DESIGN ENGINEERING REPORT

WORK ASSIGNMENT D004440-23

KLIEGMAN BROTHERS SITE, OU NO. 1
GLENDALE

SITE NO. 2-41-031
QUEENS (C), NY

Prepared for:

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
625 Broadway, Albany, New York

Alexander B. Grannis, Commissioner

DIVISION OF ENVIRONMENTAL REMEDIATION

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April 2007

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Albany, New York 12233

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1.0 INTRODUCTION

1.1 Scope

This report presents the design rationale, criteria, computations, and analysis for a remedial design at the Kliegman Brothers Site Operable Unit No. 1 (OU1), New York State Department of Environmental Conservation (NYSDEC) Site No. 2-41-031. This work is being performed for the NYSDEC by URS Corporation (URS) under Work Assignment D004440-23 of the NYSDEC Standby Design and Construction Contract. This document has been prepared under Task 2 – Design, and represents the Final (100%) Design phase submittal for the project.

1.2 Site Description and History

The Kliegman Brothers Site is located at 76-01 77th Avenue in Queens County, New York. The site is bordered to the north by the Long Island Railroad. Residences border the site to the east, west and south. This site has an area of approximately 37,000 square feet, of which 26,000 is occupied by a building (see Figure 1-1). A basement exists under the western portion of the building.

The site was formerly owned by Kliegman Bros. Inc. This site was used as a warehouse and distribution center for laundry and dry-cleaning supplies from the 1950s through the 1990s. The site contained two 6,000 gallon above ground storage tanks (ASTs) which were used to store tetrachloroethene (PCE). The tanks have since been removed from the property. Although these tanks are the presumed source of contamination, it is unknown if, and when, product was released or, whether contamination was due to a single catastrophic release or a chronic leak problem. Kliegman Bros. ceased operation in 1999. The site was purchased in 2000 and is currently being used as a warehouse for an imported food distributor. Known contamination at the site is unrelated to operations since 2000.

In general, the site geology consists of a fill layer of variable thickness (up to two feet) at the surface, containing concrete or asphalt underlain by reworked native materials. Brown loose to dense, fine to coarse silty sand to sandy silt with localized sandy clay seams was observed to depths of approximately 10 feet below ground surface (bgs). This layer is underlain by brown loose to dense, fine to coarse sand with variable amounts of fine to coarse gravel to depths of 148 feet bgs. The regional groundwater table occurs at the site at approximately 70 feet bgs within the upper glacial aquifer. However, perched groundwater was observed in several wells above a clay layer in the eastern portion of the site.

On-site contamination consists of vadose zone (above the water table) soil contamination and groundwater contamination. Within the vadose zone, perched water was detected in the eastern area of the site. The perched water accumulates on a clay layer that is about 12 feet below ground surface in this eastern region of the site (Figure 1-1). The groundwater table is about 65-70 feet below ground surface at the site.

Groundwater contamination has migrated offsite as shown by the RI. VOCs, particularly PCE, have been detected above groundwater criteria in all directions around the site. VOCs have also migrated offsite in soil gas. The source of the soil gas contamination is mainly contamination in vadose zone soil.

The remedial action being addressed by this work assignment is for the OU1 portion of the site, which is defined as only the on-site contaminated soil and soil vapor issues. The OU1 portion of the site is being addressed separately from the remaining OU2 portion of the site, which consists of the groundwater both on-site and off-site, as well as the off-site soil vapor impacts.

1.3 Previous Investigations

Soil and/or soil gas sampling has been performed at the site on at least six different occasions from 1997 through 2002. The initial investigations were performed by Tradewinds Environmental Restoration, Inc. and Advanced Cleanup Technologies (ACT) in 1997 and 1998, respectively. These investigations comprised soil gas collection and analysis in the area between the building and the railroad, where the PCE storage tanks were located. Additional soil gas sampling was performed by EEA, Inc. (for a prospective site owner) and URS (for NYSDEC) in 2000. All of these investigations revealed the presence of PCE, often at high concentrations. A fifth investigation was performed by Enviroscience Consultants, Inc. in 2001 as part of a Voluntary Cleanup Program (VCP) agreement with NYSDEC, and included soils and groundwater sampling as part of a Focused Remedial Investigation/Interim Remedial Measure/(FRI/IRM). The objective of the FRI/IRM was to delineate on-site soil contamination sufficiently to enable design of a soil vapor extraction system or systems to remediate on-site soil. As part of the study, Enviroscience Consultants, Inc. collected soil samples from nine borings up to approximately 70-feet deep (SVE-1 through SVE-5 and EB-1 through EB-4), shown on Figure 1-1. Enviroscience also collected soil samples from 0 – 12 inches below the subfloor of the building at 26 different locations. Deeper samples (up to 12 feet bgs) were collected from five of the 26 locations.

Between October 2000 and August 2001, the New York State Department of Health (NYSDOH) conducted ambient air sampling in 17 residences east, west, and south of the facility. NYSDOH sampled on five occasions, although individual residences were sampled only one to three times each. Vapors were detected in 16 of the 17 residences tested.

In September 2002, the site owner discontinued his participation in the VCP and thus responsibility for addressing on-site subsurface contamination reverted back to NYSDEC. Because of documented ongoing PCE vapor exposures in adjacent residences, NYSDEC tasked URS to implement a soil vapor extraction (SVE) system as an interim remedial measure (IRM). The IRM is discussed in Section 1.4.

In 2005, URS prepared a Focused Feasibility Study (FFS) report to evaluate alternatives for achieving the Remedial Action Objectives (RAOs) for the site. The RAOs generally were to address the three main potential pathways of exposure at the site including: 1) direct human contact with soil contamination, 2) migration of volatile organic contaminants (VOCs) in soil gas to nearby residences, and 3) migration of VOCs from soil to groundwater. The FFS selected SVE as the preferred remedial method to achieve the RAOs for the site.

In March 2006, the NYSDEC issued a Record of Decision (ROD) for the Kliegman Brothers OU1. The ROD formalizes the assessment of the site threats, as well as the components of the remedial action selected for the site

1.4 Current Interim Remedial Measure (IRM)

URS completed construction of an SVE system at the Kliegman Brothers site as an IRM in 2003. The system utilizes three extraction wells (SVE-1, SVE-6S and SVE-6D) as shown on Figure 2-1. SVE-1 is a one-inch diameter well screened from 5 to 25 feet below ground surface (bgs). Wells SVE-6S and 6D are two-inch diameter wells screened from 5 to 25 feet bgs (6S) and 30 to 65 feet bgs (6D). SVE-6S and SVE-6D are separate wells installed at the same location. Other wells (SVE-2 through 5), originally installed by Enviroscience as SVE wells (shown on Figure 1-1), were not used for the IRM. The three active extraction wells are connected through subsurface piping to the SVE system, consisting of a moisture separator, an extraction blower, and vapor phase carbon vessels. The extraction blower is an approximately 250 standard cubic feet per minute (scfm), 5 horsepower regenerative blower, and the two carbon vessels each contain 1,000 pounds of carbon. Operation of the system began on August 23, 2004. Between August 23, 2004 and August 26, 2006 the SVE system is estimated to have removed nearly 36,500 pounds of PCE from the vadose zone.

1.5 Summary of the Remediation Goals

The remediation goals for this site, as identified by the NYSDEC in the ROD, are to eliminate or reduce to the extent practicable:

- Exposure of persons at or around the site to PCE and its degradation products (TCE, DCE, and vinyl chloride) in contaminated soils
- The release of contaminants from soil into groundwater that may create exceedances of groundwater quality standards
- The release of contaminants from soil vapor into indoor air through vapor intrusion

Further, the remediation goals for the site include attaining to the extent practicable:

- Ambient groundwater quality standards (based on NYSDEC "Ambient Water Quality Standards and Guidance Values" and Part 5 of the New York State Sanitary Code).

- Soil standards, criteria, and guidance (SCGs) (based on NYSDEC "Technical and Administrative Guidance Memorandum (TAGM) 4046, Determination of Soil Cleanup Objectives and Cleanup Levels").

1.6 Record of Decision (ROD) Requirements

The NYSDEC selected the following remedy for this site as outlined in the ROD for the OU No. 1 at this site.

- A Remedial Design program will provide the details required to implement the remedial program.

- The existing Interim Remedial Measure (IRM) – SVE system will remain in-place and continue to operate.

- New components will be added to the existing IRM remedial system including: 1) additional vapor extraction wells and 2) a Soil Vapor Extraction (SVE) Treatment System.

- Development of a site management plan to address residual contamination and any use restrictions.

- Imposition of an environmental easement.

- Periodic certification of the institutional and engineering controls.

- Long term monitoring.

This Design Engineering Report (DER) covers the only the first three bullet items of the stipulated remedy for the site: a remedial design program, continuation of the existing IRM, and addition of new SVE wells and an SVE treatment system.

2.0 SOIL VAPOR EXTRACTION (SVE) SYSTEM

2.1 Description

The new SVE system is designed to extract and treat soil vapor containing VOCs from the unsaturated (vadose) zone. The major components of the system will include extraction wells, blowers, and a treatment system to remove contaminants from the extracted soil vapor prior to discharge. The major components of the new SVE system are outlined in the following sections, as well as the criteria and/or reasoning that was used in the design of the system.

2.2 Area to be Remediated

On-site contamination consists of vadose zone (above the water table) soil contamination and groundwater contamination, although the groundwater contamination will not be directly addressed by this remedial action. The groundwater table is about 65-70 feet below ground surface at the site. Within the vadose zone, perched water occurs in the eastern area of the site due to a clay layer that is about 12 feet below ground surface.

Soil analytical results have shown elevated concentrations of benzene, toluene, ethylbenzene, xylene (BTEX), tetrachloroethene (PCE), and 1,2-dichloroethene (DCE). PCE was detected most frequently, and at the highest concentrations. Several detections of PCE were above the Recommended Soil Cleanup Objective (RSCO) value of 1,400 micrograms per kilogram presented in the NYSDEC Technical Administrative Guidance Memorandum (TAGM) #4046. PCE was detected in soils above the clay layer at concentrations above the RSCO value in the eastern portion of the north yard; however, samples were not collected below the clay layer.

Soil samples collected from underneath the building indicate that concentrations of PCE generally exceed the RSCO only in shallow (less than one foot below the floor) samples. However, deep samples were only collected at five locations. Although soil sampling results seem to indicate that the VOCs are limited to shallow depths in some areas of the site (under the building), there is not enough soil data to confirm this. Soil gas data indicates that contamination is likely widespread and extends throughout the depth of the vadose zone. For example, significant quantities of VOCs have been removed by the existing deep well (screened from 30 to 65 feet bgs) during the IRM and high photoionization detector (PID) readings were recorded at depth in some borings.

For the purpose of the remedial design, it is assumed that the entire vadose zone onsite is contaminated by VOCs – mainly PCE. The estimated area of the site is 37,000 square feet and the depth to the water table is approximately 70 feet. On this basis, the volume of contaminated soil in the vadose zone is approximately 96,000 cubic yards. In the eastern area of the site, where the clay layer and the perched water zone are present, samples have not been collected from below the clay layer. It is also assumed that the clay layer will not be disturbed or penetrated with extraction wells for the purpose of the remedial action.

2.3 Design Criteria

Design criteria for the major components of the new SVE system are as follows:

Extraction Wells: All SVE extraction wells will be vertical construction. Due to the depth of vadose zone at the site, wherever possible, the wells will be installed as pairs, with a well dedicated to treating the shallow zone, and a second well dedicated to treating the deeper zone, terminating just above the water table. This configuration will offer flexibility in operation and allow for more specific treatment of particular zones at the site. This same shallow/deep configuration was used for the construction of the existing IRM extraction wells. In the eastern area of the site, where the clay layer is present, only shallow wells will be installed. Because the extent of the clay layer is not known, the shallow wells to the east will be drilled with continuous split spoon sampling. If the samples show the clay layer is present at the well location, the well will be installed only to the top of the clay. If there is no evidence of a clay layer, the wells will be installed to the same depth as the shallow wells to the west.

All extraction wells will be located outside of the existing buildings due to the difficulties that would be presented by the presence of a basement (under the western portion of the building) as well as due to the existing business that operates a warehouse in the structures. To best address the entire extent of the site, the wells should be located as close as possible to the center of the site, which means that the extraction wells will be located just to the north of the existing building. However, because the current business at the site has indicated that installation of the wells near the building would disrupt their operations, work will be arranged to occur during off-peak business hours and on slower days of the week.

The SVE extraction wells will be completed at-grade using concrete road boxes to house all valves, fittings, and piping so that neither wells nor appurtenances project above the surface. Valves will be provided at each extraction well to regulate pressure and flow rate, or to isolate the well from the system completely. The well box cover will be designed to handle loading from onsite truck traffic.

Vacuum Monitoring Points: A total of five vacuum monitoring points (VMPs) have been proposed for the site. Most vacuum monitoring points are installed to a depth of 30 feet bgs in order to straddle both the shallow and deep extraction zones. Vacuum monitoring points generally are installed at the periphery of the extraction zone(s) to evaluate subsurface performance. However, in the case of this site, the building limits the available locations for installation of VMPs. All but one will be located on the sidewalk that surrounds the property.

Extraction Blower: The existing IRM installation utilizes only one blower to extract soil vapor. In the case of the system being installed for this remedial action, two blowers are proposed for the six new extraction wells. This configuration will allow for flexible and efficient operation of the system, including the ability to shut down a blower and focus treatment on a smaller area of the site as the remediation progresses.

Condensate Control: Based on the existing IRM, it is expected that the new SVE system will generate significant quantities of condensate during certain times of the year (typically when the soil is still warm, but the air is cool). Several measures will be taken to deal with the condensate. First, the piping from the extraction wells to the treatment system will be constructed with a slope toward the well, to avoid any collection of water within the system piping. Second, extraction wells and piping will be designed with a larger diameter in order to lower the air velocity in the piping thus helping to avoid the entrainment of moisture. Finally, a moisture separator will be located in the soil gas stream prior to the extraction blower. Any water that is collected in the separator will be periodically collected, drummed, and shipped offsite for disposal.

Piping: Piping will be installed underground, at least 18 inches below the surface, both for protection of the piping and also to minimize soil excavation and disposal. The pipe will be sloped to allow condensate to drain back to the extraction wells. Piping for specific well pairs will be manifolded together for routing to the treatment plant. To minimize impacts on the existing business during construction, it is expected that the major pipe runs will be located along the northern boundary of the site.

Air Emissions: Based on the existing IRM, it is assumed that the air emissions from the new SVE system also will require treatment. The fact that the site is immediately surrounded by residential properties on three sides greatly restricts the allowable emissions. Section 3.0 further discusses the air treatment for the remedial action.

System Automation: Due to the simplicity of the new SVE system, an automated monitoring and/or control system will not be included. The system will be designed so that system monitoring (vacuums, temperatures, flow measurements, and soil gas concentrations via PID) will be accomplished only on site. The telephone autodialer from the existing IRM system will be used for both the existing and the new SVE systems. The telephone dialer automatically notifies the operator of an alarm condition, e.g. system shut down.

Surface Cover: The area of extraction for SVE systems are often covered to increase the effectiveness of soil gas extraction. There is an existing asphalt pavement cover located at the Kliegman Brothers site. No additional cover system will be employed.

2.4 Design Parameters

Design parameters for the SVE system are summarized in Table 2-1. The calculations and basis for these parameters is in included in Appendix A. The parameters are discussed further below.

2.4.1 Extraction Wells

Table 2-2 summarizes the construction of the existing extraction wells for the IRM system, and the proposed construction of the extraction wells for the new SVE system. Figure 2-1 shows the location of both the existing and the proposed extraction wells.

Quantity and Location of Wells: A total of six additional wells are proposed. Four of the wells will be installed as shallow/deep well pairs in the middle and western part of the site. In the eastern area of the site, where the clay layer is present, only two shallow wells will be installed.

The location and spacing of the extraction wells is based on a desired 80-foot radius of influence for each of the extraction wells. While this is a somewhat larger radius than is typical for SVE, given the sandy site conditions, it should be achievable. For the purpose of design, assuming an 80-foot radius for each well achieves coverage of the entire site with the exception of a few areas along the far southern boundary. Figure 2-2 shows the vacuum coverage for the site based on the proposed well locations and an 80-foot radius of influence. It is assumed that after the system has operated for a while, the flow can be redistributed and limited to specific wells in order to pull more air and extend the area of treatment beyond 80 feet.

Diameter: Four-inch diameter extraction wells are proposed instead of the two-inch diameter extraction wells that were installed for the IRM system. Four-inch is a typical size used for higher flow extraction wells and will help to minimize the pressure drop across the well screen, as well as to reduce the air velocity within the well piping, thus helping to minimize the entraining of moisture and soil particles. Due to the larger diameter of the extraction wells, each of the wells in the well pairs will be installed in dedicated boreholes, as opposed to the shared borehole utilized for the IRM extraction wells.

Well Depth and Screen Length: The proposed extraction wells will be installed to one of three different depths. All of the well screens will start a minimum of 3 to 5 feet below the ground surface and then extend to the depth of the well. The shallowest wells will be 9S and 10S, proposed for the eastern area of the site. These wells will be installed to about twelve feet below ground surface (bgs), terminating just above the clay layer. For the well pairs, the shallow wells (7S and 8S) will be installed to a depth of approximately 25 feet bgs. The deeper well pairs (7D and 8D) will be installed to approximately 65 feet bgs, but will be screened only for the interval from 30 to 65 feet bgs. The deep wells will terminate approximately 5 feet above the water table in order to minimize the entraining of water and to account for the rise in the groundwater elevation that is created by the SVE.

2.4.2 Extraction Blowers and Appurtenances

Type: Regenerative blowers will be used for SVE. This type of blower is commonly used for SVE and is best suited for this application because they provide relatively large capacities (extraction volumes) at moderate vacuums. These blowers generally require less maintenance than other types of blowers. The existing blower installed for the IRM is a regenerative blower.

Quantity: Based on the total blower flow, as well as the relatively limited quantity of extraction wells, it was determined that the best combination of operating flexibility versus blower cost would be provided by utilizing two blowers for this application. These two blowers would be in addition to the one blower that is already part of the existing IRM system. Although one blower meeting the entire air flow needs could be provided, the use of two blowers allows the system to operate at a reduced rate in the future. It also provides the flexibility that if a blower shuts down, the entire system could be operated using only one, albeit at a reduced flow rate.

Capacity: As shown in Appendix A, the calculated extraction rate for each of the well pairs (7S/D and 8S/D) is 220 scfm. The design flow rate for extraction wells 9S and 10S was calculated to be 40 scfm each. Therefore, the total design capacity for the two blowers is 520 scfm, or approximately 260 scfm per blower. The actual blower selected may be larger based on available units and to allow for an additional "safety factor" in the flow rate.

Vacuum: Based on calculations presented in Appendix A, an extraction vacuum of 10 inches of water column (in. wc) was calculated to provide the desired radius of influence for the extraction wells. The worst-case estimated pressure drop though each of the SVE system components between the extraction well and the blower was determined to be approximately 25 inches water column (in. wc). Therefore, the design criteria for each extraction blower is a flow rate of 260 scfm at a vacuum of 35 in. wc.

Appurtenances: Additional components of the blower package will include an inlet air filter, silencers (both inlet and outlet), and a bypass air inlet.

2.4.3 Piping

It is assumed that the each of the three well pairs (considering 9S and 10S to be a pair) will be installed with a dedicated line to the treatment system. This arrangement will allow for some system monitoring and control from the treatment building, without the need to separately visit each of the extraction wells. Based on this arrangement, the maximum flow through any of the pipes will be 220 scfm. It is assumed that all pipes from the wells to the extraction system manifold will be constructed with 4-inch diameter pipe. The headers inside the treatment facility may be 6 to 8 inches diameter pipe, depending on the total gas flow rate in the pipe and the length of the run. The piping will be sloped slightly towards the extraction wells so that any vapors condensing in the pipe are directed back to the extraction wells.

Piping also will be installed to interconnect the existing IRM system to the new system being installed. This will allow for additional operating flexibility between the two extraction systems.

2.5 Site Construction and Installation

Construction Activities: The major construction activity associated with the installation of the SVE system will be drilling the extraction wells, installing the well piping, and installing the vacuum monitoring points. A total of six boreholes in four separate areas will be installed at the site for the extraction wells. Installation of the wells will have to be coordinated with the business in order to minimize impacts to their operations. Trenching for the pipes also will have to be closely coordinated with the on-going business activities. Road plates, limited excavations, and other measures will be employed to ensure that the existing operations experience minimal impacts. Shallow installation of the pipe will also help to ensure that the pipes are quickly and easily installed. Since most of the VMPs are proposed for the sidewalk surrounding the facility, their installation should be easier to coordinate.

Treatment System: The SVE system itself will be housed in a trailer or other "box" type structure that will allow the SVE system and all components to be constructed in an off-site location. The system will be mobilized to the site with hookups for the SVE lines, air discharge lines, and power. This method also will help to minimize the on-site construction activities and thus any impacts to the existing business operations. The proposed location of the system is shown on Figure 2-1.

Support Services: There is only limited space available at the site for office/construction trailers. It is anticipated that the office trailers will be located just outside the property, in a temporary, off-street or sidewalk location. Any large meetings, if necessary, can be arranged at an off site location. Equipment decontamination (decon pad) and short-term storage can be located in the location designated for the placement of the SVE system trailer. The contractor will not be guaranteed any overnight storage for drilling and/or excavation equipment at the site, although arrangements with the business may be possible.

Soil Disposal: Because the purpose of the SVE system is to address the entire vadose zone at the site, all of the subsurface construction areas will be located within the targeted zone of influence for the SVE system. For that reason, it is proposed that as much excavated soil as possible be reused onsite for the backfill of the trench excavation, assuming that the soil is of suitable quality and can be compacted to minimize future subsidence. Excess soil, in addition to any soil that cannot be used as backfill, will be drummed or placed in a rolloff for testing and subsequent off-site disposal, as appropriate. If necessary due to a lack of storage at the site, all of the soil will be assumed to be hazardous to help expedite the disposal process.

3.0 AIR EMISSIONS CONTROL

3.1 Description

Operation of the SVE system will generate a contaminated air stream that must be discharged to the atmosphere. Prediction of contaminant concentrations in the air stream is extremely difficult for an SVE system due to the unknown and highly variable nature of the contamination in the subsurface, as well as the fact that the concentrations will typically drop exponentially after a relatively short period of extremely high concentrations. Given the location of this site in a residential area, with residents in very close proximity to the facility, there is no doubt that treatment of the air stream prior to discharge will be required, especially considering that the discharge limitations for PCE typically are very low.

The two types of emissions control generally employed for the treatment of the air discharge from an SVE system are either incineration (e.g., thermal or catalytic oxidation) or vapor phase carbon adsorption. The existing IRM system uses vapor phase carbon for treatment of the air stream.

For the purpose of this design, vapor phase carbon also is proposed as the method of air treatment. Carbon adsorption will offer several advantages over the use of incineration:

- The highly variable contaminant concentrations in the vapor phase air stream make the design and operation of an incineration system very difficult. Vapor phase carbon is effective at treating variable concentrations, so long as the carbon is not exhausted.

- Installation of an incineration system would require additional permits as well as a connection to the local gas supply. Given the air flow stream and the expected contaminant loading, significant quantities of supplemental fuel (i.e., natural gas) will be required. Installation of a vapor phase carbon system will not require any utility hookups.

- Given the low allowable emissions of PCE, the contaminant removal required from the air stream is likely to exceed 99%. Such high removals, while possible to achieve, are difficult to guarantee with an incineration system and typically are much more expensive to operate due to increased catalyst costs. Vapor phase carbon typically provides 100% contaminant removal until the carbon becomes exhausted. While the initial carbon costs are expected to be very high, the costs will decrease exponentially, consistent with the contaminant concentrations found in the air stream. Incineration costs typically remain constant and/or increase as lower contaminant concentrations require additional supplemental fuel to sustain the destruction efficiencies.

- Vapor phase carbon adsorption does not generate any byproducts except for spent carbon, which is taken off site and regenerated or disposed of. Incineration however will generate hydrochloric acid (HCl) as and end product of the oxidation of chlorinated compounds. Again, given the proximity of the site to the nearest residence, and the expected high contaminant concentrations (at least initially) a significant quantity of HCl could be generated, most likely requiring additional treatment for the air stream prior to discharge. This treatment would include scrubbing of the combustion gases to remove the HCl. The addition of a scrubber to the incinerator not only increases the capital cost of the system, but also greatly increases the operating cost of the system due to utility costs (e.g., water) and the cost for chemical supplies.

- Given that the remediation system will be installed within the site of an operating business, control of outside persons from tampering with the incineration system may be difficult, and could be more dangerous due to the nature of the combustion.

3.2 Design Criteria

Contaminant Loading: It is extremely difficult to estimate the contaminant concentrations that will be generated by the SVE system with the limited soil data available. However, as an indication, the existing IRM system is estimated to have collected approximately 36,500 pounds of contamination over a 24-month period. This averages out to approximately 2 pounds per hour of contamination. Given that the new system will operate at a higher flow rate, contaminant mass flow rates are likely to be higher. However, the fact that the IRM system was located in close proximity to the source of the contamination, coupled with the fact that the system most likely has a large radius of influence, may mean that the existing system already has pulled out the highest contaminant concentrations, and that the concentrations collected by the new system will be lower.

For the purpose of this design, smaller carbon units capable of treating a flow rate of 520 scfm with a pressure drop less than say 3 in. wc were selected. These smaller units will contain nominally 1,000 pounds each, consistent with the IRM system. If a larger footprint for locating the units is available, then larger units will be considered. Ease in changeout of the carbon units will be a major factor in selection of the specific size for the units.

System Configuration: Two carbon adsorption units will be utilized at all times. The units will be installed in a series configuration with sufficient hoses and flexible connections to allow them to operate between "lead" and "lag" operation. For ease in carbon changeouts, and to reduce the size of the system housing, the carbon units will be installed as stand-alone units, directly outside of the housing for the blowers and other system components. The carbon adsorption units will be located downstream of the SVE blowers.

A permanent discharge stack will be located at the site in close proximity to where the carbon units are located. The stack will be similar to the stack from the IRM system. Also, for additional flexibility, the discharge from the new SVE system blowers will be interconnected with the discharge from the IRM blowers. Thus, either SVE system could discharge to either carbon adsorption system.

Control Technology: With a vapor phase carbon adsorption system, no automatic control or monitoring systems are required. Typically, the influent and effluent concentrations from the carbon units will be monitored with a PID, supplemented with periodic collection of the air samples for laboratory analysis. These samples will be used to estimate contaminant breakthrough in the carbon beds.

3.3 Design Parameters

The specifications for the vapor phase carbon units will be based on the following:

Quantity:	2
Flow Rate:	600 scfm each
Configuration:	Series operation
Capacity:	1,000 pounds each, minimum

Given the likely contaminant loading when the system is first started, it is highly likely that the carbon units will become exhausted during the first day of operation, and will continue to quickly exhaust for the first several months of operation. When the units are exhausted, the system will manually be shut down until the carbon units can be exchanged. While this may not be the most efficient method of operation, it will help to minimize the footprint required for the SVE treatment system.

4.0 SAMPLING AND MONITORING

4.1 Routine Monitoring

Monitoring for the newly installed SVE system will be essentially the same as the monitoring being conducted for the existing IRM system. The most important task will be for the operator to determine whether or not the vapor phase carbon units are exhausted and need to be exchanged. If so, the operator will make those arrangements. Other monitoring by the operator will include the measurement of vacuum, flow rate, and VOC concentration via PID at each of the extraction well locations. Actual air samples for laboratory analysis will periodically be collected from the extraction wells. The results of these samples will be used to correlate the PID readings to the actual contaminant concentrations in the air stream, and thus to help estimate the total removal and effectiveness of the SVE system.

During the first two weeks of operation, the system requires frequent monitoring, assumed to be on an almost daily basis. For subsequent months, the frequency of operation will be reduced. The results from the first months of operation will be used to determine the frequency of monitoring required for the subsequent months.

4.2 Confirmatory Soil Sampling

At some point in the future, it will be necessary to collect soil samples to verify that the SVE system has achieved its desired goal, and that the contaminant concentrations remaining in the ground are acceptable. However, based on the contaminant concentrations observed at the site, it is not expected that this sampling will be required during the course of the standard construction contract.

5.0 UTILITIES

One significant issue during the construction of the IRM system was the availability of power for system operation. Eventually, after much delay, a separate service was installed by the local utility (ConEd) at the site. The existing service is 3-phase, 230 volt, and 150 amp. Due to the reluctance of the utility to install this second service at the site, it is reasonable to expect that a separate, third utility is not very likely. The existing service for the IRM system will be upgraded to meet the capacity required by the two additional blowers and other equipment.

The only other utility required is an autodialer system to notify an operator in the event of a system shutdown. However, the new system will be connected to the autodialer system for the existing IRM system.

No other utilities for the system are expected.

6.0 PERMITS

No state environmental permits will be required for the construction or operation of the SVE system at the Kliegman Brother site. However, URS will assist the NYSDEC in supplying air discharge information as required for an air equivalency determination.

Any building permits that may be required will be the responsibility of the contractor. It is believed that electrical or other building permits may be required.

City permits also will be required for placing the construction trailer in an off-street or sidewalk location, as well as for the vacuum monitoring points to be installed on the sidewalks.

REFERENCES

"Remedial Investigation/Feasibility Study Project", Remedial Investigation Report, February 2004, prepared by URS Corporation.

"Remedial Investigation/Feasibility Study Project", Focused Feasibility Study Report, October 2005, prepared by URS Corporation.

"Operation and Maintenance Manual and As-Built Drawings for Soil Vapor Extraction System"; Kliegman Bros. Site, Queens County, Site #2-41-031, May 12, 2003, prepared by Envirotrac Ltd.

"Operation and Monitoring Monthly Report, Soil Vapor Extraction System, Interim Remedial Measure, for the Period November 1, 2005 – December 8, 2005"; Kliegman Brothers, prepared by URS Corporation.

"Record of Decision"; Kliegman Brothers Site, Operable Unit No. 1, Glendale, Queens, New York, Site Number 2-41-031, March 2006, prepared by the NYSDEC.

TABLE 2-1

SUMMARY OF SVE DESIGN PARAMETERS

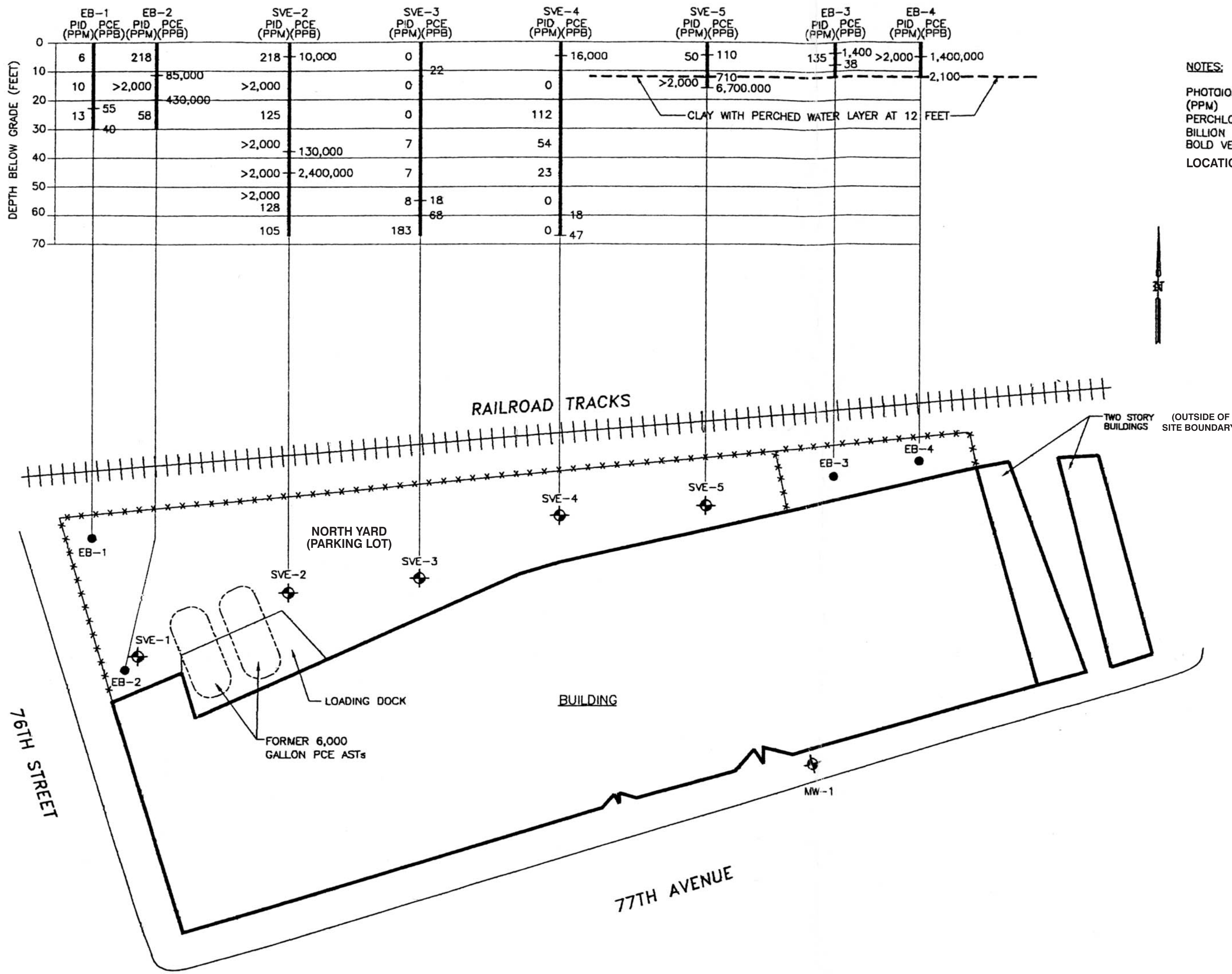
COMPONENT	PARAMETER	VALUE
Extraction Wells	Number Diameter Well Depth Extraction Rate	6 4 inch 2 @ ~ 12 feet 2 @ ~ 30 feet 2 @ ~ 70 feet (screened bottom portion only) 2 @ 40 scfm 2 pairs @ 220 scfm
Extraction Blower	Type Number Capacity Vacuum	Regenerative 2 260 scfm each 35 inches water column each
Piping	Diameter	4 – 8 inches

TABLE 2-2

SUMMARY OF SVE WELL CONSTRUCTION

Extraction Wells	**Diameter** (inches)	**Screened Interval** (feet)
SVE-1 (existing)	1	5 – 25
SVE-6S (existing)	2	5 – 25
SVE-6D (existing)	2	30 – 65
SVE-7S	4	5 – 25
SVE-7D	4	30 – 65
SVE-8S	4	5 – 25*
SVE-8D	4	30 – 65
SVE-9S	4	5 – 12*
SVE-10S	4	5 – 12*

* - Actual depth to be determined based on the presence of a shallow clay layer.



NOTES:

PHOTOIONIZATION DETECTOR (PID) READINGS ARE REPORTED IN PARTS PER MILLION (PPM)

PERCHLOROETHYLENE (PCE) LABORATORY RESULTS ARE REPORTED IN PARTS PER BILLION (PPB)

BOLD VERTICAL LINE REPRESENTS DEPTH OF BORING LOCATION

LOCATION SVE-1 WAS NOT SAMPLED DURING THE INVESTIGATION.

LEGEND

SVE-4 SAMPLING LOCATION & SOIL VAPOR EXTRACTION WELL LOCATION

EB-3 SOIL SAMPLING LOCATION

FENCE

FORMER AST LOCATIONS

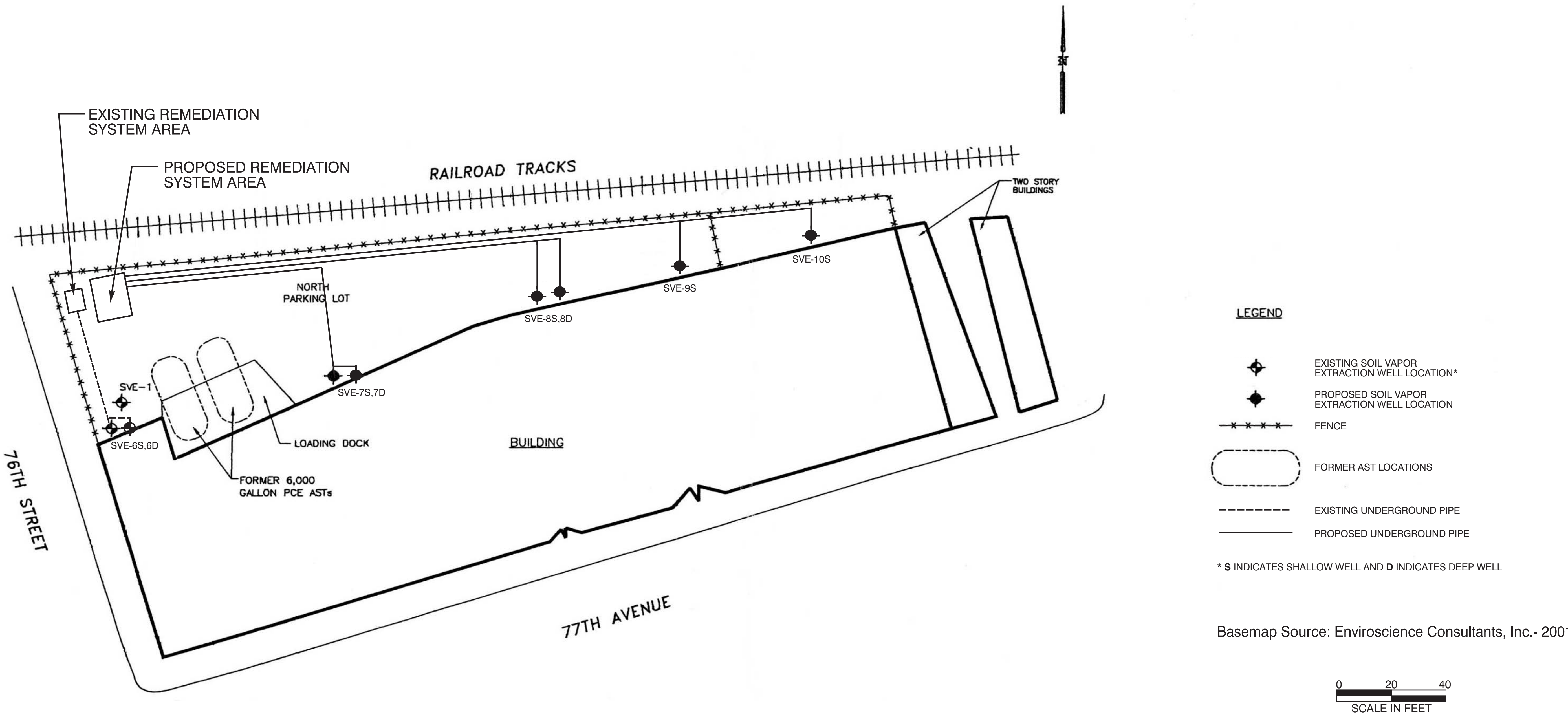
Source: Enviroscience Consultants, Inc.- 2001

0 20 40 SCALE IN FEET

URS

BORING LOCATIONS AND PCE SOIL RESULTS FROM 2001 INVESTIGATION

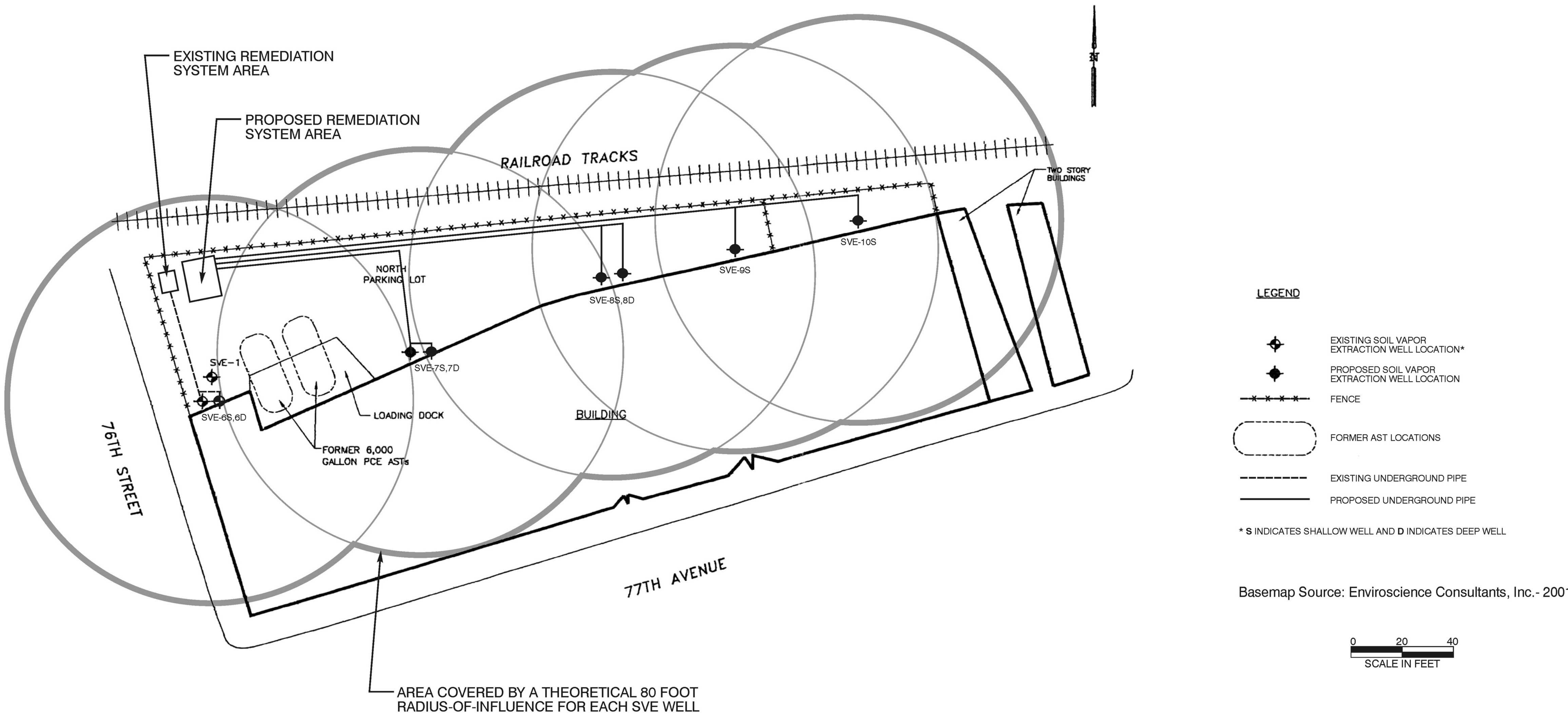
FIGURE 1-1



URS

PROPOSED SVE WELL LOCATIONS AND SYSTEM LAYOUT

FIGURE 2-1



URS	THEORETICAL SVE RADIUS-OF-INFLUENCE	FIGURE 2-2

APPENDIX A

CALCULATION

URS **EXHIBIT 4.7-2**

CALCULATION COVER SHEET

Client: NYSDEC Project Name: Kliegman OU I

Project/Calculation Number: 11171964

Title: SVE System Design Parameters

Total Number of Pages (including cover sheet): 25

Total Number of Computer Runs: 0

Prepared by: Donald McCall Date: 10-5-06

Checked by: John Busse Date: 10/5/06

Description and Purpose:

See Attached

Design Basis/References/Assumptions

See Attached

Remarks/Conclusions/Results:

See Attached

Calculation Approved by: ______________________

Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

URS

JOB NO.: 11171964

MADE BY: D. McCall DATE: 10-5-06
CHECKED BY: JHB DATE: 10/5/06

PROJECT: **Kliegman Bros. OU No. 1 Remedial Design**

SUBJECT: **SVE System Design Parameters**

Problem: Determine the design parameters for a soil vapor extraction (SVE) system to be installed at the Kliegman Brothers site. The design parameters to be determined include the quantity of extraction wells, well construction, flow rate, and vacuum for the SVE blower(s).

References:

1. *Operations & Monitoring Monthly Report - Soil Vapor Extraction System Interim Remedial Measure for the Period November 1, 2005 - December 8, 2005, Kliegman Bros. OU#1*, Work Assignment D003825-49.1, URS Corporation, January 2006.

2. *Soil Vapor Extraction and Bioventing, EM-1110-1-4001*, US Army Corps of Engineers, June 3, 2002

3. *Practical Design Calculations for Groundwater and Soil Remediation*, Jeff Kuo, PhD, PE, Lewis Publishers, 1999.

4. *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites*, EPA 510-B-95-007, USEPA, May 1995.

5. *Ametek® Rotron® Industrial Products*, www.rotronindustrial.com, September 28, 2006.

6. *Industrial Ventilation, A Manual of Recommended Practice*, American Conference of Governmental Industrial Hygienists, 1980.

7. www.tigg.com/remediation_products/standard_products/steel_vessel1.html, September 28, 2006.

General Assumptions:

1. Due to a lack of pilot testing data, the design of the SVE system will be based on published values and equations for the estimation of SVE design parameters, as well as data from the existing IRM system.

2. For the purpose of these calculations, the surface of the site is assumed to be a complete impermeable layer. The site is currently asphalt paved.

3. Approximately ½ of the building includes a basement, while the other half does not, and is assumed to be a slab on grade construction. Soil beneath the existing structures on site was previously analyzed and was found to be contaminated, primarily with PCE. In general, the entire site is assumed to be contaminated.

4. Due to the existing business operations at the site, no extraction wells will be installed inside of the building structure. Remediation will be attempted via vertical extraction wells placed outside the footprint of the building. Ideally, the extraction wells would be located just to the north of the existing building so that an approximately 80 foot radius of influence from each extraction well would be adequate to address the soil underneath the building to the southern property line. However, the business owner has indicated that all new wells should only be installed along the northern boundary of the site. Wells at those locations would require a radius of influence nearly 120 foot in diameter to treat the extent of the property. Such a large radius would be very unusual and most likely would not be achieved. Additionally, to obtain that radius, a very large airflow rate would be required from each well. Therefore, for the purpose of this design, it is assumed that an acceptable compromise can be made with the business, and an 80-foot radius is assumed.

5. For the sake of flexibility in operation of the SVE system, it is assumed that an extraction well pair will be installed at each extraction location that extends to the water table. This will allow for the shallow and deep areas to be separately targeted as the remediation progresses. This design approach

was utilized for the IRM extraction wells, and appears to be working effectively.

6. In the eastern area of the site where the shallow clay layer has previously been found, the SVE extraction wells will be installed only to the depth of the clay layer, approximately 12 feet bgs.

7. New SVE wells are assumed to be 4-inch diameter. The existing IRM wells are only 2-inch diameter.

---

1. **Determination of Flow Rate for Deep Well Pairs (7S/D and 8S/D)**

As stated above, it is assumed that most locations will be well pairs screened in separate intervals. However, for the purpose of the well design calculations, each is assumed to be one well screened the entire depth.

Ref. 2 presents the following equation to determine the flow rate from a single-well extraction system with an impermeable cover:

$$Q_v = \frac{\pi r^2 b n_a}{t_{ex}}$$

Where:

Q_v = volumetric flow rate at atmospheric pressure

r = radius of the treatment zone
Based on the assumption that the wells must treat the extent of the soil located underneath the existing building, r = **80 feet**.

b = vadose zone thickness = **65 feet** based on the approximate depth to groundwater and assuming that the entire extent is screened.

n_a = air-filled porosity of the soil
Based on Ref. 2, and assuming that the soil at the site is primarily graded as sand, an average air-filled porosity of **0.24** is assumed.

t_{ex} = time required for one pore volume exchange
Ref. 4 recommends that a minimum of one pore volume of soil vapor be extracted per day for effective remediation by SVE. t_{ex} = 24 hours = **1440 minutes.**

Substituting into the equation:

$$Q_v = \frac{\pi(80ft)^2(65ft)(0.24)}{(1440\,\text{min})} = 218 ft^3/\text{min}$$, say **<u>220 scfm</u>** per deep well pair

2. **Determination of Flow Rate for Shallow Wells (9S and 10S)**

These are the shallow wells to be located on the eastern portion of the site where the clay layer previously has been found. The same equations and assumptions as above were used, except where noted.

$$Q_v = \frac{\pi r^2 b n_a}{t_{ex}}$$

Where:

Q_v = volumetric flow rate at atmospheric pressure

r = radius of the treatment zone
Based on the assumption that the wells must treat the extent of the soil located underneath the existing building, **r = 80 feet.**

b = vadose zone thickness = **12 feet** based on the approximate depth to the clay layer and perched water

n_a = air-filled porosity of the soil = 0.24

t_{ex} = time required for one pore volume exchange = **1440 minutes**

Substituting into the equation:

$$Q_v = \frac{\pi(80ft)^2(12ft)(0.24)}{(1440\min)} = 40.2ft^3/\min$$, say **40 scfm** per shallow well

3. **Wellhead Vacuum for Deep Well Pairs**

Without the results of pilot testing, the required vacuum for the blower can only be estimated from applicable equations based on the properties of the vadose zone. The results from operation of the IRM, as reported in Ref. 1, showed that the assumptions made in the calculations appear to be valid.

Ref. 3 present the following equation:

$$Q_w = H\left(\frac{\pi k}{\mu}\right)\left[\frac{P_w}{\ln(R_w/R_I)}\right]\left[1-\left(\frac{P_{RI}}{P_w}\right)^2\right]$$

Where:

Q_w = flow rate from the well, cm^3/s
As determined above, Q_w = 220 ft^3/min. Converting units: (220 ft^3/min) x (1 min/60 sec) x (0.02832 m^3/ft^3) x ($1x10^6 cm^3/m^3$) = **103,840 cm^3/s**.

H = the screened interval of the extraction well, cm

Assuming that the well is constructed from 5 to 25 feet, and then 30 to 65 feet, the length of the screened interval is 55 feet. Converting units: (55 feet) x (12 inches/ft) x (2.54 cm/in) = **1676 cm**

k = intrinsic permeability, cm^2
Lacking any site-specific information, a k value for sand/gravel of **$1x10^{-6}$ cm^2** was assumed from Ref. 4.

μ = viscosity of air, g/cm·s
Per Ref. 3, a value of 0.018 centipoise (at 20°C) is used.
Converting units: (0.018 cp) x (0.01 g/cm·s / cp) = **$1.8x10^{-4}$ g/cm·s**

P_w = absolute pressure at the extraction well, $g/cm \cdot s^2$
This is the value to be determined.

R_w = Radius of the vapor extraction well, cm
Based on a 4-inch diameter extraction well, the radius is 2 inches. Converting units: (2 in) x (2.54 cm/in) = **5.08 cm**

R_I = Radius of influence where the vacuum is equal to a preset value, cm.
As outlined above, a radius of influence of 80 feet is assumed. Converting the units: (80 ft) x (12 in./ft) x (2.54 cm/in) = **2438 cm.**

P_{RI} = Pressure at the radius of influence, $g/cm \cdot s^2$
As a conservative assumption, assume that a vacuum of 0.5 in. WC will be maintained at the defined radius of influence. Converting units:
(0.5 in. WC vacuum) x (1 ft/12 in.) x ($1.01x10^6$ $g/cm \cdot s^2$ / 33.91 ft. WC) = 1241 $g/cm \cdot s^2$.
Now converting to absolute pressure by subtracting from standard pressure:

$1.01x10^6$ - 1241 = **1,008,759 g/cm·s²**

Now, substituting all values into the equation:

$$103{,}840 = 1676\left(\frac{\pi(1x10^{-6})}{1.8x10^{-4}}\right)\left[\frac{P_w}{\ln(5.08/2438)}\right]\left[1-\left(\frac{1{,}008{,}759}{P_w}\right)^2\right]$$

Using the attached spreadsheet to solve for P_w yields a result of 997,860 $g/cm \cdot s^2$. Now, converting back to vacuum:

$1.01x10^6$ - 997,860 = 12,140 $g/cm \cdot s^2$

Converting units:
(12,140 $g/cm \cdot s^2$) x (33.91 ft WC / $1.01x10^6$ $g/cm \cdot s^2$) x (12 in. WC/ft) = 4.89 in. WC.

However, considering that the wellhead vacuum is based on calculations and published values, and that there will be additional pressure loss across the well itself, an additional safety factor will be included, and the blower will be sized for a minimum wellhead vacuum of say **10 in. wc**.

4. **Wellhead Vacuum for Shallow Wells**

Using the same equation and assumptions as for the deep wells:

$$Q_w = H\left(\frac{\pi k}{\mu}\right)\left[\frac{P_w}{\ln(R_w/R_I)}\right]\left[1-\left(\frac{P_{RI}}{P_w}\right)^2\right]$$

Where:

Q_w = flow rate from the well, cm^3/s

As determined above, Q_w = 40 ft^3/min. Converting units: (40 ft^3/min) x (1 min/60 sec) x (0.02832 m^3/ft^3) x ($1x10^6 cm^3/m^3$) = **18,880 cm^3/s.**

H = the screened interval of the extraction well, cm
Assuming that the well is constructed to 12 feet. Converting units: (12 feet) x (12 inches/ft) x (2.54 cm/in) = **365.76 cm**

Now, substituting all values into the equation:

$$18{,}880 = 365.76\left(\frac{\pi(1x10^{-6})}{1.8x10^{-4}}\right)\left[\frac{P_w}{\ln(5.08/2438)}\right]\left[1-\left(\frac{1{,}008{,}759}{P_w}\right)^2\right]$$

Using the attached spreadsheet to solve for P_w yields a result of 999,671 g/cm·s². Now, converting back to vacuum:

$1.01x10^6 - 999{,}671 = 10{,}329$ g/cm·s²

Converting units:
(10,329 g/cm·s²) x (33.91 ft WC / $1.01x10^6$ g/cm·s²) x (12 in. WC/ft) = 4.16 in. WC.

However, considering that the wellhead vacuum is based on calculations and published values, and that there will be additional pressure loss across the well itself, an additional safety factor will be included, and the blower will be sized for a minimum wellhead vacuum of say <u>**10 in. wc**</u>.

5. **Blower Specifications**

<u>Total Flow Rate</u>: The proposed new wells at the site include 2 shallow / deep well pairs and 2 additional shallow wells. Based on the flow rates calculated above, the total flow required from the blowers is:

2 @ 220 scfm + 2 @ 40 scfm = 520 scfm total.

This is the total blower flow rate required. It is likely that at least two blowers will be installed in a parallel configuration to allow for flexibility in operation, each sized for a minimum of 260 scfm.

Pressure Drop: In order to maintain the desired vacuum on the extraction wells, it is necessary to select a blower with sufficient vacuum to account for pressure drop across the equipment and pipe located between the blower and the extraction well.

- Moisture Separator: Based on Ref. 5, the pressure drop across the moisture separator is in the range of **3.5 in. wc.**
- Flow Meter: Based on Ref. 5, the pressure drop across the flow meter is estimated to be in the range of 2-4 in. wc. Assume **4 in. wc** for the purpose of this estimate.
- Piping: it is expected that each well pair will be piped together in a dedicated line back to the SVE system. The highest pressure drop will occur from the second well pair. This pipe is estimated to be approximately 200 feet long, with a flow rate of 220 scfm. Assuming that the pipe is 4-inch diameter, Ref. 6 shows that the pressure drop through the pipe would be:

  200' x 3"/100' = **6 in. wc**
- Carbon treatment system: the size of the carbon adsorption system for removal of contaminants from the air stream will be more a factor of the carbon loading as opposed to any air flow requirements. As a worst case, as shown in Ref. 7, the pressure drop across a carbon bed would be on the order of 3 inches. Assuming two units installed in series, the total pressure drop would be **6 in. wc.**
- Other Losses: an allowance of **5 in. wc** is included to account for all other miscellaneous piping, filters, silencers, and other losses.

Summing the total of the desired vacuum and all system losses, the selected blower will be designed for a vacuum of **34.5 say 35 in. wc.**

The selected blowers should then be capable of providing a flow rate of 260 scfm at a vacuum of 35 in. wc. Product information from a blower that meets these requirements (an Rotron® Model EN808) is included with Ref. 5.

This blower is equipped with a 7.5 HP, three phase motor, is capable of a maximum 97 inches wc vacuum and a flow rate of 140 scfm.

6. **Modified Operation**

As described under Assumption #4 above, a maximum radius of 80 feet was assumed, despite the fact that the business owner has determined that all of the extraction wells should be located at the northern boundary of the site.

For the sake of comparison, the calculations were re-run assuming that one or more of the extraction wells were shut, and that the flow from the open well was doubled. Using the same equations and assumptions as above for the deep well pairs, doubling the flow rate (440 scfm) would theoretically provide a radius of 114 feet, which would be very close to reaching across the site to treat the entire extent from the northern to the southern boundary.

Calculating the vacuum required at this larger radius and flow rate, again using the same equations and assumptions, shows that a vacuum of 9.73 in. wc theoretically would be required to achieve those conditions. Considering that the vacuum from the wells in the previous calculations was rounded up to 10 in. wc, it is possible that the existing blowers would be able to meet these conditions by operating one well at a time.

The assumption that the wells can be designed for a radius of 80 feet, and then use targeted extraction from specific wells to achieve remediation of the remainder of the site appears to be valid.

Calculation Spreadsheet

	Deep Wells	Shallow Wells
Q	103,837	18,880
H	1,676	366
π	3.14	3.14
k	1.00E-06	1.00E-06
μ	1.80E-04	1.80E-04
P_w	997,861	999,671
R_w	5.08	5.08
R_i	2,438	2,438
P_{ri}	1,008,759	1,008,759

The calculated parameter is circled.
Refer to calculation sheet for units and explanation.

N:\11171964.00000\EXCEL\[SVE calc.xls]Sheet1

Ref. 1

OPERATIONS & MONITORING MONTHLY REPORT
SOIL VAPOR EXTRACTION SYSTEM INTERIM REMEDIAL MEASURE

FOR THE PERIOD NOVEMBER 1, 2005 – DECEMBER 8, 2005

KLIEGMAN BROS. SITE

SITE #2-41-031

QUEENS, NEW YORK

PREPARED FOR:

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

DIVISION OF ENVIRONMENTAL REMEDIATION

WORK ASSIGNMENT D003825-49.1

PREPARED BY:

URS CORPORATION

77 GOODELL ST.

BUFFALO, NEW YORK 14203

JANUARY 2006

Ref. 2

EM 1110-1-4001
3 June 2002

US Army Corps
of Engineers®

ENGINEERING AND DESIGN

Soil Vapor Extraction and Bioventing

This manual is approved for public release, distribution is unlimited.

ENGINEER MANUAL

Ref. 2

Table 4-8
Saturation ranges and Typical Air Filled Porosities for Various Soils*

Soil Type	Field Capacity** Range (cm³ water/cm³ soil)	Saturation Range*** (cm³ water/cm³ soil)	Average air filled porosity (θ_A) @ field capacity (cm³ air/cm³ soil)
Sand	0.13 - 0.16	0.36 – 0.40	0.24
Loam Sand	0.15 - 0.19	0.36 – 0.43	0.22
Sand Loam	0.17 - 0.24	0.37 – 0.44	0.20
Loam	0.23 – 0.30	0.42 – 0.49	0.19
Sandy Clay Loam	0.21 – 0.30	0.44 – 0.49	0.21
Sand Clay	0.28 – 0.38	0.49 – 0.52	0.18
Silt Loam	0.24 – 0.33	0.40 – 0.51	0.17
Silt	0.30 – 0.30	0.45 – 0.47	0.16
Clay Loam	0.29 – 0.38	0.49 – 0.52	0.17
Silt Clay Loam	0.33 – 0.39	0.50 – 0.53	0.16
Silt Clay	0.39 – 0.47	0.53 – 0.55	0.11
Clay	0.39 – 0.49	0.51 – 0.55	0.09

*Estimated based on soil texture characteristics (Saxton et al. 1986)
**Water content of "drained" soil
***Volumetric water content when all pores are water filled

(e) For this example problem, the following assumptions were made regarding the parameters A, D_o, and C:

- The soil was a poorly-sorted sand, similar to the mixed-grain loose sand in Table 4-7, which can be expected to drain well and have pore spaces mostly filled with air, not water
- Total soil porosity = 0.4, and air-filled soil porosity, $\theta_A = 0.24$ (from Table 4-8)
- Soil bulk density = 1,590 kg soil/m³
- D_O = 1,330 mg/l at standard temperature and pressure
- One mole of hexane (0.086 kg) requires 9.5 moles of O_2 (0.304 kg) to completely oxidize it to CO_2 and water, for a mass ratio, C, of 1:3.5

(f) Using these assumptions and the empirical data for K_O, a biodegradation rate was found by substituting the values into Equation 4-13:

$$K_B = \frac{-10 \times \left(\frac{5\%}{day}\right)\left(\frac{0.24\, m^3 - air}{m^3 - soil}\right)\left(\frac{1{,}330\, mg - O_2}{l - air}\right)\left(\frac{1\, mg\, C_6H_{14}}{3.5\, mg\, O_2}\right)}{1{,}590\, kg - soil/m^3 - soil} = 2.9\, mg\ hexane\ per\ kg - soil\ per\ day$$

Ref. 3

PRACTICAL DESIGN CALCULATIONS

for Groundwater and Soil Remediation

JEFF KUO, PH.D., P.E.
Civil and Environmental Engineering
California State University, Fullerton

LEWIS PUBLISHERS
Boca Raton London New York Washington, D.C.

where u_r is the vapor flow velocity at a radial distance "r" away from the well. The velocity at the wellbore, u_w, can be found by replacing r with R_w in the above equation as

$$u_w = \left(\frac{k}{2\mu}\right)\left[\frac{P_w}{R_w \ln(R_w / R_I)}\right]\left[1-\left(\frac{P_{RI}}{P_w}\right)^2\right] \qquad \text{[Eq. V.1.4]}$$

The volumetric vapor flow rate entering the extraction well, Q_w, can then be found as

$$Q_w = 2\pi R_w u_w H$$

$$= H\left(\frac{\pi k}{\mu}\right)\left[\frac{P_w}{\ln(R_w / R_I)}\right]\left[1-\left(\frac{P_{RI}}{P_w}\right)^2\right] \qquad \text{[Eq. V.1.5]}$$

where H is the perforation interval of the extraction well.

To convert the vapor flow rate entering the well to equivalent standard flow rates, Q_{atm} (where $P = P_{atm}$ = 1 atm), the following relationship can be used

$$Q_{atm} = \left(\frac{P_{well}}{P_{atm}}\right)Q_{well} \qquad \text{[Eq. V.1.6]}$$

Example V.1.4A *Estimate the extracted vapor flow rate of a soil venting well*

A soil venting well was installed at a site. Determine the radius of influence of this soil venting well using the following information:

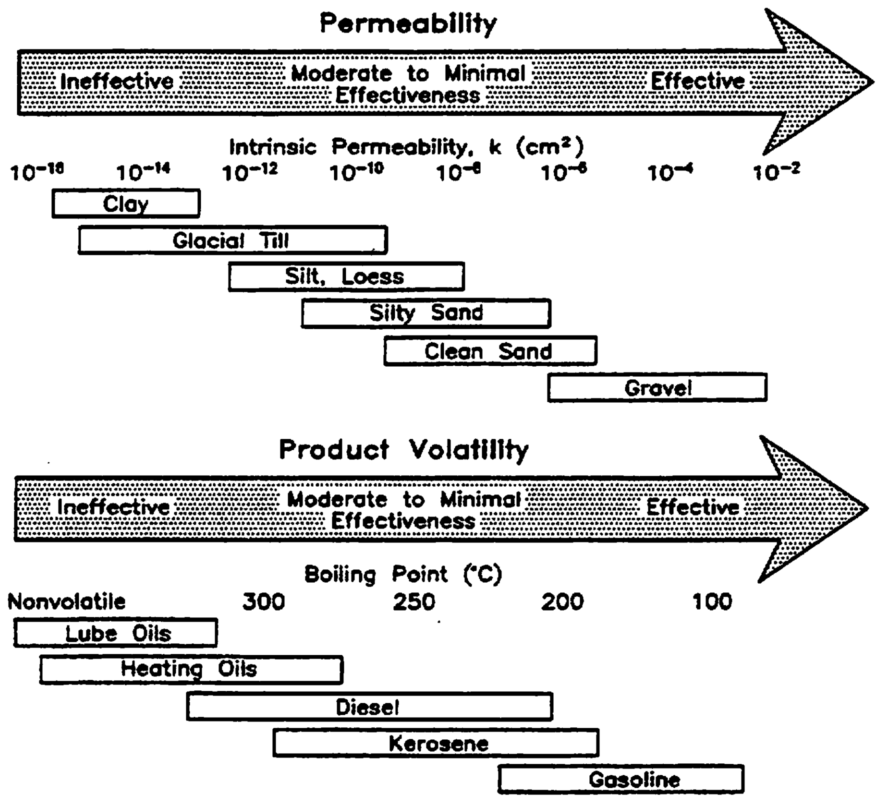
Pressure at the extraction well = 0.9 atm
Pressure at a monitoring well 30 ft away from the venting well = 0.95 atm
Diameter of the venting well = 4 in

Calculate the steady-state flow rate entering the well per unit well screen length, vapor flow rate in the well, and the vapor rate at the extraction pump discharge by using the following additional information:

Permeability of the formation = 1 Darcy
Well screen length = 20 ft
Viscosity of air = 0.018 centipoise
Temperature of the formation = 20°C

Ref. 4

Exhibit II-4
Initial Screening For SVE Effectiveness



Detailed Evaluation Of SVE Effectiveness

Once you have completed the initial screening and determined that SVE may have the potential to be effective for the soils and petroleum product present, further scrutinize the CAP to confirm that SVE will be effective.

Begin by reviewing the two major factors that determine the effectiveness of SVE: (1) permeability of the soil and (2) constituent volatility. The combined effect of these two factors results in the initial contaminant mass extraction rate, which will decrease during SVE operation as concentrations of volatile organics in the soil (and soil vapor) are reduced.

Many site-specific parameters can be used to determine permeability and volatility. These parameters are summarized in Exhibit II-5.

Ref. 5

EN 707, EN 808 Single-Phase and CP Options Sealed Regenerative Blower w/Explosion-Proof Motor

FEATURES

- Manufactured in the USA – ISO 9001 compliant
- Maximum flow: 295 or 345 SCFM
- Maximum pressure: 88 or 56 IWG
- Maximum vacuum: 84 or 64 IWG
- Standard motor: 5.5 HP, explosion-proof
- Cast aluminum blower housing, cover, impeller & manifold; cast iron flanges (threaded); teflon lip seal
- UL & CSA approved motor with permanently sealed ball bearings for explosive gas atmospheres Class I Group D minimum
- Sealed blower assembly
- Quiet operation within OSHA standards

MOTOR OPTIONS

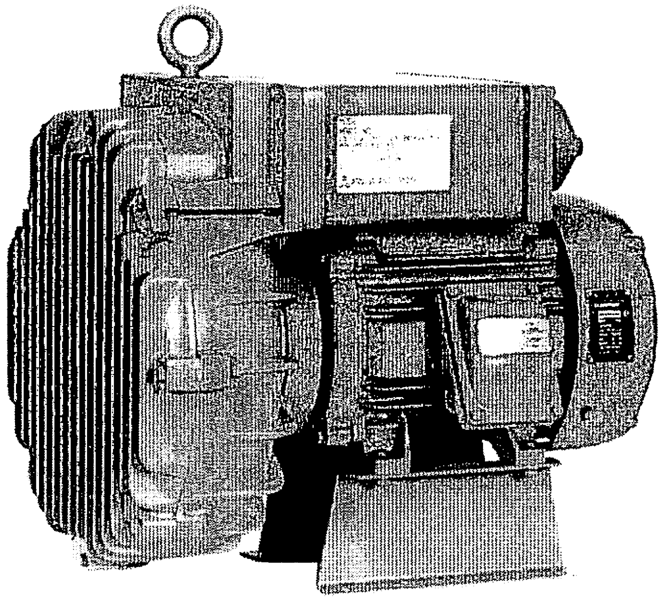
- International voltage & frequency (Hz)
- Chemical duty, high efficiency, inverter duty or industry-specific designs
- Various horsepowers for application-specific needs

BLOWER OPTIONS

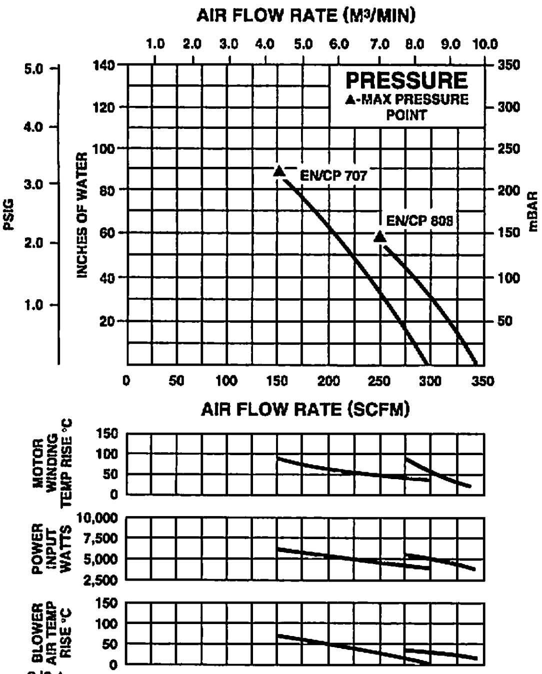
- Corrosion resistant surface treatments & sealing options
- Remote drive (motorless) models
- Slip-on or face flanges for application-specific needs

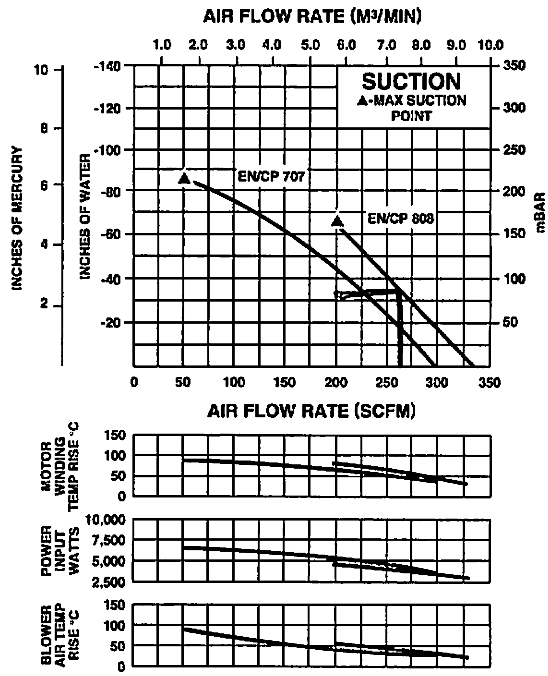
ACCESSORIES (See Catalog Accessory Section)

- Flowmeters reading in SCFM
- Filters & moisture separators
- Pressure gauges, vacuum gauges & relief valves
- Switches – air flow, pressure, vacuum or temperature
- External mufflers for additional silencing
- Air knives (used on blow-off applications)
- Variable frequency drive package



BLOWER PERFORMANCE AT STANDARD CONDITIONS





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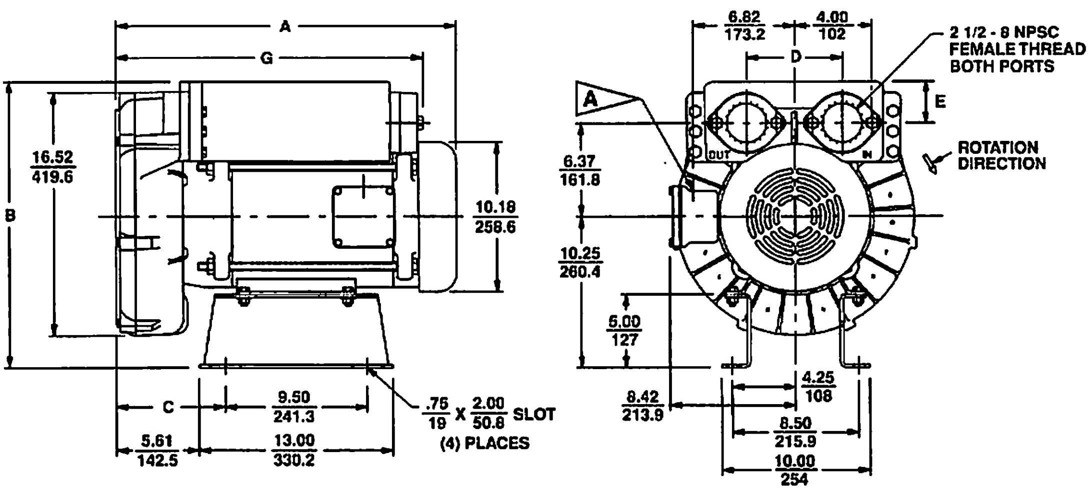
AMETEK Technical and Industrial Products, Kent, OH 44240 • e mail: rotronindustrial@ametek.com • internet: www.ametektmd.com

Ref. 5

ROTRON® Regenerative Blowers

EN 707, EN 808 Single-Phase and CP Options Sealed Regenerative Blower w/Explosion-Proof Motor

Scale CAD drawing available upon request.



	EN/CP707		EN/CP808	
	IN	MM	IN	MM
A	23.0	584	23.0	582
B	19.47	494	19.5	494
C	7.4	187	7.4	187
D	6.44	164	7.1	180
E	2.82	72	3.4	86
F	16.5	419	16.5	419
G	20.23	514	20.7	526

DIMENSIONS: $\frac{IN}{MM}$
TOLERANCES: .XX ± $\frac{.1}{2.5}$
(UNLESS OTHERWISE NOTED)

A — 0.75" NPT CONDUIT CONNECTION AT 12 O'CLOCK POSITION

SPECIFICATIONS

MODEL	EN707FL5MWL	EN808FL5MWL	CP707FX5MWLR	CP808FX5MWLR
Part No.	038712	038732	080616	–
Motor Enclosure – Shaft Material	Explosion-proof – **CS**	Explosion-proof – **CS**	Chem XP – **SS**	Chem XP – **SS**
Horsepower	5.5	5.5	Same as EN707FL5MWL – 038712 except add Chemical Processing (CP) features from catalog inside front cover	Same as EN808FL5MWL – 038732 except add Chemical Processing (CP) features from catalog inside front cover
Phase – Frequency	Single - 60 Hz	Single - 60 Hz		
Voltage	230	230		
Motor Nameplate Amps	21.7	21.7		
Max. Blower Amps [2]	29.9	29.9		
Inrush Amps	155	155		
Starter Size	1	1		
Service Factor	1.0	1.0		
Thermal Protection [1]	Class B - Pilot Duty	Class B - Pilot Duty		
XP Motor Class – Group	I-D	I-D		
Shipping Weight	244 lb (111 kg)	378 lb (172 kg)		

[1] Maximum operating temperature: Motor winding temperature (winding rise plus ambient) should not exceed 140°C for Class F rated motors or 120°C for Class B rated motors. Blower outlet air temperature should not exceed 140°C (air temperature rise plus inlet temperature). Performance curve maximum pressure and suction points are based on a 40°C inlet and ambient temperature. Consult factory for inlet or ambient temperatures above 40°C.

[2] Maximum blower amps corresponds to the performance point at which the motor or blower temperature rise with a 40°C inlet and/or ambient temperature reaches the maximum operating temperature.

Specifications subject to change without notice. Please consult your Local Field Sales Engineer for specification updates.

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Measurement Accessories

Blower Connection Key
NPT – American National Standard Taper Pipe Thread (Male)
NPSC – American National Standard Straight Pipe Thread for Coupling (Female)
SO – Slip On (Smooth – No Threads)

Air Flow Meter

FEATURES

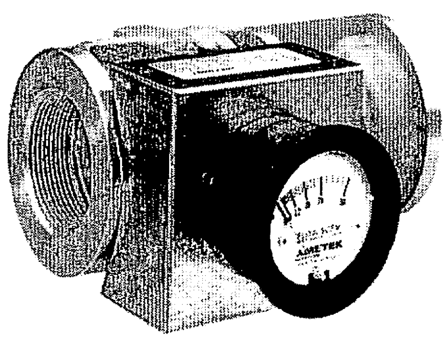
- Direct reading in SCFM
- Low pressure drop (2-4" typical) across the flow meter
- Non-clogging, low impedance air stream
- Light weight aluminum
- No moving parts
- Large easy-to-read dial
- Accurate within 2% at standard conditions
- Good repeatability
- Available in 2", 3" and 4" sizes
- Factory configured for quick installation
- .048" Allen key supplied for gauge adjustment

OPTIONS

- Corrosion-resistant version with Chem-Tough™ or in stainless steel
- FDA-approved Food Tough™ surface conversion

BENEFITS

- OPTIMIZE SYSTEM EFFICIENCY
  Measuring the correct air flow can assist you in fine-tuning to your system's optimal efficiency.
- BALANCE MULTI-PIPING SYSTEMS
  When evacuating CFM from more than one pipe, different run lengths or end system impedance can cause one pipe to handle more CFM than the other. With an accurate CFM reading, piping can be balanced by bleeding air in/out or by creating an extra impedance.
- DETECT CHANNELING OR PLUGGING
  For systems in which channeling or plugging can occur, a change in the CFM measured can help indicate the unseen changes in your system.



Current Models		Flow Range	B	C	D	E	F
Model	Part #	(SCFM)	Threads	Length	Width		
FM20C030Q	550599	6-30	2" - 11.5 NPSC	7.18"	7.0"	2.0"	3.75"
FM20C045Q	550600	9-45					
FM20C065Q	550601	13-65					
FM20C125Q	550602	25-125			5.6"		
FM20C175Q	550603	35-175					
FM20C225Q	550604	45-225					
FM30C250Q	550605	50-250	3" - 8 NPSC	7.52"	7.4"	2.5"	4.43"
FM30C350Q	550606	70-350					
FM30C475Q	550607	95-475					
FM40C450Q	550608	90-450	4" - 8 NPSC	8.00"	7.7"	2.7"	5.43"
FM40C600Q	550609	120-600					
FM40C850Q	550610	170-850					

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Filtration Accessories

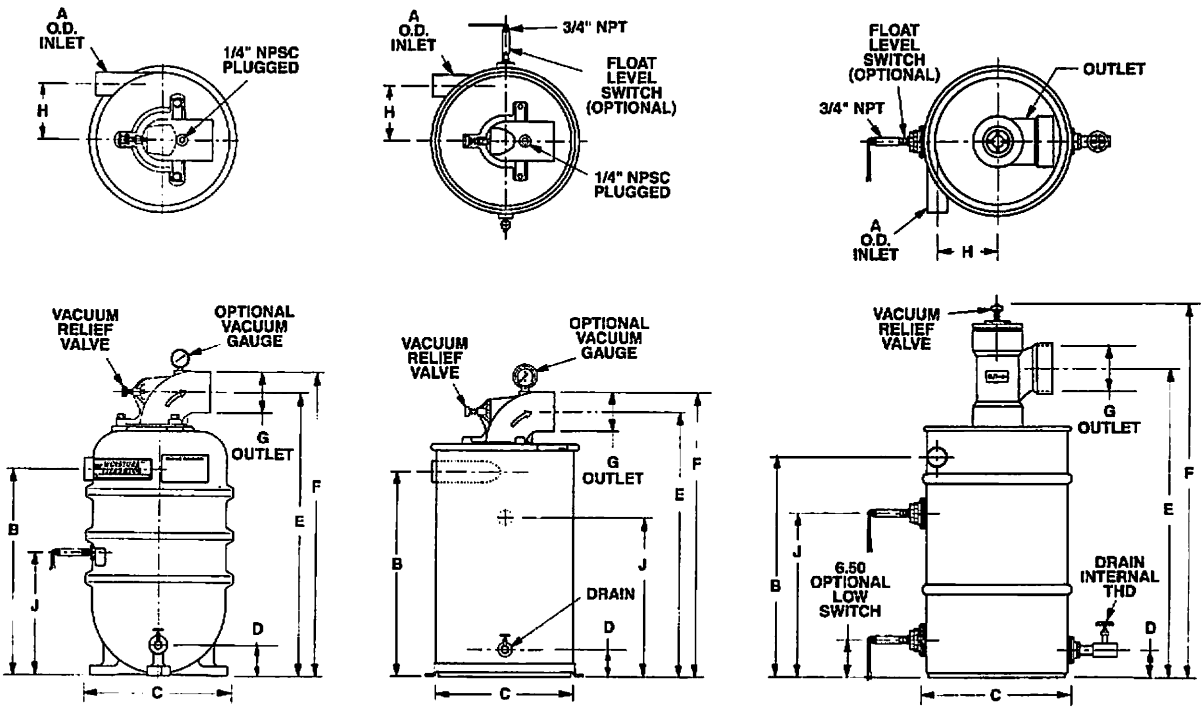
Blower Connection Key
NPT – American National Standard Taper Pipe Thread (Male)
NPSC – American National Standard Straight Pipe Thread for Coupling (Female)
SO – Slip On (Smooth – No Threads)

Moisture Separator™

By separating and containing entrained liquids, Rotron's moisture separator helps protect our regenerative blowers and the end treatment system from corrosion and mineralization damage. Recommended for all soil vacuum extraction applications.

SPECIFICATIONS:

SEPARATION METHOD – High Efficiency Cyclonic
RELIEF VALVE MATERIAL – Brass & Stainless Steel
FLOAT MATERIAL – Copper
FLOAT SWITCH – SPDT, Explosion-proof NEMA 7&9, 5 Amp max.



PLASTIC "P" DESIGN — METAL "D" DESIGN — METAL "B" DESIGN

Model	Part No.	CFM Max.	A Dia.	B	C Dia.	D	E	F	G Dia.	H	J Switch	Drain Internal THD	Shipping Weight
MS200PS	038519	200	2.38	22.46	16.00	3.25	31.05	33.30	4.50 OD	6.00	13.25	3/4" NPT	42 lb.
MS300PS	038520	300	2.88										
MS200DS	080086	200	2.00	22.12	16.75	2.75	27.92	30.17		6.56	12.62		
MS300DS	080087	300	2.50							6.81			
MS350BS	038357	350	3.25	28.00	23.00	4.00	37.25	39.50		9.75	17.50	1" NPT	82 lb.
MS500BS	080660	500					37.37	54.50	6.63 ID				95 lb.
MS600BS	080659	600	4.00	27.00						9.25			96 lb.
MS1000BS	038914	1000	6.00	31.00	27.00		47.32	51.70	8.62 OD	10.00	19.88		150 lb.

Models without float switch available. Metal MS200/300DS models are not the standard stocked, but are available.

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Blower Model Reference Key	
A = SPIRAL	E = DR/EN/CP 656, 6, 623, S7
B = DR/EN/CP 068, 083, 101, 202	F = DR/EN/CP 707, 808, 858, S9, P9 (Inlet Only)
C = DR/EN/CP 303, 312, 313, 353	G = DR/EN/CP 823, S13, P13 (Inlet Only)
D = DR/EN/CP 404, 454, 513, 505, 555, 523	H = DR/EN/CP 909, 979, 1223, 14, S15, P15 (Inlet Only)

Filtration Accessories

2.0 Moisture Separator™ Specifications

2.1 DUTY

The moisture separator shall be designed for use in a soil vapor extraction system capable of continuous operation with a pressure drop of less than six inches of water at the rated flow of _____ SCFM. The separator shall be capable of operation under various inlet conditions ranging from a fine mist to slugs of water with high efficiency.

2.2 PRINCIPLE OF OPERATION

The moisture separator shall incorporate cyclonic separation to remove entrained water. The separator must protect against an overflow by fail safe mechanical means. An electrical switch or contact(s) alone is not an acceptable means of protection against overflow, but is a good backup.

2.3 CONSTRUCTION

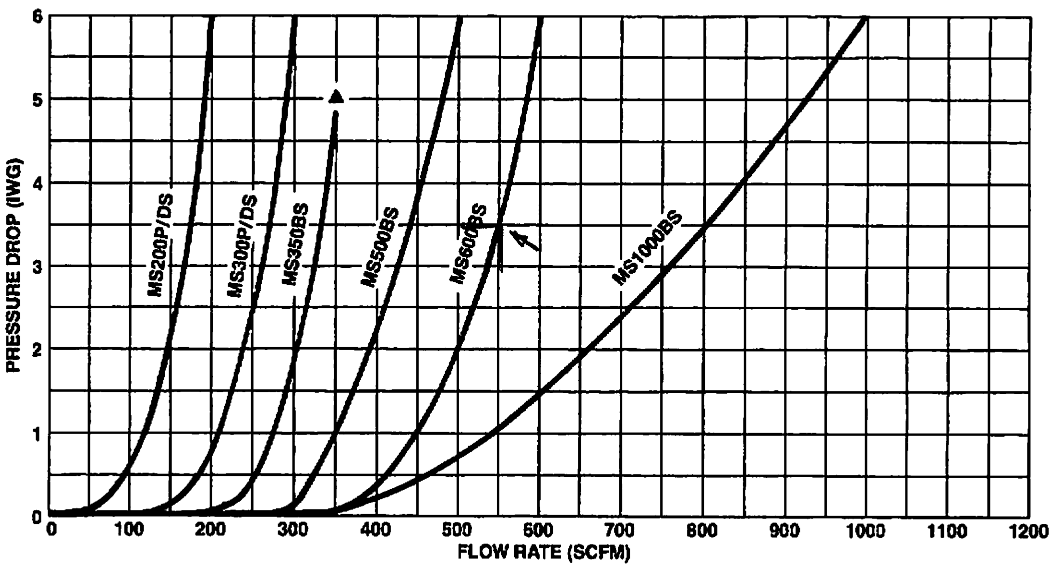
The body of the moisture separator shall be constructed of heavy wall plastic or heavy gauge cold rolled steel. The steel interior and exterior shall be epoxy (powder) coated to resist abrasion, corrosion, and chipping that might expose the surface. The inlet shall be tangentially located and welded to the body. The outlet port shall be constructed of PVC or cast aluminum alloy, flanged and sealed to the center of the top of the separator. The separator shall incorporate a non-sparking copper float ball and an adjustable relief valve to protect against overflow and overheating the blower.

2.4 CAPACITY AND DIMENSIONS

The moisture separator must have a liquid capacity of _____ gallons. The inlet shall be _____ inch OD slip-on type. The outlet shall be _____ inch OD slip-on type.

For DR/EN/CP Blower Model	Selector Moisture Separator Model	Liquid-holding Capacity (gallons)	Inlet (OD)	Outlet	Max Vacuum Allowed (IHg)
404 454 505 513	MS200PS	7	2.38	4.5" OD	12
523 555 623 823	MS200DS	10	2.0		22
656 6 707	MS300PS	7	2.88		12
	MS300DS	10	2.5		22
808	MS350BS	40	3.25		
858 1223	MS500BS			6.63" ID	
909	MS600BS		4.0"		
979 14	MS1000BS	65	6.0"	8.62" OD	

2.5 PRESSURE DROP



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Ref. 6

INDUSTRIAL VENTILATION

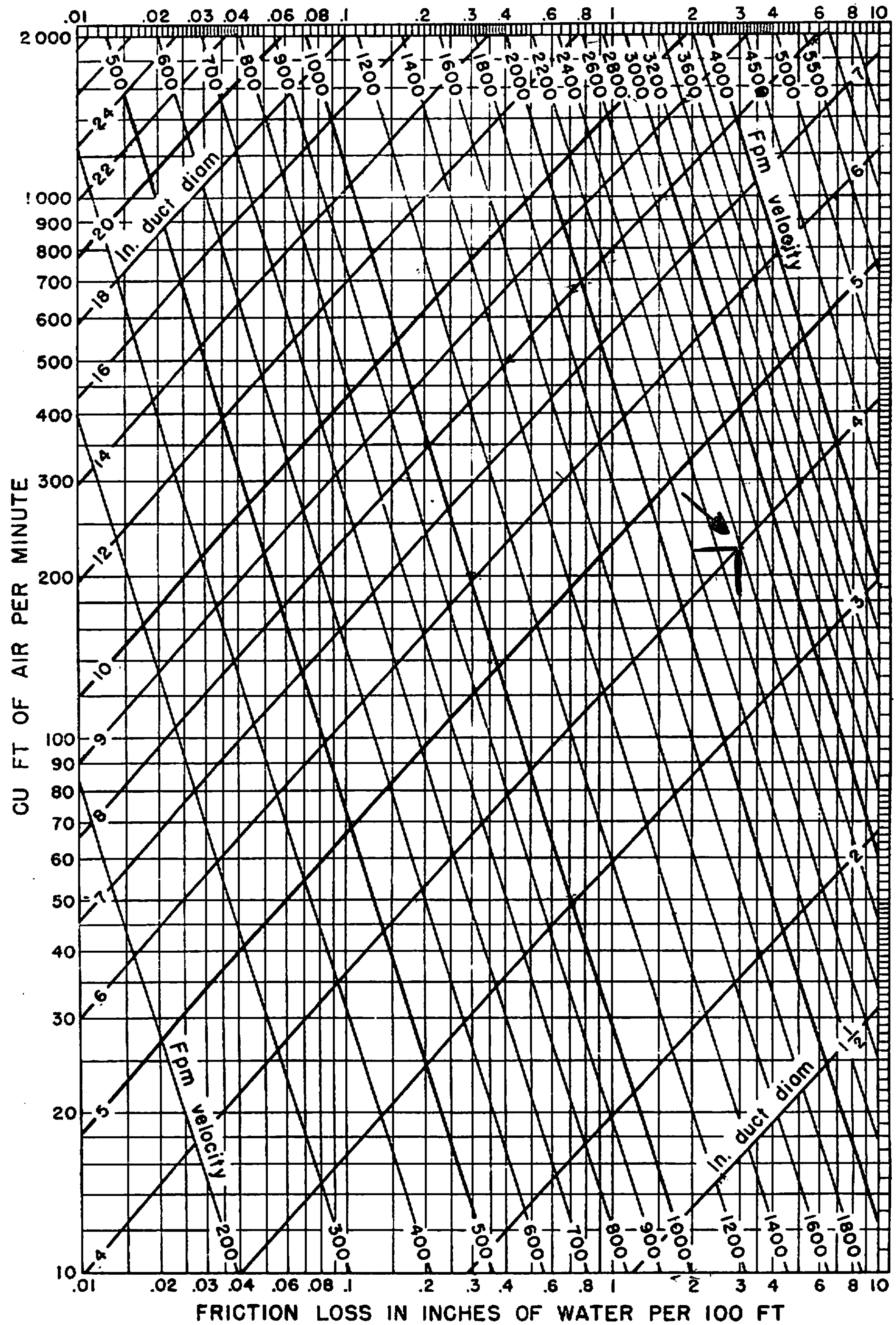
A Manual of Recommended Practice

1980

COMMITTEE ON INDUSTRIAL VENTILATION
P.O. BOX 16153
LANSING, MICHIGAN, 48901, U.S.A.

American Conference of Governmental Industrial Hygienists

Ref. 6



(Based on Standard Air of 0.075 lb per cu ft density flowing through average, clean, round, galvanized metal ducts having approximately 40 joints per 100 ft.)
Caution: Do not extrapolate below chart.

For proprietary duct, obtain data from manufacturer. Friction of Air in Straight Ducts for Volumes of 10 to 2000 Cfm

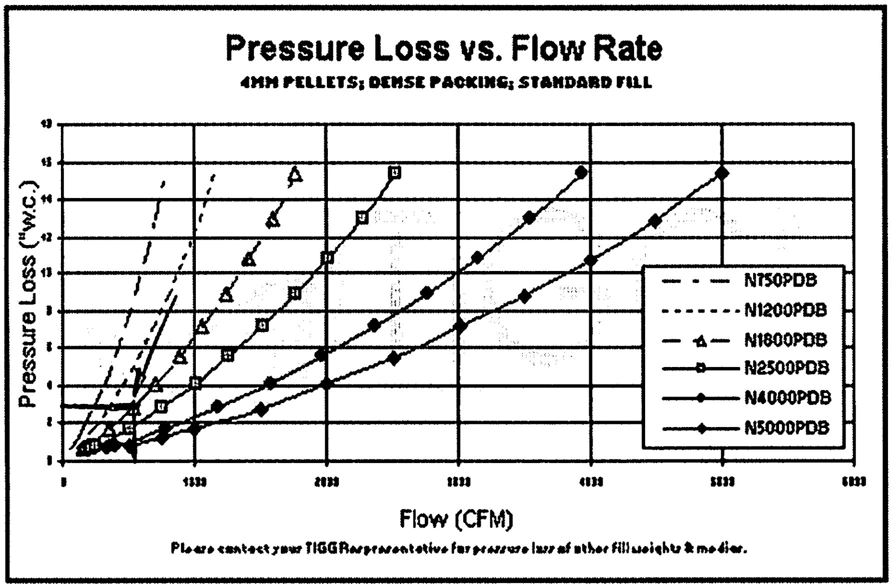
$$\text{Friction Loss}/100' = \frac{2.74\left[\frac{V_{fpm}}{1000}\right]^{1.9}}{[D_{inches}]^{1.22}}$$

(Ref. 130)

Note: Both "1.9" and "1.22" are exponents.

Fig. 6-15A

Ref. 7


Pressure Loss vs. Flow Rate
4MM PELLETS; DENSE PACKING; STANDARD FILL
Pressure Loss ("W.C.)
Flow (CFM)
N150PDB
N1200PDB
N1800PDB
N2500PDB
N4000PDB
N5000PDB