Remediation of Embedded Piping

Trojan Nuclear Plant Decommissioning Experience

Technical Report

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1000908

Final Report, October 2000

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Portland General Electric, Trojan Nuclear Plant

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CITATIONS

This report was prepared by

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This report describes research sponsored by EPRI.

The report is a corporate document that should be cited in the literature in the following manner:

Remediation of Embedded Piping: Trojan Nuclear Plant Decommissioning Experience, EPRI, Palo Alto, CA: 2000. 1000908.

REPORT SUMMARY

Characterization, decontamination, survey, and/or removal of contaminated embedded piping can have a substantial financial impact on decommissioning projects, depending on the project approach. This report presents a discussion of the Trojan Embedded Pipe Remediation Project (EPRP) activities, including categorization and characterization of affected piping, modeling for the proposed contamination acceptance criteria, and evaluations of various decontamination and survey techniques. The report also describes the decontamination tools, techniques, and survey instrumentation as well as the methods used to track work status and costs.

Background

Trojan—a four-loop PWR designed by Westinghouse and owned by Portland General Electric (PGE)—achieved initial criticality in 1975 and operated until November 1992. PGE received a Possession Only License from the NRC in May 1993. In 1995, limited dismantlement activities began at the plant, including completion of the Large Component Removal Project, which involved removal and disposal of the four steam generators and the pressurizer from the Containment Building. In April 1996, the NRC approved Trojan's Decommissioning Plan and more aggressive component removal activities began. In late 1998, when most of the contaminated equipment removal activities had been completed, PGE began removing portions of radioactive drain systems from service and commenced with embedded pipe decontamination and survey activities. The Trojan plant included more than 29,000 ft (5.5 miles or 8,839.2 m) of contaminated embedded piping throughout the power block. The scope of this piping included various drain systems, embedded ventilation ductwork, buried process piping, and embedded conduit. Additionally, a large number of process pipe sections passed through thick masonry walls. Although most were less than 4 ft (1.22 m) long, these pipe sections were not easily removed and many required cleaning and surveying in place.

Objective

To describe the approaches used and considered as well as lessons learned at Trojan for remediation and survey of contaminated embedded piping.

Approach

PGE performed substantial research into the available options for pipe cleaning and surveying and hosted several on-site cleaning and survey demonstrations. Methods considered included hydrolasing, media blasting, chemical decontamination, and piping removal. PGE also performed on-site radiological characterization studies to support development of a dose model for remaining embedded piping. The Trojan Decommissioning Plan calls for completion of the 10 CFR 50 site release survey with the site buildings largely intact. Surgical removal of the embedded piping, while leaving the buildings intact and structurally sound, would substantially

increase costs due to structural considerations and the depth of embedded pipe. Given the expense, PGE chose to clean and survey in place the bulk of the embedded piping to meet final site survey acceptance criteria, with much success. Use of specialized survey instrumentation has allowed PGE to perform in situ surveys on the piping to verify it to be acceptably clean. PGE and contract personnel have planned the project, demonstrated various decontamination and survey techniques, and successfully performed decontamination and survey of a substantial quantity of embedded piping. The project is ongoing, with the majority of decontamination and preliminary survey work completed.

Results

Trojan employed a combination of piping remediation methods for several reasons. First, while radioactive waste drain piping at Trojan is highly contaminated, it has proven to be relatively free of debris. In addition, because the piping is stainless steel, no significant corrosion layer exists on the piping interior. Media blasting, therefore, served as the primary method used to clean the waste drain piping. PGE used hydrolasing for the turbine building drain cleaning, since the piping was cast iron and contained significant debris and scale on the piping walls. They followed the high-pressure cleaning with a high-volume water washdown to remove material from the piping prior to survey. Finally, exposed portions of drain piping in the building overhead areas and piping buried outside are being removed, as this has proven the most cost-effective option. Some removal of embedded hot spots that could not be sufficiently cleaned was required to meet contamination acceptance levels. Surveyable surfaces remained upon completion of all removal activities.

The success of the Trojan EPRP depended largely on 1) advance planning, 2) the decontamination options selected, 3) integration of the project activities with other decommissioning activities, and 4) regulatory approval of the proposed embedded piping fixed contamination acceptance criteria. In the vast majority of embedded pipes, contamination levels have been reduced below acceptance levels using various decontamination methods. Project cost tracking has shown that cleaning and survey of piping is significantly less expensive than pipe removal on a cost-per-foot basis. As of July 2000, Trojan’s cleaning and survey activities for embedded piping were about 80% complete. The remaining EPRP activities are on hold pending complete transfer of the spent nuclear fuel to the dry storage facility.

EPRI Perspective

A key goal of the EPRI Decommissioning Technology Program is to capture the growing utility experience in nuclear plant decommissioning activities for the benefit of other utilities that will face similar challenges in the future. For decommissioning projects attempting to leave site buildings intact at the time of 10 CFR 50 license termination, an approach similar to Trojan’s can be effectively applied. EPRI report 1000951, <u>Embedded Pipe Dose Calculation</u>, summarizes techniques presently used to measure radioactive contamination on interior surfaces of embedded piping. Together, 1000951 and this report, 1000908, provide a comprehensive technical reference for embedded piping characterization and remediation.

Keywords

Decommissioning
Decommissioning project management
Reactor piping

ABSTRACT

In-place decontamination and survey of contaminated embedded piping represents one area of decommissioning with potentially significant financial and schedule impacts to the overall project. At Trojan, over 29,000 feet (5.5 miles) of contaminated embedded piping existed throughout the power block. The scope of this piping included various drain systems, embedded ventilation ductwork, buried process piping, and embedded conduit. Additionally, a large number of process pipe sections passed through thick masonry walls. Although most were less than 4-ft long, these pipe sections were not easily removed and many required cleaning and surveying in-place.

The Trojan Decommissioning Plan intends to complete the 10 CFR 50 site release survey with the site buildings largely intact. For this reason, surgical removal of the affected embedded piping (i.e. leaving the affected buildings intact and structurally sound) was evaluated to result in a substantially increased cost due to structural considerations and the depth of pipe embedment. Therefore, Trojan chose to clean and survey-in-place the bulk of the embedded piping to meet final site survey acceptance criteria, with much success.

The success of the Trojan Embedded Pipe Remediation Project (EPRP) depended largely on advance planning, the decontamination option(s) chosen, integration of the project activities with other decommissioning activities, and regulatory approval of proposed embedded piping fixed contamination acceptance criteria. Substantial research into the available options for cleaning and surveying of the pipe was performed along with several on-site cleaning and survey demonstrations. Trojan performed on-site radiological characterization studies to support development of a dose model for remaining embedded piping. Extensive backout planning for the EPRP was completed. This planning was necessary to support integration of EPRP activities into the overall site decommissioning schedule. As of July 2000, cleaning and survey activities for embedded piping at Trojan were about 80% complete. The remaining EPRP scope is on hold pending completion of transfer of the spent nuclear fuel to the dry storage facility.

This report presents a discussion of the Trojan Embedded Pipe Remediation project (EPRP) activities, including categorization and characterization of affected piping, modeling for the proposed contamination acceptance criteria, and evaluations of various decontamination and survey techniques. Additionally, the report describes the decontamination tools, techniques and survey instrumentation used for the project, as well as the methods used for work status and cost tracking.

ACKNOWLEDGEMENTS

The contributions of the following people for their support in providing amplifying information on survey instrumentation and project controls are gratefully acknowledged:

Gary Frank *Utility Engineering/ S. A. Robotics*

George Collins *TTX Associates*

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1
INTRODUCTION

The Trojan Nuclear Plant, a four-loop pressurized water reactor designed by Westinghouse and operated by Portland General Electric (PGE), achieved initial criticality in 1975 and operated until November 1992. In early 1993, the plant permanently ceased operation due to both financial and reliability considerations, and PGE received a Possession Only License from the NRC in May of that year. Trojan chose to implement the prompt decontamination approach to decommissioning. However, since Trojan ceased operation before having a fully funded decommissioning trust fund, the best course of action financially was to complete the activities required to release the 10 CFR 50 license, and delay completion of non-radiological site remediation activities to a later date. For this reason, the decommissioning plan was to leave the site buildings intact and remove all the radiological contamination as necessary to complete the final site survey.

In 1995, limited dismantlement activities began at the plant, including completion of the Large Component Removal project, which removed the four steam generators and the pressurizer from the Containment Building. In April 1996, the NRC approved Trojan's Decommissioning Plan and more aggressive component removal activities began. Beginning in late 1998, when most of the contaminated equipment removal activities had been completed, modifications were implemented to remove portions of radioactive drain systems from service and allow embedded pipe decontamination and survey activities to begin. The supporting modifications to liquid radioactive waste systems were implemented in stages over the period of approximately one year. Because of the plan to leave the buildings intact while completing the 10 CFR 50 site release survey, the option of encapsulating the contamination within the embedded piping and removing the piping in conjunction with building demolition was not practical.

In-place decontamination and survey of contaminated embedded piping represents one area of decommissioning with potentially significant financial and schedule impacts to the overall project. At Trojan, over 29,000 feet (5.5 miles) of contaminated embedded piping existed throughout the power block. The scope of this piping included various drain systems, embedded ventilation ductwork, buried process piping, and embedded conduit. Additionally, a large number of process pipe sections passed through thick masonry walls. Although most were less than 4-ft long, these pipe sections could not be easily removed and many required cleaning and surveying in-place.

For Trojan, complete removal of the affected embedded piping (leaving the affected buildings intact and structurally sound) would have resulted in substantially increased costs due to structural considerations and the depth of pipe embedment. Therefore, Trojan chose to clean and survey-in-place the bulk of the embedded piping to meet final site survey acceptance criteria, with much success.

The success of the Trojan Embedded Pipe Remediation Project (EPRP) depended largely on advance planning, the decontamination option(s) chosen, integration of the project activities with other decommissioning activities, and regulatory approval of proposed embedded piping fixed contamination acceptance criteria. Substantial research into the available options for cleaning and surveying of the pipe was performed along with several on-site cleaning and survey demonstrations. Trojan performed on-site radiological characterization studies to support development of a dose model for remaining embedded piping. Extensive backout planning for the EPRP was completed. This planning was necessary to support integration of EPRP activities into the overall site decommissioning schedule.

Cleaning and survey activities for embedded piping at Trojan were about 80% complete as of July 2000. The remaining EPRP scope is on hold pending completion of transfer of the spent fuel rods to the dry storage facility.

The following sections presents a discussion of the Trojan Embedded Pipe Remediation project (EPRP) activities, including categorization and characterization of affected piping, evaluation of radiological aspects of the project, and evaluations of various decontamination and survey techniques. The report describes the decontamination tools, techniques and survey instrumentation used for the project, as well as the methods used for work status and cost tracking. Lessons learned for various aspects of the project are also discussed.

2
SCOPE OF TROJAN EMBEDDED PIPING

Categorization of Piping

The bulk of contaminated embedded piping at Trojan can generally be divided into four broad categories: drain piping, ventilation ducting, buried process piping, and miscellaneous items.

Drain Piping: This category includes piping from various radioactive waste drain systems (Aux Building, Chemical, Clean, and Dirty Radwaste) in the Auxiliary, Fuel and Containment Buildings. Additionally, this category includes affected portions of the Oily and Acid Waste Drain systems in the Turbine building which were found to be contaminated during site radiological characterization efforts.

Ventilation Ducting: This category includes ducting inside the perimeter wall of the Refueling Cavity in the Containment Building and around the Spent Fuel Pool (SFP).

Process Piping: This category includes buried process piping outside the plant buildings in the tank farm area and piping within the walls surrounding the SFP and Refueling Cavity.

Miscellaneous: This category includes pipe stubs passing through thick walls and embedded conduit in the Containment Building.

Table 2-1
Embedded Pipe Summary

Category	Total Length (ft)
Drain Piping	16500
Ventilation Ducting	720
Process Pipe	2700
Miscellaneous	9500
TOTAL	29420

Configuration of Piping

Drain Piping: Radioactive waste system drain piping in the Auxiliary, Fuel, and Containment buildings is stainless steel, Schedule 10 for piping larger than 2-inches (in.) and Schedule 40 for 2-in. and smaller. Piping size ranges from 1-4-in., with the majority of the piping being 4-inch. Pipe joints are butt-welded with primarily mitered transition joints, and 90 and 45-degree elbows are used for routing changes. The piping design utilizes sloped horizontal headers below floor elevations, with the majority of the risers being located within masonry walls. The systems are connected to collection tanks at the lower building levels. Turbine Building drain piping is Schedule 40 cast iron ranging from 2-8-in., with the majority being 4-in. Mechanical pipe joints are used and the piping is routed to an open sump in the building.

Ventilation Ducting: The ductwork consists of 10-gauge stainless steel duct embedded approximately 6-ft below floor level in concrete. The ductwork ranges from 8-in. diameter scuppers at the SFP / Refueling Cavity edge up to 30-in. diameter where it becomes accessible and ties into the exhaust ventilation system. The ductwork is constructed in telescoping fashion using a welded collar at each transition point.

Process Piping: Piping in the walls surrounding the SFP and Reactor Cavity is Schedule 10 stainless steel, ranging from 3-8-in.. Outside buried process piping ranges from ¾- 30-in. diameter, consisting of both carbon steel and stainless steel material. The carbon steel piping contains very low levels of contamination. The piping in the yard area is buried from grade level to approximately 5-ft deep.

Miscellaneous: Embedded conduit in Containment is of various sizes ranging from ¾-6-in. and accounts for approximately 8000 linear feet. Process pipe stubs passing through thick walls are of various sizes and materials. The stubs generally pass straight through a wall allowing unobstructed access to both ends of the pipe. The proces pipe stub scope is approximately 1500 linear feet. Most stubs are removed in conjunction with equipment removal activities. The openings remaining in the walls after removal of the stubs are typically surveyed using the embedded pipe instrumentation.

Identification Methodology

The primary focus of EPRP efforts to date has been centered on the various drain systems at the plant. A detailed review of plumbing and drainage drawings was performed along with numerous field walkdowns to identify all affected drains. Based upon these reviews, a series of elevation sketches was created showing an overview of system flowpaths and interconnections. A database was developed to uniquely identify each drain input and header by drain system to support project control efforts and development of work packages for field personnel. Each drain system was further classified into several logical survey units, which typically contained multiple drains and headers. The “unit” approach was a successful way to coordinate cleaning and survey field activities. Using the database and sketches, the drain data could be easily sorted by decommissioning work area, system, header, or survey unit, which was useful in coordinating drain remediation activities with other ongoing decommissioning work.

The as-built plumbing and drainage drawings were used to establish the lengths of the drain headers. Additionally, after loose contamination had been removed from the piping, the lines were typically inspected using video equipment that provided a validation of the pipe lengths. The final lengths of the pipes were used to ensure a complete survey had been taken. The video inspection also allowed verification that no debris or grit remained in the pipes. The cabling for the survey instrumentation was marked in 1-foot increments to allow control over the survey length for repeatability of measurements.

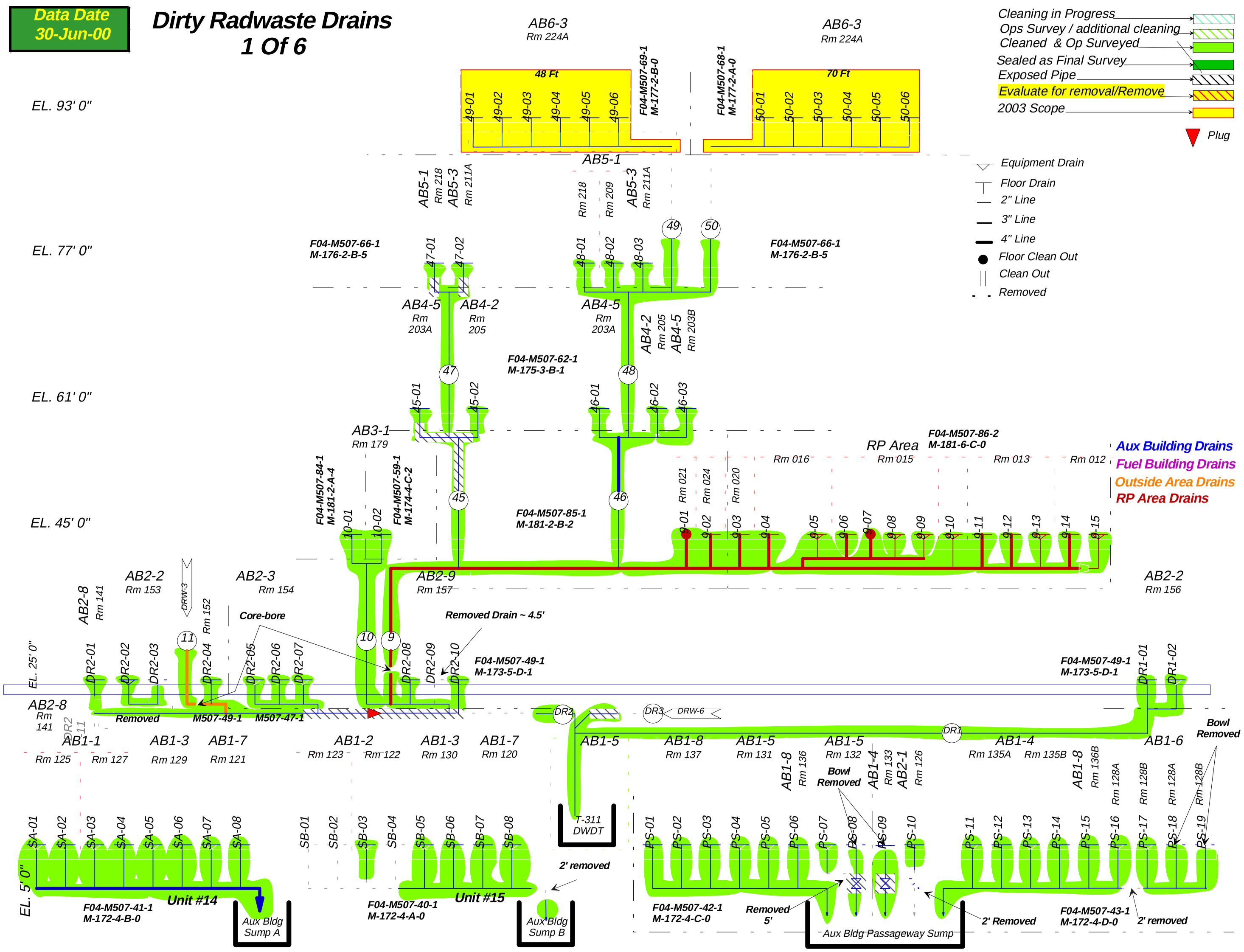

Figure 2-1
Typical Drain Flowpath and Interconnection Sketch

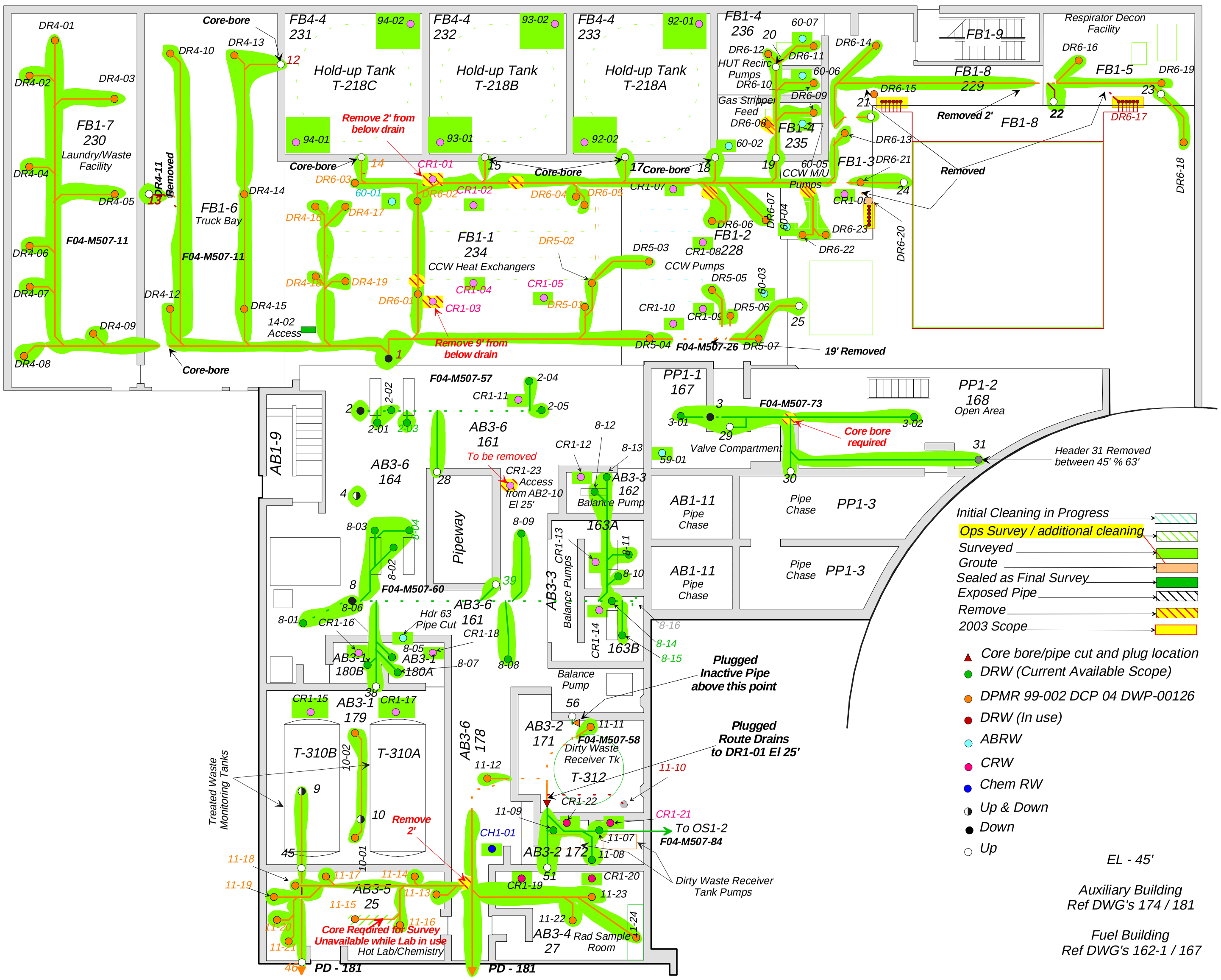

Figure 2-2
Typical Plan View Layout of Drain Piping

Aux Bldg Radwaste

Drain	Dia.	Length	Elev.	Area	Dwg	
Header #	**16Aux Bldg RW**					**Survey Unit # 200F**
16-01	2.00	20.00	61	FB2-7	163	
16-02	2.00	2.00	61	FB2-7	163	
16-03	2.00	6.00	77	FB3-5	164	
16-04	2.00	1.00	77	FB3-5	164	
16-05	2.00	5.00	77	FB3-5	164	
16-HA	4.00	50.00	61	FB3-5	163	
16-HB	2.00	16.00	61	FB2-7	164	
16-HC	4.00	30.00	77	FB3-5	164	
Survey Unit 200F Total:		**130.00**				
Header 16 Total:		**130.00**				
Header #	**58Aux Bldg RW**					**Survey Unit # 200C**
58-HA	4.00	12.00	25	FB2-3	173	
58-HB	4.00	17.00	25	FB2-3	173	
Survey Unit 200C Total:		**29.00**				
Header 58 Total:		**29.00**				
Header #	**59Aux Bldg RW**					**Survey Unit # 200A**
59-01	2.00	4.00	45	PP1-1	178	
59-HA	4.00	15.00	25	PP1-1	173	
59-HB	4.00	17.00	45	PP1-1	178	
Survey Unit 200A Total:		**36.00**				
Header 59 Total:		**36.00**				
Header #	**60Aux Bldg RW**					**Survey Unit # 200G**
60-01	4.00	71.00	45	FB1-1	162-1	
60-02	2.00	11.00	45	FB1-4	167	
60-03	2.00	3.00	45	FB1-3	167	
60-04	4.00	67.00	45	FB1-3	167	
60-05	2.00	3.00	45	FB1-4	167	
60-06	2.00	3.00	45	FB1-4	167	
60-07	2.00	28.00	45	FB1-4	167	
60-HA	4.00	47.00	45	FB1-4	162-1	
60-HB	4.00	21.00	45	FB1-4	162-1	
Survey Unit 200G Total:		**254.00**				
Header 60 Total:		**254.00**				
Header #	**61Aux Bldg RW**					**Survey Unit # 200D**
61-01	2.00	17.00	77	AB6-1	176	
61-02	2.00	4.00	77	AB6-1	176	
61-HA	4.00	22.00	77	AB6-1	175	
61-HB	4.00	10.00	77	AB6-1	175	
Survey Unit 200D Total:		**53.00**				
Header 61 Total:		**53.00**				

Figure 2-3
Typical Drain Database Information

3
EVALUATION OF REMEDIATION OPTIONS

Numerous remediation options were reviewed for use in dealing with embedded drain piping and several onsite demonstrations were conducted. Additionally, experience and processes used at the Shoreham, Fort St. Vrain, and Yankee Rowe nuclear plants were reviewed for their potential applicability to Trojan. The Trojan radwaste system drain piping was highly contaminated. The goal of the remediation efforts was to completely remove all loose surface contamination and reduce fixed contamination below predetermined acceptance levels. Ultimately, abrasive grit media blasting was chosen as the primary remediation method for the radioactive waste drain piping in the Auxiliary and Fuel Buildings, but other methods, including pipe removal, have been used to a lesser degree as well.

Hydrolasing

This method removes contamination using high-pressure water. Hydrolasing was originally considered to be the method of choice due to previous experience by decontamination personnel. Cleaning of drains for dose reduction had been performed several times during plant operation, and plant liquid waste processing systems were in service and available for use. Also, this method had been successfully used at Shoreham Nuclear Plant to complete cleaning of the drain piping. However, after several onsite demonstrations and extensive research into available equipment, use of this cleaning method was rejected.

Strengths:

- Provides for removal of debris/scale in piping
- Relatively low cost

Weaknesses:

- Unavailability of rotating nozzles for high pressure (> 20 kpsi) operation in small piping to ensure pipe wall coverage
- Must maintain a collection and processing system for liquid wastes.
- Drain piping must remain intact to route water flow
- Personnel safety issues associated with high pressure water
- 20 kpsi or greater pressure required to clean piping to required levels (based upon demonstrations)
- Pump maintenance required to refurbish seals

- Size and inflexibility of nozzles and hoses for maneuvering multiple bends in drain piping at required pressures

Media Blasting

This method utilizes pressurized air entrained with grit material to clean the piping walls. One application uses a vacuum blast unit capable of using various types of blast media (e.g. garnet, aluminum oxide, silicon carbide) and multi-directional nozzles. A collection unit positioned at the lower elevations collects the grit and allows it to be recycled a number of times. This is the primary method used at Trojan, and this method was previously successful at Fort St. Vrain.

Strengths:

- Flexible blast hoses and small nozzles.
- Reusable grit
- Low pressure (100 psig) operation; relatively good for personnel safety
- Various types and grades of grit are commercially available to allow process flexibility
- Spent media can be directly disposed of in LSA boxes. No need to maintain liquid radwaste collection system for cleaning operation.
- Exposed portions of drain piping can be removed immediately
- Essentially dust free operation with vacuum blast equipment

Weaknesses:

- Piping must be relatively free of debris, buildup
- Piping must be relatively dry
- Initial startup costs associated with air compressor and tooling

Chemical Decontamination

This method utilizes a heated chemical solution to remove a layer of the metal surface of the drain piping. Commonly, a recirculation unit consisting of heater(s), pump(s), a surge tank and hoses is used to provide flow of the chemical solution over the equipment being decontaminated. One example is the EPRI DfD (Decontamination for Decommissioning) process, which uses timed applications of Fluoboric Acid, Potassium Permanganate, and Oxalic Acid to complete a cycle. Certain chemical parameters are monitored throughout the evolution to determine when activity removal for a cycle is complete, with the process being repeated a number of times.

Strengths:

- Coverage of the entire drain pipe by the process
- Removal of base metal; removal of fixed contamination

- Recirculation and reuse of chemicals for several applications

Weaknesses:

- Potential hazardous material spill concerns
- Potential generation of mixed waste
- Personnel safety due to hot process fluids (typically >180°F)
- Generates radioactive demineralizer resin
- Logistics problems of routing process hoses in areas with other work in progress
- Relatively high costs -- equipment setup and operation and chemicals required
- Provisions must be made to collect and remove debris to avoid pump damage

Removal of Piping

This method completely removes the piping from the wall, ceiling, or floor through which it passes. Removal eliminates any contribution of dose from piping in these areas to remaining overall room dose rates. No evaluation of contamination remaining in piping is required, but structural evaluations are necessary depending on the extent of removal.

Strengths:

- Contaminated piping is removed altogether
- No contribution from drain piping to overall remaining dose rates

Weaknesses:

- Relatively high cost; some piping is substantially embedded
- Potential effects on building structural integrity
- Potential personnel safety issues
- Water collection system required to process water from concrete cutting evolution.

Remediation Methods Used at Trojan

Radioactive waste drain piping at Trojan is highly contaminated, but has proven to be relatively free of debris. Also, because it is stainless steel, there is not a significant corrosion layer on the piping interior. Therefore, media blasting was chosen as the primary method used to clean the piping. A vacuum blast unit was located in the lower elevation of the plant and used air supplied from a dedicated air compressor. The vacuum blast unit used a portion of the air supply to operate the vacuum on the collection system and a smaller portion to provide the blast pressure. The blast hoses were routed through plant pipe chases to various drain input locations. The collection hose was attached to the common portion of the drain header at the lowest available location to minimize the required setups. A small portable blasting unit with clean grit was routinely used for the final cleaning passes and for remediation of hotspots discovered during the preliminary pipe radiological surveys. The large vacuum blast unit was capable of providing collection for multiple blast nozzles. A portable HEPA vacuum was routinely used for grit collection on individual or isolated runs of pipe. Various customized nozzles were used to ensure adequate contact with all pipe surfaces. Pipe configuration was the limiting factor in nozzle selection.

Problems with available tooling and equipment maneuverability in the drain piping eliminated hydrolasing as an option for the radioactive waste drains. However, hydrolasing was used for the Turbine Building drain cleaning, since the piping was cast iron and contained a significant amount of debris and scale on the piping walls. The high pressure cleaning was followed with a high volume water washdown (e.g. fire hose) to remove material from the piping prior to survey.

Exposed portions of drain piping in the building overhead areas and piping buried outside is being removed, as this has been found to be the most cost effective option. Some removal of embedded hotspots that could not be sufficiently cleaned was required to meet contamination acceptance levels. These removals from walls or floors were typically performed using core drills, chipping hammers, or a combination of concrete removal methods. Leaving a surveyable surface upon completion of the removal activity was a consideration in the choice of the removal process.

4
EVALUATION OF RADIOLOGICAL ASPECTS

Radiological Characterization

Representative samples (pipe scrapings and debris samples) were taken from various drain systems to determine the radionuclide distribution. The predominant radionuclides included ^{55}Fe, ^{60}Co, ^{63}Ni, ^{90}Sr -^{90}Y, ^{241}Pu, and ^{241}Am. Typical initial fixed contamination levels in the drain piping have been found to be in the range of 50-350-kdpm/100 cm^2, with portions in excess of 10,000-kdpm/100 cm^2.

Evaluation of Fixed Contamination Acceptance Criteria

Using the characterization data and typical embedded drain piping construction details, a model was developed to determine an acceptable fixed contamination level to allow the piping to remain in place. Based upon remaining activity levels, the model approximated the dose to an average member of the critical group for a building occupancy scenario, a building renovation scenario, and a residential scenario. This fixed contamination acceptance level was intended to support final site radiological survey requirements. Additionally, activity concentration limits established by the State of Oregon for radioactive material to be left onsite were considered in development of the planned criteria.

The principal approach is to reduce fixed piping contamination levels below Derived Guideline Concentration Levels (DGCLs). Loose surface activity will be completely removed from the piping. The acceptance criteria assume average contamination levels for a length of pipe, with some flexibility for localized hotspots. After cleaning and survey are complete, the current plan is to fill the remaining pipes with grout. Encapsulates, such as grout, are recognized as effective immobilizing agents for radioactive material that may leach from the internal surfaces of the pipe. Grout also provides shielding and prevents the re-use or recycle of the pipe.

The acceptance criteria and methodology currently await NRC approval in conjunction with the Trojan License Termination Plan (LTP), which includes the Final Survey Plan. Although the cleaning and preliminary surveys are nearly 80 percent complete as of July 2000 based upon the proposed fixed contamination acceptance levels, final surveys will not be performed until the LTP has been approved.

Evaluation of Survey Instrumentation

Several vendors capable of performing surveys on embedded piping were reviewed. Utility Engineering / S.A. Robotics, Science and Engineering Associates, and Radiological Services Inc.

conducted onsite demonstrations of instrumentation and survey techniques in contaminated drain piping. Trojan personnel performed a comparison of each vendor's capabilities, and all were found to able to perform surveys and generate data in a form compatible with the Trojan final survey database. Ultimately, Utility Engineering / S.A. Robotics was chosen to support the project to provide single vendor support for both the cleaning and surveying evolutions. Survey and instrument calibration procedures have been developed and incorporated into the Trojan QA program.

Survey Techniques and Data Collection

The instrument used to collect embedded pipe survey data is the Ludlum 2350-1 Datalogger. The ability to record 1000 data points make the 2350-1 a very effective tool for embedded pipe surveys. Recording of the survey results and the ability to readily download the data to a computer to perform the analysis for the survey report provides a clean paper trail.

Surveying the embedded piping typically involves two general steps: the first being the "operational" survey and the second the "final" survey. The operational survey is performed after a pipe or system was clear of any debris and found to be smearably clean. This survey ensures the pipe section in question has met the required criteria and is ready for the final survey. The pipes are typically scanned at a rate of approximately 2 inches per second, with readings recorded at one-foot intervals or at the highest reading around each foot increment. A background reading is taken at each survey point to ensure readings are as accurate as possible. Because remediation of hotspots occurs as a result of operational survey results, a given section of line may be surveyed multiple times. The operational survey data and survey results are maintained in a historical package for each drain and header. See Figure 4-1 for a typical example of an instrument download and the resulting survey documentation.

When performed, the final survey will be accomplished in the same manner as the operational survey. The final survey data and survey results will be maintained in a manner similar to those for other final surveys of buildings and surfaces.

DR6_19 Count 3

Description:	DR6-19 0'-20' Count 3			**Survey Unit:**	203Q
File#:	MIC2000032	**Serial#:**	129435	**Date:**	05/18/2000
Instrument:	2350-1	**Cal.Due:**	08/22/2000	**Time:**	1300
Detector:	TP3/3 #010	**Cal.Due:**	08/28/2000	**User ID:**	GWF0600
Count Time:	0.5	**Avg. Bkgd:**	33	**MDC(avg):**	4555
Efficiency:	0.048	**Max. Bkgd:**	110	**MDC(high):**	7989
Det. Area:	27	**Type:**	Beta		
				Average dpm/100cm2:	2565
				Maximum dpm/100cm2:	12191

Pipe Depth	Sample#	Gross Counts	Sample#	Bkgd Counts	Net Counts	Dpm/100cm2	Comments
0	41	37	0	18	19	2932	
1	42	30	1	18	12	1852	
2	43	42	2	33	9	1389	
3	44	39	3	22	17	2623	
4	45	34	4	23	11	1698	
5	46	37	5	31	6	926	
6	47	47	6	38	9	1389	
7	48	34	7	26	8	1235	
8	49	35	8	29	6	926	
9	50	35	9	27	8	1235	
10	51	31	10	22	9	1389	
11	52	94	11	25	69	10648	
12	53	61	12	29	32	4938	
13	54	30	13	27	3	463	
14	55	34	14	24	10	1543	
15	56	34	15	26	8	1235	
16	57	28	16	28	0	0	
17	58	34	17	31	3	463	
18	59	49	18	45	4	617	
19	60	78	19	51	27	4167	
20	61	189	20	110	79	12191	

Figure 4-1
Typical Instrument Download and Survey Data

Embedded Pipe Survey Detectors

A combination of Geiger-Mueller detectors (GM) and Gas Flow Proportional Detectors (GFPD) were used to perform the radiological surveys of the Trojan embedded piping. Calibration of the equipment was performed onsite on a regular basis. Because the equipment is subject to signal weakening line losses, the calibration accounted for the length of cable used. The detectors used are described in the following sections of the report. Table 4-1 provides a tabular summary of the details of each detector.

Table 4-1
Summary of Detector Details

Model	Physical Size (diameter)	Diameter of Detector	Effective[1] Area of Probe cm^2	Number of Detectors	Density mg/cm^2	Anode Position	Number of Anode Wires	Pipe Size	Effective Survey Area[1]	Total Effective Area[2]
SN2/3	1.5”	28.6 mm	6.4	3	1.5-2	Note 3	1	2”	30 cm^2	30 cm^2
SN2/3	1.5”	28.6 mm	6.4	3	1.5-2	Note 3	1	3”	60 cm^2	60 cm^2
SN2/3	1.5”	28.6 mm	6.4	3	1.5-2	Note 3	1	4”	90 cm^2	90 cm^2
TP3/3	3”	28.6 mm	6.4	3	1.5-2	Note 3	1	4”	45 cm^2	45 cm^2
TP3/5	3.25”	28.6 mm	6.4	5	1.5-2	Note 3	1	4”	75 cm^2	75 cm^2
SP4-6	Variable	28.6 mm	6.4	3	1.5-2	Note 3	1	4” – 6”	25 cm^2	25 cm^2
SP6-8	Variable	44.5 mm	15.9	3	1.5-2	Note 3	1	6” - 8”	60 cm^2	70 cm^2
43-94	0.5”	12.5 mm	39	1	0.8	Note 3	1	1”	78 cm^2	75 cm^2
43-111	1”	25 mm	80	1	0.8	Note 4	4	1.5”	119 cm^2	100 cm^2
43-98	1.5”	38 mm	110	1	0.8	Note 4	6	2”	157 cm^2	150 cm^2
43-98	1.5”	38 mm	110	1	0.8	Note 4	6	2.5”	197 cm^2	185 cm^2
PSR-4	2.25”	57 mm	72	1	0.8	Note 4	1	3”	119.4 cm^2	100 cm^2
PSR-4	2.25”	57 mm	72	1	0.8	Note 4	1	4”	192.3 cm^2	185 cm^2

Notes:
1. The Effective Area is the open area of the detector, taking into consideration protective screening used on the Ludlum 43-94, 43-111, and the 43-98 which provide shielding to the detector and thus lower the sensitive area of the probe.
2. Total Effective Area is normally lower than the ‘real’ effective area in order to remain conservative in establishing activity.
3. Anode centered in the detector.
4. Centered between canter support and the detector surface.

Geiger Mueller Detectors

The bulk of the embedded piping surveys are performed with the Geiger Mueller (GM) detector arrays, due to their ruggedness and ability to go around 45 and 90 degree bends. The GM arrays can be made fairly long, up to approximately 100 feet if necessary, due to the large pulse generated by the GM detector. The GM detectors used for various embedded piping surveys include the SN2/3, TP3/3 , TP3/5, SP4-6, and the SP6-8.

- **SN2/3**

  The SN2/3 detector series (Figure 4-2) consists of three LND 7231 GM detectors in a string. The detectors are offset 120° along the axis to allow total scan of the pipe. Fiberglass fish tape is used as stiffening device to push the detector array through piping. A hook is built into the nose of the detector array, allowing the detector to be pulled through long sections of pipe. Of all the detectors, the SN2/3 is perhaps the most fragile due to the exposed wiring and the lack of protection afforded by the detector carriers due to size constraints.

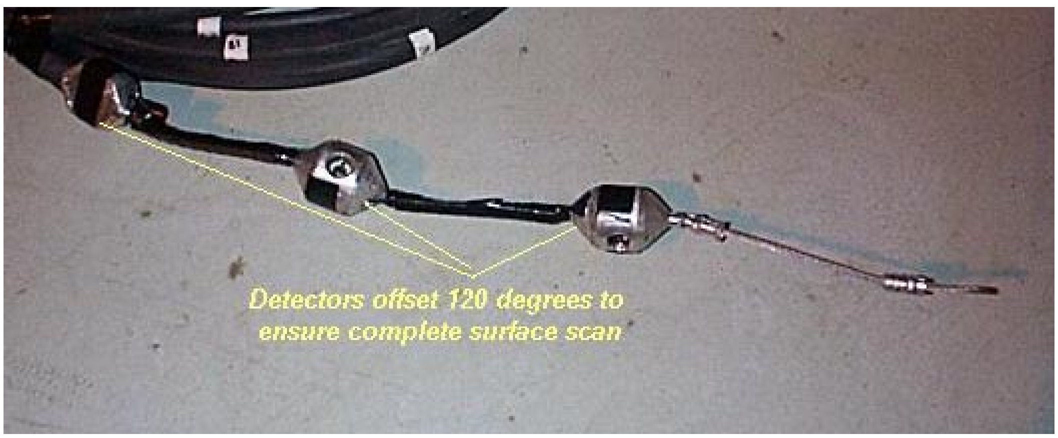

Figure 4-2
SN2/3 Detector Configuration

- **TP3/3**

The TP3/3 detector series (Figures 4-3 and 4-4) consists of three LND 7231 GM detectors in an aluminum case. The detectors are placed 120^0 apart on the array. The detector case is approximately 4" in length and approximately 3" in diameter. A modification was performed to split the case of all the TP3/3 units in service (held together with recessed screws) to ease maintenance and replacement of detectors. This detector was used for surveys of 4-inch drain piping and could readily pass through 90-degree elbows. The survey length could be 80-90-ft without excessive line losses.

Figure 4-3
TP3/3 Detector Configuration

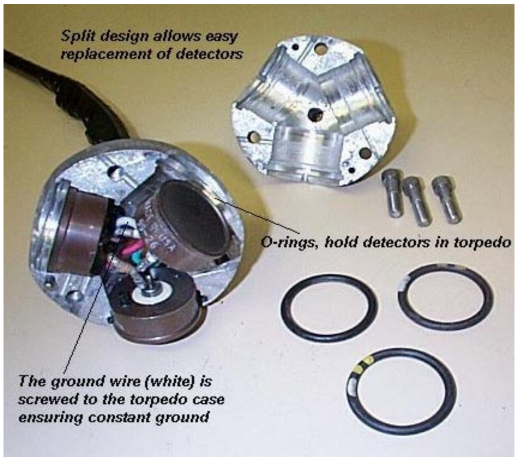

Figure 4-4
TP3/3 Detector Cutaway View

- **TP3/5**

The TP3/5 detector series (Figure 4-5) is the same as the TP3/3 with the following exceptions: five LND 7231 detectors and the case is slightly larger in diameter in order to hold the extra two detectors. This detector was not used at Trojan because the small increase in diameter over the TP3/3 prevented it from being able to pass through 90-degree elbows. However, with the increased detector surface area, it would provide more thorough coverage than the TP3/3.

Figure 4-5
TP3/5 Detector

- **SP4-6 and SP6-8**

The SP4-6 is infinitely adjustable for pipe diameter of 4” through 6”. The SP6-8 is identical to the SP4-6 with the exceptions that the useful range of adjustment is 6” to 8” and the detectors are larger having a 44.5mm active area. Figure 4-6 shows the typical configuration. The adjustment is motor driven and adjustments are made remotely by use of the control box. These detector configurations use the LND 7231 detectors. This style of detector was used to survey of the Turbine Building drain piping and was typically outfitted with a camera. Higher detector efficiency as compared to the TP3/3 style resulted from the ability to center the instrument in the pipe and effectively fine tune the distance of each detector from the pipe wall

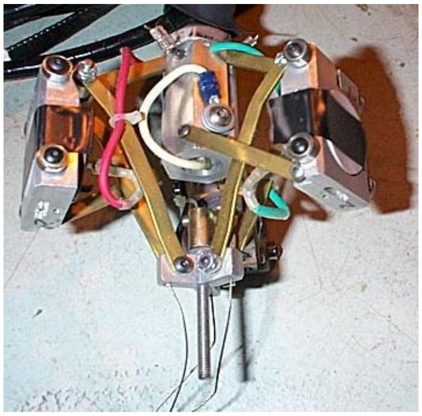

Figure 4-6
Adjustable SP Series Detector

Gas Flow Proportional Detectors

Four different gas flow proportional detectors (GFPD) are used for embedded piping surveys. The gas flow equipment offers a decided advantage over the GM style as the area of the detectors "see" the entire circumference of the pipe. The areas of the detectors are adjusted to compensate for "dead areas" of the individual GFPD. The main disadvantages of the GFPD are length, which restrict use of some of the GFPDs in piping with 45 and 90 degree elbows, and cable length, which also limits the extent of survey areas.

- **Ludlum Model 43-94**

  The Ludlum Model 43-94 (Figure 4-7) is a cylindrical GFPD, ½-inch in diameter. Gas supply for the 43-94 is provided through the signal cable, which minimizes the clutter when using the detector in the field. The detector has one anode wire in the center. The Model 43-94 was used primarily for the survey of straight conduit and pipe penetrations ¾ and 1-inch in diameter.

Figure 4-7
Ludlum Model 43-94

- **Ludlum Model 43-111**

  The Ludlum Model 43-111 (Figure 4-8) is a cylindrical GFPD, 1-inch in diameter. Gas supply for the 43-111 is provided through the signal cable, which minimizes the clutter when using the detector in the field. The detector has four anode wires located between the center support post and the outer window. The Model 43-111 was used primarily for the survey of straight conduit and pipe penetrations 1½-inches in diameter.

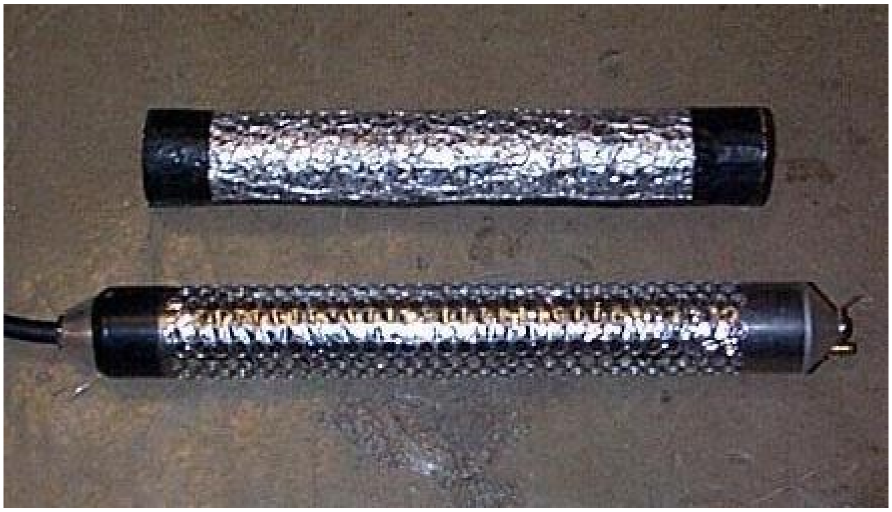

Figure 4-8
Ludlum Model 43-111

- **Ludlum Model 43-98**

  The Ludlum Model 43-98 (Figure 4-9) is a cylindrical GFPD, 1½-inches in diameter. Gas supply for the 43-98 is provided through a separate gas supply cable, which causes tubing clutter when using the detector in the field. The detector has six anode wires located between the center support post and the outer window. The Model 43-98 was used primarily for the survey of straight conduit and pipe penetrations 2-inches and larger in diameter.

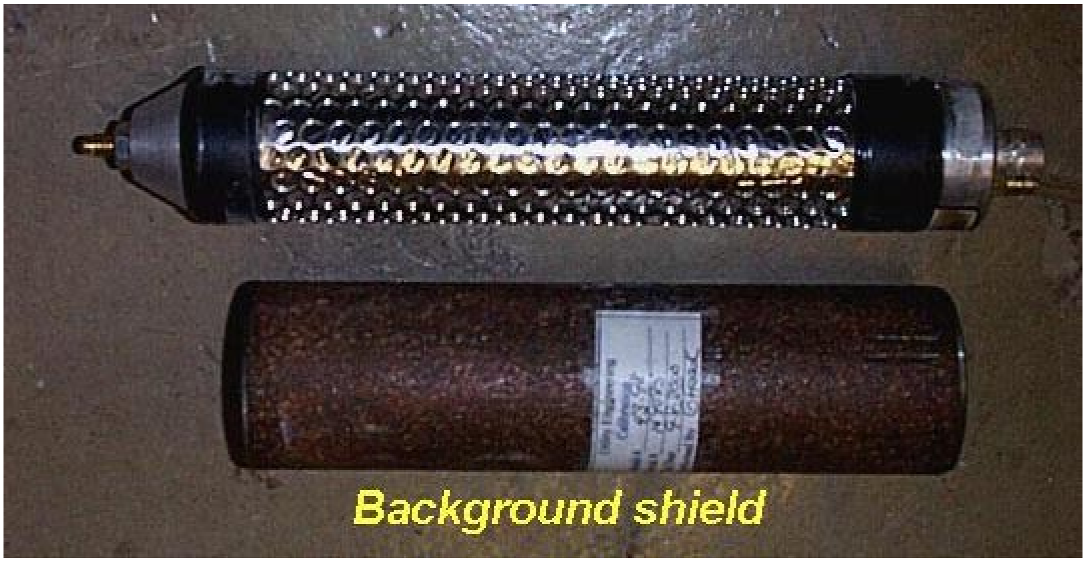

Figure 4-9
Ludlum Model 43-98

- **Automated Engineering & Electronic Services, Inc (AEES) Model PSR-4**

  The AEES Model PSR-4 (Figure 4-10) is a GFPD used for piping systems with a diameter between 3 and 4 inches. The gas supply for the probe is provided through the signal cable. The detector has a fitting on the connector end to allow use of a metal fish tape (provided by the manufacturer) to push the detector through and extract the detector from piping without placing undo strain on the signal cable. The probe originally provided by the manufacturer was fitted with spring loaded wheels. Unfortunately, while they looked good, a test through typical Trojan piping resulted in the wheels hanging up on a weld. The wheels were removed and replaced with stainless steel wire runners to place the detector approximately ½-inch off the surface and to allow the probe to slide through the piping easier. Because the wiring configuration limited the survey length to less than 25-feet, this instrument was routinely used to survey wall penetrations and other short straight sections of piping.

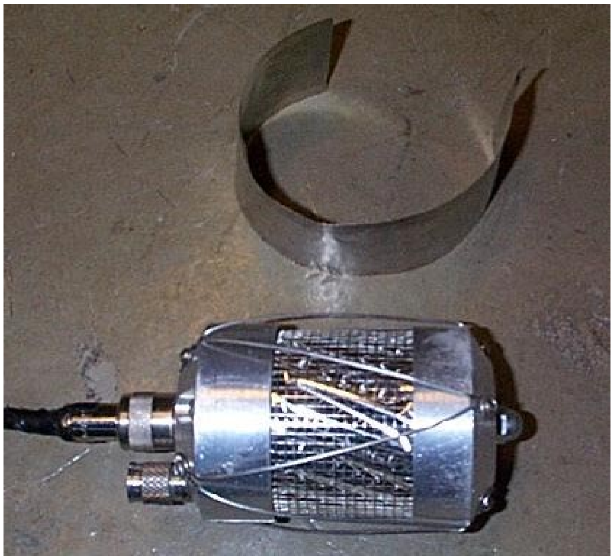

Figure 4-10
AEES Model PSR-4

5 LESSONS LEARNED

Blast Media

Various types and sizes of grit were used, with the most aggressive being 54-grit Silicon Carbide. Garnet was effective for gross cleaning and removal of loose contamination. The harder grit types, such as Silicon Carbide, were found to be best for removing fixed contamination on pipe walls. The harder grit materials removed the contamination faster, but the degradation of blast nozzles and hoses was accelerated. Also, the garnet and aluminum oxide were significantly less expensive than the harder materials. Generally, the initial cleaning passes were made with aluminum oxide and garnet, while remedial cleaning was done with the more aggressive grit materials.

Debris in Piping

Debris in drain piping was a problem for some lines, with long horizontal runs typically being the worst. Waste materials in drains, such as epoxy, grout, and fire barrier foam, resulting from various construction and modification activities, made it difficult to push the blast nozzles through. Additionally, the blockage typically provides a place for contamination to collect resulting in a hotspot. Mechanical removal methods such as scraping, core drilling or vacuuming were used to remove the material or to work around the blockage. Video equipment was routinely used to inspect the pipe interior after loose surface contamination was removed.

Pipe Configuration

Trojan’s drain piping was typically welded stainless steel construction with mitered transition joints. Multiple bends and elbows in a run of pipe resulted in increased friction on the blast hose and survey equipment. Since most of the pipe was embedded in walls and floors, core drills were made as necessary on various pipe runs to provide additional access locations to the drain header for both cleaning and survey. The survey equipment used was limited to approximately a 70-80-ft length based upon the equipment calibration.

Blast Nozzles and Hoses

Blast nozzles and hoses were considered a consumable item for the media blast process. Their service life was most affected by the type of blast media used and the existence of slight fabrication defects. Various types and sizes of nozzles were custom fabricated for specific application to Trojan piping. Reverse-blasting nozzles were developed to allow more effective cleaning of elbows and joints. Due to problems with use of standard hoses with the aggressive grit materials, heavy duty nylon-reinforced hoses were used in the process.

Project Staffing

The EPRP activities occurred in parallel with equipment removal and surface decontamination activities, which resulted in some conflicts and inefficient use of resources. In order to minimize these conflicts, the project was staffed sufficiently to allow two-shift per day coverage. This allowed more equipment runtime and flexibility to avoid conflicts with other ongoing decommissioning work.

Survey Equipment Certification

Delays in approval of the instrumentation and survey procedures hampered initial cleaning efforts in the project. Therefore, since final pipe survey data is a quality record, efforts should be made to incorporate the equipment and procedures into the plant’s QA program as early in the project as possible. This early start is critical to ensure that cleaning activities are not delayed awaiting approval of the survey equipment, since the effectiveness of the cleaning process is determined by periodic surveys. An additional consideration is to verify the pipe survey instruments and data accumulation equipment are capable of providing data in a form compatible with the final site survey database to enhance project efficiency.

Project Controls

The drain configuration sketches and database described previously were extremely valuable assets to the project. A work breakdown structure (WBS) code was assigned to each drain and header to allow incorporation of the embedded piping into the master decommissioning cost tracking software (Decom Expert) and schedule. Using Decom Expert and the drain database, project costs could be tracked at the building, system, header, or drain levels of detail. Scheduling and sequencing of decommissioning work was primarily done on an area-by-area basis, and the drain database was routinely used to determine drains and drain systems in a given area. Project status was readily available thorough periodic database updates.

Through July 2000, the overall cost of decontamination and survey of drain piping was approximately $250/foot. Removal of embedded piping from within walls and floors and underground was averaging about $500/foot.

GM Detector Wiring

Early in the project, a number of reoccurring problems with wiring on the GM detectors necessitated a fix. The solution was replacing all GM detector wiring with electrical wiring (18-4), with the exception of the SP (adjustable) type because of the required motor wiring. While the electrical cable was not shielded, no problems were encountered with interference. This cable proved to be very reliable and continues to provide improved serviceability over the original cable.

6 CONCLUSIONS

Trojan has had much success in the performance of in-place decontamination and survey of the plant's contaminated embedded piping. The project integrated crews of plant personnel with a service contractor to perform the decontamination and survey work. Members of the plant's engineering staff have provided project management and oversight functions.

Embedded pipe remediation work began in late 1998, and was approximately 80 percent complete as of July 2000. The most highly contaminated drain piping systems were included in the early project scope, since they were the first to be removed from operational service operation and provided the bounding test of the cleaning and survey process. Most of the remaining floor drain piping was removed from service in 1999 to allow cleaning and survey activities to occur in parallel with scheduled spent fuel transfer activities. The goal was to reduce the post-fuel load work scope to minimize the impact of the EPRP activities on the overall decommissioning schedule. The remaining portion of the project scope, which includes piping and ductwork in, around, and supporting the Spent Fuel Pool, cannot be completed until the spent fuel has been transferred to the onsite dry storage facility.

Trojan plans to clean the embedded piping to the anticipated fixed contamination level criteria, then secure access to the piping. After the NRC approves the Final Site Survey Plan in conjunction with the License Termination Plan, final pipe survey readings will be taken. After the NRC accepts the final survey readings, the piping will be filled with grout in accordance with plan requirements.

In early 1999, a successful demonstration was performed to clean and survey a portion of the embedded ventilation ducting around the Refueling Cavity in the Containment building. A similar approach will likely be used for the embedded ducting around the SFP. Despite the successful cleaning demonstration, it was subsequently determined that extensive concrete removal would be required in Containment. In conjunction with the concrete removal, all the embedded piping and ductwork will be removed in the building. Contaminated embedded piping in outside areas will be removed by excavation.

As discussed previously, the decision was made to complete the final site survey at Trojan with the buildings intact and delay completion of non-radiological site remediation activities. If the buildings were to be demolished and removed in conjunction with license termination, it would likely be less expensive with respect to the embedded piping to encapsulate the contamination within the pipes (with grout or other means), remove and bury them in conjunction with the building demolition activities. However, for Trojan, the choice to decontaminate and survey-in-place the bulk of the embedded piping is the most cost-effective option for the utility.

Target:

Decommisssioning and Shutdown Plant Technology

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