Experimental Testing of Innovative High-Level Waste Pipeline Unplugging Technologies

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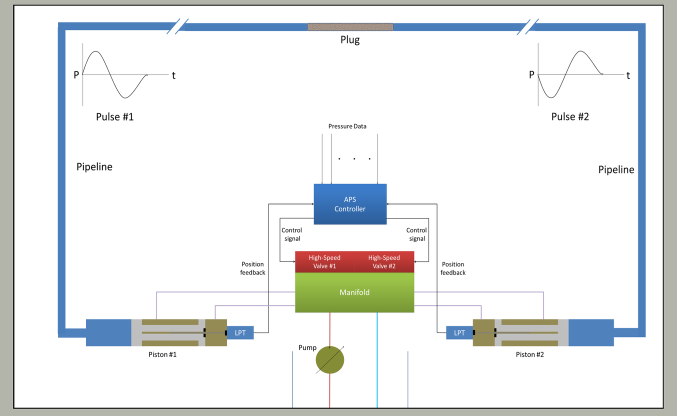
BACKGROUND

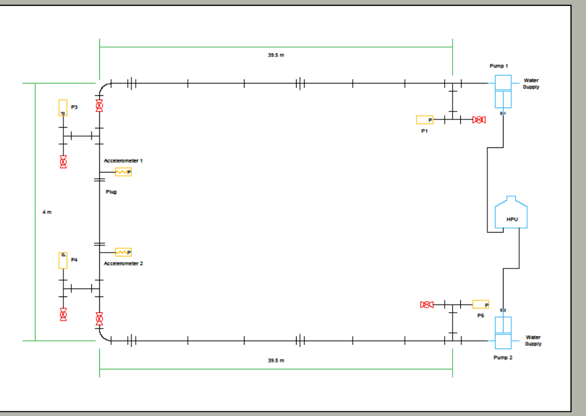
- Florida International University (FIU) is currently working on the development and optimization of two innovative pipeline unplugging methods: the asynchronous pulsing system (APS) and the peristaltic crawler system (PCS).
- Experiments were conducted on the APS in a 270 ft. large scale pipeline to determine how air in the pipeline influences the system's performance.
- Improvements were implemented to the third generation crawler system (PCS). The improvements include the re-design of the rims of the unit to accommodate a camera system that provides visual feedback of the

Asynchronous Pulsing System

- The asynchronous pulsing system (APS) utilizes two hydraulically-driven piston pumps that are driven by a hydraulic power unit with two electronically controlled high-speed valves that are driven by a controller that utilizes pressure transducer data, as well as position feedback from a piston position transducer (LPT) to determine the optimal valve throttle position.
- Previous experiments were conducted on the APS to determine how air in the pipeline influences the system's performance as well as determine the effectiveness of air mitigation techniques in a pipeline.
- Experiments were conducted to determine the effects of varying static pressure, amplitude of the pulse pressure and pulse frequency on an engineering scale pipeline. Research also focused on manufacturing a plug that had the necessary material characteristics that could not be removed by a static pressures less than 300 psi.



Asynchronous Pulsing System


Engineering Scale Test Loop P&ID

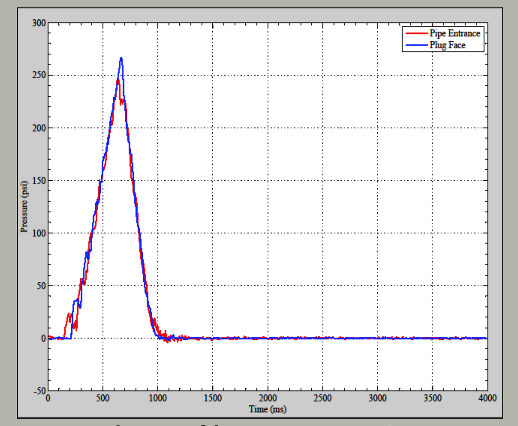

Engineering Scale Test Loop

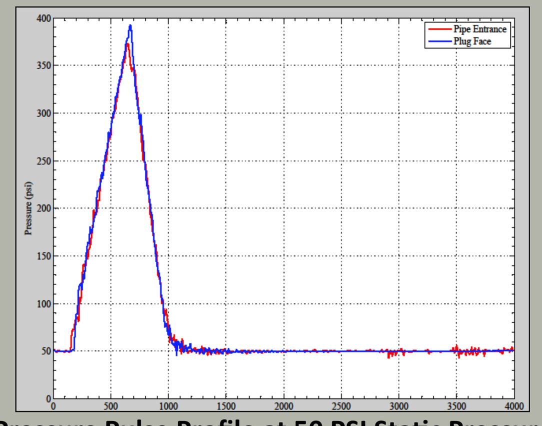

Pump


Power Unit

Pressure Pulse Tests

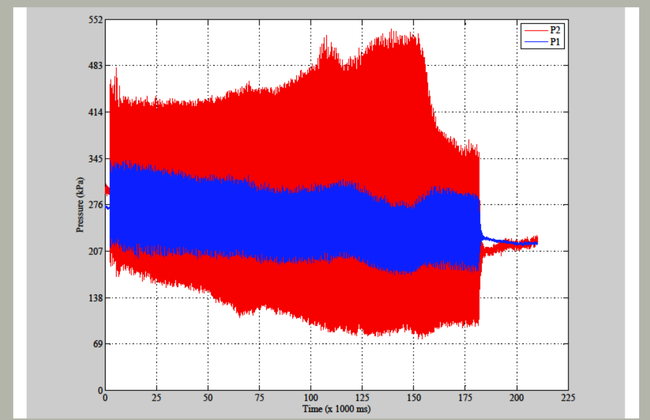
- Experiments were conducted on a fully flooded pipeline and with air quantities equal to the either half or full displacement of the pump. The pump's half and full displacements are 64.35 cm^3 and 127.1 cm^3, respectively.
- The pump was used to produce a 500 millisecond pulse in the pipeline.
- The pressure pulses for the scenarios were evaluated by comparing the inlet pressure transducer and the endpoint pressure transducer profiles.

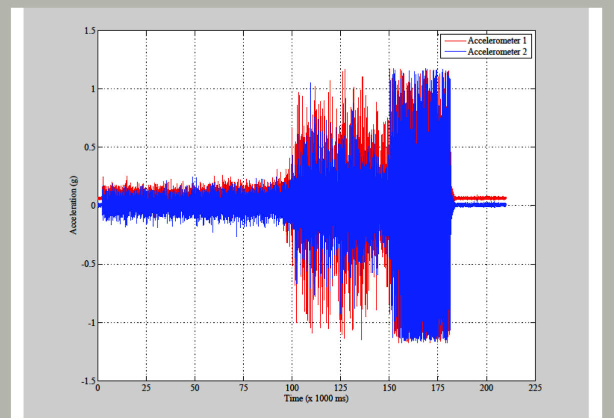

Pressure Pulse Profile at 0 PSI Static Pressure


Pressure Pulse Profile at 50 PSI Static Pressure

Unplugging Tests

- 3-ft. kaolin-plaster plugs were manufactured using different recipes until a blowout pressure of around 300 psi was obtained.
- Various pulse frequencies were used during the unplugging tests ranging from 0.5 to 2.0 Hz. Unplugging occurred at 0.5 & 1.5 Hz.
- As in the smaller loops, air entrapment in the pipeline hindered the system's performance due to the system's fixed volume pumps.


Pressure data for an unplugging at 0.5 Hz.


Accelerometer data for an unplugging at 0.5 Hz.


Kaolin-plaster plug before and after unplugging

Results

- After analyzing the data from asynchronous pulsing system test runs, it was observed that the system is capable of unplugging long pipelines.
- Just as in the smaller test loops, air entrapment in the pipeline hinders the asynchronous pulsing system performance due to the system's fixed volume piston pumps.
- A piston type pump system with a fixed water volume is very sensitive to the water/pipeline-volume ratio.
- Just as in the smaller test loops, air entrapment in the pipeline hinders the asynchronous pulsing system performance due to the system's fixed volume piston pumps.

Future Plans

- The next phase of work will utilize the data obtained from the experimental testing to develop a numerical analysis model that will be capable of predicting the system's performance on any length pipeline with any amount of entrapped air.

Peristaltic Crawler System

- The peristaltic crawler system (PCS) is a pneumatic/hydraulic operated pipeline unplugging and inspection technology that consist of a crawler unit, a tether-reel assembly, an unplugging tool, a visual feedback system, and a control station.
- The crawler unit propels itself by a sequence of pressurization and depressurization of cavities. The changes in pressure result in the translation of the vessel by peristaltic movements.
- The crawler unit is designed to navigate inside a pipeline having a 3 in inside diameter and negotiate through 90° elbows.
- Current configuration (tether length) and has maximum reach of 500 ft but it can be extended to 1000 ft.

Engineering-Scale Testing

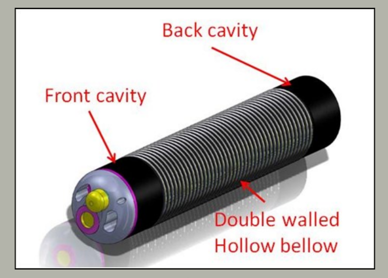
- Previous test conducted in a testbed consisting of two 3 ft PCV pipe sections coupled with a 90° elbow showed that the crawler can navigate with a speed at a speed of 38 ft/hr.
- To test the performance of the PCS on longer pipelines a 430ft carbon steel pipeline consisting of four straight sections an three 90° elbows was assembled.
- Differences in pipeline geometry between the carbon steel (ID 3.26 in) and PCV pipes (ID 2.83) created expansion requirements of the front and rear cavities that exceeded their initial design parameters.
- Manual pulling tests of the tether inside the engineering scale pipeline were conducted to predict the crawler requirements to navigate the testbed. A stainless steel wire was wounded to the tether to reduced the contact area with the pipeline.

Results

- Fatigue tests conducted showed that increasing the distance between the two clamps that hold the front and rear cavities to 0.75 in increases the life of the cavities to 15,000 cycles approximately (3,600 required to navigate 500 ft).
- Manual pulling force test showed that flooding the pipeline significantly reduces the coefficient of friction with the tether. The maximum pulling force recorded was 47 lb.
- Tests were conducted to determine the response of the crawler under different pulling force requirements.

Future Plans

- The navigational performance of the PCS will be tested in a 500 ft testbed.
- Unplugging operations using the engineering-scale testbed will be conducted using different plug simulants to evaluate the crawler's unplugging ability .



Rendering of the crawler

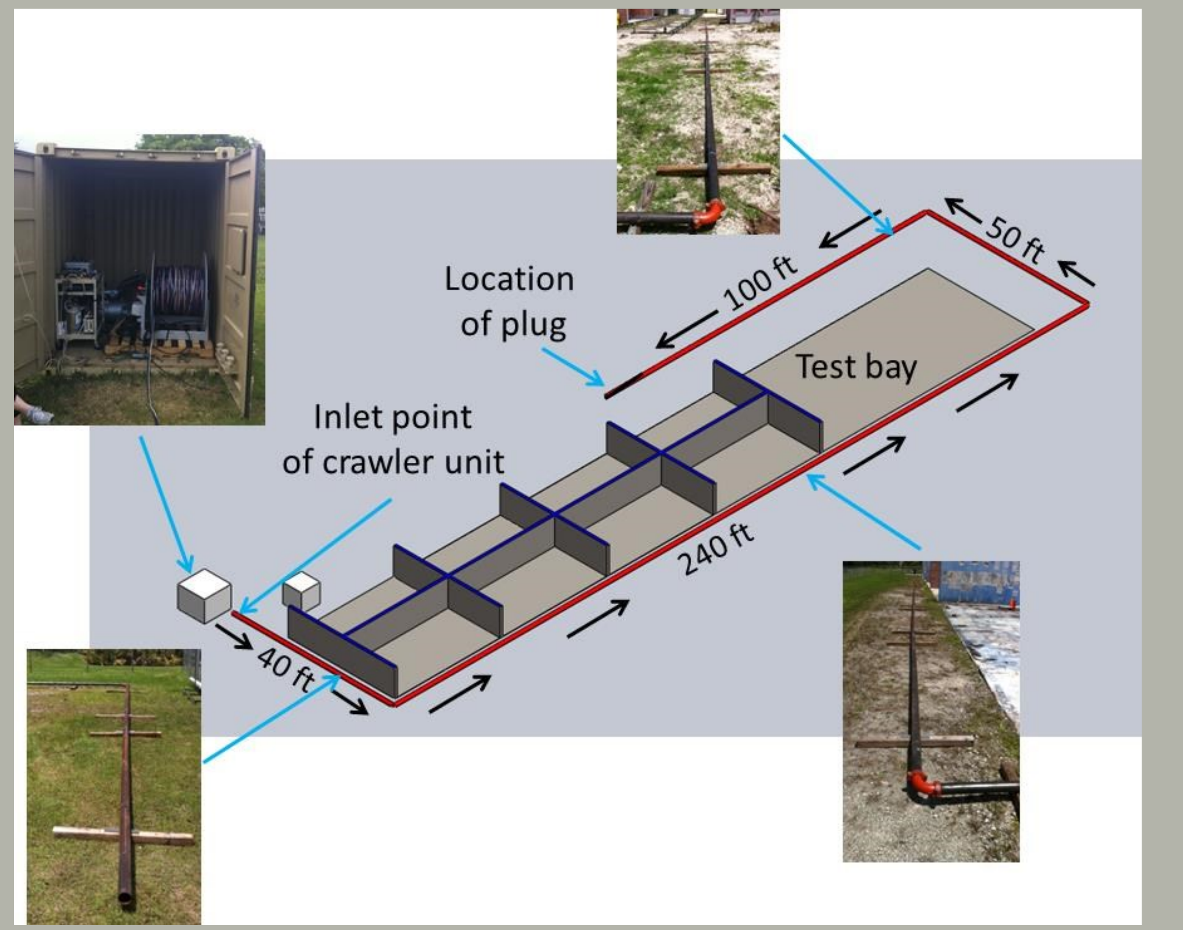

Front end of The crawler


Failure of cavity


Test of cavity material

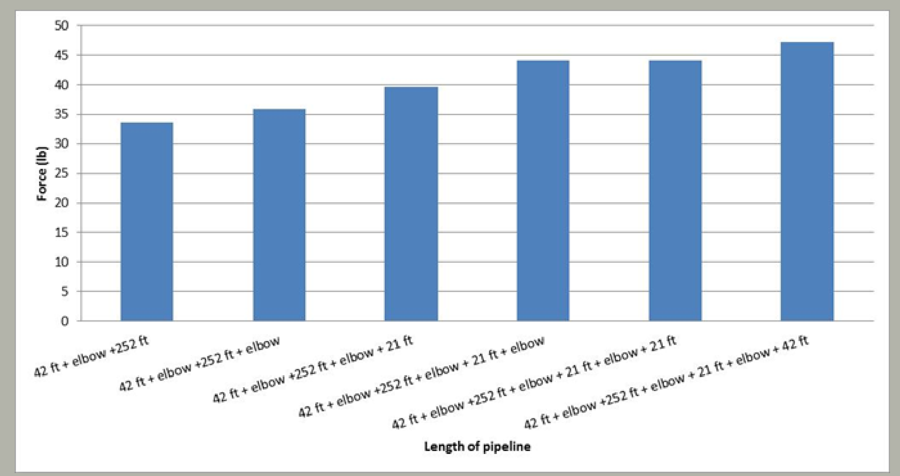

Fatigue fixture


Crawler designed for 0.75 in spacing between clamps



Engineering-scale testbed


Tether with stainless steel wire



Manual pulling force test results


Set-up used to test the performance of the crawler

			1st Trial			2nd Trial			3rd Trial			
Pounds	Bellow Pressure (psi)	Rim Pressure (psi)	Time (minutes. seconds)	Inches	Speed (ft/hr)	Time (minutes. seconds)	Inches	Speed (ft/hr)	Time (minutes. seconds)	Inches	Speed (ft/hr)	AVERAGE
0	10	80	6.08	15.81	**13.00**	6.57	16.50	**12.56**	7.46	20.69	**13.87**	**13.14**
5	10	80	5.01	13.00	**12.97**	5.22	11.63	**11.14**	5.20	12.13	**11.66**	**11.92**
10	10	80	3.38	8.25	**12.20**	5.08	11.75	**11.56**	3.59	8.88	**12.36**	**12.04**
Pounds	Bellow Pressure (psi)	Rim Pressure (psi)	Time (minutes. seconds)	Inches	Speed (ft/hr)	Time (minutes. seconds)	Inches	Speed (ft/hr)	Time (minutes. seconds)	Inches	Speed (ft/hr)	
0	20	80	5.06	10.50	**10.38**	5.03	11.81	**11.74**	4.50	11.63	**12.92**	**11.68**
5	20	80	5.16	9.75	**9.45**	5.20	11.38	**10.94**	5.21	11.44	**10.98**	**10.45**
10	20	80	4.17	7.50	**8.99**	4.31	9.38	**10.88**	4.36	9.25	**10.61**	**10.16**
15	20	80	6.10	10.69	**8.76**	6.25	11.25	**9.00**	6.41	12.06	**9.41**	**9.06**
20	20	80	7.28	13.13	**9.01**	6.19	11.38	**9.19**	7.13	10.50	**7.36**	**8.52**
25	20	80	7.44	9.00	**6.05**							

System response under different loads