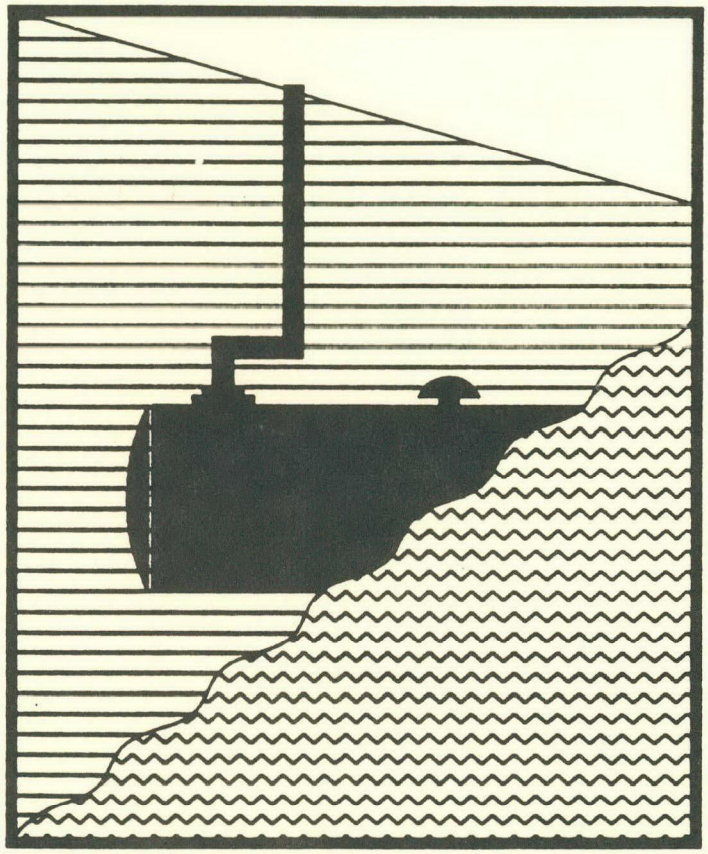
EPA Underground Storage Tank Research Program

Volume II – Appendices



DRAFT

Prepared for:

Science Advisory Board

Prepared by:

Risk Reduction Engineering Laboratory and
Environmental Monitoring Systems Laboratory – LV
Office of Research and Development
U.S. Environmental Protection Agency

Underground Storage Tank Research Program

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VOLUME II

APPENDICES

APPENDIX A

SUMMARY OF FEDERAL UST REGULATIONS

Federal UST Regulations

Reg. Citation		Compliance Requirements	Reporting/Record Keeping
Subpart B: Performance Standards			
280.20(a)	NEW TANK OPTIONS • FRP or • Steel with CP or • Steel-FRP composite or • Metal without CP if approved	• Design, construction, and CP must be in accordance with code(s). Compliance with CP must be documented	• UST notification form to IA (within 30 days) • Certificate of Compliance for CP. CP analysis required if CP not used.
280.20(b)	NEW PIPING OPTIONS • FRP or • Steel with CP or • Metal without CP (if approved)		
280.20(c)	SPILL PREVENTION • Catch basin or equivalent		
280.20(c)	OVERFILL PREVENTION OPTIONS • Automatic shut-off valves or • Flow restrictors or • High-level alarm		
280.20(d)	INSTALLATION • Must be in accordance with code and manufacturer's instructions	• Compliance with installation must be documented	• Certificate of Compliance for installation
280.21(b)	UPGRADING EXISTING TANKS • Interior lining and/or CP	• By December 22, 1998 all UST systems must be replaced, upgraded, or closed	
280.21(c)	UPGRADING EXISTING PIPING • CP	• Installation must be in accordance with code(s) and inspections as per regulations	
280.21(d)	UPGRADING FOR SPILL AND OVERFILL PREVENTION • Same as for new systems		
Subpart C: Operating Requirements			
280.30	SPILL AND OVERFILL CONTROL • If spill occurs → GO TO SUBPART E		• Report to IA
280.31	OPERATION & MAINTENANCE OF CP • Must be inspected by qualified tester	• Within 6 months of installation; then every 3 years • If impressed current CP; inspect every 60 days	• Maintain test results of last 2 inspections • Maintain test results of last 3 inspections
280.32	COMPATIBILITY with stored substances required		
280.33	REPAIRS		
	• FRP tanks and fiberglass pipes/fittings	• Repair as per code(s) or manufacturer's instructions and tightness test	• Maintain records of compliance
	• Metal pipes/fittings that have released product	• Must replace	
	• CP	• Repair and test	

Subpart D: Release Detection			
280.40	ALL USTs MUST HAVE RD	• Within phase-in period; otherwise UST must be closed	
	• Performance requirements must be met	• Methods used after December 22, 1990 must detect at $P_d = 0.95$ and $P_{fa} = 0.05$ for that method	• Submit performance claims and how determined; maintain records for 5 years
	• Installation, calibration, O & M, repair	• As per manufacturer's instructions	• Maintain documentation of servicing for 1 year • Maintain manufacturer's schedules of required servicing for 5 years
	• Sampling, testing, monitoring	• As per regulations	• Maintain results for 1 year
	IF RD INDICATES LEAK → GO TO SUBPART E		• Report to IA
280.41	**REQUIREMENTS FOR PETROLEUM UST SYSTEMS**		
280.41(a)	TANKS—MONITOR EVERY 30 DAYS EXCEPT		
	• New/upgraded monthly inventory controls & Tank TT	• Tank TT: every 5 years until December 22, 1998 or until 10 years after installation/upgrade	
	• Existing monthly inventory controls & Tank TT	• Tank TT: annually until December 22, 1998 when upgrade is required	
	• If UST is less than 550 gallons: tank gauging allowed	• Weekly	
280.41(b)	PIPING—PRESSURIZED MUST HAVE • Automatic line leak detection and line TT or monitoring	• Line TT: annual; monitoring (vapor, groundwater, interstitial): monthly	
280.41(b)	PIPING—SUCTION MUST HAVE • Line TT of monitoring	• Line TT: every 3 years; monitoring (vapor, groundwater, interstitial): monthly	
280.42	**REQUIREMENTS FOR HAZARDOUS SUBSTANCE UST SYSTEMS**		
	EXISTING SYSTEMS—MEET REQUIREMENTS FOR PETROLEUM UST SYSTEMS	• By December 22, 1998 must meet RD for new hazardous systems (interstitial monitoring)	
	NEW SYSTEMS MUST HAVE RD FOR • Secondary containment systems • Double-walled tanks • External liners • Piping with secondary containment	• Several requirements apply; see regulations	

	TANKS—MONTHLY METHODS	PERFORMANCE STANDARDS	
280.43(d)	• ATGS	• 0.2 gal/hr with inventory control requirements	
280.43(e)	• Vapor monitoring (requires site assessment)	• Any significant increase in concentration above background	
280.43(f)	• Groundwater monitoring (requires site assessment)	• 1/8" of free product on groundwater table	
280.43(g)	• Interstitial monitoring	• Standard requirements apply	
280.43(h)	• Other methods	• 0.2 gal/hr or 150 gallons within a month	
	TANKS—OTHER METHODS		
280.43(a)	• Inventory controls (measure daily, reconcile monthly)	• 1% of flow-through plus 130 gal monthly	
280.43(b)	• Manual tank gauging (weekly or monthly) Only for tanks ≤2000 gal nominal capacity	• If tank ≤550 gal, detect 10 gal/week or 5 gal/month (may use this as sole method of RD) If tank >550 and ≤1000 gal, detect 13 gal/week or 7 gal/month (may use in place of manual inventory controls If tank >1000 and ≤2000 gal, detect 26 gal/week or 13 gal/month (may use in place of manual inventory controls)	
280.43(c)	• Tank tightness testing (frequency: see above §280.41)	• 0.1 gal/hr and account for various effects	
280.44	PIPING—(frequency: see above §280.41)		
280.44(a)	• Automatic line leak detectors	• 3 gal/hr at 10 psi within 1 hour	
280.44(b)	• Line tightness testing	• 0.1 gal/hr at 1.5 times operating pressure	
280.44(c)	• Vapor, groundwater, or interstitial monitoring	• See above	

Subpart E: Release Reporting, Investigation, Confirmation

	SUSPECTED RELEASES		
280.50 280.51	IF • Discover leak at/near site or • Observe unusual operating conditions (and equipment is not defective) or • RD indicates leak (and equipment is not defective and additional monitoring is negative) or • Off-site impacts might indicate a leak		• Report within 24 hours
280.52	THEN Investigate & confirm • Conduct tightness tests on system, IF • Leak → repair, replace or upgrade → GO TO SUBPART F • No leak and no contamination → STOP • No leak and contamination → DO SITE CHECK	• Within 7 days unless CA is initiated	
	• Conduct site check (excavation zone & site) IF • Leak → GO TO SUBPART F • No leak → STOP		
280.53	SPILLS AND OVERFILLS—CONTAIN AND CLEANUP and	• If cleanup of releases of <25 gal (petroleum) or <RQ (hazardous substance) cannot be accomplished in 24 hours, must notify agency	
	IF • Release >25 gal petroleum or creates sheen		• Report within 24 hours
	• Or if release >RQ (under CERCLA) → GO TO SUBPART F		• Report immediately

Subpart F: Release Response and Corrective Action			
280.61	INITIAL RESPONSE: Stop leak, mitigate hazards	• Within 24 hours—mandatory	• Report confirmation within 24 hours
280.62	INITIAL ABATEMENT MEASURES AND SITE CHECK	• Mandatory	• Report progress within 20 days
280.63	INITIAL SITE CHARACTERIZATION: Assemble information	• Mandatory	• Submit information within 45 days
280.64	FREE PRODUCT REMOVAL: Abate migration	• Mandatory	• Submit report within 45 days
280.65	INVESTIGATIONS FOR SOIL & GROUNDWATER CLEANUP	• If on-site conditions warrant	• Submit information when practicable
280.66	CORRECTIVE ACTION PLAN: • IA sets schedule and goals	• At direction of IA	• Submit per IA schedule
	• Owner/operator establishes strategy	• Upon approval, implement plan	
	• IA notifies affected public		
Subpart G: Out-of-Service UST Systems and Closure			
280.70	TEMPORARY REMOVAL FROM USE: MUST CONTINUE O&M OF CP AND RD UNLESS UST IS EMPTY		
	• If out-of-service more than 3 months → close off access		
	• If out-of-service more than 12 months → permanent closure unless it has maintained CP and RD		
280.71	PERMANENT CLOSURE AND CHANGES IN SERVICE MUST PERFORM SITE ASSESSMENT		• Maintain records of compliance
	• If closing: empty, clean, and remove or fill with inert solid material		• Notify 30 days prior to closure
	• If change in service: empty, clean, and store non-regulated substance		• Notify 30 days prior to change in service
280.72	SITE ASSESSMENT MEASURE FOR RELEASES	• External RD meets requirement	• Maintain assessment results for 3 years
	• If release discovered → GO TO SUBPART F		
280.73	UST SYSTEMS CLOSED PRIOR TO DECEMBER 22, 1988: Perform site assessment and close per regulations	• At agency direction	

Abbreviations

ATGS Automatic tank gauging system
CA Corrective action
CP Corrosion protection
Code Code of practice developed by a nationally recognized association or independent testing laboratory (specified throughout regulations)
FRP Fiberglass-reinforced plastic
IA Implementing agency
O&M Operation and maintenance
P_D Probability of detection
P_{FA} Probability of false alarm
RD Release detection
RQ Reportable quantity (of hazardous substance under CERLCA)
TT Tightness test
UST Underground Storage Tank

Please note: This chart is not exhaustive. Many exceptions apply. Specific requirements are detailed in the regulations—see regulatory citation numbers for applicable section of the final regulations as published in the Federal Register on September 23, 1988 (40 CFR Part 280).

APPENDIX B

LISTING OF RESEARCH PRODUCTS

RISK REDUCTION ENGINEERING LABORATORY

UNDERGROUND STORAGE TANK RESEARCH PROGRAM PRODUCTS

SITE ASSESSMENT/CHARACTERIZATION	EPA No./NTIS No.
1. Underground Tank Leak Detection Methods: A State-of-the-Art Review	EPA/600/2-86/001, 1/86 NTIS/PB86-137155
2. Leak Prevention in Underground Storage Tanks: A State-of-the-Art Survey	EPA/600/2-87/018, 3/87 NTIS/PB87-168662/REB
3. A Leak Detection Performance Evaluation of Automatic Tank Gauging Systems and Product Line Leak Detectors at Retail Stations	American Petroleum Institute Publication, 1/88
4. Evaluation of Volumetric Leak Detection Methods for Underground Fuel Storage Tanks, Volume 1	EPA/600/2-88/068a, 11/88 NTIS/PB89-124333
5. Evaluation of Volumetric Leak Detection Methods for Underground Fuel Storage Tanks, Volume 2	EPA/600/2-88/068b, 11/88 NTIS/PB89-124341/REB
6. Volumetric Tank Testing: An Overview	EPA/625/9-89/009, 4/89 NTIS/PB89-205983/REB
7. Pressure and Temperature Fluctuations in Underground Storage Tank Pipelines Containing Gasoline	Oil and Chemical Pollution Journal, Volume 7, 1990 EPA/600/J-90/519 NTIS PB91-206912/AS
8. Test Procedures for Evaluating the Performance of Underground Storage Tank Leak Detection Methods	National Water Well Association Conference, 8/90
9. Standard Test Procedures for Evaluating Leak Detection Methods: Pipeline Leak Detection Systems	EPA/530/UST-90/010, 9/90 EPA/600/S2-90/050, 2/90 NTIS/PB91-106245
10. Evaluation of Volumetric Leak Detection Methods Used in Underground Storage Tanks	Journal of Hazardous Materials, Volume 26, 1991 EPA/600/J-91/155 NTIS PB91-226316/AS:A03
11. State-of-the-Art Procedures and Equipment for Internal Inspection of Underground Storage Tanks	EPA/600/2-90/061, 1/91 NTIS/PB91-149609/REB
12. Volumetric Leak Detection in Underground Storage Tanks Containing Chemicals	Proceedings 84th Annual Meeting of the Air & Waste Management Association, 6/91

RREL PRODUCTS (cont'd)

13. Volumetric Leak Detection in Large Underground Storage Tanks	EPA/600/2-91/044a, 8/91 NTIS/PB91-227942
14. Chemicals Stored in USTs: Characteristics and Leak Detection	EPA/600/2-91/037, 8/91 NTIS/PB91-219592/AS
15. Leaking Underground Storage Tanks on Indian Lands: Awareness is the Key to Mitigating Environmental Threat	Journal of American Indian Sciences and Engineering, 3/92
16. Characteristics of Underground Storage Tanks Containing Chemicals	ASTM STP 1160 Proceedings on Leak Detection in USTs, 6/92
17. Location of Leaks in Pressurized Petroleum Pipelines by Means of Passive Acoustic Methods	ASTM STP 1160 Proceedings on Leak Detection in USTs, 6/92
18. Extrapolating the Performance Capability of a Volumetric Leak Detection System from Small Tanks to Large Tanks	EPA Report Pending, 7/92
19. Locating Leaks in Underground Pressurized Petroleum Pipeline Systems	EPA Report Pending, 9/92
20. Evaluation of Leak Detection Methods for Large Underground Storage Tanks	Journal of Hazardous Materials, In Press
21. Technical Aspects of UST Closure	EPA/600/R-92-057, 5/92 EPA/600/SR-92/057

CORRECTIVE ACTION

22. Underground Storage Tank Corrective Action Technologies	EPA/625/6-87-015, 1/87
23. Motor Fuel and Organic Chemicals Released in an Underground Environment	Internal EPA Report, 2/88
24. Assessment of Vacuum Extraction Technology Application: Belleview, Florida LUST Site	Internal EPA Report, 9/88
25. Evaluation of Soil Washing Technology for Remediation of LUST Sites	Proceedings HMCRI 10th Superfund Conference, 11/89
26. Assessing UST Corrective Action Technologies: Site Assessment and Selection of Unsaturated Zone Treatment Technologies	EPA/600/2-90/011, 3/90 NTIS/PB90-1872200/REB

RREL PRODUCTS (cont'd)

27. Assessing UST Corrective Action Technologies: Early Screening of Cleanup Technologies for the Saturated Zone	EPA/600/2-90/027, 6/90 NTIS/PB90-266727/REB
28. Bench Scale Evaluation of Soil Washing Technology For Cleaning Up Releases From Leaking Underground Storage Tanks	Internal EPA Report, 9/90
29. Soil Vapor Extraction Technology Reference Handbook	EPA/540/2-91/003, 2/91 NTIS/PB91-168476/REB
30. Soil Vapor Extraction Air Permeability Method Evaluation	Proceedings Hazardous Materials Control Northeast Conference, Boston, MA, 7/91
31. Column Vapor Extraction Experiments on Gasoline-Contaminated Soil	Proceedings Hydrocarbon Contaminated Soil Conference, Univ. of Massachusetts, Volume 5, 9/91, Lewis Publications
32. Assessing UST Corrective Action Technologies: A Scientific Evaluation of the Mobility and Degradability of Organic Contaminants in Subsurface Environments	EPA/600/2-91/053, 9/91 NTIS/PB 92-114552/AS
33. Thermal Desorption of Petroleum-Contaminated Soils	Proceedings Hydrocarbon Contaminated Soils Conference, University of Massachusetts, Volume 5, 9/91, Lewis Publications
34. Understanding the Fate of Petroleum Hydrocarbons in the Subsurface Environment	Journal of Chemical Education (accepted 2/92)
35. Treatment of Petroleum Contaminated Soils by Thermal Desorption Technology	Journal of Air & Waste Management Association, 3/92
36. Screening Methodology for Assessing Leaking UST Site Cleanup Technologies	ASTM STP 1161 Proceedings on Leak Detection in USTs, 6/92
37. Non-Intrusive Subsurface Identification Techniques for Improved Remediation of LUST Sites	EPA Report Pending, 6/92
38. Potential Reuse of Petroleum-Contaminated Soils: A Directory of Permitted Recycling Facilities	EPA Report Pending, 6/92

RREL PRODUCTS (cont'd)

39.	Generic QA Project Plan for Field Evaluation of Soil Vapor Extraction/ Air Sparging	EPA Report Pending, 8/92
40.	Assessment of SVE/Air Sparging Technology for LUST Sites	EPA Report Pending, 8/92
41.	Guidance Document for the Application of Thermal Desorption for Treating Petroleum Contaminated Soils	EPA Report Pending, 8/92
42.	Enhanced SVE for Removal of Gasoline from the Groundwater Zone	EPA Report Pending, 9/92
43.	Assessment of Ex-Situ Bio-oxidation Technology	EPA Report Pending, 9/92
44.	Assessment of the Applicability of Innovative Technologies to Treat LUST Sites	EPA Report Pending, 9/92
45.	Preliminary Assessment of SVE P.C. Models for Application to LUST Sites	EPA Report Pending, 9/92
46.	Assessing UST Corrective Action Technologies	EPA Report Pending, 9/92

TECHNOLOGY TRANSFER: COMPUTERIZED ON-LINE INFORMATION SYSTEM

47.	Computerized On-Line Information System for Underground Storage Tank Technology Transfer	User's Guide/On-Line System Call (908) 906-6871
48.	Case History Database of Underground Storage Tank Corrective Action	Proceedings 15th Annual RREL Hazardous Waste Research Symposium, 4/89 EPA/600/9-90/006, 2/90 NTIS/PB 91-145524
49.	Computerized Management and Information for Research and Development Operations at Technical Information Exchange	Proceedings 15th Annual RREL Hazardous Waste Research Symposium, 4/89 EPA/600/9-90/006, 2/90 NTIS/PB 91-145524
50.	An Outreach Process: Case History of Underground Storage Tank Corrective Actions	Proceeding 15th Annual RREL Hazardous Waste Research Symposium, 4/89 EPA/600/9-90/006, 2/90 NTIS/PB 91-145524

RREL PRODUCTS (cont'd)

51. An Interactive Case History File of Underground Storage Tank Corrective Action	Proceedings Environmental Hazardous Conference and Exposition, Hartford, CT 10/89
52. EPA UST Case History Database and Library System is Up and Running	EPA/600/J-90/321 NTIS/PB 91-149617/AS:A01
53. Assessing Leaking Underground Storage Storage Tank Case Histories and Publications Through EPA's Computerized On-Line Information System	Proceedings 17th Annual RREL Hazardous Waste Research Symposium, 4/91 EPA/600/9-91/002, 4/91 NTIS/PB 91-233267
54. Remediation of Leaking USTs: A System for Assessing Case Histories and Related Documents	Journal of Air & Waste Management Association, Volume 42, No. 3, 3/92
55. EPA Computerized On-Line Information System for Underground Storage Tank Technology Transfer	Numerous "Briefs" in various publications such as Waste Tech News, Water Well Journal, Steel Tank Institute, Lust Line, Tank Talk, etc.

TECHNOLOGY TRANSFER: RREL ANNUAL RESEARCH SYMPOSIUM

56. U.S. EPA Evaluation of Volumetric UST Leak Detection Methods	Proceedings 13th Annual HWERL Research Symposium, 5/87 EPA/600/9-87/015, 7/87
57. Discovery of a New Source of Error in Tightness Tests on Overfilled Tanks	Proceedings 14th Annual HWERL Research Symposium, 5/88 CERI-88-20, 5/88
58. Computerized Management and Information for Research and Development Operations at Technical Information Exchange	Proceedings 15th Annual RREL Hazardous Waste Research Symposium, 4/89 EPA/600/9-90/006, 2/90 NTIS/PB 91-145524
59. An Outreach Process: Case History of Underground Storage Tank Corrective Actions	Proceedings 15th Annual RREL Hazardous Waste Research Symposium, 4/89 EPA/600/9-90/006, 2/90 NTIS/PB 91-145524
60. Case History Database of Underground Storage Tank Corrective Action	Proceedings 15th Annual RREL Hazardous Waste Research Symposium, 4/89 EPA/600/9-90/006, 2/90 NTIS/PB 91-145524

RREL PRODUCTS (cont'd)

61. The Role of Site Investigation in the Selection of Corrective Actions for Leaking Underground Storage Tank Sites	Proceeding 15th Annual RREL Hazardous Waste Research Symposium, 4/89 EPA/600/9-90/006, 2/90 NTIS/PB 91-145524
62. Summary of the Results of EPA's Evaluation of Volumetric Leak Detection Methods	Proceedings 15th Annual RREL Research Symposium, 4/89 EPA/600/9-90/006, 2/90 NTIS/PB 91-145524
63. Consideration of Underground Storage Tank Residuals at Closure	Proceeding 15th Annual RREL Hazardous Waste Research Symposium, 4/89 EPA/600/9-90/006, 2/90 NTIS/PB 91-145524
64. Evaluation of Internal Leak Detection Technology for Large Underground Storage Tanks	Proceedings 16th Annual RREL Research Symposium, 4/90 EPA/600/9-90/037, 8/90 NTIS/PB 91-148379
65. Soil Vapor Extraction Technology Assessment	Proceedings 16th Annual RREL Hazardous Waste Research Symposium, 4/90 EPA/600/9-90/037, 8/90 NTIS/PB 91-148379
66. Evaluation of Soil Washing Technology for Remediation of LUST Sites	Proceedings 16th Annual RREL Hazardous Waste Research Symposium, 4/90 EPA/600/9-90/037, 8/90 NTIS/PB 91-148379
67. Sources of Contamination Associated With Closure of Underground Storage Tanks	Proceedings 16th Annual RREL Hazardous Waste Research Symposium, 4/90 EPA/600/9-90/037, 8/90 NTIS/PB 91-148379
68. Subsurface Fate and Transport of Petroleum Hydrocarbons From Leaking USTs	Proceedings 17th Annual RREL Hazardous Waste Research Symposium, 4/91 EPA/600/9-91/002, 4/91 NTIS/PB 91-233267
69. Soil Vapor Extraction Air Permeability Testing and Estimation Methods	Proceedings 17th Annual RREL Hazardous Waste Research Symposium, 4/91 EPA/600/9-91/002, 4/91 NTIS/PB 91-233267

RREL PRODUCTS (cont'd)

70. Assessing Leaking Underground Storage Tank Case Histories and Publications through EPA's Computerized On-Line Information System	Proceedings 17th Annual RREL Hazardous Waste Research Symposium, 4/91 EPA/600/9-91/002, 4/91 NTIS/PB 91-233267
71. Underground Storage Tank Containing Hazardous Chemicals	Proceedings 17th Annual RREL Hazardous Waste Research Symposium, 4/91 EPA/600/9-91/002, 4/91 NTIS/PB 91-233267
72. Review of Soil Vapor Extraction Computer Models	18th Annual RREL Research Symposium, 4/92
73. Site Assessment & Technologies for Removal of LNAPL from LUST Sites	18th Annual RREL Research Symposium, 4/92
74. Subsurface Remediation of Gasoline by Air Sparging and SVE	18th Annual RREL Research Symposium, 4/92
75. Remediating Leaking UST Sites on Native American Lands	18th Annual RREL Research Symposium, 4/92

TECHNOLOGY TRANSFER: OUST SPONSORED CONFERENCES/WORKSHOPS

76. Internal Tank and Pipeline Leak Detection Methods	CERI Technology Transfer Seminars on Leak Detection Methods for USTs; San Francisco, CA - 9/88; King of Prussia, PA - 9/88; Atlanta, GA - 10/88; Rosemont, IL - 11/88
77. Tank Closure Practices	"Making It Work" - 1st Annual UST/LUST Conference, Santa Fe, NM, 11/88
78. UST Case Histories Database	Presentation and Workshop, "Making It Work" - 1st Annual UST/LUST Conference, Santa Fe, NM, 11/88
79. Corrective Action Case Histories	Presentation and Workshop, "Continuous Improvement" - 2nd Annual UST/LUST Conference, Tucson, AZ, 11/89
80. Leak Detection: Volumetric Tank Methods and Pipeline Leak Detection	Presentation and Workshop, "Continuous Improvement" - 2nd Annual UST/LUST Conference, Tucson, AZ, 11/89

RREL PRODUCTS (cont'd)

81.	A Comprehensive State UST Management System	Presentation and Exhibit, "Continuous Improvement" - 3rd Annual UST/LUST Conference, New Orleans, LA, 11/90
82.	RREL Underground Storage Tank Research Program Overview	Panel Discussion, "Continuous Improvement" - 3rd Annual UST/LUST Conference, New Orleans, LA, 11/90
83.	RREL Underground Storage Tank Research Program Overview	Poster Presentation, "Meeting the Challenge" 4th Annual UST/LUST Conference, Fort Lauderdale, FL, 11/91

TECHNOLOGY TRANSFER: RREL ENGINEERING/TECHNOLOGY BULLETINS

84.	Solvent Extraction Treatment	EPA/540/2-90/013, 9/90
85.	In Situ Steam Extraction	EPA/540/2-91/005, 5/91
86.	In Situ Soil Vapor Extraction Treatment	EPA/540/2-91/006, 5/91
87.	Thermal Desorption Treatment	EPA/540/2-91/008, 5/91
88.	Soil Washing Treatment	EPA/540/2-90/017, 9/91
89.	In Situ Soil Flushing	EPA/540/2-91/021, 10/91
90.	In Situ Biodegradation Treatment	Draft

ENVIRONMENTAL MONITORING SYSTEMS LABORATORY-LAS VEGAS

UNDERGROUND STORAGE TANK RESEARCH PROGRAM PRODUCTS

LEAK DETECTION

101.	Modeling Vapor Transport for Evaluating Tank Leak Detectors	Abstract/Oral Presentation at 5th Annual Hazardous materials Control Research Institute's Conference 9/87 UST Conference Sturbridge, Maine Sponsored by the Source Education Institution, Inc., 4/88 Symposium Paper for NWWA Conference on Petroleum Hydrocarbon in Ground Water, Las Vegas, NV
102.	Strategies for External Leak Detection of Underground Storage Tanks	Symposium Paper, 2/88
103.	Development of Procedures to Assess the Performance of External Petroleum Leak Detection Devices-Performance Test Procedures-Draft	EPA/600/X-88/141, 3/88
104.	Development of Procedures to Assess the Performance of External Petroleum Leak Detection Devices-Executive Summary Draft	EPA/600/X-88/142, 3/88
105.	Internal Report-Network Design for External Release Monitoring of Underground Storage Tanks	EPA/600/X-88/143, 3/88
106.	Hydrocarbon Vapor Concentrations Adjacent to Tight Underground Gasoline Storage Tanks	Published Conference Proceedings, MWWA Outdoor Action Conference, Las Vegas, NV, 4/88
107.	Detection of Subsurface Gasoline Contamination in New England Glaciated Terrain Using Soil Gas Surveying	Published Conference Proceedings, 7/88
108.	Modeling Vapor Transport for Evaluating Tank Leak Detectors	Published Conference Proceedings, 8/88
109.	Modeling Vapor Transport for Evaluating Tank Leak Detectors	Symposium Paper, 1/89

110.	Soil Vapor Monitoring for Fuel Leak Detection--Data Compiled for Thirteen Case Studies	EPA/600/X-89/092, 3/89
111.	Estimation of Leak Rates from Underground Storage Tanks	Ground Water Review Journal 5/89
112.	Direct Comparison of Vapor-, Free-Product and Aqueous-Phase Monitoring for Gasoline Leaks from Underground Storage Systems	Abstract/Proceedings of Petroleum Hydrocarbon and Organic Chemicals in Ground Water, 7/89
113.	Vapor Transport in Fine-Grained High-Water Content Soils: A Field Example and Implications for Leak Detection	Abstract, NWWA Conference on Petroleum Hydrocarbon in Ground Water, 7/89
114.	Direct Comparison of Vapor-, Free-Product and Aqueous-Phase Monitoring for Gasoline Leaks from Underground Storage Tanks	Symposium Paper, NWWA Conference on Petroleum Hydrocarbon in Ground Water, 10/89
115.	EPA's Development of Evaluation Tests for Extramural Leak Detectors Used with Underground Storage Tanks	Journal of Nondestructive Testing, 10/89
116.	Final Report: Summary of Results of the Validation of Test Method for Evaluating the Performance of External Leak Detection Devices--Vapor-Phase ASTM Formatted Methods and Liquid Phase ASTM Formatted Methods	EPA/600/X-90/044, 2/90
117.	Development of Procedures to Assess the Performance of External Leak Detection Devices. Draft Summary Report on Laboratory Evaluation of Vapor-Phase Interference Test Method	EPA/600/X-90/363, 12/90
118.	Standard Test Method for Interferences for Vapor-Phase Out-of-Tank Petroleum Detectors	EPA/600/X-90/364, 12/90
119.	Background Hydrocarbon Vapor Concentration Study for Underground Fuel Storage Tanks	EPA/600/4-91/009, 4/91

120.	Soil Gas, Carbon Dioxide and Oxygen Anomalies Associated with Subsurface Gasoline Leakage	Proceedings, Geological Society of America, Northeastern Section Meeting, 3/92

SITE ASSESSMENT

121.	Hydrocarbon Vapor Concentrations Adjacent to Tight Underground Gasoline Storage Tanks	Abstract/Oral Presentation, 12/87
122.	Strategies for External Leak Detection of Underground Storage Tanks	Abstract/Oral Presentation, Hazardous Materials Control Research Institute's 5th National RCRA Conference (presented 4/88), Las Vegas, NV, Abstract 9/87
123.	Density-Driven Vapor Transport in the Vadose Zone	Abstract/Oral Presentation, Hazardous Materials Control Research Institute's 5th National RCRA Conference, Las Vegas, NV 9/87
124.	The Use of Industrial Hygiene Samplers for Soil-Gas Measurement	EMSL-LV/#8135, 12/88
125.	Soil Gas Sampling at a Site with Deep Contamination by Fuels	Symposium Paper, 11/88
126.	A New Method for Field Analysis of Soils Contaminated with Aromatic Hydrocarbon Compounds	Abstract Proceedings of NWWA, Northeastern States Conference 10/88
127.	Modeling Vapor Phase Movement in Relation to UST Leak Detection-Phase I	EPA/600/X-88/273, 4//88
128.	Quality Assurance Project Plan for Long Term Monitoring at Underground Fuel Storage Tanks	EPA/600/X-88/144, 3/88
129.	Measurement of Carbon Dioxide in Soil Gases for Indication of Subsurface Organic Contamination	Ground Water Monitoring Review Journal, 3/89
130.	Project Summary--Background Hydrocarbon Vapor Concentration Study for Underground Storage Tanks	EPA/600/X-88/043, 1/88

EMSL-LV PRODUCTS (Cont'd)

131.	The Role of QA/QC in Soil-Gas Surveys	ASTM Symposium, 1/88
132.	Long Term Soil-Gas Monitoring of Underground Storage Tanks	Symposium Proceedings Petroleum Hydrocarbon and Organic Chemicals in Groundwater, 10/89
133.	Soil Gas Surveying for Subsurface Gasoline Contamination Using Total Organic Vapor Detection Instrumentations: Part II, Field Experimentation	Ground Water Monitoring Review Journal, 12/89
134.	Soil Gas Surveying for Subsurface Gasoline Contamination Using Total Organic Vapor Detection Instrumentations: Part I, Laboratory Theory and Experimentation	Ground Water Monitoring Review Journal, 12/89
135.	Spatial Design Requirements for Total Hydrocarbon Vapor Monitors Around Underground Storage Tanks	Abstract, 12/89
136.	Development of Standard, Pure-Compound Base Gasoline Mixture for Use as a Reference in Field and Laboratory Experiments	Ground Water Monitoring Review Journal, 10/89
137.	Manual Headspace Method to Analyze for the Volatile Aromatics of Gasoline in Ground Water and Soil Samples	Analytical Chemistry, 10/89
138.	Vertical Dispersion of Ground-Water Contaminants in the Near Field of Leaking Underground Storage Tanks	Abstract, NWWA Conference on Petroleum Hydrocarbons in Ground Water, 7/89
139.	Mass Continuity and Distribution Implications for Collection of Representative Ground-Water Samples from Monitoring Wells	Abstract, NWWA Conference on Petroleum Hydrocarbons in Ground Water, 7/89
140.	Proposed Guidance Document for External Monitoring of Underground Storage Tanks	EPA/600/X-89/019, 1/89
141.	Simulation of Subsurface Vapor Movement from a Leaking Tank	Symposium Paper, Association of International Hydrological Sciences, 1/89

EMSL-LV PRODUCTS (Cont'd)

142.	A Manual for Conducting Field Screening for Subsurface Gasoline Contamination	EPA/600/8-90/067, 8/90
143.	A Field Study Examining Mass Continuity Influences Characterizing Ground Water Contamination at a Gasoline Service Station	Journal of Contaminant Hydrology, 8/90
144.	Spatial Design Requirements for Total Hydrocarbon Vapor Monitors Around Storage Tanks	Journal of Contaminant Hydrology, 7/90
145.	Tank Issues: Site Characterization for External Leak Monitoring	Pending Printing, 2/91
146.	The Sensing Characteristics of Adsistor and Figaro Gas Sensors for Underground Storage Tank Leak Detection	Poster Presentation, Second International Symposium: Field Screening Methods for Hazardous Wastes and Toxic Chemicals 2/91
147.	Systematic Variations in Relative Abundances of Aromatic Compounds in Gasoline Contaminated Ground Water	NWWA Focus Eastern Conference Proceedings, Portland, MA. (10/91) Abstract 5/91
148.	Comparison Between Field and Laboratory Measurement for Volatile Aromatics in Gasoline Contaminated Ground-Water Sampling	Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, New Orleans, LA. (3/92) Abstract, 8/91
149.	High-Speed Gas Chromatography Used with the Static Headspace Method to Analyze for the Volatile Aromatics in Gasoline	Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, New Orleans, LA. (3/92) Abstract, 8/91
150.	Evaluation of the Interrelationship of Soil-Gas and Ground-Water at a Gasoline Contaminated Site	Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, New Orleans, LA. (3/92) Abstract, 8/91

151.	A New Method for Determining Henry's Law Constants for Volatile Compounds by Static Headspace/Gas Chromatography	Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, New Orleans, LA. (3/92)
152.	Physical Modeling of Fuel Leaks in Simulated Underground Environments	Video, 8/91 EMSL-LV #460
153.	High Speed Gas Chromatography used with the Static Headspace Method to Analyze for the Volatile Aromatics in Gasoline	Journal of High Resolution Chromatography and Chromatography Communications, Vol 14, 11/91
154.	Apparent Plume Attenuation Distortions due to Vertical Concentration Averaging in Monitoring Wells	Abstract/Conference and Proceedings, Geological Society of America, Northeastern Section Meeting, 3/92
155.	Evaluation of Slug Test Methods for Determining Hydrologic Conductivity	Proceedings, Geological Society of America, Northeastern Section Meeting, 3/92
156.	Multi-Level Groundwater Sampling in Glacial Tills	Proceedings, Geological Society of America, Northeastern Section Meeting, 3/92
157.	Multi-Faceted Evaluation of a Gasoline Contaminated Bedrock Aquifer in Connecticut	Proceedings, Geological Society of America, Northeastern Section Meeting, 3/92
158.	Soil-Gas Surveys: Planning Implementation, and Interpretation	EPA Internal Report Pending 6/92

CORRECTIVE ACTION

159.	Is Soil-Gas Analysis an Effective Means of Tracking Contaminant Plumes in Ground Water?	Ground Water Monitoring Review Journal, 12/87
160.	Prototype Expert System for the Selection of External Monitoring Methods for Underground Storage Tanks	EPA/600/X-87/413, 11/87

EMSL-LV PRODUCTS (Cont'd)

161.	Soil-Gas Surveying for Subsurface Organic Contamination: Active and Passive Techniques	Hazardous Materials Control Research Institute's 8th National Conference and Exhibition Washington, D.C. (11/87) Abstract 8/87
162.	Field Evaluation of Three Methods of Soil-Gas Measurement for Delineation of Ground-Water	Symposium Paper, Solid Waste Testing and Quality Assurance Conference, Washington, D.C. 6/87
163.	Soil Venting for Remediation of Subsurface Gasoline Releases: Experiments in Very Large Physical Model	NWWA Conference on Petroleum Hydrocarbon in Ground Water, Abstract 7/89
164.	Long-Term Monitoring of Soil Gas Concentrations Near Underground Storage Tanks	NWWA Conference on Petroleum Hydrocarbon in Ground Water, Abstract 7/89
165.	Protocols for Ground-Water and Vapor Monitoring--Procedures for Determining: 1) The Lower Detection Limit of Vapor Phase Detectors, 2) The Lower Detection Limit of Liquid-Phase Detectors, 3) The Specificity of Dissolved Liquid-Phase Detectors, 4) The Accuracy and Response Time of Dissolved Liquid-Phase Detectors, 5) The Accuracy and Response Time for Thin-Layer, Liquid-Phase Detectors, 6) The Specificity of Thin-Layer Liquid-Phase Out-of-Tank Petroleum Detectors	EPA/600/X-89/091, 3/89
166.	A Field Screening Method for Gasoline Contamination Using a Polyethylene Bag Sampling System	Ground Water Monitoring Review, 1/89
167.	Draft Summary Report on Laboratory Evaluation of Vapor-Phase Interference Test Method	EPA/600/X-90/363, 12/90
168.	Mass Continuity Modeling of Monitoring Well Purging	Contaminant Hydrology, 8/90

EMSL-LV PRODUCTS (Cont'd)

169.	Simulated Monitoring Well Purging Using Mass-Continuity Modeling	AGU Meeting, Abstract, 3/90
170.	Tank Issues: Design and Placement of Floating Liquid Monitoring Wells	Pending Printing, 2/91
171.	Tank Issues: Design and Placement of Vapor Monitoring Wells	Pending Printing, 2/91
172.	Applications of Field Screening Techniques for Expediting and Improving Site Investigations at LUST Sites	ASTM Symposium, New Orleans, LA (1/92) Abstract 4/91
173.	"Lab in a Bag" - A New Field Screening Method for Volatile Organic Contaminants Using Total Organic Vapor Detectors	NWWA Convention and Exposition, Washington, D.C., Conference Proceedings (10/91) Abstract 6/91
174.	Measurement and Analysis of Adsistor and Figaro Gas Sensors Used for Underground Storage Tank Leak Detection	EPA Report Pending, 6/92
175.	A Laboratory In-Soil Evaluation of 3M Badge and Barringer Passive Soil Gas Samplers	EPA Report Pending, 7/92
176.	Use of Ion Selective Electrodes in the Field to Examine Inorganic Groundwater Quality in Relation to Biological Activity at Gasoline Contaminated Sites	Pending Journal Article in Environmental Science and Technology, 7/92

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APPENDIX C

PROJECT DESCRIPTIONS

RREL - PROJECT DESCRIPTION

TITLE: Identification of the State of the Art in Leak Prevention for Underground Storage Tanks

DURATION: FY85

RESOURCES: $100K

OBJECTIVE:

To examine the structural design and operational practices associated with USTs in the context of leak prevention and to identify research and development needs to advance leak prevention technology.

RATIONALE:

Many standards, guidelines, and recommended practices for the design and operation of UST systems were promulgated by several professional and industrial organizations. Because many of these procedures had overlapping requirements, a cohesive and coordinated approach was needed that applies to all types of UST systems.

DESCRIPTION:

This project reviewed the current practices in UST structural design, corrosion protection, installation, testing, and operation. It examined the available statistical information on the demographics of leaking USTs and the most dominant failure mechanisms. The applicable codes and standards for the design, installation, and operation of UST systems were investigated and deficiencies were identified.

Recommendations derived from this study include: (1) establishing a national data- base to provide information on failure rates and mechanisms and their correlation to design, engineering, installation, and operation practices and corrective actions; (2) assessing the effectiveness of cathodic protection methods, their interaction with the environment, and the performance of retrofitting existing USTs; (3) developing compatibility protocols for the selection of appropriate materials of construction and long-term protection; and (4) developing methods to assess the life expectancy of both new and existing systems and to extend their useful life.

OUTPUT:

Final report entitled "Leak Prevention in Underground Storage Tanks: A State of the Art Survey," EPA/600/2-87/018, March 1987.

RREL - PROJECT DESCRIPTION

TITLE: Identification of the State of the Art in Underground Tank Leak Detection Methods

DURATION: FY85

RESOURCES: $150K

OBJECTIVE:

To identify and assess the performance of existing and developing techniques to detect leaks in underground fuel storage tanks.

RATIONALE:

The Resource Conservation and Recovery Act directed EPA to develop regulations for the prevention, detection, and corrective action of releases from USTs containing petroleum and other hazardous substances. Although release detection was a main focus of the regulation, a lack of information was available on the identification and capabilities of existing leak detection methods.

DESCRIPTION:

Existing and developing leak detection methods were reviewed, and techniques for offsetting the effects of variables that impact accuracy were evaluated. Volumetric, nonvolumetric, and other leak detection methods were detailed in a final report that summarized general information, general operational capabilities, and compensation for the effects of these variables.

The American Petroleum Institute (API) and the Petroleum Equipment Institute (PEI) were contacted for assistance in developing a comprehensive list of available detection methods. A limited patent search was performed to identify methods currently being developed but not yet available commercially. Fifteen volumetric leak testing methods, seven nonvolumetric leak testing methods, three inventory monitoring methods, and eleven leak effects monitoring methods were identified.

The project identified the need for additional data on the performance of individual leak detection methods to determine relative accuracy among methods. Performance claims up to this time were not well documented and were entirely based on manufacturer's literature and practitioner's information.

OUTPUT:

Final report entitled "Underground Tank Leak Detection Methods: A State-of-the-Art Review," EPA/600/2-86/001, January 1986.

RREL - PROJECT DESCRIPTION

TITLE: Construction of a Full-Scale Underground Storage Tank Test Apparatus

DURATION: FY85 and FY86

RESOURCES: $1,400K

OBJECTIVE:

To design and construct a full-scale equivalent of a commercial underground tank facility that can be operated under the controlled conditions necessary to obtain reproducible test results.

RATIONALE:

The Resource Conservation and Recovery Act directed EPA to develop regulations for the prevention, detection, and corrective action of releases from underground storage tanks containing petroleum and other hazardous substances. Although release detection was a main focus of the regulation, information was insufficient to specify either a performance standard or method of detecting leaks. Furthermore, the basic experimental information necessary to develop accurate leak detection methods was not available. To obtain the data necessary to support the development of the UST release detection regulations, EPA needed a full-scale test apparatus.

DESCRIPTION:

The UST Test Apparatus was built specifically to evaluate the performance of volumetric leak detection equipment. Before the Test Apparatus was designed, a detailed program plan showing how the equipment would be evaluated was prepared. Preliminary field experiments were conducted to support the development of the Test Apparatus design and instrumentation. During construction, the instrumentation, calibration procedures, data acquisition and analysis software, and quality assurance procedures were developed. Once construction was complete, the UST Test Apparatus underwent an extensive check-out to verify its effectiveness for evaluating commercial leak detection methods.

The experimental setup consists of two 8,000-gal underground tanks (one made of coated steel, the other of fiberglass); secondary containment (a synthetic membrane) for each underground tank; 3,000-gal and 6,000-gal aboveground tanks with heat exchange coils; a 154,000-Btu/h electric heater and a 60,000-Btu/h chiller; 400-gal-minimum transfer/circulation pumps; and monitoring wells (both inside and outside the secondary containment). The apparatus was designed to provide maximum control over the major factors that affect the performance of volumetric leak detection systems. Leaks of different sizes can be simulated in the tanks. Control over the product temperature and other factors that affect the accuracy (or performance) of leak detection methods is possible.

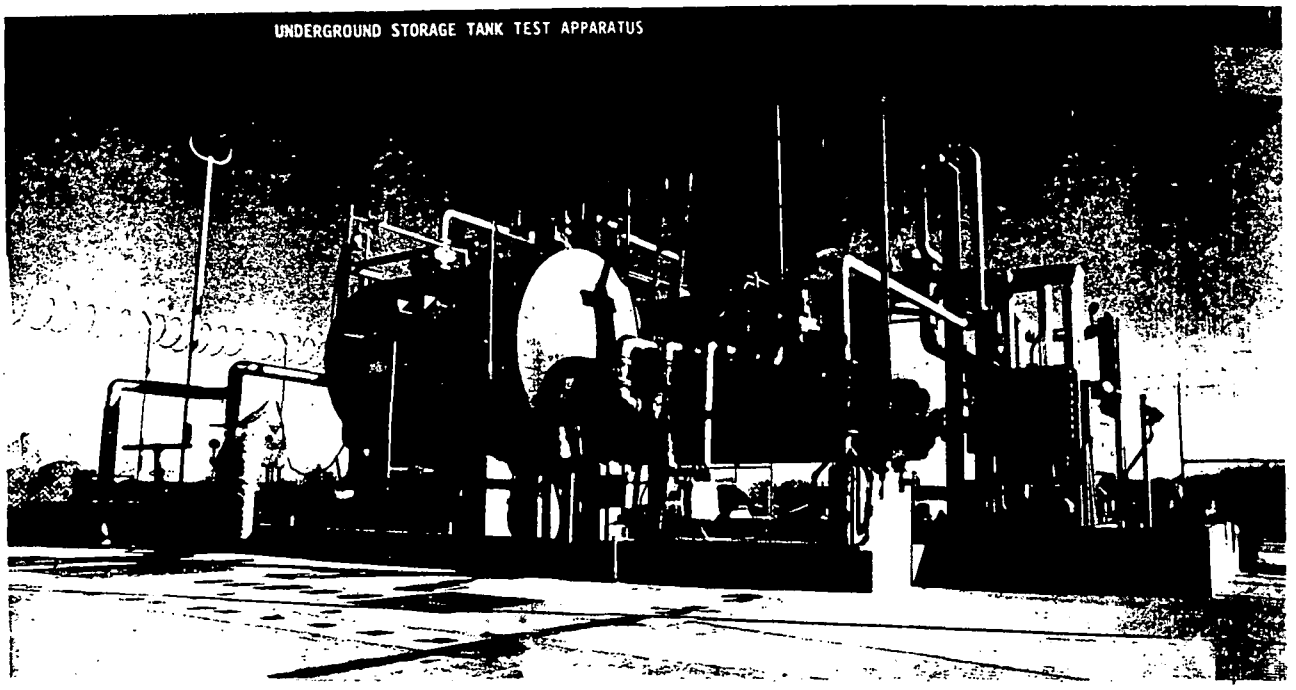
OUTPUTS:

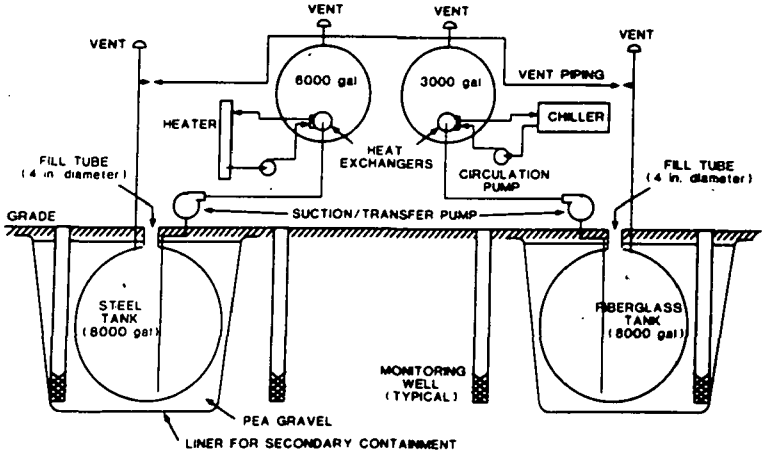
1. Internal EPA report entitled "A Program Plan to Evaluate Underground Storage Tank Test Methods," March 1985.

2. Internal EPA report entitled "Preliminary Experiments on the Ambient Noise Sources in Underground Tank Testing," September 1985.

3. Internal EPA report entitled "Test Plan for the EPA Tank Test Method Evaluation Program," May 1986.

4. Internal EPA report entitled "Protocol for Evaluating Volumetric Leak Detection Methods for Underground Storage Tanks," June 1986.





RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Leak Detection Methods for Underground Storage Tank Systems

DURATION: FY87 to FY89

RESOURCES: $1835K

OBJECTIVE:

To evaluate the current performance of commercially available volumetric test methods and automatic tank gauging systems for leak detection and inventory control in underground gasoline storage tanks. Specific objectives were to: (1) produce the technical data necessary to support the development of release detection regulations, (2) define the current practice of commercially available systems, (3) make specific recommendations to improve the current practice, and (4) provide technical information that would help users select suitable methods for testing the integrity of underground storage tanks.

RATIONALE:

The Resource Conservation and Recovery Act directed EPA to develop regulations for the prevention, detection, and corrective action of releases from underground storage tanks (USTs) containing petroleum and other hazardous substances. Although release detection was a main focus of the regulation, information was insufficient to specify either a performance standard or methods of detecting leaks. Furthermore, the basic experimental information necessary to develop accurate leak detection methods was not available. With the completion of EPA's UST Test Apparatus in Edison, New Jersey, these data needs could be addressed under controlled conditions.

DESCRIPTION:

Phase I - Evaluation of Volumetric Leak Detection Methods. Twenty-five commercially available volumetric leak detection systems were evaluated at the UST Test Apparatus. The fundamentals of testing tanks volumetrically were established and incorporated into a unique approach to determine and resolve the technological and engineering issues associated with volumetric leak detection, as well as to define the current practice of commercially available test methods. The approach uses experimentally validated models of the important sources of ambient noise that effect volume changes in nonleaking and leaking tanks, a large database of product-temperature changes that result from the delivery of product to a tank at temperatures different from the extant product, and a mathematical model of each test method to estimate the performance of that method. The test-method model includes the instrumentation noise, the configuration of the sensors, the test protocol, the data analysis algorithms, and the detection criterion. This study, along with the ambient noise experiments, contributed to a better understanding of the environmental factors that inhibit detection (temperature, structural deformation, trapped vapor, evaporation and condensation, and waves).

An estimate of the performance of each system was made in terms of the probability of detection and probability of false alarm against a 0.38-L/h (0.10-gal/h) leak rate, using the detection threshold employed by each system at the time of the evaluation. The measured performance was found to be considerably poorer than the often claimed 0.19 L/h (0.05 gal/h) and limited by current protocol and practice rather than by hardware design. Recommendations were made for each volumetric system evaluated and for the technology in general. As part of this study, an estimate was made of the potential performance that could be achieved by the systems evaluated. The results showed that, with the recommended modifications, it was possible for over 60% of these systems to achieve a performance

between 0.19 L/h (0.05 gal/h) and 0.56 L/h (0.15 gal/h), and for 100% to achieve a performance of approximately 0.80 L/h (0.20 gal/h), given that a probability of detection of 99% and a probability of false alarm of 1% were to be achieved.

Phase II - Evaluation of Automatic Product Leaking Monitoring Devices. Among the methods of leak detection that could be permanently installed in a tank system, the most commonly used was an automatic tank gauge (ATG). These gauges had been developed for inventory control and were used primarily for that purpose, not for leak detection. They had, however, an inherent capability to perform accurate tests.

An evaluation of the performance of automatic tank gauges for both leak detection and inventory control was performed. The leak detection evaluation was based on data collected at the UST Test Apparatus, and the inventory control evaluation was based on a simulation model of important noise sources. The analyses verified that the 0.2-gal/h regulatory standard could be met with automatic tank gauges. Because of the expense involved, all of the commercial ATGs could not be evaluated. Instead, RREL focused on the technical aspects needed for developing a regulatory standard, and OUST prepared standard test procedures with which a manufacturer could evaluate its own equipment (or have it evaluated by a third party).

The experiments were conducted at the UST Test Apparatus. Temperature and level measurements were reduced into a database for evaluation of ATGs according to the same protocol that had been used to evaluate volumetric tank tightness test methods. From this database, a preliminary estimate of the performance of two ATGs was made. In addition, a preliminary assessment of the errors produced by evaporation and condensation was made. RREL also developed a model of the sources of noise for inventory analysis that could be used to predict the performance of a wide variety of test protocols. Several important sources of noise that were not being compensated for (i.e., the temperature changes that occur in the pipeline) were identified for the first time. The model was used to evaluate the most common methods of doing inventory-control-based leak testing. The model results were found to be in good agreement with those obtained with a large database of inventory records.

Phase III - Technology Transfer. Most of the technical information developed in EPA's R&D programs in leak detection was initially directed toward the developers of the federal regulations (OUST) and the developers of leak detection equipment. Once technically defensible standards had been developed, and the leak detection industry had sufficient technical information to develop new methods (or adapt old ones) that would be in compliance with the regulatory standard, an effort was made to effect technology transfer to the regulated community. Information was needed by the tank owners and operators who had to select test equipment that would comply with the regulations, by the state and local regulators who had to implement the federal regulations, and by the engineering community that had to design UST facilities.

RREL prepared and delivered four all-day presentations summarizing the results of EPA's research on underground storage tank leak detection. In addition to the technical presentations on methods and systems, presentations were given on how to select a method, how to assess the cost of the selection, and how to evaluate the performance of the selection. RREL also prepared a variety of different types of reports and papers to address all sectors of the regulated community.

OUTPUTS:

The primary output of this study provided the technical framework for the development of the regulatory standards and changed the way industry tested tanks. Selected products from this work include:

1. Technical paper entitled "U.S. EPA Evaluation of Volumetric UST Leak Detection Methods," Proceedings of the 13th Annual Research Symposium, May 1987; EPA/600/9-87/015, July 1987.

2. Technical report entitled "A Leak Detection Performance Evaluation of Automatic Tank Gauging Systems and Product Line Leak Detectors at Retail Stations," American Petroleum Institute, January 1988.

3. Technical report entitled "Inventory Analysis in Underground Storage Tank Leak Detection," March 1988.

4. Technical report entitled "Common Errors in Leak Detection Usage," March 1988.

5. Technical paper entitled "Discovery of a New Source of Error in Tightness Tests on Overfilled Tanks," Proceedings of the 14th Annual Research Symposium, May 1988; CERI-88-20, May 1988.

6. Technology Transfer Seminars entitled "Leak Detection Methods for USTs," San Francisco, CA - September 1988; King of Prussia, PA - September 1988; Atlanta, GA - October 1988; Rosemont, IL - November, 1988.

7. Final report entitled "Evaluation of Volumetric Leak Detection Methods for Underground Fuel Storage Tanks," EPA/600/2-88/068a,b, November 1988.

8. Technical paper entitled "Evaluation of the Accuracy of Volumetric Leak Detection Methods for Underground Storage Tanks Containing Gasoline," Proceedings of the 1989 Oil Spill Conference, San Antonio, Texas.

9. Final report entitled "Volumetric Tank Testing: An Overview," EPA/625/9-89/009, April 1989.

10. Technical paper entitled "Summary of the Results of EPA's Evaluation of Volumetric Leak Detection Methods," Proceedings of the 15th Annual Research Symposium, April 1989; EPA/600/9-90/006, February 1990.

11. Technical paper entitled "Test Procedures for Evaluating the Performance of Underground Storage Tank Leak Detection Methods," National Water Well Association, August 1990.

12. Peer review journal article entitled "Evaluation of Volumetric Leak Detection Methods Used in Underground Storage Tanks," Journal of Hazardous Materials, Volume 26, 1991; EPA/600/J-91/155.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Pipeline Leak Detection Methodologies

DURATION: FY87 and FY88

RESOURCES: $310K

OBJECTIVE:

To evaluate the performance of methods that use pressure tests to determine the integrity of pressurized underground pipelines containing petroleum products and to determine whether these pressure-based detection systems could meet the same performance standards as leak detection systems for tanks.

RATIONALE:

The Resource Conservation and Recovery Act directed EPA to develop regulations for the prevention, detection, and corrective action of releases from underground storage tanks and associated pipelines containing petroleum and other hazardous substances. Although release detection was a main focus of the regulation, information was insufficient to specify either a performance standard or method of detecting pipeline leaks. Data were needed so that UST regulations for line tightness and line monitoring could be established. Experiments were required to measure how leaks and temperature changes affect pressure changes in the line. Furthermore, the basic theoretical and experimental information necessary for the industry, as a whole, to conduct such tests was not available.

This project was particularly important because it was suspected that the majority of all leaks occurred not in the tanks themselves, but in the associated piping. A pressurized pipeline system can remain functional and dispense product even if it is leaking. Because of the high operational pressures, a large release of product can occur in a very short period of time.

DESCRIPTION:

To support the development of pipeline release detection regulations, a full-scale pipeline test apparatus was constructed and tied into the UST Test Apparatus. Two systems were designed to allow for the development and assessment of both pipeline leak prevention and leak detection technologies. Both systems are instrumented to allow for monitoring of the product in the line, the backfill, the operating characteristics of the line, and all appurtenances on the line. Both systems can be pressurized, and leaks can be simulated.

The pipeline test apparatus consists of two 200-ft, 2-in.-diameter pipelines filled with gasoline. One of the lines is made of fiberglass-reinforced plastic and the other of steel. Temperature sensors were placed in each line at 10-ft intervals, in the backfill surrounding the lines, and in the native soil. The pressure in the lines was monitored with mechanical and electronic pressure sensors. The lines can be divided, by means of valves, into 50-, 100-, 150- or 200-ft sections. The lines contain other appurtenances normally found at retail service stations (e.g., a mechanical line leak detector).

RREL designed and conducted a set of experiments on both the fiberglass and steel pipelines to determine performance of the mechanical line leak detector and pressure-sensing pipeline leak detection systems. The mechanical line leak detector experiments verified that a 3-gal/h standard was technically defensible, but the device was sensitive to temperature changes and to the presence of vapor in the line. Physical models were developed of the pressure changes due to a leak and due to product temperature

changes that occur in a pressurized pipeline. A simulation was developed, validated experimentally, and used to show that a waiting period of 4 to 12 hours was required for the temperature changes to decay sufficiently to allow a line tightness or monitoring test and to permit an overnight line test. RREL developed a finite-element model to estimate the rate of temperature change in the pipeline. This model was validated experimentally, and the thermal diffusivity constants necessary to make predictions were developed in a set of laboratory experiments. The output of this model was input to the simulation.

OUTPUTS:

1. This project resulted in the establishment of technically defensible standards for pipeline tightness testing and automatic line leak detectors. The project also demonstrated that it was possible to reliably test the 2-in.-diameter pipelines normally used at retail service stations and private storage facilities. All sectors of the UST community had a direct need for this information; however, the primary audience was the EPA regulator.

2. Peer review journal article entitled "Pressure and Temperature Fluctuations in Underground Storage Tank Pipelines Containing Gasoline," Journal of Oil and Chemical Pollution, Vol. 7 (1990).

RREL - PROJECT DESCRIPTION

TITLE: Development of a Protocol for Evaluating Pipeline Leak Detection Systems for Petroleum USTs

DURATION: FY89 and FY90

RESOURCES: $140K

OBJECTIVE:

To develop and validate a protocol for evaluating the performance of pipeline leak detectors that measure pressure or volume changes in the line.

RATIONALE:

EPA's UST regulations require that the owners of tank systems periodically test their tanks and pipelines using leak detection systems that meet minimum performance standards. No leak detection system can be used unless it can be certified as capable of meeting these Federal standards. In order to support this certification program for demonstrable performance, the EPA Office of Underground Storage Tanks required standardized test procedures to evaluate seven different types of leak detection systems. This project addressed the development of a standardized certification procedure for pipeline leak detection devices.

DESCRIPTION:

All approaches to quantifying the performance of line leak detectors involve the development of a histogram of the noise and a histogram of the signal-plus-noise for the test conditions under which a leak detection system will be used. The noise histogram is developed from the flow-rate output of many leak detection tests on nonleaking pipelines. The signal-plus-noise histogram is estimated from the noise histogram and the relationship between the signal and the noise. The calculations necessary to estimate the probability of detection and probability of false alarm from the noise and signal-plus-noise histograms are well defined. Approaches to characterizing the histogram of the noise were developed and validated at the UST Test Apparatus.

Unlike the case of leak detection systems for underground tanks (volumetric tank tightness methods and automatic tank gauging systems), no evaluation procedures existed for systems used on pipelines. A general-purpose evaluation protocol was developed that allowed the data to be collected in five different ways and that was applicable to tanks as well as pipelines. This protocol was designed for use with pipeline leak detectors that measure pressure or volume changes in the line. The main technical issue that needed to be addressed was the standardization of the test conditions under which the evaluation was to be performed. Unlike tanks, most of the pipeline leak detection systems are coupled to the characteristics of the pipeline. A number of novel devices were developed to make all pipelines have the same characteristics. A numerical, finite-difference heat-conduction model was used to simulate the product temperature conditions in the line so that the method used to generate the temperature conditions in the evaluation could be standardized. The protocol that was developed addressed (1) the 3-gal/h automatic leak monitors, (2) the 0.1-gal/h line tightness test methods, and (3) 0.2-gal/h automatic monitoring methods. The protocol allowed for data to be collected on a full-scale test apparatus (e.g., the UST Test Apparatus) or from operational retail stations. The statistical procedures for analyzing the data were more realistic and were greatly simplified in comparison to previous methods.

OUTPUTS:

1. Final report entitled "Standard Test Procedures for Evaluating Leak Detection Methods: Pipeline Leak Detection Systems," EPA/600/S2-90/050, July 1990.

2. Journal article entitled "Test Procedures for Evaluating the Performance of Underground Storage Tank Leak Detection Methods," National Water Well Association Conference, August 1990.

3. Final report entitled "Standard Test Procedures for Evaluating Leak Detection Methods: Pipeline Leak Detection Systems," EPA/530/UST-90/010, September 1990.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of the Technical Aspects of Underground Storage Tank Closure

DURATION: FY89 and FY90

RESOURCES: $135K

OBJECTIVE:

To obtain a thorough technical and scientific understanding of UST residuals at closure: their origins, physical and chemical properties, and ease of removal by different cleaning methods.

RATIONALE:

Federal UST regulations address removing USTs from service. A key concern in UST closure activities is the manner and extent of tank cleaning that is appropriate and feasible when removing a tank in order to ensure that the surrounding area is not contaminated during tank cleaning and excavation efforts and damage to the environment and resulting additional cost for site remediation may be avoided.

DESCRIPTION:

Initially, information was obtained via phone contacts with knowledgeable individuals associated with tank cleaning companies from published and unpublished literature, from site visits, and from worksheets completed by State representatives. This initial effort was followed by a field sampling and analysis program at sites-of-opportunity where USTs were currently undergoing closure. The primary objective of the field program was to obtain an independent assessment of cleaning effectiveness; a secondary objective was to obtain additional information on the hazardous characteristics and composition of the residuals generated from the closure activities. The investigation was limited to underground storage tanks containing gasoline and diesel fuels.

Gasoline and diesel USTs were found to have significant quantities of residuals in them at closure, typically tens to a few hundreds of gallons. Although little explicit guidance is available, however, tank cleaning and removal companies are apparently capable of removing most of these residuals with fairly simple cleaning techniques. Sludges from both gasoline and No. 2 fuel oil USTs were found to contain significant concentrations of lead, barium, chromium, cadmium, and arsenic.

As expected, both fuel residuals also contained significant concentrations of benzene, toluene, ethylbenzene, and xylene (BTEX). Aqueous rinse solutions generated from tank cleaning operations were found to contain levels of total petroleum hydrocarbons (up to 480 ppm) and BTEX (up to 70 ppm) that would require pretreatment prior to discharge.

OUTPUT:

1. Technical paper entitled "Consideration of Underground Storage Tank Residuals at Closure," Proceedings of the 15th Annual Research Symposium, April 1989; EPA/600/9-90/006, February 1990.

2. Final report entitled "Technical Aspects of UST Closure," EPA/600/R-92-057, May 1992.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Procedures and Equipment for Internal Inspection of Underground Storage Tanks

DURATION: FY89 and FY90

RESOURCES: $155K

OBJECTIVE:

To identify and evaluate existing procedures and equipment used for internal inspection of underground storage tanks.

RATIONALE:

Internal inspection fulfills an important role in preventing leaks from tanks. Inspections can be conducted during installation, repair, maintenance, and upgrading with methods ranging from simple to complex. The UST regulations focused primarily on leak detection rather than tank inspection and referred UST users to the many standards developed by nationally recognized associations. No data were available, however, to evaluate the various methods and equipment available. A standard identification and evaluation of the state of the art in internal inspection procedures and equipment was needed by the regulated community.

DESCRIPTION:

Current techniques for inspecting USTs to identify weaknesses of tank walls, detect the presence of corrosion, observe the quality of lining material, and determine the suitability of cleaning techniques prior to closure were identified and evaluated. Seventeen methods were identified based upon an analysis of the literature and through discussions with standards-writing organizations, UST manufacturers, trade and professional societies, and industry experts. The study examined the various tools, techniques, and protocols for conducting internal inspections and documented the significant factors that are addressed during UST inspections. Each method was evaluated based on its objective, its procedural steps, the equipment and instrumentation needed, the circumstances under which it is performed, and important considerations for its use in the field.

OUTPUT:

Final report entitled "State-of-the-Art Procedures and Equipment for Internal Inspection of Underground Storage Tanks," EPA/600/2-90/061, January 1991.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Leak Detection Methods for Large Underground Storage Tank Systems

DURATION: FY89 to FY93

RESOURCES: $460K

OBJECTIVE:

To provide the necessary experimental data for the leak detection industry to develop and evaluate methods for accurately and reliably testing large tanks and large pipelines that are subject to state and federal regulations.

RATIONALE:

EPA regulations require that underground tanks and pressurized pipelines containing petroleum and other hazardous substances be tested for leaks on a regular basis.

The performances of existing state-of-the-art leak detection systems on tanks of a given size range cannot be extrapolated to larger tanks without additional, supportive experimental data. Volumetric testing protocols must be modified before they can be used on larger tanks, and rules must be developed as a function of tank size. Similarly, information on large-diameter pipelines is needed for testing pipelines found at truck stops, as part of airport hydrant systems, and in aboveground tank terminals, which may be 3 to 12 in. in diameter and thousands of feet in length.

DESCRIPTION:

An ongoing project that RREL initiated in 1989 was designed to develop rules for volumetrically testing tanks with capacities between 8,000 and 50,000. Although these rules were developed for testing 50,000-gal tanks [1-4], methods based on these rules still need to be evaluated for performance. These rules also need to be modified and evaluated to test tanks with capacities between 8,000 and 50,000 gal (e.g., 20,000 gal). These rules specify the number of temperature sensors, duration of a test, precision of the level and temperature sensors, and length of the waiting periods as a function of tank size needed to test a tank of a given capacity.

A number of leak detection systems available commercially can be used to detect leaks in the small pipelines (2-in.-diameter, 100-ft-long) found at retail service stations. In a previous project [C-4], RREL developed and evaluated models of the pressure and volume changes that occur in small pressurized pipelines, separating those changes that are due to a change in temperature from those due to a leak, and developed and evaluated rules for performing a pressure test on these small pipelines.

This work has been divided into two tasks--one for tanks and one for pipelines. An experimental program is being undertaken to address both tasks.

For tanks, the objective is to gather data for a range of tank sizes and, based on these data, to develop a set of rules for conducting volumetric tests that meet the regulatory standards. Two or three tanks will be instrumented with a vertical array of closely spaced, accurately calibrated thermistors. The number of thermistors will greatly exceed the minimum number required for temperature compensation in the largest tank used in the evaluation. Several sensors with different precisions will be used to

measure liquid level. The EPA evaluation procedures for testing tanks will be followed, except that each test data will be collected continuously for 24 to 48 hours.

In posttest analyses, performance estimates will be made for different waiting periods, temperature-sensor spacings, test durations, and level/temperature sensor precisions. In addition, extra thermistors will be used to determine the impact of horizontal and vertical gradients on a test. At a minimum, a 20,000- and a 50,000-gal tank will be used and possibly a third tank of 35,000-gal capacity to allow extrapolation, as a function of tank diameter and length, of minimum waiting periods, number of thermistors, test duration, and instrument precision. Existing tanks will be used for these measurements, or one or more tanks of the required size could be installed at EPA's UST Test Apparatus. The output of this effort will consist of (1) a set of evaluated test procedures as a function of tank size and (2) guidelines by which a manufacturer could adopt these procedures.

Two types of pipeline experiments will be conducted: one to address leak detection in pipelines associated with large underground or aboveground tanks and one to address leak detection in airport hydrant systems and other very large pipelines. The former experiment will involve tests in a pipeline between 2 and 4 in. in diameter and 200 to 1,000 ft in length at EPA's UST Test Apparatus. The latter will involve tests on a pipeline 8 to 12 in. in diameter and approximately 1 mile in length; these tests may have to be performed on an operational system. The objective in both sets of tests will be to develop and validate models of the changes in volume and pressure that occur as a function of leak rate, temperature change, and line compressibility (including the effects of trapped gas). The models will then be used in developing pressure-based or volumetric methods of testing.

OUTPUTS:

1. Final report entitled "Volumetric Leak Detection in Large Underground Storage Tanks," EPA/600/2-91/044a and EPA/600/2-91/044b, August 1991.

2. Peer review journal article entitled "Evaluation of Leak Detection Methods for Large Underground Storage Tanks," Journal of Hazardous Materials (in process).

3. Technical paper entitled "Evaluation of Internal Leak Detection Technology for Large Underground Storage Tanks," Proceedings of the 16th Annual RREL Hazardous Waste Research Symposium, April 1990; EPA/600/9-90/037, August 1990.

4. EPA report pending, "Extrapolating the Performance Capability of Volumetric Leak Detection System from Small to Large Storage Tanks," July 1992.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Leak Detection in Underground Storage Tanks Containing Chemicals

DURATION: FY90 and FY91

RESOURCES: $120K

OBJECTIVE:

The objectives of this study were to (1) identify the chemicals being stored in underground storage tanks, (2) identify the leak detection practices currently being used or which are potentially applicable, and (3) assess the influence of the physical properties of these stored products on the performance of volumetric measurement systems.

RATIONALE:

In addition to petroleum products, USTs are used to store a variety of chemical compounds. These tanks come under the same leak detection requirements as USTs containing petroleum products. Numerous leak detection technologies that have been developed for use on fuel storage tanks can be applied to these tanks; however, detailed knowledge of the interaction of the contained product with these systems is required for reliable performance results.

DESCRIPTION:

UST registration program databases from 14 states were tabulated and analyzed to determine the characteristics of tank systems and the products they contain. The first use of this information was to determine if existing volumetric and inventory control systems could be used to test the integrity of the tanks. The second use of the information was to determine how these systems will be upgraded to meet the 1998 regulations.

From the state information, RREL compiled a database of the tank systems containing chemicals and analyzed their characteristics and their contents. Approximately 50 percent of the tanks containing hazardous chemicals, as defined by CERCLA, consisted of organic solvents (acetone, toluene, xylene, methanol, methyl-ethyl ketone). In general, the tanks were old (over 18 years) and large (with an average size of 7,200 gal), and over 85 percent were made of steel. A survey of the tank owners and providers of testing services revealed that most of the underground chemical tanks were being replaced with aboveground tanks or with double-walled tanks. Also, none of the tank owners used inventory control for leak detection. This method was apparently difficult to apply because of the inaccuracy of metering devices being used.

The performance of volumetric leak detection systems in USTs containing chemicals was determined to be similar to performance in USTs containing gasoline. Performance is directly related to the coefficient of thermal expansion of the product. Since gasoline has a higher coefficient of thermal expansion than most chemicals, a system that was evaluated for gasoline could be used with other products and still maintain a similar level of performance assuming that the actual hardware is compatible with the product.

OUTPUTS:

1. Technical paper entitled "Underground Storage Tanks Containing Hazardous Chemicals," Proceedings of the 17th Annual RREL Hazardous Waste Research Symposium, April 1991; EPA/600/9-91/002, April 1991.

2. Technical paper entitled "Volumetric Leak Detection in Underground Storage Tanks Containing Chemicals," Proceedings of the 84th Annual Meeting of the Air and Waste Management Association, June 1991.

3. Final report entitled "Chemicals Stored in USTs: Characteristics and Leak Detection," EPA/600/2-91/037, August 1991.

4. Peer review journal article entitled "Characteristics of Underground Storage Tanks Containing Chemicals," American Society for Testing Materials, STP 1161, June 1992.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Leak Detection in "Small" Underground Storage Tanks

DURATION: FY94 and FY95

RESOURCES: $100K

OBJECTIVE:

To develop and evaluate a simple and inexpensive method of testing for leaks in small underground storage tanks such as home-heating-oil tanks and to make this method such that it can be used by the tank owner.

RATIONALE:

There is a large population of small tanks such as home-heating-oil tanks, generally less than 500 gal in capacity, that may be leaking. The EPA release detection regulation does not require that these tanks be tested for leaks. Some states do regulate them, however, and a simple and inexpensive leak detection method that could be used by the homeowner would greatly assist in identifying and controlling this source of contamination.

DESCRIPTION:

A survey of home-heating-oil USTs will be made to determine the type of access generally available. Once the means of access is known, one or more applicable volumetric leak detection methods will be developed and then evaluated in terms of performance, cost, and ease of use. The performance evaluation of the method(s) will be conducted on a 500-gal tank installed at the UST Test Apparatus, and before being finalized, the method(s) will be field tested by 25 tank owners.

OUTPUTS:

The output of this study will be directed toward the tank owner and the tank manufacturer. A simple, easy-to-understand instructional brochure will be prepared for use by the tank owners. Additional technical details will be summarized in an ORD Final Report and a technical paper for presentation at EPA's annual RREL research symposium. As a means of further supporting technology transfer, an instructional video will be developed that illustrates how to use the method in conducting a leak detection test.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of the Effectiveness of Cathodic Protection in Underground Storage Tanks

DURATION: FY94 and FY95

RESOURCES: $250K

OBJECTIVE:

To evaluate the effectiveness of new and retrofitted cathodic protection methods for underground storage tanks.

RATIONALE:

The EPA regulation for USTs requires that all existing single-walled steel tanks be cathodically protected before 1998. Both impressed current and anode-cathode approaches are allowed, but the effectiveness of these techniques has not been investigated. Moreover, most existing tank systems will require retrofitting. If the retrofit is not done properly, it can, instead of prolonging the life of a tank, accelerate corrosion and produce leaks. A systematic experimental investigation needs to be conducted to determine the effectiveness of both new and retrofitted systems and to develop guidelines for their implementation.

DESCRIPTION:

A field study will be conducted to determine what methods of cathodic protection are being used in the field and the effectiveness of each method. A sample population consisting of 75 to 125 UST facilities containing steel tanks will be selected for analysis. The sample population will include three types of UST systems: (1) systems that have been cathodically protected when new, (2) systems that have been retrofitted with cathodic protection after installation, and (3) systems that have not been protected. Each of these categories must include at least 25 tanks, and 25 to 50 percent of the tanks in each category should be over 20 years old. A history of each tank will be compiled and a detailed set of measurements made. The data obtained from the field measurements and questionnaires will then be tabulated and statistically analyzed. From the data, guidelines for implementation of cathodic protection retrofits will be established.

OUTPUTS:

The output of this study will be directed toward consulting engineers, regulators, tank installers, and tank owners. The technical details will be summarized in an ORD Final Report. Two technical papers will also be prepared: one for submittal to a peer-reviewed journal and one for presentation at EPA's annual RREL research symposium.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Leak Detection in Underground Storage Tanks Containing Alternative Fuels and Other Petroleum Products

DURATION: FY95 and FY96

RESOURCES: $250K

OBJECTIVE:

To adapt and evaluate volumetric methods of leak detection for testing tanks containing alternative fuels and other petroleum products.

RATIONALE:

Over the next several years, alternative fuels will begin to replace traditional gasoline and diesel fuels. Some of these may not be compatible with storage tank systems designed for traditional motor fuels, or with the methods of leak detection used to determine the integrity of tanks and their associated pipelines.

DESCRIPTION:

A recently completed RREL study has indicated that volumetric methods can be used to test tanks containing a wide range of chemicals, but some modifications to the methods may be required. In particular, accurate estimates of the coefficient of thermal expansion, Ce, will be required because the accuracy of volumetric methods of leak detection is directly proportional to the accuracy of the value of Ce. Values of Ce have been tabulated for a wide range of petroleum fuels, but values for newer fuels will now have to be determined, and/or a simple field method devised for estimating Ce in situ.

This project will consist of three tasks. The first task is to develop a method to estimate the value of Ce for the newly introduced fuels. This will be done according to the procedures used by the National Bureau of Standards in developing the currently used tables. The second task is to devise a simple-to-use field method for estimating Ce from a sample of the product taken immediately before or after a leak detection test. The third task will provide recommendations for leak detection in these systems. The information obtained from the three tasks will provide a means for leak detection using volumetric methods for tanks containing alternative fuels.

OUTPUTS:

The main audience for this work will be the developers of leak detection systems and consulting engineers who may use the technology. The results of this study will provide guidance for leak detection in tanks containing alternative fuels, waste oils, jet fuel, etc. The reports will be presented in an ORD Final Report and summarized in a paper for submittal to a peer-reviewed journal.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Leak Detection in Double-Walled Underground Storage Tank Systems

DURATION: FY95 and FY96

RESOURCES: $250K

OBJECTIVE:

To develop and evaluate a set of standard test procedures for evaluating interstitial leak detection systems used on double-walled tanks and pipelines.

RATIONALE:

Many tank owners are replacing their single-walled tanks and piping with double-walled systems. There are many techniques spanning a wide range of technologies (e.g., hydrostatic tests, vapor detectors, water/petroleum detectors, vacuum/pressure monitors, etc.) that detect leaks in the interstitial space of double-walled tanks and piping. With some of these systems, the probabilities of detection and false alarm can be higher than desired. Currently, there are no evaluation procedures for interstitial leak detection systems, but a level of performance equal to 0.1 or 0.2 gal/h (depending on the frequency of testing) must be achieved with a probability of detection of 95 percent and a probability of false alarm of 5 percent.

DESCRIPTION:

RREL will develop and evaluate a set of standard test procedures for evaluating the most commonly used methods of detecting leaks in the interstitial space between the inner and outer walls of a double-walled tank or pipeline. Two double-walled tanks will be installed at the UST Test Apparatus: one made of fiberglass and the other of steel. The two tanks will be connected by doubled-walled fiberglass and double-walled steel piping. The product to be placed in the tanks will be water. A special leak-maker will be developed to produce realistic leaks in the interstitial space. Results from the study will provide a better understanding of interstitial leak detection techniques and will determine those techniques which will achieve a 95 percent probability of detection and a 5 percent probability of false alarm.

OUTPUTS:

All sectors of the tank and pipeline community (tanks owners, manufacturers and service providers, regulators, and consulting engineers) will have a need for the information generated during this project. A separate ORD Final Report will be prepared for the tank and the pipeline work. This work will also be presented at EPA's annual RREL research symposium. As a means of further supporting technology transfer, a number of technical presentations will be videotaped that will describe the work presented in the reports.

RREL - PROJECT DESCRIPTION

TITLE: Development of Improved Acoustic Techniques for Locating Leaks in Underground Pressurized Pipeline Systems

DURATION: FY91 to FY94

RESOURCES: $590K

OBJECTIVE:

To develop, evaluate, and demonstrate improved passive-acoustic methods for locating leaks in underground pipelines.

RATIONALE:

Rapid and efficient remediation can occur if the source of an underground leak can be pinpointed quickly and accurately and the material above and around a tank or its associated pipelines does not require excavation. Passive-acoustic techniques are desirable over current volumetric- and pressure-based techniques because they are noninvasive, nondestructive, and have untapped performance potential. Development, evaluation, and implementation of rapid, near-real-time acoustic leak detection/location systems can minimize damage to the environment and resulting costs for remediation.

DESCRIPTION:

In FY 1991, RREL initiated a research effort to investigate the use of passive-acoustic techniques for locating leaks in underground pressurized pipelines containing gasoline (such as those found at retail service stations). Acoustic techniques are based on measuring the acoustical signal emitted from a leaking pressurized underground pipeline. The results of the initial effort suggest that with enhanced signal processing (i.e., coherence processing as opposed to correlation processing), passive-acoustic techniques will be able to locate leaks to within 5 cm (1.9 in.) over distances of 38.1 m (125 ft) when the line is under pressures of 10 to 15 psi during the test. In tests conducted as part of the initial research project, the smallest hole had a diameter of 0.01 in. Determining the smallest locatable leaks as a function of line length, fuel type, and pipeline material will require additional work.

Future activities will also involve an investigation of pipelines that contain a product too viscous to produce a detectable signal under the normal operating pressure of the line. To address this problem, the line will be emptied and then refilled with nitrogen or another gas compatible with acoustic location techniques. Part of this effort will be devoted to better characterization of the leak signal, both single and multiple leaks, and relevant background noise. Once the basic methodology has been developed and its performance evaluated, field demonstrations will be conducted for the purpose of evaluating the method's operational applicability over a range of pipeline configurations. These tests will be performed with off-the-shelf acoustic sensors that can be attached to the line.

OUTPUTS:

The results of this program (1) can be applied to a wide diversity of underground pipelines associated with both USTs and ASTs containing petroleum products, hazardous chemicals, and radioactive waste and (2) can be used directly not only by EPA but by other government organizations with similar needs, such as DOD and DOE, and by trade associations (such as the American Petroleum Institute) and industry to develop equipment and services for application to the regulated community.
The annual output of this study will be a series of papers for submittal to peer-reviewed journals, and presentations at EPA's annual RREL research symposium or other relevant professional conferences. As a means of further supporting technology transfer, a number of well-rehearsed technical presentations describing the work will be videotaped. A simple, easy-to-understand technical brochure will be prepared for local regulators and tank owners who want a general understanding of the technology, its application, and its performance. Standard ORD Final Reports will also be prepared.

1. Final report entitled "Location of Leaks in Pressurized Underground Petroleum Pipelines by Means of Passive-Acoustic Sensing Methods," April 1992.

2. Peer review journal article, "Location of Leaks in Pressurized Petroleum Pipelines by Means of Passive-Acoustic Sensing Methods," ASTM STP 1161, 1992.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Ullage Leak Detection Systems for Underground Storage Tanks

DURATION: FY93 and FY94

RESOURCES: $200K

OBJECTIVE:

To evaluate several of the most commonly used or most promising ullage testing procedures and to provide a set of rules that will ensure that ullage tests meet the performance standards in the regulation.

RATIONALE:

There is a trend to test USTs when they are only partially filled. This is a means of reducing the total time it takes to conduct a leak detection test and to eliminate the added expense of delivering product to overfill the system for the purpose of conducting a test. When a tank is only partially filled, two tests are required in order to determine the integrity of the entire tank system: one of the liquid level and a second of the ullage space above the liquid level. Many leak detection vendors are testing the ullage space by means of a pressure-drop test when the ullage space is filled with a gas such as nitrogen or by means of an acoustic listening system when the ullage space is either pressurized or placed under a partial vacuum. Both procedures are fraught with technical problems, are applicable only under very specific conditions and are being misused, and are unvalidated experimentally. Nevertheless, these systems are being accepted by both regulators and tank owners without evaluation. Technical information is urgently required so that it can be determined whether these techniques meet regulatory standards. While many commercial testing firms are using the pressure-drop test, some of them state that accurate results cannot be obtained with tanks containing gasoline. Of the two approaches, only the acoustic methods have general applicability to tanks containing the most common fuels (e.g., gasoline, diesel). The short-term goal of this work is to facilitate compliance with the regulation, and the long-term goal is to develop acoustic methods with general application to any type of tank system.

DESCRIPTION:

Both types of leak detection methods, pressure-drop and acoustic, will be evaluated experimentally. Testing the ullage space is typically accomplished by means of a pressure-drop test when the ullage space is filled with a gas such as nitrogen or by means of an acoustic listening system when the ullage space is either pressurized or placed under a partial vacuum. The purpose of the first set of experiments will be to determine the feasibility of performing pressure-drop tests in partially filled tanks. Both diesel fuel and gasoline will be used, and the tank size will be either 8,000 or 10,000 gal. Models of the sources of noise that affect the performance of pressure-drop tests will be developed and validated during the initial experiments. If the pressure-drop testing method is feasible, additional tests will be conducted to estimate the performance of the method. The data used in the performance evaluation of the pressure-drop test will be collected over 24 24-hour periods. The pressure-drop test will be evaluated as a function of test duration, waiting period, and number of temperature sensors representative of what the industry is using or might use in the future to test the ullage space.

The purpose of the second set of experiments will be to determine the feasibility of detecting leaks in the vapor space by means of a three-dimensional array of sensors suspended in the vapor space. The initial experiments will determine the characteristics of the acoustic signal as a function of leak rate and distance from the sensor. Another set of experiments will characterize the magnitude of the important

sources of background noise. Based on these experiments, an array configuration will be selected and one or more signal processing strategies will be developed and tested. An estimate of performance will be made following a protocol similar to the ones used for volumetric tests.

OUTPUTS:

All sectors of the tank community (tank owners, manufacturers and providers of services, regulators, and consulting engineers) will have a need for the information generated during this project. An ORD Final Report will be prepared for each detection method (i.e., the pressure-drop test and the acoustic test). For each successful testing approach, a paper will be prepared for submittal to a peer-reviewed journal, and a technical presentation and proceedings paper summarizing all aspects of the work will be delivered at EPA's annual RREL research symposium. As a means of further supporting technology transfer, a number of technical presentations describing the work will be videotaped. A simple, easy-to-understand technical brochure will be prepared for use by local regulators and tanks owners who want a general understanding of the technology, its application, and its performance.

RREL - PROJECT DESCRIPTION

TITLE: Acoustic Techniques for Rapidly Detecting Leaks in Tanks and Pipelines

DURATION: FY94 and FY95

RESOURCES: $200K

OBJECTIVE:

To develop, evaluate, and demonstrate passive-acoustic methods that can test underground tanks or pipelines for leaks in less than one hour, thereby minimizing interruptions to dispensing operations.

RATIONALE:

A leak detection test that can be done in less than one hour has long been the goal of the petroleum industry. During the last five years, EPA, API, and the petroleum industry have made a significant effort to develop leak detection systems that work (i.e., achieve a high performance). These systems, if used correctly, take a long time to conduct a test, and therefore, seriously impact normal operations. A retial station may have to close for one or more business days to have its tanks or lines tested. One of the reasons why testing takes so long is that waiting periods must be observed before a test is begun; for tanks, this waiting period may be 12 to 18 h, and for pipelines, 2 to 12 h. Testing mistakes occur when the required waiting periods are not observed. There is a significant need to minimize the down-time that these waiting periods entail, so that the financial losses associated with a test can be minimized. Frequent and regular testing of tank and pipeline systems, the primary goal and underlying philosophy of EPA's UST regulation, would be a likely outcome of a successful acoustics project. At least one commercial company is using an acoustic method of testing. Industry welcomes this company's approach not only because the whole tank system can be tested in less than an hour, but because the acoustic sensor can be placed either above or below the liquid surface, and the expense and inconvenience of a product delivery prior to a test is avoided. The technology is suspect, however, because it is complex, is not well understood, and has not been experimentally validated. Furthermore, the approach being used is old, and because the background noise is not spatially filtered, false alarms are possible.

DESCRIPTION:

Passive-acoustic methods offer the most rapid and direct means of testing either a tank or pipeline for a leak. A three-dimensional array of off-the-shelf acoustic sensors will be used; this array will be mounted internally either above or below the surface of the liquid in the tank or mounted externally to one or both ends of a pipeline. Unlike volumetric tests, the relationship between the leak signal and the output of the measurement system is not well known for passive-acoustic tests. The first step in the proposed research project, therefore, will be to characterize the acoustic signal in tanks and pipelines, both under pressure and under static head. The second step will be to characterize the background noise that tends to mask the leak signal. One or more generic testing protocols and signal processing algorithms for conducting a leak detection test will be developed, and the performance of these generic tests will be evaluated. The utility of these rapid leak detection tests will then be demonstrated in the field.

OUTPUTS:

The main audience for this work will be developers of leak detection systems and consulting engineers who may want to use the technology. The annual output of this study will be a series of papers for submittal to peer-reviewed journals, and a technical presentation and proceedings paper for EPA's annual RREL research symposium or other relevant professional conference. One or more ORD Project Reports will also be prepared. As a means of further supporting technology transfer, a number of technical presentations describing the work presented in the papers or reports will be videotaped. A simple, easy-to-understand technical brochure will be prepared for local regulators and tanks owners who want a general understanding of the technology, its application, and its performance.

RREL - PROJECT DESCRIPTION

TITLE: Techniques for Estimating the Structural Integrity of UST Systems

DURATION: FY96

RESOURCES: $200K

OBJECTIVE:

To develop and evaluate acoustic emissions (AE) techniques that can test underground tanks or pipelines, both steel and fiberglass, for structural flaws and defects.

RATIONALE:

A significant environmental benefit could be obtained if tank owners could directly assess the structural integrity of a tank system. Cost-effective and environmentally safe decisions could be made to upgrade or replace a system that was in danger of failing. All of the commonly used methods for measuring thickness or material flaws and cracks require that a tank be taken out of service for the duration of the measurements and that sensors be attached directly to the wall. These methods are typically used where access to the tank walls and floor is possible. Because access to the outer walls of an underground tank is generally not possible, a method is needed that does not require the attachment of sensors to the wall. Many of the time-tested acoustic emissions techniques could be adapted for use on underground tanks if it can be shown that a three-dimensional internal array of sensors suspended in either the vapor space or the liquid is capable of detecting a signal emanating from a hole or fissure in the wall.

DESCRIPTION:

Initially a set of experiments will be conducted to determine the feasibility of using AE techniques to test pressurized tanks for structural defects and flaws. These preliminary tests will be designed to determine whether AE signals can be generated under the limited pressures that can be sustained by underground tanks and whether these signals can be detected by an array of sensors mounted in the tank and through the use of a beamforming signal processing algorithm. Two small tanks (1,000 to 2,000 gal in capacity), one steel and one fiberglass, will be instrumented, buried, and filled with water.

An array of sensors mounted directly to the outer walls of the tanks, as in traditional AE measurement methods, will provide measurements that can be compared to those made by the internal arrays. If AE signals can be generated and detected, a method for performing AE tests will be developed, and a set of experiments will be conducted in one or both tanks to validate the method. In FY 1997, a similar set of tests will be performed on both the steel and the fiberglass pipelines at the UST Test Apparatus. The pipelines will be pressurized with water or a gas such as nitrogen. If the AE method appears to be a viable means of assessing the structural integrity of either the tanks or pipelines, a large effort will be undertaken to develop the technology so that it can be transferred to industry.

OUTPUTS:

The output of this study will be an ORD Final Report. Two technical papers reporting on the tank work and the pipeline work will be submitted to peer-reviewed journals. An additional technical paper reporting the key results of this R&D effort will be presented at EPA's annual RREL research symposium. To support technology transfer, several technical presentations covering the results of this study will be videotaped and distributed.

RREL - PROJECT DESCRIPTION

TITLE: Development of Loci Conceptual Model for Selecting Corrective Actions at Leaking Underground Storage Tank Sites

DURATION: FY 87 to FY 91

RESOURCES: $400K

OBJECTIVE:

To identify the most important factors or rules that govern the transport, retention, and transformation of leaked motor fuels in the underground environment, and to develop effective decision-making tools for assessing leaking underground storage tank sites and selecting appropriate cleanup technologies.

RATIONALE:

Information is both currently available and being developed on corrective action technologies that may be applicable for cleaning up soils at leaking UST sites. To date, the selection and evaluation of the performance of these technologies has not been based on a comprehensive and complete understanding of the transport, retention, and transformation of the contaminant in the subsurface environment. Without this correlation, there is a danger that remediation technologies may be misapplied, and/or that "complete" remediation may not be accomplished.

DESCRIPTION:

An intensive and comprehensive scientific literature research effort was initiated to increase the level of understanding of the scientific principles and mechanisms governing the fate, transport, and transformation of leaked motor fuels in the underground environment. A "loci" concept was developed to identify and analyze the micro-scale location and phase, and transport, retention, and transformation of motor fuels in the saturated and vadose zones. Thirteen physicochemical phase settings were defined and the multiplicity of interactions between settings was described to obtain a better understanding of larger scale contaminant behavior in the subsurface environment.

Based on this research, a new approach was developed for evaluating site conditions and for screening and selecting effective corrective action technologies. This approach includes a methodology for identifying the key site parameters necessary to provide a preliminary assessment of the likely effectiveness of alternative corrective action technologies based on a conceptual understanding of site conditions and the critical factors that favor or inhibit the success of specific technologies. The methodology enables the user to develop a conceptual understanding of site conditions before the completion of extensive field studies, to define remediation goals, to evaluate technologies capable of meeting remediation goals, and to identify monitoring requirements during and after remediation. Working with site assessment data, the methodology provides for a preliminary assessment of the location and phases of contaminants present in the saturated and vadose zones, and for evaluating the likelihood of contaminant migration within the soil matrix. Worksheets are provided to evaluate how site-specific conditions pertain to the factors that favor or inhibit the success of specific corrective action technologies.

OUTPUTS:

1. Internal report entitled "Motor Fuel and Organic Chemicals Released in an Underground Environment," February 1988.

2. Technical paper entitled "The Role of Site Investigation in the Selection of Corrective Actions for Leaking Underground Storage Tank Sites;" Proceedings of the 15th Annual Research Symposium, April 1989; EPA/600/9-90/006, February 1990.

3. Final report entitled "Assessing UST Corrective Action Technologies: Site Assessment and Selection of Unsaturated Zone Treatment Technologies," EPA/600/2-90/011, March 1990.

4. Final report entitled "Assessing UST Corrective Action Technologies: Early Screening of Cleanup Technologies for the Saturated Zone," EPA/600/2-90/027, June 1990.

5. Technical paper entitled "Subsurface Fate and Transport of Petroleum Hydrocarbons from Leaking USTs;" Proceedings of the 17th Annual RREL Hazardous Waste Research Symposium, April 1991; EPA/600/9-91/002, April 1991.

6. Final report entitled "Assessing UST Corrective Action Technologies: A Scientific Evaluation of the Mobility and Degradability of Organic Contaminants in Subsurface Environments," EPA 600/2-91/053, September 1991.

7. Peer review journal article entitled "Understanding the Fate of Petroleum Hydrocarbons in the Subsurface Environment," Journal of Chemical Education, May 1992.

8. Peer review publication entitled "Screening Methodology for Assessing Leaking UST Site Cleanup Technologies," American Society for Testing Materials STP 1161, June 1992.

RREL - PROJECT DESCRIPTION

TITLE: Scientific Evaluation of Site Requirements for Selecting Corrective Actions at Underground Storage Sites

DURATION: FY94 to FY96

RESOURCES: $450K

OBJECTIVE:

To determine the kinetics of nonhomogeneous processes that govern the transport, retention, and transformation of leaked motor fuels in the underground environment, and to develop improved decision-making tools for more accurately assessing UST sites and selecting appropriate cleanup technologies.

RATIONALE:

As stated in the previous project description [C-19], there are at least 13 phase locations for contaminants in the subsurface, many of which contain significant contaminant mass and are not considered in current corrective-action strategies.

Since then, a variety of scientific literature on soil-contaminant-phase transfer has been published and new technologies have been developed on the cleanup of contaminants that occur as free product or NAPL, vapor phase in the unsaturated zone, or partially adsorbed to the soil matrix in the unsaturated zone. Therefore, an updated "Loci"-based technology handbook for the UST remediation is required. In addition, new research is needed to determine nonhomogeneous processes governing contaminant behavior in soil (e.g., sorption kinetics). Unless these phases and locations are also taken into consideration, the corrective action technology may be misapplied or ineffective in completing a remediation.

DESCRIPTION:

A "Loci" conceptual model was developed to identify and analyze the micro-scale location and phase, and transport, retention, and transformation of gasoline in the vadose and saturated zones. Based on this research [C-19], a new approach was developed for conducting site investigations to select appropriate remediation technologies. The majority of this work was done in 1988 and 1989; since then numerous research activities have been initiated in the area of nonhomogeneous kinetics in soil media. This research examines controlling mechanisms for vaporization, solubility, and microbial degradation of different contaminant phases and locations in soil media. Key research will be identified and incorporated into an updated and refined "Loci" model. In addition, fundamental research studies will address phases and locations that may contain significant contaminant mass and the limitations of corrective action technologies used to remediate different motor fuels in various soil media.

The corrective action screening methodology developed from the earlier loci model will also be field tested in conjunction with EPA Regions and states at leaking UST sites as part of the Regional technical support. The two documents on screening UST corrective-action technologies for the unsaturated and saturated zones will be integrated in one users' manual and updated and revised based on the field test results as well as the results from the updating of the loci model.

OUTPUTS:

1. Final report entitled "Field Evaluation of Technology Screening Methodology."

2. Revised edition, "Loci-Based Underground Storage Tank Corrective Action Technology Handbook."

3. A series of peer review technical papers will be published on the studies conducted on the behavior of different motor fuels in various porous media and on the limitation of corrective-action technologies.

RREL - PROJECT DESCRIPTION

TITLE: Methodology for Evaluating Free-Product Recovery of Low-Density Nonaqueous Phase Liquids (LNAPL)

DURATION: FY91 to FY94

RESOURCES: $300K

OBJECTIVE:

To develop and test a methodology for quantifying hydrocarbon spill volume and for designing free product recovery systems, and to implement these methodologies in an interactive PC-based program that links the decision tool with a graphical database management system.

RATIONALE:

The absence of rigorous spill volume estimation procedures complicates the selection of appropriate free product recovery systems. This absence also makes it difficult to determine if the decline in product recovery over time actually represents effective mitigation or if an inappropriate recovery system has been selected.

DESCRIPTION:

Practical tools will be developed to simplify and expedite the design of free product recovery systems at petroleum product spill sites in order to maximize product recovery. The project will be conducted in three phases with major tasks as follows:

Phase I - 1) develop a method for estimating LNAPL volume in the vadose and saturated zones, 2) develop protocols for model calibration from two-phase well tests, grain size data for estimating soil capillary parameters, total petroleum hydrocarbon measurements, and well fluid-level time series data, 3) develop procedures for evaluating plume control and product recovery with wells pumping both water and/or product, and 4) develop PC-based program that links decision tools with a graphical database system.

Phase II - 1) develop an analytical model to determine well locations and to estimate product recovery rate, 2) develop a simple method to calibrate the model from well tests, 3) compare a combined analytical simple numerical model with laboratory data and rigorous numerical simulations, and 4) incorporate recovery estimation and well test protocols in a computer program.

Phase III- 1) evaluate methods of increasing recovery efficiency using time-varying two-phase pumping, 2) perform field evaluations of two-phase well test methods, 3) perform field evaluation of recovery predictions, and 4) extend capabilities of computer program to interface with graphical software.

The results of this study can be used by UST regulatory staff, engineers, and consultants to estimate the LNAPL volume to be removed, evaluate plume control, provide decision support to evaluate appropriate product recovery systems, estimate product recovery rates, and evaluate methods for increasing recovery efficiency.

OUTPUTS:

1. Final report entitled "Methods for Estimation of LNAPL Volume in Saturated and Vadose Zones and Evaluation of Recovery Technologies."

2. A PC-based program for use as a decision tool to evaluate product recovery systems.

3. Final report entitled "LNAPL Recovery Procedures-User's Handbook."

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of the Performance of Soil Vapor Extraction (SVE) Technology for Leaking Underground Storage Tank Sites

DURATION: FY88 to FY91

RESOURCES: $900K

OBJECTIVE:

To evaluate SVE technology performance in removing the major gasoline constituents in subsurface zones, develop engineering design and operation parameters of a SVE process, determine the total system construction and operation costs, and assess the cleanability of an SVE system.

RATIONALE:

A current emphasis has evolved on source control of volatile and semivolatile hydrocarbon constituents using SVE. The engineering practices for designing, constructing, and operating an SVE system are not consistent, however, and are primarily based on each developer's experiences. Although SVE may be "simple" in design and operation, vapor behavior in the soil is complex. Consequently, a fundamental understanding of critical design parameters and system performance is needed.

DESCRIPTION:

Early work on the evaluation of the performance of the SVE technology included the assessment of a SVE system operation at an actual leaking UST site-of-opportunity. As a result of this work, a methodology for the field evaluation of SVE was developed. In FY89 an expert workshop was held in Edison, New Jersey, to discuss the various site-evaluation approaches, system design parameters, operational experiences, costs, and research needs. Based on these efforts, a soil vapor extraction technology reference handbook was prepared, including these topics as well as the principles of soil vapor transport and selected workshop presentations.

In response to the EPA Office of Underground Storage Tanks request, activities in FY 1990 and 1991 involved the field evaluation of a SVE screening procedure developed by Shell Oil Company to assess the applicability of SVE to leaking UST sites as part of a Federal Technology Transfer Agreement (FTTA). Project activities also included the development of a number of field SVE system test-and-evaluation methods including an air permeability test, a SVE quality assurance project plan, and decision support SVE computer models to assess the application of SVE to UST sites.

A procedure to determine the extent of gasoline removal from soil by SVE and aqueous solute leachability of residual gasoline components following SVE was developed and evaluated. Bench-scale vapor extraction tests were conducted on various soil/contaminant mixtures to: 1) characterize the type and quantity of residuals that remain after SVE using both the Toxicity Characteristic Leaching Procedure and an experimental aqueous solute leachability method and 2) evaluate petroleum hydrocarbons remaining in leachate generated from soils following SVE remediation. The results of this study identified 1) transport mechanisms responsible for remobilizing contaminants, 2) controlling factors to achieve maximum effectiveness, and 3) 99 percent of leachable gasoline constituents that may be removed from a sandy soil matrix by SVE.

OUTPUTS:

1. Internal EPA report entitled "Motor Fuel and Organic Chemicals Released in an Underground Environment," February 1988.

2. Internal EPA report entitled "Assessment of Vacuum Extraction Technology Application: Belleview, Florida LUST Site," September 1988.

3. Internal EPA report entitled "SVE Technology: Numerical Model Evaluation," September 1993.

4. Internal EPA report entitled "Soil Vapor Extraction Gasoline Component Remediation: Laboratory Experiments," September 1992.

5. Final report entitled "Soil Vapor Extraction Technology Reference Handbook," EPA/540/2-91/003, February 1991.

6. Technical paper entitled "Soil Vapor Extraction Technology Assessment," Proceedings of the 16th Annual RREL Hazardous Waste Research Symposium, April 1990; EPA/600/9-90/037, August 1990.

7. Technical paper entitled "Soil Vapor Extraction Air Permeability Testing and Estimation Methods," Proceedings of the 17th Annual RREL Hazardous Waste Research Symposium, April 1991; EPA/600/9-91/002, April 1991.

8. Technical paper entitled "Column Vapor Extraction Experiments on Gasoline- Contaminated Soil," Proceedings of Conference on Hydrocarbon-Contaminated Soils, University of Massachusetts, Volume 5, Lewis Publications, September 1991.

9. Technical paper entitled "Review of SVE Microcomputer Models," Proceedings of the 18th Annual Risk Reduction Engineering Laboratory Research Symposium, April 1992; EPA/600/R-92/028, April 1992.

RREL - PROJECT DESCRIPTION

TITLE: Optimization of Soil Vapor Extraction for Remediation of Gasoline-Contaminated Soil

DURATION: FY90 to FY95

RESOURCES: $550K

OBJECTIVE:

To examine the complex process of soil vapor extraction, to identify the factors that limit its effectiveness, and to develop procedures to optimize subsurface gasoline removal using SVE combined with other techniques.

RATIONALE:

Soil vapor extraction is a widely used correction technology for removing volatile organic compounds (VOCs) from contaminated soil. This in situ technology can treat large volumes of soil at reasonable costs; however, overall removal efficiencies are limited by high carbon fraction of gasoline constituents within the unsaturated zone and all constituents in the saturated zone. Practical techniques to overcome these limitations and thereby increase the value of SVE technology are required.

DESCRIPTION:

A series of remediation experiments are currently being conducted to remove gasoline from sand aquifers in large experimental aquifers at the Oregon Graduate Institute (OGI). The first experiment examined soil vapor extraction procedures as currently practiced in the field. Subsequent experiments will seek to improve the efficiency of the SVE process by: 1) manipulation of the groundwater level to increase the air-gasoline contact area, 2) pulsed pumping of the SVE system, 3) air sparging into the saturated zone to enhance volatilization and possibly biodegradation, 4) heating the subsurface by injecting hot air or hot water, and 5) otherwise adjusting subsurface conditions to optimize biodegradation. Additional experiments will focus on improving air sparging techniques to further enhance SVE by: 1) using an air disperser to produce microbubbles, 2) optimizing the extraction/sparging ratio, 3) using horizontal sparging wells, and 4) varying system configuration and spacing of extraction and sparging wells. These experiments will be conducted both in homogenous sand and in heterogeneous soil media.

During each of these experiments, a detailed analysis of subsurface vapors will be made. By tracking the spatial and temporal variations in the composition of the gasoline vapor, the overall effectiveness of the remediation process will be evaluated.

Initial results from an early part of this study have shown SVE to be effective at removing hydrocarbons from the unsaturated zone, but it is far less effective for contaminant mass at or below the water table. The removal efficiency in those cases can be improved when SVE is used in conjunction with other techniques including air injection, heating, and dewatering.

OUTPUTS:

1. Technical article entitled "Optimization of the Vapor Extraction Process: Large Physical Model Studies," Presented at the 2nd Symposium on Soil Venting, April 29-May 1, 1991, Houston, Texas.

2. Article entitled "Subsurface Remediation of Gasoline by SVE and Air Sparging," Proceedings of the 18th Annual Risk Reduction Engineering Laboratory Research Symposium, April 1992; EPA/600/R-92/028, April 1992.

3. Journal article entitled "Enhanced SVE for Removal of Gasoline From the Saturated Zone," will be submitted for publication, June 1992.

4. Article entitled "Experimental Examination of Integrated Soil Vapor Extraction Techniques," will be presented at the Hydrocarbon Conference, November 1992, Houston, Texas.

5. Final report entitled "Optimization of Soil Vapor Extraction for Improved Remediation of Subsurface Gasoline Releases," EPA Technologies Series, September 1993.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of The Performance of Soil Vapor Extraction (SVE) with Air Sparging and Bioventing Technologies at Leaking Underground Storage Tank Sites

DURATION: FY92 to FY95

RESOURCES: $800K

OBJECTIVE:

To understand the physical, chemical, and biological principles of the system processes (i.e., SVE, air sparging, and bioventing) and based on these principles to determine process control parameters and limiting factors. This will include the development of a system design approach for the application of soil vapor extraction, air sparging, and bioventing technologies at leaking UST sites, the documentation of design and performance data for the application to actual leaking UST sites, and the development of process control and monitoring strategies (in a joint research effort with EMSL) for system optimization.

RATIONALE:

SVE has been shown to be effective at removing volatile and semivolatile contaminants in the unsaturated zone. However, the transport of contaminants from the saturated zone to the vadose zone is limited by diffusion and dispersion through the groundwater to the air-water interface. The rate of contaminant transport from the groundwater to soil vapor in the unsaturated zone has been shown to increase by coupling an air sparging system with an SVE system. In addition, air sparging SVE will enhance biodegradation in soil in both the unsaturated and saturated zones. Performance factors for system design and operation are still not well understood, however, and the actual effectiveness of this technology is not known. Laboratory research in conjunction with a well-designed field evaluation of these technologies will provide valuable information to determine performance factors and effectiveness.

DESCRIPTION:

Laboratory research and field evaluations will be used to develop a technical manual for the application of SVE, air sparging, and bioventing system for cleaning up both the vadose and saturated zones at leaking underground storage tank sites. Activities in FY 92 that will be used to develop a technical manual involve the development of a technology assessment report and field evaluation/demonstration of the SVE, air sparging, and bioventing system at sites-of-opportunity in EPA Regions. The field evaluations/demonstrations of SVE, air sparging, and bioventing systems will continue during FY 1993 to 1995. Field evaluations will include tracer studies to determine the pathways of injected air, the efficiency of extraction wells for capturing the vapor from sparging system, and the effectiveness of nutrient delivery in subsurface environment. Fundamental research will also be conducted during FY 1993 to 1995 to determine bio-kinetics for different petroleum-fuels-contaminated soils as well as the effects of soil temperature, soil pH, moisture, nutrients, and oxygen.

The results from the field evaluations and basic scientific research will be used to develop a technical manual in a handbook to UST regulatory staff, engineers, and consultants. The results of this study will also be used as part of an overall integrated systems approach for cleaning up leaking UST sites [C-29].

OUTPUTS:

1. In situ panel discussion "Review of Air Sparging Soil Vapor Extraction System Efficiencies and Limitations," Proceedings of the 18th Annual Risk Reduction Engineering Laboratory Research Symposium, April 1992; EPA/600/R-92/028, April 1992.

2. Internal report entitled "Assessment of Soil Vapor Extraction-Air Sparging Technology."

3. Technical report entitled "The Design, Operation, and Monitoring of Soil Vapor Extraction-Air Sparging Systems at Actual Leaking UST Sites."

4. Technical report entitled "Soil Vapor Extraction-Air Sparging-Bioventing Technology Handbook."

5. Peer reviewed technical paper, "Field Evaluation and Demonstration of Air Sparging-Soil Vapor Extraction Systems," Presented at RREL Symposia and OUST National Conference.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Soil Washing Technology for Leaking Underground Storage Tank Sites

DURATION: FY89 to FY96

RESOURCES: $710K

OBJECTIVE:

To evaluate the application of soil washing technology for treating contaminated soil at leaking underground storage tank (UST) sites.

RATIONALE:

Soil washing is a physical process in which excavated soils undergo intimate contact with washing and rinsing solutions to promote reductions in contaminant concentrations and volume through physical separation. Under EPA's Best Demonstrated Available Technologies (BDAT) Research Program, soil washing was evaluated using synthetic soil matrices spiked with varying concentrations of chemicals representative of hazardous waste sites. This technology successfully treated many organic and inorganic contaminants. However, the feasibility and effectiveness of soil washing for cleaning up petroleum-contaminated soil at actual leaking UST sites is not fully known.

DESCRIPTION:

Early research efforts focused on bench-scale testing of synthetic soil matrix (SSM) formulations contaminated with gasoline, diesel fuel, and waste oil. Testing was also conducted on soils from several actual leaking UST sites. Results on treatment of the contaminated SSM indicated large reductions in contaminant concentration. However, the results on soils from UST sites actually were less successful, which is indicative of the complexity associated with treating "weathered" leaking UST sites. This work confirmed the need to conduct site-specific treatability studies before selecting soil washing technology for a leaking UST site cleanup. Activities in FY 94 and beyond will be to reexamine the new development of aqueous surfactant washing of residual oils from soil and applicability of the technology for cleaning up petroleum-products-contaminated soil. Since petroleum hydrocarbons do not dissolve in water, surfactants must be used to improve the washing process. Suitable surfactants will be examined to determine their effectiveness for improving the performance of this technology.

OUTPUTS:

1. Technical report entitled "Evaluation of Soil Washing Technology: Results of Bench-Scale Experiments on Petroleum Fuels-Contaminated Soils," 600/S2-91/023, September 1991."

2. Technical paper entitled "Evaluation of Soil Washing Technology for Remediation of LUST Sites," Presented at the 10th National Superfund Conference, November 1989.

3. Technical paper entitled "Evaluation of Soil Washing Technology for Remediation of LUST Sites," Presented at the 16th Annual RREL Hazardous Waste Research Symposium, April 1990; EPA/600/9-90/037, August 1990.

4. Peer review technical papers on new development of the soil washing technology with aqueous surfactant application.

RREL - PROJECT DESCRIPTION

TITLE: Technical Assessment of the Application of Thermal Desorption to Petroleum-Contaminated Leaking Underground Storage Tank Sites

DURATION: FY90 to FY94

RESOURCES: $500K

OBJECTIVE:

To provide a methodology for assessing the use of thermal desorption for treating petroleum-contaminated soil at LUST sites.

RATIONALE:

Thermal desorption systems are currently used at a limited number of sites for remediating petroleum-contaminated soils and are capable of meeting soil cleanup criteria for a variety of petroleum products. However, the relationships between organic contaminant removal efficiency, waste characteristics, soil characteristics, process operating conditions, site characteristics, environmental factors, regulatory requirements, and treatment costs are not well documented. Because these various factors are not well known among the UST community, guidance is needed on evaluating the potential for evaluating the use of thermal desorption technologies for treating petroleum-contaminated soil.

DESCRIPTION:

An extensive literature search was conducted on the application of thermal desorption to petroleum-contaminated soil to determine factors that affect the successful use of this technology. Some of these factors include contaminant characteristics, soil characteristics, regulatory requirements, process equipment characteristics, project implementation requirements, and economics for the application of thermal desorption. A research report was prepared which 1) identifies commercially available thermal desorption technologies and describes key process operating parameters, 2) describes contaminant, soil characteristics, and regulatory requirements that are necessary to assess the effective application of thermal desorption to a specific site, 3) describes procedures for selecting appropriate treatment technologies and operating conditions and for evaluating the feasibility of on-site or off-site treatment, and 4) identifies a list of requirements for either on-site or off-site use of thermal desorption services. Procedures are also provided for estimating the cost of using either on-site or off-site thermal desorption technologies.

A report on these findings is being completed and will provide UST Program Managers with an understanding of the capabilities, limitations, and costs associated with the technology. It will also provide guidance on applying the technology for treatment of petroleum-contaminated soils.

Future work in FY 1993 and 1994 will 1) ensure that information is available for maximum utilization and for consistent application of regulatory requirements, 2) address treatment of side waste streams, 3) demonstrate the application of this technology for the treatment of nonpetroleum-contaminated soil, and 4) disseminate information on thermal desorption to UST program managers and regulatory staff.

OUTPUTS:

1. Chapter entitled "Thermal Desorption of Petroleum-Contaminated Soils," Proceedings of the University of Massachusetts Sixth National Conference on Hydrocarbon-Contaminated Soils, Volume 5, September 1991, Lewis Publications, Inc.

2. Final report entitled "Guidance Document for the Application of Thermal Desorption for Treating Petroleum Contaminated Soils," EPA Technology Series, April 1992.

3. Peer review journal article entitled "Treatment of Contaminated Soils by Thermal Desorption Technologies," Journal of Air and Waste Management, June 1992.

4. Technical paper entitled "Guidance Document for the Application of Thermal Desorption for Treating Non-Petroleum Contaminated Soils."

5. A workshop will be presented on the feasibility, design, and performance evaluation of thermal desorption.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Bio-oxidation Technology for Leaking Underground Storage Sites

DURATION: FY92 to FY96

RESOURCES: $850K

OBJECTIVE:

To understand the physicochemical and biological principles of the bio-oxidation process and based on these principles to determine process control parameters and limiting factors. This will be accomplished by developing process control and monitoring strategies for better process performance and operation (joint research with EMSL), developing sound engineering design criteria and process operation procedures, and evaluating the application of aboveground bio-oxidation technology for treating soil contaminated with petroleum products.

RATIONALE:

In situ treatment system such as soil vapor extraction and/or bioventing technology is effective at removing semivolatile and volatile petroleum constituents in porous soil media. However, reduction of semivolatile and nonvolatile constituents occurs primarily from biodegradation. Petroleum-contaminated, clay-rich soil is especially difficult to treat using in situ corrective action technologies due to limited permeability and high sorption capacity; it may be treated more effectively using ex situ processes. Ex situ bio-oxidation (as a biopile) provides controlled, on-site, microbial degradation of petroleum products by using indigenous microbial populations. This bioremediation technology has been applied successfully for several years on petroleum-contaminated soils; however, specific engineering design and operation of the biopile system have not been fully evaluated and documented. In addition, evaluation of this technology in controlled environments and field applications can contribute to a better understanding of the bioventing process
[C-24].

DESCRIPTION:

The purpose of this project is to develop an engineering design and operation document for the application of this technology at actual leaking UST sites.

Activities in FY 1992 and 1993 will consist of an assessment of the technology to determine the basic engineering design criteria and control parameters of the bio-oxidation process. This assessment will involve surveying published literature and site data to identify state-of-the-art processes currently in use. Critical design and control parameters that will be examined include appropriate soil mound dimensions, spacing of vent piping rate and method of introduction of air and nutrients, amendments needed in the case of clay-rich soils, optimal temperature, relationship between soil permeability and rate of hydrocarbon removal, and relative removal rates as a function of bio-oxidation vs. hydrocarbon removal due to soil venting. Field evaluations/demonstrations of the bio-oxidation system will be conducted at sites-of- opportunity in EPA Regions in FY 1993 through FY 1996. Assistance will be provided to the participating company in preparing site-specific QAPjPs. The design, operation, and performance data from the sites will be evaluated to determine the applicability of the technology for leaking UST sites, and criteria and appropriate testing to validate "cleanness" of treated soils and guidance on when soils can be returned to the site, sent to a Subtitle C landfill, or treated further (e.g., stabilization if metals are present). In addition, basic scientific research will also be conducted to determine bio-kinetics for

different petroleum fuels-contaminated soils as well as the effects of soil temperature, soil pH, moisture, nutrients, and oxygen.

OUTPUTS:

1. Internal report entitled "Soil Mound Bioremediation Technology Assessment."

2 Technical report entitled "The Design, Operation, and Monitoring of Ex-situ Soil Mound Bio-oxidation Systems at Actual Leaking UST Sites."

3. Technical report entitled "Ex-situ Soil Mound Bio-oxidation Technology Handbook.

4. Interim peer review journal articles on soil mound bioremediation system design and operation.

RREL - PROJECT DESCRIPTION

TITLE: Potential Reuse of Petroleum-Contaminated Soil: A Directory of Permitted Recycling Facilities

DURATION: FY91 to FY95

RESOURCES: $140K

OBJECTIVE:

To identify and develop a comprehensive list of facilities that are permitted to receive and recycle soil contaminated by petroleum products leaking from underground storage tanks and explore additional soil reuse/recycling methods and improvements of the existing technologies.

RATIONALE:

Soil contaminated by petroleum products leaking from underground storage tanks is a pervasive problem in the United States. Federal legislation makes the generator responsible for soil contaminated by chemical materials, including petroleum products. Disposal of such soil is costly and will become even more so as landfill resources become scarce. An economically feasible remedy for the excavated soil contaminated by petroleum products will help the responsible party to solve the problems. This research will provide detailed information about environmentally and financially advantageous recycling options.

DESCRIPTION:

Because of stringent regulatory requirements in many states regarding mobile on-site treatment systems, lack of operational space at "neighborhood" gas stations, and relatively small amounts of feed material across which to distribute fixed operating costs, alternatives are being sought for off-site treatment, recycle, and reuse of treated soils. Various governmental and commercial organizations that may be able to identify commercial companies that are permitted to both receive and recycle/reuse petroleum-contaminated materials will be contacted to obtain detailed information regarding 1) identification of permitted facilities, 2) description of waste materials that it can receive, 3) identification of regulatory requirements, and 4) description of authorized recycle or reuse activities. A comprehensive Directory has been compiled that describes the treatment processes involved, waste classifications identified, and other client's technical and administrative information. The information will be updated in FY93 and FY95. Additional soil reuse/recycling methods and improvements of the existing technologies will be explored. Possible additional applications that may be examined include the following uses: 1) road bed base, 2) landfill daily cover/cap, 3) concrete/cinder blocks, 4) glass, 5) backfill (with liner) for industrial excavations, and 6) backfill (with liner) for abandonment of vaults, pits, or lagoons.

OUTPUTS:

1. Final report entitled "Potential Reuse of Petroleum-Contaminated Soil: A Directory of Permitted Recycling Facilities," August 1992.

2. Journal article entitled "Technologies and Facilities for Recycle and Reuse of Petroleum-Contaminated Soils," September 1992.

3. Technical reports entitled "Potential Reuse of Petroleum-Contaminated Soil: A Directory of Permitted Recycling Facilities," 2nd and 3rd editions, March 1994 and 1996.

RREL - PROJECT DESCRIPTION

TITLE: Development of an Integrated Systems Approach for Cleanup of Leaking Underground Storage Tank Sites

DURATION: FY92 to FY96

RESOURCES: $1,000K

OBJECTIVES:

To develop and evaluate an integrated strategy for the recovery of low-density non-aqueous-phase liquid (LNAPL) and clean up of motor fuel hydrocarbon- contaminated soil in both the vadose and saturated zones.

RATIONALE:

The general approach currently used to conduct corrective actions at leaking UST sites is to select and implement a specific technology that is intended to reduce subsurface contaminant concentrations to a predetermined level of cleanup while preventing the further spread of contaminants. This should be achieved by using the most efficient and cost-effective technology or combination of technologies available. No single corrective-action technology will address the entire problem (for example, pump-and-treat will not reduce residual contamination in soils, and in fact, may increase the volume of soil impacted by residual contamination). Under most situations, a combination of technologies or a "systems" approach to corrective action will be required.

DESCRIPTION:

Development of an integrated corrective-action approach will require a better basic understanding of how currently available technologies (LNAPL recovery, SVE, air sparging, and bioventing) affect petroleum hydrocarbons in the subsurface environment, and the treatability limitations of these technologies. This project will address these fundamental research needs and will be used to develop the "systems" approach to corrective action. Research has already been conducted under the corrective-action portion of the research program for specific technologies mentioned above. The results of physical and mathematical models, pilot studies, and field evaluations will be used to determine the development and use of technologies during different phases of corrective action. Several computer models have already been developed to evaluate the feasibility of free product removal, SVE, and biodegradation processes. Other models are available for groundwater and subsurface vapor flow, which facilitate the design of product recovery and SVE systems. Development of the systems approach to corrective action will involve the integration of the best of these models and new improved models that are yet to be developed. The integrated model will be used to determine appropriate application of specific technologies, to facilitate optimum remedial system design, and to interpret and analyze pilot studies and field evaluations of the integrated system. After the integrated model is developed, it will be field-validated to determine its applicability to different site conditions.

Case study data from numerous site remediations will also be used to validate software for determining when a remedial technology has reached its technical limit at a given site and to develop a series of "type curves" for rapid visual reference on various site conditions and likely endpoints of proposed remediations.

OUTPUTS:

1. Technical report entitled "Methods for Quantifying Mobile and Residual LNAPL and Procedures for Removing Product."

2. Technical report entitled "Evaluation of Site Data for Determination of Corrective Action Technology Limitations."

3. Technical report entitled "Evaluation of Computer Models on Product Recovery, SVE, Air Sparging, and Bioventing Systems."

4. Technical report entitled "Engineering Design Manual for Integrated Corrective Action Systems."

RREL - PROJECT DESCRIPTION

TITLE: Assessment of Newly Developed Technologies for Cleaning up Leaking Underground Storage Tank Sites

DURATION: FY91 to FY96

RESOURCES: $700K

OBJECTIVE:

To identify and evaluate the applicability of newly developed technologies for treating contaminated soil at leaking underground storage tank (UST) sites.

RATIONALE:

The magnitude of the large number of confirmed releases at leaking UST sites that need to be addressed make continued improvement in corrective-action technologies and approach a high priority. Few corrective-action technologies can be considered to be fully developed and routinely used (e.g., soil excavation and ground-water pump and treat). Other technologies are inconsistently being applied and are not necessarily readily acceptable to UST regulators (e.g., SVE air sparging). Many other corrective- action technologies may be potentially applicable to leaking UST sites; provide effective alternatives to technologies routinely used; and could result in quicker, more cost-effective cleanups. It is essential to assess and comprehend the potentially effective treatment technologies that are available for use, as well as the applicability and limitations of each technology for cleanup of petroleum-contaminated soils.

DESCRIPTION:

An overall approach to the technology evaluation will have two phases: Phase I - Preliminary screening of technologies, and Phase II - Rigorous assessment of technologies passing in Phase I screening. Phase I was initiated in FY91 and identified 11 technologies that could be potentially examined. Before conducting a more rigorous examination and evaluation of the selected technologies under Phase II, a technology-based prioritization system and evaluation criteria will be established. The factors that would be evaluated in more detail are: 1) current stage of development and existence of any other research program for that technology; 2) probable effectiveness for treating petroleum-contaminated soil; 3) limitations of the technology; and 4) treatment costs, cleanup time, ease of operation, and reliability. Based on the findings and recommendations of the Phase I study, an evaluation of the most promising technologies will be performed from FY 1993 to FY 1996.

Once a technology has been determined to hold promise for expediting the UST corrective action process, a focused literature review will be conducted and an expert work shop will be covered under Phase II to determine the state of the art and research needs for specific technologies. The technologies that will be examined and evaluated include: in situ steam stripping, radio frequency heating, soil flushing, ozone oxidation, and solvent extraction.

Findings from the initial part of Phase II will be summarized in a technology-specific reference handbook. Selected technologies will be further evaluated in field/pilot demonstrations at actual leaking UST sites. During the technology evaluation, the results will be reported to the UST community through technical papers and peer-reviewed journal articles. Upon completion of the Phase II

evaluation, an engineering design handbook will be developed for UST regulators, engineers, and consultants.

OUTPUTS:

1. Internal EPA report entitled "Selection of Innovative Treatment Technologies for LUST Sites, Phase I: Preliminary Screening of Technologies," July 1991.

2. Technical reports, papers, and peer reviewed journal articles on evaluation of selected corrective-action technologies.

RREL - PROJECT DESCRIPTION

TITLE: Remediation Approaches for Petroleum Contamination in Fractured Rock Media at Underground Storage Tank Sites

DURATION: FY92 to FY96

RESOURCES: $950K

OBJECTIVE:

To develop a methodology for selecting cleanup technologies and to identify and evaluate new and improved approaches for remediating petroleum hydrocarbon contamination in fractured rock in either the vadose or saturated zone at LUST sites.

RATIONALE:

The remediation of leaking USTs at sites underlain by fractured rock involves a number of complications that do not arise, or are much less severe, in nonfractured media. Because of large permeability differences between fractured and nonfractured zones, fractured media commonly exhibit strong anisotropy that can lead to separate phase and dissolved plume movement in unanticipated directions at larger than expected velocities. Uncertainty in rates of free product plume migration and on the effects of pumping on flow gradients makes free product control and recovery much more difficult to achieve. Recovery of residual product by using pump and treat, bioremediation, soil vapor extraction, or air sparging will also be substantially complicated as a result of difficulties in predicting mean flow and mass transfer limitations between fractured and nonfractured zones, which will reduce the efficiency of remediation measures. Practical methods are needed to characterize fractured media and to assess contaminant migration and remediation options at such sites.

In addition to the need for technology screening and selection methodologies, more effective remediation techniques must be developed and evaluated for the removal of contaminants in fractured rock media. Successful field application of in situ technologies in this media is inhibited by adverse permeability conditions. Hydraulic fracturing and horizontal drilling are two methods that create permeable zones of known dimension and location. Hydraulic fracturing is a method of creating tabular lenses filled with granular media in soil or rock. Long recognized as a method of increasing the production rate of oil wells, hydraulic fracturing has been adapted for use in the subsurface as a method to enhance environmental remediation. Unto itself, hydraulic fracturing provides little remedial effect, however it offers the potential to greatly enhance in situ technologies by creating subsurface channelways for delivery/recovery during vapor extraction, bioremediation, steam stripping, soil flushing, etc.

DESCRIPTION:

The proposed research will provide a better understanding of contaminant transport in heterogeneous and anisotropic media. Based on this information, a methodology will be developed to identify, evaluate, and select appropriate corrective action technologies for mitigating petroleum releases in fractured media. In addition, enhanced remediation techniques will be evaluated for improved contaminant removal at these sites. The project will be conducted in three phases with major tasks as follows:

Phase I - Initial work will include 1) an expert workshop, 2) an overview and analysis of the current practices for evaluating and mitigating petroleum releases in fractured bedrock through review of published literature and studies, 3) literature reviews and experimental investigations of effects of

fracture geometry; surface wettability; fluid interfacial tensions; and capillary, gravitational, and viscous forces on flow in fractured media, and 4) investigations of mass transfer kinetics between fractured and nonfractured regions.

Phase II - Information from the initial phase will be used to focus and prioritize the research activities under Phase II. Activities will include the development of practical approaches for evaluating the contaminant behavior in fractured porous media and identification of critical factors that favor or inhibit the success of specific corrective action technologies. Field experiments will also be developed to determine how best to combine and apply various in situ treatment technologies with hydraulic fracturing and/or horizontal drilling.

Phase III - The approaches developed under Phase II will be evaluated and validated through field demonstrations/verifications at actual UST sites-of-opportunity. The field evaluations will be conducted in conjunction with EPA Regions and States. Assistance will be provided in preparing site-specific QAPjPs for the field evaluations. Results will be used to refine the methodology for identifying the key site parameters necessary to assess the likely effectiveness of alternative corrective action technologies.

As part of the Phase III effort, the application of hydraulic fracturing and/or horizontal drilling in combination with selected in situ treatment processes will be evaluated to determine the combined remedial effectiveness at actual LUST sites. Performance of the process (including economic advantages) will be monitored by collection of appropriate data according to established QA/QC procedures.

OUTPUTS:

Technical reports, peer reviewed journal articles, and conference presentations will be prepared for the tasks under each phase. A guidance document/user's manual will also be developed for the remediation approach developed under this project.

RREL - PROJECT DESCRIPTION

TITLE: Evaluation of Technologies for Cleaning Up Soils Contaminated with Alternative Fuels

DURATION: FY94 to FY96

RESOURCES: $550K

OBJECTIVE:

To evaluate the available technologies and study the new technologies for the remediation of alternative fuel contaminated soils.

RATIONALE:

In recent years, the United States has emphasized an interest in the development of alternative fuels to replace traditional petroleum products due to concerns over oil embargoes of oil producing countries and the deterioration of air quality. Most of the alternative fuels under consideration contain oxygenated organic compounds. Their properties are different from those of hydrocarbons as are the mechanisms of their transport and transformation in the subsurface environment. Consequently, the treatment of soils contaminated by these products must be evaluated in terms of their differences from traditional fuels stored in USTs.

DESCRIPTION:

Laboratory and pilot studies of existing technologies such as soil washing, low- temperature thermal desorption, soil vapor extraction, and biodegradation will be conducted to assess their applicability for treating soils contaminated with alternative fuels. New technologies such as solvent extraction and ozonation will be studied that may be effective for these soils.

OUTPUTS:

1. Technical report entitled "Evaluation of the Feasibility of Remediating Alternative Fuels-Contaminated Soils with SVE, LTTD, Soil Washing, and Biodegradation."

2. Technical report entitled "Assessment of Ozonation and Solvent Extraction Technologies on the Remediation of Alternative Fuel Contaminated Soils."

RREL - PROJECT DESCRIPTION

TITLE: Development, Demonstration, and Maintenance of a Computerized On-Line Information System for Underground Storage Tank Technology Transfer

DURATION: FY87 to FY96

RESOURCES: $50K (annually)

OBJECTIVE:

To design, develop, and maintain a computerized on-line technical information system for UST technology transfer; collect and incorporate UST case histories information into the computerized system; and provide technical documentation for accessing this information.

RATIONALE:

The experiences of UST Program Managers at all levels of government and the consulting community vary widely. Information that would allow these personnel to obtain the immediate benefit of the experiences of others involved in UST cleanup actions is extremely useful. This information needs to be available throughout the user community.

DESCRIPTION:

A computerized on-line information system containing case history information from UST Program Managers has been designed and developed. The system is organized into two sections, a database section and a narrative section. The database section allows file searches by 27 criteria (e.g., type of incident, geographic location, hydrogeologic conditions, cleanup technology etc.) to select incidents of interest. The narrative section is composed of ten subsections in text format which contain detailed information on various UST incidents (e.g., chemical, site characteristics, effectiveness of immediate/long-term corrective actions, etc.) The system has been fully operational since 1989 and currently contains approximately 150 case histories, many describing the application of innovative technologies. A modified system has also been developed for in-house use by UST Program Managers in tracking and monitoring LUST Trust Fund cleanup actions.

OUTPUTS:

1. On-line system developed for UST case histories (11/88)
2. UST case histories user's guide (4/89)
3. Fully operational system for UST technology transfer (8/89)
4. Demonstration of LUST Trust Fund Management System (11/90)
5. Expanded/Updated system with multi-user capability (8/91)

RREL - PROJECT DESCRIPTION

TITLE: Development and Evaluation of Methods for Detection and Prevention of Leaks in Aboveground Storage Tanks

DURATION: FY93 to FY96

RESOURCES: ($350,000 estimated annually)

OBJECTIVE:

The objective is to develop, evaluate and demonstrate methods for the detection and prevention of leaks in small and large aboveground storage tanks (ASTs).

RATIONALE:

Leak detection and prevention measures for ASTs are deferred under the present EPA regulations. At the current time, the Spills Prevention, Control, and Countermeasures Act (SPCC), which covers releases from ASTs, is undergoing modifications in several phases. Research in underground liners is presently being done by EPA, but the problem of leak detection has not been addressed. The American Petroleum Institute (API) is in the third phase of a three-phase program to assess the state of the art in leak detection for ASTs; the first phase was a survey of existing technology, performed in 1990 [1,2], and the second was a set of field experiments to assess the applicability of volumetric and acoustic methods [3-7]. During the third phase, additional field experiments are being done to evaluate the testing recommendations made during the second phase. The results suggest that both passive-acoustics and mass-measurement systems, when properly implemented, will be able to detect small leaks in the floors of ASTs. In these tanks a leak of 1 gal/h or more might be considered small. This value is consistent with the leak detection standards required of USTs (0.1 gal/h for tank tightness tests and 0.2 gal/h for monthly monitoring tests), because in an aboveground tank the hydrostatic head of the liquid may be 5 to 10 times greater than it is in an underground tank. The API work is being done on large tanks, typically 100 ft in diameter, containing petroleum fuels. No experimental work is being done on small tanks 10 to 50 ft in diameter, or on very large tanks, for example, those that are 150 to 200 ft in diameter.

The current SPCC calls for internal inspection of an AST every 10 years. Periodic leak testing/monitoring is not presently required, but is under consideration for inclusion in the rule changes proposed for Fall 1992. In order for the tank to be inspected, it must be taken out of service, emptied, and cleaned. This process takes several weeks to several months to complete. The regulatory standards for testing ASTs are quite inconsistent with those for testing USTs (the latter being 0.2 gal/h for tests that are conducted monthly). This inconsistency is more pronounced because the area of the bottom (or buried) surface of a moderately sized AST is larger than the total buried area of the largest UST, and the hydrostatic pressure exerted by the product is 5 to 10 times greater in ASTs than in USTs.

DESCRIPTION:

The most pressing problem is to evaluate the capability of the technologies that can be used for leak detection. The API work has been done on 100-ft-diameter tanks containing a light-end fuel. There is a wide spread in the size of ASTs, which range in diameter from 10 to 200 ft, and leak detection system that work on the smaller tanks will not work on the larger ones. Also, methods that work on the larger tanks may constitute a case of "overkill" for the smaller tanks. Finally, some of the techniques that will work with the light-end products may not work with the heavier ones. A multi-year program

is necessary to evaluate mass-measurement and passive-acoustic detection techniques for small and large tanks containing both light and heavy fuels. Two types of experiments will be conducted. The first type will be controlled tests in a captive tank that are designed to evaluate each technology; leaks will be simulated by means of a leak-maker device developed and validated in the API program. The second type of experiment will evaluate each technology on a variety of tanks for the purpose of assessing the ambient noise characteristics. For each viable technique, a standard test procedure for evaluating performance will be developed and demonstrated.

At the present time RREL has no funds to undertake any AST research, but it is the EPA laboratory that has the functional responsibility for performing this work. The API research shows that it is possible to test ASTs for leaks and that additional work is required before standards and general methods of testing can be developed.

OUTPUTS:

1. Final report entitled, "Leak Detection Technologies for Aboveground Storage Tanks When In Service." American Petroleum Institute, August 1989.

2. Final report entitled, "An Engineering Assessment of Volumetric Methods of Leak Detection System for Aboveground Storage Tanks," API Publication Number 306, October 1991.

3. Final report entitled, "An Engineering Assessment of Acoustic Methods of Leak Detection in Aboveground Storage Tanks." API Publication Number 307, January 1992.

4. Technical paper entitled, "Aboveground Tank Leak Detection Technologies." Proceedings of the 10th Annual ILTA Operating Conference, June 1990.

5. Technical paper entitled, "Detection of Leaks in the Floor of Aboveground Storage Tanks by Means of a Passive Acoustic Sensing System." Proceedings of the 84th Annual Meeting and Exposition of the Air and Waste Management Association, June 1991.

6. Technical paper entitled, "Field Tests of Passive-Acoustic Leak Detection Systems for Aboveground Storage Tanks." Proceedings of the 85th Annual Meeting and Exposition of the Air and Waste Management Association, 1992.

BSA/PPA: D109/R62 **DEVELOPMENT OF METHODS FOR STORAGE TANK LEAK MONITORING**

Project 01 **Monitoring Methods for Characterizing and Remediating Releases at Underground Storage Tank Sites**

Tasks: FY 1991 and FY 1992

I. Leak Detection Monitoring

01 A. Evaluation of External Vapor Monitoring Sensors

02 B. Laboratory Model of Gasoline Leakage

II. Real-Time Site Assessment

03 A. Improved Field Methods for UST Investigations and Monitoring

04 B. Improved Free Product Monitoring and Recovery

III. Remediation Monitoring

05 A. BTEX Monitoring Methods for Active Bioremediation

06 B. Field Monitoring and Decision Support for Assessing In-Situ Biocontainment of Plumes

07 C. Design and Monitoring of Permeable Remediation Barrier

08 D. Monitoring Review of Field Data for In-Situ Air Sparging

IV. Technology Transfer

09 A. ASTM -- UST Subcommittees for Leak Detection, Site Assessment and Remediation

10 B. UST Issue Papers

EMSL-LV-PROJECT DESCRIPTIONS

RESEARCH CATEGORIES and TASKS DESCRIPTIONS

I. Leak Detection Monitoring

01 I. A. Evaluation of External Vapor Monitoring Sensors

Cooperative Agreement : Carnegie Mellon University
Principal Investigator: Mark Portnoff

Goal: To evaluate sensors used for external monitoring of petroleum hydrocarbon vapors in order to: (1) develop a classification system based on individual sensor types (eg., adsistors, Figaro, metal oxide sensors, and catalytic bead sensors), and (2) to develop a scale of comparative usefulness for purchasers and users of external vapor monitors.

Rationale:

There are a variety of sensors capable of measuring hydrocarbon vapors. These sensors operate according to different physical principles and are subject to different kinds of environmental interferences. The effects of these interferences on instrument sensitivity, specificity and drift is not well known. This lack of information impedes proper selection of existing monitors as well as development of improved sensing devices.

Approach:

This study will evaluate various sensors to determine their sensitivity and specificity to petroleum hydrocarbons. The study will be carried out using specially prepared laboratory chambers that control for temperature, humidity and methane interferences. The study will provide quantitative data on: 1) precision and accuracy, 2) detection limits, 3) false positive and false negatives and 4) the effects of potential interferences.

Deliverables:

Report quantifying the comparative strengths and weaknesses of the sensors in order to inform purchasers.

I. Leak Detection Monitoring

02 I. B. Laboratory Model of Gasoline Leakage

Cooperative Agreement : University of Nevada, Las Vegas
Principal Investigator: David Kreamer

Goal: To provide time-lapse videos and computer graphics on results of physical model testing. The tests will quantitatively characterize hydrocarbon liquid and vapor movement in the vadose zone and across the water table in small- and moderate-size physical models.

Rationale:

The assessment and characterization of UST sites can be improved by examining how variables such as fuel type, leak rate, moisture content, temperature, and backfill affects the distribution of contaminants. This project will also provide video records to enhance transfer of this information as stand-alone videos or video segments for inclusion in other videos.

Approach:

This work is being transferred from Arizona State University to UNLV in FY 1991. The project uses controlled laboratory experiments where petroleum fuel is leaked into glass-walled tanks filled with various backfill materials. Parameters that are varied in the sand-tank apparatus include: fuel type, leak rate, moisture, soil distribution and permeability. Time-lapse video photography will record liquid movements in the tanks. Gas samples will be periodically withdrawn from a network of sampling ports throughout the tank and be analyzed by gas chromatography. Computer graphics will be developed based on the findings.

Deliverables:

'92 Videos and computer graphics of spill movement.

II. Real-Time Site Assessment

03 II. A. Improved Field Methods for UST Investigations and Monitoring

Cooperative Agreement : University of Connecticut
Principal Investigators: Gary Robbins and James Stuart

Goal:

Continue expanded use of field methods for site investigation and remediation monitoring.

Deliverables:

'92 - '94 Protocols for profiling the vertical distribution of contaminants; conducting air permeability tests; conducting slug tests for UST sites; delineating fracture zones. Developing course content for training courses for Regions and State UST programs.

II. Real-Time Site Assessment

04 II. B. Improved Free Product Monitoring and Recovery

Cooperative Agreement : Western Michigan University
Principal Investigator: Duane Hampton

Goal: To develop and field test the "aquifer dipstick" for real-time measurement of free product thicknesses in shallow aquifers and to develop and test innovative hydrophobic well packs to improve the recovery of free product.

Rationale:

Many UST release sites require delineation of the free product plume and the design of a product recovery system, yet current methods for carrying out these activities are inaccurate and ineffective.

Approach:

Prior work conducted under this cooperative agreement resulted in development of a prototype aquifer dipstick and hydrophobic well pack. Ongoing work is focused on refining and improving both prototypes to improve their ability to be deployed in the field. The devices will be tested both in the laboratory and at a field site in Michigan. The results will be compared to other approaches, including ground penetrating radar.

The aquifer dipstick consists of two tubes, one inside the other. The inner tube rotates to expose the detectors (dye material or electric sensors) that indicate fuel thickness. Studies will also be conducted to evaluate the influence of hydrophobic well-construction materials in free-product monitoring and in improved recovery of free product by skimming. Field tests will also be conducted to evaluate various tracers for free product and their value in site characterization studies.

Deliverables:

'92 - '93. New prototype devices, such as the aquifer dipstick, for real-time measurement of actual product thicknesses on the capillary fringe; use of gasoline compounds or added tracers to monitor recovery of product; new well packs constructed of hydrophobic materials to increase recovery of free product from the subsurface.

III. Remediation Monitoring

05 III. A. BTEX Monitoring Methods for Active Bioremediation

Interagency Agreement : Air Force and R.S. Kerr Laboratory
Principal Investigator: Neil Amick

Goal: To develop methods for monitoring benzene, toluene, ethylbenzene, and xylene (BTEX) in soil, soil gas, and ground water. The study will test and use field methods to identify the occurrence and concentration of BTEX. The study will assist in the development and design of protocols to monitor the bioremediation of BTEX compounds through field tests and pilot studies.

Rationale:

Currently, many state UST regulations include standards for total petroleum hydrocarbons (TPH) in soil. Although TPH standards often conflict with standards for BTEX, the TPH measurements are still widely used because states are familiar with methods for TPH analysis and because they have few viable alternative measurement methods. In contrast, BTEX is the most water soluble fraction of petroleum hydrocarbons and includes known carcinogens. Thus, there is interest in using BTEX to supplement or possibly replace TPH measurements in UST regulations in order to target scarce monitoring and regulatory resources on the most mobile and toxic fractions of UST releases.

Approach:

This study will test available techniques for measuring BTEX in the laboratory and in the field. Methods to be tested include: 1) immunoassay test, 2) disc techniques, using a modified luminoscope, 3) BTEX sensor systems, and 4) a filter fluorometer or modified luminoscope. Special emphasis will be placed on assessing how these techniques can be used to characterize sites and to monitor the progress of bioremediation of BTEX compounds. The first year efforts will focus on evaluating and improving the field deployability of the test methods. In conjunction with the Kerr Laboratory, the second year efforts will focus on using these techniques to monitor a site undergoing active bioremediation. Results from this project will be used to assist in developing protocols for ASTM standards for use of these BTEX measurement techniques.

Deliverables:

'93. Report evaluating the field deployability of BTEX measurement methods based on field tests; specific recommendations for modification of devices for improved field performance.

III. Remediation Monitoring

06 III. B. Field Monitoring and Decision Support for Assessing In-Situ Biocontainment of Plumes

Cooperative Agreement : Utah State University
Principal Investigator: Ryan Dupont

Goal: The objectives of this study are: 1) to assess natural biodegradation reactions at a well defined fuel spill site; 2) to assess and select practical field sampling and analytical methods that best quantify the observed biodegradation reactions based on a comparison with rigorous laboratory analysis methods; 3) to assess the effectiveness of simple, low cost biostimulation techniques; 4) to use field generated biodegradation monitoring data as input to a fate and transport model for plume containment and remediation; and 5) to produce a decision support system to enable UST site managers to assess the feasibility of biodegradation on a site-by-site basis using field monitoring methods.

Rationale:

As the number of UST release sites continues to grow, the regulatory community is under increasing pressure to determine which sites will require full-scale corrective action in order to protect environmental quality and human health. This project will identify and validate field monitoring techniques and decision criteria to enable rapid and conclusive determination of whether naturally occurring or easily stimulated biodegradation may be a feasible remediation option on a site-by-site basis.

Approach:

This study will be conducted in four phases: 1) the use of field characterization methods to determine the distribution of contaminants and the hydraulic characteristics of the site; 2) the use of field techniques to monitor in-situ biodegradation processes, as manifested in groundwater and soil gas chemistry; 3) the evaluation of the ability of simple soil aeration techniques to stimulate natural biodegradation; and 4) the integration of the field data into a decision support system to verify in-situ biodegradation processes and to assess the long-term effects on the plume as it is attenuated by natural biodegradation processes.

Deliverables:

late '93. Field monitoring protocols and complementary decision support system for interpreting field data in order to make site management decisions. The decision support system is designed for conversion to computer software.

III. Remediation Monitoring

07 III. C. Design and Monitoring of Permeable Remediation Barriers

Cooperative Agreement : University of South Carolina and
University of North Carolina
Principal Investigators: Bob Borden and Art Cohen

Goal:

This study will conduct ground water monitoring around permeable barriers designed to remove dissolved petroleum contaminants from the ground water.

Rationale:

Conventional pump and treat methods for remediating dissolved hydrocarbon contamination is increasingly viewed as an inefficient long-term process with high operation and maintenance costs for pumping large volumes of water above ground for treatment and subsequent discharge. As an alternative to treating the groundwater contaminants above ground, this study is investigating the use of innovative permeable barriers which could be installed at UST release sites to treat the dissolved contamination in-situ.

Approach:

This study focuses on the materials to be placed within the permeable barrier and on monitoring the effects of the barrier on water quality. An initial study defining the physical and chemical characteristics of several peats and determining their capacity to adsorb petroleum hydrocarbons has been completed. Ongoing studies will investigate the ability of specially prepared "briquets" to release the proper amount of nutrients over time, as well as the ability of peat to denitrify any excess nitrogen.

Deliverables:

'92 - '93. Report evaluating the ability of peat and "fertilizer briquettes" in permeable trenches to treat groundwater contamination in-situ; evaluation trench effect on local groundwater flow patterns.

III. Remediation Monitoring

08 III. D. Monitoring Review of Field Data for In-Situ Air Sparging

Cooperative Agreement : Environmental Research Center, UNLV
Principal Investigators: Rich Johnson, Paul Johnson, Robert Hinchee, and David McWhorter

Goal:

Determine the relative contributions of physical and biological processes (e.g., immiscible fluid displacement, volatilization, biodegradation) in reducing subsurface contaminant levels of hydrocarbons through in-situ air sparging.

Deliverables:

'92 Issue paper on potential use of air sparging at UST sites and strategic areas for additional research.

IV. Technology Transfer

09 IV. A. ASTM -- UST Subcommittees for Leak Detection, Site Assessment and Remediation

Goal:

To accelerate the development of ASTM standards related to underground storage tanks. The goal is for ASTM to generate consensus standards that can be referred to by state regulations. The standards will be primarily related to leak detection monitoring, site assessment, and remediation.

Rationale:

The responsibly for carrying out the UST program is primarily in the hands of state programs. EPA can provide assistance by working on guidance that is based on the consensus of interested parties. ASTM provides an ideal opportunity to bring together regulators, vendors, and researchers to develop standards. By supporting this project, EPA can help set the agenda for standards development, but not have to take on the full burdens of cost and effort to produce this guidance.

Approach:

The Underground Storage Tank Subcommittee of ASTM has produced a Standard Guide and Standard Practice for leak detection monitoring. Future efforts by Subcommittee task groups will support development of standards for site assessment and remediation monitoring. State UST programs face many common questions, such as procedures for streamlining and improving their remediation efforts. The ASTM Task Groups will reach a consensus and publish such procedures. OUST is also participating in this work effort.

Deliverables:

ASTM standard for leak detection, site assessment and remediation (Deliverables are of continuing nature, drafts for site assessment to be completed late '92).

IV. Technology Transfer

10 IV. B. UST Issue Papers

Cooperative Agreement : Environmental Research Center, UNLV
Principal Investigator: Doug Bedinger

Goal:

To transfer the research findings of EMSL-LV regarding UST problems by intermittently publishing issue papers that focus on the practical information needs of regulators and practitioners.

Rationale:

There is a strong need in the UST program to provide timely information to a wide range of people involved with underground storage tanks. A tremendous number of owner/operators, consultants and regulators have an interest in USTs. Most of these people are new to the field and they would find "nuggets" of information obtained from UST research extremely helpful in their daily work.

Approach:

A series of papers will be produced through the Environmental Research Center in cooperation with OUST and other ORD laboratories. They will be published and distributed by CERI. These issue papers will be based on both research and field experience and will represent the "state-of-the-knowledge" on relevant UST topics. Papers may be developed and written by one person or a group of experts and each paper will be reviewed.

Deliverables:

Series of issue papers to be delivered to UST programs, the regulated community, and leak detection and remediation consultants. Current mailing list is over 4,000. (Continuing through '95. Four issues complete; others will be developed as research findings unfold).