Pipeline Unplugging Assessment and Recommendations for the Fernald Environmental Management Project

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Summary

An assessment team from Oak Ridge National Laboratory was contracted to identify commercially available methods for pipeline unplugging. The assessment team contacted various industrial companies, which provide pipeline unplugging services, technologies, and systems to determine their applicability for use at the Fernald Environmental Management Project near Cincinnati, Ohio. The team provided recommendations for Fernald's consideration. Fernald set specific criteria against which each pipeline unplugging method was evaluated. Six technologies were investigated: mechanical cleaning, hot tapping and plugging, hydroblasting, chemical cleaning, Hydrokinetics ™, and fluidic wave action. Based on the established requirements and constraints of this study, the assessment team recommended two technologies for unplugging systems applications at Fernald. Hydrokinetics was the preferred option with fluidic wave action as an alternative. The assessment team also recommended that an on-site demonstration be conducted by one or both of the proposed vendors.

1.0 Introduction

The Fernald Environmental Management Project (FEMP) near Cincinnati, Ohio, is preparing to remove the contents of two domed silos, which contain ~10,000 tons of radium-bearing, low-level waste. The waste, known as K-65 material, consists primarily of solids remaining from processing ores from the former Belgian Congo to recover uranium. The silos are 80 ft in diameter, 36 ft high at the center of the dome, and 26.75 ft to the top of the vertical sidewalls. The silos were constructed in 1951 and 1952 of concrete wrapped with steel post-tensioning wires, and the sides were covered with gunite. Earthen berms have been formed around the outside silo walls, and a radon collection system has been installed to reduce exposure levels to workers and releases to the environment.

Waste materials were originally transferred to silos 1 and 2 by pumping them in the form of a slurry. The waste solids settled and the supernatant was removed by overflowing from the decant ports, with the lowest port located 1 ft from the bottom of each silo. Silo 1 contains 115,900 ft^3 of K-65 waste and 12,600 ft^3 of bentonite clay. Silo 2 contains 100,400 ft^3 of K-65 waste and 11,100 ft^3 of bentonite clay (Bentogrout). The bentonite clay in both silos was added in 1991 in a layer over the existing K-65 waste to reduce the potential for radioactive emissions to the environment. The average thickness of the bentonite clay is estimated to vary between 6 in. and 2 ft. The average moisture level of the waste in silos 1 and 2 is ~30% and increases with depth.

The Accelerated Waste Retrieval (AWR) project will retrieve the majority of the K-65 waste from silos 1 and 2, transfer the material to interim storage tanks for staging before final remediation, reduce the radon concentration in each silo headspace, provide radon control during retrieval and material storage, clean the silos and equipment in preparation for system closure, and handle the secondary waste generated during the AWR Project. The AWR Project will use sluicing technology in conjunction with a submersible sludge removal pump to retrieve the K-65 material down to a heel approximately 20 in. deep. The Heel Retrieval Project will then retrieve the remaining waste. The residual waste must be removed to the point of "no visible material" to allow for the planned demolition of the silos.[1,2]

A cold test facility has been installed at the FEMP site to assess the performance of the AWR equipment and provide a facility to train the operators to be tasked with the day-to-day operation of the equipment. The cold test facility is located near the silos. Four-inch diameter PVC pipe is used to connect the discharge from the transfer pump in the cold test facility to the doubly contained carbon steel discharge line installed on the bridge work above the silos. The inner pipe is 4-in. diam sch 80 carbon steel pipe and the outer

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[1] Varma, V. K., Lewis, B. E, and Hughes, J., *Fernald Silos Remote Retrieval Tool Development*, ANS 10th International Topical Meeting on Robotics and Remote Systems for Hazardous Environments, Gainesville, FL, March 28-31, 2004.

[2] T. J. Abraham and J. F. Walker Jr., Cold Test Loop Integrated Test Loop Results, ORNL/TM-2004/259, Oak Ridge National Laboratory, UT-Battelle LLC, September 2003.

pipe is 8-in. diam pipe. The doubly contained carbon steel piping is used to connect the discharge from the waste retrieval system to four 750,000 gal receipt tanks.

A surrogate waste material is used in the cold test facility to simulate the physical properties of the K-65 material. The K-65 material contains a significant amount of lead (8.9%), iron (4.1%), and barium (4.4%). Therefore, this material is slightly denser, with a higher specific gravity (average 2.97, standard deviation of 0.13) than that of typical sands or minerals (specific gravity of 2.65). A physical surrogate was developed by PNNL, which consists of a combination of 23% crushed block material and 77% crushed limestone material.

1.1 Problem Description

Operational experience during cold testing at Fernald has shown that plugs can form in the PVC lines connecting the cold test facility to the steel transfer lines to be used with the actual silo waste retrieval system. Transfer line plugs formed on four occasions, three of which were located in the transfer pump and in a vertical section of the discharge from the pump. The fourth plug formed at multiple locations downstream of the transfer pump. The last plug formed after operating the transfer pump for ~7 min with a flow rate of ~200 gal/min. This plug required ~3.5 days to remove from the system. Plugging appears to occur when the flow drops below 8-12 ft/sec. The system was designed to be operated with a solid content in the range of 5 to 7 wt %. Higher concentrations are more desirable and therefore cold tests have been conducted in an effort to achieve 25 to 30 wt % solids. The velocity of the slurry in the transfer line is critical to the successful transfer of wastes. The heavier material can easily settle and accumulate on the walls of the transfer line to form a plug when the velocity is reduced. Administrative controls and alarms are being used to warn the operators when the flow in the discharge line drops below a preset limit (~250 gal/min) in an effort to minimize plug formation. As a result of the variable nature of the waste retrieval process, it is recognized that the possibility of the formation of a plug cannot be completely eliminated. Therefore a reliable method of safely and efficiently removing a plug is needed.

A kickoff meeting was held on June 10, 2004 at the FEMP site to further describe the problem and establish the requirement for the assessment. The assessment team met with engineers and operations personnel from Fernald and toured the cold test area and AWR installation. The assessment team was tasked with contacting appropriate industrial companies which provide pipeline unplugging services, technologies, and systems to determine their applicability for use at Fernald and to prepare recommendations for Fernald’s consideration. Specifically, this task will (1) determine methods that are commercially available and have a success record for unplugging lines that are plugged with materials having similar thixotropic characteristics as K-65 material and (2) identify vendors capable of providing either specialized equipment or equipment and services to rapidly unplug a plugged transfer line at Fernald. Special consideration will be required for handling radioactive wastes. A deployment plan will be developed and implemented by Fernald to solve this problem.

1.2 Requirements

Any pipeline unplugging system utilized at Fernald must satisfy the following requirements:

1. Safe to operate
2. Versatile system that is easy to operate by trained operations staff
3. Off-the-shelf, readily available, and proven
4. Compatible with existing piping and equipment configurations with minimal modification to existing systems – cleanouts throughout the pipe system provide access points – a drawing of a typical cleanout is provided in Fig. 1.
5. Maintain containment of system to prevent the release of radioactive materials
6. Capable of connecting/installing in remote and elevated access points – most access points are several meters above grade and may only be accessible via a man-lift
7. Does not add chemicals to the waste that are not already planned or present – no plug dissolution techniques are to be considered

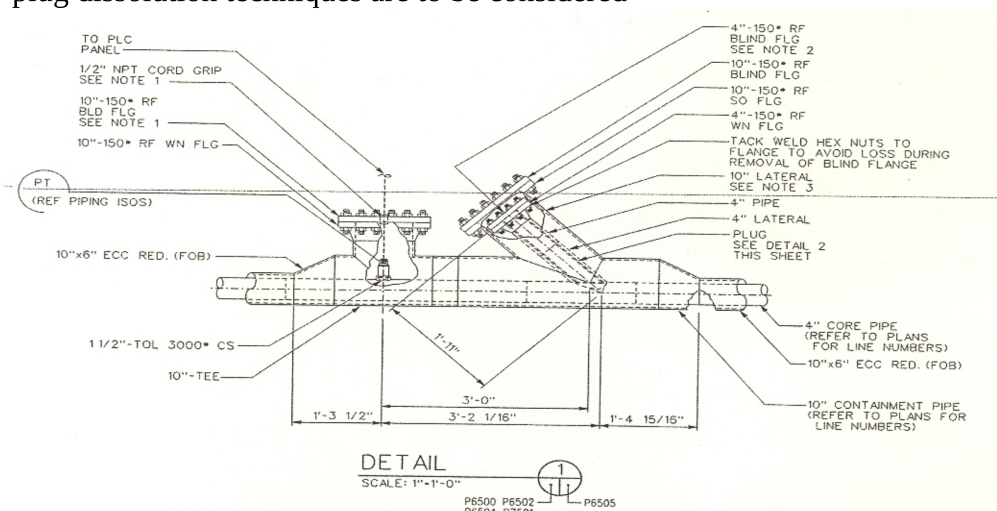


Fig. 1. Diagram of typical cleanout in the Fernald pipe system.

1.3 Goals

This effort has the following goals:

1. Conduct an assessment of proven pipeline unplugging technologies
2. Prepare a list of technologies and technology providers
3. Determine availability
4. Develop a list of pros and cons for each technology
5. Qualify vendors with promising technologies

6. Determine rough order of magnitude cost
7. Provide assessment and recommendations to Fernald

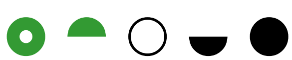
2.0 Assessment Methodology

Data collection methods for this assessment will utilize telephone contacts with vendors, internet searches for service and equipment providers, site visits (if appropriate and time permits), and review of published literature. A standardized data collection/survey form was used to guide the collection of information and ensure completeness. A subjective assessment of the technologies patterned after ORNL's Life Cycle Analysis methodology and based on the information collected on each vendor was conducted.[3] The requirements listed in Sect. 1.2 were used in the assessment to determine the best available technologies for application at Fernald. The form given in Table 1 was used to rate the technologies and to arrive at a recommendation.

Table 1. Alternatives evaluation form

Technology Alternative	Evaluation Criteria						
	Safe	Ease of Operation	Availability	System Compatibility	Environmental Impact	Remote Access	Foreign Materials
Technology 1							
Technology 2							
Technology 3							
Technology 4							
Technology 5							

Each criterion in Table 1 was assigned a subjective rating of Best, Better, Acceptable, Some concern, or Major concern based on information gathered during this study. The following graphical indicators were used to depict the ratings:



Best ←→ **Major Concern**

The information used to determine the rating for each rating factor is defined as follows:

1. Safe: Process/vendor safety record
2. Ease of Operation: Versatile system that is easy to operate
3. Availability: Off-the-shelf, readily commercially available, and proven

[3] Michael I. Morris, Katherine L. Yuracko, and Richard A. Govers, *Life Cycle Analysis for Treatment and Disposal of PCB Waste at Ashtabula and Fernald*, ORNL/TM-2000/254, Oak Ridge National Laboratory, UT-Battelle, LLC, Sept. 2000.

4. System Compatibility: Compatible with existing piping and equipment configurations with minimal modification to existing systems and/or operating conditions
5. Environmental Impact: Maintain containment of system to prevent the release of radioactive materials or contamination of unplugging equipment
6. Remote Access: Capable of connecting/installing in remote and elevated access locations
7. Foreign Materials: Does not add chemicals to the waste that are not already planned or present – no plug dissolution techniques

3.0 Pipeline Unplugging Technologies and Vendors

A variety of pipeline unplugging technologies are available. This section provides a comprehensive list of the available technologies as well as a brief description of each. Although many of the technologies listed in this section do not meet the specified requirements for application at Fernald, they have been included for completeness. In most cases a variety of vendors are available and capable of providing a particular pipeline unplugging technology. This section also provides a partial listing of the vendors and/or service providers for each of the technologies described.

3.1 Mechanical Cleaning

Mechanical cleaning encompasses a variety of technologies involving direct mechanical contact of the unplugging system with the pipeline obstruction. The technologies assessed include pigging and rotary pipe cleaning systems.

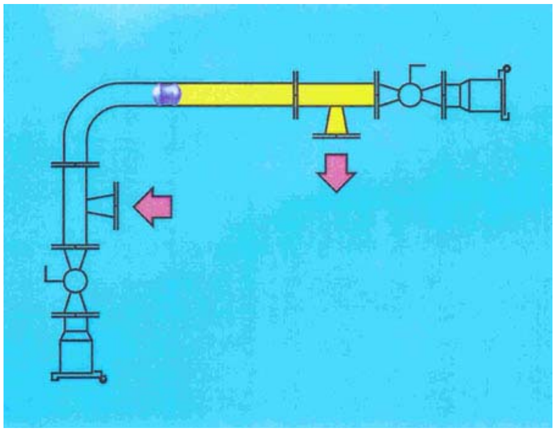


Fig. 2. Diagram of pigging application. Source: I.S.T. Pigging Technology, LLC web site, **http://www.istpiggingsystems.com/**

Pipeline pigging was developed in the 1950s and is used most commonly used in oil, gas, and petrochemical industries. The pig acts like a free moving piston inside the pipeline, as indicated in Fig. 2. It seals against the wall of the pipe with a number of sealing elements. Pigs can be used to clean debris from the line, remove residual product in the pipe, and gauge the internal bore of the pipe. Pigging generally requires specially designed launching and receiving vessels to introduce the pigs into the pipeline. A pig is inserted into the line to be cleaned by means of a launcher, an oversized barrel with a reducer mating to the existing line. Once in the launcher, a propelling medium (liquid or air) is introduced to launch the pig. Pigs can be propelled hydraulically or pneumatically. On the receiving end, the same over-sized barrel design is used as a receiver, allowing for easy removal of the pig from the line. Pigs are available for pipelines of diameters of 2-70 in. and possibly larger.

Pigging is a very useful technology for the purpose of product movement and line cleaning; however, pigging would not be the best method for line unblocking. It would be necessary to propel the pig in such a way to break through the plug and if not then the pig would add to the blockage. Pigs do not easily maneuver values, changes in pipe diameter, or bends. Pigging requires many modifications to the system in order to install the launchers and receivers. Pigging is primarily used in the following industries: chemicals, petrochemicals, paints, coatings, personal care products, pharmaceuticals, and foods and beverages.

The following are typical of vendors that provide pigging services:

I.S.T. Pigging Technology, LLC
431 Ohio Pike, Suite 211N
Cincinnati, Ohio 45255
Phone: (513) 528-4949
Fax: (513) 528-4994
Email: info@istpiggingsystems.com
Website: http://www.istpiggingsystems.com/
Contact: Charlie Holder
This company is not interested in this type of work. IST is involved in moving product from point A to B and line cleaning to prevent cross contamination not line unplugging.

Flowmore Services
P.O. Box 692005-300
Houston, Texas 77269
Phone: 1-800-356-9667
Fax: (281) 255-2385
Website: http://www.pipepigs.com/
Flowmore Services is shown as another representative but was not contacted.

Fig. 3. Rigid Snake. Source: RIGID tool web site at **http://www.ridgid.com/MenuDriver.asp?ParentID=650&ProdID=23**

Rotary pipe cleaning technologies encompasses many things. Ridgid Snake technology (Fig. 3), typically consists of a ~150-ft long semi-flexible steel rod with a cutting blade tip that is inserted inside the pipeline for cleaning blockages. The snake is housed inside a rotating drum, which is used to feed and retract the snake from the pipeline[4].

[4] M.A. Ebadian, *Plugging Prevention and Unplugging of Waste Transfer Pipelines, Part 1-Equipment Tests of Blockage Locating, Detecting, and Unplugging Technologies on the Full-Size Test Beds*, HCET-1998-M004-001-04, Hemispherical Center for Environmental Technology, Florida International University, 2002.

HydroChem's Roto-Mole line mole (Fig. 4) uses high pressure water to back flush under pressure, ridding lines of loosened debris. Rotating the hose provides 360° coverage with minimal water consumption. Hose friction losses are minimized, which provides more cleaning power at the nozzle tip and reduces downtime. Because it is fully automated and remotely controlled, workers are away from the cutting edge of the water, making the job of line mole jetting safer than other similar cleaning processes. It also requires fewer operators and is therefore economical to use. This technology is primarily used in water/wastewater systems and public works industries. HydroChem offers a wide variety of cleaning processes and equipment, including a Roto-Jet system (Fig. 5) for operation inside a variety of enclosed environments such as tanks, towers, reactors, piping, and ducts.

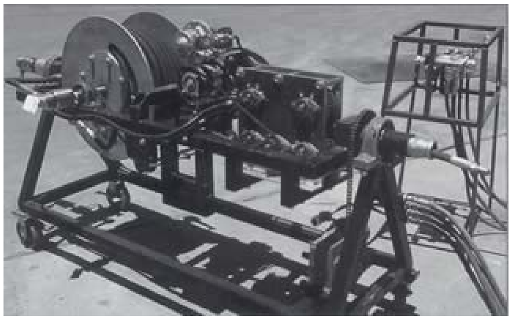


Fig. 4. HydroChem's Roto-Mole line mole. Source: HydroChem web site at **http://www.hydrochem.com/home.asp**

Fig. 5. HydroChem's Roto-Jet. Source: HydroChem web site at **http://www.hydrochem.com/home.asp**

The following vendors provide Rotary Cleaning services:

Roto-Rooter® Plumbing and Drain Services
1-800-GET-ROTO
Various locations nationwide

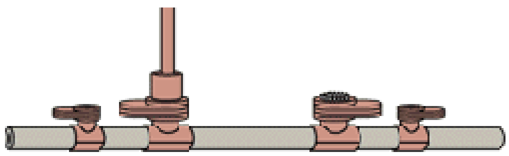
HydroChem
900 Georgia Avenue
Deer Park, TX 77536
Phone: 800-WE CLEAN, 713-393-5600
Fax: 713-393-5950
Email: CorpCom@HydroChem.com
Website: http://www.hydrochem.com/home.asp

3.2 Hot Tapping and Plugging

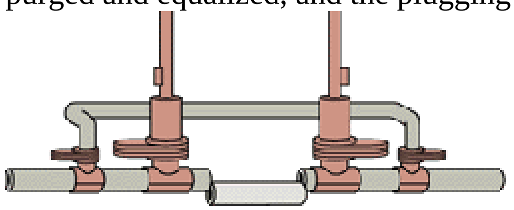
According to TD Williamson, Inc. this technology can be used on pipelines at pressures of 10-2220 psi and requires the following steps (Note: The illustrations used in this section were taken from the TD Williamson, Inc. web site at http://www.tdwilliamson.com/hottaptdw/ServBro/line_plugstop.html.

1. Four fittings are permanently secured to the plugged line.

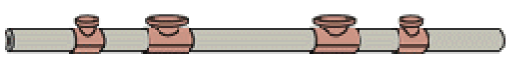
2. Temporary SANDWICH® valves are installed on the fittings, and taps are made through the valves.



3. Two STOPPLE® Plugging Machines are installed and product is diverted through the temporary bypass. The isolated section of piping is purged and modifications are made to the isolated pipe section. The new section is purged and equalized, and the plugging heads are retracted.



4. The temporary bypass is removed and LOCK-O-RING® plugs are installed in the STOPPLE® fittings with a tapping machine. All equipment is then removed and blind flanges installed on the fittings to complete the job. The method can be used on pipelines with pressures of 10-2220 psi.



One advantage to hot tapping and plugging is no line shutdown. Hot tapping and plugging would require modification to the current system only after a plug had formed, but the modifications would be extensive since double wall piping is used at Fernald. Training requirements would require that the vendor do the repair. Hot tapping and plugging is primarily used in oil and gas transmission pipelines, gas distribution systems, refinery and petrochemical facilities, power plants, industrial plants, offshore applications, water/wastewater systems, commercial construction, nuclear plants, and district heating systems.

The following vendors provide hot tapping and plugging services:

Kerr Engineering Sales
5940 Baum Square
Pittsburgh, Pennsylvania 15206
Phone: 800-245-3198

Fax: 412-362-6556
Email: sales@kerrengineeredsales.com
Website: http://www.kerrengineeredsales.com
Kerr Engineered Sales Company is a sales and service arm for manufacturers and service providers who outsource their field sales, and uses TDW for hot tapping and plugging.

T.D. Williamson, Inc
P. O. Box 2217
Tulsa, Oklahoma 74101-2217
Phone: 1-888-839-6766
Fax: 1-918-446-6327
Email: contact@tdwilliamson.com
Website: http://www.tdwilliamson.com/
Contact: Ken Yazelle, 918-447-5281, Dave Hicks 918-447-5543 (senior engineer), Larry Oden (project manager) 918-447-5542

Petersen Products Co
P.O. Box 340
421 Wheeler Avenue
Fredonia, Wisconsin 53021-0340
Phone: 800-926-1926
Fax: 800-669-1434
Website: http://www.petersen.cc/index.html
Contact: Phil Ludman
Petersen offers a service that is hot tapping and plugging with water blasting. The pipe is tapped and an inflatable plug is installed. Air, water, or steam is used to propel the plug as well as blast the blockage free.

3.3 Hydroblasting

Hydroblasting, also called water blasting or water jetting, is primarily used for sewer, drain, and pipe cleaning. Plugs are blasted free using a high pressure water stream. There are many disadvantages to using water blasting in the current situation. The burst pressure for the 4-in. diam Sch 80 piping used at Fernald is 9,700 psi – Water blasting technology uses high pressure pumping systems to supply water at pressures of 7,000 to 20,000 psi. Fresh water must be used in the system. Also, waste material would be blown back unto the operator, as indicated in the application shown in Fig. 6.

Fig. 6. Water blasting/water jetting technology application. Source: HydroChem web site at **http://www.hydrochem.com/home.asp**

Water blasting/water jetting is primarily used in power plants, industrial plants, water/wastewater systems, and public works.

The following vendors provide water blasting services:

US Jetting
850 McFarland Road
Alpharetta, GA 30004
Phone: 800-538-8464
Fax: 770-740-0297
Email: sales@usjetting.com
Website: http://www.usjetting.com/index.htm

HydroChem
900 Georgia Avenue
Deer Park, TX 77536
Phone: 800-WE CLEAN, 713-393-5600
Fax: 713-393-5950
Email: CorpCom@HydroChem.com
Website: http://www.hydrochem.com/home.asp
HydroChem provides several varieties of hydroblasting equipment, including a water lance. The water lance is very similar to water blasting. The lance is forced through the pipe using air or water pressure and actually cuts away the plug.

HydroChem also provides water laser services. The water laser is very similar to the water lance; only the laser uses much higher pressures, some up to 40,000 psi. The pressures necessary for the water laser is much too great for the current system. Also, waste material would be blown back unto the operator.

AAA Pipe Cleaning Corporation
7277 Bessemer Avenue
Cleveland, Ohio 44127
Phone: 800-542-0072, 216-231-1000
Fax: 216-341-6681
Email: aaapipe@en.com
Website: http://www.aaapipecleaning.com/

Roto-Rooter® Plumbing and Drain Services
1-800-GET-ROTO
Various locations nationwide

3.4 Chemical Cleaning

Chemical cleaning would require the addition of a cleaning agent to the pipe system in order to remove the blockage. Due to concerns over waste form compatibility, this technology is not recommended. This technology is primarily used in power plants, industrial plants, water/wastewater systems, public works, and the petrochemical industry.

The following vendor provides chemical cleaning services:

HydroChem
900 Georgia Avenue
Deer Park, TX 77536
Phone: 800-WE CLEAN, 713-393-5600
Fax: 713-393-5950
Email: CorpCom@HydroChem.com
Website: http://www.hydrochem.com/home.asp

3.5 Hydrokinetics™

The Hydrokinetic™ process is based on the induction of sonic resonance within a cleaning water stream. This sonic resonance travels through the water stream and transfers vibrations to both the pipe and the blockage, as diagramed in Fig. 7. A pig may also be used in conjunction with this technology and is shown in part 3 of Fig. 7 as an optional step in certain applications. The use of pig is not envisioned for the Fernald application. Because of the different compositions of the pipe wall and the blockage material, the blockage and the pipe wall vibrate at different frequencies, thus breaking the cohesive bond between them and allowing the blockage to be expelled from the pipe. By amplifying the pulsation with a high-pressure plunger pump, the water stream accelerates to achieve a velocity of 2,100 ft/s. The generation of the sonic vibration takes a few milliseconds to complete, and the tube or pipe being cleared is exposed to the sonic wave for only a fraction of the process time. A maximum frequency of 11,250 vibrations per minute can be achieved, far below the number of cycles per second needed to cause metal fatigue in even soft metals such as copper-nickel alloys or copper.

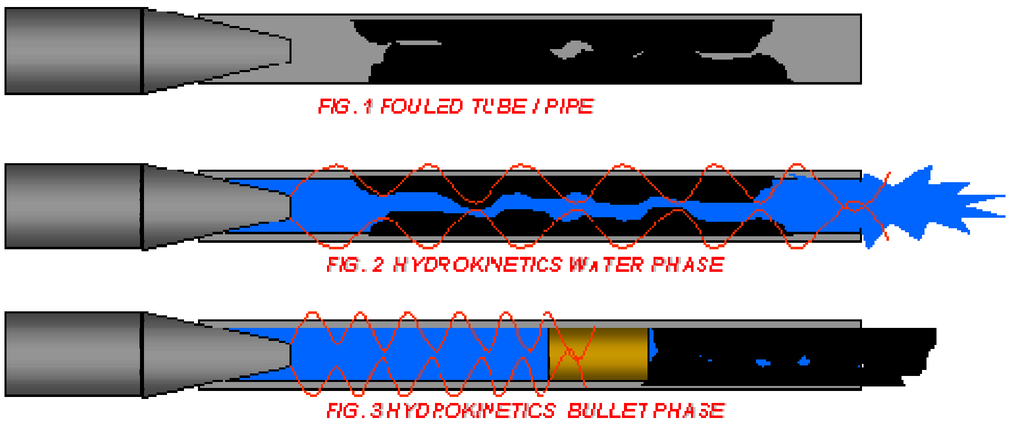


Fig. 7. Diagram of the application of hydrokinetic technology. Source: AIMM Technologies web site at http://www.aimmtechnologies.com/

This process is unaffected by piping configuration or distance from plug. It can be operated remotely with minimal exposure. Process line fluid does not come in contact with equipment. It typically requires no system modification; hook up to single access point connection. Operating equipment is minimal; consisting of a pump skid and valve operating console. Operation is simple and mobilization/demobilization is quick and easy. Unplugging time is effected by distance from entry port but not length of plug. However, some plugs may require pressures up to 10,000 psi. Expected pressures in the Fernald application are in the range of 500 to 2,500 psi. This patented technology is presently available from only two vendors and has primarily been applied in the chemical, petrochemical, and public works industries.

The following vendors provide Hydrokinetics™ service:

AIMM Technologies
111 35th Street South
Texas City, TX 77590
Phone: 409-945-5414
Fax: 409-945-6022
Email: www.aimmtech@wt.net
Website: www.aimmtechnologies.com
Contact(s): Brooks Bradford and Ralph Garcia
AIMM was visited and is discussed in detail later in the report.

Tube Cleaning Technologies
1480 East Highway 6
Alvin TX 97511
Phone: 281-842-1904
Fax: 281-842-1905
Contact: Danny Blackwell

3.6 Fluidic Wave Action

Fluidic Wave Action technology is based on a fluid wave-action principle that operates much like ocean wave-action on beach erosion coupled with positive and negative pressure pulses that tend to loosen the blockage. The cleaning process can be aided by use of a solvent in lieu of water. It can operate on a long pipeline that has drained down below a blockage. The system consists of a water/solvent tank, pressurized/vacuum vessel, portable air compressor, jet pump pairs and valve manifold, fluidic control unit, vacuum finishing pump, system controller, and system module, shown in Fig. 8. A vacuum pump is used to evacuate any air that may be present in the pipeline below the blockage in elevation. Once a vacuum has been established, a ball valve is opened, and water or other solvent is allowed to back-fill the pipeline. The fluidic control system is then used to provide pressure and vacuum to the fluid in a cyclic manner. During the drive cycle, fluid impacts the blockage as a wave flowing under the air bubble at the high point of the blockage, and during the suction cycle, water retreats away from the blockage. These cycles are repeated many times until the blockage is eroded away. The frequency and duration, as well as the pressure, of each cycle can be controlled via the fluidic control unit. This, coupled with the dissolving action of a selected solvent (if needed) and the physical action of the vacuum and pressure cycles, works to both erode and loosen the blockage. This pipeline unplugging method is unaffected by the piping configuration or the distance from the plug and can be operated remotely with minimal exposure to the operators. The method typically requires no system modification and requires only a single access point connection. Process line fluids do come in contact with the equipment, but are contained. The technology has been demonstrated at Florida International University (FIU) for line unplugging operations but has not been used in an actual field application. AEA Technology was the only company found that may be able to supply this technology. Fluidic wave action technology has primarily been applied in the nuclear industry.

Fig. 8. Equipment and control module used in the FIU demonstration of the AEA Technology Fluidic Wave Action process. Source: M.A. Ebadian, *Plugging Prevention and Unplugging of Waste Transfer Pipelines, Part 1-Equipment Tests of Blockage Locating, Detecting, and Unplugging Technologies on the Full-Size Test Beds*, HCET-1998-M004-001-04, Hemispherical Center for Environmental Technology, Florida International University, 2002.

The following vendor provides Fluidic Wave Action technology:

AEA Technology
184 B Rolling Hill Rd
Mooresville, North Carolina 28117
Phone: 704-799-2707
Fax: 704-799-6426
Email: paul.murray@aeatech.com
Contact: Paul Murray

4.0 Technology Ratings

Table 2 summarizes the ratings for each of technologies assessed during this brief study. The methodology described in Sect. 2 was used to arrive at the indicated ratings.

Table 2. Completed alternatives evaluation form for the technologies surveyed

Technology Alternative	Evaluation Criteria						
	Safe	Ease of Operation	Availability	System Compatibility	Environmental Impact	Remote Access	Foreign Materials
Hydrokinetics	◉	◉	◉	◓	◉	◉	◉
Fluidic Wave Action	◉	◉	○	◉	◓	◉	◉
Hydroblasting	○	◓	◉	○	◒	◒	◉
Mechanical Cleaning	◓	◒	◉	○	◒	●	◉
Hot Tap	◒	○	◉	◒	◓	◒	◉
Chemical Cleaning	◓	◓	◉	○	◉	◉	●

◉ ◓ ○ ◒ ●

Best ←→ Major Concern

5.0 Recommendations

Based on review of the available pipeline unplugging technologies and the identified requirements the following recommendations are made:

1. The following technologies appear to offer the necessary flexibility and ease of use to meet the identified requirements for application at Fernald. Additional information on each of these technologies is presented in Appendix I.
    a. Hydrokinetics™
    b. Fluidic Wave Action
2. Regardless of the technology selected, cold checkout of the system is advisable prior to hot deployment.
3. Further assessment of the applicability of the recommended technologies should be conducted to ensure compatibility with Fernald operations and planned deployment schedules.

Appendix I: Completed Pipeline Unplugging Vendor Survey Forms for Recommended Technologies

Pipeline Unplugging Vendor Survey Form for Hydrokinetics™ Technology Provider AIMM Technologies

Company Contact Information
AIMM Technologies
111 35th Street South
Texas City, TX 77590
Phone: 409-945-5414
Fax: 409-945-6022
Email: aimmtech@wt.net
Website: www.aimmtechnologies.com
Contact(s): Brooks Bradford, and Ralph Garcia

Process name: HYDROKINETICS™

Process description: The Hydrokinetic™ process is based on the induction of sonic resonance within a cleaning water stream. This sonic resonance travels through the water stream and transfers vibration to both the pipe and the blockage. Because of the different compositions of the pipe wall and the blockage material, the blockage and the pipe wall vibrate at different frequencies, thus breaking the cohesive bond between them and allowing the blockage to be expelled from the pipe. By amplifying the pulsation with a high-pressure plunger pump, the water stream accelerates to achieve a velocity of 2,100 ft/s. The generation of the sonic vibration takes a few milliseconds to complete, and the tube or pipe being cleared is exposed to the sonic wave for only a fraction of the process time. A maximum frequency of 11,250 vibrations per minute can be achieved, far below the number of cycles per second needed to cause metal fatigue in even soft metals such as copper-nickel alloys or copper.

Advantages:
1. Unaffected by piping configuration or distance from plug.
2. Can be operated remotely, minimal exposure.
3. Non-intrusive, process line fluid does not come in contact with equipment
4. Typically requires no system modification; hook up to single access point connection.
5. Operating equipment minimal consisting of pump skid and valve operating console.
6. Operation simple
7. Quick and easy mobilization and demobilization.
8. Unplugging time effected by distance from entry port but not length of plug.
9. Manual or automated system.

10. Commercially available.

Disadvantages:

1. For some plugs may require pressures up to 10,000 psi. Expected pressures in this application up to 2,500 psi.
2. Patented process only one other company found that may be able to supply this technology.

Company safety record: Zero recorded accidents for the company and the process.
Worker's compensation Experience Modification Rate (EMR): 0.77 FY03

Failure rate and reasons for failures: Low pressure and/or small diameter piping where unplugging equipment could not operate at the needed pressure. Acrylic material type plugging also can cause problems

Company size (employees, sales): 30 employees (average), which fluctuates depending on work load. ~$3 Million (FY-03)

Number of years in business: 15

Insurance: Zurich North America

Industries served: Chemical, petrochemical and public works

List of clients and references: At end of report

Comparison with competing technologies: Hydroblasting, chemical cleaning, mechanical cleaning

Current projects: Ongoing services to the chemical and petrochemical industry

Experience working with DOE? Sites and Projects: FIU demonstration only.

Radioactive environment experience: None

Experience with various lengths, diameters, and materials of piping: Have processed the whole gambit of piping. Low pressure rated lines could hinder process.

Experience with plugs of various materials (i.e. $CaCO_3$): Many different kinds

Maximum size of plugs cleared and time required: Up to 36-in. diam, and 100+ ft long plug. Time relative to the distance from the plug. A few minutes up to worst case of several days.

Experience with closed systems and/or remote operations: System is especially effective in this environment – See advantages.

Contracting services:

Rent or lease: ~$9-15K/month depending on length of lease.
Service on as needed basis: $20-50K
Purchase: Probably not. Available
Demonstration Cost: AIMM would perform at no cost (Provided if demonstration was successful AIMM would be awarded a lease agreement)

System connections needed (size and type): Single flange – Variable size and type.

Number of people required to operate: 2-3

Amount of training required: One week for this single application. Training is dependant on the type of application. There is some "art or technique" involved.

References: Checked two references (Bayer and Eastman) both said that AIMM has been able to handle all their plugging problems effectively and efficiently. FIU pipe plugging study project manager, Marshall Allen felt the hydrokinetic technology had the best chance of success for the silo application.

Other: Mike Morris and Jennifer Ladd- Lively visited AIMM on June 16, 2004. They observed a demonstration of the process cleaning a heat exchanger. General comment from the demonstration; "The equipment and operation of it are quite simple but very effective."

Photographs:

Fig. 9. Typical installation of Hydrokinetic™ System.

Fig. 10. View of partially plugged line before use of Hydrokinetics™.

Fig. 11. Solidified line plug removed using Hydrokinetics™.


Fig. 12. Calcium carbonate line plug removed using Hydrokinetics™.


Fig. 13. Trailer mounted high pressure pump.

Fig. 14. Control system for Hydrokinetics™ system.

PARTIAL CLIENT LISTING – REFERENCE LIST

The Atlantic Group 5426 Robin Hood Rd. Norfolk, Virginia USA 235**13** Attn: John McLaughlin Marine Operations Phone: 800-446-8131 E-mail: jmclaughlin@atlanticgrp.com	Numerous exchangers aboard ships and Power Plant Condensers. Fouling material ranged from totally blocked tubes to those with marine life and algae.
Aqua Drill International 1300 FM 646 East Dickinson, TX 77539 Attn: Chris Geppert President Ph: 281-337-0900 Email: Thomas@aquadrillinternational.com	Various exchangers, pipes, and tank cleaning applications. Pipe sixes ranged from ½- to 8–in. diam with multiple “90’s” and “T’s”.

Bayer Chemical 8500 West Bay Road Baytown, Texas USA 77520 Attn: Roger Burwell Maintenance Manager Phone: 281-421-0364 E-mail: roger.burwell.b@bayer.com	Numerous pipe and exchangers plugged with various types of plastics; HDPE, LDPE, Makrolon, BPA, etc. Fouling ranges from very hard to film.
Chevron Phillips Chemical Puerto Rico Core Inc. Road 710, Bo. fLas Mareas Guayama, P.R. 00784 Attn: Carlos E. Pales Ph: 787-864-1515 x 2293 Email: palesce@cpchem.com	Crude furnace – 8 Pass – 2 ½ in.-diam tubes. All passes were 100% blocked.
Chevron Phillips Chemical Puerto Rico Core Inc. Road 710, Bo. fLas Mareas Guayama, P.R. 00784 Attn: Hector Marin Ph: 787-864-1515 x 2293 Email: marinha@cpchem.com	Multiple pipes.
Chevron Phillips Bartlesville, Oklahoma USA Attn: Nathan Stacy Senior Research Engineer Phone: 918-661-9596 E-mail: nestacy@ppco.com	Pipe cleaning of 1.5 mile 8-in. diam. line blocked with Styrene.
ConocoPhillips Alaska, Inc. Kuparuk Field Planners Office P.O. Box 196105 Anchorage, AK 99519-6105 Attn: Cal Davison / Brett Alexandra CPF-1 & CPF-2 Field Planner Phone: 907-659-7321 E-mail: n1063@conocophillips.com	Production crude heaters and coolers. Crude -water – sand – fouling material.

<u>ConocoPhillips Alaska, Inc.</u> Kuparuk CPF-1 Unit P.O. Box 196105 Anchorage, AK 99519-6105 Attn: Mark Jerling / Tom Austin Facility Engineer Phone: 907-659-7332 E-mail: N1066@conocophillips.com	3–in. OD Pipe 1600 ft long – oily waste line.
<u>ConocoPhillips Alaska, Inc.</u> Alpine Operations P.O. 196860 Anchorage, AK 99519-6860 Attn: David Earl Senior Facility Engineer Phone: 907-670-4039 E-mail: alp1201@conocophillips.com	Production crude coolers (2000 tubes) and various short sections of pipes from crude production.
<u>DOW Chemical USA</u> 2301 North Brazoport Blvd. Freeport, Texas USA 77541 Attn: Jack Russell Process Cleaning Subject Matter Expert Maintenance Technical Services Phone: 979-238-2382	Expert on cleaning process.
<u>DOW Chemical USA</u> 2301 North Brazoport Blvd. Freeport, Texas USA 77541 Attn: Johnny Sweatt Maintenance Planner/Scheduler Phone: 979-238-9906 E-mail: jrsweat@dow.com	Perform various heat exchanger and pipe cleaning jobs in 3 different units – blocks at Dow. Large diameter heater – tube 12-in. diam and 200 ft long
<u>DOW Chemical USA</u> P.O. Box 150, Bldg. 807 Plaquemine, Louisiana 70765 Attn: Ray LeJeune Process Technologist / Polyethylene A Phone: 225-353-4005 E-mail: rtlejeune@dow.com	Various pipe (2- to 10-in. diam) plugged with polyethylene.

<u>DOW Chemical</u> PO Box 50 Hahnville, LA 77005 Attn: Brad Hatfield Maintenance Engineer Phone: 985-783-3897 E-mail: bahatfield@dow.com	Removed approximately 40-ft long plug of polymer from process piping. Cleaned 3–in. diam line from tank farm to reactor approximately 1500 ft.
<u>DuPont</u> DuPont Packing and Industrial Polymers Sabine River Works FM 1006 P.O. Box 1089 Orange, Texas USA 77630 Attn: Dan Lynd Contract Admin Phone: 409-886-6106	Wax structure coolers, hypersuction coolers, suction coolers, and recycle discharge coolers, assorted piping, and reactor tails line.
<u>DuPont</u> DuPont Packing and Industrial Polymers Sabine River Works FM 1006 P.O. Box 1089 Orange, Texas USA 77630 Attn: Natalie Hayes Division Engineer Email: natalie.g.hayes@usa.dupont.com	
<u>Equate Petrochemicals</u> Ahmadi (Kuwait City), Kuwait Attn: Qassem Deshti Maintenance – Reliability Engineer PO Box 9717 Ahmadi 61008, Kuwait Tel: 965-326-0326 Email: qassemdi@shb.equate.com	Cleaning of Cycle Gas Cooler
<u>EquiStar Chemical</u> Channelview, Texas USA Attn: John Swanson OP1 Unit Superintendent Phone: 281-452-8888	2.3 Miles of 4–in. diam line.

EXXONMobil Plastics P.O. Box 1607 Baton Rouge, Louisiana USA Attn: Richard Bowman Maintenance Superintendent Phone: 225-977-6255	Various high and low pressure piping of 1.0- to 6-in.diam and Serpentine coolers.
EXXONMobil Chemical P.O. Box 241 Baton Rouge, Louisiana USA 70821-0241 Attn: Kent Allain Mechanical Supervisor Phone: 225-977-8357	Exchanger plugged with cobalt plated catalyst.
EXXONMobil 3700 West 190th Street Torrance, California 90509-2929 Attn: John Turner Maintenance Special Projects Planner Phone: 310-212-2897 Email: John.w.turner@exxonmibil.com	
EXXONMobil 3700 West 190th Street Torrance, California 90509-2929 Attn: W.G. (Bill) Blashford Turnaround Planner Phone: 310-212-4422 Email: William.g.blashford@exxonmobil.com	
EXXONMobil 3700 190th Street, 102 Hinze Building Torrance, CA 90509 Attn: Evan Hyde Advanced Engineer Phone: 310-212-1905 Email: Evan.p.hyde@exxonmobil.com	
Kellogg Brown & Root 8500 West Bay Road Baytown, Texas USA 77520 Attn: Roy Weesner Maintenance Superintended Phone: 281-383-6448 E-mail: roy.weesner.b@bayer.com	Exchangers and piping fouled with polypropylene and misc. plastics. Exchangers ¾-in. diam, reboilers, Fin-Fans, and piping 1- to 8-in diam.

Methanex Limited Chile Cape Horn Facility P.O. Box 64D Punta Arenas, Chile Attn: Pedro Salas Chief Maintenance Engineer Phone: 56-61-202230 Email: psalas@methanex.com	Multiple re-boiler cleaning projects.
Noltex 12220 Strange Road LaPorte, Texas USA 77572 Attn: Randy Boeding Plant Manager Phone: 281-842-5057 E-mail: randy.boeding@noltex.com	Assorted piping ½- thru 8–in. diam throughout the entire plant.
North Atlantic Refining Limited P.O. Box 40 Come By Chance, Newfoundland Canada A0B 1N0 Attn: Nola Chaytor Facility Engineer Phone: 709-463-3484 E-mail: nolachaytor@na-refining.nf.ca	18 Banks of fin-fans and reboilers.
Shell Chemical Company (Bassell) 473 Hwy 3142 Taft, Louisiana USA 70057 Attn: Chad Weidert Make Change Coordinator Phone: 504-465-5232 E-mail: CW315867@msxscc.shell.com	180-ft U-bundle plugged with tar like substance.
Shell Chemicals America P.O. Box 100 Deer Park, Texas USA 77536 Attn: Christy Duncan Plant Engineer Phone: 713-246-4351 E-mail: cbduncan@shellus.com	4–in. diam crude furnace.

Shell Gabon B.P. 146 Port Gentil Republique Gabonaise Attn: Edwin Blom Head of Maintenance OMS/4 Phone: 241-55-8502 E-mail: edwin.e.blom@shellgb.shell.com	Production crude heat exchangers plugged tubes from oil productions; crude, water, sand, wax.
Shell Global Solutions International B.V. Fluid Flow and Flow Assurance Badhuisweg 3 1031 CM PO Box 38000 1030 BN Amsterdam, The Netherlands Attn: Jeroen LMM Oomen Tel: +31 (0) 20 630 2117 - Mobil: +31 (0) 65 512 3394 Email: jeroen.oomen@shell.com	Process cleaning experts.
Solvay Polymers P.O. Box 1000 Deer Park, Texas 77536-1000 Attn: John MacDonald Maintenance Planner Phone: 713-307-3907 E-mail: john.macdonald@solvay.com	Perform various heat exchanger and pipe cleaning.
Texas Eastman P.O. Box 7444 Longview, Texas USA 75607 Attn: Steve Lewis Phone: 903-237-5757	Various lines including double piped serpentine cooler, various exchangers.
Sterling Chemicals, Inc. PO Box 1311 Texas City, TX 77592-1311 Attn: Lloyd H. Johnson Maintenance Team Leader – Styrene Phone: 409-942-3346 E-mail: ljohnson@sterlingchemicals.com	80 Banks of Fin-fans and assorted 2- thru 4–in. diam piping.

Sterling Chemicals, Inc. PO Box 1311 Texas City, TX 77592-1311 Attn: Tommy Baker Maintenance Planner Phone: 409-942-3346 E-mail: tlbaker@sterlingchemicals.com	Various piping to remove sea water fouling and misc. styrene lines.

Completed Pipeline Unplugging Vendor Survey Form for Fluidic Wave Action Technology Provider AEA Technologies

Company Contact Information
AEA Technologies
184 B Rolling Hill Rd
Mooresville, North Carolina 28117
Phone: 704-799-2707
Fax: 704-799-6426
Email: paul.murray@aeatech.com
Contact: Paul Murray

Process name: Fluidic Wave Action

Process description: AEA Technologies' unplugging process is based on a fluid wave-action principle that operates much like ocean wave-action on beach erosion coupled with positive and negative pressure pulses that tend to loosen the blockage. The cleaning process can be aided by use of a solvent in lieu of water. It can operate on a long pipeline that has drained down below a blockage. The system consists of a water/solvent tank, pressurized/vacuum vessel, portable air compressor, jet pump pairs and valve manifold, fluidic control unit, vacuum finishing pump, system controller, and system module. A vacuum pump is used to evacuate any air that may be present in the pipeline below the blockage in elevation. Once a vacuum has been established, a ball valve is opened, and water or other solvent is allowed to back-fill the pipeline. The fluidic control system is then used to provide pressure and vacuum to the fluid in a cyclic manner. During the drive cycle, fluid impacts the blockage as a wave flowing under the air bubble at the high point of the blockage, and during the suction cycle, water retreats away from the blockage. These cycles are repeated many times until the blockage is eroded away. The frequency and duration, as well as the pressure, of each cycle can be controlled via the fluidic control unit. This, coupled with the dissolving action of a selected solvent (if needed) and the physical action of the vacuum and pressure cycles, works to both erode and loosen the blockage.

Fig. 15. Equipment and control module used in the FIU demonstration of the AEA Technology Fluidic Wave Action process. Source: M.A. Ebadian, *Plugging Prevention and Unplugging of Waste Transfer Pipelines, Part 1-Equipment Tests of Blockage Locating, Detecting, and Unplugging Technologies on the Full-Size Test Beds*, HCET-1998-M004-001-04, Hemispherical Center for Environmental Technology, Florida International University, 2002.

Advantages:

1. Unaffected by piping configuration or distance from plug.
2. Can be operated remotely, minimal exposure.
3. Typically requires no system modification; hook up to single access point connection.
4. Operating equipment minimal consisting of vacuum pump, air injection and water injection system.
5. Operation simple
6. Quick and easy mobilization and demobilization.
7. Low pressure.

Disadvantages:

1. Process line fluid does come in contact with equipment.
2. Technology has been demonstrated (FIU) for line unplugging but has not been used in an actual application.
3. Not a lot of data available to predict duration for various types of plugging materials.

Company safety record: 100,000 + hours of operation at 54 locations. Process for line unplugging has no safety record. However this same process is also used for tank cleanout and has operated at many DOE sites including ORNL, Mound, LANL and INEL.

Failure rate and reasons for failures: No record for pipe unplugging.

Company size (employees, sales): 40,000 employees' world wide with ~50 employees in USA.

Industries served: Nuclear

Comparison with competing technologies: Hydrokinetics, hydroblasting, chemical cleaning, mechanical cleaning

Current projects: Ongoing services to the nuclear industry and DOE.

Experience working with DOE? Sites and Projects: Many sites including Fernald.

Radioactive environment experience: Yes

Experience with various lengths, diameters, and materials of piping: Based on the FIU testing ~1,700 linear feet and various diameters. .

Experience with plugs of various materials (i.e. $CaCO_3$): minimal

Maximum size of plugs cleared and time required: See above.

Experience with closed systems and/or remote operations: System is effective in this environment. However the process fluid does come in contact with the unplugging equipment.

Contracting services: Purchase only. There is a system at Mound that could be refurbished for ~$100K. New equipment would cost $250-300K Training and consulting cost ~$1,500/day.

System connections needed (size and type): Single flange – Variable size and type.

Number of people required to operate: 2

Amount of training required: 1-2 days

Other: Mike Morris and Jennifer Ladd-Lively meet with Paul Murray and T. J. Abraham of AEAT. AEAT has a project at ORNL for tank cleanout and we will be visiting the site on Monday.