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Stakeholder Involvement Report for the Cryocell® Demonstration at Hanford

Principal Investigator/Project Manager

J. D. Vick

Stakeholder Involvement Team

T.S. Peterson[a]
G.H. McCabe[a]
K. A. Niesen[b]
P.J. Serie[b]

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Pacific Northwest Laboratory
Richland, Washington 99352

(a) Battelle Seattle Research Center, Seattle, WA
(b) Environmental Issues Management, Inc., Seattle, WA

This work was prepared with the support of the following contributors:

Headquarters:	Office of Technology Development Plume Focus Area Jeffrey Walker, DOE Headquarters Program Manager
Operations Office:	Richland Operations Office Technology Development Division Deborah E. Trader, Technical Program Officer
Contractor:	Pacific Northwest Laboratory Environmental Management Directorate Steven C. Slate, Technical Program Manager

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DISCLAIMER

EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) is evaluating frozen soil subsurface barriers as a way to contain the spread of contamination. CRYOCELL® is one such technology being evaluated in terms of technical performance, operating requirements, and cost of deployment in arid soils. The primary source of data for this evaluation will be a full-scale field demonstration to be conducted at an uncontaminated site at the Hanford Reservation during fiscal years 1994-96.

Experience has shown that not addressing stakeholder concerns early on in the process of technology development can lead to expending resources on remedial approaches that are ultimately not deployable. Therefore the CRYOCELL® project worked with stakeholders to help ensure that stakeholder issues and concerns, that if left unacknowledged could delay or block the deployment of the technology, were addressed during the technology's demonstration.

Stakeholders included regulators, representatives of public interest and environmental groups, Native Americans, technology users, elected officials and interested citizens. Their concerns were recorded in individual interviews and two workshops. Twenty-three stakeholders were interviewed and 27 participated in the workshops..

A number of themes emerged from analysis of stakeholder comments and data requirements. In essence, these concerns are principles recommending the way technologies in general and CRYOCELL® in particular are used.

General Stakeholder Concerns

- Stakeholders want DOE to examine in concept the need for and practicality of subsurface barriers at any Hanford location (including the Single Shell Tank farms) before specific subsurface barrier technologies or designs are evaluated.

- Stakeholders would like innovative technologies to be used in as aggressive a manner as possible while holding to the principal stakeholder value of "do no harm."

- Stakeholders regard reversible technologies, especially reversible barriers, more favorably than irreversible ones.

- Stakeholders have a sense of urgency about demonstration and cleanup and advocate getting on with these activities even if this means accepting some risk.

- Demonstrations of all new technologies should be designed to take into account as many different applications and circumstances as possible. Single-purpose demonstrations (such as demonstrating for only that information necessary to deploy a technology at the Hanford Single Shell Tank farms) do not sufficiently portray a technology's versatility.

Analysis of the responses of the stakeholder groups with the most to say about the CRYOCELL® technology – regulators, representatives of tribal governments and public interest and environmental groups – shows that these stakeholders were principally concerned about five issues:

- Determining the permeability of the barrier
- Determining the effects of any moisture added to the subsurface
- Defining the degree of physical containment the barrier could achieve
- Calculating the cost of deploying the technology
- Identifying the appropriate location for the demonstration

During the interviews and workshops, the stakeholder involvement team asked stakeholders to define what they wanted the CRYOCELL® technology's test plan to include. Stakeholders identified the following specific data requirements:

Specific CRYOCELL® Test Plan Data Requirements

- Stakeholders want the demonstration to provide detailed information on the permeability of the frozen soil barrier. Permeability data are required regarding liquid and vapor-phase chemical, radioactive, and high-temperature constituents.

- Stakeholders want detailed information on the fate and effects of moisture added to the subsurface before, during, and after placement and operation of the barrier. In particular, stakeholders want the demonstration to provide information about the possibility that added moisture will carry and spread contamination.

- Stakeholders want a detailed explanation of the functioning of the barrier including freeze/thaw effects on contained and nearby structures, demonstration of complete containment formation, seismic stability and repairability, installation requirements, and effects of heat on the system.

- Stakeholders want an analysis of the compatibility of this technology with companion technologies, as it is not an independent remediation system.

- Stakeholders want detailed cost information, specifically the cost of the electricity needed to form the frozen subsurface wall, presented in comparison to other barrier technologies, and other methods of remediation.

The insights gained from stakeholder involvement in the CRYOCELL® demonstration project apply to other remediation technologies. Section IV and Appendix A of this report provide additional information about stakeholder comments. Understanding these insights will allow remedial project managers to anticipate issues of concern to stakeholders, to involve them effectively and to speed up technology development, deployment, and environmental cleanup.

Table of Contents

List of Figures and Tables

I. Stakeholder Involvement in the CRYOCELL® Technology Evaluation

Introduction

The U.S. Department of Energy (DOE) is evaluating frozen soil subsurface barriers as a way to contain the spread of plumes of contamination until appropriate remedial techniques can be applied. Further, the hazards posed by leaking underground storage tanks, and the retrieval of waste from tanks may necessitate interim containment during retrieval or until remediation is complete.

The CRYOCELL® frozen soil subsurface barrier technology[1] is part of the Plume Focus Area managed by the DOE Environmental Management Office of Technology Development (EM-50). CRYOCELL® will be evaluated emphasizing its technical performance, operational requirements, and cost for deployment in arid soils. The primary source of data for evaluation will be a full-scale field demonstration conducted at an uncontaminated site at the Hanford reservation during Fiscal Years 1994-96.

This demonstration project currently involves the DOE and its Hanford contractors (Pacific Northwest Laboratory, Westinghouse Hanford Company, Bechtel Hanford Company); a private technology development team led by RKK, Ltd. composed of Scientific Ecology Group, Inc., freezeWALL, Inc., and Water Development Corporation; the U.S. EPA Superfund Innovative Technology Evaluation Program, and the U.S. Army Cold Regions Research and Engineering Laboratory.

Should CRYOCELL® be found in the demonstration to be an effective technology, its continued development and eventual deployment at Hanford will need stakeholder acceptance. Experience underscores the importance of involving stakeholders in the process of solving remediation problems at Hanford. This report summarizes stakeholder activities conducted in support of this field demonstration project and the information obtained from stakeholder involvement.

Stakeholder Involvement Strategy

Experience has shown that not addressing stakeholder issues and concerns early on in technology development can lead to expending resources on remedial approaches that are

[1] CRYOCELL® is the registered trademark of RKK Limited, Arlington, Washington.

ultimately not deployable. Therefore, this project obtained stakeholder input as early as possible in the technology development process -- primarily to help ensure that stakeholders issues and concerns, that if left unacknowledged could ultimately delay or block the deployment of the technology, were addressed during the technology's demonstration.

Additionally, early participation in the technology development process would enable stakeholders to learn and contribute right along with the project team, and continuing involvement would allow expectations to evolve. Lastly, stakeholders' acquired knowledge and familiarity with the government and industry team would establish trust, identify performance expectations and, overall, help reach consensus on the applicability of this technology in arid environments.

Stakeholder involvement was planned for the demonstration project's three principal phases: pre-demonstration, demonstration, and post-demonstration. During the pre-demonstration phase (see Figure 1), activities were focused on identifying stakeholders' expectations and concerns in regards to barrier performance, and the demonstration field test plan. During the demonstration phase, stakeholders will tour the test site. Lastly, after the demonstration, stakeholders will review and comment on the draft test results and conclusions prior to the publishing of a final report.

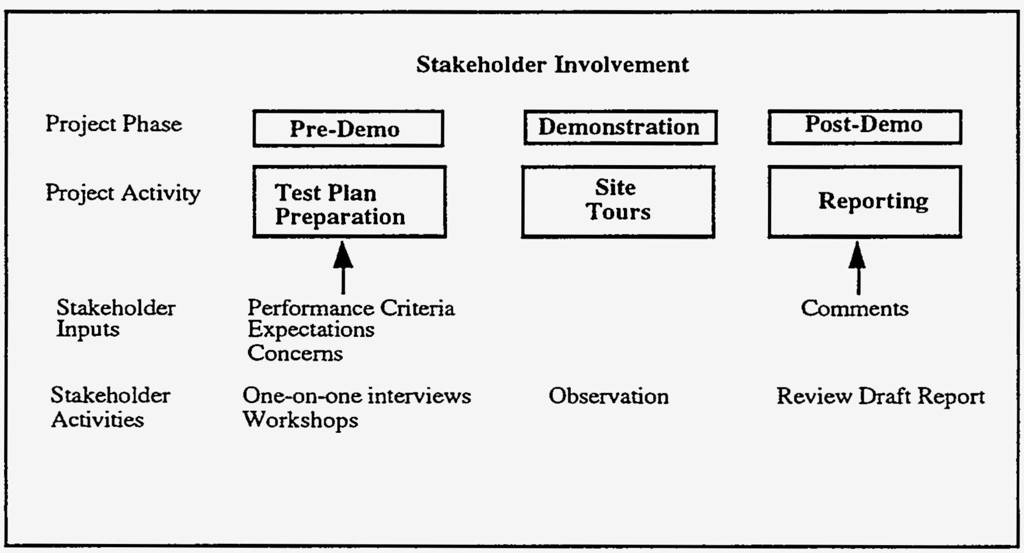

Figure 1. Stakeholder Involvement

A stakeholder involvement team supported by the Battelle Seattle Research Center and Environmental Issues Management, Inc. was organized for the pre-demonstration phase.

Capitalizing on the experience of the DOE's VOC-Arid Integrated Demonstration public involvement program,[2] the team's approach emphasized interacting with a broad cross-section of Hanford stakeholders through personal interviews followed by workshops. Concurrent interaction with a broad cross section of stakeholders offered the following benefits:

- First, the diversity of workshop participants fosters an energetic discussion and mutual learning.

- Second, responses from a diversity of stakeholders will be more apt to influence remediation project managers about what they need to take into account when selecting remediation methods.

The balance of this report addresses what the demonstration project team learned from stakeholders during the pre-demonstration activities.

Pre-Demonstration Stakeholder Activities

In interviews during August, 1994, 23 Hanford stakeholders were consulted concerning the CRYOCELL® technology. This group included:

Four public interest or environmental group representatives
Nine regulators
Three Native American representatives
Six users of technology
One elected official

Prior to the interviews, a fact sheet and a more detailed profile of the CRYOCELL® technology, written for stakeholders, were sent to serve as the basis of discussion. (See Appendix B.)

The stakeholder involvement team went on to conduct two workshops, on October 18 and November 22, 1994, to consider plans for the upcoming field demonstration of CRYOCELL® and to further define stakeholders' data requirements for incorporation in the test plan. A total of 27 stakeholders participated in the workshops. Section II of this report briefly describes participating stakeholders.

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2 These activities have been subsequently incorporated into the Plumes Focus Area.

At the workshops, stakeholders were provided additional data on the technology and the intent of the field evaluation. Subsequently, stakeholders discussed issues and concerns with representatives of the technology demonstration team, and identified additional specific data requirements for the technology's field test.

This discussion yielded insight into what the field demonstration, and related tests and analyses will need to evaluate regarding the frozen soil subsurface barrier. Providing answers to these data requirements will enable stakeholders to make reasoned judgments about the technology's acceptability for deployment. The project intends to use these data requirements and other stakeholder comments to shape the demonstration where practical and, where not, to highlight them as open issues that need to be addressed through other means in the future.

Most of the rest of this report documents stakeholders' concerns, expectations, and data requirements for frozen soil subsurface barrier technology in general and, specifically, for the CRYOCELL® field demonstration at Hanford. In addition, many of these comments will likely be applicable to other barrier technologies. Section III summarizes the major findings and conclusions of the interviews and workshops. Section IV lists the data requirements stakeholders identified, and Appendix A quantifies stakeholders responses in terms of criteria. Those with responsibility for making decisions about technology deployment can use these responses to aid in selecting technologies that will be deployable.

II. Composition of Stakeholders

Stakeholders participating in the formulation of data requirements for the CRYOCELL® demonstration were drawn from a range of individuals and organizations concerned about the cleanup of the Hanford site and other DOE weapons complex sites. Most have been involved in the evaluation of other innovative technologies for cleaning up hazardous waste at arid DOE sites in the Western United States. Several served on the Tank Waste Remediation Task Force, and the Hanford Future Site Uses Task Force. A number are now members of the Hanford Advisory Board or remain active in the evaluation of technology and in other decision processes at the Hanford site. Some are technical specialists with professional responsibility for environmental remediation. Stakeholders include regulators, representatives of public interest and environmental groups, Native Americans, technology users, elected officials, and interested citizens.

Representatives from the following agencies, organizations, private companies, and Indian Nations participated in the CRYOCELL® Demonstration Project's stakeholder involvement activities:

The League of Women Voters of Washington
The Hanford Advisory Board
CH2M Hill
Foster Wheeler, Inc.
Heart of America Northwest
Nuclear Safety Campaign
Hanford Education Action League
The United States Environmental Protection Agency, Region 10
Washington State Department of Ecology
The Oregon State Water Resources Department
The Oregon Department of Energy
The Confederated Tribes of the Umatilla Indians
The Yakama Indian Nation
The Nez Perce Tribe
Washington State Department of Health
Washington State Legislature

III. Major Findings and Conclusions

Interviews and workshops with stakeholders yielded a large quantity of information. The stakeholder involvement team analyzed and organized this information in order to define data requirements of greatest concern as well as recurring themes. This section of the report presents these salient points.

To clearly record stakeholder data requirements specifically for the CRYOCELL® demonstration as well as other significant issues that could become important in subsequent evaluation, major findings have been separated into two groups:

- General stakeholder concerns and comments about CRYOCELL®, subsurface barriers, and their use in environmental remediation;

- Specific stakeholder data requirements for the Hanford demonstration test plan.

Stakeholder involvement in the CRYOCELL® project focused on identifying stakeholder data requirements for inclusion in the demonstration test plan. Gaining stakeholder input to the test plan has, however, also included discussion of other issues. This additional stakeholder interest may have resulted from RKK, Ltd.'s previous discussion of CRYOCELL® with DOE representatives, regulators, interest groups, and tribal nations. RKK, Ltd. also has presented proposals to use the CRYOCELL® subsurface barrier for applications separate from the demonstration. As a result, stakeholders have formulated opinions and questions about the technology and its possible application, and wanted to address these issues in addition to identifying specific test plan data requirements. Further, the scope and location of the demonstration in comparison to other RKK proposals needed clarification. For example, RKK, Ltd. has conducted a demonstration at the Oak Ridge Site in Tennessee.

A number of themes emerged from analysis of stakeholders' comments and data requirements. In essence, these concerns are principles recommending the way technologies in general and CRYOCELL® in particular are used.

General Stakeholder Concerns

- Stakeholders want DOE to examine in concept the need for and practicality of subsurface barriers at any Hanford location (including the Single Shell Tank farms) before specific subsurface barrier technologies or designs are evaluated.

- Stakeholders would like innovative technologies to be used in as aggressive a manner as possible, while holding to the principal stakeholder value of "do no harm." In other words, if demonstrations can be conducted so that remediation and demonstration occur simultaneously, and further environmental harm is not an appreciable risk, that should be done.

- Reversible technologies, especially reversible barriers, are regarded more favorably than irreversible ones.

- Stakeholders have a sense of urgency regarding demonstration and cleanup and advocate getting on with these activities even if this means accepting some uncertainty.

- Demonstrations of all new technologies should be designed to take into account as many different applications and circumstances as possible. Single-purpose demonstrations (such as demonstrating for only that information necessary to deploy a technology at the Hanford Single Shell Tank farms) do not sufficiently portray a technology's versatility.

Analysis of the responses of those stakeholder groups with the most to say about the CRYOCELL® technology – regulators, representatives of tribal governments and public interest and environmental groups – shows that these stakeholders were principally concerned about five issues:

- Determining the permeability of the barrier
- Determining the effects of any moisture added to the subsurface
- Defining the degree of physical containment the barrier could achieve
- Calculating the cost of deploying the technology
- Identifying the appropriate location for the demonstration.

During the interviews and workshops, the stakeholder involvement team asked stakeholders to define what they wanted the CRYOCELL® technology's test plan to include. Stakeholders identified the following specific data requirements that in most cases further define the issues of greatest concern listed above:

Specific Stakeholder CRYOCELL® Test Plan Data Requirements

- Stakeholders want the demonstration to provide detailed information on the permeability of the frozen soil barrier. Permeability data regarding liquid and vapor-phase chemical, radioactive, and high-temperature constituents are required.

- Stakeholders want detailed information on the fate and effects of moisture added to the subsurface before, during, and after placement and operation of the barrier. In particular, stakeholders want the demonstration to provide information about the possibility that added moisture will carry and spread contamination.

- Stakeholders want a detailed explanation of the functioning of the barrier, including freeze/thaw effects on contained and nearby structures, demonstration of complete containment formation, seismic stability and repairability, installation requirements, and effects of heat on the system.

- Stakeholders want an analysis of the compatibility of this technology with companion technologies, as it is not an independent remediation system.

- Stakeholders want detailed cost information, specifically the cost of the electricity needed to form the frozen subsurface wall, presented in comparison to other barrier technologies, and other methods of remediation.

The following section presents detailed stakeholder comments on the CRYOCELL® demonstration, as recorded during personal interviews and later clarified, or expanded in the two workshops.

IV. Detailed Data Requirements for CRYOCELL® Demonstration

The stakeholder involvement team summarized input received from stakeholders in interviews for further discussion during the workshops. In many cases, stakeholders amplified or clarified points at the workshops that were raised during the interviews. In some instances, interview statements were simply affirmed and retained. The table that ends this section presents the stakeholder input specific to the technology test plan based on both the interviews and the workshops, organized according to the categories of performance (including practicality, works as intended, and process waste), environmental impacts, cost, public perception, and time.

The preponderance of stakeholders' comments on the CRYOCELL® technology and on subsurface barriers in general fell into five categories of criteria, listed here in order of how often they were mentioned:

- Practicality
- Works as Intended
- Environmental Impacts
- Cost
- Process Waste

Of the 64 comments[3] recorded during the individual interviews, three fourths (48) fell in the first four categories above, of which 22 (34%) concerned practicality, 11 (17%) concerned the technology working as intended (i.e., performance), 9 (14%) concerned environmental impacts, and 6 (9%) concerned cost. In evaluating these 48 comments, which expressed the most frequent concerns, 40% of them came from regulators, 15% from tribal representatives, and 38% from interest group representatives. During the interviews, technology users and public officials had fewer comments than the groups noted above. (Of the 64 comments received, only 6 (9%) came from technology users or public officials.) This interest from tribes, regulators, and interest groups may reflect discussions about CRYOCELL® with RKK, Ltd. prior to this stakeholder participation effort.

[3]Many comments were duplicative, and have been consolidated for inclusion in the table.

The following table lists stakeholders' data requirements as derived from individual interviews and two workshops. Appendix A, which follows this table, quantifies stakeholder responses and records specific comments according to stakeholder group.

Table 1. CRYOCELL® TEST PLAN DETAILED DATA REQUIREMENTS

INTERVIEW COMMENTS	WORKSHOP COMMENTS
PERFORMANCE	
1. Stakeholders asked why the demonstration is being conducted in an uncontaminated area. It was suggested that the demonstration be conducted in a contaminated area so dual benefits of remediation and demonstration could be realized.	1. There was extensive discussion of this issue at both workshop sessions. Many different views were expressed. It was only after explanation of subsurface water addition requirements in the second workshop, that a strong statement was made by one stakeholder that under no circumstances should the demonstration be conducted in a "hot" (contaminated) area. There was no stakeholder objection voiced to this statement even though earlier conversations had indicated support for demonstrating in a contaminated location. Another stakeholder stated that he would rather not see a freeze wall placed through a contaminant plume. These statements, and the lack of objection to them, seemed to indicate a shift in the stakeholder position on this issue to support of demonstrating in an uncontaminated area.
2. The Yakama Nation representative stated that CRYOCELL® would be effective to seal off the N-Springs area. He questioned why the demonstration is not being conducted at the N-Springs.	2. Stakeholders discussed this matter during both workshops. Following these discussions, the stakeholder consensus was that the CRYOCELL® test plan should be formulated with as many different applications in mind as possible. (The Hanford Single Shell Tank application alone was seen as too limited.)
3. Evaluate the range of soil types in which this technology will be effective. Is homogeneous soil necessary for it to succeed? Investigate how the technology deals with a large obstruction in the freeze wall (e.g., a boulder); if an obstruction does not freeze, will a contaminant pathway develop around that obstruction?	3. It was suggested that the wall be located such that a boulder is contained within the ice wall and that data be obtained as to the effects of the boulder on formation and permeability of the barrier.
4. Define any effects outside and inside the frozen area, such as ground heave and motion during freezing or thawing. Also define how the technology will function in the vicinity of dry wells, lateral leak detection structures, and other utilities such as those around the SST tank farm.	4. Define the effects of the freeze/thaw cycle. Include information on freeze/thaw effects on any object contained within the perimeter of the freeze wall or within the ice of the wall itself. Obtain these data by reliable instrumentation.

5. Test whether ice is really impervious to chemical and nuclear materials in liquid and vapor state. Does diffusion through the ice occur?	5. Define actual permeability through the ice wall. Obtain these data for liquid and vapor, including chemical and radioactive compounds. Compounds of particular stakeholder concern are: Cesium 137, Chromium 6, Iodine 129, Strontium 90, tritium, and organic solvents (hydrophobic and hydrophilic).
6. Demonstrate that the ice columns will completely overlap to form a seamless, solid wall of ice.	6. Also demonstrate that the joint(s) between the vertical freeze wall component and the angled component will form and seal. The presentation indicated that subsurface imaging technologies, such as ground penetrating radar (GPR), are size limited and cannot accurately determine formation details of the ice wall. Therefore, stakeholders suggested the scale of the demonstration be decreased to a size where available imaging techniques would be effective.
7. Address the management of drill cuttings (secondary wastes) from use of this technology.	7. No further comment.
8. Assess whether radioactive constituents will freeze in place but continue the radioactive decay process if they are captured within the ice wall.	8. Stakeholders also requested data on the effects of radiation on the formed wall.
9. Assess how hot liquid in the soil or in a source (i.e., buried waste tank) will affect the ice wall. How close can the heat source be to the ice wall? What are the acceptable temperature ranges at specific distances and for specific durations if a heat source is present?	9. This data need was reiterated.
10. Conduct a comprehensive failure analysis and address response scenarios, exploring particularly at what temperature and loading the technology fails (e.g., evaluate ice wall performance in the event of a tank rupture or other major liquid source within the barrier).	10. Stakeholders requested a detailed explanation of the functioning of the unit. They also requested that seismic and repairability analyses be conducted as part of the demonstration. A request was made that data on the barrier be presented in units common to geologic formation analysis. This request was made based on the assumption that performance of the barrier may be conducted in comparison to geologic barriers. (Grams of ice per gram of soil was suggested as a unit of reporting.)
11. Demonstrate that the pipes can be successfully removed after thawing the ice wall. Can they be reused? Assess any remaining impacts of holes or residual materials.	11. No further comment.
12. Determine the maximum and minimum distance away from the contaminant source that the pipes can be placed and still remain effective. Also determine the maximum distance the refrigeration plant can be from the barrier system (pipes).	12. Stakeholders also requested information on the minimum distance away from a contained object the freeze wall can be placed.
13. Test the technology in the saturated zone as well as the vadose zone, in particular to assess its effects on ground water flow.	13. See Item 2 above.

CRYOCELL® TEST PLAN DETAILED DATA REQUIREMENTS

INTERVIEW COMMENTS	WORKSHOP COMMENTS
14. Assess the technology's compatibility with remediation technologies. For example, would cold soil at the edges of the treatment area slow or stop in-situ bioremediation? Are there other treatment technologies that use heat sources that might melt the barrier wall?	14. The demonstration should seek this type of compatibility information for all potential companion technologies to CRYOCELL®.
15. Assess the range of soil depths at which the technology will be effective (cost-effective).	15. No further comment.
16. Evaluate the length of time that the technology maintains its containment without energy (relate this to seasons, soil moisture, and contaminants present).	16. Present detailed data on the functioning of the technology that addresses these parameters.
17. Assess the maximum area that can be frozen and define how long it takes to thaw. Define the maximum length of time the system can operate.	17. See Items 10 and 16 above. Stakeholders also requested that data be gathered on the long-term ecological effects of the freeze wall on flora and fauna.
18. Address the possibility that contamination could spread to the outside of the pipes before the technology has effectively contained contaminants.	18. See Items 10 and 16 above. Determine and describe specifically how the unit functions.
19.	19. Define the effects of a high concentration salt solution on the barrier. Specifically, data were requested on how high a concentration of salt solution would be required to breach the barrier.
20.	20. Stakeholders requested details on the installation and operational limitations of the technology. Specific information was requested on the at-surface space requirements, clearances necessary from structures and operations, and the size, type and limits of the equipment involved in installation, operation, and decommissioning.
COST	
21. The cost of drilling at Hanford is high, and should be accurately accounted for in the cost portion of the demonstration. The number of holes needed is a disadvantage of this technology.	21. Stakeholders indicated an interest in having all costs associated with the technology's design, installation, maintenance, and decommissioning detailed in the demonstration report. They also requested that this detailed information be compared to other subsurface barrier costs and that it include the expected duration of operation of any barrier in the analysis.
22. Concern was expressed about the expense of this technology, specifically concerning high energy costs and the large number of pipes required.	22. Stakeholders requested that cost data be presented in the demonstration report in several understandable ways such as: cost per foot, cost per unit of volume contained, and cost per unit of time the wall is operational.
23.	23. Data were requested on DOE's budget for this demonstration, the contribution made by RKK, Ltd., and comparison of these budgets to the overall DOE OTD budget.
ENVIRONMENTAL IMPACTS	

INTERVIEW COMMENTS	WORKSHOP COMMENTS
24. There were negative perceptions regarding injection of water into the earth.	24. Stakeholders requested specific information on what happens to water that is added to the earth to form the ice wall (during addition, wall formation, and thawing). Most importantly, define what happens to any pre-existing subsurface water and contaminants that may be driven ahead of the added moisture.
25. Define if water needs to be added to the ground to form the wall, and if so, how and how much; determine the effects of that added water in the soil after the barrier thaws.	25. See Item 24 above for detailed data requirements.
26. Assess potential environmental impacts of coolants used, and the potential for using less problematic coolants such as R-22, ammonia, and butane.	26. No further comment.
PUBLIC PERCEPTION	
27. Stakeholder review of the test plans prior to the demonstration is desirable.	27. Stakeholders reiterated this request in both workshop sessions.
28. An objective, outside evaluation of the technology's performance is needed.	28. Stakeholders suggested a technology and demonstration plan be peer reviewed by recognized technical experts who have no vested interest in the CRYOCELL® technology or the PNL demonstration program. It was also suggested that this peer review be conducted in a "value engineering" format so that emphasis is placed on better and cheaper implementation of the demonstration as opposed to academic criticism. Stakeholders requested that the results of the peer review be provided to them.
29. Use an actual below-grade tank for the demonstration to make conditions optimally realistic. (Some interviewees did not see this as necessary.)	29. Stakeholders requested that detailed information be presented on the pros and cons of using a tank in the CRYOCELL® demonstration.
TIME	
30.	30. An analysis of the projected time line for this demonstration compared to the action time line for the Hanford SSTs was requested, to determine if the technology can be ready in time to have the SSTs be a likely deployment application.

Appendix A

Quantification of CRYOCELL® Stakeholder Input

CRYOCELL - STAKEHOLDER								
	Technol							
Sites/ Stakeholder Categories	Remaining Contamination	Process Waste	Practicality	Works as Intended	Cost	Time	Worker Safety	P Hea S
HANFORD								
Regulators	1	3	7	5	2			
Tribes		1	3	1	1			
Interest Groups		1	8	5	3			
Technology Users			3					
Public Officials			1					

NPUT - NUMBER OF COMMENTS

y Evaluation Criteria Category

lic and ty	Environ-mental Impacts	Public Perception	Tribal Rights & Future Land Uses	Socio-economic Interests	Compatibility with Cleanup Milestones	Regulatory Infrastructure & Track Record	Regulatory Compliance	Other
	5	1						3
	2							1
	2		2					1
								2

This section records comments offered during interviews conducted in August, 1994. Some of these perspectives changed as the result of additional information and subsequent discussions during the workshops. Comments have been divided into sections based on the group which offered them.

Regulators' Comments

Issue	Comment
Practicality	• Determine if and how freeze pipes can be installed when boulders are present. • Determine if the technology will work in the saturated zone also. • Determine if high temperatures within the barrier might melt it. • Determine if certain technologies would be less effective within the barrier (e.g., bioremediation). • Determine what occurs when this technology is used in saturated zones. • Demonstrate effectiveness in the face of a tank rupture. • Determine how the barrier will form and function around subsurface utilities and structures such as dry wells and leak detection structures.
Works as Intended	• Determine if the barrier will be effective in heterogeneous soils. • Determine what happens if there is a big boulder between the freeze pipes. • Present the basis for and design of the demonstration. • Describe how the performance of the technology will be verified. • Conduct the demonstration using a below grade tank to simulate real subsurface contamination conditions.

Environmental Impacts	• Must develop moisture addition scheme that assures most moisture freezes before it moves away from the area. Minor water losses are not a concern at 200 West due to travel times and remoteness of the area. • Determine the fate of the added moisture in the subsurface after the ice barrier melts. Does the water mobilize radioactive contaminants? • Determine if injecting moisture into the subsurface will mobilize contaminants. • Determine how many holes must be drilled into the ground to implement this technology and what cost and environmental effects these holes will have. • Determine the fate of subsurface moisture during melt down of the barrier.
Cost	• Determine drilling methods that can be used with this technology and evaluate comparative costs because so many holes are required. • Determine if this technology can be placed in a reasonable time at a reasonable cost. Determine if there are other non-patented competing technologies.
Process Waste	• Determine if and how easily freeze pipes can be removed. • Determine the amount and fate of the drill cutting associated with installing the freeze pipes and all other pipes associated with implementing, maintaining, and decommissioning this technology. • Determine if sonic drilling can install freeze pipes without drill cuttings or cores being generated.

Public Perception	• A tank in the demonstration barrier area would be helpful in future application of the technology at the tank farms.
Remaining Contamination	• Determine the consequences of radon and tritium
Other	• Seems to be worth demonstrating. • What is the planned depth of the demonstration? • This technology seems most suited to excavation of the contained contamination.

Interest Groups' Comments

Issue	Comment
Practicality	• Determine the effects outside the frozen area including ground heave and motion. • The potential for greater efficiency in removal actions was seen as an advantage of this technology. • Determine the soil types and conditions that are appropriate and inappropriate for this technology. • Determine the effects of hot liquid or a hot contained object, such as a tank. Determine the temperature and distance ranges at which effects are observed. • Determine all kinds of failure and how they can be managed. • Determine what kind of area the barrier will enclose. Is the barrier meant to keep contaminants in or out? • Determine if this technology imposes any constraints on other technologies that might be used in conjunction with it. • Determine if the technology can focus on more than one contaminant at a time.

Works as Intended	• Determine if the ice wall is impervious to chemical and nuclear materials. • Define the length of time the barrier could and would be in place. Define the parameters which limit time and discuss the bases for these limits. • Determine if freeze pipes can be installed horizontally. • Determine the degree of effectiveness at the edge of the frozen barrier. For example, does the soil freeze completely on the boundary of the contaminated area? • Determine if contaminants diffuse through the ice barrier.
Environmental Impacts	• Determine the effects of water being added to the ground. • Determine the effects if freeze pipes are installed so that contamination exists outside the frozen barrier.
Cost	• Determine real costs based on current goods and services prices. • Determine the cost-effectiveness of the technology. • Define the bases of the cost estimate. Have industrial partners in the oil and gas industry been considered?
Process Waste	• Determine if the freeze pipes are contaminated after use.
Future Land Use	• Reversibility was seen as an advantage of this technology. • Determine the reversibility or removability of the technology. Can the freeze pipes be successfully pulled out after the wall is thawed?
Other	• The technology is being demonstrated in an uncontaminated area. This does not seem appropriate and represents no risk.

Tribes' Comments

Issue	Comment
Practicality	• Determine frost heave effects. • Determine maximum area that can be frozen. • Determine the length of time the barrier stays frozen without energy addition. Determine the length of time required to thaw the barrier.
Works as Intended	• Determine if the barrier will hold water, acid water, and ionic solutions (some of these have a lower freezing point than water).
Environmental Impacts	• Addition of water to the subsurface did not represent an area of high concern. • Environmentally friendly coolants such as R-22 or ammonia would be perceived more positively.
Cost	• Determine the cheapest and most efficient drilling technique so that this technology can be cost-effective. Examine contour drilling, too.
Process Waste	• Determine if the casings (freeze pipes) can be pulled out of the ground and reused or recycled. This is not essential, but it is preferred.
Other	• Strong support of this technology was expressed, especially for use at Hanford's N-Springs area.

Technology Users' Comments

Issue	Comment
Practicality	• Define the ability of the barrier to contain hot liquids. • Define the fate of all water added to form the ice wall. If some water escapes before freezing, determine its quality and fate. • Determine if a barrier can be formed around a heat source.
Cost	• Determine the cost of the electricity to form the barrier. The cost of electricity may be prohibitive.
Other	• The technology is excavation oriented. Exposing it after formation of the barrier is a good examination method. • Why is it necessary to have a tank within the barrier? Measurement within the enclosed area is most important.

Public Officials' Comments

Issue	Comment
Practicality	• Evaluate effect of hot tank contents on containment capability; assess potential for melting.

Appendix B

CRYOCELL® Technology Profile

Technology Information Profile
Frozen Subsurface Soil Barrier

Full Name of Technology: CRYOCELL® - Frozen Subsurface Soil Barrier

Principal Investigator: Jeffrey D. Vick, Pacific Northwest Laboratories (509) 375-4438

Technology Category: Contaminant Containment

Developed by: RKK, Ltd.

1. **What is the need for the technology? (If this technology is part of a system of technologies, what is its role in the system and what is the need for the system?)**

It is often necessary to confine, contain, or isolate waste or contamination in the earth to prevent it from further polluting valuable water resources in the ground. It is also often necessary to contain an area of a site to allow more effective, but otherwise risky, remediation techniques to be used. This technology is designed to meet these needs.

2. **What are the technology's objectives? (How does it satisfy the needs identified above?)**

a. **What are the objectives of this technology (for example, will this technology destroy volatile organic compounds [VOCs] in groundwater)?**

The objective of this technology is to provide a temporary impervious barrier that surrounds or isolates a waste source or contamination in the earth. This technology can be used for short-term containment during removal or treatment. Another objective could be isolation of new storage and disposal facilities. In other words, the barrier could be installed prior to disposal or management of wastes to provide an additional measure of security.

b. **What technology is currently used for this application (baseline technology)?**

Baseline barrier technologies for in-situ soil containment to block subsurface flow include slurry walls, deep soil mixing, and sheet piling.

3. **Process Description (Please describe the technology in terms that can be easily understood by interested members of the public. Include information on where the technology is applied—in place or above ground—what media the technology is used in—soil, groundwater, air—and what contaminants the technology targets)**

CRYOCELL® technology is an adaptation of ground freezing techniques used in civil engineering applications. The technological basis of the frozen soil subsurface barrier essentially rests upon freezing the moisture in the pore spaces of the soil, thereby forming bonds between the soil particles. To accomplish this, a drilling rig is used to bore holes in the ground into which leakproof steel pipes are inserted. An extremely cold refrigeration fluid (brine) is circulated through the pipes to freeze the soil particles and water. The brine is typically made up of calcium chloride and water, which is commonly used in the food industry and is environmentally safe. (For some applications, liquid nitrogen is used in order to reach a colder temperature.) To form a barrier, these "freezepipes" need to be placed every few feet around the contaminated site. If complete containment is the purpose of the barrier, freezepipes must also be placed under the site. A mobile refrigeration unit is then connected to all the pipes using insulated manifolds, circulating the coolant. (This is a completely closed system; no fluids are released.) Various common refrigerants can be used in the refrigeration unit, including ammonia and R-22 (monochlorodifluoromethane). The refrigeration unit cools the brine that is circulated through the freezepipes. After the refrigeration unit has been operating for a period of time, the moisture in the ground will freeze; ice forms around each pipe, creating a column of frozen soil. After the refrigeration unit has been running for three to four months, the ice columns in the soil will grow and overlap. This creates a wall of ice. After the contamination source is removed, treated in place, or otherwise remediated, the refrigeration unit can be turned off and the soil ice barrier will thaw.

4. **What is the status of the technology's development?**

One environmental demonstration project is now in progress for the Department of Energy through Martin Marietta Energy Systems in Oak Ridge, Tennessee. The project involves formation of a frozen soil barrier surrounding a small tank in a moist, clay soil. Numerous tests, including ones measuring diffusion, ground movement, and thermal effects are part of the project.

5. **Summary of Technology Advantages (compared with the baseline technology, is it faster, better, cheaper, safer?)**

The primary advantage of frozen soil barrier technology is that it is reversible and removable. No waste material is added to the earth. There is no addition of steel, concrete, or any other material to the contaminant source that could increase the amount of waste that needs to be remediated. Another advantage of this technology is that it can be applied to fully surround a contamination source in the earth. A third advantage is that this technology is well understood and has been used since the 1860s for civil engineering projects in a wide range of applications.

6. Summary of Technology Limitations (compared with the baseline technology)

The technology has not been demonstrated widely as a barrier for hazardous contaminant migration. Consequently, its applicability, performance parameters, and limitations are not yet fully understood. This demonstration project at Hanford, along with some related research at several universities and government laboratories, will help fill this knowledge gap.

7. Major Technical Challenges for the Technology

The major technological challenge for CRYOCELL®, and for any frozen soil barrier technology, is to operate effectively in dry, hot, desert environments above the groundwater. The Hanford-based demonstration is designed to test the effectiveness of the technology under these conditions.

8. Technical Effectiveness: Performance Criteria

Positive technical results have been obtained from bench-scale (laboratory) testing and analysis of frozen soil as a chemical and physical barrier. Ice is resistant to diffusion and corrosion by many types of contaminants (this is still under study). It is expected to be self healing in that any crack in the barrier will readily refreeze.

Performance for the demonstration at the Hanford site will principally evaluate diffusion and the ability of the technology to contain large releases from tanks. The barrier must have complete integrity throughout. Acceptable performance criteria and measurements are not well defined by the regulatory agencies at this time and, therefore, these agencies are collaborating with the demonstration team to help determine what would be considered success for this technology.

a. What contamination will remain after the technology is applied? (Will the mobility of the contamination be reduced? Will the volume be reduced? Will the contaminant be less toxic? This criterion applies primarily to retrieval treatment technologies.)

This technology does not directly reduce contamination, but rather serves as a support technology for remediation by other methods. In terms of the barrier itself, nothing is added to the site, except ordinary water, and therefore no residuals are left when the barrier is thawed and pipes are removed.

b. What process waste (secondary waste) does the technology produce? (Is the secondary waste mobile? What is its volume? What hazards are associated with the secondary waste? Can it be recycled?)

The technology produces no process waste.

c. **Describe the treatment or storage needed for the secondary waste and its availability.**

The technology application requires no treatment or storage of secondary waste.

d. **Describe the requirements for decontamination or decommissioning of equipment.**

The design of a barrier is intended to insure that the freezepipes would not pass through a contaminated area and, thereby, become contaminated themselves. Should the pipes become contaminated, they would need to be disposed in accordance with existing contaminated material procedures at Hanford. For the demonstration, a location has been chosen that will preclude contact with contamination of any type.

e. **How must the secondary waste be disposed of? Is disposal available?**

No secondary waste is expected.

f. **What future cleanup options are precluded by this technology? (Applies primarily to treatment technologies)**

The frozen soil barrier will not preclude any future cleanup options or the use of any follow-on treatment technology. By forming a reversible frozen soil barrier, any cleanup that would go on without the barrier could go on inside the barrier, with an extra margin of safety. If it is decided that containment is not needed, the site can be allowed to thaw, the pipes removed, and the site restored to its original condition.

g. **How reliable is the technology? (Please address potential breakdowns, effectiveness, and sensitivity to operating conditions).**

The technology has been extremely reliable in civil engineering applications. As a civil engineering technique, it has been used for 130 years, routinely to depths of several thousand feet. Part of the Hanford demonstration is to help assess the reliability of its performance for contaminated soils.

h. **If the technology fails, how are the effects of the failure controlled?**

The demonstration will measure the containment effectiveness of the technology. At this time, failures other than incomplete containment have not been projected.

i. **How easy is the technology to use? (Please describe the level of skills and training required to use the technology.)**

The skills required (drilling, piping, equipment maintenance) are essentially the same as those required during civil engineering projects where ground freezing is applied for excavation of shafts, or for mining. Refrigeration plants are maintained by local refrigeration companies, and their operation is routine.

j. What infrastructure (buildings, power sources, personnel) is needed to support the technology?

Buildings are portable and similar to those used on any construction project. Power sources for the trailers and refrigeration plants are 460-volt, three phase diesel generators, or power can be provided by means of an electrical utility hookup. Trained operators are available within the U.S. and overseas.

k. How versatile is the technology? (That is, can it be applied to other types of contamination, in other media, or at other locations?)

Ice barriers are believed to be an effective containment barrier for all types of waste -- biological, chemical, radioactive, and mixed waste. Ice is impervious to chemical, biological, and nuclear materials. It forms barriers in heterogeneous soils where sand, gravels, differing soil types, and moving groundwater create difficult subsurface conditions. Freezing technology has been used all over the world for civil engineering applications.

l. Describe the technology's compatibility with other elements of the system. (Please include a general description of the system that the technology is part of.)

The system will enhance remediation because it confines and controls an area for treatment or removal. If excavation is the selected remediation method, there would be no need for pumping to lower groundwater within the excavation, or for shoring the excavations. The frozen soil barrier provides the required structural strength and groundwater control. The system's compatibility with specific remediation techniques, contaminants, and soil conditions will vary and would be applied only after engineering and supporting laboratory analysis.

m. Can the technology be procured "off-the-shelf"? (Is it an innovative use of an existing technology?) Which components are available and which must be developed?

Yes.

n. How difficult is the technology equipment to maintain? (Please include information on frequency as well as ease of maintenance. Also describe the level of skill or training required to maintain the technology.)

The technology is easy to maintain. Experienced refrigeration companies are available to provide both operation and maintenance.

o. **What equipment safety measures (such as automatic shutdown devices) are needed and in place to protect workers and the public?**

The refrigeration equipment is remotely controlled. System performance data are collected and fed back to the refrigeration plant control systems. Some automatic line features exist to call operators if there is any problem with the equipment. Refrigerants that have minimal environmental effects can be used.

p. **Describe the technology's ability to function as intended. (Does the technology work as intended? If not, describe functional problems.)**

The demonstration in arid soils will determine the technology's ability to function as intended.

q. **What are the scale-up issues and how are they being addressed?**

The currently planned demonstration scale (a tank about one-third the size of a Hanford Tank Farm single shell tank) has been selected to allow realistic scale-up calculations to be made. The challenges facing this demonstration at this scale are obtaining the drilling accuracies and moisture levels needed to place the barrier as designed, and to control the extent of the frozen region.

9. **Cost (Please include assumptions on which you base your estimates.)**

a. **What is the start-up cost of the technology (including development costs, procurement and construction, permitting, and other costs necessary to begin operation)?**

The up-front development cost of the technology for the Hanford demonstration is estimated at $200,000; mobilization for support trailers and freeze plants will add another $40,000 to $50,000. The cost of installation and formation of the freeze barrier is roughly $1.5 million. Six months of operation adds another $270,000 for labor, rental of the freezing plants, and utilities. With demobilization, administrative costs, fees, and royalties, the total is approximately $2.7 million.

b. **What are the operations and maintenance costs of the technology?**

For six months of operation at the demonstration scale and site estimates are as follows:

Plant operators	$60,000
Refrigeration plants	$150,000
Utilities	$60,000

c. What are the life cycle costs of the technology (including facility capital cost; startup, operation, and maintenance; decommissioning, regulatory, or institutional oversight; and future liability)?

As part of this demonstration project, a complete life cycle analysis will be performed.

10. Time

a. When will the technology be available for commercial use or use at other sites?

Generally speaking, the technology is available today. There are deployment questions related to performance criteria and measurement, compatibility with other remediation technologies and contaminants, and cost effectiveness. It is the intention of this demonstration to better estimate what performance can be achieved and what is expected by stakeholders.

b. What is the speed or rate of the technology? (Please use metrics)

Three to four months are required to form the soil barrier once the freezing process is begun. The frozen barrier can be kept in place as long as it is required.

c. At the speed or rate identified in 10(b), what is the total time required for the technology to achieve its objectives?

It takes ten to twelve weeks to install freeze barrier components (subsurface pipes), and then ten to sixteen weeks to form a frozen subsurface barrier. The barrier begins to be effective before it is fully formed (frozen to -20°C or -30°C).

11. Environmental Safety and Health: Worker Safety

a. What potential is there for workers to be exposed to hazardous materials and/or other hazards? Describe those materials and hazards.

The only potential hazards are related to drilling in contaminated soil. Refrigerants have known properties, and their proper management is routine.

b. What are the physical requirements for workers?

Standard drilling rig capabilities and standard refrigeration plant operating skills are required.

c. How many people are required to operate the technology?

Once the refrigeration plant is installed and functioning, management of the operation is done through remote control, using the phone lines and personal computer systems. During the Hanford demonstration, however, one person will be on the site during operation.

12. Environmental Safety and Health: Public Health and Safety

a. What is the technology's history of accidents? (Has there been a history of accidents and, if so, what was the nature of the accidents.)

There is no known history of accidents with this technology.

b. Does this technology produce routine releases of contaminants?

No.

c. Are there potential impacts from transportation of equipment, samples, waste, or other materials associated with the technology?

No.

13. Environmental Impacts

a. What impact will this technology have on the ecology of the area (for example, wildlife, vegetation, air, water, soil, or people)?

The soil will be frozen within a limited area, temporarily altering subsurface conditions, including a below freezing temperature and, potentially, an increased subsurface moisture level if the natural soil moisture level is too low.

b. What aesthetic impacts does the technology have (for example, visual impacts, noise)?

Minimal impacts are expected, as the components are mobile and removable.

c. What natural resources are used in the technology's development, manufacture, or operation? (Address energy resources in 14[d].)

The technology's development, manufacture, and operation place no unusual demands on natural resources.

d. What are the technology's energy requirements? (Use metrics)

For this demonstration, approximately $200,000 of electrical power will be required to form the barrier and $60,000 of electrical power will be required to maintain it for six months.

14. Socio-Political Interests: Public Perception

a. What is the reputation of the technology's developer and/or user? (Principal investigators: this is a point of discussion for stakeholders; do not answer.)

Unknown.

b. How familiar is the technology to the public?

The basic principle on which the technology operates, refrigeration, is very familiar to the public in its most basic form. However, this application is somewhat less familiar.

c. How easy is the technology to explain to the public?

The technology is easy to explain to the public.

15. Socio-Political Interests: Tribal Rights/Future Land Use

a. How will the technology affect future unrestricted use of land and water?

One of the advantages of this technology is that it will not restrict future use of land and water at sites where it is applied.

16. Socio-Economic Interests

a. What are the potential economic impacts of this technology? (For example, what are the effects on the economic base of the community? Are there infrastructure requirements?)

This technology will have a positive but minimal effect on the economy.

b. How will the technology affect labor force demands?

In a limited way, this technology will have a positive effect on employment.

17. Regulatory Objectives

a. Describe the technology's compatibility with cleanup milestones.

If the technology is demonstrated to be effective at Hanford, it can support meeting regulatory milestones in combination with other technologies and cleanup methods. As a side benefit for Hanford, the demonstration results will satisfy in part or in whole Milestone M-45-07 of the Tri-Party Agreement, "Complete evaluation and demonstration testing of small-scale subsurface barriers by 9/97."

b. How familiar are regulators with this or a similar technology?

Regulators are very familiar with this technology. Both the EPA Site Program and the Washington State Department of Ecology are aware of the demonstration and are collaborating on a regular basis with the demonstration project team.

c. What is the technology's regulatory track record?

There is no regulatory track record at this time for environmental applications.

d. How does the technology comply with applicable regulations?

At this time, regulatory requirements are not defined.

18. Industrial Partnerships

a. What is the name of the industrial partner?

RKK, Ltd.

b. What is the rationale for this partnership?

RKK, Ltd., owns the patents for this technology, and has formed a partnership with SEG and freezeWALL, Inc. to provide technical and management support.

c. What is the contract mechanism?

A Cooperative Research and Development Agreement (CRADA) has been established between the Pacific Northwest Laboratory, Richland, WA. (representing the DOE) and RKK, Ltd., for the purposes of collaborating and conducting the demonstration at Hanford.

d. Are there other potential partners?

Water Development Corporation (California) has expressed interest in potentially providing RKK, Ltd., with drilling services for this demonstration.

e. Are there potential international partners?

There are potential international interests, particularly in Russia, in the area of high-level nuclear waste containment.

19. Intellectual Property

RKK, Ltd., holds U.S. patents for the emplacement of frozen soil subsurface barriers for the containment or control of hazardous wastes.

a. Who owns the patent for this technology?

RKK, Ltd.

b. Are there other patent owners?

No.

c. Is there a patent number for this technology?

U.S. Patent No. 4,860,544
U.S. Patent No. 4,974,425
U.S. Patent No. 5,050,386

20. Cost Sharing

a. What is the background of this technology? (Where did the idea come from? Who else is doing similar work? What have the results been to date? What is the most significant competitor to this technology?)

The idea came from the concept of disposing of chemical waste in Alaska's permafrost. The potential to freeze nuclear waste in place was suggested and subsequently patented. There are companies doing ground freezing, but not for environmental containment and treatment applications. The technology's most significant competitor is DOE's in-house development of technologies in the areas of subsurface control (e.g., grout and solidification technologies).

21. References

Dr. Greg Dash, University of Washington, (206) 543-2787

Dr. David Wiggert, Michigan State University, (517) 355-0250

Dr. Alex Iskander, U.S. Army Cold Region Research Engineering Laboratory, (603) 646-4198

Mr. Jeffrey D. Vick, Pacific Northwest Laboratory, (509) 375-4438

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W. Bixby EM-60

U.S. Department of Energy
Morgantown Energy Tech. Center
P.O. Box 880
3610 Collins Ferry Road
Morgantown, WV 26507-0880
R.C. Bedick

U.S. Department of Energy
Oak Ridge Operations Office
P.O. Box 2001
Oak Ridge, TN 37831
J. Moore

U.S. Department of Energy
Savannah River Operations Office
P.O. Box A
Aiken, SC 29808
J. Wright

Brookhaven National Laboratory
Building 703-50 Rutherford
Upton, NY 11973
J. Heiser

2 CH2M Hill
PO Box 91500
Bellevue, WA 98009-2050
W. A. Wallace
David Waite

CH2M Hill
PO Box 428
Corvallis, OR 97339
Dave Livesay

3 CH2M Hill
2300 NW Walnut Blvd
Corvallis, OR 97339
David R. Lee
Dennis A. Peters
Jerry Tracey, P.E.

2 City of Richland
PO Box 190
Richland, WA 99352
Joe King
Roger Wright

2 Confederated Tribes of the Umatilla Indians
PO Box 638
Pendleton, OR 97801
Tom Gilmore
J.R. Wilkinson

EG&G Idaho, Inc.
Idaho National Engineering Laboratory
P.O. Box 1625
Idaho Falls, ID 83415
K. M. Kostelnik

Enserch Environmental
1201 Jadwin Avenue, Suite 202
Richland, WA 99352
Rick Cameron

Foster Wheeler, Inc.
1981 Snyder Road, Suite 3
Richland, WA 99352
R. Treat

Golder Federal Services, Inc.
4104 148th Avenue NE
Redmond, WA 98502
C. Voss

Hanford Education Action League
1720 North Ash
Spokane, WA 99205-4202
Todd Martin

HAZWRAP
P.O. Box 2003
Oak Ridge, TN 37831-7606
R. Swatzell

Heart of America Northwest
1305 4th Avenue, #208
Seattle, WA 98101
Cynthia Sarthou

Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720
G. Moridis

League of Women Voters
c/o Pacific Northwest Laboratory
PO Box 999, MSIN K1-90
Richland, WA 99352
Maureen McCarthy

2 Nez Perce Tribe
PO Box 365
Lapwai, ID 83540
Donna L. Powaukee
Rico O. Cruz

Nuclear Safety Campaign
1914 North 34th Street #407
Seattle, WA 98103
Bill Mitchell

Oregon Dept. of Energy
625 Marion Street NE
Salem, OR 97310
Dirk Dunning

Oregon Water Resources Dept.
3850 Portland Rd., NE
Salem, OR 97310
Ralph Patt

Gordon Rogers
1108 Road 36
Pasco, WA 99301

RUST Geotech Inc.
P.O. Box 14000
Grand Junction, CO 81502-2567
S.J. Morrison

6 RKK, Limited
16404 Smokey Point Blvd., Suite 303
Arlington, WA 98223
R.K. Krieg (6)

Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185
J. Phelan

Sierra Club
2439 Crestline Drive NW
Olympia, WA 98502
Doris Cellarius

2 U.S. EPA - SITE
W. Martin Luther King Dr.
Cincinnati, OH 45268
A. Gatchett (2)

2 U.S. EPA
712 Swift Blvd, Suite 5
Richland, WA 99352
D.R. Sherwood
Dennis Faulk

U.S. EPA
Region 10 - ES-098
1200 Sixth Avenue
Seattle, WA 98101
J. Barich

University of Texas
Dept. of Civil Engineering
26th St. at San Jacinto, ECJ 9.227
Austin, TX 78712-1076
D.E. Daniel

3 Washington Dept. of Ecology
PO Box 47600
Olympia, WA 98504-7600
Chuck Cline
Lynn Coleman
Toby Michelena

3 Washington Dept. of Ecology
1315 W. 4th Avenue
Kennewick, WA 99336-6018
Dib Goswami
Norm Hepner
Nancy Uziemblo

2 Washington Dept. of Health
Airdustrial Building 5
PO Box 47827
Olympia, WA 98504-7827
John Erickson
Allan Danielson

Washington Dept. of Health
PO Box 47820
Olympia, WA 98504-7820
Al Conklin

Washington Environmental Council
1063 South Capitol Way Room 212
Olympia, WA 98504
Betty Tabbutt

Washington League of Women Voters
7806 Manzanita Drive NW
Olympia WA 98502
Karen Verrill

Westinghouse Hanford Company
PO Box 1950, MSIN S4-53
Richland, WA 99352
Ken Hampsten

Westinghouse Savannah River Co.
Savannah River Site
P.O. Box 616
Aiken, SC 29808
J. Steele

WSU Tri-Cities Campus
100 Sprout Road
Richland, WA 99352
James Cochran

Yakama Indian Nation
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