CHAPTER 6
SOIL VAPOR EXTRACTION SYSTEMS

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6-1. GENERAL. This section describes the installation of soil vapor extraction (SVE) systems. SVE systems are intended to remove volatile contaminants from the soils above the water table by either evaporation or biodegradation. The air is extracted from wells or trenches (and in some cases injected) using air blowers or vacuum pumps and associated above ground equipment. SVE projects include system installation, start-up, and usually limited operations and maintenance. This section does not cover vapor treatment or air discharge permit requirements. Refer to EM 1110-1-4001, Soil Vapor Extraction and Bioventing for more detail on the design, construction, and operation of soil vapor extraction systems.

a. Equipment.

(1) Well Drilling Equipment.

(a) Use only drilling equipment not requiring the use of liquids (water, drilling mud) for installation of air injection or extraction wells.

(b) If the soil vapor extraction wells will also be used for the extraction of ground water and/or floating product, refer to the checklist on Ground Water and Leachate Collection for appropriate equipment. Use of fluids should be avoided if possible in any event.

(2) Refer to Chapter 3 on covers and liners for equipment appropriate for installation of any required surface cover.

(3) Trenching equipment for below-grade piping installation only need be large enough to reach required excavation depth and provide necessary trench width.

b. Preconstruction Submittals. The contractor should provide preconstruction submittals as required by the specifications. The following is a list of typical submittal requirements.

(1) Drilling and Well Installation Plan which describes:

- the drilling method and equipment;
- well installation procedures;
- soil/rock logging procedures and forms;
- soil sampling and sample handling procedures; and
- well construction diagrams.

Verify that the drilling subcontractor has read the well installation specifications prior to mobilization to the site.

(2) Qualifications for the driller should be submitted if licensed drillers are required in that state. Verify that the qualifications meet the specifications and any state requirements. The qualifications, including education and experience, of the geologist or engineer responsible for logging the materials encountered in drilling should also be submitted for information.

(3) Catalog information on:

- well screen and casing;
- cement and/or bentonite well sealant;
- precast well head vaults (if applicable);
- piping;
- blower(s) and associated equipment (or package unit containing these items);
- gauges and controls; and
- electrical components.

(4) Gradation test results for filter pack material and piping bedding/backfill, if required.

(5) Shop drawings on any fabricated above-ground equipment.

c. Construction Submittals. The contractor should provide construction submittals as required by the specifications. The following is a list of typical submittal requirements.

(1) Boring logs for extraction, injection, or monitoring wells.

(2) Proposed well locations or well screen placement may be a submittal if well construction was left to the contractor based on conditions encountered. Proposed locations and construction must achieve the objectives of the system. Contact the designer if uncertainty exists about the adequacy of the proposal.

(3) Well construction diagrams for all wells installed under the contract. Include copies of any permits required by state or local authorities.

(4) Airflow test results for individual extraction (or injection) wells. These are determined by testing air yields at various pressures/vacuums and are used to verify design assumptions.

(5) Leak test results on wells, piping, and above-ground equipment.

(6) Backfill density test results, if required.

(7) Well chemical sampling results from initial sampling.

(8) Alignment test results, for blower and motors.

d. Start-up Submittals. The contractor should provide start-up submittals as required by the specifications. The following is a list of typical submittal requirements.

(1) Completed Pre-startup Checklist. This checklist requires that a review be made of the equipment and controls to assure that the system will perform safely and as expected. This would include testing of blower alignment and rotation, control circuits, alarm settings and operation. Verify items on the checklist with the contractor, if possible.

(2) Start-Up Monitoring Plan. This plan identifies procedures for initial start-up of the system including step-by-step procedures for valve settings, circuit checks and energizing, and monitoring.

(3) Start-up monitoring results. These results must be provided within the time required by the specifications or the regulators.

(4) Operations and Maintenance Plan.

(5) Air Discharge Permit. The requirements for obtaining an air discharge permit vary by project and by state. Verify coordination with applicable regulatory agencies prior to startup. Such coordination is best started during design.

e. Related Requirements. Consult other Quality Assurance Representative Guides for ground water extraction well installation (if water extraction is conducted jointly with soil vapor extraction), piping systems, underground utility systems, and ventilation, air supply and distribution systems.

f. Site Evaluation.

(1) Other Contaminant Sources. Evaluate the potential for other nearby contaminant sources or air-flow pathways prior to initiation of construction. These can include building basements, utility corridors, industrial shops, aboveground/underground fuel (or waste oil, solvent) storage tanks. Alert the designer to any such condition that was not considered in design.

(2) Power Supply. Verify that adequate utility services (e.g. electrical power) are available for the equipment.

(3) Noise. Identify any constraints on the acceptable noise levels at the site. This may require use of silencers or equipment housings.

6-2. PRODUCTS.

a. Above-Ground Equipment. There are several above-ground components in a soil vapor extraction system. These may be specified separately or as a package system. If specified as a package system, there may be overall requirements for total pressure drop; air throughput; electrical phase, current draw, voltage; and maximum inlet vacuum/pressure. There may be specifications for specific components of the package system as well. Specifications must be carefully reviewed prior to approving use of a package system. Verify that equipment installed is consistent with the contract documents and catalog information submitted prior to construction.

(1) Blower/Motor. SVE requires a blower or vacuum pump typically driven by electric motor. Compliance with the specifications for type and size of blower, motor rating and horsepower, or vacuum/pressure range and airflow rate must be assured. The motor must be appropriately rated for the area classification.

(2) Condensate Tank. The condensate tank must meet specifications, particularly for capacity, pressure/vacuum rating, construction, and level sensors. Verify that the tank has a suitable means to drain condensate. Confirm that any rental equipment is empty and was cleaned following the last use.

(3) Particulate Filter. Verify that the particulate filter meets specifications for type, pressure drop, and filter size or removal efficiency.

(4) Silencers. Silencers must meet specification for flow capacity and noise reduction in the frequency range emitted by the blower.

(5) Piping. All piping for above- and below-grade installation must meet specifications for material, diameter, schedule, and joints. Piping may be installed above ground. If PVC or other plastic piping is installed above ground, verify that the piping is resistant to degradation from sunlight.

(6) Off-gas Treatment Equipment. Not covered here.

b. Below-Ground Equipment.

(1) Screen. Verify that well screen slot type, slot size and shape meet specified requirements. Also verify material composition and wall thickness are consistent with the specifications. Well screen should be new and cleaned and wrapped at the factory. On-site storage should be in a clean, safe location where the screen will not be damaged by other equipment.

(2) Casing. Verify that well casing schedule and material meet specified requirements. Assure that joints can be made air-tight. Well casing should be new and cleaned and wrapped at the factory. On-site storage should be in a clean, safe location where it will not be damaged by other equipment.

(3) Filter Pack. The filter pack must meet the specified requirements gradation. If none is given, check that the filter pack is uniform sand or gravel of gradation large enough to prevent entry of the pack through the screen slots. Uniform means it has a uniformity coefficient of 2.5 or less. The uniformity coefficient is the sieve aperture passing 60 percent of the material divided by the sieve aperture passing 10 percent of the material.

(4) Well Seal. Bentonite used for well seals must be sodium type and provided in the form required by the specifications; dry powder is not appropriate for bentonite seal installation. Pellets or granules are preferred for bentonite seals. Bentonite powder is acceptable for use in cement-bentonite grout. Cement must meet specified requirements for type and must be mixed with the appropriate amount of water. In the absence of a specified mix, allow the use of 26-35 liters (6-8 gallons) of water to one 43 kg (94 pound) bag of cement. Bentonite may be mixed with the cement to reduce shrinkage. If not specified, allow a 3-5 percent addition of bentonite in the cement by weight. The bentonite powder should be mixed with the water before adding the cement to assure adequate mixing.

(5) Well vaults. Assure compliance with specification. Verify consistent diameters of vault penetrations with associated casing, piping, or utility conduits. Vault covers must be appropriate for traffic conditions if flush-mounted. Assure that adequate means of opening large vault covers are provided.

(6) Piping. Piping must meet requirements for schedule, diameter, and joints. Above-ground piping must be UV resistant.

6-3. EXECUTION.

a. Installation.

(1) Wells. Well installation is difficult to evaluate after the wells are completed. Direct oversight of installation process is recommended.

(a) Permits. Confirm that the necessary notifications/drilling permits have been obtained from the installation, State, County or appropriate agency before any drilling commences.

(b) Utility Clearances. Check that all utility clearances have been received for the subsurface work and that there are no overhead hazards that will interfere with raising or lowering the drill mast.

(c) Decontamination. Well drilling equipment must be decontaminated prior to use on the site and between boreholes.

(d) Locations. Verify that the drilling location conforms to the specifications. If it is impossible to install the wells in a specified location, determine the best alternative location that meets the requirements of the design. If there are any questions as to the design goals or a possible location, contact the project designer to confirm a new location.

(e) Borehole Diameter. Borehole diameter must meet specifications. In the absence of a specified size, require boreholes 4 inches in diameter larger than specified well screen and casing. If the well or monitoring point is placed by direct push methods, no requirement for borehole size is applicable.

(f) Borehole Depth. Borehole depth must either meet specification or achieve the objective. Depths are often tailored in the field based on conditions encountered. Instructions to the field from the designer must clearly identify the objectives of the wells. If there is any doubt about the adequacy of the borehole depth, contact the designer.

(g) Safety. Confirm that safe drilling procedures are used and that an exclusion zone is well defined around the drill rig. Also determine that required safety equipment is present and that it is operated in accordance with the requirements of the SSHP.

(h) Cuttings Disposal. If required, confirm that all drill cuttings and or liquids are drummed and disposed of in accordance with the approved work plan.

(i) Sampling and Logging. Adequate logs must be made by a qualified geologist or engineer of the materials encountered. Soil sampling should be performed to support the logging. Verify that soil samples are obtained for chemical analysis as directed by the sampling and analysis plan. Chemical samples provide a baseline contaminant level against which later sample results obtained following operation can be compared. Such samples are more appropriately obtained from monitoring points rather than extraction wells since soils at the extraction wells will be subjected to the most intense remediation and are not representative of the majority of soils at the site.

(j) Screen and Casing Placement. Length of screen and casing must match specified requirements. Verify that joints are air-tight

and secure. Screen and casing must be suspended in the hole to assure proper alignment. Centralizers may also be required.

(k) Filter Pack Placement. Filter pack should be placed dry via a tremie pipe. Pack material must be kept clean. Verify depth to pack after placement to assure adequate thickness.

(l) Seal and Grout Placement.

- Place bentonite seal materials dry via tremie pipe, unless placement depth is less than 10 feet.
- Verify proper thickness and location of bentonite. Bentonite must not be placed in the screened interval.
- Bentonite seal must be adequately hydrated with clean or distilled water. Hydration must be conducted for a period of time and by a method meeting the specifications. In the absence of specified requirements, hydration must be allowed for a minimum of 1 hour and a maximum of 4 hours prior to placement of the grout.
- Grout must be placed by tremie pipe submerged in the grout until the grout flows to the surface.
- Require the contractor to "top off" the grout as exfiltration causes the grout to settle.

(m) Wellhead Completion and Vault Placement. Well vault placement depends on the type of vault. The contractor must use care to avoid damage to well casing during vault placement. Below-grade completions must prevent surface water from running in. Open drain holes are not compatible with air-tight surface seal requirements.

(n) Surveys. Well locations and elevations must be surveyed. Wells are typically surveyed to the nearest 1 foot horizontally and .01 foot vertically.

(2) Collection Trenches and Below-Grade Piping. Underground piping installation requirements are covered in detail in Volume 1, General Information and Site Work. General guidance is provided here. Normal excavation techniques are assumed; use of pipe jacking, directional drilling, or trenching/pipe laying machines have other requirements not covered here.

(a) Trench Dimensions. The trench width is typically 610 mm (24 inches) plus pipe diameter.

(b) Trench Bottom Preparation and Pipe Placement. Thrust blocking is typically not required for air conveyance piping. Proper preparation and placement includes the following steps:

- level to required grade to promote drainage of condensate or other liquids;
- remove rocks and angular debris from the subgrade;
- scarify trench bottom and lower sides if trench is to be used as a collection (not utility) trench and ensure excessive mud/clay smeared on trench surfaces is removed;
- install screen and piping in manner minimizing debris in

the lines;

- prevent surface water from running in;
- join pipe and/or screen in a manner consistent with material and manufacturer's instructions; and
- comply with all safety requirements.

(c) Access Port. An access port to allow later survey or measurement should be required in collection trenches. Verify that no fitting or joint will prohibit survey or maintenance equipment from accessing the piping.

(d) Trench Spoil Disposal. Verify that potentially contaminated soils excavated from the trench are appropriately stockpiled and disposed of in accordance with the specifications and/or regulation.

(e) Filter Pack/Backfill Placement. Filter pack or coarse bedding material as required by the specifications should be placed in the trench before piping/screen placement. Filter pack should be placed at least 150 mm (6 inches) above the pipe prior to any compaction for typical 100 mm (4 inch) diameter PVC schedule 40 pipe/screen. Larger diameters or weaker pipe material may require more cover prior to compaction. Remainder of specified backfill must be compacted to required density in the prescribed lifts. If lift thickness is not specified, allow up to 200 mm (8 inch) lifts.

(f) Cleaning. Contractor should blow all debris from the lines prior to start-up. Debris must not be blown into the screen or condensate tank.

(3) Above-Ground Equipment and Piping. Volume 4, Special Construction, Conveying Systems, Mechanical, and Electrical Features covers many of the electrical, above ground piping, and air handling systems which are applicable to soil vapor extraction. General guidance is provided here. A project-specific Pre-startup Checklist is recommended to assure that all components are properly installed.

(a) Blowers. Blowers must be:

- vibration isolated;
- aligned with drive motors;
- checked for rotation direction;
- inspected for appropriate guards, housing, and shields, as per manufacturer’s recommendation and safety requirements; and
- lubricated in accordance with manufacturer's requirements.

(b) Above-Ground Piping and Valves. Above ground piping must be:

- protected from UV degradation if not inherently resistant;
- protected from traffic or vandalism;
- cleaned of all debris;

- suitably supported and anchored;
- securely joined by air tight connections, including flexible connections;
- sloped to drain/collect condensate; and
- checked for proper valve operation.

Flow control valves must be provided at each trench header pipe or well head. Verify clear access to all valve boxes.

(c) Condensate Knock-outs, Particulate Filter, and Relief Valves. Verify:

- condensate tank has proper connection to air piping and drain line, or if the drain is not connected that the valve is shut;
- easy access is provided to condensate tank drain and particulate filter;
- particulate filter is equipped with the specified filter;
- vacuum relief valve is provided upstream of the blower and pressure relief valve is provided downstream and both operate properly; and
- all connections are tight.

(d) Electrical, Control and Instrumentation System. Verify:

- gauges are calibrated, provided in specified locations and have ranges that are appropriate for conditions expected;
- gauges should read in the middle 50 percent of range during operation;
- electrical continuity and appropriate grounding is provided for equipment operation and lighting;
- electrical connections are placed according to the plans and specifications. Also verify the connections are securely made and insulated;
- shut down controls and alarms function as required; and
- process control logic is consistent with contract documents.

b. Tests.

(1) Leak Tests.

(a) Piping should be checked for leaks using either a hydrostatic, air-pressure, or vacuum tests. Ensure valves are closed at all well-heads and at the blower. If leakage is discovered, verify the tightness of each connection.

(b) Well short-circuiting is difficult to verify. Look for drastically lower than expected well head vacuum at design flow

rates, or pressurize well, wet area around well head with soapy solution and observe any bubbling indicating air leakage around casing or well head.

(2) Soil Testing.

(a) Confirmatory QC or QA gradation tests on filter pack or bedding material may be required. If testing procedures are not specified, require ASTM D 422, Particle Size Analysis of Soils.

(b) Density testing of trench backfill above the filter pack may be required to ensure the backfill provides an air-tight seal. Compaction testing to determine maximum density and optimum moisture should follow ASTM D 698, Testing Method for Laboratory Compaction Characteristics of Soil Using Standard Effort. In-place density testing should be measured using ASTM D 2922 (Nuclear Density Gauge Method), ASTM D 1556 (Sand Cone Method), and/or ASTM D 2167 (Rubber Balloon Method).

(3) System Checks. A start-up checklist should be completed prior to operating the system. This requires tests of electrical, control, and instrumentation systems. See paragraphs above for additional detail.

c. Start-up. Start-up procedures are very site-specific. Refer to Chapter 7, Start-Up Requirements, EM 1110-1-4001, Soil Vapor Extraction and Bioventing for a discussion of start-up strategy and procedures. The start-up process can take days to weeks and is often dependent on the "fine tuning" of off-gas treatment equipment.

(1) System Operator Qualifications. The qualifications of the operator in charge of start-up should be reviewed for adequate experience and education on the type of equipment used at the site. Note that the “operator” may be the construction contractor or a subcontractor or may be hired as a separate contractor.

(2) Pre-Startup Checklist. The pre-startup checklist must be carefully followed to assure that the equipment is properly installed and wired prior to start-up. Appropriate valve settings must be checked prior to blower start to assure air flow to the blower.

(3) Start-up.

(a) Start-up should be initiated with the atmospheric air bleed valve fully open. Once blower(s) are started, these can be incrementally closed to draw in subsurface air without risk to the blower(s).

(b) The operator must monitor all flow rates and vacuums at individual wells and at blower inlet and outlet and compare to design assumptions. The operator must then balance flow based on system objectives and subsurface response. Verify that all gauges are reading in an acceptable range. If not, the contractor should replace gauges as necessary.

(c) Operator must check for plugging of particulate filters and collection of condensate soon after the system is started, particularly if there was the possibility of debris or moisture in the line.

(d) Vacuum (or pressure) response at monitoring points should be recorded at system start-up to verify proper well operation and to

estimate air permeability. These data should be compared to design assumptions and should be used as a basis for deciding when steady-state flow conditions are reached. Steady-state flow is necessary to complete start-up.

(e) Temperatures upstream and downstream of the blower(s) should be observed for abnormal rise. Blower motor current draw should also be noted for comparison to motor specifications. Any indication of abnormal conditions may be basis for blower shutdown and system repair or adjustment.

(f) Chemical sampling of soil, extracted soil gas, and/or condensate should be performed as required for determining treatment system performance. Verify that sampling is done according to the approved contractor Chemical Data Quality Management Plan.

(g) Start-up Report. A report documenting all monitoring and sampling results should be prepared.

d. Operation and Maintenance. It is important for QA Representatives overseeing contractor operations to understand the basic principles of soil vapor extraction and the project objectives. Proper operation of the system is as critical as proper construction. Construction personnel often are responsible for overseeing a year or more of operation.

(1) Refer to the Soil Vapor Extraction and Bioventing Engineer Manual, EM 1110-1-4001, Chapter 8, Operations and Maintenance for further information.

(2) Verify that all equipment is maintained in accordance with the vendor's requirements.

(3) Condensate recovery and disposal must be done in accordance with applicable specification requirements and regulations.

(4) Check particulate filters for plugging (most likely only a problem early in the system operation).

(5) Monitor air flow rate (flow from each well and total flow), well head vacuum, monitoring point vacuums, blower inlet and outlet temperatures, blower amperage, water table response (water levels), and vapor concentrations (contaminants, oxygen, etc. from each well and before and after treatment) as required by the O&M plan. Refer to EM 1110-1-4001 for more information.

(6) Operational strategy is very site specific. In some cases, as the contaminant concentrations go down, cycling the operation of wells may allow more efficient use of the blower. In other cases, the flow rate from wells may be reduced as contaminant concentrations diminish. For petroleum contaminated sites, a conversion from soil vapor extraction to bioventing may be appropriate after contaminant removal rates drop.

(7) High fuel vapor concentrations in the extracted air can result in potentially explosive conditions or operating problems for the off-gas treatment system. High fuel vapor concentrations may require bleeding in of atmospheric air through a relief valve.

(8) Maintain adequate records of the data collected.