Numerical Calculations of Heating Solvents Recovery Services of New England (SRSNE) Southington, Connecticut

Prepared for:

SRSNE Site Group

April 2010

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1.0 INTRODUCTION

The purpose of the water and energy balance calculations is to investigate the importance of groundwater flux, heater spacing, power input, heater boosting, and thickness of vapor cover for the temperatures that can be achieved in-situ. Calculation output includes sizing parameters for the thermal treatment system.

A water and energy balance has been developed by TerraTherm to estimate the addition, removal, and loss of energy in each layer of the site separately, with the layers exchanging both fluids (water, steam, air) and energy along their boundaries. The calculations also estimate crucial heat losses along the top, sides, and bottom of the treatment zone, and the impact of groundwater flow into the treatment area, such that relatively accurate total energy demands are derived.

These water and energy balance calculations are referred to in the following sections as the “calculations.”

The result of the calculations will be used to select the heating approach and for sizing of the off-gas treatment system.

In the following sections the basic calculation setup is described along with the results of the conducted water and energy balance calculations.

2.0 MODEL SETUP

2.1 Description of Calculations

The calculations are based on simplified mass and energy balance principles relevant for ISTD operation. The calculations can include up to 9 layers, each with different input and derived parameters, including:

- Surface area of the treatment zone
- Depth of each calculation layer
- Area of perimeter of each calculation layer
- Porosity of each calculation layer
- Initial water saturation in each calculation layer
- Initial bulk density for each calculation layer
- Initial heat capacity for each calculation layer
- Initial thermal conductivity for each calculation layer

During the calculations, parameters such as thermal conductivity and heat capacity are changed automatically based on the water saturation of each layer, This means, for instance, that as a zone is drying out due to boiling and steam removal, the water saturation is reduced, and therefore both the heat capacity and thermal conductivity are reduced, such that only the remaining water contributes to these parameters. This gives a more realistic heating prediction than if constant values are assumed.

Figure 2.1 shows a schematic cross-section of the calculation setup for the SRSNE Site.

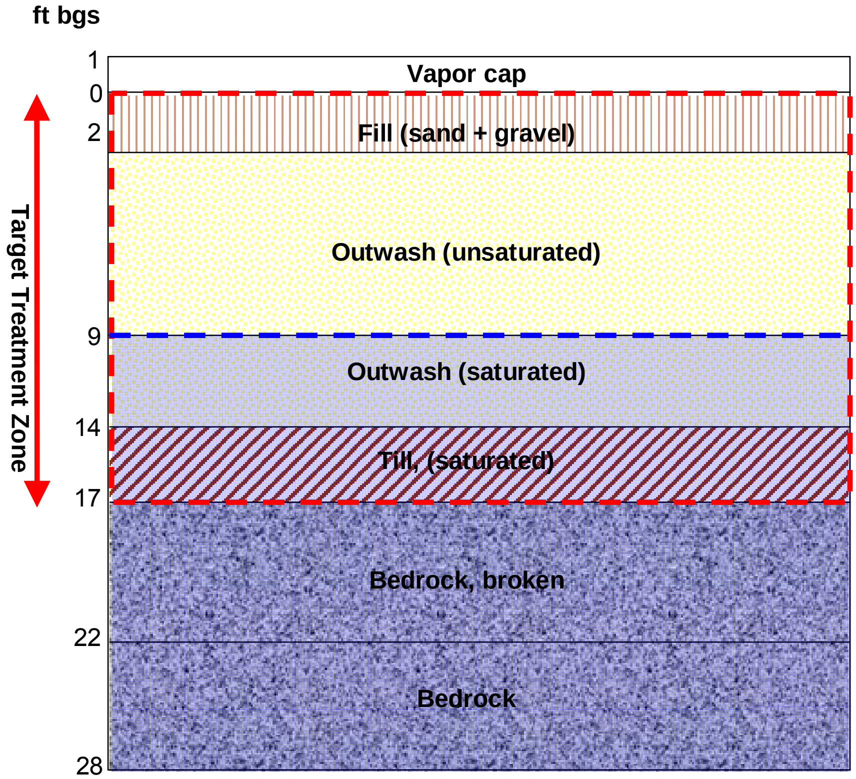

Figure 2.1. Schematic Cross-Section of the Calculations Setup for the SRSNE Site.

2.1.1.1 Water Mass Balance Methods

For each layer, the water mass balance is calculated as follows:

$M_{\text{net extraction}} = M_{\text{out, liquid}} + M_{\text{out,vapor}}$

Where M denotes cumulative water masses. Note that no fluids are injected when using the ISTD technology.

The mass removal in the liquid form is a simple summation of flow rate measurements:

$M_{out,\ liquid} = \Sigma\ (m_{liquid} \times \Delta t)$

Where the values for the flow rate m_{liquid} is determined manually for each operational phase.

For this site, small amounts of entrained liquids are expected in the vapor extraction system. No pumping wells are included in the design.

Influx of groundwater in the calculations are based on numbers from the site-specific groundwater model provided by ARCADIS and as used in the Heat Dissipation Model /Ref. 1/.

The water mass removal in the form of vapor (steam, water vapor) is calculated as follows:

$M_{out,vapor} = \Sigma\ (m_{steam} \times \Delta t) = \Sigma\ (m_{total\ vapor} - m_{non\text{-}cond}) \times \Delta t$

Where m_{steam} is the vapor flow rate made up of steam, $m_{total\ vapor}$ is the total incoming vapor flow rate, and $m_{non\text{-}cond}$ is the vapor flow rate minus the steam component (air mostly).

For these calculations, the steam extraction rates are calculated based on the energy injected by the ISTD system. The equation calculating the ratio between injected energy and extracted steam is derived based on observations made on several recent full-scale ISTD projects. Figure 2.2 illustrates the streams that take part in the water mass balance in the Heated Zone (HZ).

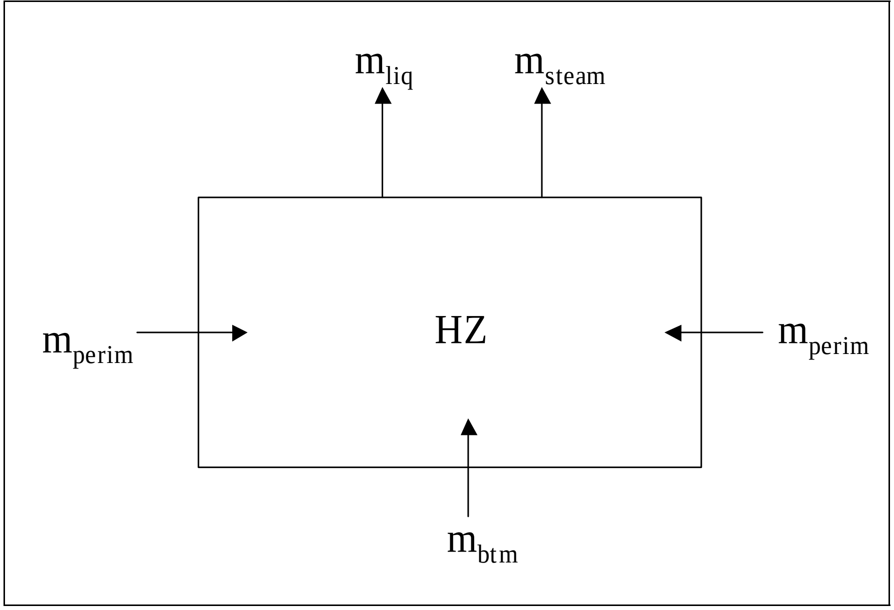

Figure 2.2. Mass Balance Principles for Water (One Layer Shown for Simplicity).

Total water extraction rates are estimated by the sum of the measured flows:

$m_{extraction} = m_{liquid} + m_{steam}$

The calculations keep track of the volume or mass of water stored in each layer, based on extracted water and estimates for the influx of water from the sides, bottom, and top by infiltration (the perimeter and bottom arrows shown on Figure 2.2).

$M_{present,\ t1} = M_{present,\ t0} - M_{liquid} – M_{steam} + M_{bottom} + M_{perimeter}$

Where M denotes cumulative water masses.

The quantity of water removed from the subsurface is readily measured during operations. Therefore, this quantity can be compared to a relatively accurate estimate of the pre-treatment quantity of water within each layer in the vadose zone, based on values of porosity and saturation for the different zones below the vapor cap and to the water table.

Water entering the model domain in the saturated zone and not extracted as steam will leave the site on the down gradient edge of the Heated Zone. The energy carried away by the heated water is included in the calculations.

For the SRSNE-Site it will be assumed that the surface cover is intact and graded to promote runoff to minimize any standing surface water thus reducing the potential for infiltration from the top through the vapor cover.

2.1.1.2 Energy Balance Estimation Methods

Cumulative energy (E) is calculated as a summation of enthalpy fluxes (Q):

$$E = \Sigma (Q \times \Delta t)$$

An estimated energy balance is maintained for each layer in the calculations based on energy delivered by the ISTD-heaters, energy extracted in the vapor and liquid streams and heat loss to the areas outside of the Heated Zone (HZ).

$E_{in} = E_{out} + E_{storage} + E_{loss}$

The energy fluxes are related for each time step as follows:

$Q_{in} = Q_{out} + Q_{storage} + Q_{loss}$

Where Q denotes enthalpy flux (in BTU/hr). Figure 2.3 shows the schematic energy balance for one layer.

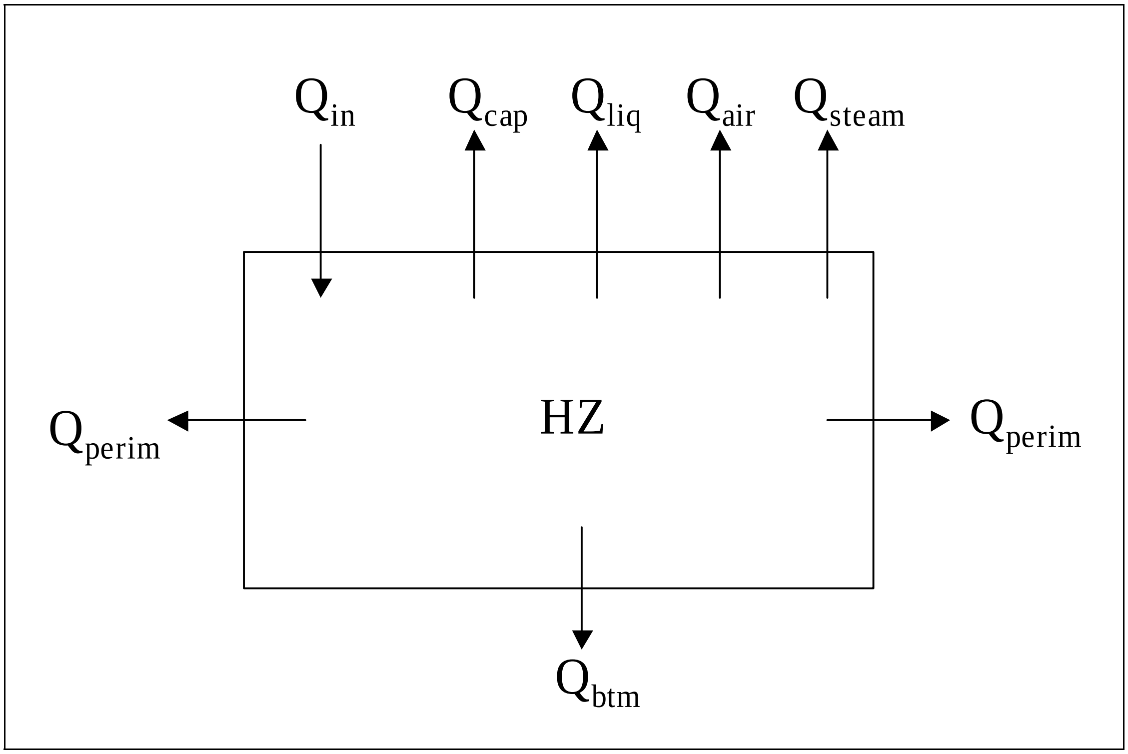

Figure 2.3. Energy Balance Schematic (One Layer Shown for Simplicity).

The estimate for Q_{in} will be based on ISTD energy input. The need for boosting heaters is addressed in the basic calculations layout. By boosting the heaters it will be possible to deliver more energy in layers difficult to heat.

The total energy removal from each layer is estimated as follows:

$Q_{out} = Q_{liq} + Q_{non\ cond.\ gas} + Q_{steam\ out}$

The energy flux in the extracted liquid is given by:

$Q_{liq} = m_{liquid} \times cp_{,\ water} \times (T - T_0)$

Where cp is heat capacity, and T_0 is the ambient temperature.

For the extracted vapor stream, the energy flux in vapor and steam is estimated as follows:

$Q_{non\ cond.\ gas} = m_{air} \times cp_{,\ air} \times (T - T_0)$

$Q_{steam\ out} = m_{condensate} \times \Delta H_{steam\text{-}ambient}$

Where m is mass flux, H is specific enthalpy (in BTU/lb), cp is heat capacity (in BTU/lb/F), and T is temperature. The enthalpy of the steam can be estimated from steam tables.

The actual heat loss cannot be calculated using accurate measures. An estimate can be made based on thermal profiles at the bottom and top of each layer, and along the perimeter, using the following equation:

$Q_{\text{heat loss}}$ = A x KT x dT/dz

Where A is the surface area through which energy is conducted, KT is the thermal conductivity of the subsurface material, and dT/dz is the temperature gradient across the surface also expressed as $(T_1-T_2)/(z_1-z_2)$.

For the loss through the vapor cap, the temperature difference between the top and bottom of the layer can be used to calculate the gradient. For the calculations, it is assumed that the top of the vapor cap remains near ambient temperatures due to a combination of wind cooling, ventilation, and simple heat radiation. The area of the heated zone may be estimated based on the zone designated HZ, which is slightly larger than the footprint of the wells due to the heat migration outside.

Heat loss through the bottom and sides are accounted for in a similar manner. The layers exchange energy by thermal conduction such that energy leaves the warmer layer and enters the cooler layer.

All heat migration through the sides and through the vapor cap and the bottom layer are considered lost from the calculation domain. Heat migration from the bottom of a layer and into the top of the underlying layer remains as energy in the calculations if both layers are in the heated zone.

In the calculations average layer temperatures are calculated based on the energy balance and the estimated heat capacity of each layer. The stored energy is related to the heated zone heat capacity, and the average temperature as follows:

$E_{storage} = Cp \ \text{x} \ (T_{avg} - T_0) + m_{steam} \ \text{x} \ 6H_{steam\text{-}ambient}$

Where $Cp_{,site}$ is the overall heat capacity of the heated layer, estimated from the volume, saturation, and specific heat capacity of the soil and water:

$Cp = V_{soil} \ \text{x} \ cp_{, soil} \ \text{x} \ V_{water} \ \text{x} \ cp_{, water}$

The steam energy stored as a vapor at any given time is relatively small, and will be neglected in the calculations. For comparison with the measured temperatures, the energy balance can be used to estimate the average temperature ($T_{energybal}$) of the heated volume:

$T_{energybal} = T_0 + Es_{torage}/Cp_{,site} = T_0 + (E_{in} - E_{out} - E_{loss})/ Cp_{,site}$

The steam energy stored as a vapor at any given time is relatively small, and will be neglected in the calculations.

3.0 SITE-SPECIFIC CALCULATIONS SET UP

3.1 Treatment Area and Volume

The thermal treatment area at SRSNE is divided into three regions (Area 1, Area 2 and Area 3) as shown in Figure 3.1. Area 1 represents the shallow western portion of the Target Treatment Zone (TTZ), Area 2 represents the intermediate middle portion of the TTZ, while Area 3 represents the deeper eastern portion of the TTZ. The treatment depth in the three areas is 12 feet, 15 feet and 21 feet respectively.

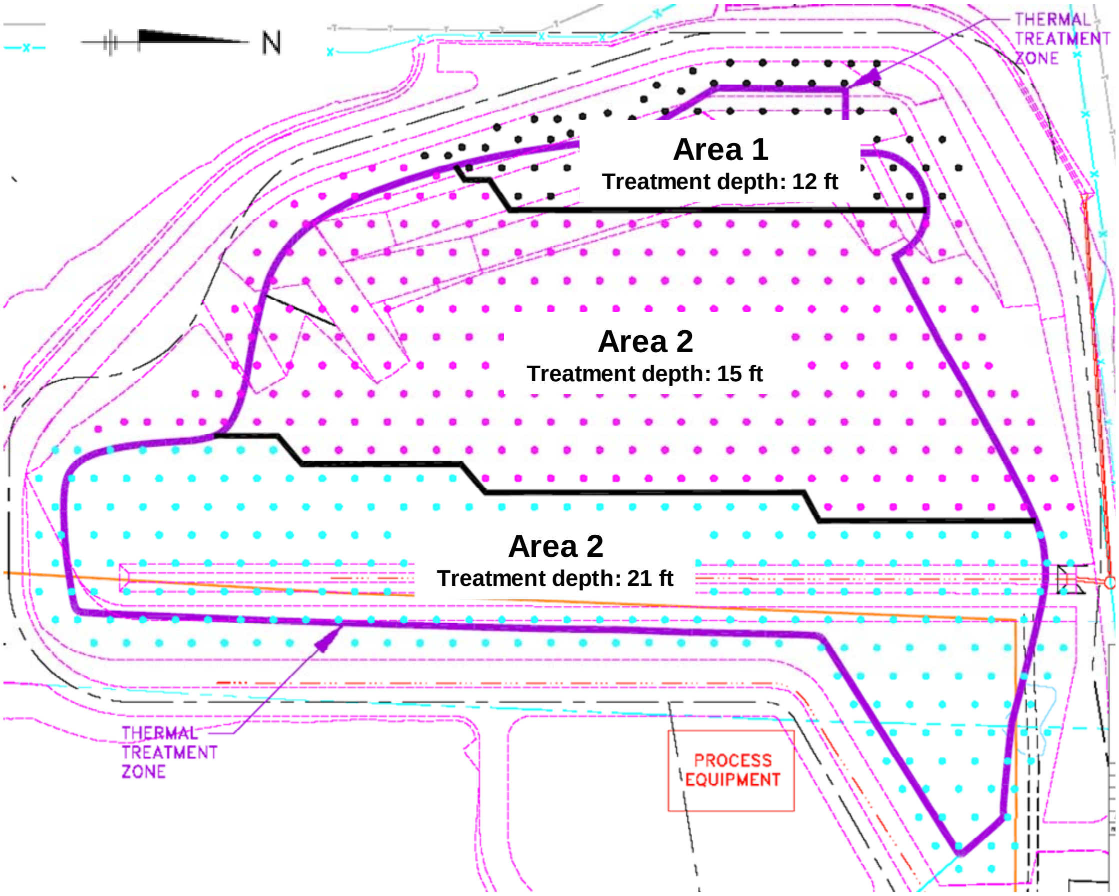

Figure 3.1. Thermal Treatment Areas at SRSNE.

For simplicity, the calculations have been set up based on average depths across the entire TTZ. This simplification is not considered to affect the calculation results significantly since the important parameters for the mass and energy balances is the area and volume of the heated zone.

Table 3.1 presents the estimated thermal treatment area and volume.

Table 3.1. Area and Volume of the Thermal Treatment Zone.

Location	**Treatment Area [ft^2]**	**Treatment Depth [ft]**	**Treatment Volume [cy]**
Area 1	6,855	12	3,047
Area 2	36,560	15	20,311
Area 3	30,780	21	23,940
Total	**74,195**		**47,298**

The average treatment depth is calculated to be 17 feet based on the areas and volumes shown in Table 3.1.

3.2 Calculations Layers

In the calculations, the TTZ was divided into nine layers based on the predominant geological properties of the formation present at the site, water saturation and the contaminant distribution. Layers 2 through 6 in the model are all within the TTZ, while the remaining layers are outside of the TTZ. Layer 1 represents the surface cover, while layers 7-9 represent the bedrock underlying the thermal treatment zone. Layers 5-9 are all considered to be initially saturated in the calculations. The layers and general geology in the calculations are shown in Figure 3.2.

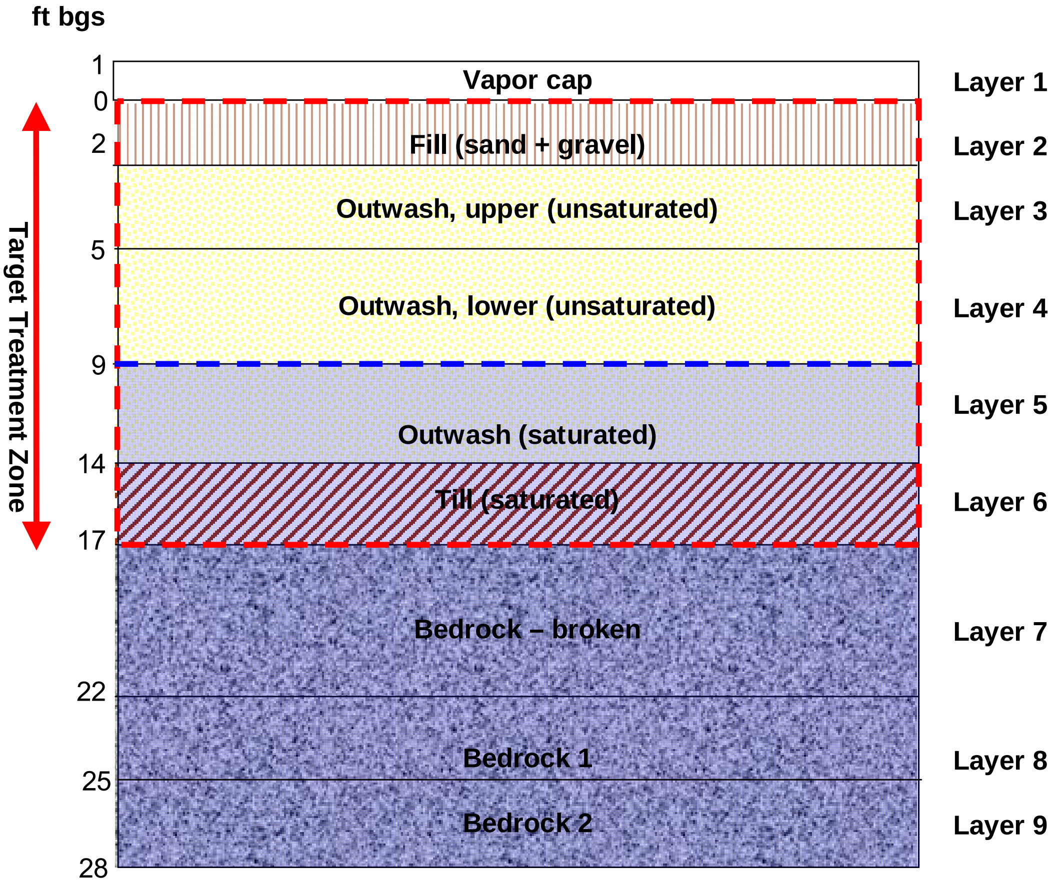

Figure 3.2. Calculation Layers and Geology.

3.2.1 Input Parameters for Calculations

Input values of porosity, initial saturation and ambient temperature for the model layers appear in Table 3.2. These values serve as the starting basis for the energy balance calculations conducted in the model.

Table 3.2. Porosity, Initial Saturation and Ambient Temperature for Each Layer in the Treatment Zone.

Layer	Geology	Top [ft]	Bottom [ft]	Thickness [ft]	Porosity [-]	Initial saturation [-]	Ambient temp [°F]
Layer 1	Vapor cap	+1.0	0.0	1.0	0.01	0.1	59
Layer 2	Fill, sand, gravel	0.0	2.0	2.0	0.275	0.5	59
Layer 3	Outwash, upper (unsaturated)	2.0	5.0	3.0	0.275	0.7	59
Layer 4	Outwash, lower (unsaturated)	5.0	9.0	4.0	0.275	0.8	59
Layer 5	Outwash (saturated)	9.0	14.0	5.0	0.275	1.0	59
Layer 6	Till (saturated)	14.0	17.0	3.0	0.275	1.0	59
Layer 7	Bedrock, weathered	17.0	22.0	5.0	0.077	1.0	59
Layer 8	Bedrock 1	22.0	25.0	3.0	0.077	1.0	59
Layer 9	Bedrock 2	25.0	26.0	3.0	0.077	1.0	59

Porosity and saturation throughout the various layers of the TTZ may vary within the individual layers.

3.2.2 Heat Capacity

Table 3.3 provides a summary of the heat capacity in the modeled zones.

Table 3.3. Volume and Heat Capacity.

Heat Capacity	Number	Unit
Total volume, TTZ	47,298	cy
Solids volume	34,311	cy
Air volume	2,063	cy
Water volume	10,924	cy
Soil weight	152,786,000	lbs soil
Water weight	18,396,000	lbs water
Soil heat capacity	38,197,000	BTU/F
Water heat capacity	18,396,000	BTU/F
Total heat capacity, TTZ	56,593,000	BTU/F

While the soil within the TTZ comprises nearly nine times the weight of the water within the TTZ, the heat capacity of the water in the TTZ is nearly half of that of the soil. Thus, it is apparent that the heat capacity of the water in the TTZ and therefore the flux of water moving through the TTZ are critical considerations in the design of the thermal remediation system.

3.3 Duration

In order to spread out the VOC loading on the vapor treatment system, a phased approach was chosen where 50% of the well-field is operated for the first 60 days, then the remaining 50% of the well-field is turned on. This sequence is shown in Figure 3.3.

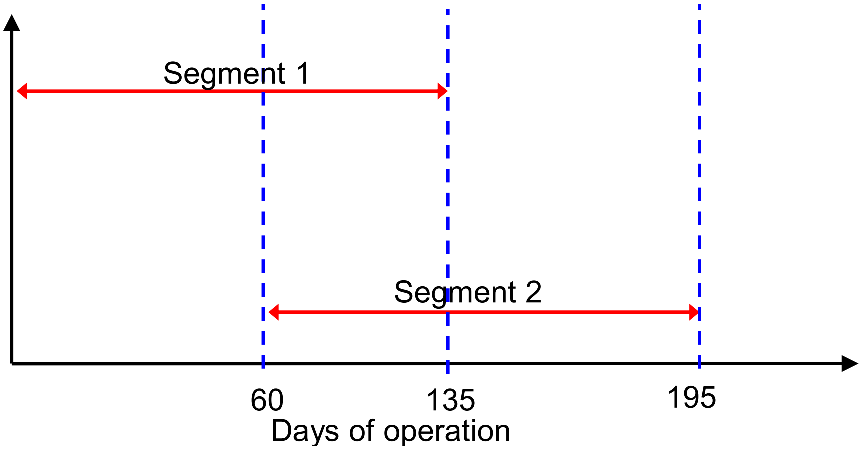

Figure 3.3. Phased operation. Each segment represents 50% of the treatment volume.

Each segment is operated for 135 days with a total operations period of 195 days. The sequences shown in Figure 3.3. have been included in the calculations.

3.4 Heater Numbers and Boosting

The amount of energy added to the treatment area in the calculations appears in Table 3.4. All heaters extend 3 feet below the TTZ. All heaters are boosted at the bottom in the base case to allow more energy to be supplied in the deep part of the TTZ. The boosted section is 5 feet in Area 1 and 6 feet in Area 2 and Area 3.

Table 3.4. Heater numbers, depth and boosted section in base case calculation.

Location	**Heater count [-]**	**Heater depth [ft]**	**Heater boosting per heater [ft]**
Area 1	80	15	5
Area 2	262	18	6
Area 3	251	24	6
Total	**593**		

The boosted section of the heater delivers 435 W/ft while the remaining part delivers 300 W/ft.

Based on the numbers above the average heater length has been calculated to be 20 feet while the average boosted heater length is 5.9 feet.

3.5 Groundwater Influx

For the base case, a water influx of 10 gpm was assumed. This value corresponds to the base case scenario in the Heat Dissipation Model described in /Ref. 1/.

The water is assumed to flow only into the saturated part of the treatment zone (layer 5 and 6 in the model). The amount of water flowing into each layer is distributed based on the thickness of each of the two layers. In the base case 6.25 gpm is flowing into Layer 5 while 3.75 gpm is flowing into layer 6.

Layer 7 only receives an inflow of groundwater corresponding to the amount of water extracted as steam from the layer.

4.0 RESULTS – BASE CASE

This section presents the result of the base case scenario. Two calculations were conducted.

The first calculation is performed on a single of the two segments to simulate the predicted average heat up of each layer in the TTZ as a function of time. The duration of the heating is 135 days in the calculation corresponding to the actual predicted operation time for each of the two segments.

The second calculation is completed for the entire site with phased operation corresponding to a total duration of 195 days. The results from this calculation provide design numbers for the overall ISTD system design.

In the base case the following input parameters are applied:

- Heater spacing 15 feet, corresponding to a total of 593 heaters
- Heaters extend 3 feet into the bedrock
- Vapor cap thickness is 1 feet. Thermal conductivity for the cap is 0.15 W/m*K.
- 10 gpm horizontal influx of groundwater into the treatment area. No vertical influx.
- Heaters are boosted at the bottom. Boosted output is 435 W/ft compared to the regular heater output at 300 W/ft.

4.1 Heating of Each Segment

The heat-up and boiling of soil pore water occur simultaneously as the heat front moves away from the ISTD heater wells. The last regions to boil and achieve sufficient steam stripping and contaminant removal are the coolest locations within the TTZ, which typically correspond to the mid-points between the ISTD wells, termed “centroid” locations. Figure 4.1 shows the predicted average temperature in each segment as a function of time.

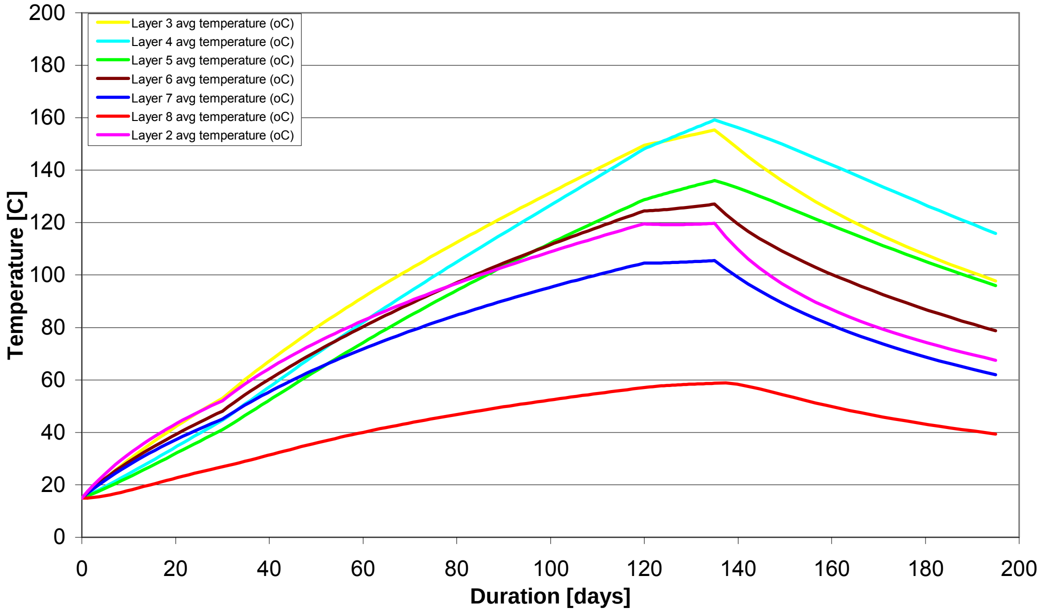

Figure 4.1. Average Temperature Curves for Layer 2 to Layer 8 for a Segment.
(Note: Layer 7 and 8 are both outside the TTZ)

The results of the calculations indicate that the entire TTZ (layers 2 through 6) reaches average temperatures between 120°C and 160°C during the 135 day treatment period. The temperature reflects that the areas close to the heaters may reach temperatures above the boiling point due to drying-out.

The upper part of the TTZ (layer 2) and the lower part (layers 5 and 6) have the lowest average temperatures (approximately 120 to 135°C) and are the last to achieve target temperature. This is due to the higher heat loss at the upper and lower boundary of the layer compared with the remainder of the treatment zone and for layers 5 and 6 due to cooling from the groundwater flowing into the treatment area. However, the simulation results indicate that these areas will achieve the target treatment temperature after approximately 85-90 days of operation.

The calculations indicate a maximum average temperature in layers 3 and 4 (unsaturated outwash) of up to 160°C.

Figure 4.2 depicts the temperature profiles at 25-day increments during operation including the final temperature at day 135 of operation, using the average temperature for each layer. Figure 4.3 shows the same plot, but with temperatures corrected for the local boiling points, which represents the temperatures achieved at the centroid locations.

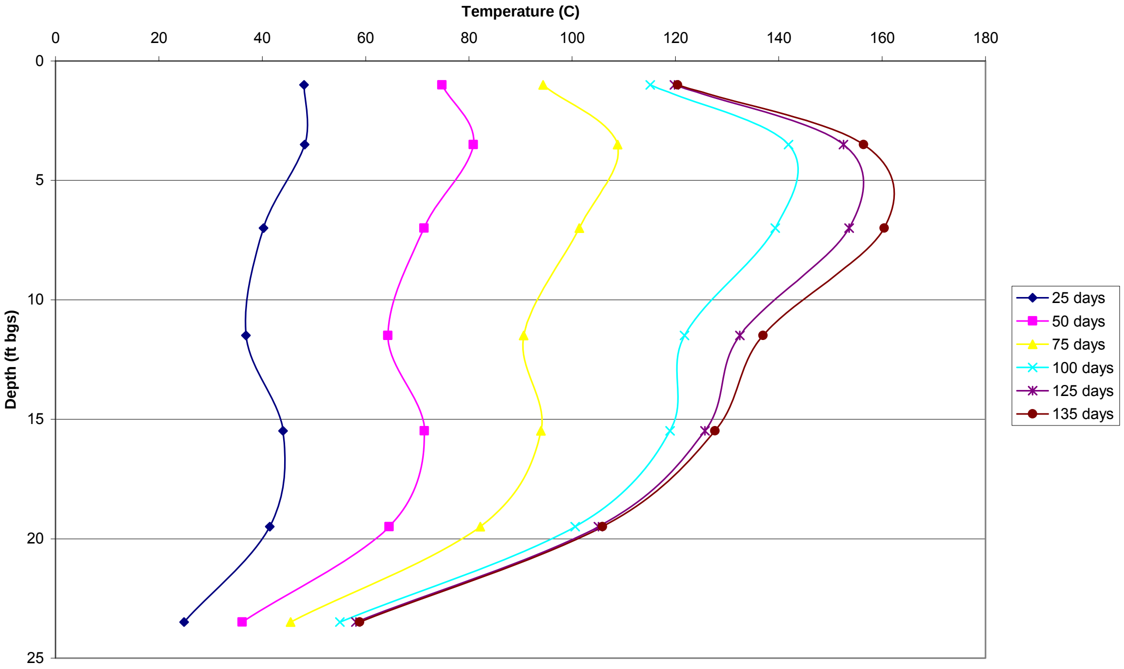

Figure 4.2. Average Temperature Profiles for a Segment.

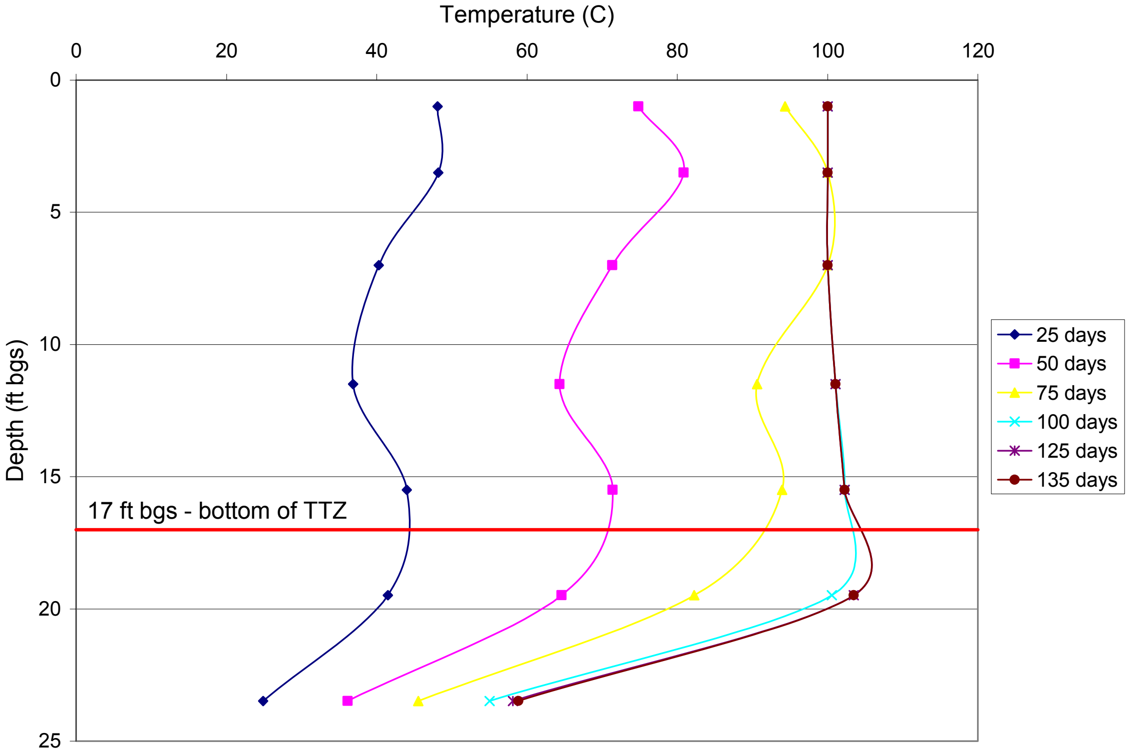

Figure 4.3. Average Temperature Profiles at Coolest Locations (Centroids) for a Segment.

Note that the heating progresses fastest in unsaturated zone from 2 to 9 ft bgs (the unsaturated outwash).

Figure 4.4 shows the calculated saturations for each layer during the thermal operations.

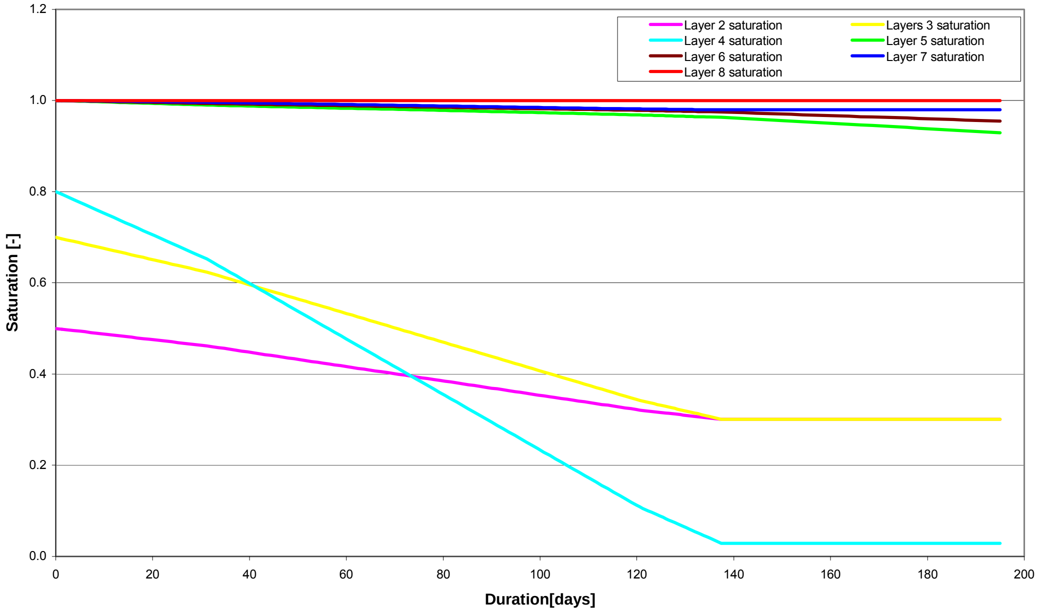

Figure 4.4. Average Saturation for a Segment.

Note that all zones below the water table stay relatively wet since inflowing groundwater will re-saturate zones where a substantial amount of steam is produced and removed. The unsaturated zone (layers 2 through 4) is predicted to reach low saturations during the thermal treatment due to the water removed a steam without substantial recharge by inflowing water.

4.2 Heating of Entire Site

The following sections show average temperatures and saturations for the entire site, taking into account that the two segments do not operate simultaneously during operation. These numbers are not important with respect to the remedy in each segment but indicate what average treatment temperatures to expect during the 195 days operation period.

Figure 4.5 shows the predicted average temperature for the entire site as a function of time.

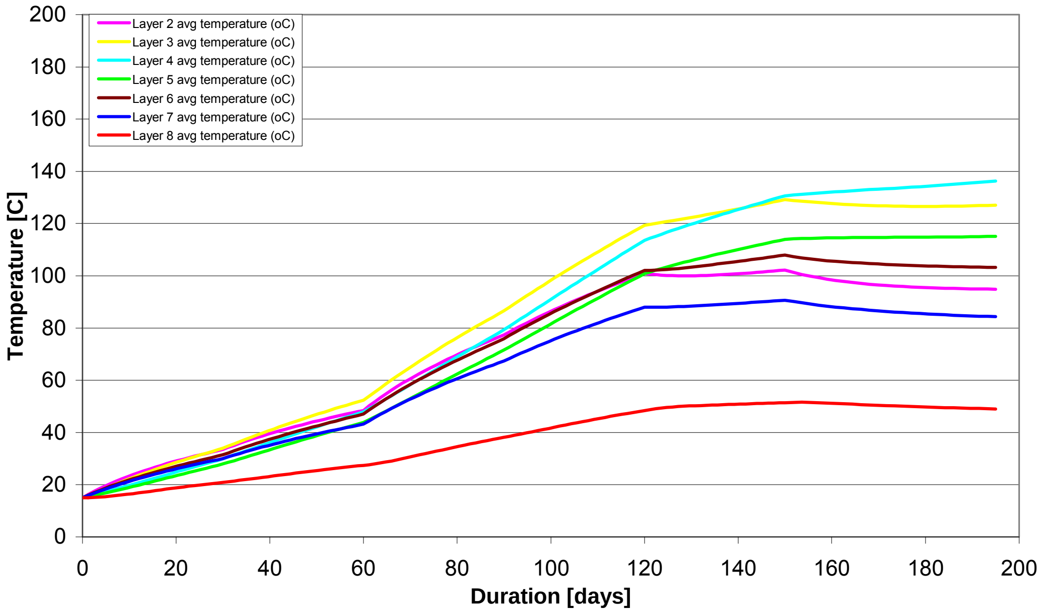

Figure 4.5. Average Temperature Curves for Layer 2 to Layer 8 for a Segment.
(Note: Layers 7 and 8 are both outside the TTZ.)

The calculations indicate that all layers in the TTZ (layers 2 through 6) reaches average temperatures above 100°C.

Figure 4.6 shows the calculated average saturations for each layer of the entire site during the thermal operations.

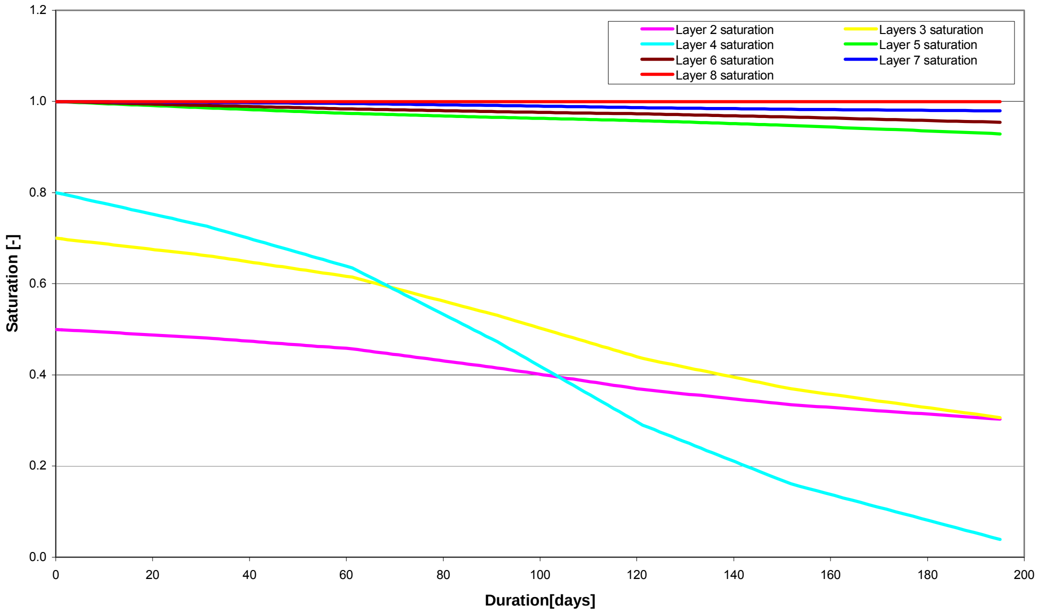

Figure 4.6. Average Temperature Profiles at Coolest Locations (Centroids) for a Segment.

The final saturation for each layer in the calculation for the entire site is the same as indicated in Figure 4.4. The only difference is that the saturation decreased slower due to the longer operation period.

4.3 Basic System Design Parameters

Based on the conducted calculations for the staged operation of the two segments, key numbers for sizing of the thermal treatment system and the ISTD system were obtained.

4.3.1 Process Equipment

Tables 4.1 and 4.2 below present design parameters and effluent discharge estimates resulting from the calculations.

Table 4.1. Process Equipment

Process Equipment	Estimate Based on Model	Units
ISTD power supply, max	4,052	kW
Non-condensable vapor, max	1,300	scfm
Condensable vapor (steam), max	5,386	lbs/hr
Condensed liquid rate, max	10.8	gpm

Based on the calculated values, the vapor treatment system is designed to treat a minimum of 1,300 scfm of non-condensable vapor plus a minimum of 5,386 lbs of steam/hr. The liquid treatment system is designed to treat a minimum of 10.8 gpm of condensate.

Table 4.2 shows the predicted water and vapor extraction rates and quantities.

Table 4.2. Water and Vapor Extraction Rates and Total Volumes

		Water		Vapor extracted	
	Days	Average Rate gpm	Total Volume Gallons	Rate SCFM	Total volume Million CF
Period 1	30	4.2	181,000	650	28
Period 2	30	5.4	233,000	650	28
Period 3	30	9.6	414,000	1,300	56
Period 4	30	10.9	470,000	1,300	56
Period 5	30	7.5	323,000	1,300	56
Period 6	45	5.0	323,000	1,300	84
Total	195		1,944,000		309

Over the course of the thermal treatment, an estimated 1.9 million gallons of water and approximately 323 million cubic feet of non-condensable vapor will be extracted from the subsurface.

4.3.2 Energy Demand

Table 4.3 summarizes the power usage by the ISTD and steam systems along with the effluent treatment system throughout the duration of the thermal treatment system operation.

Table 4.3 Power Usage

Power and Steam Usage	Duration Days	Power Usage ISTD kWh	Power Usage Effluent Treatment kWh	Total Power Usage kWh
Period 1	30	1,016,000	390,000	1,405,000
Period 2	30	1,306,000	445,000	1,751,000
Period 3	30	2,321,000	501,000	2,822,000
Period 4	30	2,612,000	501,000	3,113,000
Period 5	30	1,814,000	473,000	2,287,000
Period 6	45	1,814,000	612,000	2,426,000
Total	195	10,883,000	2,922,000	13,805,000

Based on the numerical calculations, it is estimated that a total energy input of approximately 10.9 million kW-hr of electricity must be injected into the subsurface. With the additional approximate 2.9 million kW-hr power demand of the effluent treatment system, the total estimated electrical energy consumption for the project is estimated at approximately 14 million kW-hr for the full scale remediation.

The resulting total energy demand is larger than the energy needed just to heat the site to the target treatment temperatures. This is due to the removal of heat as steam, heat losses through the perimeter and the need to vaporize a minimum of approximately 30% of the pore water in the ISTD zone, which TerraTherm has found is necessary to achieve the required removal of CVOC contaminants.

5.0 SENSITIVITY ANALYSIS

After setting up the basic scenario, a sensitivity analysis was performed to determine the sensitivity of heater spacing versus duration, vapor cap insulation and horizontal and vertical groundwater flux. In addition, the effect of boosting the heater output in the deepest sections was evaluated.

Prior to deciding the proposed heating strategy as presented in the base case scenario described above, similar preliminary sensitivity calculations were performed to confirm the appropriateness of the design, and to make small adjustments for improved heating performance.

The sections below present the impact of changes in important base case scenario assumptions and compared them to the actual final design (base case design).

5.1 Base Case Scenario

Figure 5.1 shows the average temperature profiles at coolest locations (centroids) for a segment. This temperature profile is the base case for the sensitivity analysis, and all sensitivity calculations are compared to the base case average temperature profile.

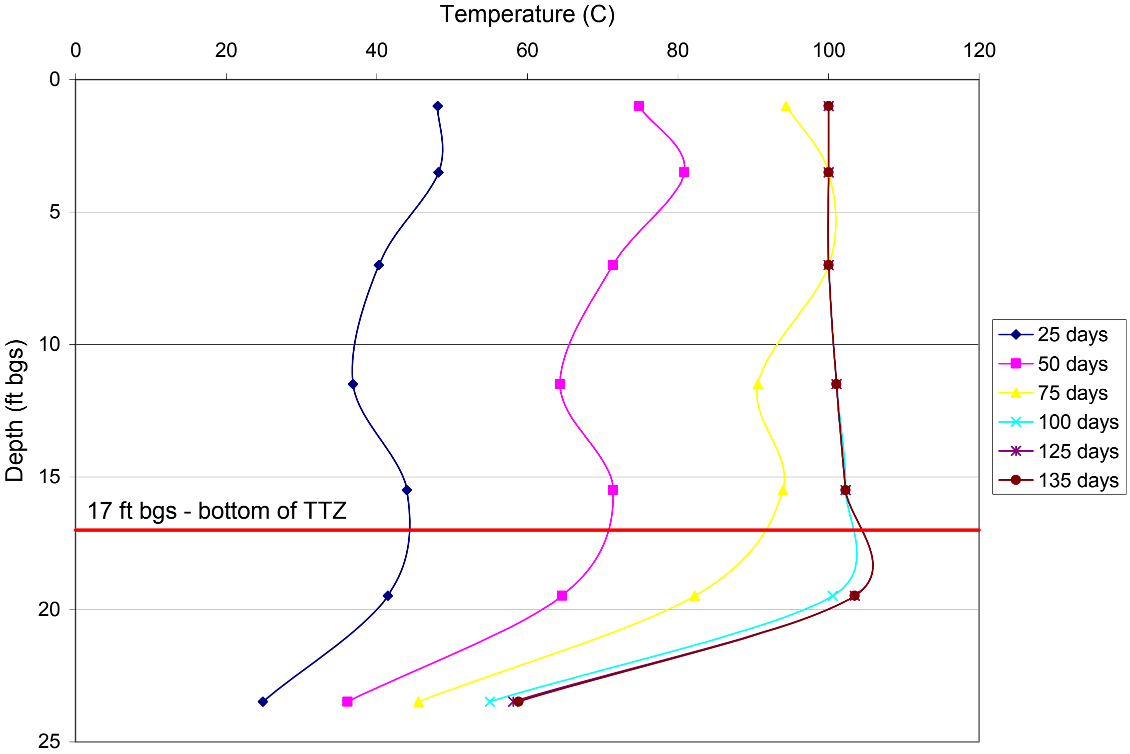

Figure 5.1. Average Temperature Profile for Base Case Scenario.

5.2 Heater Spacing Versus Duration

For the ISTD method, the duration of heating is closely associated with the spacing between each of the heater wells. A sensitivity analysis was conducted using two different heater spacings apart from the 15 foot spacing as presented in the base case.

Figures 5.2 and 5.3 presents the temperature profile with a heater spacing of 14 feet and 16 feet, respectively. In the base case 593 heaters will be placed in the treatment zone. If a 14 foot well spacing were chosen approximately 650 wells would have been used, while a 16 foot heater spacing would require a total of approximately 480 wells.

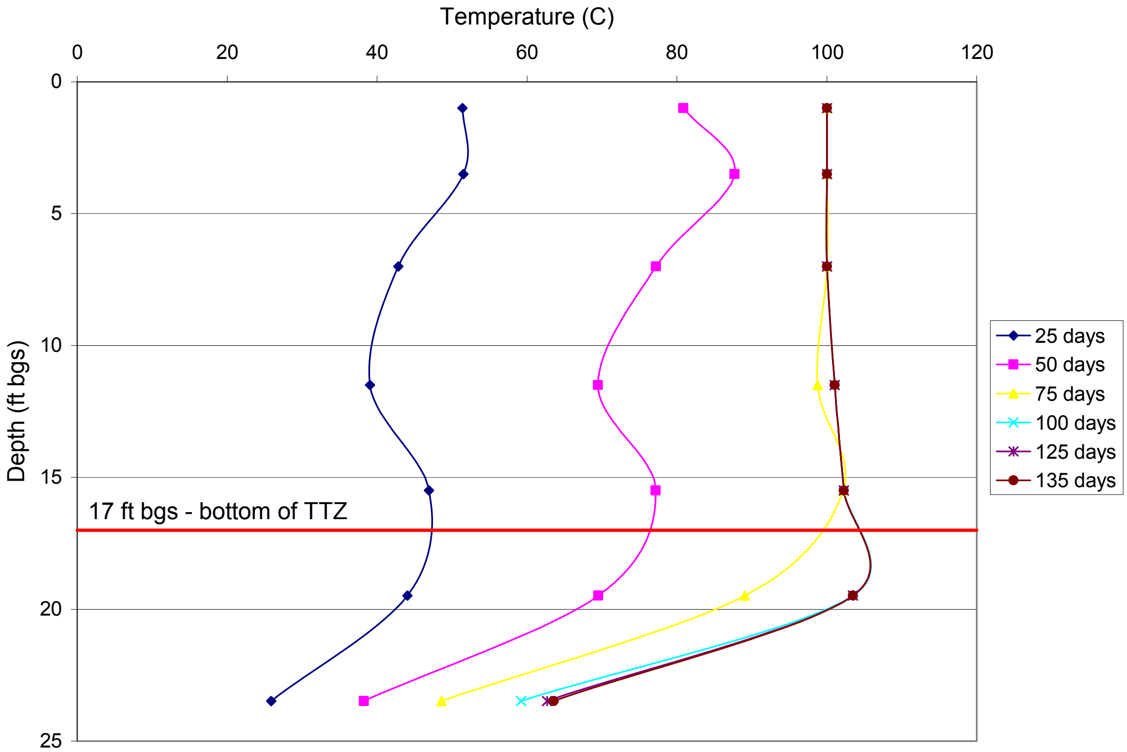

Figure 5.2. Average Temperature Profile with a 14 Foot Heater Spacing

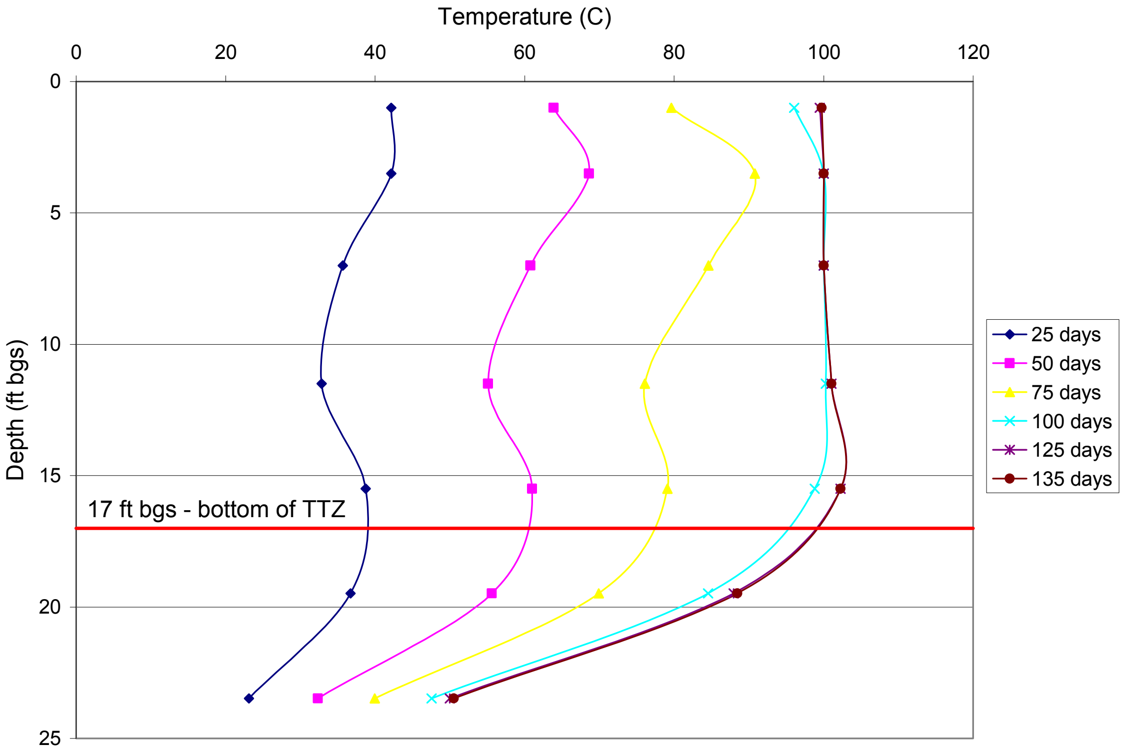

Figure 5.3. Average Temperature Profile with a 16 Foot Heater Spacing

A 14 foot heater spacing would speed up the overall heating process and the boiling point in the entire TTZ would be reached after approximately 85 days of operation compared to approximately 100 days in the base case. By using a 16 foot heater spacing it would not be possible to reach the boiling point at the very bottom of the treatment zone within 135 days of operation.

5.3 Vapor Cap Insulation

The sensitivity for vapor cap insulation and its impact on achievable temperatures in the upper part of the treatment zone was evaluated by running calculations with three different vapor cap thermal conductivities. In the base case the thermal conductivity was assumed to be 0.15 W/m*K. A sensitivity analysis was conducted using a vapor cap thermal conductivity value of 0.25 and 0.35 W/m*K.

Figures 5.4 and 5.5 present the temperature profile with a vapor cap thermal conductivity of 0.25 and 0.35 W/m*K. The latter value corresponds to the insulation value of a wet or poor vapor cap.

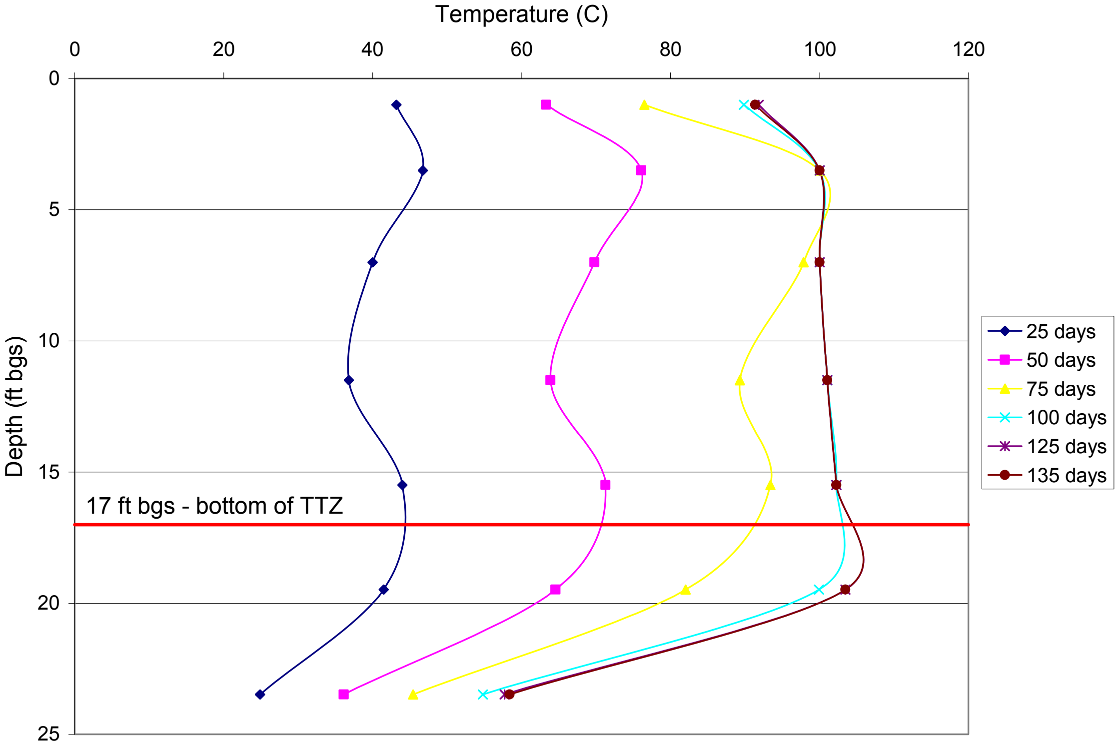

Figure 5.4. Average Temperature Profile with a Vapor Cap Thermal Conductivity of 0.25 W/m*K.

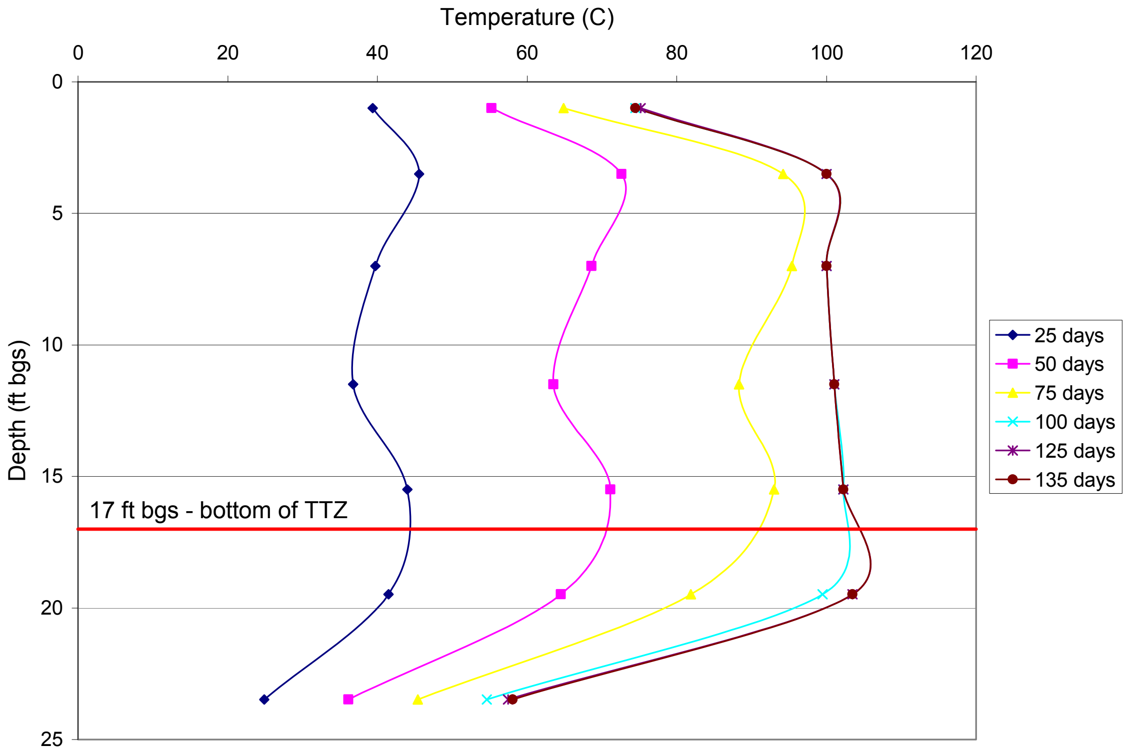

Figure 5.5. Average Temperature Profile with a Vapor Cap Thermal Conductivity of 0.35 W/m*K.

None of the proposed higher thermal conductivity values will be acceptable at the SRSNE site. The increase in thermal conductivity for the vapor cap would lead to a much higher heat loss at the surface and thus insufficient heat-up of the upper part of the treatment zone. By using a 0.25 W/m*K thermal conductivity for the vapor cap in the calculations, the temperature in the upper layer in the model reaches a steady state temperature at about 90 °C. For the 0.35 W/m*K vapor cap the steady state temperature is as low as 75 °C.

The insulation value of the vapor cap can either be improved by using a material with low thermal conductivity or by increasing the thickness of the cap. A 1 foot thick 0.15 W/m*K vapor cap as used in the base case scenario is acceptable for the SRSNE site.

5.4 Horizontal and Vertical Groundwater Flux

Calculations have been performed to investigate the overall sensitivity of water influx into the treatment area. Scenarios have been run with a horizontal influx of 0 and 20 gpm respectively, and with a vertical influx of 3 and 6 gpm. In the base case scenario, a horizontal influx of groundwater to the target area of 10 gpm was assumed. No vertical influx of groundwater was applied in the base case scenario.

The resulting average temperature profiles when the horizontal influx is varied are shown in Figures 5.6 through 5.7.

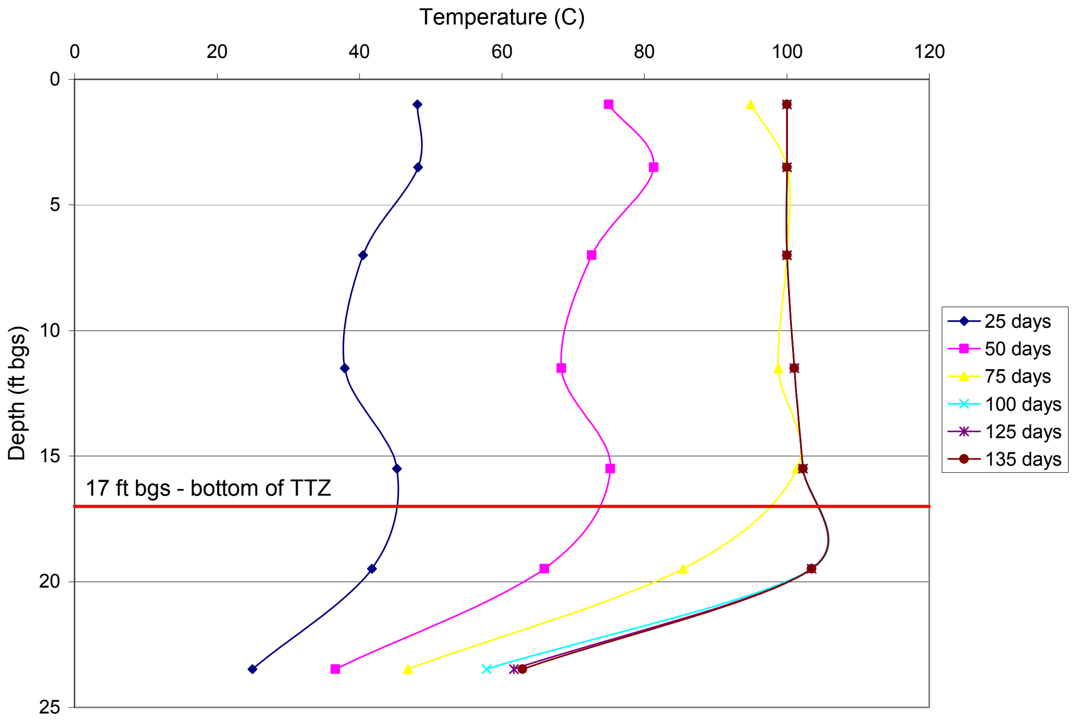

Figure 5.6. Average Temperature Profile with 0 gpm Horizontal and 0 gpm Vertical Influx of Groundwater.

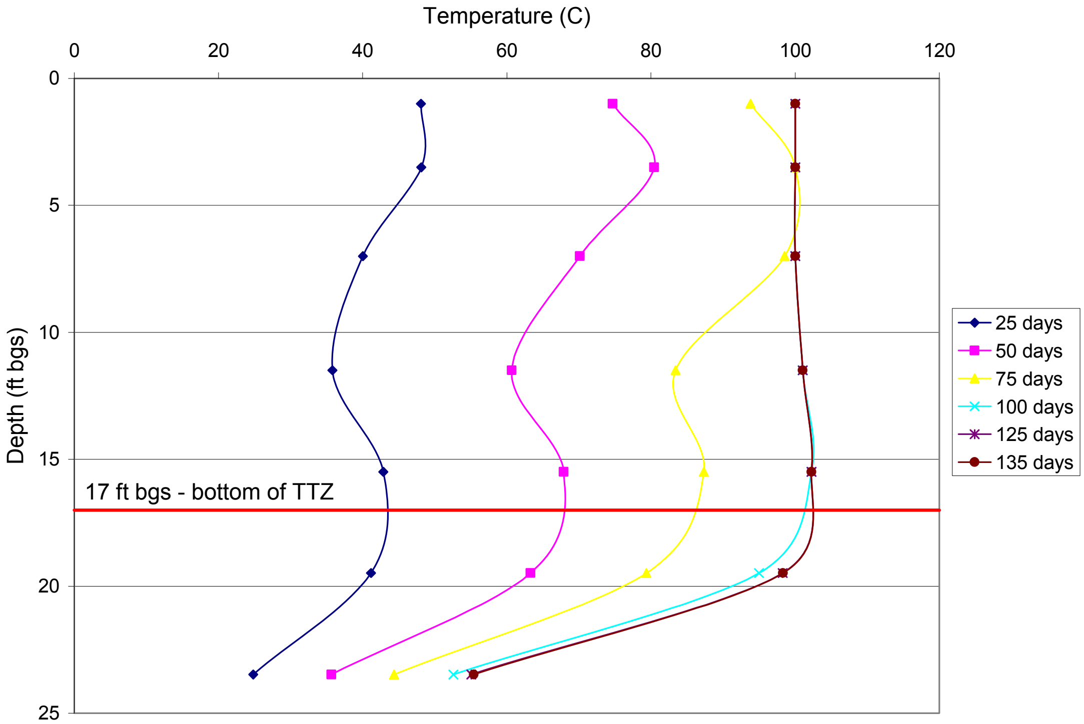

Figure 5.7. Average Temperature Profile with 20 gpm Horizontal and 0 gpm Vertical Influx of Groundwater.

The figures show that the sensitivity for horizontal groundwater influx is modest. The higher groundwater influx increase the time to get the lower part of the treatment area up to temperature, but even when assuming a horizontal influx of 20 gpm the entire treatment zone is up to temperature after 100 days of operation. It should be noted that this is true for the site as an average, but may not hold true at the up-gradient edge where the cool water enters.

The resulting average temperature profiles when the vertical influx of groundwater is varied are shown in Figures 5.8 through 5.9.

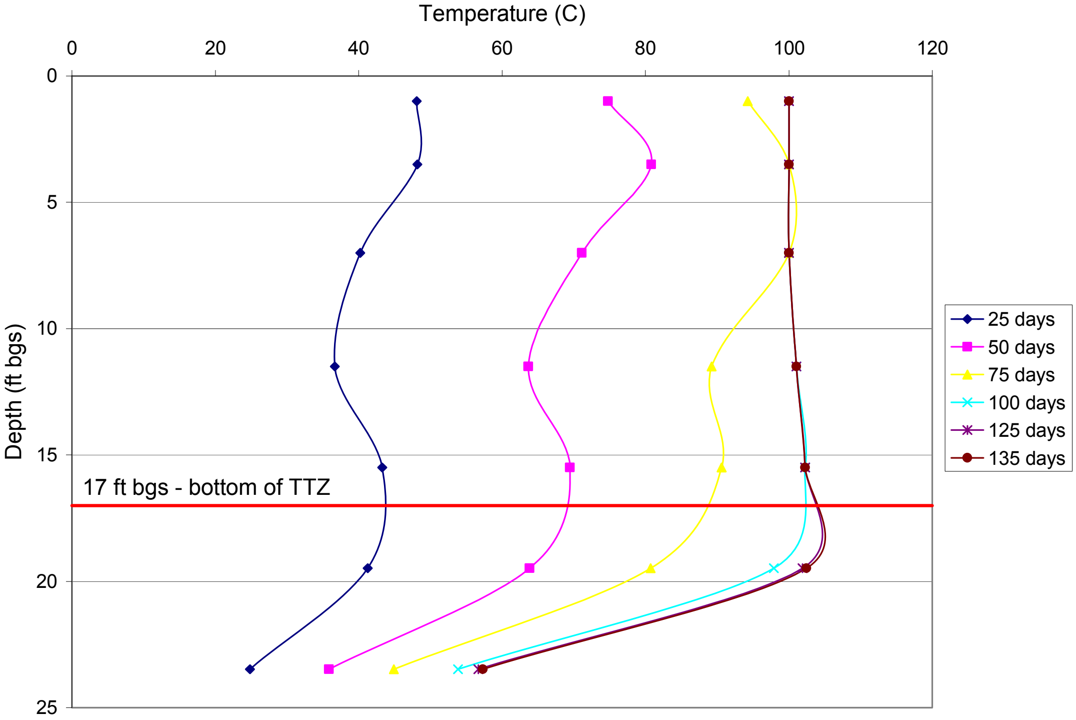

Figure 5.8. Average Temperature Profile with 10 gpm Horizontal and 3 gpm Vertical Influx of Groundwater.

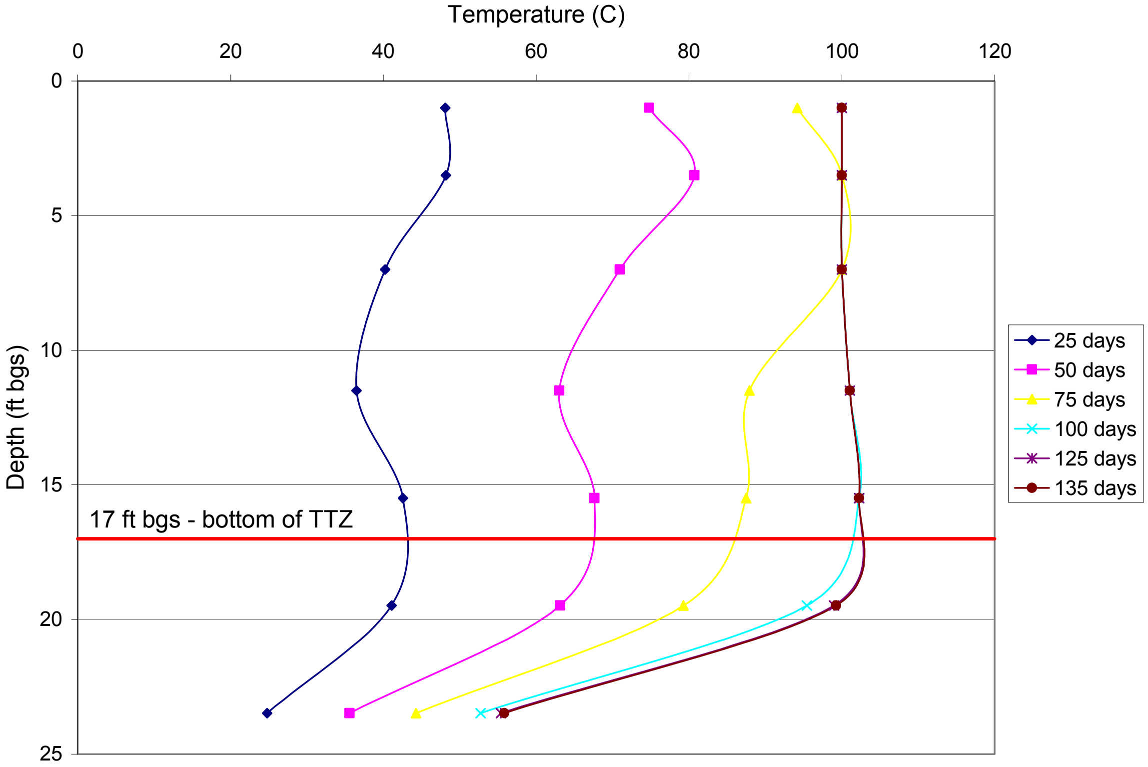

Figure 5.9. Average Temperature Profile with 10 gpm Horizontal and 6 gpm Vertical Influx of Groundwater.

According to the sensitivity calculations, the temperature in the bottom of the treatment zone is almost not affected by varying th vertical influx of groundwater between 3 and 6 gpm. It should be noted that this is true for the site as an average, but may not hold true locally for zones of higher flow.

5.5 Heater Boosting

The effects of adding more energy per unit length of heater near the bottom have been evaluated.

In the base case scenario the lower approximately 6 feet of the heaters are boosted and the heaters are drilled 3 feet into the bedrock. The boosted sections of the heaters are able to deliver approximately 435 W per foot of heater to the treatment zone. By comparison the non-boosted sections only deliver approximately 300 W/ft.

The effects of installing non-boosted heaters 3 and 5 feet into the bedrock was evaluated together with scenarios with boosted heaters installed 2 and 5 feet into the bedrock. The boosted section of the heaters starts approximately 3 feet above the bedrock in all scenarios where boosting is used e.g. the length of the boosted sections are approximately 5 and 8 feet in the two scenarios.

Figures 5.10 and 5.11 shows the situation where the heaters are installed 3 and 5 feet into the bedrock and none of the heaters are boosted.

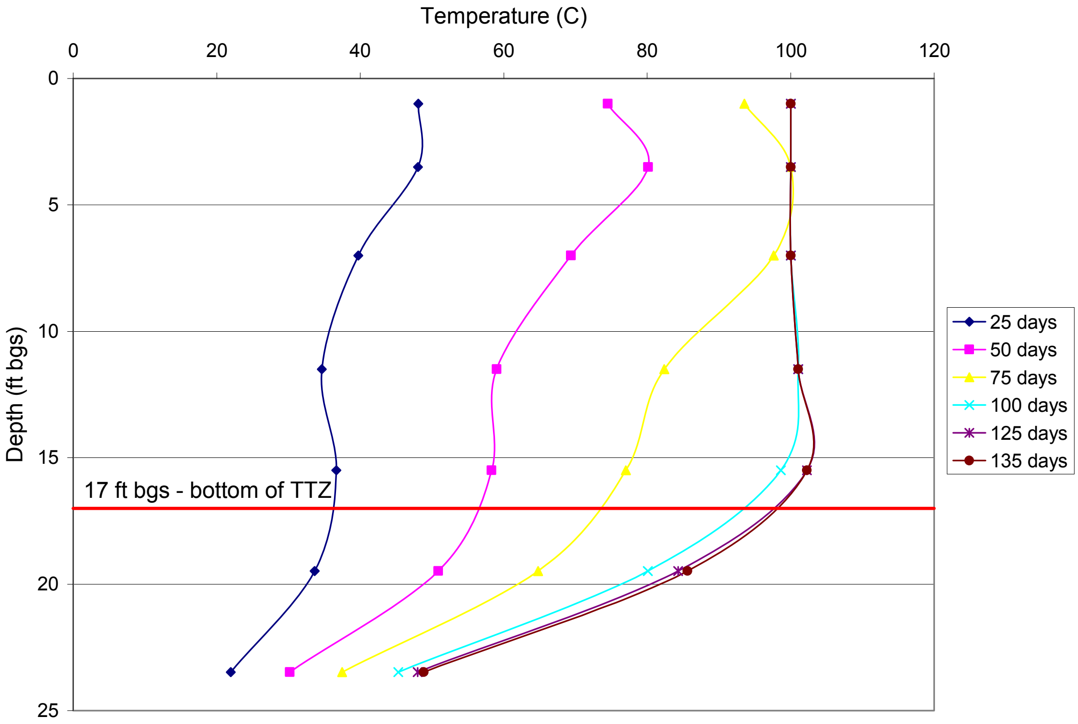

Figure 5.10. Average Temperature Profile with Non-Boosted Heaters Installed 3 feet into the Bedrock.

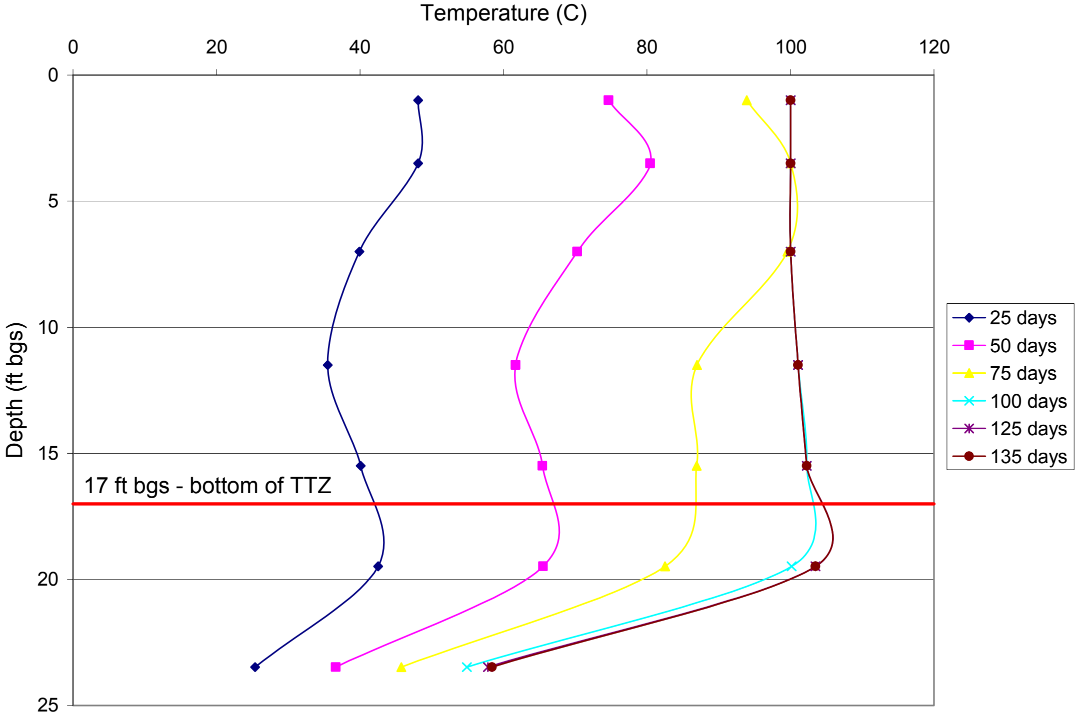

Figure 5.11. Average Temperature Profile with Non-Boosted Heaters Installed 5 feet into the Bedrock.

The sensitivity analysis shows that non-boosted heaters need to be installed 5 feet into the bedrock to ensure to heat up the bottom of the target zone. If heaters are kept 3 feet into the bedrock the bottom of the treatment zone will not get up to temperature.

Figures 5.12 and 5.13 show the case where the heaters are boosted and installed 2 and 5 feet into the bedrock.

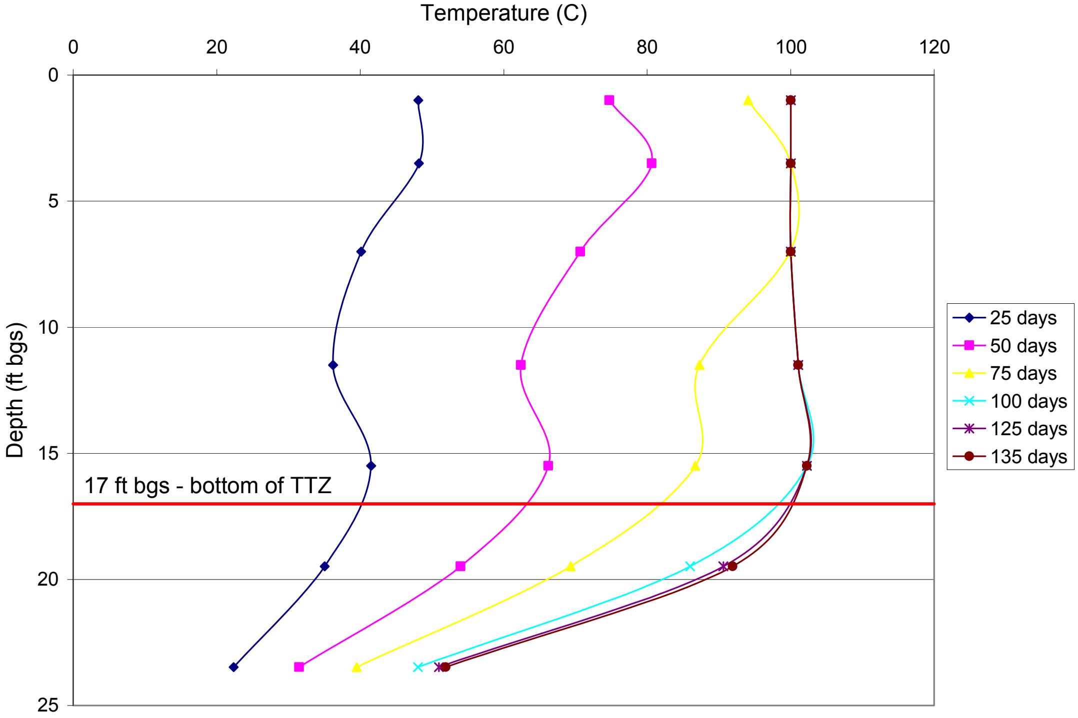

Figure 5.12. Average Temperature Profile with Boosted Heaters Installed 2 feet into the Bedrock.

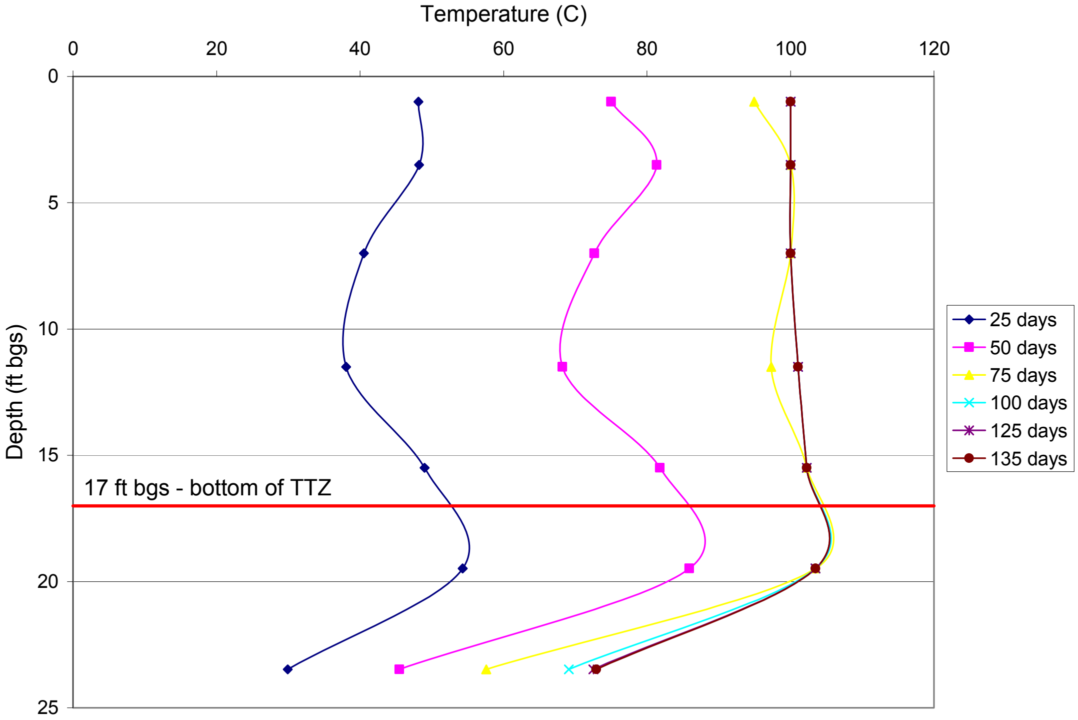

Figure 5.13. Average Temperature Profile with Boosted Heaters Installed 5 feet into the Bedrock.

The calculations show that a 2 foot boosted heater installation into the bedrock will not be sufficient to get the temperature at the bottom of the target zone up to temperature. By using boosted heaters and installing those 5 feet into bedrock, the bottom will be heated sufficiently during treatment. In the base case, the boosted heaters are installed 3 feet into the bedrock (see Figure 5.1) which also is found to be sufficient.

6.0 REFERENCES

/Ref. 1/ Heat Dissipation Model, Solvents Recovery Service of New England (SRSNE) Southington, Connecticut, TerraTherm, Inc. March 2010

SRSNE MATERIALS COMPATIBILITY STUDY`
SOUTHINGTON, CONNECTICUT

KEMRON PROJECT #: SE-0313

January 25, 2010

Prepared for:

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TERRATHERM
Think Thermal

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Prepared by:

KEMRON
ENVIRONMENTAL SERVICES

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Submitted By:	Reviewed By:
Mark Clark Project Manager	Tommy Jordan, P.G. Program Manager

INTRODUCTION

KEMRON Environmental Services, Inc. (KEMRON) is pleased to present the results of the Materials Compatibility Testing study. The treatability study was performed to evaluate the resistance of construction materials to degrade when subjected to site materials and conditions anticipated during full-scale thermal treatment. This report includes the methodology followed during each phase of the study, photographic documentation, and visual and weight degradation.

KEMRON received duplicate samples of six metallic construction materials (coupons). These coupons were labeled B3, 20CB3, 304, AL6XN, C1023, and C276. In addition to the material coupons, KEMRON received a sample of Dense Non-aqueous Phase Liquid (DNAPL). TerraTherm indicated that this DNAPL material contained chlorinated contaminants from the site.

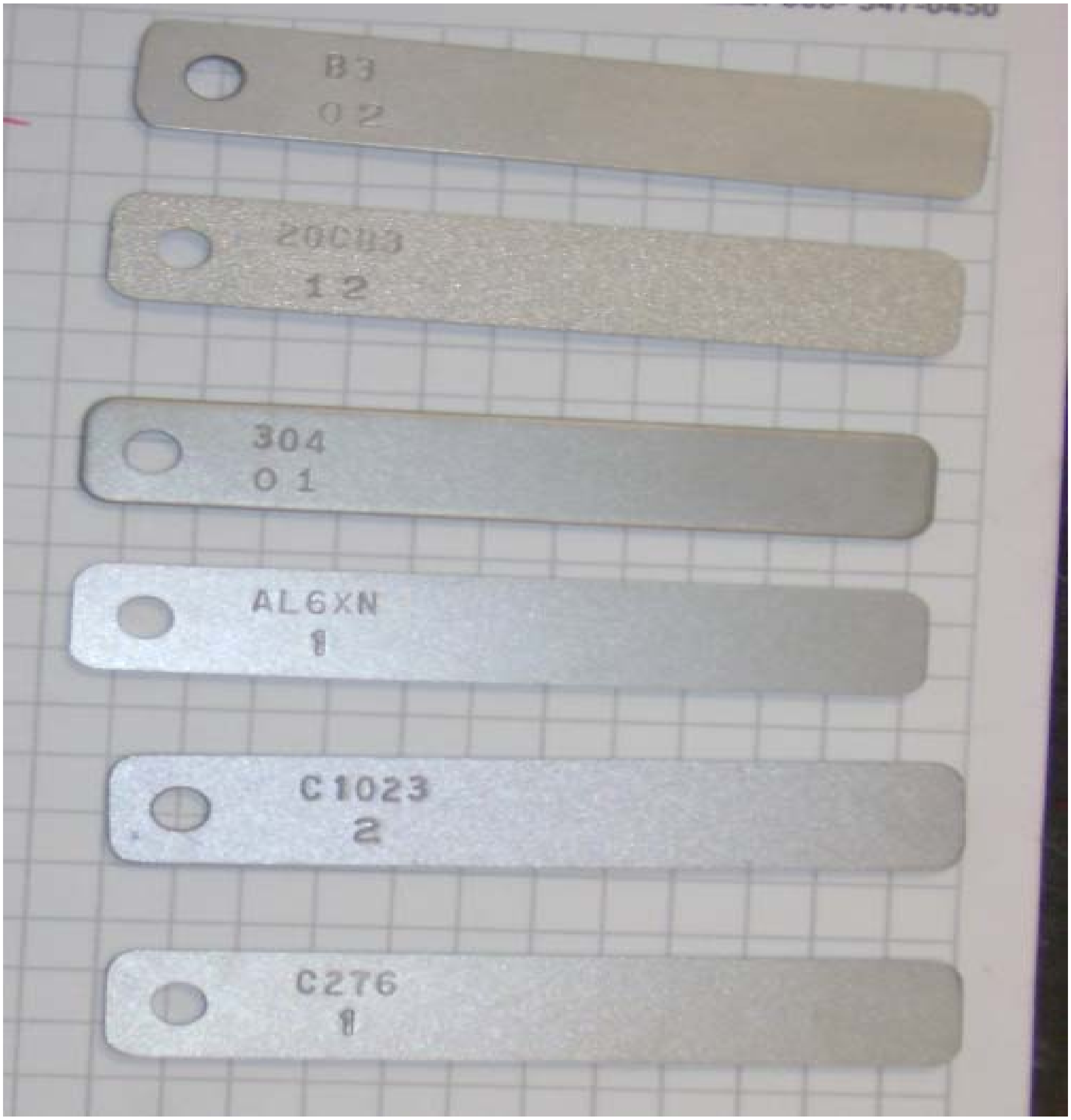
Compatibility testing was conducted in two distinct phases. Initially, a sample of the DNAPL was heated to boiling, producing vapors which may be encountered during full-scale activities. This vapor was then passed through one reactor containing sand which was maintained at a temperature of approximately 700 degrees Celsius (^oC). This reactor provided heating and retention of the vapors in order to degrade or break-down compounds in a manner anticipated during full-scale treatment. It was anticipated that in the first reactor chlorinated vapors from the DNAPL form hydrochloric acid. The hot acidic vapors were then passed into a second reactor containing samples of the test coupons and sand. The second reactor was maintained at a temperature of approximately 650 ^oC. This reactor served to expose the coupons to the highly degrading acid vapors. Finally, vapors from the second reactor were condensed and retained for use in Phase II of the study.

Phase II of testing included subjecting the construction materials to lower temperatures and constantly condensing and vaporizing acidic compounds as may be experienced in the periphery of the thermal treatment areas. This phase was accomplished by boiling the acidic condensate from Phase I. The metal coupons were placed into Soxhlet columns connected to the condensate boiling flask. A cold water condenser was situated on the top Soxhlet column to condense the acidic vapors. As the acidic condensate boiled vapors passed over the coupons and were condensed in the condenser and allowed to fall back into the Soxhlet columns which exposed the coupons to the acidic liquid. When the volume of liquid reached the appropriate level within the columns the liquid siphoned back to the heating pot and the process was repeated.

PHASE I TESTING

The high temperature phase of the testing was conducted using two cylindrical titanium reactors measuring approximately 6 inches in length and 3 inches in diameter. Each reactor was fitted with bolt-on end caps which contained stainless steel Swagelok fittings to allow the connection of inlet and outlet tubing to the reactors. Note that in further sections of this section of the report one end will be referred to as inlet and the other as outlet. Glass fiber material was placed over the opening of each Swagelok fitting, inside of the reactor, to prevent sand in the reactors from entering the tubing. The first reactor was filled with pre-cleaned sand only. The second reactor contained a coupon for each construction material furnished. KEMRON prepared this reactor by securing one end-cap onto the reactor. Approximately 3 inches of sand was then placed into the reactor. The coupons were then inserted into the sand so that they were oriented parallel to the long axis of the reactor. Note that care was taken so that the coupons were surrounded on all sides by sand. The remainder of the reactor was filled with sand and then capped.

The following is a sample photograph of the coupons prior to testing:



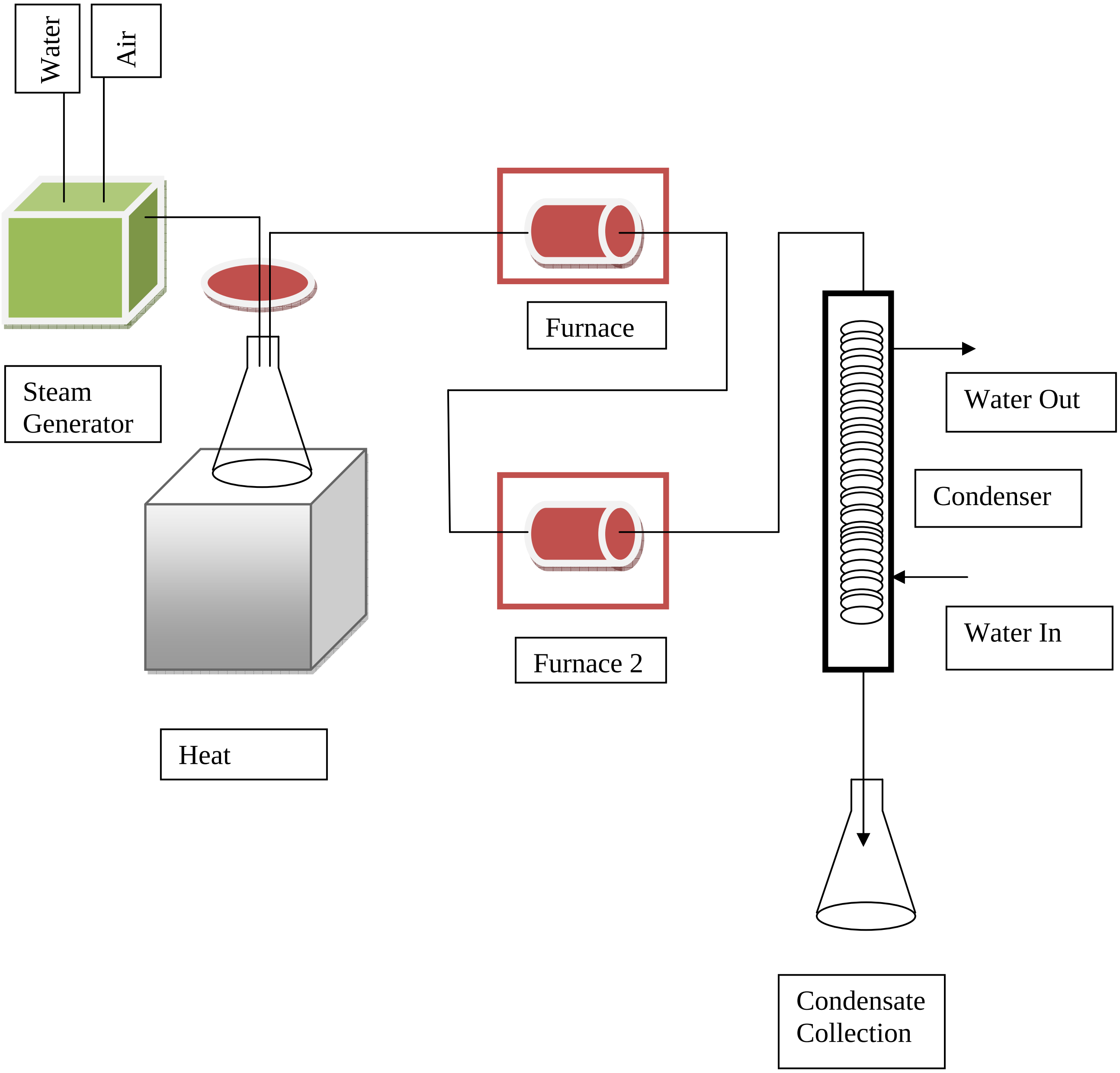
Prior to testing each coupon was cleaned using Alconox, dried and weighed. The following is a summary of the weights of each coupon utilized in Phase I.

TABLE 1

COUPON ID	**INITIAL WEIGHT (g)**
B 3	17.0097
20CB3	14.4856
304	10.6564
AL6XN	11.5524
C1023	11.0208
C276	13.4156

The reactors were placed into separate Fisher Isotemp muffle furnaces. A steam generating vessel consisting of a kitchen pressure cooker placed on a heating plate was connected to a breathing quality air source via a Swagelok connector. Stainless steel tubing was connected from the steam generator to a heating pot containing the site DNAPL material. This heating pot was also placed on a heating plate to allow heating of the DNAPL. Additional stainless steel tubing was used to connect the DNAPL heating pot to the inlet port of Reactor #1. Tubing was then utilized to attach the outlet port of Reactor #1 to the inlet port of Reactor #2. Finally, the outlet port from Reactor #2 was connected to a cold water condensing system using stainless steel tubing.

The following is a depiction of the test set-up for Phase I.

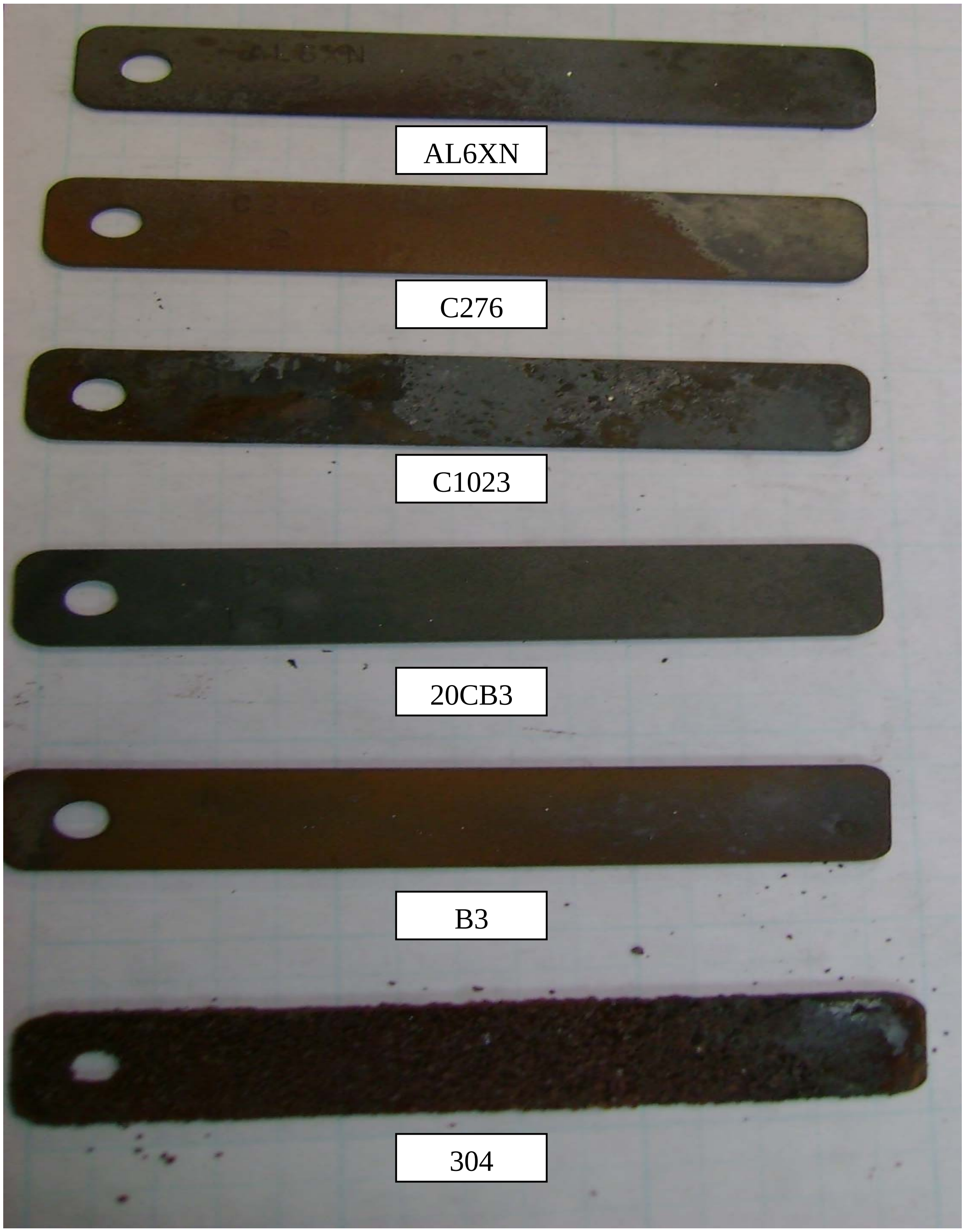


The picture below was taken during the actual set-up of during Phase I. In addition to the equipment shown a cold water condenser and condensate collection vessel was connected to Reactor #2 left of the picture.

Throughout testing activities in Phase I, air was passed through the steam generator and the remainder of the system at a rate of approximately 10 milliliters per minute (ml/min). Once the system was prepared KEMRON began treatment by heating each reactor to the appropriate operating temperature. Once the reactor target temperatures were achieved, KEMRON began heating the steam generator and DNAPL source. Specifically, the steam generator was heated to a target temperature of 110 ^{o}C, and the DNAPL source was heated to approximately 80 ^{o}C. TerraTherm had requested that the steam generator be used to constantly pass a flow of steam through the system at a rate equal to 10% of the quantity of condensate being collected during testing. However, KEMRON was unable to consistently maintain this rate of steam generation. In order to provide the appropriate amount of steam through the system, KEMRON periodically injected water into the hot generator at an amount equal to 10% of the condensate being collected. In the absence of water the steam generator provided heating of the air being injected into the treatment system.

KEMRON tested the pH of the condensate being recovered on a daily basis. Results indicated that the average pH of the condensate was approximately 5 standard units. The pH monitoring was performed using both pH indicator paper and direct read instrument.

Following 10 days of DNAPL heating the testing was terminated and the system was dismantled. The material coupons from Reactor #2, rinsed, photographed and forwarded to a metallurgical laboratory contracted by TerraTherm for further evaluation. The following is a photograph of the post treatment coupons.



Note that due to the amount of damage to the coupons KEMRON had difficult identifying two of the coupons. Specifically, coupons C1023 and 304 labeled in the above picture were in question during coupon identification.

Table 2 presents the final weights of each material coupon.

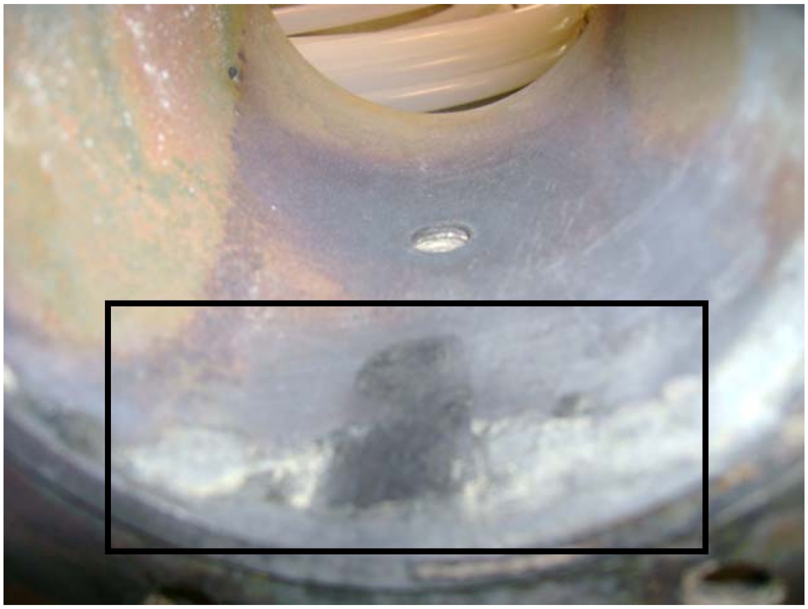
TABLE 2

COUPON ID	INITIAL WEIGHT (g)	FINAL WEIGHT (g)
B 3	17.0097	17.0241
20CB3	14.4856	14.4966
304	10.6564	10.4960
AL6XN	11.5524	11.5639
C1023	11.0208	12.1520
C276	13.4156	13.4230

The data in Table indicates that with the exception of coupon C1023, all of the coupons increased in weight due to the testing conditions.

As previously mentioned KEMRON collected condensate from Phase I testing. During testing KEMRON encountered several occurrences where condensate collection was interrupted. It was determined that the outlet lines from the reactors had gotten clogged. At these instances KEMRON disconnected the outlet lines from the reactors and removed the blockage. Upon dismantling of the system KEMRON observed that the glass fiber material used to prevent sand from entering the outlet lines had melted. KEMRON believes that this glass fiber material was the cause of the majority of the blockages. Over the 10 day testing period, KEMRON collected approximately 750 grams of clear condensate with a pH of 5 s.u..

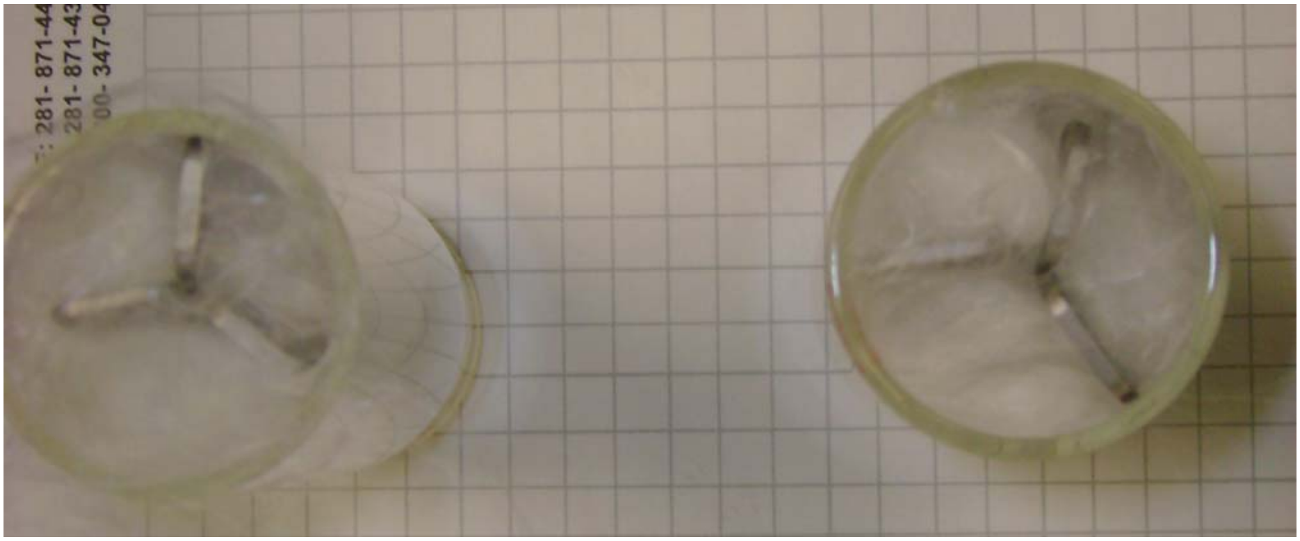
On inspection of the titanium reactors used during Phase I testing, KEMRON observed significant oxidation and pitting of the inside of Reactor I, the sand only reactor. Specifically, KEMRON has outlined the portion of the reactor showing significant pitting.



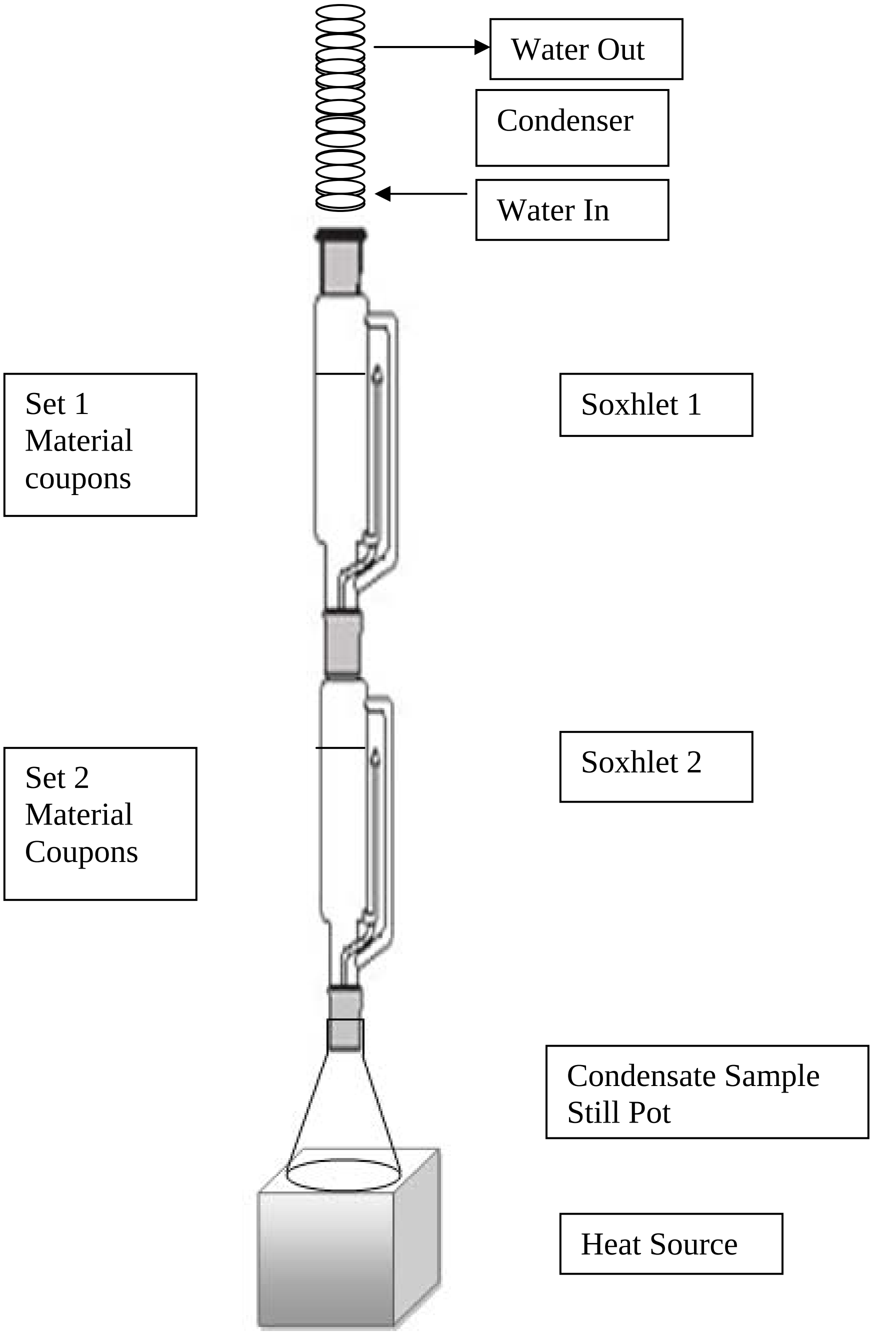
PHASE II TESTING

As previously outlined, Phase II testing was designed to evaluate the degradation of construction material when subjected to lower temperatures and acidic liquids and vapors. Testing was performed by boiling the condensate material from Phase I. The acidic vapors were passed through two Soxhlet columns containing the material test coupons and condensed in a colder water condenser. The condensed liquid fell back into the columns where they collected. When the liquid level in the columns reached a certain level they were returned to the heating pot via siphon tubes in the columns.

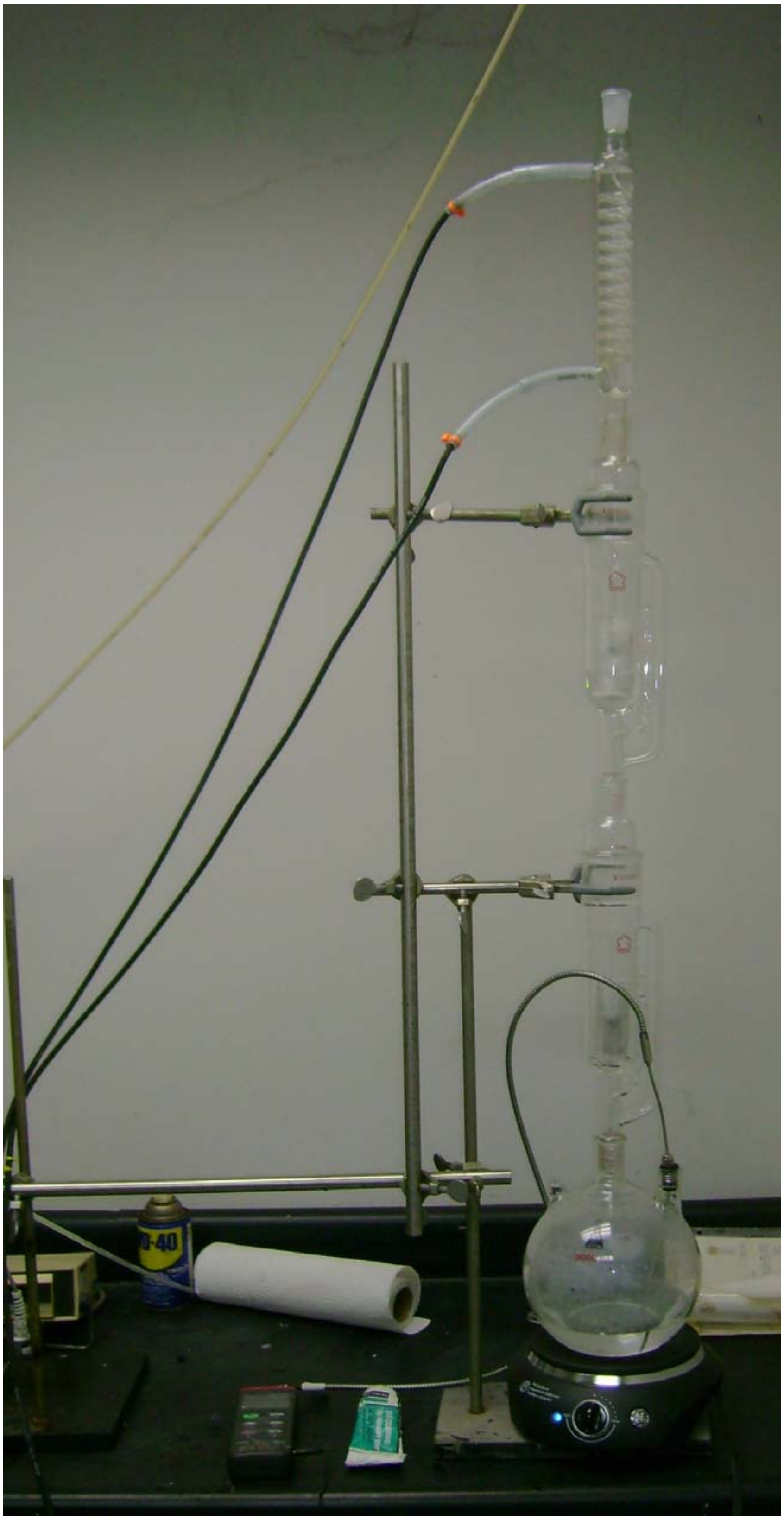
The coupons were held within the columns using glass holders and glass fiber material. Specifically, coupons B3, 20CB3, and 304 were placed into one holder and coupons AL6XN, CL023, and C276 were placed into the second holder. The following is a photograph of the coupons within the glass holder:



The following is a diagram of the system set-up utilized for Phase II:



The photograph presented below is of the actual test set-up used for Phase II testing:



Testing was conducted for a period of 10 days. Over this 10-day period KEMRON calculated that the system cycled approximately 420 times, or once every 45 minutes. That is, liquid collected in the Soxhlet columns to the level it was siphoned back into the heating pot. During this 10 day period the condensate in the heating pot turned from clear to cloudy in the heating pot. At the completion of the 10 day period, testing was terminated and the system dismantled. The coupon materials were then removed from the system, rinsed, weighed and forwarded to TerraTherm's metallurgical laboratory. The photograph below shows the coupons after the 10 day testing study.

Table 3 summarizes the initial and final weights of the coupons used during Phase II testing:

TABLE 3

COUPON ID	INITIAL WEIGHT (g)	FINAL WEIGHT (g)
B 3	16.6013	16.6603
20CB3	14.4763	14.4896
304	10.6211	10.6256
AL6XN	11.5402	11.5343
C1023	11.0019	11.0225
C276	13.4330	13.4397

Photographs and review of the coupon weights before and after testing indicate that the coupons in Phase II were less affected by the test conditions than those in Phase I.

KEMRON Environmental Services, Inc. appreciates the opportunity to provide treatability testing to TerraTherm.

January 26, 2010

Transmitted Via Email
Email Address: lconant@terratherm.com

Mr. Larry Conant
TerraTherm, Inc.
10 Stevens Road
Fitchburg, MA 01420

Subject: Laboratory Evaluation of 12 Corrosion Tested Coupons (Intertek-APTECH Report AES 09087234-3-1) (Final Report)

Dear Mr. Conant:

Intertek-APTECH is pleased to submit this report to TerraTherm, Inc. regarding the results of the laboratory evaluation of 12 corrosion-tested coupons.

INTRODUCTION

Intertek-APTECH performed laboratory evaluation for corrosion mechanisms on 12 coupons. Two coupons from 6 different materials, as listed in Table 1, were selected by TerraTherm for corrosion testing at Kemron Industrial Services. The coupons were initially sent to Intertek-APTECH for weight and dimensional measurements prior to the corrosion testing. The first set of coupons referred as "Well samples" were then (reportedly) tested at 650°C hydrochloric acid vapor environment for 10 days (240 hours). The second set of coupons referred as" Piping samples" was tested in condensing hydrochloric acid environment at 100^{o}C for 5 days (120 hours). At the end of the testing, Well samples and Piping samples were returned to Intertek-APTECH for evaluation.

The objective of the laboratory evaluation was to:

1. Evaluate the coupons for corrosion mechanisms.
2. Calculate corrosion rate based on weight loss.

APPROACH

TerraTherm provided 12 coupons for initial weight and dimensional measurements. The coupons were documented in the as-received condition (Figures 1 and 2). The as-received dimensions of the coupons are summarized in Table 2.

16100 Cairnway Drive, Suite 310 ■ Houston ■ Texas 77084-3597 ■ 832.593.0550 ■ FAX 832.593.0551
601 West California Avenue ■ Sunnyvale ■ California 94086-4831 ■ 408.745.7000 ■ FAX 408.734.0445
139,11215 Jasper Avenue ■ Edmonton ■ Alberta T5K 0L5 ■ 780.669.2869 ■ FAX 780.669.2509
Website: www.aptechtexas.com

Photographs were taken to document the post-test appearance of the coupons. The coupons were weighed before cleaning. The coupons were ultrasonically cleaned using citronox and rust remover to remove the corrosion products. The coupons were weighed after cleaning and documented in the as-cleaned condition (Figures 3 through 14). The general corrosion rates of the coupons were calculated (using Equation 1) by measuring the weight loss of test coupons. All the coupons were visually and microscopically examined for evidence of pitting/crevice corrosion.

The corrosion rate[1] of the coupons is calculated using:

Corrosion Rate = $(K \times W) \div (A \times T \times d)$ → Equation 1

Where

K – Corrosion constant (534)
W – Weight loss, mg
A – Surface area, in^2
T – Time of exposure, hrs
D – Density of material, gm/cm^3
Corrosion rate – mils per year (mpy)

Table 1

ROSTER OF COUPON DESIGNATIONS AND THEIR RESPECTIVE MATERIAL GRADES

Material Class	Coupon ID [650°C (1202°F)]	Coupon ID [100°C (212°F)]
Stabilized Austenitic Stainless Steel (Alloy 20)	20CB3-13	20CB3-12
Austenitic Stainless Steel	304-03	304-01
Super Austenitic Stainless Steel	AL6XN-2	AL6XN-1
Hastelloy	B3-01	B3-02
Carbon Steel	C1023-1	C1023-2
Nickel-Chromium-Molybdenum Alloy	C276-2	C276-1

Table 2

DIMENSIONS OF AS-RECEIVED COUPONS

Coupon No.	Length (in)	Width (in)	Thickness (in)
20CB3-12	3.006	0.5005	0.075
20CB3-13	3.005	0.497	0.074
304-01	3.000	0.495	0.056
304-03	3.001	0.494	0.0565
AL6XN-1	3.003	0.501	0.0585
AL6XN-2	3.003	0.501	0.0595
B3-01	3.009	0.506	0.075
B3-02	3.011	0.505	0.075
C1023-1	3.008	0.510	0.0565
C1023-2	3.008	0.512	0.0565
C276-1	3.004	0.502	0.063
C276-2	3.005	0.501	0.064

RESULTS

Visual and Microscopic Examination of the Well samples exhibited uniform corrosion on Coupons 304-03, AL6XN-2, and C1023-1. The other coupons in this batch did not exhibit pitting/crevice corrosion, but the surface appears to be tarnished. Representative photographs of the coupons are provided in Figures 3 through 8.

Examination of the Piping samples did not exhibit corrosion or pitting. The coupons 304-01 and C1023-2 exhibited discoloration even after cleaning. Representative photographs of the coupons are provided in Figures 9 through 14.

The weight loss and corrosion rate results of the tested coupons are presented in Tables 3 and 4.

Table 3

WEIGHT LOSS AND GENERAL CORROSION RATE OF WELL SAMPLES AT 650°C (Vapor Phase)

Coupon ID number	Density (g/cm3)	Time (hr)	Surface Area (sq. in)	Initial Weight (g)	Weight Before Cleaning (g)	Weight After Cleaning (g)	Weight Change (mg)*	Corrosion Rate (mpy)
20CB3-13	8.08	240	3.51	14.485	14.50	14.49	-8.0	N/R
304-03	7.9		3.36	10.656	10.49	10.43	223.0	18.7
AL6XN-2	8.06		3.43	11.552	11.56	11.55	3.0	0.2
B3-01	9.22		3.57	17.009	17.02	17.01	0.0	N/R
C1023-1	7.86		3.47	11.020	11.98	9.06	1961.2	160.2
C276-2	8.94		3.46	13.415	13.42	13.42	-3.0	N/R

**Negative values indicates weight gain*
N/R - Not reported due to weight gain

Table 4

WEIGHT LOSS AND GENERAL CORROSION RATE OF PIPING SAMPLES AT 100°C (Condensing Environment)

Coupon ID number	Density (g/cm3)	Time (hr)	Surface Area (sq. in)	Initial Weight (g)	Weight Before Cleaning (g)	Weight After Cleaning (g)	Weight Change (mg)	Corrosion Rate (mpy)
20CB3-12	8.08	120	3.53	14.49	14.49	14.49	1.8	0.3
304-01	7.90		3.36	10.63	10.63	10.62	2.3	0.4
AL6XN-1	8.06		3.42	11.53	11.53	11.53	0.9	0.1
B3-02	9.22		3.57	16.66	16.66	16.66	0.9	0.1
C1023-2	7.86		3.48	11.02	11.02	11.01	14.0	2.3
C276-1	8.94		3.46	13.44	13.44	13.44	1.2	0.2

DISCUSSION

The corrosion rate calculation for the Well samples determined that carbon steel (C1023-1) and stainless steel (304-03) experienced the highest corrosion rates of 160.2 and 18.7 mpy, respectively. The other coupons in this batch showed no corrosion during the testing. Coupons 20CB3-13 and C-276 exhibited weight gain suggesting oxidation may have occurred during testing. High temperature oxidation typically results in oxide film on the surface resulting in weight gain. The thickness of the film formed depends on the exposure time and temperature.

The corrosion rate of the carbon steel and 304 stainless steel is not unusual, as they are expected to corrode in the hydrochloric acid at elevated temperatures. The corroded coupons exhibited uniform corrosion, with no localized corrosion (i.e., pitting, crevice) observed on these coupons. The other coupons (C 276-2, B3-01, AL6XN-2, and 20 CB3-13) exhibited a tarnished appearance, which is likely due to the oxidation of the coupons and possible solution contamination at elevated temperatures.

Based on the corrosion rate and examination, the Piping samples were unaffected by the testing conditions. Carbon steel exhibited the maximum corrosion rate (2.3 mpy), while the other coupon materials exhibited a corrosion rate between 0.1 and 0.4 mpy. The random discoloration observed on 304-01 and C1023-2 may be due to the contamination or initiation of random oxidation from the testing solution.

CONCLUSION

Based on the characterization of the corrosion-tested coupons, the following conclusions were made:

1. Among the group of Well samples, carbon steel coupon (C1023-1) and stainless steel coupon (304-03) showed the highest corrosion rates. The super austenitic stainless steel, stabilized austenitic stainless steel, and nickel alloys showed good corrosion resistance. None of the Well samples exhibited any evidence of pitting or crevice corrosion.

2. The Piping samples showed a negligible corrosion rate (except carbon steel). The samples in this group did not exhibit pitting or crevice corrosion.

RECOMMENDATIONS

1. Should TerraTherm select one of the materials for application, Intertek-APTECH could perform a cost analysis on the selected materials. This cost analysis would involve a comparison of the purchase price of the material (cost of production, fixed costs) and cost of ownership (service life, inspection frequencies, etc).

2. If TerraTherm does not have a Risk Based Inspection (RBI) program for piping, Intertek-APTECH recommends implementation of a RBI program on the new piping material and existing piping to monitor corrosion, minimize inspection intervals, and plan for turnaround activities in the future.

Should you have any questions regarding this report, please contact me at Intertek-APTECH's Houston office (832-593-0550) or by email at *velu.palaniyandi@intertek.com.*

Sincerely,

Velu Palaniyandi
Supervisor, Metallurgical Services

VP/rje
cc: HOU File
SV File

REFERENCES

1. Denny .A .Jones, Principles and Prevention of Corrosion, 2nd Edition, P-31.

Figure 1 — Photographs of As-received Coupons.

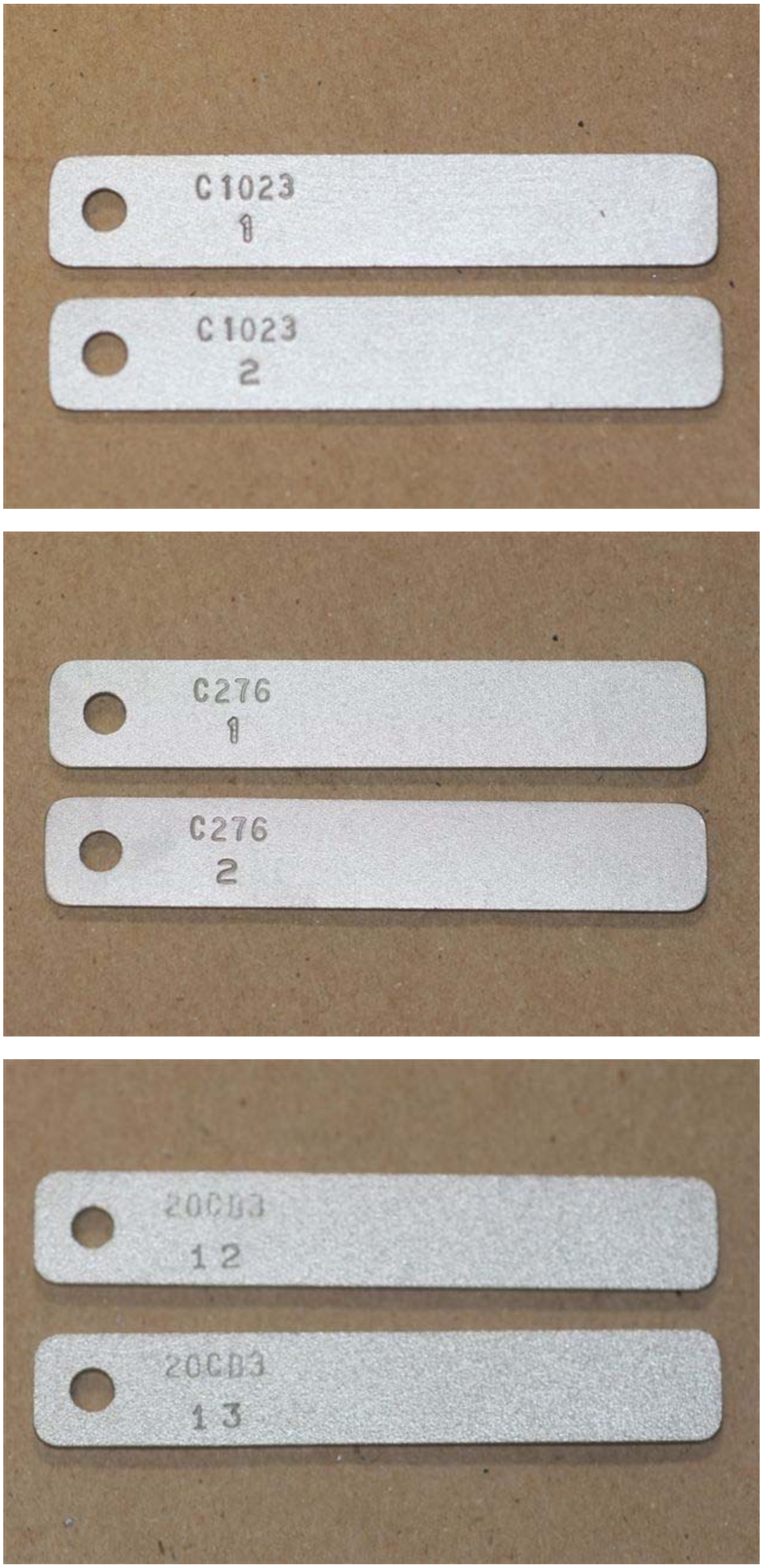


Figure 2 — Photographs of As-received Coupons.

Figure 3 — B3-01 Coupons before (Top) and after Cleaning (Bottom).

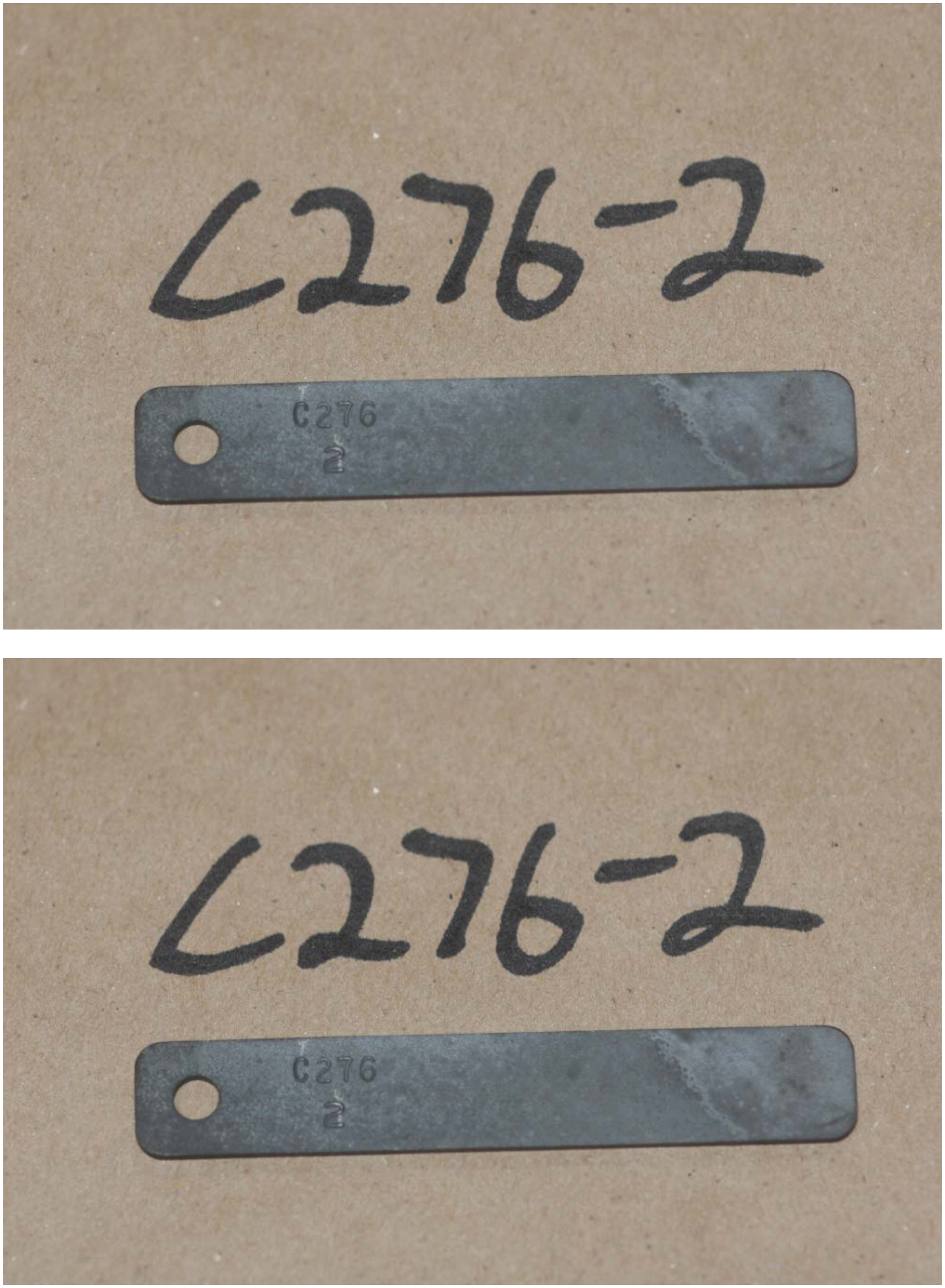


Figure 4 — C-276 Coupons before (Top) and after Cleaning (Bottom).

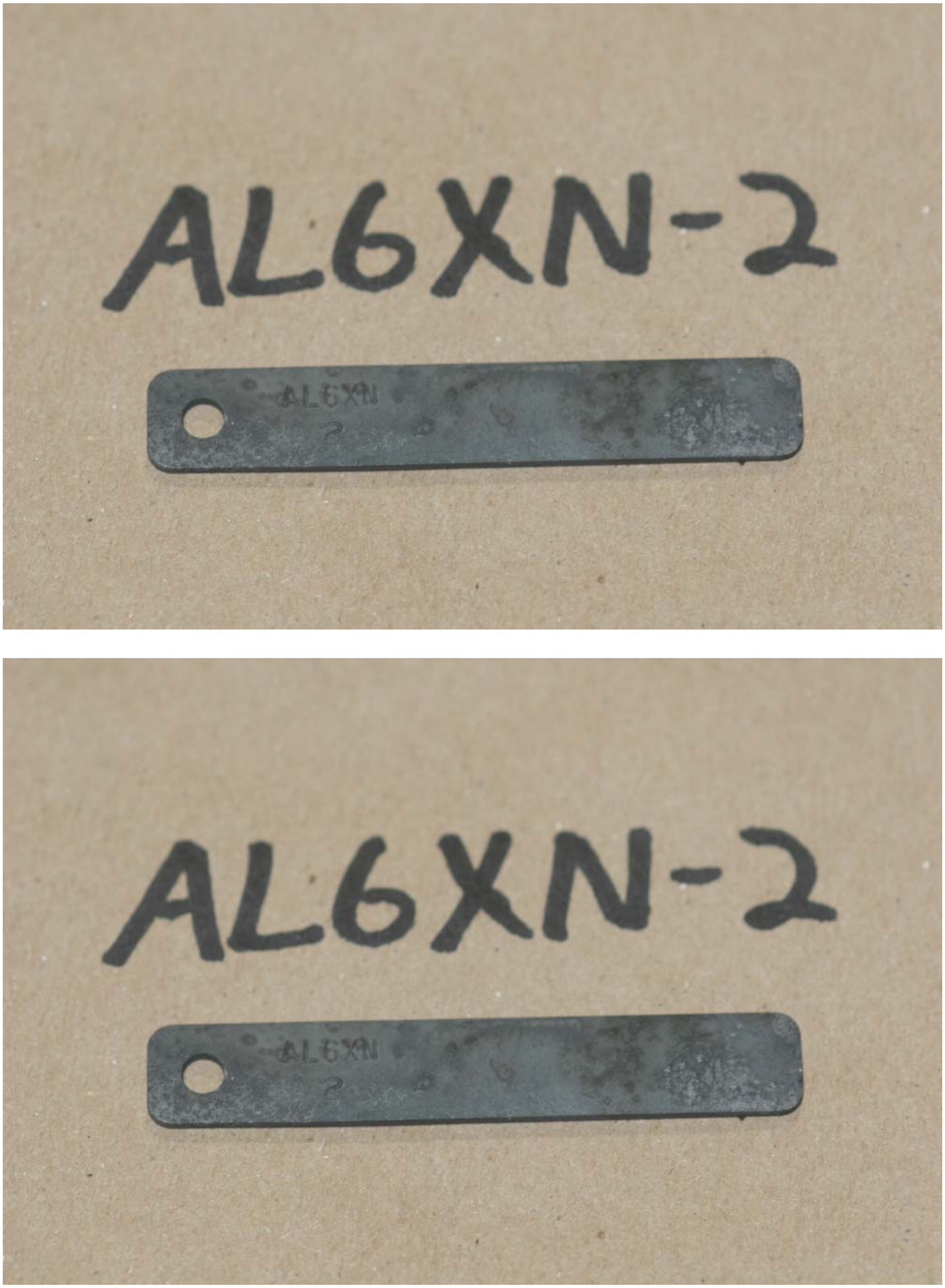


Figure 5 — AL6XN-2 Coupons before (Top) and after Cleaning (Bottom).

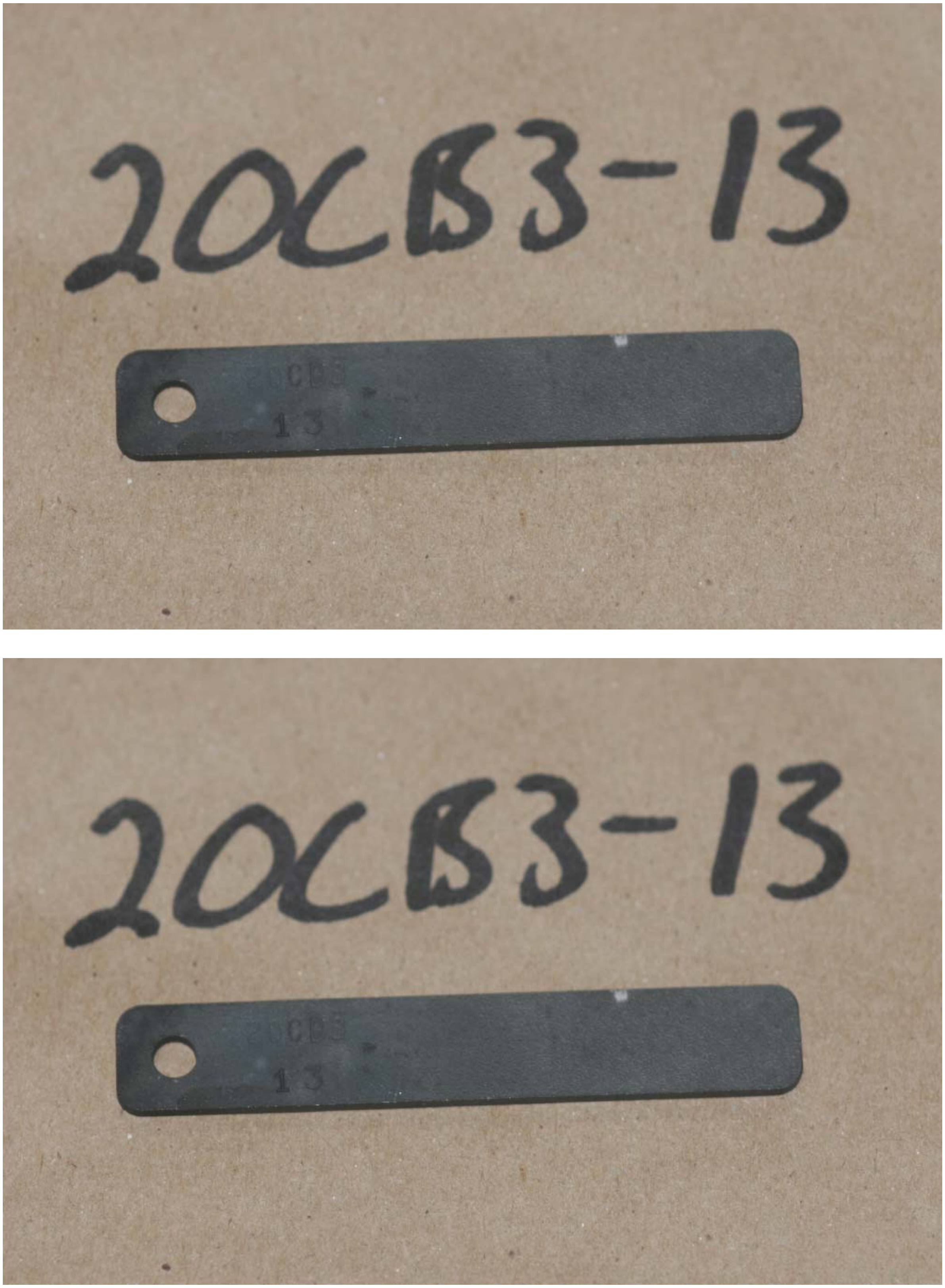


Figure 6 — 20 CB3-13 Coupons before (Top) and after Cleaning (Bottom).

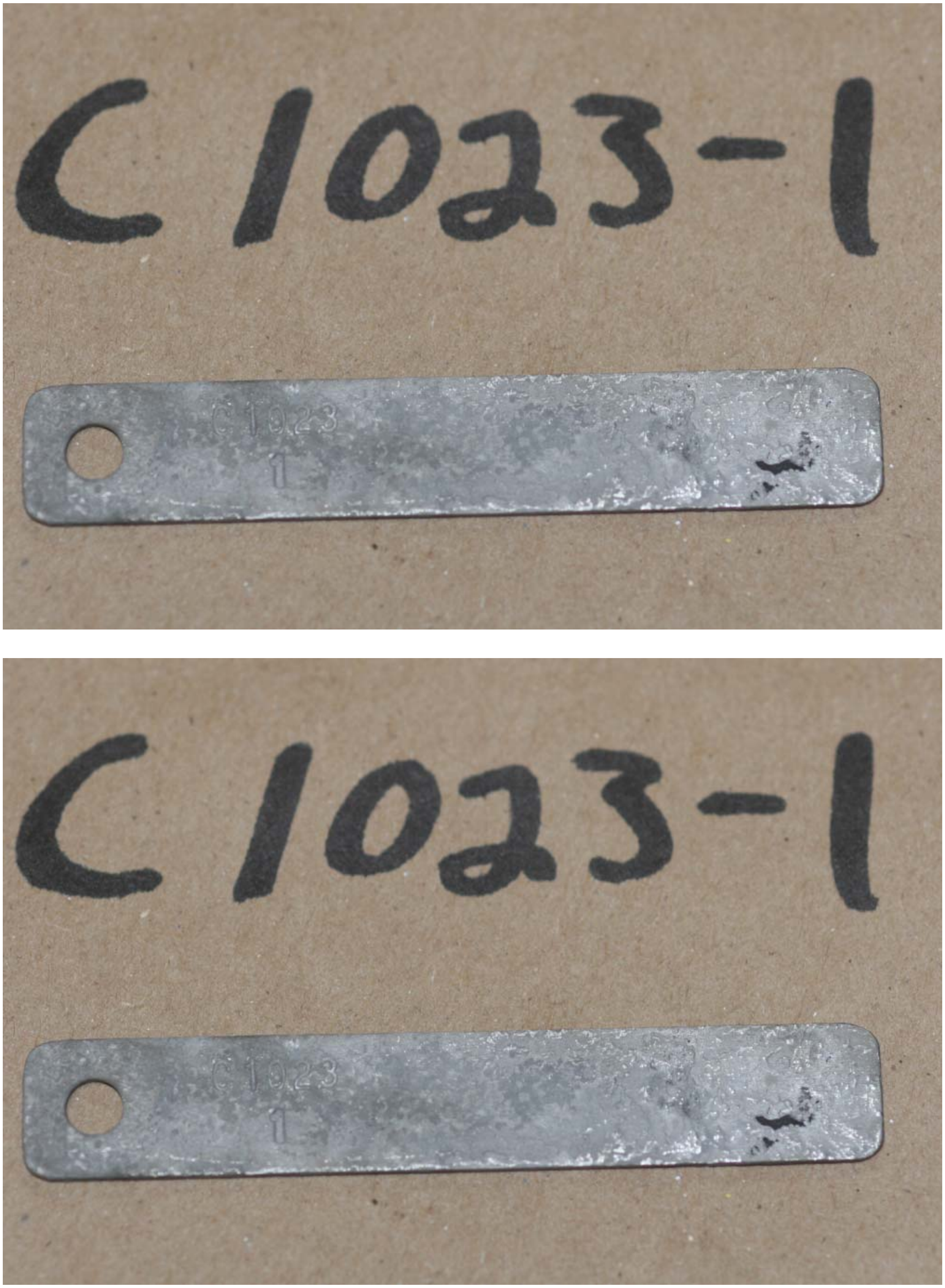


Figure 7 — 20 C1023-1 Coupons before (Top) and after Cleaning (Bottom).

Figure 8 — 304-03 Coupons before (Top) and after Cleaning (Bottom).

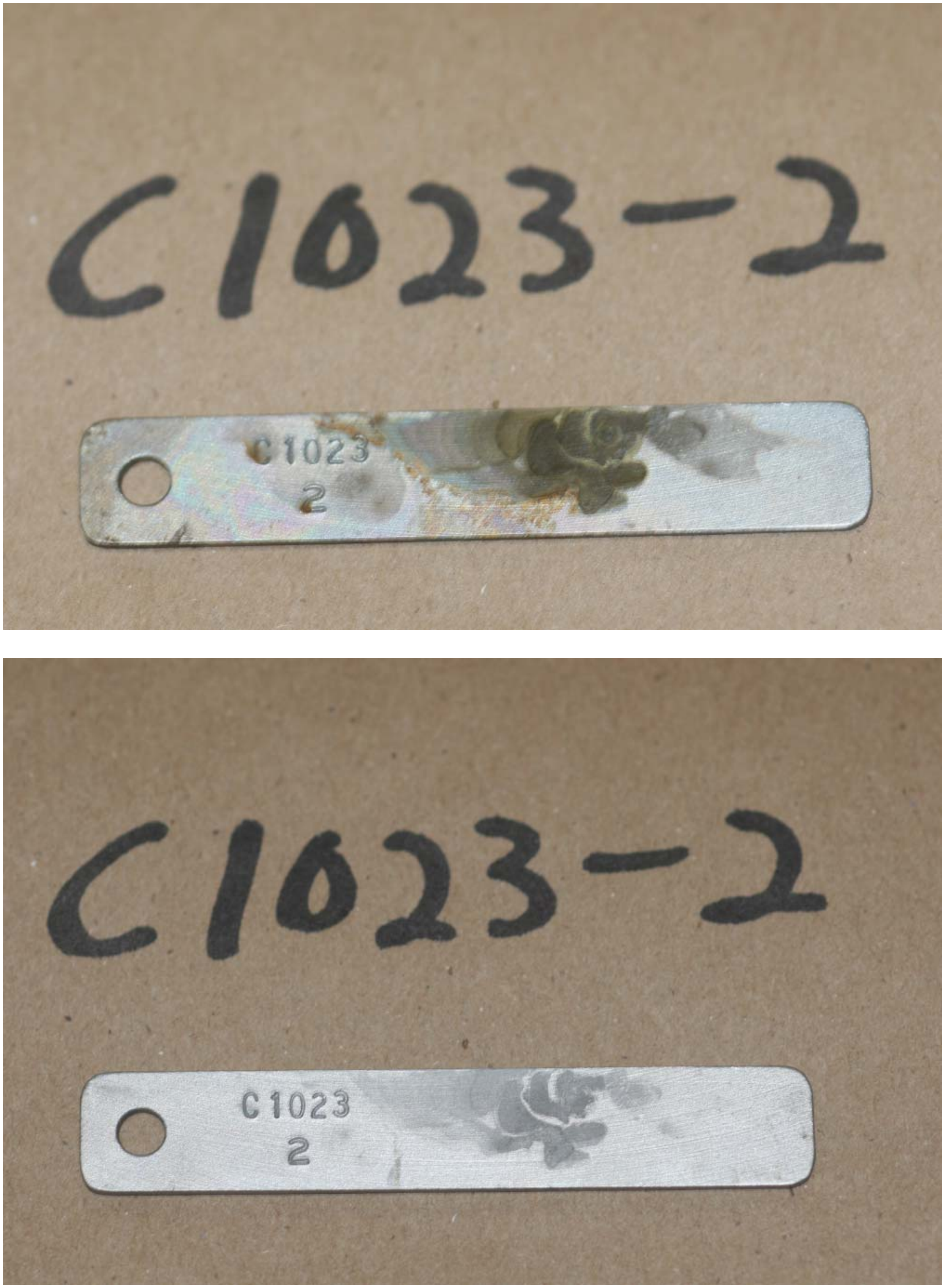


Figure 9 — C1023-2 Coupons before (Top) and after Cleaning (Bottom).

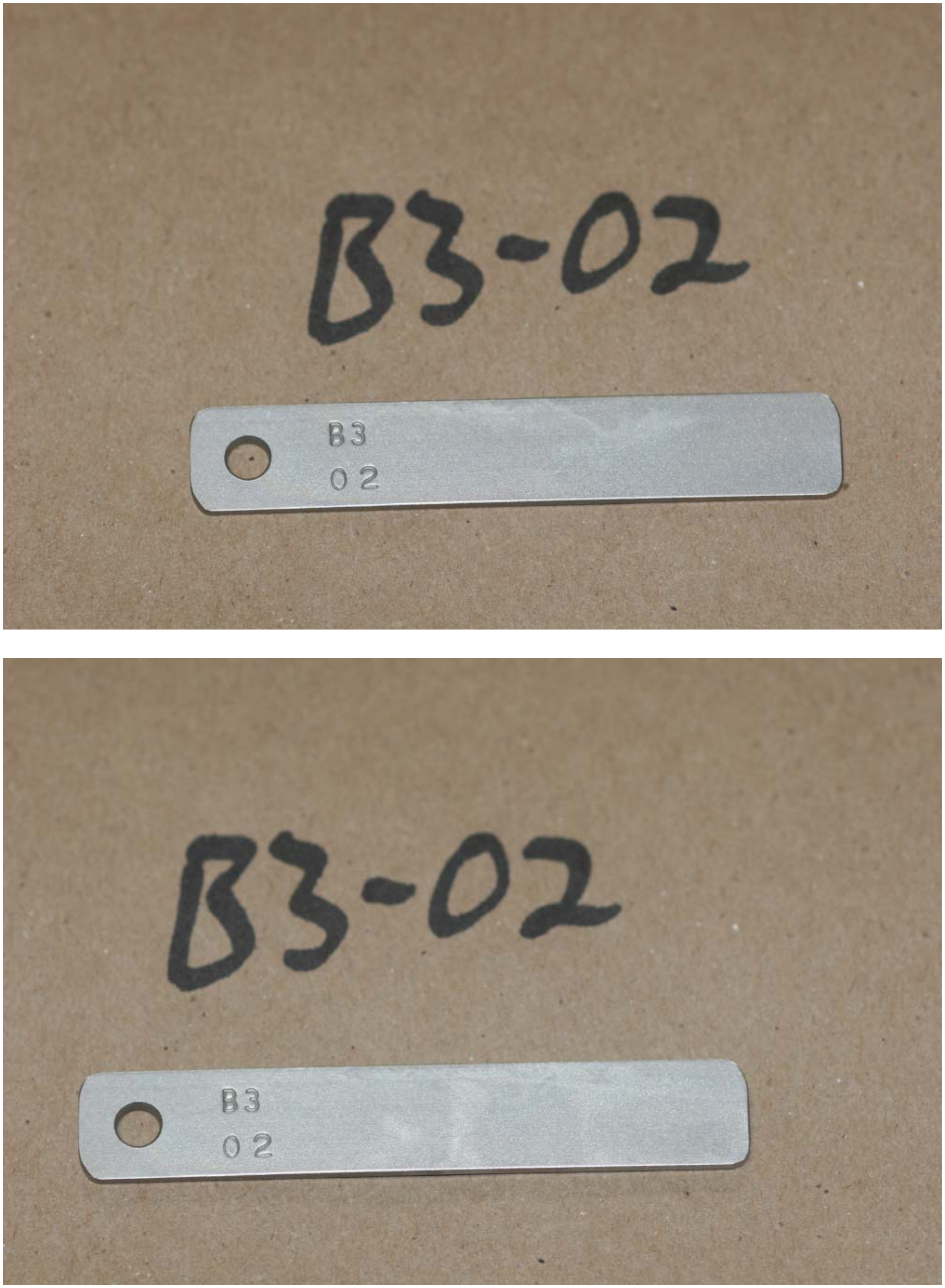


Figure 10 — B3-02 Coupons before (Top) and after Cleaning (Bottom).

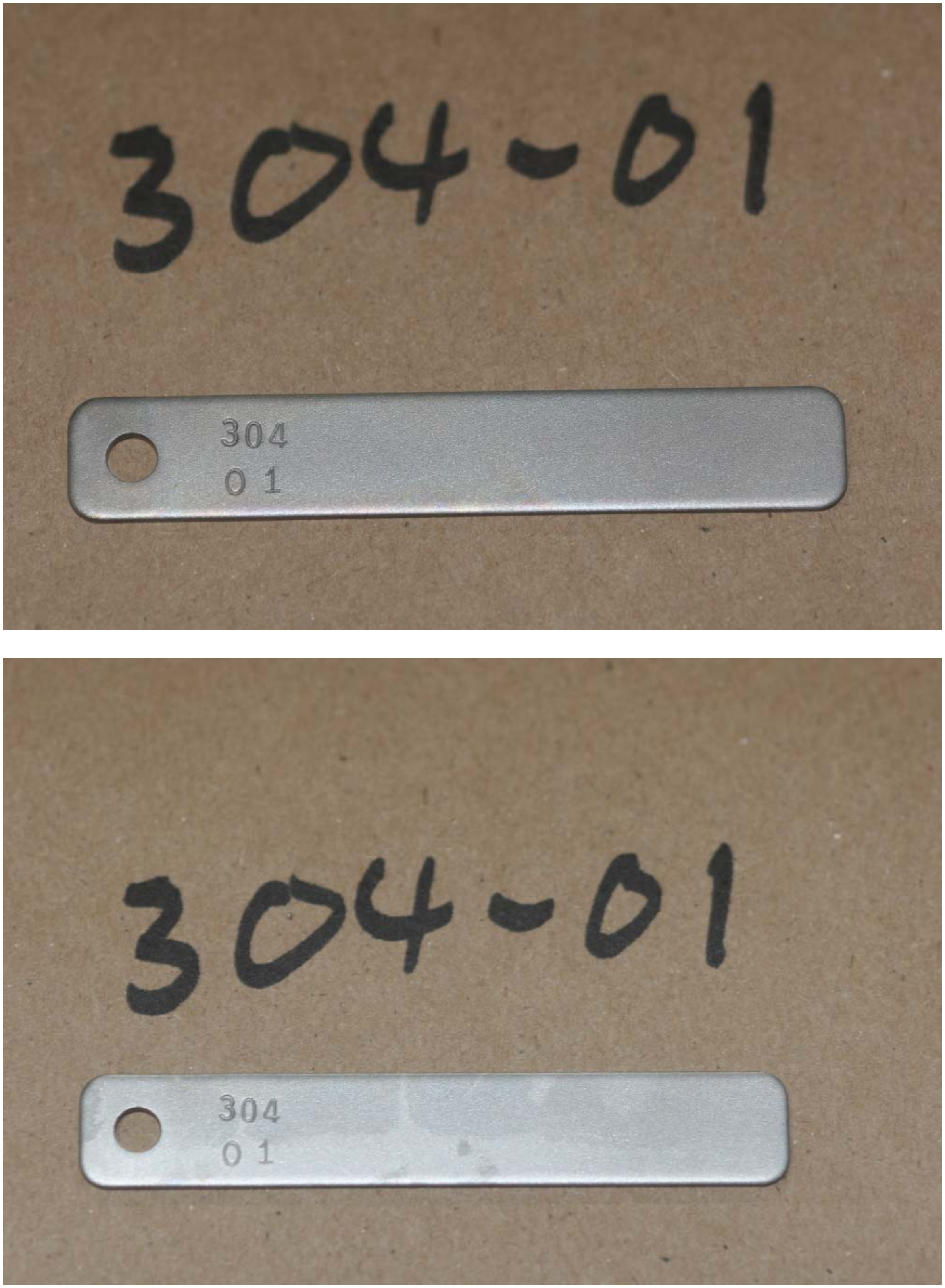


Figure 11 — 304-01 Coupons before (Top) and after Cleaning (Bottom).

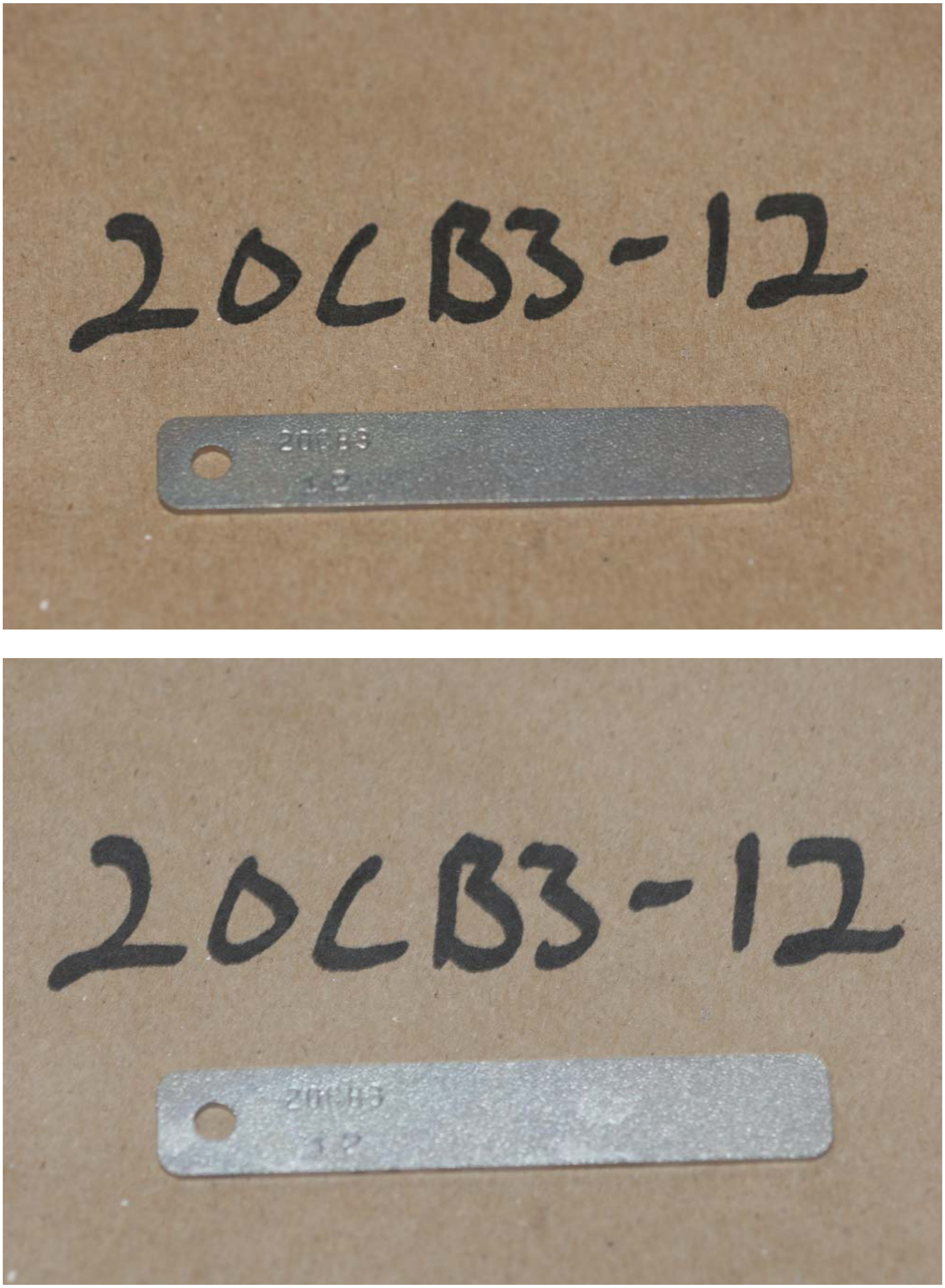


Figure 12 — 20CB3-12 Coupons before (Top) and after Cleaning (Bottom).

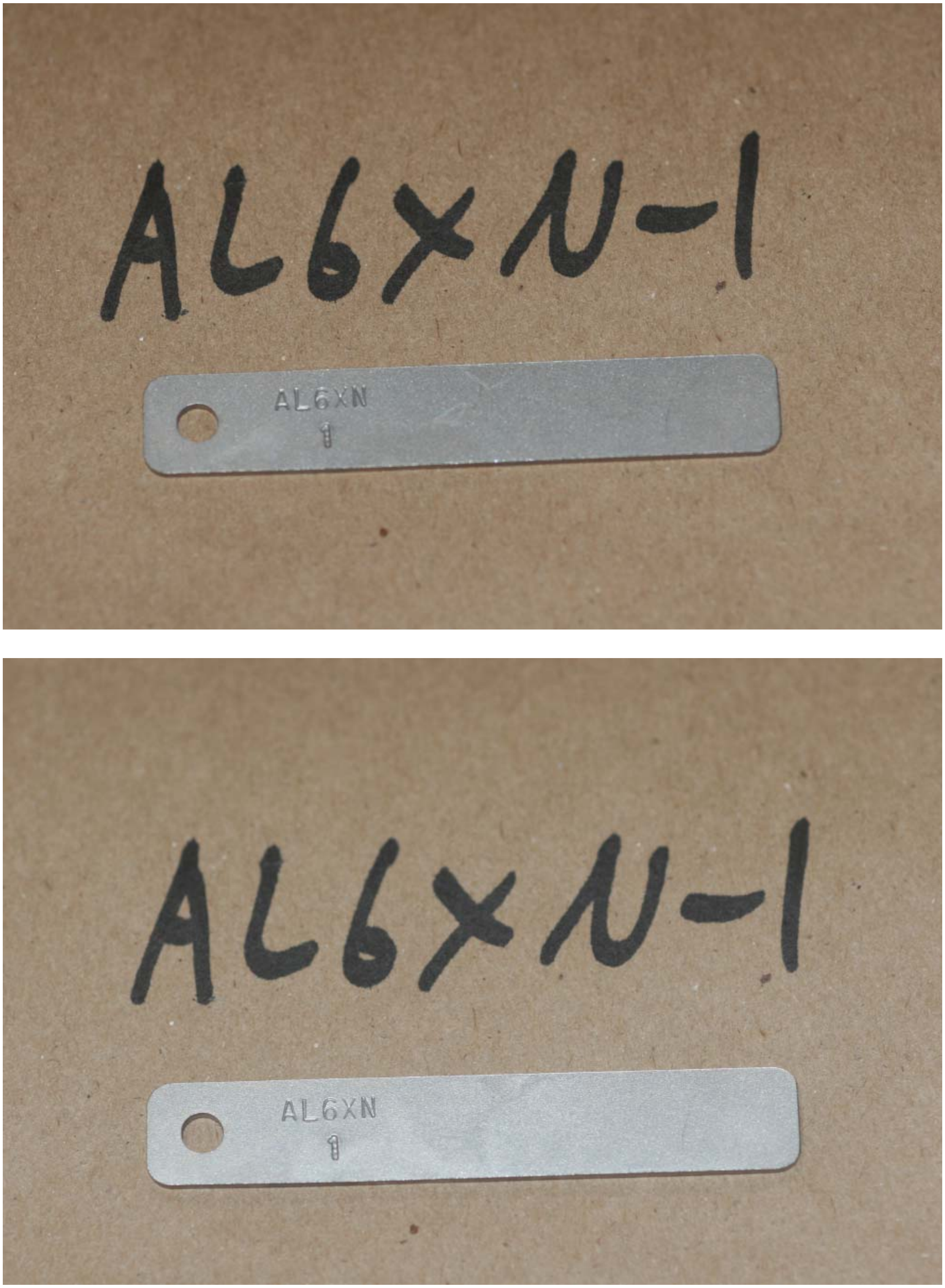


Figure 13 — AL6XN-1 Coupons before (Top) and after Cleaning (Bottom).

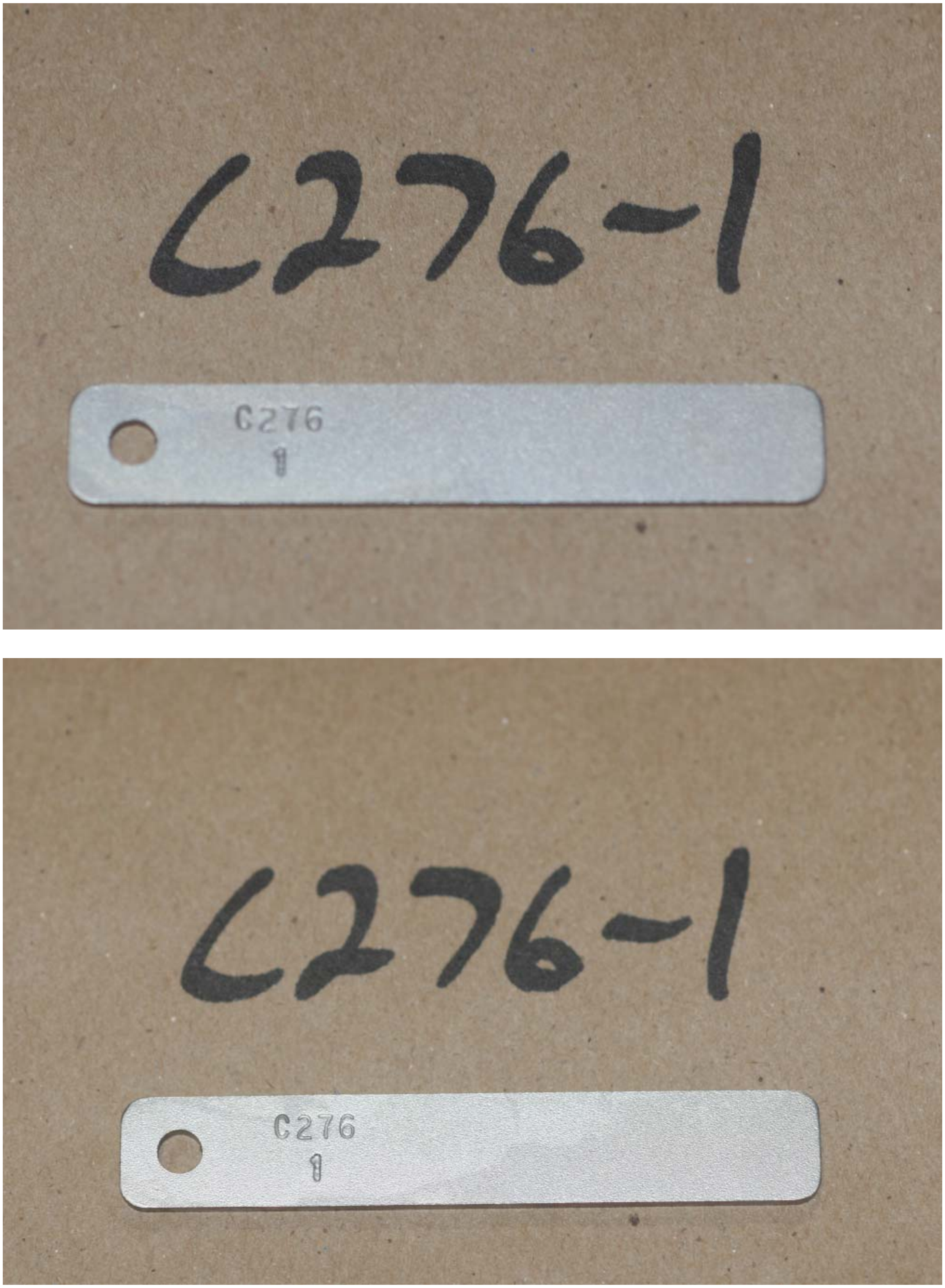


Figure 14 — C276-1 Coupons before (Top) and after Cleaning (Bottom).

TERRATHERM
10 Stevens Road
Fitchburg, MA 01420
Phone: (978) 343-0300
Fax: (978) 343-2727

August 20, 2009

Bruce Thompson
de maximis, inc.
200 Day Hill Road
Suite 200
Windsor, CT 06095

Re: Summary of Analytical Results

Dear Bruce:

Attached please find the laboratory data report for the non aqueous phase liquid (NAPL) collected from the source area at the Solvents Recovery Service of New England, Inc. (SRSNE) Superfund Site in Southington, Connecticut.

Data results indicate that the heat of combustion was higher than previous samples at 13,012 BTU/lb. This is consistent with the chloride content being lower than earlier estimates at 319,957 ppm and the presence of large quantities of non-chlorinated petroleum hydrocarbons including 1t,2-dimethylcyclopentane (11 Vol %), methylcyclohexane (1.1 Vol %), n-nonane (1.2 Vol %), 1-3 ethylmethylbenzene (1.4 Vol %), 1,3,5-trimethylbenzene (0.9 Vol %). These petroleum hydrocarbons are not reported in the previous volatile organic compound analysis.

These data suggest a higher heat load to the oxidizer and a lower salt production due to the lower chlorine content. Given the variability of the DNAPL and NAPL present in the treatment zone, we expect to use these and other available data to establish the upper ranges of the design criteria (e.g., heat load and salt production rates) for the off-gas treatment system.

Please contact me at the number above with any questions.

Sincerely,

TerraTherm, Inc.

Robin Swift
Project Manager

cc: John Hunt, *de maximis, inc.*

Encl.

HOUSTON LABORATORIES
8820 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
PHONE (713) 660-0901

Certificate of Analysis

Number: 1030-2009060590-001A

July 07, 2009

Robin Swift
Terra Therm, Inc.
10 Stevens Road
Fitchburg Maine 01420

Sample ID:	DNAPL	Sampled By:	RS
Project Name :	SRSNE	Sample Of:	Liquid
Project Number :		Sample Date:	03/27/2009 11:30
Project Location:		Sample Condition:	
Sample Point:		PO / Ref. No:	9101-002

ANALYTICAL DATA

Test	Method	Result	Unit	Detection Limit	Lab Tech.	Date Analyzed
Heat of Combustion	ASTM-D-240	13012	Gross BTU / lb		EM	07/07/09
Heat of Combustion	ASTM-D-240	NR	Net BTU/lb		EM	07/07/09
Heat of Combustion	ASTM-D-240	NR	Gross BTU/Gal		EM	07/07/09
Heat of Combustion	ASTM-D-240	NR	Net BTU/Gal		EM	07/07/09
Flash Point, (PM)	ASTM-D-93	72	°F		MES	07/01/09

Comments: NR= No result
Sample On: 03/27/2009 11:30

Alis Staley

Hydrocarbon Laboratory Manager

Quality Assurance: The above analyses are performed in accordance with ASTM, UOP or GPA guidelines for quality assurance, unless otherwise stated.

HOUSTON LABORATORIES
8820 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
PHONE (713) 660-0901

Certificate of Analysis

Number: 1030-2009060590-001A

July 08, 2009

Robin Swift
Terra Therm, Inc.
10 Stevens Road
Fitchburg Maine 01420

Sample ID: DNAPL
Project Name : SRSNE
Project Number :
Project Location:
Sample Point:

Sampled By: RS
Sample Of: Liquid
Sample Date: 03/27/2009 11:30
Sample Conditions:
PO / Ref. No: 9101-002

ANALYTICAL DATA

ASTM D86 Distillation

% Recovery	° F @ 762 mm Hg	Lab Tech.	Date Analyzed
Initial Boiling Point	168	BAC	07/08/09
5	170		
10	216		
20	228		
30	252		
40	262		
50	280		
60	306		
70	366		
80	640		
85	662		
90	670		
95	NR		
Final Boiling Point	672		
Volume % Recovery	94.0		
Volume% Residue	5.0		
Volume % Loss	1.0		

Comments: Modified: Used 50 mL of sample, due to foaming.
Visual color is dark straw.
Residue and loss are observed.
Temperatures are uncorrected for baromteric pressure.
Sample cracked at 672°F and 94 volume % recovery.
NR - No Result

Sample On: 03/27/2009 11:30

Staley

Hydrocarbon Laboratory Manager

Quality Assurance: The above analyses are performed in accordance with ASTM, UOP or GPA guidelines for quality assurance, unless otherwise stated

Certificate of Analysis

HOUSTON LABORATORIES
8820 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
PHONE (713) 660-0901

Analysis Number: 2009060590-001A

Sample ID:	DNALP	**Date of Sample:**	06/24/09
Project:	SRSNE	**Time Sampled:**	
Project Location:		**Date Sample Analyzed:**	07/06/09

Client	TerraTherm, Inc.		**Contact(s):**	Robin Swift		
Address	10 Stevens Road					
Suite / Department						
City	Fitchburg		**State**	Maine	**Zip**	6241
Phone	(978) 343-0300	**Ext**	**E-Mail**	rswift@terratherm.com		
Fax	(978) 343-2727					

Color:	Dark	**Odor:**	Aromatic
Specific Gravity @ 60° F.	1.0452	**API @ 60° F.**	3.75
Carbon Range	C5 - C26, C30+	**Major Range**	C7 - C10

Paraffin	7.1161	wt%	**N-Hexane**	0.475	wt%
Isoparaffins	12.1770	wt%	**Benzene**	0.020	wt%
Naphthenics	24.3064	wt%	**Ethyl Benzene**	6.957	wt%
Aromatics	55.1495	wt%	**Toluene**	12.989	wt%
Olefins	1.1291	wt%	**Meta-Xylene**	12.045	wt%
Unknowns	N/D	wt%	**Para-Xylene**	3.434	wt%
2,2,4-Tri Methylpentane	N/D	wt%	**Ortho-Xylene**	4.913	wt%
			Xylenes	20.392	wt%

Calculated Research Octane	N/A		**EDB**	N/A	wt%
Lead / Manganese	N/A		**EDC**	N/A	wt%
Oxygnates	0.0598	wt%	**Ethanol**	N/D	wt%
C_{17}	0.074	wt%	**C_{18}**	0.061	wt%
Pristane	N/D	wt%	**Phytane**	N/D	wt%
Naphthalene	0.162	wt%	**2-Methyl Naphthalene**	N/D	wt%
1-Methyl Naphthalene	0.033	wt%			

Gasoline Range:	C_4-C_{13} Indicators:	2,2,4-TMP; MTBE; Olefins, Lead
Diesel Range:	C_7-C_{20} Indicators:	Pristane, Phytane
Condensate Range:	C_2-C_{25}+ Indicators:	No Olefins, Light & Heavies
Heavy Oil:	C_{20+}	

Comments: **N/A Not Applicable N/D None Detected**

Chris Staley
Hydrocarbon Laboratory Manager

Detailed Hydrocarbon Analysis Summary Report -

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf
Sample: 2009060590-001A JL
Processed 214 Peaks
Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA

Acquired: 07/06/09 06:07:02
Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Comments:

SUMMARY REPORT

Group Type	Total(Mass%)	Total(Vol%)	Total(Mol%)
Paraffins:	7.1161	7.6124	6.1009
I-Paraffins:	12.1770	12.8523	10.3308
Olefins:	1.1291	1.2717	1.4815
Napthenes:	24.3064	24.6142	26.3440
Aromatics:	55.1495	53.5287	55.5128
Total C30+:	0.0621	0.0621	0.0167
Total Unknowns:	0.0000	0.0000	0.0000

Oxygenates:

Total:	0.0598(Mass%)	0.0586(Vol%)
Total Oxygen Content:	0.0299(Mass%)	
Multisubstituted Aromatics:	12.4159(Mass%)	11.0073(Vol%)

Average Molecular Weight: 114.2696

Relative Density: 0.7745

Vapor Pressure: 0.3383

Calculated Octane Number: 87.9106

	IBP	T10	T50	T90	FBP
Boiling Point (Deg F)	145.89	197.37	277.16	354.68	695.48

Percent Carbon: 89.8540

Percent Hydrogen: 10.1161

Bromine Number (Calc): 2.0700

Detailed Hydrocarbon Analysis Detail Report -

Report Date: 7/6/2009 1:37:30 PM

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Comments:

Acquired: 07/06/09 06:07:02
Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Oxygenates

Compound	Mass%	Mass% Oxygen	Vol%
methanol : X1	0.060	0.030	0.059

Molecular Weight and Relative Density Data

Group	Avg Mw.	Avg Rel. Density
C1	0.000	0.000
C2	0.000	0.000
C3	0.000	0.000
C4	0.000	0.000
C5	70.847	0.634
C6	84.955	0.685
C7	95.326	0.797
C8	118.172	0.744
C9	122.517	0.823
C10	138.237	0.793
C11	152.735	0.777
C12	157.697	0.832
C13	184.370	0.756
C14	198.390	0.763
C15	205.000	1.020
C16	226.450	0.773
C17	233.964	0.776
C18	242.605	0.778
C19	268.530	0.777
C20	272.904	0.781
C21	287.532	0.790
C22	310.610	0.794
C23	324.640	0.797
C24	332.426	0.798
C25	352.690	0.800
C26	352.690	0.800
C27	0.000	0.000
C28	0.000	0.000

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Sample: 2009060590-001A JL
Processed 214 Peaks
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Comments:

Acquired: 07/06/09 06:07:02
Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

C29	370.000	0.800
Total Sample:	114.00	0.77

Octane Number

Research Octane Number: 87.90
(Calculated from Individual Component Values)

Contribution to Total by:

Paraffins:	4.45
Iso-Paraffins:	9.29
Aromatics:	51.80
Napthenes:	20.80
Olefins:	1.49
Oxygenates:	0.06

Detailed Hydrocarbon Analysis Detail Report -

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Acquired: 07/06/09 06:07:02
Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Comments:

Totals by Group Type & Carbon Number (in Mass Percent)

	Paraffins	I-Paraffins	Olefins	Napthenes	Aromatics	Total
C1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C5	0.02603	0.01251	0.02834	0.00000	0.00000	0.06688
C6	0.47467	0.46119	0.78717	0.43464	0.02031	2.17798
C7	0.70913	1.19301	0.31361	11.90179	12.98879	27.10634
C8	0.79310	0.78089	0.00000	10.06922	27.34829	38.99150
C9	1.12467	2.29221	0.00000	0.94171	9.35776	13.71635
C10	1.79466	3.93828	0.00000	0.95905	4.50203	11.19402
C11	1.16308	2.12563	0.00000	0.00000	0.70634	3.99505
C12	0.22563	0.52756	0.00000	0.00000	0.22594	0.97913
C13	0.11350	0.00000	0.00000	0.00000	0.00000	0.11350
C14	0.07249	0.00000	0.00000	0.00000	0.00000	0.07249
C15	0.08867	0.00000	0.00000	0.00000	0.00000	0.08867
C16	0.06105	0.00000	0.00000	0.00000	0.00000	0.06105
C17	0.07439	0.06076	0.00000	0.00000	0.00000	0.13515
C18	0.06105	0.32316	0.00000	0.00000	0.00000	0.38421
C19	0.06032	0.00000	0.00000	0.00000	0.00000	0.06032
C20	0.05133	0.10768	0.00000	0.00000	0.00000	0.15901
C21	0.04422	0.07676	0.00000	0.00000	0.00000	0.12098
C22	0.03742	0.00000	0.00000	0.00000	0.00000	0.03742
C23	0.03261	0.00000	0.00000	0.00000	0.00000	0.03261
C24	0.06320	0.04859	0.00000	0.00000	0.00000	0.11179
C25	0.04488	0.00000	0.00000	0.00000	0.00000	0.04488
C26	0.00000	0.19051	0.00000	0.00000	0.00000	0.19051
C27	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C28	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C29	0.00000	0.03823	0.00000	0.00000	0.00000	0.03823
Total:	7.11609	12.17697	1.12913	24.30641	55.14947	99.87806

Oxygenates	0.05981	Total C30+:	0.06213
Total Unknowns:	0.00000	Grand Total:	100.00000

Totals by Group Type & Carbon Number (in Volume Percent)

	Paraffins	I-Paraffins	Olefins	Napthenes	Aromatics	Total
C1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C5	0.03222	0.01564	0.03384	0.00000	0.00000	0.08170
C6	0.55784	0.54297	0.89973	0.44383	0.01791	2.46227
C7	0.80377	1.34472	0.33811	12.24896	11.60969	26.34525
C8	0.87489	0.86012	0.00000	10.06504	28.81349	40.61353

Detailed Hydrocarbon Analysis Detail Report -

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf
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Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA

Acquired: 07/06/09 06:07:02
Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Comments:

C9	1.21455	2.46600	0.00000	0.92661	8.31416	12.92131
C10	1.90515	4.14446	0.00000	0.92975	3.96227	10.94164
C11	1.21146	2.16049	0.00000	0.00000	0.61447	3.98641
C12	0.23221	0.48358	0.00000	0.00000	0.19674	0.91253
C13	0.11628	0.00000	0.00000	0.00000	0.00000	0.11628
C14	0.07364	0.00000	0.00000	0.00000	0.00000	0.07364
C15	0.06737	0.00000	0.00000	0.00000	0.00000	0.06737
C16	0.06118	0.00000	0.00000	0.00000	0.00000	0.06118
C17	0.07410	0.06088	0.00000	0.00000	0.00000	0.13499
C18	0.06090	0.32189	0.00000	0.00000	0.00000	0.38279
C19	0.06013	0.00000	0.00000	0.00000	0.00000	0.06013
C20	0.05044	0.10734	0.00000	0.00000	0.00000	0.15778
C21	0.04329	0.07543	0.00000	0.00000	0.00000	0.11872
C22	0.03650	0.00000	0.00000	0.00000	0.00000	0.03650
C23	0.03171	0.00000	0.00000	0.00000	0.00000	0.03171
C24	0.06129	0.04725	0.00000	0.00000	0.00000	0.10854
C25	0.04347	0.00000	0.00000	0.00000	0.00000	0.04347
C26	0.00000	0.18454	0.00000	0.00000	0.00000	0.18454
C27	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C28	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C29	0.00000	0.03703	0.00000	0.00000	0.00000	0.03703
Total:	7.61238	12.85235	1.27167	24.61418	53.52873	99.87931

Oxygenates 0.05856
Total C30+: 0.06212
Total Unknowns: 0.00000
Grand Total: 100.00000

Detailed Hydrocarbon Analysis Detail Report -

Report Date: 7/6/2009 1:37:30 PM

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Sample: 2009060590-001A JL
Processed 214 Peaks
Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA

Acquired: 07/06/09 06:07:02
Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Comments:

Totals by Group Type & Carbon Number (in Mol Percent)

	Paraffins	I-Paraffins	Olefins	Napthenes	Aromatics	Total
C1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C2	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C4	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C5	0.04125	0.01982	0.04686	0.00000	0.00000	0.10794
C6	0.62977	0.61190	1.06941	0.59047	0.02974	2.93129
C7	0.80915	1.36127	0.36519	13.85926	16.11747	32.51235
C8	0.79383	0.78162	0.00000	10.25963	25.89138	37.72647
C9	1.00260	2.04342	0.00000	0.85291	8.90176	12.80069
C10	1.44215	3.16733	0.00000	0.78175	3.86751	9.25873
C11	0.85076	1.59425	0.00000	0.00000	0.54571	2.99071
C12	0.15145	0.39927	0.00000	0.00000	0.15920	0.70992
C13	0.07039	0.00000	0.00000	0.00000	0.00000	0.07039
C14	0.04178	0.00000	0.00000	0.00000	0.00000	0.04178
C15	0.04945	0.00000	0.00000	0.00000	0.00000	0.04945
C16	0.03082	0.00000	0.00000	0.00000	0.00000	0.03082
C17	0.03537	0.03068	0.00000	0.00000	0.00000	0.06605
C18	0.02742	0.15365	0.00000	0.00000	0.00000	0.18107
C19	0.02568	0.00000	0.00000	0.00000	0.00000	0.02568
C20	0.02077	0.04585	0.00000	0.00000	0.00000	0.06662
C21	0.01705	0.03106	0.00000	0.00000	0.00000	0.04811
C22	0.01377	0.00000	0.00000	0.00000	0.00000	0.01377
C23	0.01148	0.00000	0.00000	0.00000	0.00000	0.01148
C24	0.02134	0.01711	0.00000	0.00000	0.00000	0.03845
C25	0.01455	0.00000	0.00000	0.00000	0.00000	0.01455
C26	0.00000	0.06176	0.00000	0.00000	0.00000	0.06176
C27	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C28	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
C29	0.00000	0.01181	0.00000	0.00000	0.00000	0.01181
Total:	6.10085	10.33080	1.48146	26.34401	55.51276	99.76989

Oxygenates	0.21343	Total C14+:	0.01668
Total Unknowns:	0.00000	Grand Total:	100.00000

Detailed Hydrocarbon Analysis Detail Report -

Report Date: 7/6/2009 1:37:30 PM

RawFile: M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf
Sample: 2009060590-001A JL
Processed 214 Peaks
Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA
Comments:

Acquired: 07/06/09 06:07:02
Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Hold

Components Listed in Chromatographic Order

Minutes	Index	Group	Component	Mass %	Volume %	Mol %
8.183	378.330	X1	methanol	0.060	0.059	0.213
9.810	474.970	I5	i-pentane	0.013	0.016	0.020
10.550	500.000	P5	n-pentane	0.026	0.032	0.041
10.967	512.150	O5	t-pentene-2	0.015	0.018	0.024
11.663	529.730	O5	3-methylbutadiene-1,2	0.014	0.016	0.023
11.957	536.330	I6	2,2-dimethylbutane	0.017	0.020	0.022
13.533	565.950	I6	2,3-dimethylbutane	0.035	0.041	0.047
13.770	569.740	I6	2-methylpentane	0.217	0.257	0.287
14.723	583.760	I6	3-methylpentane	0.193	0.225	0.256
15.310	591.520	O6	hexene-1	0.787	0.900	1.069
16.003	600.000	P6	n-hexane	0.475	0.558	0.630
18.133	626.980	I7	2,2-dimethylpentane	0.025	0.029	0.029
18.343	629.350	N6	methylcyclopentane	0.281	0.291	0.382
18.710	633.380	I7	2,4-dimethylpentane	0.033	0.038	0.037
19.143	637.980	I7	2,2,3-trimethylbutane	0.328	0.369	0.375
20.680	653.040	A6	benzene	0.020	0.018	0.030
21.330	658.900	I7	3,3-dimethylpentane	0.021	0.023	0.024
21.713	662.230	N6	cyclohexane	0.154	0.153	0.209
22.760	670.900	I7	2-methylhexane	0.250	0.285	0.285
22.957	672.460	I7	2,3-dimethylpentane	0.090	0.100	0.102
23.270	674.910	N7	1,1-dimethylcyclopentane	0.048	0.049	0.055
23.783	678.820	I7	3-methylhexane	0.294	0.332	0.336
24.547	684.420	N7	1c,3-dimethylcyclopentane	0.092	0.095	0.107
24.997	687.610	N7	1t,2-dimethylcyclopentane	10.668	11.003	12.423
25.220	689.160	I7	3-ethylpentane	0.153	0.170	0.174
26.860	700.000	P7	n-heptane	0.709	0.804	0.809
28.193	711.430	O7	3-methyl-t-hexene-2	0.314	0.338	0.365
29.463	721.670	N7	methylcyclohexane	1.094	1.102	1.274
29.907	725.110	N8	1,1,3-trimethylcyclopentane	0.100	0.104	0.102
30.610	730.420	I8	2,5-dimethylhexane	0.117	0.130	0.117
31.080	733.890	I8	2,2,3-trimethylpentane	0.082	0.089	0.082
31.273	735.290	N8	1c,2t,4-trimethylcyclopentane	0.064	0.065	0.065
31.540	737.210	I8	3,3-dimethylhexane	0.097	0.106	0.097
32.320	742.710	N8	1t,2c,3-trimethylcyclopentane	0.083	0.084	0.085
32.533	744.190	I8	2,3,4-trimethylpentane	0.033	0.035	0.033
33.353	749.740	I8	I1	0.080	0.086	0.080
34.243	755.570	A7	toluene	12.989	11.610	16.117
35.370	762.680	N8	1,1,2-trimethylcyclopentane	0.093	0.093	0.094

Detailed Hydrocarbon Analysis Detail Report -

Report Date: 7/6/2009 1:37:30 PM

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Processed 214 Peaks
Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA
Comments:

Acquired: 07/06/09 06:07:02
Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Hold

Components Listed in Chromatographic Order

Minutes	Index	Group	Component	Mass %	Volume %	Mol %
36.290	768.280	I8	2-methylheptane	0.373	0.414	0.373
36.517	769.630	N8	1c,2c,4-trimethylcyclopentane	0.110	0.112	0.112
36.777	771.170	N8	1c,3-dimethylcyclohexane	0.037	0.037	0.037
37.463	775.170	N8	1t,4-dimethylcyclohexane	0.269	0.273	0.274
37.680	776.420	N8	1,1-dimethylcyclohexane	0.386	0.383	0.393
37.993	778.200	I9	2,2,5-trimethylhexane	0.151	0.165	0.134
38.907	783.290	N8	3c-ethylmethylcyclopentane	0.051	0.051	0.052
39.497	786.500	N8	3t-ethylmethylcyclopentane	0.037	0.038	0.038
39.877	788.540	N8	2t-ethylmethylcyclopentane	0.042	0.042	0.042
40.087	789.660	N8	1,1-methylethylcyclopentane	0.069	0.068	0.070
40.970	794.280	N8	1t,2-dimethylcyclohexane	0.169	0.169	0.172
41.590	797.450	N8	1t,3-dimethylcyclohexane	8.185	8.173	8.339
42.097	800.000	P8	n-octane	0.793	0.875	0.794
42.287	801.090	N8	1c,4-dimethylcyclohexane	0.095	0.094	0.097
46.073	821.840	N8	N2	0.029	0.029	0.030
46.947	826.340	N8	N3	0.092	0.091	0.094
48.087	832.070	I9	2,2-dimethylheptane	0.334	0.364	0.298
48.420	833.710	N8	N4	0.160	0.159	0.163
49.327	838.110	I9	2,2,3-trimethylhexane	0.180	0.195	0.161
49.917	840.930	I9	4,4-dimethylheptane	0.153	0.166	0.136
52.253	851.710	A8	ethylbenzene	6.957	6.218	7.492
53.007	855.070	I9	I3	0.082	0.087	0.073
54.500	861.560	A8	m-xylene	12.045	13.674	10.909
54.777	862.740	A8	p-xylene	3.434	3.899	3.110
55.103	864.130	N9	1c,3c,5c-trimethylcyclohexane	0.131	0.130	0.118
57.053	872.200	I9	I5	0.139	0.148	0.124
57.307	873.230	I9	4-ethylheptane	0.200	0.215	0.178
58.613	878.440	I9	3-ethylheptane	0.802	0.856	0.715
58.787	879.120	I9	3-methyloctane	0.251	0.270	0.224
59.627	882.390	A8	o-xylene	4.913	5.023	4.380
60.993	887.600	N9	N18	0.061	0.061	0.055
61.210	888.410	N9	N19	0.193	0.191	0.174
61.660	890.090	N9	N20	0.119	0.118	0.108
64.390	900.000	P9	n-nonane	1.125	1.215	1.003
64.770	902.900	N9	1,1-methylethylcyclohexane	0.167	0.160	0.151
66.050	912.530	A9	i-propylbenzene	0.296	0.266	0.282
66.573	916.410	I10	I11	0.107	0.114	0.086
66.963	919.280	N9	i-propylcyclohexane	0.066	0.064	0.060

Detailed Hydrocarbon Analysis Detail Report -

Report Date: 7/6/2009 1:37:30 PM

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Processed 214 Peaks
Reference File: H:\DHA Application Software\References\DHA REF0906 JL_06042009.DHA
Comments:

Acquired: 07/06/09 06:07:02
Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Hold

Components Listed in Chromatographic Order

Minutes	Index	Group	Component	Mass %	Volume %	Mol %
67.353	922.130	I10	I12	0.034	0.037	0.028
67.683	924.530	I10	2,4-dimethyloctane	0.146	0.156	0.117
68.447	930.020	N9	N29	0.090	0.088	0.081
68.747	932.160	I10	2,6-dimethyloctane	0.292	0.311	0.235
68.877	933.090	I10	2,5-dimethyloctane	0.149	0.159	0.120
69.310	936.150	N9	n-butylcyclopentane	0.117	0.115	0.106
69.533	937.730	N10	N30	0.075	0.073	0.061
70.253	942.760	I10	3,3-dimethyloctane	0.400	0.419	0.321
70.540	944.740	N10	N31	0.068	0.065	0.055
70.800	946.540	A9	n-propylbenzene	0.686	0.617	0.653
71.100	948.600	I10	3,6-dimethyloctane	0.077	0.081	0.062
71.310	950.040	I10	3-methyl-5-ethylheptane	0.160	0.171	0.129
71.670	952.490	N10	N32	0.047	0.045	0.038
71.953	954.410	A9	1,3-methylethylbenzene	1.582	1.418	1.505
72.237	956.330	A9	1,4-methylethylbenzene	0.730	0.657	0.694
72.793	960.060	N10	N33	0.139	0.134	0.113
73.080	961.970	A9	1,3,5-trimethylbenzene	1.014	0.908	0.964
73.227	962.940	I10	2,3-dimethyloctane	0.566	0.595	0.455
73.373	963.920	I10	I15	0.118	0.124	0.095
73.700	966.070	I10	I16	0.069	0.073	0.056
74.003	968.070	I10	5-methylnonane	0.104	0.110	0.084
74.243	969.640	I10	4-methylnonane	0.286	0.299	0.230
74.363	970.420	A9	1,2-methylethylbenzene	0.832	0.732	0.792
74.603	971.990	I10	2-methylnonane	0.337	0.360	0.271
74.853	973.610	I10	C10-Iso-Paraffin	0.063	0.068	0.051
75.027	974.730	I10	3-ethyloctane	0.151	0.158	0.121
75.233	976.060	N10	N35	0.106	0.103	0.087
75.457	977.500	I10	3-methylnonane	0.335	0.354	0.269
75.660	978.800	N10	N36	0.156	0.151	0.127
76.017	981.080	I10	I19	0.110	0.116	0.089
76.387	983.430	A9	1,2,4-trimethylbenzene	3.342	2.957	3.179
76.637	985.010	N10	i-butylcyclohexane	0.253	0.247	0.206
76.993	987.250	I10	I21	0.254	0.266	0.204
77.123	988.070	I10	I22	0.046	0.048	0.037
77.287	989.090	I10	I23	0.042	0.044	0.034
77.467	990.210	N10	N37	0.053	0.051	0.043
77.613	991.130	I10	C10-Iso-Paraffin	0.045	0.044	0.037
78.110	994.210	N10	1t-methyl-2-n-propylcyclohexane	0.033	0.032	0.027

Components Listed in Chromatographic Order

Minutes	Index	Group	Component	Mass %	Volume %	Mol %
78.317	995.480	A10	i-butylbenzene	0.080	0.073	0.068
78.717	997.940	A10	sec-butylbenzene	0.118	0.106	0.100
78.833	998.650	I10	C10-Iso-Paraffin	0.043	0.039	0.037
79.053	1000.000	P10	n-decane	1.795	1.905	1.442
79.287	1002.350	I11	I26	0.050	0.052	0.036
79.740	1006.920	A9	1,2,3-trimethylbenzene	0.875	0.758	0.833
80.003	1009.550	A10	1,3-methyl-i-propylbenzene	0.165	0.149	0.141
80.380	1013.310	A10	1,4-methyl-i-propylbenzene	0.148	0.134	0.126
81.000	1019.440	A10	2-3-dihydroindene	0.198	0.159	0.192
81.360	1022.990	N10	sec-butylcyclohexane	0.030	0.028	0.024
81.543	1024.780	I11	I30	0.276	0.289	0.202
81.877	1028.040	A10	1,2-methyl-i-propylbenzene	0.439	0.388	0.374
82.270	1031.860	I11	3-ethylnonane	0.126	0.131	0.092
82.417	1033.280	I11	I31	0.373	0.390	0.273
82.870	1037.650	I11	I32	0.088	0.085	0.065
83.073	1039.600	A10	1,3-diethylbenzene	0.164	0.147	0.140
83.167	1040.500	I11	C11-Iso-Paraffin	0.072	0.064	0.061
83.357	1042.310	A10	1,3-methyl-n-propylbenzene	0.413	0.372	0.352
83.623	1044.860	A10	1,4-diethylbenzene	0.110	0.099	0.093
83.763	1046.190	A10	1,4-methyl-n-propylbenzene	0.142	0.128	0.121
83.887	1047.360	A10	n-butylbenzene	0.139	0.125	0.119
84.100	1049.380	A10	1,3-dimethyl-5-ethylbenzene	0.249	0.220	0.213
84.313	1051.400	A10	1,2-diethylbenzene	0.042	0.037	0.036
84.507	1053.220	I11	C11-Iso-Paraffin	0.052	0.046	0.044
84.673	1054.790	I11	C11-Iso-Paraffin	0.181	0.159	0.154
84.980	1057.660	A10	1,2-methyl-n-propylbenzene	0.199	0.176	0.169
85.147	1059.220	I11	I35	0.038	0.040	0.028
85.527	1062.760	I11	I37	0.315	0.330	0.230
85.847	1065.720	I11	I38	0.200	0.209	0.146
86.063	1067.720	A10	1,4,dimethyl-2-ethylbenzene	0.190	0.168	0.162
86.227	1069.230	A10	A3	0.395	0.356	0.336
86.423	1071.040	I11	I39	0.135	0.141	0.099
86.850	1074.950	A10	1,2-dimethyl-4-ethylbenzene	0.438	0.388	0.373
87.433	1080.260	A10	1,3-dimethyl-2-ethylbenzene	0.094	0.081	0.080
87.683	1082.520	I11	I42	0.076	0.080	0.056
88.060	1085.920	I11	I43	0.060	0.062	0.044
88.190	1087.080	I11	C11-Iso-Paraffin	0.037	0.039	0.027
88.457	1089.480	A12	1,3-di-n-propylbenzene	0.049	0.043	0.034

Detailed Hydrocarbon Analysis Detail Report -

Report Date: 7/6/2009 1:37:30 PM

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Comments:

Acquired: 07/06/09 06:07:02
Analyzed: 7/6/2009 1:31:39 PM

Normalized to 100.0000%

Hold

Components Listed in Chromatographic Order

Minutes	Index	Group	Component	Mass %	Volume %	Mol %
88.680	1091.470	A11	1,4-methyl-t-butylbenzene	0.076	0.069	0.058
88.830	1092.810	A10	1,2-dimethyl-3-ethylbenzene	0.135	0.117	0.115
89.293	1096.930	A11	1,2-ethyl-i-propylbenzene	0.053	0.047	0.041
89.407	1097.930	I11	C11-Iso-Paraffin	0.047	0.041	0.036
89.640	1100.000	P11	n-undecane	1.163	1.211	0.851
89.897	1103.100	A11	1,4-ethyl-i-propylbenzene	0.050	0.043	0.038
90.020	1104.590	A10	1,2,4,5-tetramethylbenzene	0.159	0.139	0.136
90.333	1108.370	A11	1,2-methyl-n-butylbenzene	0.203	0.177	0.157
90.517	1110.570	A10	1,2,3,5-tetramethylbenzene	0.096	0.083	0.082
90.973	1116.030	A11	1,2-methyl-t-butylbenzene	0.044	0.039	0.034
91.430	1121.470	I12	C12-Iso-Paraffin	0.084	0.073	0.064
91.900	1127.030	A10	5-methylindan	0.141	0.123	0.122
92.047	1128.760	I12	C12-Iso-Paraffin	0.063	0.055	0.055
92.293	1131.660	I12	I44	0.136	0.140	0.091
92.487	1133.930	A10	4-methylindan	0.036	0.031	0.031
92.763	1137.170	A11	1,2-ethyl-n-propylbenzene	0.206	0.179	0.159
93.200	1142.260	I12	C12-Iso-Paraffin	0.113	0.098	0.087
93.313	1143.570	A12	1,3-di-i-propylbenzene	0.030	0.026	0.021
93.720	1148.280	A11	n-pentylbenzene	0.041	0.036	0.032
94.600	1158.400	I12	C12-Iso-Paraffin	0.063	0.055	0.049
94.723	1159.810	A12	1,4-di-i-propylbenzene	0.057	0.050	0.040
95.047	1163.500	A10	tetrahydronaphthalene	0.051	0.041	0.044
95.237	1165.660	I12	C12-Iso-Paraffin	0.036	0.029	0.031
95.360	1167.060	A10	naphthalene	0.162	0.122	0.144
95.963	1173.870	A12	1,4-ethyl-t-butylbenzene	0.052	0.045	0.036
96.270	1177.320	I12	I45	0.034	0.034	0.022
98.313	1200.000	P12	n-dodecane	0.226	0.232	0.151
99.580	1217.240	A12	1,3,5-triethylbenzene	0.039	0.034	0.027
104.407	1280.830	A11	1-methylnaphthalene	0.033	0.025	0.026
105.910	1300.000	P13	n-tridecane	0.113	0.116	0.070
112.807	1400.000	P14	C14	0.072	0.074	0.042
118.990	1498.400	P15	C15	0.089	0.067	0.049
124.280	1598.940	P16	C16	0.061	0.061	0.031
128.150	1682.930	I17	C17-Iso-Paraffin	0.061	0.061	0.031
128.893	1698.790	P17	C17	0.074	0.074	0.035
129.147	1704.880	I18	C18-Iso-Paraffin	0.032	0.031	0.015
130.447	1736.970	I18	C18-Iso-Paraffin	0.192	0.192	0.091
131.363	1759.400	I18	C18-Iso-Paraffin	0.099	0.099	0.047

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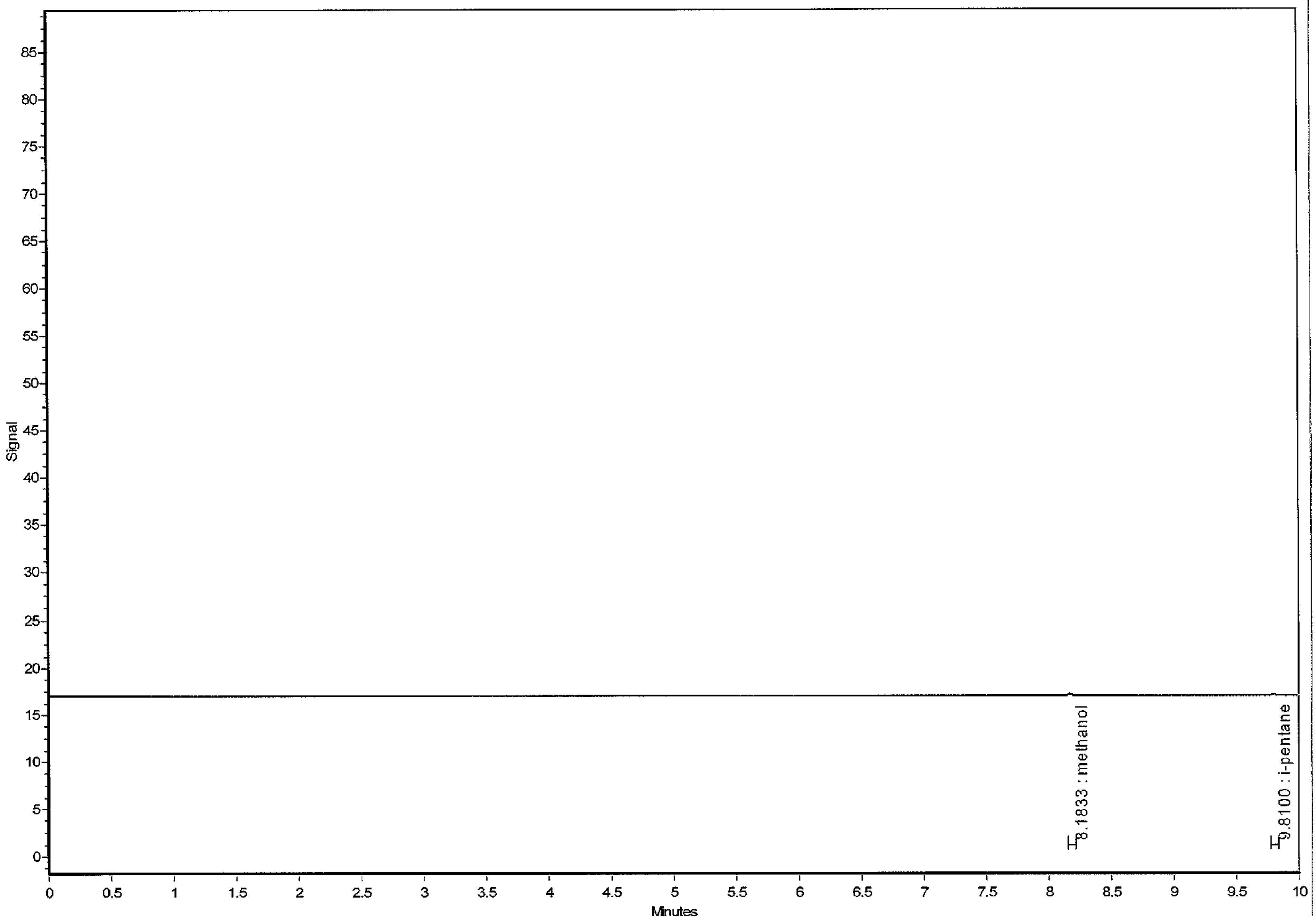
Hold

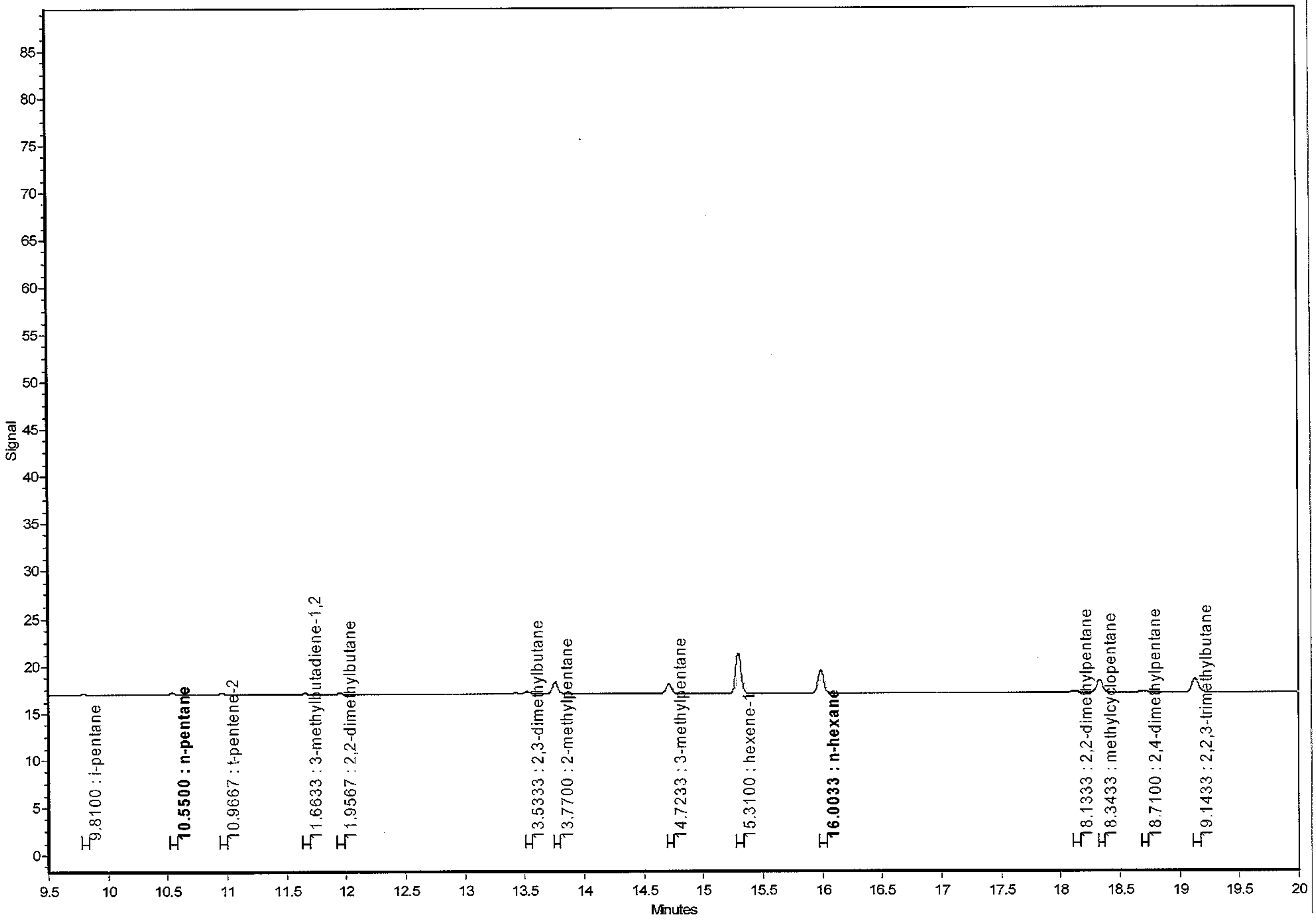
Components Listed in Chromatographic Order

Minutes	Index	Group	Component	Mass %	Volume %	Mol %
133.017	1799.430	P18	C18	0.061	0.061	0.027
136.763	1895.130	P19	C19	0.060	0.060	0.026
137.687	1922.110	I20	C20-Iso-Paraffin	0.108	0.107	0.046
140.233	1998.320	P20	C20	0.051	0.050	0.021
141.807	2047.880	I21	C21-Iso-Paraffin	0.077	0.075	0.031
143.477	2100.000	P21	C21	0.044	0.043	0.017
146.553	2196.980	P22	C22	0.037	0.037	0.014
149.767	2300.000	P23	C23	0.033	0.032	0.011
150.150	2310.270	I24	C24-Iso-Paraffin	0.049	0.047	0.017
153.360	2395.280	P24	C24	0.063	0.061	0.021
157.530	2496.880	P25	C25	0.045	0.043	0.015
158.283	2512.420	I26	C26-Iso-Paraffin	0.158	0.153	0.051
159.760	2541.660	I26	C26-Iso-Paraffin	0.032	0.031	0.010
162.660	2598.260	P26	C26	0.000	0.000	0.000
184.330	2890.320	I29	C29-Iso-Paraffin	0.038	0.037	0.012
185.250	2900.080	+	C30+	0.000	0.000	0.000
186.383	2910.220	+	C30+	0.062	0.062	0.017

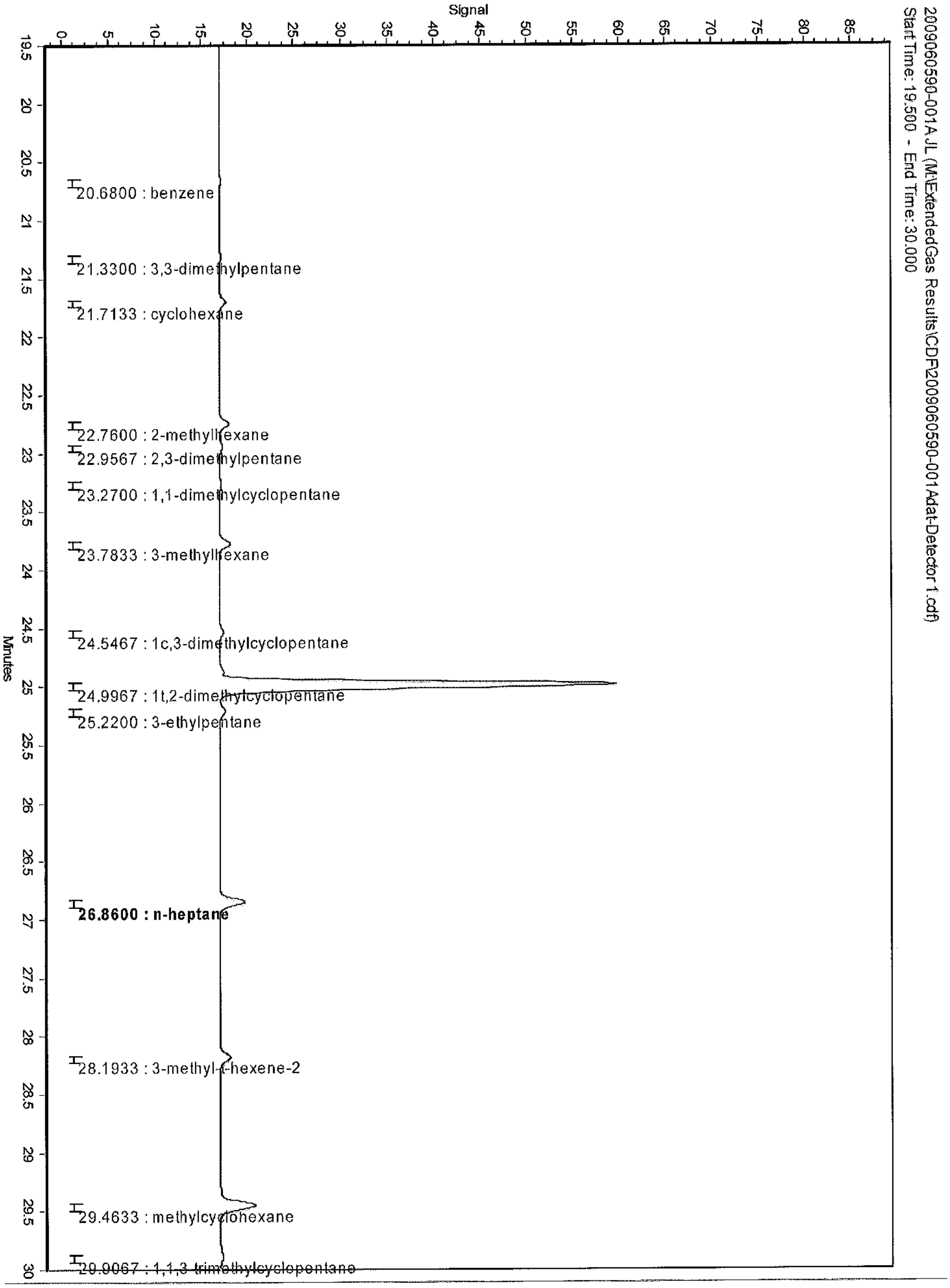
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 0.000 - End Time: 10.000



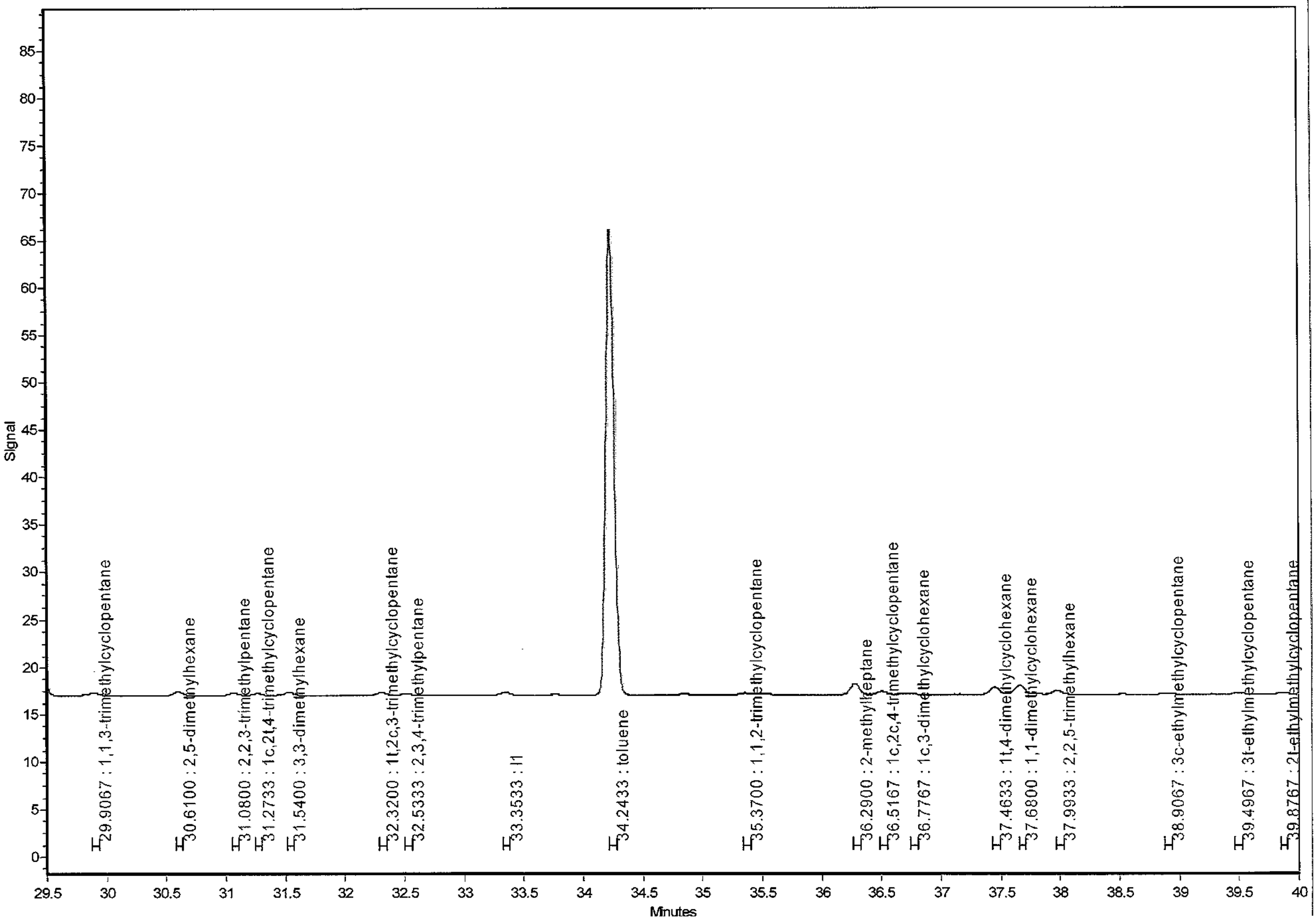
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 9.500 - End Time: 20.000



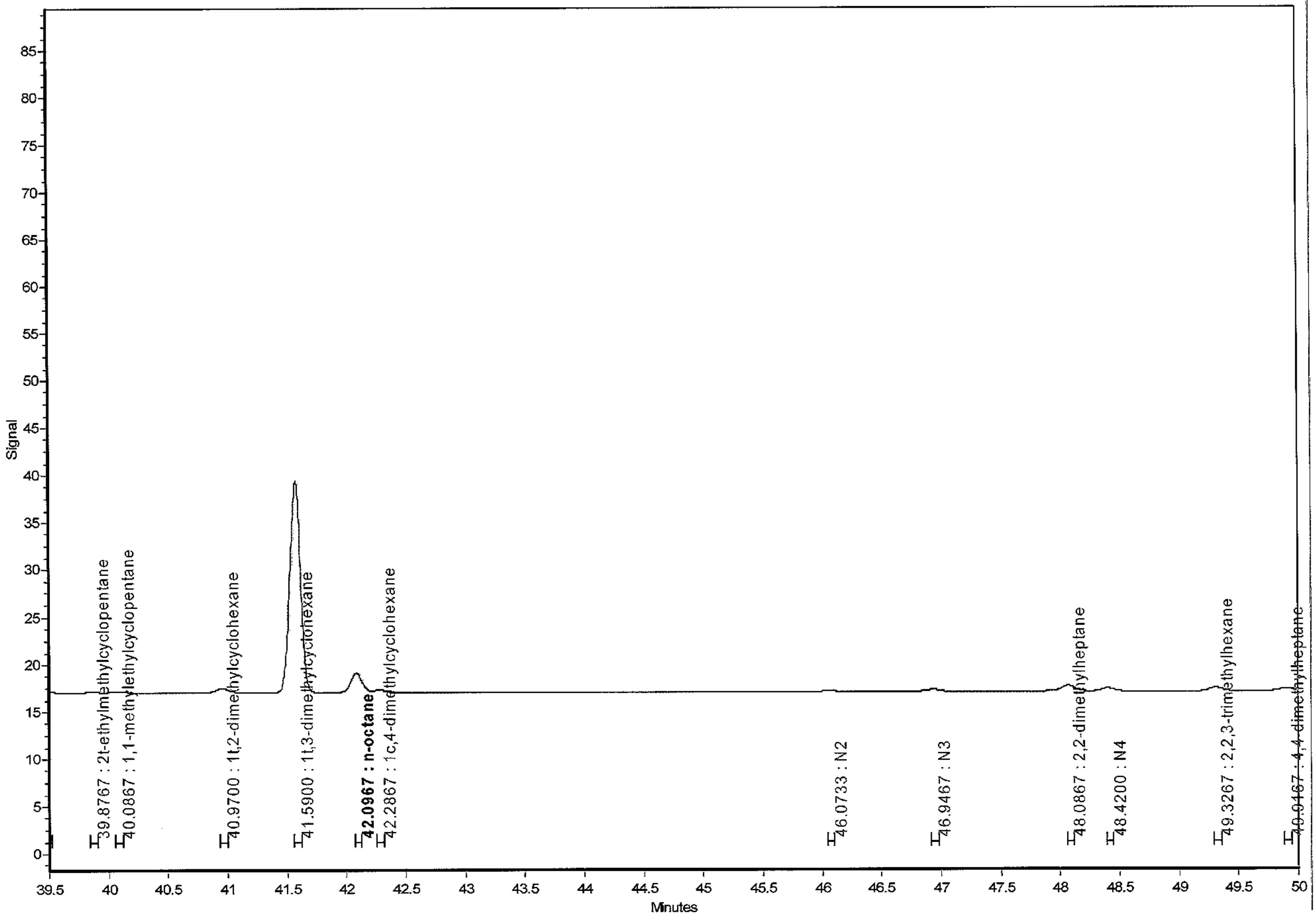
2009060590-001A.JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 19.500 - End Time: 30.000



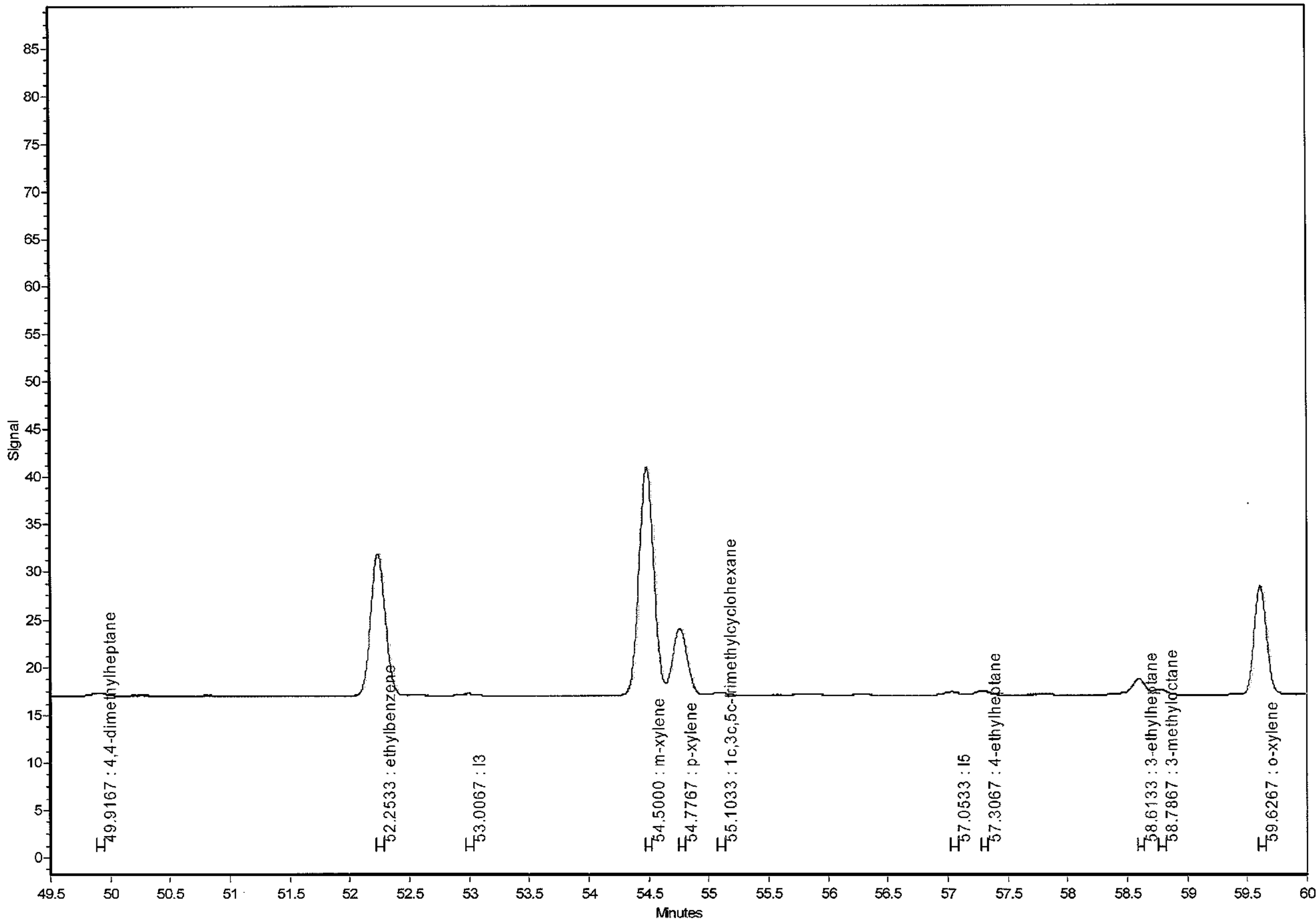
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 29.500 - End Time: 40.000



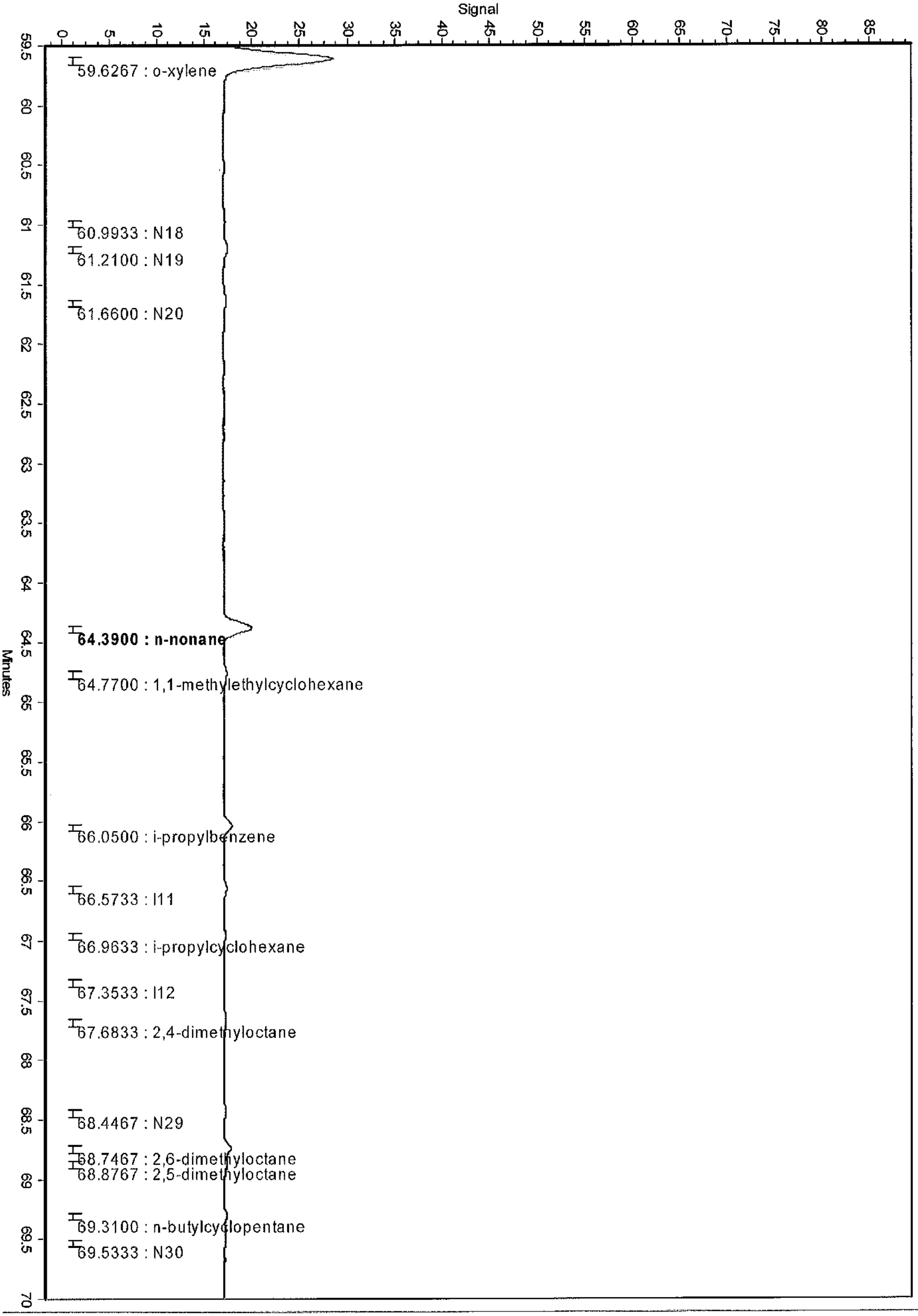
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 39.500 - End Time: 50.000



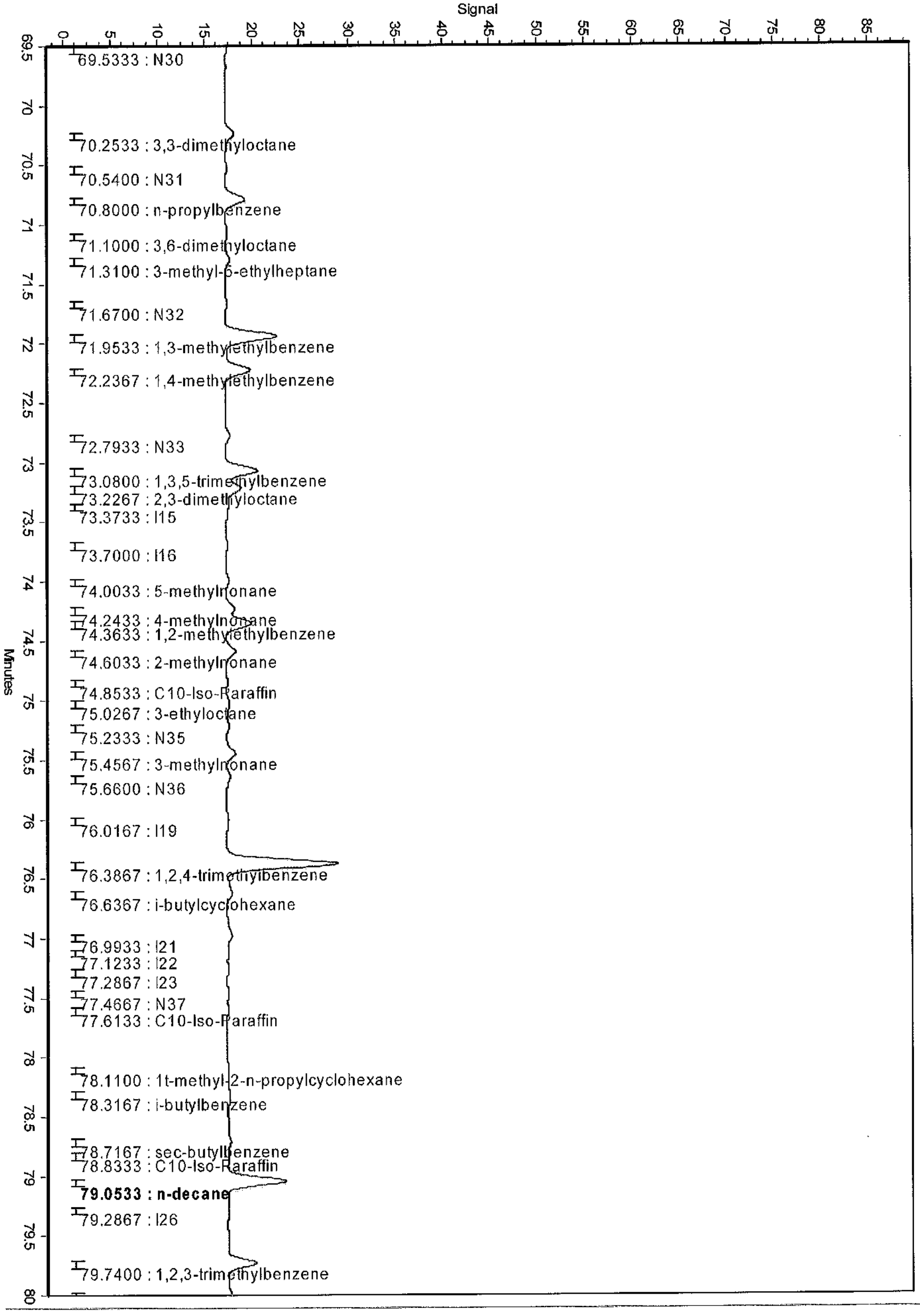
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 49.500 - End Time: 60.000



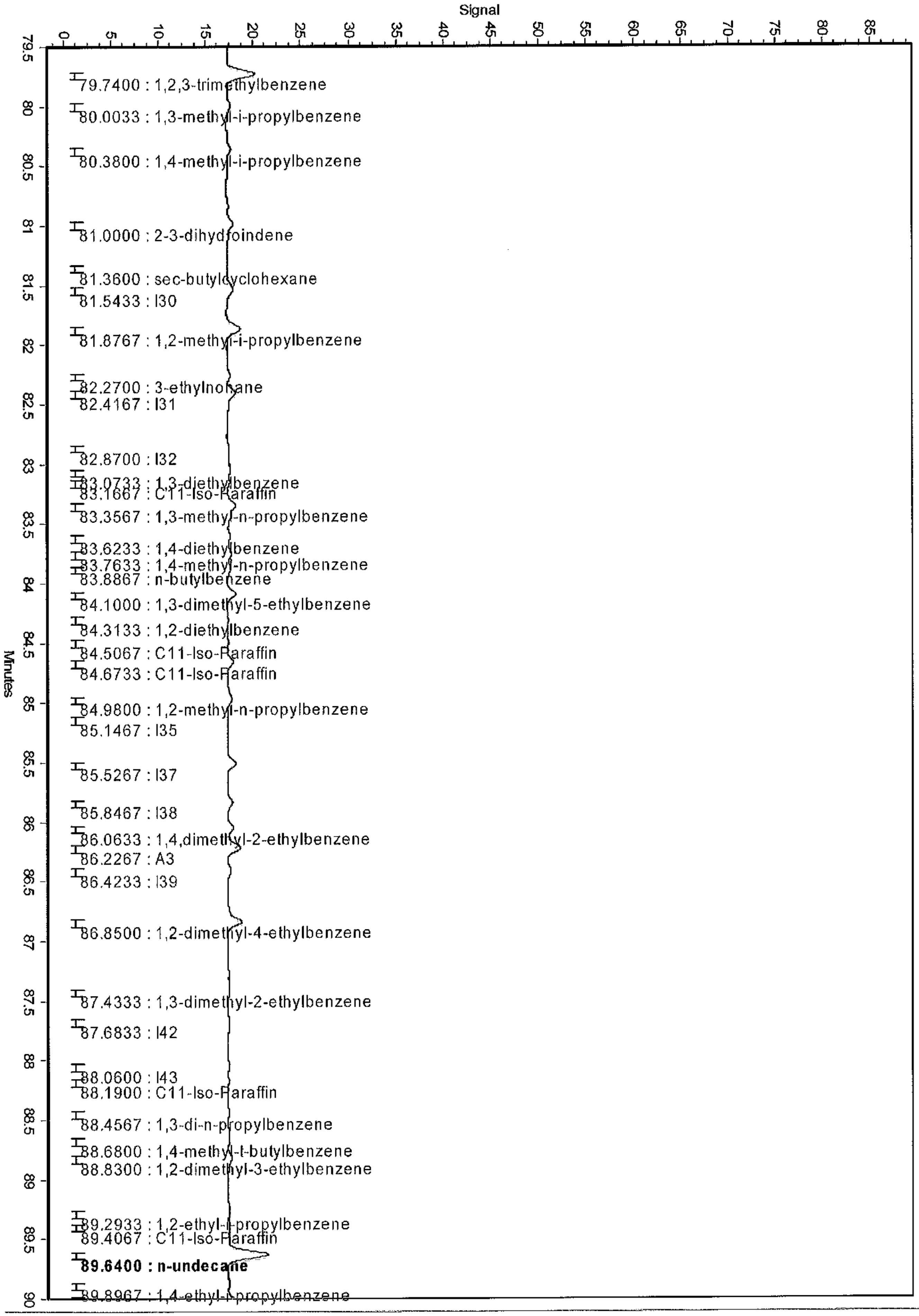
20090605 90-001A.JL (M:\ExtendedGas Results\CDF\20090605 90-001Adat-Detector 1.cdf)
Start Time: 59.500 - End Time: 70.000



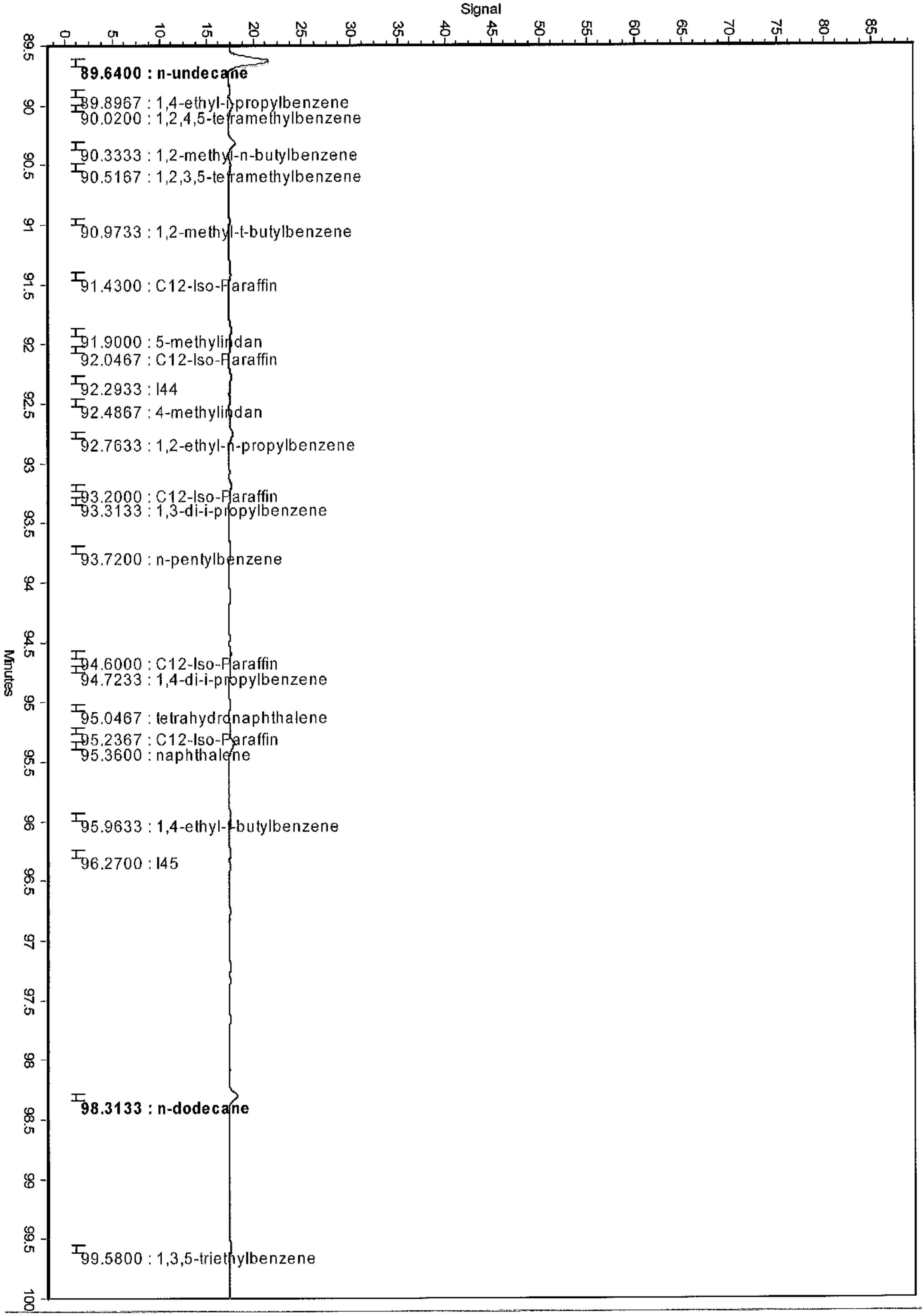
2009060590-001A.JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 69.500 - End Time: 80.000



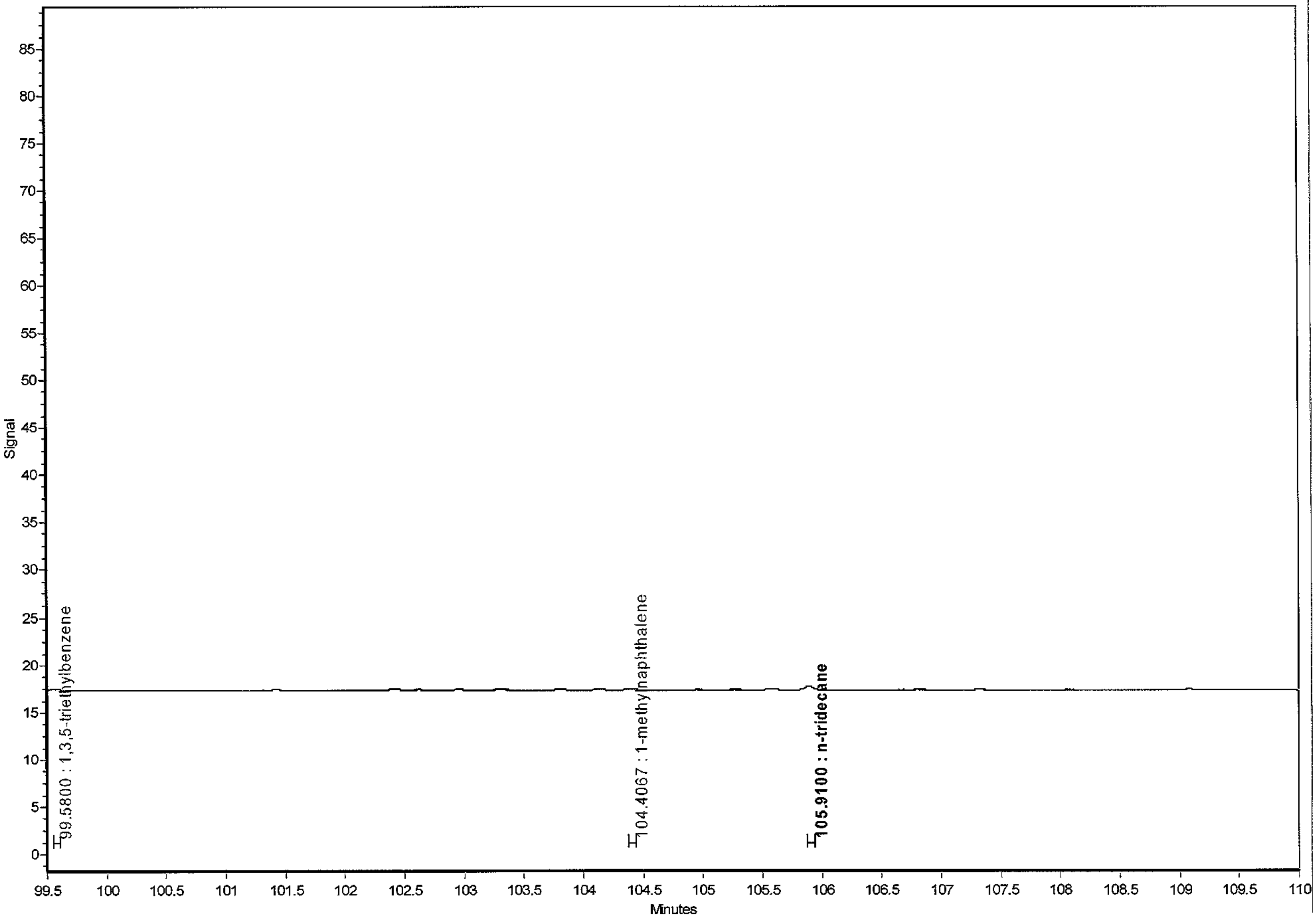
2009060590-001A.JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 79.500 - End Time: 90.000



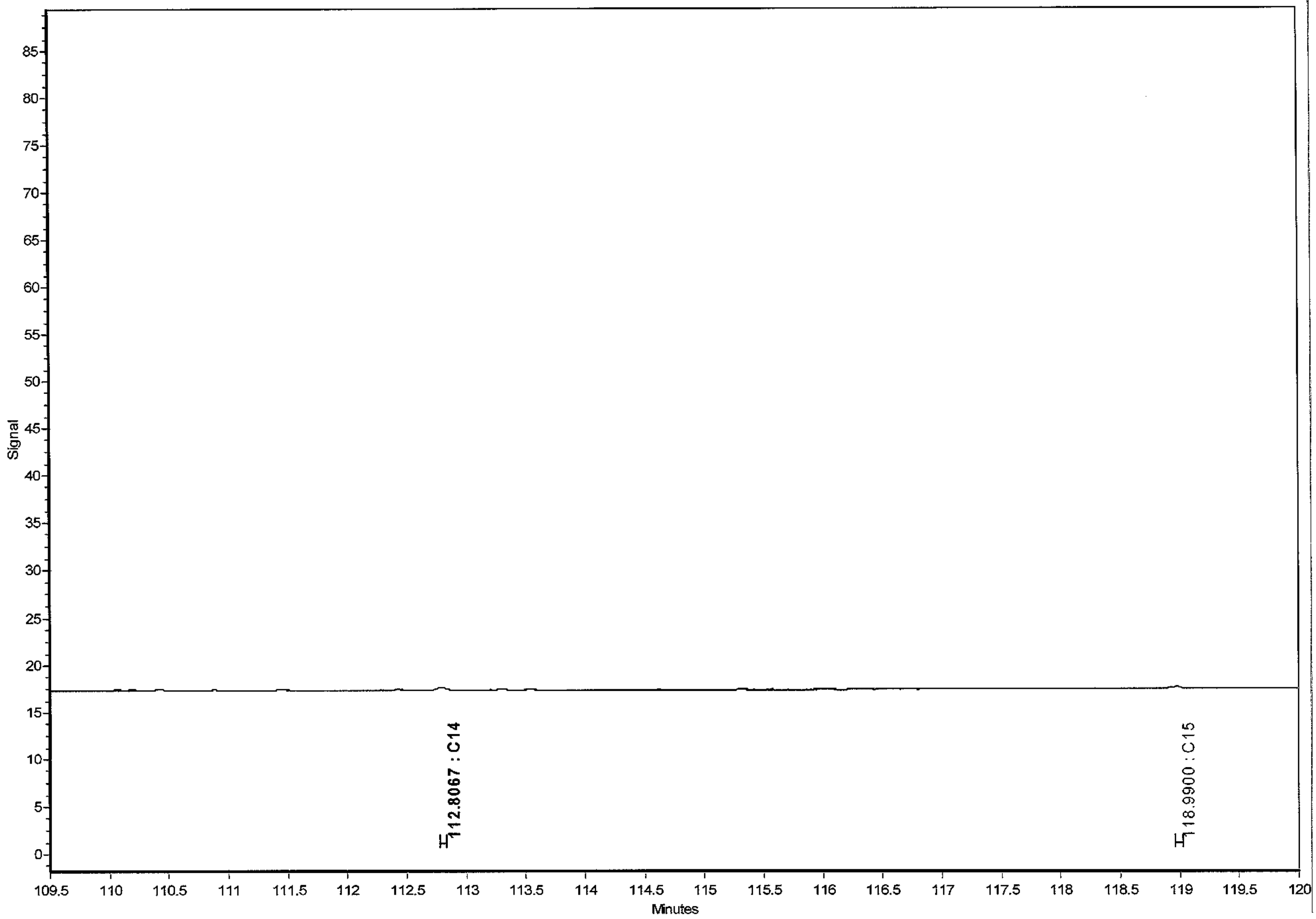
20090560-001AJL (M:\ExtendedGas Results\CDF\20090560-001Adat-Detector 1.cdf)
Start Time: 89.500 - End Time: 100.000



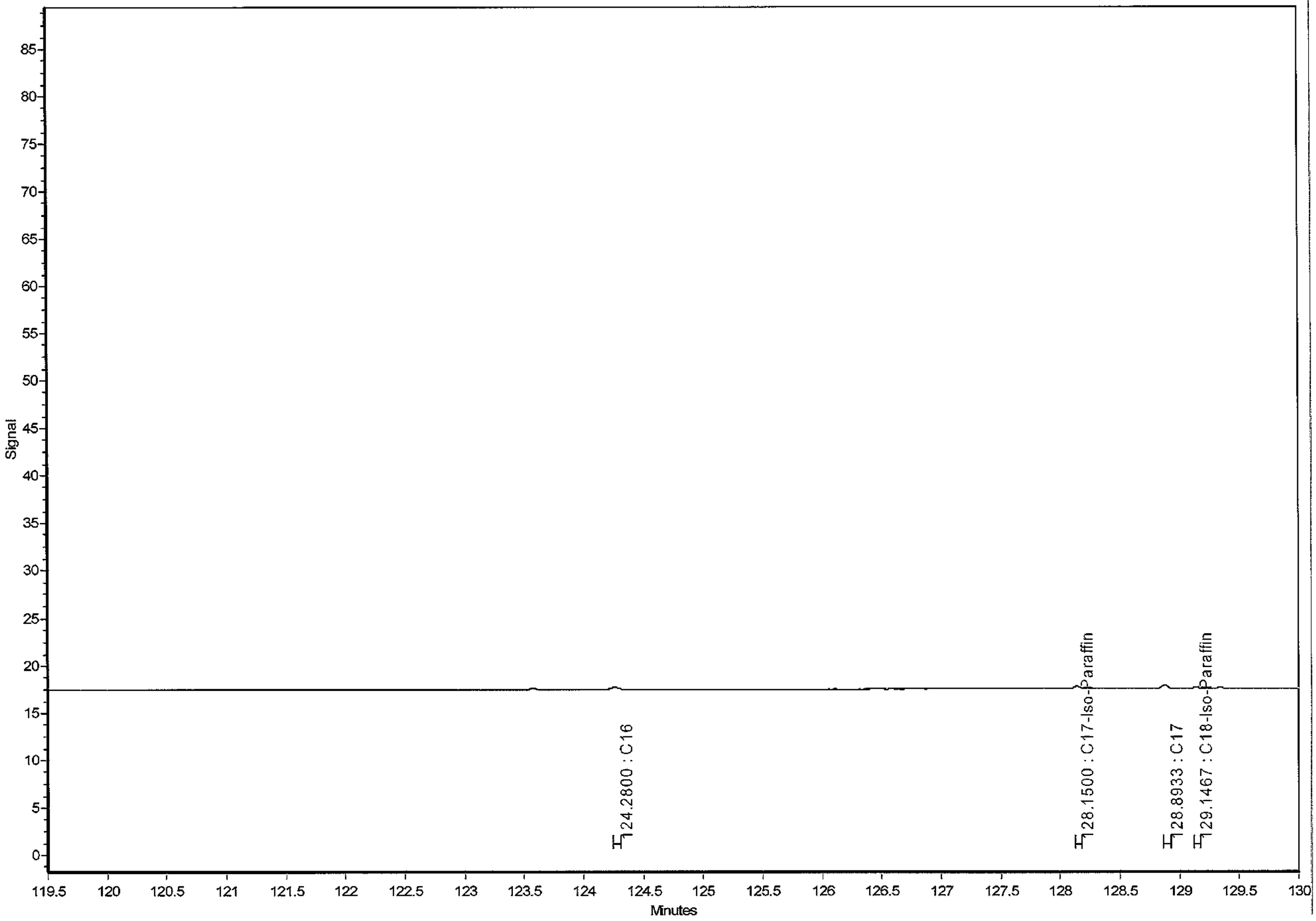
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 99.500 - End Time: 110.000



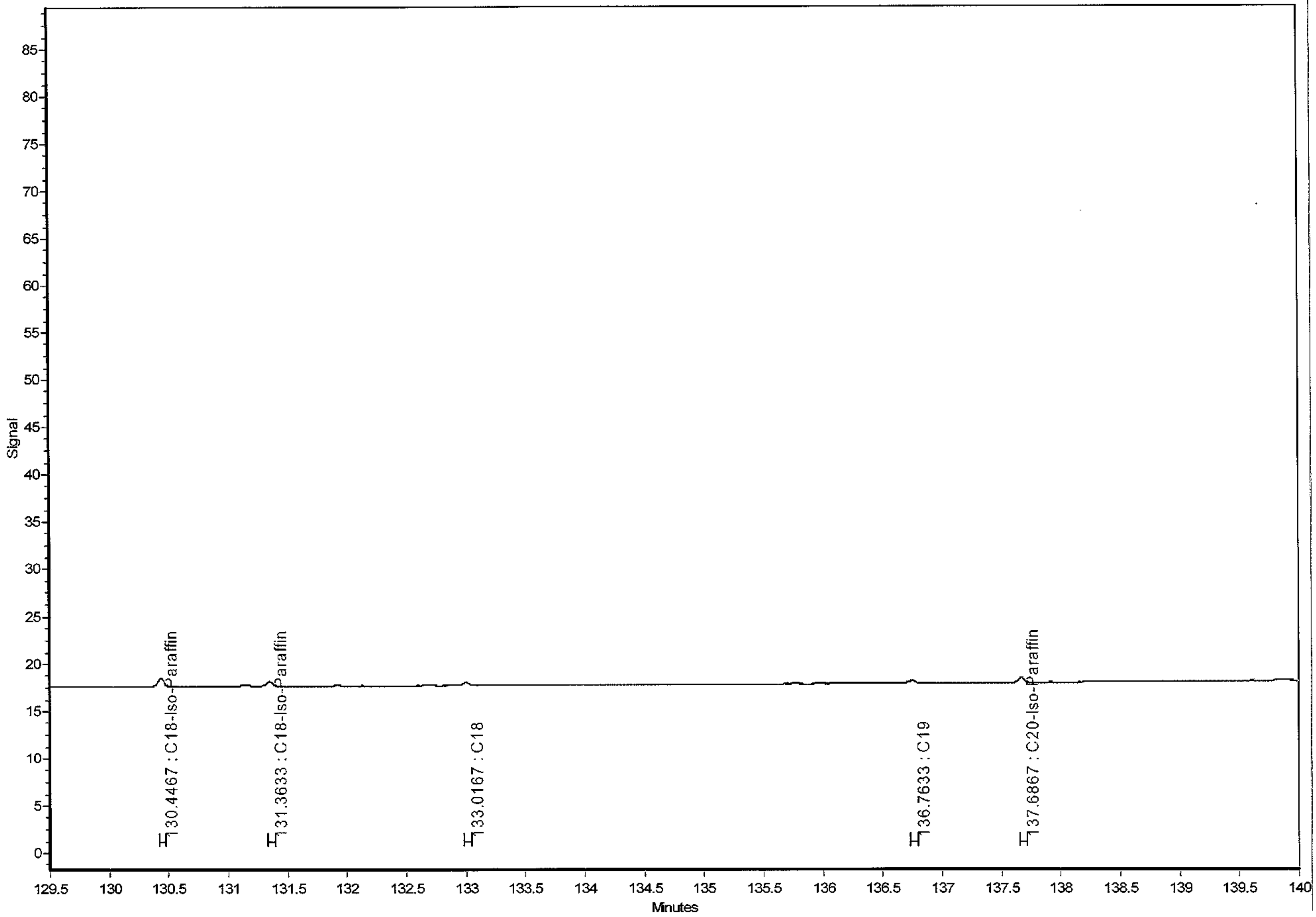
2009060590-001A.JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 109.500 - End Time: 120.000



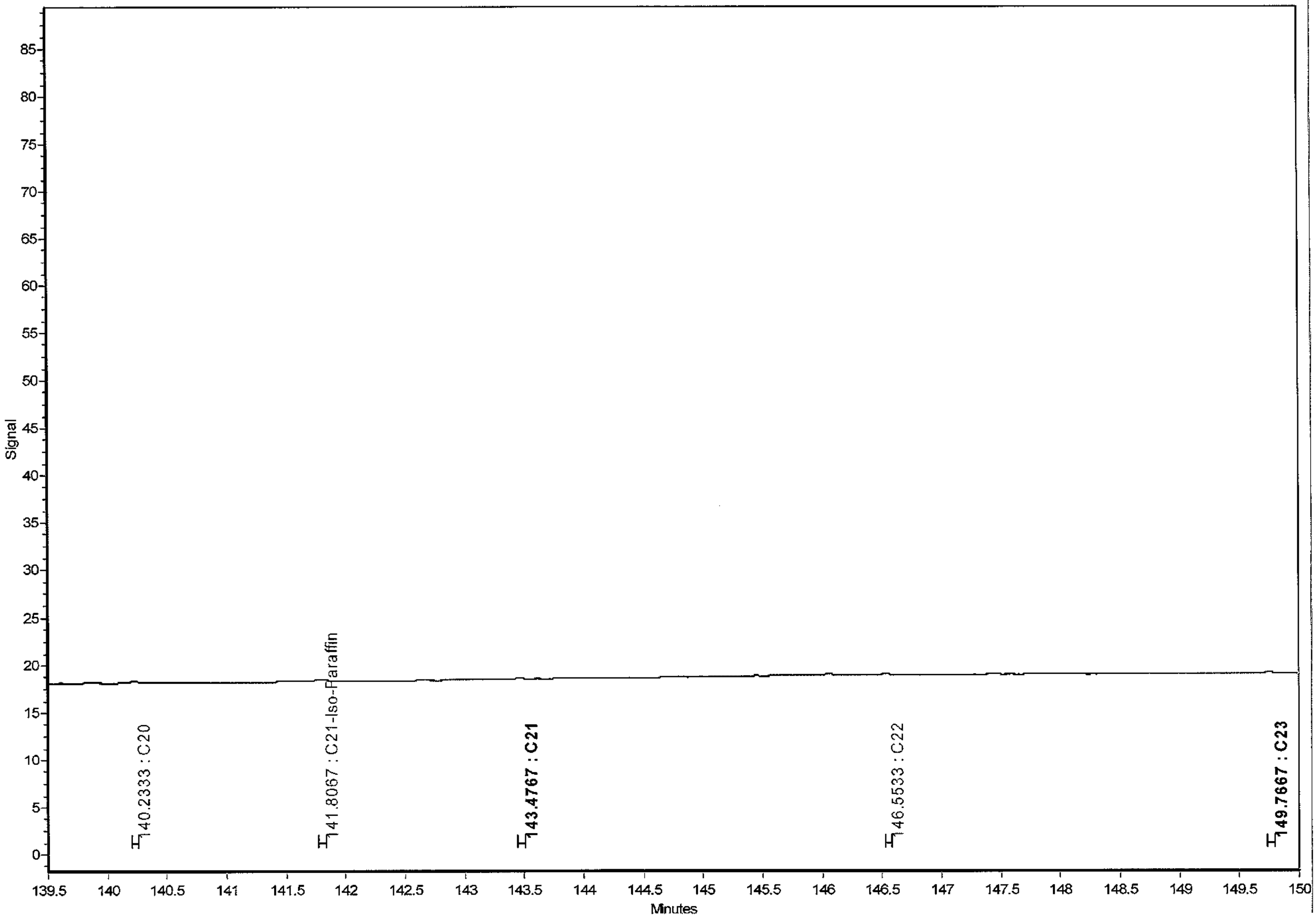
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 119.500 - End Time: 130.000



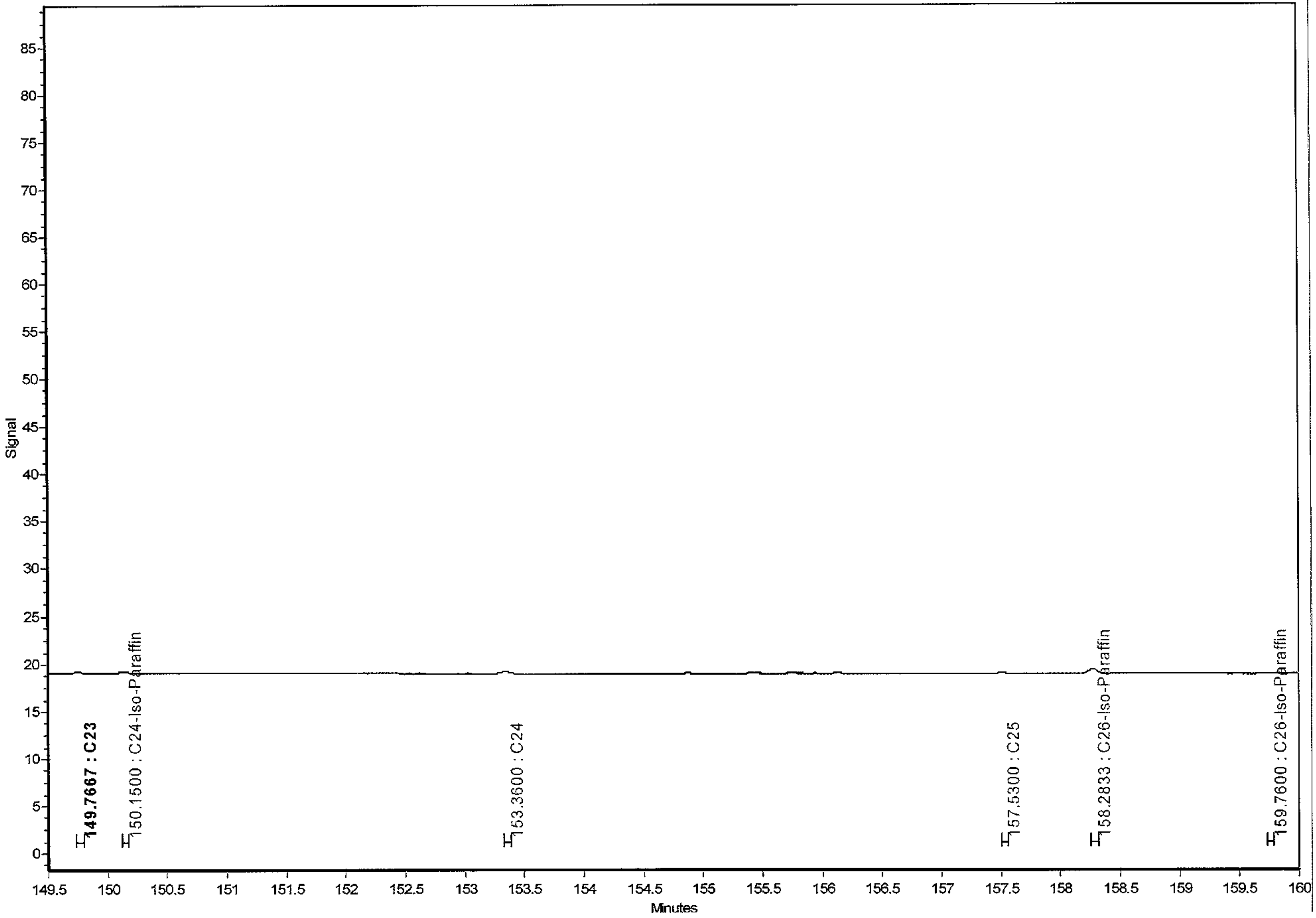
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 129.500 - End Time: 140.000



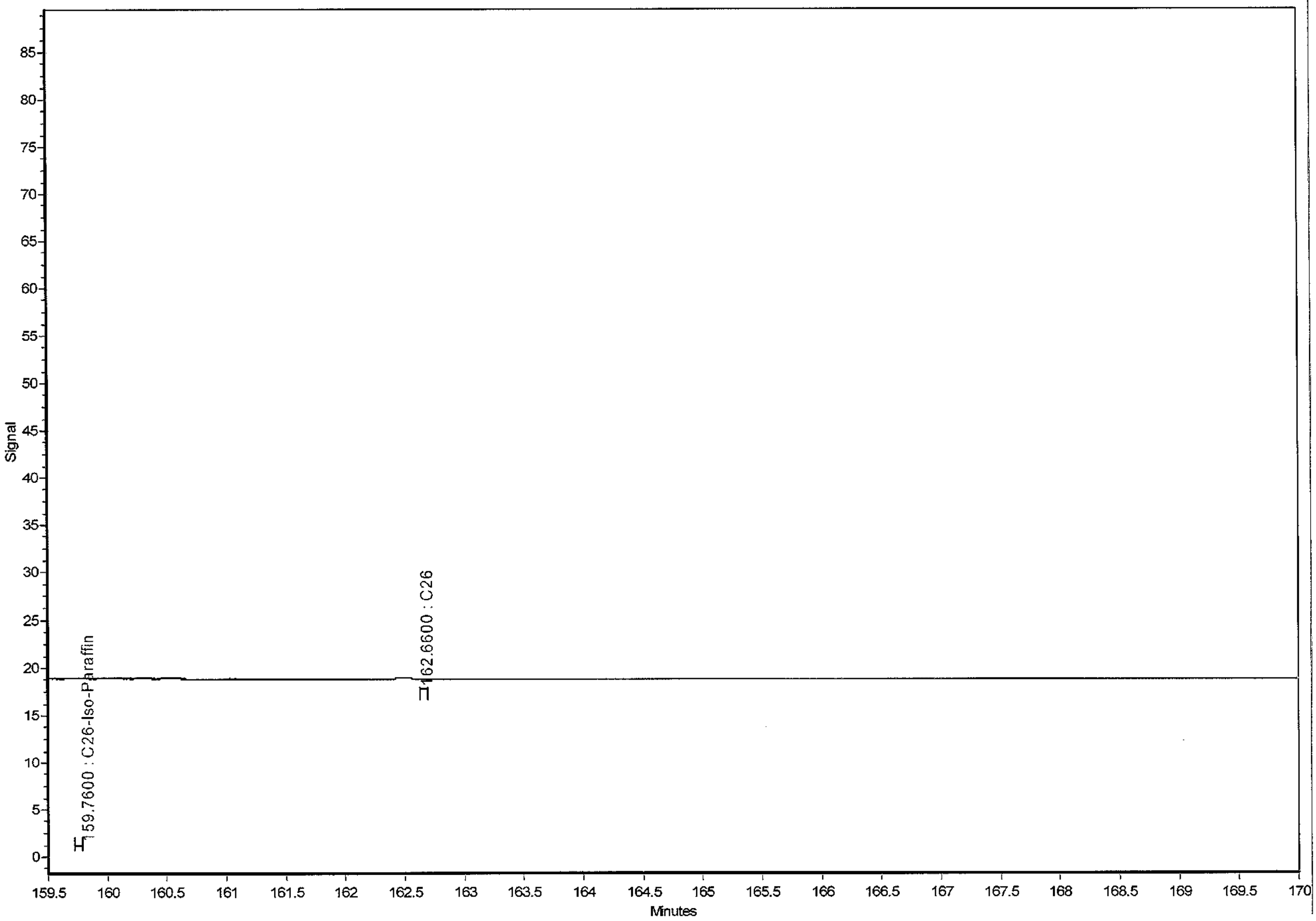
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 139.500 - End Time: 150.000



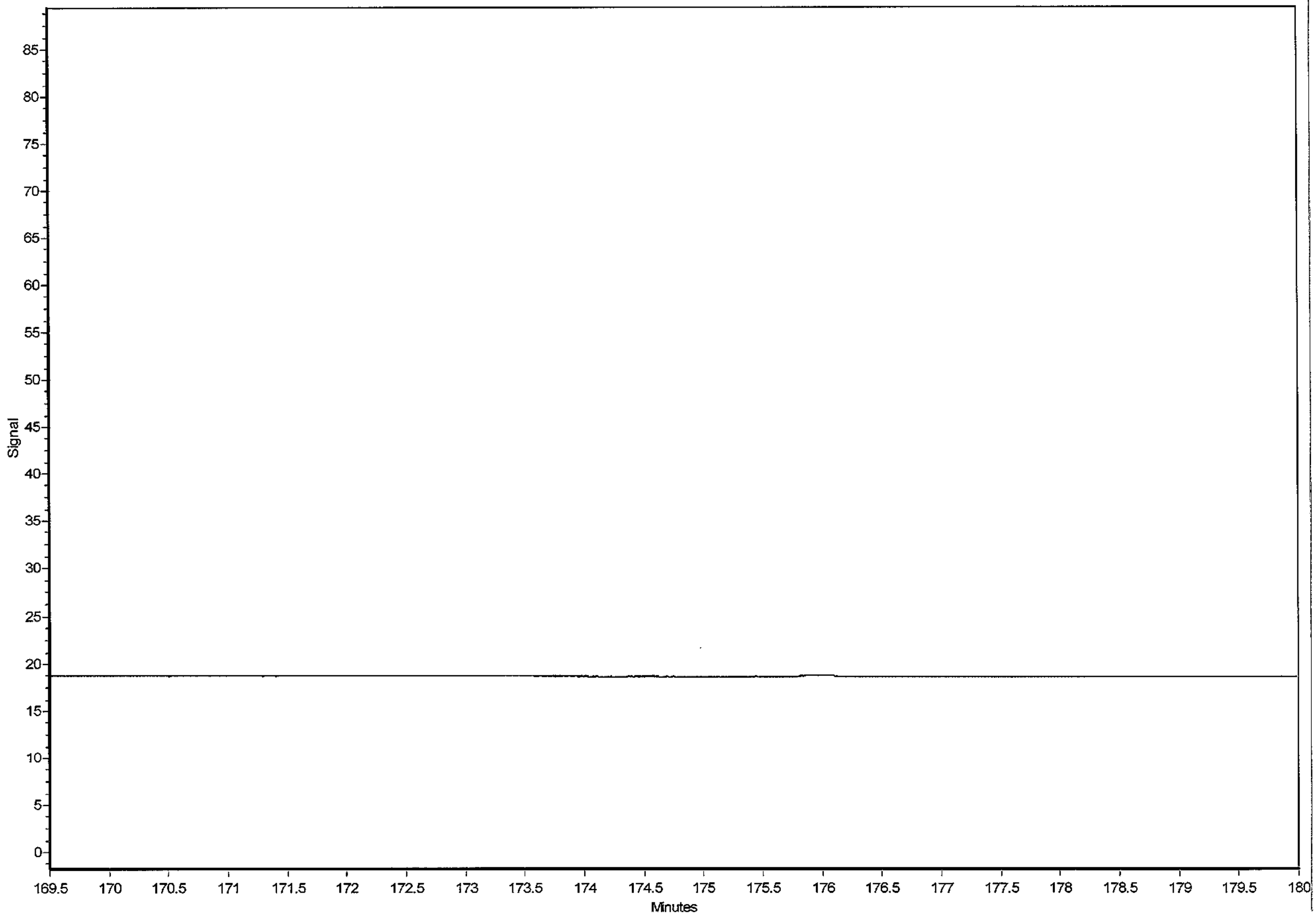
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 149.500 - End Time: 160.000



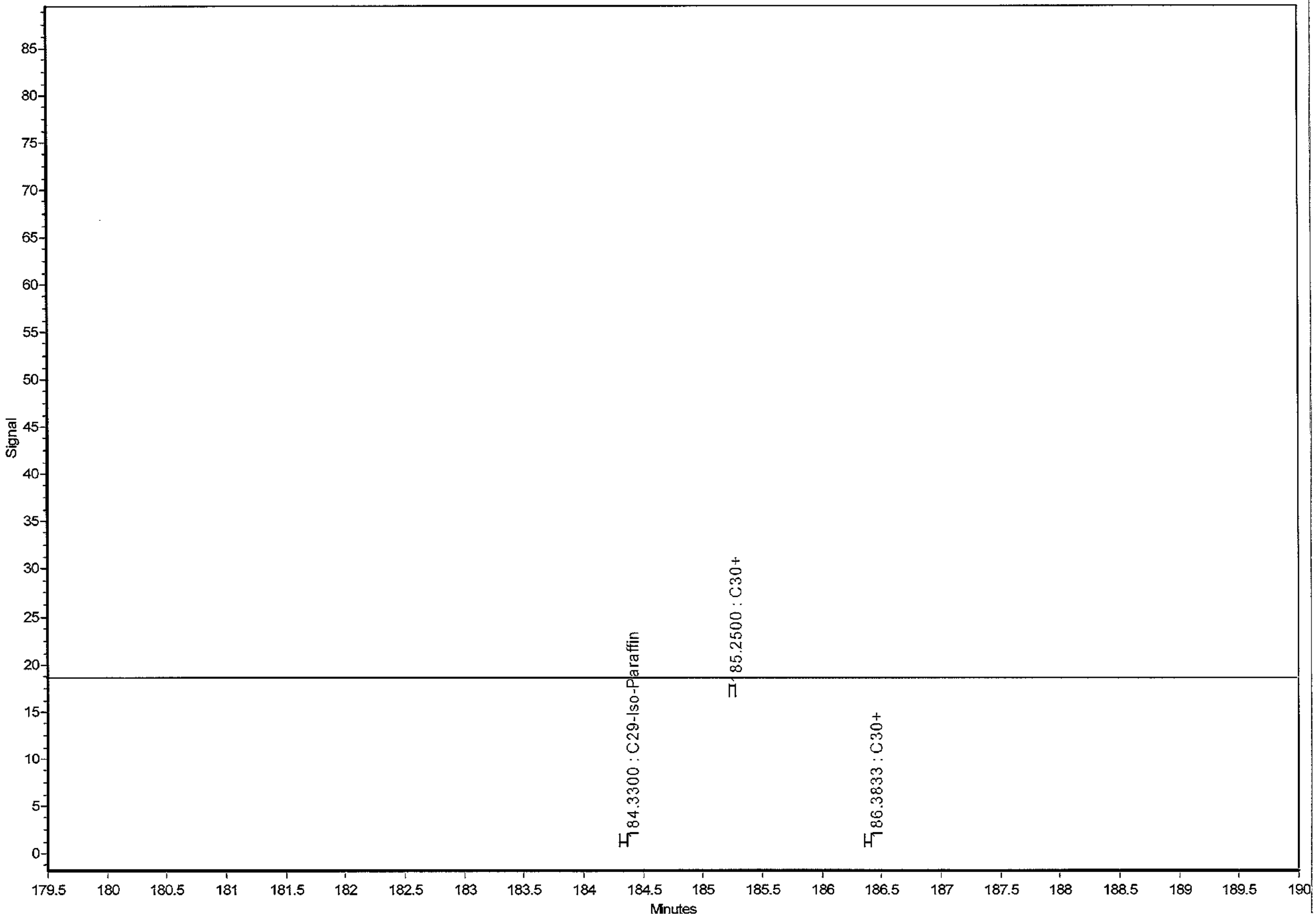
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 159.500 - End Time: 170.000



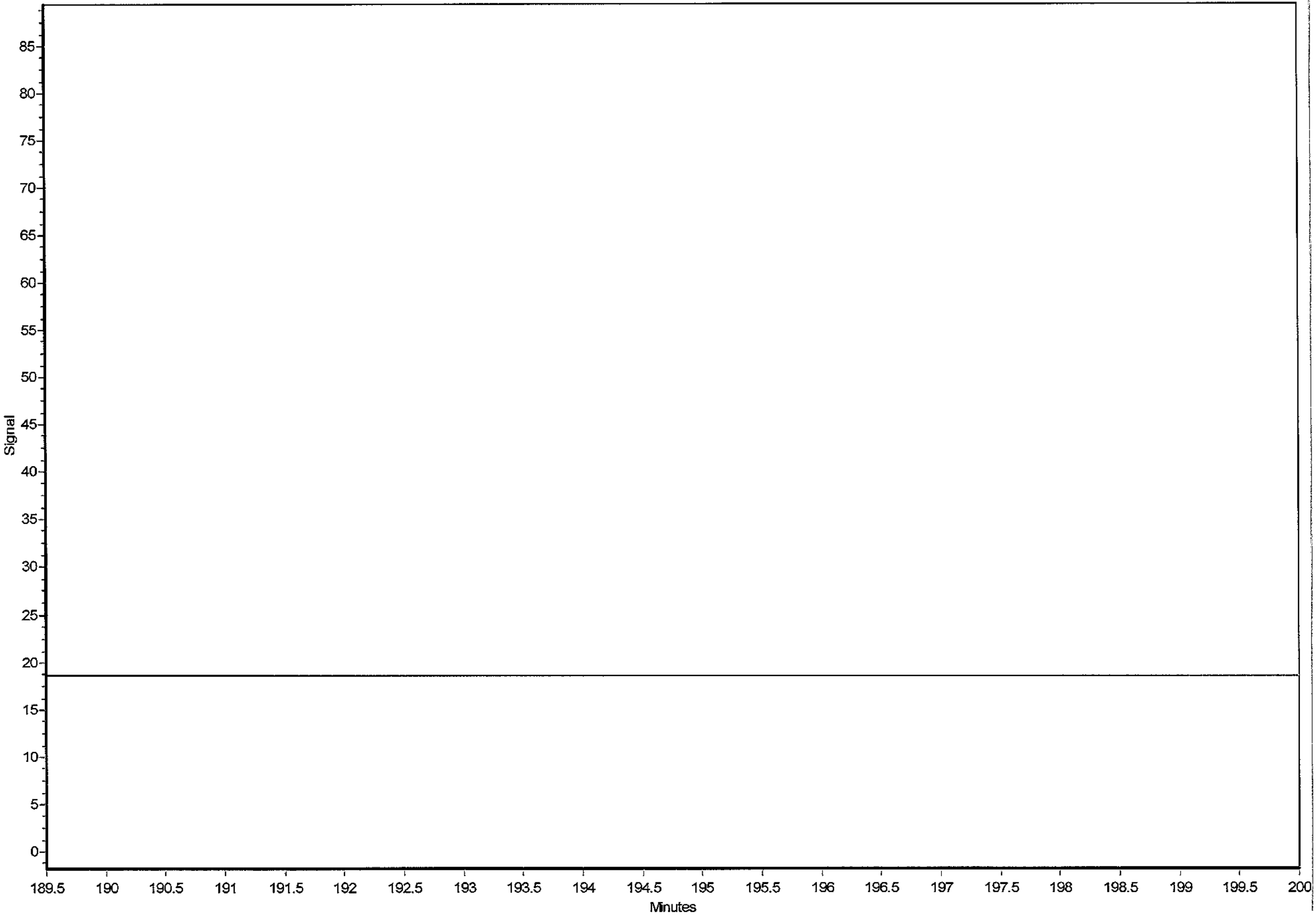
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 169.500 - End Time: 180.000



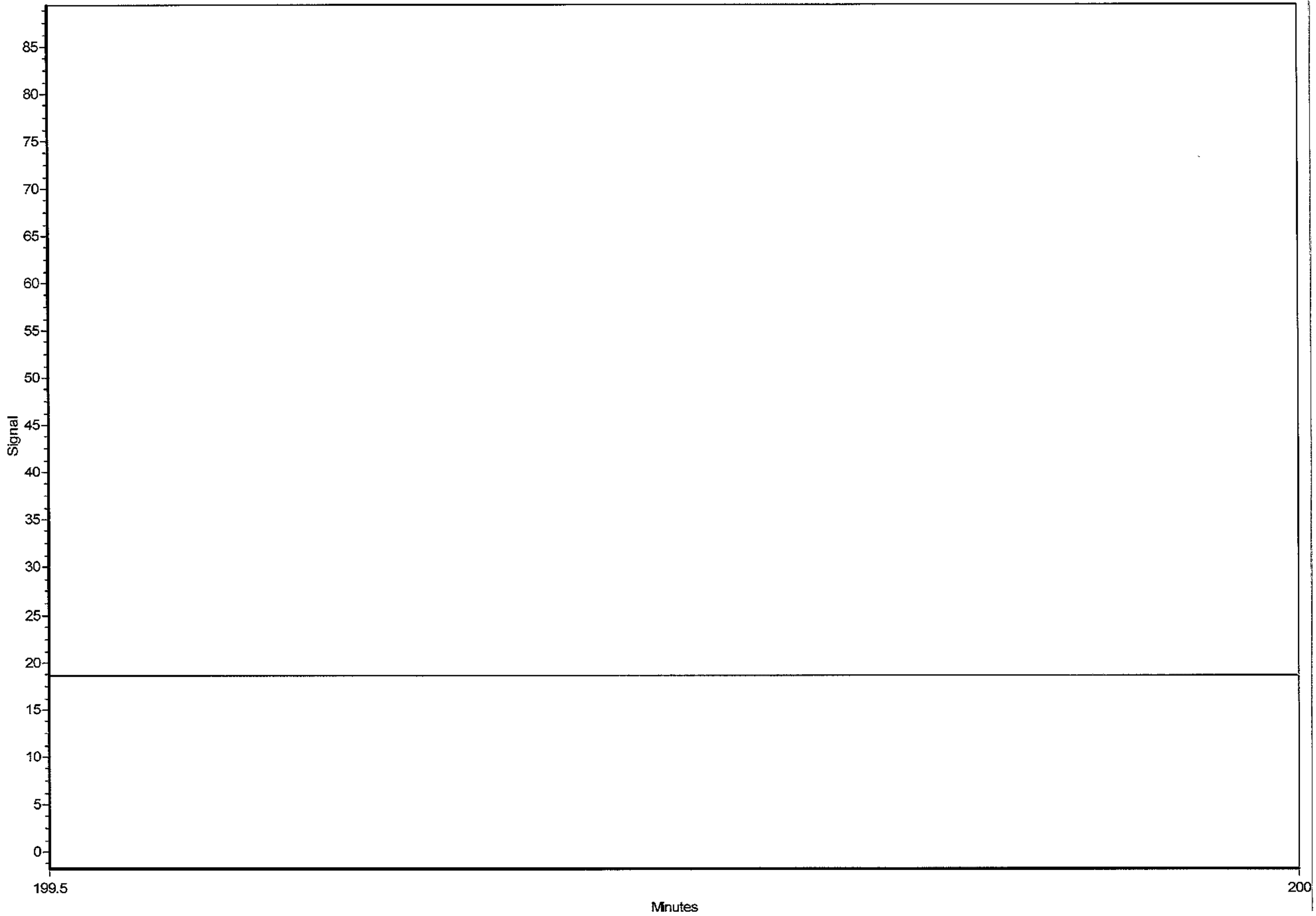
2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 179.500 - End Time: 190.000



2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 189.500 - End Time: 200.000



2009060590-001A JL (M:\ExtendedGas Results\CDF\2009060590-001Adat-Detector 1.cdf)
Start Time: 199.500 - End Time: 200.000



HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

SPL, Inc.

Certificate of Analysis Number:

09071163

Report To:		**Project Name:**	2009060590/RRR03865A
	SPL, Inc. Chris Staley 8820 Interchange Drive	**Site:**	Houston, TX
		Site Address:	
	Houston TX 77054-	**PO Number:**	
		State:	Texas
		State Cert. No.:	T104704205-06-TX
	ph: (713) 660-0901 fax:	**Date Reported:**	

This Report Contains A Total Of 14 Pages

Excluding This Page, Chain Of Custody

And

Any Attachments

7/29/2009

Date

Test results meet all requirements of NELAC, unless specified in the narrative.

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Case Narrative for:
SPL, Inc.

Certificate of Analysis Number:
09071163

Report To:	**Project Name:**	**2009060590/RRR03865A**
SPL, Inc.	**Site:**	**Houston, TX**
Chris Staley	**Site Address:**	
8820 Interchange Drive		
	PO Number:	
Houston		
TX	**State:**	**Texas**
77054-	**State Cert. No.:**	**T104704205-06-TX**
ph: (713) 660-0901 **fax:**	**Date Reported:**	

SAMPLE RECEIPT:

All samples were received intact. The internal ice chest temperatures were measured on receipt and are recorded on the attached Sample Receipt Checklist.

GENERAL REPORTING COMMENTS:

Results are reported on a wet weight basis unless dry-weight correction is denoted in the units field on the analytical report (" mg\kg-dry " or " ug\kg-dry ").

Matrix spike (MS) and matrix spike duplicate (MSD) samples are chosen and tested at random from an analytical batch of "like" matrix to check for possible matrix effect. The MS and MSD will provide site specific matrix data only for those samples which are spiked by the laboratory. Since the MS and MSD are chosen at random from an analytical batch, the sample chosen for spike purposes may or may not have been a sample submitted in this sample delivery group. The validity of the analytical procedures for which data is reported in this analytical report is determined by the Laboratory Control Sample (LCS) and the Method Blank (MB). The Laboratory Control Sample (LCS) and the Method Blank (MB) are processed with the samples and the MS/MSD to ensure method criteria are achieved throughout the entire analytical process.

Some of the percent recoveries and RPD's on the QC report for the MS/MSD may be different than the calculated recoveries and RPD's using the sample result and the MS/MSD results that appear on the report because, the actual raw result is used to perform the calculations for percent recovery and RPD.

Any other exceptions associated with this report will be footnoted in the analytical result page(s) or the quality control summary page(s).

Please do not hesitate to contact us if you have any questions or comments pertaining to this data report. Please reference the above Certificate of Analysis Number.

This report shall not be reproduced except in full, without the written approval of the laboratory. The reported results are only representative of the samples submitted for testing.

SPL, Inc. is pleased to be of service to you. We anticipate working with you in fulfilling all your current and future analytical needs.

I certify that this data package is in compliance with the terms and conditions of the contract, both technically and for completeness, for other than the conditions detailed above. Release of the data contained in this hardcopy data package has been authorized by the Laboratory Manager or by his designee, as verified by the following signature.

Agnes V. Vicknair

7/29/2009

Agnes V. Vicknair
Project Manager

Date

Test results meet all requirements of NELAC, unless specified in the narrative.

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

SPL, Inc.

Certificate of Analysis Number:

09071163

Report To: SPL, Inc.
Chris Staley
8820 Interchange Drive

Houston
TX
77054-
ph: (713) 660-0901 fax: (713) 660-6035

Fax To:

Project Name: 2009060590/RRR03865A
Site: Houston, TX
Site Address:

PO Number:
State: Texas
State Cert. No.: T104704205-06-TX
Date Reported:

Client Sample ID	Lab Sample ID	Matrix	Date Collected	Date Received	COC ID	HOLD
2009060590-001B	09071163-01	Liquid	3/27/2009	7/22/2009 3:04:00 PM	H55633	☐

Agnes V. Vicknair 7/29/2009

Agnes V. Vicknair
Project Manager

Date

Kesavalu M. Bagawandoss Ph.D., J.D.
Laboratory Director

Ted Yen
Quality Assurance Officer

Client Sample ID:2009060590-001B **Collected:** 03/27/2009 0:00 **SPL Sample ID:** 09071163-01

Site: **Houston, TX**

Analyses/Method	Result	QUAL	Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
VOLATILE ORGANICS BY METHOD 8260B				**MCL**	**SW8260B**	**Units: ug/Kg**	
1,1,1,2-Tetrachloroethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,1,1-Trichloroethane	2400000	J	5000000	1000000	07/22/09 19:41	LU_L	5127155
1,1,2,2-Tetrachloroethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,1,2-Trichloroethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,1-Dichloroethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,1-Dichloroethene	94000		50000	10000	07/22/09 18:19	LU_L	5127154
1,1-Dichloropropene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,2,3-Trichlorobenzene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,2,3-Trichloropropane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,2,4-Trichlorobenzene	160000		50000	10000	07/22/09 18:19	LU_L	5127154
1,2,4-Trimethylbenzene	7400000		5000000	1000000	07/22/09 19:41	LU_L	5127155
1,2-Dibromo-3-chloropropane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,2-Dibromoethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,2-Dichlorobenzene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,2-Dichloroethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,2-Dichloropropane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,3,5-Trimethylbenzene	2100000	J	5000000	1000000	07/22/09 19:41	LU_L	5127155
1,3-Dichlorobenzene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,3-Dichloropropane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
1,4-Dichlorobenzene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
2,2-Dichloropropane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
2-Butanone	ND		200000	10000	07/22/09 18:19	LU_L	5127154
2-Chloroethyl vinyl ether	ND		100000	10000	07/22/09 18:19	LU_L	5127154
2-Chlorotoluene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
2-Hexanone	ND		100000	10000	07/22/09 18:19	LU_L	5127154
4-Chlorotoluene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
4-Isopropyltoluene	320000		50000	10000	07/22/09 18:19	LU_L	5127154
4-Methyl-2-pentanone	ND		100000	10000	07/22/09 18:19	LU_L	5127154
Acetone	ND		1000000	10000	07/22/09 18:19	LU_L	5127154
Acrylonitrile	ND		500000	10000	07/22/09 18:19	LU_L	5127154
Benzene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Bromobenzene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Bromochloromethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Bromodichloromethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Bromoform	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Bromomethane	ND		100000	10000	07/22/09 18:19	LU_L	5127154
Carbon disulfide	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Carbon tetrachloride	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Chlorobenzene	ND		50000	10000	07/22/09 18:19	LU_L	5127154

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
* - Surrogate Recovery Outside Advisable QC Limits
J - Estimated Value between MDL and PQL
E - Estimated Value exceeds calibration curve
TNTC - Too numerous to count

>MCL - Result Over Maximum Contamination Limit(MCL)
D - Surrogate Recovery Unreportable due to Dilution
MI - Matrix Interference

Client Sample ID:2009060590-001B **Collected:** 03/27/2009 0:00 **SPL Sample ID:** 09071163-01

Site: Houston, TX

Analyses/Method	Result	QUAL	Rep.Limit	Dil. Factor	Date Analyzed	Analyst	Seq. #
Chloroethane	ND		100000	10000	07/22/09 18:19	LU_L	5127154
Chloroform	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Chloromethane	ND		100000	10000	07/22/09 18:19	LU_L	5127154
Dibromochloromethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Dibromomethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Dichlorodifluoromethane	ND		100000	10000	07/22/09 18:19	LU_L	5127154
Ethylbenzene	16000000		5000000	1000000	07/22/09 19:41	LU_L	5127155
Hexachlorobutadiene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Isopropylbenzene	750000		50000	10000	07/22/09 18:19	LU_L	5127154
Methyl tert-butyl ether	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Methylene chloride	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Naphthalene	220000		50000	10000	07/22/09 18:19	LU_L	5127154
n-Butylbenzene	330000		50000	10000	07/22/09 18:19	LU_L	5127154
n-Propylbenzene	1600000		50000	10000	07/22/09 18:19	LU_L	5127154
sec-Butylbenzene	260000		50000	10000	07/22/09 18:19	LU_L	5127154
Styrene	1500000		50000	10000	07/22/09 18:19	LU_L	5127154
tert-Butylbenzene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Tetrachloroethene	82000000		5000000	1000000	07/22/09 19:41	LU_L	5127155
Toluene	29000000		5000000	1000000	07/22/09 19:41	LU_L	5127155
Trichloroethene	100000000		5000000	1000000	07/22/09 19:41	LU_L	5127155
Trichlorofluoromethane	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Vinyl acetate	ND		100000	10000	07/22/09 18:19	LU_L	5127154
Vinyl chloride	ND		100000	10000	07/22/09 18:19	LU_L	5127154
cis-1,2-Dichloroethene	5200000		5000000	1000000	07/22/09 19:41	LU_L	5127155
cis-1,3-Dichloropropene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
m,p-Xylene	33000000		5000000	1000000	07/22/09 19:41	LU_L	5127155
o-Xylene	9900000		5000000	1000000	07/22/09 19:41	LU_L	5127155
trans-1,2-Dichloroethene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
trans-1,3-Dichloropropene	ND		50000	10000	07/22/09 18:19	LU_L	5127154
Xylenes,Total	42900000		5000000	1000000	07/22/09 19:41	LU_L	5127155
1,2-Dichloroethene (total)	5200000		5000000	1000000	07/22/09 19:41	LU_L	5127155
Surr: 1,2-Dichloroethane-d4	86.1		% 78-116	10000	07/22/09 18:19	LU_L	5127154
Surr: 1,2-Dichloroethane-d4	88.8		% 78-116	1000000	07/22/09 19:41	LU_L	5127155
Surr: 4-Bromofluorobenzene	96.3		% 74-125	10000	07/22/09 18:19	LU_L	5127154
Surr: 4-Bromofluorobenzene	97.7		% 74-125	1000000	07/22/09 19:41	LU_L	5127155
Surr: Toluene-d8	98.9		% 82-118	10000	07/22/09 18:19	LU_L	5127154
Surr: Toluene-d8	97.9		% 82-118	1000000	07/22/09 19:41	LU_L	5127155

Prep Method	Prep Date	Prep Initials	Prep Factor
SW5030B	07/22/2009 16:29	XML	1.00

Qualifiers:

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D - Surrogate Recovery Unreportable due to Dilution
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Quality Control Documentation

Quality Control Report

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

SPL, Inc.

2009060590/RRR03865A

Analysis:	**Volatile Organics by Method 8260B**	**WorkOrder:**	**09071163**
Method:	**SW8260B**	**Lab Batch ID:**	**R279002**

Method Blank

RunID: K_090722C-5127153 Units: ug/Kg

Analysis Date: 07/22/2009 17:25 Analyst: LU_L

Samples in Analytical Batch:

Lab Sample ID	**Client Sample ID**
09071163-01A	2009060590-001B

Analyte	Result	Rep Limit
1,1,1,2-Tetrachloroethane	ND	250
1,1,1-Trichloroethane	ND	250
1,1,2,2-Tetrachloroethane	ND	250
1,1,2-Trichloroethane	ND	250
1,1-Dichloroethane	ND	250
1,1-Dichloroethene	ND	250
1,1-Dichloropropene	ND	250
1,2,3-Trichlorobenzene	ND	250
1,2,3-Trichloropropane	ND	250
1,2,4-Trichlorobenzene	ND	250
1,2,4-Trimethylbenzene	ND	250
1,2-Dibromo-3-chloropropane	ND	250
1,2-Dibromoethane	ND	250
1,2-Dichlorobenzene	ND	250
1,2-Dichloroethane	ND	250
1,2-Dichloropropane	ND	250
1,3,5-Trimethylbenzene	ND	250
1,3-Dichlorobenzene	ND	250
1,3-Dichloropropane	ND	250
1,4-Dichlorobenzene	ND	250
2,2-Dichloropropane	ND	250
2-Butanone	ND	1000
2-Chloroethyl vinyl ether	ND	500
2-Chlorotoluene	ND	250
2-Hexanone	ND	500
4-Chlorotoluene	ND	250
4-Isopropyltoluene	ND	250
4-Methyl-2-pentanone	ND	500
Acetone	ND	5000
Acrylonitrile	ND	2500
Benzene	ND	250
Bromobenzene	ND	250
Bromochloromethane	ND	250
Bromodichloromethane	ND	250
Bromoform	ND	250
Bromomethane	ND	500
Carbon disulfide	ND	250
Carbon tetrachloride	ND	250
Chlorobenzene	ND	250
Chloroethane	ND	500
Chloroform	ND	250
Chloromethane	ND	500
Dibromochloromethane	ND	250
Dibromomethane	ND	250
Dichlorodifluoromethane	ND	500
Ethylbenzene	ND	250

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
TNTC - Too numerous to count
MI - Matrix Interference
D - Recovery Unreportable due to Dilution
* - Recovery Outside Advisable QC Limits

QC results presented on the QC Summary Report have been rounded. RPD and percent recovery values calculated by the SPL LIMS system are derived from QC data prior to the application of rounding rules.

SPL, Inc.

2009060590/RRR03865A

Analysis: **Volatile Organics by Method 8260B**
Method: **SW8260B**

WorkOrder: **09071163**
Lab Batch ID: **R279002**

Method Blank

RunID: K_090722C-5127153 Units: ug/Kg
Analysis Date: 07/22/2009 17:25 Analyst: LU_L

Analyte	Result	Rep Limit
Hexachlorobutadiene	ND	250
Isopropylbenzene	ND	250
Methyl tert-butyl ether	ND	250
Methylene chloride	ND	250
Naphthalene	ND	250
n-Butylbenzene	ND	250
n-Propylbenzene	ND	250
sec-Butylbenzene	ND	250
Styrene	ND	250
tert-Butylbenzene	ND	250
Tetrachloroethene	ND	250
Toluene	ND	250
Trichloroethene	ND	250
Trichlorofluoromethane	ND	250
Vinyl acetate	ND	500
Vinyl chloride	ND	500
cis-1,2-Dichloroethene	ND	250
cis-1,3-Dichloropropene	ND	250
m,p-Xylene	ND	250
o-Xylene	ND	250
trans-1,2-Dichloroethene	ND	250
trans-1,3-Dichloropropene	ND	250
1,2-Dichloroethene (total)	ND	250
Xylenes,Total	ND	250
Surr: 1,2-Dichloroethane-d4	92.4	78-116
Surr: 4-Bromofluorobenzene	97.5	74-125
Surr: Toluene-d8	100.0	82-118

Laboratory Control Sample (LCS)

RunID: K_090722C-5127152 Units: ug/Kg
Analysis Date: 07/22/2009 16:56 Analyst: LU_L

Analyte	Spike Added	Result	Percent Recovery	Lower Limit	Upper Limit
1,1,1,2-Tetrachloroethane	20.0	23.3	116	71	128
1,1,1-Trichloroethane	20.0	18.5	92.7	61	135
1,1,2,2-Tetrachloroethane	20.0	20.1	100	60	133
1,1,2-Trichloroethane	20.0	21.7	109	77	127
1,1-Dichloroethane	20.0	15.8	78.9	68	132

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
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Quality Control Report

SPL, Inc.

2009060590/RRR03865A

Analysis: **Volatile Organics by Method 8260B** **WorkOrder:** **09071163**
Method: **SW8260B** **Lab Batch ID:** **R279002**

Laboratory Control Sample (LCS)

RunID: K_090722C-5127152 Units: ug/Kg
Analysis Date: 07/22/2009 16:56 Analyst: LU_L

Analyte	Spike Added	Result	Percent Recovery	Lower Limit	Upper Limit
1,1-Dichloroethene	20.0	17.6	87.9	65	134
1,1-Dichloropropene	20.0	18.7	93.7	68	126
1,2,3-Trichlorobenzene	20.0	23.3	117	36	154
1,2,3-Trichloropropane	20.0	19.8	98.9	38	153
1,2,4-Trichlorobenzene	20.0	22.8	114	69	144
1,2,4-Trimethylbenzene	20.0	21.4	107	64	128
1,2-Dibromo-3-chloropropane	20.0	19.6	97.8	44	141
1,2-Dibromoethane	20.0	21.8	109	75	124
1,2-Dichlorobenzene	20.0	21.8	109	68	124
1,2-Dichloroethane	20.0	16.9	84.6	61	138
1,2-Dichloropropane	20.0	20.7	103	76	123
1,3,5-Trimethylbenzene	20.0	20.4	102	61	127
1,3-Dichlorobenzene	20.0	23.1	115	68	127
1,3-Dichloropropane	20.0	20.4	102	76	125
1,4-Dichlorobenzene	20.0	20.5	102	68	124
2,2-Dichloropropane	20.0	17.8	89.0	42	142
2-Butanone	20.0	12.6	63.0	22	183
2-Chloroethyl vinyl ether	20.0	19.5	97.3	10	179
2-Chlorotoluene	20.0	22.6	113	64	132
2-Hexanone	20.0	15.2	76.2	31	178
4-Chlorotoluene	20.0	21.6	108	61	132
4-Isopropyltoluene	20.0	21.1	105	63	136
4-Methyl-2-pentanone	20.0	17.7	88.6	10	159
Acetone	20.0	7.67	38.3	10	200
Acrylonitrile	20.0	14.8	74.1	54	155
Benzene	20.0	19.9	99.5	74	123
Bromobenzene	20.0	21.1	106	68	125
Bromochloromethane	20.0	18.9	94.4	71	124
Bromodichloromethane	20.0	20.0	100	72	128
Bromoform	20.0	22.0	110	73	143
Bromomethane	20.0	15.6	78.0	53	130
Carbon disulfide	20.0	17.6	88.2	41	143
Carbon tetrachloride	20.0	21.8	109	59	142
Chlorobenzene	20.0	21.8	109	75	125

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SPL, Inc.

2009060590/RRR03865A

Analysis:	**Volatile Organics by Method 8260B**	**WorkOrder:**	**09071163**
Method:	**SW8260B**	**Lab Batch ID:**	**R279002**

Laboratory Control Sample (LCS)

RunID:	K_090722C-5127152	Units:	ug/Kg
Analysis Date:	07/22/2009 16:56	Analyst:	LU_L

Analyte	Spike Added	Result	Percent Recovery	Lower Limit	Upper Limit
Chloroethane	20.0	14.7	73.5	60	134
Chloroform	20.0	18.4	91.8	71	127
Chloromethane	20.0	15.5	77.5	50	139
Dibromochloromethane	20.0	22.0	110	65	130
Dibromomethane	20.0	20.0	100	79	124
Dichlorodifluoromethane	20.0	15.4	76.8	22	162
Ethylbenzene	20.0	21.3	107	72	127
Hexachlorobutadiene	20.0	28.2	141	45	152
Isopropylbenzene	20.0	19.0	94.9	58	130
Methyl tert-butyl ether	40.0	29.6	73.9	63	123
Methylene chloride	20.0	16.5	82.6	61	135
Naphthalene	20.0	19.8	99.2	33	148
n-Butylbenzene	20.0	22.6	113	62	136
n-Propylbenzene	20.0	21.0	105	57	131
sec-Butylbenzene	20.0	22.3	111	63	131
Styrene	20.0	21.5	108	69	120
tert-Butylbenzene	20.0	21.2	106	59	131
Tetrachloroethene	20.0	20.7	103	45	173
Toluene	20.0	21.3	106	74	126
Trichloroethene	20.0	21.4	107	79	131
Trichlorofluoromethane	20.0	17.6	88.2	49	153
Vinyl acetate	20.0	13.4	67.2	10	167
Vinyl chloride	20.0	15.2	76.1	51	148
cis-1,2-Dichloroethene	20.0	19.1	95.7	71	128
cis-1,3-Dichloropropene	20.0	21.6	108	67	128
m,p-Xylene	40.0	43.6	109	71	129
o-Xylene	20.0	22.0	110	74	130
trans-1,2-Dichloroethene	20.0	17.2	86.0	66	128
trans-1,3-Dichloropropene	20.0	19.8	99.2	60	128
1,2-Dichloroethene (total)	40.0	36.3	90.9	66	128
Xylenes,Total	60.0	65.6	109	71	130
Surr: 1,2-Dichloroethane-d4	50.0	44	88.1	78	116
Surr: 4-Bromofluorobenzene	50.0	50.1	100	74	125
Surr: Toluene-d8	50.0	50.3	101	82	118

Qualifiers:

ND/U - Not Detected at the Reporting Limit
B/V - Analyte detected in the associated Method Blank
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MI - Matrix Interference
D - Recovery Unreportable due to Dilution
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N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
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Analysis:	**Volatile Organics by Method 8260B**	**WorkOrder:**	**09071163**
Method:	**SW8260B**	**Lab Batch ID:**	**R279002**

Matrix Spike (MS) / Matrix Spike Duplicate (MSD)

Sample Spiked:	09070822-01		
RunID:	K_090722C-5127157	Units:	ug/kg-dry
Analysis Date:	07/22/2009 20:35	Analyst:	LU_L
Preparation Date:	07/20/2009 14:03	Prep By:	Method SW5030B

Analyte	Sample Result	MS Spike Added	MS Result	MS % Recovery	MSD Spike Added	MSD Result	MSD % Recovery	RPD	RPD Limit	Low Limit	High Limit
1,1,1,2-Tetrachloroethane	ND	1120	1150	103	1120	1130	101	1.65	20	68	124
1,1,1-Trichloroethane	ND	1120	919	82.1	1120	930	83.0	1.15	20	69	123
1,1,2,2-Tetrachloroethane	ND	1120	1000	89.6	1120	992	88.6	1.15	20	69	130
1,1,2-Trichloroethane	ND	1120	1150	102	1120	1160	103	0.973	20	75	126
1,1-Dichloroethane	ND	1120	792	70.7	1120	817	72.9	3.04	20	65	129
1,1-Dichloroethene	ND	1120	869	77.6	1120	882	78.8	1.54	22	61	139
1,1-Dichloropropene	ND	1120	944	84.3	1120	942	84.2	0.173	20	69	121
1,2,3-Trichlorobenzene	ND	1120	904	80.7	1120	987	88.2	8.84	20	53	127
1,2,3-Trichloropropane	ND	1120	1010	90.6	1120	1010	90.1	0.456	20	79	124
1,2,4-Trichlorobenzene	ND	1120	1000	89.6	1120	1040	92.6	3.32	20	58	118
1,2,4-Trimethylbenzene	ND	1120	1130	101	1120	1140	102	0.552	20	43	132
1,2-Dibromo-3-chloropropane	ND	1120	884	79.0	1120	909	81.2	2.80	20	46	131
1,2-Dibromoethane	ND	1120	1140	101	1120	1100	97.9	3.48	20	76	122
1,2-Dichlorobenzene	ND	1120	1130	101	1120	1190	106	5.18	20	74	110
1,2-Dichloroethane	ND	1120	778	69.5	1120	783	69.9	0.601	20	60	129
1,2-Dichloropropane	ND	1120	1080	96.6	1120	1110	98.8	2.18	20	76	116
1,3,5-Trimethylbenzene	ND	1120	1040	93.1	1120	1080	96.5	3.59	20	51	121
1,3-Dichlorobenzene	ND	1120	1160	103	1120	1180	105	1.94	20	71	110
1,3-Dichloropropane	ND	1120	1030	92.4	1120	1040	92.5	0.0546	20	80	119
1,4-Dichlorobenzene	ND	1120	1010	90.2	1120	1070	95.1	5.32	20	69	110
2,2-Dichloropropane	ND	1120	828	74.0	1120	847	75.7	2.26	20	52	122
2-Butanone	ND	1120	886	79.2	1120	916	81.8	3.28	20	10	133
2-Chloroethyl vinyl ether	ND	1120	1130	101	1120	1130	101	0.173	20	10	182
2-Chlorotoluene	ND	1120	1120	100	1120	1190	107	6.21	20	69	112
2-Hexanone	ND	1120	725	64.7	1120	717	64.0	1.07	20	10	163
4-Chlorotoluene	ND	1120	1050	93.8	1120	1150	102	8.78	20	37	110
4-Isopropyltoluene	ND	1120	1010	89.8	1120	1040	92.6	3.13	20	65	116
4-Methyl-2-pentanone	ND	1120	932	83.2	1120	921	82.2	1.21	20	10	103
Acetone	ND	1120	0	43.9	1120	0	50.0	12.9	20	10	160
Acrylonitrile	ND	1120	746	66.6	1120	756	67.5	1.32	20	45	155

Qualifiers:

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B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
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Quality Control Report

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

SPL, Inc.

2009060590/RRR03865A

Analysis:	**Volatile Organics by Method 8260B**	**WorkOrder:**	**09071163**
Method:	**SW8260B**	**Lab Batch ID:**	**R279002**

Matrix Spike (MS) / Matrix Spike Duplicate (MSD)

Sample Spiked:	09070822-01		
RunID:	K_090722C-5127157	Units:	ug/kg-dry
Analysis Date:	07/22/2009 20:35	Analyst:	LU_L
Preparation Date:	07/20/2009 14:03	Prep By:	Method SW5030B

Analyte	Sample Result	MS Spike Added	MS Result	MS % Recovery	MSD Spike Added	MSD Result	MSD % Recovery	RPD	RPD Limit	Low Limit	High Limit
Benzene	ND	1120	1120	99.9	1120	1100	98.6	1.30	22	70	124
Bromobenzene	ND	1120	1060	94.9	1120	1110	98.8	4.07	20	72	111
Bromochloromethane	ND	1120	972	86.8	1120	1030	92.3	6.19	20	73	126
Bromodichloromethane	ND	1120	1030	92.3	1120	1040	92.9	0.669	20	68	125
Bromoform	ND	1120	1030	92.2	1120	1060	94.4	2.32	20	44	132
Bromomethane	ND	1120	707	63.2	1120	733	65.4	3.54	20	50	140
Carbon disulfide	ND	1120	828	74.0	1120	835	74.6	0.807	20	46	143
Carbon tetrachloride	ND	1120	1080	96.4	1120	1040	93.2	3.35	20	66	126
Chlorobenzene	ND	1120	1140	101	1120	1120	100	1.43	21	68	123
Chloroethane	ND	1120	672	60.0	1120	669	59.8	0.367	20	59	134
Chloroform	ND	1120	933	83.3	1120	955	85.3	2.35	20	68	127
Chloromethane	ND	1120	783	69.9	1120	797	71.2	1.78	20	51	137
Dibromochloromethane	ND	1120	1080	96.3	1120	1040	93.1	3.33	20	58	131
Dibromomethane	ND	1120	1010	90.1	1120	1040	93.0	3.18	20	82	123
Dichlorodifluoromethane	ND	1120	788	70.4	1120	804	71.8	1.97	20	35	143
Ethylbenzene	ND	1120	1290	115	1120	1200	107	7.34	20	76	122
Hexachlorobutadiene	ND	1120	1250	111	1120	1300	116	4.24	20	43	137
Isopropylbenzene	ND	1120	1230	109	1120	1220	109	0.637	20	57	124
Methyl tert-butyl ether	ND	2240	1430	63.7	2240	1490	66.6	4.35	20	10	200
Methylene chloride	ND	1120	812	72.5	1120	851	76.0	4.61	20	70	134
Naphthalene	ND	1120	1850	165 *	1120	1900	170 *	2.90	20	42	140
n-Butylbenzene	ND	1120	1190	106	1120	1230	110	2.86	20	82	112
n-Propylbenzene	ND	1120	1940	173 *	1120	1970	176 *	1.47	20	73	108
sec-Butylbenzene	ND	1120	1130	101	1120	1170	105	3.21	20	76	110
Styrene	ND	1120	1120	100	1120	1130	101	0.559	20	58	152
tert-Butylbenzene	ND	1120	1020	91.5	1120	1060	94.7	3.50	20	66	120
Tetrachloroethene	ND	1120	1790	160 *	1120	1570	140 *	12.9	20	71	130
Toluene	ND	1120	1270	114	1120	1200	107	6.07	24	80	117
Trichloroethene	ND	1120	1640	147 *	1120	1480	132 *	10.4	21	82	121
Trichlorofluoromethane	ND	1120	885	79.0	1120	893	79.7	0.837	20	74	138
Vinyl acetate	ND	1120	733	65.5 *	1120	739	65.9 *	0.714	20	66	135
Vinyl chloride	ND	1120	497	44.4 *	1120	493	44.0 *	0.699	20	45	143

Qualifiers:

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J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
TNTC - Too numerous to count

MI - Matrix Interference
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Quality Control Report

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

SPL, Inc.

2009060590/RRR03865A

Analysis:	**Volatile Organics by Method 8260B**	**WorkOrder:**	**09071163**
Method:	**SW8260B**	**Lab Batch ID:**	**R279002**

Matrix Spike (MS) / Matrix Spike Duplicate (MSD)

Sample Spiked: 09070822-01
RunID: K_090722C-5127157 Units: ug/kg-dry
Analysis Date: 07/22/2009 20:35 Analyst: LU_L
Preparation Date: 07/20/2009 14:03 Prep By: Method SW5030B

Analyte	Sample Result	MS Spike Added	MS Result	MS % Recovery	MSD Spike Added	MSD Result	MSD % Recovery	RPD	RPD Limit	Low Limit	High Limit
cis-1,2-Dichloroethene	ND	1120	991	88.5	1120	1020	91.2	2.97	20	67	132
cis-1,3-Dichloropropene	ND	1120	1100	98.0	1120	1140	102	3.99	20	67	116
m,p-Xylene	ND	2240	2570	115	2240	2520	113	2.02	20	69	127
o-Xylene	ND	1120	1200	107	1120	1190	106	0.840	20	84	114
trans-1,2-Dichloroethene	ND	1120	855	76.4	1120	883	78.8	3.18	20	68	131
trans-1,3-Dichloropropene	ND	1120	1000	89.4	1120	1000	89.7	0.332	20	56	131
1,2-Dichloroethene (total)	ND	2240	1846	82.44	2240	1903	85.01	3.068	20	67	132
Xylenes,Total	ND	3360	3770	112	3360	3710	110	1.64	20	69	127
Surr: 1,2-Dichloroethane-d4	ND	2800	2470	88.1	2800	2520	89.9	2.04	30	78	116
Surr: 4-Bromofluorobenzene	ND	2800	2760	98.5	2800	2740	97.8	0.753	30	74	125
Surr: Toluene-d8	ND	2800	2720	97.1	2800	2710	96.9	0.137	30	82	118

Qualifiers:

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B/V - Analyte detected in the associated Method Blank
J - Estimated value between MDL and PQL
E - Estimated Value exceeds calibration curve
N/C - Not Calculated - Sample concentration is greater than 4 times the amount of spike added. Control limits do not apply.
TNTC - Too numerous to count
MI - Matrix Interference
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Sample Receipt Checklist

And

Chain of Custody

HOUSTON LABORATORY
8880 INTERCHANGE DRIVE
HOUSTON, TX 77054
(713) 660-0901

Sample Receipt Checklist

Workorder:	**09071163**	Received By:	**T_B**
Date and Time Received:	**7/22/2009 3:04:00 PM**	Carrier name:	**SPL**
Temperature:	**24.0°C**	Chilled by:	**Not Chilled**

1.	**Shipping container/cooler in good condition?**	Yes ☑	No ☐	Not Present ☐
2.	**Custody seals intact on shippping container/cooler?**	Yes ☐	No ☐	Not Present ☑
3.	**Custody seals intact on sample bottles?**	Yes ☐	No ☐	Not Present ☑
4.	**Chain of custody present?**	Yes ☑	No ☐	
5.	**Chain of custody signed when relinquished and received?**	Yes ☑	No ☐	
6.	**Chain of custody agrees with sample labels?**	Yes ☑	No ☐	
7.	**Samples in proper container/bottle?**	Yes ☑	No ☐	
8.	**Sample containers intact?**	Yes ☑	No ☐	
9.	**Sufficient sample volume for indicated test?**	Yes ☑	No ☐	
10.	**All samples received within holding time?** Received sample out of holding time logged with analysis, date on sample 3/27/09.	Yes ☑	No ☐	
11.	**Container/Temp Blank temperature in compliance?** Received sample with low coolant.	Yes ☐	No ☑	
12.	**Water - VOA vials have zero headspace?**	Yes ☐	No ☐	VOA Vials Not Present ☑
13.	**Water - Preservation checked upon receipt (except VOA*)?**	Yes ☐	No ☐	Not Applicable ☑

***VOA Preservation Checked After Sample Analysis**

SPL Representative: ______ **Contact Date & Time:** ______

Client Name Contacted: ______

Non Conformance Issues: ______

Client Instructions: ______

SPL-ENV

SPL, Inc.
Analysis Request Chain of Custody Record

SPL

SPL Work Order No.: 2009060590

SPL Work Order No.: 9907163

Acct. Mate Code:

Dept. Code

SPL H55633

Page 1 of 1

Report To:
(Company Name): SPL-Hydrocarbons

Address 8820 Interchange Dr.

City/State/Zip Houston TX 77054

Contact: CStacey CForeman
Phone: Fax:

Invoice To:
(Company Name):

Address SAME

City/State/Zip

Contact: Cheryl Foreman
Phone: Fax:

PO / Ref. No.: RRR03865A

Contract/Proposal #:

Project/Station Name:

Project/Station Number:

Project/Station Location:

Special Instructions: Due Date 7/23/09

Indicate Billing Type: Net 30 day Acct. ☐ Check # Cash Recv'd $
Credit Card ☐ Contact SPL, Inc for CC payment arrangements.

* Terms: Cylinders will be rented for $10/cyl. All cylinders checked out are to be returned within 21 days, whether they contain sample or not. Cylinders not returned after 30 days will be considered lost and will be billed at current replacement cost.

Requested TAT
- ☒ 24hr *
- ☐ 48hr *
- ☐ 72hr *
- ☒ Standard
- ☒ Other Indicate Below

Due Date 7/23/09

* Surcharges May Apply

Requested Analysis

Sample ID & Point	Sample Date	Sample Time	Sample Type (Gas/Liq. Solid)	Duplicate	Composite	Spot	Cylinder #	Date Out	Date In	C_6+	C_7+	C_{10}+ - Cap GC/Extended	C_{14}+ - Cap GC/Extended	Pod	Heat of Combustion (BTU)	Sulfur	Other - 8260-Vol	Other -	Other -	Other -	Other -	Comments
2009060590-001	3/27/09		Liq			X											✓					

Sampled By-Print Name:
Signature:

Company Name:

Relinquished By-Print Name: Signature:	Date: 7/22/09	Time: 15:04	Received By-Print Name: Leslie Dixon Signature:	Date: 7/22/09	Time: 15:04
Relinquished By-Print Name: Signature:	Date:	Time:	Received By-Print Name: Signature:	Date:	Time:
Relinquished By-Print Name: Signature:	Date:	Time:	Received By-Print Name: Signature:	Date:	Time:

☒ 8820 Interchange Dr. Houston, TX 77054
(713) 660-0901

☐ 9221 Highway 23 Belle Chasse, LA 70037
(504) 391-1337

☐ P.O. Box 3079 Laurel, MS 39442
(601) 428-0842

☐ 500 Ambassador Caffery Pkwy. Scott, LA 70583
(337) 237-4775

☐ 1595 US 79 South Carthage, TX 75633
(903) 693-6242

☐ 459 Hughes Dr. Traverse City, MI 49686
(616) 947-5777

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HOUSTON LABORATORIES
8820 INTERCHANGE DRIVE
HOUSTON, TEXAS 77054
PHONE (713) 660-0901

®CERTIFICATE OF ANALYSIS

Number : **1030-2009060590-001C**

Terra Therm, Inc.
Robin Swift
10 Stevens Road
Fitchburg, Maine. 01420

Sample ID:	DNAPL	**Report Date:**	07/06/09
Project Name:	SRSNE	**Sample of / Type:**	Liquid / Spot
Project Number:		**Sample Date:**	03/27/2009
Project Location:		**Sample Conditions:**	N.G. psi, @ N.G. °F
Sample Point:		**PO / Ref. No.:**	9101-002

Analytical Data

Test	Method	Results	Unit	Detection Limit	Lab Tech	Date Analyzed
Carbon, Hydrogen and Nitrogen by Instrumental Method						
Carbon Content	ASTM D 5291	58.61	wt%		TOT	7/6/2009
Hydrogen Content	ASTM D 5291	7.44	wt%		TOT	7/6/2009
Nitrogen Content	ASTM D 5291	<0.3	wt%		TOT	7/6/2009
Total Chlorides By Bomb-Method-Ion Select	ASTM D 808	319,957	ppm		TOT	7/6/2009

Hydrocarbon Laboratory Manager

SPL, Inc.
Analysis Request Chain of Custody Record

SPL

Report To: (Company Name): TERRA THERM	SPL Work Order No.: RRRQ3379-02	SPL Work Order No.:	Acct. Mate Code:	Dept. Code	SPL Page 1 of 1
Address 10 STEVENS RD	Project/Station Name: SRSNE	Project/Station Number:	Project/Station Location:		Requested TAT
City/State/Zip FITCHBURG, MA 01420 Contact: Phone: 9783430300 Fax: 9783432727	Special Instructions:				☐ 24hr * ☐ 48hr * ☐ 72hr * ☑ Standard ☐ Other Indicate Below
Invoice To: (Company Name): SAME Address	Indicate Billing Type:	Net 30 day Acct. ☐	Check #	Cash Recv'd \$	
		Credit Card ☐	Contact SPL, Inc for CC payment arrangements.		
City/State/Zip Contact: Phone: Fax PO / Ref. No.: 9101-002 Contract/Proposal #:	* Terms: Cylinders will be rented for \$10/cyl. All cylinders checked out are to be returned within 21 days, whether they contain sample or not. Cylinders not returned after 30 days will be considered lost and will be billed at current replacement cost.				* Surcharges May Apply

							Cylinder Tracking Info *			Requested Analysis												
Sample ID & Point	Sample Date	Sample Time	Sample Type (Gas/Liq. Solid)	Duplicate	Composite	Spot	Cylinder #	Date Out	Date In	Natural gas GPA 2261	Total Sulfur ASTM D-6667	BTU AS-D-240	Flash Pt AS-D-93.A	Distillation AS-D-86	Carbon, Hydrogen D5-D-5291	Chlorine D5-D-808	PIANO GPA-2186M	PCB EPA 8082				Comments
LNAPL	62409	—	LNAPL									✓	✓	✓	✓	✓	✓	✓				
DNAPL	62409	—	DNAPL									✓	✓	✓	✓	✓	✓	✓				

Sampled By-Print Name: Robin Swift Signature:			Company Name: Terra Therm		
Relinquished By-Print Name: Robin Swift Signature:	Date: 62409	Time: 1500	Received By-Print Name: Signature: FedEx	Date:	Time:
Relinquished By-Print Name: Signature:	Date:	Time:	Received By-Print Name: Signature:	Date:	Time:
Relinquished By-Print Name: Signature:	Date:	Time:	Received By-Print Name: Signature:	Date:	Time:

☐ 8820 Interchange Dr. Houston,TX 77054
(713) 660-0901

☐ 9221 Highway 23 Belle Chasse, LA 70037
(504) 391-1337

☐ P.O. Box 3079 Laurel, MS 39442
(601) 428-0842

☐ 500 Ambassador Caffery Pkwy. Scott, LA 70583
(337) 237-4775

☐ 1595 US 79 South Carthage, TX 75633
(903) 693-6242

☐ 459 Hughes Dr. Traverse City, MI 49686
(616) 947-5777

SPL, Inc.
Analysis Request Chain of Custody Record

SPL Work Order No.: RRRQ3379-02
SPL Work Order No.:
Acct. Mate Code:
Dept. Code
SPL
Page 1 of 1

Report To:
(Company Name): Terra Therm
Address 10 Stevens Road
City/State/Zip Fitchburg, MA 01420
Contact:
Phone: 978-343-0300 Fax: 978-343-2727

Project/Station Name: SRSNE
Project/Station Number:
Project/Station Location:

Special Instructions: **Client requesting analysis on both phases.**

Requested TAT

☐ **24hr ***
☐ **48hr ***
☐ **72hr ***
☐ **Standard**
☐ **Other** Indicate Below

* Surcharges May Apply

Invoice To:
(Company Name): Same as above
Address
City/State/Zip
Contact:
Phone: Fax:
PO / Ref. No.: 9101-002
Contract/Proposal #:

Indicate Billing Type:
Net 30 day Acct. ☐ Check # Cash Recv'd $
Credit Card ☐ Contact SPL, Inc for CC payment arrangements.

* Terms: Cylinders will be rented for $10/cyl. All cylinders checked out are to be returned within 21 days, whether they contain sample or not. Cylinders not returned after 30 days will be considered lost and will be billed at current replacement cost.

WO# and Fraction	Sample Date	Sample Time	Sample Type (Gas/Liq. Solid)	Duplicate	Composite	Spot	Cylinder Tracking Info * Cylinder #	Date Out	Date In	Requested Analysis	BTU, AS D 240	FLASH POINT D93	DISTILLATION D86	CARBON, HYDROGEN d5291	CHLORINE D808	PIANO GPA2186	PCD'S EPA 8082					Comments
LNAPL/DNAPL	06/24/09		LIQUID		X																	
LNAPL/DNAPL	06/27/09		LIQUID	X																		

Sampled By-Print Name:
Signature:
Company Name:

Relinquished By-Print Name: Date: Time: Received By-Print Name: Date: Time:
Signature: Signature:

Relinquished By-Print Name: Date: Time: Received By-Print Name: Date: Time:
Signature: Signature:

Relinquished By-Print Name: Date: Time: Received By-Print Name: Date: Time:
Signature: Signature:

☐ 8820 Interchange Dr. Houston,TX 77054
(713) 660-0901

☐ 500 Ambassador Caffery Pkwy. Scott, LA 70583
(337) 237-4775

☐ 9221Highway 23 Belle Chasse, LA 70037
(504) 391-1337

☐ 1595 US 79 South Carthage, TX 75633
(903) 693-6242

☐ P.O. Box 3079 Laurel, MS 39442
(601) 428-0842

☐ 459 Hughes Dr. Traverse City, MI 49686
(616) 947-5777

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SPL, Inc.
8820 Interchange Drive
Houston, TX 77054
P: 713-660-0901
F: 713-660-6035

Client Code: TERRA02

ORDER CONFIRMATION - Delivery 24 hour

Quote/ Sold To:
Terra Therm, Inc.
Robin Swift
10 Stevens Road
Fitchburg, Maine 01420

Phone: 978-343-0300 **Ext:**
Fax:
Email: rswift@terratherm.com

Order Date	
Order #	RRRO3865
Ref. Doc. #	

Project/Station:
Project/Station #:
Location:
Purchase Order #:
Need Date: **7/17/2009**
SPL Work Order#: **2009060590**
Amex/Visa/MC:
Name on Card:
CC # Ending:

Report/ Ship To:
Terra Therm, Inc.
Robin Swift
10 Stevens Road
Fitchburg, Maine 01420

Phone: 978-343-0300 **Ext:**
Fax:
Email: rswift@terratherm.com

Bill To:
Terra Therm, Inc.
Robin Swift
10 Stevens Road
Fitchburg, Maine 01420

Phone: 978-343-0300 **Ext:**
Fax:
Email: rswift@terratherm.com

Special Instructions:

Ln #	Qty	Analytical Parameter	Methodology	Price/Unit		Ext. Price
1	2	Total VOC, SW-846 8015BZ (W)	VOCBZ_W	$81.00	ea	$162.00

Please note this quote/order may not reflect your final invoice amount.
Review our terms and conditions for more information.

SubTotal	$162.00
Sales Tax	$0.00
Total	**$162.00**

Order logged in by:

Memo

TerraTherm, Inc.
10 Stevens Rd.
Fitchburg, MA 01420
Phone: (978) 343-0300
Fax: (978) 343-2727

To: John Hunt, Bruce Thompson, *de maximis, inc.*
From: Larry Conant, John LaChance, TerraTherm, Inc.
Date: December 4, 2009
Re: SRSNE Superfund Site Treatment Process Options

This memorandum presents a review of vapor treatment system options for the planned thermal remediation of the Observed NAPL in the Overburden Groundwater Unit (ONOGU) area at the Solvents Recovery Systems of New England Superfund Site (SRSNE) in light of new data and analyses, and provides our revised recommended approach for vapor treatment. We begin with an evaluation of the design basis and the approach put forth in our proposal that was the basis for our Best and Final Offer (BAFO) and the contract award. Next, we present recently acquired information that was used to revise the design basis; then, we summarize our review by presenting three treatment scenarios and treatment approaches that frame the issues and options for designing a treatment system for the site. Finally, we present our revised recommended approach for the SRSNE site.

Attached to this memorandum is a table of system components for each option, with estimated equipment, operation, waste disposal, fuel, and energy costs. Please note that fuel and energy costs were estimated using today's market rate and may change at the time of project startup.

Original Design Basis Used for Proposal/Bid

The design basis for the vapor treatment system presented in our proposal and assumed for the contract award is as follows:

- NAPL characteristics: fuel load of 8,000 BTU/lb with 80% chlorides
- Design for 1,000,000 lbs present within treatment volume (however, actual mass unknown and thought to likely be in the range of 500,000 to 2,000,000 lbs)
- Minimize duration of operational phase in order to reduce potential for EPA requested add-on days of operation

Original Treatment System Design as Awarded

The original treatment system design, as presented in our BAFO and shown below (Figure 1), used two Regenerative Thermal Oxidizers (RTO) to destroy constituents of concern (COCs) in the vapors extracted from the wellfield. For this system, vapors from the wellfield would be processed through a heat exchanger to condense out the moisture/steam from the wellfield prior to the RTOs. This reduces the flow rate and size requirements and operating costs of the RTOs. Additional process steps included an oil/water separator to recover organic material that also condensed out and two scrubbers to neutralize any acids created in the oxidizers (e.g., HCL). The operational period over which the mass present in the treatment volume (assumed to be 1,000,000 lbs) would be removed and sent to the treatment system was 135 days. As indicated above, this design was based on laboratory data which indicated that the contaminant mass (i.e., NAPL) had a fuel load of 8,000 BTU/lb and was comprised of 80% chlorides.

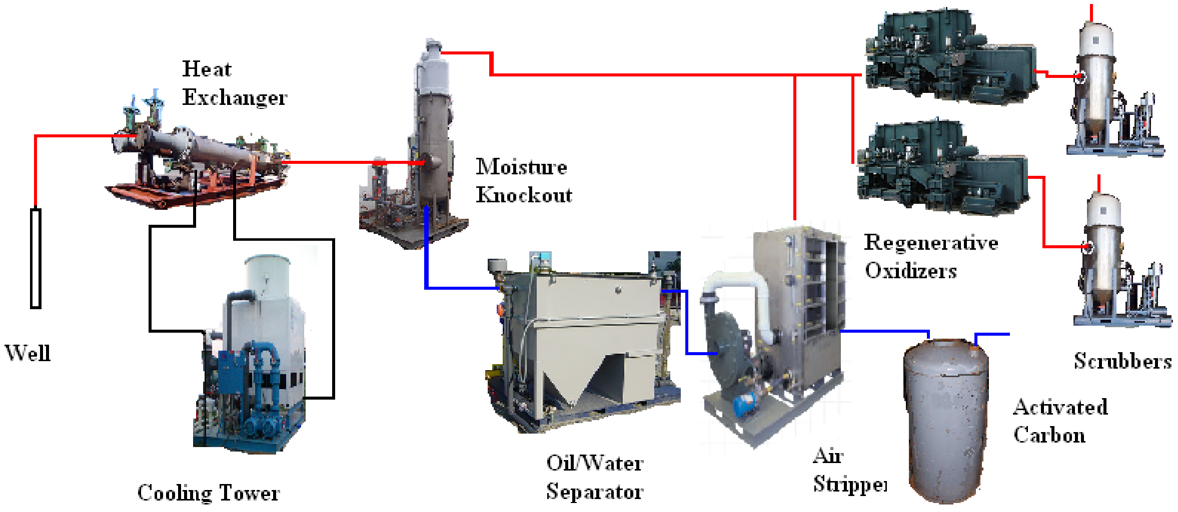

Figure 1. Treatment System Presented in Proposal

Revised Treatment System Considerations

Recent laboratory data from the NAPL sample collected from the SRSNE site for the materials compatibility testing indicated a higher BTU value and a lower chlorine content than the data used for the original design. These new values are 13,000 BTU/lb and 30% chlorine. A vapor stream rich with NAPL with these characteristics would not be handled efficiently in the original design. The primary concern is thermal overload of the RTOs due to the high BTU or fuel value of the vapor stream. The regenerative concept of the RTO relies on recycling energy from the exhaust into the inlet to pre-heat the incoming vapors. This recycling concept reduces the supplemental fuel load, and also cools the exiting gas. This is the most efficient approach for a vapor stream with a moderate to low BTU fuel load. However, a vapor stream with a high BTU fuel value will create temperatures within the RTOs above the operating limits of the units and very hot exhaust. This can be addressed by adding dilution air to the inlet vapor stream, but this would require significant increases in the size and/or number of RTOs and the size and capacities of all of the down stream piping and equipment (e.g., blowers and scrubbers). Given the potential for relatively high BTU loads and the uncertainty in the actual mass present in the treatment volume and thus the peak loading rate, this approach was determined to not be satisfactory.

In addition, based on the chemical composition of the NAPL, it was determined that several low-boiling point azeotropes would be formed and that the NAPL would boil in the presence of water at a temperature around 75ºC (this has been confirmed in the laboratory during the initial condensate production phase of the materials compatibility testing). What this means is that a significant portion of the mass present in the treatment volume (e.g., 80-90%) will be produced over a period of 4-6 weeks as the average temperature approaches 75ºC, well before the target temperature of 100ºC is reached. Furthermore, due to thermal coasting (i.e., the treatment volume will continue to heat-up even if the heater wells are shut down due to heat dissipation), it will not be possible to effectively control the arrival or duration of the peak loadings. If the mass present in the treatment volume is closer to 2M lbs than 1M lbs, then the peak loadings could easily be more than the treatment system can handle.

For example, if the entire treatment volume was heated all at once, and the total mass of COCs present was closer to 2M lbs than 1M lbs, and 80% of this mass was produced over a 4 week period corresponding to achieving temperatures around 75ºC, the average loading to the treatment system would be ~2,400 lbs/hr or 31M BTU/hr. Peak loading rates could be 2-3 times higher.

Installation and operation of a system large enough to handle these potential maximum peak loadings would be very expensive and may not be necessary if the actual mass present in the treatment zone is significantly lower than what is assumed. Therefore, as described below, we evaluated: 1) different equipment designs that could handle higher mass/fuel loadings and 2) different operational strategies to control and reduce the potential peak loadings to ranges that would be economically more feasible to design for. For instance, the treatment systems proposed for the three design scenarios evaluated below all use Thermal Accelerators (TA) instead of the original RTO's. A TA does not have as much thermal recycling capability as the RTO, and therefore is designed for a higher BTU vapor load. In addition, we evaluated extending the operation phased from 135 to 195 days and dividing the treatment area up into quarters and phasing the start of heating of each quarter by 2-3 weeks. This has the distinct advantage of providing a means to regulate the loading rates and attenuating and spreading out the peak loadings.

Each scenario and treatment approach will be explained in detail below, including which of the three is our recommended approach.

Scenario 1

Summary of Assumptions and Objectives:

- Design and size treatment system for 1,000,000 lbs of mass, but be prepared to treat unknown mass (up to 2,000,000 lbs) in most economical way.

Summary of Approach:

- Replace RTOs with TAs.

- Extend treatment period from 135 to 195 days to allow phased startup and treatment and control/regulation of peak loadings to treatment system. This provides flexibility and will allow treatment of more than 1,000,000 lbs without sizing and building an overly large and expensive treatment system.

- System will be designed and run primarily to minimize condensation and removal of NAPL from vapor stream (condense out water only). However, the system can be easily adjusted to facilitate the removal of NAPL from the vapor stream by simply lowering the cooling temperature of the heat exchanger in front of the knock out pot. This would only be done if the mass loadings were too high and could not be controlled by phasing the operation of the heaters. The condensed NAPL would have to be sent off for disposal at a regulated disposal facility.

The treatment system for Scenario 1 consists of replacing the original RTO's with two TAs and removing one scrubber while still using a single incoming heat exchanger/moisture knockout and an oil/water separator similar to the original design (see Figure 2). In addition to replacing the original RTO's with TAs, this option extends the processing time from 135 days to 195 days which would allow for a phased startup of the heaters and treatment of additional mass over 1,000,000 pounds. This extension of time also allows for a gradual ramp-up of the wellfield temperature and therefore a control of the removal rate from the wellfield.

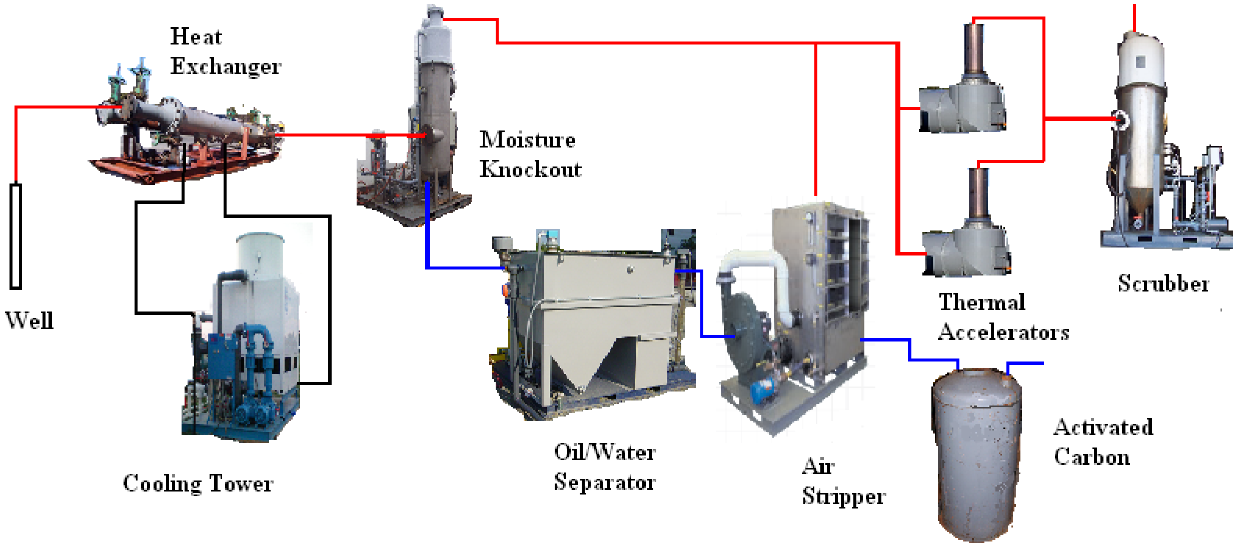

Figure 2. Treatment System for Scenario 1

Scenario 2

Summary of Objectives:

- Design and size system for 2,000,000 lbs of mass in 135 days.

Summary of Approach:

- Replace RTOs with TAs.
- Treatment period from remains at 135 (no phased startup).
- System will be designed and run primarily to minimize condensation and removal of NAPL from vapor stream (condense out water only). However, the system can be easily adjusted to facilitate the removal of NAPL from the vapor stream by simply lowering the cooling temperature of the heat exchanger in front of the knock out pot. This would only be done if the mass loadings were too high and could not be controlled by phasing the operation of the heaters. The condensed NAPL would have to be sent off for disposal at a regulated disposal facility.

The treatment system for Scenario 2 consists of replacing the original RTO's with four TAs (see Figure 3). Everything else would remain the same as the original design. The increase in oxidizer capacity will handle up to 2,000,000 pounds in the same operational period as the original proposal (i.e., 135 days).

The major disadvantage of this option is the higher capital cost for the extra TAs and scrubber and the significantly higher operations costs, including natural gas for the TAs.

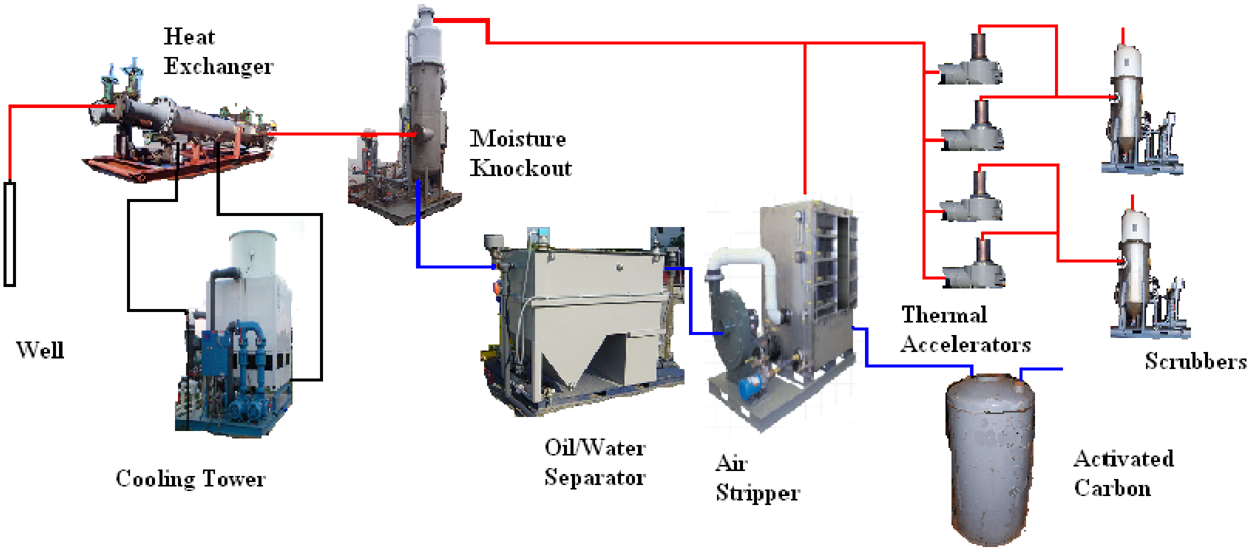

Figure 3. Treatment System for Scenario 2

Scenario 3

Summary of Objectives:

- Design and size system for 2,000,000 lbs in 135 days.

Summary of Approach:

- Replace RTOs with TAs;
- Treatment period remains at 135 (no phased startup).
- An additional heat exchanger and knockout will be added to allow two-stage condensing of water and petroleum hydrocarbon NAPL. The system will be designed and run to maximize removal of petroleum hydrocarbon NAPL while keeping chlorinated volatile organic compounds (CVOCs) in vapor phase for destruction in the TAs.
- NAPL condensate will require disposal at an approved regulated facility.

The treatment system for Scenario 3 consists of replacing the original RTO's with two heat exchangers and two TAs with a single scrubber (see Figure 4). The assumed operational time period is the same as the original at 135 days, but the mass to be removed is assumed to be 2,000,000 pounds. The mass and fuel load would be attenuated by the two-stage condensing of water and petroleum hydrocarbons. The first heat exchanger and knock out would remove water moisture from the vapor stream. The second heat exchanger and knock out would be configured and operated to primarily remove the petroleum hydrocarbons while leaving the CVOCs in vapor stream for treatment by the TAs. By removing the petroleum hydrocarbons the fuel load can be reduced to levels that two TAs can handle. Leaving the CVOCs in the vapor stream ensures that the petroleum hydrocarbon NAPL can be disposed of as non-hazardous and therefore reduces the cost of disposal.

This option has a higher capital cost than the treatment approach for Scenario 1 due to the added heat exchanger and cooling tower and generates a NAPL waste stream that has to be sent for off-site disposal.

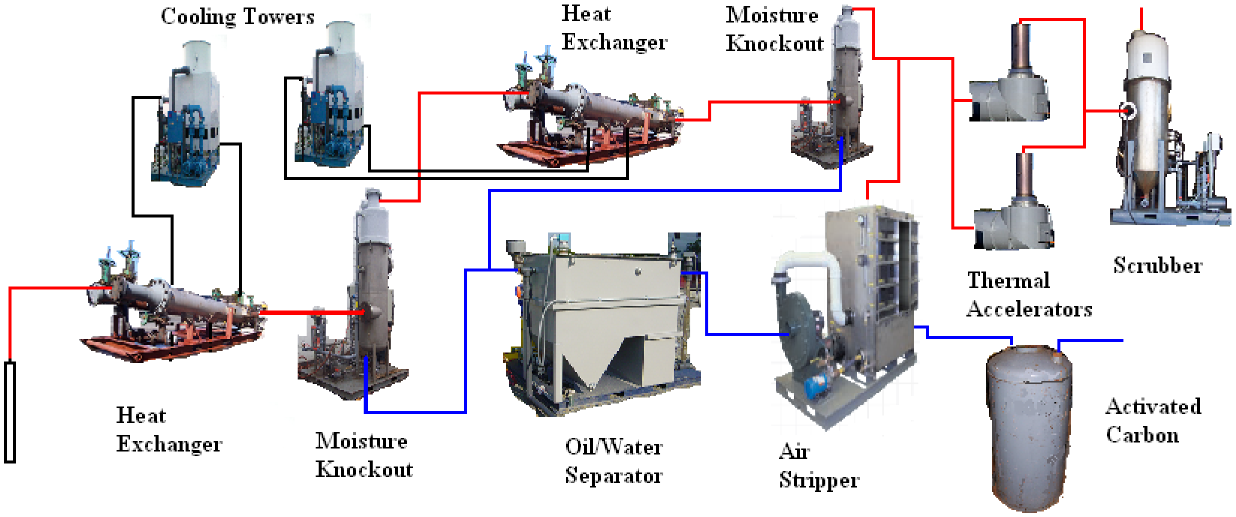

Figure 4. Treatment System for Scenario 3

Conclusion and Recommendation

The original process design was based on the NAPL having an 8,000 BTU/lb fuel loading rate and consisting of 80% chlorine. The most recent laboratory data indicates a 13,000 BTU/lb vapor fuel loading rate with only 30% chlorine. The change in chlorine isn't a concern, but the higher BTU value cannot be processed in the original design without severely limiting the process rate. Therefore, three revised scenarios/treatment options have been proposed.

All of the treatment approaches replace the RTOs with TAs which are designed to handle the higher BTU fuel.

The treatment approach for Scenario 1 increases the operating time but has the lowest capital cost and greatest flexibility to handle the unknown amount of mass present in the treatment volume.

The treatment approach for Scenario 2 doubles the number of oxidizers and scrubbers increasing the capital cost over the system for Scenario 1, but brings the process time back to the original 135 days without creating a condensate stream requiring offsite disposal.

The treatment approach for Scenario 3 doubles the heat exchange capacity increasing the capital cost over the system for Scenario 1, but still uses two oxidizers. The process time is the original 135 days; however, there is an additional NAPL waste stream produced that requires off-site disposal.

Our recommended approach for the SRSNE site is to use the treatment approach outlined for Scenario 1 for the following reasons:

- Its total cost is similar to the original proposal,
- It allows for flexibility and control of the removal rate of contaminants, specifically if the estimated mass exceeds 1,000,000 pounds, and
- The NAPL waste stream requiring off-site disposal is estimated to be minimal.

SRSNE Superfund Site
Matrix of Major System Components and Estimated Costs

TerraTherm, Inc.
10 Stevens Road
Fitchburg, MA 01420

Scenario/ Option	Feed	Assumed Total Treatment Quantity Pounds	Operating Days	Major Equipment	Quantity	Size/Description	Estimated Equipment Cost	Estimated Operation Cost	Estimated Waste Disposal Cost	Power kWh	Fuel Therms	Total Costs
Proposed												
Original												
Approach	8,000 Btu/#	1,000,000	135	Heat Exchanger/Condenser	1	259 ft2						
	80% Cl			Cooling Tower	1	200 Tons						
				Duplex Blower Skid	1	2,500 ACFM						
				Moisture Sep Skid	1	1,700 SCFM						
				Thermal Oxidizer	2	2,000 SCFM						
				Scrubber	2	2,000 SCFM						
				Oil Water Seperator	1	10 gpm						
				Air Stripper Skid	1	11 gpm						
				Venturi Quench	2	Hastelloy 2,000 SCFM						
				Caustic Feed & Tank	2							
Total							$1,100,000	$500,000	$0	$57,000	$5,000	**$1,662,000**
1	13,000 Btu/#	1,000,000	195	Heat Exchanger	1	259 ft2						
		capable of efficiently	Phased									
		treating between	startup of									
		500,000 to 2,000,000	heaters									
	30% Cl	lbs		Cooling Tower	1	100 Tons						
				Venturi Quench	1	Hastelloy 2,000 SCFM						
				Duplex Blower Skid	1	2,500 ACFM						
				Thermal Accelerators	2	4 million Btu/hr						
				Oil-Water Sep	1	10 gpm						
				Air Stripper	1	11 gpm						
				Caustic Package	1							
				Scrubber	1	1600 scfm						
Total							$890,000	$750,000	$0	$83,000	$25,000	**$1,748,000**
2	13,000 Btu/#	2,000,000	135	Heat Exchanger	1	259 ft2						
	30% Cl			Cooling Tower	1	100 Tons						
				Venturi Quench	2	Hastelloy 2,000 SCFM						
				Duplex Blower Skid	1	2,500 ACFM						
				Thermal Accelerators	4	4 million Btu/hr						
				Oil-Water Sep	1	10 gpm						
				Air Stripper	1	11 gpm						
				Caustic Package	2							
				Scrubber	2	1600 scfm						
Total							$1,500,000	$500,000	$0	$57,000	$34,000	**$2,091,000**
3	13,000 Btu/#	2,000,000	135	Heat Exchanger	2	259 ft2						
	30% Cl			Cooling Tower & Chiller	2	100 Tons						
				Venturi Quench	1	Hastelloy 2,000 SCFM						
				Duplex Blower Skid	1	2,500 ACFM						
				Compressors	2							
				Thermal accelerators	2	4 million Btu/hr						
				Oil-Water Sep	1	10 gpm						
				Air Stripper	1	11 gpm						
				Caustic Package	1							
				Scrubber	1	1600 scfm						
Total							$1,100,000	$500,000	$225,000	$57,000	$17,000	**$1,899,000**

Note: Actual costs to be finalized upon completion of the treatment design.

Memo

TerraTherm, Inc.
10 Stevens Rd.
Fitchburg, MA 01420
Phone: (978) 343-0300
Fax: (978) 343-2727

To: John Hunt, Bruce Thompson, *de maximis, inc.*
From: Robin Swift, Larry Conant, John LaChance, TerraTherm, Inc.
Date: December 21, 2009
Re: SRSNE Superfund Site Treatment Process Options - Scrubber Clarification

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This memorandum clarifies the use of a single 1,600 SCFM scrubber as proposed for Scenario 1 in the SRSNE Superfund Site Treatment Process Options Memorandum rather than the original two 2,000 SCFM scrubbers proposed in the proposal.

Scenario 1 proposes to extend the treatment period from 135 days to 195 days to allow for a phased treatment approach. This extended period allows for a gradual ramp up of the wellfield heaters which will provide more control of the mass removal rate. Given the ability to control and reduce the peak mass removal rates, less peak dilution air and neutralization will be required. Thus, with Scenario 1, one 1,600 SCFM scrubber will be sufficient. A second scrubber could be added for redundancy for approximately $50K, however, based on our experience, scrubbers are very reliable pieces of equipment. Other than occasional quench nozzles plugging, there is very little maintenance required. Therefore we believe that adding a second scrubber would not be cost effective.

January 26, 2010

Transmitted Via Email
Email Address: lconant@terratherm.com

Mr. Larry Conant
TerraTherm, Inc.
10 Stevens Road
Fitchburg, MA 01420

Subject: Laboratory Evaluation of 12 Corrosion Tested Coupons (Intertek-APTECH Report AES 09087234-3-1) (Final Report)

Dear Mr. Conant:

Intertek-APTECH is pleased to submit this report to TerraTherm, Inc. regarding the results of the laboratory evaluation of 12 corrosion-tested coupons.

INTRODUCTION

Intertek-APTECH performed laboratory evaluation for corrosion mechanisms on 12 coupons. Two coupons from 6 different materials, as listed in Table 1, were selected by TerraTherm for corrosion testing at Kemron Industrial Services. The coupons were initially sent to Intertek-APTECH for weight and dimensional measurements prior to the corrosion testing. The first set of coupons referred as "Well samples" were then (reportedly) tested at 650°C hydrochloric acid vapor environment for 10 days (240 hours). The second set of coupons referred as" Piping samples" was tested in condensing hydrochloric acid environment at 100^{o}C for 5 days (120 hours). At the end of the testing, Well samples and Piping samples were returned to Intertek-APTECH for evaluation.

The objective of the laboratory evaluation was to:

1. Evaluate the coupons for corrosion mechanisms.
2. Calculate corrosion rate based on weight loss.

APPROACH

TerraTherm provided 12 coupons for initial weight and dimensional measurements. The coupons were documented in the as-received condition (Figures 1 and 2). The as-received dimensions of the coupons are summarized in Table 2.

Photographs were taken to document the post-test appearance of the coupons. The coupons were weighed before cleaning. The coupons were ultrasonically cleaned using citronox and rust remover to remove the corrosion products. The coupons were weighed after cleaning and documented in the as-cleaned condition (Figures 3 through 14). The general corrosion rates of the coupons were calculated (using Equation 1) by measuring the weight loss of test coupons. All the coupons were visually and microscopically examined for evidence of pitting/crevice corrosion.

The corrosion rate[1] of the coupons is calculated using:

Corrosion Rate = $(K \times W) \div (A \times T \times d)$ → Equation 1

Where

K – Corrosion constant (534)
W – Weight loss, mg
A – Surface area, in^2
T – Time of exposure, hrs
D – Density of material, gm/cm^3
Corrosion rate – mils per year (mpy)

Table 1

ROSTER OF COUPON DESIGNATIONS AND THEIR RESPECTIVE MATERIAL GRADES

Material Class	Coupon ID [650°C (1202°F)]	Coupon ID [100°C (212°F)]
Stabilized Austenitic Stainless Steel (Alloy 20)	20CB3-13	20CB3-12
Austenitic Stainless Steel	304-03	304-01
Super Austenitic Stainless Steel	AL6XN-2	AL6XN-1
Hastelloy	B3-01	B3-02
Carbon Steel	C1023-1	C1023-2
Nickel-Chromium-Molybdenum Alloy	C276-2	C276-1

Table 2

DIMENSIONS OF AS-RECEIVED COUPONS

Coupon No.	Length (in)	Width (in)	Thickness (in)
20CB3-12	3.006	0.5005	0.075
20CB3-13	3.005	0.497	0.074
304-01	3.000	0.495	0.056
304-03	3.001	0.494	0.0565
AL6XN-1	3.003	0.501	0.0585
AL6XN-2	3.003	0.501	0.0595
B3-01	3.009	0.506	0.075
B3-02	3.011	0.505	0.075
C1023-1	3.008	0.510	0.0565
C1023-2	3.008	0.512	0.0565
C276-1	3.004	0.502	0.063
C276-2	3.005	0.501	0.064

RESULTS

Visual and Microscopic Examination of the Well samples exhibited uniform corrosion on Coupons 304-03, AL6XN-2, and C1023-1. The other coupons in this batch did not exhibit pitting/crevice corrosion, but the surface appears to be tarnished. Representative photographs of the coupons are provided in Figures 3 through 8.

Examination of the Piping samples did not exhibit corrosion or pitting. The coupons 304-01 and C1023-2 exhibited discoloration even after cleaning. Representative photographs of the coupons are provided in Figures 9 through 14.

The weight loss and corrosion rate results of the tested coupons are presented in Tables 3 and 4.

Table 3

WEIGHT LOSS AND GENERAL CORROSION RATE OF WELL SAMPLES AT 650°C (Vapor Phase)

Coupon ID number	Density (g/cm3)	Time (hr)	Surface Area (sq. in)	Initial Weight (g)	Weight Before Cleaning (g)	Weight After Cleaning (g)	Weight Change (mg)*	Corrosion Rate (mpy)
20CB3-13	8.08	240	3.51	14.485	14.50	14.49	-8.0	N/R
304-03	7.9		3.36	10.656	10.49	10.43	223.0	18.7
AL6XN-2	8.06		3.43	11.552	11.56	11.55	3.0	0.2
B3-01	9.22		3.57	17.009	17.02	17.01	0.0	N/R
C1023-1	7.86		3.47	11.020	11.98	9.06	1961.2	160.2
C276-2	8.94		3.46	13.415	13.42	13.42	-3.0	N/R

**Negative values indicates weight gain*
N/R - Not reported due to weight gain

Table 4

WEIGHT LOSS AND GENERAL CORROSION RATE OF PIPING SAMPLES AT 100°C (Condensing Environment)

Coupon ID number	Density (g/cm3)	Time (hr)	Surface Area (sq. in)	Initial Weight (g)	Weight Before Cleaning (g)	Weight After Cleaning (g)	Weight Change (mg)	Corrosion Rate (mpy)
20CB3-12	8.08	120	3.53	14.49	14.49	14.49	1.8	0.3
304-01	7.90		3.36	10.63	10.63	10.62	2.3	0.4
AL6XN-1	8.06		3.42	11.53	11.53	11.53	0.9	0.1
B3-02	9.22		3.57	16.66	16.66	16.66	0.9	0.1
C1023-2	7.86		3.48	11.02	11.02	11.01	14.0	2.3
C276-1	8.94		3.46	13.44	13.44	13.44	1.2	0.2

DISCUSSION

The corrosion rate calculation for the Well samples determined that carbon steel (C1023-1) and stainless steel (304-03) experienced the highest corrosion rates of 160.2 and 18.7 mpy, respectively. The other coupons in this batch showed no corrosion during the testing. Coupons 20CB3-13 and C-276 exhibited weight gain suggesting oxidation may have occurred during testing. High temperature oxidation typically results in oxide film on the surface resulting in weight gain. The thickness of the film formed depends on the exposure time and temperature.

The corrosion rate of the carbon steel and 304 stainless steel is not unusual, as they are expected to corrode in the hydrochloric acid at elevated temperatures. The corroded coupons exhibited uniform corrosion, with no localized corrosion (i.e., pitting, crevice) observed on these coupons. The other coupons (C 276-2, B3-01, AL6XN-2, and 20 CB3-13) exhibited a tarnished appearance, which is likely due to the oxidation of the coupons and possible solution contamination at elevated temperatures.

Based on the corrosion rate and examination, the Piping samples were unaffected by the testing conditions. Carbon steel exhibited the maximum corrosion rate (2.3 mpy), while the other coupon materials exhibited a corrosion rate between 0.1 and 0.4 mpy. The random discoloration observed on 304-01 and C1023-2 may be due to the contamination or initiation of random oxidation from the testing solution.

CONCLUSION

Based on the characterization of the corrosion-tested coupons, the following conclusions were made:

1. Among the group of Well samples, carbon steel coupon (C1023-1) and stainless steel coupon (304-03) showed the highest corrosion rates. The super austenitic stainless steel, stabilized austenitic stainless steel, and nickel alloys showed good corrosion resistance. None of the Well samples exhibited any evidence of pitting or crevice corrosion.

2. The Piping samples showed a negligible corrosion rate (except carbon steel). The samples in this group did not exhibit pitting or crevice corrosion.

RECOMMENDATIONS

1. Should TerraTherm select one of the materials for application, Intertek-APTECH could perform a cost analysis on the selected materials. This cost analysis would involve a comparison of the purchase price of the material (cost of production, fixed costs) and cost of ownership (service life, inspection frequencies, etc).

2. If TerraTherm does not have a Risk Based Inspection (RBI) program for piping, Intertek-APTECH recommends implementation of a RBI program on the new piping material and existing piping to monitor corrosion, minimize inspection intervals, and plan for turnaround activities in the future.

Should you have any questions regarding this report, please contact me at Intertek-APTECH's Houston office (832-593-0550) or by email at *velu.palaniyandi@intertek.com.*

Sincerely,

PVP

Velu Palaniyandi
Supervisor, Metallurgical Services

VP/rje
cc: HOU File
SV File

REFERENCES

1. Denny .A .Jones, Principles and Prevention of Corrosion, 2nd Edition, P-31.

Figure 1 — Photographs of As-received Coupons.

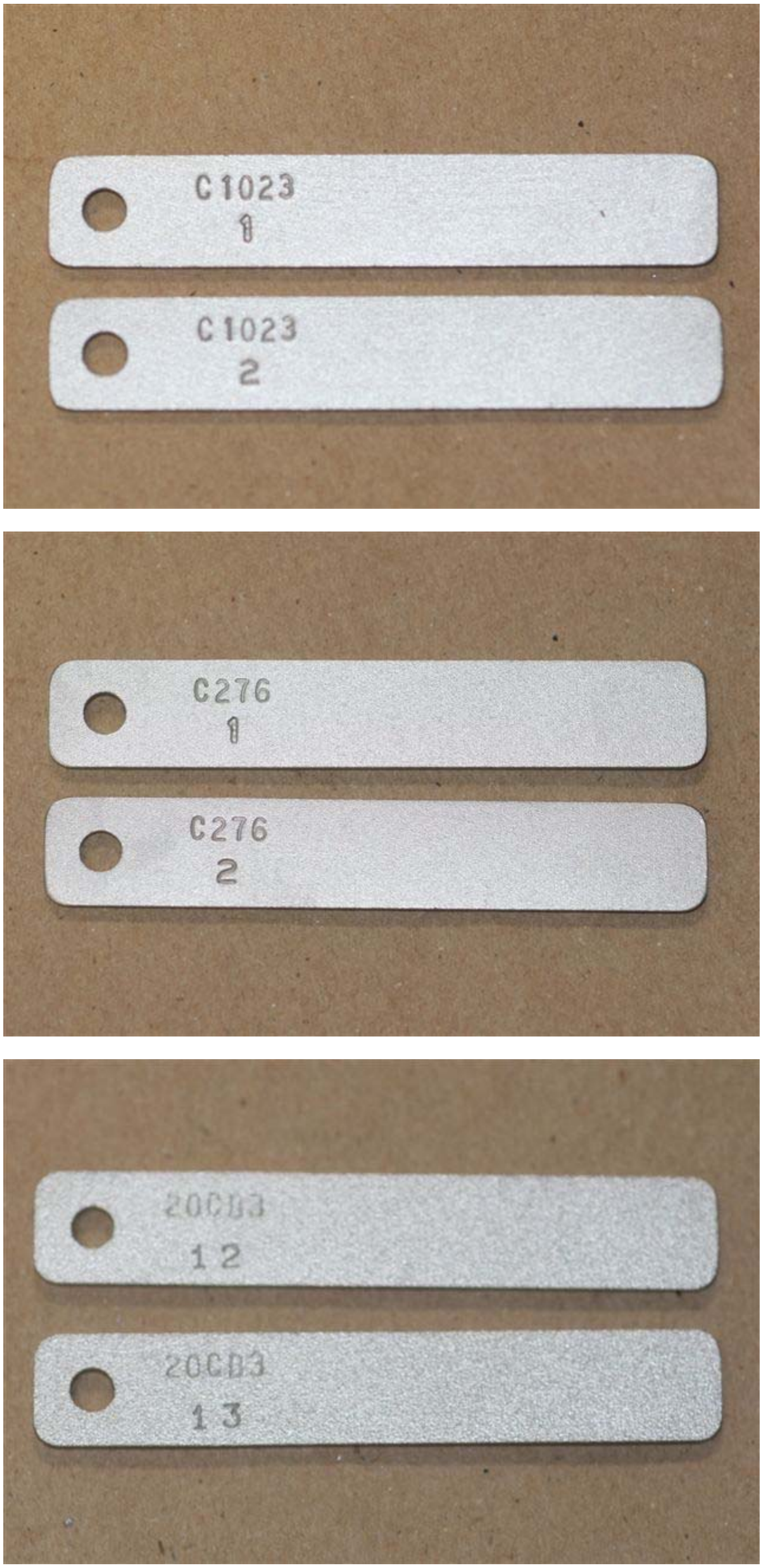


Figure 2 — Photographs of As-received Coupons.

Figure 3 — B3-01 Coupons before (Top) and after Cleaning (Bottom).

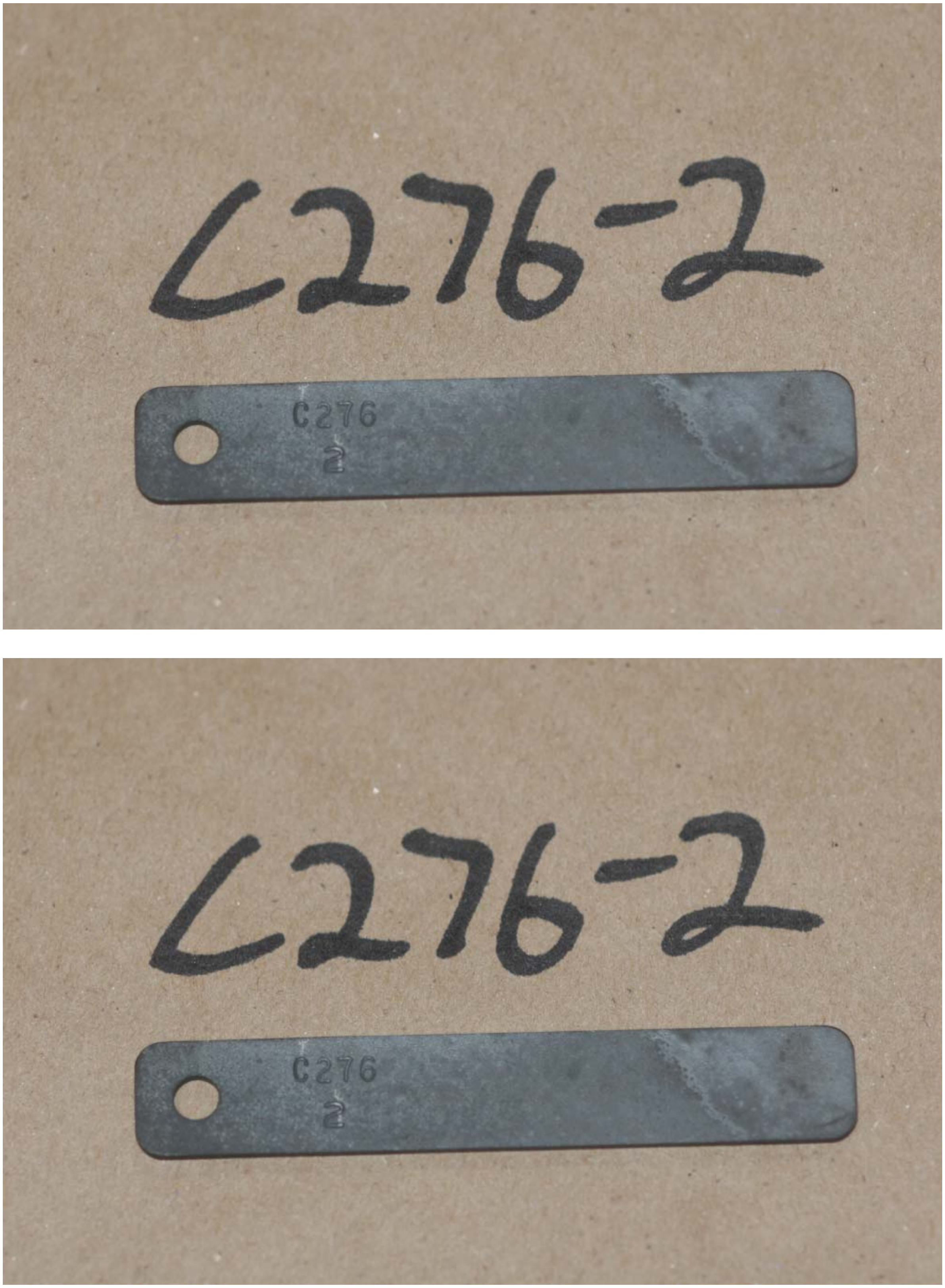


Figure 4 — C-276 Coupons before (Top) and after Cleaning (Bottom).

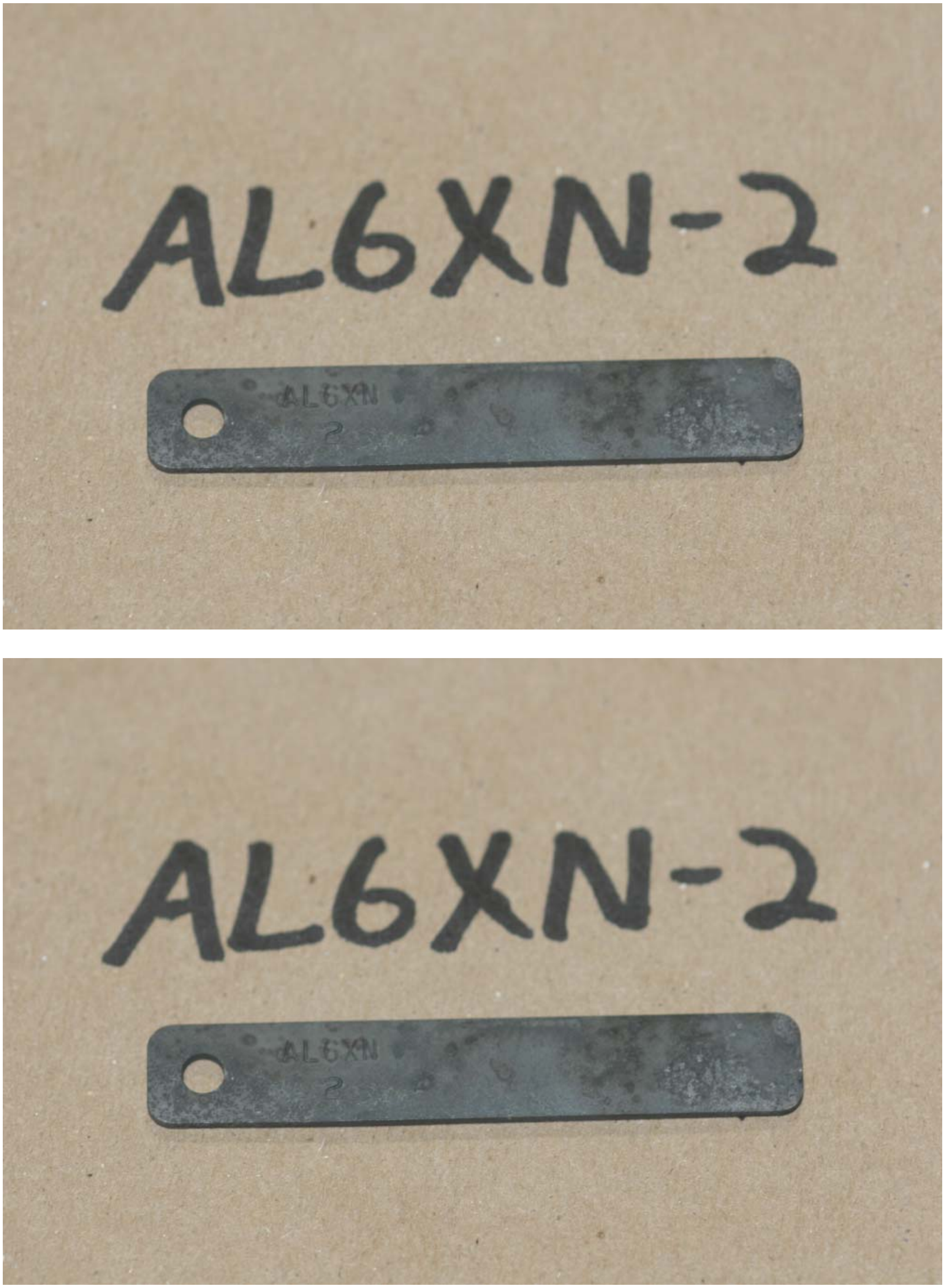


Figure 5 — AL6XN-2 Coupons before (Top) and after Cleaning (Bottom).

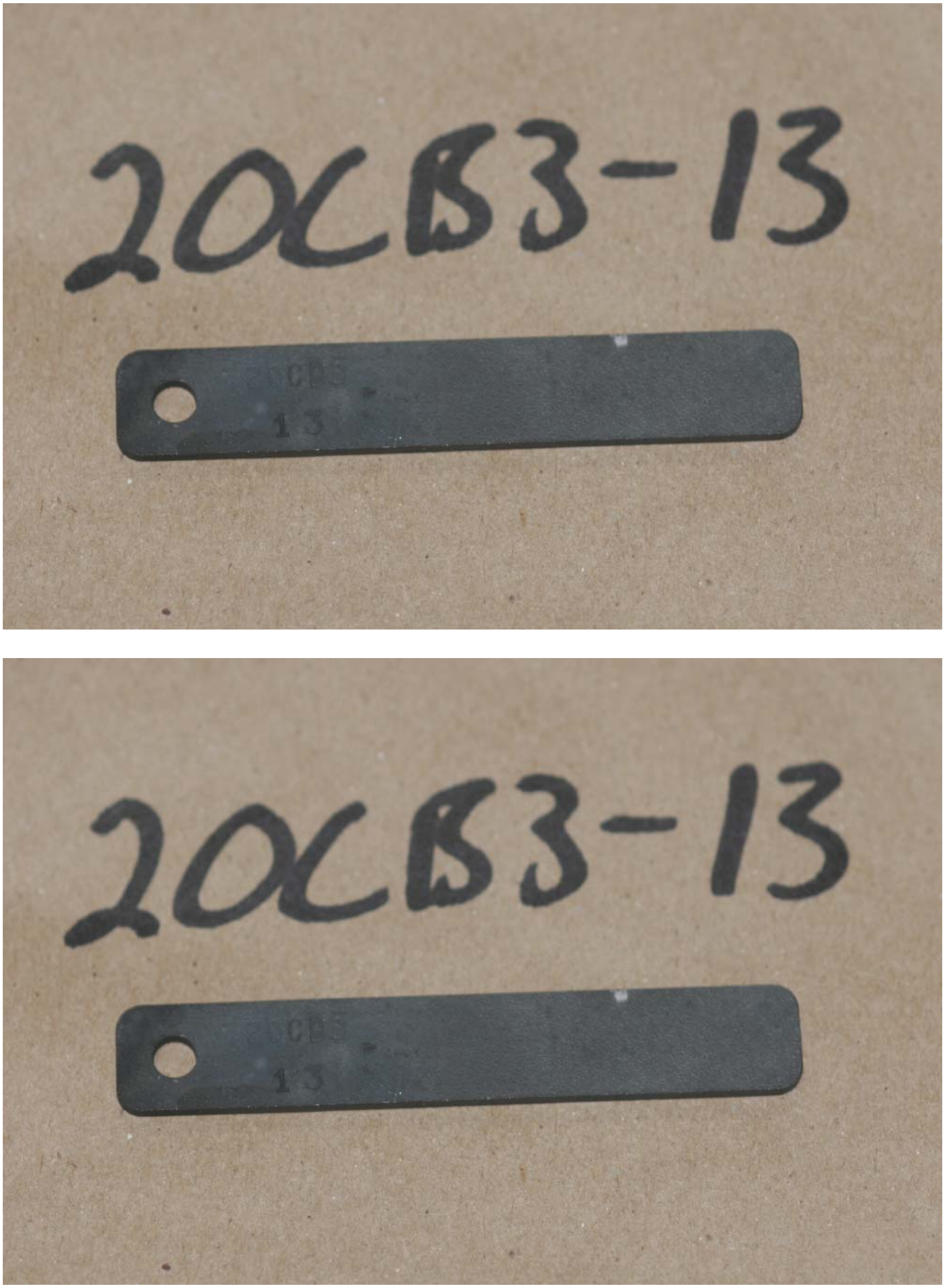


Figure 6 — 20 CB3-13 Coupons before (Top) and after Cleaning (Bottom).

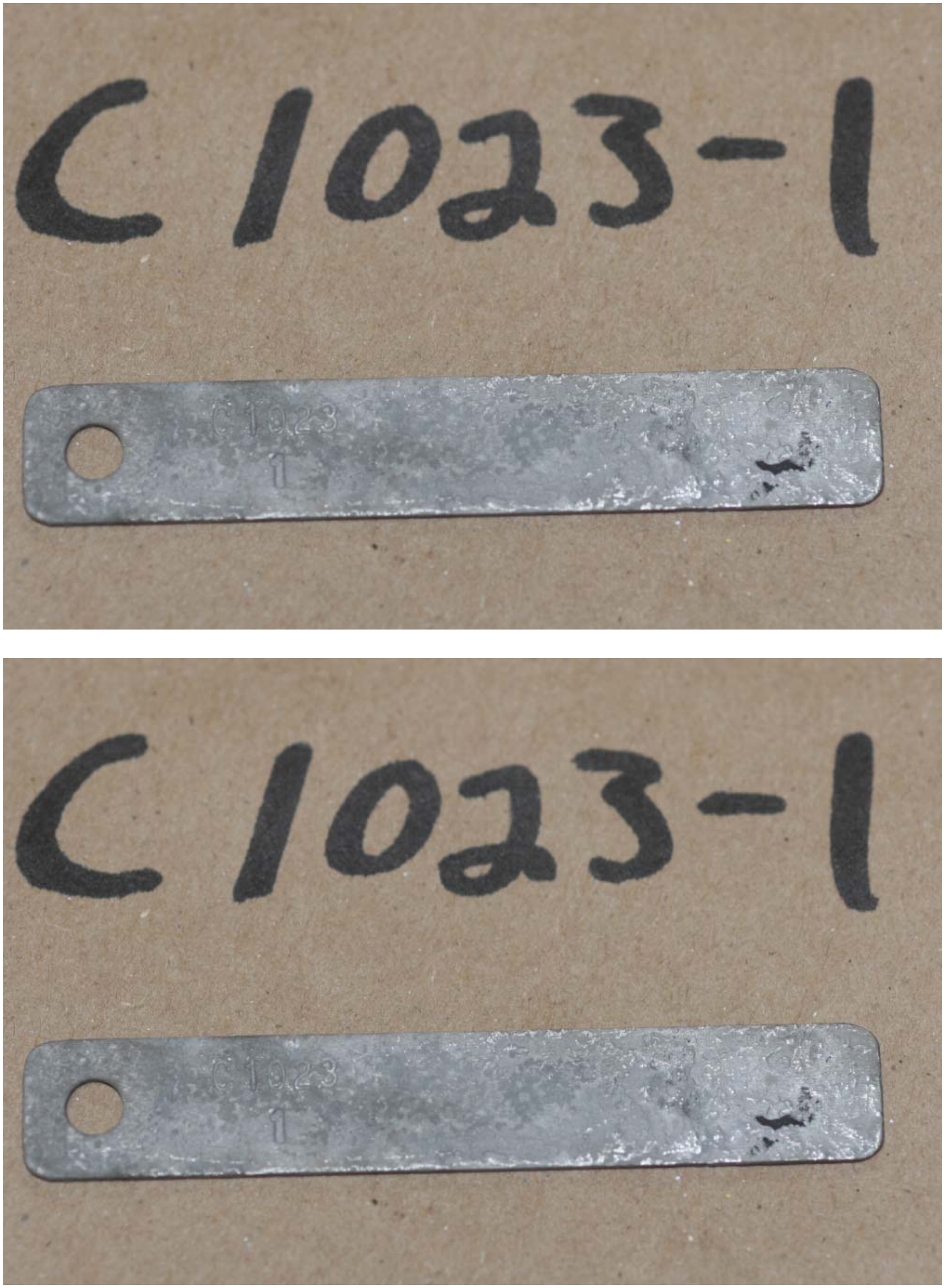


Figure 7 — 20 C1023-1 Coupons before (Top) and after Cleaning (Bottom).

Figure 8 — 304-03 Coupons before (Top) and after Cleaning (Bottom).

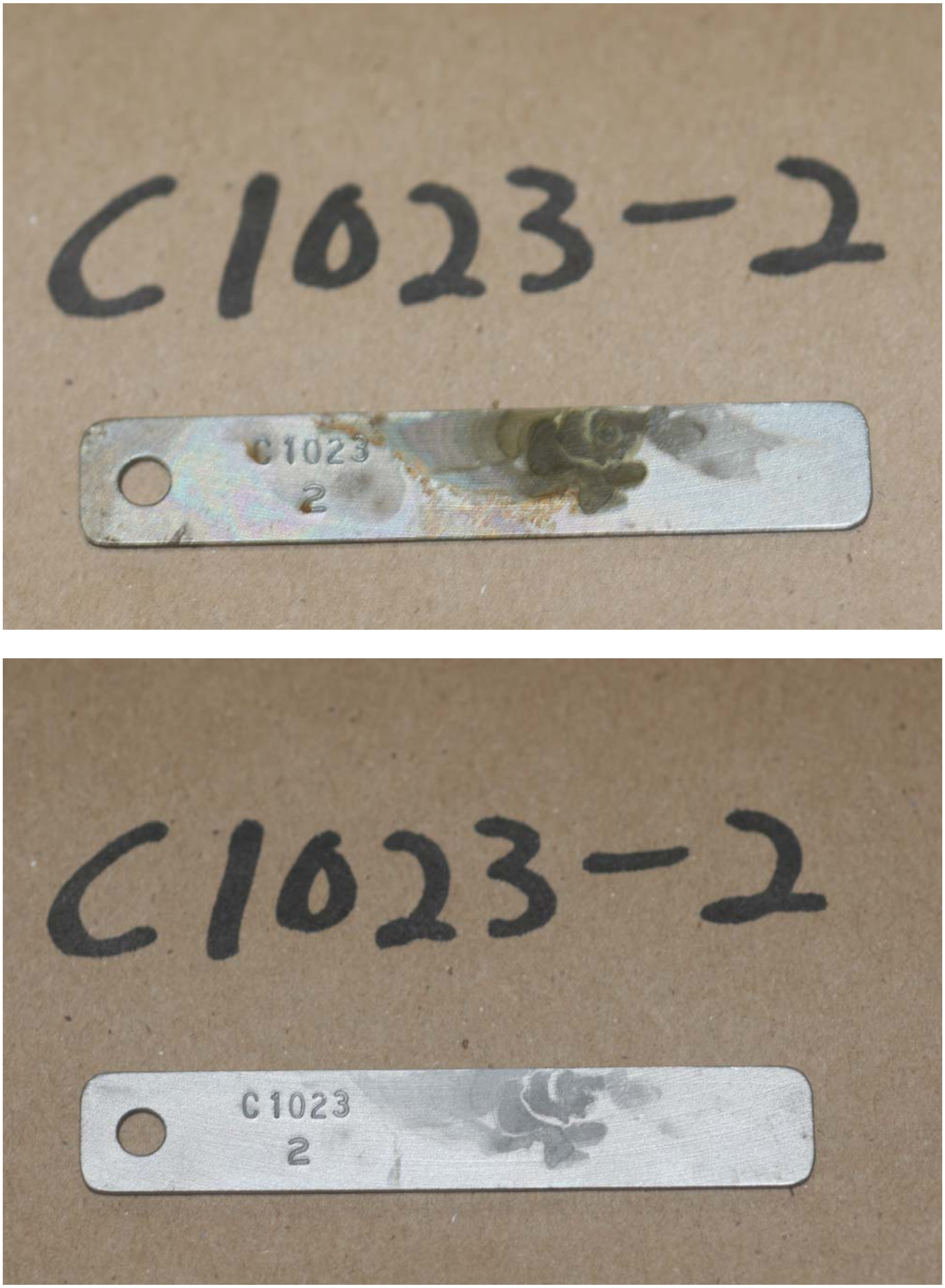


Figure 9 — C1023-2 Coupons before (Top) and after Cleaning (Bottom).

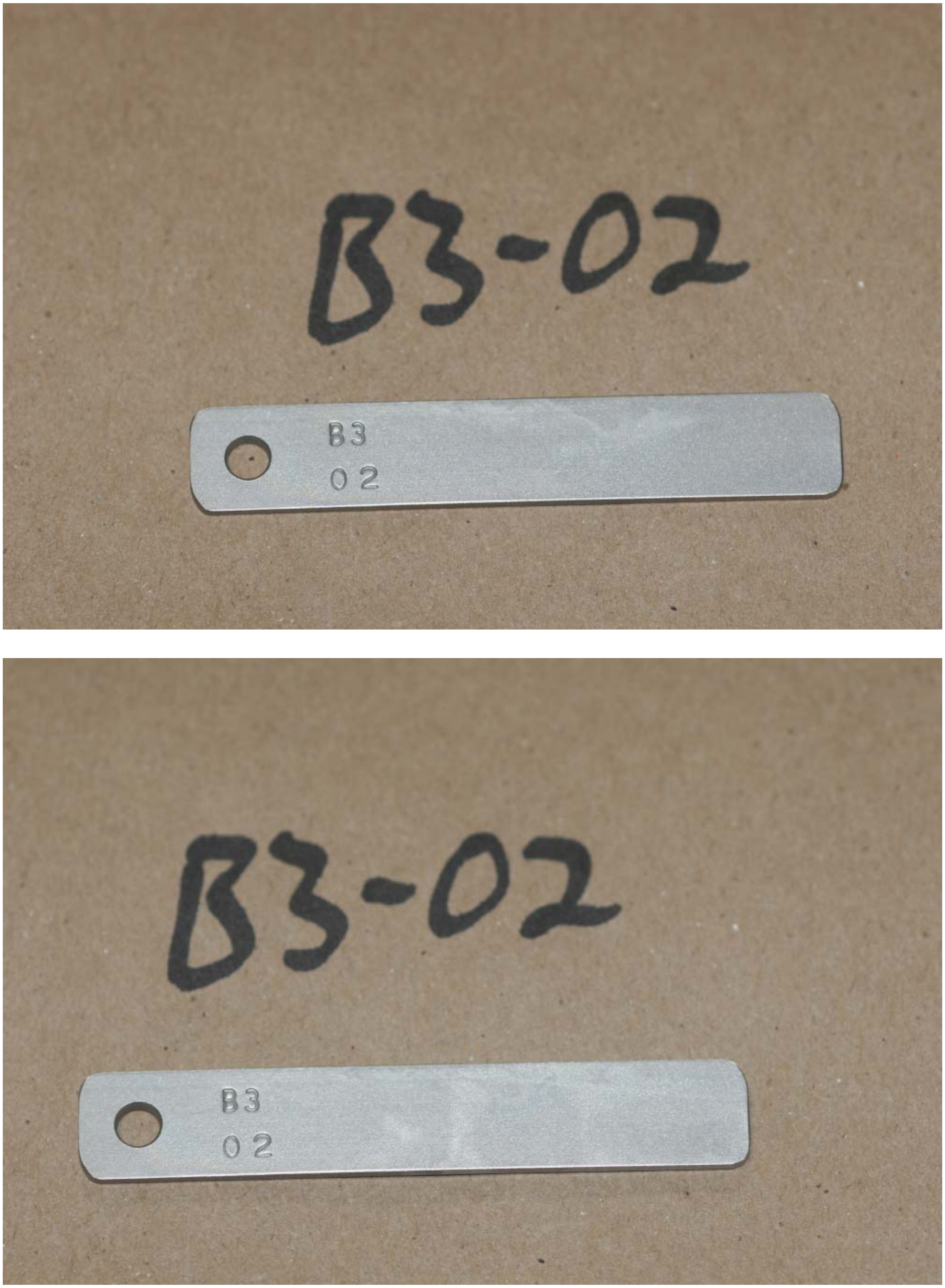


Figure 10 — B3-02 Coupons before (Top) and after Cleaning (Bottom).

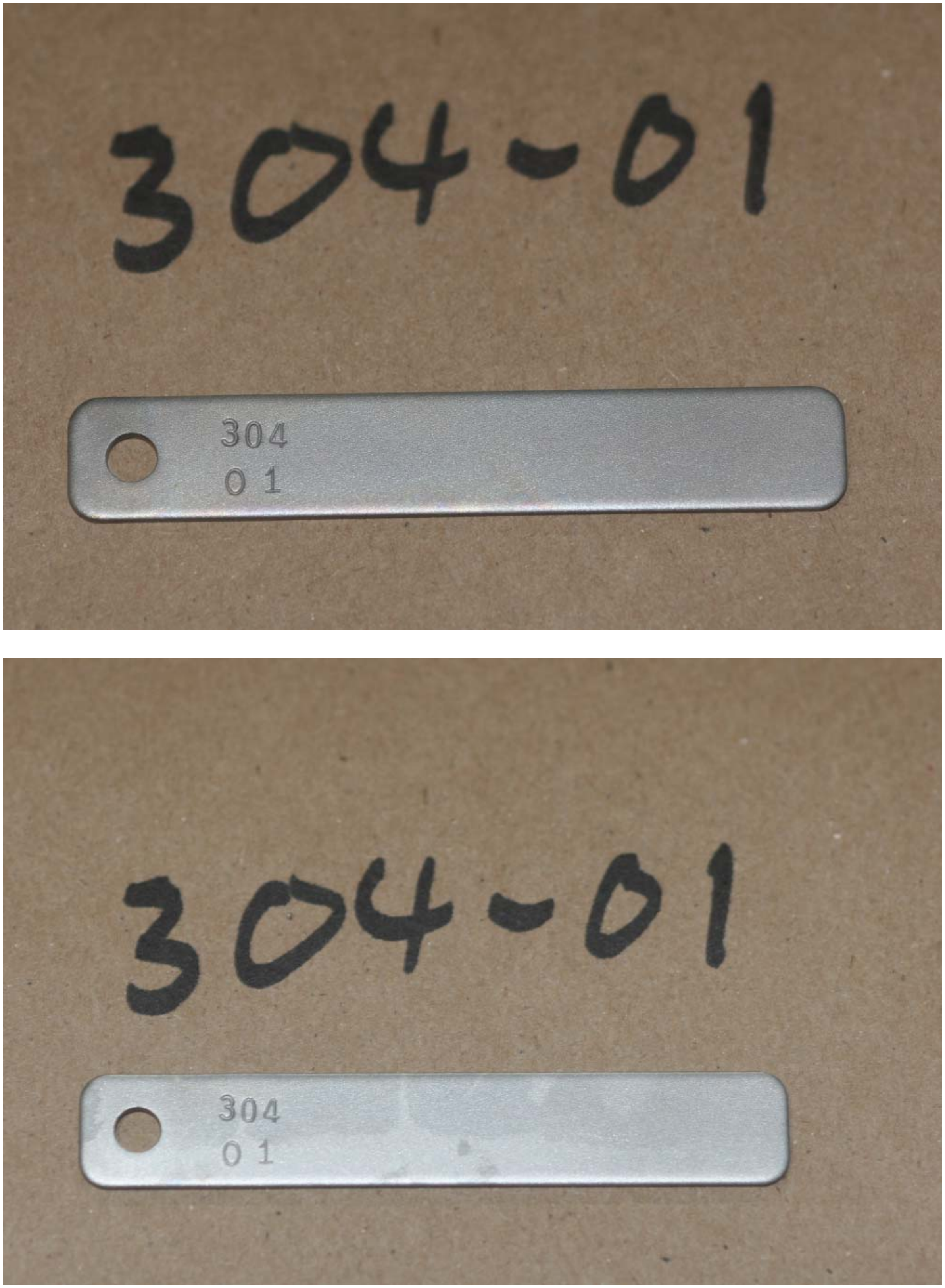


Figure 11 — 304-01 Coupons before (Top) and after Cleaning (Bottom).

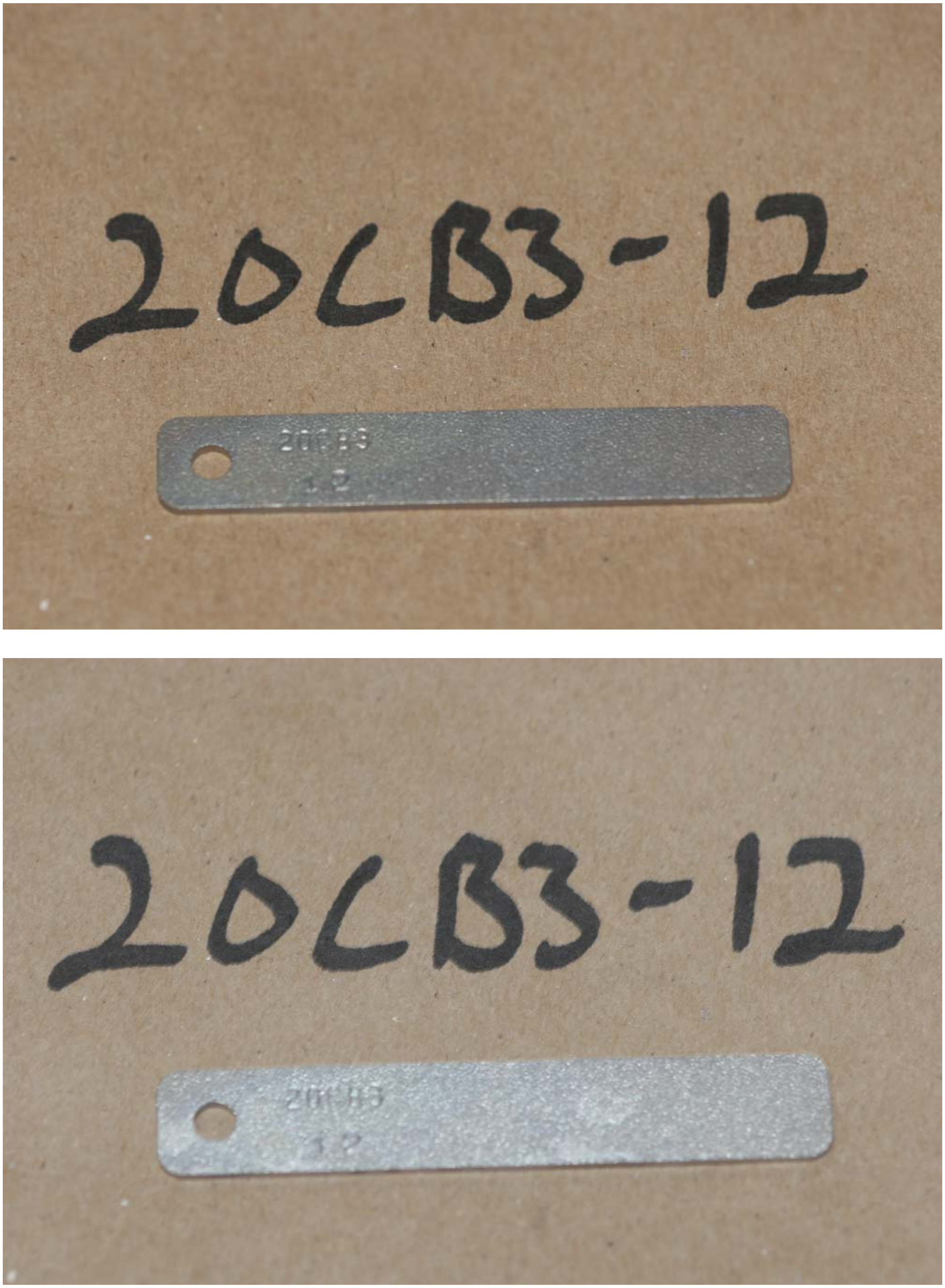


Figure 12 — 20CB3-12 Coupons before (Top) and after Cleaning (Bottom).

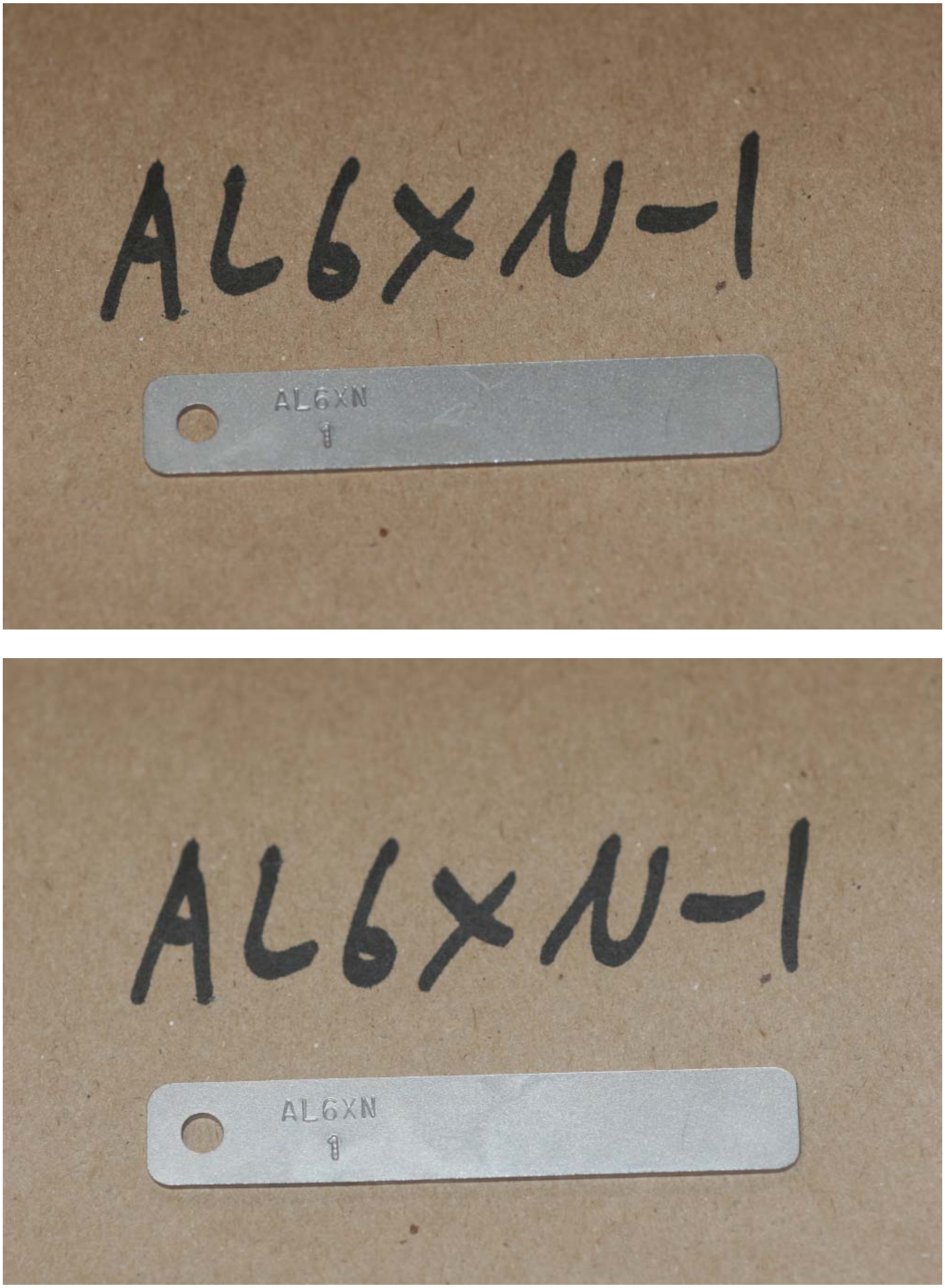


Figure 13 — AL6XN-1 Coupons before (Top) and after Cleaning (Bottom).

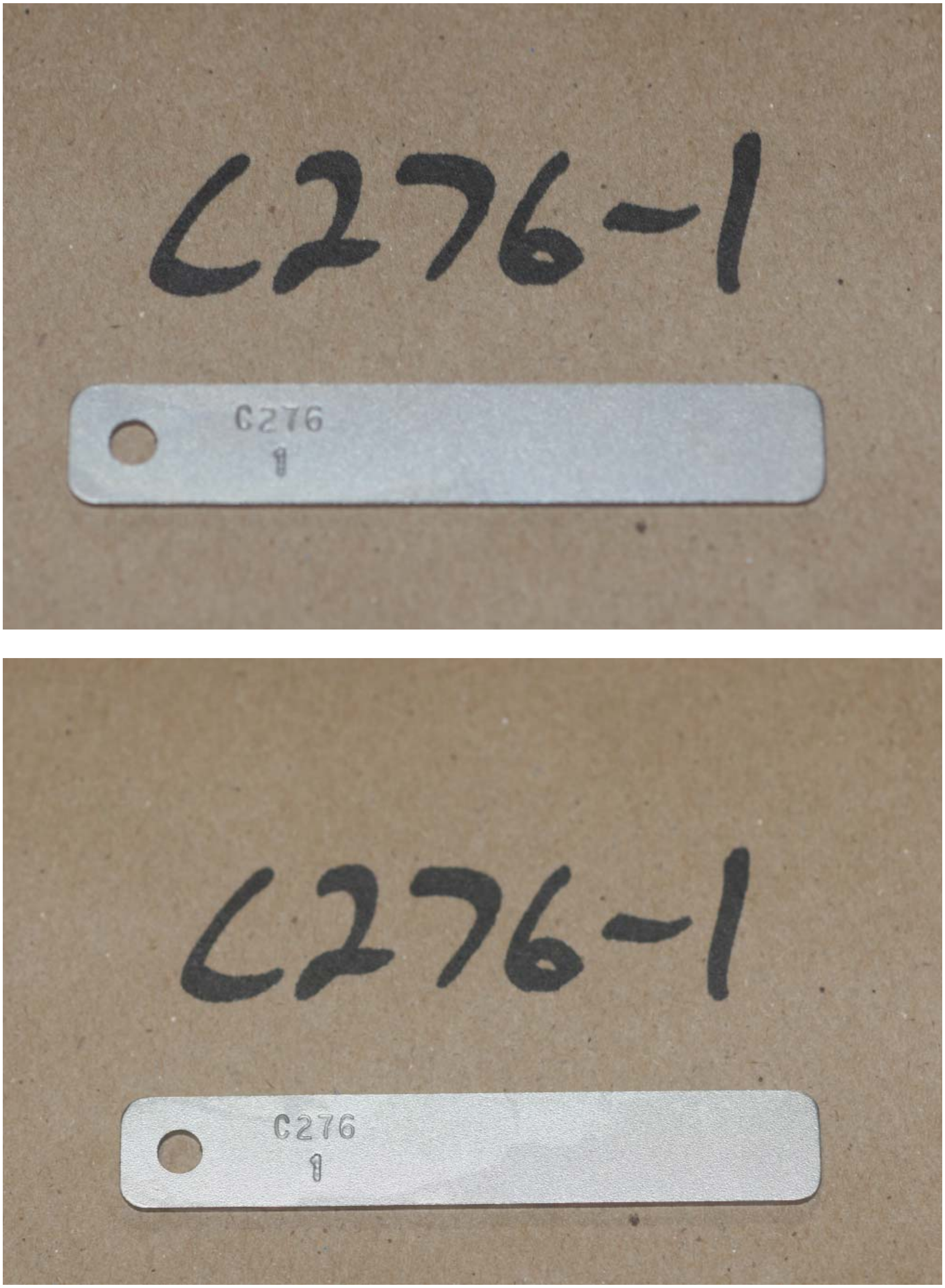


Figure 14 — C276-1 Coupons before (Top) and after Cleaning (Bottom).

Heat Dissipation Model

Solvents Recovery Service of New England (SRSNE)

Southington, Connecticut

Prepared for:

SRSNE Site Group

March 2010

Prepared by:

TerraTherm, Inc.
28900 Indian Point
Keene, CA 93531
661-823-1620

TerraTherm is an exclusive licensee/owner of (a) U.S. Patent Nos. 4,984,594; 5,076,727; 5,114,497; 5,190,405; 5,221,827; 5,229,583; 5,244,310; 5,271,693; 5,318,116; 5,553,189; 5,656,239; 5,660,500; 5,997,214; 6,102,622; 6,419,423; 6,485,232; 6,543,539; 6,632,047; 6,824,328; 6,854,929; 6,881,009; 6,951,436; 6,962,466; and 7,004,678, (b) U.S. Patent Publication 2004-0228690, and (c) certain non-U.S. counterpart applications/patents of the above-referenced patents and application.

TABLE OF CONTENTS

APPENDIX

1.0 INTRODUCTION

The SRSNE Site Group has elected to undertake an evaluation to determine the dissipation of heat outside of the treatment area during and after heating of the treatment zone. TerraTherm has set up a two dimensional heat dissipation numerical model to simulate the down gradient transport of heat during the thermal remedy and subsequent cooling. The purpose of the evaluation has more specifically been to answer the following questions:

- How long will it take before the site returns to an equilibrium state, near ambient temperatures?
- What temperatures will be observed down gradient of the treated zone, particularly at locations of existing monitoring wells in the NTCRA containment area?
- How will the temperature of the water extracted by the NTCRA wells vary over time?

The following sections describe the basis of the heat dissipation model and present the results of the modeling.

2.0 MODEL SETUP

2.1 Model Domain

A finite-element, numerical model has been developed to simulate the heat transport by advection and conduction. Figure 1 shows a map of the site with the selected orientation of the two dimensional, vertical simulation domain.

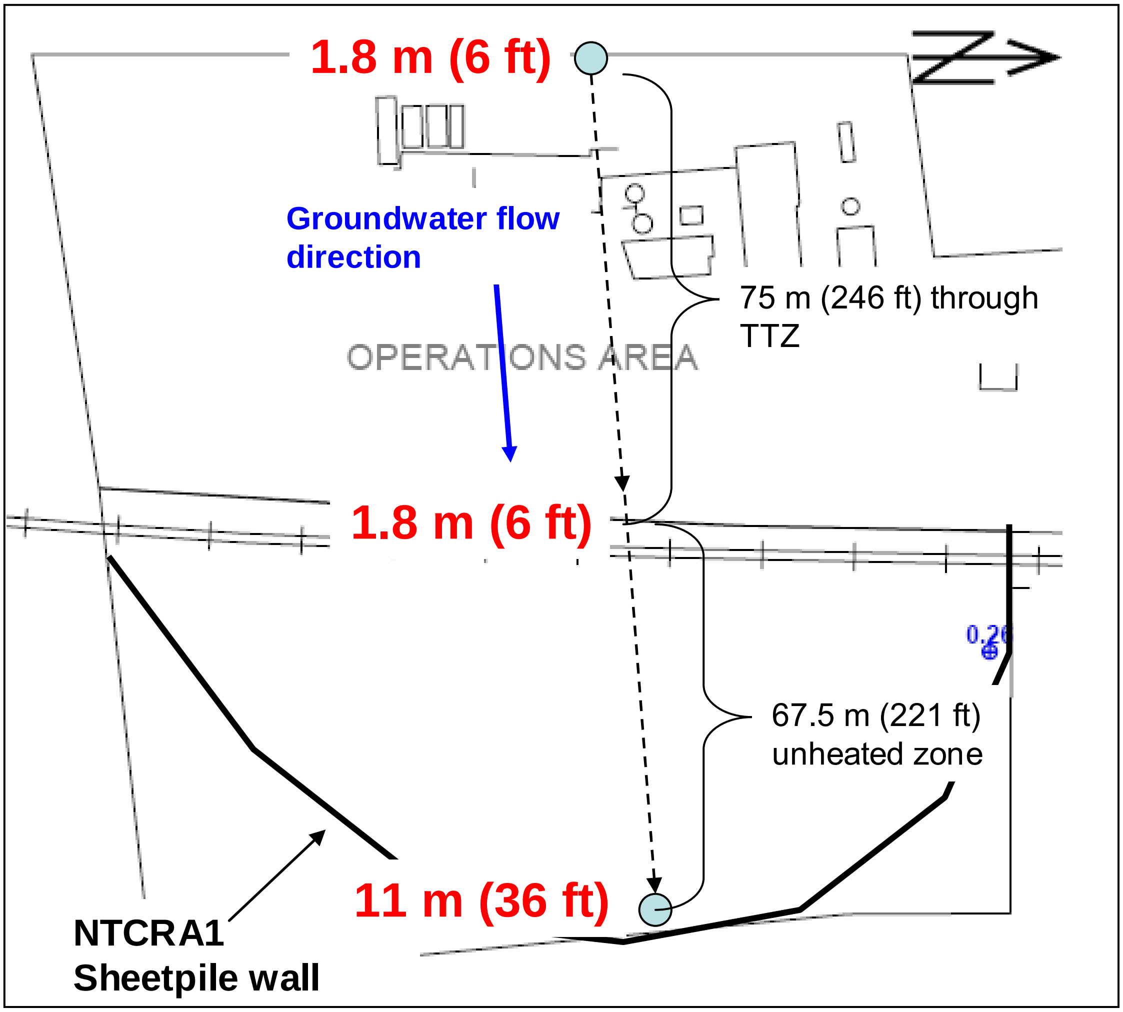


Figure 1. Location of Simulated Vertical Transect from West to East. Note the varying thickness of the saturated overburden (red numbers).

The model is set up to calculate the temperatures in a 142.5 meter (m) (468 ft) cross section through and downgradient of the Target Treatment Zone (TTZ). Seventy-five m (246 ft) of the model cross section are located in the TTZ and 67.5 m (221 ft) are located in the unheated area downgradient of the TTZ.

The model is divided into five simplified layers based on the geology at the site, as presented in Figure 2.

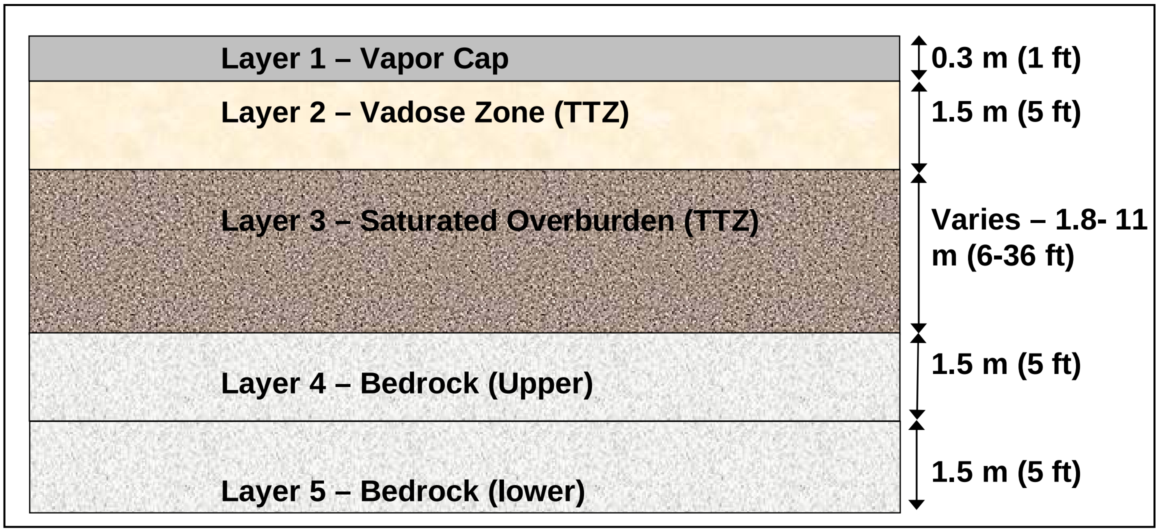


Figure 2. Model Layers in Heat Dissipation Model

Layer 1 is the insulated cover on top of the treatment zone while Layer 2 is the vadose zone. Both Layer 1 and 2 are modeled assuming a constant thickness, but only Layer 2 is located in the TTZ.

Layer 3 represents the saturated overburden and is within the TTZ. It is 1.8 m (6 ft) thick throughout the majority of the TTZ, but the thickness increases from the eastern edge of the TTZ and toward the NCTRA 1 sheet pile wall (Figure 1) to reflect the actual geological settings at the site. At the sheet pile wall, Layer 3 is 11 m (36 ft). The depth of Layer 3 is increased by linear interpolation.

Layers 4 and 5 are the upper and the lower bedrock below the site. Layers 4 and 5 have a constant thickness for the purpose of the model.

Figure 3 shows the vertical transect/slice and a simplified model domain.

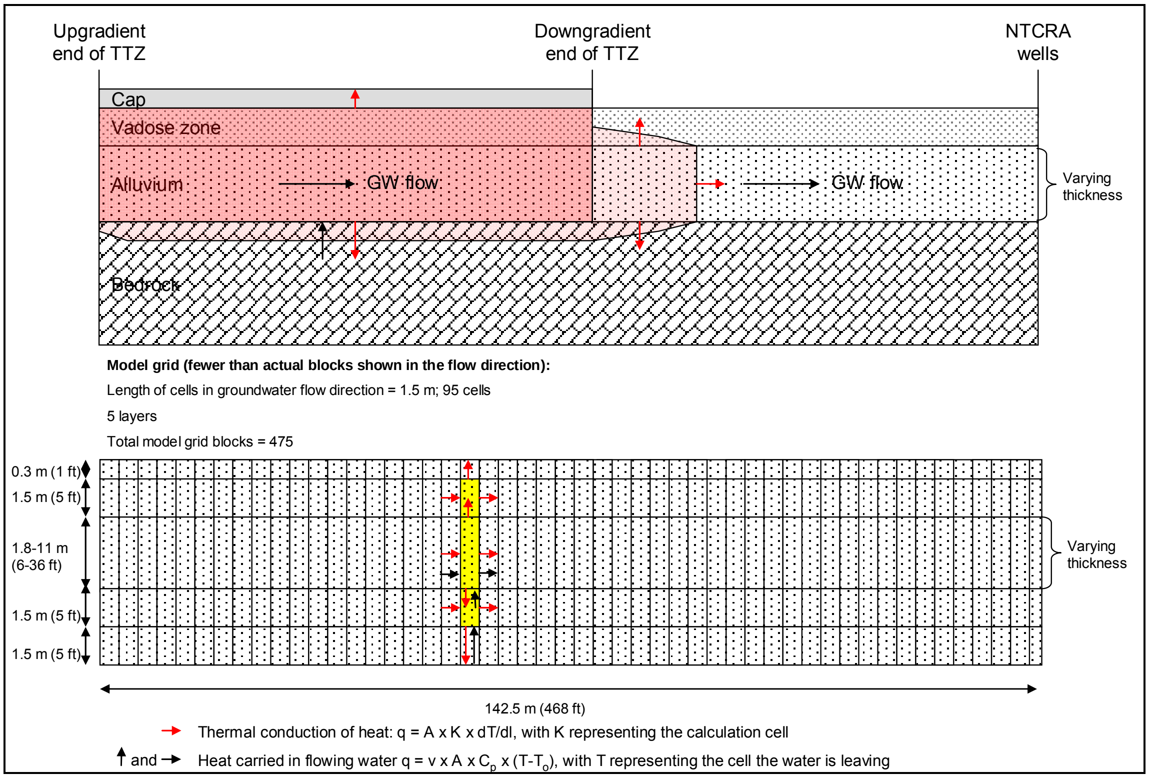


Figure 3. Conceptual Cross-Section of the Model, and Model Grid. Note that not all blocks are shown in the figure

The grid-blocks are 1.5 m (5 ft) long (95 cells) in the flow direction, 50 of the cells are within the TTZ. The simulation slice is 142.5 m long and contains 475 grid-blocks.

Aquifer properties and pumping data provided by ARCADIS have been used for the simulations. These include a porosity of 0.275 for the saturated overburden. Heat capacities and thermal conductivity have been derived by assuming that the solid matrix is quartz, and that the pores are water saturated. The thickness of the overburden will be varied along the model to represent the deepening of the saturated overburden, as indicated in Figure 3.

2.2 Model Scenarios

To test the importance of horizontal and vertical groundwater flow on the thermal analysis, the following scenarios have been modeled:

1) No vertical flow – model starts from day 125 of operation (assumes TTZ has reached 100 °C and heaters are turned off)

- Scenario 1: No water flow (shows only diffusive heat transport). Model starts from the day the heat is terminated in TTZ.

- Scenario 2: 5 gallons per minute (gpm) water flow through TTZ. All 5 gpm assumed to flow through model horizontally (no inflow of water from bedrock). Model starts from the day the heat is terminated in TTZ.

- Scenario 3 (Base case): 10 gpm water flow through TTZ. All 10 gpm assumed to flow through model horizontally (no inflow of water from bedrock). Model starts from the day the heat is terminated in TTZ.

- Scenario 4: 15 gpm water flow through TTZ. All 15 gpm assumed to flow through model horizontally (no inflow of water from bedrock). Model starts from the day the heat is terminated in TTZ.

2) Vertical flow – model from day 125 of operation (assumes TTZ has reached 100 °C and heaters are turned off)

- Scenario 3A: 13 gpm water flow through TTZ. 10 gpm assumed to flow through model horizontally. 3 gpm is inflow of water from bedrock. Model starts from the day the heat is terminated in TTZ.

- Scenario 3B: 16 gpm water flow through TTZ. 10 gpm assumed to flow through model horizontally. 6 gpm is inflow of water from bedrock. Model starts from the day the heat is terminated in TTZ.

3) No vertical flow – model from day 1 of operation

- Scenario 5: 10 gpm water flow through TTZ. All 10 gpm assumed to flow through model horizontally. Model starts from day 1 of operation (heat-up period is included).

The model scenarios are summarized in Table 1 below.

Table 1. Table Summarizing the Seven Model Runs

Scenario	Horizontal flow [gpm]	Vertical flow [gpm]	Start of model [day of operation]
Scenario 1	0	0	125
Scenario 2	5	0	125
Scenario 3 (base case)	10	0	125
Scenario 4	15	0	125
Scenario 3A	10	3	125
Scenario 3B	10	6	125
Scenario 5	10	0	1

Scenario 3 is considered the most representative scenario and is set up as the base scenario for the modelling. This scenario assumes that hydraulic control is maintained during the thermal remedy and no hot water is leaving the TTZ.

The simulation period was 550 days. Scenario 1 through 4 start at day 125 of operation and extend through day 675 after startup of operation. Scenario 5 ran from day 1 of operation. After 125 days of operation the heat was turned off in the model, and the model ran for another 425 days assuming no additional heat added to the model domain.

2.3 Energy Balance Estimation Methods

For each time-step, an energy balance is kept for each grid-block. The equations used are described below.

Cumulative energy (E) for a block is calculated as a summation of enthalpy fluxes (Q), for the time-step Δt:

$$E = \Sigma (Q \times \Delta t)$$

An estimated energy balance will be maintained for each block in the model.

$$E_{in} = E_{out} + E_{storage} + E_{loss}$$

The energy fluxes are related for each time step as follows:

$$Q_{in} = Q_{out} + Q_{storage} + Q_{loss}$$

where Q denotes enthalpy flux (in BTU/hr). Figure 3 shows the schematic energy balance for one layer.

All the water transport in the model occurs in the saturated overburden and the bedrock. For the vadose zone grid-blocks, heat only migrates by thermal conduction. In scenarios without any vertical groundwater flow, heat in the bedrock only migrates by thermal conduction. This is not a precise representation of field conditions, but will make the simulations conservative – the heat dissipation will not be overestimated.

The energy flux in the flowing groundwater is given by:

$$Q_{liq} = m_{liquid} \times c_{p,\ water} \times (T - T_0)$$

where c_p is heat capacity, T is the temperature of the grid-block, and T_0 is the ambient temperature.

An estimate of the diffusive (conductive) heat loss can be made based on thermal profiles at the bottom and top of each layer, and along the perimeter, using the following calculations:

$$Q_{heat\ loss} = A \times K_T \times dT/dz$$

where A is the surface area through which energy is conducted, K_T is the thermal conductivity of the subsurface material, and dT/dz is the temperature gradient across the surface also expressed as $(T_1-T_2)/(z_1-z_2)$.

For the loss through the vapor cap, the temperature difference between the top and bottom of the layer can be used to calculate the gradient. For the calculations, it is assumed that the top of the vapor cap remains near ambient temperatures due to a combination of wind cooling and simple heat radiation.

Heat loss calculations through the bottom are accounted for in a similar manner. The layers exchange energy by thermal conduction such that energy leaves the warmer layer and enters the cooler layer.

The model calculates average layer temperatures based on the energy balance and the estimated heat capacity of each layer. The stored energy is related to the heated zone, heat capacity, and the average temperature as follows:

$$E_{storage} = C_p \times (T - T_0)$$

where C_p is the heat capacity of the grid-block, estimated from the volume, saturation, and specific heat capacity of the soil and water:

$$C_p = V_{soil} \times C_p \times V_{water} \times c_{p,\,water}$$

In each time-step, the energy balance can be used to estimate the temperature of each grid-block ($T_{energybal}$):

$$T_{energybal} = T_0 + E_{storage}/C_p = T_0 + (E_{in} - E_{out} - E_{loss})/ C_p$$

The model uses 550 time steps of 24 hours each, with 160,000 energy balance calculation steps.

2.4 Starting Conditions

The starting temperature condition for Scenario 1 to 4 in the model is shown in Figure 4.

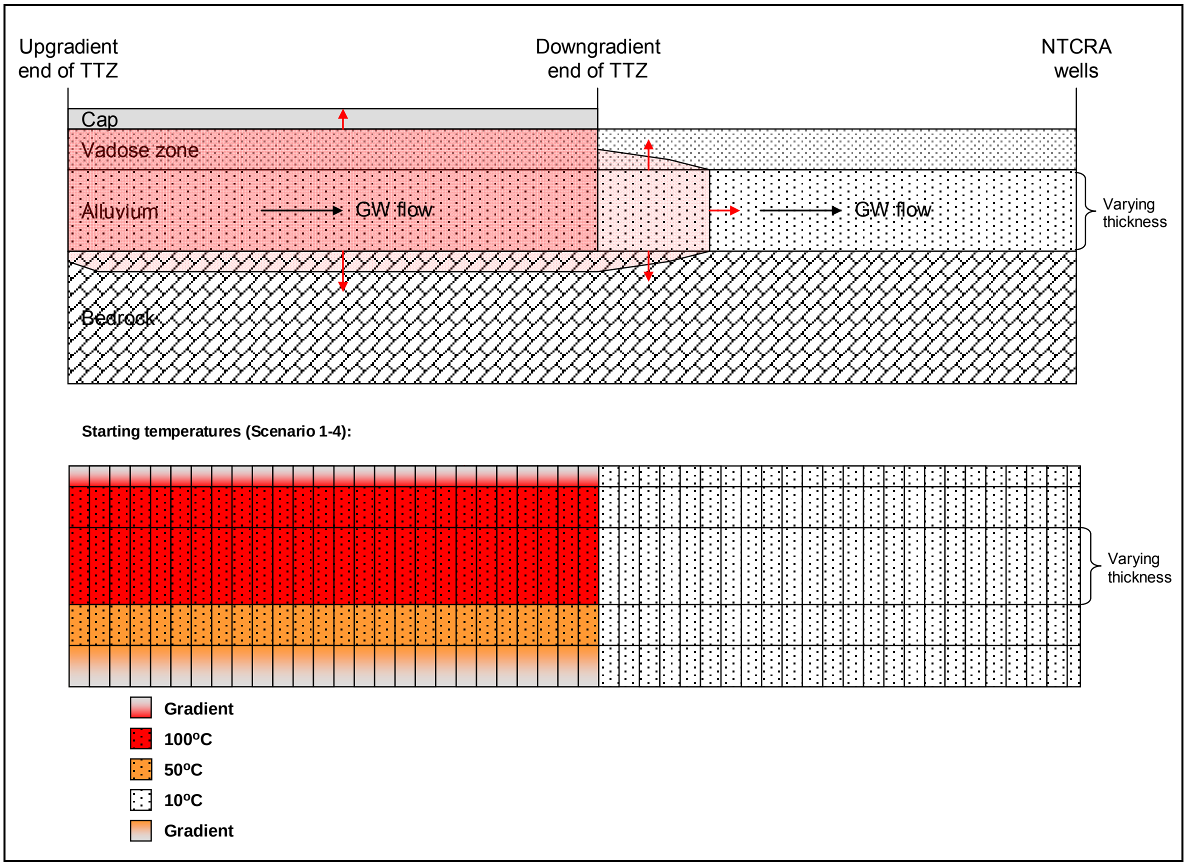
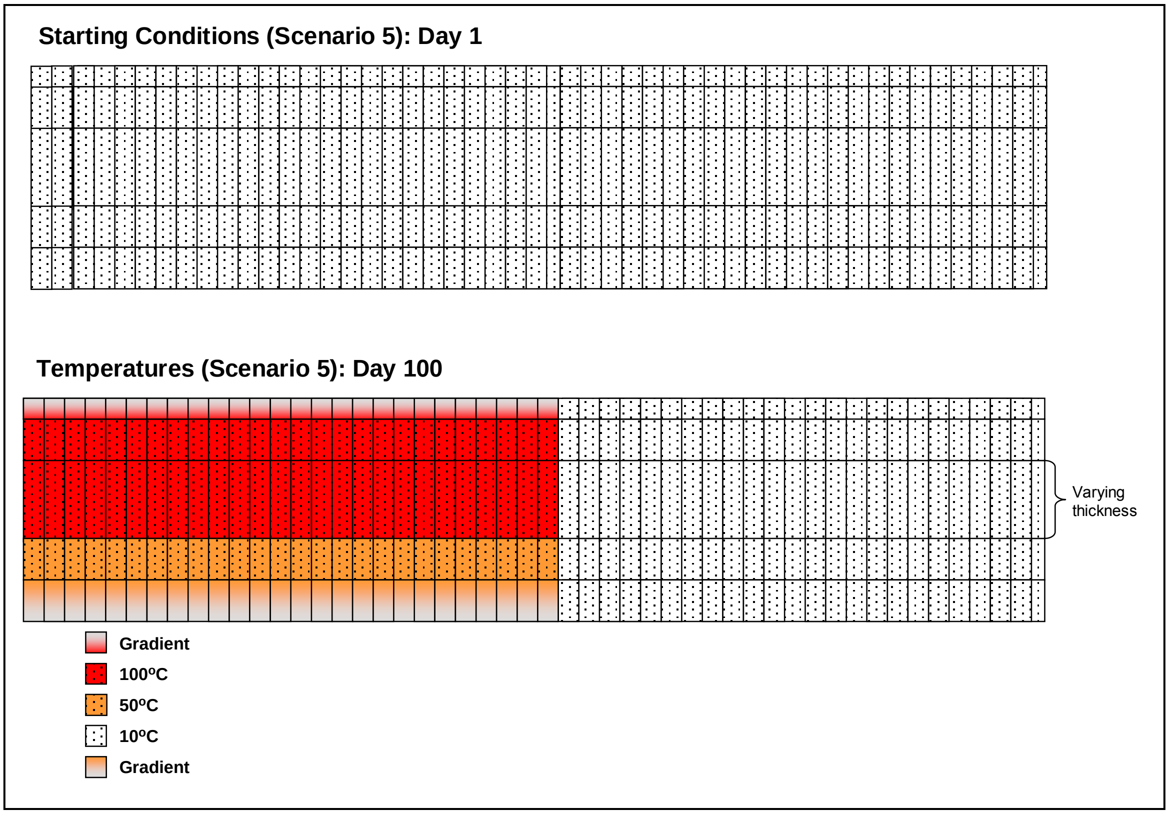


Figure 4. Starting Temperatures for Scenario 1 through 4 in the Model

The temperature distribution represents the condition within the footprint of the TTZ at the end of thermal treatment, where the target treatment volume has been heated to 100°C. The upper 1.5 m of the bedrock is expected to have an average temperature of 50°C. Both the vapor cap and the bedrock deeper than 1.5 m below the overburden will have varying temperatures due to the heat transport through those zones during thermal treatment.

The starting temperature conditions within the TTZ for Scenario 5 are shown in Figure 5. Note that the heat transferred downgradient from the TTZ from day 1 to day 100 is not shown in Figure 5, but is included in the model calculations.


Starting Conditions (Scenario 5): Day 1

Temperatures (Scenario 5): Day 100

Figure 5. Starting Temperatures in the Model for Scenario 5.

The temperature distribution at day 1 represents the condition at startup of operation. After 100 days of heating the average temperature in the heated zone is expected to be 100 °C and kept there until day 125 of operation where the heating is terminated and the target treatment volume has been heated to 100°C.

From day 1 and until day 100 of operation the temperature in the heated zone (Layer 2 and 3 in the model) is increased from ambient temperatures (10 °C) to the boiling point (100 °C) according to the graphs shown in Figure 6. The graphs present the expected heat up of the heated zone. From day 100 to day 125 of operation, the average temperature in Layer 2 and 3 is kept at 100 °C to represent expected field conditions.

In Scenario 5, the upper 1.5 m of the bedrock (layer 4) is expected to have an average temperature of 50 °C after 100 days of operation. Figure 6 shows the assumed heat up of the upper bedrock layer (Layer 4 in the model).

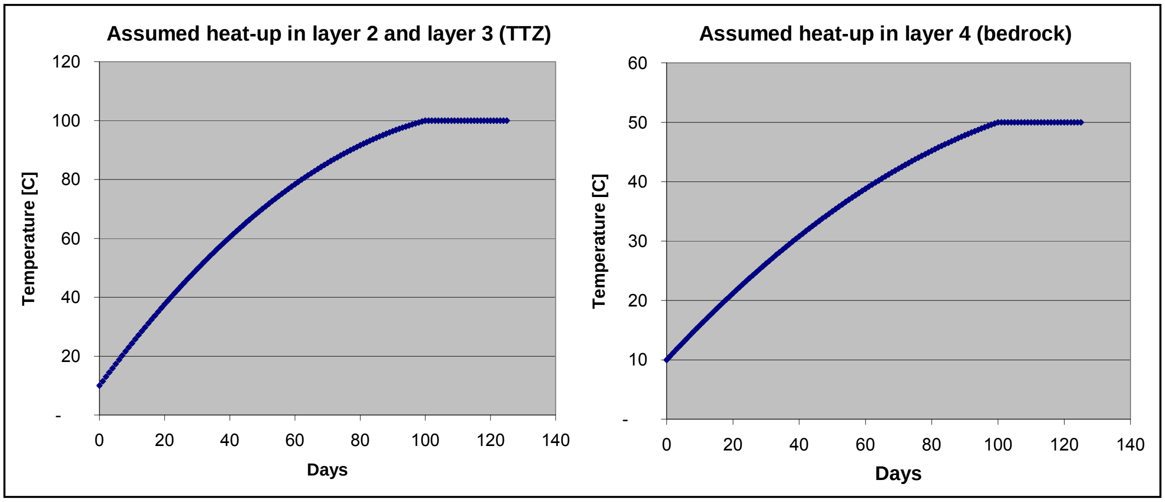


Figure 6. Assumed Heat-up of Layer 2 to 4 in Scenario 5

Both the vapor cap and the bedrock deeper than 1.5 m below the overburden will have varying temperatures due to the heat transport through those zones during thermal treatment.

2.5 Simulation Output

The model calculates temperature data for the saturated overburden, the vadose zone, and the upper 1.5 m of the bedrock. Example output data are provided for the saturated overburden for the base case (Scenario 3) in Figure 7 and 8.

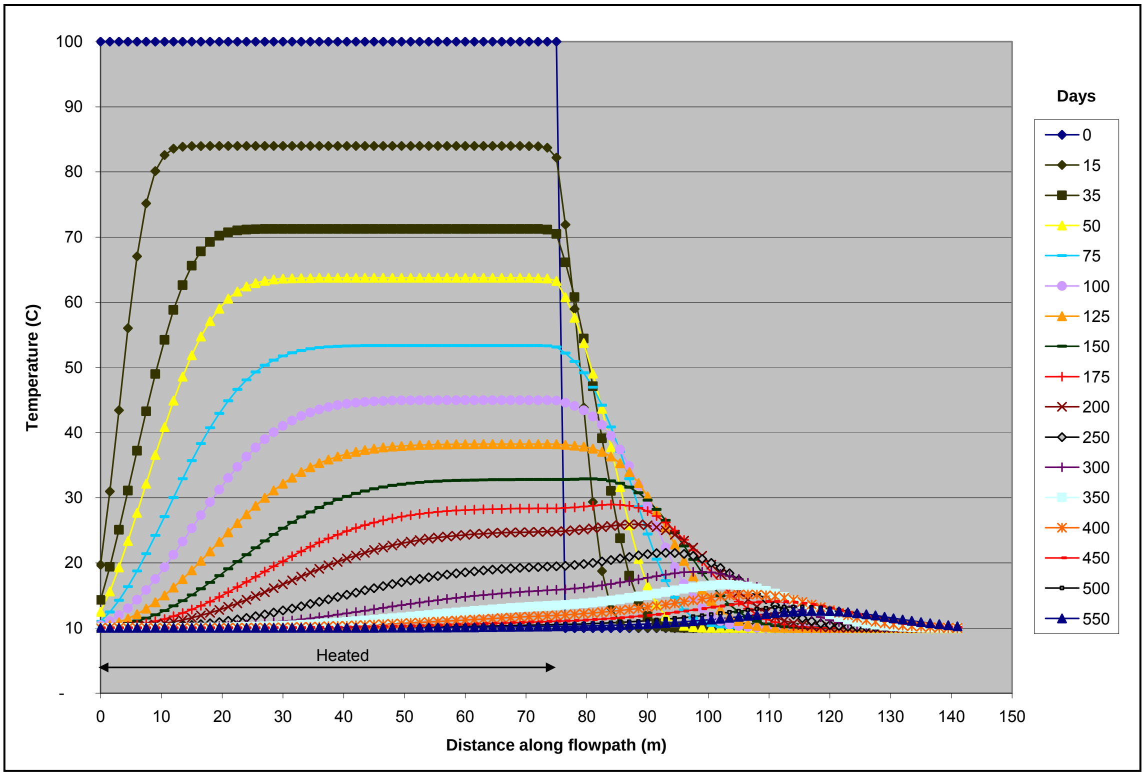


Figure 7. Saturated Overburden Temperatures along the Flow Path for Scenario 3 (Base Case). Horizontal flow is 10 gpm and vertical flow is zero.

Figure 7 shows the temperature along the flow path from the time when heating is terminated in the TTZ (day 0) until 550 days after shutdown. The existing NTCRA wells are located between 15 m (50 ft) and 55 m (180 ft) from the TTZ, corresponding to 90 – 130 m (295 - 427 ft) along the flowpath.

The base case results indicate that the temperature impact at the pumping wells will be between 5 and 20 °C *above* the ambient temperature of 10 °C (i.e., between 15 and 30 °C predicted temperature), depending on specific well locations.

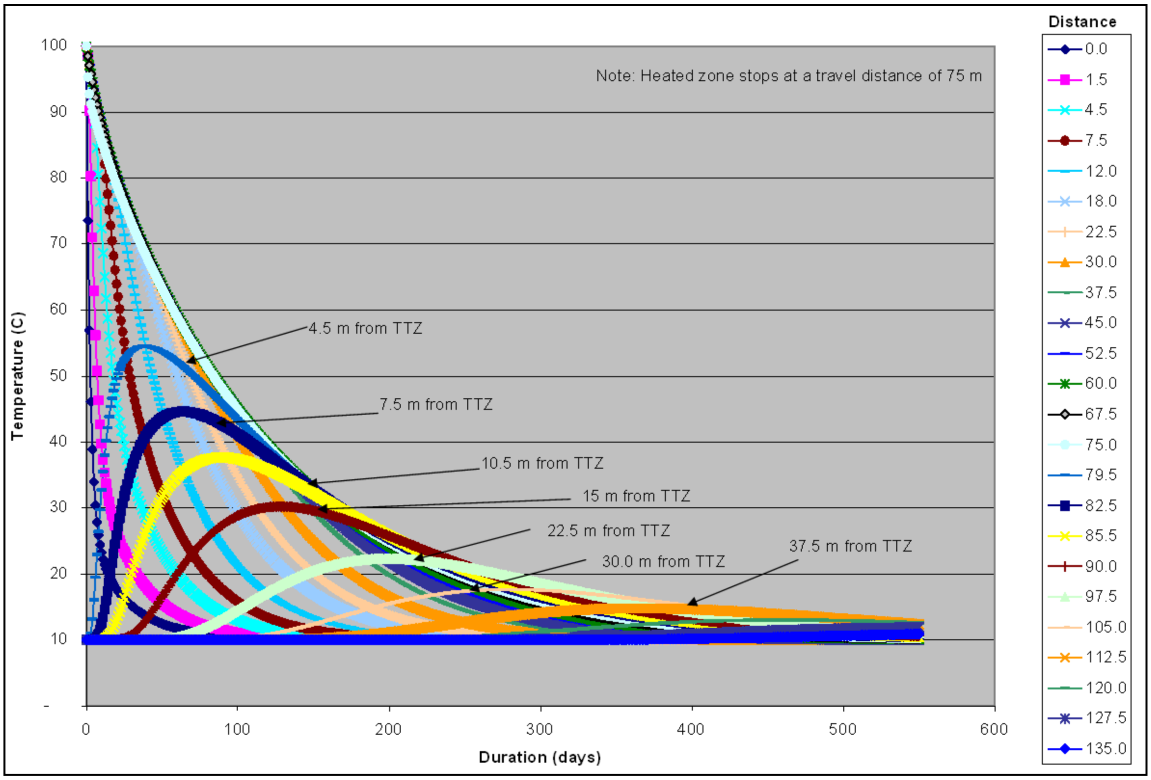


Figure 8. Saturated Overburden Temperatures with Time for Scenario 3 (base case). Horizontal flow is 10 gpm and vertical flow is zero.

Figure 8 shows the temperature with time for modeling points located at different distances from the upgradient edge of the TTZ (distances indicated in the legend). In addition, labeled data sets shown in the graph indicate distances from the downgradient edge of the TTZ. Different locations within and downgradient of the TTZ will experience different temperature increases, as illustrated in the figure. The soil and water temperature, for example, 15 m (49 ft) from the TTZ is predicted to reach a temperature of 30 °C and the temperature is predicted to peak approximately 130 days after the heat is turned off.

Appendix A contains the simulation results for Scenarios 1 to 5.

3.0 RESULTS

The following sections address the questions of concern listed in the opening of this document. All results are focused on the temperatures in the saturated overburden (Layer 3 in the model), where water flows towards the NCTRA wells located downgradient of the treatment area.

3.1 Estimated Time for Return to Equilibrium

Based on the calculations, the cooling of the site can be predicted. The ambient soil temperature at the site has been assumed to be 10 °C. Furthermore, due to natural variability and fluctuation in groundwater temperatures, it is assumed that a temperature within 10 °C of ambient temperature, e.g. below 20 °C, will be considered close to the equilibrium state. This is consistent with natural variations in groundwater temperature, which have shown to fluctuate seasonally by up to 12 °C.

Table 2 summarizes the time for the TTZ to return to temperatures below 20 °C. For comparison, the corresponding times to cool down the areas below 15 °C are shown. The table shows both the time to reach an average temperature of 15 and 20 °C, and the time before the maximum temperature within the TTZ is below 15 and 20 °C.

Table 2. Time for TTZ to Return to Ambient Temperature

	Horizontal flow [gpm]	Vertical flow [gpm]	Max 20 °C [days]	Max 15 °C [days]	Average 20 °C [days]	Average 15 °C [days]
Scenario 1	0	0	241	316	234	309
Scenario 2	5	0	240	317	210	275
Scenario 3 (base case)	10	0	239	307	182	235
Scenario 4	15	0	220	270	156	199
Scenario 3A	10	3	231	296	176	227
Scenario 3B	10	6	224	285	171	220
Scenario 5	10	0	364	432	307	360

Excluding Scenario 5, the model predicts the average temperature in the TTZ to be below 20 °C after 156 to 234 days after the energy input to the TTZ is terminated. The time to reach a maximum temperature in the TTZ below 20 °C is between 220 and 241 days.

In Scenario 5 where the heat-up period is included in the calculations, the corresponding time to reach an average and maximum temperature in the TTZ is 307 and 364 days. Subtracting 125 days to account for the different starting time for this scenario, the resulting times to average and maximum temperatures in the TTZ (182 and 239 days) are within the ranges predicted by the other scenarios.

Table 3 summarizes the time for the treatment area and the area downgradient of the treatment area to return to temperatures below 15 and 20 °C.

Table 3. Time for TTZ and Downstream Area to Return to Ambient Temperature

	Horizontal flow	Vertical flow	Max 20 °C	Max 15 °C	Average 20 °C	Average 15 °C
	[gpm]	[gpm]	[days]	[days]	[days]	[days]
Scenario 1	0	0	241	316	164	239
Scenario 2	5	0	244	335	165	241
Scenario 3 (base case)	10	0	267	387	160	235
Scenario 4	15	0	292	437	153	228
Scenario 3A	10	3	266	392	160	235
Scenario 3B	10	6	264	396	159	235
Scenario 5	10	0	428	<550	300	381

If the downgradient area is included in the model, it predicts the average temperature in the TTZ and the downgradient area to be below 20 °C after 153 to 165 days after the energy input to the TTZ is terminated. The time to reach a maximum temperature in the TTZ and the downgradient area below 20 °C is between 241 and 292 days.

In Scenario 5, where the heat-up period is included in the calculations, the corresponding time to reach an average and maximum temperature below 20 °C in the TTZ is 300 and 428 days.

Please note that the stated times in Table 2 and 3 are from the time the heaters are shut down for Scenario 1 to 4 (corresponding to day 125 of operation), while the time stated for Scenario 5 is from startup of operation.

3.2 Predicted Downgradient Temperatures

The model was used to calculate groundwater temperatures expected to occur in downgradient NTCRA area wells as a result of heating within the TTZ.

The model calculates the downgradient temperature up to 67.5 m (221 ft) from the edge of the treatment area. Since the NTCRA monitoring wells are located in different distances from the edge of the treatment zone, the maximum expected temperature to be observed at a distance of 10 m (33 ft), 20 m (66 ft), 40 m (131 ft) and 67.5 m (221 ft) from the downgradient edge of the treatment zone are summarized in Table 4.

Table 4. Predicted Maximum Temperatures along the Flowpath in the Model Domain. All distances are measured from the downgradient edge of the heated zone, which corresponds to 75 m along the flowpath in the model.

	Horizontal flow [gpm]	Vertical flow [gpm]	Maximum temperature 10 m from edge of TTZ [°C]	Maximum temperature 20 m from edge of TTZ [°C]	Maximum temperature 40 m from edge of TTZ [°C]	Maximum temperature 67.5 m from edge of TTZ [°C]
Scenario 1	0	0	10	10	10	10
Scenario 2	5	0	22	14	10	10
Scenario 3 (base case)	10	0	35	24	14	10
Scenario 4	15	0	44	32	18	12
Scenario 3A	10	3	38	26	15	11
Scenario 3B	10	6	40	28	17	12
Scenario 5	10	0	52	33	16	10

The predicted maximum temperature 10 m (33 ft) from the edge of the TTZ is up to 52 °C. The temperature decreases dramatically with distance from the TTZ. 67.5 m (220 ft) downgradient of the TTZ, the expected increase in temperature is in the order of a few degrees Centigrade.

Graphs showing the maximum temperatures as a function of the distance along the flowpath are attached in Appendix A.

3.3 Temperature Variation at the NTCRA Extraction Wells

The average NTCRA extraction well is located approximately 34 m (110 ft) from the TTZ corresponding to 109 m (358 ft) along the flowpath in the model. In Appendix A, the temperature variation over time is shown for the different model scenarios.

The average temperature increase in the water extracted by the NTCRA wells over time is predicted to be in the order of 5-10 °C assuming an average distance and equal flow rate through the TTZ and the downgradient area.

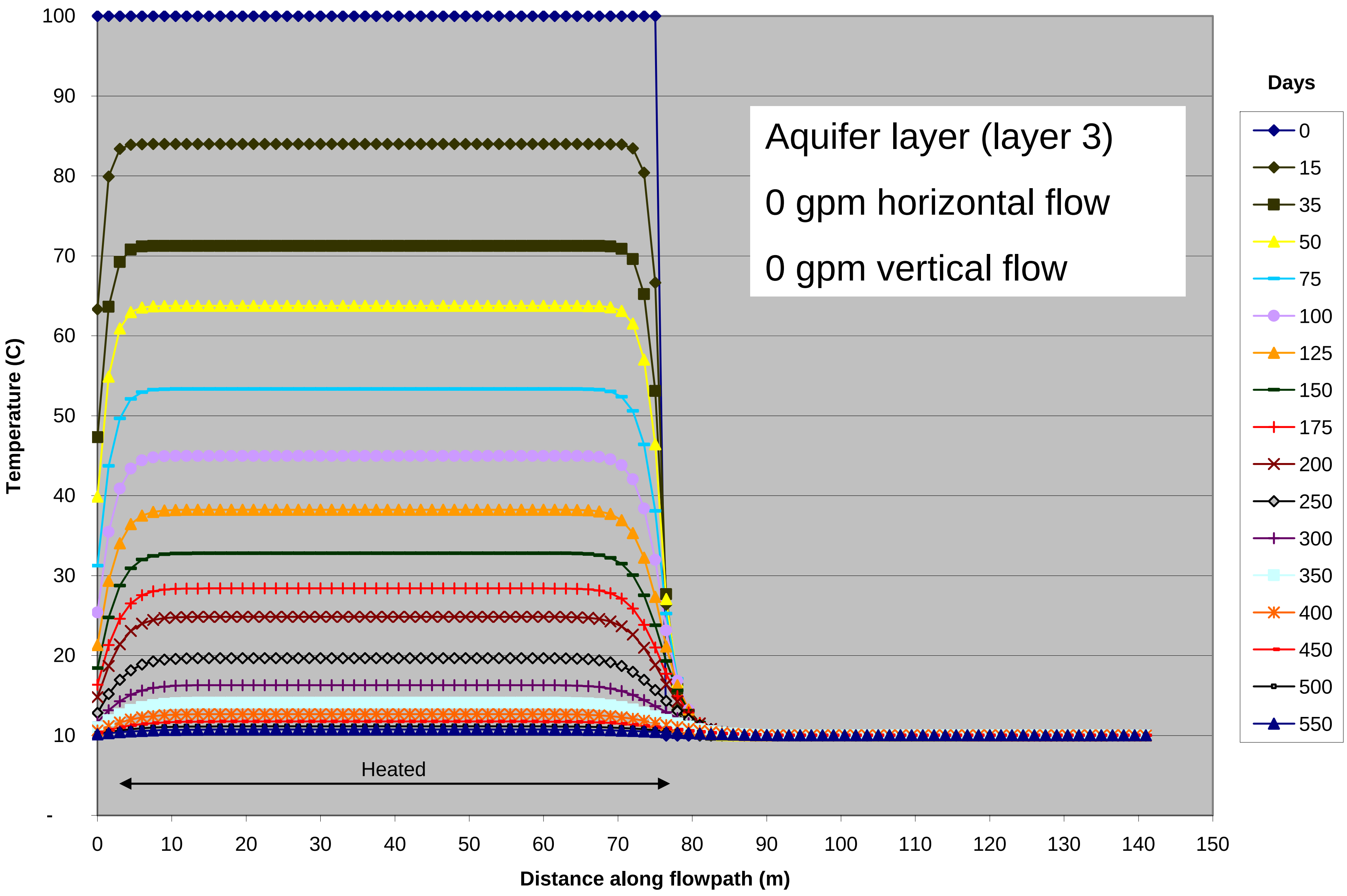
Appendix A

Simulation Results for Scenarios 1 through 5

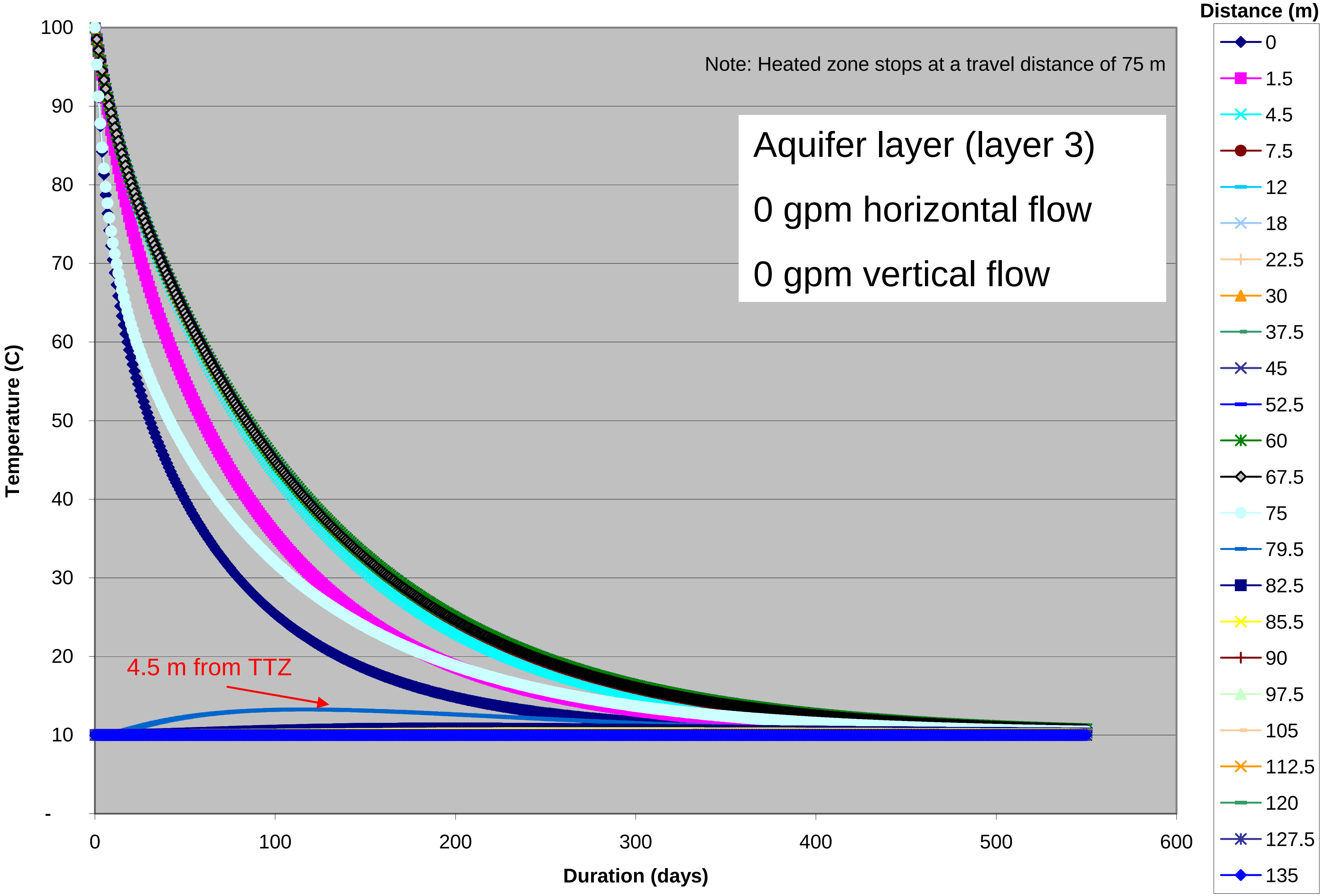
Scenario 1

No pumping. Model starts at shut down of thermal system (Day 125 of thermal operation)

Scenario 1 - No pumping. Model starts at shut down of thermal system.



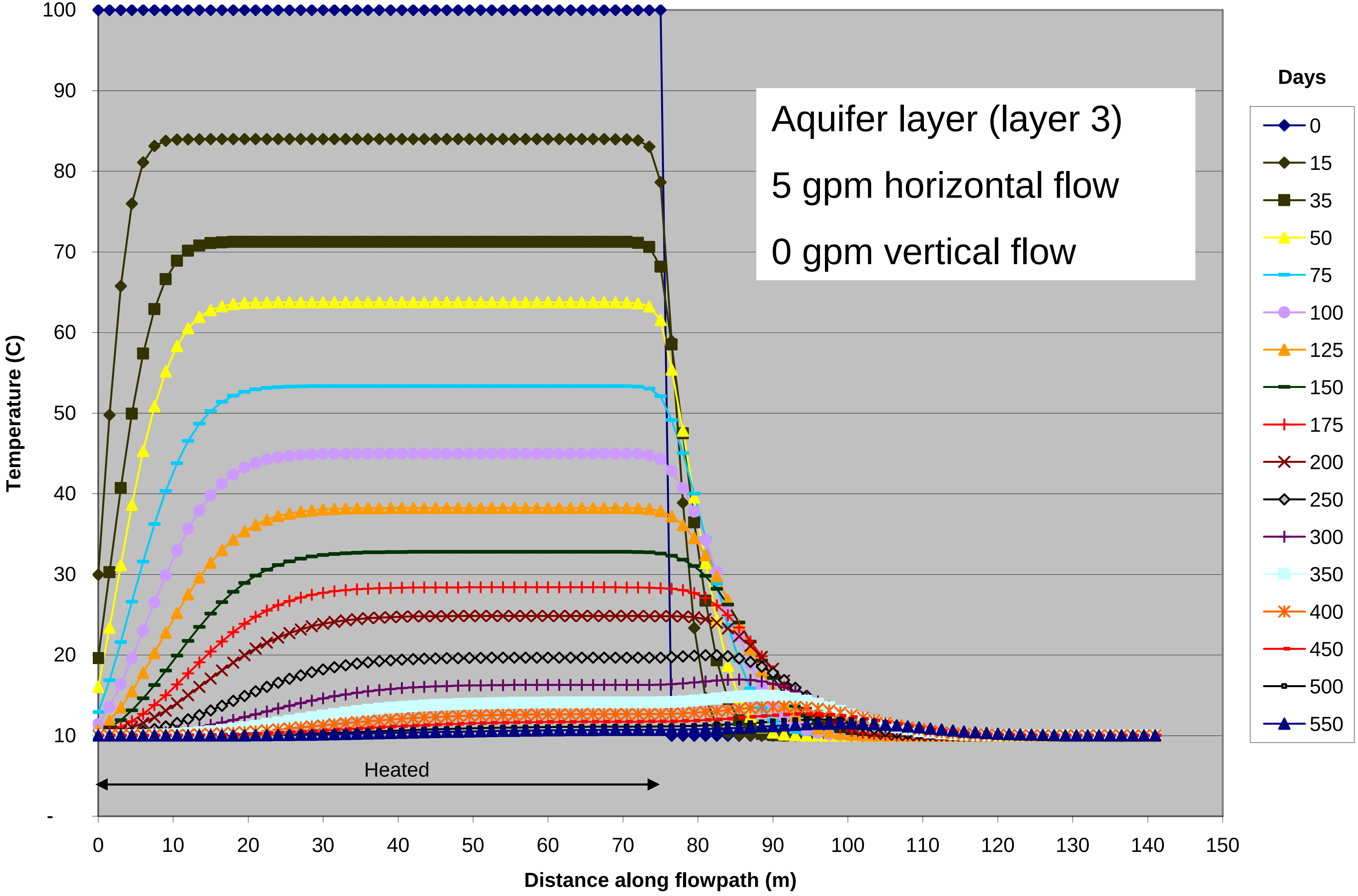
Scenario 1 - No pumping. Model starts at shut down of thermal system.



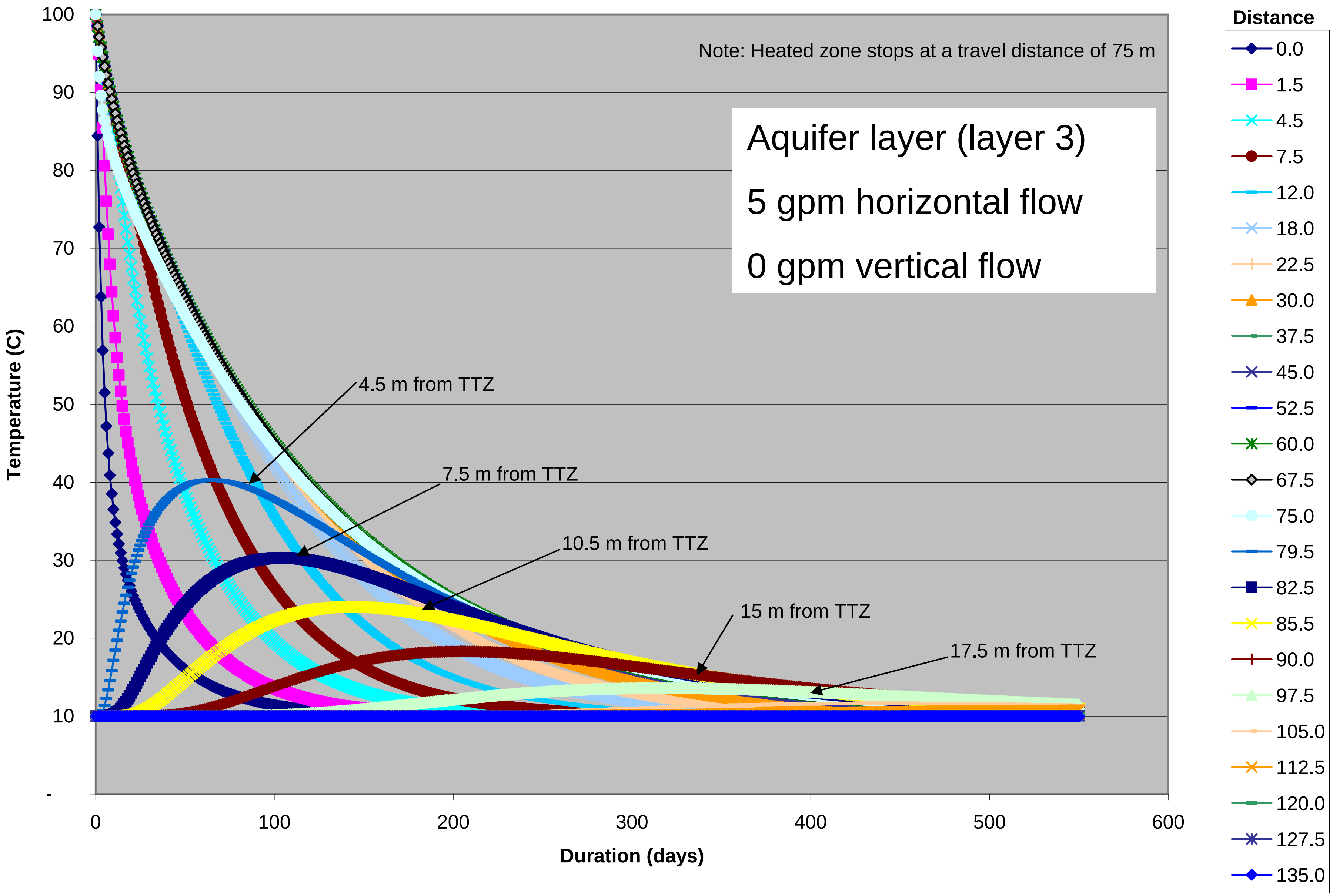
Scenario 2

5 gpm pumping. Model starts at shut down of thermal system.

Scenario 2 - 5 gpm pumping. Model starts at shut down of thermal system.



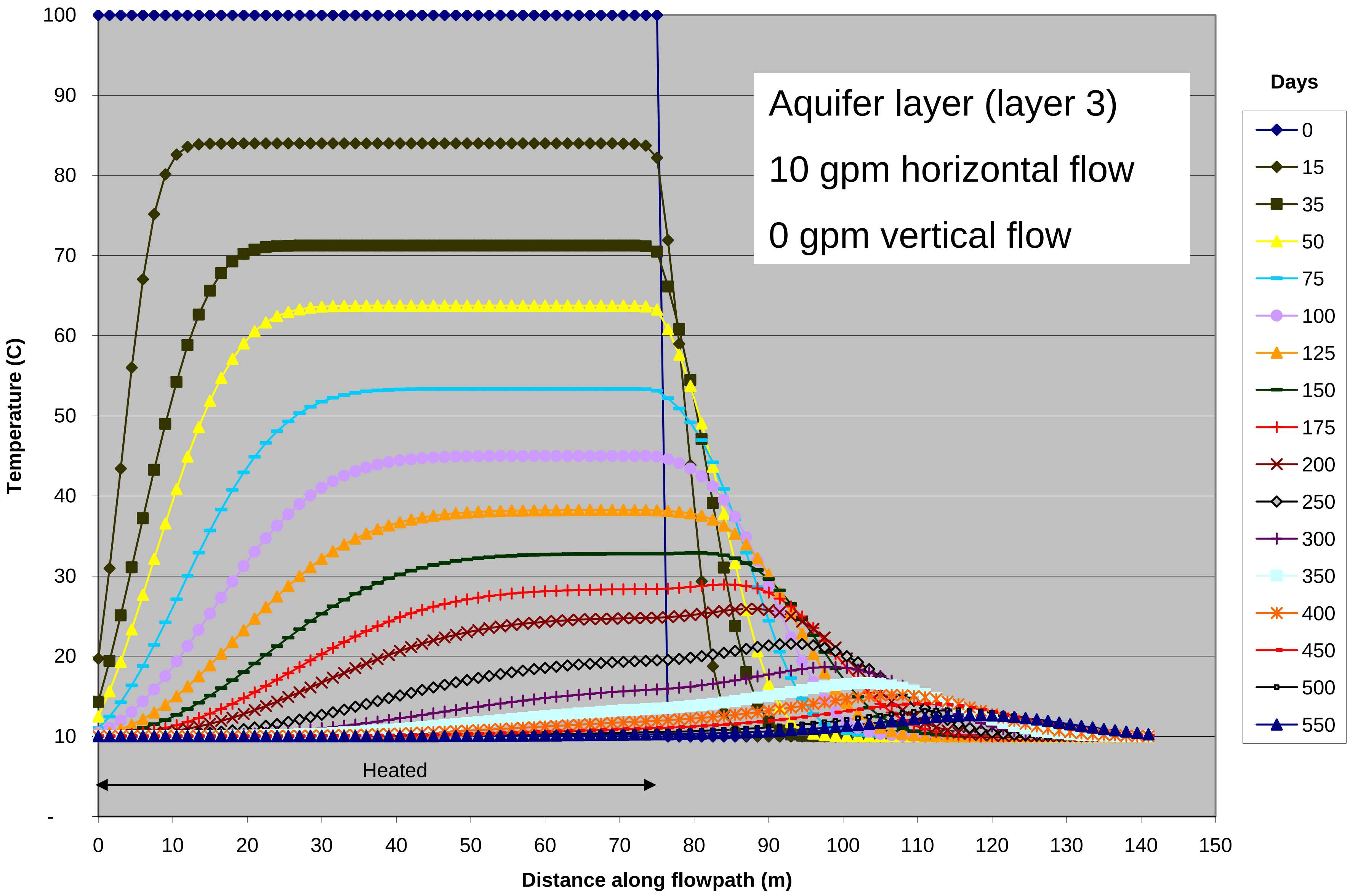
Scenario 2 - 5 gpm pumping. Model starts at shut down of thermal system

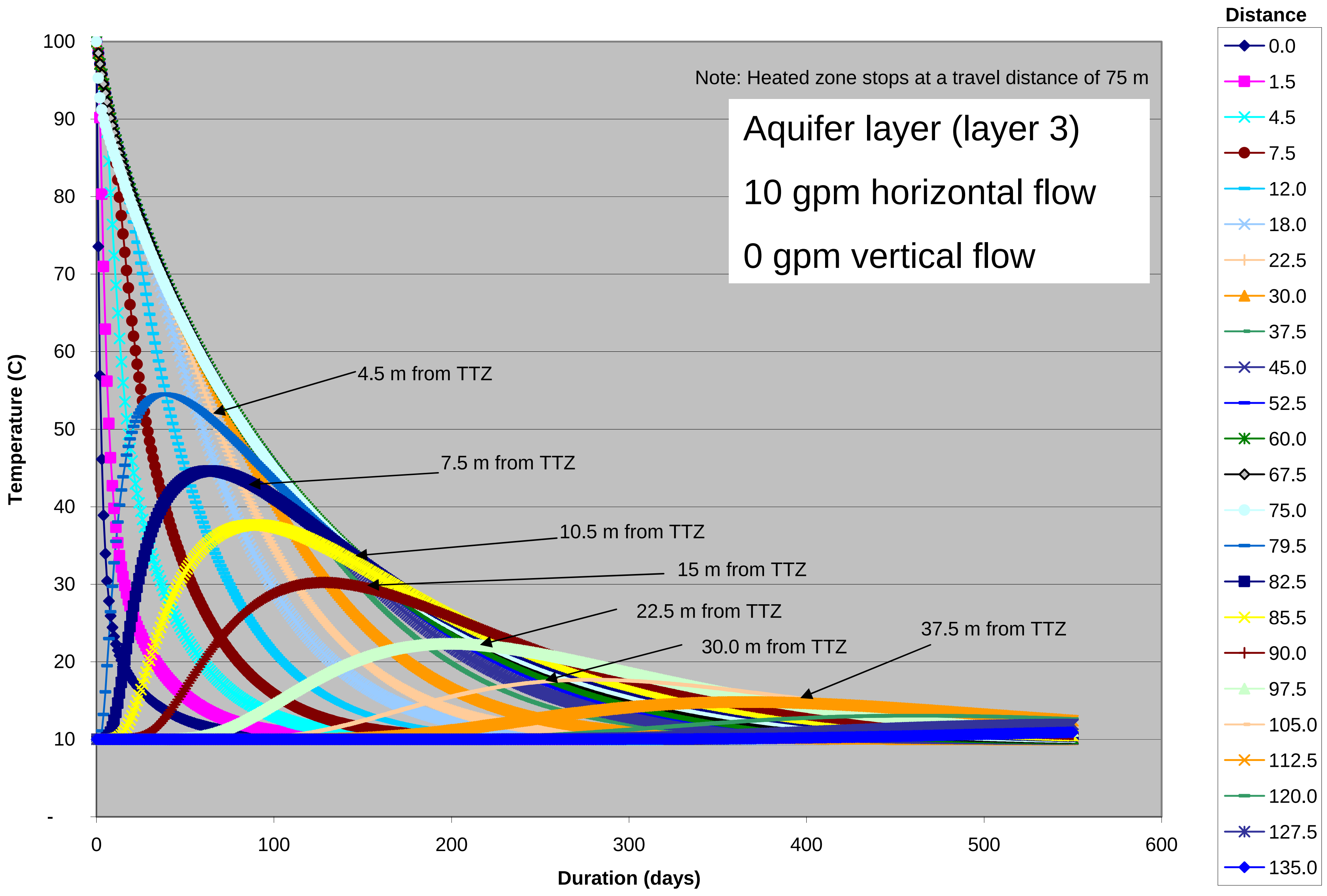


Scenario 3

10 gpm pumping. Model starts at shut down of thermal system

Scenario 3 - 10 gpm pumping. Model starts at shut down of thermal system

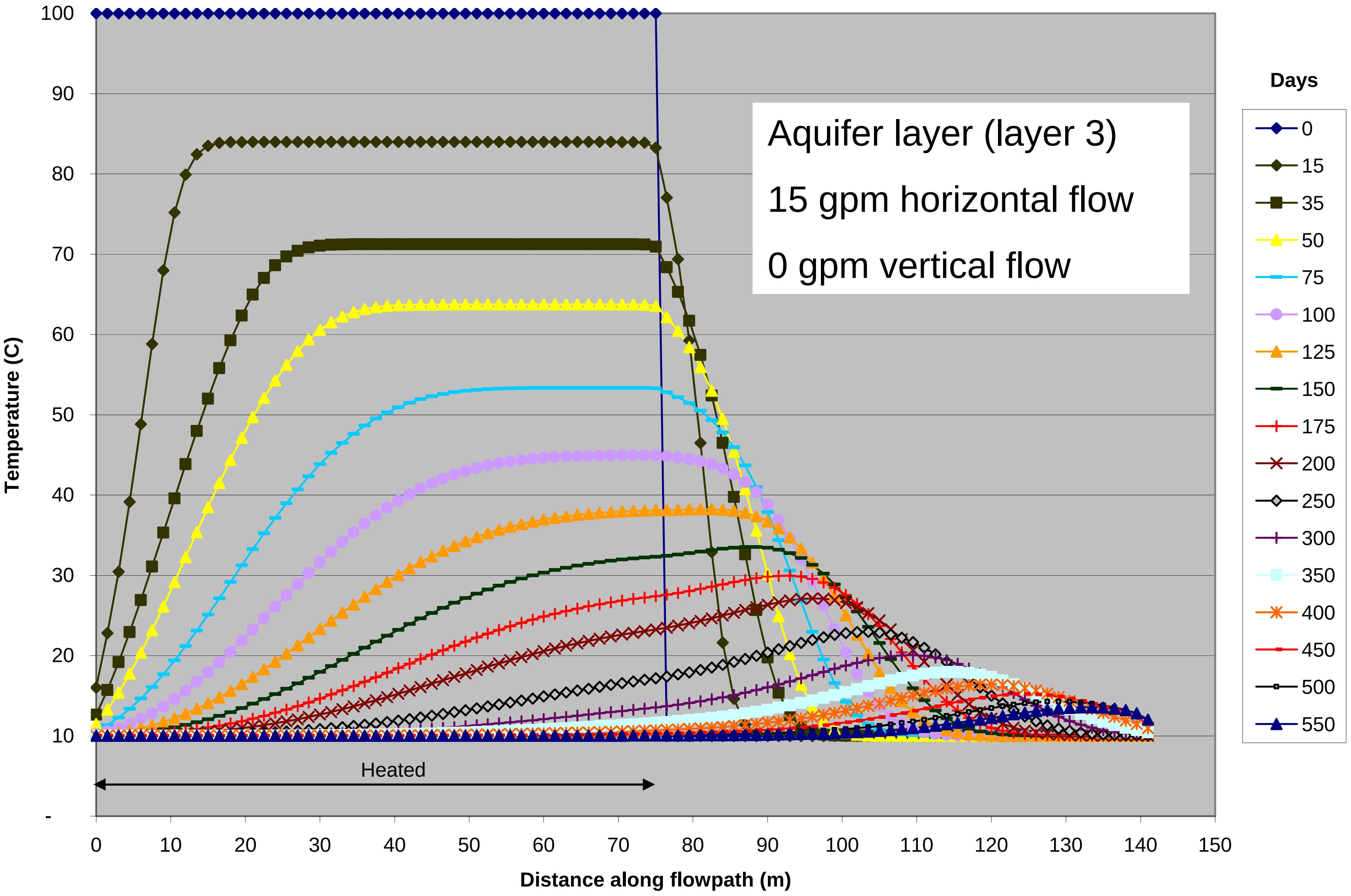



Scenario 3 - 10 gpm pumping. Model starts at shut down of thermal system
Note: Heated zone stops at a travel distance of 75 m
Aquifer layer (layer 3)
10 gpm horizontal flow
0 gpm vertical flow
4.5 m from TTZ
7.5 m from TTZ
10.5 m from TTZ
15 m from TTZ
22.5 m from TTZ
30.0 m from TTZ
37.5 m from TTZ
Temperature (C)
100
90
80
70
60
50
40
30
20
10
-
Duration (days)
0
100
200
300
400
500
600
Distance
0.0
1.5
4.5
7.5
12.0
18.0
22.5
30.0
37.5
45.0
52.5
60.0
67.5
75.0
79.5
82.5
85.5
90.0
97.5
105.0
112.5
120.0
127.5
135.0

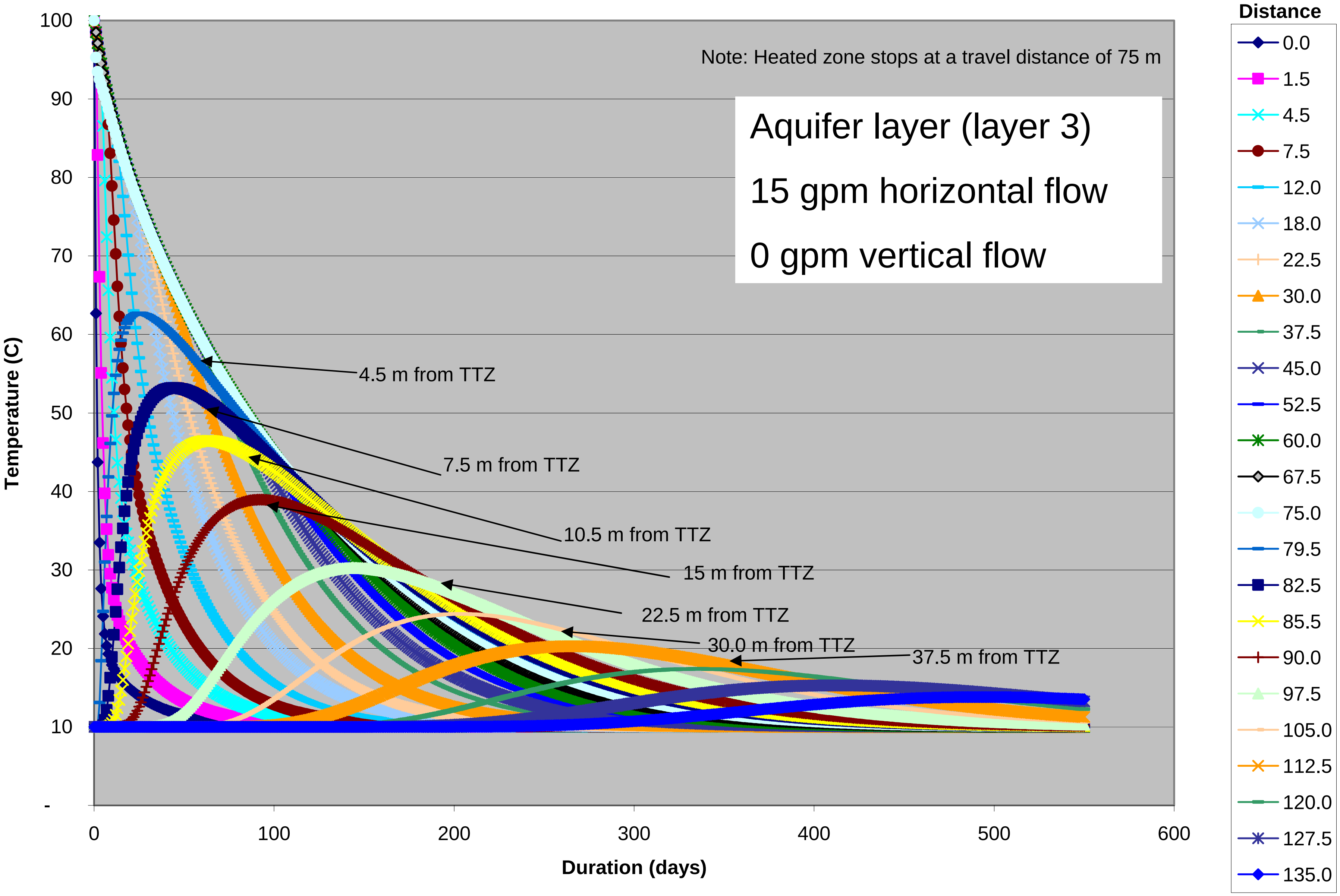
Scenario 4

15 gpm pumping. Model starts at shut down of thermal system

Scenario 4 - 15 gpm pumping. Model starts at shut down of thermal system



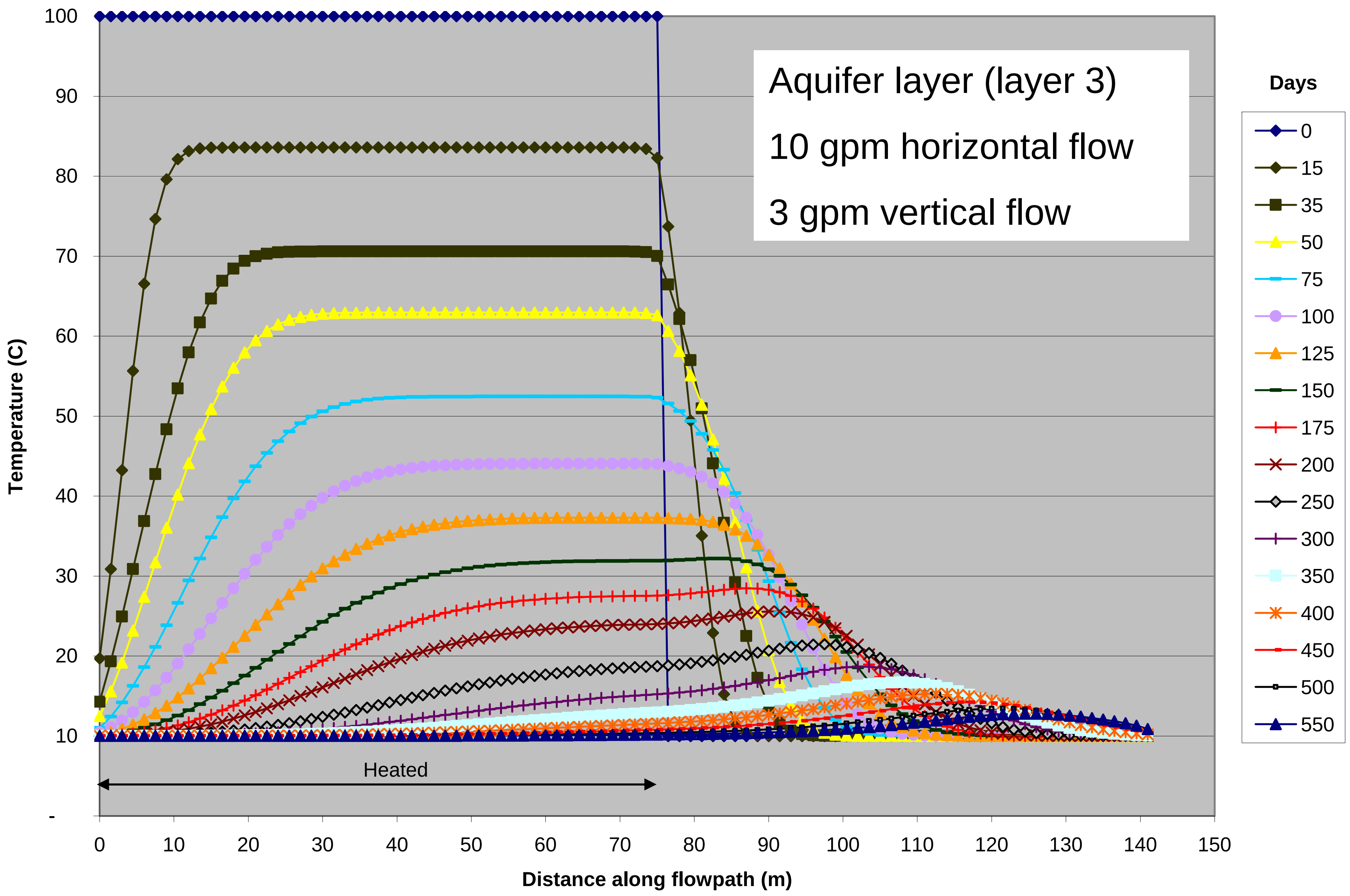
Scenario 4 - 15 gpm pumping. Model starts at shut down of thermal system



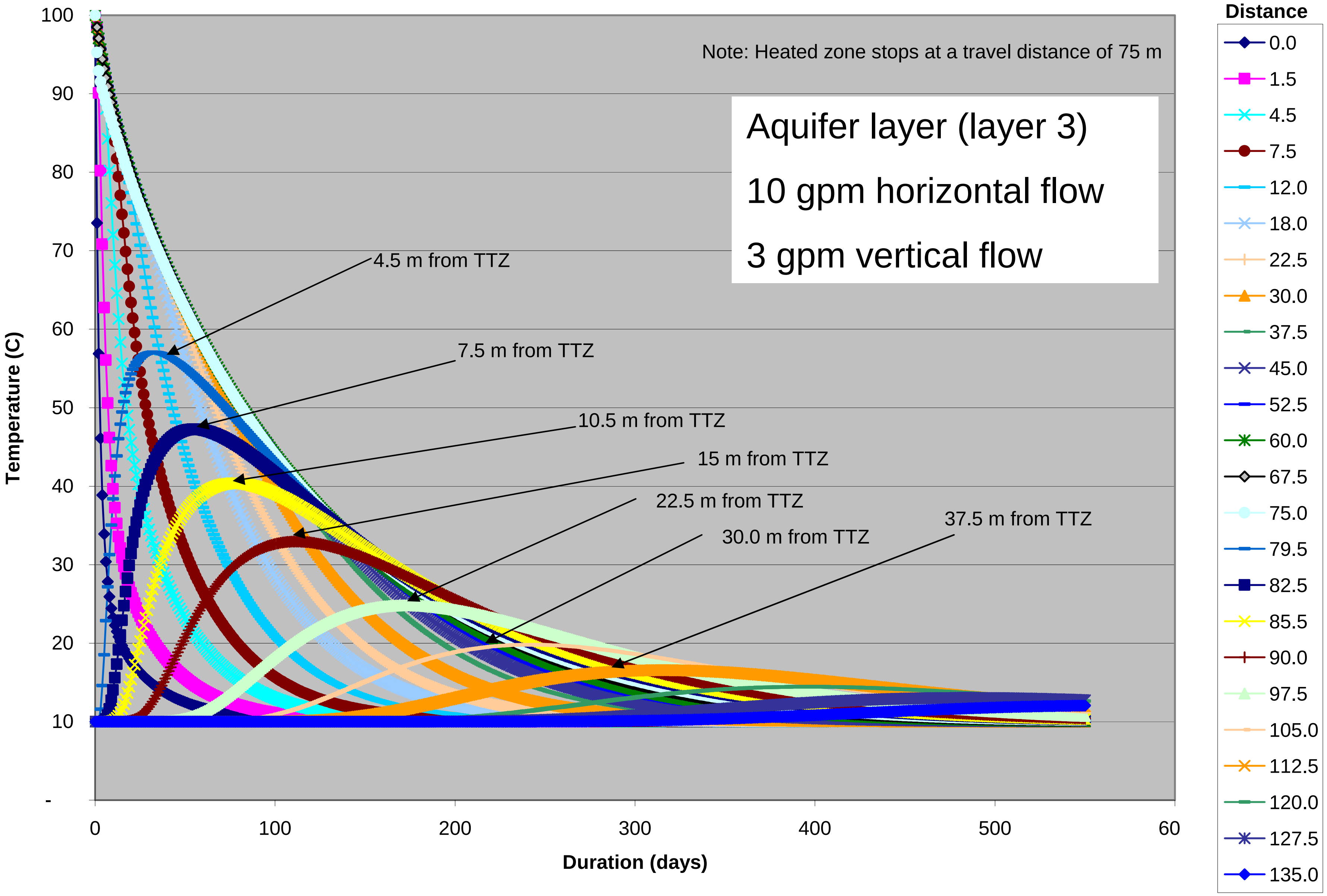
Scenario 3 – with vertical upflow of water

Scenario 3 A -10 gpm horizontal flow, 3 gpm vertical upflow of water, total 13 gpm
Scenario 3 B -10 gpm horizontal flow, 6 gpm vertical upflow of water, total 16 gpm

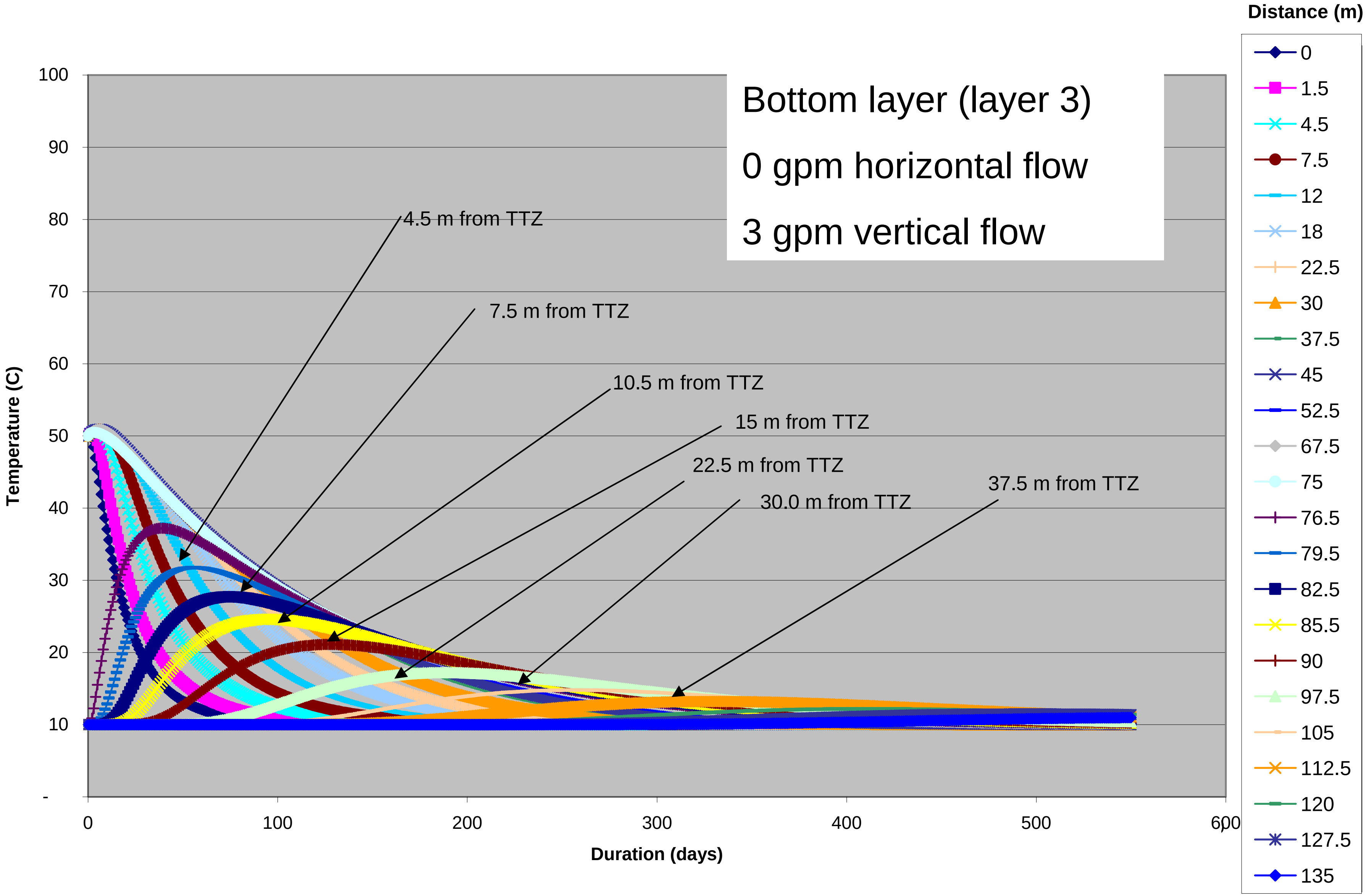
Scenario 3A: 10 gpm horizontal – 3 gpm vertical. Model starts at shut down of thermal system



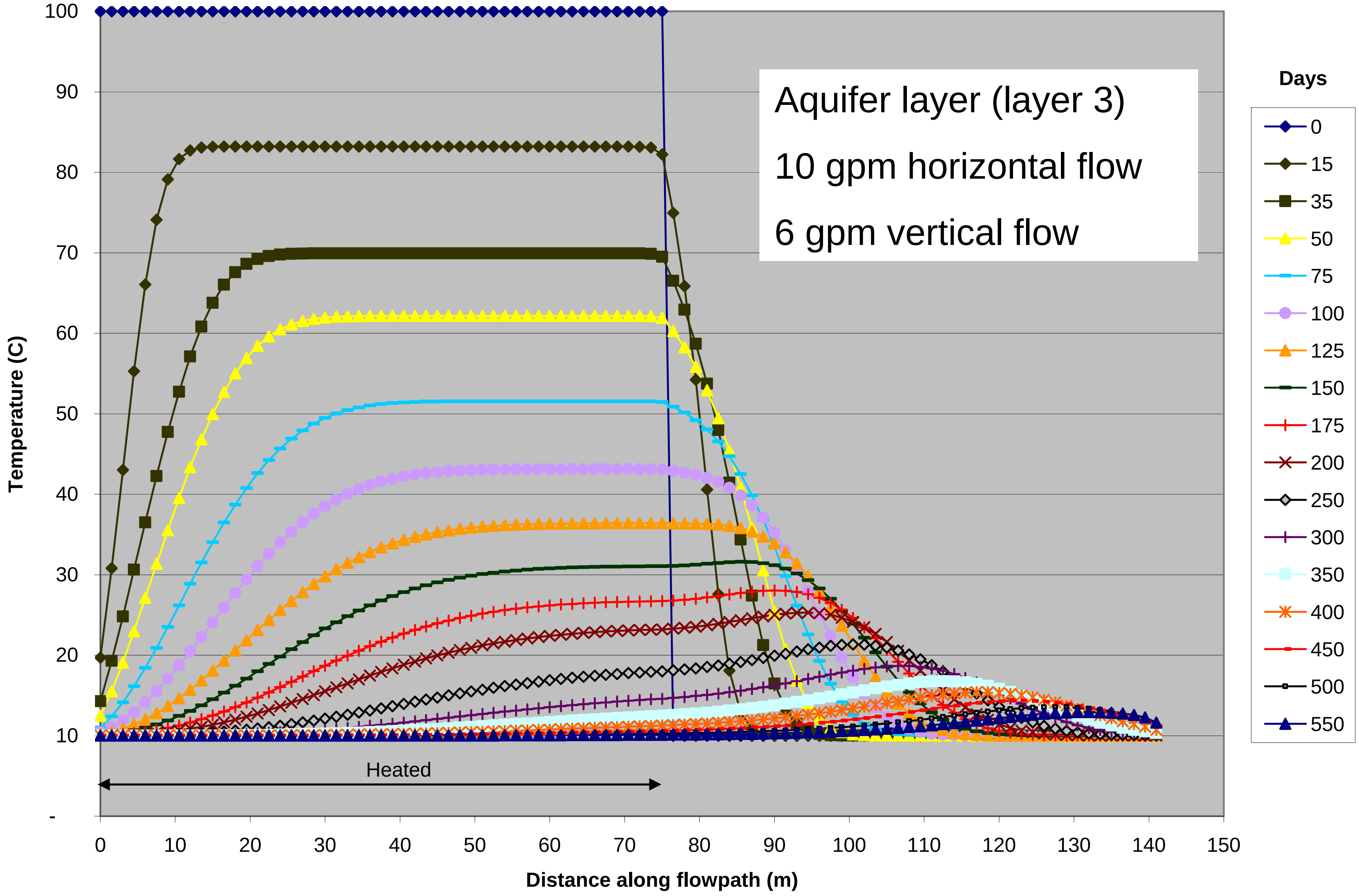
Scenario 3A: 10 gpm horizontal – 3 gpm vertical. Model starts at shut down of thermal system



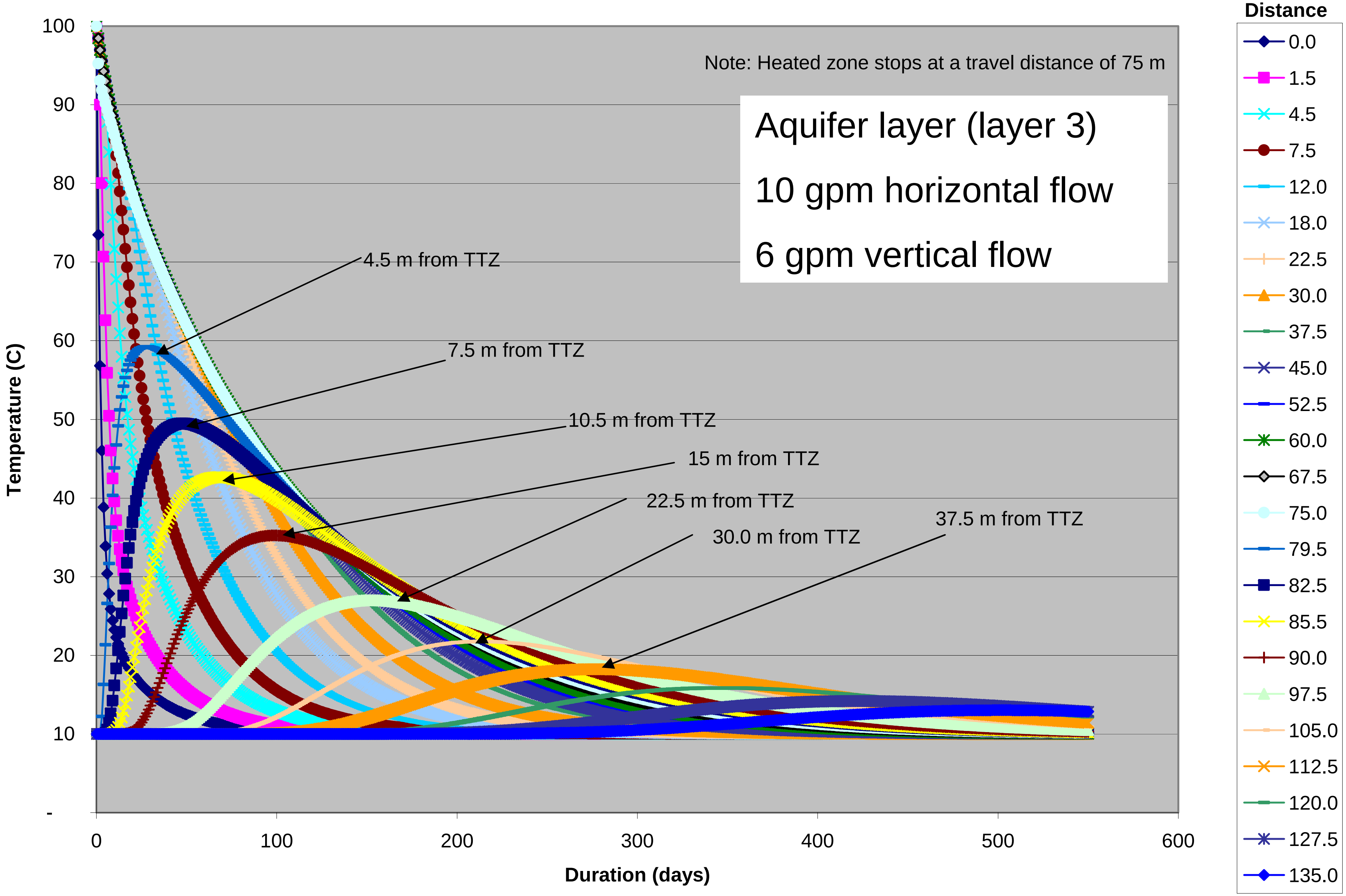
Scenario 3A - Bottom Layer: 0 gpm horizontal – 3 gpm vertical.
Model starts at shut down of thermal system



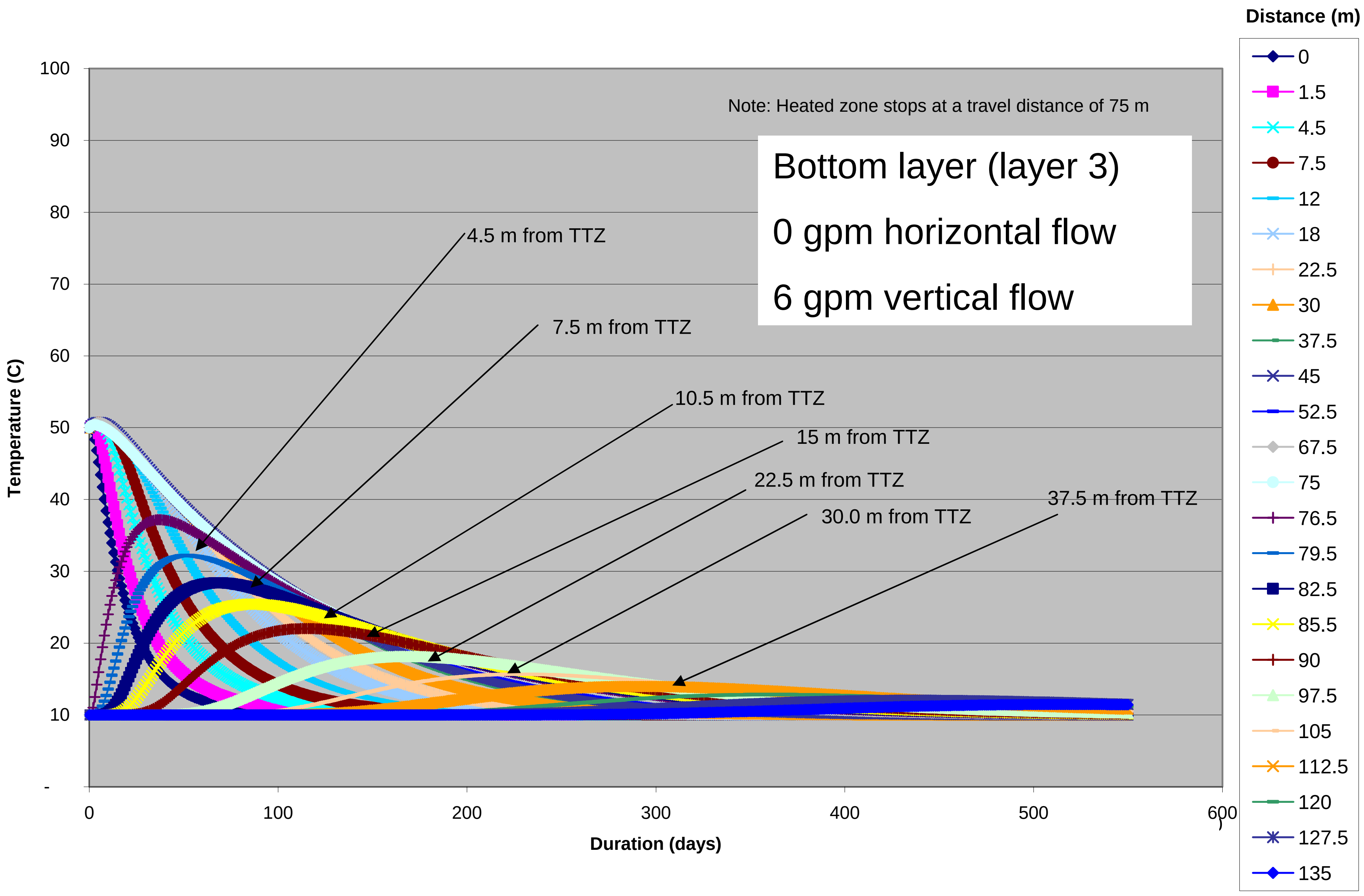
Scenario 3B: 10 gpm horizontal – 6 gpm vertical. Model starts at shut down of thermal system



Scenario 3B : 10 gpm horizontal – 6 gpm vertical.
Model starts at shut down of thermal system

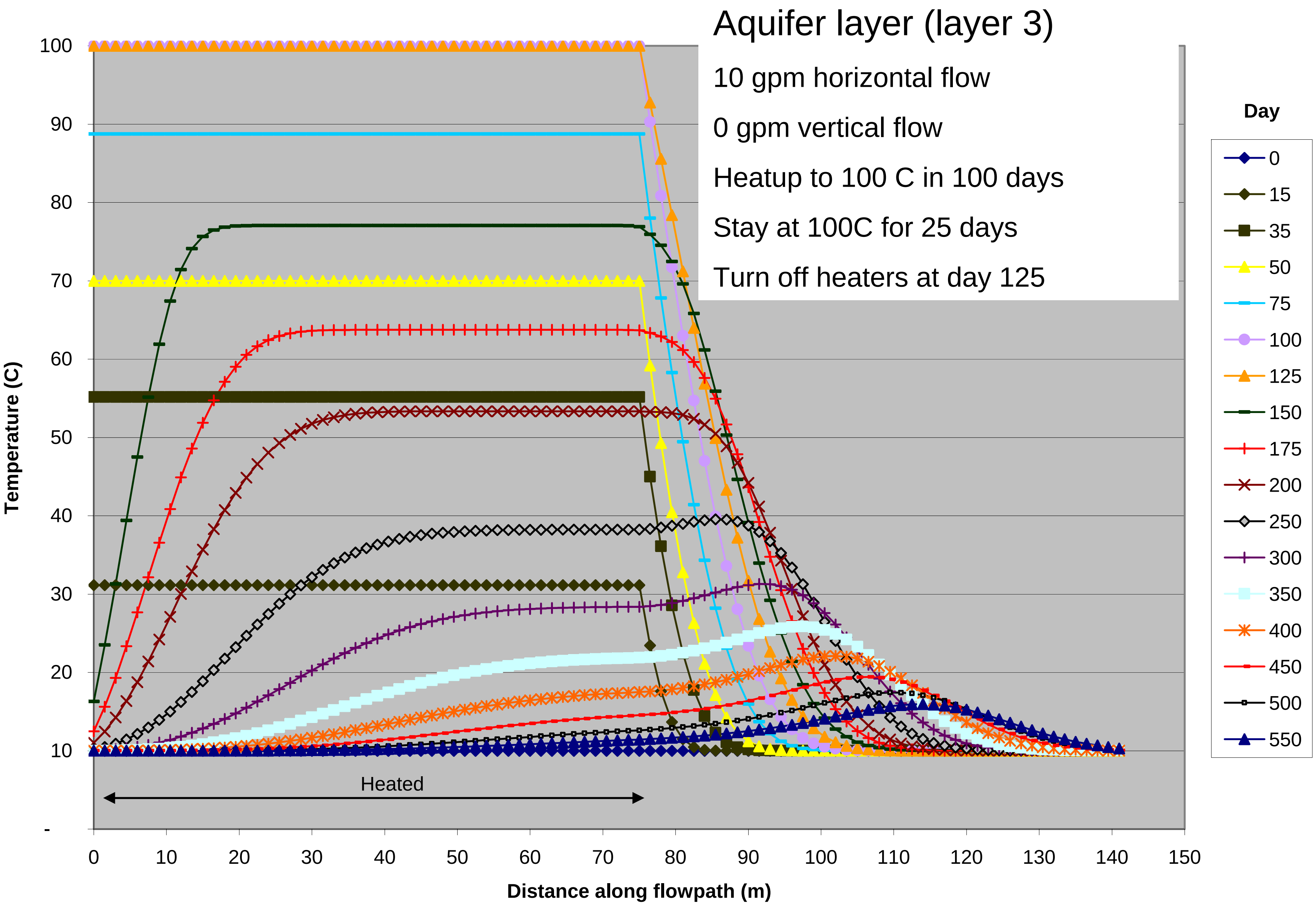


Scenario 3B - Bottom Layer: 0 gpm horizontal – 6 gpm vertical.
Model starts at shut down of thermal system



Scenario 5 – Model starts at startup of thermal system (day 1 of thermal operation)

Scenario 5: Model start at startup of thermal system



Scenario 5: Model start at startup of thermal system

Aquifer layer (layer 3)

10 gpm horizontal flow

0 gpm vertical flow

Heatup to 100 C in 100 days

Stay at 100C for 25 days

Turn off heaters at day 125