IN SITU THERMAL DESORPTION (ISTD) OF PCBs

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ABSTRACT

A field demonstration is described in which a new *in-situ* thermal desorption soil remediation process (ISTD–Thermal Wells) is shown to remove high-concentration PCB contamination from clay soils. The demonstration was conducted at the Missouri Electric Works (MEW) Superfund site in Cape Girardeau, Missouri, from April 21 through June 1, 1997. For this demonstration, twelve heater/vacuum wells were completed in a multiple triangular array with a 5-foot well spacing to a depth of 12 feet. During the remediation, electrical-resistance heating and vacuum were applied to the wells for a period of 42 days. Soil temperatures were monitored throughout the experiment, and soil samples were taken with a split-spoon sampler fitted with six-inch brass coring sleeves to verify the removal of contaminants. Temperatures above 1000°F were achieved in the interwell regions, and PCB concentrations in the treated area were reduced from a maximum concentration of approximately 20,000 ppm to non-detect (i.e., <33 ppb) by EPA Method 8080. The system destruction removal efficiency (DRE) for PCBs was 99.9999998%.

INTRODUCTION

The difficulty in remediating the large number of sites contaminated by toxic, carcinogenic, or radioactive chemicals has generated interest in developing improved processes for cleaning these sites. *In-situ* processes, which either destroy contaminants in place or remove them without disturbing the soil, offer distinct advantages over those requiring excavation in that they eliminate exposures and handling/preparation costs.

One of the most versatile and effective of these *in-situ* processes is *In-Situ* Thermal Desorption (ISTD), in which heat and vacuum are applied simultaneously to subsurface soils. For shallow soil contamination, an ISTD method using surface heater blankets[1–3] has been developed. Recently, ISTD–Thermal Blankets have been demonstrated[2–3] to be highly effective in removing polychlorinated biphenyls (PCBs) from soils, and commercial remediation services are now available.[4] For deep soil contamination, a similar thermal vacuum process using heater wells (ISTD–Thermal Wells) has been proposed.[5] As with the thermal blanket, this process is a clean, closed system that is simple and fast. It destroys pollutants in place without having to move the soil. It can be used under roads, foundations, and other fixed structures. If required, the thermal wells can be slanted or drilled horizontally. The operations are low profile and quiet and cause little disruption of adjoining neighborhoods. The process possesses a high removal efficiency because the narrow range of soil thermal conductivities provides excellent sweep efficiency and because its high operating temperature assures complete displacement efficiency of contaminants in the gas phase. Unlike fluid injection processes, ISTD is applicable to tight soils and clay layers or in soils with wide variations in permeability and water content.

The ISTD–Thermal Wells process utilizes an array of heater/vacuum wells emplaced vertically in the ground in triangular patterns. The wells are equipped with high-temperature electric heaters and connected to a vacuum blower. As heat is injected and soil temperatures rise, the vaporized formation fluids, including contaminants, are collected by the vacuum drawn at the wells. Produced vapors are treated in surface facilities to remove residual contaminants that have not been destroyed *in-situ*.

A twelve-well pilot of the ISTD–Thermal Wells Process was carried out by Shell Oil and General Electric Companies in the winter of 1996 at Shell's Gasmer Road Test Facility in Houston, Texas.[6] In that pilot, a sand pit was prepared with two surrogate high-boiling-point soil contaminants, hexadecane and methyl salicylate. The ISTD–Thermal Wells process completely removed the contaminants after electrical-resistance heating and vacuum were applied to the wells for a period of 70 days.

PROCESS DESCRIPTION

As shown in **Figures 1a** and **1b**, there are two forms of the ISTD technology: Thermal Blankets for removal of surficial contamination down to about 3 feet, and Thermal Wells which can be placed to virtually any depth. The fundamental processes, including heat flow, fluid flow, phase behavior and chemical reactions, are similar for each method. In each case, heat is applied to soil from a high-temperature surface in

contact with the soil, so that radiation and thermal conduction heat transfer are effective near the heater, and thermal conduction and convection occur in the bulk of the soil volume. Overall thermal conduction accounts for over 80% of the heat transfer. A significant feature of the ISTD process is the creation of a zone of very high temperature (>1000°F) near the heaters, which causes rapid destruction of the contaminants before they exit the soil.

CAPE GIRARDEAU FIELD DEMONSTRATION DESCRIPTION

Objectives

To test full-scale remediation of contaminants using the ISTD–Thermal Well technology, TerraTherm carried out a field demonstration at the Missouri Electric Works (MEW) Superfund site in Cape Girardeau, Missouri. The Thermal Well technology was demonstrated on deep soil contamination near a former storage pad area of the MEW site where the PCB contamination was as high as 20,000 ppm Aroclor 1260. The site clean-up level specified in the ROD was 2 ppm total PCBs. The objectives of the MEW field test included (1) clean-up clay soils in the interior portion of the well array to less than 2 ppm, (2) demonstrate that stack discharges were in compliance with state and federal standards for PCBs and polychlorinated dibenzodioxins/ polychlorinated dibenzofurans (PCDDs/PCDFs), and (3) obtain a system destruction removal efficiency (DRE) for PCBs greater than 99.9999%. The demonstration was conducted in support of TerraTherm's application for a modification of the TSCA permit for alternate PCB treatment. The Demonstration Test Plan for this project was accepted by EPA, Region VII and the Missouri Department of Natural Resources (MODNR) in January, 1997.

Description of Site

The MEW site was contaminated with PCBs in both shallow and deeper soils during past operations including selling, servicing, and re-manufacturing transformers, electric motors, and electrical equipment controls, and recycling dielectric fluids containing PCBs. The MEW site was issued a Record of Decision (ROD) by the EPA, Region VII in September, 1990 and was issued an Explanation of Significant Differences (ESD) in January, 1995. On-site thermal treatment, including thermal desorption technologies, is the selected remedy for the site.

The field demonstration was carried out in an area devoid of underground gas, water, or electric utilities. The natural stratigraphy is brown clay soil; the water table is about 40 feet deep.

Pre-Test Soils Characterization

The Thermal Well demonstration area was sampled to determine the pretest concentrations and the required depth of wells. Samples were obtained using Geoprobe tools and disposable plastic liners. The soils in the selected area of the site were brown clay with traces of silt, overlain by a thin layer of organically rich topsoil. Gravel had been spread over the area during previous investigation activities. Samples were collected from discrete 2 ft intervals from 0 to 12 ft at the locations of the twelve Thermal Wells. Sample intervals were homogenized and analyzed for total PCBs by Method 8080 by ATAS Labs of St. Louis, Missouri. **Table 1** and **Figure 2** show the results of the sample analysis. All Thermal Well areas deeper than 10 feet were determined to meet the site clean-up criteria.

Equipment

Heater/Vacuum Wells. The pattern of twelve wells used is shown in **Figure 3**. Well spacing was 5 ft. The wells were completed vertically in 6-in. OD boreholes to a depth of 12 ft. The well completion consisted of (1) a 10–20 mesh sand-filled annulus between the soil face and a liner; (2) a 4-in. OD stainless steel, slotted (0.032 in. x 2 in.) liner; (3) a 2.5-in. OD pipe sealed at the bottom to provide a "heater can" to isolate the heater element from the product stream; and (4) Nichrome wire heating elements threaded through ceramic insulators. Wells were equipped with 12 ft long, dual hairpin heaters in series. To compensate for heat losses to the atmosphere and to the lower soil, the upper 1 ft and the lower 2 ft were designed to deliver 57% more power than the middle 9 ft (Nichrome wire diameter 0.102 in. vs 0.128 in.). The sand-filled annulus improved inflow of fluids from the soil, and the gap between the slotted liner and the heater can allowed flow up the well and into the surface vacuum manifold connected to the wells. Thermal wells had the capability of injecting 350–700 watts/ft at heater temperatures in the range of 1600 to 1800°F. Surface heating pads were placed at the center of each triangle on the surface metal vapor seal to assist in heating the near-surface soils between the wells. The surface heating pads were 18-inch square and energized with 500 watts/ft^2.

Thermocouple Wells. A number of 1-in. OD steel thermocouple (TC) tubes were driven into the soil to a depth of 7 ft at locations A through O shown in Figure 3. These tubes, which were sealed at the bottom, allowed temperature logging during the experiment using fixed thermocouple arrays. The thermocouple tubes were located at the centroid of each of the thirteen triangular heating patterns and at additional locations within the center triangle.

Vapor Seal. A vacuum frame structure was constructed around the well area to insulate the surface and to provide a surface seal. The vapor seal was provided by rectangular steel shim stock (4 ft x 20 ft) on the soil surface. These sheets were fitted together along the 20 ft sides so as to cover the whole test area, and the sheets were welded to the heater and logging wells at their points of penetration. A 16-in. thick layer of vermiculite insulation was placed over the steel plates. This layer served to reduce heat losses and to insulate the surface piping manifold embedded within the vermiculite. The insulation was covered with an impermeable silicone tarpaulin to prevent rainwater inflow and to provide an additional seal against vapor emissions to the atmosphere. This cover extended 5 ft beyond the edges of the treated area.

Vacuum Monitoring. Subsurface vacuum monitoring in the array was conducted using two pressure monitoring wells, PW-1, -2, constructed from perforated pipe and completed with 1 foot of sand at a depth of 6 feet and sealed with bentonite grout to the surface. The pressure monitoring wells were located in the center triangle about 2 feet from the nearest heater/vacuum wells.

Water Influx. A 1 ft deep trench was added around the perimeter and equipped with a sump pump to control surface run-off water during the demonstration.

Description of MU-125 Mobile Process Unit

The Thermal Wells were connected to a single manifold which delivered the desorbed and partially treated *in-situ* vapors to the TerraTherm MU-125 mobile process unit. The MU-125 is a 125 scfm mobile demonstration trailer equipped with a particulate cyclone, flameless thermal oxidizer (Thermatrix ES-125), two carbon canisters in series, main and backup vacuum blowers, discharge stack with continuous emission monitoring (CEM) system, and control room for the system operator. The control room houses the programmable logic controller (PLC), heater controllers, and PC-based data acquisition system. The system is powered from shore power but has a backup 70 Kw diesel generator in case of power failure to the site. The stack emissions are continuously monitored for wet and dry oxygen, carbon monoxide, carbon dioxide, and total petroleum hydrocarbons. In addition, Drager tubes are used to monitor HCl emissions from the stack.

OPERATION OF THE DEMONSTRATION

After equipment shakedown, the Thermatrix oxidizer was started, vacuum was applied to the wells, and emissions were monitored at a baseline flow rate for 24 hours to assure acceptable levels of stack emission before well heating was initiated. The vacuum was applied to the twelve wells by opening knife valves at each well and adjusting them to roughly equal vacuum in the range of 25 inches of water. The vacuum levels in the pressure monitoring wells (PW-1, -2) two feet away were 1 inch of water, indicative of the low permeability of the clay soil.

Well heaters were energized on April 21, 1997. Power to the twelve injectors was increased over a 3-hour period to an average initial rate of 500 watts/ft. Power was increased in all injectors until the control thermocouples next to the heating elements reached the maximum operating temperature (1600°F). Within 48 hours the vacuum decreased at the heater wells from 25 to 5 inches of water and the pressure monitoring wells increased in vacuum from 1 to 4.5 inches of vacuum. This indicated a substantial increase in soil permeability from the heating process. Once the soil permeability had increased, the surface heating pads were energized at 500 watts/ft^2. Injected power was slowly decreased once the maximum heating element operating temperatures was reached.

The flow rate from the well manifold was maintained between 50–70 scfm with a well vacuum of 3–5 inches of water for the majority of the 42-day demonstration.

TEMPERATURE PROFILES

The temperatures in the process were recorded using fixed thermocouples (TC) at 1 ft intervals with thermocouple arrays. Temperatures were measured every 12 hours during the test.

Because of the additional contribution from the surface heating pads, heating progressed from the surface downwards. After the upper foot of soil reached 900°F, the power to the surface heating pads was reduced to avoid excessive corrosion of the metal shim-stock vapor seal.

The temperature history at the centers of the triangles near the middle of the heated interval (depth 6 ft) is shown in **Figure 4**. There were three distinct phases in the heating process. During the first phase, the soil temperature rose nearly to the boiling point of water in about 250 hours from the start of heating. During the second phase, water boiling occurred and the temperature remained near the boiling point of water. The duration of this phase was dependent on the pore water content and the water inflow. This phase ended at between 560 and 630 hours, with the center and adjoining triangles drying first and the outer triangles later. During the third (superheating) phase, soil temperatures rose rapidly until the heaters were turned off on day 42. Maximum temperatures over 900°F were reached at the center of the triangles, and about 50% of the

volume was over 1100°F. **Figure 5** shows the maximum temperatures reached along profile I7-G.

SAMPLING METHOD AND RESULTS

Soil samples were taken after 42 days of heating, at the locations shown in Figure 3. The coring was performed on the hot soils by Philips Environmental using a truck-mounted drill rig, hollow-stem augers, and split spoon sampler with brass sleeves. After retrieval of the coring tube, the contents of each sleeve were immediately emptied into a glass bottle and sealed. The total coring depth was 10 ft except at the center location where the coring proceeded until moist soil was contacted at 16 ft. Most of the samples were observed to be reddish-brown, very dry, high porosity and fine grained. On rehydrating, the clay plasticity appeared to be lost and the soil behaved as a siltstone.

Post-heat soil samples showed a large increase in both porosity and permeability. The porosity increased from approximately 30% of pore volume initially to a post-heat value of 40%. The horizontal air permeability, measured with *in-situ* moisture retained, increased from $3x10^{-3}$ md to 50 md. The vertical air permeability increased from $1x10^{-3}$ md to 30 md. Mechanisms for increasing porosity and permeability included fracturing, clay desiccation, and removal of organic material (as evidenced by scanning electron microscopy, SEM). Additional air permeability was created through the evaporation of *in-situ* moisture.

The heating process also affected soil texture. In areas exposed to at least 1100°F, the soil became solidified (to a siltstone) and ochre in color from an iron oxide grain coating observed in SEM dispersive images. The solidification of the silica grains may occur by sintering silicate minerals, particularly the clay minerals which are dispersed through the soil and bridge between particles. The iron oxide coating may also be contributing to cementing the grains together. Analysis by X-ray diffraction showed that thermal effects alter the structure of the clays from a crystalline to an amorphous state, reducing the measured values from about 12% illite/smectite volume to 8% amorphous clay material.

Soil samples were analyzed for total PCBs by EPA Method 8080 at ATAS Labs. Results of this sampling are given in **Table 2**. All samples were treated to below the site clean-up criteria of 2 ppm. Nearly all of the samples in the center treated area (0 to 10 ft) were treated to below the limits of method detection (<33 ppb). These results indicated no evidence of vertical or lateral migration of contaminants at the end of the test.

Additionally, soil samples were composited vertically and areally in the treated zone and analyzed for PCDD and PCDF by EPA Method 8280 at Triangle Labs in Durham, North Carolina. The vertical composite sample 0–10 ft at the center of the treated pattern was non-detect for PCDD/PCDF by EPA Method 8280. The 0–2 ft areal composite showed 0.00284 ppb toxic equivalent (TEQ), the 2–4 ft areal composite showed 0.00684 ppb TEQ, and the 4–6 ft areal composite showed 0.0033 ppb TEQ. These levels are well below the RCRA universal treatment standard of 1 ppb TEQ, and even below the background level of 8 ppt for uncontaminated soil in North America.

STACK SAMPLING

HCl emissions in the stack were used to select the period of peak emissions for the 30-hour stack sampling test. Effluent stack sampling by EPA Method 23/modified 680 and CEM demonstrated that the discharge of PCBs and combustion byproducts (PCDDs/PCDFs) was in compliance with the ambient air requirements prescribed by MODNR and USEPA 40CFR Part 266 Appendix V.

Continuous emission monitoring (CEM) showed the average stack composition contained about 20,000 ppm CO_2, 2 ppm CO, and 1 ppm THC. The peak HCl concentration in the stack was 60 ppm from the decomposition of the PCBs. The HCl concentration in the stack was found to be a good indicator of when the remediation process was complete.

AMBIENT AIR MONITORING RESULTS

Vacuum was maintained in the soil and in the vapor treatment equipment throughout the whole test. Organic vapor analysis of the ambient air around the demonstration area was performed periodically using NIOSH Method 5503 to check for leakage of contaminants. No PCB contaminants (<10 $\mu g/m^3$) were detected, and no odors were noticed at any time during the test.

SUMMARY

The principal results of the Cape Girardeau field demonstration are as follows:

1. About 500 watts/foot were initially injected into the clay soil at heater temperatures of 1600°F. Later in the process, as the soil dried, about 350 watts/ft could be injected.
2. After 42 days of heating with well spacing of 5 ft between triangular patterned wells, soil temperatures reached over 900°F at the center of all triangles and exceeded 1100°F in about half of that volume.

3. Sampling after 42 days showed complete clean-up of all contaminants to levels below 1 ppm to a depth of 10 feet below ground surface. Eighty-one samples in the treatment zone were non-detect (<33 ppb) by EPA Method 8080.
4. No evidence of vertical or lateral migration of contaminants was observed.
5. Stack testing of emissions from the process indicated 99.9999998% destruction removal efficiency (DRE) of the PCBs by combined *in-situ* and surface treatment. The sampling and analysis results of the Method 680 analysis performed on the stack samples indicates that a total of 0.10 mg of PCB were emitted from the MU-125 stack from a conservative estimate of 40 kilograms of PCB in the treated area.
6. Post-treatment soil samples composited vertically and areally from the treated zone were analyzed for PCDD and PCDF and exhibited TEQ levels from non-detect to 0.00684 ppb, with an average of 0.003 ppb. This is below the background level of 8 ppt for uncontaminated soil in North America.

In summary, the ISTD–Thermal Well technology was effective in achieving the site remediation goals of <2.0 ppm at all locations sampled within the well treatment zone. The Thermal Well technology volatilized, extracted, and effectively treated high concentrations of the highest-boiling-point PCBs from dense clay overburden soils without excavation. The discharge of PCBs and combustion by-products detected during stack testing activities conducted on the MU-125 treatment system during the demonstration confirmed that ambient air quality was not adversely impacted by the ISTD process.

ACKNOWLEDGMENTS

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6. Vinegar, H.J. et al: "Remediation of Deep Soil Contaminants Using Thermal Vacuum Wells," paper SPE 39291, 1997 SPE Annual Technical Conference, San Antonio, Texas, October 5–8.

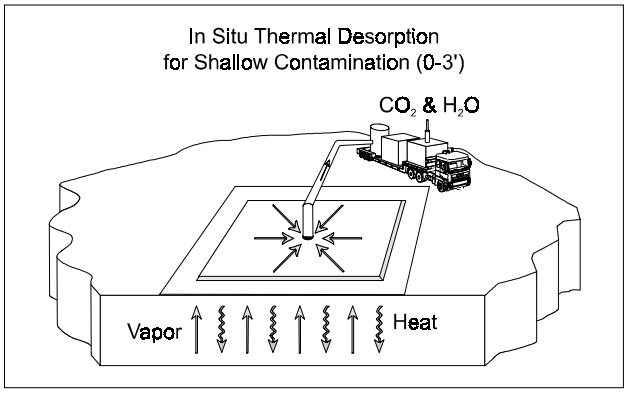

Figure 1a - ISTD-Thermal Blankets.

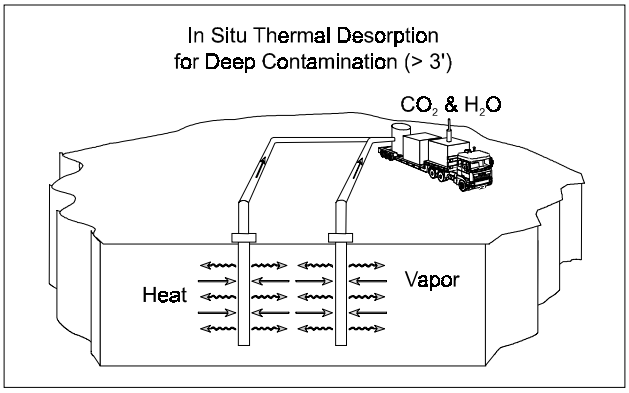

Figure 1b - ISTD-Thermal Wells.

CLIENT REFERENCES:

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REGULATORY AGENCY REFERENCES:

Donald Van Dyke, MODNR - Jefferson City, MO (573) 751-3176

Paulette France-Isetts, EPA Region VII - Kansas City, KS (913) 551-7701

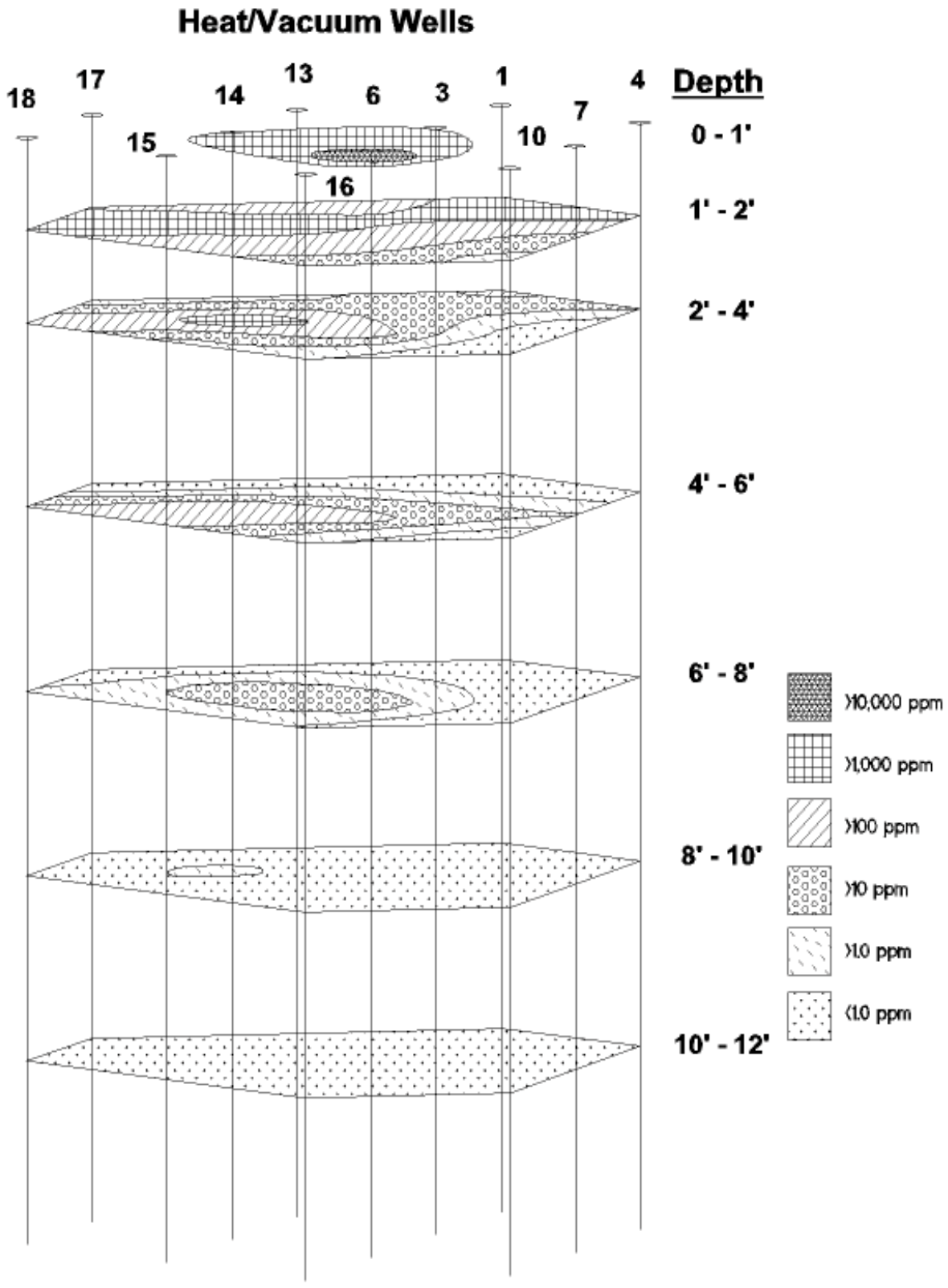
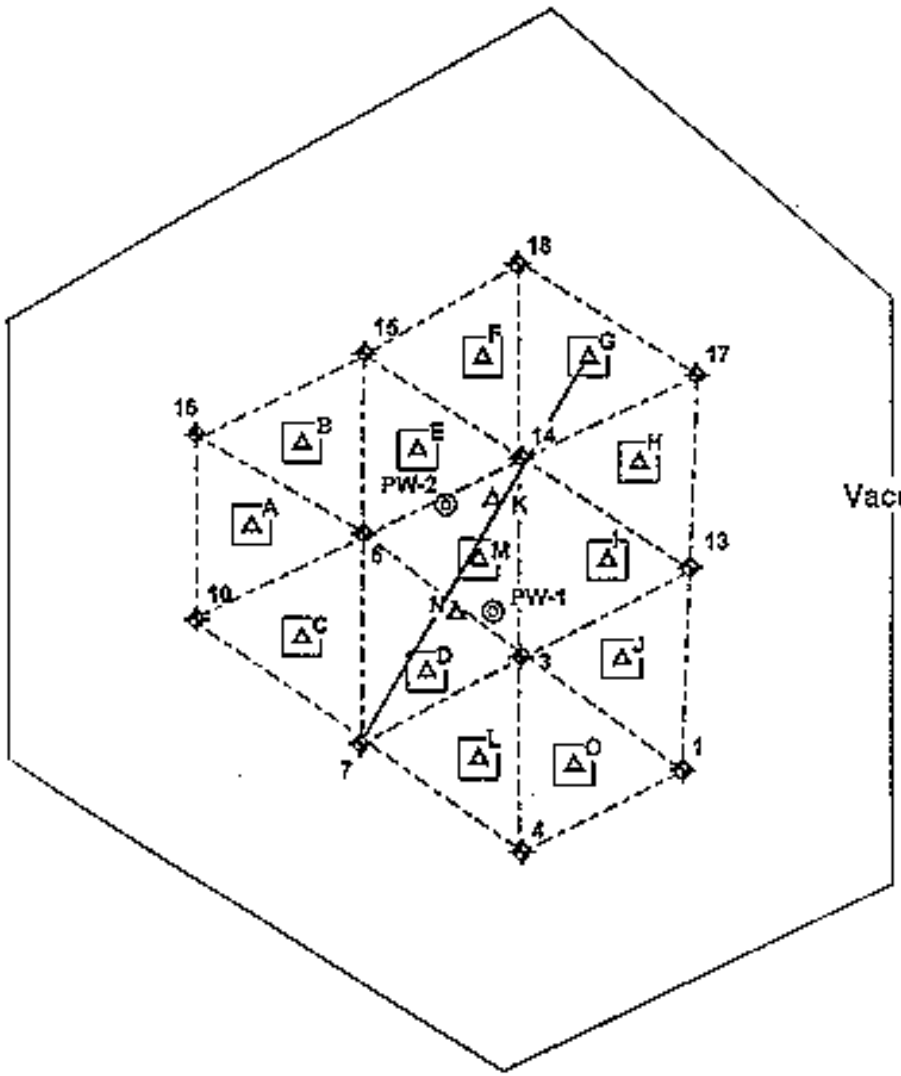


Figure 2.Contour values of initial PCB concentration

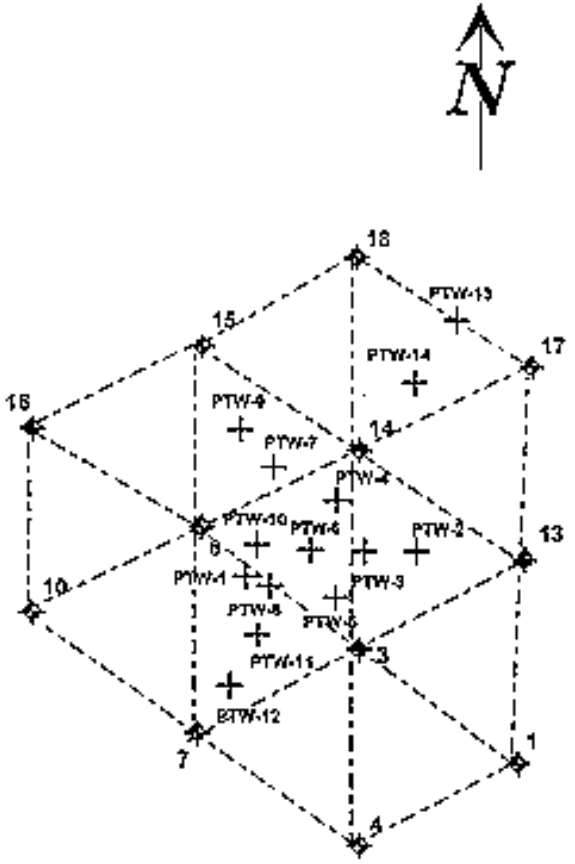
MEW - Cape Girardeau Demonstration

Thermal Well Pattern Layout

Figure 3



Vacuum Frame



Legend:

- 18 — Thermal Well
- C — Thermocouple Location
- PTW-13 — Post-Heat Sample Location
- BabyBlanket Location
- PW-1 — Pressure Monitor Well

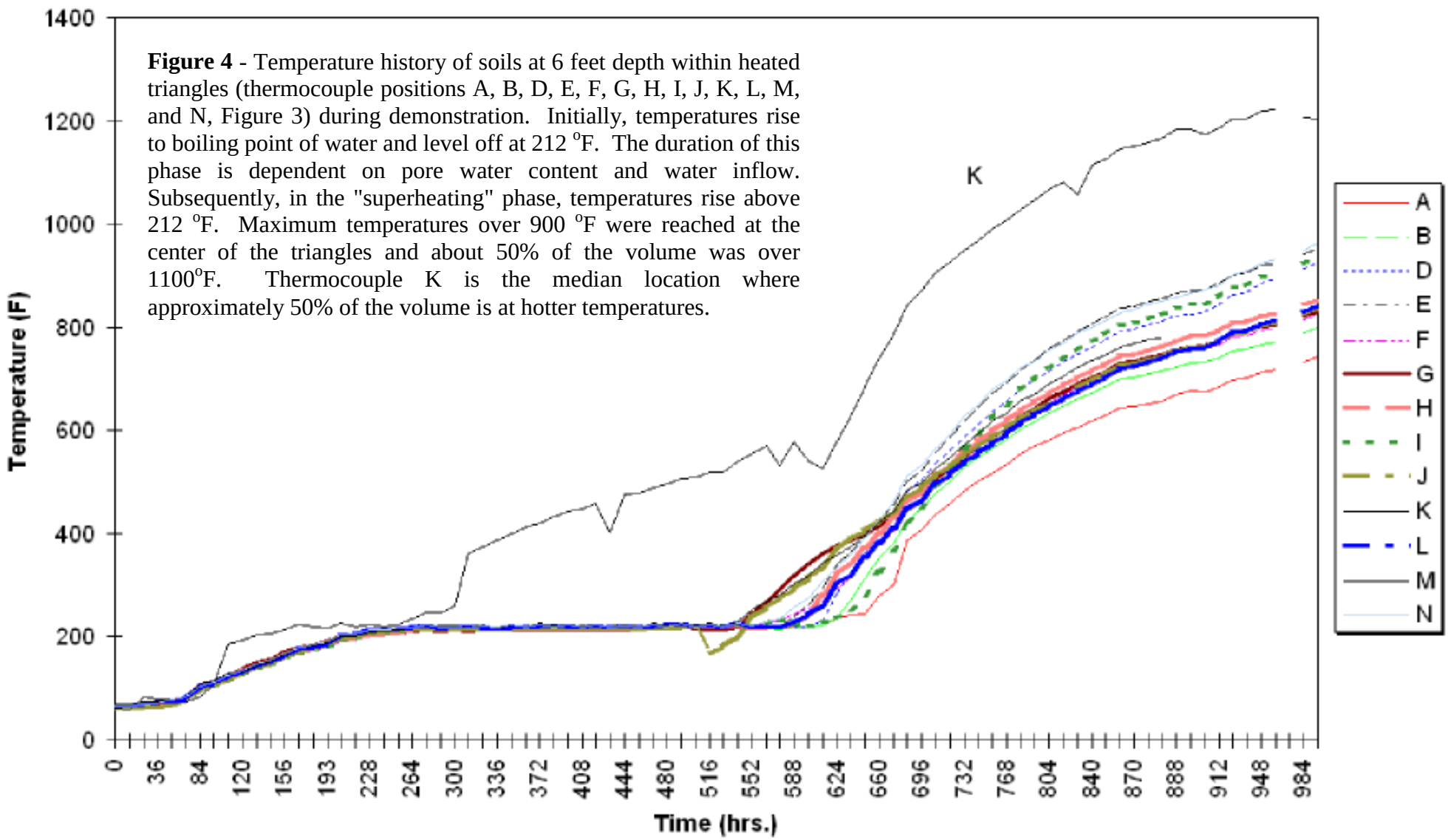
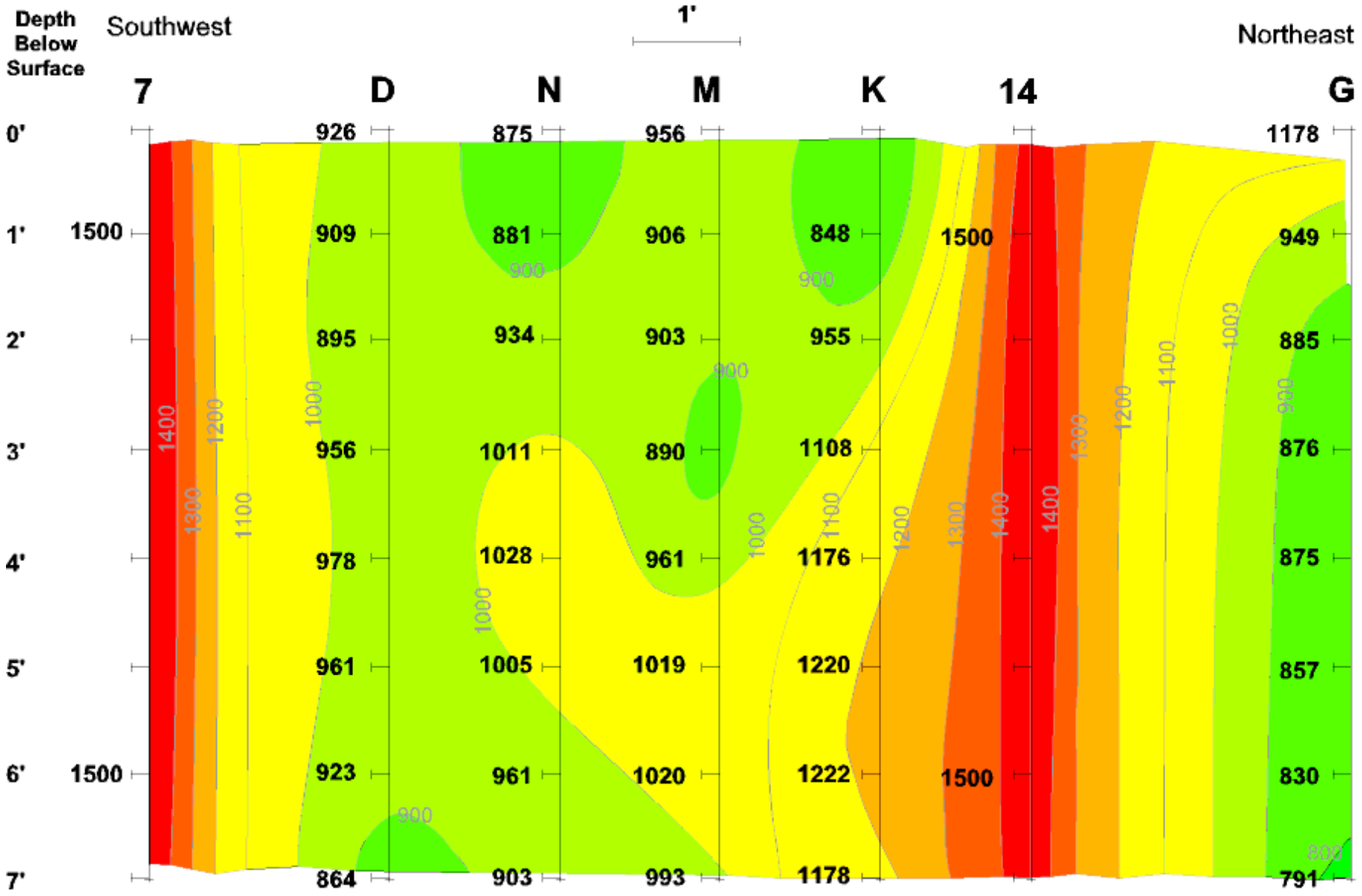


Figure 4 - Temperature history of soils at 6 feet depth within heated triangles (thermocouple positions A, B, D, E, F, G, H, I, J, K, L, M, and N, Figure 3) during demonstration. Initially, temperatures rise to boiling point of water and level off at 212 ^{o}F. The duration of this phase is dependent on pore water content and water inflow. Subsequently, in the "superheating" phase, temperatures rise above 212 ^{o}F. Maximum temperatures over 900 ^{o}F were reached at the center of the triangles and about 50% of the volume was over 1100^{o}F. Thermocouple K is the median location where approximately 50% of the volume is at hotter temperatures.

Figure 5.

Maximum Temperatures, Deg. F

Profile Through Well Pattern



CAPE GIRARDEAU, MO.
SOIL SAMPLE RESULTS SUMMARY

Table 1. Thermal Wells Pre-Demo Soil Sampling Results

Boring ID	Sample #	Depth (ft)	ATAS Lab Result PCB Concentration (ppm)	Boring ID	Sample #	Depth (ft)	ATAS Lab Result PCB Concentration (ppm)
TW-1	S1-A	0.0-2.0	1590	TW-13	S1	0.2-2.2	253
	S1-B	2.0-3.4	357		S2	2.2-4.2	2.23
	S2-A	3.4-5.4	<0.5		S3	4.2-6.2	0.099
	S2-B	5.4-8.1	<0.5		S4	6.2-8.2	NA
	S5	8.2-10.0	NA		S5	8.2-10.2	<0.50
	S6	10.0-12.0	13.5*		S6	10.2-12.2	<0.50
TW-3	S1-A	0.2-2.2	2190	TW-14	S1	0.2-2.2	4100
	S1-B	2.2-4.2	59.5		S2	2.2-4.2	1060
	S2-A	4.2-6.2	ND		S3	4.2-6.2	276
	S2-B	6.2-8.2	ND		S4	6.2-8.2	67.5
	S5	8.2-10.0	6.37*		S5	8.2-10.2	3.98
	S6	10.0-12.0	4.34*		S6	10.2-12.2	<0.50
TW-3T	S1	0.0-0.5	614	TW-14T	S1	0.0-0.5	9210
	S2	0.5-1.0	2970		S2	0.5-1.0	1450
	S3	1.0-2.0	16.5		S3	1.0-2.0	984
	S4	2.0-4.0	0.694		S4	2.0-4.0	1470
	S5	4.0-6.0	4.42		S5	4.0-6.0	134
	S6	6.0-8.0	2.32		S6	6.0-8.0	11.8
	S7	8.0-10.0	0.084		S7	8.0-10.0	<0.033
	S8	10.0-12.0	<0.033		S8	10.0-12.0	<0.033
	S9	12.0-14.0	<0.033		S9	12.0-14.0	<0.033
	S10	14.0-16.0	<0.033		S10	14.0-16.0	<0.033
TW-4	S1-A	0.2-2.2	3030/8030				
	S1-B	2.2-4.2	NA	TW-15	S1	0.2-2.2	93.8
	S2-A	4.2-6.2	0.913		S2	2.2-4.2	5.3
	S2-B	6.2-8.2	<0.50		S3	4.2-6.2	NA
	S5	8.2-10.0	0.418		S4	6.2-8.2	2.03
	S6	10.0-12.0	3.63*		S5	8.2-10.2	NA
TW-6	S1-A	0.2-2.2	299		S6	10.2-12.2	8.35*
	S1-B	2.2-4.2	393				
	S2-A	4.2-6.2	342	TW-16	S1	0.2-2.2	61.8
	S2-B	6.2-8.2	114		S2	2.2-4.2	NA
	S3-A	8.2-10.2	<0.50		S3	4.2-6.2	1.14
	S3-B	10.2-12.2	0.973		S4	6.2-8.2	NA
TW-6T	S1	0.0-0.5	19900		S5	8.2-10.2	3.11
	S2	0.5-1.0	2190		S6	10.0-12.0	1.22 (10.2)*
	S3	1.0-2.0	885				
	S4	2.0-4.0	234	TW-17	S1	0.0-0.5	93.7
	S5	4.0-6.0	46.2		S2	0.5-1.0	2530
	S6	6.0-8.0	5.33		S3	1.0-2.0	<0.50
	S7	8.0-10.0	0.061		S4	2.0-4.0	1.66
	S8	10.0-12.0	0.158		S5	4.0-6.0	<0.50
	S9	12.0-14.0	0.22		S6	6.0-8.0	<0.033
	S10	14.0-16.0	0.043		S7	8.0-10.0	0.146
					S8	10.0-12.0	<0.033
TW-7	S1-A	0.2-2.2	25.7		S9	12.0-14.0	1.27
	S1-B	2.2-4.2	<0.50		S10	14.0-16.0	0.395
	S2-A	4.2-6.2	11.4				
	S2-B	6.2-8.2	<0.50	TW-18	S1	0.0-0.5	9090
	S3-A	8.2-10.2	<0.50		S2	0.5-1.0	1690
	S3-B	10.2-12.2	<0.50		S3	1.0-2.0	762
					S4	2.0-4.0	450
TW-10	S1-A	0.2-2.2	2.39		S5	4.0-6.0	293
	S1-B	2.2-4.2	<0.50		S6	6.0-8.0	1.53
	S2-A	4.2-6.2	<0.50		S7	8.0-10.0	0.421
	S2-B	6.2-8.2	<0.50		S8	10.0-12.0	0.136
	S5	8.2-10.0	0.475		S9	12.0-14.0	0.051
	S6	10.0-12.0	<0.50		S10	14.0-16.0	<0.033

Table 2. Thermal Wells Post-Demo Soil Sampling Results

Boring ID	Sample #	Depth (ft)	ATAS Lab Result PCB Concentration (ppm)	Boring ID	Sample #	Depth (ft)	ATAS Lab Result PCB Concentration (ppm)
PTW-1	S1	0.0-0.5	<0.033	PTW-8	S1	0.0-0.5	<0.033
	S2	0.5-1.0	<0.033		S2	0.5-1.0	<0.033
	S3	1.0-1.5	<0.033		S3	1.0-2.0	<0.033
	S4	1.5-2.0	<0.033		S4	2.0-4.0	<0.033
	S5	2.0-2.5	<0.033		S5	4.0-6.0	0.036
PTW-2	S1	0.0-0.5	<0.033	PTW-9	S1	0.0-0.5	<0.033
	S2	0.5-1.0	<0.033		S2	0.5-1.0	<0.033
	S3	1.0-2.0	<0.033		S3	1.0-2.0	<0.033
	S4	2.0-4.0	<0.033		S4	2.0-4.0	<0.033
	S5	4.0-6.0	<0.033		S5	4.0-6.0	<0.033
	S6	6.0-8.0	<0.033		S6	6.0-8.0	<0.033
	S7	8.0-9.9	<0.033		S7	8.0-9.9	<0.033
PTW-3	S1	0.0-0.5	<0.033	PTW-10	S1	0.0-0.5	<0.033
	S2	0.5-1.0	<0.033		S2	0.5-1.0	<0.033
	S3	1.0-2.0	<0.033		S3	1.0-2.0	<0.033
	S4	2.0-4.0	<0.033		S4	1.0-2.0	<0.033
	S5	4.0-6.0	<0.033		S5	2.0-4.0	<0.033
	S6	6.0-8.0	<0.033		S6	4.0-6.0	<0.033
	S7	8.0-9.9	<0.033		S7	6.0-8.0	<0.033
					S8	8.0-9.9	0.302
PTW-4	S1	0.0-0.5	<0.033				
	S2	0.5-1.0	<0.033	PTW-11	S1	0.0-0.5	<0.033
	S3	1.0-2.0	<0.033		S2	0.5-1.0	<0.033
	S4	2.0-4.0	NS		S3	1.0-2.0	<0.033
					S4	1.0-2.0	<0.033
PTW-6	S1	0.0-0.5	<0.033		S5	2.0-4.0	<0.033
	S2	0.5-1.0	<0.033		S6	4.0-6.0	<0.033
	S3	1.0-2.0	<0.033		S7	6.0-8.0	<0.033
	S3 DUP	1.0-2.0	<0.033		S8	8.0-9.0	<0.033
	S4	2.0-4.0	<0.033		S9	9.0-9.9	<0.033
	S5	4.0-6.0	<0.033				
	S6	6.0-8.0	<0.033	TW-12	S1	0.0-0.5	<0.033
	S7	8.0-10.0	<0.033		S2	0.5-1.0	<0.033
	S8	10.0-12.0	<0.033		S3	1.0-2.0	<0.033
	S9	12.0-13.5	<0.033		S4	1.0-2.0	<0.033
	S10	13.5-14.0	0.072		S5	2.0-4.0	<0.033
	S11	14.0-15.5	<0.033		S6	4.0-6.0	<0.033
					S7	6.0-8.0	<0.033
PTW-7	S1	0.0-0.5	<0.033		S8	8.0-9.9	<0.033
	S2	0.5-1.0	<0.033				
	S3	1.0-2.0	<0.033	TW-13	S1	0.0-0.5	0.045
	S4	2.0-4.0	<0.033		S2	0.5-1.0	0.045
	S5	4.0-6.0	<0.033		S3	1.0-2.0	0.042
	S6	6.0-8.0	<0.033		S4	2.0-4.0	<0.033
	S7	8.0-9.9	0.168		S5	4.0-6.0	<0.033
					S6	6.0-8.0	<0.033
					S7	6.0-8.0	<0.033
				PTW-14	S1	0.0-0.5	<0.033
					S2	0.5-1.0	<0.033
					S3	1.0-2.0	<0.033
					S4	1.0-2.0	<0.033
					S5	2.0-4.0	<0.033
					S6	4.0-6.0	<0.033
					S7	6.0-8.0	<0.033
					S8	8.0-9.9	<0.033

NOTES:

1. NA denotes that sample analysis results are not available at this time.
2. NS indicates no sample was collected.
3. Samples taken at locations of thermal wells, e.g., TW-1 as shown on Figure 3.
4. "T" denotes twinned geoprobe location.
5. * Split spoon sample, possible contamination from shallow cavings
6. PTW-8 samples were collected adjacent to the PTW-1 location.