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LOAN DOCUMENT

Part I

Bioventing Pilot Test Work Plan for Site FT40 and Site FT41 Dyess AFB, Texas

Part II

Draft Interim Pilot Test Results Report for Site FT40 and Site FT41 Dyess AFB, Texas

Prepared for

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

Dyess Air Force Base
Abilene, Texas

March 1994

ES ENGINEERING-SCIENCE

722408

AQM01-03-0521

ENGINEERING-SCIENCE, INC.

8000 Centre Park Drive, Suite 200 • Austin, Texas 78754 • (512) 719-6000 • Fax: (512) 719-6099

March 16, 1994

Via Federal Express

Marty Faile
AFCEE/EST
2504 D Drive, Suite 3
Brooks AFB, TX 78235-5103

Dear Mr. Faile:

Attached please find three draft copies of the Dyess AFB draft bioventing pilot test results interim report. A copy has also been provided to Jeff Brewer of Dyess AFB.

If you should have any questions regarding this report, or on the progress of the Dyess AFB continuing bioventing pilot test activities, please call Brian Vanderglas in the Engineering-Science Austin office at (512) 719-6000, or myself in the Denver office at (303) 831-8100.

Sincerely,

Brian Vanderglas for

Douglas C. Downey
Project Manager

xc: Brian Vanderglas, ES Austin

Part I
Bioventing Pilot Test Work Plan for Site FT40 and Site FT41 Dyess AFB, Texas

Prepared for

Air Force Center for Environmental Excellence
Brooks AFB, Texas
and

Dyess Air Force Base
Abilene, Texas

Prepared by

Engineering-Science, Inc.
Austin, Texas

March 1994

CONTENTS

FIGURES

BIOVENTING PILOT TEST WORK PLAN FOR SITE FT40 AND SITE FT41 DYESS AFB, TEXAS

1.0 INTRODUCTION

This work plan presents the scope of multi-phase bioventing pilot tests for *in situ* treatment of fuel-contaminated soils at site FT40 and site FT41 at Dyess Air Force Base (AFB), Texas. Both sites are located at offbase transmitter and receiver buildings, respectively. The pilot tests will be performed by Engineering-Science, Inc. (ES). The three primary objectives of the proposed pilot tests are: 1) to assess the potential for supplying oxygen throughout the contaminated soil interval, 2) to determine the rate at which indigenous microorganisms will degrade fuel when supplied with oxygen-rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated to concentrations below regulatory standards.

The pilot tests will be conducted in two phases. A vent well (VW) and vapor monitoring points (MPs) will be installed during site investigation activities. The initial test phase at each site will also include an *in situ* respiration test, an air permeability test, and installation of a blower system for air injection. This initial testing is expected to take approximately 2 weeks. If the initial phase is successful, the second phase will begin immediately. During the second phase, the bioventing systems will be operated and monitored over a 1-year period.

If bioventing proves to be an effective means of remediating soil contamination at these sites, pilot test data may be used to design full-scale remediation systems and to estimate the time required for site cleanup. An added benefit of the pilot testing at site FT40 and site FT41 is that a significant amount of the fuel contamination should be biodegraded during the 1-year pilot test, as the testing will take place within the most contaminated soils at the sites. Additional background information on the development and recent success of the bioventing technology is found in the document entitled *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee et al., 1992). This protocol document will serve as the primary reference for pilot test well designs and the detailed procedures to be used during the test.

2.0 SITE DESCRIPTION

2.1 Site FT-40 Underground Diesel Tank Removal at Building 1001

2.1.1 Site History and Location

As shown on Figure 2.1, site FT40 is located ½ mile to the west of Dyess AFB, Texas, adjacent to building 1001 in the transmitter annex facility. A 1,000-gallon underground storage tank (UST) was constructed at the site in 1956 and was reportedly abandoned in 1970. The tank was reportedly used for storage of heating fuel oil (Dyess AFB 7CES/CEV, 1993). Releases from the tank were observed during the UST removal in 1991. During the removal, soil around the tank was excavated to a depth of about 9 feet. Soil samples obtained from the sides and bottom of the excavation and visual observations indicated that contamination may extend beyond the limits of the excavation and underneath the transmitter building (building 1001). Further excavation could not be continued due to the presence of the existing facility and power line support structures.

A thin plastic liner was placed in the excavated pit prior to backfilling with clean fill material. This plastic will act as a barrier to air flow and may adversely affect the ability of the blower system to supply air to contaminated soils on the side opposite of where the VW is constructed. The plastic barrier and clean fill material are taken into consideration in selecting the placement of pilot test VWs and MPs.

2.1.2 Site Geology

Information concerning the geology is fairly limited and comes from a communications with Kevin Wonder of Woodward-Clyde who drilled and sampled four borings at the site (Wonder, 1993). The soils were observed to be very dry, predominantly silty clay with very little gravel. Shale was encountered at approximately 14 to 15 feet below grade. No groundwater or evidence of a water producing zone was encountered in any of the soil borings.

2.1.3 Site Contaminants

Seven soil samples were recently collected and analyzed from the four borings drilled at the site (Wonder, 1993) and soil samples were collected and analyzed from the sides and bottom of the excavation during tank removal (Dyess AFB, 1993). Total petroleum hydrocarbon (TPH) levels ranged up to 24,200 parts per million (ppm) in the sidewall sample collected nearest building 1001. Visual evidence also suggests that contaminated soils extend beneath the facility. Results from soil boring samples collected from borings drilled on each side of the building indicated TPH levels ranging from nondetect to 630 ppm (Dyess AFB, 1993). A soil gas survey will need to be performed prior to pilot system placement to assure VW construction in the most oxygen depleted areas.

2.2 Site FT41 Underground Diesel Tank Removal at Building 2001

2.2.1 History and Location

Site FT41 is located 1 mile west of Dyess AFB, Texas, adjacent to building 2001 in the receiver annex facility, as shown on Figure 2.1. A 1,000-gallon UST was constructed at the site and was later abandoned inplace in 1970. The tank was

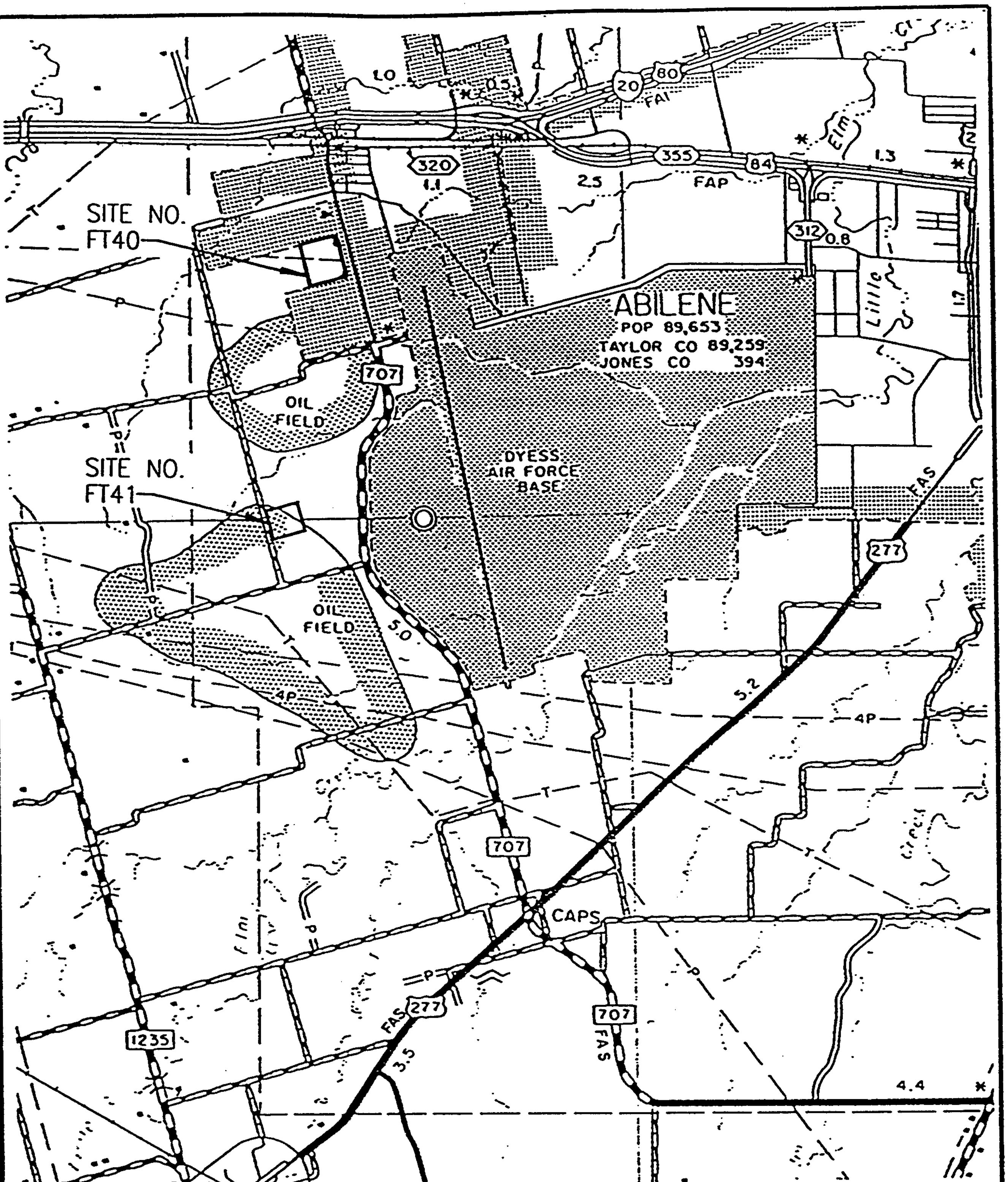

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FIGURE 2.1
FT40 AND FT41
SITE LOCATIONS

DYESS AIR FORCE BASE
ABILENE, TEXS

DYESTBLK 11/04/93

reportedly used for storage of heating fuel oil (Dyess AFB, 1993). Releases from the tank were observed during the 1991 UST removal. During the removal, the soil around the tank was excavated to a depth of about 8 feet. Soil samples collected from the sides and bottom of the excavation were tested for TPH. TPH levels ranged up to 2,860 ppm (Dyess AFB, 1993). Visual observations during excavation activities also indicated that the contamination may extend underneath building 2001. Further excavation was discontinued due to the presence of existing structures at the site.

A thin plastic liner was placed in the excavated pit prior to backfilling with clean fill material. This plastic will act as a barrier to subsurface air flow and may adversely affect the ability of the blower system to aerate contaminated soils on the sides opposite where the vent well is constructed. This plastic barrier will be considered when designing the pilot test system.

2.2.2 Site Geology

The geology of site FT41 is similar to that of FT40 (section 2.1.2). These soils were very dry, silty clays with little to no gravel. Shale was encountered at approximately 14 feet. No groundwater or evidence of water-producing zones were indicated during drilling of three soil borings around building 2001 (Wonder, 1993).

2.2.3 Site Contaminants

Eleven soils samples were recently collected and analyzed from the sides and bottom of the UST excavation during tank removal activities (Dyess AFB, 1993). TPH levels ranged up to 2,860 ppm in the side wall samples, and ranged from nondetect to 920 ppm in the soil boring samples (Dyess AFB, 1993). Visual evidence also suggests that contaminated soils extend beneath the facility. A soil gas survey will need to be performed prior to drilling to verify pilot system placement to assure construction in the most oxygen depleted areas.

3.0 PILOT TEST ACTIVITIES

The purpose of this section is to describe the pilot test activities to take place at site FT40 and site FT41. The proposed locations and construction details for the central VWs and vapor MPs are discussed. Criteria for locating a suitable background well position are outlined. Soil and soil gas sampling procedures and the blower configuration that will be used to inject air (oxygen) into contaminated soils are also discussed in this section. Finally, a brief description of the pilot test procedures is provided.

The bioventing technology is intended to remediate contamination only in the unsaturated zone. Therefore, pilot test activities will be confined to unsaturated soils. Groundwater has not been encountered in previous borings to bedrock. Additionally, before beginning drilling, a soil gas survey may be performed to locate the most contaminated and therefore most oxygen depleted area of the sites for placement of the pilot test system.

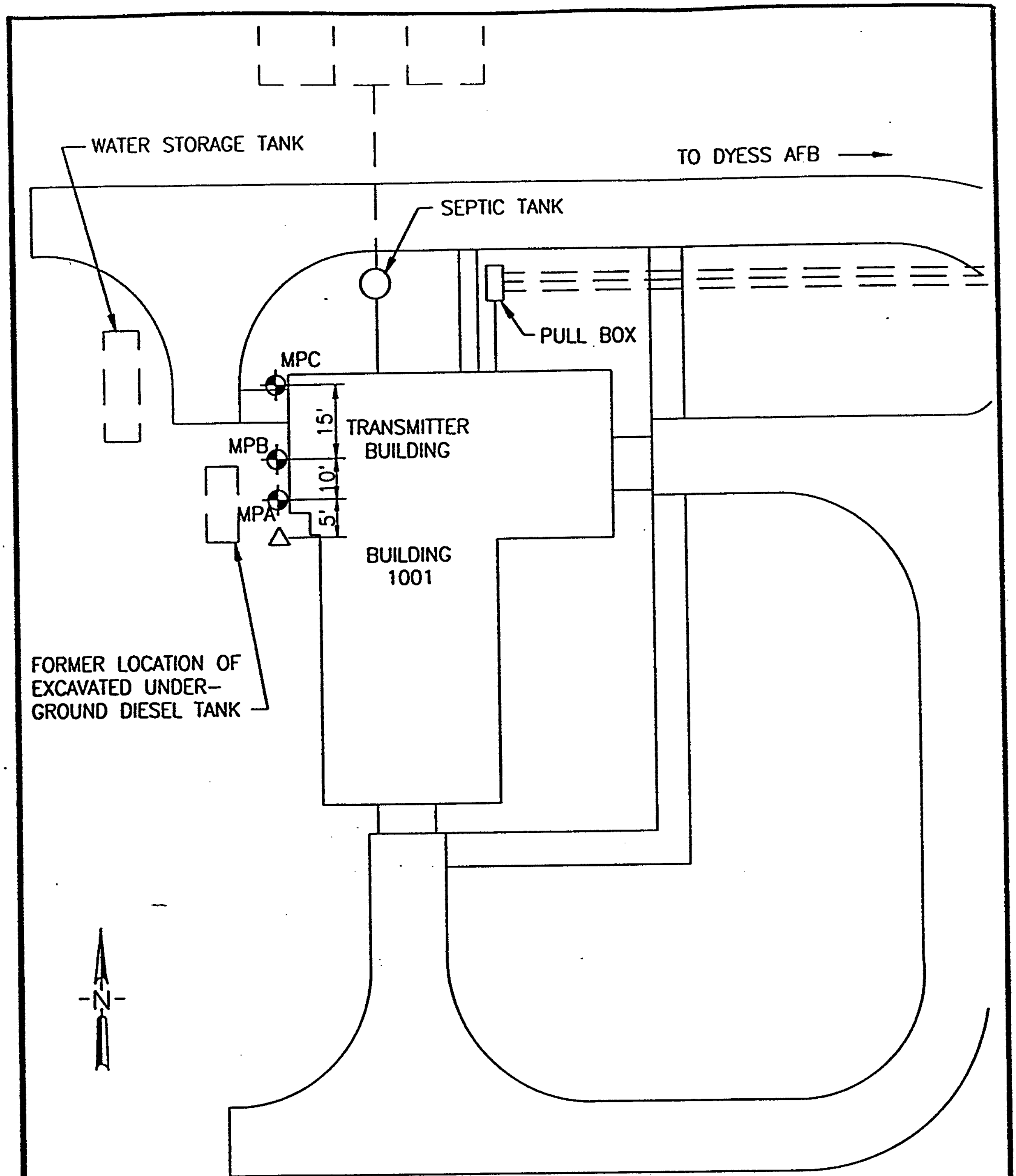
3.1 Bioventing Test Design for Site FT40

A general description of criteria for siting a central VW and vapor MPs is included in the protocol document (Hinchee et al., 1992). Figure 3.1 illustrates the proposed locations of the central VW and MPs at this site. The final locations may vary slightly from the proposed locations if significant fuel contamination is not observed in the boring for the central VW. The proposed VW and MP configuration will allow for testing along the building, where the greatest contamination concentrations were encountered. Soils in this area are expected to be TPH contaminated and oxygen depleted (<2%), and biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations. Effectiveness at providing air to the points at depths below the depth of the plastic lining will indicate the likelihood of aerating soils on the opposite side of the plastic barrier.

Due to the relatively shallow depth of contamination at this site and the potential for low-permeability soils, the potential radius of venting influence around the central VW is expected to be 20 to 30 feet. Three vapor MPs (MPA, MPB, and MPC) will be located within a 30-foot radius of the central VW.

The VW will be constructed of 4-inch-diameter schedule 40 polyvinyl chloride (PVC) casing, with a 10-foot interval of 0.04-inch slotted screen set at 6 to 16 feet bgs. Flush-threaded PVC casing and screen with no organic solvents or glues will be used. The filter pack will be clean, well-rounded silica sand with a 6 to 9 grain size and will be placed in the annular space to 1 foot above the screened interval. A 3-foot layer of bentonite will be placed directly over the filter pack. The first 6 inches of bentonite will consist of bentonite pellets hydrated in place with potable water. This layer of pellets will prevent the addition of bentonite slurry from saturating the filter pack. The remaining 30 inches of bentonite will be fully hydrated and mixed aboveground, and the slurry will be placed into the annular space to produce an air-tight seal above the screened interval. The borehole will then be completed to the ground surface with a bentonite/cement grout. A complete seal is critical to prevent injected air from short-circuiting to the surface during the bioventing test. Figure 3.2 illustrates the proposed central VW construction detail for this site.

A typical multi-depth vapor MP installation for this site is shown in Figure 3.3. Soil gas oxygen and carbon dioxide concentrations will be monitored at depths of 4 to 5 feet, 8 to 9 feet, and 12 to 13 feet at each location. These intervals may be changed depending on the depth of contamination and plastic liner placement in the backfilled trench. Multi-depth monitoring will confirm that the entire soil profile is receiving oxygen and will be used to measure fuel biodegradation rates at the three depths. The annular spaces between the three screened MP intervals will be sealed with bentonite to isolate the monitoring intervals. As with the central VW, several inches of bentonite pellets will be used to shield the filter pack from rapid



LEGEND

△ PROPOSED VENT WELL

MPA PROPOSED MONITORING POINT

SOURCE: DYESS AFB, TEXAS

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FIGURE 3.1
SITE FT40
PROPOSED VENT WELL/
MONITORING POINT LOCATIONS

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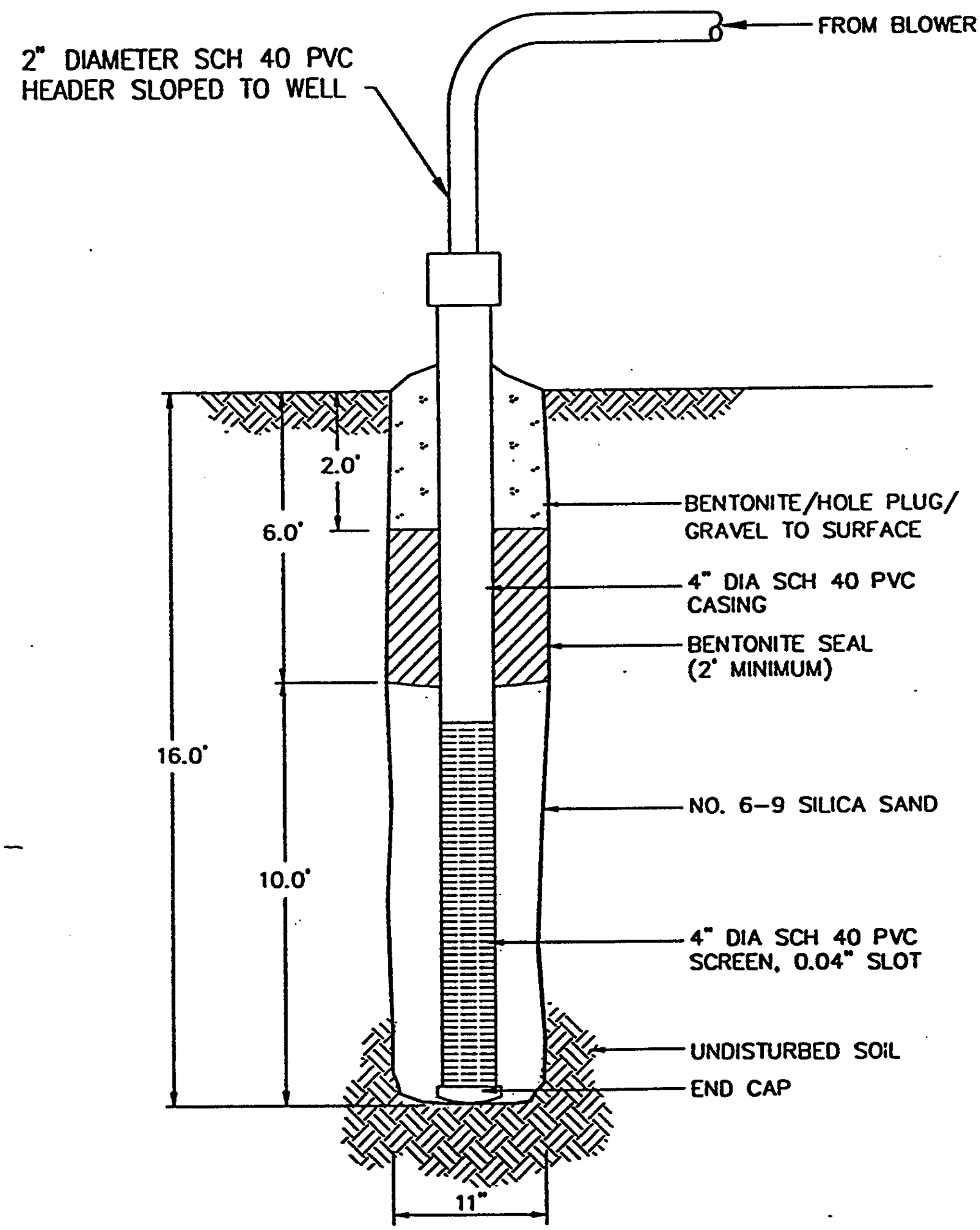

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FIGURE 3.2
PROPOSED INJECTION VENT
WELL CONSTRUCTION DETAIL
SITES FT40 AND FT41

DYESS AIR FORCE BASE
ABILENE, TEXAS

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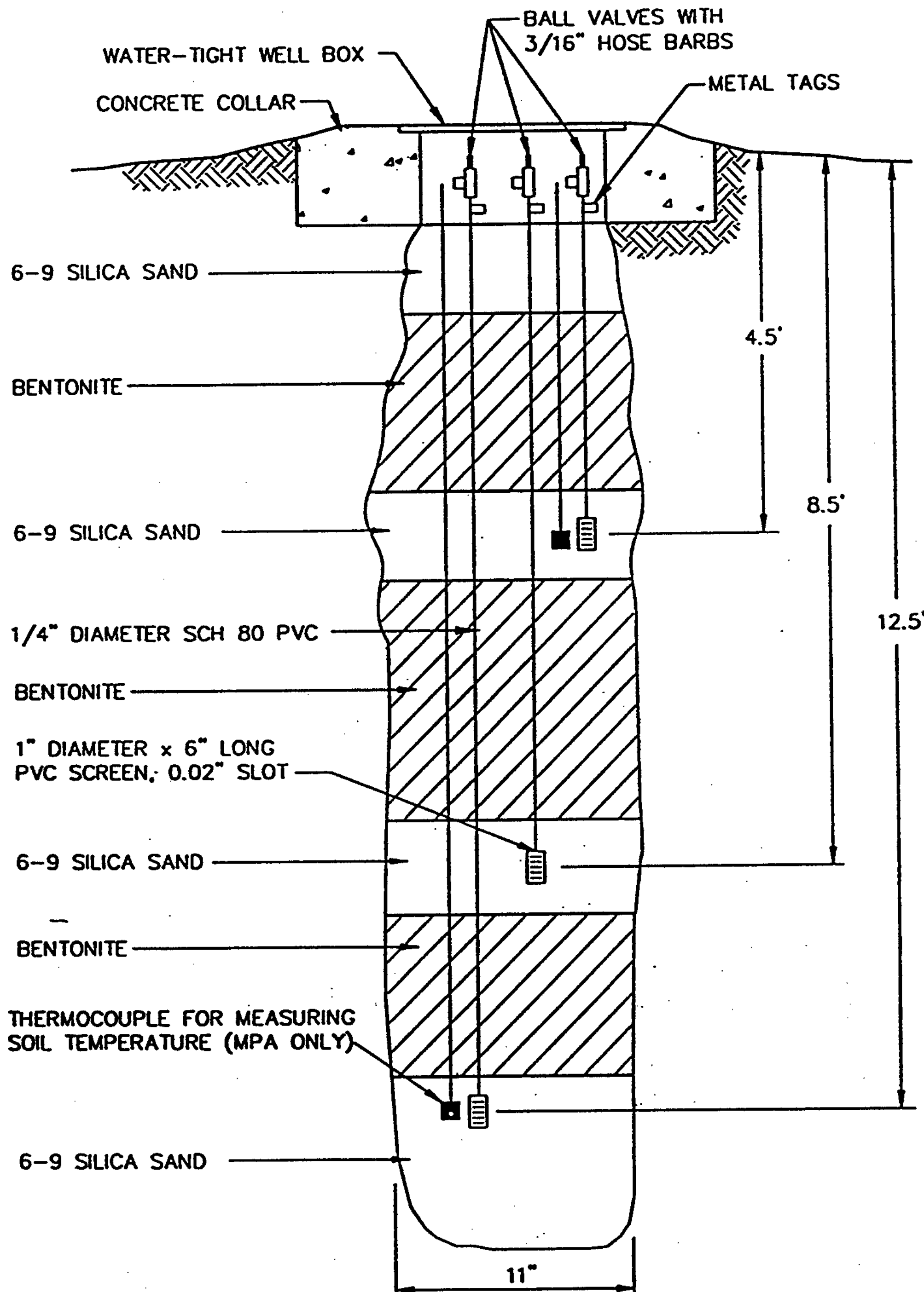

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FIGURE 3.3
PROPOSED MONITORING POINT
CONSTRUCTION DETAIL
SITES FT40 AND FT41

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ABILENE, TEXAS

DETLDYES 11/04/93

infiltration of bentonite slurry additions. Thermocouples will be installed at 4- to 5-foot and 12- to 13-foot depths on MPA to measure soil temperature. Additional details on VW and MP construction are presented in section 4 of the protocol document (Hinchee et al., 1992). If possible, all MP locations will be outside of the trench backfilled with clean fill, since this soil will not be oxygen depleted. In addition, the plastic sheets placed in the trench to separate clean fill from contaminated soils remaining in the trench will act as a barrier to air flow to soils on opposite sides of the vent well.

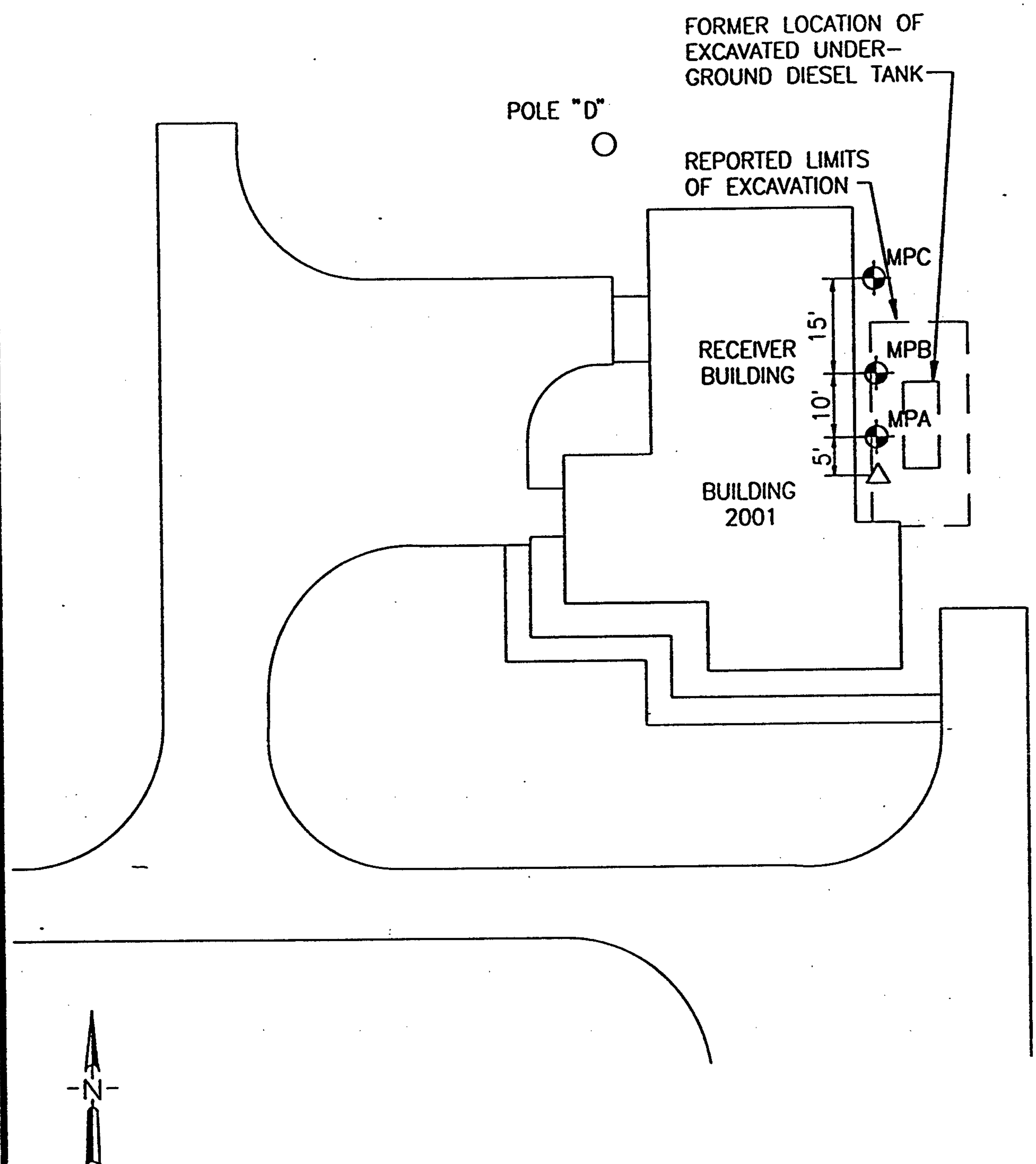
3.2 Site FT41

Figure 3.4 illustrates the proposed locations of the central VW and MPs at this site. The final locations may vary slightly from those proposed if significant fuel contamination is not observed in the boring for the central VW. The VW and MP configuration tentatively selected will allow for testing along the building where the greatest contamination concentrations were encountered. Effectiveness of aerating soils on the opposite side of the plastic can be assessed by measuring the effectiveness of aerating soils at depths below the plastic lining in the pilot test line. Soils in this area are expected to have an average TPH concentration exceeding 1,000 mg/kg, and to be oxygen depleted (<2%). Biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Due to the relatively shallow depth of contamination at this site and the potential for low-permeability soils, the potential radius of influence around the central VW is expected to be 20 to 30 feet. Three vapor MPs (MPA1, MPA2, and MPA3) will be located within a 30-foot radius of the central VW.

The VW will be constructed of 4-inch-diameter schedule 40 PVC, with a 10-foot interval of 0.04-inch slotted screen set at 6 to 16 feet bgs (Figure 3.2). Flush-threaded PVC casing and screen with no organic solvents or glues will be used. The filter pack will be clean, well-rounded silica sand with a 6 to 9 grain size and will be placed in the annular space to 1 foot above the screened interval. A 3-foot layer of bentonite will be placed directly over the filter pack. The first 6 inches of bentonite will consist of bentonite pellets hydrated in place with potable water. This layer of pellets will prevent the rapid addition of bentonite slurry from saturating the upper portion of the filter pack. The remaining 30 inches of bentonite will be fully hydrated and mixed aboveground, and then tremmied into the annular space to produce an air-tight seal above the screened interval that will prevent injected air from short-circuiting to the surface during the bioventing test. The well will be completed to the ground surface with a bentonite/cement grout. Figure 3.2 illustrates the proposed central VW construction for this site.

A typical multi-depth vapor MP installation design for this site is shown in Figure 3.3. Soil gas oxygen and carbon dioxide concentrations will be monitored at depth intervals of 4 to 5 feet, 8 to 9 feet, and 12 to 13 feet at each location. These intervals may be adjusted depending on the depth of the plastic liner placed in the trench beneath the clean fill material. Multi-depth monitoring will confirm that the entire soil profile is receiving oxygen, and will be used to measure fuel biodegradation rates at each depth. The annular spaces between the three



LEGEND

△ PROPOSED VENT WELL

MPA PROPOSED MONITORING POINT

SOURCE: DYESS AFB, TEXAS

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ES

FIGURE 3.4
SITE FT41
PROPOSED VENT WELL/
MONITORING POINT LOCATIONS

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ABILENE, TEXAS

DYEFT41 11/05/93

monitoring intervals in each MP will be sealed with bentonite to isolate the intervals. As in the central VW, several inches of bentonite pellets will be used to shield the filter pack from rapid infiltration of bentonite slurry additions. Thermocouples will be installed at the 4- to 5-foot and 12- to 13-foot depth on MPA1 to measure soil temperature. Additional details on VW and MP construction are provided in section 4 of the protocol document.

3.3 Background Well

The construction of an additional vapor MP (MPBG) will be required to measure background levels of oxygen and carbon dioxide and to determine if natural carbon sources are contributing to oxygen uptake during the *in situ* respiration test described in section 3.7. This background well would be installed in an area of uncontaminated soil and in the same stratigraphic formation as the VWs and MPs to be installed at sites FT40 and FT41. The background well would be similar in construction to the MPs (Figure 3.3), and would be screened at three depths. ES may require some assistance from Dyess AFB in selecting an appropriate location for the proposed background well.

Existing monitoring wells located in the vicinity of the two sites may be used as a potential background well because it is partially screened above the water table and located in an apparently uncontaminated area. If initial soil gas samples indicate that any monitoring well in the vicinity of the sites does not contain hydrocarbon contamination, and the samples contain oxygen in excess of 15 percent, it may be selected as a background MP.

3.4 Handling of Investigation Derived Waste

3.4.1 Drill Cuttings

Drill cuttings from all VW and MP borings will be collected and placed in the existing piles of excavated material still present at each site. These drill cuttings will become the responsibility of Dyess AFB, and will be handled, and disposed of in accordance with the current procedures used for the existing piles of excavated soils.

3.4.2 Decontamination Waters

Decontamination waters generated during cleaning of the augers and sampling tools will be collected in temporary decontamination pads or containment vessels. Decontamination waters will be transferred to 55-gallon drums for temporary storage on site.

3.5 Soil and Soil Gas Sampling

3.5.1 Soil Samples

Three soil samples will be collected from each pilot test area during the installation of the VW and MPs. Sampling procedures will follow those outlined in the protocol document. One sample will be collected from the most contaminated interval of each VW boring, and one sample will be collected from the interval of highest apparent contamination in each of the borings for the two MPs closest to the VW. Soil samples will be analyzed for TPH, benzene, toluene, ethyl benzene, and xylenes (BTEX), soil moisture, pH, particle sizing, alkalinity, total iron, and nutrients. One sample will be collected from the background MP boring and analyzed for total Kjeldahl nitrogen (TKN).

Samples for TPH and BTEX analysis will be collected by hand with stainless steel sampling spoons or using a split-spoon sampler containing brass tube liners. Soil samples collected in the brass tubes for TPH and BTEX analyses will be immediately trimmed, and the ends will be sealed with aluminum foil or Teflon® fabric held in place by plastic caps. Hand collected samples will be immediately placed in glass bottles with Teflon-lined lids. Soil samples collected for physical parameter analyses will be placed in glass sample jars or other appropriate sample containers specified in the base sample handling plan. Soil samples will be labeled following the nomenclature specified in the protocol document (section 5), wrapped in plastic, and placed in a cooler for shipment. A chain-of-custody form will be filled out, and the cooler will be shipped to Pace Laboratories, Inc., in Huntington Beach, California, for analysis.

3.5.2 Soil Gas Samples

A total hydrocarbon vapor analyzer will be used during auguring to screen split-spoon soil samples for intervals of high fuel contamination. Initial and final soil gas samples will be collected in SUMMA® cannisters, in accordance with the bioventing field sampling plan (Engineering-Science, Inc., 1992), from the VWs and from the MPs closest to and furthest from the VWs. Additionally, these soil gas samples will be used to predict potential air emissions, to determine the reduction in BTEX and TPH during the 1-year test, and to detect any migration of these vapors from the source area.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples will not be sent on ice in order to prevent condensation of hydrocarbons. A chain-of-custody form will be filled out, and the cooler will be shipped to the Air Toxics, Inc., laboratory in Folsom, California, for analysis.

3.6 Blower System

A 3-horsepower positive-displacement blower may be used to conduct the initial air permeability tests. Air injection rates of 10 to 30 standard cubic feet per minute (scfm) are anticipated for initial testing. Figure 3.5 is a schematic of a typical air injection system used for pilot testing. The maximum power requirement anticipated for this pilot test is 208-volt, single-phase, 30-amp service.

The base is requested to provide a breaker box with 208 volt/single phase/30 amp power, one 208 volt receptacle, and two 115 volt receptacles. The new breaker box should be located as near as possible to the proposed VW locations (Figures 3.1 and 3.4). A licensed electrician subcontracted to ES will perform the connections to the existing power source and assist in wiring to blower to line power.

Additional details on power supply requirements are described in section 5, Base Support Requirements.

3.7 In Situ Respiration Tests

The objective of the *in situ* respiration tests is to determine the rate at which the naturally occurring soil bacteria degrade petroleum hydrocarbons. Respiration tests will be performed at every vapor MP where bacterial biodegradation of hydrocarbons is indicated by low oxygen levels and elevated carbon dioxide concentrations in the soil gas. Using a 1-scfm pump, air will be injected into each MP depth interval containing low levels (<2%) of oxygen. A 20-hour air injection period will be used to oxygenate local contaminated soils. At the end of the 20-hour air injection period, the air supply will be cut off, and oxygen and carbon dioxide levels will be monitored for the following 48 to 72 hours. The decline in oxygen and increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals. A helium tracer will also be injected at up to four MPs to determine whether there are leaks in the bentonite seals of monitoring points, allowing oxygen to escape. Additional details on the *in situ* respiration test procedures are provided in section 5.7 of the protocol document (Hinchee et al., 1992).

3.8 Air Permeability Tests

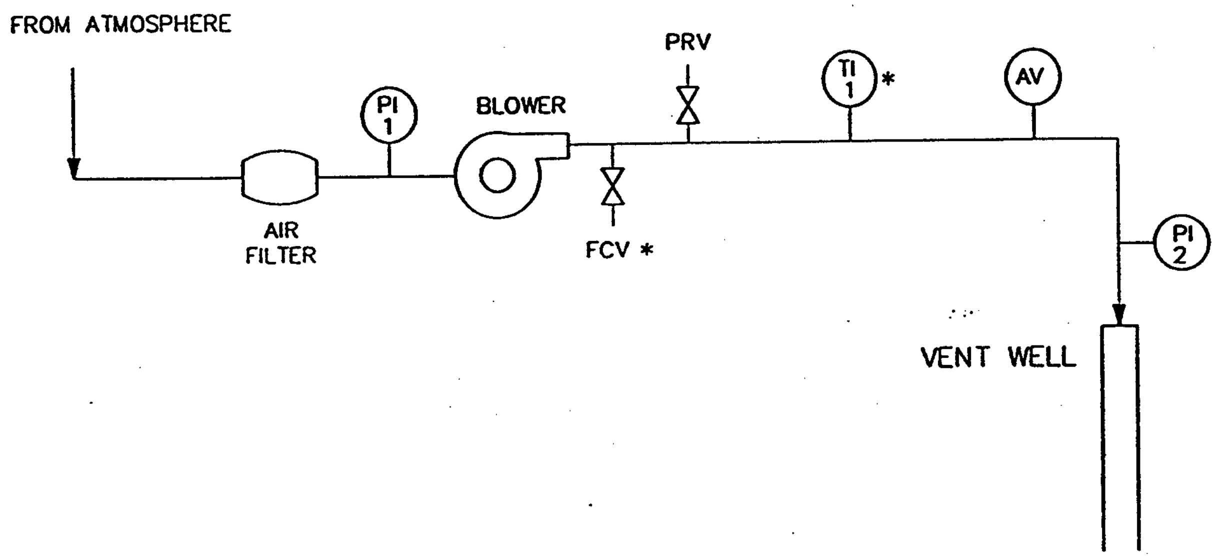
The objective of the air permeability tests is to determine the extent of the subsurface that can be oxygenated using the VW. Air will be injected into the 4-inch-diameter VW using the blower unit, and pressure response will be measured at each MP with differential pressure gauges to determine the region influenced by the unit. Oxygen will also be monitored in the MPs to ascertain whether oxygen levels in the soil increase as the result of air injection. One air permeability test lasting 4 to 8 hours will be performed at each site.

3.9 Potential for Air Emissions

The potential for air emissions is considered low for these sites. No free product remains at these sites, and due to the nature and age of the spills, BTEX concentrations in soil gas are generally less than 1 ppm, volume per volume (ppmv). During initial air injection, health and safety monitoring will ensure that breathing zone hydrocarbon concentrations do not exceed 1 ppmv. Due to the tight soil conditions, low injection rates, and low BTEX levels in the soil, the potential for measurable emissions is very low.

3.10 Extended Pilot Test Bioventing System

If initial testing shows adequate soil permeability and oxygen transport, extended bioventing systems will also be installed at FT40 and FT41. The blower systems will be chosen based on the results of the respiration and air permeability tests at each site. However, it is anticipated that the blowers will have a flow rate in the range of 10 scfm and will not exceed 3 horsepower. The blowers will be provided with vacuum, pressure, and temperature gauges, and air filters, pressure relief, and flow control valves (Figure 3.5). The blowers will be manifolded to the VWs and will be housed in small, prefabricated sheds to provide protection from the weather. A licensed electrician subcontracted to ES will perform the connections



LEGEND

(AV) AIR VELOCITY GAUGE

(PI 1) PRESSURE INDICATOR

(TI 1) TEMPERATURE INDICATOR

FCV FLOW CONTROL VALVE

PRV PRESSURE RELIEF VALVE

* OPTIONAL

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FIGURE 3.5
BLOWER SYSTEM
INSTRUMENTATION DIAGRAM
FOR AIR INJECTION

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between the existing box and the blower. The power source will be the same as that used for the initial pilot test.

The systems will be in operation for 1 year, and every 6 months ES personnel will conduct *in situ* respiration tests to monitor the long-term performance of this bioventing system. Weekly system checks will be performed by Dyess AFB personnel. If required, major maintenance of the blower unit may be performed by ES personnel. Detailed blower system information and a maintenance schedule will be included in the operation and maintenance (O&M) manual provided to the base. More detailed information regarding the test procedures can be found in the protocol document.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The procedures that will be used to measure the air permeability of the soil and *in situ* respiration rates are described in sections 4 and 5 of the protocol document (Hinchee et al., 1992). No exceptions to the protocol procedures are anticipated.

5.0 BASE SUPPORT REQUIREMENTS

The following base support is needed prior to the arrival of the drilling subcontractor and the ES pilot test team:

- Assistance in obtaining drilling and digging permits.
- Assistance in selecting a suitable location for the background well. The background well location should be in an area with no fuel contamination and with similar stratigraphy to that of site FT40 and site FT41. Preferably, 110-volt receptacle power will be available within 150 feet of the background well location.
- Installation of a new breaker box as close as practical to the proposed blower locations at each site. The breaker box should include a 208-volt, 30-amp, single-phase service and a breaker box with one 208-volt receptacle and two 115-volt/30 amp receptacles.
- Provision of any paperwork required to obtain gate passes and security badges for approximately three ES employees, three drillers, and an electrician (if a base electrician is not available). Vehicle passes may be needed for one truck and a drill rig.

During the initial testing, the following base support is needed:

- A decontamination area near each test site where the driller can construct a small decontamination pad to clean augers between borings.
- Acceptance of responsibility by Dyess AFB for drill investigation-derived waste including cuttings from VW and MP borings and decontamination water.
- Twelve square feet of desk space and a telephone in a building located as close to the site as practicable.

- The use of a facsimile machine for transmitting 15 to 20 pages of test results.

During the 1-year extended pilot test, base personnel will be required to perform the following activities:

- Check the blower system once per week to ensure that it is operating and to record the air injection pressure and temperature. Change air filters when required. ES will provide a brief training session on these procedures and an O&M manual.
- If the blower stops working, notify Brian Vanderglas of ES-Austin at (512) 467-6200, or Doug Downey, ES-Denver, at (303) 831-8100, or Marty Faile, AFCEE, at (210) 536-4331.
- Arrange site access for an ES technician to conduct *in situ* respiration tests approximately 6 months and 1 year after the initial pilot test.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan.

Event	Date
Draft Test Work Plan to AFCEE/Dyess AFB	18 November 1993
Notice to Proceed	24 November 1993
Begin Initial Pilot Tests	1 December 1993
Complete Initial Pilot Tests	16 December 1993
Interim Results Report	17 March 1993
Second Respiration Tests	16 June 1994
Final Respiration Tests	December 1994

7.0 POINTS OF CONTACT

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8.0 REFERENCES

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Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing*. January 1992.

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Part II
Draft Interim Pilot Test Results Report for Site FT40 and Site FT41 Dyess AFB, Texas

Prepared for

Air Force Center for Environmental Excellence
Brooks AFB, Texas
and

Dyess Air Force Base
Abilene, Texas

Prepared by

Engineering-Science, Inc.
Austin, Texas

March 1994

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FIGURES

TABLES

PART II

DRAFT
INTERIM PILOT TEST RESULTS REPORT
SITE FT40 AND SITE FT41
DYESS AFB, TEXAS

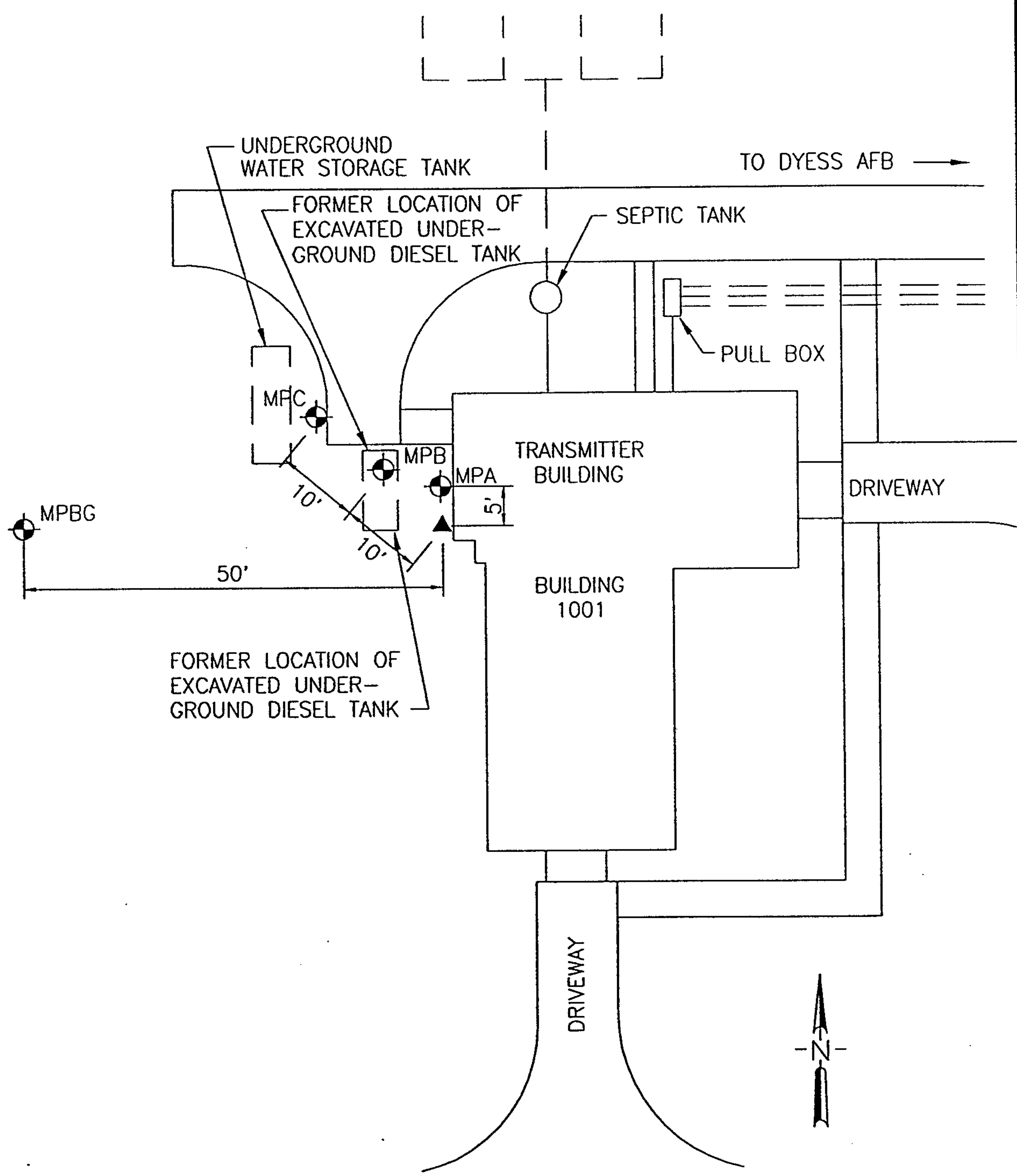
Initial bioventing pilot tests were completed at sites FT40 and FT41 at Dyess Air Force Base (AFB), Texas, during the period of 1 through 29 December 1993. The purpose of this Part II report is to describe the results of the initial pilot tests at these sites and to make specific recommendations for extended testing to determine the long-term impact of bioventing on site contaminants. Descriptions of the history, geology, and contamination at each site are contained in Part I, the Bioventing Pilot Test Work Plan.

Installation of an air injection vent well (VW) and three vapor monitoring points (MPs) at both sites began on December 1, 1993, and was completed on December 6, 1993. Drilling services were provided by Rone Engineers, Inc., of Dallas, Texas. Well installation and soil sampling were directed by Brian Vanderglas, the Engineering-Science, Inc. (ES) site manager, and Rusty Frishmuth. The following sections describe the final design and installation of the bioventing system at this site.

1.0 SITE FT40

1.1 Introduction

One VW, three MPs (MPA, MPB, and MPC), a background monitoring point (MPBG), and a blower unit were installed at site FT40. Figures 1.1 and 1.2, respectively, depict the locations of and hydrogeologic cross sections for the VW and MPs completed at site FT40. The locations of MPB and MPC were changed from those proposed in the work plan because only a small amount of contamination was encountered in MPA during drilling along the west side of building 1001. Boring logs for the MPs and VW are included in appendix A. An MPBG MP was installed in clean soils, in soil conditions very similar to those found at a 10-foot depth at FT40, but no soil gas sample was collected due to tight soil formations encountered at this location. Therefore, no background soil gas data were collected for evaluation of soil gas at site FT40.



LEGEND

- EXISTING MONITORING WELL
- MPA MONITORING POINT LOCATION AND I.D.
- VENT WELL LOCATION

SOURCE: DYESS AFB, TEXAS

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FIGURE 1.1
AS BUILT VENT WELL AND
MONITORING POINT LOCATIONS
SITE FT40

DYESS AIR FORCE BASE
ABILENE TEXAS

DYEFT40 3/1/94

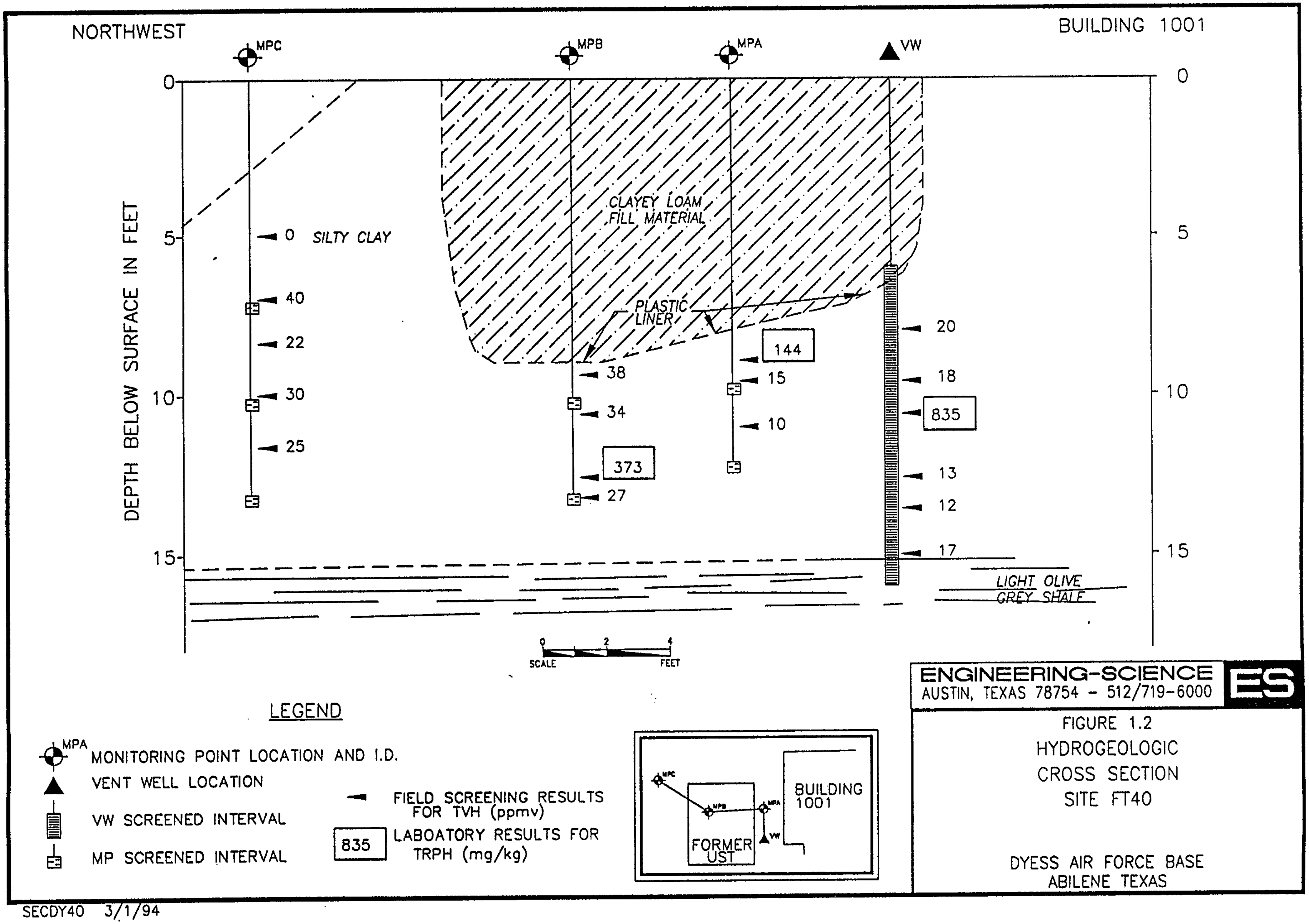
NORTHWEST
BUILDING 1001
MPC
MPB
MPA
VW
DEPTH BELOW SURFACE IN FEET
0
5
10
15
0 SILTY CLAY
40
22
30
25
CLAYEY LOAM FILL MATERIAL
PLASTIC LINER
38
34
373
27
144
15
10
20
18
835
13
12
17
LIGHT OLIVE GREY SHALE
0 2 4
SCALE FEET
LEGEND
MPA MONITORING POINT LOCATION AND I.D.
VENT WELL LOCATION
VW SCREENED INTERVAL
MP SCREENED INTERVAL
FIELD SCREENING RESULTS FOR TVH (ppmv)
835 LABOATORY RESULTS FOR TRPH (mg/kg)
MPC
MPB
MPA
VW
FORMER UST
BUILDING 1001
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FIGURE 1.2
HYDROGEOLOGIC CROSS SECTION
SITE FT40
DYESS AIR FORCE BASE
ABILENE TEXAS
SECDY40 3/1/94

1.1.1 Air injection vent well

The air injection VW was installed following procedures described in the Air Force Center for Environmental Excellence (AFCEE) bioventing protocol document (Hinchee*). Figure 1.3 shows construction details for the VW. The VW was installed in dry silty clay that contained hydrocarbon contamination at all sampling locations. No groundwater was encountered at the site. The total depth drilled in the VW was 16.5 feet below ground surface (bgs). The VW was constructed using 4-inch-diameter, schedule 40 polyvinyl chloride (PVC) casing, with approximately 10 feet of 0.04-inch slotted PVC screen installed from 6.3 to 15.9 feet bgs. The annular space between the well casing and borehole was filled with 6-9 silica sand from the bottom of the borehole to approximately 1.0 foot above the well screen. Approximately 4.0 feet of granular bentonite was placed above the sand in 6-inch lifts, with each lift being hydrated in place. Approximately 1.5 feet of concrete was placed above the bentonite seal and brought up flush with the surface. The well casing was cut off approximately 2 feet above the surface, and a Fernco® pipe coupler modified with a hose barb and ball valve was attached to the top of the VW for soil gas testing.

1.1.2 Monitoring points

At site FT40, the MP screens were installed at two or three depths depending on conditions encountered in each borehole. The three MPs (MPA, MPB, and MPC) were constructed as shown in Figures 1.2, 1.4 and 1.5. Each MP monitoring interval was constructed using a 6-inch section of 1-inch-diameter PVC well screen and a 0.25-inch-diameter schedule 80 PVC riser pipe extending to the ground surface. At the top of each riser, a ball valve and a 3/16-inch hose barb were installed. The top of each MP was completed with a flush-mounted metal well protector set in a concrete base. Thermocouples were installed at the 9.5- and 12.5-foot depths at MPA to measure soil temperature variations.

The depths of screened intervals at MPA where chosen based on encountering the plastic liner to a depth of 7 feet below surface. The borehole for MPA was in primarily uncontaminated fill material until it penetrated beneath the plastic liner. The two depths selected (9.5 and 12.0 feet) represent soil gas conditions in the naturally occurring silty clay from below the liner and from just above the shale present at depths of 14 to 15 feet bgs across the site. The borehole for MPB penetrated the plastic liner containing fill material at a depth of 9 feet. The MPs in MPB were placed at 10 and 13 feet so that a bentonite seal could be placed above the fill material and across the plastic liner, and to allow adequate separation between the two monitoring interval's depths. MPC was located outside of the fill area from the excavated underground storage tank. Evidence of possible contamination was first observed at 7 feet below ground level (bgl), so MPs were constructed at 7, 10, and 13 feet in the MPC borehole.

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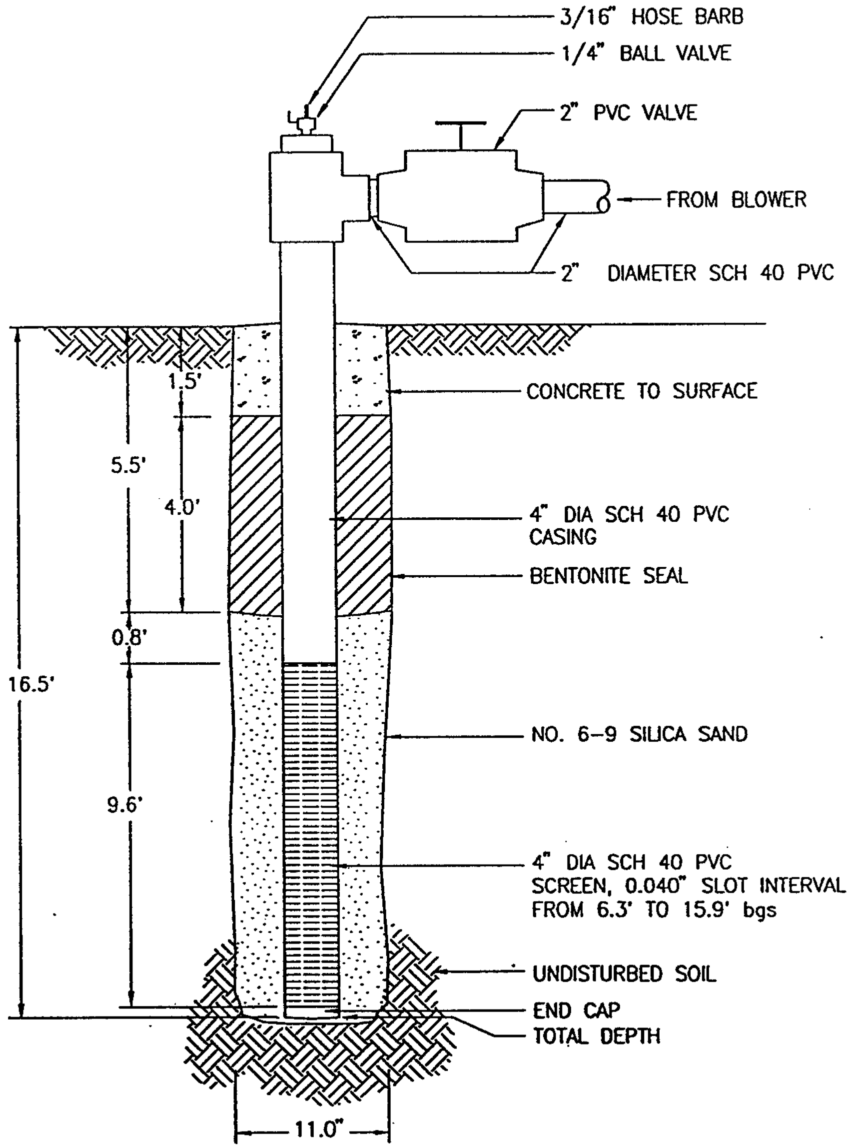
* Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* January 1992.



NOT TO SCALE

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FIGURE 1.3
AS BUILT INJECTION VENT WELL
CONSTRUCTION DETAIL
SITE FT40

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ABILENE, TEXAS

DETDY40 3/1/94

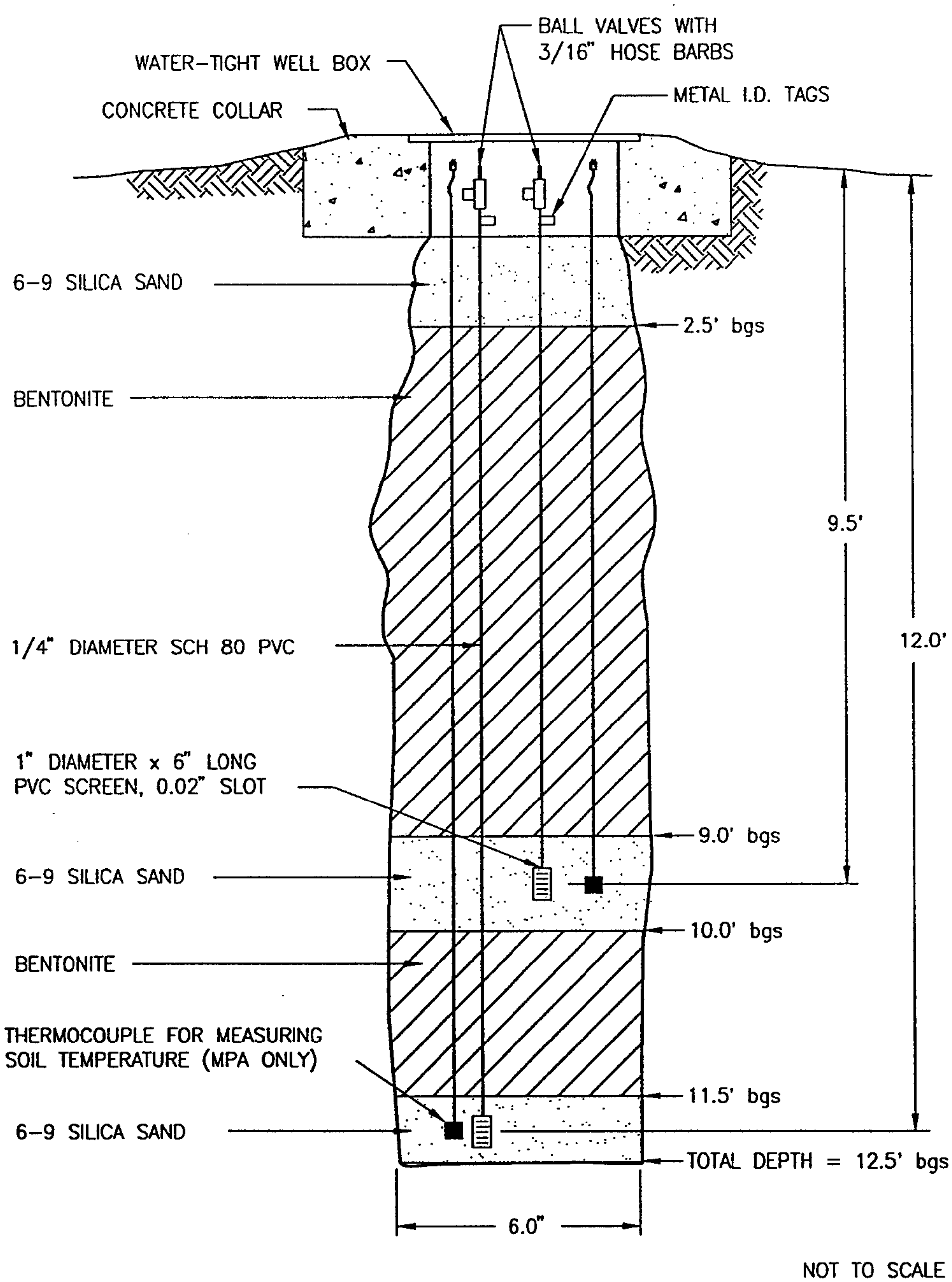

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FIGURE 1.4
AS BUILT MPA MONITORING POINT
CONSTRUCTION DETAIL
SITE FT40

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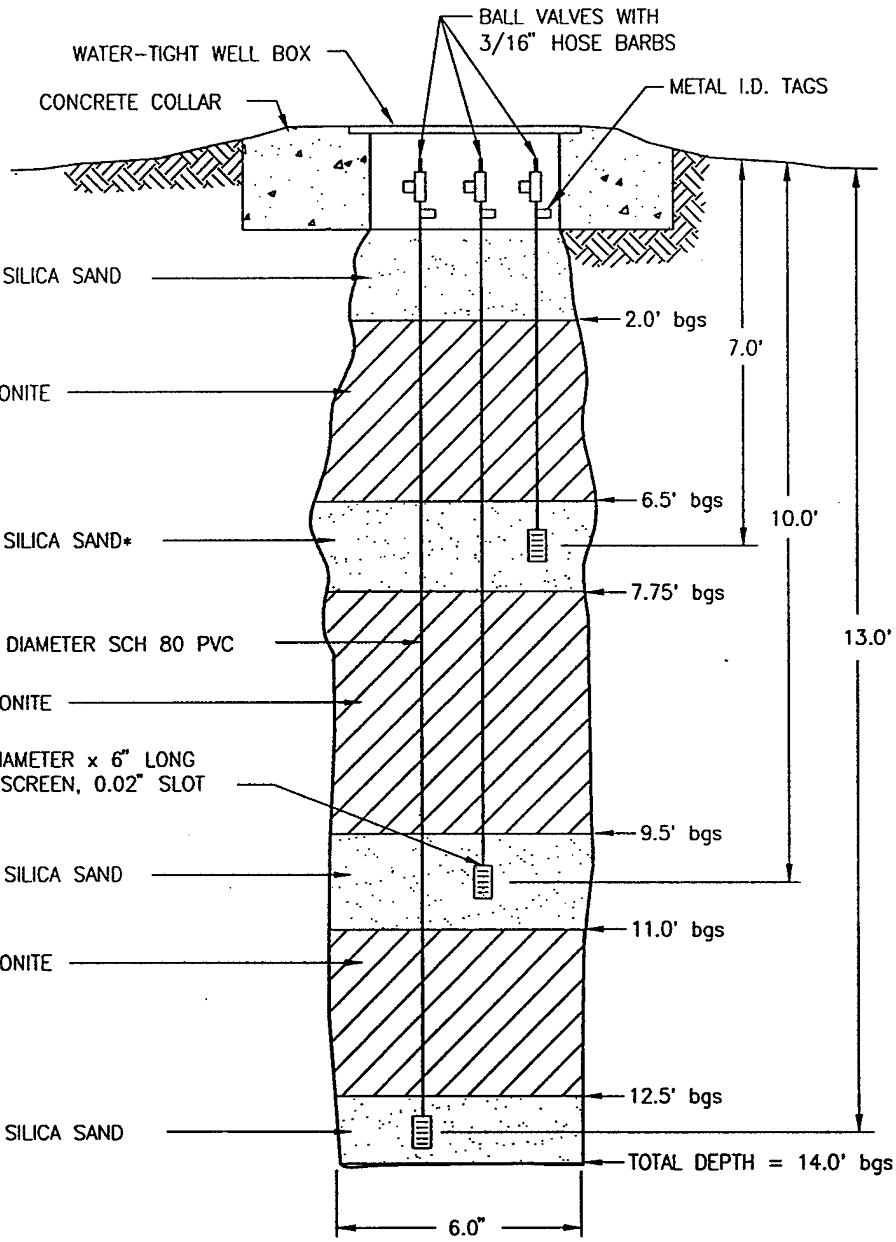

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* 7.0' INTERVAL IS PRESENT IN MPC ONLY.
MPB IS SOLID BENTONITE FROM 9.5' TO 2.0' BGS.

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FIGURE 1.5
AS BUILT MPB AND MPC MONITORING POINT CONSTRUCTION DETAIL
SITE FT40

DYESS AIR FORCE BASE
ABILENE, TEXAS

DETDY40 3/15/94

1.1.3 Blower unit

A 1.0-horsepower (hp) Gast® regenerative blower unit was used at site FT40 for both the initial testing and for the extended pilot test. The pilot test blower is energized by 208-volt, single-phase, 20-amp line power originating in nearby building 1001. A disconnect switch was set up on the outer wall of building 1001 near the blower. The configuration, instrumentation, and specifications for this blower system are shown on Figure 1.6. From the blower curve for model R4 blower series, the blower was transporting air at a flow rate of approximately 55 actual cubic feet per minute (acfm) for the extended pilot test, as of readings taken on December 29, 1993. After blower installation and startup, ES engineers provided an operation and maintenance (O&M) manual, including maintenance instructions, equipment specifications, and monitoring forms to base personnel. A copy of the O&M instructions is provided in appendix B.

1.2 Pilot Test Soil and Soil Gas Sampling Results

1.2.1 Sampling results

Soils at this site primarily consist of dry, silty clays with little or no gravel. Shale was encountered at depths of approximately 14 to 15 feet. Soil within the backfilled excavation consist of clayey loam soils which appear to be lightly packed. No groundwater or evidence of water-producing zones were indicated during drilling activities at the site other than a slight moist portion of the fill material located just above the plastic liner. More detailed hydrogeologic information regarding site FT40 can be found in the hydrogeologic cross section (Figure 1.2) and the geologic boring logs (appendix A).

Contaminated soils were identified based on visual appearance, odor, and results of total hydrocarbon analyzer field screening for volatile organic compounds (VOCs). Hydrocarbon contamination at this site appears to extend from about 7 to 15 feet (top of shale) bgs in the VW and all MP boreholes. Contaminant concentrations appeared to be greatest at depths of 8 to 10 feet bgs in soils directly beneath the excavation of the former underground storage tank. In some instances, dark-stained macropores were identified within sampled cores.

Soil samples for laboratory analysis were collected from 18-inch split-spoon samplers with 2-inch-diameter brass liners. Soil samples were screened for VOCs using a hydrocarbon analyzer to determine the presence of contamination and to select soil samples for laboratory analysis. Soil samples for laboratory analysis were collected from MPA and MPB at a depth of 9.0 to 12.5 feet bgs, respectively, and from the VW at a depth of 10.5 feet bgs.

Soil gas samples were collected at 9.5 feet bgs from MPA and 10.0 feet bgs at MPB. Soil gas samples were collected using 3-liter Tedlar® bags and vacuum chambers. After the samples were collected with Tedlar bags, they were transferred to 1-liter SUMMA® canisters and shipped to the laboratory. A soil gas sample was not collected for laboratory analysis from the completed VW because readings obtained were near ambient conditions.

Soil samples were shipped via express mail to PACE Laboratories, Inc., for chemical and physical analysis. Soil samples were analyzed for total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene and xylenes (BTEX); iron; alkalinity; total Kjeldahl nitrogen (TKN); and several physical parameters. Soil gas samples were shipped via to Air Toxics, Inc., in Folsom, California, for total volatile hydrocarbon (TVH) and BTEX analysis. The TVH analyses were referenced to JP-4 jet fuel. The results of these analyses are provided in Table 1.1. Chain-of-custody forms are provided in appendix C.

1.2.2 Exceptions to test protocol procedures

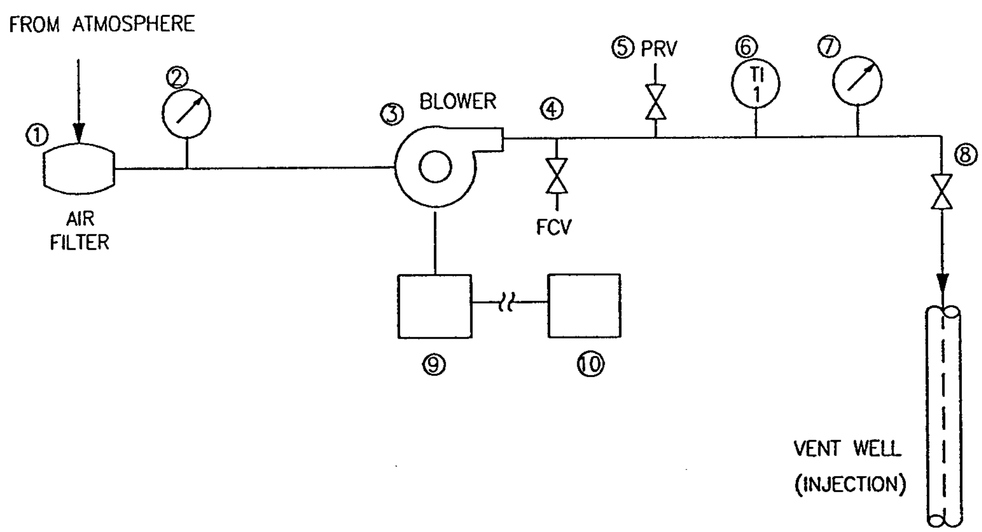
Procedures described in the protocol document (Hinchee et al., 1992) were used to complete the pilot test at site FT40, with the following exceptions:

- Initial soil gas oxygen levels ranged from 12.5 percent at MPB; 10.0 to 19.0 percent in VW. Air samples were only able to be collected in MPA 9.5, MPB 10.0, and MC 7.0, MPC 10.0, and the VW due to tightness of soils at deeper intervals. Air injection into the monitoring points prior to the respiration test was determined not be necessary since the soil gas already has rather high oxygen levels. Instead, the blower was installed and turned on for an air permeability test. The intent of noninjection was to be able to monitor for oxygen influence in the MPs from air injection during air permeability testing.
- A background monitoring point (MPBG) was constructed according to plan located approximately 50 feet west of the VW at site FT40 and with the 6-inch screen located at a depth of 10 feet. Due to the tightness of the clay soils, collection of sufficient soil gas samples from MPBG was not achieved during pilot test activities.

1.3 Pilot Test Results

1.3.1 Initial soil gas chemistry

Prior to initiating air injection, all MPs and the VW were purged, and initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). Table 1.2 summarizes the initial soil gas chemistry at site FT40. Sufficient air sample volume for testing was not able to be collected from the deepest intervals in each MP. The results indicate that aerobic conditions are present in the subsurface soil environment at depths where the soils appear to contain hydrocarbon contamination. Visual evidence during drilling revealed spotty discoloration of the soils in areas exhibiting hydrocarbon odors. The well structured soils which were described based on visual and manual examination of soil borehole cores, exhibited a wide-pore size distribution for fine grained soils consisting of larger macropores between clay aggregates while the aggregates contain many small internal or intra-aggregate pores. In selected soil cores, dark staining from the presence of fuel was observed in macropores, but was not visually noticed in other nearby pores in the same core. this observation suggests that the majority of the fuel contamination may be limited to a small portion of the macropores.



LEGEND

① INLET AIR FILTER – SOLBERG® AJ 134E
② VACUUM GUAGE (0–60 in. H20)
③ BLOWER – GAST® 1hp R4110–50
④ MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2 in. GATE
⑤ AUTOMATIC PRESSURE RELIEF VALVE, SET TO RELEASE AT 48 in. H20 PRESSURE.
⑥ TEMPURE GUAGE (0–250 °F)
⑦ PRESSURE GUAGE (0–100 in. H20)
⑧ FLOW CONTROL GATE VALVE – 2 in. PVC
⑨ DISCONNECT SWITCH, MOUNTED ON BUILDING 1001 NEAR BLOWER
⑩ BREAKER BOX – 208 V/SINGLE PHASE/20 A

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FIGURE 1.6
AS BUILT BLOWER SYSTEM
INSTRUMENTATION DIAGRAM
FOR AIR INJECTION
SITE FT40

DYESS AIR FORCE BASE
ABILENE, TEXAS

DETDY40 3/1/94

Table 1.1 Site FT40
Soil and Soil Gas Analytical Results
Dyess AFB, Texas

Analyte (Units)[a/]	Sample Location-Depth (Feet bgs)		
Soil hydrocarbons	**VW-10.5**	**MPA-9**	**MPB-12.5**
TRPH (mg/kg)	835	144	373
Benzene (mg/kg)	ND[b/]	ND	ND
Toluene (mg/kg)	ND	ND	ND
Ethylbenzene (mg/kg)	ND	ND	ND
Xylenes (mg/kg)	0.38	2.4	ND
Soil gas hydrocarbons	**VW**	**MPA-9.5**	**MPB10**
TVH (ppmv)	NT [c/]	28	70
Benzene (ppmv)	NT	0.019	0.010
Toluene (ppmv)	NT	0.074	0.086
Ethylbenzene (ppmv)	NT	0.006	0.015
Xylenes (ppmv)	NT	0.017	0.067
Soil inorganics	**VW-10.5**	**MPA-9**	**MPB-12.5**
Iron (mg/kg)	14,000	12,100	24,500
Alkalinity (mg/kg as $CaCO_3$)	3,180	2,980	3,230
pH (units)	8.7	8.5	9.0
TKN (mg/kg)	160	180	190
Phosphates (mg/kg)	<12	190	390
Soil physical parameters	**VW-10.5**	**MPA-9**	**MPB-12.5**
Moisture (% wt.)	17.0	17.0	17.7
Gravel (%)	0.0	0.0	0.4
Sand (%)	9.9	12.9	13.1
Silt (%)	28.4	30.8	37.2
Clay (%)	61.7	56.2	49.3
Soil temperature (°F) (measured 12/06/93)	67.2	68.2	
Background TKN (mg/kg)	200		

a/ TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram; TVH=total volatile hydrocarbons; ppmv=parts per million, volume per volume; $CaCO_3$=calcium carbonate; TKN = total Kjeldahl nitrogen; °F = degrees Fahrenheit.
b/ ND= not detected.
c/ NT = not tested.

Table 1.2 Site FT40
Initial Soil Gas Chemistry
Dyess AFB, Texas

MP	Depth (ft)	O_2 (%)	CO_2(%)	Field TVH (ppmv)	Lab TVH (ppmv)	TRPH (mg/kg)
VW	6-16	19.0	2.00	45	NS [a]	835
MPA	9.5	13.0	3.75	120	28	144
MPA	12.5	UN [b]	UN	UN	NS	NS
MPB	10.0	12.5	6.10	120	70	NS
MPB	13.0	UN	UN	UN	NS	373
MPC-SH[c]	7.0	17.0	3.00	105	NS	NS
MPC-SH	10.0	17.0	2.80	82	NS	NS
MPC	13.0	UN	UN	UN	NS	NS
MPBG	10.0	UN	UN	UN	NS	NS

a/ NS = not sampled
b/ Unable to collect sample.
c/ SH = short circuiting suspected between MPC 7 and MPC 10.

None of the five sampling points at site FT40 were under anaerobic conditions, and soil gas at the remaining three sampling points could not be sampled, probably due to the tightness of the formation. The background MP, installed in uncontaminated soil approximately 50 feet west of the VW could not be sampled either, so naturally occurring oxygen and carbon dioxide levels in soil gas could not be assessed for these uncontaminated subsurface soils. Significant oxygen depletion and carbon dioxide production does indicate that some fuel biodegradation is occurring at this site. Carbon dioxide was present at elevated concentrations, ranging from 2.0 to 6.1 percent, in all initial soil gas samples collected at site FT40. The background MP carbon dioxide levels were not determined due to the inability to collect a soil gas sample. An attempt to resample background soil gas will be made during the 6-month respiration test.

1.3.2 Air permeability

An air permeability test was attempted at site FT40 according to protocol document procedures. Air was injected into the VW for over 24 hours at a rate of approximately 34 scfm and an average pressure of 48 inches of water. The pressure responses measured using Magnehelic® gauges became erratic approximately 30 minutes after starting the air permeability test. The pressure response readings, including the pressure response measured at the end of 24 hours of continuous blower operation, are presented in Table 1.3. Due to the unstable nature of the pressure response measurements, the steady-state method of determining air permeability was selected using the values from the 24-hour reading. A soil gas permeability value of 6.3 darcys was calculated for this site (appendix D).

Given the steady-state pressure responses from the 10-foot depth intervals, and assuming a linear relationship exists, the estimated radius of influence for this site at 34 scfm appears to be approximately 25 feet. Figure 1.7 depicts the steady-state responses of MPs measured during air permeability testing after running the long-term blower for 24 hours. No response was observed in the deeper monitoring points. Future monitoring will determine pressure influence if soils near the deep MPs become more permeable with time.

1.3.3 Oxygen influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 1.4 describes the change in soil gas oxygen levels that occurred during a 24- and 48-hour air injection test at the site. This air injection period at approximately 34 scfm produced changes in soil gas oxygen levels at a distance of at least 20 feet from the central VW at all monitored depth intervals where samples could be collected. Increases in the oxygen concentration were measured at each MP interval. Based on measured pressure response, which is an indicator of long-term oxygen transport, it is anticipated that the radius of influence for a long-term bioventing system at this site will exceed 25 feet. Monitoring during the extended

Table 1.3 Site FT40, Pressure Response
During the Air Permeability Test
Dyess AFB, Texas

Elapsed Time (Minutes)	Depth (In Feet)	Pressure Response in MP (Inches of Water)					
		MPA		MPB		MPC	
		9.5	12.5	10.0	13.0	10.0	13.0
5		0.05	0.10	-- a/	--	--	--
10		0.05	0.15	0.0	0.045	0.0	0.26
20		0.05	0.23	0.0	0.065	0.0	0.25
30		0.05	0.35	0.0	0.090	0.0	0.39
40		0.07	0.43	0.0	0.05	0.0	--
50		0.07	0.50	0.0	0.125	0.0	0.0
60		0.07	0.07	--	-- b/	--	0.05
70		0.04	0.80	--	--	--	--
80		0.04	0.90	--	--	--	--
90		0.04	0.98	--	--	--	--
100		0.04	1.00	--	--	--	--
110		0.04	2.10 b/	--	--	--	--
120		0.04	1.45 b/	--	--	--	--
1,560 (26 hours)		0.14	0.00	0.08	0.0	0.03	0.05

a/ Denotes no reading taken at this time.
b/ Magnehelic pressure gauge is exposed to bright sunshine/cover placed on magnehelic gauge.

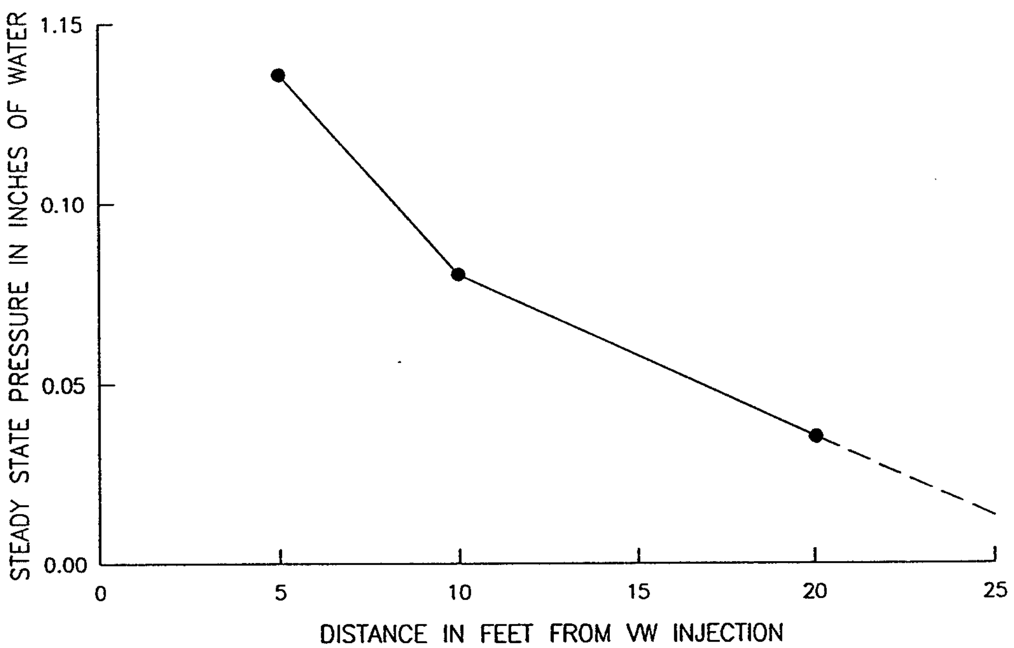

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FIGURE 1.7
RADIUS OF INFLUENCE
PRESSURE vs. DISTANCE
DETERMINATION
SITE FT40

DYESS AIR FORCE BASE
ABILENE, TEXAS

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Table 1.4 Influence of Air Injection at VW1 on Monitoring Point Oxygen Levels, FT 40 Dyess AFB, Texas

MP	Distance From VW (Feet)	Depth (Feet)	Initial Oxygen	24 Hour Oxygen	48 Hour Oxygen
A	5	9.5	13.0	17.0	19.1
B	10	10.0	12.5	15.2	18.0
C	20	7.0	17.0 *	15.75	16.25
C	20	10.0	17.0 *	15.50	17.50

* Short circuit from atmosphere suspected. Water poured on top of bentonite seal believed to have sealed MP from surface.

Average air flow = 34 scfm.

pilot test at this site will better define the effective treatment radius. Based on the pressure responses observed, oxygen influence in the deeper MP intervals may not extend beyond 5 feet from the VW at injection pressures of 48 inches of water or less. It is likely that no pressure response was observed in the deeper MP intervals because flow was preferentially entering the less tight and better structured clays in the shallower depths of the formation. The amount of oxygen available for long-term diffusion into the deeper clays will be determined during the 6-month site visit.

1.3.4 In Situ respiration rates

In situ respiration testing was attempted at site FT40 with a slight variance from the protocol document. Air was injected into the VW for 48 hours at a rate of approximately 30 to 34 scfm. Air injection was initiated for the air permeability testing and was continued to monitor oxygen influence in the monitoring points. After 48 hours of air injection the oxygen levels had risen from 13.0 to 19.1 percent in MPA 9.5, from 12.5 to 18.0 percent in MPB 10, and in MPC 10 from 15.5 to 17.5 percent. Air injection was ceased and changes in soil gas composition were monitored over a period of 2 days with a final reading taken during a return trip to Dyess AFB 17 days after ceasing air injection. The blower injected air for approximately 6 hours after taking the 45 hour reading. Injection was discontinued to allow for soil gas testing after 2 weeks to determine whether oxygen uptake was continuing. The observed rates of oxygen utilization were then used to estimate the aerobic fuel degradation rates at site FT40. Figures 1.8, 1.9, and 1.10, present the results of *in situ* respiration testing MPA 9.5, MPB 10, and VW, respectively, at the site, and Table 1.5 provides a summary of the observed oxygen utilization rates.

At site FT40, an estimated 10 to 20 milligrams (mg) of fuel per kilogram (kg) of soil can be degraded each year. This value is the range of the fuel consumption rates calculated for every point at which a respiration test was conducted. The point-specific fuel consumption rates were calculated using observed oxygen utilization rates, estimated air-filled porosities, and a conservative ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Oxygen loss was slow but linear at every sampling point during approximately the initial 2,700 minutes of the *in situ* respiration test. The oxygen utilization rates observed at site FT40 ranged from .0001 percent per minute (%/min) to .0002 percent/min (Table 1.5), demonstrating that hydrocarbon contamination may be sparsely spread throughout the pilot test area. The air-filled porosity calculated for each sampling point ranged from .03 to .04 liters of air per kilogram of soil. The final readings were taken 17 days after initiating the respiration test, and 15 days after the previous readings. Therefore, it is difficult to determine whether oxygen levels will continue to decline or if natural oxygen diffusion rates will exceed biological oxygen demand.

At all sampling points, the oxygen utilization rates appeared to remain slow and fairly stable during the first 2 days of the test (Figures 1.8 and 1.9). At site FT40, loosely packed fill area of loose, silty soil is located in the middle of the pilot test area separated only by a thin plastic liner (Figure 1.1). The clean silty material is backfill material that was placed after the excavation and removal of the underground storage tank. Although the backfilled soils in the pilot test area are

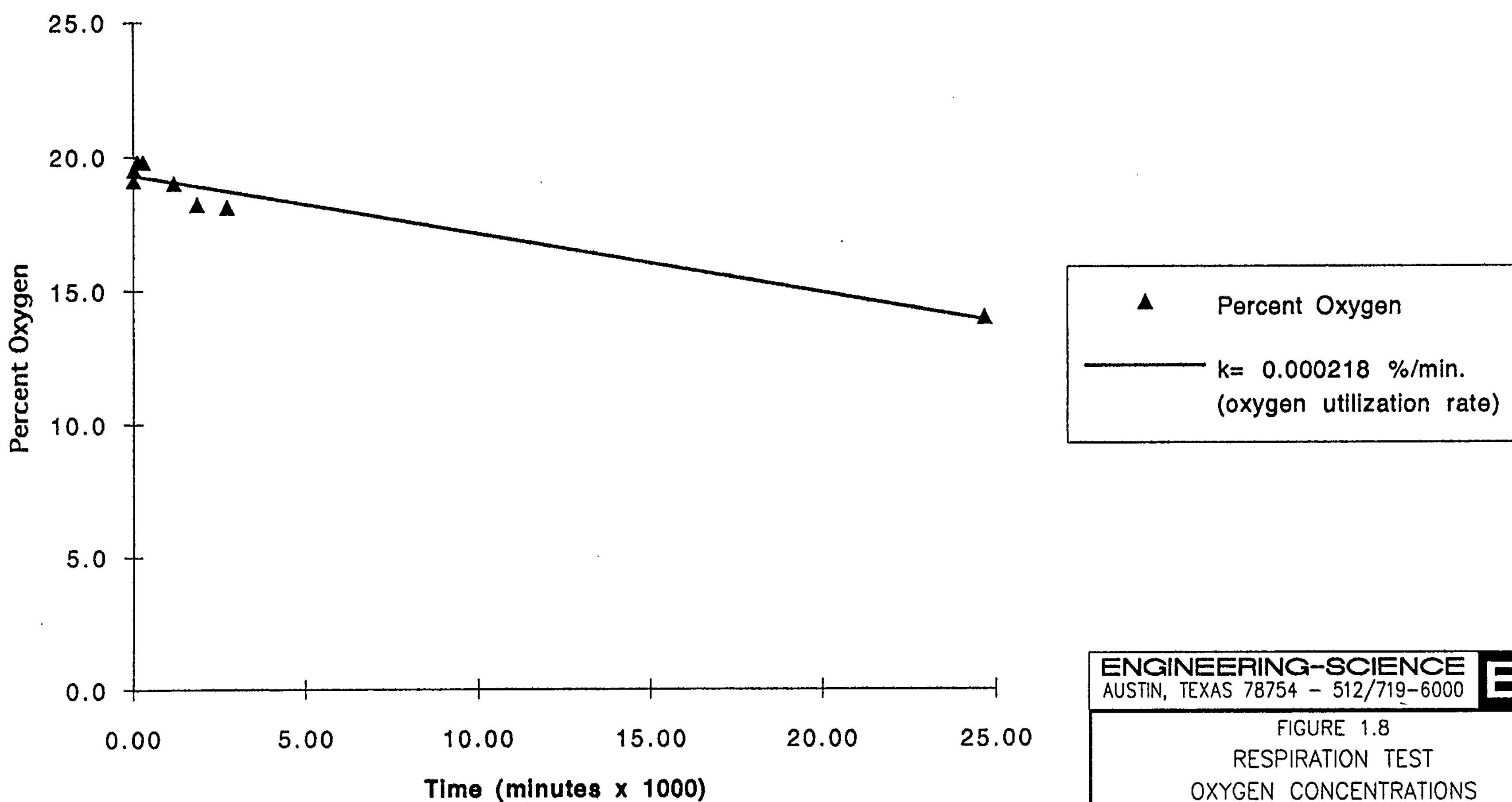

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FIGURE 1.8
RESPIRATION TEST
OXYGEN CONCENTRATIONS
MPA-9.5
SITE FT40

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ABILENE TEXAS

DETDY40 3/1/94

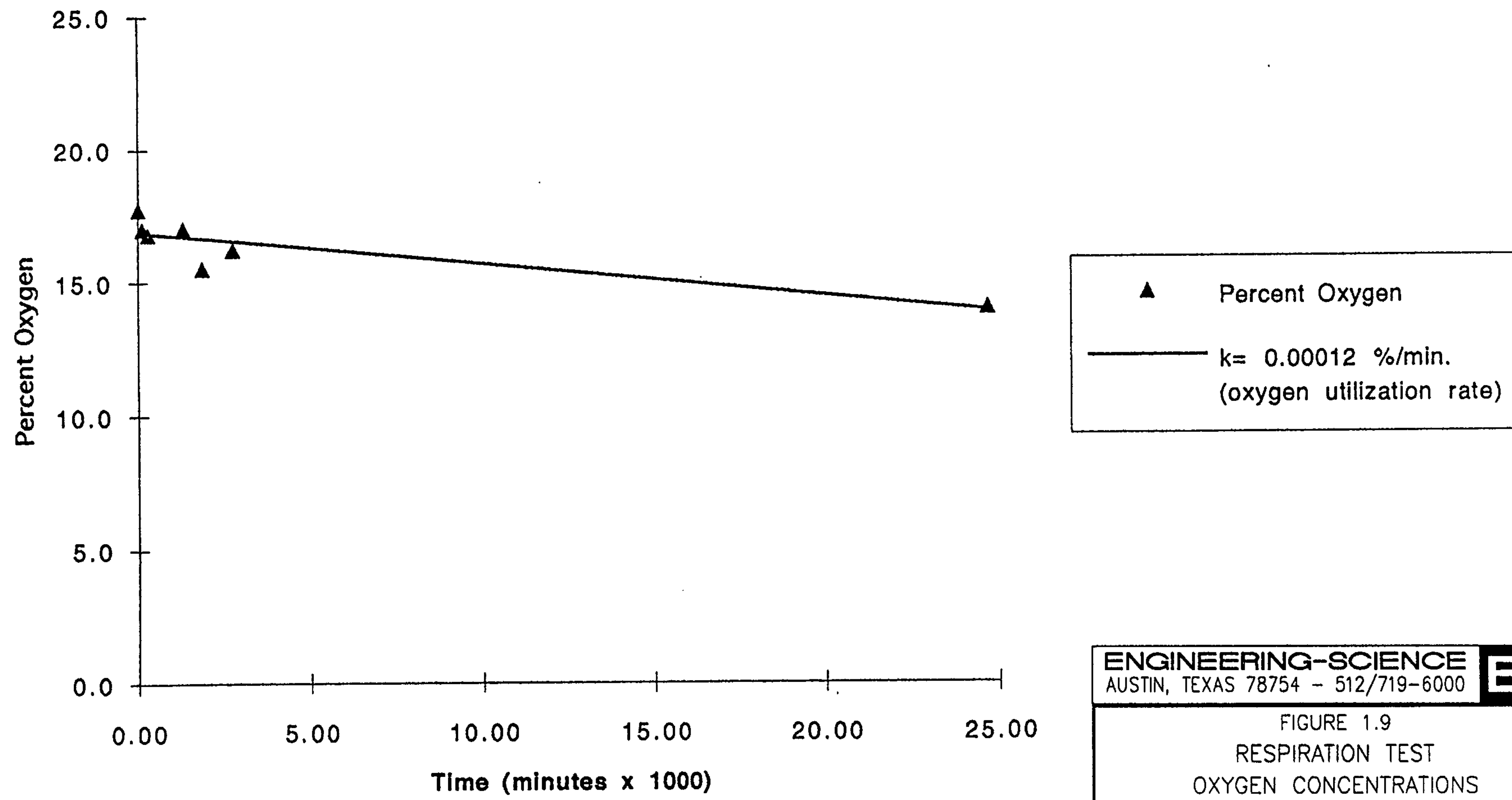

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FIGURE 1.9
RESPIRATION TEST
OXYGEN CONCENTRATIONS
MPB-10
SITE FT40

DYESS AIRFORCE BASE
ABILENE TEXAS

DETDY40 3/1/94

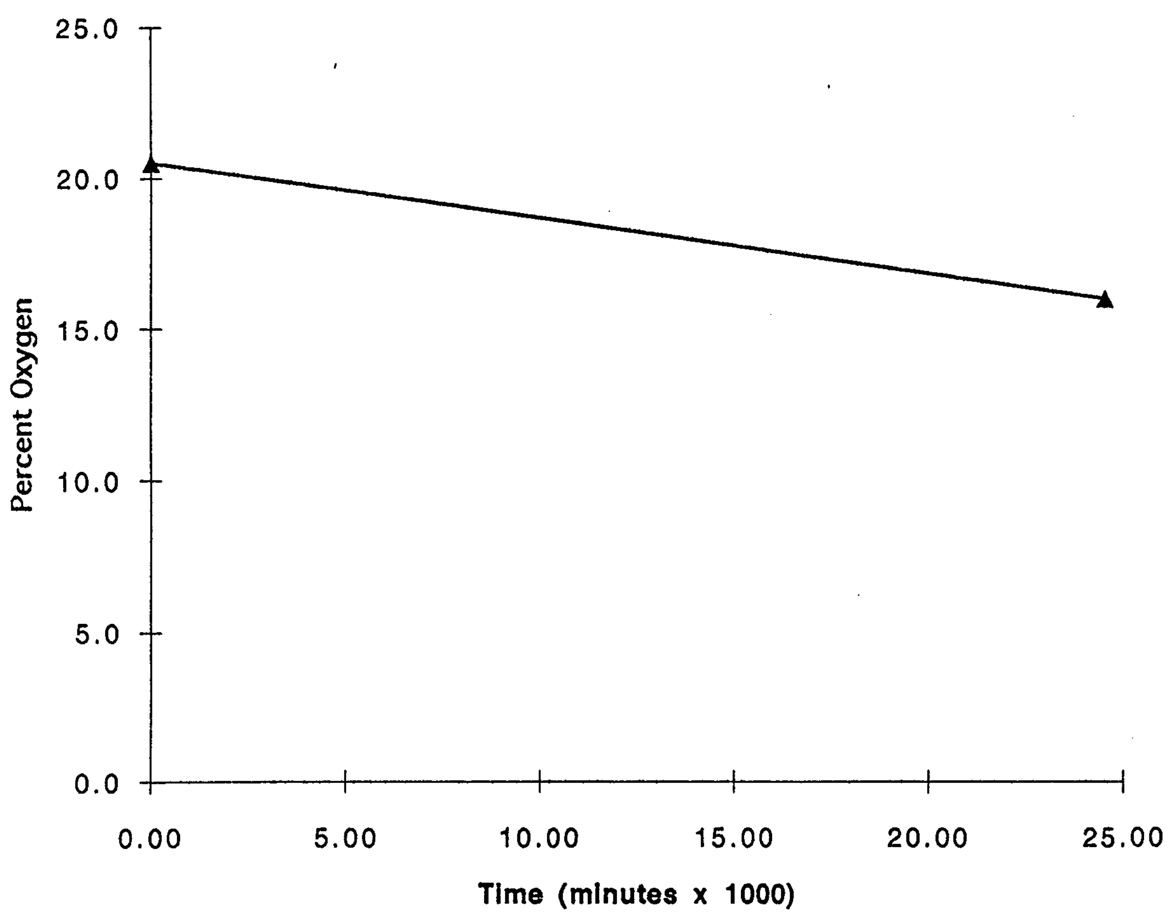

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FIGURE 1.10
RESPIRATION TEST
OXYGEN CONCENTRATIONS
VW
SITE FT40

DYESS AIRFORCE BASE
ABILENE TEXAS

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Table 1.5 Site FT40, Oxygen Utilization Rates
Dyess AFB, Texas

MP	O_2 Loss [a/] (%)	Test Duration (Hour)	O_2 Utilization [a/] Rate (%/minutes)
VW	4.5	410	0.000183
MPA-95	5.8	410	0.000218
MPB-10	3.75	410	0.00012

[a/] Values based on linear regression (Figures 1.8 and 1.9).

surrounded by the thin plastic, the loosely packed soil is a potential pathway for oxygen diffusion. As oxygen is rapidly consumed by fuel-degrading bacteria in contaminated soils, the oxygen diffusion gradient between the contaminated soil and the atmosphere becomes substantial. The depth of this backfilled soil is approximately 9 feet which provides a fairly large oxygen sink to supply oxygen to fuel degrading bacteria in adjacent soils. As a result, oxygen begins to diffuse from the atmosphere through the backfill and into the contaminated soils. This inward oxygen diffusion appears to be nearly equal to the actual bacterial oxygen uptake rates. Generally, the fuel biodegradation generally consumes oxygen at a rate that exceeds diffusion, causing the oxygen concentrations to return to anaerobic conditions in contaminated soils. However, in this case, the large volume of coarse backfill soils, and their close proximity to the contaminated soils and MPs, may be allowing significant oxygen diffusion to maintain oxygen levels in contaminated soils at fairly aerobic levels.

1.3.5 Potential air emissions

Soil concentrations of BTEX compounds detected were less than 5 mg. Thus, the long-term potential for air emissions from full-scale bioventing operations at this site is low. Initial emissions should be minimal because accumulated vapors will move slowly outward from the air injection point and will be biodegraded as they move horizontally through the soil.

1.4 Recommendations

Initial bioventing tests at this site indicate that oxygen had not been depleted in the contaminated soils adjacent to the backfilled excavation. However, air injection was demonstrated to be an effective method of providing oxygen to contaminated soils at the site. Some of these contaminated soils likely extend beneath building 1001, and have no other source of obtaining oxygen except through diffusion or air injection. ES has recommended that air injection continue at this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates. Air injection may also increase soil permeability and allow air to penetrate into tighter formation soils as well. This would enable soil gas testing at the deeper MP intervals.

A 1-horsepower regenerative blower has been installed at the site for continuous air injection. In June 1994, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In December 1994, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade the pilot-scale system, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist

the base in obtaining regulatory approval for upgrading and continued operation.

2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.

3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and MPs.

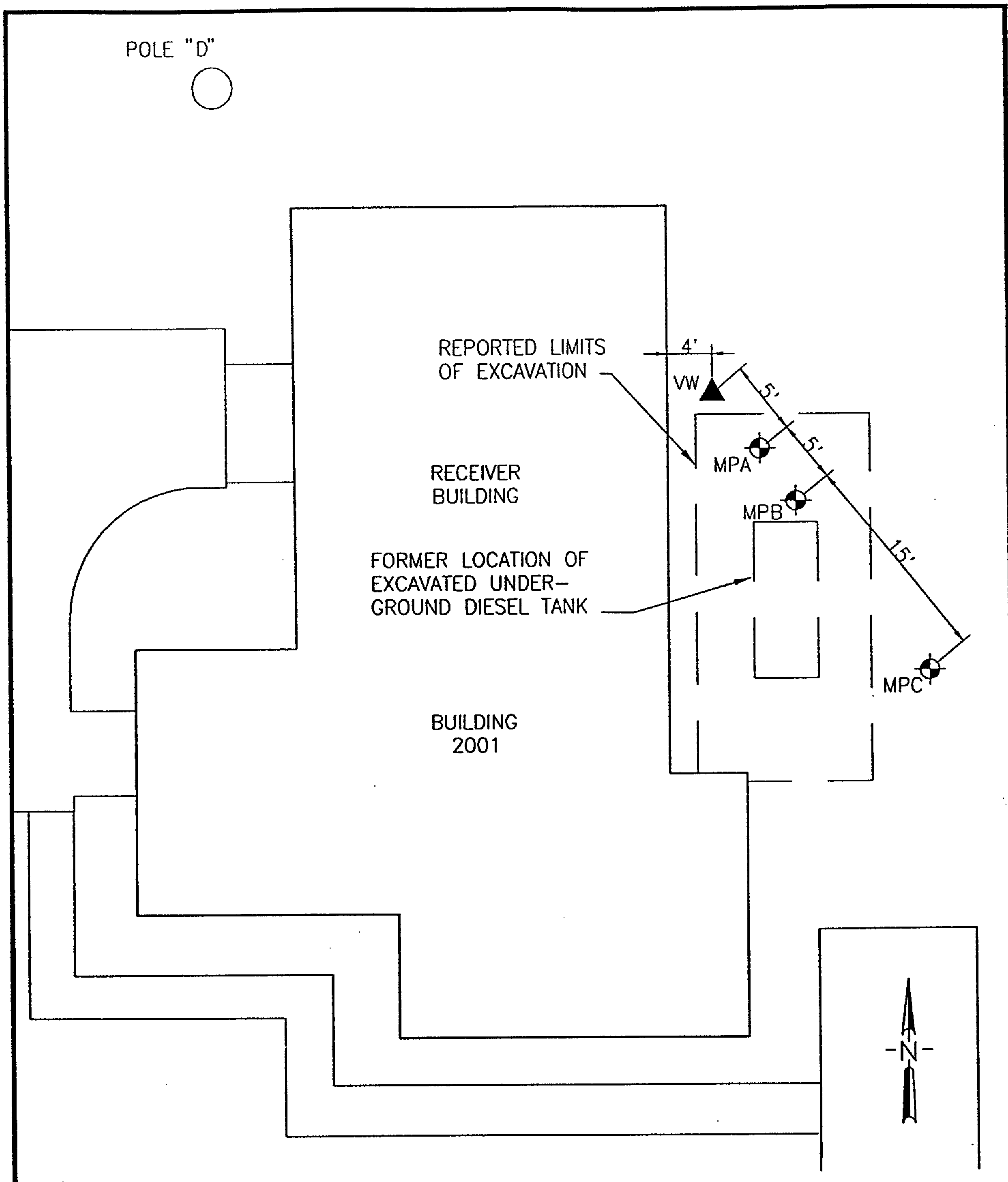
2.0 SITE FT41

2.1 Introduction

One VW, three MPs (MPA, MPB, and MPC), and a blower unit were installed at site FT41. Figures 2.1 and 2.2, respectively, depict the locations of and hydrogeologic cross sections for the VW and MPs completed at the site. The locations of VW and MPs were changed from those proposed in the work plan because analytical data from soil boring samples indicated the greatest levels of petroleum hydrocarbon (TRPH) contamination near a soil boring identified as MW1-SB located approximately 8 feet from the east wall of building 2001. The VW was positioned between the staked location of MW1-SB and building 2001 approximately 4.0 feet from the wall and the MPs were configured away from the building toward the reported location of the underground tank excavation. Boring logs for the MPs and VW are included in appendix A. A background MP was installed in clean soils at site FT40 in soil conditions very similar to those found at site FT41. However, no sample could be collected due to tight soil formations encountered at the site. An attempt to collect a background soil gas sample will be made during the 6-month respiration test.

2.1.1 Air injection vent well

The air injection VW was installed following procedures described in the AFCEE bioventing protocol document (Hinchee et al., 1992). Figure 2.3 shows construction details for the VW. The VW was installed in dry silty clay that contained hydrocarbon contamination at all sampling locations. No groundwater was encountered at the site. The total depth drilled in the VW was 16.0 feet bgs. The VW was constructed using 4-inch-diameter, schedule 40 PVC casing, with approximately 10 feet of 0.04-inch slotted PVC screen installed from 5.8 to 15.4 feet bgs. The annular space between the well casing and borehole was filled with 6-9 silica sand from the bottom of the borehole to approximately 1 foot above the well screen. Approximately 3.0 feet of granular bentonite was placed above the sand in 6-inch lifts, with each lift being hydrated in place. Approximately 2.0 feet of concrete was placed above the bentonite seal and brought up flush with the surface. The well casing was cut off approximately 2 feet above the surface, and a Fernco® pipe coupler modified with a hose barb and ball valve was attached to the top of the VW for soil gas testing.



LEGEND

- EXISTING MONITORING WELL
- MPA MONITORING POINT LOCATION AND I.D.
- VENT WELL LOCATION

SOURCE: DYESS AFB, TEXAS

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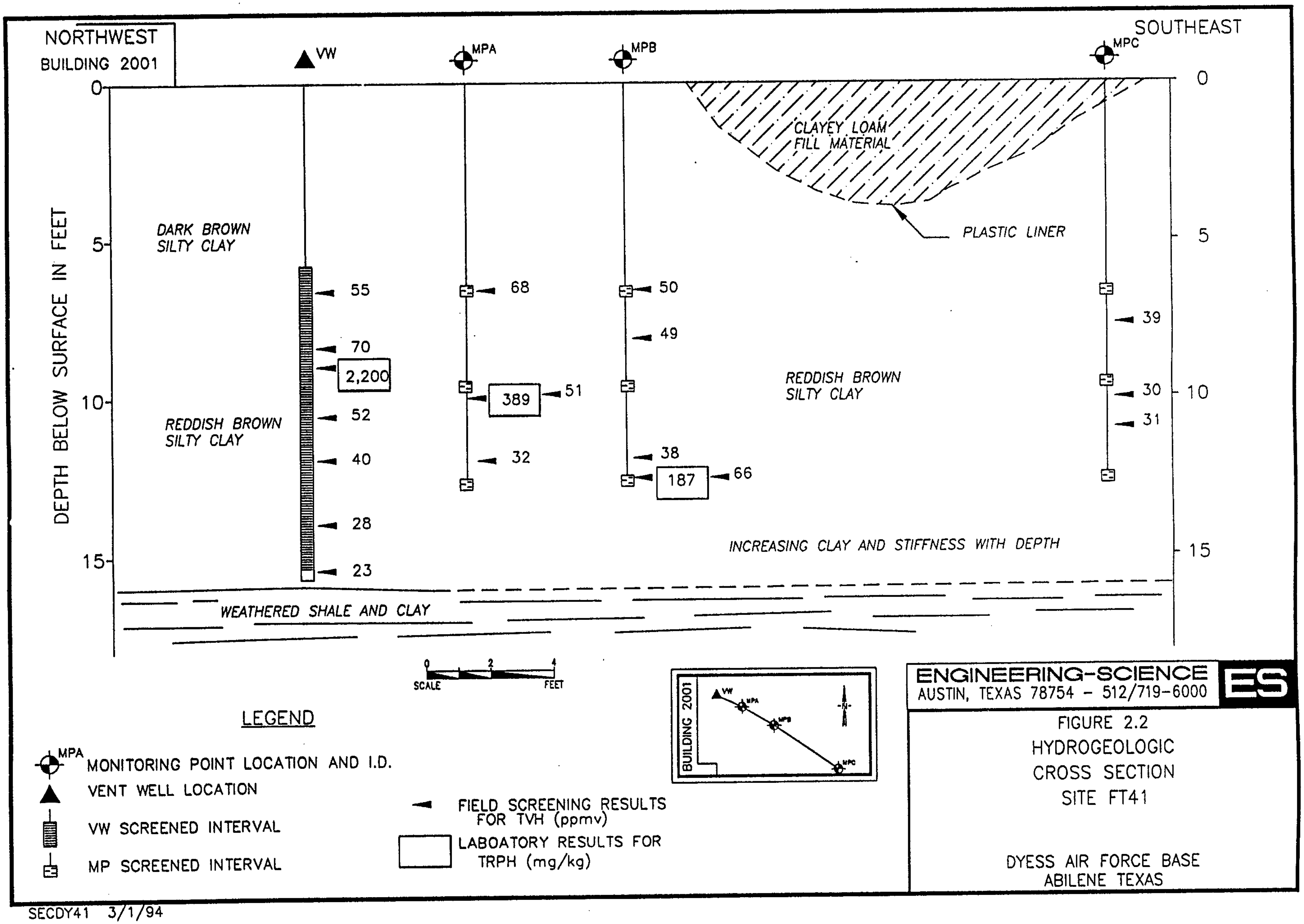
FIGURE 2.1
AS BUILT VENT WELL AND
MONITORING POINT LOCATIONS
SITE FT41

DYESS AIR FORCE BASE
ABILENE TEXAS



NORTHWEST
BUILDING 2001
SOUTHEAST
VW
MPA
MPB
MPC
DEPTH BELOW SURFACE IN FEET
0
5
10
15
DARK BROWN SILTY CLAY
REDDISH BROWN SILTY CLAY
55
70
2,200
52
40
28
23
68
389
51
32
50
49
38
187
66
39
30
31
CLAYEY LOAM FILL MATERIAL
PLASTIC LINER
REDDISH BROWN SILTY CLAY
INCREASING CLAY AND STIFFNESS WITH DEPTH
WEATHERED SHALE AND CLAY
SCALE
0
2
4
FEET
LEGEND
MONITORING POINT LOCATION AND I.D.
VENT WELL LOCATION
VW SCREENED INTERVAL
MP SCREENED INTERVAL
FIELD SCREENING RESULTS FOR TVH (ppmv)
LABORATORY RESULTS FOR TRPH (mg/kg)
BUILDING 2001
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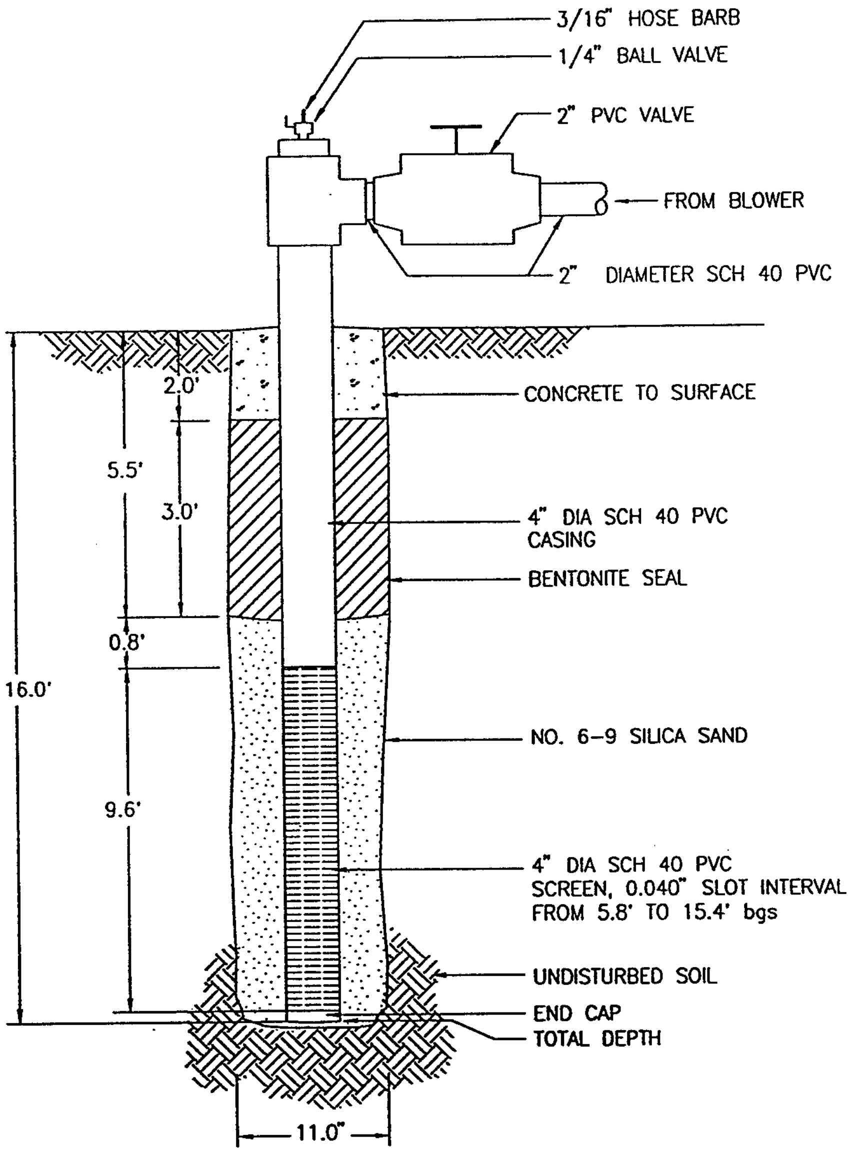
ES
FIGURE 2.2
HYDROGEOLOGIC
CROSS SECTION
SITE FT41
DYESS AIR FORCE BASE
ABILENE TEXAS
SECDY41 3/1/94



NOT TO SCALE

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FIGURE 2.3
AS BUILT INJECTION VENT WELL
CONSTRUCTION DETAIL
SITE FT41

DYESS AIR FORCE BASE
ABILENE, TEXAS

DETDY41 3/1/94

2.1.2 Monitoring points

At site FT41, the MP screens were installed at 6.5-, 9.5-, and 12.5-foot depths in each borehole. The three MPs (MPA, MPB, and MPC) were constructed as shown in Figures 2.2 and 2.4. Each MP monitoring interval was constructed using a 6-inch section of 1-inch-diameter PVC well screen and a 0.25-inch-diameter schedule 80 PVC riser pipe extending to the ground surface. At the top of each riser, a ball valve and a 3/16-inch hose barb were installed. The top of each MP was completed with a flush-mounted metal well protector set in a concrete base. Thermocouples were installed at the 6.5- and 12.5-foot depths at MPA to measure soil temperature variations.

2.1.3 Blower unit

A 1.0-horsepower (hp) Gast® regenerative blower unit was used at site FT41 for both the initial testing, and for the extended pilot test. The pilot test blower is energized by 208-volt, single-phase, 20-amp line power originating in nearby building 2001. A disconnect switch was set up on the outer wall of building 2001 near the blower. The configuration, instrumentation, and specifications for this blower system are shown on Figure 2.5. From the blower curve for the model R4 blower series, the blower was transporting air at a flow rate of approximately 61 acfm for the extended pilot test, as of readings taken on December 29, 1993. After blower installation and startup, ES engineers provided an O&M manual, including maintenance instructions, equipment specifications, and monitoring forms to base personnel. A copy of the O&M instructions is provided in appendix B.

2.2 PILOT TEST SOIL AND SOIL GAS SAMPLING RESULTS

2.2.1 Sampling results

Soils at this site primarily consist of dry, silty clays with little or no gravel. Weathered shale was encountered at a depth of approximately 15 to 16 feet. No groundwater or evidence of water-producing zones were indicated during drilling activities at the site. More detailed hydrogeologic information regarding site FT41 can be found in the hydrogeologic cross section (Figure 2.2) and the geologic boring logs (appendix A).

Contaminated soils were identified based on visual appearance, odor, and results of total hydrocarbon analyzer field screening for VOCs. Hydrocarbon contamination at this site appears to extend from about 7 to 15 feet (top of shale) bgs in the VW and all MP boreholes. Contaminant concentrations appeared to be greatest in soils along the building side and beneath the excavation depth of the former UST. In some instances, dark-stained streamers were observed with exposed macropores identified within sampled cores.

Soil samples for laboratory analysis were collected from 18-inch split-spoon samplers with 2-inch-diameter brass liners. Soil samples were screened for VOCs using a hydrocarbon analyzer to determine the presence of contamination and to

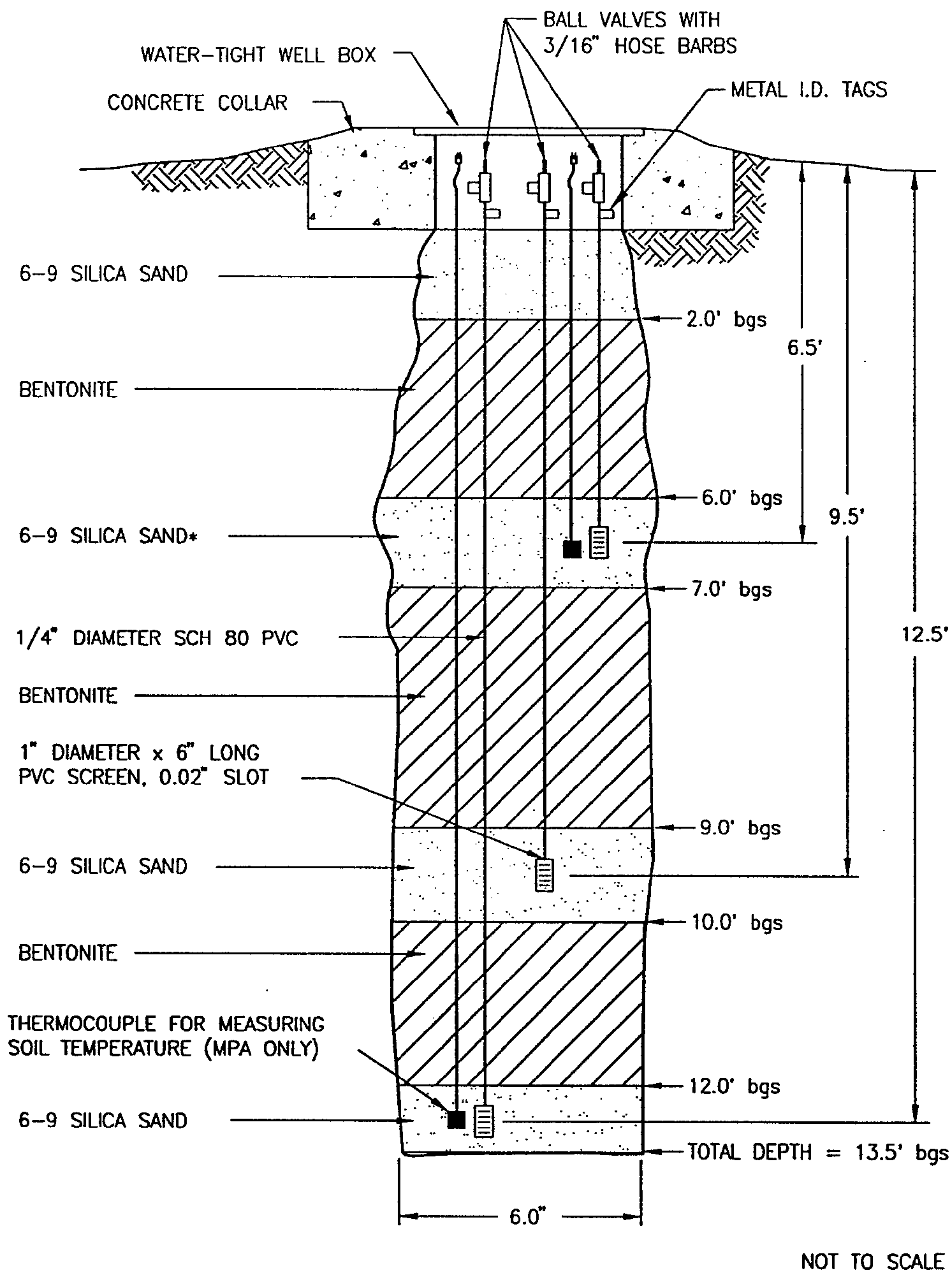

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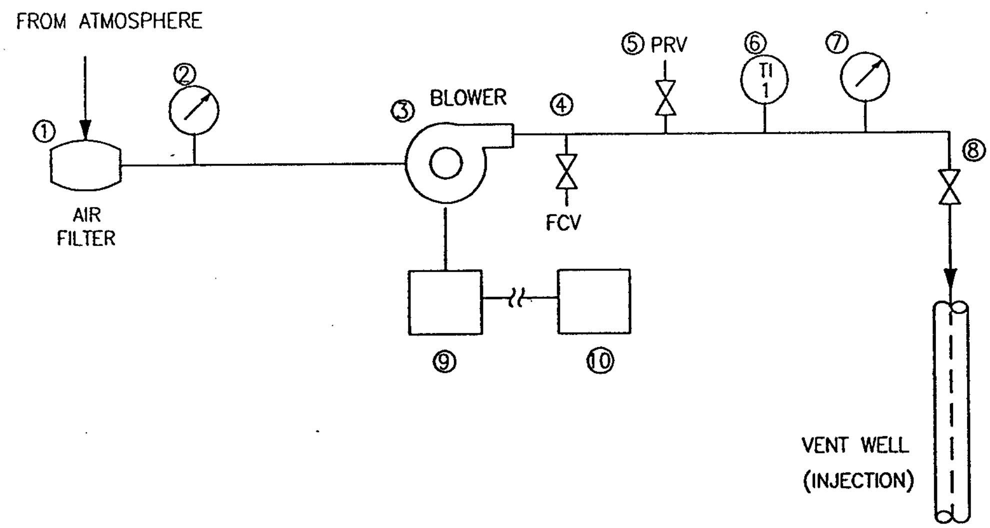
FIGURE 2.4
AS BUILT MONITORING POINT
CONSTRUCTION DETAIL
SITE FT41

DYESS AIR FORCE BASE
ABILENE, TEXAS

DETDY41 3/15/94



LEGEND

① INLET AIR FILTER – SOLBERG® AJ 134E
② VACUUM GUAGE (0–60 in. H20)
③ BLOWER – GAST® 1hp R4110-50
④ MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2 in. GATE
⑤ AUTOMATIC PRESSURE RELIEF VALVE, SET TO RELEASE AT 46 in. H20 PRESSURE.
⑥ TEMPURE GUAGE (0–250 °F)
⑦ PRESSURE GUAGE (0–100 in. H20)
⑧ FLOW CONTROL GATE VALVE – 2 in. PVC
⑨ DISCONNECT SWITCH, MOUNTED ON BUILDING 2001 NEAR BLOWER
⑩ BREAKER BOX – 208 V/SINGLE PHASE/20 A LOCATED IN BUILDING 2001.

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FIGURE 2.5
AS BUILT BLOWER SYSTEM
INSTRUMENTATION DIAGRAM
FOR AIR INJECTION
SITE FT41

DYESS AIR FORCE BASE
ABILENE, TEXAS

DETDY41 3/1/94

select soil samples for laboratory analysis. Soil samples for laboratory analysis were collected from MPA and MPB at a depth of 10.0 to 12.5 feet bgs, respectively, and from the VW at a depth of 9.0 feet bgs.

Soil gas samples were collected at 6.5 feet bgs from MPC and 9.5 feet bgs at MPB. Soil gas samples were collected using 3-liter Tedlar bags and vacuum chambers. After the samples were collected with Tedlar bags, they were transferred to 1-liter SUMMA canisters and shipped to the laboratory. A soil gas sample was not collected for laboratory analysis from the completed VW because readings obtained were near ambient oxygen and carbon dioxide levels.

Soil samples were shipped via air express to Pace Laboratories, Inc., in Huntington Beach, California, for chemical and physical analysis. Soil samples were analyzed for TRPH, BTEX, iron, alkalinity, TKN, and several physical parameters. Soil gas samples were shipped via air express to Air Toxics, Inc. in Folsom, California, for total volatile hydrocarbon (TVH) and BTEX analysis. The results of these analyses are provided in Table 2.1. Chain-of-custody forms are provided in appendix C.

2.2.2 Exceptions to test protocol procedures

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete the pilot test at site FT41, with the following exceptions:

- Initial soil gas oxygen levels ranged from 10 percent in MPC 6.5 to 20.5 percent in VW and MPB 9.5. Air samples were only able to be collected in these three points due to tightness of soils encountered in MPA, and in the deeper points at MPB and MPC. Air injection into the monitoring points prior to the respiration test was determined not be necessary since the soil gas already has rather high oxygen levels. Instead, the blower was installed and turned on for an air permeability test. The intent of noninjection was to be able to monitor for oxygen influence in MPC from air injection during air permeability testing and to attempt to loosen the soil in MPA.
- An MPBG to be used for site FT40 was constructed according to the plan located approximately 50 feet west of the VW at site FT40 and with the 6-inch screen located at a depth of 10 feet. Due to the tightness of the clay soils, collection of sufficient air volume for testing from MPBG was not achieved during initial pilot test activities. This point will be resampled during 6-month respiration testing.

2.3 PILOT TEST RESULTS

2.3.1 Initial soil gas chemistry

Prior to initiating air injection, all MPs and the VW were purged, and initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). Table 2.2 summarizes the initial soil gas chemistry at site FT41. Sufficient air sample volume for testing was not able to be collected from the deepest intervals in

Table 2.1 Site FT41
Soil and Soil Gas Analytical Results
Dyess AFB, Texas

Analyte (Units)[a]	Sample Location-Depth (Feet bgs)		
Soil hydrocarbons	VW-8.5	MPA-10	MPB-12.5
TRPH (mg/kg)	2,200	389	187
Benzene (mg/kg)	ND[b]	ND	ND
Toluene (mg/kg)	ND	ND	ND
Ethylbenzene (mg/kg)	ND	ND	ND
Xylenes (mg/kg)	ND	ND	ND
Soil gas hydrocarbons	VW	MPB-9.5	MPC-6.5
TVH (ppmv)	NT[c]	100	540
Benzene (ppmv)	NT	0.020	ND
Toluene (ppmv)	NT	0.150	0.22
Ethylbenzene (ppmv)	NT	0.072	0.21
Xylenes (ppmv)	NT	0.170	0.35
Soil inorganics	VW-8.5	MPA-10	MPB-12.5
Iron (mg/kg)	18,900	23,300	16,200
Alkalinity (mg/kg as $CaCO_3$)	3,090	2,480	2,790
pH (units)	8.8	8.8	8.8
TKN (mg/kg)	180	250	280
Phosphorouss (mg/kg)	130	370	340
Soil physical parameters	VW-8.5	MPA-10	MPB-12.5
Moisture (% wt.)	16.8	16.5	16.5
Gravel (%)	0.2	0.0	0.0
Sand (%)	13.5	5.5	7.7
Silt (%)	32.1	31.7	41.3
Clay (%)	54.2	62.8	51.0
Soil temperature (°F) (measured 12/06/93)	MPA-6.5	MPA-12.5	
	65.0	68.0	
Background TKN (mg/kg)	200		

a/ TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram; TVH=total volatile hydrocarbons; ppmv=parts per million, volume per volume; $CaCO_3$=calcium carbonate; TKN = total Kjeldahl nitrogen; °F = degrees Fahrenheit.

b/ ND = not detected.

c/ Not tested.

Table 2.2 Site FT41
Initial Soil Gas Chemistry, Dyess AFB, Texas

MP	Depth (ft)	O_2 (%)	CO_2(%)	Field TVH (ppmv)	Lab TVH (ppmv)	TRPH (mg/kg)
VW	6-16	20.6	0.50	115	NS*	2,200
MPA	6.5	UN[b/]	UN	UN	NS	NS
MPA	9.5	UN	UN	UN	NS	389
MPA	12.5	UN	UN	UN	NS	187
MPB	6.5	UN	UN	UN	NS	NS
MPB	9.5	20.50	0.75	100	100	UN
MPB	12.5	UN	UN	UN	UN	187
MPC	6.5	10.0	7.50	170	540	NS
MPC	9.5	UN	UN	UN	NS	NS
MPC	12.5	UN	UN	UN	NS	NS
MPBG (from FT40)	10.0	UN	UN	UN	NS	NS

* NS = not sampled

each MP and in the shallow MPs at MPB 6.5, and MPC 9.5 (which was oversaturated with water during bentonite hydration). The results indicate that aerobic conditions are present in the subsurface soil environment at depths where the soils appear to contain hydrocarbon contamination. Visual evidence during drilling revealed spotty discoloration of the soils in areas exhibiting hydrocarbon odors. The well structured soils described at the site based on visual and manual examination of soil borehole cores exhibited a wide pore size distribution for fine-grained soils consisting of larger macropores between clay aggregates while the aggregates contain many small internal or intra-aggregate pores. In selected soil cores, dark staining from the presence of fuel was observed in the identified macropores, but was not visually noticed in other nearby pores in the same core suggesting that the majority of the fuel contamination may be limited to a small portion of the macropores.

None of the three sampling points at site FT41 were under anaerobic conditions, however MPC 6.5 had depleted oxygen levels indicating possible biological oxygen demand. Soil gas at the remaining seven sampling points could not be sampled, probably due to the tightness of the formation, or because of excessive bentonite hydration during MP constructing. The background MP, installed in uncontaminated soil at site FT40 also could not be sampled, therefore naturally occurring oxygen and carbon dioxide levels in the soil gas in soil gas could not be assessed for uncontaminated subsurface soils. Carbon dioxide was present at elevated concentrations, ranging from 0.50 to 7.5 percent, in the initial soil gas samples collected at site FT41. The background MP carbon dioxide levels were not determined due to the inability to collect a soil gas sample.

2.3.2 Air permeability

An air permeability test was attempted at site FT41 according to protocol document procedures. Air was injected into the VW for over 24 hours at a rate of approximately 34 scfm and an average pressure of 48 inches of water. The pressure responses measured using Magnehelic gauges became erratic after starting the air injection. The pressure response was measured after 24 hours of continuous blower operation. Those values are also presented in Table 2.3. Due to the unstable nature of the pressure response measurements, the steady-state method of determining air permeability was selected using the values from the 24-hour reading. A soil gas permeability value of 5.2 darcys for the 9.5- and 12.5-foot depths, and 6.3 darcys for the 6.5-foot depth was calculated for this site (appendix D).

Given the steady-state pressure responses from the 6.5-foot depth intervals, and assuming a linear relationship exists, the estimated radius of influence for this site at 34 scfm appears to be slightly greater than 25 feet. Little or no response was observed in the deeper MPs. Future pressure monitoring will determine the influence on deeper soils if soils near MPs become more permeable over time.

2.3.3 Oxygen influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW

Table 2.3 Site FT41 24-Hour Pressure Response
During the Air Permeability Test
Dyess AFB, Texas

Monitoring Point	Distance from VW (feet)	Depth (Feet bgs)	Pressure Response (Inches H_2O)
A	5	6.5	0.35
B	10	6.5	0.03
C	25	6.5	0.02
A	5	9.5	0.02
B	10	9.5	0.02
C	25	9.5	-0.12
A	5	12.5	0.01
B	10	12.5	0.01
C	25	12.5	0.00

systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 2.4 describes the change in soil gas oxygen levels that occurred in MPC 6.5 and MPB 9.5 during a 24- and 48-hour air injection test at the site. This air injection period at approximately 34 scfm produced changes in soil gas oxygen levels at a distance of 25 feet from the central VW in the shallow sampling intervals. MPB 9.5 was near ambient air levels prior to injecting air. Based on the observed oxygen increase in MPC 6.5 it is anticipated that the radius of influence for a long-term bioventing system at this site will exceed 25 feet in shallow soils (<8 feet) based on the measured pressure response, which is an indicator of long-term oxygen transport. Monitoring during the extended pilot test at this site will better define the effective treatment radius at all depths. Initial oxygen influence in the deeper MP intervals did not extend beyond 10 feet from the VW at injection pressures of 48 inches of water or less. It is likely that the small pressure response was observed in the deeper MP intervals because flow preferentially entering the less tight and better structured clays in the shallower depths of the formation. The amount of oxygen available for diffusion into the deeper clays shall be increased however to a radius equal to that observed in the 6.5-foot-interval.

2.3.4 In Situ respiration rates

In situ respiration testing was attempted at site FT41 with a slight variance from the protocol document. Air was injected into the VW for 48 hours at a rate of approximately 30 to 34 scfm Air injection was initiated for the air permeability testing and was continued to monitor oxygen influence in the monitoring points. After 48 hours of air injection, the oxygen level in MPC 6.5 had risen from 10.0 to 17.5 percent. Air injection was ceased and changes in soil gas composition were monitored over a period of 2 days with a final readings taken during a return trip to Dyess AFB 17 days after ceasing air injection. The oxygen levels continue to increase to 18.5 percent the first day after ceasing air injection. It then declined slightly to 18 percent after 48 hours. After rechecking 17 days later, the oxygen level remained in the 18 to 19 percent range. Since no oxygen utilization was observed over time, it was not possible to calculate a degradation rate at site FT41. It is our opinion that natural diffusion of oxygen exceeds biological utilization in the upper soils at this site. Deeper contaminated soils may be more anaerobic and benefit from extended air injection. An additional benefit of air injection will be a gradual drying of the soils which should alter soil gas sampling at deeper points. Sampling of the deeper points will be reattempted during the 6-month respiration testing.

2.3.5 Potential air emissions

Soil concentrations of BTEX compounds were not detected in any of the three samples collected at site FT41. Thus, the long-term potential for air emissions from full-scale bioventing operations at this site is very low. Initial emissions of other volatile petroleum hydrocarbons should be minimal because accumulated vapors will move slowly outward from the air injection point and will be biodegraded as they move horizontally through the soil.

Table 2.4 Influence of Air Injection at VW1 on Monitoring Point Oxygen Levels, FT 41 Dyess AFB, Texas

MP	Distance From VW (Feet)	Depth (Feet)	Initial Oxygen	24 Hour Oxygen	48 Hour Oxygen
C	25	6.5	10.0	14.5	17.3
B	10	9.5	20.5	20.5	20.6

Average air flow = 34 scfm.

2.4 Recommendations

Initial bioventing tests at this site indicate that oxygen had not been depleted in the three MP intervals that were able to be sampled, however, high TRPH concentrations were detected in soils from the VW and MPA boreholes. All three screened intervals at MPA could not be sampled. Air injection was demonstrated to be an effective method of providing oxygen to contaminated soils during the 48 hours oxygen influence testing performed at the site. Contaminated soils likely extend beneath building 2001, and these soils will likely benefit from the introduction of oxygen from the injection blowers. ES has recommended that air injection continue at this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates. Air injection may also loosen soils such that air penetrates more readily into tighter formation soils. This might allow soil gas testing at the deeper MP intervals.

A 1-horsepower regenerative blower has been installed at the site for continuous air injection. In June 1994, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In December 1994, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade the pilot-scale system, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. Evaluate the need for integrating bioventing with free product recovery. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operation.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.
3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and MPs.

Appendix A

Boring Logs

GEOLOGIC BORING LOG

BORING NO.	VW	CONTRACTOR:	Rone Eng.	DATE SPUD:	12/3/93 14:15
CLIENT:	DYESS AFB	RIG TYPE:	CME	DATE CMPL:	
JOB NO.:	DE268.18.04	DRLG METHOD:	H/S	ELEVATION:	
LOCATION:	FT-40 (DY I)	BORING DIA.:	11'	TEMP.:	≈ 55 °F
GEOLOGIST:	RAF	DRLG FLUID	N/A	WEATHER:	Wind out of N/Cloudy

COMMENTS:

Elev. (ft.)	Depth (ft.)	Profile	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			Redish brown SILT, Fill mat'l					
		F		trace fine SAND, chewing up					
		i		plastic liner.					
		L							
		L							
	5			SAA					
		LINER ?							
		C							
		L		Dk Brn to Red CLAY w/			SS	4	HS = 18 ppm
		A		sm SAND, sl moist, sl odor		10-11'		6 7	
	10	Y		stiff	DY-1		SS	5	HS = 18 ppm
				SAA strong odor	VW			6 10	
							SS		HS = 13 ppm
				SAA					
				SAA, more plastic, some gray staining			SS		HS = 13 ppm
	15			sl. odor, more red than brown, tight			SS		HS = 17 ppm
		S		@ 15'3" SHALE, olive-gray, no odor					
		H		TD = 15.5'					
		A							
		L							
		E							
	20								
	25								
	30								

sl – slight	v – very	f – fine	SAMPLE TYPE
tr – trace	lt – light	m – medium	D – DRIVE C Core recovery
sm – some	dk – dark	c – coarse	C – CORE
& – and	bf – buff	BH – Bore Hole	G – GRAB Core lost
@ – at	brn – brown	SAA – Same As Above	
w – with	blk – black		Water level drilled

Sheet of

GEOLOGIC BORING LOG

BORING NO.	MPA	CONTRACTOR:	Rone Eng.	DATE SPUD:	12/3/93 16:05
CLIENT:	Dyess AFB	RIG TYPE:	CME	DATE CMPL:	
JOB NO.:	722 268.18.04	DRLG METHOD:	H/S	ELEVATION:	
LOCATION:	FT-40 Bldg 1001	BORING DIA.:	~~N/A~~ 6"	TEMP.:	55° F
GEOLOGIST:	RAF	DRLG FLUID	N/A	WEATHER:	Cloudy / wind from N

COMMENTS:

Elev. (ft.)	Depth (ft.)	Profile	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1	FILL		reddish brown SILT, tr CLAY and fine sand, fill mat'l					
	4								No liner
	5						SS		
				SAA, sampling along vertical portion of the liner			SS		No liner
		CLAY		red CLAY sl moist, stiff sl odor	DY1-9		SS		Liners HS=15
	10								
							SS		No liner HS=10
				SAA			SS		No liner
				SHALE @ 13.5' olive to grey					
	15	SHALE		TD = 13.5'					
	20								
	25								
	30								

sl – slight	v – very	f – fine	SAMPLE TYPE
tr – trace	lt – light	m – medium	D – DRIVE C Core recovery
sm – some	dk – dark	c – coarse	C – CORE
& – and	bf – buff	BH – Bore Hole	G – GRAB Core lost
@ – at	brn – brown	SAA – Same As Above	
w – with	blk – black		Water level drilled

GEOLOGIC BORING LOG

BORING NO.: MPB
CLIENT: DYESS AFB
JOB NO.: DE268.18.04
LOCATION: FT-40
GEOLOGIST: RAF
COMMENTS:

CONTRACTOR: Rone Eng.
RIG TYPE: CME
DRLG METHOD: H/S - Solid Stem
BORING DIA.: 5½
DRLG FLUID: N/A

DATE SPUD: 12/4/93
DATE CMPL:
ELEVATION:
TEMP.: ≈50°
WEATHER: Clear

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1	F		Reddish SILT, fill mat'l, tr.					
		I		sand and clay, sl. moist					
		L							
		L							
	5								
				SAA			SS		Geotech sample
				SAA			SS		"
		LINER					SS		HS= 38 ppm
	10			Reddish to brown CLAY, stiff			9.5		sl odor below liner
				sl. moist tr. SAND.			SS 11.5		HS = 34 ppm
							11.5		
				SAA			SS		HS = 27 ppm
				SHALE - olive to gray TD= 13.5'			13.5		
	15								
	20								
	25								
	30								

sl – slight
tr – trace
sm – some
& – and
@ – at
w – with

v – very
lt – light
dk – dark
bf – buff
brn – brown
blk – black

f – fine
m – medium
c – coarse
BH – Bore Hole
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost
Water level drilled

GEOLOGIC BORING LOG

BORING NO.: MPC
CLIENT: DYESS AFB
JOB NO.: DE268.18.04
LOCATION: FT-40 BLDG.1001
GEOLOGIST: RAF
COMMENTS:

CONTRACTOR: RONE ENG
RIG TYPE: CME
DRLG METHOD: SOLID FLIGHT
BORING DIA.: 5½"
DRLG FLUID: N/A

DATE SPUD: 12/4/93
DATE CMPL:
ELEVATION:
TEMP.: ≈ 60°
WEATHER: CLEAR

Elev. (ft.)	Depth (ft.)	Pro-file	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1	CLAY		Dark brown CLAY w/ SILT					
				dry, very stiff					
	5								
				SAA			SS		
				reddish brown CLAY w/ SILT and					
				tr. SAND, sl. moist, sl. odor.			SS		HS =
							SS		HS 5
	10						SS		
				SAA					HS =
							SS		HS =
				SHALE TD = 14'					
	15	SHALE							
	20								
	25								
	30								

sl – slight; tr – trace; sm – some; & – and; @ – at; w – with
v – very; lt – light; dk – dark; bf – buff; brn – brown; blk – black
f – fine; m – medium; c – coarse; BH – Bore Hole; SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery
Core lost
Water level drilled

GEOLOGIC BORING LOG

BORING NO.	MPBG	CONTRACTOR:	RONE ENG	DATE SPUD:	12/4/93
CLIENT:	Dyess AFB	RIG TYPE:	CME	DATE CMPL:	12/4/93
JOB NO.:	DE268.1804	DRLG METHOD:	HSA	ELEVATION:	
LOCATION:	FT-40 (DY1)	BORING DIA.:	6"	TEMP.:	~57°F
GEOLOGIST:	BRV	DRLG FLUID	N/A	WEATHER:	Sunny & breezy
COMMENTS:					

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			Dark brown clay/w/silt, dry					
				v. stiff. no odors.					
	5								
				reddish brown clay w/ silt,					Sample collected
				tr. sand, sl. damp. no odors					from 8-10' for
									TKN analysis
	10								
				TD = 11.0 feet.					
	15								
	20								
	25								
	30								

sl – slight
tr – trace
sm – some
& – and
@ – at
w – with

v – very
lt – light
dk – dark
bf – buff
brn – brown
blk – black

f – fine
m – medium
c – coarse
BH – Bore Hole
SAA – Same As Above

SAMPLE TYPE
D – DRIVE
C – CORE
G – GRAB

C Core recovery

Core lost

Water level drilled

GEOLOGIC BORING LOG

BORING NO.:	VW	CONTRACTOR:	ROWE ENG.	DATE SPUD:	12/5/93
CLIENT:	DYESS AFB	RIG TYPE:	CME	DATE CMPL:	
JOB NO.:	DE268.18.04	DRLG METHOD:	SOLID FLIGHT	ELEVATION:	
LOCATION:	FT-41 BLDG 2001	BORING DIA.:	11"	TEMP.:	≈50°
GEOLOGIST:	RAF	DRLG FLUID	N/A	WEATHER:	OVERCAST / PTLY CLDY

COMMENTS:

Elev. (ft.)	Depth (ft.)	Profile	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			Dark brown SILT w/ CLAY and tr. sand, sl. moist and plastic					
				Drk brn CLAY w/ sm SILT, moist, plastic			SS		
	5			SAA, odor @ 6'			SS		
							SS	7.5	HS = 55 ppm
				SAA, strong odor, gray staining	DYZ-VW	8.25	SS	9.5	HS = 70 ppm
	10								
				SAA, less moisture, stiffer, sm gravel			SS	11.5	HS = 52
				sl. odor, sm staining, stiffer			SS	13	HS = 40
				red CLAY, very stiff, flaky, sl. odor			SS	14.5	HS = 28
	15								
				SAA, no odor			SS	16	HS = 23
				TD = 16.0'					
	20								
	25								
	30								

sl – slight	v – very	f – fine	**SAMPLE TYPE**
tr – trace	lt – light	m – medium	D – DRIVE C Core recovery
sm – some	dk – dark	c – coarse	C – CORE
& – and	bf – buff	BH – Bore Hole	G – GRAB Core lost
@ – at	brn – brown	SAA – Same As Above	
w – with	blk – black		Water level drilled

GEOLOGIC BORING LOG

BORING NO.:	MPA	CONTRACTOR:	Rowe Eng.	DATE SPUD:	12/5/93
CLIENT:	DYESS AFB	RIG TYPE:	CME	DATE CMPL:	
JOB NO.:	DE 268.18.04	DRLG METHOD:	SOLID FLIGHT	ELEVATION:	
LOCATION:	FT-41	BORING DIA.:	5 1/2"	TEMP.:	~60°
GEOLOGIST:	RAF	DRLG FLUID	N/A	WEATHER:	PTLY CLDY
COMMENTS:					

Elev. (ft.)	Depth (ft.)	Pro-file	US CS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			dk brown CLAY w/ sm SILT,					Log from cuttings
				dry, stiff					
	5								
						~~[illegible]~~		6	
				red/brown CLAY w/ black and			SS		HS =
				gray staining / sm SILT strong				7.5	
				odor.			SS		NO RECOVERY
	10			SAA				9.5	
					DYZ	SS			
				red CLAY, very stiff sm staining	MPA-				
					10	~~9.5'~~	SS		
				SAA		10'			
				TD = 12.0'					
	15								
	20								
	25								
	30								

sl – slight	v – very	f – fine	**SAMPLE TYPE**	
tr – trace	lt – light	m – medium	D – DRIVE	C Core recovery
sm – some	dk – dark	c – coarse	C – CORE	
& – and	bf – buff	BH – Bore Hole	G – GRAB	Core lost
@ – at	brn – brown	SAA – Same As Above		
w – with	blk – black			Water level drilled

GEOLOGIC BORING LOG

BORING NO.:	MPB	CONTRACTOR:	RONE ENG.	DATE SPUD:	12/5/93 12:50
CLIENT:	DYESS AFB	RIG TYPE:	CME	DATE CMPL.:	
JOB NO.:	DE268.18.04	DRLG METHOD:	SOLID FLIGHT	ELEVATION:	
LOCATION:	FT-41	BORING DIA.:	5½"	TEMP.:	≈ 65°
GEOLOGIST:	RAF	DRLG FLUID	N/A	WEATHER:	PTLY CLDY
COMMENTS:					

Elev. (ft.)	Depth (ft.)	Pro-file	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			dark brn CLAY w/ SILT,					Log from cuttings
				sl. moist and plastic					
	5			SAA					
								6	
							SS		
								7.5	
				red/brown CLAY, tr SAND, sl.			SS		
	10			moist/plastic, sl. odor				9	
				SAA			SS		
								11	
					DY2 MPB 12.5	12.5	SS		
				SAA					
				TD = 13.0'				13	
	15								
	20								
	25								
	30								

sl – slight, tr – trace, sm – some, & – and, @ – at, w – with

v – very, lt – light, dk – dark, bf – buff, brn – brown, blk – black

f – fine, m – medium, c – coarse, BH – Bore Hole, SAA – Same As Above

SAMPLE TYPE

D – DRIVE
C – CORE
G – GRAB

C Core recovery

Core lost

Water level drilled

Sheet of

GEOLOGIC BORING LOG

BORING NO.: MPC
CLIENT: Dyess AFB
JOB NO.: DE268.18.04
LOCATION: FT-41 BLDG 2001
GEOLOGIST: BRV
COMMENTS:

CONTRACTOR: Rone Eng
RIG TYPE: CME HSA
DRLG METHOD: Solid Flit HSA
BORING DIA.: 6"
DRLG FLUID: N/A

DATE SPUD: 12/5/93
DATE CMPL: 12/5/93
ELEVATION:
TEMP.: ~65°F
WEATHER: Sunny/Ptly Cloudy

Elev. (ft.)	Depth (ft.)	Profile	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1			dark brown clay w/ silt					Plastic @ 1/2'
				plastic, no odors to 7.0'					
	5								
				~~Fill~~					
				Fill material @ 6-6.5' Uniform, soft			SS		
				sand and silt.			SS		
				reddish brown clay with silt					HS = 39 ppm
	10			sl. plastic, firm, sl. odors			SS		HS = 30 ppm
				SAA, stiffer clay			SS		HS = 31 ppm
				increasing sm. to med. gravel					
				TOTAL Depth = 13.5'					
	15								
	20								
	25								
	30								

sl - slight
tr - trace
sm - some
& - and
@ - at
w - with

v - very
lt - light
dk - dark
bf - buff
brn - brown
blk - black

f - fine
m - medium
c - coarse
BH - Bore Hole
SAA - Same As Above

SAMPLE TYPE
D - DRIVE
C - CORE
G - GRAB

C Core recovery
Core lost
Water level drilled

Appendix B

O&M Instructions

BLOWER SYSTEM OPERATIONS AND MAINTENANCE MANUAL FOR EXTENDED PILOT TESTING SYSTEM

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE

DYESS AFB, TEXAS

USAF CONTRACT F41624-92-D-8036, DELIVERY ORDER 14

March 1994

Prepared by:

Engineering-Science, Inc.
7800 Shoal Creek Blvd., Suite 222W
Austin, Texas 78757

320SA\AU380\EXT-PLT

CONTENTS

SECTION 1

INTRODUCTION

This document has been prepared by Engineering-Science, Inc. to support the bioventing initiative contract awarded by the Air Force Center for Environmental Excellence. The contract involves the conducting of bioventing pilot tests at 35 sites on 23 Air Force bases across the United States.

At most sites, bioventing systems will be installed upon completion of the initial bioventing pilot tests for the purpose of extended pilot testing. These systems will operate for a 1-year period to provide further information as to the feasibility of the technology at each site, and to provide interim remedial action.

This Operations and Maintenance Manual has been created for sites at which regenerative or rotary-vane blowers have been installed for extended pilot testing. Basic maintenance of these systems is the responsibility of the Air Force facility. This manual is to be used by facility personnel to guide and assist them in operating and maintaining the blower system. Section 2 provides a summary of the bioventing system components installed. Section 3 of this document describes the blower system. Section 4 details the maintenance requirements and provides maintenance schedules. Section 5 describes the system monitoring that is required to forecast system maintenance needs and to provide data for the extended pilot test. Blower performance curves and relevant service information for regenerative blowers are provided in section 6, and a data collection sheet is provided in section 7.

SECTION 2

BLOWER SYSTEM CONFIGURATION SUMMARY

System Type (injection, extraction): Injection

Blower (regenerative, rotary vane): Regenerative

Blower Model: GAST® R4110N-50

Motor (Hp): 1

Inlet Vacuum Gauge (range): 0 - 60" of H_2O

Inlet Filter (part no.): AJ 134E

Outlet Temperature Gauge (range): 0 - 250°F

Outlet Pressure Gauge (range): 0 - 100" of H_2O

Pressure Relief Valve Set @ (give unit of measure): 52" of H_2O

SECTION 3

BIOVENTING SYSTEM OPERATION

3.1 PRINCIPLE OF OPERATION

Bioventing is the forced injection of fresh air, or withdrawal of soil gas, to enhance the supply of oxygen for *in situ* bioremediation. Either a pressure (air injection) or vacuum (vapor extraction) blower unit is used to inject or withdraw air into or from the soil, thereby supplying fresh air with approximately 20.8 percent oxygen to the contaminated soils. Once oxygen is provided to the subsurface, existing bacteria will proceed with the breakdown of fuel residuals.

At Dyess Air Force Base FT40 and FT41 sites, injection blower systems have been installed.

3.2 SYSTEM DESCRIPTION

3.2.1 Blower System

A regenerative blower (GAST® R1140N-50) powered by a 1-horsepower direct-drive motor is the workhorse of the bioventing system. This blower is rated at a flow rate of 92 standard cubic feet per minute (scfm) at a pressure of 51 inches of water ; however, the actual performance of the blower will vary with changing site conditions. As installed, the blower was producing an estimated flow rate of 55 to 61 actual cfm at pressures of 37 and 30 inches of water, respectively, for sites FT40 and FT41. The system includes an air filter to remove any particulates which are entrained in the air stream, and several valves and monitoring gauges which are described in the next section. Schematics of the blower systems installed at Dyess Air Force Base is shown on the as-built drawings in the Part II interim reports. Corresponding blower performance curves, and relevant service information are provided in section 6.

3.2.2 Monitoring Gauges

The bioventing system is equipped with vacuum and pressure gauges, and temperature gauges. Gauges have been installed on the system at the following locations: a vacuum gauge in the inlet piping and a pressure gauge in the outlet piping. In addition, a temperature gauge is provided in the discharge piping. The as-built drawings show the locations of the gauges installed on the blower systems at these sites. Temperature gauges may be located at the inlet and outlet of the blower system. These gauges are used to monitor the inlet and outlet temperature to determine the change in temperature across the blower. For the Dyess AFB system, ambient air temperature should be used as an inlet temperature gauge is not provided.

SECTION 4

SYSTEM MAINTENANCE

Although the motor and blower are relatively maintenance free, periodic system maintenance is required for proper operation and long life. Recommended maintenance procedures and schedules are described in detail in the instruction manuals included in section 6, and briefly summarized in this section.

Filter inspection must be performed with the system turned off. To re-start the motor, open the manual air pressure release valve to protect the motor from excessive strain, start motor, and slowly close the pressure release valve.

4.1 Blower/Motor

The blower and motor are relatively maintenance free and should not require any periodic maintenance during the 1-year extended testing period. Both blower and motor have sealed bearings and do not require lubrication.

4.2 AIR FILTER

To avoid damage caused by passing solids through the blower, an air filter has been installed in-line before the blower. The filter element is paper and is accompanied by a polyurethane foam prefilter. The filter should be checked weekly for the first 2 months of operation. Again, a facility employee should determine the best schedule for filter replacement. The polyurethane prefilters can be washed with lukewarm water and a mild detergent. Paper filter elements should never be washed, but should be disposed of and replaced as necessary. When the vacuum drop across the filter is above 15 inches of water, a dirty filter element should be suspected, and cleaning or replacement should be performed.

To remove the filter, loosen the three clamps or the wing nut, lift the metal top off the air filter, and lift the air filter from the metal housing. Remove the polyurethane prefilter (if applicable) and wash before replacing. When replacing the filter, be careful that the rubber seals remain in place.

The filter element is manufactured by Solberg Manufacturing, Inc. in Itasca, Illinois. Their telephone number is (708) 773-1363. Additional filters can also be obtained through Engineering-Science, Inc. (ES), in Denver, Colorado. The ES contacts are Brian Vanderglas of ES Austin, and Rusty Frishmuth of ES Denver, and they can be reached at (303) 831-8100. The filter model number is AJ 134E. It is recommended that the base keep at least one spare air filter at the site; four spare filters were supplied with the blower system.

4.3 MAINTENANCE SCHEDULE

The following maintenance schedule is recommended for these systems. During the initial months of operation more frequent monitoring is recommended to ensure that any startup problems are quickly corrected. A daily drive-by inspection is recommended during the initial 2 weeks of operation to ensure that the blower system is still operating with no unusual sounds. Data collection sheets that can be used to record maintenance activities is included in section 7.

Maintenance Item	Maintenance Frequency
Filter	Check once per month, wash or replace as necessary (see Section 4.2).

4.4 MAJOR REPAIRS

Blowers systems are very reliable when properly maintained. Occasionally, a motor or blower will develop a serious problem. If a blower system fails to start, and a qualified electrician verifies that power is available at the blower or starter, the Engineering-Science, Inc. site manager Mr. Brian Vanderglas should be called at (512) 719-6000. ES is responsible for major repairs during the first year of operation.

SECTION 5

SYSTEM MONITORING

5.1 BLOWER PERFORMANCE MONITORING

To monitor the blower performance, vacuum, pressure, and temperature will be measured. These data should be recorded weekly on a data collection sheet (provided in section 7). All measurements should be taken at the same time while the system is running. Because the system is loud, hearing protection should be worn at all times.

5.1.1 Vacuum/Pressure

With hearing protection in place, open the blower enclosure and record all vacuum and pressure readings directly from the gauges (in inches of water). Record the measurements on a data collection sheet (section 7).

5.1.2 Flow Rate

The flow rate through the vent well and soils can be calculated when the inlet vacuum and outlet pressure of the blower are known. This pressure change across the blower (vacuum + pressure) can be compared to the performance curves for the blower in section 6 to determine the approximate flow rate.

5.1.3 Temperature

With hearing protection in place, open the blower enclosure and record the temperature readings directly from the gauge in degrees Fahrenheit (°F). Record the measurement on a data collection sheet (provided in Appendix B). The temperature change can be converted to degrees Celsius (°C) using the formula °C = (°F - 32) X 5/9.

5.3 MONITORING SCHEDULE

The following monitoring schedule is recommended for this system. During the initial months of operation, more frequent monitoring is recommended to ensure that any start up problems are quickly corrected. Data collection sheets have been provided to assist your data collection.

Monitoring Item	Monitoring Frequency
Vacuum/Pressure	Daily during first week, then once per week.
Temperature	Daily during first week, then once per week.

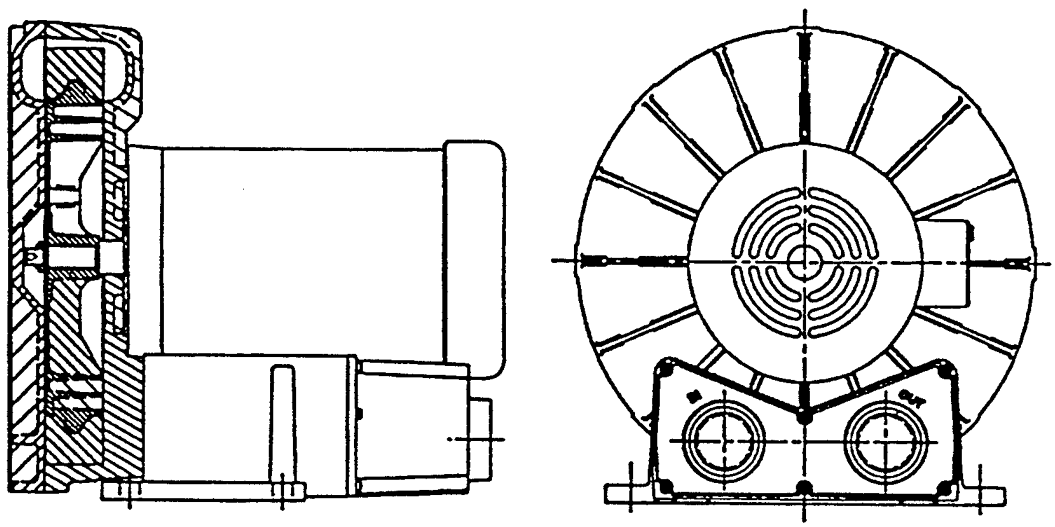
SECTION 6

REGENERATIVE BLOWER INFORMATION

GAST

Post Office Box 97
Benton Harbor, Michigan 49023-0097
Ph: 616/926-6171
Fax: 616/925-8288

Maintenance Instructions for Gast Standard Regenerative Blowers



For original equipment manufacturers special models, consult your local distributor

Gast Rebuilding Centers

Gast Mfg. Corp.
2550 Meadowbrook Rd.
Benton Harbor MI. 49022
Ph: 616/926-6171
Fax: 616/925-8288

Gast Mfg Corp.
505 Washington Avenue
Carlstadt, N. J. 07072
Ph: 201/933-8484
Fax: 201/933-5545

Brenner Fiedler. & Assoc.
13824 Bentley Place
Cerritos, CA. 90701
Ph: 213/404-2721
Fax: 213/404-7975

Wainbee, Limited
121 City View Drive
Toronto, Ont. Canada M9W 5A9
Ph: 416/243-1900
Fax: 416/243-2336

Wainbee, Limited
215 Brunswick Drive
Pointe Claire, P.Q. Canada H9R 4R7
Ph: 514/697-8810
Fax: 514/697-3070

Gast Mfg. Co. Limited.
Halifax Rd, Cressex Estate
High Wycombe, Bucks HP12 3SN
Ph. 44 494 523571
Fax: 44 494 436588

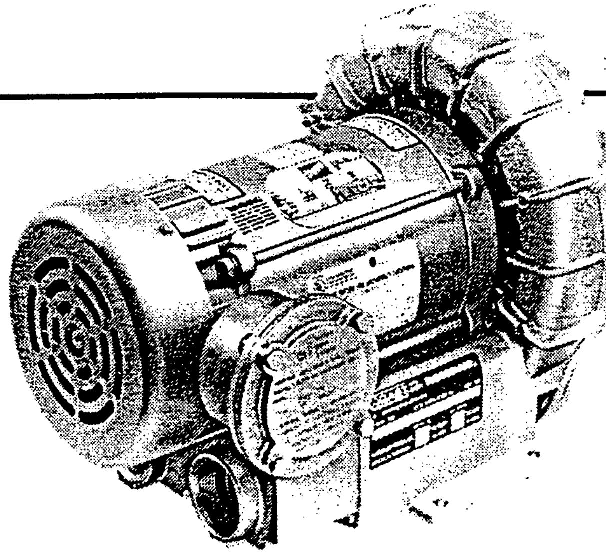
Japan Machinery Co. Ltd.
Central PO Box 1451
Tokyo 100-91 Japan
Ph: 813/3573-5421
Fax: 813/3571-7865

Regenerative Blowers For Soil Remediation to 260 cfm

(5-91)

GAST

R4, R5, R6P Series



MODEL R4 SERIES
48" H_2O MAX. VAC., 88 CFM OPEN FLOW

MODEL R5 SERIES
60" H_2O MAX. VAC., 145 CFM OPEN FLOW

MODEL R6P SERIES
90" H_2O MAX. VAC., 260 CFM OPEN FLOW

PRODUCT FEATURES

- Explosion-proof motors UL (class 1, group D; class 2, groups F & G)
- Sealed air stream
- Rugged construction
- Low maintenance

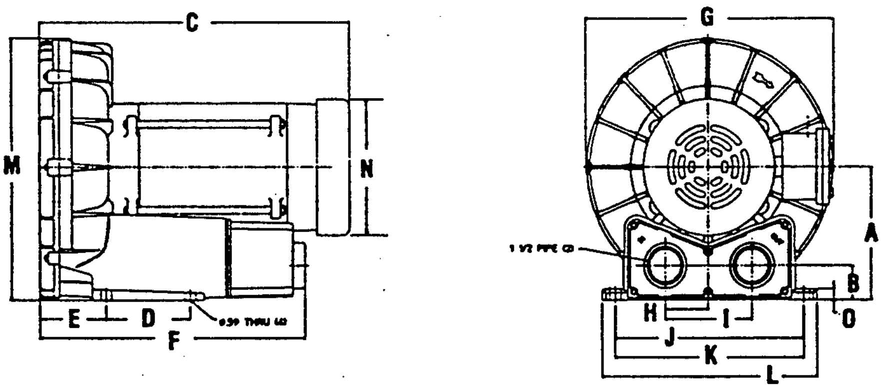
RECOMMENDED ACCESSORIES

- Inlet filter AJ151G (Reducing filter plumbing from 2½" to 1½" is needed to accommodate filter on R4 and R5 models.)
- Relief valve AG258
- Vacuum gauge AE134

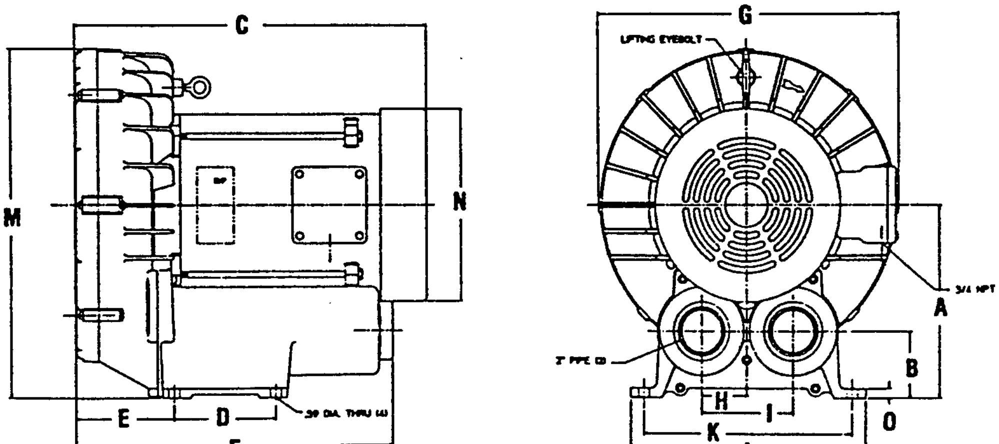
Product Dimensions Metric (mm) U.S. Imperial (inches)

Model	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
R4110N-50	157	43	360	95	72	316	313	50	101	225	227	254	293	175	11
	6.18	1.68	14.16	3.75	2.85	12.44	12.31	1.98	3.96	8.86	8.93	10.00	11.73	6.88	.44
R4310P-50	157	43	360	95	72	316	313	50	101	225	227	254	293	175	11
	6.18	1.68	14.17	3.75	2.84	12.44	12.31	1.98	3.96	8.86	8.93	10.00	11.73	6.88	.44
R5325R-50	178	46	423	114	91	361	344	60	121	260	262	298	350	183	15
	7.00	1.82	16.66	4.50	3.58	14.22	13.56	2.38	4.75	10.25	10.31	11.75	13.78	7.19	.59
R6P355R-50	248	80	482	140	137	438	428	64	127	–	290	325	463	257	13
	9.77	3.15	18.98	5.51	5.39	17.25	16.87	2.50	5.00	–	11.42	12.80	18.21	10.12	.50

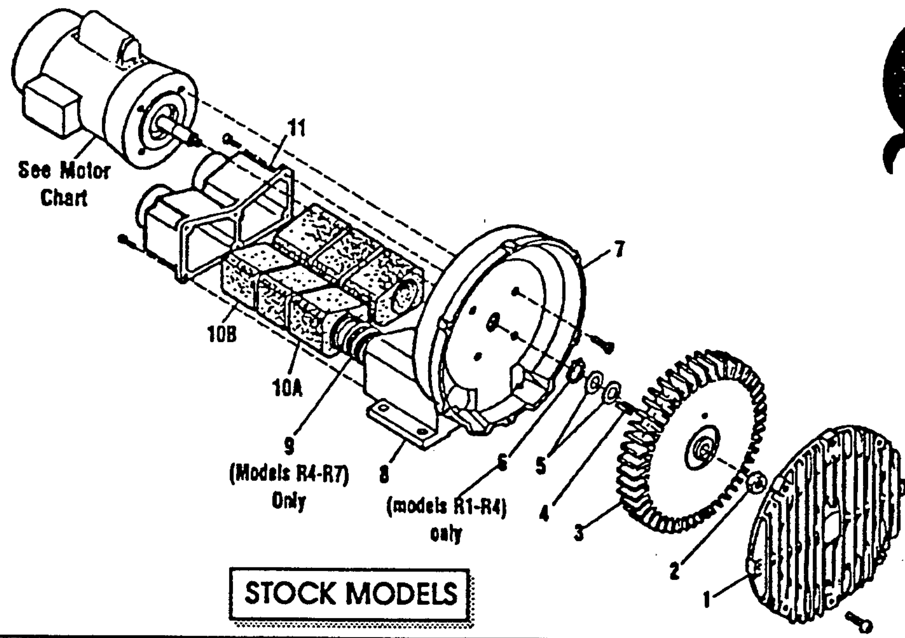
Model R4 Series
Model R5 Series



Model R6P Series



NOTE: These units with explosion-proof motors are designed specifically for qualified OEMs in the soil remediation industry. They are not intended to be applied for other uses without written acknowledgement from an authorized employee of Gast Manufacturing Corporation.



STOCK MODELS

Part Name	R1	R2	R3	R4	R5	R6	R6P	R6PP/R6PS	R7
#1 Cover	AJ101A	AJ101B	AJ101C	AJ101D	AJ101EQ	AJ101F	AJ101K	(2)AJ101KA	AJ101G
#2 Stopnut	BC187	BC187	BC181	BC181	BC181	BC181	BC181	(2)BC182	BC183
#3 Impeller	AJ102A	AJ102BQ	AJ102C	AJ102D	AJ102E	AJ102FR	AJ102K	(2)AJ102KA	AJ102GA
#4 Square Key	AH212C	AH212	AB136A	AB136D	AB136	AB136	AB136	(2)AB136	AC628
#5 Shim Spacer (s)	AJ132	AE686-3	AJ109	AJ109	AJ109	AJ116A	AJ116A	AJ116A	AJ110
#6 Retaining Ring	AJ145	AJ145	AJ149	AJ149					
#7 Housing	AJ103A	AJ103BQ	AJ103C	AJ103DR	AJ103E	AJ103F	AJ103K	AJ103KD	AJ103GA
#8 Muffler Box					AJ104E	AJ104F			
#9 Spring				AJ113DR	AJ113DQ	AJ113FQ	AJ113FQ		AJ113G
#10A Foam	(4)AJ112A	(4)AJ112B	(4)AJ112C	(4)AJ112DS	(4)AJ112ER	(6)AJ112F	(8)AJ112K		(8)AJ112GA
#10B Foam		(2)AJ112BQ	(2)AJ112CQ	(2)AJ112DR	(2)AJ112EQ				
#11 Muffler Extension/ Adapter Plate	AJ106H	AJ106BQ	AJ106CQ	AJ106DQ	AJ106EQ	AJ106FQ	AJ104K		AJ104GA
Shim Kit	K396	K396							K395

MOTOR CHART

REGENAIR MODEL NUMBER	MOTOR NUMBER	MOTOR SPECIFICATIONS 60 HZ VOLTS	50 HZ VOLTS	PHASE
R1102	J111X	115/208-230	110/220-240	1
R1102C	J112X	115		1
R2103	J311X	115/208-230	110/220	1
R2105	J411X	115/208-230	110/220	1
R2303A	J310	208-230/460	220/380-415	3
R2303F	J313	208-230	220	3
R3105-1/R3105-12	J411X	115/208-230	110/220-240	1
R3305A-1/R3305A-13	J410	208-230/460	220/380-415	3
R4110-2	J611AX	115/208-230	110/220-240	1
R4310A-2	J610	208-230/460	220/380-415	3
R5125-2	J811X	115/208-230		1
R5325A-2	J810X	208-230/460	220/380-415	3
R6125-2	J811X	115/208-230		1
R6325A-2	J810X	208-230/460	220/380-415	3
R6335A-2	J910X	208-230/460	220/380-415	3
R6150J-2	J1013	230		1
R6350A-2	J1010	208-230/460	220/380-415	3
R6P335A	J910X	208-230/460	220/380-415	3
R6P350A	J1010	208-230/460	220/380-415	3
R6P355A	J1110A	208-230/460	220/380-415	3
R7100A-2*	J1210B	208-230/460	220/380-415	3
R6PP/R6PS3110M	JD1100	208-230/460	220/380-415	3

* No lubrication needed at start up. Bearings lubricated at factory.

* Motor is equipped with alemite fitting. Clean tip of fitting and apply grease gun. Use 1 to 2 strokes of high quality ball bearing grease.

Consistency	*Type*	*Typical Grease*
Medium	Lithium	Shell Dolium R

Hours of service per year	*Suggested Relube Interval*
5,000	3 years
Continual NormalApplication	1 year
Seasonal service motor idle for 6 months or more	1 year beginning of season
Continuous-high ambients, dirty or moist applications.	6 months

60 HZ FLOW DATA (CFM)

All performance figures relate to stock models. A few high pressure units may be available. Consult your local distributor.

Regenair Model Number	PRESSURE 0"H_2O	20"H_2O	40"H_2O	60"H_2O	80"H_2O	100"H_2O	Maximum Pressure "H_2O"*
R1	26	14					28
R2	42	26					38
R3105-1	52	38	14				42
R3105-12	52	36	23				55
R3305A-13	52	36	23				55
R4	90	70	50				52
R5	145	130	100				65
R6125-2	200	180					35
R6325A-2	200	180	152				40
R6335A-2	205	175	155	135			70
R6350A-2	200	180	150	130	110	80	105
R6P335A	290	250					30
R6P350A	300	260	230	200			60
R6P355A	300	260	230	200	160		90
R7100A-2	420	380	340	310	280	230	115
R6PP311OM	485	452	420	380	330		95
R6PS311OM	265	258	252	244	236	226	170

Regenair Model Number	VACUUM 0"H_2O	20"H_2O	40"H_2O	60"H_2O	80"H_2O	Maximum Vacuum "H_2O"*
R1	25	14				26
R2	40	22				34
R3105-1	50	34	9			40
R3105-12	51	34	20			50
R3305A-13	51	34	20			50
R4	82	62	39			48
R5	140	115	90	50		60
R6125-2	190	155	125			45
R6325A-2	190	155	125			45
R6335A-2	190	150	125	100		75
R6350A-2	190	180	150	100	70	90
R6P335A	270	230				37
R6P350A	280	240	210	170		70
R6P355A	280	240	210	170	100	86
R7100A-2	410	350	300	250	170	90
R6PP311OM	470	425	375	320	220	80
R6PS311OM	240	225	210	195	175	130

***This number indicates the maximum static pressure differential recommended (with cooling air still flowing through unit). In general, units 1hp or less can be dead headed. Check with local representative or distributor to verify which models apply.**

Operation of the blower above the recommended maximum duty will cause premature failure due to the build up of heat damaging the components.

Performance data was determined under the following conditions:

1) Unit in a temperature stable condition.
2) Test conditions: Inlet air density at 0.075lbs. per cubic foot. (20°C(68°F), 29.92 in. Hg(14.7PSIA)).
3) Normal performance variations on the resistance curve within +/- 10% of supplied data can be expected.
4) Specifications subject to change without notice.
5) All performance at 60Hz operation.

70-6100
F2-205/8/92
AK811 Rev. E

GAST®

Post Office Box 97
Benton Harbor, MI. 49023-0097
Ph: 616/926-6171
Fax: 616/925-8288

INSTALLATION AND OPERATING INSTRUCTIONS FOR GAST HAZARDOUS DUTY REGENAIR BLOWERS

This instruction applies to the following models ONLY: R3105N-50, R4110N-50, R4310P-50, R4P115N-50, R5125Q-50, R5325R-50, R6130Q-50, R6P155Q-50, R6350R-50, R6P355R-50 and R7100R-50.

Gast Authorized Service Facilities are Located in the locations listed below

Gast Manufacturing Corporation
505 Washington Avenue
Carlstadt, N. J. 07072
Ph: 201/933-8484
Fax: 201/933-5545

Gast Manufacturing Corporation
2550 Meadowbrook Road
Benton Harbor, MI. 49022
Ph: 616/926-6171
Fax: 616/925-8288

Brenner Fiedler & Associates
13824 Bentley Place
Cerritos, CA. 90701
Ph: 213/404-2721
Ph: 800/843-5558
Fax: 213/404-7975

Wainbee Limited
215 Brunswick Blvd.
Pointe Claire, Quebec
Canada H9R 4R7
Ph: 514/697-8810
Fax: 514/-697-3070

Wainbee Limited
5789 Coopers Ave.
Mississauga, Ontario
Canada L4Z 3S6
Ph: 416/243-1900
Fax: 416/243-2336

Japan Machinery
Central PO Box 1451
Toyko 100-91, Japan
Ph: 813 3573-5421
Fax: 813 3571-7896

Gast Manufacturing Co. Ltd.
Halifax Road, Cressex Estate
High Wycombe, Bucks HP12 3SN
England
Ph: 44 494 523571
Fax: 44 494 436588

Safety

⚠ This is the safety alert symbol. When you see this symbol, personal injury is possible. The degree of injury is shown by the following signal words:

⚠ DANGER: Severe injury or death will occur if hazard is ignored.

⚠ WARNING: Severe injury or death can occur if hazard is ignored.

⚠ CAUTION: Minor injury or property damage can occur of hazard is ignored.

Review the following information carefully before operating.

General Information

⚠ DANGER: Do not pump flammable or explosive gases or operate in an atmosphere containing them. Ambient temperature for normal operation should not exceed 40 degrees C (105 degrees F). For higher ambient operation, consult the factory. Blower performance is reduced by the lower atmospheric pressure of high altitudes. If it applies to this unit, consult a Gast distributor or the factory for details.

Installation

⚠ WARNING: Electric Shock can result from bad wiring. Wiring must conform to all required safety codes and be installed by a qualified person.

Grounding is required.

The Gast Regenair blower can be installed in any position. The flow of cooling air over the blower and motor must not be blocked.

PLUMBING - The threaded pipe ports are designed as connection ports only and will not support the plumbing. Be sure to use the same or larger size pipe and fittings to prevent air flow restriction and over-heating of the blower. When installing plumbing, be sure to use a small amount of pipe thread lubricant. This protects the threads in the aluminum blower housing. Dirt and chips, often found in new plumbing, should not be allowed to enter the blower.

NOISE - To reduce noise and vibration, the unit should be mounted on a solid surface that will not increase sound. The use of shock mounts or vibration isolation material is recommended. If needed, inlet or discharge noise can be reduced by attaching muffler assemblies (see accessories).

ROTATION - The Gast Regenair blower should only rotate clockwise as viewed from the electric motor side. This is marked with an arrow in the casting. Proper rotation can be confirmed by checking air flow at the IN and OUT ports. On blowers powered by a three phase motor, rotation is reversed by changing any two of the three power wires.

Operation

⚠ WARNING: Solid or liquid material exiting the blower or piping can cause eye damage or skin cuts. Keep away from air stream.

⚠ CAUTION: Attach blower to solid surface before starting. Prevent injury or damage from unit movement.

Air containing solid particles or liquid must pass through a filter before entering the blower (see accessories list for filter suggestions). Blowers must have mufflers, filters, other accessories and all piping attached before starting. Any foreign material passing through the blower may cause internal damage.

⚠ CAUTION: Outlet piping can burn skin. Guard or limit access.

Mark "CAUTION Hot surface. Can cause burns."

Air temperature increases when passing through the blower. When run at duties above 50 in. H_2O, metal pipe may be required for hot exhaust air.

The blower must not be operated above the limits for continuous duty. 'Standard' R1, R2, R3 and R4 can operate continuously with not air flowing through the blower. Other units can only be run at the rating shown on the model number label. Do *not* close off inlet (for vacuum) or exhaust (for pressure) to reduce extra air flow. This could cause added heat and motor load.

ACCESSORIES - Gast pressure gauges AJ496 or AE133 and vacuum gauges AJ497 or AE134 show blower duty. The Gast pressure/vacuum relief valve, AG258, will limit the operating duty by admitting or relieving air. It also allows full flow through the blower when the relief valve closes.

Servicing

⚠ **WARNING: Disconnect electric power before servicing. Be sure rotating parts have stopped. Electric shock or severe cuts can result. Inlet and exhaust filters need occasional cleaning or replacement of the elements. Failure to do so will result in more pressure drop, reduced air flow and hotter operation. The outside of the unit requires cleaning of dust and dirt. The inside of the blower also may need cleaning to remove material coating the impeller and housing. If not done, the buildup can cause vibration, hotter operation and reduced flow. Noise absorbing foam in the mufflers may need replacement.**

KEEP THIS INFORMATION WITH THE BLOWER. REFER TO IT FOR SAFE INSTALLATION, OPERATION OR SERVICE.

TROUBLESHOOTING

Symptom	*Possible Diagnosis*	*Possible Remedy*
Excess Vibration	Impeller damaged by foreign material Impeller contaminated by foreign material	Replace impeller Clean impeller, install adequate filtration.
Abnormal sound	Motor bearing failed Impeller rubbing against cover or housing	Replace bearings Repair Blower, check clearances.
Increase in sound	Foreign material can coat or destroy muffler foam.	Replace foam muffler elements, trap or filter foreign material.
Blown fuse	Electrical wiring problem	Have qualified person check fuse capacity and wiring.
Unit very hot	Running at too high a pressure or vacuum	Install a relief valve

OPERATING AND MAINTENANCE INSTRUCTIONS

SAFETY

This is the safety alert symbol. When you see this symbol personal injury is possible. The degree of injury is shown by the following signal words:

⚠ DANGER Severe injury or death will occur if hazard is ignored.

⚠ WARNING Severe injury or death can occur if hazard is ignored.

⚠ CAUTION Minor injury or property damage can occur if hazard is ignored.

Review the following information carefully before operating.

GENERAL INFORMATION

This instruction applies to the following models ONLY: R3105N-50, R4110N-50, R4310P-50, R4P115N-50, R5125Q-50, R5325R-50, R6130Q-50, R6P155Q-50, R6350R-50, R6P355R-50 and R7100R-50. These blowers are intended for use in Soil Vapor Extraction Systems. The blowers are sealed at the factory for very low leakage. They are powered with a U.L. listed electric motor Class 1 Div. 1 Group D motors for Hazardous Duty locations. Ambient temperature for normal full load operation should not exceed 40° C (105° F). For higher ambient operation, contact the factory.

Gast Manufacturing Corporation may offer general application guidance: however, suitability of the particular blower and/or accessories is ultimately the responsibility of the user, not the manufacturer of the blower.

INSTALLATION

⚠ *DANGER Models R5325R-50, R6130Q-50, R6350R-50, R5125Q-50, R6P155Q-50, R6P355R-50 AND R7100R-50 use Pilot Duty Thermal Overload Protection. Connecting this protection to the proper control circuitry is mandated by UL674 and NEC501. Failure to do so could/ may result in a EXPLOSION. See pages 3 and 4 for recommended wiring schematic for these models.*

⚠ *WARNING Electric shock can result from bad wiring. A qualified person must install all wiring, conforming to all required safety codes. Grounding is necessary.*

⚠ *WARNING This blower is intended for use on soil vapor extraction equipment. Any other use must be approved in writing by Gast Manufacturing. Corp.* Install this blower in any mounting position. Do not block the flow of cooling air over the blower and motor.

PLUMBING - Use the threaded pipe ports for connection only. They will not support the plumbing. Be sure to use the same or larger size pipe to prevent air flow restriction and overheating of the blower. When installing fittings, be sure to use pipe thread sealant. This protects the threads in the blower housing and prevents leakage. Dirt and chips are often found in new plumbing. Do not allow them to enter the blower.

NOISE - Mount the unit on a solid surface that will not increase the sound. This will reduce noise and vibration. We suggest the use of shock mounts or vibration isolation material for mounting.

ROTATION - The Gast Regenair Blower should only rotate clockwise as viewed from the electric motor side. The casting has an arrow showing the correct direction. Confirm the proper rotation by checking air flow at the IN and OUT ports. If needed reverse rotation of three phase motors by changing the position of any two of the power line wires.

OPERATION

⚠ *WARNING Solid or liquid material exiting the blower or piping can cause eye damage or skin cuts. Keep away from air stream.*

⚠ *WARNING - Gast Manufacturing Corporation will not knowingly specify, design or build any blower for installation in a hazardous, combustible or explosive location without a motor conforming to the proper NEMA or U. L. standards.* Blowers with standard TEFC motors should never be utilized for soil vapor extraction applications or where local state and/or Federal codes specify the use of explosion-proof motors (as defined by the National Electric Code, Articles 100,500 c1990).

⚠ CAUTION *Attach blower to solid surface before starting to prevent injury or damage from unit movement.* Air containing solid particles or liquid must pass through a filter before entering the blower. Blowers must have filters, other accessories and all piping attached before starting. Any foreign material passing through the blower may cause internal damage to the blower.

⚠ CAUTION *Outlet piping can burn skin. Guard or limit access.* Mark *"CAUTION Hot Surface. Can Cause Burns".* Air temperature increases when passing through the blower. When run at duties above 50 in. H_2O, metal pipe may be required for hot exhaust air. The blower must not be operated above the limits for continuous duty. Only models R3105N-50, R4110N-50 and R4310P-50 can be operated continuously with no air flowing through the blower. Other units can only be run at the rating shown on the model number label. Do not Close off inlet (for vacuum) to reduce extra air flow. This will cause added heat and motor load. Blower exhaust air in excess of 230°F indicates operation in excess of rating which can cause the blower to fail.

ACCESSORIES ...Gast pressure gauge AJ496 and vacuum gauges AJ497 or AE134 show blower duty. The Gast pressure/vacuum relief valve, AG258, will limit the operating duty by admitting or relieving air. It also allows full flow through the blower when the relief valve closes.

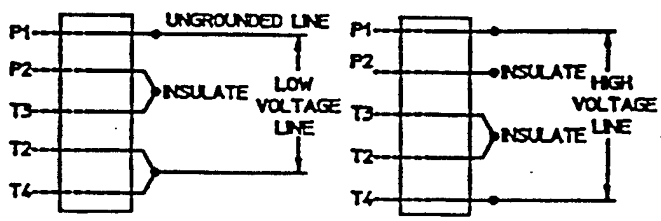
SERVICING

⚠ *WARNING To retain their sealed construction they should be serviced by Gast authorized service centers ONLY.* These models are sealed at the factory for very low leakage.

⚠ *WARNING Turn off electric power before removing blower from service. Be sure rotating parts have stopped. Electric shock or severe cuts can result.* Inlet and exhaust filters attached to the blower may need cleaning or replacement of the elements. Failure to do so will result in more pressure drop, reduced air flow and hotter operation of the blower. The outside of the unit requires cleaning of dust and dirt. The inside of the blower also may need cleaning to remove foreign material coating the impeller and housing. This should be done at a Gast Authorized Service Center. This buildup can cause vibration, failure of the motor to operate or reduced flow.

KEEP THIS INFORMATION WITH THIS BLOWER.
REFER TO IT FOR SAFE INSTALLATION,
OPERATION OR SERVICE.

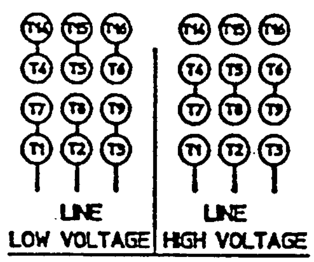
MOTOR WIRING DIAGRAM FOR R4110N-50 & R3105N-50



>>* WARNING
THIS MOTOR IS THERMALLY PROTECTED AND WILL AUTOMATICALLY RESTART WHEN PROTECTOR RESETS. ALWAYS DISCONNECT POWER SUPPLY BEFORE SERVICING.

MOTORS WIRING DIAGRAM FOR R4310P-50

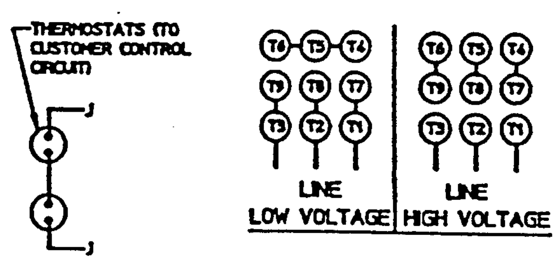
TO REVERSE ROTATION, INTERCHANGE THE EXTERNAL CONNECTIONS TO ANY TWO LEADS.



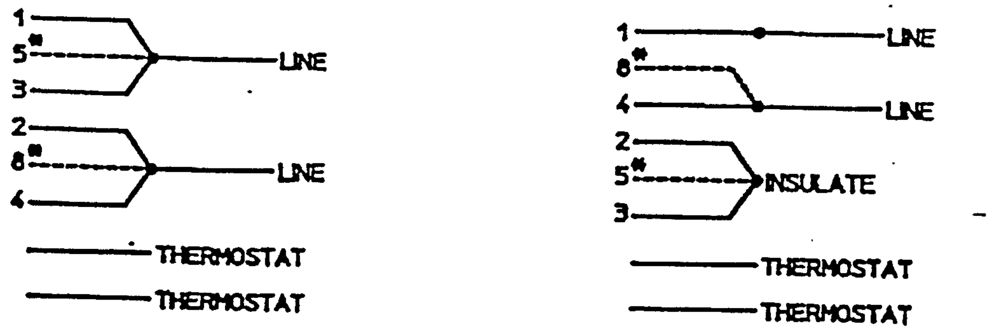
>>* WARNING
THIS MOTOR IS THERMALLY PROTECTED AND WILL AUTOMATICALLY RESTART WHEN PROTECTOR RESETS. ALWAYS DISCONNECT POWER SUPPLY BEFORE SERVICING.

MOTORS WIRING DIAGRAM FOR
R5325R-50, R6350R-50, R6P355R-50, & R7100R-50

TO REVERSE ROTATION, INTERCHANGE THE EXTERNAL CONNECTIONS TO ANY TWO LEADS.



MOTOR WIRING DIAGRAM FOR R5125Q-50 & R4P115N-50



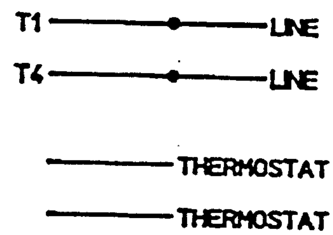
LOW VOLTAGE

HIGH VOLTAGE

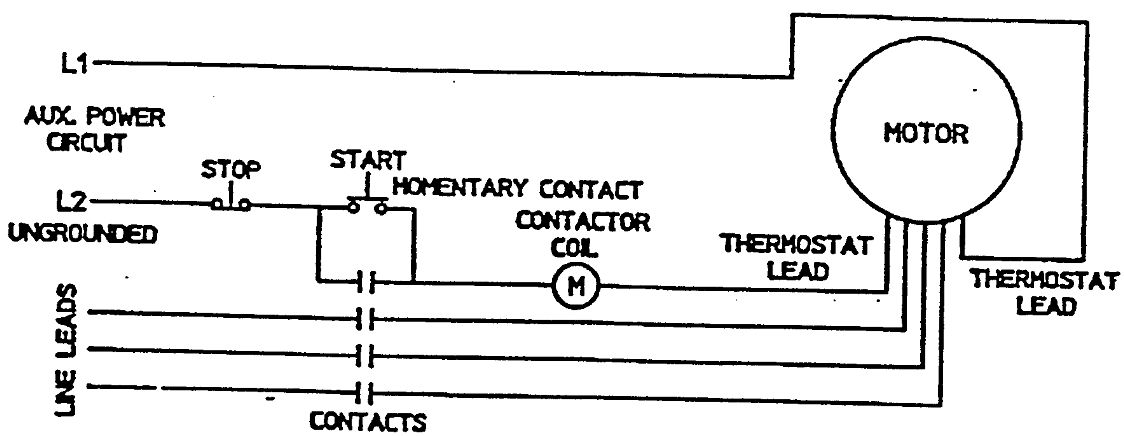
* R5125Q-50 BLOWERS PRODUCED AFTER SEPTEMBER 1992 (SER. NO. 0992) DO NOT HAVE MOTOR LEADS 5 & 8.

MOTOR WIRING DIAGRAM FOR R6130Q-50 & R6P155Q-50

CONNECT THERMOSTAT TO MOTOR PROTECTION CIRCUIT



CONNECTION FOR THERMOSTAT MOTOR PROTECTION



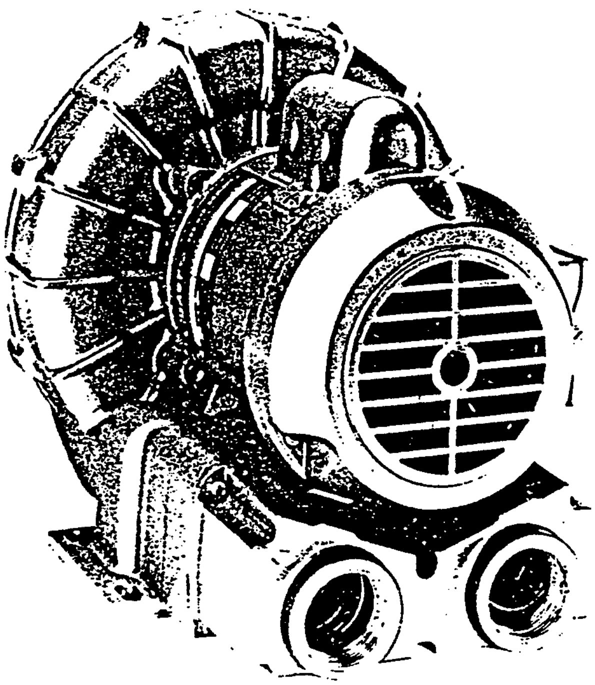
TERMOSTATS TO BE CONNECTED IN SERIES WITH CONTROL AS SHOWN. MOTOR FURNISHED WITH AUTOMATIC THERMOSTATS RATED A.C. 115-600V. 720VA

AK811 rev. E

Oilless Regenerative Blowers, Motor Mounted to 92 cfm

GAST

REGENAIR® R4 Series



MODEL R4110-2
52" H_2O MAX. PRESSURE, 92 CFM OPEN FLOW

PRODUCT FEATURES

- Oilless operation
- TEFC motor mounted
- Can be mounted in any plane
- Rugged construction/low maintenance
- Can be operated blanked-off

COMMON MOTOR OPTIONS

- 115/208-230V, 60 Hz; 110/220-240V, 50 Hz, single phase
- 208-230/460V, 60 Hz; 190-230/380-415V, 50 Hz, three phase
- 575V, 60 Hz, three phase

RECOMMENDED ACCESSORIES

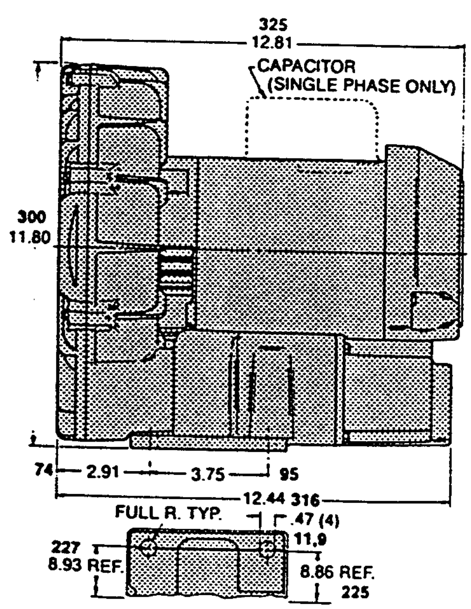
- Pressure gauge AJ496
- Filter AG338
- Muffler AJ121D
- Relief valve AG258

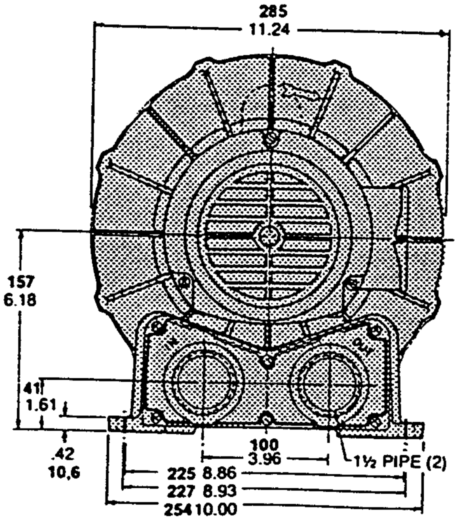
Various brand name motors are used on any model at the discretion of Gast Mfg. Corp.

Important Notice:

Pictorial and dimensional data is subject to change without notice.

Product Dimensions Metric (mm) U.S. Imperial (inches)



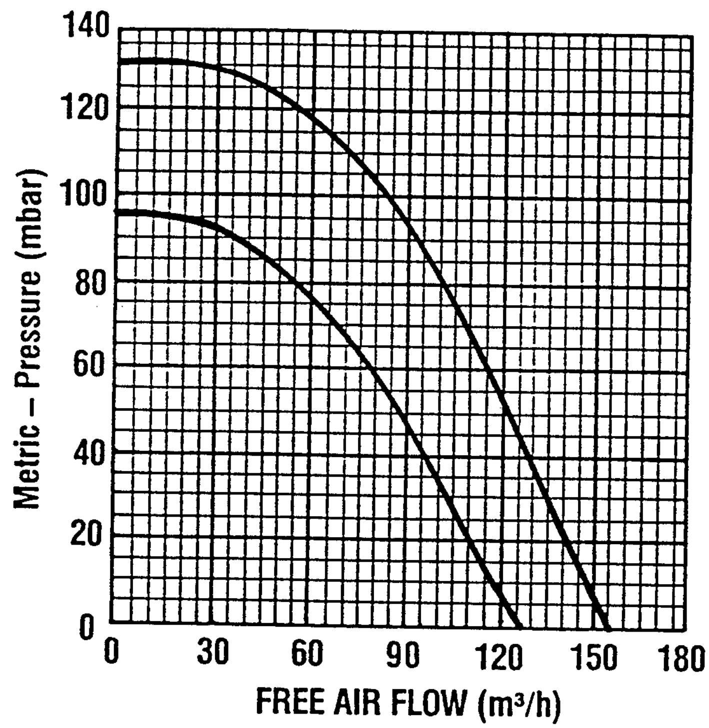


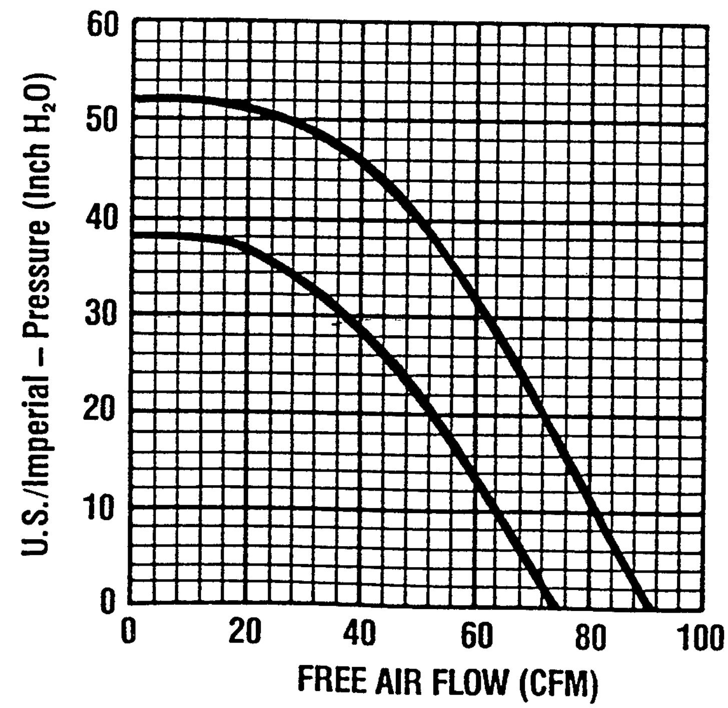
Product Specifications

Model Number	Motor Specs	Full Load Amps	HP	RPM	Max Pressure		Max Flow		Net Wt.	
					"H_2O	mbar	cfm	m³h	lbs.	kg
R4110-2	110/220-240-50-1	9.0/4.5-5.7	0.6	2850	38	95	74	126	41	18,6
	115/208-230-60-1	9.8/5.2-4.9	1.0	3450	52	130	92	156		
R4310A-2	190-220/380-415-50-3	2.6-3.3/1.3-1.4	0.6	2850	38	95	74	126	41	18,6
	208-230/460-60-3	3.4-3.2/1.6	1.0	3450	52	130	92	156		

Product Performance (Metric U.S. Imperial)

Black line on curve is for 60 cycle performance.
Blue line on curve is for 50 cycle performance.





SECTION 7
DATA COLLECTION SHEET

BLOWER EXTRACTION SYSTEM DATA COLLECTION SHEET

SITE:________

DATE	TIME	INLET VACUUM 1 (IN. WATER) a/	INLET TEMP. (DEGREES F) a/	INLET VACUUM 2 (IN. WATER) b/	OUTLET TEMP. (DEGREES F) c/	FILTER CHANGED (Y or N)	BLOWER FUNCTIONING UPON ARRIVAL (Y or N)	COMMENTS	CHECKED BY

a/ Gauge is located between the well and the air filter.
b/ Gauge is located between the air filter and the blower unit.
c/ Gauge is located on the blower outlet piping.

BLOWER INJECTION SYSTEM DATA COLLECTION SHEET

SITE:________

DATE	TIME	INLET VACUUM (IN. WATER)	OUTLET TEMP. (DEGREES F)	OUTLET PRESSURE (IN. WATER)	FILTER CHANGED (Y or N)	BLOWER FUNCTIONING UPON ARRIVAL (Y or N)	COMMENTS	CHECKED BY

Appendix C
Chain-of-Custody Forms

731207. 500

CHAIN OF CUSTODY RECORD

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

AFCEE BIOVENTING PILOT TESTS

Base: DYESS AFB

Site: FT-40, BLDG. 1001
FT-41, BLDG. 2001

ES Job No. DE268. 1 8 .08

Sampler(s): (Signature)
RUSSELL FRISHMUTH [signature]
BRIAN VANDERGLAS [signature]

Ship To:
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					Preservative: NONE				HOLD	AT 4C	NONE					
					Analysis Required											
Date	Time	Sample Description	Lab I.D.	No. of Contrs.	SW 9045 (PH)	A 403 (ALKA)	SW 7380 (IRON)	SW 846 (MOIST)	SW 8020 (BTEX)	E 418.1 (TRPH)	E 351.2 (TKN)	E 365.3 (PHOS)	UCM (CLASS)	Sample Type	Matrix	Remarks
12/3/93	14:45	DY1-VW-10.5		3	X	X	X	X	X	X	X	X	X	(G) C	SOIL	191628
12/3/93	16:20	DY1-MPA-9		3	X	X	X	X	X	X	X	X	X	(G) C	SOIL	191636
12/4/93	10:35	DY1-MPB-12.5		3	X	X	X	X	X	X	X	X	X	(G) C	SOIL	191644
12/4/93	13:27	DY1-BG-9		1							X			(G) C	SOIL	191652
12/5/93	09:15	DY2-VW-8.75		3	X	X	X	X	X	X	X	X	X	(G) C	SOIL	191660
12/5/93	11:23	DY2-MPA-10		3	X	X	X	X	X	X	X	X	X	(G) C	SOIL	191679
12/5/93	13:15	DY2-MPB-12.5		3	X	X	X	X	X	X	X	X	X	(G) C	SOIL	191687
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
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														G C	SOIL	
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														G C	SOIL	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
[signature]	12/6/93 17:30	FED EX	
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time
VIA FEDEX	12-7 0940	[signature] PACE	12-7 0940

Remarks: REC'D @ 4°C GW

G - Grab Sample, C - Composite Sample

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CHAIN OF CUSTODY RECORD

PROJECT # DE268.18.04 PO # DE268.18.09 COLLECTED BY (Signature) Brian Vandefus
REMARKS: Dyess Air Force Base Sites FT40 (DY1) and FT41 (DY2)
AIRBILL # 1968959635 (Fed Ex)

	FIELD SAMPLE I.D.#	SAMPLING MEDIA (Tenax, Canister etc.)	DATE/TIME	ANALYSIS	VAC./PRESSURE	LAB I.D. #
01A	DY1 MPA9.5	Soil Air/Summa Canister	9 Dec 93/1240	TO3 (BTEX, TPH)	2.0" Hg	
02A/B	DY1 MPB10.0	Soil Air/Summa	9 Dec 93/1245	TO3 (BTEX, TPH)	2.0" Hg	
03A	DY2 MPB9.5	Soil Gas/Summa	9 Dec 93/1630	TO3 (BTEX, TPH)	2.0" Hg	
04A	DY2 MPC6.5	Soil Gas/Summa	9 Dec 93/1640	TO3 (BTEX, TPH)	2.0" Hg	

RELINQUISHED BY: DATE/TIME	RECEIVED BY: DATE/TIME	RELINQUISHED BY: DATE/TIME	RECEIVED BY: DATE/TIME
Brian Vandefus 12/9/93/1710HR	FED EX 12/9/93 1710HR	Fed-X 12/10/93	[signature] 12-10-93 9:52

LAB USE ONLY

SHIPPER NAME	AIR BILL #	OPENED BY: DATE/TIME	TEMP(°C)	CONDITION

REMARKS

Appendix D

Data and Calculation Sheets

DYESS AFB – Site FT–40

Biodegradation Rate Calculations

enter data	calculated data

Formula: $K_b = K_o \times 1/100\% \times A \times D_o \times C$ Where:

K_b = fuel biodegradation rate

K_o = O_2 utilization rate (%/min.)

A = volume of air/kg soil

D_o = O_2 density = 1340 mg/L

C = Carbon/O_2 ratio for hexane mineralization = 1/3.5

Test Results: VW

K_o = max. observed rate 0.000183 %/min.

w = moisture content 17.0 %

Assume: Soil properties for stiff clay Specify from Table 1.4 (Ref. Foundation Engineering, Peck, Hanson, and Thornburn, John Wiley Press, 1974)

Porosity:	n =	0.37
Unit weight (dry):	$^g d$ =	2.07
Void ratio:	$e = n/(1-n)$ =	0.59
Specific gravity:	G =	2.65

Calculate A = Air filled volume (V_a)/unit wt.

Solving for 1 liter of soil

a) $V_v = n * 1$ L

V_v = 0.37 liters V_v = void volume

b) $S_r = Gw/e$

S_r = 0.76 S_r = degree of saturation

c) $V_w = S_r \times V_v$

V_w = 0.28 liters V_w = volume of water

d) $V_a = V_v - V_{vw}$

V_a = 0.09 liters V_a = volume of air

e) Bulk density = $^g d + (V_w \times {}^g w)$ = 2.4 kg/l soil

f) A = V_a/Bulk density = 0.038 l air/kg soil

$K_b = K_o \times 1/100\% \times A \times D_o \times C \times$ 525,600 min/yr = 10 mg TPH/year

afbio4/1dyesskb/lcw/3.3.94

DYESS AFB – Site FT–40
Biodegradation Rate Calculations

enter data	calculated data

Formula: $K_b = K_o \times 1/100\% \times A \times D_o \times C$ Where:

K_b = fuel biodegradation rate

K_o = O_2 utilization rate (%/min.)

A = volume of air/kg soil

D_o = O_2 density = 1340 mg/L

C = Carbon/O_2 ratio for hexane mineralization = 1/3.5

Test Results: MPA–9.5

K_o = max. observed rate 0.000218 %/min.

w = moisture content 17.0 %

Assume: Soil properties for stiff clay Specify from Table 1.4 (Ref. Foundation Engineering, Peck, Hanson, and Thornburn, John Wiley Press, 1974)

Porosity:	n =	0.37
Unit weight (dry):	$^g d$ =	2.07
Void ratio:	$e = n/(1-n)$ =	0.59
Specific gravity:	G =	2.65

Calculate A = Air filled volume (V_a)/unit wt.

Solving for 1 liter of soil

a) $V_v = n * 1\ L$

V_v = 0.37 liters V_v = void volume

b) $S_r = Gw/e$

S_r = 0.76 S_r = degree of saturation

c) $V_w = S_r \times V_v$

V_w = 0.28 liters V_w = volume of water

d) $V_a = V_v - V_{vw}$

V_a = 0.09 liters V_a = volume of air

e) Bulk density = $^g d + (V_w \times {}^g w)$ = 2.4 kg/l soil

f) $A = V_a$/Bulk density = 0.038 l air/kg soil

$K_b = K_o \times 1/100\% \times A \times D_o \times C \times$ 525,600 min/yr = 20 mg TPH/year

afbio4/2dyesskb/lcw/3.3.94

DYESS AFB – Site FT–40

Biodegradation Rate Calculations | enter data | calculated data |

Formula: $K_b = K_o \times 1/100\% \times A \times D_o \times C$ Where:

K_b = fuel biodegradation rate

K_o = O_2 utilization rate (%/min.)

A = volume of air/kg soil

D_o = O_2 density = 1340 mg/L

C = Carbon/O_2 ratio for hexane mineralization = 1/3.5

Test Results: MPB–10

K_o = max. observed rate 0.000120 %/min.

w = moisture content 17.7 %

Assume: Soil properties for stiff clay Specify from Table 1.4 (Ref. Foundation Engineering, Peck, Hanson, and Thornburn, John Wiley Press, 1974)

Porosity:	*n* =	0.37
Unit weight (dry):	^{g}d =	2.07
Void ratio:	$e = n/(1-n)$ =	0.59
Specific gravity:	G =	2.65

Calculate A = Air filled volume (V_a)/unit wt.

Solving for 1 liter of soil

a) $V_v = n * 1$ L

V_v = 0.37 liters V_v = void volume

b) $S_r = Gw/e$

S_r = 0.8 S_r = degree of saturation

c) $V_w = S_r \times V_v$

V_w = 0.3 liters V_w = volume of water

d) $V_a = V_v - V_{vw}$

V_a = 0.07 liters V_a = volume of air

e) Bulk density = ^{g}d + ($V_w \times {}^{g}$w) = 2.4 kg/l soil

f) A = V_a/Bulk density = 0.029 l air/kg soil

$K_b = K_o \times 1/100\% \times A \times D_o \times C \times$ 525,600 min/yr = 10 mg TPH/year

afbio4/3dyesskb/lcw/3.3.94

DYESS AFB – Site FT–40 9.5' Depth
Steady–state Equation – Air Injection

Enter data

Calculated data

$$k = \frac{Q \mu \ln(Rw/Ri)}{H \pi Patm[1 - (Pw/Patm)^2]}$$

Where:

Q = Volumetric flow rate of vent well

34.0	scfm x (30.48 cm/ft)^3 x (1 min/60 s) =	1.60E+04	cm^3/s
	μ = Viscosity of Air @ 18° C =	1.80E–04	g/cm s

Patm = Ambient pressure @ 1800 feet of elevation

382	inches H2O x (3.61E–2 psia/in. H2O) =	13.790	psia
13.790	psia x (6.89476E4 g/cm s^2)/psia =	9.51E+05	g/cm s^2

Rw = Radius of Vent Well

2	inches x 2.54 cm/in =	5.08	cm

H = Depth of Screen (length of screened interval)

9.6	feet x 30.48 cm/ft =	293	cm

Ri = Maximum Radius of Venting Influence

25	feet x 30.48 cm/ft =	762	cm

Pw = Absolute Pressure at Vent Well

48	inches H2O x (3.61E–2 psia/in. H2O) =			1.733	psia
1.733	psia +	13.790	psia =	15.523	psia
15.523	psia x (6.89476E4 g/cm s^2)/psia =			1.07E+06	g/cm s^2

	k =	6.199E–08	cm^2
6.200E–08	cm^2 x (1 m/100 cm)^2 =	6.200E–12	m^2
6.200E–12	m^2 x 1 darcy/(9.870E–13 m^2) =	6.28	darcys

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DYESS AFB – Site FT–41 6.5' Depth
Steady–state Equation – Air Injection

Enter data

Calculated data

$$k = \frac{Q \mu \ln (Rw / Ri)}{H \pi \, Patm [1 - (Pw / Patm)^2]}$$

Where:

Q = Volumetric flow rate of vent well

34.0	scfm x $(30.48\ cm/ft)^3$ x (1 min/60 s) =	1.60E+04	cm^3/s

μ = Viscosity of Air @ 18° C = 1.80E–04 g/cm s

Patm = Ambient pressure @ 1800 feet of elevation

382	inches H2O x (3.61E–2 psia/in. H2O) =	13.790	psia
13.790	psia x (6.89476E4 g/cm s^2)/psia =	9.51E+05	g/cm s^2

Rw = Radius of Vent Well

2	inches x 2.54 cm/in =	5.08	cm

H = Depth of Screen (length of screened interval)

9.6	feet x 30.48 cm/ft =	293	cm

Ri = Maximum Radius of Venting Influence

25	feet x 30.48 cm/ft =	762	cm

Pw = Absolute Pressure at Vent Well

48	inches H2O x (3.61E–2 psia/in. H2O) =	1.733	psia
1.733	psia + 13.790 psia =	15.523	psia
15.523	psia x (6.89476E4 g/cm s^2)/psia =	1.07E+06	g/cm s^2

	k =	6.199E–08	cm^2
6.200E–08	cm^2 x $(1\ m/100\ cm)^2$ =	6.200E–12	m^2
6.200E–12	m^2 x 1 darcy/(9.870E–13 m^2) =	6.28	darcys

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DYESS AFB – Site FT–41 9.5' and 12.5' Depths
Steady–state Equation – Air Injection

Enter data

Calculated data

$$k = \frac{Q \mu \ln(Rw/Ri)}{H \pi Patm[1 - (Pw/Patm)^2]}$$

Where:

Q = Volumetric flow rate of vent well

34.0 scfm x $(30.48 cm/ft)^3$ x (1 min/60 s) = 1.60E+04 cm^3/s

μ = Viscosity of Air @ 18° C = 1.80E–04 g/cm s

Patm = Ambient pressure @ 1800 feet of elevation

382 inches H2O x (3.61E–2 psia/in. H2O) = 13.790 psia

13.790 psia x (6.89476E4 g/cm s^2)/psia = 9.51E+05 g/cm s^2

Rw = Radius of Vent Well

2 inches x 2.54 cm/in = 5.08 cm

H = Depth of Screen (length of screened interval)

9.6 feet x 30.48 cm/ft = 293 cm

Ri = Maximum Radius of Venting Influence

10 feet x 30.48 cm/ft = 305 cm

Pw = Absolute Pressure at Vent Well

48 inches H2O x (3.61E–2 psia/in. H2O) = 1.733 psia

1.733 psia + 13.790 psia = 15.523 psia

15.523 psia x (6.89476E4 g/cm s^2)/psia = 1.07E+06 g/cm s^2

k = 5.066E–08 cm^2

5.070E–08 cm^2 x $(1 m/100 cm)^2$ = 5.100E–12 m^2

5.100E–12 m^2 x 1 darcy/(9.870E–13 m^2) = 5.17 darcys

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Respiration Test
Site FT-40
Dyess AFB, Texas

Monitoring Point	Date	Days Elapsed (frac. days)	Time	Hrs elapsed (fractional days)	Days Elapsed	Elapsed Time (min. x 1000)	O2%	CO2%	Total Hydro-carbon	Comments	Trend of O2/ Time	New x-values	k
MPA-9.5	12/06/93	0.00	10:52	0.01	0.01	0.01	20.3	0.80	640	Initial soil gas purge - 1 min.	19.279512	0	0.000218
MPA-9.5	12/07/93	1.00	08:21	-0.10	0.90	1.30	13.0	3.75	120	Redo initial soil gas.	13.893517	24.67	
MPA-9.5	12/07/93	1.00	12:44	0.09	1.09	1.56	12.5	4.50	NA	Redo initial soil gas.			
MPA-9.5	12/08/93	2.00	07:49	-0.12	1.88	2.71	12.5	5.00	78	Redo initial soil gas.			
MPA-9.5	12/12/93	6.00	10:20	-0.01	5.99	0.00	19.1	5.00	NA				
MPA-9.5	12/12/93	6.00	10:38	0.00	6.00	0.02	19.5	5.50	57				
MPA-9.5	12/12/93	6.00	12:25	0.07	6.07	0.13	19.8	3.60	55				
MPA-9.5	12/12/93	6.00	15:10	0.19	6.19	0.29	19.8	3.00	165				
MPA-9.5	12/13/93	7.00	06:00	-0.19	6.81	1.18	19.0	3.00	290				
MPA-9.5	12/13/93	7.00	17:10	0.27	7.27	1.85	18.2	3.00	220				
MPA-9.5	12/14/93	8.00	07:41	-0.12	7.88	2.72	18.1	3.25	NA				
MPA-9.5	12/29/93	23.00	13:30	0.12	23.12	24.67	14.0	3.80	NA				
MPB-10	12/06/93	0.00	11:05	0.02	0.02	0.03	19.3	2.30	170	Initial soil gas purge - 1 min.	16.850448	0	0.00012
MPB-10	12/07/93	1.00	08:25	-0.09	0.91	1.31	12.5	6.10	120	Redo initial soil gas.	13.896562	24.66	
MPB-10	12/07/93	1.00	12:48	0.09	1.09	1.57	12.5	6.10	NA	Redo initial soil gas.			
MPB-10	12/08/93	2.00	07:53	-0.12	1.88	2.71	12.3	6.50	NA	Redo initial soil gas.			
MPB-10	12/12/93	6.00	10:34	0.00	6.00	0.00	17.8	5.50	53				
MPB-10	12/12/93	6.00	12:30	0.08	6.08	0.12	17.0	5.80	58				
MPB-10	12/12/93	6.00	15:14	0.19	6.19	0.28	16.8	5.75	240				
MPB-10	12/13/93	7.00	07:56	-0.11	6.89	1.29	17.0	5.50	290				
MPB-10	12/13/93	7.00	17:14	0.27	7.27	1.84	15.5	6.10	220				
MPB-10	12/14/93	8.00	07:45	-0.12	7.88	2.72	16.2	6.20	NA				
MPB-10	12/29/93	23.00	13:32	0.12	23.12	24.66	14.0	5.80	230				
VW	12/06/93	0.00	10:47	0.00	0.00	0.01	18.9	1.75	50	Initial soil gas purge - 1 min.	20.5	0	0.000183
VW	12/07/93	1.00	08:17	-0.10	0.90	1.30	19.0	2.10	45	Redo initial soil gas.	15.999083	24.54	
VW	12/12/93	6.00	12:40	0.08	6.08	0.00	20.5	0.25	0				
VW	12/29/93	23.00	13:35	0.12	23.12	24.54	16.0	1.10	140				

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