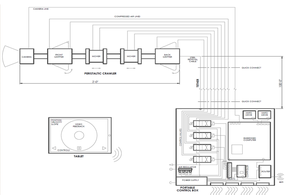
Revised Grip Hinge





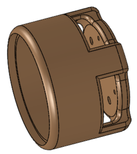




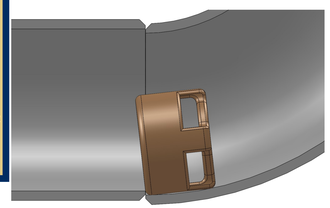


The crawler will be controlled by a rig designed to be compact and portable. The rig currently consists of a Raspberry Pi single-board computer, control valves, air regulator, and relays. The final product will also include hard drives, a router, and several fans to regulate the heat dissipation which will arise when the rig is enclosed in a small case.

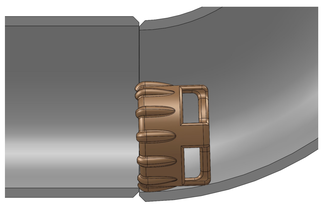
Old Design—Smooth surface



New Design—Surface ribbings included



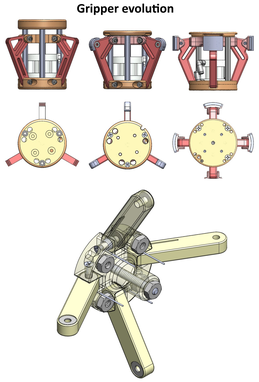
Prior to implementing the ribbed camera case, the sharp angle could get caught on any imperfect pipe connection.



The newer design of the camera case uses these ribbings to prevent any catching on the pipe division.

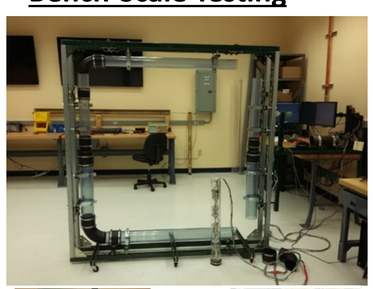
Camera Casing Improvement

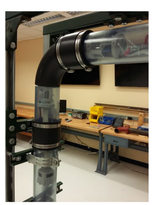
Gripper evolution

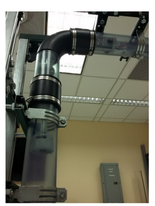


Newly Implemented Guiding Structure intended to keep the crawler pipe-centered

Bench-Scale Testing







Current design

The basic design is composed of five modules: a front camera, front and back grippers, and two middle movers.