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		Design Authority				4	2	D.P. Niebuhr (RSO Rep)	[signature]	9/13/00	S5-03
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ASSESSMENT OF CONCRETE REPAIR TECHNIQUES FOR RADIOLOGICALLY-CONTAMINATED TANK FARM PUMP & VALVE PITS

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Key Words: study, cost, risk, benefit, pit, coating, polyurea, secondary containment.

Abstract:
This study identifies and evaluates several technologies and methods that could be used to repair tank farm pump and valve pit interior concrete surfaces to ensure radiological waste containment integrity.

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Assessment of Concrete Repair Techniques for Radiologically-Contaminated Tank Farm Pump and Valve Pits

Executive Summary

Background

As part of the scope of Project W-314, "Tank Farm Restoration and Safe Operations," the condition of pump and valve pit walls and floors is being assessed, and repairs made as needed, to support upgrading the infrastructure necessary to safely transfer tank waste for treatment. Flaws in the surfaces of the pits (e.g., concrete cracks/faults, protective coating deterioration) must be repaired to ensure containment integrity and to facilitate future decontamination of the pits.

Scope

This engineering study presents a cost/risk/benefit evaluation of concrete and protective coating repair methods in pump and valve pits using various manual and remote tool systems.

Evaluation of Potential Repair Methods

The first portion of this study involved the evaluation of 49 combinations of pit repair methods for the various crack repair, surface preparation, and coating application tasks using both manual and remotely-operated equipment. For example, cracks can be repaired with grout or polymer, surfaces can be prepared (e.g., stripped) using anything from grinders to high-pressure water and particle sprayers to lasers, a variety of coating materials are available, and application methods range from manual to remotely-operated manipulator arms and cable/track-driven systems. Selection of the various repair techniques was driven primarily by research of commercially available technologies. Evaluation of each repair task was accomplished through application of cost/risk/benefit criteria developed specifically for these repair tasks. For example, hardware costs, installation costs, schedule, operability/maintainability, and radiological risks are all considered important evaluation criteria for any repair method. In all, thirteen cost/risk/benefit criteria were selected to evaluate each repair method. Ranking values and weighting factors were applied to each criterion to enable quantitative comparisons of the various methods.

One method stood out from all others. This method involves the application of a thick polymer-type (e.g., polyurea) coating to the pit surfaces. Not only does use of this type of coating dramatically reduce the time and resources required for crack repair (none required) and surface preparation (little prep required), it is virtually a one-step, one-coat process. The spray-on coating can be applied as thick as desired, is durable, elastic (more so than traditional epoxy-type coatings), and has good surface decontamination properties. A polymer coating, including all required crack and surface prep, can be feasibly applied both manually (from within the pit or from the edges of the pit) and via remote-controlled systems.

Detailed Evaluation of Preferred Repair Method

With the preferred repair method identified (i.e., polymer-type coating), the last portion of this study involved determining the best application technique (i.e., manual or remote). All remotely-operated systems ranked closely in regards to the cost/risk/benefit evaluation criteria.

Thus, if remote methods are necessary, the particular system that has already been evaluated by project engineers is the logical preferred choice. This system, called the "Pit Ram," is basically a backhoe-mounted, remotely-operated manipulator arm capable of performing the surface prep and coating application tasks. The criteria used for evaluation of the manual methods versus the Pit Ram remote system included the direct hardware/implementation costs and the cost/risk associated with the estimated radiological dose (i.e., dollars per man per rem) in performing the work tasks. The results of this evaluation show that performing the coating repairs manually from the edges of the pit is the most cost effective method in all cases up to an average in-pit radiation level of 55 mrem/hr. Above this level, it is most cost effective to perform the repairs using the remote-controlled Pit Ram system.

Conclusion

Based on the evaluation criteria discussed in this engineering study, the recommended method of performing concrete surface repairs in pump/valve pits is to apply (spray) a thick polymer (e.g., polyurea) coating. Given also the unknown radiological conditions achievable within a given pit, it is recommended that the polymer coating (including prep work) be performed using a remotely-operated manipulator arm system (Pit Ram), unless radiological or other special conditions warrant manually performing the work tasks in-pit or from the edges of the pit.

TABLE OF CONTENTS

SECTION NUMBER & TITLE

LIST OF TABLES

TABLE NUMBER & TITLE

LIST OF FIGURES

FIGURE NUMBER & TITLE

1.0 PURPOSE

This study identifies and evaluates several technologies and methods that could be used to repair tank farm pump and valve pit interior concrete surfaces to ensure radiological waste containment integrity.

2.0 SCOPE

The following general categories of tank farm pump and valve pit interior concrete surface repair alternatives are evaluated in this study.

- Pit surface preparation via grinding, followed by crack repair and pit coating application (manual and remote methods).
- Pit surface preparation via blasting (e.g., water/steam, abrasive particle) or other mechanical means that incorporate vacuum/filter technology, followed by crack repair and pit coating application (manual and remote methods).
- Minor pit surface preparation, followed by spraying thick polymer coating (manual and remote methods).
- Stainless steel enclosure within pit.
- Abandon existing pit and construct new pit.

These categories are further broken down into separately analyzed pit repair options, as detailed in Section 6.0. In all, 49 repair options involving various methods and equipment have been analyzed. Preferred options are identified. Detailed cost and radiological dose estimates are provided for the preferred option(s) in Section 7.0. Conclusions and recommendations are given in Section 8.0.

3.0 BACKGROUND

The mission of the River Protection Project (RPP) program is to store, treat, and immobilize highly radioactive tank waste in an environmentally sound, safe, and cost-effective manner. Within this program, "Tank Farm Restoration and Safe Operations" (Project W-314) has been established to provide major upgrades in the areas of instrumentation and control, tank ventilation, waste transfer, and electrical distribution for existing double-shell tank (DST) farm facilities (LMHC 1999b, LMHC 1998, NHC 2000a, NHC 2000b, WHC 1996). These upgrades are intended to ensure that the tank farm infrastructure can support the continued safe management of tank waste.

The project W-314 waste transfer infrastructure upgrades include modifications to selected pump and valve pits. The approximately 33 pits to be assessed by project W-314 are located in double shell tank (DST) tank farms 241-AN, AP, AW, and SY. In addition to cover block, nozzle, and valve manifold modifications in the pits, the pit walls and floors and their protective coatings will be assessed and repaired as necessary (e.g., repair cracks/faults). General descriptions of pump and valve pits and associated equipment are provided in CHG 2000a/2000b. The protective pit coatings and crack/fault repair are necessary to facilitate future decontamination, protect the concrete from potentially damaging chemicals and the environment, and ensure containment integrity (LMHC 1999b).

Current methods of repairing the pit walls and floors involve manually preparing (e.g., grinding/cutting) and grouting cracks within the pit structure. Repairing the protective coatings involves manually stripping or roughing the surfaces (e.g., via grinder), cleaning, followed by the coating application. This type of work is very time consuming and thus, expensive. It also results in potential radiation exposure to personnel working in the often highly contaminated areas. Other repair methods are, thus, desired.

Many types of equipment/tools for concrete surface preparation and repair are commercially available. Some of the various methods include ultra-high pressure water spray, hot water/pressure spray, abrasive blasting, plastic blasting, cyrogenic (CO_2) blasting, chemical decon, concrete planers, scabblers and needle guns, and lasers. These systems typically can utilize a high efficiency vacuum and filter containment system. Various spray-on coatings are also commercially available, including some requiring only minor surface preparation. In addition, remotely-controlled and automated manipulator mechanisms are commercially available and could be used to deploy the various equipment/tools necessary for the pit repair process.

4.0 METHODOLOGY

The selection of pit repair technique alternatives was created by assessing the existing condition (i.e., pit surface repair needs) and identifying possible solutions that are technically feasible to implement. The potential options were further researched via extensive product searches, discussions with manufacturers and vendors, and discussions with project engineers and field personnel.

Once the potential alternatives were identified and the research completed for each, a decision analysis process was used to evaluate and rank the alternatives relative to each other (for similar studies see LMHC 1999a, LMHC 1998, WHC 1995). The decision analysis process used involves three basic components. These components, discussed below, include evaluation criteria, ranking values, and weighting factors.

a) Evaluation criteria - The evaluation criteria are selected based on what would be considered key attributes of any given alternative. For example, hardware costs, installation costs, schedule, and radiological risks are all considered important evaluation criteria for any alternative. In all, thirteen criteria were selected to evaluate each alternative. A description of each criterion is given below.

- Hardware/material costs – include direct cost of procuring the equipment and materials, including any necessary fabrication (non-field) costs.

- Installation costs – associated primarily with field-work activities, but also include training and testing.

- Radiological and other health risks – based on the estimated severity of radiological and chemical exposures. Considers the form of generated waste (e.g., particle size, solid, liquid, easily airborne, etc.) in addition to exposure time.

- Complexity of required permits and work package documentation – based primarily on the estimated level of regulatory-type approvals and other oversight involvement (e.g., federal/state/local government, environment, safety and health, nuclear safety, quality assurance) required to perform the work activities.

- Technical feasibility – based on an engineering perspective of the practicality of performing the tasks and implementing the technology. Related to the perceived complexity of engineering support required.

- Level of waste generation – based on the estimated quantity of waste generated as a result of the work task.

- Level of support equipment required – based on the quantity and set-up complexity of equipment needed to perform the work tasks, e.g., containment tent, crane, generator, air compressor, paint sprayer, remote-operated equipment.

- Lead time of hardware – based on equipment and material availability, component fabrication estimates.

- Completion time – based on estimated length of time required to complete task.

- Level of operability and maintainability – based on the type of equipment used for the work task and its perceived reliability.

- Complexity of labor issues – based primarily on whether work task will be performed by plant personnel already trained for task, whether plant personnel will need to be specially trained for task, or whether off-site labor will be used. Considers also the degree of technical support personnel required (e.g., from vendors, manufacturers).

- Degree of pit floor and wall preparation or decontamination – based on the scope and effort required to prepare pit surfaces for coating application.

- Performance/life expectancy – based on the perceived level of maintenance required for the finished product.

b) Ranking Value - For each evaluation criterion, a ranking value is assigned, based on the pertinent research data and/or engineering judgement. The ranking values provide a way to quantitatively compare each alternative. Ranking values for each criterion are applied as follows. NOTE: Ranking values for tasks associated with using remotely-operated equipment may be assigned zero or negative values to account for reductions in cost/risk over use of manual methods (applied in Section 6.4.2).

- Hardware/material cost – assigned a value of 1 for each $100,000.

- Installation costs – assigned a value of 1 for each $100,000.

- Radiological and other health risks – assigned a value of 1 to 10, where 1 is minimal risk, 5 is average risk, and 10 is maximum risk (e.g., from excessive production of dust or other airborne contaminates). Values in between low/average/high are ranked qualitatively relative to other similarly-ranked tasks. Detailed radiological cost/risk estimates are provided for the recommended methods in Section 7.0.

- Complexity of required permits and work package documentation – assigned a value of 1 to 10, where 1 is low site-level oversight, 5 is average site-level oversight (e.g., E, S, QA), and 10 is high site-level and/or governmental oversite. Values in between low/average/high are ranked qualitatively relative to other similarly-ranked tasks.

- Technical feasibility – assigned a value of 1 to 10, where 1 is a low level of required engineering support, 5 is average support, and 10 is a high level of required engineering support. Values in between low/average/high are ranked qualitatively relative to other similarly-ranked tasks.

- Level of waste generation – assigned a value of 1 to 10, where 1 is low (or none) waste generation, 5 requires at least two 33 gallon barrels (average), and 10 requires multiple barrels or at least 1 burial box (high). Values in between low/average/high are ranked qualitatively relative to other similarly-ranked tasks.

- Level of support equipment required – assigned a value of 1 to 10, where 1 is low required equipment support, 5 is average (e.g., crane, normal support vehicles, electrical hook up), and 10 requires multiple equipment and infrastructure installations. Values in between low/average/high are ranked qualitatively relative to other similarly-ranked tasks.

- Lead time of hardware – assigned a value of 1 for each month.

- Completion time – assigned a value of 1 for each month.

- Level of operability and maintainability – assigned a value of 1 to 10, where 1 is low attention required for installation/task equipment, 5 is average, and 10 requires significant attention to operation and maintenance. Values in between low/average/high are ranked qualitatively relative to other similarly-ranked tasks.

- Complexity of labor issues – assigned a value of 1 to 10, where 1 is low, i.e., work tasks will be performed by plant personnel already trained for task and minimal technical support is required, 5 is average, i.e., some plant personnel will need to be specially trained for task and some engineering/technical support will be required, and 10 is if a specialized, off-site team is required to operate equipment and/or significant engineering/technical support is required during field work tasks. Values in between low/average/high are ranked qualitatively relative to other similarly-ranked tasks.

- Degree of pit floor and wall preparation or decontamination – assigned a value of 1 to 10, where 1 is a low level of required surface preparation, 5 is average (e.g., cleaning, roughing, significant spot preparation), and 10 is if the entire surface must be stripped. Values in between low/average/high are ranked qualitatively relative to other similarly-ranked tasks.

- Performance/life expectancy - assigned a value of 1 to 10, where 1 is a low level of required re-work/maintenance on finish product (life expectancy > 15 years), 5 is average (life expectancy > 5 years), and 10 is high maintenance of finished product (life expectancy 2 years or less). Values in between low/average/high are ranked qualitatively relative to other similarly-ranked tasks.

c) Weighting Factor - A weighting factor is also applied to each evaluation criterion to emphasize its relative importance to the other criteria. The weighting factor is assigned based on engineering judgement and input from the various disciplines that reviewed this document. Weighting factors range from 5 to 20, where 5 is considered the lowest relative importance when compared to other criteria, and 20 is considered the highest relative importance.

The table below summarizes the evaluation criteria, the range of ranking values, and the weighting factors used in this study.

TABLE 4-1 – DECISION ANALYSIS PROCESS OUTLINE		
EVALUATION CRITERION	RANKING VALUE	WEIGHTING FACTOR
Hardware/material cost	1 for each $100K	10
Installation cost, including training and testing	1 for each $100K	10
Radiological and other health risks	1 to 10	20
Complexity of required permits and work package documentation	1 to 10	5
Technical feasibility	1 to 10	5
Level of waste generation	1 to 10	15
Level of support equipment required	1 to 10	5
Lead time on hardware	1 for each month	5
Completion time	1 for each month	5
Level of operability and maintainability	1 to 10	10
Complexity of labor issues	1 to 10	5
Degree of pit floor and wall preparation or decontamination	1 to 10	15
Performance/life expectancy	1 to 10	20

Using this decision analysis process outline, all identified pit repair methods were evaluated according to task (i.e., by the various methods of crack repair, surface preparation, coating application, and remotely-controlled equipment). The sum of the products of each ranking value and corresponding weighting factor is used as the indicator for that task's overall cost/risk/benefit (CRB) value. The individual task evaluations are contained in Sections 6.1 through 6.5. The combinations of these tasks (i.e., the various methods of crack repair, surface preparation, coating application, and remotely-controlled equipment) into repair methods are tabulated in Section 6.6. In all, 49 combinations of pit repair methods and equipment were evaluated.

The preferred repair methods identified through this decision analysis process (i.e., those having significantly lower CRB values than all other methods) were further evaluated (Section 7.0) to determine the best possible method to be recommended for implementation. The criteria used for the more detailed evaluation of the preferred methods included all direct hardware and implementation costs, and the estimated cost/risk of radiological exposure while performing the work (e.g., dollars per man per dose rate).

The overall conclusions and recommendations of this study are discussed in Section 8.0.

Specific manufacturer and product trade names have specifically not been used in this study. Rather, the various pit repair methods are discussed as general methods, with any product-specific information (e.g., hardware cost, procurement lead-time) based on research of the currently available and most easily implemented (e.g., off-the-shelf) technologies.

5.0 ASSUMPTIONS

Some basic assumptions are made regarding the selection and evaluation of alternatives in this study, including the following:

- Section 6.0 of this document presents only rough order magnitude of cost and schedule estimates for the purposes of comparing alternatives only. Detailed cost and schedule information is further developed in Section 7.0 for the recommended alternative(s).
- Because of the states of the art in machine and materials (e.g., protective coatings) technologies, it is assumed that all technologies discussed herein are able to meet all applicable design, installation, and operation requirements with little or no modification. The adequacy of any particular technology in meeting such requirements will be verified for the recommended alternative(s) and documented, if pursued by the project, by subsequent design and requirements reviews.
- It is assumed that all technologies discussed herein may be procured as "off-the-shelf" equipment with little or no modification required.
- The decontamination factors (i.e., ratio of radiation levels before and after a given decontamination method is performed) for all pit coating alternatives are assumed to be similar and therefore do not have a significant influence on the criteria used to assess each alternative. For example, a decontamination factor of 49 = 1-(1/49) = 98% reduction. A decontamination factor of 99 = 1-(1/99) = 99% reduction. This difference is assumed to be negligible as it relates to the real costs of doing work.
- Radiological worker "burn-out" (i.e., reaching administrative limits for exposure) is assumed to not occur and thus have any significant influence on the criteria (e.g., installation costs) used to assess each alternative in Section 6.0. Radiological cost/risk is factored into the detailed evaluations in Section 7.0. Implementation of all applicable ALARA (as low as reasonably achievable) controls is assumed for all field work activities.
- Installation of a radiological containment tent around the pump/valve pit is assumed necessary for all pit repair alternatives discussed in Section 6.0. Thus, this cost is not factored into the assessment of each alternative, nor does it need to be since it would have no effect on the decision analysis process used to compare each alternative.
- Pit cover block removal costs are assumed to be basically the same for all pit repair alternatives discussed in Section 6.0. Thus, this cost is not factored into the assessment of each alternative, nor does it need to be since it would have no effect on the decision analysis process used to compare each alternative.

6.0 EVALUATION OF POTENTIAL REPAIR METHODS

6.1 SURFACE PREPARATION

6.1.1 GRINDER

Probably one of the most straightforward methods of preparing pit wall and floor surfaces for re-coating is simply to use a manually-operated electric or pneumatic grinder. Hardware costs are relative minimal. The field work, however, is very labor intensive. This method is also considered to be one of the most risky in terms of potential radiological exposure because of the time required to perform the work and the fact that the pits may be highly contaminated.

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.1-1 – PIT SURFACE PREP USING GRINDER				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Grinders and miscellaneous equipment and supplies = $15K. Active ventilation system potentially required for containment tent = $5K. Cost of containment tent considered common to all alternatives and thus omitted.	0.2	10	2
Installation cost, including training and testing	Estimate = 1 PIC, 1 HPT, 3 tank farm and/or equipment operators, 1/4 engineering support x 80 hr @ $75/hr x 33 pits = $1040K.	10.4	10	104
Radiological and other health risks	Qualitatively judged to be highest exposure of all alternatives because of the time required to perform the surface preparation tasks and the level of dust generation.	10	20	200
Complexity of required permits and work package documentation	Considered higher than average compared to other alternatives. Will involve numerous radiological and industrial safety issues.	8	5	40
Technical feasibility	Considered somewhat routine, non-sophisticated tank farm work.	1	5	5
Level of waste generation	Considered minimal quantity of dust and debris to dispose of. However, plastic sleeving will likely be used for cords, etc. and also there is a potential for contaminated equipment.	4	15	60
Level of support equipment required, e.g., containment tent, crane, generator	Considered relatively minimal compared to other options. Need containment tent.	2	5	10
Lead time on hardware	Considered minimal – 1 month.	1	5	5

TABLE 6.1-1 – PIT SURFACE PREP USING GRINDER				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Completion time	Assume 3 weeks x 33 pits.	25	5	125
Level of operability and maintainability	Equipment maintenance during surface preparation considered minimal.	1	10	10
Complexity of labor issues	Use on-site personnel already trained for tank farm work.	1	5	5
Degree of pit floor and wall preparation or decontamination	Nature of this task is maximum surface preparation.	10	15	150
Performance/life expectancy	Not considered an issue for this work task.	N/A	20	0
TOTAL CRB VALUE				716

6.1.2 HIGH PRESSURE STEAM/WATER & VACUUM SYSTEM

High pressure and ultra-high pressure steam/water blasters are commercially available for stripping and/or decontaminating concrete surfaces. These technologies commonly incorporate high efficiency vacuum and filtering mechanisms to collect and filter the waste streams. Generally, this method would be more efficient and cleaner than the manual grinding method. However, hardware costs are significant. Radiological exposure would be lower than for the manual grinding method, especially if a remote tool handing system was used (evaluated separately in Section 6.4).

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.1-2 – PIT SURFACE PREP USING HIGH PRESSURE STEAM/WATER				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	High pressure water sprayer and vacuum system with spare parts = $311K. Cost of containment tent considered common to all alternatives and thus omitted.	3.11	10	31.1
Installation cost, including training and testing	More labor intensive than grinding method because of set up time required for equipment and "touch-up" where equipment can't reach (e.g., corners). Estimate = 1 PIC, 1 HPT, 3 tank farm and/or equipment operators, 1/4 engineering support x 120 hr @ $75/hr x 33 pits = $1,560K.	15.6	10	156

TABLE 6.1-2 – PIT SURFACE PREP USING HIGH PRESSURE STEAM/WATER				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Radiological and other health risks	Considered less risk than grinding method, more risk than remote methods. However, requires set up time and "touch-up" in places equipment can't reach. Thus, considered average overall compared to other alternatives.	5	20	100
Complexity of required permits and work package documentation	Considered less complex compared to the grinding method. Nonetheless, still significant because of the potential air emissions (vacuum/filtration system).	7	5	35
Technical feasibility	Tool head (sprayer/vacuum) can't access all areas. May require significant "touch-up" work.	7	5	35
Level of waste generation	Considered minimal. Dust, debris, and water captured by filtration system.	1	15	15
Level of support equipment required, e.g., containment tent, crane, generator	Considered above average – need containment tent, crane, two equipment skids.	7	5	35
Lead time on hardware	Estimated at 3 months.	3	5	15
Completion time	Assume 3 weeks x 33 pits.	25	5	125
Level of operability and maintainability	High maintenance required for spray and vacuum systems.	8	10	80
Complexity of labor issues	Use on-site personnel already trained for tank farm work. However, will require additional training for equipment operation and maintenance.	3	5	15
Degree of pit floor and wall preparation or decontamination	Nature of this task is maximum surface preparation.	10	15	150
Performance/life expectancy	Not considered an issue for this work task.	N/A	20	0
TOTAL CRB VALUE				792

6.1.3 ABRASIVE PARTICLE BLASTER & VACUUM SYSTEM

Abrasive particle blasters are commercially available for stripping and/or decontaminating concrete surfaces. These technologies may be incorporated with high efficiency vacuum and filtering mechanisms to collect and filter the waste streams. Generally, this method would be more efficient and cleaner than the manual grinding method, but probably less clean than the water blaster method. Hardware costs are significant. Radiological exposure would be slightly higher than the water blaster method, due to increased dust and debris potential.

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.1-3 – PIT SURFACE PREP USING ABRASIVE PARTICLE BLASTER				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Abrasive blaster = $90K. Vacuum/filtration system = $150K. Cost of containment tent considered common to all alternatives and thus omitted.	2.4	10	24
Installation cost, including training and testing	Similar to steam/water blasting method. Estimate = 1 PIC, 1 HPT, 3 tank farm or equipment operators, 1/4 engineering support x 120 hr @ $75/hr x 33 pits = $1,560K	15.6	10	156
Radiological and other health risks	Considered greater risk than water blasting method, but much less than grinding method.	7	20	140
Complexity of required permits and work package documentation	Considered more complex than for water blasting because of the "dry" process and increased potential for air emissions (vacuum/filtration system). May require addition permitting and/or engineering controls.	8	5	40
Technical feasibility	Tool head (blaster/vacuum) can't access all areas. May require significant "touch-up" work.	7	5	35
Level of waste generation	Considered relatively small. Dust, debris, and blasting particles captured in filtration system.	2	15	30
Level of support equipment required, e.g., containment tent, crane, generator	Considered above average – need containment tent, crane, equipment skids.	7	5	35
Lead time on hardware	Estimated at 3 months.	3	5	15
Completion time	Assume 3 weeks x 33 pits.	25	5	125
Level of operability and maintainability	High maintenance needed for blaster and vacuum systems.	8	10	80
Complexity of labor issues	Use on-site personnel already trained for tank farm work. However, will require additional training for equipment operation and maintenance.	2	5	10
Degree of pit floor and wall preparation or decontamination	Nature of this task is maximum surface preparation.	10	15	150
Performance/life expectancy	Not considered an issue for this work task.	N/A	20	0
TOTAL CRB VALUE				840

6.1.4 CYROGENIC (CO_2) BLASTER & VACUUM SYSTEM

"Dry ice" blasters are commercially available for stripping and/or decontaminating concrete surfaces. These technologies may incorporate high efficiency vacuum and filtering mechanisms to collect and filter the waste streams. Generally, this method would be cleaner than the abrasive particle blasting method. However, this method is relatively slow and would probably take as long or longer than the grinding methods. Radiological exposure may therefore be similar to the abrasive particle blasting method.

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.1-4 – PIT SURFACE PREP USING CO2 BLASTER

EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	CO2 blaster system = $100K. Vacuum/filtration system = $150K. Cost of containment tent considered common to all alternatives and thus omitted.	2.5	10	25
Installation cost, including training and testing	Similar to other blasting options. Estimate = 1 PIC, 1 HPT, 3 tank farm or equipment operators, 1/4 engineering support x 120 hr @ $75/hr x 33 pits = $1,560K	15.6	10	156
Radiological and other health risks	Considered greater risk than water blasting but less than grinding method. In this case, the increase in radiological risk is not due to dust potential, but to increased time of exposure because this method is considered much slower than other blasting methods.	7	20	140
Complexity of required permits and work package documentation	Considered more comparable to other blasting alternatives because of the potential air emissions (vacuum/filtration system).	7	5	35
Technical feasibility	Tool head (blaster/vacuum) can't access all areas. May require significant "touch-up" work. Slow compared to other types of blasters. Large amount of dry ice handling required.	9	5	45
Level of waste generation	Considered minimal. Dust and debris captured in filtration system.	1	15	15
Level of support equipment required, e.g., containment tent, crane, generator	Considered above average – need containment tent, crane, equipment skids, dry ice supply.	8	5	40
Lead time on hardware	Estimated at 3 months.	3	5	15
Completion time	Assume 4 weeks x 33 pits.	33	5	165

TABLE 6.1-4 – PIT SURFACE PREP USING CO2 BLASTER				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Level of operability and maintainability	High maintenance needed for blaster and vacuum systems.	8	10	80
Complexity of labor issues	Use on-site personnel already trained for tank farm work. However, will require additional training for equipment operation and maintenance.	3	5	15
Degree of pit floor and wall preparation or decontamination	Nature of this task is maximum surface preparation.	10	15	150
Performance/life expectancy	Not considered an issue for this work task.	N/A	20	0
TOTAL CRB VALUE				881

6.1.5 SCABBLER & VACUUM SYSTEM

Devices that mechanically chip or scale surface material are commercially available for stripping and/or decontaminating concrete surfaces. These technologies may be incorporated with high efficiency vacuum and filtering mechanisms to collect and filter the waste streams. Generally, this method would not be as clean as the blasting methods (e.g., water, abrasive particle, dry ice), mainly due to the quantity of waste potentially produced in this process. Surface finishes may require additional work to smooth, depending on coating properties. Hardware costs are significant. Radiological exposure would be considered only slightly lower than for the manual grinding method.

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.1-5 – PIT SURFACE PREP USING SCABBLER				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Scabbler unit with spare parts = $150K. Vacuum/filtration system = $150K. Cost of containment tent considered common to all alternatives and thus omitted.	3	10	30
Installation cost, including training and testing	Considered faster than other water/particle/dry ice blasting methods. Estimate = 1 PIC, 1 HPT, 2 tank farm and/or equipment operators, 1/4 engineering support x 80 hr @ $75/hr x 33 pits = $842K.	8.4	10	84

TABLE 6.1-5 – PIT SURFACE PREP USING SCABBLER				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Radiological and other health risks	Considered only slightly less than the grinding method due to the nature of dust and debris generation.	9	20	180
Complexity of required permits and work package documentation	Considered more complex compared to other alternatives because of the potential air emissions (vacuum/filtration system).	8	5	40
Technical feasibility	Tool head (with vacuum) can't access all areas. May require significant "touch-up" work.	6	5	30
Level of waste generation	Considered average compared to other alternatives. Even though a filtration system can be used, considered significant source of dust and debris generation.	5	15	75
Level of support equipment required, e.g., containment tent, crane, generator	Considered above average – need containment tent, crane, equipment skid.	6	5	30
Lead time on hardware	Estimated at 3 months.	3	5	15
Completion time	Assume 3 weeks x 33 pits.	25	5	125
Level of operability and maintainability	Relatively high maintenance for equipment.	7	10	70
Complexity of labor issues	Use on-site personnel already trained for tank farm work. However, will require additional training for equipment operation and maintenance.	2	5	10
Degree of pit floor and wall preparation or decontamination	Nature of this task is maximum surface preparation.	10	15	150
Performance/life expectancy	Not considered an issue for this work task.	N/A	20	0
TOTAL CRB VALUE				839

6.1.6 LASER & VACUUM SYSTEM

Laser technology is available for stripping and/or decontaminating concrete surfaces. Such technology may be incorporated with high efficiency vacuum and filtering mechanisms to collect and filter the waste streams. Generally, this method would be cleaner than the manual grinding method. However, hardware costs are significant. Radiological exposure would be lower than for the manual grinding method, especially if a remote tool handing system was used (evaluated separately in Section 6.4). The limiting factor, however, with this technology is that, for practical purposes, it is commonly used on a "micro" scale. Discussion with various manufacturers reveals that using this technology to clean the extensive areas of the pump and valve pits is not considered feasible. Thus, no further assessment of laser technology is performed.

6.1.7 SPOT PREP

This alternative is intended for use in conjunction with applying a thick polymer coating to the pit surfaces (discussed in Section 6.3). The walls of the pits have typically been painted. The paint is potentially not a desirable adhesion point for the polymer. Some surface prep may be needed to ensure proper adhesion to the concrete. An alternative to removing all paint using a grinding or blasting method is to remove small areas (e.g., 3" diameter) of the paint with a grinder or other simple means to expose the concrete.

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.1-7 – PIT SURFACE SPOT PREP				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Grinder and miscellaneous equipment and supplies = $10K. Cost of containment tent considered common to all alternatives and thus omitted.	0.1	10	1
Installation cost, including training and testing	Estimate = 1 PIC, 1 HPT, 2 tank farm or equipment operators, 1/4 engineering support x 40 hr @ $75/hr x 33 pits = $421K.	4.2	10	42
Radiological and other health risks	Considered less risk compared to other surface preparation alternatives.	4	20	80
Complexity of required permits and work package documentation	Considered relatively low compared to other alternatives. Will involve standard radiological and industrial safety issues.	3	5	15
Technical feasibility	Considered somewhat routine tank farm work.	1	5	5
Level of waste generation	Considered minimal, dust and debris.	2	15	30
Level of support equipment required, e.g., containment tent, crane, generator	Considered average – need containment tent.	5	5	25
Lead time on hardware	Considered minimal – estimated 1 month max.	1	5	5
Completion time	Assume 1 week x 33 pits.	8.3	5	41.5
Level of operability and maintainability	Minimal equipment maintenance required.	1	10	10
Complexity of labor issues	Use on-site personnel already trained for tank farm work.	1	5	5
Degree of pit floor and wall preparation or decontamination	Only minimal spot grinding/prep required.	1	15	15

TABLE 6.1-7 – PIT SURFACE SPOT PREP				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Performance/life expectancy	Not considered an issue for this work task.	N/A	20	0
TOTAL CRB VALUE				275

6.1.8 ANCHORS

This alternative is intended for use in conjunction with applying a thick polymer coating to the pit surfaces (discussed in Section 6.3). The walls of the pits have typically been painted. The paint is potentially not a desirable adhesion point for the polymer. Some surface prep may be needed to ensure proper adhesion to the concrete. An alternative to removing some or all of the paint using a grinding or blasting method is to manually install bolts/screws/anchors into the concrete every three square feet or so to act as an additional structural binding mechanism for the polymer. Remote installation of the anchors is also feasible if a remote control method is utilized for coating application (discussed in Section 6.4).

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.1-8 – PIT SURFACE PREP USING ANCHORS				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Anchors and misc. tools = $5K. Cost of containment tent considered common to all alternatives and thus omitted.	0.05	10	0.5
Installation cost, including training and testing	Estimate = 1 PIC, 1 HPT, 2 tank farm or equipment operators, 1/4 engineering support x 8 hr @ $75/hr x 33 pits = $84K.	0.84	10	8.4
Radiological and other health risks	Although pit access is required, time in pit is minimal. Risk is considered comparable to, but less than, spot preparation.	3	20	60
Complexity of required permits and work package documentation	Considered below average compared to other alternatives.	3	5	15
Technical feasibility	Considered somewhat routine tank farm work.	1	5	5
Level of waste generation	Considered minimal - dust and debris.	1	15	15

TABLE 6.1-8 – PIT SURFACE PREP USING ANCHORS				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Level of support equipment required, e.g., containment tent, crane, generator	Considered average – need containment tent.	5	5	25
Lead time on hardware	Considered minimal – estimate 1 month max.	1	5	5
Completion time	Assume 1 week x 33 pits.	8.3	5	41.5
Level of operability and maintainability	Minimal equipment maintenance required during anchor installation.	1	10	10
Complexity of labor issues	Use on-site personnel already trained for tank farm work.	1	5	5
Degree of pit floor and wall preparation or decontamination	Nature of this task is minimal surface preparation.	1	15	15
Performance/life expectancy	Long expected anchor life.	1	20	20
TOTAL CRB VALUE				225

6.2 CRACK/FAULT REPAIR

6.2.1 GROUT

Grinding and cutting tools are commonly used to prepare crack edges in concrete for repair. Like the manual surface preparation alternative discussed previously, hardware costs are relative minimal. The field work, however, is labor intensive. This method is also considered to be one of the more risky in terms of potential radiological exposure because of the time required to perform the work and the fact that the pits may be highly contaminated. Another consideration is that this repair method may not have a long life because the cause of the initial cracking is likely to produce further cracking or damage to the grout repair.

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.2-1 – CRACK REPAIR, GROUT				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Tools and materials = $10K. Cost of containment tent considered common to all alternatives and thus omitted.	0.1	10	1
Installation cost, including training and testing	Estimate = 1 PIC, 1 HPT, 2 tank farm operators and/or craft, 1/4 engineering support x 20 hr @ $75/hr x 33 pits = $210K.	2.1	10	21
Radiological and other health risks	Qualitatively judged to be among highest exposure of all alternatives because of preparation required for grouting.	9	20	180
Complexity of required permits and work package documentation	Although a relatively simple task and work package, considered higher than average compared to other alternatives. Will involve numerous radiological and industrial safety issues.	6	5	30
Technical feasibility	Considered somewhat routine tank farm work.	1	5	5
Level of waste generation	Considered minimal quantity of dust and debris to dispose of. However, plastic sleeving will likely be used for cords, etc. and also there is a potential for contaminated equipment.	4	15	60
Level of support equipment required, e.g., containment tent, crane, generator	Considered relatively minimal compared to other options. Need containment tent.	2	5	10
Lead time on hardware	Considered minimal – estimate 1 month max.	1	5	5
Completion time	Assume 0.5 weeks x 33 pits.	4.1	5	20.5
Level of operability and maintainability	Minimal equipment maintenance required during grouting.	1	10	10
Complexity of labor issues	Use on-site personnel already trained for tank farm work.	1	5	5
Degree of pit floor and wall preparation or decontamination	Nature of this task is maximum surface preparation for grout.	10	15	150
Performance/life expectancy	Considered high maintenance, i.e., cause of original cracking may produce future cracks.	10	20	200
TOTAL CRB VALUE				698

6.2.2 POLYMER

An alternative to the labor-intensive cutting and grinding tasks necessary to prepare crack edges in concrete for grout, a polymer-type compound could be applied directly (with no edge preparation other than removing dirt and debris) to fill the cracks. Hardware and field work costs would be minimal relative to the crack grouting alternative.

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.2-2 – CRACK REPAIR, POLYMER				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Materials and tools = $5K. Cost of containment tent considered common to all alternatives and thus omitted.	0.05	10	0.5
Installation cost, including training and testing	Estimate = 1 PIC, 1 HPT, 2 tank farm operators and/or craft, 1/4 engineering support x 20 hr @ $75/hr x 33 pits = $210K.	2.1	10	21
Radiological and other health risks	Qualitatively judged to be among lowest exposure of all alternatives.	2	20	40
Complexity of required permits and work package documentation	Considered to be a relatively simple task and work package.	2	5	10
Technical feasibility	Considered somewhat routine tank farm work.	1	5	5
Level of waste generation	Very minimal.	1	15	15
Level of support equipment required, e.g., containment tent, crane, generator	Considered relatively minimal compared to other options. Need containment tent.	2	5	10
Lead time on hardware	Considered minimal – estimate 1 month max.	1	5	5
Completion time	Assume 0.5 weeks x 33 pits.	4.1	5	20.5
Level of operability and maintainability	Minimal equipment maintenance required during crack repair.	1	10	10
Complexity of labor issues	Use on-site personnel already trained for tank farm work.	1	5	5
Degree of pit floor and wall preparation or decontamination	Nature of this task is minimal surface preparation for fill. However, dirt and debris must be removed from cracks.	3	15	45
Performance/life expectancy	Considered relatively high maintenance, i.e., cause of original cracking may produce future cracks.	8	20	160
TOTAL CRB VALUE				347

6.3 COATING

6.3.1 PRIME AND COAT (PAINT)

Once the pit wall and floor surfaces are stripped, roughed and/or decontaminated, and the cracks repaired, a primer and coating (e.g., epoxy paint) can be manually applied (remote application is assessed in Section 6.4). Material and hardware costs are considered to be the lowest of the coating options. Labor to apply the primer and coating is estimated to be greater than applying a thick polymer coating (discussed in following section). Two coats of primer and at least two coats of the epoxy coating are required per manufacturer instructions. This process is labor and time intensive, and subjects workers to radiation within the pits. Another consideration is that this repair method may not have a long life because the cause of the initial concrete cracking is likely to produce further cracking and damage to the coating.

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.3-1 – COATING, PRIME AND COAT (PAINT)

EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Materials & supplies = $30K. Cost of containment tent considered common to all alternatives and thus omitted.	0.3	10	3
Installation cost, including training and testing	Estimate = 1 PIC, 1 HPT, 2 tank farm and/or equipment operators or craft, 1/4 engineering support x 20 hr @ $75/hr x 33 pits = $210K.	2.1	10	21
Radiological and other health risks	Judged to be average compared to other coating options (more than polymer coating, less than stainless steel).	5	20	100
Complexity of required permits and work package documentation	Considered to be a relatively simple task and work package.	4	5	20
Technical feasibility	Considered somewhat routine tank farm work.	1	5	5
Level of waste generation	Considered minimal – potential for contaminated equipment.	3	15	45
Level of support equipment required, e.g., containment tent, crane, generator	Considered relatively minimal compared to other options. Need containment tent and equipment skids.	3	5	15
Lead time on hardware	Considered minimal – estimate 1 month max.	1	5	5
Completion time	Assume 0.5 weeks x 33 pits.	4.1	5	20.5

TABLE 6.3-1 – COATING, PRIME AND COAT (PAINT)				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Level of operability and maintainability	Minimal equipment maintenance required during coating application if brushed/rolled. If sprayed (assumed), then somewhat average equipment maintenance is expected.	5	10	50
Complexity of labor issues	Use on-site personnel already trained for tank farm work.	1	5	5
Degree of pit floor and wall preparation or decontamination	Nature of this task is maximum surface preparation for coating.	10	15	150
Performance/life expectancy	Life of paint is considered to be only a few years. Integrity of pit containment is dependent on the periodic maintenance of the coating, which is considered to be extremely labor intensive.	10	20	200
TOTAL CRB VALUE				640

6.3.2 THICK POLYMER-TYPE COATING (POLYUREA)

As discussed previously, surface preparation for a thick polymer-type coating can be performed by one of several alternatives (e.g., spot removal, install anchors). Once the surfaces are prepared for coating, the application of the coating can be achieved two different ways:

- Application by an outside contractor.
- Application by a newly trained Hanford team. This option entails the purchase of the coating equipment, training and technical support. The manufacturer of the polymer would train this team.

Given the magnitude of this project (i.e., number of pits) and potential uses of this coating system elsewhere at Hanford, purchase of the equipment and training of Hanford personnel is recommended.

The simplest way to apply the coating would be from inside the pit if radioactivity allows or with an extension applicator from outside the pit. Additional remote-controlled methods are assessed in Section 6.4.

One available polymer-type coating is approximately $50.00 per gallon. If the coating is sprayed to a thickness of ¼ inch, coverage equals about 6.4 ft²/gallon. Each pit is assumed to be approximately 600 ft² (does not include bottom side of cover blocks). The equipment required for this option costs approximately $37K. Training is estimated at 4 days to be about $5K. An air compressor (approximately 20 cfm @ 100 psi) and electrical power (220V, 50 amp) are required to support this equipment.

These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.3-2 – COATING, THICK POLYMER				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Coating x 33 pits = $155K. Equipment/materials = $55K. Cost of containment tent considered common to all alternatives and thus omitted.	2.1	10	21
Installation cost, including training and testing	Estimate = 1 PIC, 1 HPT, 3 tank farm and/or equipment operators, 1/4 engineering support x 20 hr @ $75/hr x 33 pits = $260K.	2.6	10	26
Radiological and other health risks	Qualitatively judged to be lowest exposure of all coating alternatives. Compared with exposure from all tasks, it is still considered to be amount the lowest exposure due to the amount of time required to spray the pit.	2	20	40
Complexity of required permits and work package documentation	Considered to be a relatively simple task and work package with standard radiological control and industrial safety requirements.	4	5	20
Technical feasibility	Considered somewhat routine tank farm work.	2	5	10
Level of waste generation	Considered minimal – potential for contaminated equipment.	2	15	30
Level of support equipment required, e.g., containment tent, crane, generator	Considered average – need containment tent, equipment (air compressor, pump, heater, reservoir) skids.	5	5	25
Lead time on hardware	Considered minimal – estimated 1 month.	1	5	5
Completion time	Assume 0.3 weeks x 33 pits.	2.5	5	12.5
Level of operability and maintainability	Somewhat significant equipment maintenance is assumed due to two-part spray systems, air compressor.	7	10	70
Complexity of labor issues	Use on-site personnel already trained for tank farm work. However, will required coordination with manufacturer/vendor, as well as potential technical support.	3	5	15
Degree of pit floor and wall preparation or decontamination	Nature of this task is minimal surface preparation for coating.	1	15	15
Performance/life expectancy	Life of polymer is 30+ yr. Low maintenance is expected. Future cracking in concrete will not necessarily cause polymer to fail.	1	20	20
TOTAL CRB VALUE				310

6.3.3 STAINLESS STEEL

Lining a pit with stainless steel has been previously evaluated (WHC 1995). Information from that evaluation is considered in establishing cost and labor estimates. These and other considerations identified in the table below provide the basis for each ranking value associated with this alternative. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of the table as a Total Cost/Risk/Benefit (CRB) Value for this alternative.

TABLE 6.3-3 – COATING, STAINLESS STEEL

EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Materials and tools = $330K. Fabrication = $825K. Cost of containment tent considered common to all alternatives and thus omitted.	11.6	10	116
Installation cost, including training and testing	Estimate = 1 PIC, 1 HPT, 6 tank farm and/or equipment operators or craft, 1/2 engineering support x 200 hr @ $75/hr x 33 pits = $4,210K.	42.1	10	421
Radiological and other health risks	Qualitatively judged to be highest exposure of all coating alternatives and also high compared to other tasks.	10	20	200
Complexity of required permits and work package documentation	Considered to be a relatively complex task and work package, with numerous radiological control and industrial safety requirements.	9	5	45
Technical feasibility	Intensive engineering support. Difficult to do research of as-built condition of pits without inspection.	10	5	50
Level of waste generation	Considered minimal dust and debris with high potential for contaminated tools/equipment.	6	15	90
Level of support equipment required, e.g., containment tent, crane, generator	Considered above average – need containment tent, crane, supply truck/trailer, welder/generator.	8	5	40
Lead time on hardware	Estimated 3 months.	3	5	15
Completion time	Assume 3 weeks fabrication + 5 weeks field work x 33 pits.	66	5	330
Level of operability and maintainability	Assume fairly minimal equipment maintenance required for this option.	2	10	20
Complexity of labor issues	Use on-site personnel already trained for tank farm work.	1	5	5
Degree of pit floor and wall preparation or decontamination	Minimal concrete surface preparation required. However, multiple connections with floor penetrations need to be made.	9	15	135
Performance/life expectancy	Expected lifetime is long with little required maintenance.	1	20	20
TOTAL CRB VALUE				1487

6.4 APPLICATION METHODS

6.4.1 MANUAL

Manual application of the surface preparation, crack repair, and coating technologies discussed in previous sections was assumed in their respective Total Cost/Risk/Benefit (CRB) Value estimates. The CRB values for the remote/automated application methods discussed below may be added directly to the CRB values for any of the manual methods.

6.4.2 REMOTELY-OPERATED & AUTOMATED

Numerous remotely-operated systems are commercially available for tooling manipulation. Such devices are capable of actuating the various grinders, blasters, and sprayers necessary for pit surface preparation, crack repair, and coating application. Several different concepts were investigated, including:

- backhoe-mounted manipulator arm system ("Pit Ram")
- cable-suspended "wall-walking" system
- track/scaffold-mounted system

The same criteria used to evaluate the previously presented work tasks associated with surface prep, crack repair, and coating application (e.g., hardware and installation costs, radiological risk, schedule, etc.) are used to evaluate the various remotely-operated equipment. The only difference in the tables presented below, is that the ranking values for each criterion are based on the amount of cost/risk that is added to, or removed from, the cost/risk of performing the tasks manually. Thus, in these tables the ranking values can be zero or negative (e.g., to effect a reduction in the radiological risk over performing the repair manually). The tables are set up in this manner so that the Cost/Risk/Benefit (CRB) values for the various repair methods can be totaled and compared (Section 6.6) more easily.

These and other considerations identified in the tables below provide the basis for each ranking value associated with the alternatives. The ranking values and weighting factors are combined for each criterion, the sum reported at the conclusion of each table as a Total Cost/Risk/Benefit (CRB) Value for the alternative.

TABLE 6.4.2-1 – APPLICATION METHOD, REMOTELY-OPERATED MANIPULATOR ARM				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Estimated equipment cost = $600K. Cost of containment tent considered common to all alternatives and thus omitted.	6	10	60
Installation cost, including training and testing	An additional 1 tank farm and/or equipment operator or craft, and 1/2 engineering support x 20 hr @ $75/hr x 33 pits = $74K.	0.74	10	7.4
Radiological and other health risks	This equipment is judged to considerably reduce the radiological risks associated with the pit repair tasks.	-5	20	-100
Complexity of required permits and work package documentation	Little added complexity to this documentation is assumed due to use of a remote/automated system.	1	5	5
Technical feasibility	Remote and/or automated equipment control systems may slightly increase overall job complexity.	1	5	5
Level of waste generation	Considered minimal – potential for equipment contamination (but less than cable and track-mounted systems).	1	15	15
Level of support equipment required, e.g., containment tent, crane, generator	No additional support equipment is assumed.	0	5	0
Lead time on hardware	Equipment availability to project assumed – no additional lead time.	0	5	0
Completion time	Added set-up and testing time estimated at 0.5 week x 33 pits.	4.1	5	20.5
Level of operability and maintainability	Added equipment troubleshooting and maintenance.	2	10	20
Complexity of labor issues	Requires added interfaces with equipment manufacturer/vendor and technical support for training and/or field work (but not as much as for cable or track-mounted systems).	1	5	5
Degree of pit floor and wall preparation or decontamination	N/A	N/A	15	0
Performance/life expectancy	N/A	N/A	20	0
TOTAL CRB VALUE				38

TABLE 6.4.2-2 – APPLICATION METHOD, REMOTELY-OPERATED CABLE-SUSPENDED SYSTEM				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Additional equipment to control remote/automated operation = $110K. Cost of containment tent considered common to all alternatives and thus omitted.	1.1	10	11
Installation cost, including training and testing	An additional 1 tank farm and/or equipment operator or craft, and 1/2 engineering support x 40 hr @ $75/hr x 33 pits = $149K.	1.49	10	14.9
Radiological and other health risks	This equipment is judged to considerably reduce the radiological risks associated with the pit repair tasks (but not as much as compared to manipulator arm system, due to more set up time required in and around the pits).	-3	20	-60
Complexity of required permits and work package documentation	Little added complexity to this documentation is assumed due to use of a remote/automated system.	1	5	5
Technical feasibility	Remote and/or automated equipment control system may slightly increase overall job complexity (considered more complex than manipulator arm system).	2	5	10
Level of waste generation	Potential for additional equipment contamination. More equipment around and in pits.	2	15	30
Level of support equipment required, e.g., containment tent, crane, generator	Need additional equipment skids, power supplies, contamination control.	2	5	10
Lead time on hardware	Adds an estimated 2 months to other equipment procurement.	2	5	10
Completion time	Added set-up and testing time estimated at 1 week x 33 pits.	8.3	5	41.5
Level of operability and maintainability	Added equipment troubleshooting and maintenance (considered more than manipulator arm system).	3	10	30
Complexity of labor issues	Requires added interfaces with equipment manufacturer/vendor and technical support for training and/or field work.	2	5	10
Degree of pit floor and wall preparation or decontamination	N/A	N/A	15	0
Performance/life expectancy	N/A	N/A	20	0
TOTAL CRB VALUE				112

TABLE 6.4.2-3 – APPLICATION METHOD, REMOTELY-OPERATED TRACK/SCAFFOLD-MOUNTED				
EVALUATION CRITERION	RANKING BASIS	RANKING VALUE (RV)	WEIGHTING FACTOR (WF)	RV x WF
Hardware/material cost	Additional equipment to control remote/automated operation = $130K. Cost of containment tent considered common to all alternatives and thus omitted.	1.3	10	13
Installation cost, including training and testing	An additional 1 tank farm and/or equipment operator or craft, and 1/2 engineering support x 40 hr @ $75/hr x 33 pits = $149K.	1.49	10	14.9
Radiological and other health risks	This equipment is judged to reduce the radiological risks associated with the pit repair tasks (but not as much as compared to the cable system, due to more set up time required in and around the pits).	-2	20	-40
Complexity of required permits and work package documentation	Little added complexity to this documentation is assumed because of use of a remote/automated system.	1	5	5
Technical feasibility	Remote and/or automated equipment control system may slightly increase overall job complexity (considered more complex than cable system).	3	5	15
Level of waste generation	Potential for additional equipment contamination. More equipment around/over/in pit.	3	15	45
Level of support equipment required, e.g., containment tent, crane, generator	Need additional equipment skids, power supplies, contamination control on instrument cables.	2	5	10
Lead time on hardware	Adds an estimated 3 months to other equipment procurement.	3	5	15
Completion time	Added set-up and testing time estimated at 1 week x 33 pits.	8.3	5	41.5
Level of operability and maintainability	Added equipment troubleshooting and maintenance (considered more than manipulator arm system).	3	10	30
Complexity of labor issues	Requires added interfaces with equipment manufacturer/vendor and technical support for training and/or field work.	2	5	10
Degree of pit floor and wall preparation or decontamination	N/A	N/A	15	0
Performance/life expectancy	N/A	N/A	20	0
TOTAL CRB VALUE				159

6.5 CONSTRUCT NEW PIT

The estimated cost for the construction of a new pit is at least several million dollars, not including the cost associated with removal and proper disposal of the existing pit. This option is therefore considered too costly to warrant further evaluation.

6.6 REPAIR METHOD COMBINATIONS AND COMPARISONS

The table below presents the cost/risk/benefit (CRB) totals for each of the 49 combinations of the previously assessed pit repair methods/tasks. A discussion of the best repair method(s) follows.

Table 6.6-1 – Pit Repair Method Combinations - Cost/Risk/Benefit (CRB) Totals

Option	Description of Required Tasks	CRB Values			
		Manual (a)	Manipulator Arm (b)	Cable-Driven (c)	Track-Mounted (d)
1	Grind pit surfaces and cracks, clean, grout cracks, spray paint coating	2054	2092	2166	2213
2	Grind pit surfaces, clean, fill cracks with polymer/caulk, paint coating	1703	1741	1815	1862
3	Steam/water blast pit surfaces, grind and grout cracks, paint coating	2130	2168	2242	2289
4	Steam/water blast pit surfaces, fill cracks with polymer/caulk, paint coating	1779	1817	1891	1938
5	Abrasive blast pit surfaces, grout cracks, paint coating	2178	2216	2290	2337
6	Abrasive blast pit surfaces, fill cracks with polymer/caulk, paint coating	1827	1865	1939	1986
7	Cyrogenic blast pit surfaces, grout cracks, paint coating	2219	2257	2331	2378

Table 6.6-1 – Pit Repair Method Combinations - Cost/Risk/Benefit (CRB) Totals					
Option	Description of Required Tasks	CRB Values			
		Manual (a)	Manipulator Arm (b)	Cable-Driven (c)	Track-Mounted (d)
8	Cyrogenic blast pit surfaces, fill cracks with polymer/caulk, paint coating	1868	1906	1980	2027
9	Use scabbler on pit surfaces, grind and grout cracks, paint coating	2177	2215	2289	2336
10	Use scabbler on pit surfaces, fill cracks with polymer/caulk, paint coating	1826	1864	1938	1985
11	Spot prep (grind) pit surfaces, spray thick polymer coating on surfaces and cracks	585	623	697	744
12	Install anchors in pit surfaces, spray thick polymer coating on surfaces and cracks	535	573	647	694
13	Install stainless steel liner in pits	1487	N/A	N/A	N/A

As shown in Table 6.6-1 above, there are many different options for repairing the concrete surfaces of the pump and valve pits. In all, 49 combinations of pit repair methods/tasks were evaluated.

Many of the less desirable methods evaluated (i.e., those having higher CRB values) involve the use of an epoxy-type coating. Epoxy coating has been used in pits in the past, and has performed somewhat adequately. However, the surface prep and application are very time consuming. The entire concrete surface must be prepared and crack repairs performed. Existing epoxy coating that has deteriorated, in addition to dirt, grease, oil, and other contaminants, must be fully removed to ensure proper adhesion of the new epoxy coating to the concrete. The coating application involves multiple recommended primer and finish coats. The life expectancy of an epoxy-type coating in the pit application is questionable, as the same mechanisms that lead to failure of the concrete (e.g., cracks) inhibit the coating's effectiveness and long life.

Preferred Repair Method(s)

As shown in Table 6.6-1, the alternatives involving a polymer-type coating (Options #11 & #12) best meet the evaluation criteria, having the lowest cost/risk/benefit (CRB) values which are roughly ¼ to 1/3 that of all other alternatives. Polymer-type coatings (e.g., polyurea) offer advantages over any other process contained within this study. Use of a polymer coating is therefore recommended as an integral part of the preferred pit surface repair method for project W-314. The driving factors that give the polymer coating alternatives their low CRB value include:

- Relatively little pit surface preparation required
- Relatively low labor costs to install
- Relatively small radiological exposure
- Coating durability

With the polymer-type coating (e.g., polyurea), the majority of the expensive, time consuming surface prep work is eliminated. One specific polyurea product researched offers a quick set-up time, which allows the coating to be sprayed on in one coat at nearly any thickness desired. The product structurally bridges cracks without all of the prep work involved with traditional crack repairs. Ideally the polyurea coating would be sprayed directly to the bare concrete wall and floor surfaces, because the coating's adhesion strength is only as strong as the compound it is attached to. Because there is an existing epoxy coating on the concrete surfaces of these pump and valve pits, some surface prep work will be necessary. Removing all of the previous coating, however, is not necessary for this application. Two methods can be used to best prepare the concrete surface for the polyurea spray. The first is to install concrete anchors in a matrix pattern every 2-3 feet (walls only). The anchors provide adequate structural support for the coating. This prep work is going to generate very little dust/debris. The second option is to use a grinder to strip away the epoxy coating from the concrete in small areas in a matrix pattern every 2-3 feet. This process will allow the polymer to bond directly to the exposed concrete regions for sufficient structural support.

Polyurea coatings are incorporated at other nuclear facilities in a variety of applications. The physical properties of the polyurea set this product apart from other compounds for use as a durable secondary containment coating. Some of its key attributes include:

- set-up time as low as 15 seconds
- elongation properties of over 500%
- tensile strength of over 3000 psi
- excellent chemical resistance
- decontamination of up to 98% with water
- working temperature range of –50°F to 350°F
- tear strength of 495 pli
- abrasion resistant
- does not decompose or degrade over time, estimated expected lifetime within the valve pit environment is 50-75 years

- self-extinguishing - a constant flame with the heat of an acetylene torch would be required to keep this product burning
- no environmental threat in final form
- 100% solid
- no volatile organic compounds
- hydrophobic
- polyurea manufacturers report no issues relating to static electrical build-up on the surface of the coating

The surface prep (e.g., anchors) and application of the polymer coating can be performed remotely. The remote systems' increased hardware costs are generally offset by radiological risk reductions. If remote methods are necessary, the particular system that has already been evaluated by project engineers is the logical preferred choice. This system, called the "Pit Ram," is basically a backhoe-mounted manipulator arm capable of remotely performing the surface prep and coating application tasks. Alternatively, a spray-gun extension tool is available for applying the coating from the outside edge of the pit. Such extension tools are widely used within the industry for application of coatings in hard to reach areas. Similar extension tools may be used to prepare the walls (e.g., install anchors) as well. These alternatives (i.e., prep and coating application from within pit, from edge of pit, or using remote equipment such as the Pit Ram) are further evaluated in Section 7.0.

7.0 DETAILED EVALUATION OF PREFERRED REPAIR METHOD

As previously established, pit concrete surface repair methods involving the use of a one-coat, spray-on polymer (e.g., polyurea) coating are preferred. Depending on the radiation levels encountered in the various tank farm valve and pump pits, it may be desirable to apply the polyurea coating from within pit, from the outside edge of the pit, or using remote equipment. Tables 7-1, 7-2 and 7-3 below provide more detailed cost/risk/benefit estimates of these three application options. The criteria used for evaluation of these options include the direct hardware and implementation costs, and the cost/risk associated with the estimated radiological dose (i.e., dollars per man per rem) in performing the work. For the purposes of the cost estimates in this section, direct labor costs are assumed to be $75/hr for all tasks (e.g., engineering or craft). Radiological dose costs are based on the methodology present in FDH 1998, and are assumed to be $30K per man-hr-rem. Exposure estimates are based on average in-pit exposure. A discussion of the results of these cost estimates follows Table 7-3.

Table 7-1 – Estimated Costs of Applying Polyurea Coating Manually From Within Pit

Equipment & Task Descriptions	Cost Basis	Total Costs ($ x 1000)
Hardware & Materials		
Containment tent & misc. sleeving/plastic	Tent, $5K x 4 farms. Sleeving, $500 x 33 pits.	37
Spray equipment, with spare parts	Per verbal/e-mail quote from manufacturer.	40
Coating	Assume average pit surface area (not including cover block) is 600 sq. ft. (x 33 pits). Coverage is about 12.8 sq. ft. per gallon at 0.125 inch thickness. Assume ¼ inch thick application. Cost is $50/gallon.	155
Anchors and power loads	100 anchors/pit at $15/100 x 33 pits.	1
Anchor installation equipment	$0.5K x 2 + 2 spares.	2
Tooling for nozzle and penetration masking	Material procurement and fabrication.	10
Waste containers, handling, storage & disposal	Assume 1 drum/pit x $2100 x 33 pits. Assume 1 burial box/farm x $6200 x 4 tank farms.	95
Engineering & Documentation		
Drawings & drawing changes	Drawings/ECNs needed to show anchors, coatings and other minor mods. 20 man-hr x $75/hr x 33 pits. Fabrication drawings for pit masking tools. 120 man-hr x $75/hr.	59
Supporting calculations, specifications, etc.	640 man-hr x $75/hr.	48
Misc. evaluations (USQ, dome load)	24 man-hr x $75/hr x 33 pits.	60
Fabrication work package(s) (for pit masking tools)	80 man-hr x $75/hr.	6
Field work packages	80 man-hr x $75/hr x 33 pits.	198

Table 7-1 – Estimated Costs of Applying Polyurea Coating Manually From Within Pit		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Training		
Sprayer system op & maint.	120 man-hr x $75/hr.	9
Field Work Activities		
Install containment tent	Erect tent, 96 man-hr x $75/hr x 4 farms. Move tent, 24 man-hr x $75/hr x 33 pits. Install plastic, sleeving, etc., 24 man-hr x $75/hr x 33 pits. Radiological exposure costs are based solely on final tent prep (tent is erected outside of the tank farm and moving it inside results in negligible exposure) – assumed 24 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	148 + 0.75/mrem
Flush pit	16 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 16 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	40 + 0.5/mrem
Remove cover blocks	48 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 48 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	119 + 11.9/mrem
Remove jumpers and misc. equipment	40 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 40 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	99 + 9.9/mrem
Additional flushing	12 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 12 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	30 + 3/mrem

Table 7-1 – Estimated Costs of Applying Polyurea Coating Manually From Within Pit		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Install shielding	80 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 80 man-hr x $30/man-hr-mrem x 33 pits x 1 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	198 + 39.6/mrem
Install wall anchors	24 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 24 man-hr x $30/man-hr-mrem x 33 pits x 1 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	60 + 11.9/mrem
Install spray equipment	48 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 4 man-hr x $30/man-hr-mrem x 33 pits x 1/8 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	119 + 0.25/mrem
Spraying operations	16 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 16 man-hr x $30/man-hr-mrem x 33 pits x 1 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	40 + 7.9/mrem
Remove spray equipment	16 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 4 man-hr x $30/man-hr-mrem x 33 pits x 1/8 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	40 + 0.25/mrem
Remove shielding	60 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 60 man-hr x $30/man-hr-mrem x 33 pits x 1 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	149 + 29.7/mrem
Install jumpers and misc. equipment	40 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 40 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	99 + 9.9/mrem

Table 7-1 – Estimated Costs of Applying Polyurea Coating Manually From Within Pit		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Install cover blocks	48 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 48 man-hr x $30/man-hr-mrem x 33 pits x 1/4 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	119 + 5.9/mrem
Remove containment tent	Move tent, 24 man-hr x $75/hr x 33 pits. Radiological exposure costs are based solely on readying tent for removal – assumed 24 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	60 + 0.75/mrem
Package/remove waste	8-man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 8 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	20 + 0.25/mrem
Total Estimated Average Cost Per Pit (x 1000)		**$63 + $4/mrem**

Table 7-2 – Estimated Costs of Applying Polyurea Coating Manually From Edges of Pit		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Hardware & Materials		
Containment tent & misc. sleeving/plastic	Tent, $5K x 4 farms. Sleeving, $500 x 33 pits.	37
Spray equipment, with extensions and spare parts	Per verbal/e-mail quote from manufacturer.	42
Coating	Assume average pit surface area (not including cover block) is 600 sq. ft. (x 33 pits). Coverage is about 12.8 sq. ft. per gallon at 0.125 inch thickness. Assume ¼ inch thick application. Cost is $50/gallon.	155
Anchors and power loads	100 anchors/pit at $15/100 x 33 pits.	1
Anchor installation equipment	$1 x 2 + 2 spares.	4
Tooling for nozzle and penetration masking	Material procurement and fabrication.	10
Waste containers, handling, storage & disposal	Assume 1 drum/pit x $2100 x 33 pits. Assume 1 burial box/farm x $6200 x 4 tank farms.	95

Table 7-2 – Estimated Costs of Applying Polyurea Coating Manually From Edges of Pit		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Engineering & Documentation		
Drawings & drawing changes	Drawings/ECNs needed to show anchors, coatings and other minor mods. 20 man-hr x $75/hr x 33 pits. Fabrication drawings for pit masking tools. 120 man-hr x $75/hr.	59
Supporting calculations, specifications, etc.	640 man-hr x $75/hr.	48
Misc. evaluations (USQ, dome load)	24 man-hr x $75/hr x 33 pits.	60
Fabrication work package(s) (for pit masking tools)	80 man-hr x $75/hr.	6
Field work packages	80 man-hr x $75/hr x 33 pits.	198
Training		
Sprayer system op & maint.	120 man-hr x $75/hr.	9
Field Work Activities		
Install containment tent	Erect tent, 96 man-hr x $75/hr x 4 farms. Move tent, 24 man-hr x $75/hr x 33 pits. Install plastic, sleeving, etc., 24 man-hr x $75/hr x 33 pits. Radiological exposure costs are based solely on final tent prep (tent is erected outside of the tank farm and moving it inside results in negligible exposure) – assumed 24 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	148 + 0.75/mrem
Flush pit	16 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 16 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	40 + 0.5/mrem
Remove cover blocks	48 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 48 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	119 + 11.9/mrem
Remove jumpers and misc. equipment	40 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 40 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	99 + 9.9/mrem

Table 7-2 – Estimated Costs of Applying Polyurea Coating Manually From Edges of Pit		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Additional flushing	12 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 12 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	30 + 3/mrem
Install shielding	60 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 60 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	149 + 14.9/mrem
Install wall anchors	32 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 32 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	80 + 7.9/mrem
Install spray equipment	48 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 4 man-hr x $30/man-hr-mrem x 33 pits x 1/8 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	119 + 0.25/mrem
Spraying operations	24 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 24 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	60 + 5.9/mrem
Remove spray equipment	16 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 4 man-hr x $30/man-hr-mrem x 33 pits x 1/8 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	40 + 0.25/mrem
Remove shielding	40 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 40 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	99 + 9.9/mrem

Table 7-2 – Estimated Costs of Applying Polyurea Coating Manually From Edges of Pit		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Install jumpers and misc. equipment	40 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 40 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	99 + 9.9/mrem
Install cover blocks	48 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 48 man-hr x $30/man-hr-mrem x 33 pits x 1/4 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	119 + 5.9/mrem
Remove containment tent	Move tent, 24 man-hr x $75/hr x 33 pits. Radiological exposure costs are based solely on readying tent for removal – assumed 24 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	60 + 0.75/mrem
Package/remove waste	8-man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 8 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	20 + 0.25/mrem
Total Estimated Average Cost Per Pit (x 1000)		**$61 + $2.5/mrem**

Table 7-3 – Estimated Costs of Applying Polyurea Coating Remotely Using Pit Ram System		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Hardware & Materials		
Containment tent & misc. sleeving/plastic	Tent, $5K x 4 farms. Sleeving, $500 x 33 pits.	37
Pit Ram system, with accessories & spare parts	Estimated delivery cost of system.	600
Spray equipment, with spare parts	Per verbal/e-mail quote from manufacturer.	40
Coating	Assume average pit surface area (not including cover block) is 600 sq. ft. (x 33 pits). Coverage is about 12.8 sq. ft. per gallon at 0.125 inch thickness. Assume ¼ inch thick application. Cost is $50/gallon.	155

Table 7-3 – Estimated Costs of Applying Polyurea Coating Remotely Using Pit Ram System		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Anchors and power loads	100 anchors/pit at $15/100 x 33 pits.	1
Anchor installation equipment	$1K x 2 + 2 spares.	4
Tooling for nozzle and penetration masking	Material procurement and fabrication.	10
Waste containers, handling, storage & disposal	Assume 1 drum/pit x $2100 x 33 pits. Assume 1 burial box/farm x $6200 x 4 tank farms.	95
Engineering & Documentation		
Drawings & drawing changes	Drawings/ECNs needed to show anchors, coatings and other minor mods. 20 man-hr x $75/hr x 33 pits. Fabrication drawings for pit masking tools. 120 man-hr x $75/hr.	59
Supporting calculations, specifications, etc.	640 man-hr x $75/hr.	48
Misc. evaluations (USQ, dome load)	24 man-hr x $75/hr x 33 pits.	60
Fabrication work package(s) (for pit masking tools)	80 man-hr x $75/hr.	6
Field work packages	100 man-hr x $75/hr x 33 pits.	248
Training		
Pit Ram operation & maint.	240 man-hr x $75/hr.	18
Sprayer system op & maint.	120 man-hr x $75/hr.	9
Field Work Activities		
Install containment tent	Erect tent, 96 man-hr x $75/hr x 4 farms. Move tent, 24 man-hr x $75/hr x 33 pits. Install plastic, sleeving, etc., 24 man-hr x $75/hr x 33 pits. Radiological exposure costs are based solely on final tent prep (tent is erected outside of the tank farm and moving it inside results in negligible exposure) – assumed 24 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	148 + 0.75/mrem
Flush pit	16 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 16 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	40 + 0.5/mrem

Table 7-3 – Estimated Costs of Applying Polyurea Coating Remotely Using Pit Ram System		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Remove cover blocks	48 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 48 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	119 + 11.9/mrem
Remove jumpers and misc. equipment	40 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 40 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	99 + 9.9/mrem
Additional flushing	12 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 12 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	30 + 3/mrem
Install shielding	40 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 40 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	99 + 9.9/mrem
Install Pit Ram system	Tractor, 16 man-hr x $75/hr x 33 pits. Sleeving, 32 man-hr x $75/hr x 33 pits. Control equipment, 16 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 32 man-hr x $30/man-hr-mrem x 33 pits x 1/8 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	159 + 2/mrem
Install wall anchors	48 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be negligible using remote installation method.	119
Install spray equipment	48 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 4 man-hr x $30/man-hr-mrem x 33 pits x 1/8 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	119 + 0.25/mrem

Table 7-3 – Estimated Costs of Applying Polyurea Coating Remotely Using Pit Ram System		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Spraying operations	32 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be negligible using remote spray method.	80
Remove spray equipment	16 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 4 man-hr x $30/man-hr-mrem x 33 pits x 1/8 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	40 + 0.25/mrem
Remove Pit Ram system	32 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 32 man-hr x $30/man-hr-mrem x 33 pits x 1/8 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	80 + 2/mrem
Remove shielding	30 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 30 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	75 + 7.4/mrem
Install jumpers and misc. equipment	40 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 40 man-hr x $30/man-hr-mrem x 33 pits x ½ (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	99 + 9.9/mrem
Install cover blocks	48 man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 48 man-hr x $30/man-hr-mrem x 33 pits x 1/4 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	119 + 5.9/mrem
Remove containment tent	Move tent, 24 man-hr x $75/hr x 33 pits. Radiological exposure costs are based solely on readying tent for removal – assumed 24 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	60 + 0.75/mrem

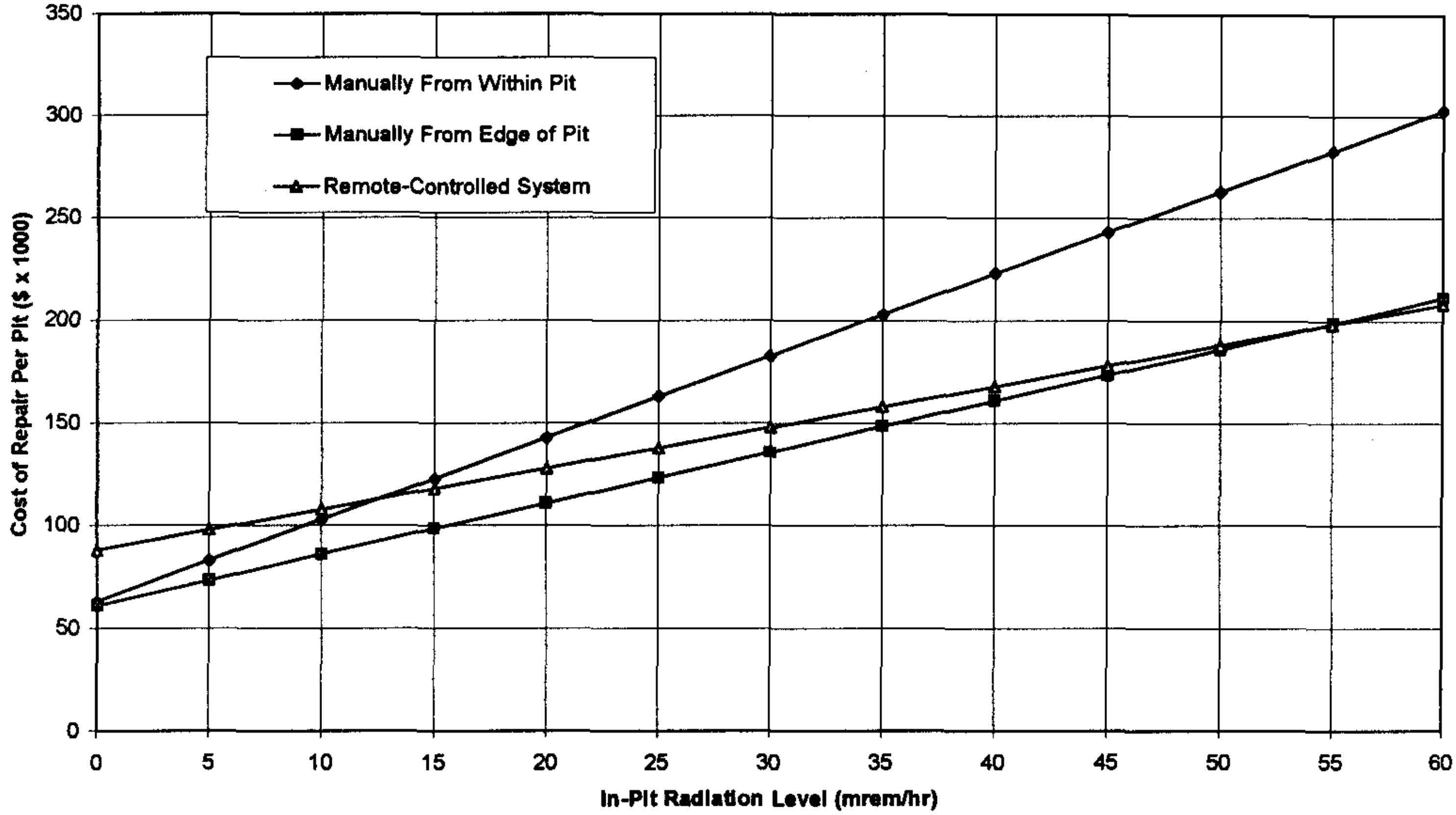
Table 7-3 – Estimated Costs of Applying Polyurea Coating Remotely Using Pit Ram System		
Equipment & Task Descriptions	**Cost Basis**	**Total Costs ($ x 1000)**
Package/remove waste	8-man-hr x $75/hr x 33 pits. Radiological exposure costs assumed to be 8 man-hr x $30/man-hr-mrem x 33 pits x 1/16 (due to distance/shielding from pit interior) x ½ (due to number of workers actually near pit).	20 + 0.25/mrem
Total Estimated Average Cost Per Pit (x 1000)		**$88 + $2/mrem**

From the tables above, the following estimated costs for applying a polymer-type (e.g., polyurea) coating are derived:

Manually from within pit	$63K + $4K/mrem	(per pit)
Manually from edges of pit	$61K + $2.5K/mrem	(per pit)
Remotely using Pit Ram system	$88K + $2K/mrem	(per pit)

The primary differences between these costs are associated with the increased hardware and deployment costs when using the remote Pit Ram system. The costs of radiological exposure decrease as expected when working from the pit edges or remotely. These cost relationships are plotted at various pit radiation levels, as shown in the figure below.

Figure 7.1 - Comparison of Polymer Application Method Costs



Two main conclusions can be drawn from this figure. First, at an average in-pit radiation level of approximately 12 mrem/hr it becomes more cost effective to perform the coating repairs remotely than manually from within the pit. Note that at this radiation level, however, it is still most cost effective to perform the repairs manually from the edges of the pit using equipment extension arms. The second conclusion is that working manually from the edges of the pit remains most cost effective method until the average in-pit radiation levels reach about 55 mrem/hr. Above this level, it is most cost effective to perform the repairs using the remote-controlled Pit Ram system.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The pit coating repair method evaluation presented initially in this study (Section 6.0) showed that of 49 possible repair methods, those involving the application of a one-coat, spray-on polymer (polyurea) coating yielded the lowest (i.e., best) cost/risk/benefit values by a large margin (approximately by a factor of 3 to 4). Cost/risk/benefit values were established based on 13 evaluation criteria, ranking values, and weighting factors (discussed in Section 4.0). The main reason for preferring the polymer coating (discussed in Section 6.6) involves significant reductions in pit wall and crack preparation times, labor costs, and radiation exposure. Furthermore, this repair method was determined to be most advantageous whether performed manually (in-pit or from pit edge) or with remote equipment. If remote equipment is considered for use, the "Pit Ram" system is recommended (discussed in Section 6.6). Further detailed evaluation was performed (Section 7.0) to assess the various options for applying the polymer coating (manually from inside pit, manually from pit edge, and remotely using the Pit Ram system).

The detailed evaluation of the polymer application methods (Section 7.0) consisted of estimating hardware and implementation costs for the various options, as well as assessing the cost/risk associated with radiological exposure for each job task. This evaluation yielded two main conclusions. First, at an average in-pit radiation level of approximately 12 mrem/hr it becomes more cost effective to perform the coating repairs remotely than from within the pit. Note that at this radiation level, however, it is still most cost effective to perform the repairs manually from the edges of the pit using equipment extension arms. The second conclusion is that working manually from the edges of the pit remains most cost effective method until the average in-pit radiation levels reach about 55 mrem/hr. Above this level, it is most cost effective to perform the repairs using the remote-controlled Pit Ram system. These conclusions are graphically depicted in Figure 7.1.

Working-level radiation doses will remain largely unknown in the various pump and valve pits until pit flushing is performed, cover blocks are removed, contaminated equipment is removed, and shielding is installed. For this reason it is recommended that the remote-controlled Pit Ram system be pursued as a likely required method of performing the pit coating repairs.

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