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FINAL REMOVAL AND CLOSURE OF FUEL HYDRANT SYSTEMS SAMPLING AND
ANALYSIS PLAN NAS FORT WORTH TX
1/1/1995
JACOBS ENGINEERING



**NAVAL AIR STATION
FORT WORTH JRB
CARSWELL FIELD
TEXAS**

**ADMINISTRATIVE RECORD
COVER SHEET**

AR File Number 355



United States Air Force Air Force Base Conversion Agency

FINAL

NAS Fort Worth JRB, Texas
(Formerly Carswell AFB, Texas)

REMOVAL/CLOSURE OF THE
FUEL HYDRANT SYSTEM
SAMPLING AND ANALYSIS PLAN

JANUARY 1995



United States Air Force Air Force Base Conversion Agency

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NAS Fort Worth JRB, Texas
(Formerly Carswell AFB, Texas)

SAMPLING AND ANALYSIS PLAN

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
Air Force	U.S. Air Force
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
BTEX	benzene, toluene, ethylbenzene, and xylene
CCV	continuing calibration verification
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
COE	U.S. Army Corps of Engineers
COR	Contracting Officer's Representative
CQP	Construction Quality Plan
DBCRA	Defense Base Closure and Realignment Act
DERP	Defense Environmental Restoration Program
DOD	U.S. Department of Defense
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
FS	feasibility study
FSP	Field Sampling Plan
GC	gas chromatograph
HSP	Health and Safety Plan
HSWA	Hazardous and Solid Waste Amendments
ICV	initial calibration verification
IR	infrared
IRA	interim remedial action
IRP	Installation Restoration Program
IRPIMS	Installation Restoration Program Information Management System
I-30	Interstate Highway I-30
ITIR	Informal Technical Information Report

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- Appendix A Immunoassay Testing Procedure
- Appendix B Instrument Calibration and Operating Manuals
- Appendix C Field Forms

ACRONYMS AND ABBREVIATIONS

Jacobs	Jacobs Engineering Group Inc.
JRB	Joint Reserve Base
MDL	method detection limit
MS	mass spectrometer
NAS	Naval Air Station
NCP	National Oil and Hazardous Substances Contingency Plan
NIST	National Institute of Standards and Technology
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PID	photoionization detector
POC	point of contact
ppm	parts per million
PQL	practical quantitation limit
PVC	polyvinyl chloride
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
Riedel	Riedel Environmental Services, Inc.
RPD	relative percent difference
SAP	sampling and analysis plan
SARA	Superfund Amendments and Reauthorization Act
SHSC	Site Health and Safety Coordinator
SOP	standard operating procedure
TPH	total petroleum hydrocarbons
USCS	Unified Soil Classification System
UST	underground storage tank
°C	degrees centigrade

1.0 QUALITY ASSURANCE PROJECT PLAN

This Quality Assurance Project Plan (QAPP) is the first part of the Sampling and Analysis Plan (SAP) for the Removal/Closure of the Fuel Hydrant System at Naval Air Station (NAS) Fort Worth Joint Reserve Base (JRB), Carswell Field, Fort Worth, Texas. The station was formerly called Carswell Air Force Base (AFB) and will be referred to in this document as NAS Fort Worth. Section 2.0 of the SAP is the Field Sampling Plan (FSP). The QAPP describes quality assurance (QA) and quality control (QC) procedures that will be performed during the 1995 sampling effort and sample analyses. The sampling will be conducted as part of the remedial action to close the fuel hydrant system. This QAPP pertains only to the field sampling effort; a companion document to this QAPP is the Construction Quality Plan (CQP). The CQP outlines the quality procedures to be followed for all construction-related activities during the 1995 field effort.

The removal/closure of the fuel hydrant system is being performed by Jacobs Engineering Group Inc. (Jacobs) under contract number F41624-94-D-8116, Delivery Order 0002, issued by the Air Force Center for Environmental Excellence (AFCEE), located at Brooks AFB, Texas. Jacobs will conduct this effort with its team subcontractor, Riedel Environmental Services, Inc. (Riedel).

1.1 INTRODUCTION

The removal/closure of the fuel hydrant system at NAS Fort Worth will include underground storage tank (UST) removal, demolition of pumping station C, and abandonment of nearly 4 miles of underground fuel pipeline. Subsurface soil sampling will be conducted along the pipeline and at the location of the USTs. The analytical scope of work will include field screening analysis for benzene, toluene, ethylbenzene, and xylene (BTEX) and polycyclic aromatic hydrocarbons (PAH) using immunoassay test kits. Ten percent of the field screening samples will be sent to an offsite fixed laboratory for confirmation analysis. Eighteen samples collected from the UST excavation will be sent to a fixed laboratory for analysis of BTEX and total petroleum hydrocarbons (TPH).

The FSP describes specific field operations including procedures for field sampling, sample handling, the field QA/QC program, and record keeping. Appendices for the SAP include Appendix A, Immunoassay Testing Procedures, Appendix B, Instrument Calibration and Operation Manuals, and Appendix C, Field Forms.

This SAP was prepared in accordance with all applicable U.S. Air Force (Air Force), State of Texas, and U.S. Environmental Protection Agency (EPA) guidance including EPA's *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans*, QAMS-005/80 (EPA 1980). As appropriate, this document follows the outline for planning documents as provided in the *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS), Volume I* (Air Force 1993).

1.1.1 The U.S. Air Force Installation Restoration Program

The IRP was developed by the U.S. Department of Defense (DOD) in 1981 to investigate hazardous material disposal sites on DOD facilities. The Air Force integrated the IRP with the following:

- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 as amended by both the Superfund Amendments and Reauthorization Act of 1986 (SARA) and the CERCLA Act of 1992;
- the National Oil and Hazardous Substances Contingency Plan (NCP);
- pertinent provisions of the Resource Conservation and Recovery Act of 1976 (RCRA) statutes as amended by Hazardous and Solid Waste Amendments of 1984 (HSWA);
- Executive Order 12580;
- the Defense Environmental Restoration Program (DERP);

- the Defense Base Closure and Realignment Act (DBCRA); and
- all applicable or relevant and appropriate requirements (ARARs) and regulations.

The objective of the Air Force IRP is to assess past hazardous waste disposal and spill sites on Air Force installations and develop remedial actions consistent with the NCP for those sites that pose a threat to human health and welfare or the environment.

Originally, the IRP was a multiphased effort that included the following steps:

- Phase I - records search;
- Phase II - identify magnitude, rate of movement, and extent of contamination;
- Phase III - research and development of appropriate technologies to remediate contaminated sites; and
- Phase IV - remedial (cleanup) action.

The phases of the Air Force IRP are sequential steps as compared with the steps of the Superfund remedial process, which can take place simultaneously. Although the procedures are slightly different, the targets of the two programs are the same. In response to SARA and in order for the Air Force program to parallel the Superfund process, DOD directed the Air Force to implement the RI/FS methodology to conduct the IRP, and to abandon the phased approach.

1.1.2 Purpose and Scope

The purpose of this QAPP is to define the QA and QC procedures that will be used to make certain that data generated during the sampling investigation are precise, accurate, representative, comparable, and complete. The SAP defines the function, specific responsibilities, and authorities for data quality. It also prescribes the requirements for ensuring that the sampling is planned and executed in a manner consistent with Air Force guidelines. The Environmental Cleanup Plan describes the rationale for the sampling.

This plan provides guidance and specifications to make certain that the following are accomplished:

- a consistent framework is established for the generation of analytical data;
- data quality goals are defined;
- field measurements and analytical results are of known and acceptable quality and quantity through the use of standard methods; preventive maintenance; standardized calibration and analytical protocols; and QC measurements, reviews, and audits, procedures are established to recognize out-of-control conditions and to correct these conditions;
- actions are identified and implemented to ensure the validity of analytical data; and
- procedures for record keeping, including sample tracking and chain-of-custody protocols, are established and followed.

1.2 PROJECT DESCRIPTION

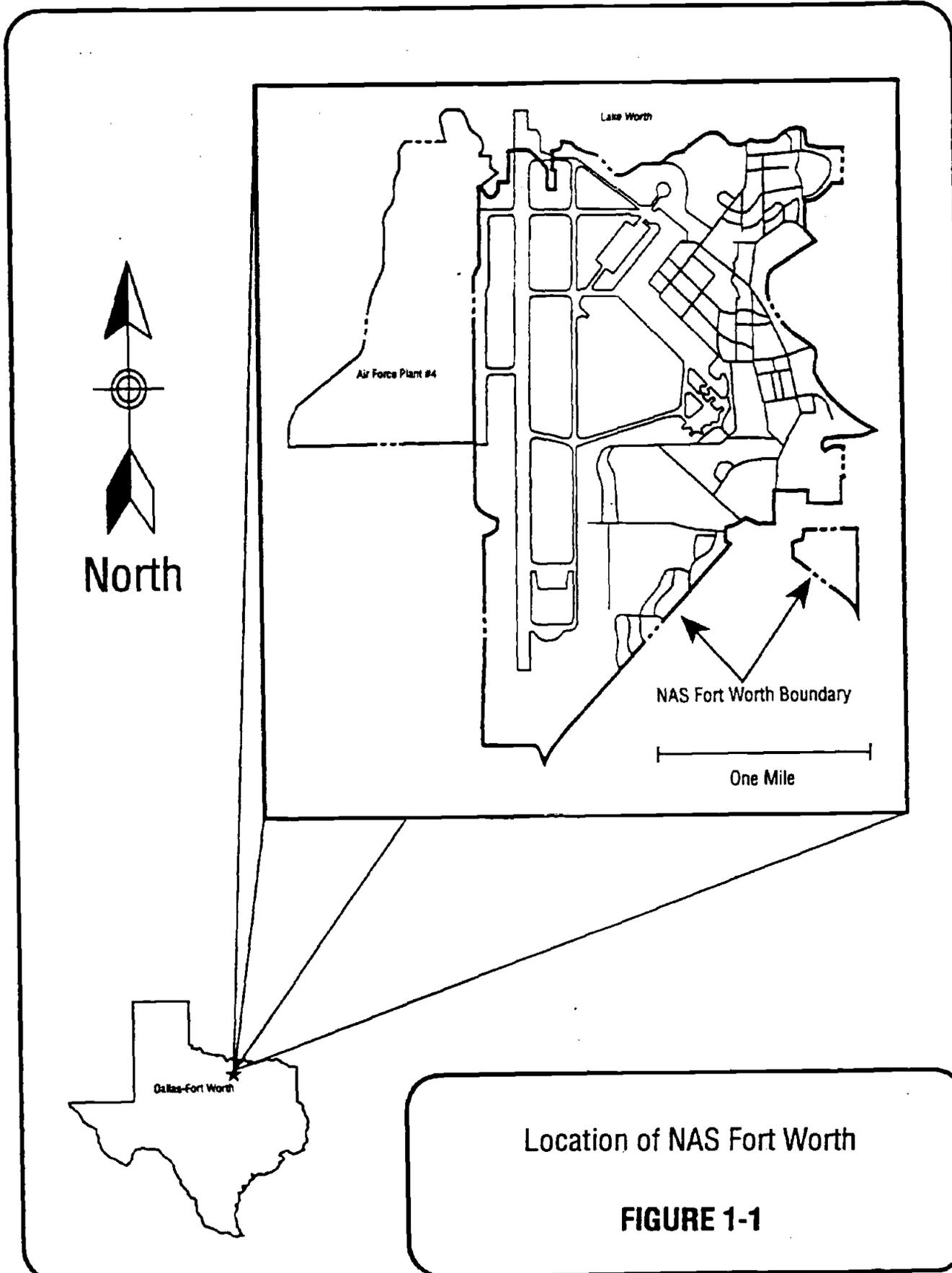
Site description, previous investigations and project scope and objectives are discussed in the following sections.

1.2.1 Project Background

The following sections present the site description and project background.

1.2.1.1 Site Description

NAS Fort Worth is located in north-central Texas in Tarrant County, 8 miles west of downtown Fort Worth (Figure 1-1). The area surrounding the station is mostly suburban, including the residential areas of the cities of Fort Worth, Westworth Village, and White Settlement. The main station totals 2,264 acres and is bordered on the north by



Location of NAS Fort Worth

FIGURE 1-1

Lake Worth, on the east by the Trinity River and Westworth Village, on the northeast and southeast by Fort Worth, on the west and southwest by White Settlement, and on the west by Air Force Plant 4 (Lockheed).

The existing land uses in the immediate vicinity of the station include industrial, commercial, residential, and recreational. The land uses west of the station are primarily industrial as a result of industrial complexes at Air Force Plant 4 and in White Settlement. Additional uses to the west include residential and some supporting commercial. South of the station are commercial areas at the interchange of Interstate Highway I-30 (I-30) and State Highway 183. This area includes a regional shopping mall, a discount shopping center, and a smaller convenience center. Both single-family and multifamily residential development dominate the area southeast of the station and north of I-30 and the area east of the station. The area north of the station is predominantly composed of recreational and public facilities. The south shore of Lake Worth is restricted to public access because of the presence of NAS Fort Worth and Air Force Plant 4, but the lake is open for recreation. A fish hatchery, a YMCA camp, and private recreational land are along the West Fork of the Trinity River northeast of the station. The area surrounding the Offsite Weapons Storage Area is primarily rural, although a residential development is located south of White Settlement Road.

1.2.1.2 Previous Investigations

The fuel hydrant system at NAS Fort Worth was installed when the station was originally constructed and was expanded during the past 50 years of Air Force activity. The system consisted of five pumping stations with six 25,000-gallon USTs, a filtering system, a delivery pump, and a shelter at each pumping station and approximately 20,000 feet of 3-, 6-, and 8-inch diameter steel pipeline. Each station serves several refueling hydrants on the edge of the Alert Apron.

In 1984, the IRP was initiated at NAS Fort Worth with a records search by CH2M Hill, Inc. that identified 15 sites requiring further evaluation (CH2M Hill 1984). Several other

IRP studies have been conducted at the station that included the fuel hydrant system, including a 1989 RCRA Facility Assessment by A.T. Kearney, Inc. (A.T. Kearney, Inc. 1989) and a 1990 report by the Maxim Engineers Inc. on a potential JP-4 fuel leak called "Spot 35" (Maxim Engineers Inc. 1990). The latter study documented that both soil and groundwater had been contaminated and that additional investigations would be necessary to delineate the extent of contamination (Maxim Engineers Inc. 1990). No other investigations have been conducted under the IRP at the fuel hydrant system. In September 1993, Carswell AFB officially closed pursuant to the 1990 DBCRA. On 1 October 1994, the U.S. Navy assumed control of the former Carswell AFB, which was renamed NAS Fort Worth.

Interim remedial action (IRA) at the fuel hydrant system began in 1992 when pumping station E and its associated piping were removed by the U.S. Army Corps of Engineers (COE). Fuel-contaminated soil was encountered during the removal, but no soil was removed from the site and the area of contamination was not delineated. During the summer of 1994, the COE removed pumping stations A, B, and D under a second IRA project.

1.2.2 Project Scope and Objectives

The project scope and objectives are discussed in detail in the following sections. The sections describe the scope of work, the objectives, the project management strategy, the residual and waste management objectives, record keeping and reporting, and data quality and data submittal requirements.

1.2.2.1 Scope of Work

The scope of work consists of an IRA to abandon a portion of the fuel hydrant system at NAS Fort Worth. This scope includes abandonment of approximately 4 miles of fuel pipeline, demolition of pumping station C, removal of six 25,000-gallon USTs, and sampling associated soils near the tanks and piping. The work will be accomplished by

Jacobs and its team subcontractor Riedel. Subcontracts will be issued by Jacobs for drive-point sampling services and by Riedel for grouting services.

1.2.2.2 Approach and Objectives

The initial field task will include pumping residual fluids out of the USTs and filling them with an inert substance. Once the tanks are prepared, the superstructure of pumping station C will be demolished and decontaminated. Following demolition of the structure, the tanks will be excavated and removed. Drive point samples will be collected around the perimeter of the tanks. Soil samples will be collected from beneath the tanks following tank removal. If the soil contains contaminants above Texas UST soil contaminant levels, treatment or removal options will be presented to the Air Force. Soil samples collected from the area of the USTs will be analyzed for BTEX (SW8020) and TPH (E418.1).

The remainder of the field effort will focus on abandoning the fuel pipeline system. Lines will be cleaned by pushing a "pig" through them and collecting the residual fuel for disposal. The lines will then be filled with a cement, fly ash, and bentonite grout slurry and abandoned in place. This approach, rather than excavation and removal, was reviewed with the Air Force on 27 July, 1994. Soil sampling will be conducted along the pipeline using drive-point methodology. Sample analysis will be primarily by field screening methods to determine the presence or absence of fuel-based contamination. Laboratory confirmation will be performed on 10 percent of samples. Additional investigation will be required to determine the extent and concentrations of any contamination identified during this investigation. Samples will be selected for analysis based on visible stains, odors, or indication of organic vapors using an HNu. Wastes generated during the field activities will be recycled if possible or disposed of offsite. The final two weeks of the field effort will involve demobilization.

Following completion of fieldwork, the Jacobs/Riedel team will begin report preparation. The reports will be submitted in draft and final form over a four-month period to allow

sufficient time for Air Force review and comment. The period of performance for the entire project is estimated at 15 months, from September 1994 to December 1995.

1.3 PROJECT ORGANIZATION AND RESPONSIBILITIES

The organization for the Jacobs project team includes technical professionals with experience in project management, QA, analytical chemistry, environmental engineering, field investigations, data management, and other technical/engineering skills. An organization chart that shows all key project personnel for implementing the field investigations has been prepared (Figure 1-2). Responsibilities for each of the project team positions are described below.

Contracting Officer's Representative. The AFCEE Contracting Officer's Representative (COR) for Delivery Order No. 0002 is Captain Joseph Feaster, who is located at Brooks AFB, Texas. The point of contact (POC) for this investigation is Mr. Frank Grey, who is located at NAS Fort Worth, Texas. The Jacobs project team will coordinate all activities conducted under this delivery order with these Air Force representatives through the Jacobs Project Manager, Ms. Lynn Schuetter, located at the Jacobs office in Denver, Colorado.

Jacobs Manager of Federal Programs. The Jacobs Manager of Federal Programs is Mr. Tim Forden, who is located at the Jacobs office in Houston, Texas. Mr. Forden's responsibilities for the project include monthly administrative review of project progress, as well as coordination with AFCEE on contract-related issues.

Jacobs Program Manager/Project Manager. The Jacobs Program Manager/Project Manager, Ms. Lynn Schuetter, has overall responsibility for work performed for the Air Force under this contract. As Program Manager, Ms. Schuetter, will ensure high-quality work, make resources available, and approve all work under this delivery order. In addition, the Program Manager will review progress, anticipate and resolve problems, and ensure client satisfaction.

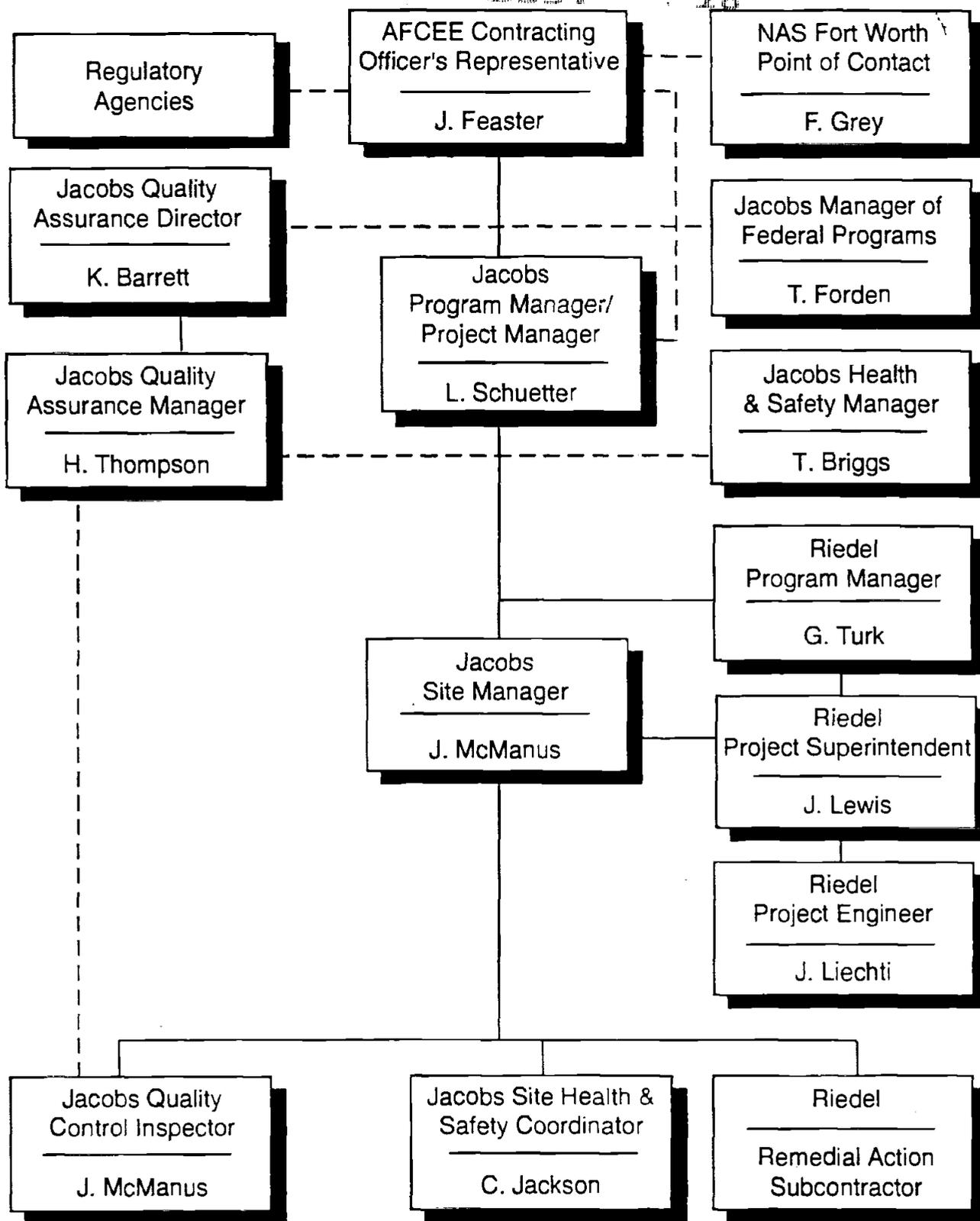


FIGURE 1-2
Project Organization Chart
Removal/Closure of Fuel Hydrant System
NAS Fort Worth, Texas

As the Jacobs Project Manager, Ms. Schuetter has day-to-day responsibility for all aspects of Jacobs work on Delivery Order No. 0002. The Project Manager maintains close communication and coordinates all activities with the AFCEE COR and the POC for NAS Fort Worth. She is responsible for identifying appropriate staff for each task and providing oversight of all work to ensure its successful completion. In addition, the Project Manager uses the information provided by Jacobs Project Controls and Accounting to track the progress of costs and schedules and prepare monthly summary reports for the COR.

Jacobs Quality Assurance Director. The Jacobs QA Director, Mr. Kris Barrett, will ensure that all work is performed according to the specifications of this SAP. Mr. Barrett will report to the Air Force and be responsible for all program QA issues. In addition, Mr. Barrett will review evaluation reports, audits, and corrective action procedures to ensure that the project meets IRP Handbook standards.

Jacobs Health and Safety Manager. The Health and Safety Manager, Dr. Terry Briggs, will make certain that all work is performed in accordance with the approved Health and Safety Plan (HSP) and the provisions of the Occupational Safety and Health Administration (OSHA) 29 Code of Federal Regulations (CFR) 1910.120 for worker health and safety. Dr. Briggs will provide assistance, oversight, and senior review of the HSP. The Health and Safety Manager or his designee will perform audits to make certain that fieldwork is conducted to the specifications of the HSP.

Riedel Program Manager. The Riedel Program Manager, Mr. Gary Turk, has overall responsibility for performance of the tasks assigned to Riedel Environmental Services, the team subcontractor. Riedel will provide resources for accomplishing the tasks described in the Work Plan and SAP. These tasks include construction of a decontamination facility, demolition of pumping station C and removal of the six associated USTs, and in-place abandonment of the fuel hydrant system.

Riedel Project Superintendent. The Riedel Project Superintendent, Mr. Jon Lewis, will report to both the Riedel Program Manager and the Jacobs Site Manager. The project superintendent is responsible for the execution of the scope of work as it relates to Riedel's field activities. He will supervise the work crews performing the removal of the USTs and fueling system, the demolition of the structure above the USTs, and the pipeline abandonment in place. Additionally, he is responsible for maintaining Riedel's schedule and budget throughout the project, making adjustments as necessary to any changed conditions, and reporting/explaining any variances that may occur. The project superintendent also makes sure that safe operating practices are used at all times onsite, and is ultimately responsible for Riedel's onsite adherence to the site health and safety plan. The project superintendent is also the manager for any second tier subcontractor, such as the grouting mix supplier, that will be used during the project.

Riedel Project Engineer. The Riedel Project Engineer, Mr. John Liechti, has responsibility for contributing to preparation of planning documents and providing overall technical oversight for all of Riedel's efforts.

Jacobs Project Quality Assurance Manager. The Jacobs Project QA Manager, Mr. Harold Thompson, will ensure that all work is performed in accordance with the SAP. Mr. Thompson will act as the Jacobs QA director's designee when reviewing and auditing field operations. Additional responsibilities of the QA Manager are outlined in the CQP. In addition, the Project QA Manager will review the project chemist's data quality review efforts, assist in performance of any field analytical audits, and report to the Jacobs Project Manager and Jacobs QA Director.

Jacobs Site Manager. The Site Manager, Mr. John McManus, has the responsibility of ensuring that the field investigation portion of the project is performed in a manner that maximizes data quality while maintaining a safe environment for the field crew. The Site Manager or his designee is responsible for reviewing all field sampling data forms for completeness, making decisions about sample locations, and making certain that the overall objectives of the field program are met while ensuring that the Air Force

Handbook procedures are followed in meeting these objectives. The Site Manager also has responsibility for ensuring QC on construction activities as described in the CQP for this project.

Jacobs Quality Control Inspector. The QC Inspector will be responsible for reviewing all documentation for completeness and correctness. In addition, the QC Inspector will be responsible for ensuring that sample integrity is maintained throughout the field investigation. Mr. John McManus will serve as QC Inspector as well as Site Manager. Additional responsibilities include audits and inspections of construction activities as discussed in the CQP.

Jacobs Site Health and Safety Coordinator. The Site Health and Safety Coordinator (SHSC), Mr. Cary Jackson, has the responsibility for ensuring that the procedures outlined in the site HSP are followed by all members of the field team. The SHSC will investigate all accidents or injuries related to the project that occur at NAS Fort Worth and has the authority to stop all work onsite if deemed necessary for the protection of personnel. The SHSC will also provide a briefing to all field sampling crew members regarding site hazards before field activities begin. The SHSC will be a member of the field team and will be identified when the field team members are assigned.

1.4 QUALITY ASSURANCE OBJECTIVES FOR DATA MEASUREMENT

The overall QA objective for this investigation is to ensure that field data, field screening analytical data, and laboratory data are technically sound, statistically valid, and properly documented. Only soil samples will be collected for this investigation effort. The soil samples will be analyzed in the field using immunoassay field screening methods. Confirmation samples for 10% of field screened samples will be sent to an AFCEE-audited laboratory, as will samples collected from the UST area at pumping station C. Actions or decisions will not be based on concentration levels indicated by the analyses except that negative results will implicitly be taken to indicate that contamination is not present. Additional investigations will be required to determine the extent of any contamination

identified during the sampling. The field screening results will provide real-time data to direct the investigation, which will be qualitative and semiquantative in nature.

All field summary forms and a portion of the raw data and calculation forms for both the field screening analyses and the laboratory analyses will be reviewed by a Jacobs chemist. Third-party validation is not required under this investigation. However, duplicate and replicate QC samples will be analyzed, instruments will be properly calibrated, and all data will be evaluated by Jacobs before being reported to the Air Force.

Total BTEX and PAH will be analyzed using immunoassay screening techniques (EPA Method SW4030). Procedures for generating data using immunoassay screening methods are detailed in Section 1.7. Manufacturer's instructions for conducting analyses using immunoassay techniques are contained in Appendix A. The confirmation samples will be analyzed for BTEX and PAH by methods SW8020 and SW8310 respectively. Samples collected at the UST area will be analyzed for BTEX (SW8020) and TPH (E418.1).

1.4.1 Field Quality Assurance/Quality Control Procedures

Immunoassay screening is a data collection technique categorized as an EPA Level I field screening method. The ability to assess data quality for this method depends on the QA/QC steps taken during the sample collection/analysis process. Such steps will include the following:

- documentation of the sample and sampling procedures;
- documentation of the field laboratory and analytical procedures;
- method calibration;
- method blanks;
- matrix-background samples
- duplicate samples; and
- matrix spike samples and matrix spike replicate samples.

Matrix spike samples will consist of clean soils collected at the site, sent to a commercial facility, and spiked and blended with BTEX or PAH to a concentration of one part per million (ppm). The BTEX spike will consist of equal parts of benzene, toluene, ethylbenzene, m-, o-, and p-xylene. Samples prepared in this way will also be used for determining accuracy.

1.4.2 Definition of Criteria

The statistical acceptance criteria for field screening data are defined according to the objectives of the investigation. The statistical acceptance criteria for the specific analyses will be expressed in terms of precision, accuracy, representativeness, comparability, and completeness.

1.4.3 Goals for Assessment Criteria

As specified in the IRP Handbook (Air Force 1993), accuracy and precision control limits will be established by the laboratory and will be unique to the laboratory performing the analysis.

The laboratory-established control limits will be evaluated at regular intervals, and scheduled control measurements will be taken to detect trends and out-of-limit values. The laboratory will maintain records of these activities. U.S. Environmental Protection Agency (EPA) Contract Laboratory Program (CLP) or method-specified control limits are unacceptable substitutions for laboratory-generated control limits, except when the laboratory limits are outside the method-specified limits. However, the laboratory must be in the process of performing corrective actions to bring their limits to within those of the published method.

Criteria assessment is discussed below.

Precision. Precision is defined as the degree of agreement between repeated measurements of the same parameter under similar conditions. Therefore, precision

represents the repeatability of the measurement. The precision of a series of measurements can be expressed in terms of relative percent difference (RPD). Precision between replicate samples can be determined by calculating the RPD between analytical results for the replicates using the following formula:

$$RPD = 100 \times (R1 - R2) / ([R1 + R2] / 2)$$

where:

RPD = relative percent difference;

R1 = original sample;

R2 = replicate value.

The acceptance criteria for replicates will be ≤ 30 RPD. The prepared matrix spike samples will be used for replicate analyses.

Accuracy. Accuracy is the measure of the degree of agreement between an analyzed value and a true or accepted value. Accuracy measurements will be performed on the previously described sample material prepared as matrix spike samples.

Accuracy will be statistically represented by calculating percent recovery of the known concentration of the contaminant in the sample.

Percent recovery will be calculated as follows:

$$\% R (Qd/Qa) \times 100$$

where:

% R = percent recovery;

Qd = quantity determined by analysis; and

Qa = true or accepted reference quantity.

The acceptance criteria for accuracy will be $\pm 20\%$ of the known value.

Representativeness. Sampling protocols have been developed to ensure that the collected samples represent the medium. Sample handling protocols (e.g., storage and transportation) have been selected to protect the representativeness of the collected sample. Measurements will be made so that results are as representative of the medium (soil) as possible. Proper documentation will establish that protocols have been followed and sample identification and integrity are ensured.

Representativeness of specific analyses will be achieved by the following means:

- selecting appropriate numbers of samples and locations to adequately characterize the actual and current site conditions;
- using appropriate sample procedures and equipment;
- selecting appropriate analytical methodologies that provide required detection limits;
- analyzing the appropriate number and type of QC samples to statistically verify proper functioning of the analytical method and equipment and the applicability of the methodology;

- documenting sampling activities and sampling locations in field logs, on chain-of-custody records, and in logbooks that are signed and dated by sampling and analysis personnel; and
- using appropriate equipment decontamination techniques.

Comparability. To ensure data set comparability, the following steps will be taken:

- Instruments will be operated within their calibrated range, and appropriate analytical methodologies will be used. Analyses will be performed using standard EPA methods.
- Measurements that appear as outliers will be reassessed. The determination of outliers will be based on assessing a statistically significant data set. Not all outlier data are a result of analytical error or sampling technique. No data will be eliminated because of lack of comparability. However, these data will require explanation. The locations of outliers may be investigated immediately because the analytical data will be received in real-time.
- Only standards supplied by the immunoassay manufacturer with each test kit will be used for field screening analysis. Data will be reported in conventional and standard units.

Completeness. Completeness for the immunoassay screening will be based on the total number of samples that are analyzed under controlled conditions that meet the field screening acceptance criteria. Completeness is expressed as a percentage of the overall data that were generated and is calculated as follows:

$$C = (V/T) \times 100$$

where:

C = percent completeness;

V = number of measurements judged valid; and

T = total number of measurements.

Valid screening data are all data that meet all acceptance criteria as specified in this QAPP. Data produced by the immunoassay analyses should achieve completeness of greater than or equal to 90 percent. Laboratory data should achieve completeness of 95 percent or greater.

Two prepared matrix spike samples will be analyzed per batch of samples to provide data for precision and accuracy calculations for the immunoassay tests. A batch of samples is defined as the number of samples that can be run using a single immunoassay test kit. For the fixed laboratory, a matrix spike and matrix spike duplicate will be analyzed for every batch of 20 samples.

1.5 SAMPLING HANDLING AND SAMPLE CUSTODY

This section describes procedures for sampling handling, sample identification, preservation, shipping, and custody, to be followed when collecting soil samples for analysis.

These procedures are designed to ensure that (1) samples are properly collected, (2) samples are labeled, preserved, and transported so that they represent field conditions, and (3) sampling results are repeatable.

1.5.1. Sample Handling

Sample collection procedures are described in Section 2.0. Tables 1-1 and 1-2 summarize the containers, preservation techniques, and holding times for solid and aqueous samples to be submitted to an offsite laboratory during the 1995 NAS Fort Worth Fuel Hydrant

TABLE 1-1
CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
SOLID SAMPLES
NAS FORT WORTH JRB, TEXAS

Parameter	Analytical Methods	Containers ¹	Preservation Techniques ²	Maximum Allowable Holding Times ³
Volatile Organic Compounds	SW8020	120 ml (4 oz) ⁴	Cool, 4°C	14 days
Polycyclic Aromatic Hydrocarbons	SW8310	240 ml (8 oz)	Cool, 4°C	14 days until extraction 40 days after extraction
Total Petroleum Hydrocarbons	E418.1	240 ml (8 oz)	Cool, 4°C	28 days
Water Content	ASTM D2216	24 oz. glass	Cool, 4°C	As soon as possible

Notes:

- ¹ Soil containers for all measurements are widemouthed glass jars with Teflon-lined caps. A double volume sample will periodically be sent to the laboratory for quality assurance/quality control tests.
- ² Sample preservation is performed immediately upon sample collection. Soil samples are cooled immediately to 4°C.
- ³ Samples are analyzed as soon as possible after collection. Times listed are the maximum times samples are to be held before analysis and still considered valid.
- ⁴ Soil samples for volatile organic analysis may also be collected in a brass or stainless-steel liner from a split-spoon sampler. Both ends of the liner will be covered with oil-free aluminum foil and capped with Teflon end-caps.

oz = ounce
ml = milliliter
°C = degrees Celsius

TABLE 1-2
CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
AQUEOUS SAMPLES
NAS FORT WORTH JRB, TEXAS

Parameter	Analytical Methods	Containers ¹	Preservation Techniques ²	Maximum Allowable Holding Times ³
Volatile Organic Compounds	SW8020	2 x 40 ml, glass vial, Teflon-lined septum cap	Cool, 4°C, HCl to pH<2, 0.008% Na ₂ S ₂ O ₃	14 days
Polycyclic Aromatic Hydrocarbons	SW8310	1 L, amber glass jar, Teflon-lined cap	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃	14 days until extraction
Total Petroleum Hydrocarbons	E418.1	1 L, glass jar, Teflon-lined cap	Cool, 4°C, H ₂ SO ₄ to pH<2	28 days
Water Content	ASTM D2216	24 oz, glass	Cool, 4°C	As soon as possible

Notes:

¹ Sample preservation is performed immediately upon sample collection.

² Samples are analyzed as soon as possible after collection. Times listed are the maximum times samples are to be held before analysis and still considered valid.

H₂SO₄ = sulfuric acid

HCl = hydrochloric acid

L = liter

ml = milliliter

Na₂S₂O₃ = sodium thiosulfate

°C = degrees Celsius

system investigation. Sample containers that are certified as analyte-free will be provided with the appropriate preservation by the laboratory. Drive-point soil samples will be collected initially in clear plastic liners. Samples for onsite immunoassay analysis will be sealed in the liners and analyzed within 48 hours of collection.

1.5.2 Sample Custody

Sample identification and handling will be documented using chain-of-custody forms (Figure 1-3). The Jacobs QC Inspector and/or the field team leader will verify that all chain-of-custody forms are legible and complete. At any time that the coolers are left without an attendant, such as samples left overnight for analysis the next day, each cooler must be sealed with a signed custody seal and kept in a locked trailer or office.

Upon receipt of the samples, the offsite laboratory will sign and keep copies of the air bill. The custody form will be signed. The temperature of the cooler will be measured and documented, and the condition of the samples will be documented. If any breaks occur or discrepancies arise between the custody form, sample tags, and requested analysis, the sample custodian will notify the QA Coordinator, Project Manager, or Site Manager within 24 hours. Any discrepancy or improper preservation will be noted by the laboratory as an out-of-control event, which will be documented and proper corrective action will be taken. The Site Manager or designee will be responsible for maintaining contact with the laboratory.

Samples will be analyzed by the fixed laboratory in laboratory batch numbers not to exceed 20 samples. Sample batches may be smaller than 20 samples based on the number of samples the laboratory receives from the field team and the sample holding times.

1.5.3 Sample Identification

Field identifiers will be assigned to the soil samples and will appear on the sample labels, chain-of-custody forms, field sampling forms, and in any field logbooks used by the site

geologists. Because the soil samples collected for this project will not be input into the Installation Restoration Program Information Management System (IRPIMS) database, IRPIMS-compatible identification numbers will not be required. For ease of identification, however, the field identifier will include predetermined abbreviations for the site, project, location, and sample number. An example of a field identifier is N-FHC-102A where N is NAS Fort Worth, FHC is the Fuel Hydrant Closure Project, 102 is the drive-point location, and A is the first sample collected at that location.

1.6 CALIBRATION PROCEDURES AND FREQUENCY FOR FIELD TESTS

To meet the data quality objectives, proper calibration procedures for the field screening analysis and monitoring will be followed. Manufacturer's instrument manuals can be found in Appendices A and B.

For the immunoassay BTEX and PAH field test kits, the QC check will be obtained by analysis of duplicates, of prepared matrix spike samples, method blanks, and calibration with standards. Duplicate analyses will be performed for 10 percent of samples collected using the drive-point sampler. Method calibration using manufacturer-supplied standards and by analysis of method blanks will be performed with each batch of samples. For this investigation, an analytical batch is defined as all samples that are analyzed using reagents and standards from a single immunoassay test kit.

Calibration of the HNu will be conducted on a daily basis. Instrument calibration will be performed using isobutylene gas of known concentration. Calibration will be performed daily according to the manufacturer's recommendations and will be recorded in a logbook. All adjustments to the instrument settings will be recorded in the field book. Routine maintenance will consist of battery charging and occasional lamp or fan cleaning.

Any instrument that does not meet the calibration criteria described in Appendices A or B will require corrective action and will not be used to perform analyses. Corrective action procedures are given in Section 1.12 and in Table 1-3.

1.7 ANALYTICAL PROCEDURES

The following sections describe the analytical methods to be used for field screening and for fixed laboratory analysis.

1.7.1. Field Screening Methods

Samples collected for this investigation will be analyzed only by a field screening immunoassay method for BTEX and for PAH (EPA draft Method SW4030).

Immunoassay analysis is a biochemical technique that relies on the specific binding characteristics of antibodies engineered to fit or bind to specific substances. The antibody is fixed to a substrate of magnetic particles in suspension in a test tube. Sample or sample extraction is added to the test tube and the analyte of interest binds to the antibody. After a specified amount of time, the excess sample is washed from the test tube. The magnetic particles with the antibodies are held in the test tube by magnets built into the test tube holders. The result is that the target analyte remains bound to the antibody while interferences and other compounds of noninterest are removed. A color indicator is then added to the test tube so the target analyte can be quantified by comparing the light absorbance of the sample to the absorbance of a standard in a photometer.

Detection limits for the BTEX immunoassay test kits for total BTEX (composed of equivalent parts of benzene, toluene, ethylbenzene, and m-, o- and p-xylene) and various other petroleum hydrocarbons are shown below.

TABLE 1-3

Instrument Calibration Frequency and Acceptance Criteria

Analytical Method	Applicable Parameter	Quality Control Check	Frequency	Acceptance Criteria	Corrective Action
Proposed SW4030	BTEX or PAH by immunoassay	Pipette calibration	Daily and after extreme mechanical shock	None	1) Identify and correct problem 2) Repeat calibration
		Photometer calibration	Daily	None	1) Identify and correct problem 2) Repeat calibration
None	Organic vapor concentrations-OVA and HNu®	Field replicate analyses	2 per analytical batch	RPD \leq 30%	Evaluate results for possible source of variability; flag affected sample results
		Field duplicate	Minimum 10% field samples	RPD \leq 30%	Evaluate results for possible source of variability; flag affected sample results
		Multipoint calibration	Monthly	$r \geq 0.995$	1) Recalibrate 2) Check instrument, replace if necessary
		Calibration verification and check	Daily at beginning and end of day	Response \pm 20% of expected value	1) Recalibrate 2) Check instrument, replace if necessary.

<u>Compound</u>	<u>Parts per Million</u> <u>(ppm)</u>
Total BTEX	0.02
m-Xylene	0.03
p-Xylene	0.13
o-Xylene	0.22
Ethylbenzene	0.24
Toluene	0.44
Benzene	0.59
Naphthalene	0.03
1,2,4-Trimethylbenzene	0.04
Anthracene	0.06
Styrene	0.07
Hexachlorobenzene	0.08
Phenanthrene	0.08
Creosote	0.10
1,3,5-Trimethylbenzene	0.14
Acenaphthene	0.17
n-Propylbenzene	0.27
n-Hexane	6.30
n-Octane	3.40
n-Nonane	4.40
n-Heptane	2.35
Cyclohexane	8.30
n-Decane	13.5
Methylene Chloride	NR*
Trichloroethylene	NR*
Gasoline	0.43
Mineral Spirits	1.12

Parts per Million

<u>Compound</u>	<u>(ppm)</u>
Diesel	1.29
Kerosene	1.50
Jet A-Fuel	2.70
Household Lubricant	15.8

*NR = Nonreactive up to 100 ppm

The detection limits for soils will be 10 times the values given above because of dilution during the extraction process.

Detection limits for the PAH immunoassay test kits for various PAHs and petroleum products are shown below.

<u>Compound</u>	<u>(ppm)</u>
Phenanthrene	0.70
Fluoranthene	0.32
Benzo[a]pyrene	0.50
Pyrene	0.20
Chrysene	0.40
Anthracene	0.54
Indenol[1,2,3-c,d]pyrene	0.78
1,2 Benzanthracene	0.77
Fluorene	1.65
Benzo[b]fluoranthene	0.91
Acenaphthylene	10.0
Benzo[k]fluoranthene	0.77
Acenaphthalene	12.9
1,12-Benzoperylene	14.7

<u>Compound</u>	<u>(ppm)</u>
Naphthalene	65.0
1,2:5,6-Dibenzanthracene	25.7
Creosote	1.1
Fuel Oil #6	5.0
Heating Oil	12.8
Diesel Fuel	19.6
Gasoline	1000
Kerosene	1250
Jet A Fuel	>10000

The detection limits for soils will be 100 times the values given above because of dilution during the extraction process.

Each test kit allows for analysis of either 30 or 70 separate samples. Samples analyzed by any single test kit will be defined as a batch. The kits are used in a four-step process. Step 1 includes extraction and preparation of the sample, including weighing, extracting, and filtering each sample. Step 2 includes preparation of standards. Step 3 is the actual testing of the sample by mixing the sample extract and standards in separate test tubes and measurement of the color in a photometer. Step 4 is the interpretation of the sample results. Manufacturer's procedures for conducting immunoassay analyses of soils are included in Appendix A.

The immunoassay test kits will be refrigerated to obtain the maximum shelf life. Test kits that have exceeded their indicated "use by" dates will not be used but will be disposed of along with other used reagents produced by the immunoassay testing process.

1.7.2 Fixed Laboratory Methods

Reporting limits will be established for reagent (blank) water using procedures outlined in one of the following references:

- applicable analytical method (these are the methods specified by the Air Force for analysis of the various study analytes);
- 40 CFR 136, Appendix B;
- *Principles of Environmental Analysis in Analytical Chemistry*, Vol. 55, pp. 2210-2218, December 1983; and
- EPA CLP, latest Statement of Work.

Any variances or deviations to the established method detection limits (MDLs) must be approved by the Jacobs Project Manager. Upon approval, the Jacobs Project Manager will request the variance on behalf of the laboratory for approval by the Air Force. No deviations or variances will be considered for approval during or 30 days before any scheduled analytical performance period.

The procedures used to establish the detection limits for organic compounds will be performed before analyzing environmental samples and are verified once a year. The limits for metals are verified semiannually. Documentation to demonstrate the established detection limits will be provided by the laboratory for review by the Jacobs QA Officer before any sampling event. No sample analyses will be performed until the established detection limits are approved in writing by the Jacobs QA Officer.

The laboratory will not establish quantitation limits by multiplying the detection limits by an arbitrary factor.

1.7.2.1 Identification of Fixed Laboratory Methods

The analytical method numbers, the source for each method, and the Air Force required maximum reporting limits for laboratory analyses are presented in Table 1-4. Analytical procedures will be in accordance with those specified in the Air Force IRP Handbook (Air Force 1993), laboratory standard operating procedures (SOPs), and the analytical method. The use of tables and flowchart will illustrate laboratory procedures and method interpretation.

Gas Chromatograph Methods. For gas chromatograph (GC) methods, analyte retention times and retention time windows will be established to accurately identify chromatographic peaks. Demonstration of appropriate retention time windows will be included in the laboratory data packages. The confirmation analyses will be performed to include all the necessary QC components and deliverables required by the method. The laboratory will identify the most reliable value and report that value as the primary quantitation. All analyses to be used for confirmation will be identified as such and reported. If it becomes necessary to confirm the presence and quantitation of a compound via GC/mass spectrometry (MS) methodology, the concentration of the chemical will be equal to or greater than the GC/MS method detection limit (MDL).

GC Second-Column Analysis. The maximum number of second-column confirmational analyses will not exceed the specified number in the Sample Analyses Summary tables in the FSP (Section 2.0). If the number of samples requiring second-column confirmation exceeds this allowance, the COR will be contacted. If GC/MS or a combination of second-column GC and GC/MS is used, the total cost of all such analyses for a particular parameter will not exceed the funding allowed for positive confirmation using only second-column GC.

All confirmation analyses will be reported in the data package and discussed in the laboratory case narrative. Data from both the primary analysis and the confirmation will be reported for all compounds of interest within the scope of the specific method. Any

compound not reported in the primary analysis, but found in the confirmation analysis, will be discussed in the laboratory case narrative. This discussion will identify those sample analyses that did not match the primary analysis and provide a rationale for the nonconformance (e.g., lack of sample homogeneity or potential laboratory contamination).

Total Petroleum Hydrocarbons (TPH), E418.1 Oil and grease are removed from the sample with a series of freon (fluorocarbon-113) extractions. The extract is treated with silica gel to remove polar materials, leaving only the recoverable petroleum hydrocarbons. Method E418.1 is an infrared (IR) spectrophotometric analysis of TPH. Hydrocarbons include gasoline-range organics (GRO), diesel-range organics (DRO), and residual extractable hydrocarbons (motor oil and lubricants) and will be reported as a total concentration value in mg/kg.

Solid Matrix Sample Analysis. All results will be reported on a dry weight basis for soil samples. The percent moisture will be reported for all solid samples. An adequate mass of solid will be used in the extraction and/or preparation phase to make certain that the detection limits are achieved. Samples that contain greater than 30 percent moisture will be noted in the laboratory case narrative, and any potential bias will be discussed.

The detection limits for all fixed laboratory analyses will be established in accordance with Appendix B of 40 CFR Chapter 1, Part 136, Guidelines Establishing Test Procedures for the Analysis of Pollutants. The documentation for all methods will be kept at the laboratory for review by the Jacobs QA Officer. This information will be verified for completeness and accuracy before any sample analyses. As necessary, this information will be provided to any subcontractors providing third-party validation.

Quantitation for all methods will be performed in accordance with the specific methodology. For GC analyses, all positive values will be quantitated using the average response factors or calibration factors from the initial calibration.

1.7.2.2 Practical Quantitation Limits

The following discussion defines the practical quantitation limit and the procedures for establishing practical quantitation limits (PQLs).

1.7.2.3 Terminology

The practical quantitation limit is the lowest level that can be reliably achieved within specified limits of precision and accuracy during routine analysis as defined by AFCEE (Air Force 1993) and EPA (EPA 1986). The PQLs for the compounds listed in Table 1-4 are identical to those found in the IRP handbook.

1.7.2.4 Procedures

The PQLs as defined above are verified by the laboratory with each initial calibration. The initial, multipoint calibration curve must include a standard at a concentration below the PQL values list in Table 1-4. All analytes reported must be present in the initial and continuing calibration standards and all calibration criteria specified must be met.

1.7.2.5 Values

The PQLs that are applicable to the NAS Fort Worth Fuel Hydrant investigation are presented in Table 1-4.

1.7.2.6 Method Calibration for Fixed Laboratory

Calibration of fixed laboratory instrumentation will be performed as specified in the analytical methodology. Sample analyses will only be conducted using calibrated equipment. Calibration criteria will be provided by the laboratory and reviewed by AFCEE prior to any sampling.

TABLE 1-4
CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
AQUEOUS SAMPLES
NAS FORT WORTH JRB, TEXAS

Parameter	Method		Analyte	Air Force Practical Quantitation Limit	
	w = water	s = soil		Water (µg/L)	Soil/Sediment (mg/kg)
Volatile Organic Compounds	SW8020 (w & s)		Benzene	2	0.002
			Chlorobenzene	2	0.002
			1,2-Dichlorobenzene	4	0.004
			1,3-Dichlorobenzene	4	0.004
			1,4-Dichlorobenzene	3	0.003
			Ethylbenzene	2	0.002
			Toluene	2	0.002
			Xylenes (total all isomers)	5	0.005
Polycyclic Aromatic Hydrocarbons	SW3510/SW8310 (w) SW3550/SW8310 (s)		<u>Base/Neutral Extractables</u>		
			Acenaphthene	18	1.2
			Acenaphthylene	23	1.54
			Anthracene	6.6	0.44
			Benzo(a)anthracene	0.13	0.009
			Benzo(b)fluoranthene	0.18	0.012
			Benzo(k)fluoranthene	0.17	0.011
			Benzo(ghi)perylene	0.76	0.05
			Benzo(a)pyrene	0.23	0.015
			Chrysene	1.5	0.1
			Dibenz(a,h)anthracene	0.3	0.02
			Fluoranthene	2.1	0.14
			Fluorene	2.1	0.14
			Ideno(1,2,3-cd)pyrene	0.43	0.03
			Naphthalene	18	1.2
			Phenanthrene	6.4	0.42
Pyrene	2.7	0.18			
Total Petroleum Hydrocarbons	E418.1 (w & s)		TPH	1	30

References:

Standard Methods for the Examination of Water and Wastewater, 16th Edition (1985).
 Methods for Chemical Analysis of Water and Wastes, EPA Manual, 600/4-79-020 (USEPA).
 Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition.

Notes:

mg/kg = milligrams per kilogram
 mg/L = milligrams per liter
 µg/L = micrograms per liter

For GC/MS methods, the response factor from the daily calibration standard will be used to quantitate target compounds. In cases where the sample analyses immediately follow the initial calibration and are within the 12-hour calibration timeframe of the MS tuning standard, the midpoint standard response factors will be used for quantitation. This standard must meet the criteria for daily calibration standard for these analyses to be acceptable.

1.7.2.7 Calibration Procedures

Calibration procedures for the laboratory instruments required for the specified analytical methods and information on the type of laboratory instruments will be provided by the laboratory. Additional information on laboratory QA is found in Section 1.10.

The materials used for all calibration standards, internal standards, surrogate standards, and QC check samples will be from EPA-certified reference or National Institute of Standards and Technology (NIST) traceable reference standards for all organic and inorganic analyses, if available. The Jacobs QA Officer will verify that the appropriate standards will be used by the laboratory before any analytical work.

1.8 DATA REDUCTION, REVIEW, AND REPORTING

Data reduction, quality review, and reporting, procedures will include evaluating the field sampling, sample handling, and field and laboratory analytical data. The overall goals of the soils investigation can be met only if the data generated in the field can be demonstrated to be valid.

1.8.1 Data Management

All data will be recorded in bound logbooks or on field forms. The following information will be documented:

- date sampled;

- sample ID;
- sample dilution (if applicable);
- analyst or sampler initials; and
- results in ppm.

Data produced by the immunoassay field screening method and by the fixed laboratory will be transcribed and presented both as a table and graphically displayed as a map.

The field team will collect the samples at locations described in the Environmental Cleanup Plan. After the team collects the samples, the sample documentation (sample tags, chain-of-custody records, etc.) will be completed. Regular QC checks will be conducted by members of the sampling team on the sample documentation. The sampler or analyst will correct mistakes by making a single line through the mistake and printing the correct information next to it. The sampler or analyst will also initial and date the correction. A black, waterproof pen will be used for all sample documentation. If sample documentation is acceptable, the samples will be retained for field screening analysis.

1.8.2 Data Reduction

Data reduction is the process of converting measurement system outputs into an expression of parameters and information from which conclusions about the site can be made. These processes must be performed accurately, and with accepted statistical techniques. All calculations and data entries will be checked during a QA review to maintain the accuracy of this process.

The data generated from this investigation will be evaluated to determine the appropriate statistical techniques that can be applied to the data set. The statistical analysis may include classical statistics and geostatistical approaches.

Field QC samples, such as replicate, duplicate, or matrix spike samples, will be evaluated to determine if any systematic or random errors are being introduced by the sampling or field screening analytical procedures.

1.8.3 Data Quality Assessment

Data quality assessment involves reviewing the field and laboratory records, maintaining proper record keeping, and assessing the field and laboratory data. These steps are discussed in the following sections. Regular review of records will be conducted by members of the sampling/analysis team. In addition, QC audits may be performed by the QC Inspector.

1.8.3.1 Review of Field Records

Field records, at a minimum, will be evaluated for the following:

- completeness;
- identification of valid samples;
- correlation of field test data with previous results, if available;
- identification of anomalous field test data; and
- assessment of the precision of the field test data and measurements.

The check of field record completeness will verify that (1) all requirements for field activities in this SAP have been fulfilled, (2) complete records exist for each field activity, and (3) the procedures specified in program planning documents have been implemented. Field documentation will ensure verification of sample integrity and provide sufficient technical information to re-create each field event. The results of the completeness check should be documented. Environmental data affected by incomplete records will be identified in technical reports.

The identification of valid samples involves interpreting and evaluating the field records to detect problems affecting the representativeness of environmental samples. For example, photographs may show the presence or absence of sources of potential contamination, such as operation of combustion engines in the vicinity of sampling.

In addition, field audits are another source of data for review. Those judgments of sample validity will be documented in the technical report. Environmental data associated with poor or incorrect fieldwork and/or record keeping will be identified.

To the extent possible, anomalous field data will be identified and explained. The assessment of the quality of field measurements will be based on instrument calibration records and a review of any corrective action reports. The accuracy and precision of field measurements will be discussed.

1.8.3.2 Laboratory Record Keeping

Record keeping procedures for the laboratory are listed below:

- The laboratory will maintain records sufficient to re-create each analytical event conducted. At a minimum, the records will contain the following:
 - chain-of-custody records;
 - initial and continuous calibration records including preparation of standards traceable to the original material and lot number;
 - instrument tuning records, if applicable;
 - method blank analyses;
 - internal standard results;

- surrogate spiking and results (if required);
 - spike and spike duplicate records and results;
 - laboratory duplicate records and results (if done);
 - raw data including instrument printouts, laboratory bench work sheets and/or chromatograms with compound identification and quantitation reports; and
 - other QC samples and results (e.g., results of the matrix quantitation limit studies, and the results of blank spiking).
- The laboratory written procedures for each analytical method will be provided prior to sampling.
 - The following units of measure will be used for reporting analytical results:
 - water samples - organics ($\mu\text{g/L}$);
 - soil samples - organics, (mg/kg , dry basis);
 - moisture content for each soil/sediment sample. The following equation for moisture content given in ASTM D-2216 will be used:

$$W = [(W_1 - W_2) / (W_1 - W_c)] \times 100$$

where:

W = moisture content, percent;

W₁ = weight of container and moist soil, grams;

W₂ = weight of container and oven-dried soil, grams; and

W_c = weight of container, grams.

1.8.3.3 Assessment of Laboratory Data

The review of laboratory data will focus on the subjects listed below. Any trends or problems associated with the data will be noted and discussed the Environmental Site Characterization Summary Report.

Chain-of-Custody Records. Chain-of-custody records will be reviewed to verify that sample preservation and temperature were checked when the laboratory received the sample. Sample preservations will be compared with requirements listed in Tables 1-1 and 1-2.

Holding Times. The time elapsed between the date of sampling and the date of analysis and/or extraction will be compared with the requirements shown in Tables 1-1 and 1-2. Sample extraction is defined as completion of the sample preparation process as described in the applicable method including any necessary cleanup before volume reduction procedures. Sample analysis completion is defined as completion of all analytical runs including dilutions, second-column confirmations, and any required reanalyses. If holding times are exceeded, evidence of resampling and analysis within proper holding times will be noted.

Method Calibration Limits. Initial calibration verification (ICV) and continuing calibration verification (CCV) standard results will be reviewed to ensure conformance to acceptance criteria. To verify results, selected ICVs and CCVs will be recalculated from the raw data. The review will also determine whether the calibration events can be re-created. In addition, using correlation coefficients or ion abundances, a verification will be performed to determine whether the instrument was in proper tune or calibration during sample analyses.

Method Blanks. The review will verify that no sample results greater than three times the Air Force MDLs or laboratory-established MDLs are present in any of the method blanks.

The review will also verify that no analytical data were corrected for the presence of analytes in the method blanks.

Laboratory-Established Reporting and Quantitation Limits. Any laboratory-established reporting quantitation limit that exceeds those in this SAP or the Air Force IRP Handbook (Air Force 1993) will be identified. The absence of records supporting the establishment of reporting and quantitation limits will also be noted.

Analytical Batch Control Records, Including Laboratory Control Sample Results, Spike Recoveries, and Duplicate Results. The results of analytical batch QC samples will be compared with SAP-specified, laboratory-established acceptance criteria. Data not within control limits require corrective action, and reviewers will check that corrective action reports and the results of reanalysis are available. Samples associated with out-of-control QC data will be identified, and an assessment of the utility of such analytical results will be recorded. Corrective action reports will be referenced in this assessment.

Corrective Actions. The review will verify that SAP-specified corrective actions have been implemented whenever contamination is detected or QC sample results exceed control limits.

Surrogates. The preparation and results of surrogate spikes will be reviewed, and selected surrogate concentrations will be recalculated.

Completeness of Data. The check of laboratory data completeness will make certain that (1) all samples and required analyses have been processed, (2) complete records exist for each analysis and the associated QC samples, and (3) the procedures specified in the Work Plan, SAP, and SOPs have been implemented. The results of the completeness check will be documented in project reports.

In addition, formulas and examples of analyte quantitation will be reviewed along with sample preparation logs. Also, because method validation is a continuous process, the

reviewer will make certain that control charts and statistical calculations have been updated to include recent data.

1.8.4 Data Reporting

Analytical data will be tabulated in the completion report. QC and cross-references will be reported in accompanying data tables. In addition, method detection limits, control limits, and holding times will be summarized. An Analytical Data Informal Technical Information Report (ITIR) as described in the Air Force IRP Handbook (Air Force 1993) will not be submitted.

1.9 QUALITY CONTROL FOR FIELD ACTIVITIES

Field and laboratory QC samples are defined below. The frequency for collection of field QC samples is discussed in Section 2.2.4. Field QC samples will apply only to those sample locations designated for fixed laboratory analyses.

1.9.1 Quality Control for Field Activities

For the field analytical data results obtained to be judged reliable and accurate, the following QA/QC procedures will be followed:

1. Sample documentation - location and depth of sample; time and date of collection, and names of the samplers.
2. Field analysis documentation - maintain records of all raw data, calculations, names of the analysts and final results of field analysis for all samples screened.
3. Method blank - analyze blank extraction solvent to document method blank. One method blank sample will be analyzed each day that samples are analyzed in the field.

4. Site-specific matrix background field analysis - collect and field analyze uncontaminated sample from site matrix to document matrix effect. A single matrix sample will be collected from each unique type of unconsolidated material identified during the investigation. Samples selected for matrix background field analysis will be collected during the course of the investigation. Samples that do not have apparent staining, odor, or readings from field monitoring equipment will be selected for matrix background analysis. If samples identified as matrix background samples contain detectable quantities of petroleum fuels, then a matrix sample will be obtained from a drive-point located at a distance of at least 50 feet from the fuel handling system.
5. Matrix spike sample - Matrix spike samples will consist of clean soils collected at the site, sent to a commercial facility, spiked and blended with BTEX or PAH to a concentration of 1 ppm. The BTEX spike will consist of equal parts of benzene, toluene, ethylbenzene, m-, o-, and p-xylene. The PAH spike will consist of phenanthrene. Prepared matrix spike samples will not be held longer than 14 days and will be preserved by cooling to 4 degrees centigrade (°C). The matrix spike samples will provide information about analytical accuracy and matrix affects of the site soils.
6. Replicate sample field analysis - analyze replicate samples to document method precision. The matrix spike samples will be analyzed as replicates. Two replicate samples will be analyzed for each batch of samples.
7. Duplicate sample analysis - Duplicate samples for analysis will be obtained from the same drive-point sample tube as the original sample; 10 percent of all samples will be duplicates. The sample chosen for duplicate analysis is preferably a sample testing positive for BTEX or PAH. Duplicate samples will be prepared by splitting the sample with a stainless-steel trowel after it is removed from the sampling tube. Comparable material from each split will be analyzed. In addition, 10% of all samples will be sent to an offsite laboratory for confirmatory analysis of BTEX

(SW8020) and PAH (SW8310). Ten percent of samples sent to the offsite laboratory will also be duplicates to assess the accuracy of the offsite laboratory.

The following are additional field activities for QC for samples being sent to the fixed laboratory:

- Trip Blank. A VOC sample bottle is filled with American Society for Testing and Materials (ASTM) Type II reagent-grade water in the laboratory or at an offsite location, transported to the site, handled like a sample, and returned to the laboratory for analysis. (trip blanks are not to be opened in the field.) The trip blank for soils is Type II reagent-grade water. In this case, the laboratory will report the trip blank results (complete data package) with the associated soils data package.
- Ambient Conditions Blank. ASTM Type II reagent-grade water is poured into a sample container at the site, then is handled like a sample and transported to the laboratory for analysis of VOCs. The laboratory will report the ambient conditions blank results (complete data package) with the associated soil or water data package.
- Equipment Blank. ASTM Type II reagent-grade water is poured into the sampling device or pumped through it (in the case of sampling pumps), transferred to sample bottles, and then transported to the laboratory for analysis. The laboratory will report the equipment blank results (complete data package) with the associated soil or water data package.
- Duplicate. Field duplicates are two co-located samples collected independently at a sampling location during a single sampling act. Field duplicates will be labeled so that laboratory personnel performing the analyses are not able to determine which samples are duplicates.
- Replicate. A replicate is a single sample that is homogenized and divided or split into two equal parts for analysis. Replicates are often called splits. Field replicates will be

identified so that laboratory personnel are unable to distinguish them from other field samples. Replicates will not be used when collecting samples for volatile organic analysis.

Note: Type II reagent-grade water will be certified by the manufacturer to verify that (1) it is free of analytes and contaminants and (2) the electrical conductivity is less than 1.0 micromhos per centimeter ($\mu\text{mhos/cm}$) at 25 degrees Celsius ($^{\circ}\text{C}$). Type II reagent-grade water will be stored in glass, stainless-steel, or Teflon containers. Distilled water from supermarkets will not be used in place of Type II reagent-grade water.

When equipment water that meets the ASTM Type II criteria (via deionization and carbon filter) can be obtained or generated in the field, the field sampling team may substitute this material for Type II reagent-grade water.

1.9.2 Quality Control for Fixed Laboratory Activities

QC for fixed laboratory activities consists of the following:

- Method Blank. Method blanks consist of analyte-free water or soil, processed in the exact manner as the samples within a batch using identical reagents and solvents. Method blanks are generated by the laboratory.
- Sample Matrix Spike. A sample that represents the matrix will be selected by the Jacobs Site Manager. The laboratory will spike this sample in duplicate (matrix spike and matrix spike duplicate) with analytes specified for each method by the laboratory. For the offsite laboratory, a minimum of one sample per 20 project samples will be selected for the matrix spike and matrix spike duplicate.
- Surrogate Spikes. Surrogate spikes are compounds that are added to every sample analyzed including the standards, blanks, matrix spikes, and QC check samples to assess the recovery of the method. Not all analytical methods are amenable to the use of surrogate spikes. Before any sampling event, any analyses that require surrogate

spikes will be identified. All applicable surrogate recovery control limits will be reviewed for approval by the Jacobs QA Officer.

- Standard Matrix Spike/QC Check Sample. A QC check sample consists of either an EPA reference or NIST traceable reference material. The QC check sample or standard matrix spike will be used to assess laboratory performance and to evaluate whether any systematic problems occurred during analysis. Any QC check sample that is found to be outside control criteria for any compound or analyte will require corrective action by the laboratory and reanalyses of all associated samples.

1.9.3 Fixed Laboratory Analytical Batches

Environmental samples will be grouped in specific analytical batches. Each batch will include sufficient calibration events and QC samples to allow the results of that batch to stand as an autonomous data set. That is, all associated data for an analytical batch will be reported with each data package. An analytical batch will consist of no more than 20 environmental samples. Laboratory QC samples will be used to assess the desired precision, accuracy, representativeness, comparability, and completeness of the data.

1.9.4 Control Limits

Control limits for each analytical method will be provided by the laboratory and reviewed by AFCEE prior to sampling.

1.10 PERFORMANCE AND SYSTEM AUDITS

Performance and system audits for sampling and analysis may be conducted. Audits may include a review of field and laboratory QA systems and onsite review of equipment for sampling, calibration, and measurement. Audits may evaluate the capability and performance of project personnel, items, activities, and documentation. The audits will ensure and document that QC measures are being used to provide data of acceptable quality and that subsequent calculations, interpretations, and other project output are

checked and validated. Scheduled and unscheduled audits will be conducted by the Jacobs QA Manager or his designee. The QA Manager or designee will audit fieldwork and review the project documentation.

During a system audit, the entire QA process is evaluated. The project or field team organization is reviewed for compliance with the proposed organization and clarity of assigned responsibility. Qualifications of personnel assigned to the project will be reviewed to make certain that assigned responsibility, skill, and training are properly matched.

A system audit may be conducted on all components of a measurement system to determine proper selection and use. The system audit includes evaluation of both field and laboratory procedures.

During a performance audit, proper execution of SOPs or QC procedures is evaluated. The audit will address whether field equipment and analytical instruments are selected and used to meet requirements specified by the stated project objectives. Equipment and facilities provided for personnel health and safety may also be evaluated. Calibration procedures for field instruments will also be audited.

A review of analytical methodology with respect to data requirements for the project will be performed. An onsite observation of analytical techniques, data reduction, and record keeping will be performed, if an audit is conducted.

QA audits are conducted at the request of project management or the Air Force. A written report of a QA project audit will include the following:

- an assessment of project team status in each major project area;
- clear statements of areas requiring improvement or problems to be corrected;

- recommendations and assistance regarding proposed corrective action or system improvements; and
- a timetable for any corrective action required.

The Jacobs QA Manager will be responsible for the coordination of audits and the disposition of audit records.

1.11 PREVENTIVE MAINTENANCE PROCEDURES AND SCHEDULES

Preventive maintenance procedures are established to make certain that field instruments perform their intended functions. Instrument maintenance records for field instrumentation will be kept in permanently bound notebooks assigned to each individual instrument. Field equipment maintenance procedures are discussed in Section 2.3.3.

Preventive maintenance is a crucial element of the QA program in any laboratory. Analysts will perform routine preventive maintenance such as replacing minor parts, cleaning exterior components, and providing the instruments with a clean, climate-controlled environment. Major instruments, such as GCs, analytical balances, and GC/MS systems, will be maintained under commercial service contracts or by qualified in-house service technicians. All instrument maintenance is recorded in the associated instrument logbook for reference and verification of scheduled maintenance.

Laboratory support systems such as the deionized water supplies, refrigerators, and ovens will also be monitored and serviced regularly. In many instances, the improper functioning of such basic equipment as a refrigerator is enough to invalidate costly data. The laboratory QA program will be designed to minimize data loss by monitoring and recording the functioning of these systems, allowing rapid correction of any malfunction before data loss can occur.

Field and laboratory instruments will be constantly monitored by using daily calibration, sensitivity, and response checks to determine when nonscheduled maintenance is required.

In the event that an instrument does fail, every effort will be made to meet obligations to clients concerning holding times and analysis due dates. Instrument calibration frequency and acceptance criteria are listed in Table 1-3.

1.12 CORRECTIVE ACTION PROGRAM

Corrective action for either field or analytical operations includes response, reestablishment of control, and documentation.

1.12.1 Response

Corrective action will be initiated when potential or existing conditions are identified that may adversely impact data quantity or quality. It will be the responsibility of the individual who first recognizes an out-of-control event to initiate corrective action.

Events that may require corrective action include the following:

- violation of established field procedures;
- violation of established field analytical procedures or controls;
- results of performance, system, or project QA audits; and

Corrective action may take several forms, but the following steps are almost always included:

- Check the calculations or field forms.
- Check the instruments for proper setup and calibration.
- Reanalyze the control item.

The Jacobs Project Manager, Site Manager, QA Manager, and sampling personnel may be involved in the corrective action. All personnel are trained to recognize and report out-of-control conditions to supervisors. QA personnel are authorized to stop work until the need for corrective action is assessed.

The corrective action may be immediate or long term. A corrective action requiring immediate response may be recalculation, reanalysis, or repeating sample collection. Long-term corrective action may be identified through, but not limited to, performance evaluation samples, standards, and control charts.

1.12.2 Reestablishment of Control

Immediate corrective action is usually applied to spontaneous, nonrecurring problems. Instrument and equipment malfunctions, and nonconforming field procedures are amenable to this type of action. The individual who suspects nonconformance to previously established criteria or protocol in equipment, instruments, data, or methods will immediately notify his/her supervisor. The supervisor and the appropriate task leader will investigate the extent of the problem and take the necessary corrective steps. If a large quantity of data is affected, the task leader will prepare a memorandum to the QA Manager. These individuals will collectively decide how to proceed.

Long-term corrective action procedures are devised and implemented to prevent the recurrence of a potentially serious problem. The QA Manager will be notified of the problem and will conduct an investigation to determine the severity and extent of the problem. A corrective action report will be filed with the project manager, field manager, and program manager. In the case of a dispute, the Jacobs corporate QA Director will make a final determination. If corrective action will impact the project budget or schedule, the action requires involvement of the Air Force Project Manager.

1.13 QUALITY ASSURANCE REPORTS

The following subsections discuss QA reporting procedures and QA reporting scope and content.

1.13.1 Reporting Procedure

The Jacobs QA Director or his designee may, at the request of the Air Force, prepare QA reports that document all audited field or analytical QC activities. These reports will be submitted to the Project Manager upon completion of fieldwork.

1.13.2 Reporting Scope and Content

If a QA report is requested, the report may include the following:

- QA activities and quality of collected data;
- equipment calibration and preventive maintenance activities;
- results of data precision calculations;
- evaluation of data completeness and contract compliance;
- field and analytical QA findings and recommended and/or implemented corrective actions;
- results of QA audit findings;
- project status and anticipated completion dates for important tasks; and
- any changes to procedures documented in the SAP.

Summary audit reports may be prepared after each task is completed to inform the staff and management of QA status. A final audit report for the project will include the following:

- periodic assessment of measurement data precision, and completeness;

- results of performance audits and/or systems audits;
- significant QA problems and recommended solutions for future projects; and
- status of solutions to any problems previously identified.

Any incidents requiring corrective action will be documented. The summary of findings will be factual, concise, and complete. These reports will be addressed to the Jacobs Project Manager and QA Director.

2.0 FIELD SAMPLING PLAN

This FSP prepared by Jacobs describes procedures that will be used to conduct activities during the 1995 field investigations for the limited subsurface investigation for the removal/closure of the fuel hydrant system at NAS Fort Worth. The description and rationale for the field activities are described in the Work Plan, which is a portion of the Environmental Cleanup Plan. This FSP is a companion document to the Work Plan. The FSP was prepared based on guidance found in the *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS), Volume I* (Air Force 1993). The following sections describe the procedures and requirements for field operations, environmental sampling, field measurements, field QA/QC, record keeping, and site management during the 1995 field investigation.

2.1 FIELD OPERATIONS

The field investigation at the fuel hydrant system will include the following activities:

- site reconnaissance, preparation, and restoration;
- subsurface soil sampling using drive-points; and
- field screening for BTEX and PAH using immunoassay techniques.
- confirmatory analysis of 10 percent of samples for BTEX (SW8020) and PAH (SW8310)

Associated activities include lithologic logging of samples, drive-point hole abandonment, geophysical utility surveys, equipment decontamination, and handling of investigation-derived wastes. The following sections describe the procedures for the field activities. These sampling protocols are designed to ensure that (1) samples are properly collected;

(2) samples are labeled, preserved, and transported so that they are representative of field conditions; and (3) sampling results are repeatable.

2.1.1 Site Reconnaissance, Preparation, and Restoration Procedures

A site reconnaissance will be conducted before initiation of the field investigations. The objective of the site reconnaissance is to obtain information to (1) recommend possible changes in the technical approach to the investigations, and (2) allow for adequate review of any such changes.

2.1.1.1 Site Reconnaissance

Where appropriate, details on specific tasks to be conducted during the site reconnaissance are listed below:

- Locate the position of the subsurface hydrant fueling system in respect to surface materials including grass, asphalt, and concrete.
- Confirm the location of the subsurface hydrant fueling system by using a utility locator. Stake the location.
- Identify potentially contaminated areas not previously documented.
- Verify and stake proposed sampling locations.
- Assess sample locations for ease of access and usefulness of data.
- Document field reconnaissance findings.
- Evaluate observations and update maps.

2.1.1.2 Preparation

Site preparation tasks will be completed during the first five to seven days of the field investigations. Some of these tasks are listed below:

- Construct a decontamination facility and waste treatment unit.
- Verify office space, communications, vehicles, utilities, etc.
- Become familiar with NAS Fort Worth rules, policies, procedures, names of local POCs, and emergency telephone numbers.
- Verify location of emergency equipment.
- Determine digging permit and utility location procedures.
- Locate underground utilities and complete Air Force Form 103 for drilling boreholes or other excavations.

2.1.1.3 Site Restoration

Each sample location will be restored as nearly as possible to its preinvestigation condition. Unused or surplus materials and supplies, stakes, flagging, and waste material will be removed from each sample location as the work is completed at that area. Equipment staging, temporary storage, and waste treatment areas will be restored to original conditions.

Site restoration will be coordinated with the station point of contact to ensure that the restoration is conducted in accordance with the facility requirements. Drive-point samples will only be collected from locations at which the surface material is asphalt, grass, or other unconsolidated material. Drive-point samples will not be collected at locations that are surfaced with concrete. Asphalt surfaces will be patched.

2.1.2 Utility Clearance and Fuel Pipeline Location

Utility clearance and locating is an important and integral part of the investigation because it involves evaluation of contamination along the subsurface fueling system. Utility clearances will be conducted and the fuel pipeline will be located in all areas in which intrusive investigations will be performed. These tasks will be accomplished before the start of intrusive activities to minimize the risk of contact with subsurface utility service lines and to optimize sampling locations.

Buried Utility Clearances. Before performing any shallow geophysical surveys to locate buried utilities, Jacobs will coordinate with the station POC, and all facilities management personnel. Completion of an Air Force Form 103 will be required as part of this process. Preliminary clearance work will be performed by station personnel using utility maps and information from previous clearances. Based on this information, actual or suspected utility locations will be staked or painted for reference. This initial survey will be used as the basis for subsequent confirmation geophysical surveys to be performed. All utility locations tasks will be documented to aid any subsequent utility clearance work.

The position of the subsurface fuel pipeline system will be clearly marked as part of the utility clearance because the objective of this investigation is to evaluate the presence or absence of petroleum contamination along the pipeline. Soil samples will be collected with a drive-point from locations spotted within 3 feet laterally of the fuel system. Depths will vary from several feet below the bottom of the fuel pipeline to up to 20 feet below the surface.

Geophysical Confirmation of Utility Locations. All utility and fuel hydrant system locations will be confirmed in areas of intrusive investigations using shallow geophysical surveys. Both conductance/inductance methods and magnetometer methods will be used for confirmation.

A conductance/inductance geophysical method will be used to locate subsurface cables and utilities. Conductance/inductance instruments rely on a transmitter and receiver in which an electrical signal can be directly placed or generated in a pipe, electrical line, manway, or other surface feature associated with an underground utility. An electrical signal is generated in the suspected utility, either directly by conductance or indirectly by inductance. A receiver is used to track the signal and thus locate the underground position and depth of the buried object. The conductance/inductance method can be used for all metal or conductive materials. Inductance does not require direct contact with the utility line being traced. However, a signal is induced in all nearby utility lines creating interference with the signal generated by any single utility line. Nonconductive utilities such as polyvinyl chloride (PVC) or clay pipes can be traced by pushing a transmitting "mole" attached to a plumber's snake through the pipeline. A manufacturer-supplied user manual for a conductance/inductance utility locator that may be used in this investigation is included in Appendix B.

Magnetometer surveys are used to confirm utility locations determined by the conductance/inductance method, or to unscramble signals in which parasitic signals are being generated by closely spaced utilities. Magnetometers detect natural magnetic fields generated by ferrous utilities.

2.1.3 Drive-Point Drilling, Logging, and Abandonment Procedures

The sampling and logging of the soils below the fuel hydrant pumping system lines and tanks will be completed without using a drill rig. The sampling system will use drive-point samplers that are hydraulically pushed into the ground using a drive-point sampling system. The following paragraphs describe the system and illustrate its soil sampling method.

2.1.3.1 Drive-Point Drilling Methods

Soil samples will be collected from temporary drive-point holes during the NAS Fort Worth fuel hydrant closure as described in the following SOP. Sample collection will employ a van- or pickup-mounted mobile drive-point system. The drive-point is hydraulically powered to push and/or hammer a hollow steel drive rod, tipped with a conical drive point, to the desired sample depth. The rods are threaded, 3 to 4 feet long, 1 inch in outside diameter, and 0.5 inch in inside diameter. No rotary drilling action is produced by the drive-point and no cuttings or dust are produced.

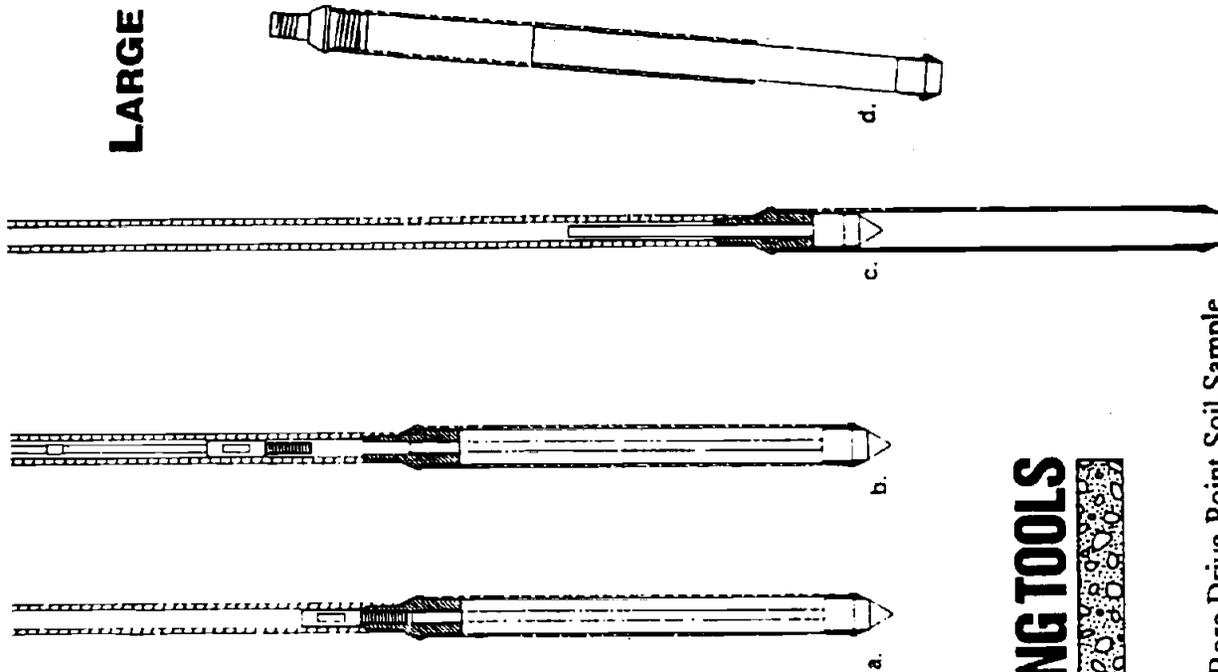
Soil samples will be collected using a hydraulically driven, rod-actuated, steel sampling probe that attaches to the end of the hollow-steel drive rods (Figure 2-1). The sampler is larger in diameter than the rods and has an inside diameter of 1 inch. If compacted or gravelly soil horizons are present, a hydraulically-actuated percussion hammer will be used to drive the sampling probe. Based on the known silty to sandy makeup of the soils at NAS Fort Worth, there should be little difficulty driving the sampling probes to depths of 20 feet.

Drive-point sample locations will be surveyed using compass and chain methods from nearby landmarks that are shown on existing engineering drawings.

2.1.3.2 Lithologic Logging and Sampling

This investigation technique allows for the collection of a 1-inch diameter by 24-inch long soil sample in a clear plastic liner that will be used for logging the hole. Immediately after removal from the drive-point sampling assembly, both ends of the sample liner will be checked with an HNu. The sample material will be checked using the HNu again at the field laboratory before sample preparation begins. The ends of the sample liner will then be capped to prevent the escape of volatiles. Only new sample liners that have been decontaminated and are certified by the manufacturer as analyte-free will be used for the drive-point sampling. The liners should be free of headspace. All samples will be

LARGE BORE SOIL SAMPLER



SOIL SAMPLING TOOLS



Figure 2-1 Large Bore Drive-Point Soil Sample

Driving and Sampling with the Large Bore Soil Sampler.

- a. Driving the Sealed Sampler
- b. Removing the Stop-pin
- c. Collecting a Sample
- d. Recovering Sample in Liner

collected and handled in a manner that reduces loss of volatile constituents. All logging and sampling information will be recorded on the field log form for documentation (Figure 2-2).

The sample interval will be approximately 1 to 5 feet below the level of the buried fuel pipelines and above the water table. Approximately three samples will be collected, logged, and analyzed at each drive-point location. Sample depths should not exceed 20 feet below land surface depending on the depth of the fuel pipelines and depth to groundwater.

Soil samples will be classified according to the Unified Soil Classification System (USCS) (Figure 2-3) and color characterized using Munsell color charts.

After logging is complete, the sample may be used to analyze BTEX or PAH. All sample liners should be free of headspace. Duplicate and confirmation samples will be obtained from 10 percent of the drive-point samples. Sample identification and handling will be documented using chain-of-custody records. Soil samples will be transported in a cooler with ice to the field laboratory for BTEX and PAH analyses using immunoassay field test kits.

All samples will be stored refrigerated at 4° C in the sealed liners. Samples will not be held for more than 48 hours after collection before analysis. The soil samples are not considered to pose a health or safety risk because the volumes and concentrations of contaminants in soil samples are extremely low.

2.1.3.3 Drive-Point Hole Abandonment

If the drive-point sampler meets refusal on a shallow obstruction or the drive-point system is unable to drive the sampler to the predetermined depth, the drive-point hole will be abandoned. In addition, after sampling of all of the drive-point holes is completed, the remaining holes will be abandoned.

FIGURE 2-2 BORING LOG FORM
Lithologic Borehole Log
Project #10K70100

Sheet ___ of ___

Weather Conditions
Names of Persons Present

Location ID
Easting
T.D.
Date Completed
Driller
Rig Type
Geo/Eng.
Backfilled Date

Site ID
Northing
Elevation
Date Started
Drilling Contr.
Drill Method
Sample Type
Hammer Wt.

N

Depth in Feet	Sampled Interval	Sample Number	Percent Recovery	HNU or OVM Reading	Blows Per 6"	Sampling Method	Water Content	USCS Code	Color	Graphic Log	Interval	Description
0												
5												
10												
15												
20												
25												
30												

FIGURE 2-3

UNIFIED SOIL CLASSIFICATION SYSTEM				
Major Divisions				General Description
Coarse-Grained Soils More than half is larger than No. 200 Sieve	<u>Gravels</u> More than half coarse fraction is larger than No. 4 Sieve	Clean gravels with little or no fines	GW	Well graded gravels, gravel sand mixtures.
			GP	Poorly graded gravels, gravel-sand mixtures.
		Gravels with over 12% fines	GM	Silty gravels, poorly graded gravel sand-silt mixtures.
			GC	Clayey gravels, poorly graded gravel sand-clay mixtures.
	<u>Sands</u> More than half coarse fraction is smaller than No. 4 Sieve	Clean sands with little or no fines	SW	Well graded sands, gravelly sands.
			SP	Poorly graded sands, gravelly sands.
		Sands with over 12% fines	SM	Silty sands, poorly graded sand-silt mixtures.
			SC	Clayey sands, poorly graded sand-clay mixtures.
Fine-Grained Soils More than half is smaller than No. 200 Sieve	<u>Silts and Clays</u> Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands. Clayey silts with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic clays and organic silty clays of low plasticity.
	<u>Silts and Clays</u> Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Organic clays of medium to high plasticity, organic silts.
			Highly Organic Soils	

Drive-point samplers create a hole approximately 1.5 inches in diameter extending from the surface to the bottom of the hole. These holes cannot be abandoned using standard borehole abandonment procedures because of the narrow diameter of the hole. To abandon the drive-point holes, the following procedures will be followed:

1. Grout will be mixed using a grout pump and tank until the grout is free of lumps. The grout will consist of 95 percent portland Type II cement and 5 percent bentonite. Sufficient water will be used to create a fluid, low viscosity grout.
2. A grout funnel will be placed in the hole. Grout from the tank will be transferred to the funnel either by pumping or by buckets and will be allowed to run down the hole. Tremie pipes cannot be used because of the narrow diameter of the hole.
3. After 15 minutes, the hole will be topped off with additional grout.

The fluid, low viscosity grout will infiltrate into the alluvium around the hole, creating a low permeability zone and sealing the hole. All drive-point holes will be examined before demobilization. Additional grout will be added to the holes at this time if needed.

2.1.4 Soil Sampling from the Underground Storage Tank Excavations

Soil samples will be collected using a drive-point sampler from around the perimeter of the UST location. Soil samples will be collected from the UST excavations beneath pumping station C after demolition of the station and removal of the USTs has been completed. Utility clearances will be conducted before the start of intrusive activities. A backhoe will be used to excavate and remove the USTs. The backhoe will also be used for collecting soil samples from beneath the UST locations. Personnel will not enter the excavation for sampling purposes. Sample locations will be determined by observing stains and monitoring the soils using an HNu as they are excavated. The backhoe bucket will remove soils from the bottom of the excavation, and the sample will be collected directly from the backhoe bucket and placed in the appropriate sample containers. Soil samples will be analyzed for BTEX (SW8020) and TPH (E418.1)

The following information will be recorded in the field logbook for samples collected from a backhoe bucket:

- sample location in the excavation, and sample designation and associated tank designation;
- estimated depth;
- type of backhoe and operator name;
- depth and thickness of distinct soil or lithologic units;
- USCS classification of sample material and Munsell color designation
- HNu readings obtained from the sample materials;
- description of any man-made materials or debris in the material sampled; and
- other pertinent information and observations.

Excavated soil will be characterized by Method E418.1 and immunoassay for BTEX, with 10% of analyses confirmed by SW8020. Sampling frequency will be approximately one per 50 cubic yards.

2.1.5 Equipment Decontamination

If high levels of contamination are evident based on visual observation and Hnu readings during the drive-point sampling, the drive-point rig will be decontaminated after the drive-point hole has been advanced. Otherwise, the rig will be decontaminated only on initial arrival at NAS Fort Worth and upon completion of the fuel hydrant system investigation. The rig will be steam cleaned until all visible soil and grease have been removed.

The actual drive-point soil sampler will be cleaned between each sample with an Alconox or Liquinox and potable water solution and brushes. The sampler will then be triple rinsed

with potable water, rinsed with American Society for Testing and Materials (ASTM) Type II reagent-grade water, rinsed with pesticide-grade methanol and pesticide-grade hexane, and left to air dry. The drive-point rod will be cleaned and decontaminated using exactly the same technique between each hole.

2.1.6 Waste Handling

A decontamination pad, soil stockpile areas, storage tanks, and recycling bins are to be located in a decontamination facility built for the demolition of pumping station C, removal of the associated USTs and for the abandonment of the fuel hydrant system. Investigation-derived wastes generated during the investigation along the fuel hydrant system will be characterized, segregated, recycled, or disposed of through this facility.

Because the drive-point method generates no cuttings or dust, the only wastes generated by the proposed sampling and analytical method are associated with disposal of soil samples, laboratory reagents, and decontamination water and chemicals.

The soil samples will be characterized as either containing contaminants or clean, by the immunoassay analyses for BTEX and PAH. The soil samples will be segregated according to their characterization and placed in separate 55-gallon ring topped drums. Periodically, the drums will be taken to the decontamination area and placed on the appropriate soil stockpiles. Imported clean soils will be used as backfill in the excavation created for the UST removal. Solid materials that are not recyclable will be placed in roll-off bins and transported to, and disposed of, at an approved landfill.

The waste potable and Type II water from equipment decontamination at the sampling site will be transferred from the tubs or pails used to catch them to either the decontamination pad or a temporary holding tank at the decontamination facility. Decontamination water will then be transported to a wastewater recycling facility for final treatment and disposal.

Waste reagents from the laboratory analyses and waste hexane and methanol from the decontamination will be caught and stored temporarily in 5-gallon plastic pails. This material will be allowed to evaporate during times when the 5-gallon buckets are secure

and monitored. Residual material at the end of the investigation will be placed in the temporary holding tank at the decontamination facility for disposal at the wastewater recycling facility for treatment.

2.2 ENVIRONMENTAL SAMPLING AND SAMPLE DESIGNATION

The sampling and sample designation at NAS Fort Worth will involve only the collection of soil samples collected via a drive-point as discussed in Section 2.1. The sampling, sample handling and identification, sample custody, and field QC procedures will be discussed briefly in the following paragraphs.

2.2.1 Subsurface Soil Sampling Procedures

The drive-point investigation technique allows the collection of a 1-inch diameter by 24-inch long soil sample in a clear plastic liner. The ends of the sample liner will be capped to prevent the escape of volatiles. All sample liners should be free of headspace. The samples will then be used to analyze total BTEX and PAH at appropriate locations..

The interval from which samples will be collected will be approximately 1 to 5 feet below the level of the buried fuel pipelines and above the water table. Approximately three samples will be collected, logged, and analyzed at each drive-point location. Sample depths will generally not exceed 20 feet below land surface, depending on the depth to the water table.

2.2.2 Sample Handling and Identification

Field identifiers will be assigned to the soil samples and will appear on the sample labels, chain-of-custody forms, field sampling forms, and in any field logbooks used by the site geologists. Sample identification and handling will be documented using chain-of-custody forms (Figure 1-3). Because the soil samples collected for this project will not be input into the IRPIMS database, IRPIMS-compatible identification numbers will not be required. For ease of identification, however, the field identifier will include

identifier will include predetermined abbreviations for the site, project, location, and sample number as previously described in Section 1.5.2.

After collection, logging, and identification with a sample number, soil samples will be placed in a cooler with wet ice for transportation to the field laboratory for BTEX and PAH analysis using immunoassay field test kits. All samples will be transported and stored in refrigerators in the sealed liners. Samples will not be held for more than 48 hours after collection before analyses. Analysis will not be conducted on samples that exceed holding times. No preservatives other than cooling to 4° C are to be used with the soil samples. Excess sample material and analytical residues will be disposed of as described in Section 2.1.6.

Immediately after confirmatory samples are collected and labeled for offsite laboratory analysis, they will be placed in a sturdy ice chest. The samples will be packed with shock-absorbent materials, such as bubble wrap, to prevent movement of sample containers during transport. The ice chest will be packed with resealable doublebagged ice packs and sealed with packaging tape. Custody tape will be affixed over the ice chest lid to prevent or indicate tampering.

Sample Packaging. Samples will be placed with ice in a cooler along with the appropriate chain of custody records. The chain of custody sample log sheet will be filled out in indelible ink, placed in a resealable plastic bag, and taped to the inside lid of the cooler. Each collected sample fraction contained in the cooler will be specified on the chain of custody records by the field sampling identification number. Sample containers will be packaged to minimize potential breakage.; Sample packaging for offsite laboratory shipping will meet U.S. Department of Transportation (DOT) requirements.

Shipping Containers. At least three bands of strapping tape will be wrapped completely around the cooler to secure the lid. The cooler will be sealed with evidence tape and labeled Fragile and This End Up on all four sides. The containers will be shipped to the laboratory for analysis in accordance with DOT regulations and procedures. Air-bills will

be properly completed and copies retained and placed in the project file. Samples collected for the field screening laboratory will be delivered directly to the laboratory. Taping and ice chest labeling are not necessary for delivery to the onsite laboratory.

Chain of Custody Record. A chain of custody record will be completed for every sample and will accompany every shipment of samples to both the onsite and offsite laboratories to establish the documentation necessary to trace sample possession from time of collection. The chain of custody record is shown in Figure 1-3. The records will contain the following information:

- sample or station identification number;
- signature of collector, sampler, or recorder;
- date and time of collection;
- place of collection;
- sample type;
- signatures of persons involved in chain of custody; and
- inclusive dates of possession.

The laboratory portion of the form will be completed by the designated laboratory personnel and will contain the following information:

- name of person receiving the sample;
- laboratory sample number;
- date of sample receipt;

- analyses requested; and
- sample condition and temperature.

Transfer of Custody and Shipment. Samples will be accompanied by chain of custody records. When transferring the samples, individuals relinquishing and receiving the samples will sign, date, and note the time on the chain of custody record. The field coordinator will notify the laboratory coordinator when samples are shipped to the offsite laboratory for analysis.

2.2.3 Sample Custody

A chain-of-custody form must accompany each cooler at all times in the field or the laboratory. An example chain-of-custody form is shown as Figure 1-3. This chain-of-custody form must be signed and dated at the time of transfer from the field geologist to the field laboratory analyst. At any time that the coolers are left without an attendant, such as samples left overnight for analysis the next day, each cooler must be sealed with a signed custody seal and kept in a locked trailer or office.

2.2.4 Field Quality Control Samples

QC samples that will be collected during the field investigation are summarized in Section 2.2.10. The following paragraphs describe the types of field QA/QC samples that will be collected.

Trip Blanks. A trip blank consists of ASTM Type II reagent-grade water. The offsite laboratory prepares the trip blanks in controlled conditions and ships the blanks to the site with the precleaned sample containers. The trip blank is then shipped back to the offsite laboratory with each sample shipment containing samples to be analyzed for BTEX. The trip blank is analyzed with the sample batch for BTEX compounds. The purpose of the trip blank is to determine whether cross contamination between samples occurs during

shipment to the laboratory. One trip blank will be included with each cooler sent to the offsite laboratory.

Ambient Blanks. Ambient blanks are prepared in the field by pouring ASTM Type II reagent-grade water into 40-mL vials at or near the sample location. The ambient blanks are labeled and handled with other field samples and analyzed for volatile organic compounds. The purpose of the ambient blanks is to determine whether ambient conditions are affecting field sample results. One ambient blank will be analyzed per volatile organic analysis sampling round.

Duplicate Samples. Field duplicate samples will be collected to assess the variability of field sampling methods and variations in contaminant concentrations within a like sample. Duplicate samples will be analyzed for the same parameters as the primary sample. Care will be taken to make certain that the samples represent the matrix sampled. Duplicate samples will constitute 10 percent of the total number of environmental samples. The duplicate samples for the offsite laboratory will be blind samples and labeled with a different sample identification number than the primary sample. Duplicate samples will be selected based on visible stains, odors, or NNU readings.

Equipment Blanks. Equipment blanks are collected by decontaminating the sampling device and collecting final rinse waters in the sample container. Equipment blanks are collected to determine whether decontamination procedures are adequate. The equipment blanks will be analyzed for the same parameters as the sample collected using the equipment. One set of equipment blanks will be analyzed for each day of sampling.

Field Replicates. Field replicates will be collected from 10 percent of the soil/sediment samples collected and divided into two equal parts for analyses. Each replicate will be labeled with a sample number different from the sample being replicated. Both replicates will be analyzed for the same parameters.

2.2.5 Sample Analysis Summary

Soil samples will be collected from an estimated 160 locations along the fuel hydrant system. Up to 3 samples will be collected at each location. All samples will be analyzed for total BTEX and samples at approximately 50 percent of locations will also be analyzed for PAH using field screening methodologies (EPA draft method SW4030). Samples for confirmatory analyses will be sent to an offsite laboratory and analyzed for BTEX (SW8020) and PAH (SW8310).

Drive point soil samples will be collected from 12 locations around the perimeter of the UST excavation at pumping station C and soil samples will be collected using a backhoe from beneath each of 6 USTs as they are removed. These samples will be sent to an offsite laboratory for BTEX (SW8020) and TPH (E418.1).

Table 2-1 summarizes the number of samples, analytical methods, and sample types to be analyzed as part of this investigation.

2.3 FIELD MEASUREMENTS

Air in the breathing zone and sample material exposed at the ends of the sample liners will be monitored using an HNu.

The primary field measurements to be performed for the NAS Fort Worth fuel hydrant project are the field screening analyses for BTEX and PAH in the soil samples collected using the drive-point sampler. The following sections describe the sample analysis procedure and the calibration, maintenance, and decontamination of the analytical equipment.

2.3.1 Parameters

The following measurements will be performed in the field during drive-point sampling and analysis at the field laboratory.

TABLE 2-1
Sample Analysis Summary
Fuel Hydrant System Investigation
NAS Fort Worth JRB, Texas

ANALYSIS	ANALYTICAL METHOD	LOCATION	ENVIRONMENTAL SAMPLES	DUPLICATES	RINSATE BLANKS	TRIP BLANKS	AMBIENT BLANKS	TOTAL NUMBER OF SAMPLES
Soil								
BTEX	SW4030 ¹	Onsite	588	59	-	-	-	647
PAH	SW4030 ¹	Onsite	240	24	-	-	-	264
BTEX	SW8020	Offsite	83 ²	9	-	-	-	92
PAH	SW8310	Offsite	24 ³	3	-	-	-	27
TPH	E418.1	Offsite	78 ⁴	8	-	-	-	86
Moisture Content	D2216	Offsite	108	11	-	-	-	119
Water								
BTEX	SW8020	Offsite	-	-	13	13	1	27
PAH	SW8310	Offsite	-	-	11	-	-	11
TPH	E418.1	Offsite	-	-	3	-	-	3

Notes:

- BTEX = benzene, toluene, ethylbenzene, xylene
- Onsite = Samples to be analyzed using immunoassay field test kits
- Offsite = Samples to be submitted to offsite laboratory for analysis.
- PAH = polycyclic aromatic hydrocarbon
- TPH = total petroleum hydrocarbon

¹ EPA proposed method
² Ten percent of BTEX samples analyzed by SW4030 plus 18 samples from UST location.
³ Ten percent of PAH samples analyzed by SW4030.
⁴ 18 samples from UST location, up to 60 from soil stockpiles

2.3.1.1 Organic Vapor Analysis

During sampling, the air in the breathing zone and exposed soil at the ends of the sample liner will be checked with an HNu for organic vapors. If organic vapors are detected in the breathing zone, procedures provided in the HSP will be followed. If organic vapors are detected in the sample, a comment specifying level of detection will be made on the chain-of-custody form alerting the field analyst to the presence of contaminants in the sample.

2.3.1.2 Immunoassay Analysis

During the field investigation, immunoassay field test kits will be used to perform rapid screening analyses of BTEX and PAH in the soil samples. The screening data will be used for two primary purposes: (1) to identify the presence or absence of BTEX contamination at each site and PAH at approximately 50 percent of sites, and (2) to select areas that may have soil contamination higher than the State of Texas soil remediation standard delineated in the state UST regulations. It is anticipated that approximately 1,000 samples, including duplicates, will be analyzed using these test kits during the project. Up to 70 individual samples can be analyzed as a single batch.

The immunoassay test kits come with all materials, equipment, and supplies to perform tests and establish calibration curves for each batch using standards supplied by the manufacturer. Higher detection limits can be achieved by additional dilution of the sample extracts. The kits are used in a four-step process. Step 1 includes extraction and preparation of the sample, including weighing, extracting, and filtering each sample. Step 2 includes preparation of standards, while Step 3 is the actual testing of the sample by mixing the sample extraction and the standard and measuring the resulting color in a photometer. Step 4 is the interpretation of the sample results. Appendix A contains detailed instructions for use of the immunoassay kits and typical detection limits provided by the manufacturer.

2.3.2 Equipment Calibration

To meet the data quality objectives set in the QAPP, proper calibration procedures for the field screening analysis and monitoring will be followed. Manufacturer's instrument manuals can be found in Appendices A and B.

For the immunoassay field test kits, the QC check will be obtained by the use of 10 percent duplicate analyses of samples collected using the drive-point sampler, method calibration using manufacturer-supplied standards, by analysis of method blanks and by analyzing two matrix spike replicates for each analytical batch.

Calibration of the HNu will be conducted on a daily basis. Instrument calibration will be performed using isobutylene gas of known concentration. Calibration will be performed according to the manufacturer's recommendations and will be recorded in a logbook. All adjustments to the instrument settings will be recorded in the field book. Routine maintenance consists of battery charging and occasional lamp or fan cleaning.

2.3.3 Equipment Maintenance

Field measurement equipment for the immunoassay field kits, HNu, and utility locator will be maintained according to the manufacturer's recommended procedures provided in the instrument operations manual in Appendices A and B. On a routine basis, the instruments will be inspected and will be thoroughly cleaned.

2.3.4 Decontamination

Field measurement equipment will be kept free of contamination. The immunoassay field test instrument will be decontaminated following the manufacturer's recommended procedures provided in the instrument operations manual in Appendix A. On a routine basis, the instrument will be thoroughly cleaned with recommended solvents and potable water and rinsed with ASTM Type II reagent-grade water.

2.4 FIELD QUALITY ASSURANCE/QUALITY CONTROL PROGRAM

To ensure that sampling and monitoring activities will meet the data quality objectives, QC checks will be implemented for parameters measured or analyzed in the field. All QC check information will be recorded in project-specific field notebooks. The following sections discuss control parameters, control units, and corrective actions for the field investigation.

2.4.1 Control Parameters

Control parameters for air monitoring and field analysis using immunoassay techniques will be monitored during the field operations. As described in Section 2.3, calibration of field instruments and operational checks will be conducted periodically according to manufacturer's specifications. The frequency of the field control check duplicates will be a minimum of 10 percent of all field measurements. As applicable, the materials used to verify the measurements will be from certified sources. Instrument use, maintenance and calibration will follow manufacturer's and IRP Handbook (Air Force 1993) guidance.

The immunoassay instrumentation will be controlled according to the method specifications and manufacturer's SOP (Appendix A). These controls will include the analysis of calibration standards, method blanks, field QC duplicate/replicate samples. Before sample analyses, the instrument will be verified for proper installation and operation.

2.4.2 Control Limits

Control limits for instrument calibration and duplicate precision are based on project data quality objectives. For air monitoring with an HNu photoionization detector (PID), the acceptable RPD between duplicate readings is ± 0.5 units.

The field control limits for the immunoassay laboratory instrumentation based on method analysis and calibration standards are included in Appendix A. For replicate immunoassay sample analysis the acceptable RPD is 30 percent.

2.4.3 Corrective Actions

Corrective actions for the HNu will include recalibrating and remeasuring.

Corrective actions for the immunoassay instrumentation are described in Appendix A. Failure to meet the required criteria described in the established methodology or within this document will result in corrective action by the onsite analyst.

Corrective action for all field instruments will involve a review of the operator's manual. If necessary, instrument maintenance and repairs will be performed as corrective actions, in addition to normally scheduled maintenance operations.

2.5 RECORD KEEPING

Records will be kept for all activities associated with the field activities, as a means of maintaining full documentation of project QA/QC procedures and compliance. Records will be kept in the form of logs and standardized forms. The following logs and forms will be used on this site:

- soil boring log (includes PID readings);
- field logbook;
- immunoassay sample preparation form;
- immunoassay measurements and calculations form;
- field laboratory logbook;
- visitor log;
- photograph log; and
- daily field activity forms.

These forms will supplement the Site Manager's Field Logbook. Examples of these forms are included in Appendix C.

2.6 SITE MANAGEMENT

The following support activities will be provided by the Air Force:

- locating underground utilities and issuing digging or other appropriate permits before commencement of digging and drive-point sampling operations;
- assigning an accumulation point;
- assisting Jacobs with obtaining existing engineering plans, drawings, diagrams, aerial photographs, digitized map files, etc. to facilitate evaluation of the investigation;
- arranging for personal identification badges, vehicle passes, or entry permits;
- arranging for staging areas for storing equipment and supplies; and providing a supply of potable water; and
- arranging for the necessary keys to locks.

Jacobs will supply the Site Manager whose responsibilities will include the following:

- ensuring that the performance of field activities are according to the contract, Work Plan and health and safety guidelines and specifications;
- coordinating overall site activities;
- scheduling;

- tracking field budget and comparing budgetary accounting with subcontractor's daily and monthly field reports; and
- liaison between contractor and client personnel.

3.0 REFERENCES

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Total BTEX RaPID Assay® 355 89

General Description

Volatile organic compounds (VOCs), such as benzene, toluene, ethylbenzene and xylene (BTEX), are principal pollutants in petroleum contaminated sites. The adverse effects of VOCs vary widely depending on the compound, or mixture of compounds, their concentrations and exposure rates. Benzene has been shown to be a multiorgan carcinogen, a human leukemogen, a mutagen and a neurotoxin. Other BTEX components have these effects to varying degrees.

Petroleum-derived fuels, such as gasoline, jet fuel, diesel fuel and kerosene, are complex mixtures of organic compounds, predominantly hydrocarbons. Their compositions vary depending on the source of the crude oil and the refining process. As a result of their widespread use, VOCs are the most prevalent chemicals at contaminated sites across the United States and abroad. Contamination of soil and groundwater by refined petroleum products occurs frequently during their transport, processing and storage. A General Accounting Office survey identified one of the most prevalent sources of groundwater contamination as leaking underground storage tanks.

Soil and groundwater contamination by one or more VOCs are the primary focus of major characterizations, assessments and remedial actions for petroleum contaminated sites.

The RaPID Assay kit for Total BTEX offers a rapid, field-portable and cost-effective method of determining light fuel concentrations. Fuels or solvents containing BTEX or closely related aromatics can be detected using this kit. Gasoline, diesel fuel, kerosene, fuel oil and jet fuels can be detected at levels consistent with state and federal clean-up standards. The specificity and sensitivity of the test offer key advantages over current field methods and costs and time savings over laboratory methods.

The Total BTEX RaPID Assay applies the principles of enzyme linked immunosorbent assay (ELISA) to the determination of Total BTEX and closely related compounds. ELISAs use selective antibodies attached to solid supports in combination with sensitive enzyme reactions. The immunochemical reaction provides high selectivity for light aromatics due to the extraordinary discriminatory capabilities of antibodies. The powerful catalytic ability of the enzyme provides highly sensitive detection.



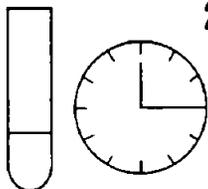
Features

- Rapid** - 50 results in less than 60 minutes after sample preparation.
- Precise** - %CV 17% at 1 ppm in soil.
%CV 12% at 10 ppm in soil.
- Accurate** - highly selective immunochemical method.
- Efficient** - rapid results can cut costs by allowing better personnel and equipment utilization.
- Sensitive** - least detectable dose is 0.02 ppm as Total BTEX Standard (90% B/Bo) in water.
- Test Range** - water: 0.02 to 3.0 ppm as Total BTEX Standard
soil: 0.2 to 30 ppm.

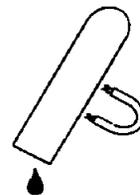
Total BTEX RaPID Assay® — Assay Protocol 355 90



1. Add 200 μ L of prepared sample, 200 μ L enzyme conjugate, and 500 μ L antibody coupled magnetic particles.



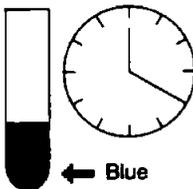
2. Incubate for 15 minutes.



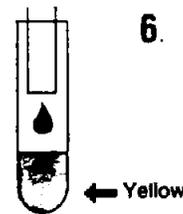
3. Using the RaPID magnetic separator, decant and wash.



4. Add 500 μ L color solution. Vortex.



5. Incubate 20 minutes. Blue color develops.



6. Stop the reaction and read color at 450 nm. Solution turns yellow.

Performance

Specificity

The Total BTEX RaPID Assay has an estimated minimum detectable concentration, based on a 90% B/Bo, of 0.02 ppm Total BTEX.

The cross reactivity of the Total BTEX RaPID Assay for various petroleum hydrocarbons can be expressed as the least detectable dose (LDD) which is estimated at 90% B/Bo, or as the concentration (IC₅₀) estimated at 50% B/Bo.

Compound	LDD (ppm)	IC ₅₀ (ppm)
Total BTEX*	0.02	0.65
<i>m</i> -Xylene	0.03	1.80
<i>p</i> -Xylene	0.13	3.10
<i>o</i> -Xylene	0.22	4.70
Ethylbenzene	0.24	7.80
Toluene	0.44	7.40
Benzene	0.59	51.0
Naphthalene	0.03	0.59
1,2,4-Trimethylbenzene	0.04	1.15
Anthracene	0.06	2.60
Styrene	0.07	28.0
Hexachlorobenzene	0.08	NR
Phenanthrene	0.08	1.60
Creosote	0.10	4.78
1,3,5-Trimethylbenzene	0.14	3.50
Acenaphthene	0.17	6.20
<i>n</i> -Propylbenzene	0.27	4.70
<i>n</i> -Hexane	6.30	NR
<i>n</i> -Octane	3.40	NR
<i>n</i> -Nonane	4.40	NR
<i>n</i> -Heptane	2.35	72
Cyclohexane	8.30	NR
<i>n</i> -Decane	13.5	NR
Methylene Chloride	NR	NR
Trichloroethylene	NR	NR
Gasoline	0.43	42.1
Mineral Spirits	1.12	24.9
Diesel	1.29	16.2
Kerosene	1.50	24.0
Jet A-Fuel	2.70	33.5
Household Lubricant	15.8	NR

* Total BTEX is defined as equivalent parts of benzene, toluene, ethylbenzene and *m*-, *o*- and *p*-xylene (i.e. 1 ppm Total BTEX is composed of 1 ppm each of benzene, toluene, ethyl benzene and *m*-, *o*- and *p*-xylene.) Alternatively, Results can be expressed as the sum of the components by multiplying the repeated value by 6.
NR - nonreactive up to 100 ppm.

Recovery

Four (4) drinking and well water samples were spiked with various levels of Total BTEX and then assayed using the Total BTEX RaPID Assay. The following results were obtained:

Amount of Total BTEX Added (ppm)	Mean (ppm)	Recovery S.D. (ppm)	%
0.15	0.13	0.02	88
0.50	0.52	0.07	105
1.00	1.12	0.13	112
1.50	1.67	0.19	111
Average			104

Precision

The following results were obtained in water:

Control	1	2	3	4
Replicates	5	5	5	5
Days	5	5	5	5
n	25	25	25	25
Mean (ppm)	0.10	0.51	1.82	2.30
% CV ^a	24.3	17.1	12.6	17.3
% CV ^b	9.6	4.4	4.8	18.5

^a (within assay)
^b (between assay)

The following results were obtained in soil:

Control	1	2
Replicates	10	10
Mean (ppm)	0.94	0.2
% CV	17.0	12.0

Results

When using the RPA-I RaPID Analyzer™, results are reported in ppm Total BTEX. If read in a standard spectrophotometer, results from the calibrators are plotted on graph paper and used to determine final results. It is recommended that a control be included in each run. A positive control (2.1 ppm) is supplied with the Total BTEX RaPID Assay kit.

As with any analytical technique (GC, HPLC, etc.) results requiring some action should be confirmed by an alternative technology.

Ordering Information

Total BTEX Products

RaPID Assay kit, 30 and 100 tubes
Sample Diluent, 100 mL
Proficiency Samples
Sample Extraction kit, 20 tests
Total BTEX Soil System, 20 tests
Total BTEX Soil System, 80 Tests

For ordering or technical assistance contact:

Sales Department
Ohmicron Environmental Diagnostics, Inc.
1-800-544-8881
(215) 860-5115
Fax (215) 860-5213



Total BTEX Sample Extraction Kit

• Intended Use

For use in conjunction with RaPID Prep™ Soil Collection Kit and the Total BTEX RaPID Assay® Kit for determination of petroleum hydrocarbons (commonly referred to as BTEX - benzene, ethylbenzene, toluene and xylene) in soil.

• Principle

Benzene, toluene, ethylbenzene and xylenes (BTEX) are part of a broad class of volatile organic compounds (VOC's) commonly found in fuels. As a result of their widespread and intensive usage, they are among the most prevalent chemicals at contaminated sites across the United States and abroad.

The reagents contained in the RaPID Prep Total BTEX Sample Extraction Kit have been optimized for fast, efficient removal of petroleum hydrocarbons from soil and convenient preparation of the sample for immunoassay at levels of interest to the investigator. The system allows for reliable, convenient and cost effective determinations at the field testing or remediation site.

• Description of Contents

1. BTEX Extraction Solution
Calcium chloride in 75% methanol
per kit: 20 bottles containing 10 mL each
2. BTEX Extract Diluent
Buffered saline solution containing preservatives and stabilizers without any detectable BTEX.
per kit: 20 vials containing 4.5 mL each
3. Five hundred microliter precision pipet.
4. Pipet tips
per kit: 21 disposable plastic tips
5. Chain of custody container labels.
per kit: 30 labels for diluent vials

• Reagent Storage and Stability

Store all reagents and components in a dry well ventilated area at 2-30°C. Reagents may be used until the expiration date shown on the vials.

Consult local, state and federal regulations for proper disposal of all reagents.

• Materials Not Provided

In addition to the materials provided, the following items will be necessary for the performance of the procedure:

- RaPID Prep Soil Collection Kit
- stopwatch or clock with second hand
- permanent marking pen
- protective gloves
- digital balance (optional, available from Ohmicron)

• Sample Information

Acquisition of soil samples should be done with as little disruption as possible during collection and handling to minimize loss of the volatile compounds.

It is recommended that extracted soil samples be stored cold and analyzed within 48 hours. Extracted samples should be diluted immediately prior to evaluation in the Total BTEX RaPID Assay.

This kit was validated for use with soil samples. Other types of sample matrices and solid wastes may require different procedures to extract petroleum hydrocarbons.

• Procedural Notes and Precautions

IMPORTANT: Open BTEX Extract Diluent bottles carefully. They have been overfilled to eliminate as much free air space as possible after addition of 500 µL of sample extract.

Do not use any reagent beyond its stated shelf life.

Avoid contact of extraction solution (75% methanol) with skin and mucous membranes. If this reagent comes in contact with skin wash with water.

The five hundred microliter pipet is considered disposable and should be discarded after the kit reagents are depleted.

The accuracy of final results will depend in part on the care taken in pipetting the soil extract into the diluent.

• Limitations

The Total BTEX RaPID Assay is sensitive to most small aromatic hydrocarbons found in fuels. Refer to the Specificity table in the Total BTEX RaPID Assay package insert for data on individual compounds as well as common mixtures, e.g. gasoline. The Total BTEX Sample Extraction Kit, when used in conjunction with RaPID Prep Soil Collection Kit and the Total BTEX RaPID Assay, will provide screening results. Results requiring some action should be confirmed by a non-immunological method.

• Extraction/Filtration Procedure

Read the Procedural Notes and Precautions and the RaPID Prep Soil Collection kit package insert before proceeding. Various soil sampling options are presented in the Soil Collection Kit package insert.

1. Write sample information on the labels provided for soil collection device, extract collection vials and BTEX Extract Diluent vials. Apply labels to appropriate vessels.

2. **Sampling:** Remove the screw cap from the soil collector and collect soil by volume or by weight as follows:

2.1 **By volume:** With the plunger fully depressed (pushed to the top of the tube), pack soil into the open end of the collection tube. Unscrew the plunger rod from its plunger by turning the handle counterclockwise. Level the soil flush with the top of the collector tube using the plunger rod. Using the base portion of the handle, push the soil sample and the plunger to the bottom.

2.2 **By weight using digital balance:**

Option 1. Remove screw cap. Tare the soil collector with its plunger rod. Collect the soil "By volume," level it off and push the soil and plunger to the bottom of the tube. Reattach plunger rod and weigh the tube containing the soil. Subtract original weight from final weight to determine soil weight. Record the weight of the soil.

Option 2. Remove the screw cap and plunger rod from an empty collection tube. Position the plunger at the bottom of the collection tube. Attach the red base piece provided and place the tube in an upright position on the balance and tare weight. Weigh 10 ± 0.1 gram of soil into the tube. Record the soil weight.

3. Extraction

3.1 Position the soil collection tube containing a soil sample upright in the Styrofoam rack.

3.2 Pour the contents of one vial of BTEX Extraction Solution into the collector. Screw the cap (without filter) on tightly and make sure that the luer cap is secured.

3.4 Shake for 60 seconds.

3.5 Position the collection tube upright in the rack and allow the mixture to settle 1 minute.

4. Filtration

- 1 Remove the screw cap and attach the filter cap. Hand tighten until resistance is felt.
 - 2.2 Attach the plunger rod to the plunger of the soil collector.
 - 4.3 Remove the luer cap and invert the soil collector so that the luer cone is positioned over a collection vial. Keep inverted for a few seconds to wet the filter and to allow the filtrate to drip through the filter into the luer cone.
 - 4.4 Apply slight pressure to the plunger handle. The filtrate will begin to flow more quickly as gentle pressure is continuously applied.
 - 5 Fill the vial with at least 30 drops (1.5 mL) of the filtrate. Cap the vial.
- This amount of filtrate is sufficient to perform duplicate analyses with RaPID Assay kits. The vial will hold up to 5 mL of filtrate if additional extract volume is desired. The filtrate containing BTEX is stable when stored in the extract collection vial at 4°C for 48 hours.

Dilution Procedure

Using the pipet provided, carefully transfer 500 µL of the extract directly into a vial of BTEX Extract Diluent (4.5 mL). Mix by inverting several times.

This mixture can now be measured as "sample" according to the package insert of the Total BTEX RaPID Assay (Total BTEX RaPID Assay kit procedure step #3). It is recommended that the sample be assayed within 30 minutes of dilution.

Calculation of Results

Calculate the Total BTEX concentration in soil by multiplying the RaPID Assay result by the factors introduced by the procedure.

$$\text{RaPID Assay result (ppm)} \times \frac{\text{vol. Extractant (mL)}}{\text{wt. of soil (g)}} \times \text{dilution factor}^*$$

$$\text{RaPID Assay result (ppm)} \times \frac{10}{\text{wt of soil (g)}} \times 10^* =$$

Total BTEX soil concentration (ppm)

NOTE:

$$\text{dilution factor} = \frac{\text{vol. extract (mL)} + \text{vol. diluent (mL)}}{\text{vol. extract (mL)}}$$

$$= \frac{0.5 + 4.5}{0.5} = 10$$

When the extraction/dilution procedure described above is performed with a ten gram soil sample the RaPID Assay result is multiplied by 10 to determine the soil Total BTEX concentration.

EXAMPLE: For a soil sample weighing 10.0 grams giving a Total BTEX RaPID Assay result of 2.5 ppm:

$$2.5 \text{ ppm} \times 10 = 25 \text{ ppm Total BTEX soil concentration}$$

Range of Detection

When this extraction/dilution procedure is used in conjunction with RaPID Prep Soil Collection Kit and the Total BTEX RaPID Assay kit, the range of detection in soil is 0.90 ppm to 30.0 ppm Total BTEX.

For samples with expected concentrations greater than the highest standard, the diluted extract should be further diluted with BTEX RaPID Assay Diluent/Zero Standard before testing. A discussion of dilution schemes for optimal interpretation of other petroleum hydrocarbon soil concentrations is given in the *RaPID Assay® Environmental User's Guide* available from the Omnicron Technical Service Department.

immunoassay results that are above or below the limits of the RaPID Assay Kit standard curve are considered estimated concentrations. Extrapolated assay concentrations should never be multiplied by the dilution factor and reported as a soil Total BTEX concentration.

Screening results

The Total BTEX Sample Extraction Kit can be utilized as a screening test for a soil contamination level of interest. Immunoassay results like all analytical results possess an amount of variability which in turn imposes a confidence interval around the result. When the method variance is characterized with appropriate studies, a screening cutoff concentration for scoring positive and negative results can be chosen and the confidence interval around that cutoff can be determined. Data characterizing the method variation can be translated in terms of normal statistical probabilities and the utility of a selected cutoff concentration can be estimated. The following table shows the frequency of positive and negative results for a screening scheme set up at a 0.9 ppm cutoff to ensure that less than 5% false negatives will be seen at a detection level of 1.4 ppm Total BTEX in soil:

True soil Total BTEX value (ppm)	Estimated Rate of Positive Results(%)	Estimated Rate of Negative Results (%)
0.8	< 0.1	> 99.9
0.7	7.8	92.4
0.6	28.8	73.4
0.9 (cutoff)	50.0	50.0
1.0	69.2	30.8
1.2	89.4	10.8
1.3	93.8	6.2
1.4 (detection level)	98.3	3.7
1.5	97.7	2.3
1.8	98.8	1.4
1.9	99.4	0.6
2.0	99.7	0.3
2.2	99.9	0.1
2.4	> 99.9	< 0.1

Similar estimates can be made for individual aromatic hydrocarbons or fuels after site characterization and determination of action levels. The *RaPID Assay® Environmental User's Guide* provides additional information regarding utility of the method as a screening tool.

Expected Results

In a study with 30 samples spiked with gasoline, kerosene, Jet-A fuel and Total BTEX, the RaPID Prep Total BTEX Sample Extraction kit results were shown to agree well with results obtained by EPA Method 8020 in determining the presence and degree of contamination.

Recovery

Recoveries of petroleum hydrocarbons will vary depending on soil type, sample handling and collection, solvent and extraction apparatus used, and levels of potentially interfering substances in the soil.

Two soils of the loam and loamy sand type were fortified with Total BTEX to final soil concentrations of 0.25, 0.50, 1.25, 2.50, 5.0, 7.5, and 10 ppm. All soils were then subjected to the above extraction/dilution procedure. Average recovery of added Total BTEX was 113%. Results ranged from 104 to 120%.

Soil Contaminants

Some contaminants found in soils that also contain BTEX can interfere with the analysis and cause false positives, false negatives or both when the compound is present at elevated concentrations. Interferences were assessed by adding increasing concentrations of some relevant contaminants to blank and Total BTEX spiked soils prior to the extraction procedure. The concentration of compounds shown below produced no evidence of interference in a positive or negative direction in the detection range of the procedure described above.

soil contaminant	concentration in soil producing no interference
greasote	1 ppm
chain lubricant	100 ppm
brake fluid	100 ppm
lithium grease	100 ppm

If additional dilutions of the soil extract are made to detect soil Total BTEX concentrations greater than 30 ppm, these interferences are diminished in direct proportion to the dilution made.

BTEX Specificity

The Total BTEX RaPID Assay kit has been calibrated to a mixture of equal parts of benzene, toluene, ethylbenzene and xylenes (i.e. 1 ppm Total BTEX is composed of 1 ppm each of benzene, toluene, ethylbenzene and xylenes). The kit antibody binds with differing affinity to the BTEX components and other related hydrocarbons. Percent cross reactivity of the common volatile organic compounds, and related compounds with the antibody is given in the Total BTEX RaPID Assay package insert. Equivalent concentrations of these substances in terms of Total BTEX can be obtained from information provided in the *RaPID Assay® Environmental User's Guide*.

Performance Data

Precision

The overall coefficient of variation (%CV) for total BTEX measurement in ten soils spiked at 1 and 10 ppm using the RaPID Prep components and Total BTEX RaPID Assay is less than 20%. This represents the amount of variability expected with different soil types, each extracted and diluted once and assayed in duplicate in a single assay run.

no. of replicates	10	10
mean assay result (ppm)	0.94	10.2
%CV	17.0	12.0

Availability

From Omnicron

Description	Part Number
Total BTEX Sample Extraction Kit (20 units)	A00165
RaPID Prep Soil Collection Kit (20 units)	A00127
Portable Digital Balance	A00131
Total BTEX RaPID Assay	
100 tests	A00182
30 tests	A00181

Assistance

For ordering or technical assistance contact:
Omnicron Environmental Diagnostics
Sales Department
Newtown, Pennsylvania 18940
(800)544-8881 • Fax(215)860-5213

200318

PO62184



PAH's RaPID Assay®

General Description

Polynuclear or polycyclic aromatic hydrocarbons (PAH's) are a group of compounds composed of two or more fused rings. The U.S. EPA has identified 16 unsubstituted PAH's as priority pollutants.

Some of the four, five and six-ring PAH's such as chrysene, benzo[a]pyrene and indeno[1,2,3-c,d]pyrene are considered to be probable or possible human carcinogens. Benzo[a]pyrene is the most potent carcinogen among PAH's. The two and three-ring PAH's, such as naphthalene, anthracene and phenanthrene, are noncarcinogenic and are found as a component of certain grades of fossil fuels. They are referred to as the fuel PAH's. PAH's are introduced into the environment as a product of natural and fossil fuel combustion.

As a source of environmental contamination, PAH's are a serious problem at manufactured gas plants (MGP), coking operations, wood preserving sites that use creosote and petrochemical waste disposal sites. They are also commonly found in fuel products such as heating oil, diesel fuel and No. 6 fuel oil. The large number of these sites contaminated by PAH's in soil and groundwater has led federal and state agencies to mandate their clean-up. These agencies have set various regulatory levels for PAH's in soil, however, the usual concentrations of interest are 1 ppm to 10 ppm.

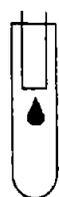
The current EPA-approved methods for the detection of PAH's are costly and require lengthy sample preparation, and large volume extraction. The PAH's RaPID Assay® eliminates the need for clean-up steps and GC/MS or HPLC instrumentation.

The PAH's RaPID Assay applies the principles of enzyme linked immunosorbent assay (ELISA) to the determination of PAH's. ELISAs use selective antibodies attached to solid supports in combination with sensitive enzyme reactions. The immunochemical reaction provides high selectivity due to the extraordinary discriminatory capabilities of antibodies. The powerful catalytic ability of the enzyme provides highly sensitive detection. These features produce an analytical system capable of detecting very low levels of chemicals.

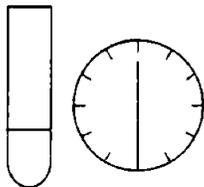


Features

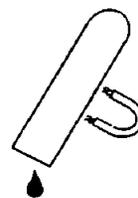
- Rapid** – 50 results in 60 minutes after sample preparation.
- Precise** – within and between assay %CV <15% at 5, 10, 20 and 40 ppb.
- Accurate** – highly selective immunochemical method.
- Efficient** – rapid results can cut costs by allowing better personnel and equipment utilization.
- Sensitive** – least detectable dose in soil of 70 ppb as Phenanthrene (90% B/Bo).
- Test Range** – assay: 0.7 to 50.0 ppb as Phenanthrene; soil: 70 ppb to 5.0 ppm as Phenanthrene.



1. Add 250 µL of prepared sample, 250 µL enzyme conjugate, and 500 µL antibody coupled magnetic particles. Vortex.



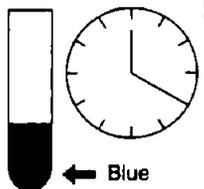
2. Incubate for 30 minutes.



3. Using the RaPID Magnetic Separator, decant, wash and vortex (2x).



4. Add 500 µL color solution.



5. Incubate 20 minutes. Blue color develops.



6. Stop the reaction and read color at 450 nm. Solution turns yellow.

Performance PAH

Specificity

The cross reactivity of the PAH's RaPID Assay for various polynuclear aromatic hydrocarbons and petroleum products can be expressed as the least detectable dose (LDD) which is estimated at 90% B/Bo, or as the dose required to displace 50% (50% B/Bo).

Compound	LDD	LDD	50%	50%
	Water (ppb)	Soil (ppm)	B/Bo Water (ppb)	B/Bo Soil (ppm)
Phenanthrene	0.93	.07	21.9	1.65
Fluoranthene	0.42	.032	6.3	.47
Benzo[a]pyrene	0.66	.050	9.2	.69
Pyrene	0.26	.020	10.2	.77
Chrysene	0.53	.040	10.4	.78
Anthracene	0.71	.054	14.6	1.1
Indeno[1,2,3-c,d]pyrene	1.03	.078	36.2	2.72
1,2-Benzanthracene	1.02	.077	37.8	2.84
Fluorene	2.19	.165	46.8	3.52
Benzo[b]fluoranthene	1.21	.091	72.1	5.42
Acenaphthylene	13.3	1.0	594	44.7
Benzo[k]fluoranthene	1.02	.077	697	52.4
Acenaphthalene	1.71	1.29	915	68.8
1,12-Benzoperylene	19.5	1.47	>1.333	>100
Naphthalene	86.4	6.50	>1.333	>100
1,2,5,6-Dibenzanthracene	34.1	2.57	>1.333	>100
Creosote	1.46	.11	21.9	1.65
Fuel Oil #6	6.65	.50	71.4	5.37
Heating Oil	17.08	1.28	388	29.2
Diesel Fuel	26.06	1.96	661	49.7
Gasoline	13.30	1.00	>13.333	>1000
Kerosene	1662.5	125	>13.333	>1000
Jet A Fuel		>1000	>13.333	>1000

100ppm Diesel = 1ppm Rapid
(Soil values are 100 times higher)

Recovery

Diluted soil extracts were spiked with various levels of PAH's (as Phenanthrene) and then assayed using the PAH's RaPID Assay. The following results were obtained:

Amount of PAH's Added (ppb)	Recovery		
	Mean (ppb)	S.D. (ppb)	%
5.0	5.48	0.80	110
7.5	8.67	1.31	116
20.0	21.98	3.01	110
40.0	42.08	4.80	105
Average			110

Precision

The following results were obtained:

Control	1	2	3	4
Replicates	5	5	5	5
Days	5	5	5	5
n	25	25	25	25
Mean (ppb)	5.48	8.67	21.98	42.08
% CV ^a	9.2	7.2	5.6	5.5
% CV ^b	12.5	14.5	13.7	10.9

^a (within assay)
^b (between assay)

Results

When using the RPA-I RaPID Analyzer™, results are reported in ppb PAH's. If read in a standard spectrophotometer, results from the calibrators are plotted on graph paper and used to determine final results. It is recommended that a control be included in each run. A positive control (25.0 ppb) is supplied with the PAH's RaPID Assay kit. If soil samples are run, results should be multiplied by the appropriate factor.

As with any analytical technique (GC, HPLC, etc.) results requiring some action should be confirmed by an alternative technology.

Ordering Information

PAH's Products

- RaPID Assay kit, 30 and 100 tubes
- Sample Diluent, 100 mL
- Proficiency Samples
- Sample Extraction kit, 20 tests
- PAH's Soil System, 20 tests
- PAH's Soil System, 80 Tests

For ordering or technical assistance contact:

Sales Department

Ohmicron Environmental Diagnostics, Inc.

1-800-544-8881

(215) 860-5115

Fax (215) 860-5213



RaPID Assays®

355 95 PAH's in Soil

• Intended Use

For detection of Polynuclear Aromatic Hydrocarbons (PAH's) in soil.

• Materials Required but Not Provided

RaPID Prep™ Soil Collection Kit and PAH's Sample Extraction Kit.

• Procedural Notes and Precautions

Prepare soil samples for analysis according to the procedure given in the PAH's Sample Extraction Kit, then, follow the immunoassay procedure as described in the PAH's RaPID Assay® Kit package insert.

As with all immunoassays, a consistent technique is the key to optimal performance. To obtain the greatest precision, be sure to treat each tube in an identical manner.

Add reagents directly to the bottom of the tube while avoiding contact between the reagents and the pipet tip. This will help assure consistent quantities of reagent in the test mixture.

Avoid cross-contaminations and carryover of reagents by using clean pipets for each sample addition and by avoiding contact between reagent droplets on the tubes and pipet tips.

• Quality Control

A control solution at approximately 25 ppb of PAH (as phenanthrene) is provided with the PAH's RaPID Assay kit. It is recommended that it be included in every run and treated in the same manner as unknown samples. Once the control results are corrected for the dilution factors (see Results section) an acceptable result should be 100 times the value stated on the vial, i.e. 2.5 ± 0.5 ppm.

• Results

Multiply the sample and control results by the appropriate dilution factor introduced by the collection, extraction and extract dilution steps. When the collection/extraction/dilution procedure described in the PAH's Sample Extraction Kit is performed with a ten gram soil sample, the RaPID Assay result is multiplied by 100 to determine the soil PAH's concentration. Alternatively, program the RPA-1 Analyzer as listed below to automatically correct for this dilution factor.

Using the RPA-1™ RaPID Analyzer, calibration curves can be automatically calculated and stored. Refer to the RPA-1 operating manual for detailed instructions. To obtain results from the PAH's RaPID Assay on the RPA-1 the following parameter settings are recommended:

Date Reagent : Lin. Regression
Xformation : Ln/LogitB
Read Mode : Absorbance
Wavelength : 450 nm
Units : PPM
Rgt Blk : 0

Calibrators:
of Cals : 4
of Reps : 2

Concentrations:
#1: 0.00 PPM
#2: 0.20 PPM
#3: 1.00 PPM
#4: 5.00 PPM

Range : 0.07 - 5.00
Correlation : 0.880
Rep. %CV : 10%

• Expected Results

In a study with 30 samples including both field contaminated soils and analytically spiked soil samples, the PAH's RaPID Assay was shown to correlate well against EPA Method 8310 (HPLC). Using a cutoff of 3.0 ppm for the immunoassay, less than 4% false positives and no false negatives were observed when compared to a 1.0 ppm detection limit.

• Performance Data

Range of Detection

The PAH's RaPID Assay has a range of detection in soil of 200 ppb to 5 ppm when used in conjunction with the PAH's Sample Extraction Kit.

Recovery

PAH's recoveries will vary depending on soil type, retention mechanism, solvent and extraction apparatus used, length of extraction period and levels of potentially interfering substances in the soil.

Twelve (12) soils of various types were fortified with PAH's (Phenanthrene) to final soil concentrations of 1.0 ppm. All soils were then subjected to the above extraction/dilution procedure. Average recovery of added PAH's was 108%. Results ranged from 82 to 124%.

Precision

The overall coefficient of variation (%CV) for PAH's measurement in soil spiked at 1 ppm using the RaPID Prep components and PAH's RaPID Assay is less than 20%. This represents the amount of variability expected when a homogeneous soil sample undergoes ten replicate collections, extractions and dilutions generating ten immunoassay results from a single run.

Method	Sample Collection	
	by weight	by volume
# of replicates	10	10
mean results (ppm)	1.43	1.28
% CV	14.3	14.4

• Assistance

For ordering or technical assistance contact:
Omicron Environmental Diagnostics
Sales Department
Newtown, Pennsylvania 18940
(800)544-8881 • Fax(215)880-5213

• Availability

Omicron
PAH's RaPID Assay
3D Test Kit
100 Test Kit
PAH's Sample Diluent
PAH's Proficiency Samples
RaPID Prep Soil Collection Kit
RaPID Prep PAH's Sample Extraction Kit

700099

1072784

PAH's Sample Extraction Kit

• Intended Use

For use in conjunction with RaPID Prep™ Soil Collection Kit and the PAH's RaPID Assay® Kit for determination of PAH's in soil.

• Principle

Polynuclear or polycyclic aromatic hydrocarbons (PAH's) are a group of compounds composed of two or more fused aromatic rings. The U.S. EPA has identified 16 unsubstituted PAH's as priority pollutants. Some of the four, five and six-ring PAH's such as chrysene, benz[a]pyrene and indeno[1,2,3-cd]pyrene are considered to be probable or possible human carcinogens. The two and three-ring PAH's such as naphthalene, anthracene, phenanthrene, and pyrene are non-carcinogenic and found as a component of certain grades of fossil fuels. PAH's are introduced into the environment as a product of natural and fossil fuel combustion. As a source of environmental contamination, PAH's are a serious problem at manufactured gas plants (MGP), coking operations, wood preserving sites that use creosote as a preservative and petrochemical waste disposal sites. The large number of these sites which are contaminated by PAH's in soil and groundwater has led federal and state agencies to mandate their clean-up. These agencies have set various regulatory levels for PAH's in soil, however the usual concentrations of interest are 1 ppm and 10 ppm. Accurate determination of the PAH content of contaminated soils is necessary to make appropriate decisions regarding site cleanup and remediation.

The reagents contained in the RaPID Prep PAH's Sample Extraction Kit have been optimized for fast, efficient removal of PAH's from soil and convenient preparation of the sample for immunoassay at levels of interest to the investigator. The system allows for reliable, convenient and cost effective determinations at the field testing or remediation site.

• Description of Contents

1. PAH's Extraction Solution
100% methanol with soil dispersion agent.
per kit: 20 bottles containing 20 mL each
2. PAH's Extract Diluent
Buffered saline solution containing preservatives and stabilizers without any detectable PAH's.
per kit: 20 vials containing 12.25 mL each
3. Chain of custody container labels.
per kit: 30 labels for diluent vials

• Reagent Storage and Stability

Store all reagents and components in a dry well ventilated area at 2-30°C. Reagents may be used until the expiration date shown on the vials.

Consult local, state and federal regulations for proper disposal of all reagents.

• Materials Not Provided

In addition to the materials provided, the following items will be necessary for the performance of the procedure:

- RaPID Prep Soil Collection Kit
- stopwatch or clock with second hand
- permanent marking pen
- protective gloves
- digital balance (optional, available from Ohmicron)
- Precision pipet and tips capable of delivering 250 µL.

• Sample Information

This kit was validated for use with soil samples. Other types of sample matrices and solid wastes may require different procedures to extract PAH's.

• Procedural Notes and Precautions

Do not use any reagent beyond its stated shelf life.

Sixty seconds of continuous agitation of the soil sample in the presence of the extraction solution is important for good extraction efficiency. Use of a one minute timer or stopwatch to ensure adequate shaking time is recommended.

Avoid contact of extraction solution (100% methanol) with skin and mucous membranes. If this reagent comes in contact with skin wash with water.

Due to the large dilution factor used, the accuracy of the final result will depend in part on the care taken in pipetting the soil extract into the diluent.

• Limitations

The PAH's Sample Extraction Kit, when used in conjunction with RaPID Prep Soil Collection Kit and the PAH's RaPID Assay, will provide screening results. Positive results may need to be confirmed by a non-immunological method.

• Extraction/Filtration Procedure

Read the Procedural Notes and Precautions and the RaPID Prep Soil Collection kit package insert before proceeding. Various soil sampling options are presented in the Soil Collection Kit package insert.

1. Write sample information on the labels provided for soil collection device, extract collection vials and PAH's Extract Diluent vials. Apply labels to appropriate vessels.

2. **Sampling:** Remove the screw cap from the soil collector and collect soil by volume or by weight as follows:

2.1 **By volume:** With the plunger fully depressed (pushed to the top of the tube), pack soil into the open end of the collection tube. Unscrew the plunger rod from its plunger by turning the handle counterclockwise. Level the soil flush with the top of the collector tube using the plunger rod. Using the base portion of the handle, push the soil sample and the plunger to the bottom.

2.2 **By weight using digital balance:**

Option 1. Remove screw cap. Tare the soil collector with its plunger rod. Collect the soil "By volume," level it off and push the soil and plunger to the bottom of the tube. Reattach plunger rod and weigh the tube containing the soil. Subtract original weight from final weight to determine soil weight. Record the weight of the soil.

Option 2. Remove the screw cap and plunger rod from an empty collection tube. Position the plunger at the bottom of the collection tube. Attach the red base piece provided and place the tube in an upright position on the balance and tare weight. Weigh 10 ± 0.1 gram of soil into the tube. Record the soil weight.

3. Extraction

3.1 Position the soil collection tube containing a soil sample upright in the Styrofoam rack.

3.2 Pour the contents of one vial of PAH's Extraction Solution into the collector. Screw the cap (without filter) on tightly and make sure that the luer cap is secured.

3.3 SNAKE VIGOROUSLY AND CONTINUOUSLY FOR AT LEAST 60 SECONDS. Additional shaking may be required to break up large or dry soil aggregates.

4 Position the collection tube upright in the rack and allow the mixture to settle at least five minutes.

batch processing is desired, up to 21 soil samples with added extraction solution can be loaded into the rack inside the Soil Collection Kit box base; the box lid is put in place and the box is shaken vigorously for at least 60 seconds.

Filtrate

4.1 Remove the screw cap and attach the filter cap. Hand tighten until resistance is felt.

4.2 Attach the plunger rod to the plunger of the soil collector.

4.3 Remove the bar cap and invert the soil collector so that the bar cone is positioned over a collection vial. Keep inverted for a few seconds to wet the filter and to allow the filtrate to drip through the filter into the bar cone.

4.4 Apply slight pressure to the plunger handle. The filtrate will begin to flow more quickly as gentle pressure is continuously applied.

4.5 Fill the vial with approximately 20 drops (1 mL) of the filtrate. Cap the vial.

This amount of filtrate is sufficient to perform multiple replicate analysis with RaPID Assay kits. The vial will hold up to 5 mL of filtrate if additional extract volume is desired. The filtrate containing PAH's is stable when stored in the extract collection vial or one week at room temperature (15 to 30 °C).

Dilution Procedure

Using the pipet provided, transfer 250 µL of the extract directly into a vial of PAH's Extract Diluent (12.25 mL). Mix by inverting several times.

This mixture can now be measured as "sample" according to the package insert of the PAH's RaPID Assay (PAH's RaPID Assay kit procedure step #3.)

Calculation of Results

Calculate the PAH's concentration in soil by multiplying the RaPID Assay result by the factors introduced by the procedure.

$$\text{RaPID Assay result (ppb)} \times \frac{\text{vol. Extractant (mL)}}{\text{wt. of soil (g)}} \times \text{dilution factor}^* =$$

$$\text{RaPID Assay result (ppb)} \times \frac{20}{\text{wt of soil (g)}} \times 50^* =$$

PAH's soil concentration (ppb)

* NOTE:

$$\text{dilution factor} = \frac{\text{vol. extract (mL)} + \text{vol. diluent (mL)}}{\text{vol. extract (mL)}}$$

$$= \frac{0.25 + 12.25}{0.25} = 50$$

When the extraction/dilution procedure described above is performed with a ten gram soil sample the RaPID Assay result is multiplied by 100 to determine the soil PAH's concentration.

EXAMPLE: For a soil sample weighing 10.0 grams giving a PAH's RaPID Assay result of 10 ppb:

$$10 \text{ ppb} \times 100 = 1,000 \text{ ppb or}$$

1.0 ppm PAH's soil concentration

Range of Detection

When this extraction/dilution procedure is used in conjunction with RaPID Prep Soil Collection Kit and the PAH's RaPID Assay kit, the range of detection in soil is 200 ppb to 5 ppm.

For samples with expected PAH's concentrations greater than 5 ppm on an initial screen, the diluted extract should be further diluted with PAH's RaPID Assay Diluent/Zero Standard before testing. A discussion of dilution schemes for optimal interpretation of other PAH's soil concentrations is given in the *Environmental User's Guide* available from the Omnicron Technical Service Department.

Immunoassay results that are above or below the limits of the RaPID Assay Kit standard curve are considered estimated concentrations. Extrapolated assay concentrations should never be multiplied by the dilution factor and reported as a soil PAH's concentration.

Screening results

The PAH's Sample Extraction Kit can be utilized as a screening test for a soil contamination level of interest. Immunoassay results like all analytical results possess an amount of variability that can be expressed as a confidence interval around the result. Data characterizing the method variation can be shown as normal statistical probabilities and the utility of a selected cutoff concentration can be estimated. The following table shows the frequency of positive and negative results for a screening scheme with a 0.70 ppm cutoff that assures less than 5% false negatives at a level of 1 ppm PAH's in soil:

True soil PAH's value (ppm)	Estimated Rate of Positive Results(%)	Estimated Rate of Negative Results (%)
0.50	1.0	99.0
0.55	5.5	94.5
0.60	16.4	83.6
0.65	32.6	67.4
0.70 (cutoff)	50.0	50.0
0.75	65.2	34.8
0.80	78.7	21.3
0.85	84.9	15.1
0.90	90.3	9.7
0.95	93.8	6.2
1.00 (detection level)	96.0	4.0
1.25	99.5	0.5
1.50	> 99.9	< 0.1
2.00	> 99.9	< 0.1

Similar estimates can be made for other PAH's detection levels of interest. The *Environmental User's Guide* provides additional information regarding utility of the method as a screening tool.

Expected Results

In a study with 30 samples including both field contaminated soils and analytically spiked soil samples, The PAH's RaPID Assay was shown to correlate well against EPA Method 8310 (HPLC). Using an appropriate cutoff for the immunoassay, less than 4% false positives and no false negatives were observed when compared to a 1.0 ppm detection limit for the reference method.

Recovery

PAH's recoveries will vary depending on soil type, retention mechanism, solvent and extraction apparatus used, length of extraction period, amount of agitation and levels of potentially interfering substances in the soil.

Twelve (12) soils of various types were fortified with PAH's (Phenanthrene) to final soil concentrations of 1.0 ppm. All soils were then subjected to the above extraction/dilution procedure. Average recovery of added PAH's was 108%. Results ranged from 92 to 124%.

Soil Contaminants

Some contaminants found in soils that also contain PAH's can interfere with the analysis and cause false positives, false negatives or both when the compound is present at elevated concentrations. Interferences were assessed by adding increasing

concentrations of some relevant contaminants to the Extraction Solution followed by dilution into the Extract Diluent. The concentration of compounds shown below produced no apparent PAH values greater than the 1.0 ppm detection limit.

soil contaminant	concentration in soil producing no interference
Biphenyl	32 ppm
Aroclor 1242	45 ppm
Aroclor 1248	84 ppm
Aroclor 1254	> 1,000 ppm
Aroclor 1280	> 1,000 ppm
1-Methylnaphthalene	54 ppm
2-Methylnaphthalene	41 ppm
Benzene	> 1,000 ppm
Toluene	> 1,000 ppm
Pentachlorophenol	> 1,000 ppm
Copper Chromium Arsenate (CCA)	> 1,000 ppm
Di-n-octyl-phthalate	> 1,000 ppm

If additional dilutions of the soil extract are made to detect soil PAH's concentrations greater than 5 ppm, these interferences are diminished in direct proportion to the dilution made.

PAH Specificity

The PAH's RaPID Assay kit has been calibrated with Phenanthrene. The kit antibody binds with differing affinity to the other PAH's. Chrysene, fluoranthene, pyrene and benzo(a)pyrene react most strongly in the system while anthracene and phenanthrene give a similar response in the assay system. Other PAH's tested react to a lesser extent. Percent cross reactivity of the common PAH's with the antibody is given in the PAH's RaPID Assay package insert. Equivalent concentrations of the other PAH's in terms of Phenanthrene can be obtained from information provided in the *Environmental User's Guide*.

Performance Data

Precision

The overall coefficient of variation (%CV) for PAH's measurement in soil spiked at 1 ppm using the RaPID Prep components and PAH's RaPID Assay is less than 20%. This represents the amount of variability expected when a homogeneous soil sample undergoes ten replicate collections, extractions and dilutions generating ten immunoassay results from a single run.

	Sample Collection Method	
	by weight	by volume
no. of replicates	10	10
mean assay result (ppm)	1.43	1.26
%CV	14.3	14.4

Availability

From Omnicron

Description	Part Number
PAH's Sample Extraction Kit (20 units)	A00160
RaPID Prep Soil Collection Kit (20 units)	A00127
Portable Digital Balance	A00131
PAH's RaPID Assay	
100 tests	A00157
30 tests	A00158

Assistance

For ordering or technical assistance contact:
 Omnicron Environmental Diagnostics
 Sales Department
 Newtown, Pennsylvania 18940
 (800)544-8881 * Fax(215)880-5213

Instruction Manual

Model MAC-51B Magnetic and Cable Locator

Manufactured By
Schonstedt Instrument Company
1775 Wiehle Avenue
Reston, Virginia 22090

Phone (703) 471-1050
TWX 710-833-9880
FAX (703) 471-1795

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Important Notice

Schonstedt believes the statements contained herein to be accurate and reliable. But their accuracy, reliability, or completeness is not guaranteed.

Schonstedt's only obligation shall be to repair or replace any instrument proved to be defective within one year of purchase. Schonstedt shall not be responsible for any injury to persons or property, direct or consequential, arising from the use of any instrument.

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Section I General

Introduction

The MAC-51B Magnetic and Cable Locator is a light-weight, dual-mode instrument designed for detecting buried iron and steel objects and tracing underground cables and pipes. The system consists of two major units: a transmitter and a dual-function receiver. Both units use alkaline C-cell batteries that provide up to 100 hours of operation.

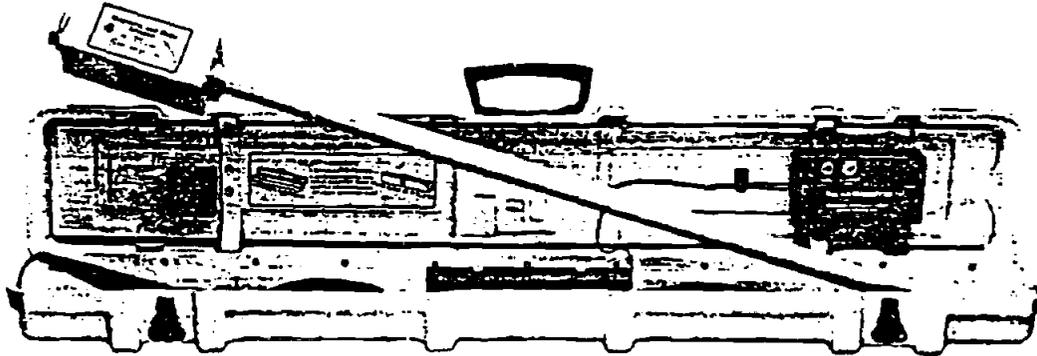


Figure 1-1. MAC-51B Magnetic and Cable Locator

Cable Locator Mode

When used in the cable locator mode, the transmitter generates a distinctive ac signal which is applied to the cable or pipe. The receiver is used to detect and trace the signal as it travels along the cable/pipe. A siren-like tone from the receiver is easily identified as the tracing signal. The approximate depth of an underground cable can be determined using the 45° null-point triangulation method. Operation of the MAC-51B in the cable locator mode is explained in Sections IV and V.

Magnetic Locator Mode

The receiver is the only unit required for operation in the magnetic mode. Set the receiver M/C function switch to "M", adjust the sensitivity control, and you have the best magnetic locator available. Operation of the magnetic locator mode is explained in Sections II and III.

Switching from cable locator mode to magnetic locator mode while tracing a cable is a unique method for unscrambling ground clutter. Gas and water pipes in the immediate vicinity of a cable can emit parasitic signals that distort the identification null. In the magnetic mode cast-iron water pipes and gas lines can be identified quickly and even classified as to type by the conventional spacing of joints, which provide the strongest signals.

Standard Accessories

Basic accessories supplied with the MAC-51B include a headphone jack, a spare batteries holder and a conductive cable assembly with ground stake. An inductive signal clamp, mini transmitter and headphones are available as options.

Optional Inductive Signal Clamp

This option increases the versatility of the MAC-51B by providing a convenient method of selectively applying the trace signal to cables or conductors covered with nonmetallic insulation.

It applies a strong trace signal to only the conductor that it is clamped around. This positive identification allows a specific cable to be traced even when located in congested areas containing cables, water and gas lines or other conductors that may emit lower level parasitic trace signals.

Operation is simple and easy. Plug the clamp lead into the transmitter accessory jack and close the clamp around the cable. No ground connection is required. Hook-up can be made to all standard metallic cable types up to three inches in diameter.

Optional Mini Transmitter

The Model MT-1 is a miniature solid-state transmitter (3 in. x 1 in.) used in combination with a MAC-51B receiver to trace nonmetallic pipes, pinpoint obstructions, and locate concrete septic tanks.

As the MT-1 (Mole) is pushed through a buried nonmetallic pipe, it emits a signal that can be detected at depths up to 18 feet by using the MAC-51B receiver.

The Mole has a concave surface so it can be taped to a plumber's snake, and a 1/4-inch tapped hole for end mounting.

One AAA penlight alkaline battery provides up to 30 hours of operation. The battery cap also serves as the On/Off switch. Power is turned off by rotating the battery cap counterclockwise until the battery moves when the MT-1 is shaken.

MAC-51B SPECIFICATIONS

TRANSMITTER

Operating Voltage	12 Volts (eight alkaline C-Cell batteries)
Battery Life	75 hours intermittent operation at 70°F
Output Frequency	82.5 kHz modulated at 382 Hz, pulsed at 4.8 Hz (inductive or conductive)
Audio Indicator	2.58 kHz pulsed at 4.8 Hz
Weight	Approximately 5.5 lb. (2.5 kg.)
Operating Temperature	- 13°F to 140°F (- 25°C to 60°C)
Overall Size	43.5 in. × 7 in. × 5 in. (110.5 cm. × 17.8 cm. × 12.7 cm.)

RECEIVER

Operating Voltage	6 Volts (4 alkaline C-Cell batteries)
Battery Life	100 hours intermittent operation at 70°F
Output Frequency	Approximately 40 Hz idling tone from speaker. Frequency of pulsing tone increases (or decreases) with signal intensity.
Weight	Approximately 3 lb. (1.36 kg.)
Operating Temperature	- 13°F to 140°F (- 25°C to 60°C)
Overall Length	42.3 in. (107.4 cm.)
Waterproof Length	34.5 in. (87.6 cm.)
Nominal Sensor Spacing	20 in. (50.8 cm.)

(Specifications subject to change without notice)

Section II

Magnetic Locator Operation

Theory of Operation

In the magnetic locator mode, the MAC-51B receiver responds when the magnetic field strength at the two sensors, which are 20 inches apart, is different. This response consists of a change in the idling frequency of the signal emitted from the speaker.

Figure 2-1 illustrates an application of the locator in which it is used to detect an iron marker of the type used for property line identification. The magnetic field of the marker is stronger at sensor A than it is at sensor B. As a result, the frequency of the signal on the speaker is higher than the 40 Hz idling frequency which exists when the field strength is the same at both sensors.

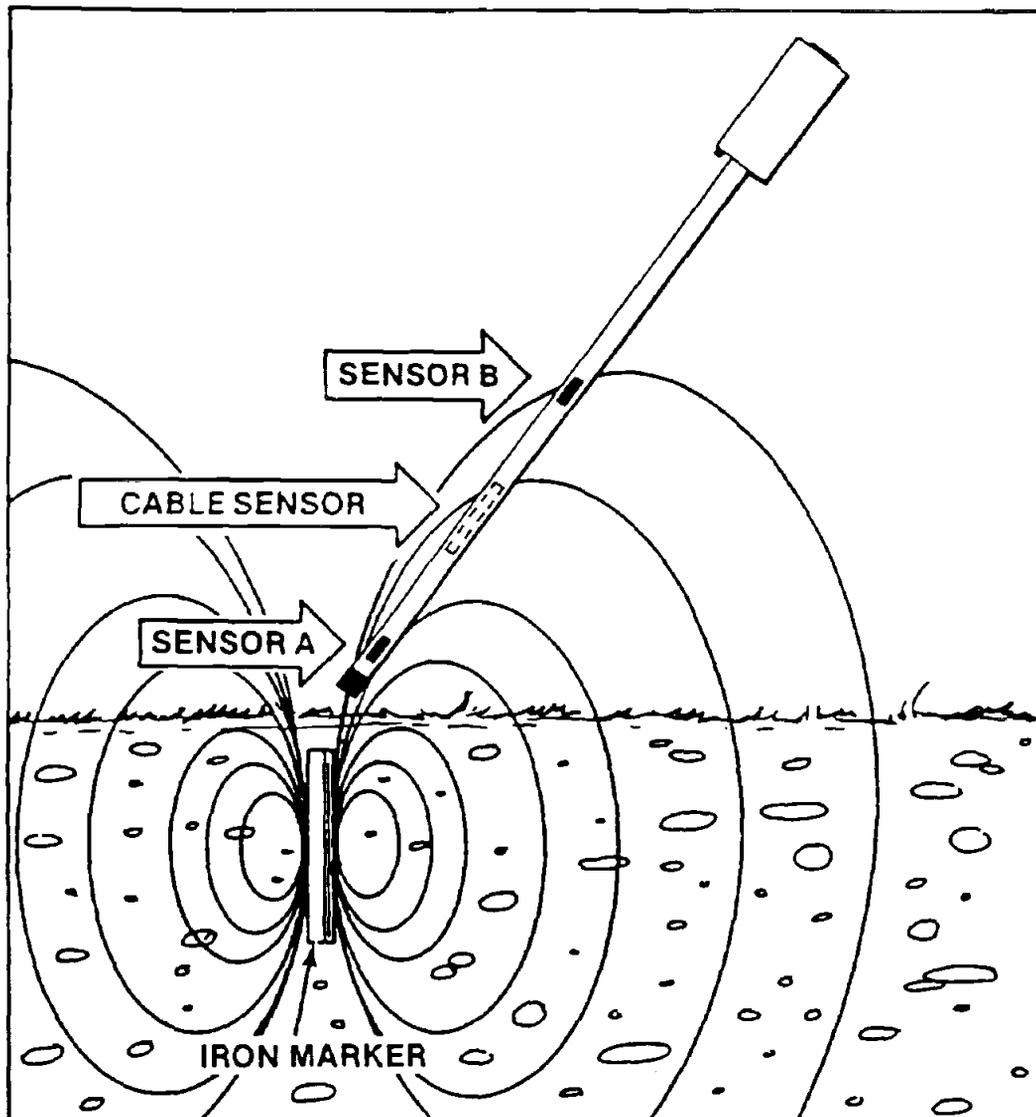


Figure 2-1. Detecting Magnetic Field of an Iron Marker

Function Selection, Turn-On and Initial Sensitivity Setting

Set the M/C Function switch to M and adjust the ON/OFF-Sensitivity control for mid-position as shown in Figure 2-2. With the knob in this position, the sensitivity is set for what is referred to as the Normal Range.

In most areas the locator can be oriented in any direction without producing a significant change in the frequency of the tone from its idling rate. However, in some areas where magnetic disturbances are encountered from nearby structures, rocks, sand or trash, the control should be adjusted for lower sensitivity as illustrated in Figure 2-3.

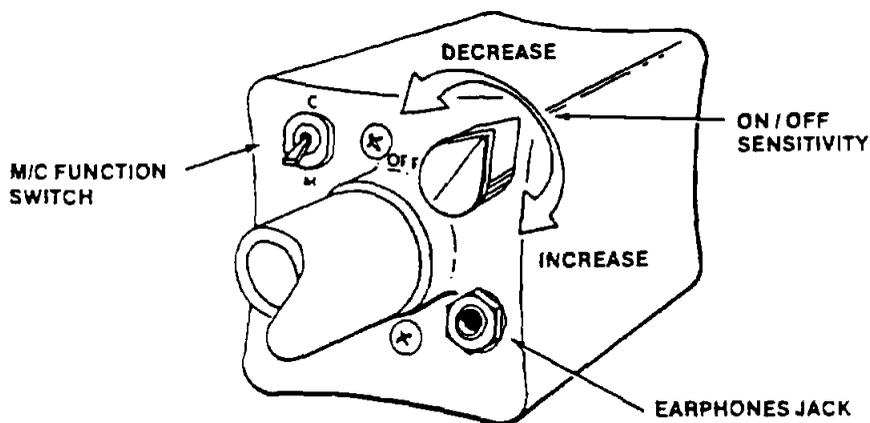


Figure 2-2. Sensitivity Set for Normal Range

Low Sensitivity Operation

Unwanted background signals due to nearby magnetic objects may require that the effective range of the locator be reduced. This is accomplished by turning the sensitivity knob in a counter-clockwise direction. Reduced range is useful for pinpointing the location of a strongly magnetized marker.

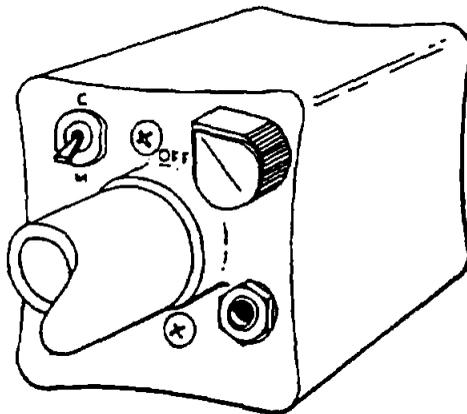


Figure 2-3. Sensitivity Set for Low Range

High Sensitivity Operation

The sensitivity of the locator is increased by turning the sensitivity knob in a clockwise direction. A high sensitivity setting imposes some constraints on operating methods. The locator tone will vary in frequency depending on the instrument's orientation relative to the Earth's magnetic field.

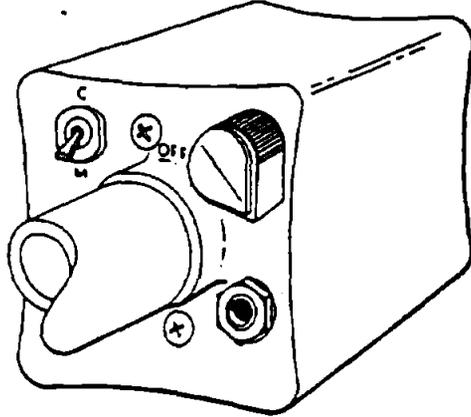


Figure 2-4. Sensitivity Set for High Range

Search Procedure

Set the sensitivity control for normal operation and hold the locator just below the large end as illustrated in Figure 2-5. Because the upper sensor is located near the area where the locator is usually held, wrist watches may produce unwanted changes in the signal frequency. Therefore, a watch worn on the the wrist of the hand holding the locator should be removed. Avoid bringing the locator close to your shoes, since they might contain magnetic material.

To obtain maximum area coverage, the locator should be swept from side-to-side with the small end of the instrument kept close to the ground. A higher frequency tone from the speaker will be heard when the locator is within range of an iron or steel object.



When using a high sensitivity setting, avoid turning the locator about its long axis. This may produce tonal variations in the output signal because of sensor misalignment.

The presence of a ferromagnetic object will be indicated by a change in the tone of the output frequency.

Figure 2-5. Searching with the Locator

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Section III

Magnetic Locator Application Notes

Basic Signal Patterns

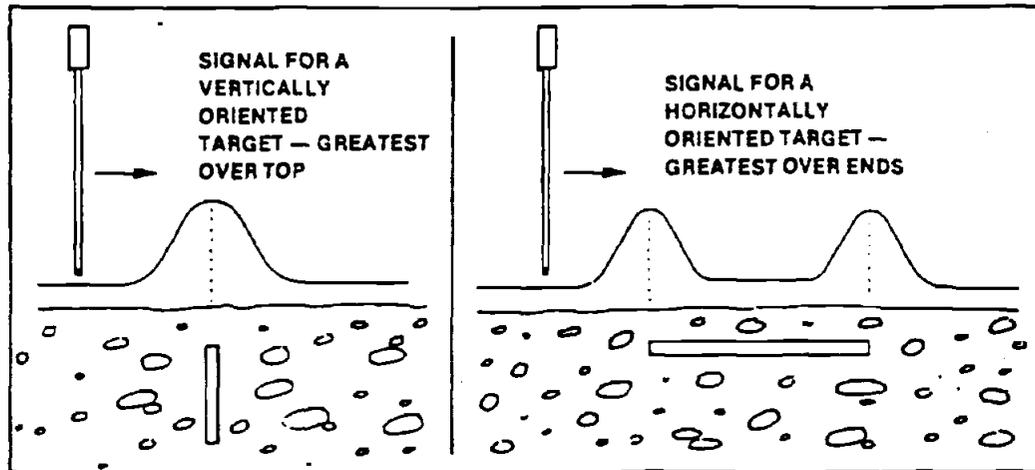


Figure 3-1. Signals from Vertical and Horizontal Targets

After you have detected the presence of a target, hold the locator vertically and move it back and forth in an "X" pattern. The peak signal occurs directly over a vertical target, and over the ends of a horizontal target.

The "X" pattern is ideal for pinpointing small objects. A 1-1/4-inch PK nail buried up to 8 inches can be located so precisely with this technique that it can be uncovered using a 1/2-inch star drill.

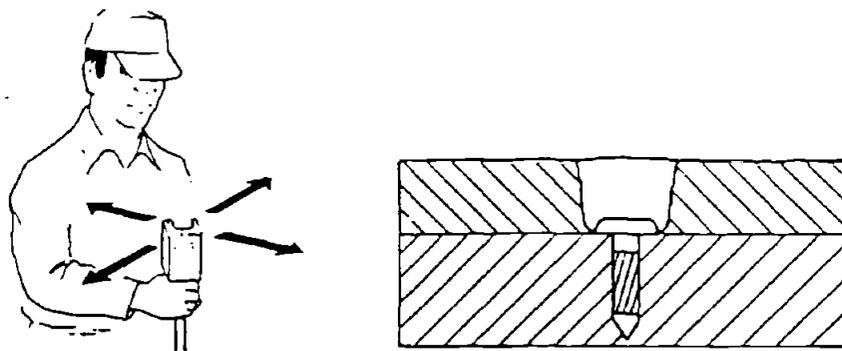


Figure 3-2. "X" Pattern Provides Precision Locating

If you find more than one signal in the vicinity of a target, just raise the locator several inches higher. Any signal that disappears when the locator is raised is probably not coming from the actual target. The signal from a rusty bolt or other small item will decrease much faster with distance than the signal from a larger target such as a corner marker. An 18-inch length of 3/4-inch pipe can be located at depths up to 7 feet.

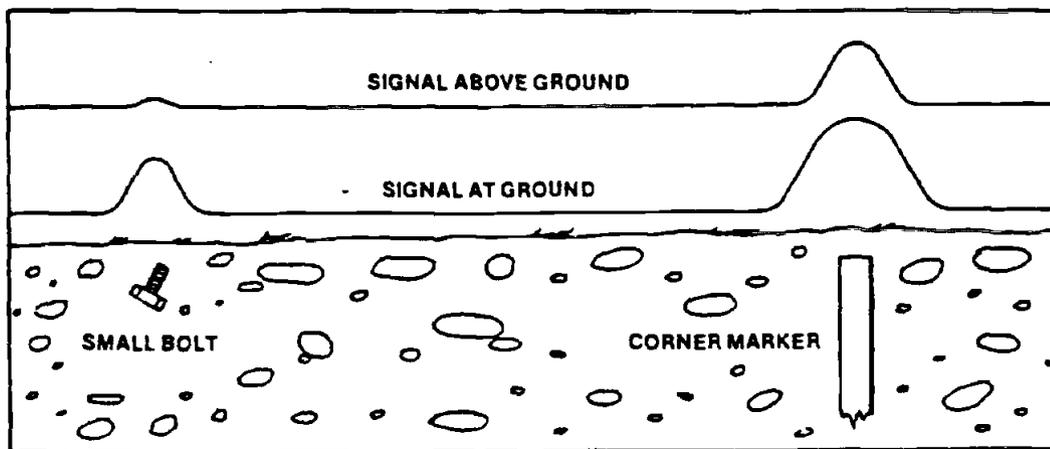


Figure 3-3. Raising the Locator Eliminates Unwanted Signals

Strongly Magnetized Markers

A strongly magnetized marker at or near the surface may provide location information that is misleading.

The heavy line in Figure 3-4 represents the variation in tone frequency when the locator is moved over the marker. When moving the instrument from A to B, the frequency of the tone increases and then suddenly decreases at B. From just beyond B the frequency of the tone increases sharply, becomes very high directly over the marker and decreases just before reaching C. From C to D the pattern is the reverse of that from A to B. It is obvious that the locator must enter the B-C region. Otherwise the marker might be assumed to be between A and B or C and D.

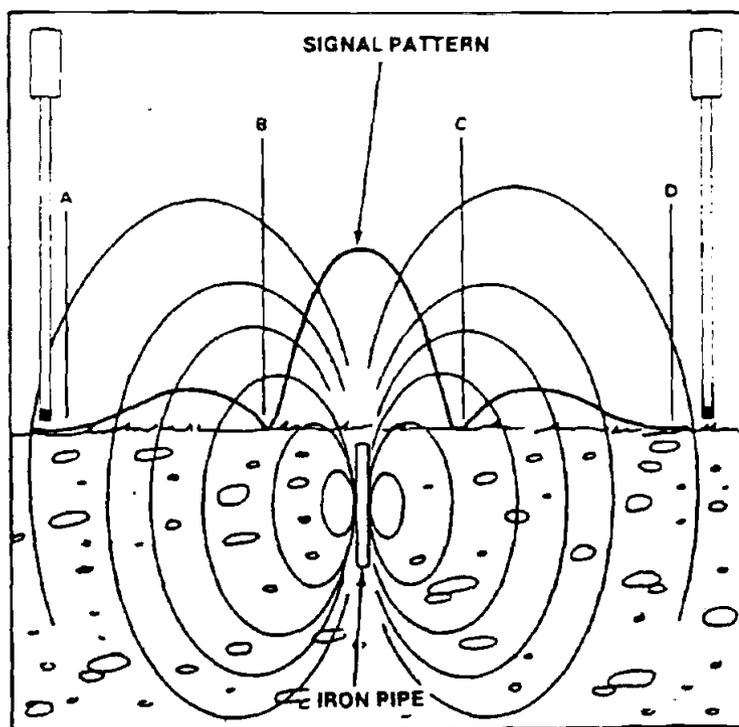


Figure 3-4. Signal Pattern From a Strongly Magnetized Marker

This phenomenon is explained by the fact that the locator is sensitive to the magnetic field components parallel to its long axis. At points B and C the field is perpendicular to the locator so no high frequency is produced at these points.

Locating Manholes, Septic Tanks and Water Wells

The magnetic field is strongest at the edge of a shallow manhole cover. Turn the sensitivity down all the way and you can easily trace the edge of covers near the surface. Locating depth ranges up to 8 feet.

The great length of a well casing provides a strong field at the surface that makes it easy to locate casings buried up to 15 feet deep.

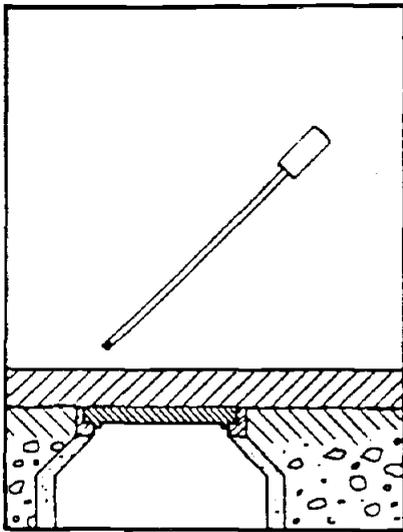


Figure 3-5. Locating Manhole Covers

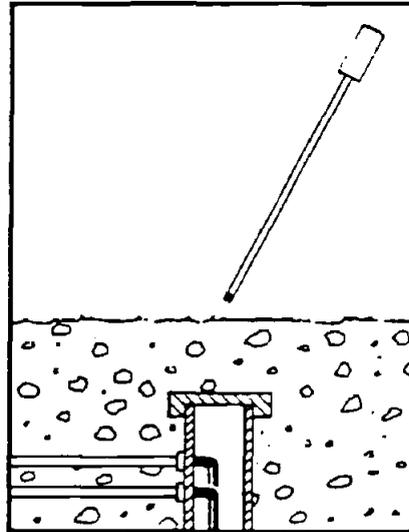


Figure 3-6. Locating Water Well Casings

The MAC-51B receiver can be used to precisely locate the metal handles or reinforcing bars on septic tank covers at depths up to 4 feet.

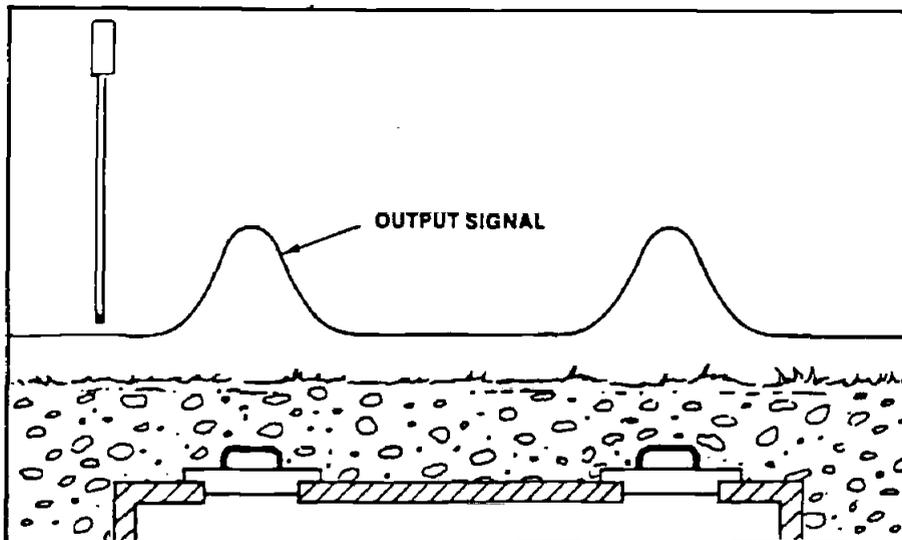


Figure 3-7. Signal Pattern Provided by Septic Tank Handles

Locating Objects under Snow or Water and Tracing Barbed Wire

The locator can be used in flooded areas—just keep the electronic unit out of the water.

Snow poses no problem. Thrust the locator into the snow as deep as necessary to locate the target.

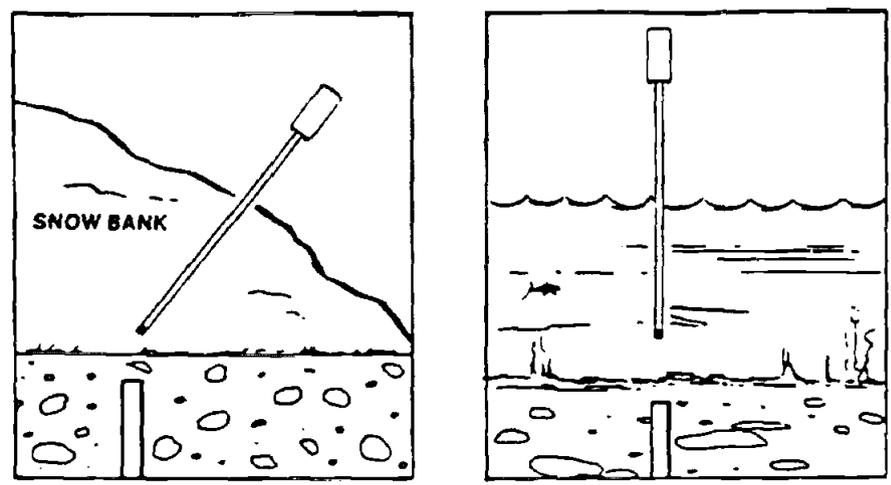


Figure 3-8. Locating Objects under Snow or Water

You can often trace barbed wire (from old fence lines) buried just beneath the surface. Even if the wire is only a trail of rust, it can still be detected near the surface. Tip the locator a little lower than usual—but not parallel with the ground.

First, examine trees for bench marks and bits of embedded barbed wire. Then hold the locator parallel with the direction of the wire.

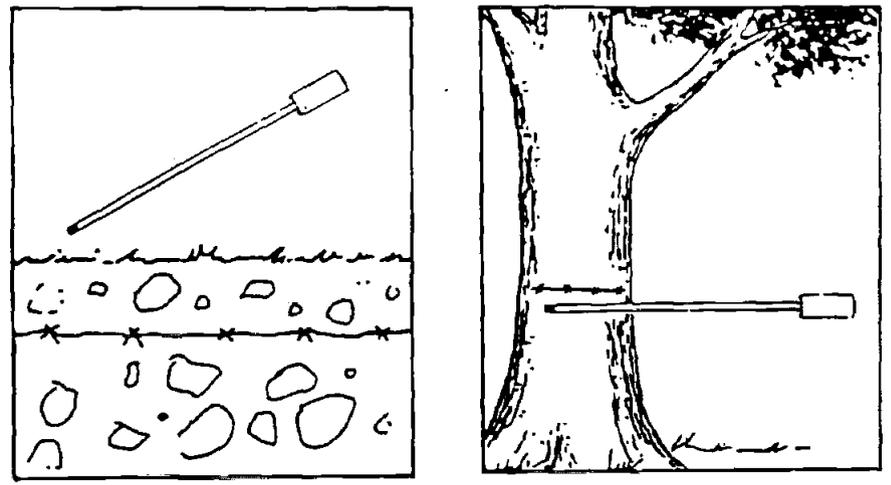


Figure 3-9. Tracing Barbed Wire from Old Fence Lines

Searching Areas Along a Chain Link Fence

Searching in the vicinity of a chain link fence requires a reduced sensitivity setting and also some control over the orientation of the locator. As illustrated in Figure 3-10, position the locator horizontally with its long axis perpendicular to the fence. This ensures that the upper sensor is kept away from the fence.

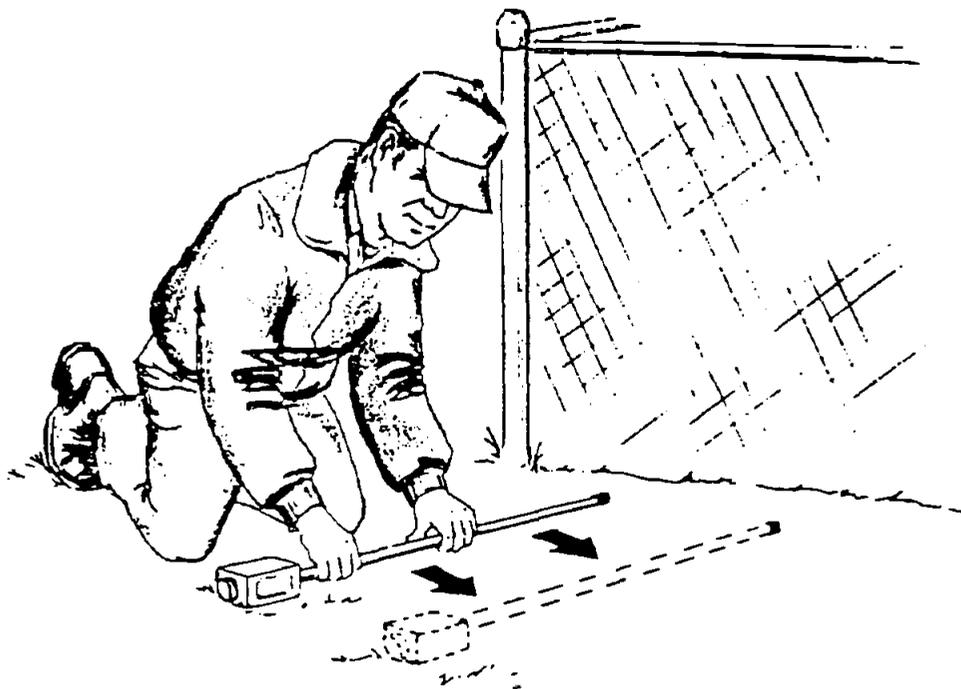


Figure 3-10. Searching in the Vicinity of a Chain Link Fence

Perform the search by moving along the fence, keeping the end a constant distance from the fence. When a point 1-5/8 inches from the end of the locator is directly over the stake, the signal will drop abruptly as shown in Figure 3-11. Any variation in the position of the locator will produce an abrupt rise in the frequency of the tone.

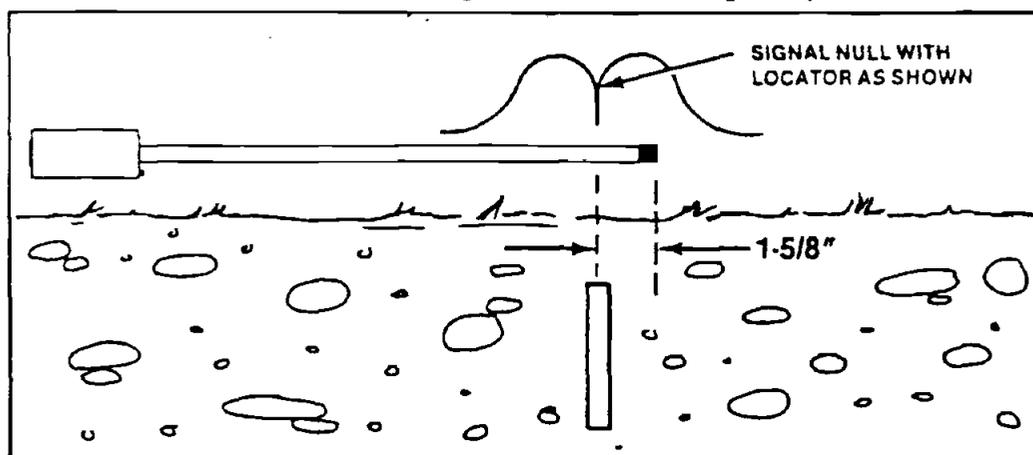


Figure 3-11. Placement of Locator While Searching Along a Chain Link Fence

Locating Valve Boxes

Both the valve and its casing, when iron, provide strong magnetic fields which make them easy to locate. Plastic enclosures containing magnets are easily located at depths of 6 feet or more.

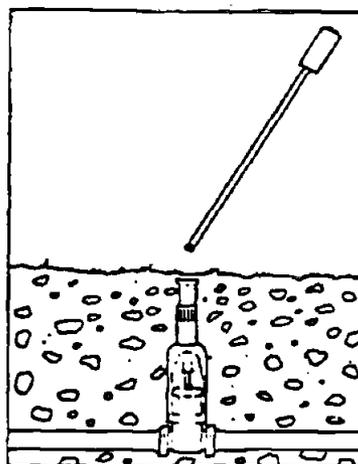


Figure 3-12. Locating Valve Boxes and Casings

Locating Cast-Iron Pipes

As illustrated in Figure 3-13, cast-iron pipes produce the strongest magnetic signals at their joints.

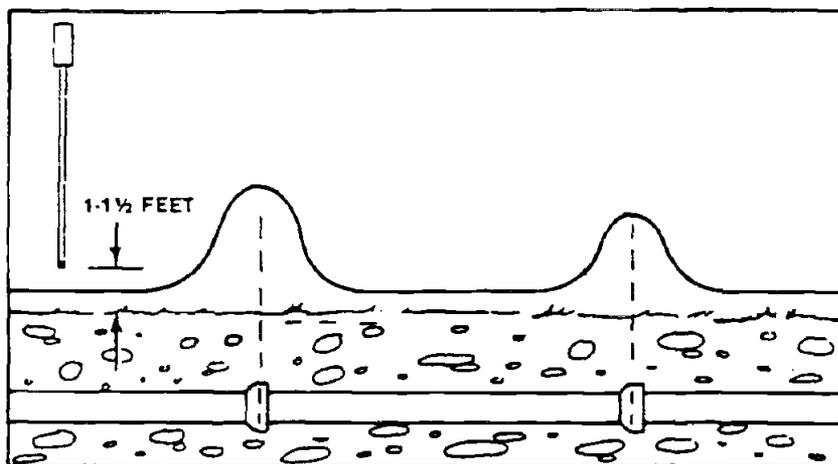


Figure 3-13. Signal Pattern Provided by Cast-Iron Pipes

The initial search should be performed as follows:

1. Adjust the sensitivity level for maximum.
2. Hold the locator vertically approximately 1 to 1-1/2 feet above the surface.
3. Walk along without turning or tilting the locator.
4. Mark the locations where the maximum signal levels occur.
5. Return to an area of maximum signal strength and hold the locator several inches above the surface. The sensitivity will probably have to be reduced during this second pass. Four-inch pipes can be located at depths up to 8 feet.

Locating Steel Drums

As shown in Figure 3-14, the MAC-51B's signal pattern will vary depending on the vertical or horizontal orientation of the drum and also how deep it is buried. A fifty-five gallon drum can be located at depths up to 8 feet.

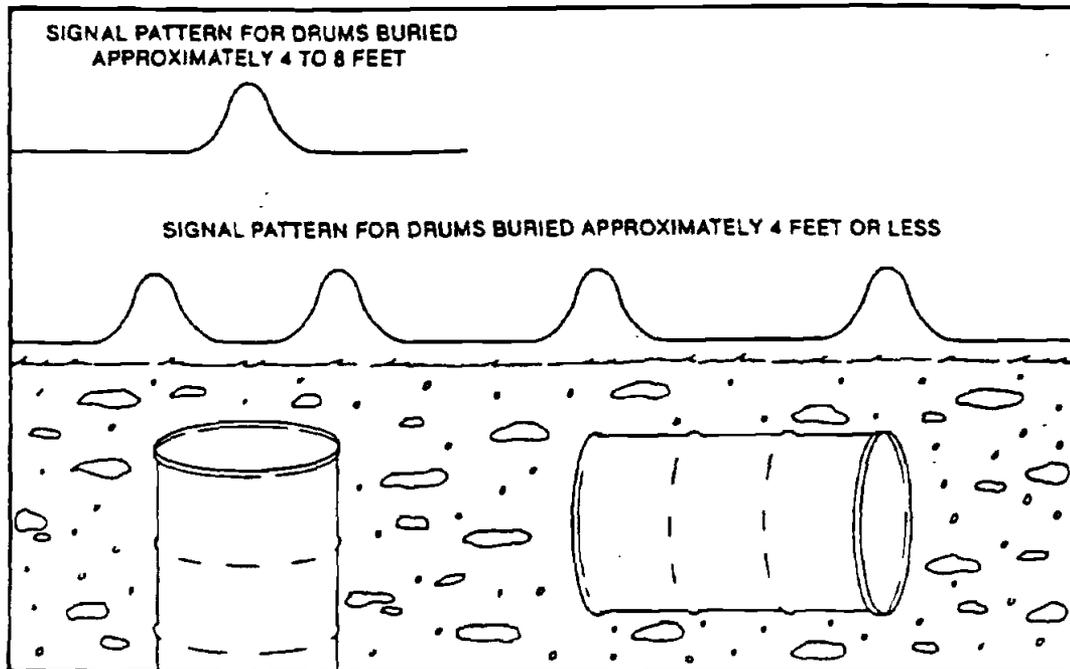


Figure 3-14. Signal Pattern Provided by Steel Drums

Additional Applications

1. The military and many local and state police departments use the MAC-51B to detect buried ordnance and discarded weapons.
2. People drilling in an area where hazardous materials might be encountered use the MAC-51B to search the area prior to drilling. Other Schonstedt gradiometers are available that can be lowered down the hole for periodic checks as drilling progresses.

Other Notes

1. A burbling sound indicates the presence of an energized power line.
2. The instrument will not detect nonmagnetic materials such as gold, silver, copper, brass and aluminum.

Section IV Cable Locator Operation

Theory of Operation

In the cable locator mode, the receiver must be used in combination with the transmitter which is housed in the carrying case.

As illustrated in Figure 4-1, the transmitter is placed over and in line with the target cable/pipe. An alternating current induced into the cable/pipe produces a signal that is detected with the receiver. The transmitter emits a steady beeping sound to indicate that it is operating, and the receiver emits a siren-like sound that is easily identified as the induced tracing signal.

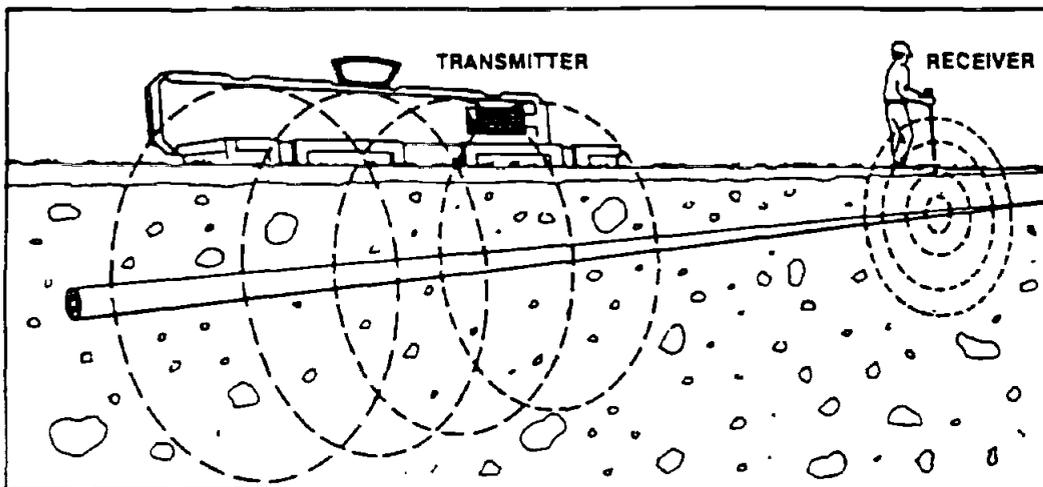


Figure 4-1. Transmitter and Receiver Placement

The tracing current generates an alternating circumferential field around the cable. This alternating field induces a signal into the receiver's sensor. As the receiver is moved back and forth across the cable in a search pattern, the pitch of the audio output from the receiver increases and decreases.

The heavy line in Figure 4-2 represents the increase and decrease in pitch of the audio signal as the receiver is moved back and forth over an energized cable. Moving from A to D causes the pitch to increase to a maximum at B and decrease to a minimum directly over the target. At C the pitch again increases and then decreases at D.

The MAC-51B can be used to trace any long conductive element such as an anode string or metalized warning tape as well as cable and pipe.

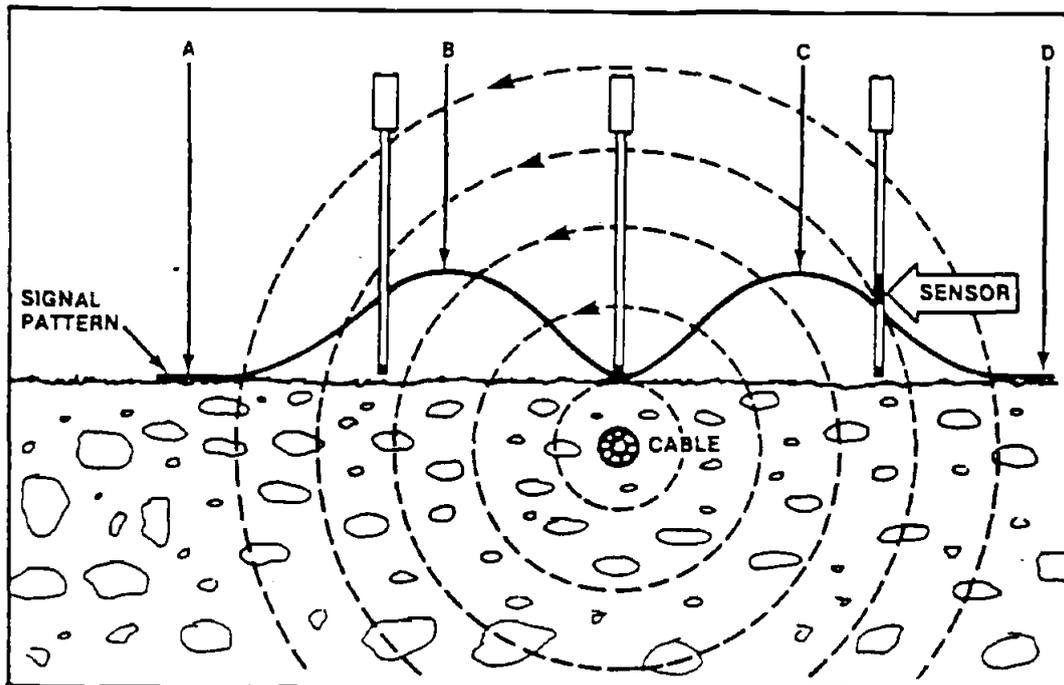


Figure 4-2. Signal Pattern from a Tracing Signal

NOTE

For convenience, all targets will be referred to as lines throughout Sections IV and V.

Transmitter, Turn-On and Battery Check

Set the ON/OFF switch to ON and listen for a steady beeping sound. If a beeping is not heard, the batteries must be replaced as described on page 6-3.

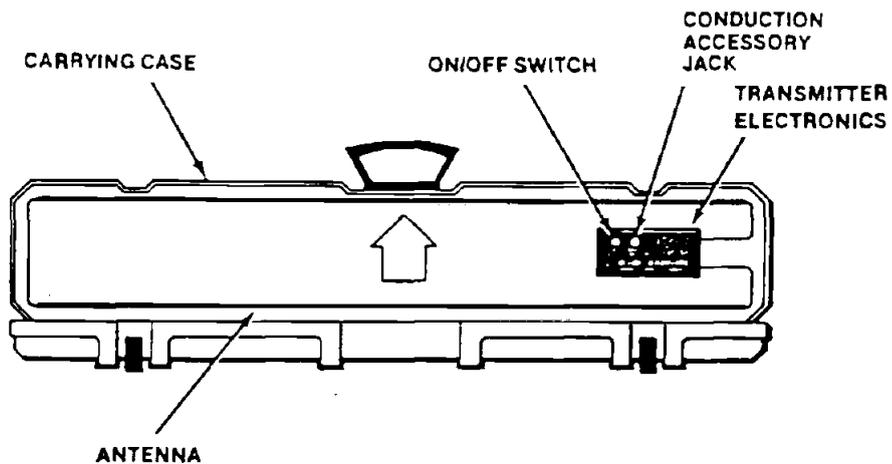


Figure 4-3. Transmitter Controls

Transmitter, Inductive Mode

The most common line excitation mode is inductive. With the cover open and the arrow pointing up, place the transmitter over the line as illustrated in Figure 4-4. The cover must be pointing up. Turn the transmitter ON/OFF switch to ON and you will hear a steady beeping sound. If not, replace the batteries.

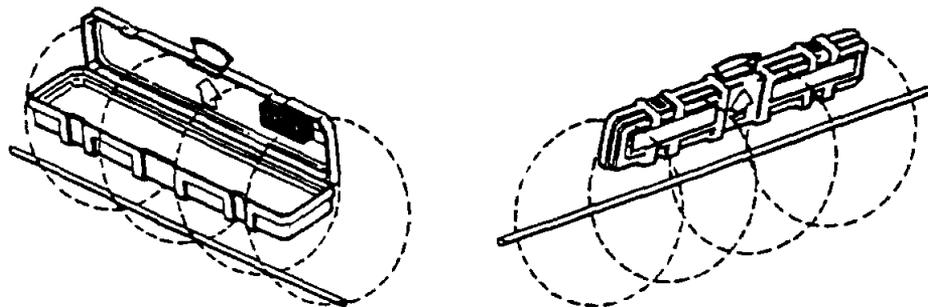


Figure 4-4. Transmitter Operating Positions

Transmitter, Conductive Mode

If an exposed section of a target gas or water pipe is accessible, the tracing signal can be applied directly to the target line.

Plug the conductive cable assembly into the transmitter accessory jack and turn the power switch to ON. (Inserting the plug automatically disables the inductive transmitter and applies exciting current to the cable clips.) Connect one cable clip to a conductive portion of the line. Drive the ground stake into the soil off to the side of the line and attach the other clip to the stake. A good electrical contact between the clips, the line, and the ground stake is very important.

WARNING

Clipping to power lines is dangerous and should not be done. Insulation on the clip is not designed to protect against power line voltages.

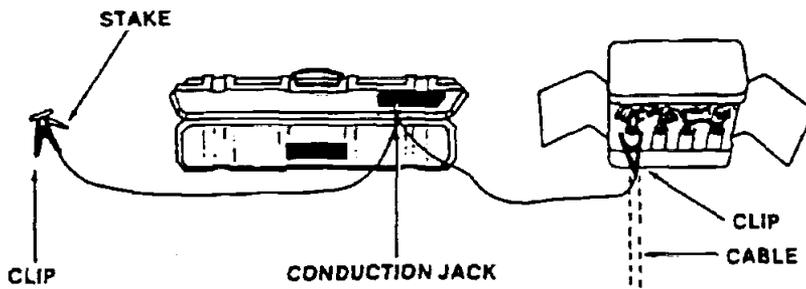


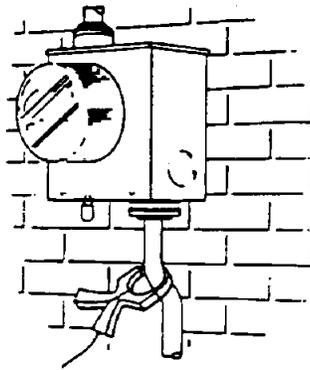
Figure 4-5. Transmitter Hookup for Conductive Operation

Transmitter, Inductive Signal Clamp Mode

The inductive signal clamp (optional) provides a convenient method of applying the tracing signal to electrical cables covered with nonmetallic insulation. Plug the clamp lead into the transmitter accessory jack, turn on the transmitter and close the clamp around the cable: No ground connection is required. It can be applied to cables up to three inches in diameter.

WARNING

Clamping around any power line involves hazard. Exercise caution. Under no circumstances clamp around high tension lines (lines carrying greater than 220 V). High tension voltage can jump to the operator through the insulation and down the wire.



Receiver, Function Selection and Turn-On

Set the M/C switch to C and adjust the ON/OFF-Sensitivity control for mid-position as shown in Figure 4-7. The volume level is preset. If the receiver is turned on when located within 15 feet of the transmitter, the receiver's speaker will emit a siren-like sound indicating that the receiver is picking up the tracing signal directly from the transmitter through the air.

The sensitivity will have to be increased as the distance between the receiver and transmitter increases.

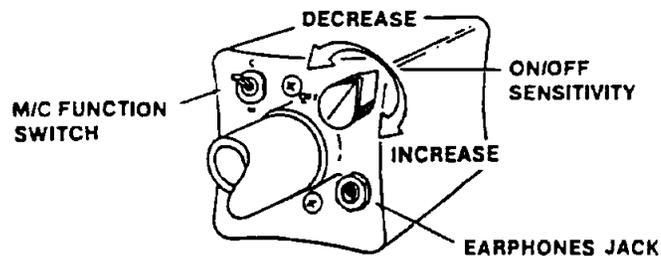


Figure 4-7. Sensitivity Set for Normal Range

Receiver, Sensitivity Settings

The right sensitivity level must be used to obtain a proper null. A null is the audio signature that lets the operator know when he is positioned directly over the target line. If the sensitivity level is set too low, the null between the two signal peaks (highest audio pitch) will cover too large an area, making it difficult to trace the line. If the sensitivity is set too high, the null will be too short and not heard. Setting the sensitivity to get the null width as illustrated by the medium sensitivity curve in Figure 4-8 is the secret to successful tracing.

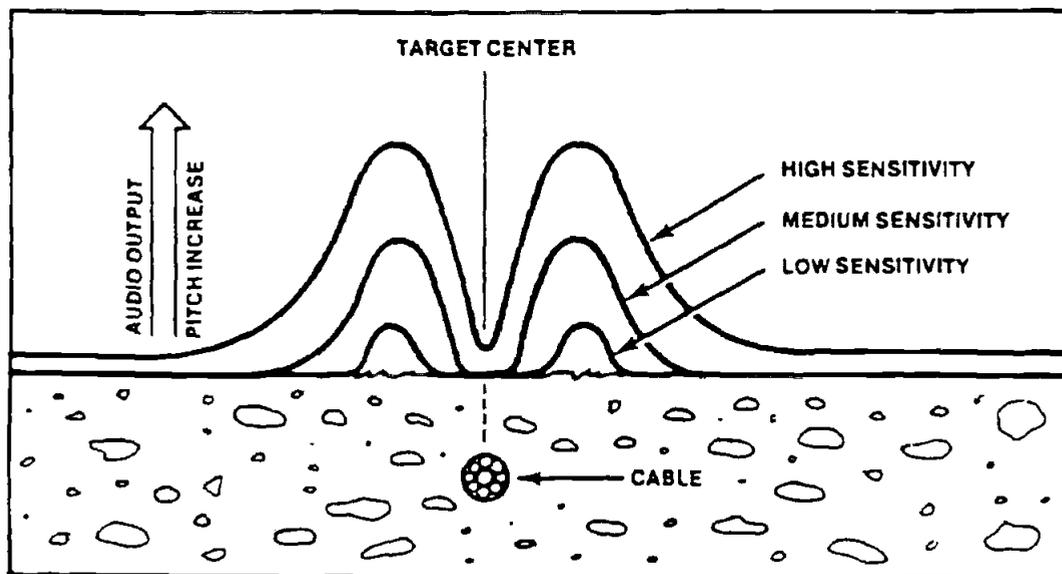


Figure 4-8. Null Shape Versus Sensitivity Setting

Tracing, Inductive Mode

Position the transmitter over the target line and turn the power switch to ON. A steady beeping will be heard that indicates the transmitter is operational. Move approximately 30 feet away from the transmitter along the suspected target line before turning on the receiver. This will ensure that the receiver is not receiving the signal through the air directly from the transmitter. Set the receiver function switch to C and adjust the sensitivity control to obtain a medium pitch signal. Hold the receiver just below the large end as illustrated in Figure 4-9.

NOTE

Do not swing the receiver. The null appears over the target only when the receiver is held in a vertical position. If it is held at an angle, the null will not indicate the true location of the target line.

Holding it in a vertical position with the sensor end close to the ground, move it back and forth across the line. Readjust the sensitivity until a sharp null (minimum pitch) is obtained. The null occurs directly over the line. As you move away from the transmitter the sensitivity level will have to be increased.

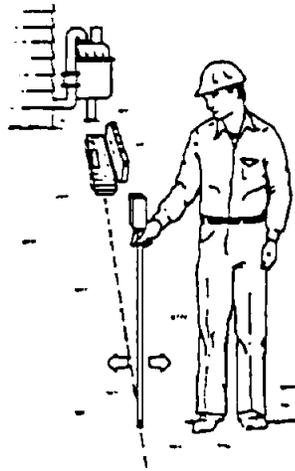


Figure 4-9. Inductive Mode Tracing

Tracing, Conductive Mode

In this mode the transmitter is physically connected to an exposed conductive section of the target line using the conductive cable assembly and the ground stake. After the two clips are connected to the line and to the ground stake (good electrical contacts are essential), the procedure for using the transmitter and the receiver is the same as for the inductive mode except that tracing can be started right next to the transmitter.

WARNING

Clipping to power lines is dangerous and should not be done. Insulation on the clip is not designed to protect against power line voltages.

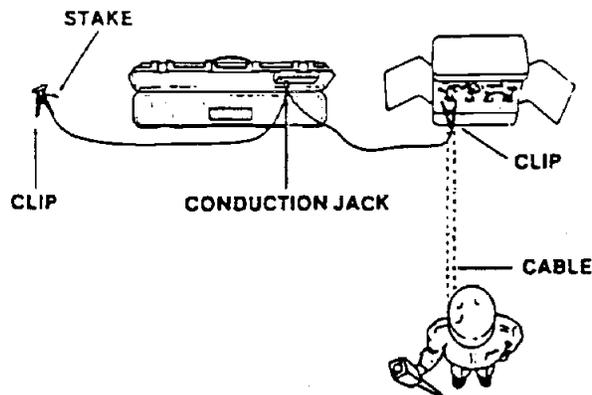


Figure 4-10. Conductive Mode Tracing

Section V

Cable Locator Application Notes

Inductive Coupling

Induction is the easiest and quickest way of applying the tracing signal to a conductor and provides a signal strong enough to trace most lines. Induction does not require access to an exposed section of the line which very often is not available. However, an induced signal is not as strong as a conductively applied signal and will fade quickly as distance from the transmitter increases when electrically poor or leaky conductors such as gas and water pipes are being traced. Any time a tracing signal is induced on a target line, the same signal will be induced on nearby utility lines which may cause some confusion when trying to identify the null.

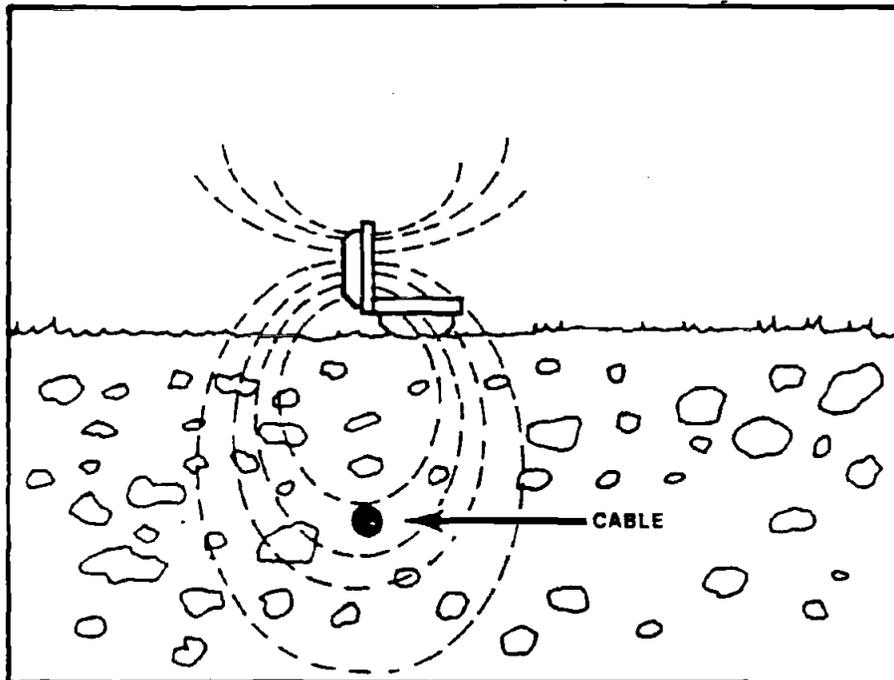


Figure 5-1. Inductive Coupling Setup

Conductive Coupling

This is the most reliable way of applying the tracing signal. A good electrical contact between the clip and the conductive portion of the target line is essential. If necessary, use a file to clean off rust or paint to ensure a good electrical connection. Electrical contact must also be made to the ground using the supplied stake. For the best results, drive the stake into the ground as far off to the side of the line as the connecting cable will permit. (See Figure 5-2)

WARNING

Clipping to power lines is dangerous and should not be done. Insulation on the clip is not designed to protect against power line voltages.

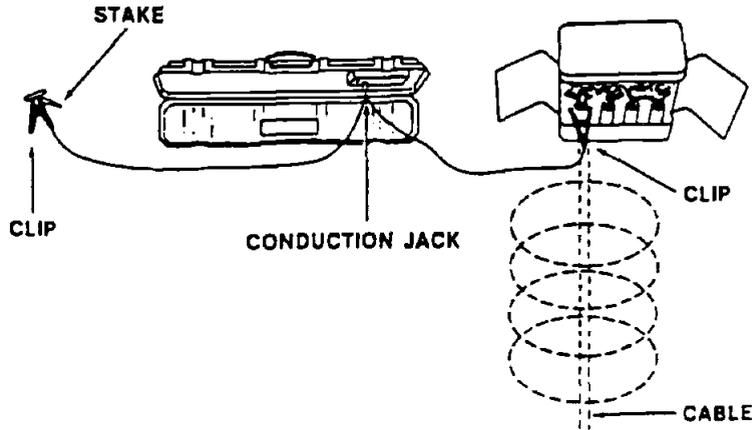


Figure 5-2. Conductive Coupling Setup

Dealing with Clutter Signals

When operating in the inductive mode, an effective method of reducing interference caused by parasitic signals from an adjacent line is to find a second spot on the line that has a good clean null (equal strength lobes on both sides). Move the transmitter to this spot. Confirm that this is the target line by back-tracking with the receiver to the first site of the transmitter and checking for a null. This procedure of leapfrogging the transmitter is also the standard method for extending the tracing range on electrically poor or leaky lines.

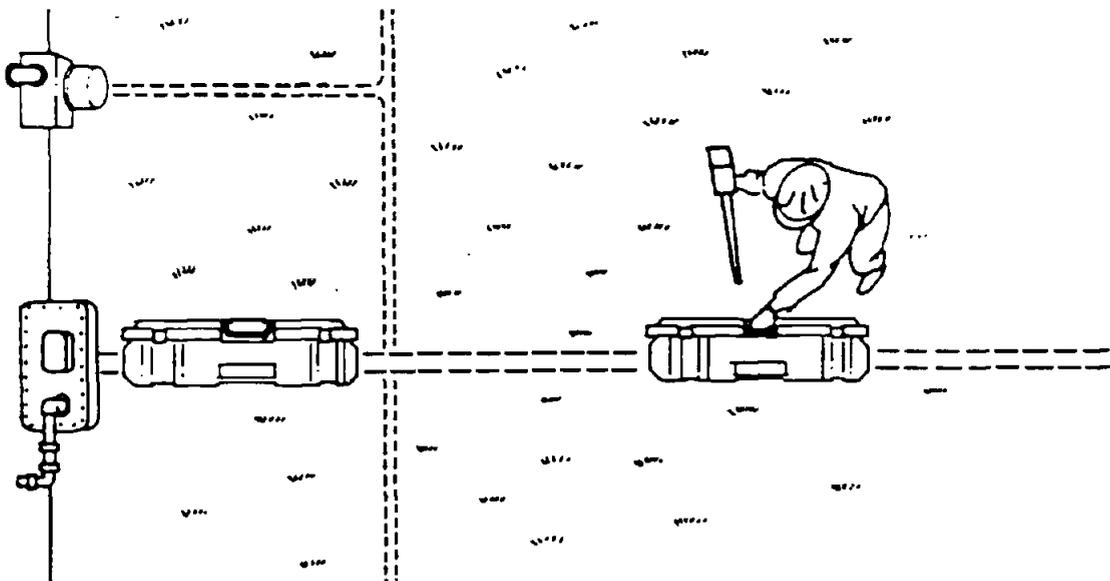


Figure 5-3. Repositioning Transmitter to Reduce Interference

Single-Lobe Identification

A second line parallel to the line being traced will emit a parasitic signal but at a reduced strength. Interaction of these signals results in unequal side lobes, which cause a large null off to one side of the target line as indicated by signal pattern curve A in Figure 5-4. To accurately trace a line under this condition will require practice. An alternate method is to hold the receiver in a horizontal position perpendicular to the line and listen for a single high pitch audio signal that occurs directly over the line as indicated by signal pattern B.

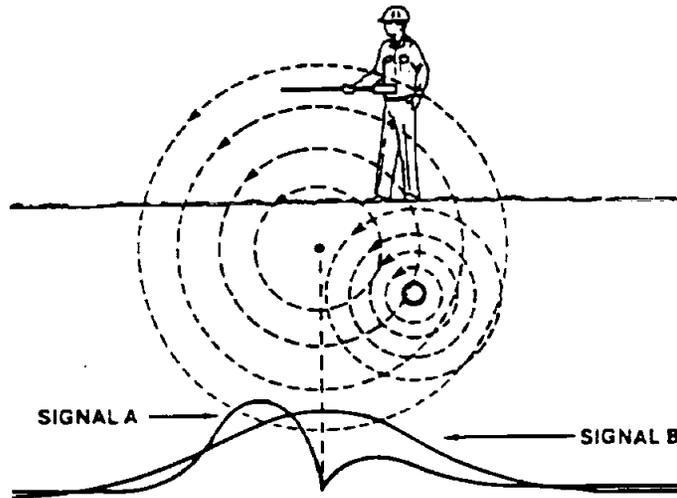


Figure 5-4. Single Lobe Identification Technique

Bends and Junctions

A variation of the two-line, single-lobe identification problem just described occurs when the line being traced has a bend or junction. As the receiver is brought near a bend or junction, the tracing signal becomes difficult to interpret. When this occurs, walk a 20-foot circle around the spot where the signal becomes confusing to detect the null that will indicate the line's new direction. However, to be certain that it is the new direction and not a junction, complete the circle to check for a second null that will indicate if the line has a branch.

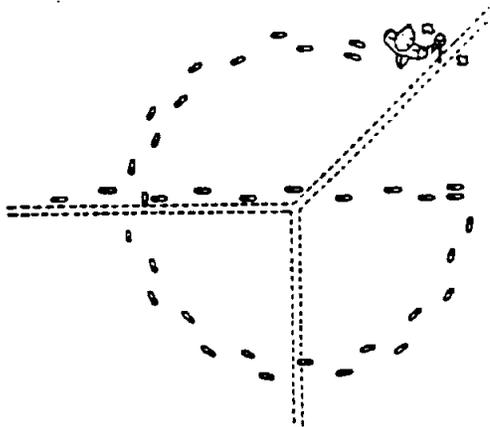


Figure 5-5. Identification of Bends and Junctions

Signal Spreading

Target lines that are poorly insulated from ground such as gas pipes, water pipes and anode strings may cause signal spreading to occur over long distances from the transmitter, even when using the conductive mode. This condition is prevalent when ground water is present. The signal also spreads to nearby lines and into the soil itself. When this situation is encountered, the transmitter must be moved closer to the section of the line to be traced and the conductive mode used if possible.

Signal spreading can also occur even when lines are well insulated. The tracing signal can travel into buildings via the ground or the shield of a line and transfer to the shields of other lines leaving the building. Signal spreading can be minimized by placing the transmitter as far as possible from the building.

Magnetic Locator Function

The MAC-51B has a unique feature designed to help the operator unscramble underground clutter. It is the option of switching to the magnetic mode for a second indication of what category of targets are in the immediate vicinity. In this mode cast-iron water and gas pipes can be readily identified and even classified as to type by the conventional spacing of joints. Power mains and some 60 Hz service drops can also be identified by a burbling sound that peaks when the receiver is directly over the power line. As the operator becomes more familiar with the MAC-51B System, switching between the M and C functions when clutter is encountered will become an invaluable tracing aid.

Isolators and Signal Path Continuity

The tracer current must travel in a closed loop. When it leaves the line being traced, it loops back, one way or another, to the beginning of the line. If the current cannot complete its loop the locating system will not operate. The operator should be aware of this system requirement when tracing lines that have electrical isolators installed.

Electrical isolators are sometimes placed in a gas line at the meter to provide an electrically open circuit which stops the flow of galvanic current and reduces corrosion. To inductively excite this type of line by placing the transmitter close to the meter, a shorting wire must be placed on the pipe to bypass the isolator. This allows the tracer current to return to the pipe through the earth ground of the building. An alternate method is to move the transmitter down the line a few yards away from the building to a point where the gas pipe riser provides a current return path.

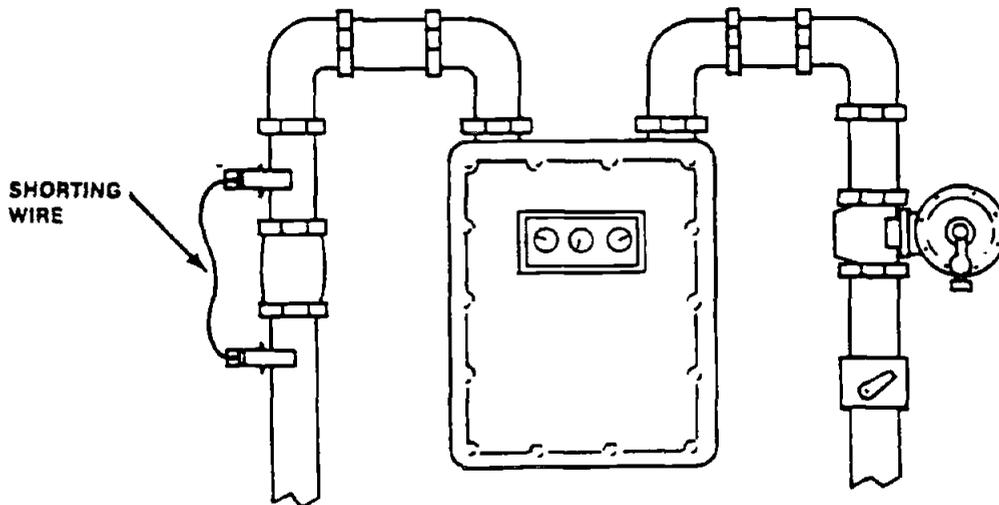


Figure 5-6. Gas Line Isolator Bypassed with Shorting Wire

Isolators and Inductive Excitation

Electrical isolation sometimes occurs inadvertently on phone cables entering a pedestal because the cable's shield is not grounded. In most jurisdictions, grounding the shield inside the pedestal is not required unless the cable shares a trench with power cables. If there is no ground wire, it is recommended that a wire and clips, as shown in Figure 5-7, be connected from the cable shield to the pedestal before using the inductive mode to excite the target cable. This will greatly improve the strength of the inducted tracing signal.

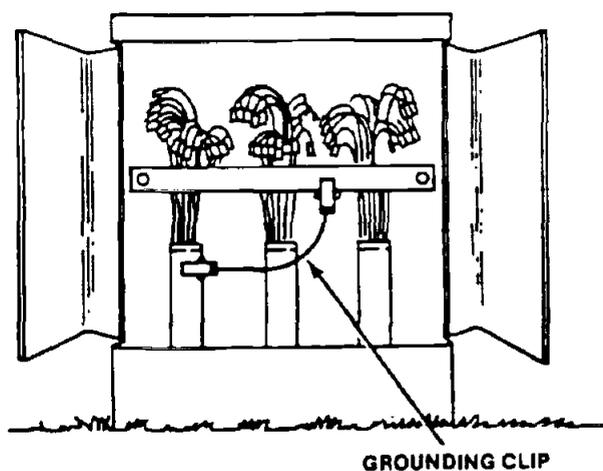


Figure 5-7. Pedestal with Grounding Clip Installed

Isolators and Conductive Excitation

When using the conductive mode to trace a phone cable from a pedestal, electrical isolation of the shield is an advantage. If a ground wire is providing a good path from the shield to earth ground through the pedestal, the trace current will use it to complete the return loop to the transmitter grounding stake instead of going down the target line. So if there is a ground wire in place, disconnect it from the pedestal before connecting the conductive cable clip to the shield to ensure that a strong tracer current is applied to the cable.

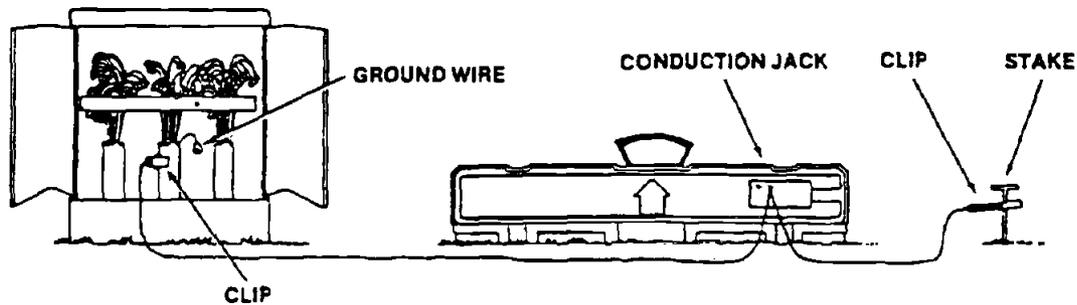


Figure 5-8. Pedestal with Groundwire Removed

Determining Target Depth by Triangulation

The receiver can be used in the traditional triangulation method to determine the approximate depth of a target as illustrated in Figure 5-9. However, when using this method it is necessary to take into account the fact that the center of the cable-sensor is located 11 inches up the receiver tube from the black tip.

When the position of the target has been determined by the null, mark the spot (#1) on the ground. Hold the receiver tip on the ground at this spot, slant the instrument at a 45° angle and slowly move directly back, to one side, from the target until a second null is obtained. Now mark a spot (#2) on the ground that is directly below a point 11 inches up the receiver tube from the black tip. Measure the distance between spot # 1 and spot #2. This measurement indicates the approximate depth of the target.

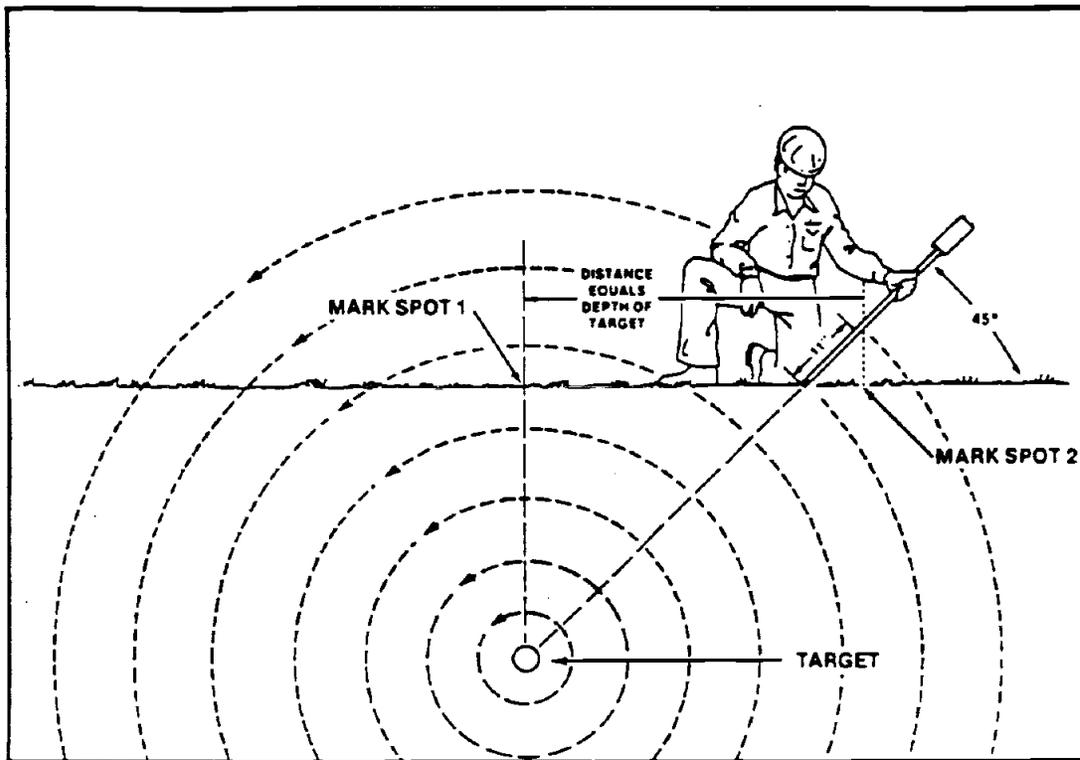


Figure 5-9. Determining Approximate Depth of Target

NOTE

Depth readings should be taken on both sides of the line at a spot where the lobes have the same signal strength. This procedure will help reduce any error in depth estimation caused by a distorted tracing signal due to interference.

Section VI Maintenance

The MAC-51B system is built to give trouble-free operation. Normally, maintenance is limited to the occasional replacement of batteries. In the event that a malfunction does occur, refer to the appropriate trouble-shooting guide on page 6-4. They list a few possible problems that can generally be corrected in the field so that you will be able to continue using the locator without interruption.

Replacement of Receiver Batteries

The receiver is powered by four C-cell batteries carried in a battery holder illustrated in the exploded view of the electronic assembly. Access to the batteries is obtained by removing the two knurled nuts and sliding off the cover.

The four batteries are connected in series. The proper polarities for the batteries are shown on the battery holder. Batteries must be removed and installed as shown in Figure 6-2.

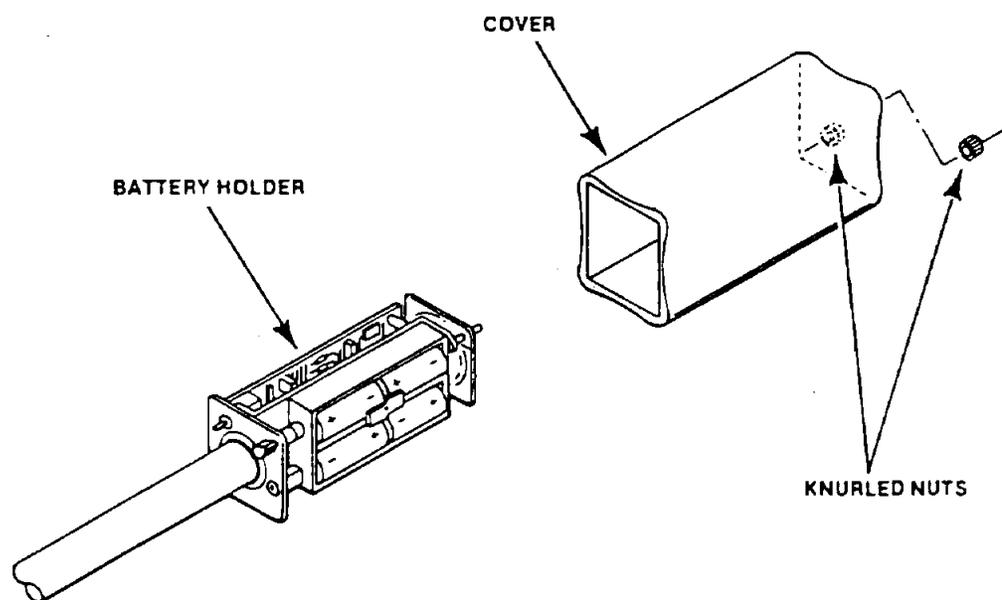


Figure 6-1. Exploded View of Receiver Electronic Unit

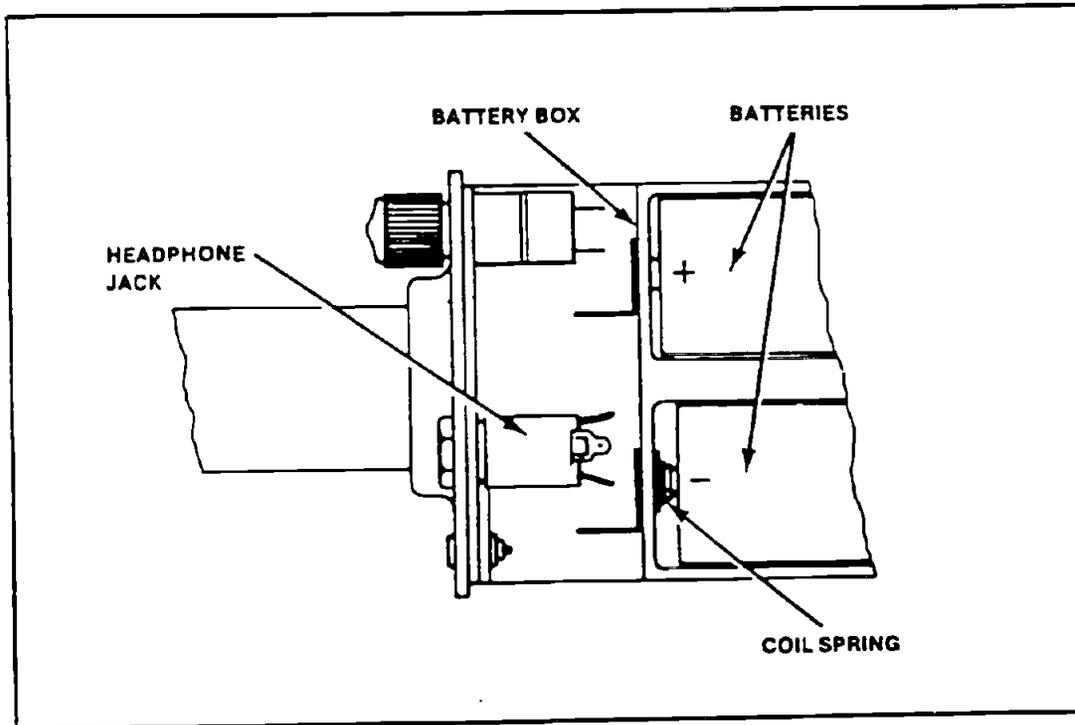
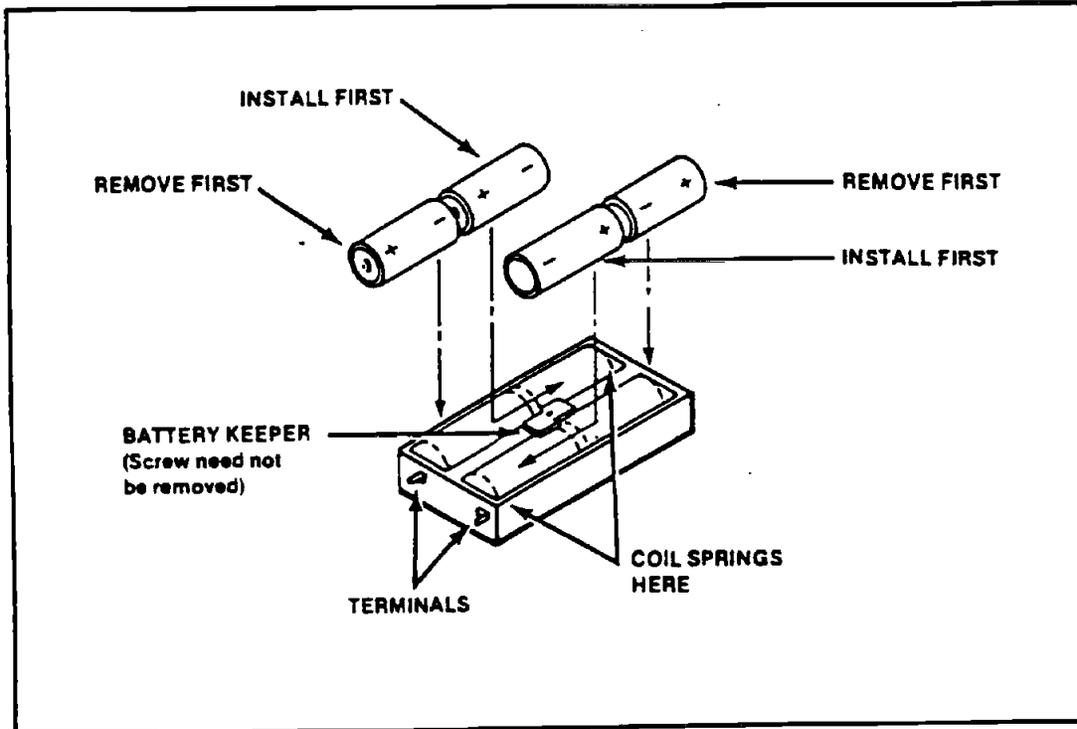


Figure 6-2. Replacement of Receiver Batteries

Replacement of Transmitter Batteries

The transmitter is powered by eight alkaline C-cell batteries located in a battery holder. Access to the batteries, as illustrated in Figure 6-3, is obtained by removing the two knurled nuts, the battery holder cover, and the spare battery holder. The eight batteries are connected in series. The proper polarities for the batteries, their removal, and installation sequence are indicated below. Batteries must be removed and installed in the order shown.

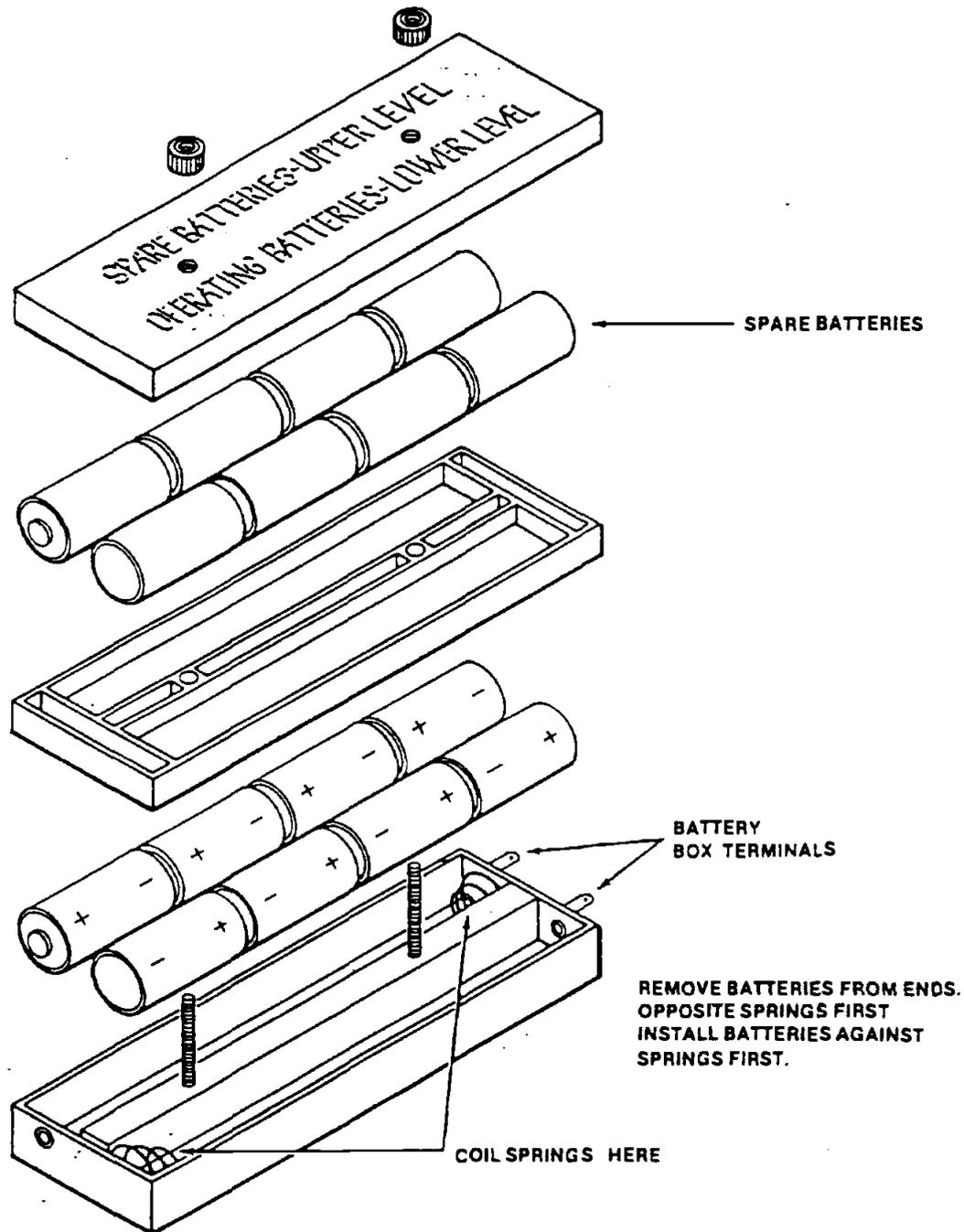


Figure 6-3. Replacement of Transmitter Batteries

RECEIVER TROUBLESHOOTING GUIDE

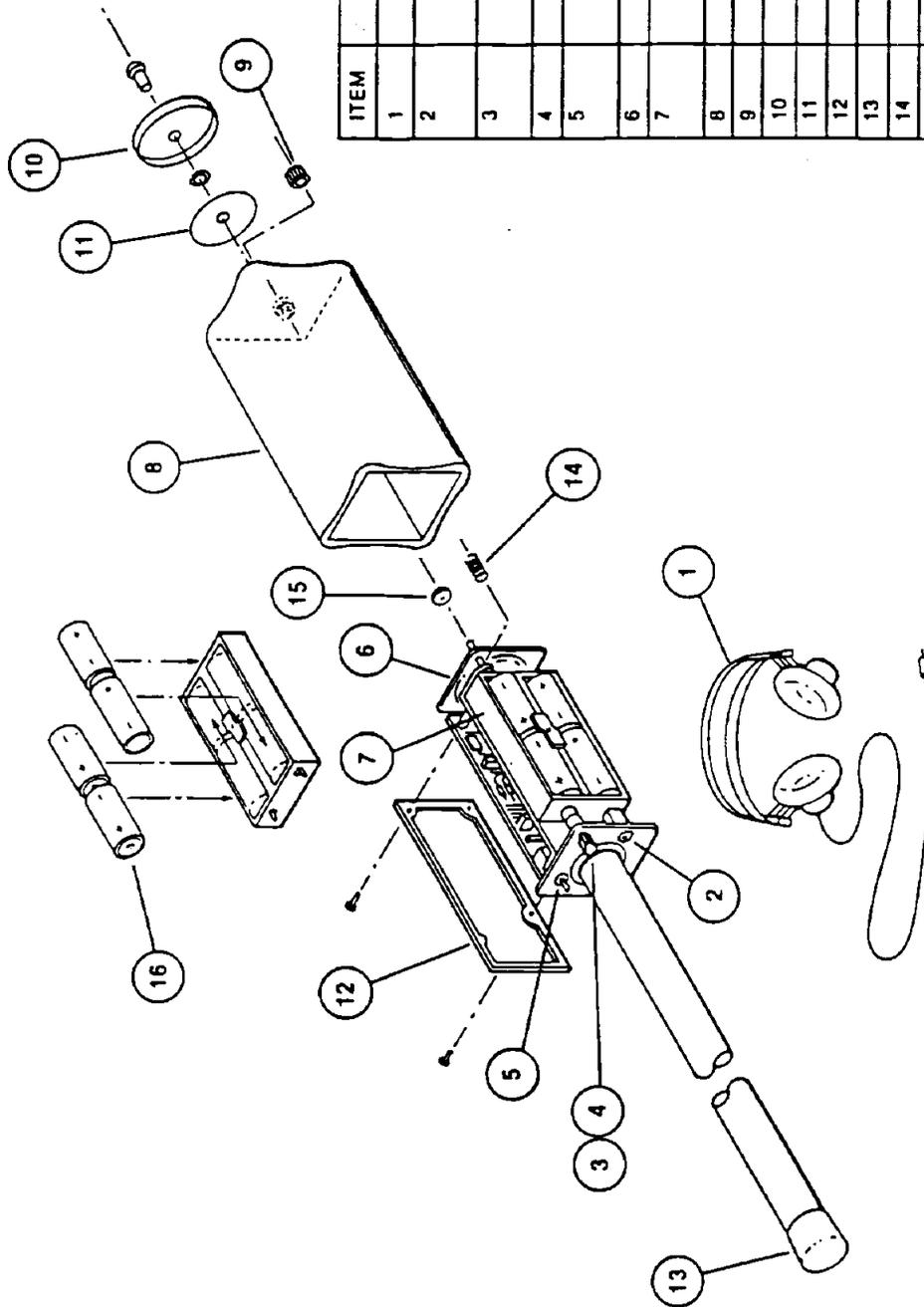
Symptom	Possible Cause	How to Check	How to Fix
Dead	Dead Batteries. Batteries not making contact. Broken Wires.	Replace. Check for contact corrosion. Visually inspect.	Replace. Clean Contacts. Resolder.
Intermittent	Batteries not making good contact.	Check for corrosion.	Clean Contacts.
No sound	Speaker terminals shorted to cover.	Visual.	Bend terminals.

TRANSMITTER TROUBLESHOOTING GUIDE

Sympton	Possible Cause	How to Check	How to Fix
No Sound	Dead Batteries. Batteries not making contact. Broken wires.	Replace. Check for contact corrosion. Visually inspect.	Replace. Clean Contacts. Resolder.
Intermittent Sound	Batteries not making contact.	Check for corrosion.	Clean contacts.

SERVICE INFORMATION

If your locator needs service, please return it to the factory along with the following information: Name, Address, Where Purchased, Date and Description of Trouble(s). A telephone estimate will be provided prior to service work being done. See shipping information on Page 6-7.



ITEM	PART NO.	DESCRIPTION
1	H30006	HEADSET*
2	207245	PHONE JACK
3	207179	J10012 WITH WIRES
4	K20011	SENSITIVITY CONTROL S35065 WITH WIRES
5	207269 B55004	OPTION SWITCH BUSHING BUSHING EXTENDER
6	206003	SPEAKER MOD.
7	207173	BATT. HOLDER AND CHASSIS ASSY.
8	207271	COVER
9	K20021	KNURLED NUT (2 REQ'D)
10	207215	CAP
11	202008	SCREEN
12	301655	PROTECTOR
13	T60003	TIP
14	S56002	SPRING (2 REQ'D)
15	R40016	"O" RING (2 REQ'D)
16	B11009	BATTERY (1 "C" SIZE, 4 REQ'D)

*OPTIONAL

Figure 6-4. MAC-51B Receiver Repair Parts

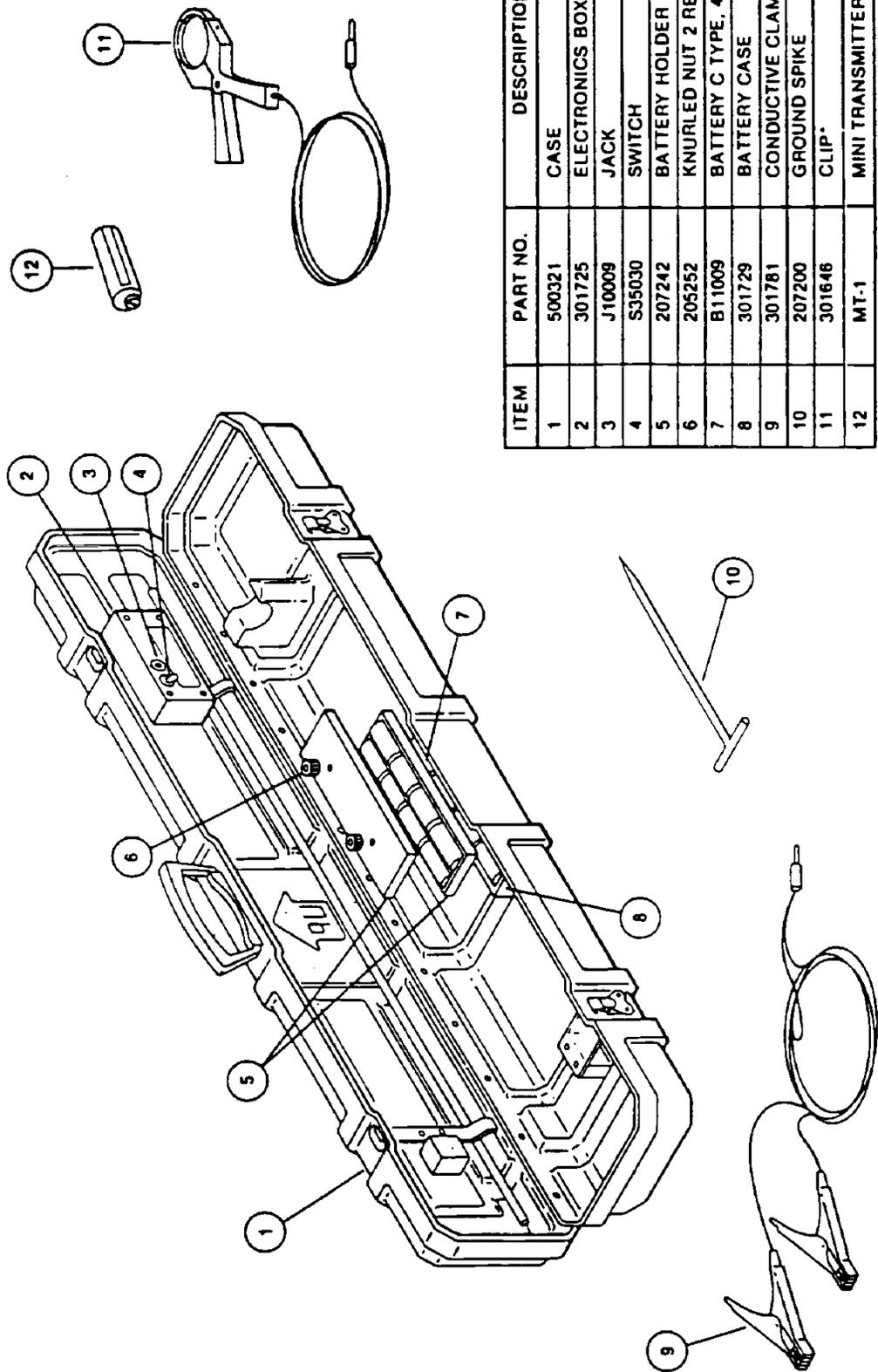


Figure 6-5. MAC-51B Transmitter Repair Parts

LIMITED WARRANTY

The Schonstedt Instrument Company (Schonstedt) warrants each product of its manufacture to be free from defects in material and workmanship subject to the following terms and conditions. The warranty is effective for one year after shipment by Schonstedt to the original purchaser.

Our obligation under the warranty is limited to servicing or adjusting any product returned to the factory for this purpose and to replacing any defective part thereof. Such product must be returned by the original purchaser, transportation charges prepaid, with proof in writing, to our satisfaction, of the defect. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. Prior to repair in this instance, a cost estimate will be submitted. Service or shipping information will be furnished upon notification of the difficulty encountered. Model and serial numbers must be supplied by user. Batteries are specifically excluded under the warranty.

Schonstedt shall not be liable for any injury to persons or property or for any other special or consequential damages sustained or expenses incurred by reason of the use of any Schonstedt product.

FOR SERVICE OR REPAIR

Please ship locator (in its case to):

Schonstedt Instrument Company
1775 Wiehle Avenue
Reston, VA 22090

PATENTS

Manufactured under the following Patents: United States: 2,916,696; 2,981,885; 3,894,283; 3,909,704; 3,961,245; 3,977,072; 4,110,689; 4,161,568; 4,163,877; 4,258,320; 4,388,592 and Design 255552. Canada: 637,963; 673,375; 1,006,915; 1,037,121; 1,141,003, 1,177,891 and 1,206,091. Great Britain: 1,446,741; 1,446,742; 1,494,865 and 2,012,430B. France: 2,205,671 and 81 12295. Germany: 25 51 968.0-09; 25 55 630; and 29 01 163. Japan: 1,595,127 and 1,413,844. Other patents pending.

INSTRUCTION MANUAL

MODEL PI 101

Portable
Photoionization
Analyzer



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WARNINGS

The following warnings appear in this manual and are repeated here for emphasis.

Do not look at the light source from closer than 6 inches with unprotected eyes. Observe only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

The instrument measures gases in the vicinity of the operator and a high reading when measuring toxic or explosive gases should be cause for immediate action for safety.

extreme care must be taken in the handling of gas cylinders. Contents are under high pressure. In some cases, the contents may be hazardous. Many gas suppliers will provide data sheets for the mixtures upon request.

Never open the valve on a gas container without a regulator attached.

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise, high voltages of 1200 V DC, will be present.

Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

Be very careful to note the toxic levels and the Lower Explosive Limits for personal safety. The PI 101 is a nondestructive analyzer and must be used in a hood when calibrating with toxic or hazardous materials.

The PI 101 is suitable for uses in Class I Division II ABCD areas except when using charger or when using recorder.

The PI 101 is a non-destructive analyzer; work in a hood if toxic or hazardous gases are used. In the interest of greater international acceptance the HNU Model PI 101-100 Photoionizer has been certified by Sira Safety Services Ltd. to conform to Article 501-3 of the National Electrical Code to be non-incendiary for Class I Division 2, Groups A, B, C and D locations Effective July 25, 1984.

SIRA Approval #APL/33/84

SECTION 1

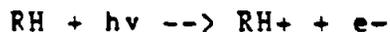
GENERAL INFORMATION

1.1 INTRODUCTION

This manual describes the operation, maintenance and parts list for the Trace Gas Analyzer, Model PI 101, HNU Systems Inc.

1.2 EQUIPMENT DESCRIPTION

The Trace Gas Analyzer (see Figure 1-1), is a portable instrument used to detect, measure, and provide a direct reading of the concentration of a variety of trace gases in many industrial or plant atmospheres. The analyzer employs the principle of photoionization. This process involves the absorption of ultra-violet light (a photon) by a gas molecule leading to ionization:



in which

RH = Trace gas

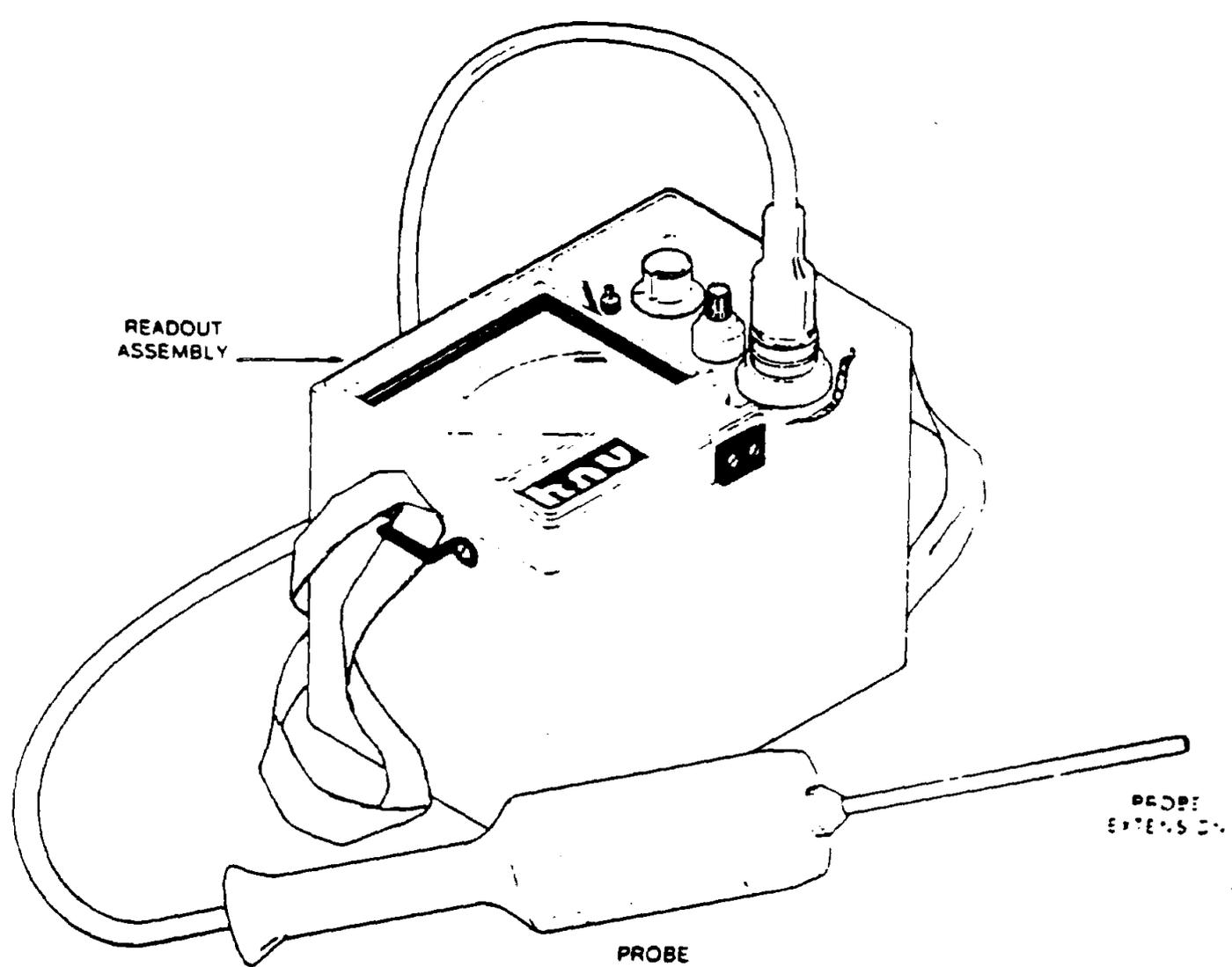
hv = Photon with an energy level equal to or greater than the ionization potential of RH.

The sensor consists of a sealed ultraviolet (UV) light source that emits photons with an energy level high enough to ionize many trace species, particularly organics, but not high enough to ionize the major components of air, O₂, N₂, CO, CO₂ or H₂O.

A chamber exposed to the light source contains a pair of electrodes, one a bias electrode and the second a collector electrode. When a positive potential is applied to the bias electrode a field is created in the chamber. Ions formed by the absorption of photons are driven to the collector electrode. The current produced is then measured and the corresponding concentration displayed on a meter directly in parts per million (ppm).

To minimize absorption or decomposition of sample gases, a rapid flow of sample gas is maintained thru the ion chamber, which is small, made of inert material and located at the sampling point.

The analyzer consists of a probe, a readout assembly, and a battery charger. The probe contains the sensing and amplifying circuitry; the readout assembly contains the meter, controls, power supply and rechargeable battery. The analyzer will operate from the battery for more than 10 hours or continuously when connected to the battery charger.



**FIGURE 1-1
TRACE GAS ANALYZER
OPERATING CONDITION**

SECTION 1.2, EQUIPMENT DESCRIPTION cont.

The PI 101 is designed for use with interchangeable probes with lamps of different energies. The analyzer is ready for use simply by connecting the probe to the readout assembly, setting the proper SPAN pot value, and then zeroing the unit. Specific data is given in the calibration memo accompanying each probe.

The standard probe uses a 10.2 eV lamp. Two optional probes use 9.5 and 11.7 eV lamps. Lamps of different eV ratings, ion chamber and amplifiers are not interchangeable between probes.

Many applications make use of the principle that some compounds respond to the more energetic lamps and not to others. Figure 1-2 shows the responses for the analyzer with each of the three lamps. Literature explaining several such applications is available from HNU Systems Inc.

An optional audible alarm is available giving an 85 decibel signal when a set concentration is exceeded. The alarm setting is variable and can be set from 0 to 100% of full scale of the meter reading. Power for the alarm is provided by the battery and does not significantly affect the rated use time of the analyzer. The alarm is non-latching and is set by a screw adjustment, preventing inadvertent changes.

When in the stored condition, the probe is contained in the instrument cover (see Figure 1-3) which attaches to the readout assembly to form a single unit (see Figure 1-4).

An optional recorder is available that can be directly attached to the readout assembly. It uses impact paper with a 2" wide chart and a speed of 2"/hour. The recorder is powered by the instrument battery and provides hard copy of the data. The analyzer will operate for approximately 4 hours with the recorder attached. Mounting information and illustration is given in Section 8.

Specification data on the analyzer is given in Table 1-1. Physical characteristics of the equipment are given in Table 1-2.

Response for the Various Ultraviolet Lamps

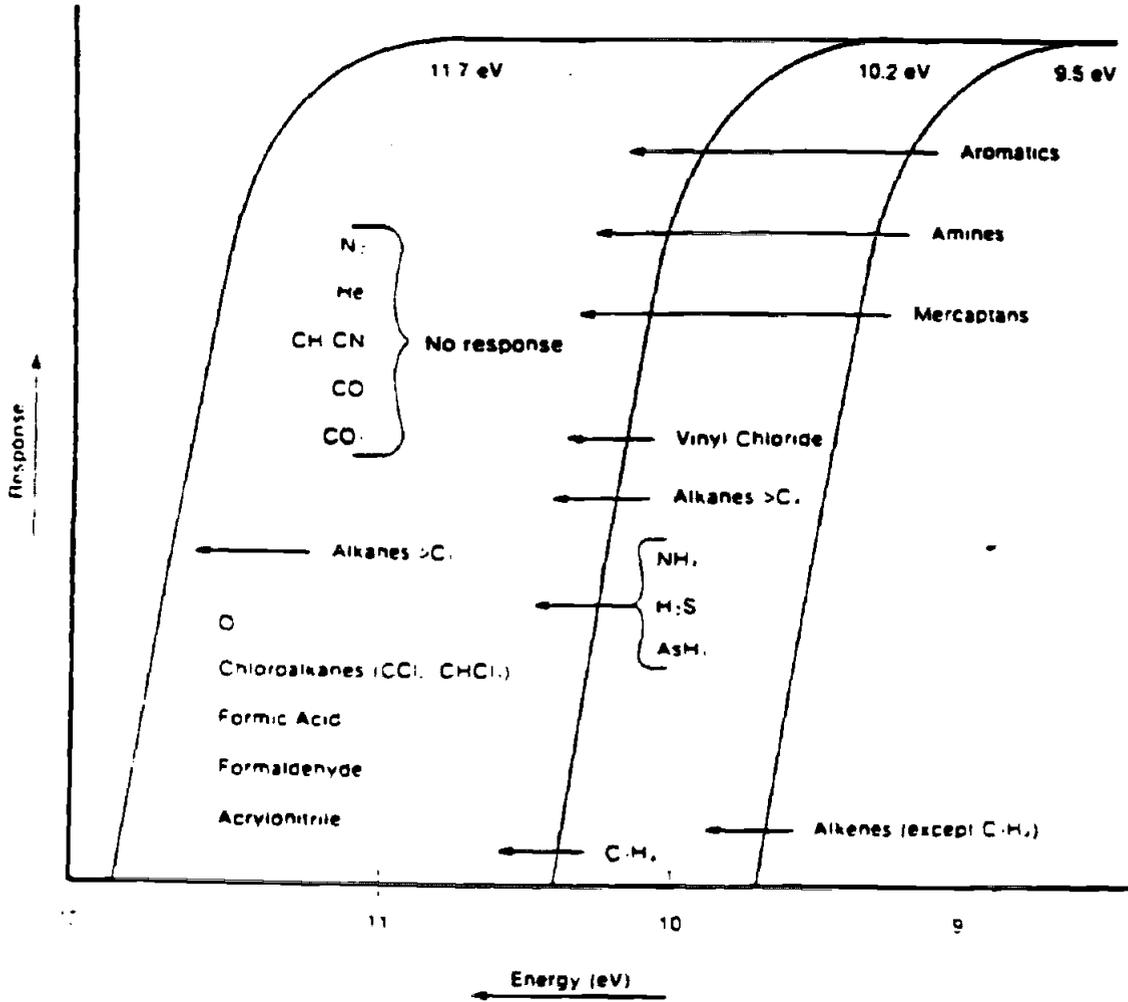
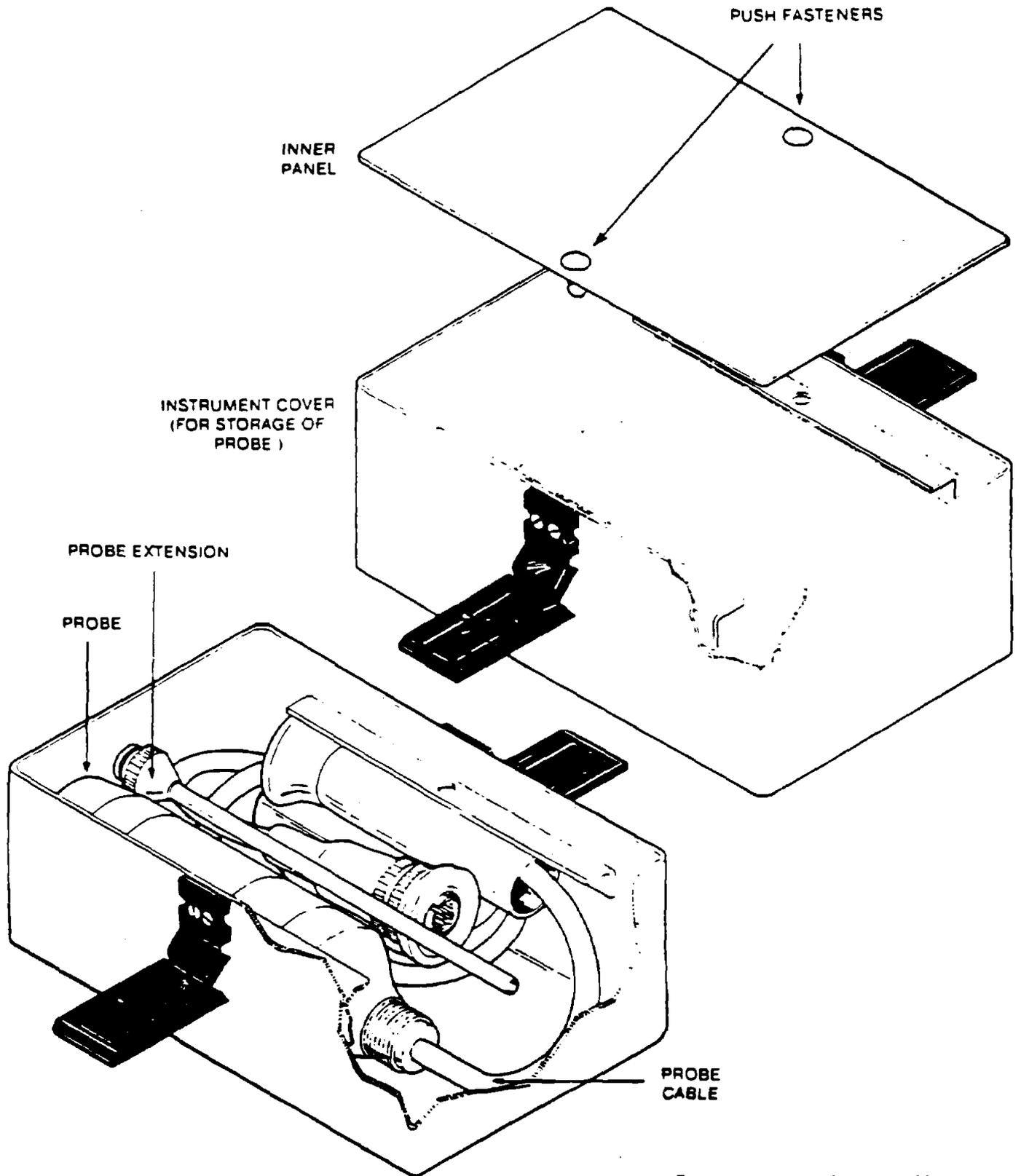
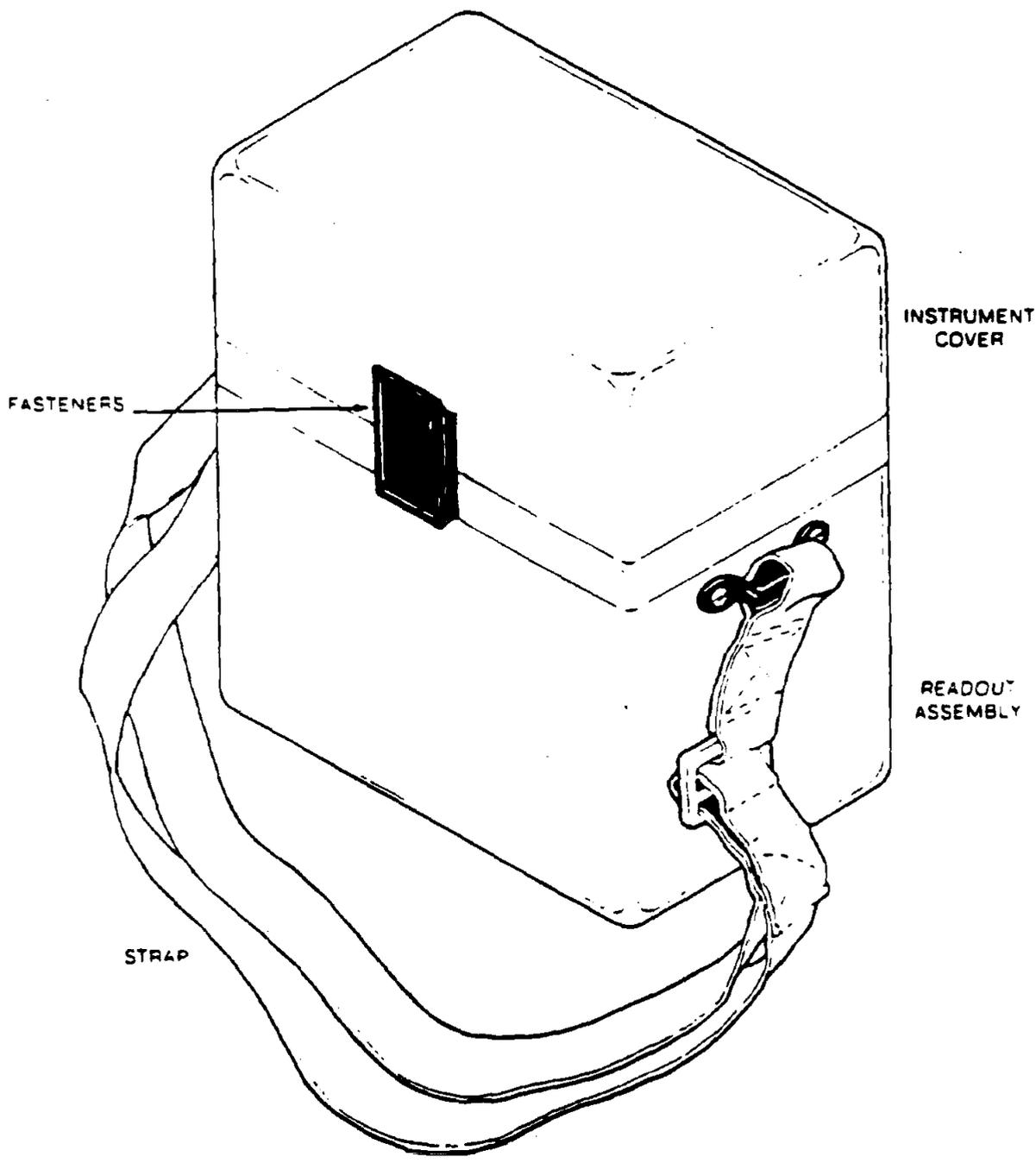


FIGURE 1-2
 RESPONSE TO VARIOUS COMPOUNDS
 FOR EACH ULTRAVIOLET LAMP



Repeated storage of probe in this manner is not recommended due to cable wear. Instrument cover may also be used for storing battery charger.

**FIGURE 1-3
PROBE STORAGE
INSTRUMENT COVER**



**FIGURE 1-4
TRACE GAS ANALYZER
STORED CONDITION**

TABLE 1-1
SPECIFICATION DATA

a. DESIGN FEATURES

Range settings	0 to 20, 200, 2000 ppm (other ranges available on request)
Lamp rating	10.2 eV standard, 9.5 or 11.7 eV optional
Audible alarm, low or high limit (optional)	85 db at 3'

b. CHARACTERISTICS (see NOTE)

Detection Range *	0.1 to 2000 ppm (parts per million by volume)
Minimum Detection Level *	0.1 ppm
Maximum Sensitivity *	0 to 20 ppm FSD at SPAN = 9.8 (full scale deflection) 0 to 2 ppm FSD at SPAN = 0.0
Repeatability *	+/- 1% of FSD
Linear Range *	0.1 to 400 ppm
Useful Range *	0.1 to 2000 ppm
Response Time	Less than 5 seconds to 90% of FSD
Ambient Humidity	up to 90% RH (relative humidity)
Operating Temperature, Ambient	-10 to 40 degrees C.
Operating Time on Battery, continuous use, without HNU recorder	Approximately 10 hours; at lower temperatures time is reduced due to effect of cold temperature on battery.
with HNU recorder (optional)	Approximately one half of normal time

TABLE 1-1 cont.

Recharge time from full discharge	Full recharge - 12 to 14 hours
Recharge current	Max 0.4 amps at 15 V DC
Battery Charger Power	120 V AC, single phase, 50-60 cycle, 1.5 Amps

NOTE: * When equipped with 10.2 eV Probe with SPAN set at 9.8 and measuring benzene. Values will vary for other compounds and conditions.

TABLE 1-2
EQUIPMENT SIZE & WEIGHT

Quantity	Name	Overall dimensions cm (inches)	Weight, kg (lbs.)	Volume, cm ³ (cu. ft.)
1	Trace Gas Analyzer (stored condition)	21W x 13D x 24H (8 1/4 x 5 3/16 x 9 1/2)	3.8 (8.2)	6552 (0.23)
	Probe Assembly	6.3 Diam x 28.5L (2 1/2 x 11 1/4)	0.55 (1.2)	564 (0.02)
	Readout Assembly	21W x 13D x 16.5H (8 1/4 x 5 3/16 x 6 1/2)	3.2 (7.0)	4504 (0.16)
1	Battery Charger with cord	10W x 12.7D x 9L (4 x 5 x 3 1/2)	0.4 (0.9)	1143 (0.04)

SECTION 2

OPERATION

2.1 INTRODUCTION/UNPACKING

Unpack the instrument carefully. The carton will contain the housing, straps, battery charger, additional probes, regulator and cylinder if ordered, spare parts, supplies and a manual. Be sure all items are removed before discarding the carton.

Attached to the instrument is a warranty card which should be filled out completely and returned to HNU Systems.

2.2 CONTROLS AND INDICATORS

The controls and indicators are located on the front panel of the readout assembly (see Figure 2-1) and are listed and described in Tables 2-1 and 2-2.

3 OPERATING PROCEDURES

The following procedures are to be used in operating the analyzer:

- a. Unclamp the cover from the main readout assembly.
- b. Remove the inner lid from the cover by pulling out the two fasteners.
- c. Remove the probe, handle and cable from the cover. Attach the handle to the front part of the probe.
- d. Connect the probe cable plug to the 12 pin keyed socket on the readout assembly panel. Carefully match the alignment slot in the plug to the key in the connector. Screw down the probe connector until a distinct snap and lock is felt.
- e. Screw the probe extension into the probe end cap. The probe may be used without the extension if desired.
- f. Set the SPAN control for the probe being used (10.2, 9.5, or 11.7 eV) as specified by the initial factory calibration or by subsequent calibrations.

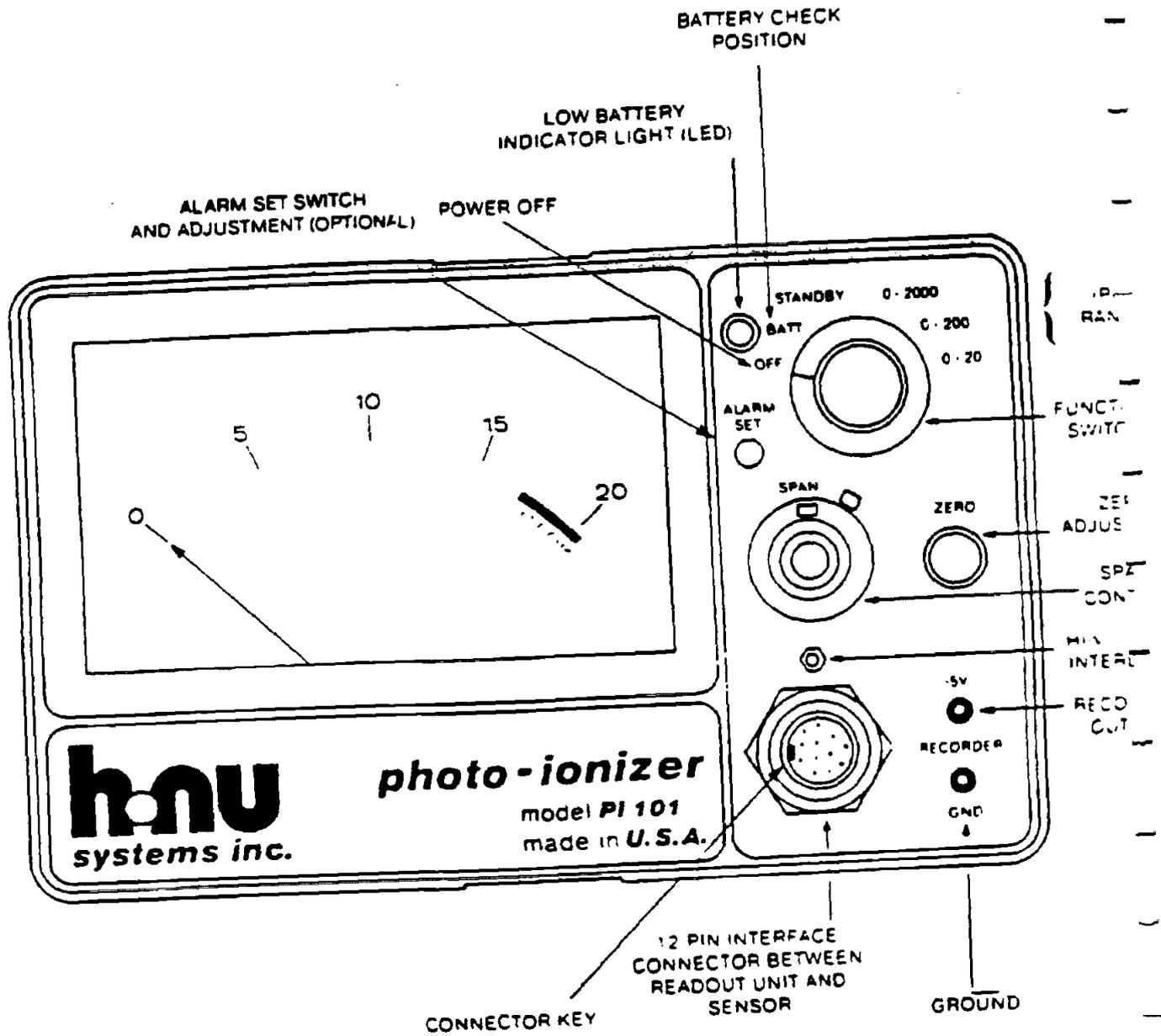


FIGURE 2-1
CONTROLS AND INDICATORS

TABLE 2-1
CONTROLS

Name	Position	Function
Function Switch	---	Controls the operation of the analyzer
	OFF	All operations OFF
	BATT (battery check)	Checks the condition of the battery. If the meter needle is in the green arc, the battery is charged. If not the battery should be recharged. Charging can be done in any position, best in OFF; see directions on charger.
	STANDBY	All electronics ON, ultraviolet (UV) light source OFF. This position conserves power and extends battery life. This position is used to set the analyzer zero position. (i.e. no UV light, no signal)
	0-2000	Sets range of meter at 0-2000 ppm.
	0-200	Sets range of meter at 0-200 ppm.
	0-20	Sets range of meter at 0-20 ppm.
ZERO	---	With the function switch in STANDBY position, this potentiometer is used to adjust the reading to zero.

NOTE: See Figure 2-1 for locations.

TABLE 2-1 cont.

SPAN	---	This vernier potentiometer is used to set the gain of the amplifier to give direct readings of the trace gas concentrations in ppm. The whole number of the setting appears in the window of the control, decimal appears on the dial. A lock secures it at a specific setting.
HI-VOLTAGE	---	This is a normally open microswitch.
	Open	Switch is open when cable not connected, disconnecting high voltage for the UV lamp from the 12 pin connector as a safety precaution.
	Closed	Switch is automatically closed when the cable is attached. This switch may also be closed manually during maintenance checks of the readout assembly without the probe cable attached.
ALARM SET (optional)	---	Potentiometer with screwdriver adjustment. Turns the audible alarm ON or OFF and sets the ppm level at which the alarm sounds. If alarm is low limit, it sounds when measured ppm falls below this value. If alarm is high limit it sounds when measured ppm exceeds this value.

NOTE: See Figure 2-1 for locations.

TABLE 2-2
INDICATORS AND DISPLAYS

Name	Function
Low Battery Indicator Light (red light) (see NOTE)	Illuminates when battery is discharged, indicates need for recharge. Do not use unit when this light is ON. Readings may be taken while battery is being recharged.
Meter (see NOTE)	Indicates concentration of measured gas.
Recorder (optional) (see Figures 2-1 And 8-3)	Provides a record of readings while analyzer operates unattended. Recorder inputs 0 to -5 V DC.

NOTE: See Figure 2-1 for locations.

SECTION 2.3, OPERATING PROCEDURES cont.

- g. Turn the function switch to the BATT (battery check) position. The needle on the meter will go to the green zone if the battery is fully charged. If the needle is below the green arc or if the Low Battery Indicator comes on, the battery must be recharged before the analyzer is used.
 - h. Set SPAN pot to the desired value based on the gas to be used.
 - i. Turn the function switch to the STANDBY position. Turn the zero adjustment until the meter needle is at zero.
 - j. Calibrate the instrument daily as described in Section 3. Calibration on the selected operating range is desirable.
 - k. If equipped with optional alarm, set or check the alarm setting at the level desired. Turn the function switch to the desired range, turn the zero adjustment control so the meter needle moves upscale thru the desired value. This simulates real conditions. Observe the reading when the alarm sounds. Adjust the ALARM SET, if required, with a screw driver. Turn the function switch to the STANDBY position and reset the zero position (para. h. above). If the range is to be changed, the alarm must be reset on that range.
 - l. To operate with optional recorder, add the recorder bracket (see Figure E-3). Remove the plug in the analyzer case and insert power cord into the recorder. Then connect the signal leads to the appropriate jacks in the control module. The recorder is now operational.
- NOTE: Ranges must be marked on the chart as the recorder prints the meter display as % of Full Scale.
- m. Turn the function switch to the appropriate operating position. Start with the 0-2000 position and then switch to the more sensitive ranges. The UV light source should be on, confirmed by briefly looking into the probe to observe a purple glow from the lamp.

WARNING

Do not look at the light source closer than 6 inches with unprotected eyes. Observe only if necessary, then only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

SECTION 2.3, OPERATING PROCEDURES cont.

- n. The analyzer is now operational.
- o. Hold the probe so that the extension is at the point where the measurement is to be made. The instrument measures the concentration by drawing the gas in at the end of the extension, through the ionization chamber, and out the handle end of the probe.

WARNING

The instrument measures gases in the vicinity of the operator and a high reading when measuring toxic or explosive gases should be cause for action for operator safety.

- p. Take the reading or readings as desired taking into account that air currents or drafts in the vicinity of the probe tip may cause fluctuations in readings. Change the ranges as required.
- q. Check battery condition as required. If the Low Battery Indicator comes on, turn analyzer off and recharge.

CAUTION

Use only in an emergency with a low battery when on battery charge.

SECTION 2.3, OPERATING PROCEDURES cont.

- r. After completion of use, check battery condition as described in para. g.
- s. Turn function switch to OFF position.
- t. When not operating, leave analyzer in assembled condition, and connected to battery charger.
- u. When transporting, disassemble probe and extension from readout assembly and return equipment to its stored condition.
- v. In case of emergency, turn function switch to OFF position.

2.4 BATTERY CHARGE

Check the battery charge as described in paragraph 2-3 g during each period of operation, at least once daily. If the battery is low as indicated by the meter reading or the warning indicator, it is necessary to recharge the battery.

To charge the battery, first insert the mini phone plug of the charger into the jack, J6, on the side of the bezel adjacent to the meter. Then insert the charger plug into a 120 or 230 V AC single phase, 50-60 cycle outlet. To ensure that the charger is functioning, turn the function switch, S1, to the battery check (BATT) position. The meter should deflect full scale if the charger is working and connections properly made. For normal battery charging, leave the function switch in the OFF position.

The analyzer can be operated, however, while recharging by turning the function switch to the desired position. Such usage will extend the time required to completely recharge the battery. The battery charger is not Div. II approved.

NOTE: On all Sira approved PI 101s it is necessary to connect the probe assembly before turning on the instrument and re-charging. Without following this procedure the instrument will not show battery check.

SECTION 3

CALIBRATION

INTRODUCTION

The PI 101 Analyzer is designed for trace gas analysis in ambient air and is calibrated at HNU with certified standards of benzene, vinyl chloride and isobutylene. Other optional calibrations are available (e.g., ammonia, ethylene oxide, H₂S, etc.). Calibration data is given in the data sheet. If a special calibration has been done, the data is given in the Application Data Sheet, which notes the sample source, type of calibration (see Section 8, Appendix), and other pertinent information.

Good instrumentation practice calls for calibration on the species to be measured in the concentration range to be used. This procedure assures the operator that the analyzer is operating properly and will generate reliable data.

Some general points to consider when calibrating the PI 101 are that the analyzer is designed for operation at ambient conditions and therefore the gas standards used for calibration should be delivered to the analyzer at ambient temperatures and pressure and at the proper flow rates.

WARNING:

The PI 101 is a non-destructive analyzer; calibrations using toxic or hazardous gases must be done in a hood.

The frequency of calibration should be dictated by the usage of the analyzer and the toxicity of the species measured. If the analyzer has been serviced or repaired, calibration should be done to verify operation and performance. It is recommended that calibration be checked frequently at first (daily or every other day) and then regularly based on the confidence level developed.

The normal meter scaleplate is 0 to 20. If the scaleplate is different, refer to the Application Data Sheet. If there are questions, consult the HNU representative before proceeding with calibration check.

An accurate and reliable method of calibration check is to use an analyzed gas cylinder in a test setup as shown in Figure 3-1 and described below. Additional material on calibration is given in Section 8, Appendix.

3.2 ANALYZED GAS CYLINDER

- a. Concentration - The calibration gas cylinder is to contain the species of interest made up in an air matrix at or near the concentration to be analyzed. If the component is unstable in air, another matrix is to be used. The final calibration mixture should be similar to the sample the PI 101 will analyze. If the expected concentration is not known then a concentration should be chosen that will cause a scale displacement of 50 to 80% on the X10 range. Calibration on X10 range will provide accurate values on the X1 range as well.

For use on the 0-2000 range, a two-standard calibration is preferred: one at 70 to 85% of the linear range and the other at 25 to 35% of the linear range. With the linear range of approximately 600 ppm for most compounds these points would lie between 420 to 510 ppm and 150 to 210 ppm, respectively.

- b. Stability - The calibration gas must be stable within the cylinder during the period of use. If the calibration is required in the field, then use of a small cylinder is recommended. In addition, the choice of cylinder material in contact with the gas must be considered (steel, aluminum or teflon). If there are any questions, the operator should request stability and usage information from the gas supplier.

WARNING

Extreme care must be taken in the handling of gas cylinders. Contents are under high pressure. In some cases, the contents may be hazardous. Many gas suppliers will provide data sheets for the mixtures upon request.

- c. Delivery - The cylinder containing the calibration mixture must be connected to a proper regulator.

WARNING

Never open the valve on a gas cylinder container without a regulator attached.

Leak test all tank/regulator connections as well as the main cylinder valve to prevent toxic or hazardous materials from leaking into the work area. Care must be taken that the materials of construction of the regulator will not interact with the calibration gas.

One method of sampling the calibration gas is illustrated in Figure 3-1. Connect the cylinder to one leg of the tee, a flow meter to the opposite leg, and the probe to the third leg. The flow meter does not require a valve. If there is a valve, it must be left wide open. The flowmeter is only to indicate excess flow. Adjust the flow from the regulator such that only a little excess flow is registered at the flowmeter.

SECTION 3.2, ANALYZED GAS CYLINDER cont.

This insures that the PI 101 sees the calibration gas at atmospheric pressure and ambient temperature.

- d. Usage - Generally, a gas cylinder should not be used below 200-300 psi as pressure effects could cause concentration variations. The cylinder should not be used past the recommended age of the contents as indicated by the manufacturer. In case of difficulty, verify the contents and concentration of the gas cylinder.
- e. Alternate means of calibration are possible. For more information, contact the HNU Service Department.

3.3 PROBE

- a. Identify the probe by the lamp label. If a question exists, disassemble the probe and inspect the lamp. The energy of the lamp is etched into the glass envelope.
- b. Connect the probe to the readout assembly, making sure the red interlock switch is depressed by the ring on the connector.
- c. Set the SPAN pot to the proper value for the probe being calibrated. Refer to the calibration memo accompanying the probe.
- d. Check the Ionization Potential (IP) of the calibration gas to be used. The IP of the calibration gas must be at or below the IP of the lamp.
- e. Proceed with the calibration as described in Section 3.4. Check the calibration memo for specific data. If any questions develop, call the HNU representative.
- f. NOTE: The 11.7eV lamp has a special cleaning compound. Do not use water or any other cleaning compound with the 11.7 eV lamp. Do not interchange ion chambers, amplifier boards or lamps between probes. (See Section 5.2).

3.4 PROCEDURE

- a. Battery check - Turn the function switch to BATT. The needle should be in the green region. If not, recharge the battery.

SECTION 3.4, PROCEDURE cont.

- b. Zero set - Turn the function switch to STANDBY. In this position the lamp is OFF and no signal is generated. Set the zero point with the ZERO set control. The zero can also be set with the function switch on the X1 position and using a "Hydrocarbon-free" air. In this case "negative" readings are possible if the analyzer measures a cleaner sample when in service.
- c. 0-20 or 0-200 range - For calibrating on the 0-20 or 0-200 range only one gas standard is required. Turn the function switch to the range position and note the meter reading. Adjust the SPAN control setting as required to read the ppm concentration of the standard. Recheck the zero setting (step b.). If readjustment is needed, repeat step c. This gives a two-point calibration; zero and the gas standard point. Additional calibration points can be generated by dilution of the standard with zero air if desired (see Section 8).
- d. 0-2000 range - For calibrating on the 0-2000 range, use of two standards is recommended as cited in Section 3.2a. First calibrate with the higher standard using the SPAN control for setting. Then calibrate with the lower standard using the ZERO adjustment. Repeat these several times to ensure that a good calibration is obtained. The analyzer will be approximately linear to better than 600 ppm, (see Figure 3-2). If the analyzer is subsequently to be used on the 0-20 or 0-200 range, it must be recalibrated as described in steps b. and c. above.
- e. Lamp cleaning - If the span setting resulting from calibration is 0.0 or if calibration cannot be achieved, then the lamp must be cleaned (see Section 5.2).
- f. Lamp replacement - If the lamp output is too low or if the lamp has failed, it must be replaced (see Section 5.3).

3.5 CALIBRATION CHECKING

Rapid calibration checking in the field can be accomplished by use of a small disposable cylinder containing isobutylene. Immediately after a calibration has been completed, a reading is taken on a special isobutylene standard. This provides a reference concentration measurement for later checking in the field. This can be done at any time with a portable cylinder containing this same special standard, using this reference reading as a check, and making adjustments to the analyzer if necessary. In effect, this is an indirect method of calibration, one maintaining the calibration to give direct readings for the original gas mixture, but using the portable isobutylene cylinder. Details are given in Section 8.2 of the Appendix.

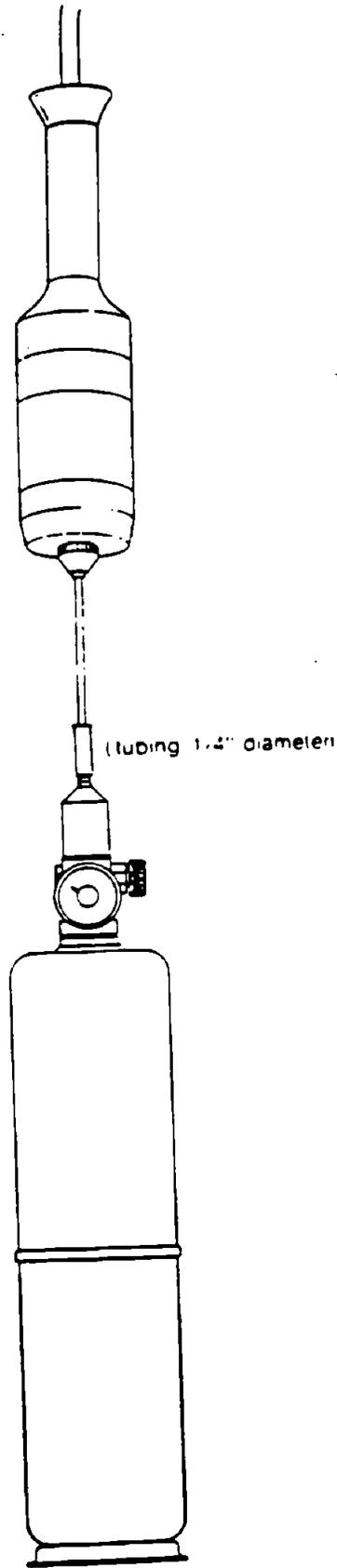


FIGURE 3-1
CALIBRATION TEST SET UP

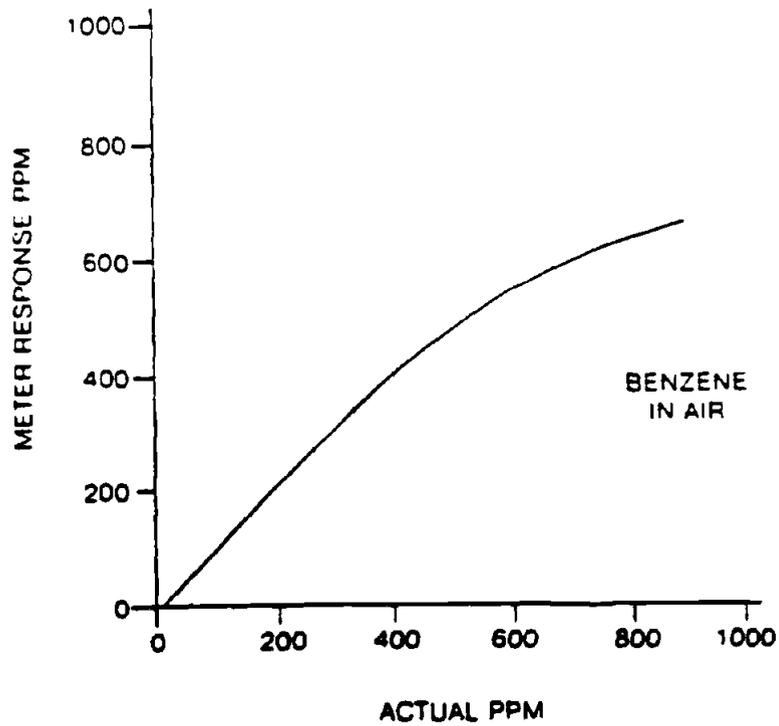
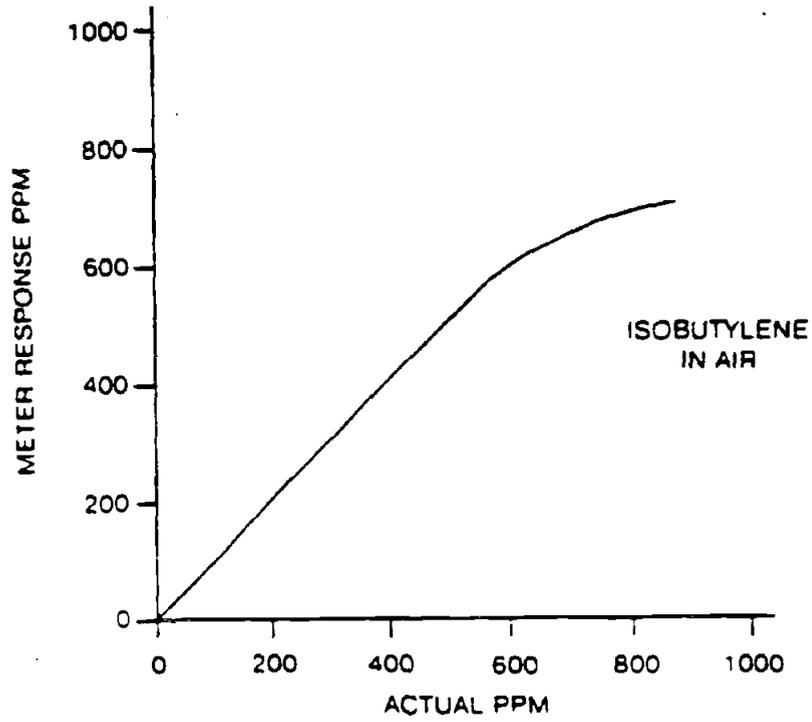


FIGURE 3-2
TYPICAL CALIBRATION CURVES (10.2 eV)

SECTION 4

FUNCTIONAL DESCRIPTION

4.1 PRINCIPLE OF OPERATION

The analyzer measures the concentration of trace gases present in the atmosphere by photoionization. Photoionization occurs when an atom or molecule absorbs a photon of sufficient energy to release an electron and become a positive ion. This will occur when the ionization potential of the molecule in electron volts (eV) is less than the energy of the photon. The source of photons is an ultraviolet lamp with an energy of either 9.5, 10.2 or 11.7 eV.

The detection process is shown in Figure 4-1. Sample gases enter through the inlet into the ion chamber and are exposed to photons emanating from the ultraviolet lamp. Ionization occurs for those molecules having ionization potentials near to or less than that of the lamp.

A positive-biased polarizing electrode causes these positive ions to travel to a collector electrode in the chamber. Thus the ions create an electrical current which is amplified and displayed on the meter.

This is proportional to the concentration of trace gas present in the ion chamber and to the sensitivity of that gas to photoionization.

In service, the analyzer is first calibrated with a gas of known composition equal, close to or representative of that to be measured.

4.2 IONIZATION POTENTIALS

Gases with ionization potentials near to or less than that of the lamp will be ionized. These gases will thus be detected and measured by the analyzer.

Gases with ionization potentials higher than that of the lamp will not be detected.

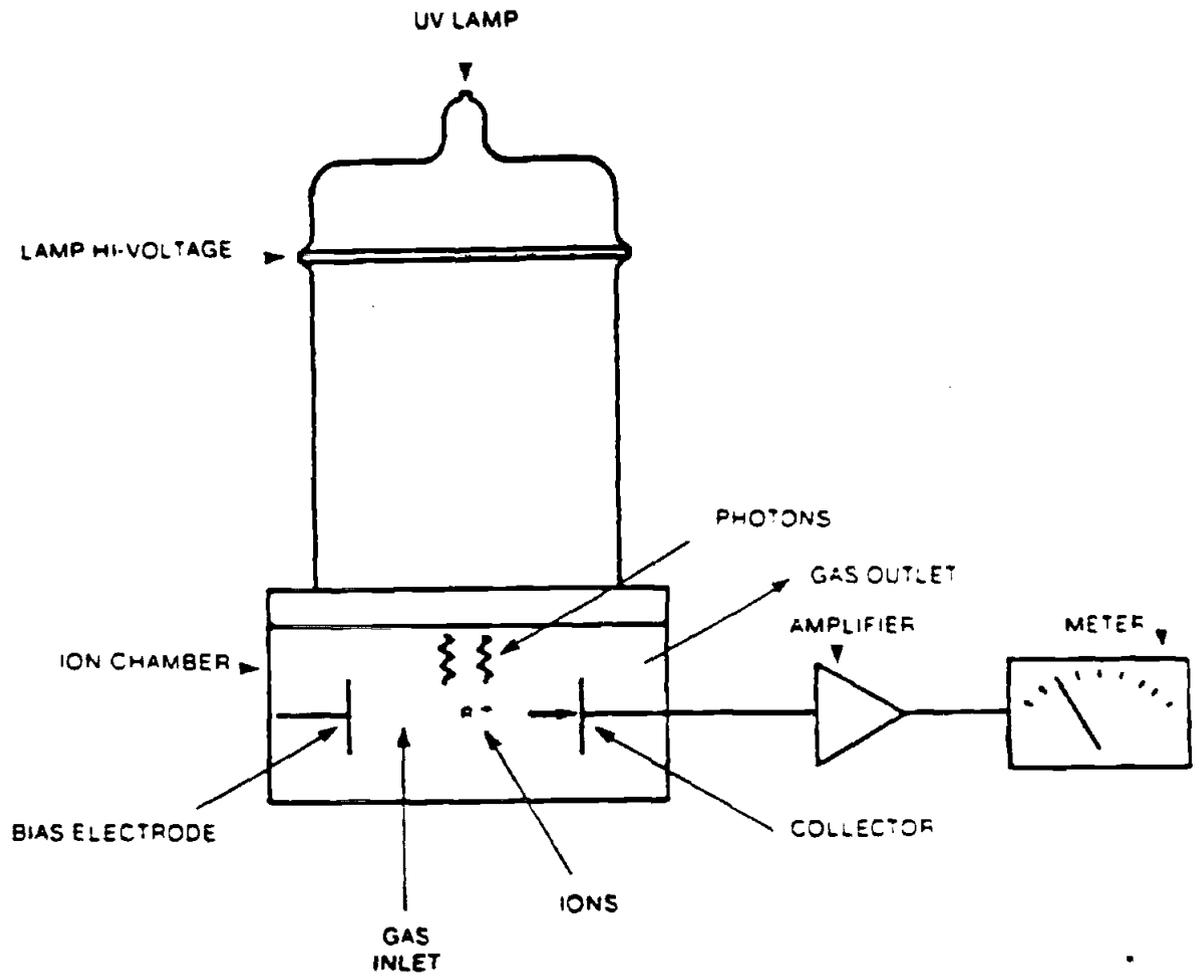
Ionization potentials for various atoms, molecules and compounds are given in Tables 8-1 thru 8-13 in Section 8, Appendix.

The ionization potential of the major components of air, i.e., oxygen, nitrogen, and carbon dioxide, range from about 12.0 eV to about 15.6 eV and are not ionized by any of the three lamps.

Gases with ionization potentials near to or slightly higher than the lamp are partially ionized, with low sensitivity.

4.3 IONIZATION SENSITIVITY

The amount of ionization of a species of gas exposed to photons, its sensitivity, is a characteristic of that particular species. This is illustrated in Table 4-1 for a number of chemical groupings and in Table 8-14 for a large number of individual species when exposed to photons from a 10.2 eV lamp.



**FIGURE 4-1
DETECTION PROCESS**

Section 4.3, SENSITIVITY cont..

The species with the higher values are more sensitive to the 10.2 eV photons than are those with lower values. For example, referring to data in Table 8-14, an analyzer calibrated for benzene, when measuring a sample containing 10 ppm of benzene, will read 10.0 and when measuring a sample containing 10 ppm of vinyl chloride will read 5.0. This shows the lower sensitivity of the vinyl chloride. Similar conditions are the case for the 9.5 and 11.7 eV lamps.

4.4 CALIBRATED PROBES AND SELECTIVITY

The standard probe provided with the analyzer contains a 10.2 eV lamp. Optional probes containing lamps of 9.5 and 11.7 eV permit selective determination or exclusion of species.

The probe with the 9.5 eV lamp permits measurement of species having IP values lower than 9.5 eV in the presence of interfering species with IP values above 9.5 eV.

The probe with the 11.7 eV lamp permits measurement of species with IP values above 10.2 up to approximately 11.7 eV.

The probes with different lamps are interchangeable in use within individual readout assemblies for different applications. The amplifier and ion chamber in the probe are selected for the specific eV lamp. Lamps of different eV ratings cannot be interchanged between probes. Examples of selective application of these probes is given in Table 4-2. Additional applications of the use of the probes are described in the sections that follow and illustrated in Figure 4-2. Further examples are given (without discussion) in Table 4-3. Re-zeroing is performed after each probe interchange.

4.5 10.2 eV PROBE

The 10.2 eV probe is the standard probe used with the Trace Gas Analyzer. The approximate span settings for a 10.2 eV probe that would give direct readings of the amounts of trace gas of a particular species in a sample is given in Table 8-14. For example, when the span control is set at 4.3 the analyzer will read 10 ppm when measuring a sample containing 10 ppm of vinyl chloride. These span settings will vary with the condition of the lamp. Application of the 10.2 eV probe is illustrated in examples "a", "b", and "c" in Figure 4-2. In each case the trace gas (or gases) is contained in a standard atmosphere.

Example "a" shows the use of the 10.2 eV probe to measure Vinyl Chloride (IP=9.995) by itself.

Example "b" shows the use of the 10.2 eV probe to measure Vinyl Chloride (IP=9.995) in the presence of a second gas, Acetylene (IP=11.4). The acetylene is not ionized and the probe gives a direct reading of the Vinyl Chloride above.

Example "c" shows the use of the 10.2 eV probe to measure Isoprene (IP=9.08) by itself. A 9.5 eV probe may also be used but is less sensitive. the 10.2 eV probe is recommended.

RELATIVE PHOTOIONIZATION SENSITIVITIES FOR GASES

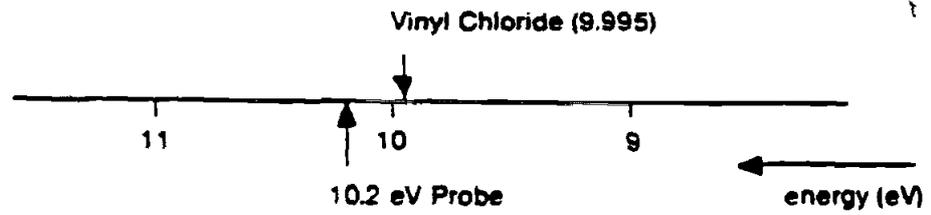
Chemical Grouping	Relative Sensitivity (see NOTE)	Examples
Aromatic	10	Benzene, Toluene, Styrene
Aliphatic Amine	10	Diethylamine
Chlorinated Unsaturated	5-9	Vinyl Chloride, Vinylidene Chloride, Trichloroethylene
Carbonyl	7-9	MEK, MiBK, Acetone, Cyclohexanone
Unsaturated	3-5	Arolein, Propylene, Cyclohexanone, Allyl Alcohol
Sulfide	3-5	Hydrogen Sulfide, Methyl Mercaptan
Paraffin (C5-C7)	1-3	Pentane, Hexane, Heptane
Ammonia	0.3	
Paraffin (C1-C4)	0	Methane, Ethane

NOTE: Relative sensitivity = meter reading when measuring 10 ppm of the listed gas with instrument with 10.2 eV probe calibrated for 10 ppm of benzene, span pot setting = 9.8 for direct reading of benzene.

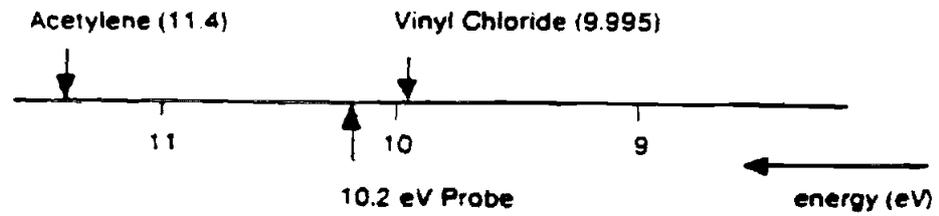
TYPICAL APPLICATIONS OF INTERCHANGEABLE PROBES

Compound	Ionization potentials (eV)	Relative Sensitivity	
		9.5/10.2 eV	11.7/10.2 eV
p-Xylene	8.44	0.10	0.104
p-Chlorotoluene	8.70	0.09	0.112
Toluene	8.82	0.09	0.112
o-Chlorotoluene	8.83	0.075	0.112
Ethyl Acetate	9.19	0.075	0.112
Benzene	9.24	0.10	0.10
Methyl Mercaptan	9.24	0.10	0.072
Pyridine	9.32	0.075	0.122
Allyl Alcohol	9.67	0.10	0.112
Crotonaldehyde	9.88	0.075	0.104
Amyl Alcohol	9.80	0.09	0.116
Cyclohexane	9.88	0.075	0.104
Vinyl Chloride	9.95	0.085	0.112
Butanol	10.94	0.09	0.176
Ammonia	10.15	0.06	0.160
Acetic Acid	10.37	0.04	0.560
Ethylene	10.52	0.0	0.320
Ethylene Oxide	10.56	0.0	0.298

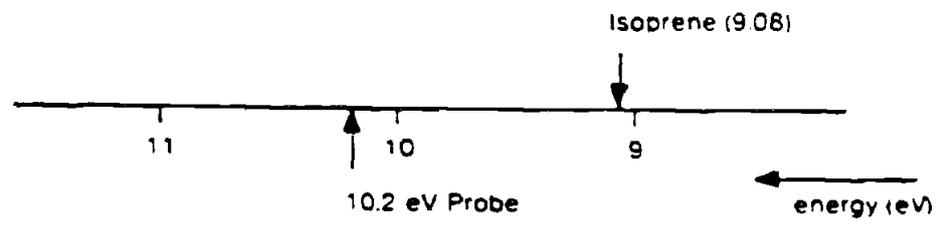
$$\text{Relative sensitivity} = \frac{\text{Response with 9.5 or 11.7 eV probe}}{\text{Response with 10.2 eV probe}}$$



a. 10.2 eV probe measures Vinyl Chloride (IP = 9.995)

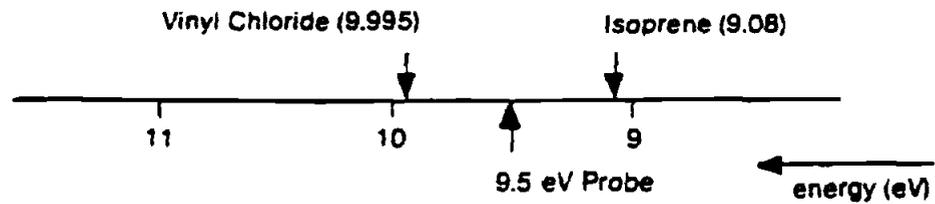


b. 10.2 eV probe measures Acetylene (IP = 11.4) and Vinyl Chloride (IP = 9.995)

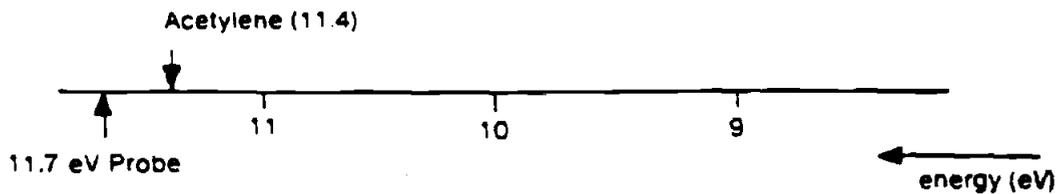


c. 10.2 eV probe measures Isoprene (IP = 9.08)

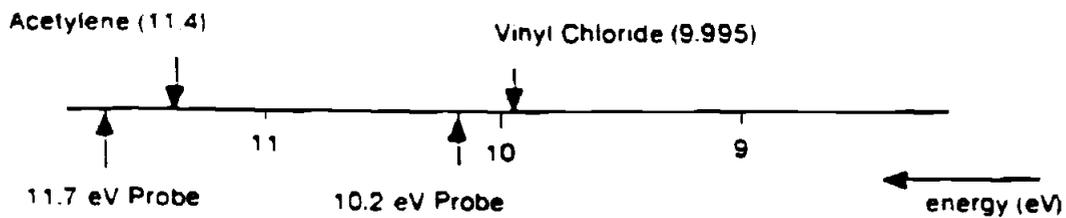
FIGURE 4-2
APPLICATION OF PROBES



10. 9.5 eV Probe measures Isoprene (IP = 9.08)
but not Vinyl Chloride (IP = 9.995)



11. 11.7 eV Probe measures Acetylene (IP = 11.4)



12. 11.7 eV Probe measures both Acetylene (IP = 11.4)
and Vinyl Chloride (IP = 9.995)

10.2 eV Probe measures Vinyl Chloride
but not Acetylene

Difference between the two readings is the
measure of Acetylene

FIGURE 4-2
APPLICATION OF PROBES CONTINUED

TABLE 4-3

PROBE APPLICATION EXAMPLES

Application	Recommended Probe
Styrene (IP = 8.47) Alone	10.2
Hexane (IP = 10.48) Alone	10.2
Formaldehyde (IP = 10.87) Alone	11.7
Styrene/Hexane Together	10.2 and 9.5 Use 10.2 to measure total, 9.5 to measure Styrene, difference will be the concentration of Hexane.
Formaldehyde/Styrene Together	10.2 and 11.7 Use 11.7 to measure total, 10.2 to measure Styrene, difference will be the concentration of Formaldehyde

SECTION 4 cont.

6 9.5 eV PROBE

The 9.5 eV probe is used to measure gases with $IP < 9.5$ when it is necessary to exclude gases that may be present having $IP > 9.5$ eV and < 10.2 eV. This is illustrated by example "d" in Figure 4-2. Here a 9.5 eV probe is used to measure Isoprene ($IP = 9.08$) in the presence of Vinyl Chloride ($IP = 9.995$).

Gain settings for a 9.5 eV probe to give direct readings for various species are given in Table 8-15.

4.7 11.7 eV PROBE

The 11.7 eV Probe is used to measure trace gases with $IP > 10.2$ eV but less than 11.7 eV. The use of this probe by itself is illustrated in example "e". Here the 11.7 eV probe is used to measure Acetylene ($IP = 11.4$ eV). The use of this probe in conjunction with a 10.7 eV probe is illustrated in example "f". In this case, two gases are present, Acetylene ($IP = 11.4$) and Vinyl Chloride ($IP = 9.995$). The objective is to obtain a measurement of the Acetylene alone.

The 11.7 eV probe measures the total presence of both Acetylene and Vinyl Chloride together. The 10.2 eV probe measures just the Vinyl Chloride, excluding the Acetylene. The difference between the two readings is the measure of the Acetylene.

Gain settings for the 11.7 eV probe to give direct readings for various species are given in Table 8-15.

4.8 EQUIPMENT DESCRIPTION

The components of the analyzer are located in the probe and the readout assembly (see Figures 4-3 and 4-4). The ion chamber, UV light source, amplifier board, and fan are located in the probe assembly. The battery, the power supply board, and the meter are located in the readout assembly. The probe and the readout assembly are connected by an 800 cm (32") cable.

The fan draws gas in through the probe and ion chamber. The flow rate is approximately 100 cubic centimeters per minute.

Small variations in the flow rate do not affect the measurement. A major obstruction to the flow, however, will prevent proper operation and lengthen response time. The fan cannot draw a sample from any distance or across a pressure drop.

The output from the ion chamber is amplified and read out on the meter.

Voltage for the light source, ion chamber, amplifier and fan is provided from a DC converter on the power supply board. The battery provides the source of power for the converter. The positive side of the battery is grounded.

Section 4.8, EQUIPMENT DESCRIPTION cont.

The input signal from the ion chamber enters at connector P1/J1 (see schematic Figure 4-5), goes to transistor Q1 and amplifier A1. The zero adjustment setting on the control panel enters thru pins 3 and C on P2/J2, thence to the transistor Q1.

Power for the amplifier enters on pins D and F respectively. Span control adjustment from the control panel enters at pin B, signal output at pin E, and ground connector at pin J.

The output signal from the amplifier goes thru pin E in the cable connector P3/J3 to pad 11 on the power supply board, to the resistor network R39 thru R49, including the adjustable pot R48. From there it goes to the meter through the function switch on the control panel.

Connections from the resistor network through the function switch serve to set the operating range of the meter. Input to the span control potentiometer comes from this same network through the function switch. The output of the span control pot provides feedback control to the amplifier through pin H on the cable, pin B on the amplifier board, and feedback resistor R5 to the amplifier input.

Power for the UV lamp, D1, is provided by rectifier networks containing CR4-9 operating from the red and white terminals of transformer T1. Voltage for the lamp (pad 22 on the power supply board or J3 pin D, Figure 4-6) will be as follows for the several different conditions that may exist.

Condition	Voltage, V DC
Probe connected, lamp operating properly	-350 to -450
Probe connected, lamp not operating properly	-1100 to -1200
Probe not connected, high voltage switch not depressed	0 to -300
Probe not connected, high voltage switch depressed manually	-1100 to -1200

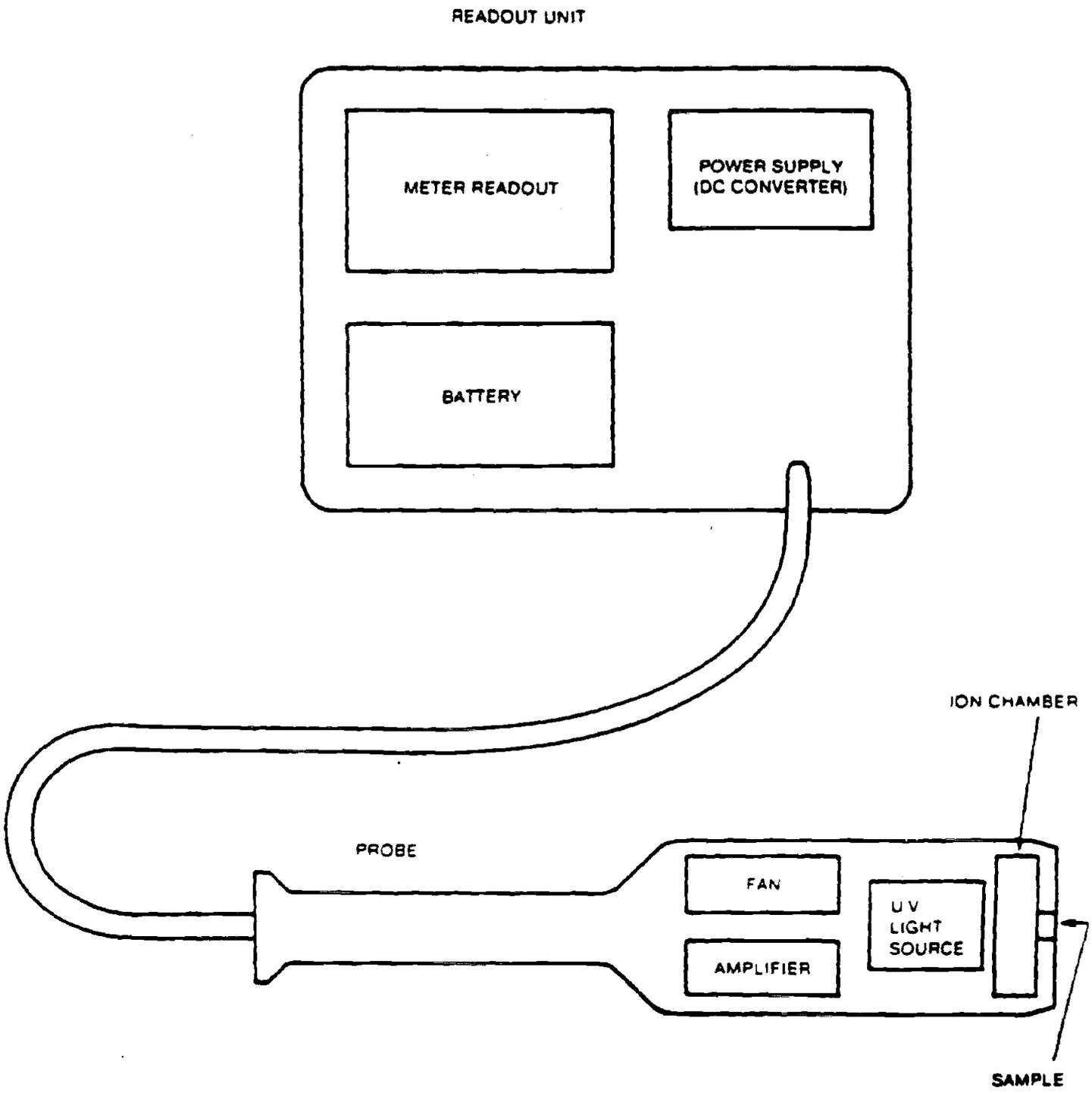
Power for the ion chamber is provided by rectifier network CR2 and 3 operating from terminals 6 and 7 of T1 and voltage regulator Z1. Power for the amplifier is provided by rectifier networks CR13-16 operating from terminals 4,5 and 8 of T1. Power for the fan motor is provided by rectifier network CR18-21 operating from terminals 1, 2 and 3 of transformer T1. Conversion of the DC from the battery for input power to T1 is accomplished by Z2. Power for a recorder is available at connector J7.

Section 4.8, EQUIPMENT DESCRIPTION cont.

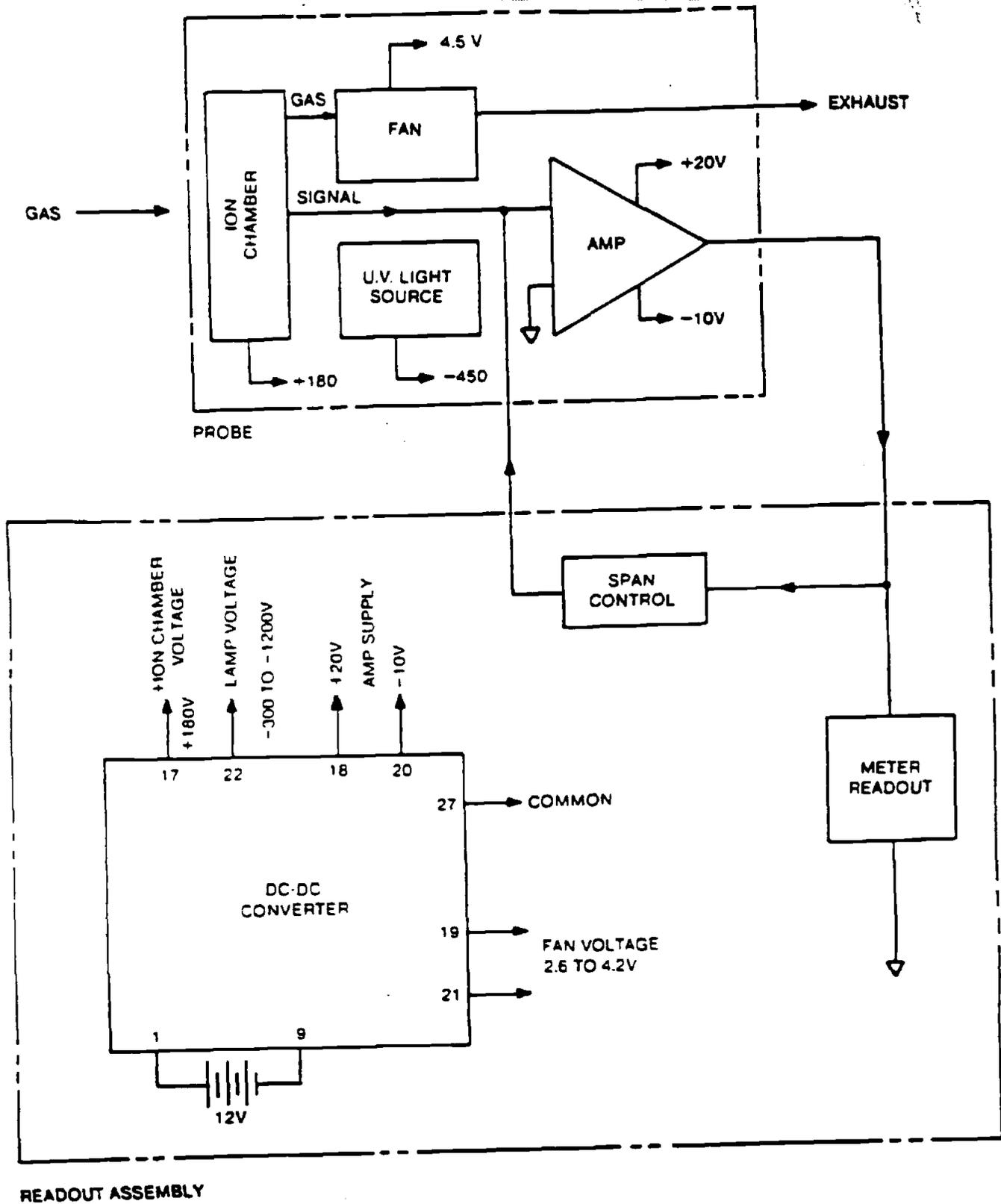
D3 provides indication if the battery voltage falls below the prescribed level of 11.23 V DC. J6 provides for connection of the battery charger. The six bank switch, S1, is the function switch. Microswitch S2 disables the high voltage power to the cable connector when disconnected.

The alarm board (optional) is connected to the power supply board by the cable containing connector P6/J6. The amplifier output signal, pin 9 on P6/J6 (see schematic Figure 4-6), goes to one input of amplifier U1 (see schematic Figure 4-5).

The output from the alarm set control on the front panel, pin 4 on P5/J6, goes to the second input of U1. The output from U1 operates the audible alarm through Q3 or Q2. Only one of these is connected at the factory to give low alarm or high alarm, respectively, as requested by the user. The alarm will operate when the signal falls or rises above this threshold. Reference power for the alarm setting enters the board at pin 2 and power for the amplifier and transistors Q1 thru Q3 enters at pin 5. The battery charger provides 15.0 V DC for recharging.

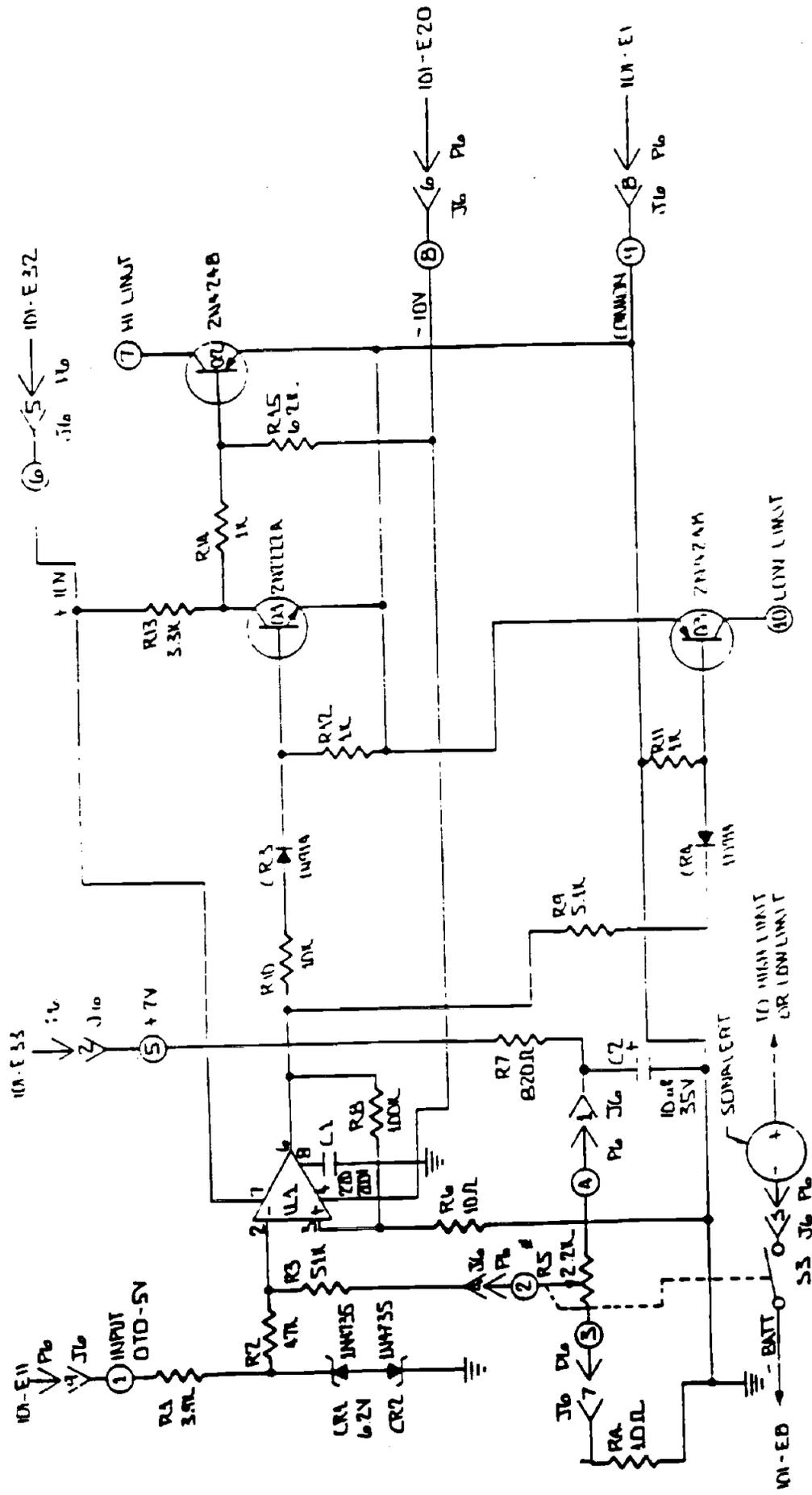


**FIGURE 4-3
BLOCK DIAGRAM
COMPONENT LOCATION**



NOTE: ALL VOLTAGES SHOWN ARE NOMINAL VALUES.

**FIGURE 4-4
BLOCK DIAGRAM
ELECTRICAL CONNECTIONS**



NOTE:
 1) ALL RESISTORS ARE 1/4W 5% OR 1% 5%.
 2) FOR BOARDMASTER SEE HWG DWG DB110584
 3) FOR P.C. MASTER SEE HWG DWG MB100583
 4) FOR SILKSCREEN SEE HWG DWG MB100585
 5) R5, S1 INDICATED ON FRONT PANEL

SECTION 5
MAINTENANCE

5.1 INTRODUCTION

Maintenance of the analyzer consists of cleaning the lamp and ion chamber, replacement of the lamp or other component parts or subassemblies.

WARNING: Turn the function switch on the control panel to the OFF position before any disassembly. Otherwise, high voltage of 1200 V DC will be present.

WARNING: Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

WARNING: Do not look at the light source from any closer than 6 inches with unprotected eyes. Observe only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

CAUTION: Do not interchange lamps of different eV ratings in a probe. Amplifier and components are selected for a specific eV lamp. A probe with the wrong lamp will not operate properly.

5.2 UV LAMP AND ION CHAMBER CLEANING

During periods of operation of the analyzer, dust or other foreign matter could be drawn into the probe forming deposits on the surface of the UV lamp or in the ion chamber. This condition is indicated by meter readings that are low, erratic, unstable, non-repeatable, or drifting, or show apparent moisture sensitivity. These deposits interfere with the ionization process and cause erroneous readings. Check for this condition monthly or as required. Cleaning can be accomplished as follows:

- a. Disassemble the probe and remove the lamp and ion chamber (see Section 5.5). Exercise great care in doing so to prevent inadvertent damage to these components.
- b. First check the lamp window for fouling by looking at the surface at an incident angle. Any deposits, films or discoloration may interfere with the ionization process. Clean the window as follows:

1) 9.5 and 10.2 eV lamps

- a) First clean by rubbing gently with lens tissue dipped in a detergent solution.
- b) If this does not remove deposit, apply a small amount of HNU cleaning compound (PA101534) directly onto the lens of the lamp and spread evenly over surface with a non-abrasive tissue (e.g. Kim-Wipe) or a lens tissue.
- c) Wipe off compound with a new tissue.
- d) Rinse with warm water (about 80 degrees F) or damp tissue to remove all traces of grit or oils and any static charge that may have built up on the lens. Dry with new tissue.
- e) Reinstall lamp in detector and check analyzer operation.
- f) If performance is still not satisfactory replace the lamp. See Section 5.3 and Section 6.

2) 11.7 eV lamp

- a) Clean by putting a freon or chlorinated organic solvent on a tissue and rubbing gently.
 - b) DO NOT CLEAN THIS LAMP WITH WATER OR ANY WATER MISCIBLE SOLVENTS (methanol or acetone). It will damage the lamp.
 - c) DO NOT USE THE CLEANING COMPOUND used for the 9.5 and 10.2 eV lamps under any circumstances on the 11.7 eV lamp.
- c. Then inspect the ion chamber for dust or particulate deposits. If such matter is present, the chamber can be cleaned by removing the outer Teflon ring, and the four screws holding the retaining ring. Carefully move the retaining ring aside (NOTE: this is soldered) and remove the screen. A tissue or cotton swab, dry or wetted with methanol, can be used to clean off any stubborn deposits. The assembly can also be gently swirled in methanol and dried gently at 50-60 degrees C for approximately a half hour. No liquid must be present at reassembly as this would affect the performance. Do not clean the ion chamber with the HNU cleaning compound cited above in para. b.1)b).
- d. Reassemble the probe and check analyzer operation.
 - e. If performance is still not satisfactory replace the lamp. See Section 5.3.

5.3 LAMP REPLACEMENT

To replace the lamp, disassemble the probe, remove the old lamp, install a new one of the same eV rating and reassemble.

WARNING

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise, high voltage of 1200 V DC will be present.

CAUTION

Do not exchange lamps of different eV ratings in a probe. Amplifier and components are selected for a specific eV lamp. A probe with the wrong lamp will not operate properly.

Set the SPAN pot to 9.8 for the 10.2 eV lamp. Remove the readout assembly case (see Section 5.6). Locate the gain control potentiometer, R48, on the power supply board as shown on Figure 6-1. Recalibrate the analyzer adjusting this potentiometer, R48, with a small screwdriver to obtain the specified ppm reading, leaving the SPAN pot set at 9.8.

For the 9.5 and 11.7 eV lamps see the Application Data Sheet or calibrations memo for the proper span pot settings and readings.

WARNING

Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

When calibration is accomplished, turn the analyzer OFF and replace the readout assembly in its case.

Adjustment of R48 potentiometer is used only when a new lamp is installed. At all other times adjustment is accomplished using the SPAN control potentiometer.

If calibration cannot be achieved, see Section 6, Troubleshooting.

SECTION 5 cont.

5.4 LAMP SIZE CHANGE

If different applications for the analyzer would require different size lamps, separate probes, each with its own eV lamp, must be used. A single readout assembly will serve for any of the probes. A change in probe will require resetting of the zero control and the span pot. Calibration should be checked to verify proper operation.

5.5 PROBE DISASSEMBLY/ASSEMBLY

WARNING

Turn the function switch on the control panel to the off position before disassembly. Otherwise high voltage of 1200 V DC will be present.

SECTION 5.5, PROBE DISASSEMBLY/ASSEMBLY cont.

Disconnect the probe cable connector at the readout assembly. Disassemble the probe by first removing the exhaust screw at the base of the probe adjacent to the handle (see Figure 5-1). Grasp the end cap in one hand and the probe shell in the other, gently pull to separate the end cap and the lamp housing from the shell.

Hold the lamp housing with the black end cap upright. Loosen the screws on the top of the end cap, separate the end cap and ion chamber from the lamp and lamp housing.

CAUTION

Care must be taken so that the ion chamber does not fall out of the end cap or the light source does not fall out of the lamp housing.

Turn the end cap over in the hand. Tap lightly on the top. The ion chamber should fall out of the end cap into the hand.

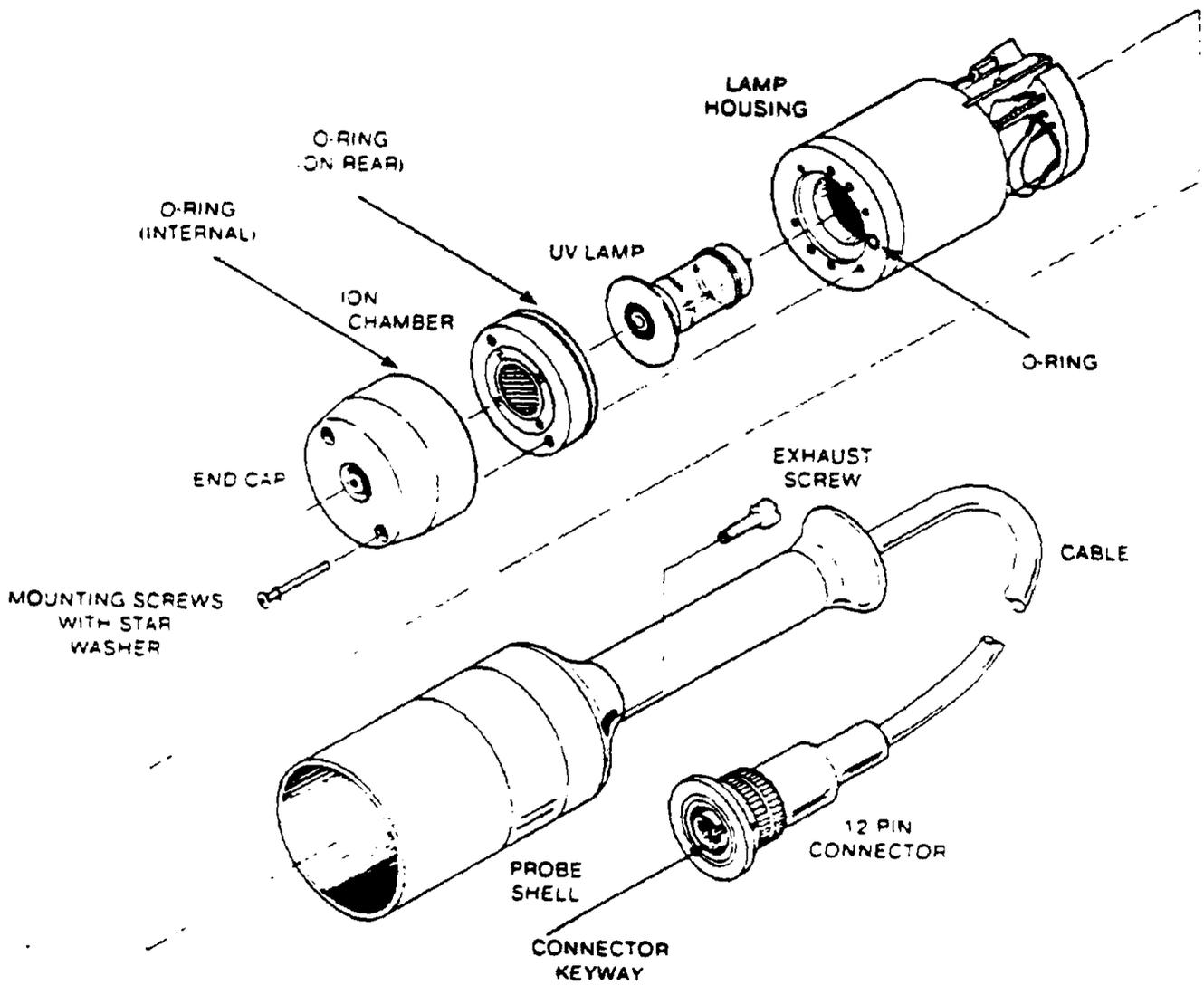
Place one hand over the top of the lamp housing and tilt slightly. The light source will slide out of the housing.

The amplifier board can be removed from the lamp source housing assembly (see Figure 5-2) by unsnapping the coaxial connector, J1, and then removing the retaining screw. The amplifier board will then slide out of the housing assembly.

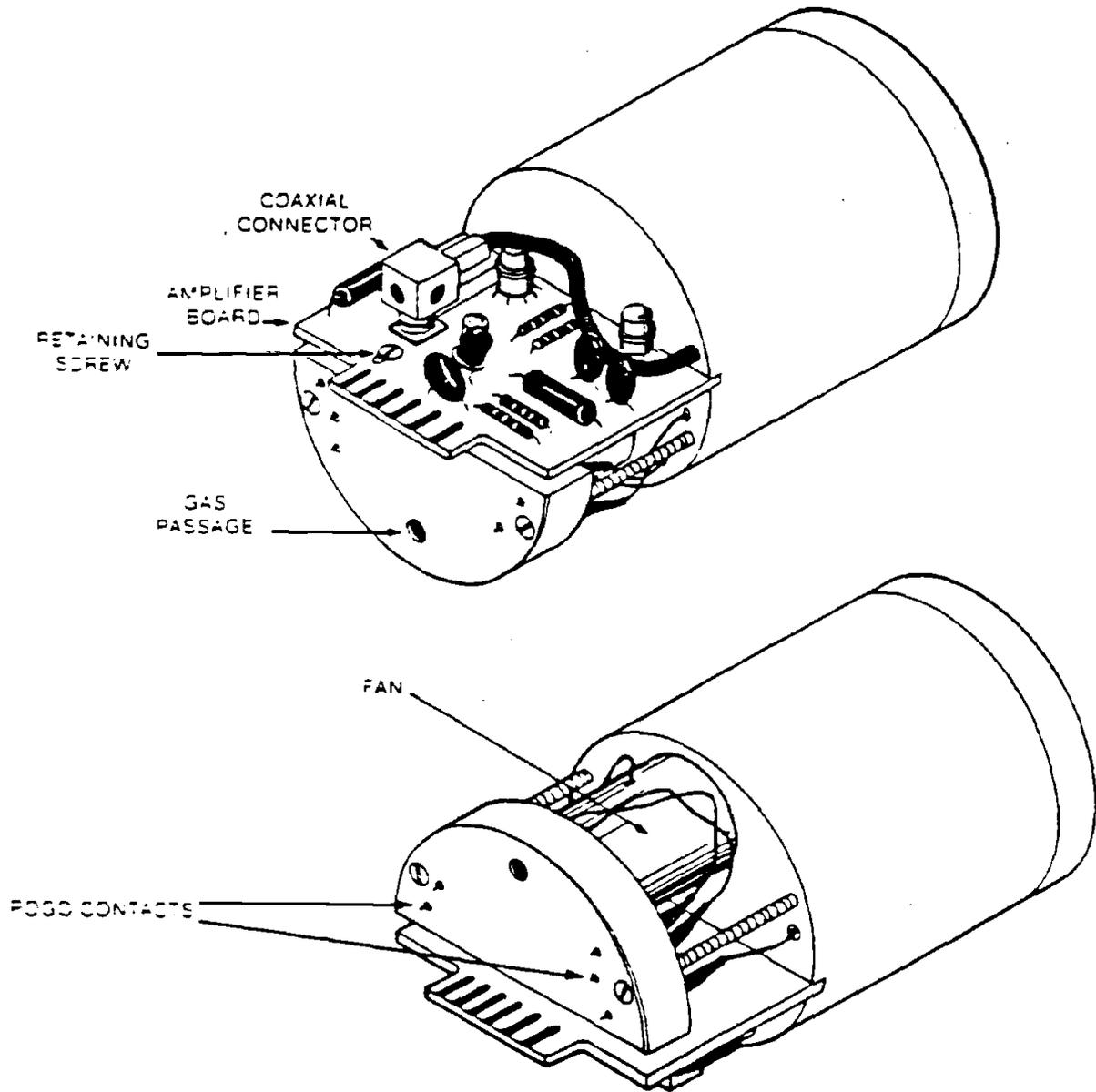
Reassemble the probe by first sliding the lamp back into the lamp housing. Place the ion chamber on top of the lamp housing, making sure that the contacts are properly aligned. The ion chamber fits only one way.

If the ion chamber is to be replaced always use one identical to the one being removed. Check the aperture (small: 3.0 mm; large: 6.0 mm) at the top of the ion chamber and materials of construction (gold-plated or Teflon) to ensure proper replacement. See Parts List, Section 7.

Place the end cap on top of the ion chamber and replace the two screws. Tighten the screws only enough to seal the O-ring.



**FIGURE 5-1
PROBE ASSEMBLY**



**FIGURE 5-2
LAMP HOUSING ASSEMBLY**

SECTION 5.5, PROBE DISASSEMBLY/ASSEMBLY cont.

CAUTION

Do not over-tighten these screws.

Line up the pins (pogo contacts) on the base of the lamp housing with the pins inside the probe shell. Gently slide the housing assembly into the probe shell.

The end cap should meet the probe shell evenly after final assembly. If not, the ion chamber may be installed wrong.

CAUTION

DO NOT FORCE the assembly into the shell.
It fits only one way.

If it does not reassemble readily, remove and check pin alignment. Check to ensure pogo contacts are not bent. Refasten the exhaust screw at the base of the probe.

Align the 12 pin probe connector to the readout assembly and reconnect with a twisting motion until a click occurs. Check to ensure the high voltage microswitch is properly depressed. The lamp should light if the function switch is turned to any position except STANDBY.

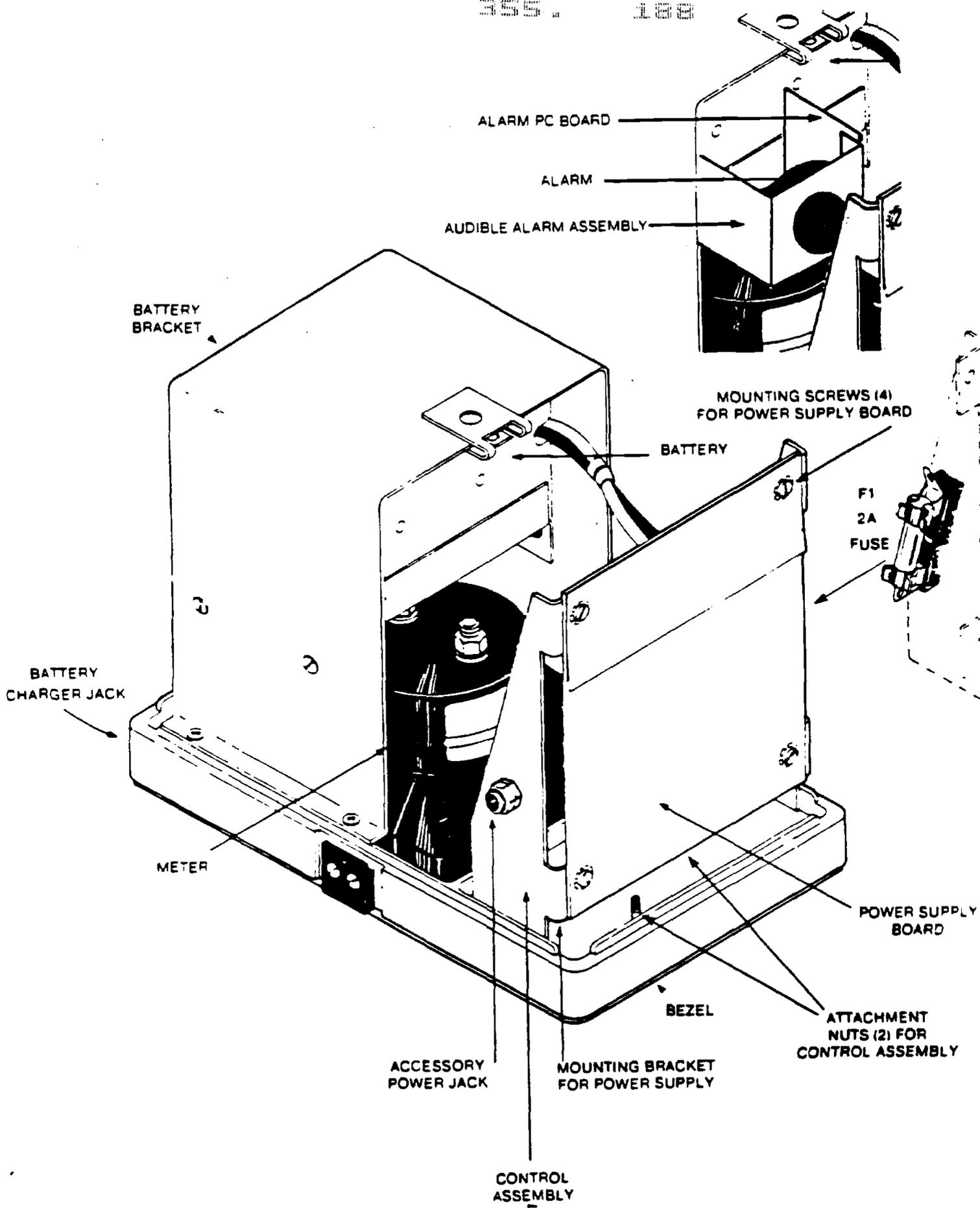
5.6 READOUT DISASSEMBLY/ASSEMBLY

WARNING

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise, high voltage of 1200 V DC will be present.

Disconnect the probe cable connection. Remove recorder jacks and cable or the plastic plug cap. Loosen the screw on the bottom of the case and, holding the instrument by the bezel, remove the case (see Figure 5-3).

- a. The control assembly consisting of the Printed Circuit Board (PCB) and control panel can be separated from the readout assembly by the following steps:



**FIGURE 5-3
READOUT ASSEMBLY**

SECTION 5.6, READOUT DISASSEMBLY/ASSEMBLY cont.

- 1) Separate the Molex connectors in the cables to the control assembly.
- 2) Remove the two attachment nuts at the base of the assembly.
- 3) Remove the two screws at the top of the power supply board holding it to the assembly brackets.
- 4) Compress the brackets and slide the assembly thru the bezel. Remove a third screw at the lower corner of the board, if necessary.

b. The optional alarm assembly can be separated as follows

- 1) Disconnect the cable (P6/J6 of Figure 4-5)
- 2) Remove the two screws holding the alarm assembly to the battery bracket

Reassembly is accomplished by reversing the above procedure.

NOTE: Be sure the function switch on the control panel is in the OFF position before inserting the control module into the case. If not, the fuse can be blown or damage can result.

SECTION 6

TROUBLESHOOTING

-6.1 INTRODUCTION

The initial step of any troubleshooting is a thorough visual inspection to look for possible loose or open connections, shorts, dust or other obvious conditions.

Detailed troubleshooting for fault location and correction is accomplished by steps outlined in the following:

Troubleshooting Data	Table 6-1
Pad Data, Power Supply PCB	Table 6-2
Pad Location, Power Supply PCB	Figure 6-1
Pin Data, Amplifier PCB, P2/J2	Table 6-3
Pin Data, Probe Cable, P3/J3	Table 6-4
Pin Data, Alarm Cable, P6/J6	Table 6-5

Disassembly and reassembly as may be required for checking the equipment or replacing parts are described in Chapter 6.

WARNING

Turn the function switch on the control panel to the OFF position before disassembly. Otherwise high voltage of 1200 V DC will be present.

WARNING

Do not observe the light source closer than 6 inches with unprotected eyes. When necessary, observe only briefly. Continued exposure to ultraviolet energy generated by the light source can be harmful to eyesight.

WARNING

Use great care when operating the analyzer with the readout assembly outside its case due to the presence of 1200 V DC.

If, after following the steps cited in this section, the analyzer is not functioning properly, contact the HNU Service Dept. for assistance. (Phone: (617) 964-6690).

TABLE b-1
TROUBLESHOOTING DATA

Symptom	Probable Cause	Corrective Action
1. Meter indicates low battery	a. Blown fuse (Fuse F1, 2A, 5-3)	1) Check fuse. If blown, check for evidence of shorts in wiring, then replace fuse.
	b. Bad connections	1) Check wiring connections. Resolder poor or bad connections.
	c. Broken meter movement	1) Tip instrument rapidly from side to side. Meter needle should move freely, and return to zero. If faulty, replace with new meter.
	d. Battery dead	1) Disconnect battery and check with volt-ohmmeter. Replace if dead.
	e. Battery charge low	1) Recharge battery, check meter with function switch in BATT position to ensure the charger is operating properly (see Table 2-1, BATT)
2. Low battery	a. Power supply defective	1) Check power supply voltages (see Table 6-2 and Figure 6-1). If in error, replace power supply assembly.
3. UV lamp not ON	a. High Voltage interlock (Micro-switch S2) at probe cable connector on readout assembly not operating	1) Check by applying pressure to switch plunger with cable in place. Adjust the screw on side of cable connector, if required, to increase throw of switch plunger.
	b. High voltage supply out or faulty	1) Check high voltage output on power supply board (pad 22). If voltage not correct, (see Table 6-2) replace power supply board.

- c. Lamp not making proper connection with high voltage contacts. 1) Remove lamp, clean and tighten contacts, reinstall lamp.
- d. Lamp faulty 1) Replace lamp.
- e. Short in high voltage lines 1) Check wiring from power supply board to probe cable connector (J3 pin D) to UV lamp contacts (D1). Remove any shorts.

4. Fan not running

- a. Fan stuck 1) Disassemble probe and clean passages and fan by blowing out dust. To remove larger particles use cotton swab, Q-tip or equal. Use care to not damage impellor rotor or blades. For disassembly see Section 5.5.
- b. Fan connections faulty 1) Check for wiring connections at fan motor and at probe cable connector (J3 pins A and C). Repair as required.
- c. Low or dead battery 1) Check battery output (power supply board, pad 9). Recharge or replace battery as required.
- d. Fan voltage not correct 1) Check fan voltage (power supply board pads 19 and 21, probe cable pins A and C). If not correct, replace power supply board.
2) If fan voltages correct replace fan.

5. Meter does not respond

- a. Dirty or open probe connection 1) Clean and tighten or resolder connections in probe.
- b. Broken meter 1) See 1-c-1 above.
- c. Dirty or open connections to meter 1) Clean and tighten connections at meter.
- d. Low or dead battery 1) See 4-c-1 above.
- e. Blown fuse 1) See 1-a-1 above.

- | | | |
|---|---------------------------------------|---|
| 6. Meter does not return to zero in STANDBY | a. Broken meter movement | 1) See 1-c-1 above. |
| | b. Dirty or open connections to meter | 1) See 5-c-1 above. |
| | c. Dirty or open connections in probe | 1) See 5-a-1 above. |
| | d. Zero adjust faulty | 1) Rotate zero adjust pot (see Fig. 2-1) (R50, Fig. 4.6). Check pot output at meter probe connector (J3 pins B and L). If voltage does not vary, replace zero adjust pot. |
| | e. Amplifier faulty | 1) Rotate zero adjust pot. Check amplifier output at probe connector (J3 pin H) or observe meter. If voltage level on meter does not respond, replace amplifier board |
| | f. Ion chamber shorted | 1) Clean ion chamber. (see Section 5.2). Recheck for return to zero in STANDBY.
2) Replace ion chamber. |
| 7. Meter readings, high or low | a. Incorrect calibration | 1) Recalibrate (see Section 3). |
| | b. Lamp dirty | 1) Clean lamp (see Section 5.2) |
| | c. Contamination in ion chamber. | 1) Clean ion chamber. (see Section 5.2) |
| | d. Power supply board faulty | 1) Check power supply board outputs (pads 17, 20 and 22 (Table 6-2). If voltage not correct, replace power supply board. |
| | e. Dirty or loose connections | 1) Clean or tighten connections at amplifier board, probe cable, and meter. |

TABLE 6-1 cont.

- | | | |
|--|--|---|
| 8. Meter erratic, unstable or non-repeatable | a. Loose cable connection | 1) Check cable connection at control panel. Observe meter. Tighten cable as required. |
| | b. Dirty or loose meter connections | 1) Check meter connections. Clean and tighten as required. |
| | c. Contamination in ion chamber | 1) Clean ion chamber. (see Section 5.2). |
| | d. Power supply board faulty | 1) See 7-d-1 above. |
| | e. Unstable or noisy lamp | 1) Observe lamp. (Important-see WARNING in Section 6.1). If operation not steady, replace lamp. |
| | f. Function switch in high gain, most sensitive position | 1) Unstable meter operation is common with function switch in most sensitive position. Turn switch to less sensitive position if desirable. |
| | g. Fan not operating properly | 1) Replace fan. |
| | h. Gas flow slow or stopped | 1) See 4-a-1 above. |
| | i. Meter contacts dirty or loose | 1) Clean and tighten contacts. |
| 9. Drifting meter or apparent moisture sensitivity | a. Ion chamber contaminated | 1) Clean ion chamber. (see Section 5.2). |

TABLE 6-2

PAD DATA, POWER SUPPLY PCB

Pad No.	Signal Name	Voltage (V DC)
1	Battery positive (+)	0
2	Ground	0
3	Battery charger (+)	0
4	Low Battery Indicator	
5	Low Battery Indicator	
6	Hi-Volt Relay Disconnect	-12
7	Battery Charger (-)	-11 to -15
8	Battery Negative (-)	-11 to -15
9	Battery Negative (-)	-11 to -15
10	Hi-volt Relay Disconnect	0 or -12
11	Amplifier Signal	0 to -5
12	Signal divider for span control	"
13	" " " " "	"
14	" " " " "	"
15	" " " " "	"
16	" " " " "	"
17	Ion Chamber accelerating voltage	+180
18	Zero adjust voltage power	+18 to +21
19	Fan Motor	-10.6 V nominal (see NOTE 2)
20	Amplifier Power	-9.5 to -10.5
21	Fan Motor	-14.5 nominal (see Section 4.8)
22	UV Lamp	up to -1200 (see Section 4.8)
23	Output Signal to Meter	0 to -5
24	Battery Check Voltage	-11 to -15
25	Not Used	---
26	Signal Feedback	0 to -5
27	Ground	0
28	Ground	0
29	Not Used	---
30	Ground	0
31	Ground	0
32	Alarm set power	+10
33	Alarm set power	+7

NOTES: 1. For Pad location, see Figure 6-1.

2. Differential potential for fan motor between pads 19 and 21 will be between 2.6 and 3.6 V DC.

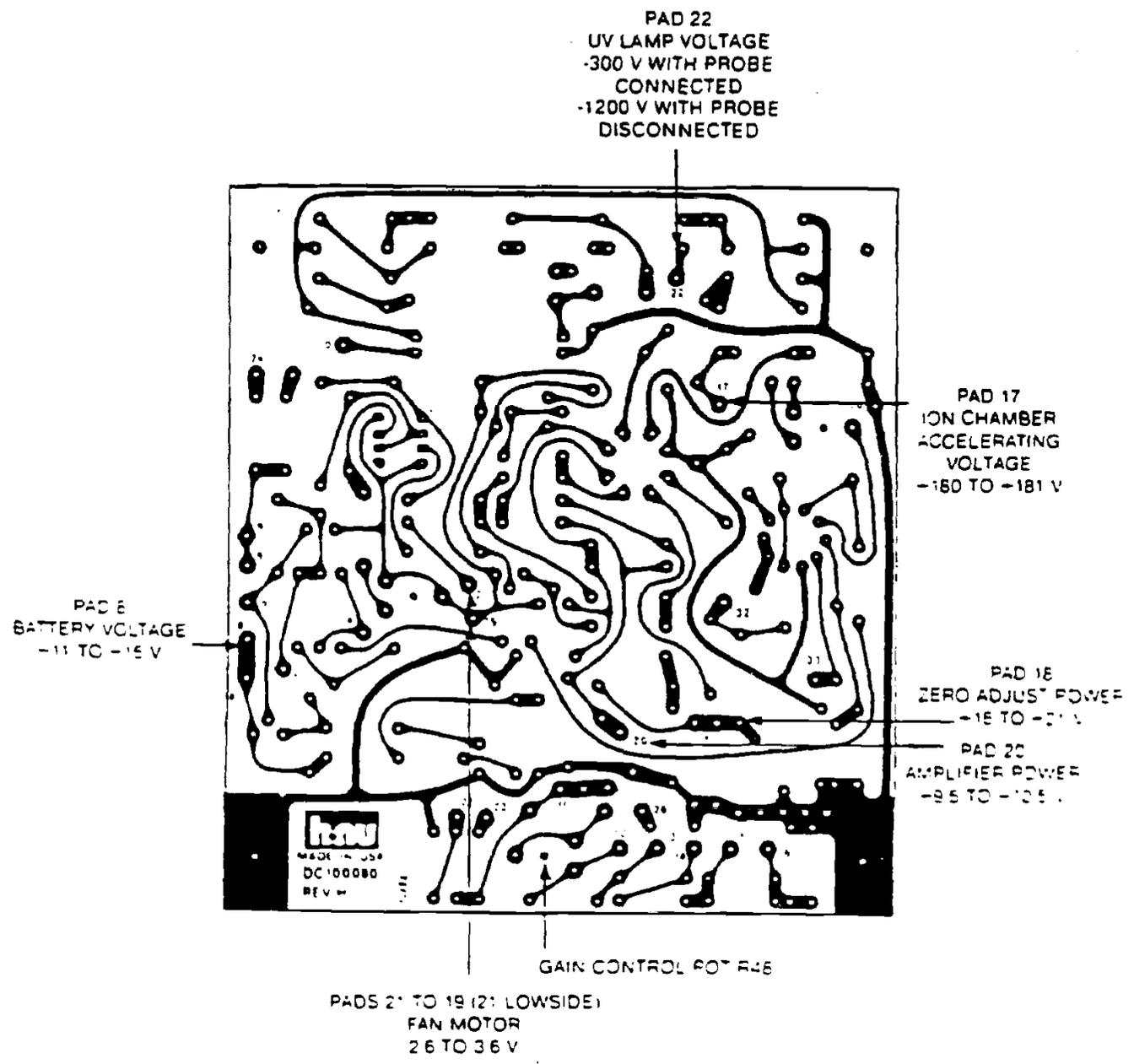


FIGURE 6-1
PAD LOCATION, POWER SUPPLY PCB

TABLE 6-3

PIN DATA, AMPLIFIER PCB, P2/J2

Pin #	Signal Name	Voltage (V DC)
A	Ground	0
B	Span Control Setting	varying
C	Zero Adjust	varying
D	Amplifier Power	-9.5 to -10.5
E	Amplifier Signal	0 to -5.0
F	Zero Adjust Voltage	+18 to +21
3	Zero Adjust Voltage	varying

TABLE 6-4

PIN DATA, PROBE CABLE, P3/J3

Pin #	Signal Name	Voltage (V DC)
A	Fan Motor	-14.5 nominal (see NOTE)
B	Zero Adjust	varying
C	Fan Motor	-10.6 nominal (see NOTE)
D	UV Lamp	up to -1200 (see Section 4.8)
E	Amplifier Signal	0 to -5.0
F	Ground	0
H	Span Control Setting	varying
J	Ground	0
K	Zero adjust Voltage	+18 to +21
	Zero Adjust	varying
M	Ion Chamber accelerating voltage	+150
N	Amplifier Power	-9.5 to -10.5

NOTE: Differential potential for fan motor between pads 10 and 21 will be between 2.6 and 3.6 V DC.

TABLE 6-5

PIN DATA, ALARM CABLE P6/J6

Pin #	Signal Name	Voltage (V DC)
1	Alarm set pot, high end	+5.1
2	Alarm set power	+7
3	Alarm power	0 or -11 to -15
4	Alarm set	+0.02 to +5.1
5	Alarm board power	+10
6	Amplifier power	-9.5 to -10.5
7	Alarm set pot, low end	+0.023
8	Ground	0
9	Amplifier signal	0 to -5.0

SECTION 7
PARTS LISTS

7.1 INTRODUCTION

This section lists and shows the location of all parts of the Photoionization Analyzer subject to repair and replacement. When ordering parts, specify model and serial numbers as well as part number. Return all defective warranty parts to HNU Systems Inc. Obtain a Return Materials Authorization Number (RMA#) from Service Department.

REPLACEMENT PARTS LIST

MODEL PI-101

(See Fig. 7-1)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

<u>Part No.</u>	<u>Refer to Fig. No.</u>	<u>Assembly</u>
	1	Probe Handle
79-AC100004	2	Probe Shell Assembly
54-DA100049	3	Exhaust Screw
79-AC100107	4	Fan/Light Source Assembly
80-101-095	5	95 eV Replacement Lamp
80-101-102		10.2 eV Replacement Lamp
80-101-117		11.7 eV Replacement Lamp
80-101-111		10.2 eV Selected Lamp (Specify Appl.)
79-AB10008	6	fan exhaust assembly
79-AB100069	7	amplifier board
79-AC100005A1	8	ion chamber assembly, sm. aperture (3.0 mm)
79-AC100005A2		ion chamber assembly, sm. aperture gold
79-AC100005A3		ion chamber assembly, lg. aperture (6.0 mm)
79-AC100005A4		ion chamber assembly, lg. aperture gold
54-DA100053	9	End cap for probe
	10	End cap screw
79-AA10011	11	Probe extension
79-PA 10010	12, 13, 14, 15	"O" ring kit
13-67-06J-14-11P	16	12 pin connector
79-AB100187A1	17	Probe cable w/connector (\$5/ft. over 3')

REPLACEMENT PARTS LIST

MODEL PI-101
(See Fig. 7-2)

1 2 3 4 5 6 7 8 9 10 11

Part No.	Refer to Fig. No.	Assembly
25-680-402	1	Front Meter Glass
	2	
45-DA101316	3	Pot (span)
45-DA100029	4	Pot (zero)
79-AC100082	5	Power Supply Board
18-MDL-2	6	fuses, box of 12
79-AA100011	7	Battery
	8	
	9	
	10	
10-39-12	11	Grayhill switch

TABLE 7-3

REPLACEMENT PARTS LIST

MODEL PI101
 (see Fig. 7-3)
 1 2 3 4 5

<u>Part No.</u>	<u>Refer to Fig. No.</u>	<u>Assembly</u>
DB100017-1	1	Strap, neck
DB100018-1	2	Strap, waist
AC100013-A1	3	Charger, battery: 15.0 VDC, 120 V AC, 1 pH input
DC100044-1	4	Case, cover
DB100050	5	Case, readout assembly

PARTS LIST
ACCESSORIES

(No figure is provided for this list.)

Part No.	Description
101-300	<p>Portable Recorder Has a 2" chart width with 2"/hour chart speed. Operates on 12 v DC power from analyzer. Complete with multiconductor interface cable for battery power and signal and mounting bracket for attaching recorder to side of analyzer.</p>
101-301	<p>Chart Paper For portable recorder, 6 rolls.</p>
AB100378	<p>Multiconductor Interface Cable For recorder, contains leads for connecting recorder to analyzer. (Included in part 101-300 above)</p>
101-350	<p>Calibration Gas Cylinder Contains 23 liters of span gas in air (300 psi) sufficient for 40-50 calibrations. (4" diameter by 12" high).</p>
101-351	<p>Regulator For use with calibration cylinder, Model 101-350, complete with gauges for reading both cylinder pressure and flow.</p>
101-500	<p>Cleaning Compound For removing deposits from window of 9.5 or 10.2 eV lamp (not the 11.7 eV lamp.)</p>

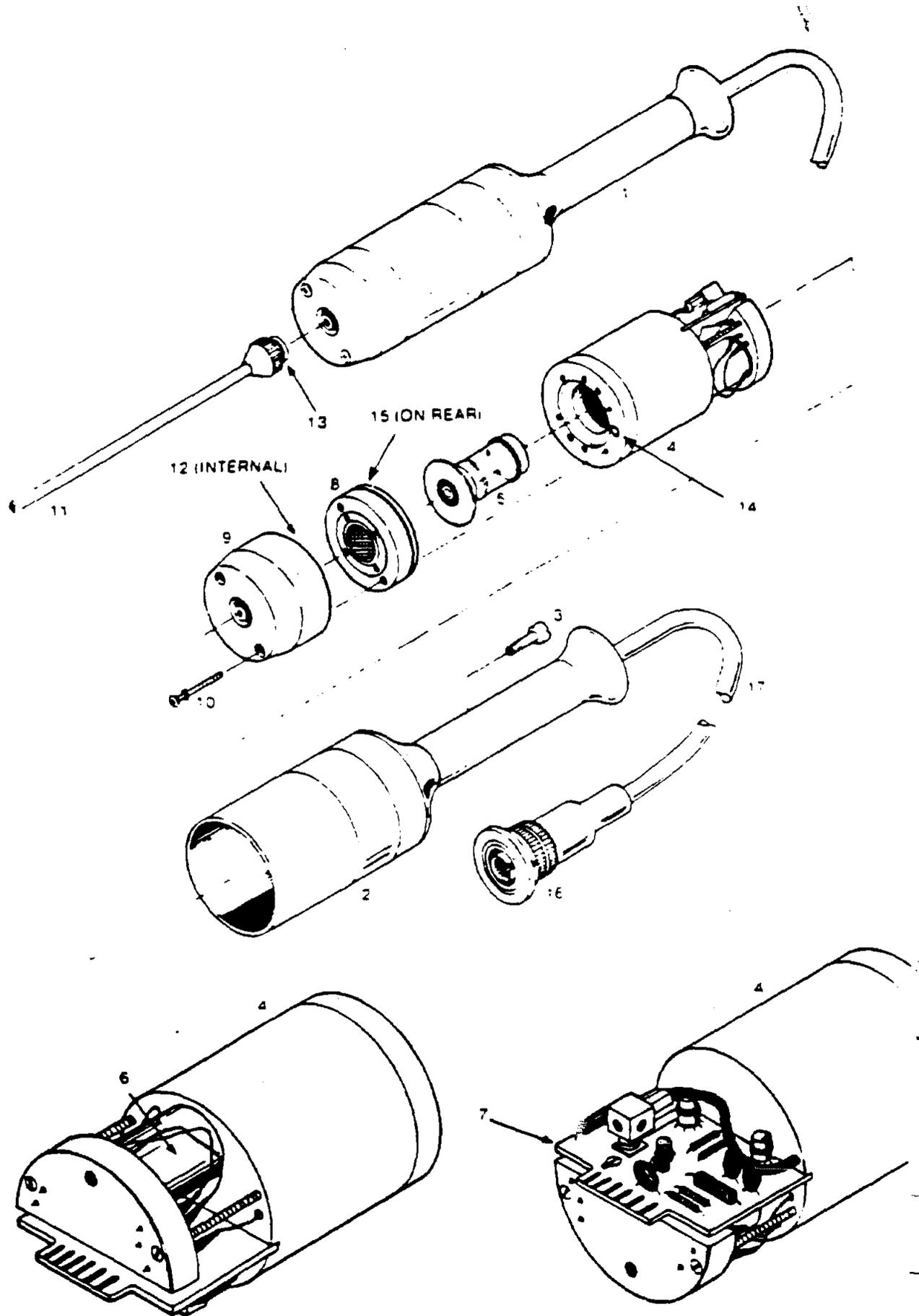


FIGURE 7-1
PARTS LOCATION, PROBE ASSEMBLY

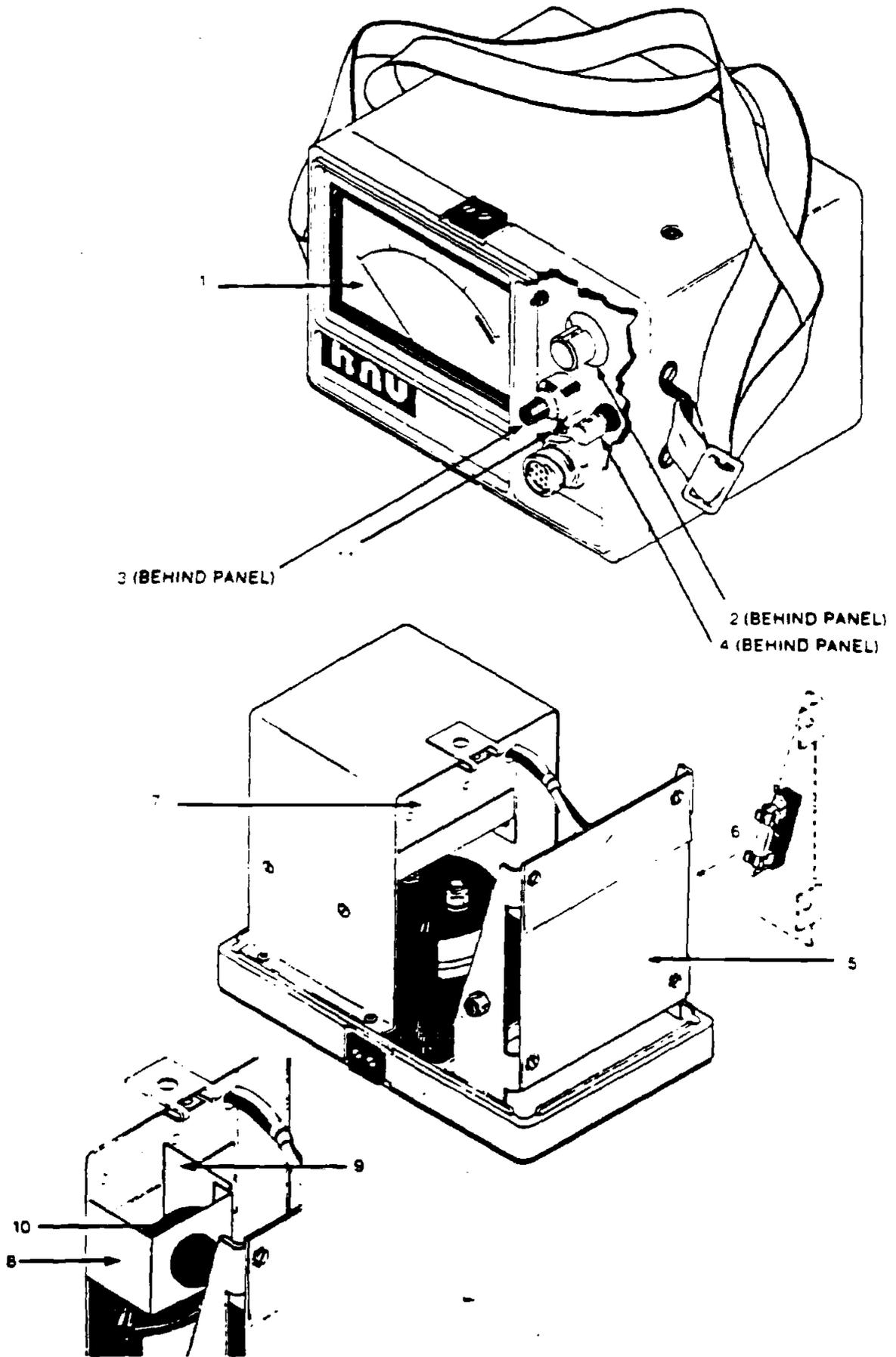


FIGURE 7-2
PARTS LOCATION, READOUT ASSEMBLY

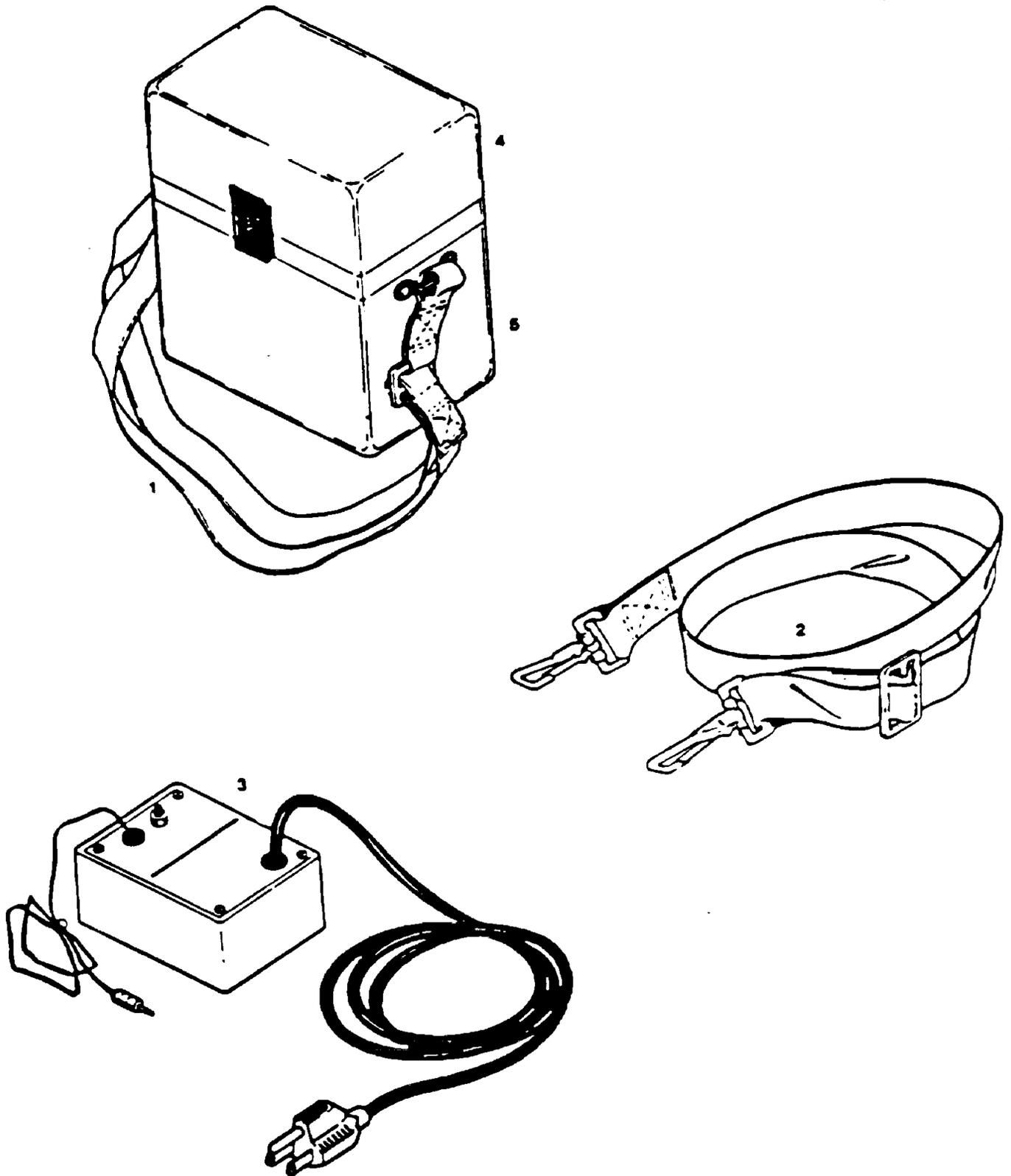


FIGURE 7-3
PARTS LOCATION, OTHER ITEMS

SECTION 8

APPENDIX

This section contains the following additional information pertinent to the PI 101 Analyzer.

Section	Subject
8.1	Static Calibration
8.2	Calibration Checking with Isobutylene
8.3	Calibration with Alternate Gas
8.4	Uncalibrated Operation
8.5	Ionization Tables
8.6	Warranty
8.7	Publications List

8.1 STATIC CALIBRATION

A technique known as static calibration is very useful when it is desired to calibrate with a particular special mixture rather than an available standard. The procedure is:

- a. Select an inert container of known volume, e.g., a 4 liter Teflon bag, and clean by filling with hydrocarbon-free air and exhausting three or four times. The container and fittings should have minimal interaction with the gas to be used.
- b. Fill the container with hydrocarbon-free air between samples and test with the analyzer. Repeat several times to determine the background level in the container. Correct instrument response by subtracting this background for accurate results.
- c. Fill a small, inert gas-tight syringe (glass/Teflon) (e.g., 1 cc) with the desired gas and inject into the container. See the sample calculations. If the desired material is a liquid at room temperature, a smaller syringe (e.g., 1 ul or 10 ul) is used. Inject a known volume of the liquid into the container. Touch the syringe tip to the inside of the container to remove any residue droplets. A needle on the syringe is not necessary, but if one is used, it should be used throughout or delivery errors are possible.
- d. Fill the container with a known volume of clean air and stopper the container. A large syringe, such as the Hamilton Model S1500 (1.5 liters) is recommended. Calibrated flowmeters may also be used. The accuracy of this calibration method is directly dependent on the accuracy used to measure the species involved.
- e. Wait several minutes until the gas is well mixed or the liquid is evaporated and mixed. Check for liquid in the container before proceeding. If the liquid does not completely evaporate, the correct concentrations will not be seen in the gas phase. Warning the bag may be necessary to ensure complete evaporation.
- f. Connect the probe inlet to the container making sure there are no leaks.
CAUTION: Work in a hood if hazardous gases are used.

WARNING

Be very careful to note the toxic levels and the Lower Explosive Limits for personal safety. The PI 101 is a nondestructive analyzer and must be used in a hood when calibrating with toxic or hazardous materials.

SECTION 2.1, STATIC CALIBRATION cont.

- g. Allow the analyzer to sample from the container. Compression of the container by hand may be necessary since the analyzer will not sample across a pressure drop. The analyzer flow is about 100 - 200 cc/min and small changes will not effect the reading. However, the flow should be constant.
- h. Observe the readings during calibration to ensure that the gas is well mixed and there are no concentration gradients within the container. This will be evident by uniform meter readings.
- i. Record the reading after about 10 seconds. The reading should be stable for up to 2 minutes since the flow rate is 100 to 200 cc/min. Large fluctuations in flow could effect the readings.
- j. Adjust the SPAN control to set the analyzer to be direct reading at a concentration level near the range to be used.
- k. Prepare 5 or 6 different concentrations of the calibration gas and plot the instrument readings versus concentration in ppm (v/v) to obtain a calibration curve. Clean the container between each point. For spot checking the calibration, two levels close to the measured concentration which agree to within 10% are acceptable. Concentrations lower than 100 ppm of a gas can be prepared by diluting a 100 or 200 ppm level with clean air. However, do not dilute a mixture by more than a factor of 10. A bias in the calibration curve could indicate preparation/container effects, such as "hang-up" on the walls of the container at high levels resulting in lower readings. At low levels, the compound may diffuse out or evaporate off the walls resulting in higher readings. Gentle heating should alleviate this condition.

STATIC CALIBRATION CALCULATIONS

GAS SAMPLING BAG

Precision: +/- 10%

Range: 20 ppm to 1 percent (see NOTE 1)

Sample Calculations:

Gaseous Sample: Assume 0.15 ml of a pure gas, e.g., vinyl chloride, is injected into the container with 1.5 liters of hydrocarbon-free air by the syringe. The concentration then is:

$$\frac{\text{volume injected (ml)}}{\text{vessel volume (ml)}} \times 10^6 = \frac{0.15 \text{ ml}}{1500 \text{ ml}} \times 10^6 = 100 \text{ ppm}$$

Liquid sample: Assume 1.0 microliters of a volatile liquid such as toluene is injected into the container and 1.5 liter syringe filled with hydrocarbon-free air is added. The concentration then is:

$$\frac{\text{volume injected (ml)} \times \text{density (g/ml)}}{\text{molecular weight (g/mole)} \times \text{volume of air (liters)}} \times \frac{24.0 \text{ liters/mole}}{\text{molar volume (liters/mole)}} = 10 = 151 \text{ ppm (see NOTE 1)}$$

$$\frac{1.001 \text{ ml} \times 0.87 \text{ g/ml} \times 24.0 \text{ liters/mole}}{92 \text{ g/mole} \times 1.5 \text{ liters}} = 10 = 151 \text{ ppm (see NOTE 1)}$$

NOTES: 1. Larger gas and liquid syringes are needed for the upper portion of this range.

WARNING

Note the toxic levels and the Lower Explosive Limits for personal safety. The PI 101 is a nondestructive analyzer and must be used in a hood when calibrating with toxic or hazardous materials.

2. The molar volume of toluene at 20 oC and one atmosphere is 24.0. This value must be corrected for the actual conditions, otherwise errors as high as 20% might be encountered. Corrections are made using the standard gas laws.

8.2 CALIBRATION CHECKING WITH ISOBUTYLENE

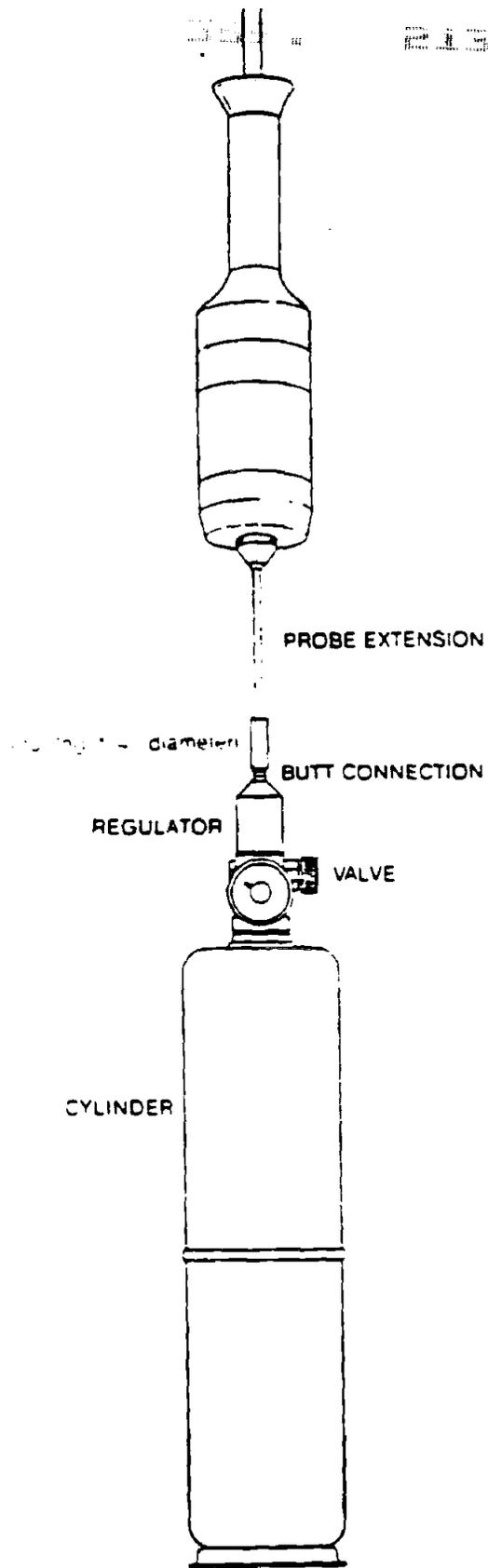
The calibration of the analyzer can be rapidly checked by the use of an HNU small disposable cylinder containing isobutylene (HNU pn 101-350) with a regulator (HNU pn 101-351).

At the factory, the analyzer is first calibrated on the desired gas standard at the specified concentration. Then a measurement is made with isobutylene.

The ppm reading along with the span setting using isobutylene is recorded in the calibration report.

In service, the analyzer calibration can be checked and readjusted if necessary by using this cylinder and regulator as follows:

- a. Connect the analyzer to the regulator and cylinder with a short piece (butt connection) of tubing as shown in Figure 8-1. The calibration gas in the cylinder consists of a mixture of isobutylene and zero air. Isobutylene is nontoxic and safe to use in confined areas. There are no listed exposure levels at any concentration.
The regulator sets and controls the flow rate of gas at a value preset at the factory. This will be about 250 cc/min.
It is important that the tubing be clean since contaminated tubing will effect the calibration reading. Do not use the cylinder below about 20 psig as readings below that level can deviate up to 10% from the rated value.
Safely discard the disposable cylinder when empty. Do not refill this cylinder.
It is against the law to transport refilled cylinders.
- b. With the SPAN setting and the function switch at the same positions as listed in the Application Data Sheet or Calibration Report, open the valve on the cylinder until a steady reading is obtained.
- c. If the reading is the same as the recorded data, the analyzer calibration for the original species of interest is still correct.
- d. If the reading has changed, adjust the SPAN setting until the reading is the same.
- e. Shut off the cylinder as soon as the reading is established.
- f. Record and maintain this new SPAN setting. Then recalibrate the analyzer on the species of interest as soon as possible.
- g. Whenever the analyzer is recalibrated, it is to be immediately checked with the small cylinder and the reading recorded. This can then be used for later checking in the field.



**FIGURE B-1
CALIBRATION CHECKING SET-UP**

8.3 CALIBRATION WITH ALTERNATE GAS

If a calibration standard with the same trace gas as that to be measured is not available or is hazardous, it is possible to use an alternate calibration gas. (Note : This technique may not be as accurate as calibration with the species of interest.)

In this case, the expected reading for calibration must be compensated for the difference between the two gases. In operation, the meter will then give a direct reading of the gas being measured.

This calibration is illustrated in the following examples: (PS = Photoionization Sensitivity. See Table 8-14)

a. Given a case in which:

- 1) The trace gas to be measured is Vinyl Chloride (PS = 5.0)
- 2) The calibration gas to be used is Isobutylene (PS = 7.0) at a 100 ppm level

What is the ppm reading to be when calibrating to give a direct reading when measuring Vinyl Chloride?

The required reading for calibration will be:

$$\begin{aligned}
 &= \text{Isobutylene ppm} \times \frac{\text{PS(Isob)}}{\text{PS(Vin Chlor)}} \\
 &= 100 \times \frac{7.0}{5.0} \\
 &= 140 \text{ ppm}
 \end{aligned}$$

In this example, using a calibration gas with 100 ppm of Isobutylene, adjust the SPAN control so the meter reads 140 ppm. In operation, the instrument will then give a direct reading of the ppm of Vinyl Chloride.

b. Given a case in which:

- 1) The trace gas to be measured is Benzene (PS = 10.0)
- 2) The calibration gas to be used is Isobutylene (PS = 7.0) at a level of 100 ppm
- 3) What is the ppm reading to be when calibrating to give a direct reading when measuring Benzene.

SECTION 8.3, CALIBRATION WITH ALTERNATE GAS cont.

The required reading for calibration will be:

$$\begin{aligned}
 &= \text{Isobutylene ppm} \times \frac{\text{PS(Isob)}}{\text{PS(Benzene)}} \\
 &= 100 \times \frac{7.0}{10.0} \\
 &= 70.0 \text{ ppm}
 \end{aligned}$$

In this example, using a calibration gas with 100 ppm of Isobutylene, adjust the SPAN control so the meter reads 70 ppm. In operation, the instrument will then give a direct reading of the ppm of Benzene.

c. Given a case in which:

- 1) The trace gas to be measured is H₂S (PS = 2.8)
- 2) The level of H₂S for which it is to be calibrated is 60 ppm.
- 3) The calibration gas available is Isobutylene (PS = 7.0)
- 4) What ppm level of Isobutylene is required to permit direct reading of H₂S, calibrating at its 60 ppm level.

The required Isobutylene level for calibration will be:

$$\begin{aligned}
 &= \text{H}_2\text{S ppm} \times \frac{\text{PS(H}_2\text{S)}}{\text{PS(Isob)}} \\
 &= 60 \times \frac{2.8}{7.0} \\
 &= 24.0 \text{ ppm}
 \end{aligned}$$

In this example, using a calibration gas with 24.0 ppm of Isobutylene, adjust the SPAN control so the meter reads 60 ppm. In operation, the instrument will then give a direct reading of the ppm of H₂S.

Care is to be taken when working with flammable gas samples to stay below the Lower Explosive Limit (LEL) and with hazardous or toxic gases to stay below the Threshold Limit Value (TLV) safe working level.

If difficulties are encountered in calibration, the user should consult the local HNU representative.

8.4 UNCALIBRATED OPERATION

Best operation of the analyzer is accomplished by its calibration for the gas to be measured. In cases where it becomes necessary to operate with a gas for which it has not been calibrated and recalibration is not possible, correction can be made to the meter reading.

One method is by use of a chart. Figure 8-2 is such a chart. It shows performance curves for various gases being measured by an instrument with a 10.2 eV lamp and calibrated for benzene. This illustrates the effect of the different sensitivities of gases. These curves can be used directly for correcting a meter reading if the instrument is calibrated for benzene and is measuring one of the gases shown. For example, if the gas being measured is Propylene and the reading is 8 ppm, then the actual concentration is about 20 ppm.

A second method is to multiply the meter reading by a correction factor as follows:

$$\text{Actual ppm} = \text{ppm reading} \times \frac{\text{PS (Cal gas)}}{\text{PS (Trace gas)}}$$

in which

PS is the photoionization sensitivity of each of the two gases. Table 8-14 gives a list of the relative photoionization sensitivities of a number of specific gases with which the analyzer might be used. Use of this method is illustrated by the following examples:

- a. Instrument calibrated for Benzene (PS = 10.0)
and measuring Acetone (PS = 6.3)

$$\text{Actual ppm} = \text{ppm reading} \times \frac{10.0}{6.3}$$

$$= \text{ppm reading} \times 1.6$$

- b. Instrument calibrated for Vinyl Chloride
(PS = 5.0) and measuring Carbon Disulfide (PS = 7.1)

$$\text{Actual ppm} = \text{ppm reading} \times \frac{5.0}{7.1}$$

$$= \text{ppm reading} \times 0.7$$

These values are valid only for an analyzer with a 10.2 eV lamp. Different sensitivities occur with 9.5 and 11.7 eV lamps.

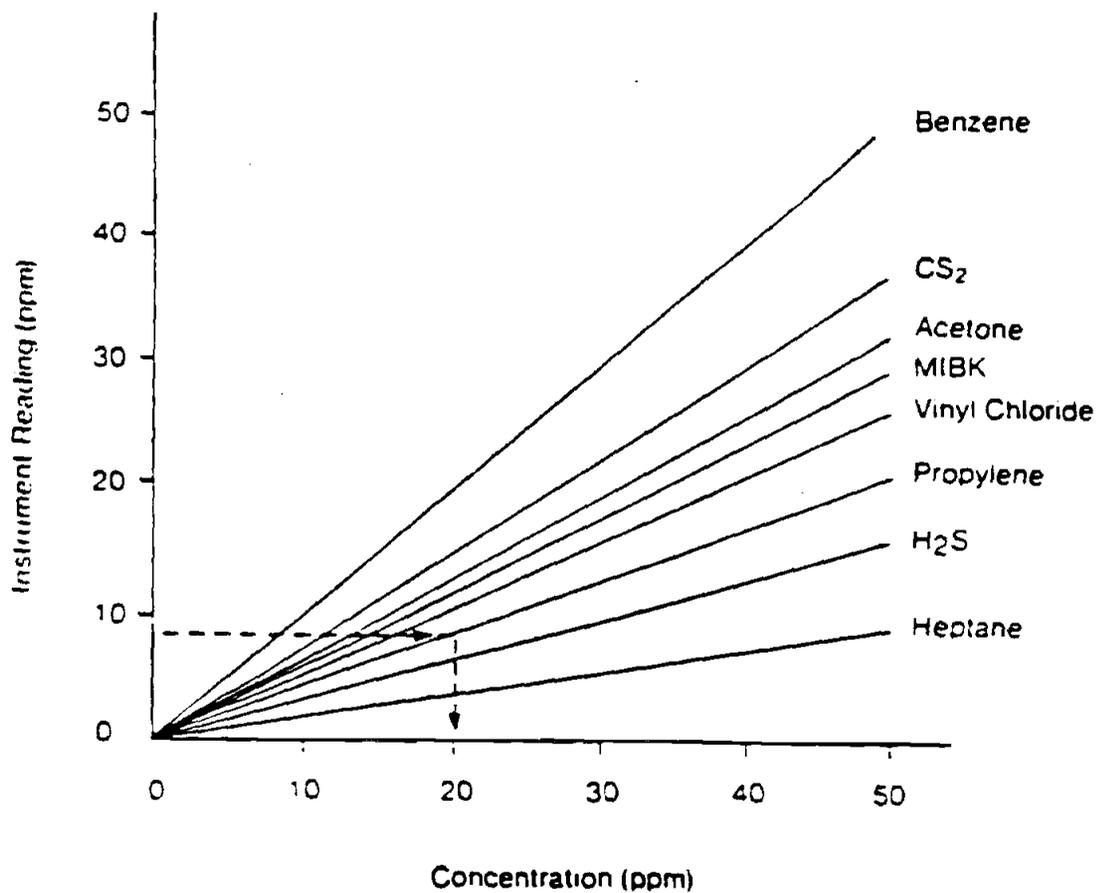
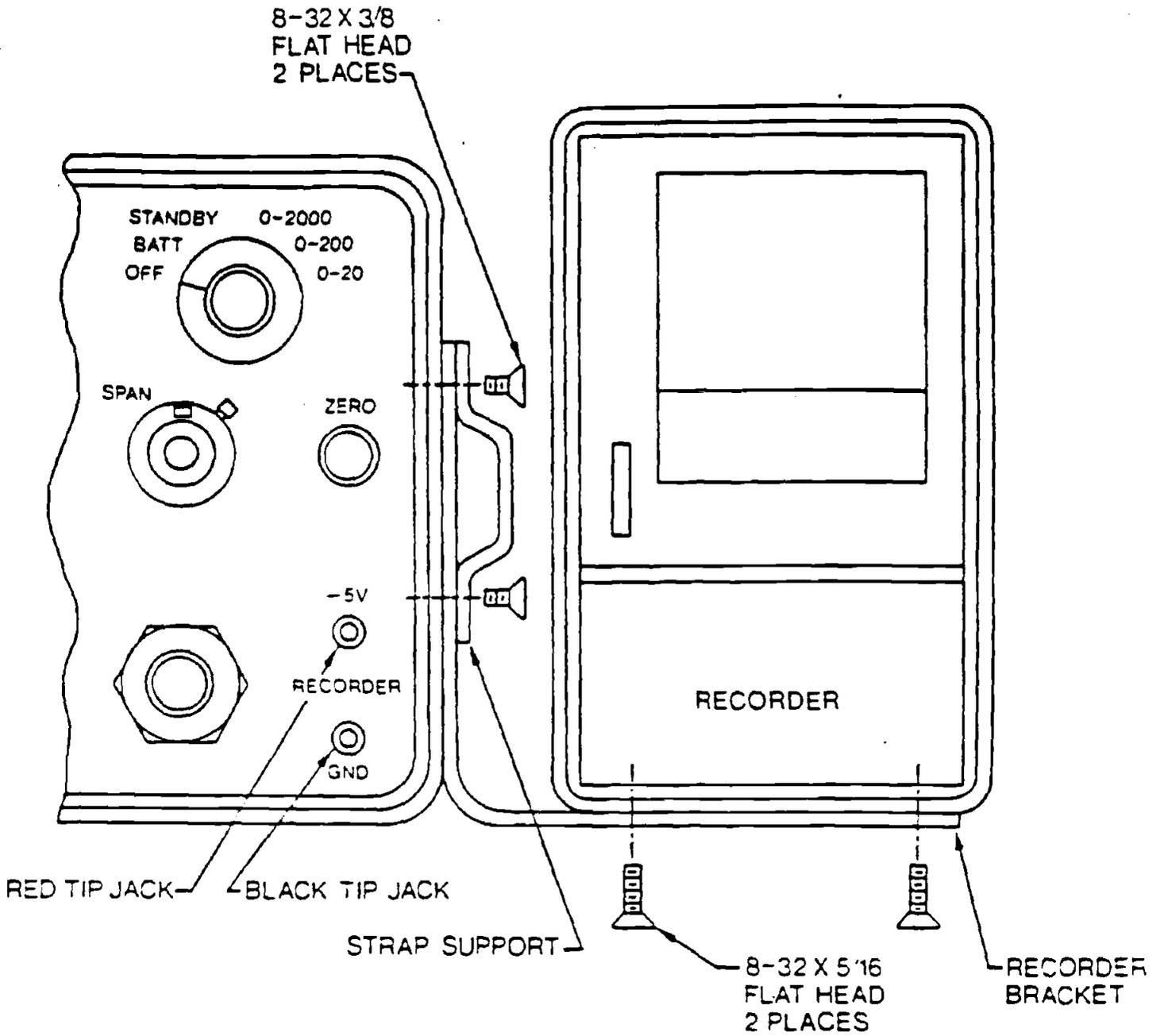


FIGURE 8-2
TYPICAL OUTPUT CURVES-
ANALYZER WITH 10.2 eV LAMP
CALIBRATED FOR BENZENE



**FIGURE 8-3
RECORDER MOUNTING**

8.5 Ionization Tables

Ionization potentials for various atoms, molecules, and compounds are given in Tables 8-1 thru 8-13. Ionization sensitivities and approximate span settings for 10.2 eV, 11.7 eV, and 9.5 eV lamps are given in Tables 8-14, 8-15, and 8-16 respectively.

TABLE 8.1

SOME ATOMS AND SIMPLE MOLECULES

	IP (eV)		IP (eV)
H	13.595	I ₂	9.28
C	11.264	HF	15.77
N	14.54	HCl	12.74
O	13.614	HBr	11.62
S	8.149	HI	10.38
S	10.357	SO ₂	12.34
F	17.42	CO ₂	13.79
Cl	13.01	CO _S	11.18
Br	11.64	CS ₂	10.08
I	10.48	N ₂ O	12.90
H ₂	15.426	NO ₂	9.78
N ₂	15.580	O ₃	12.80
O ₂	12.075	H ₂ O	12.59
CO	14.01	H ₂ S	10.46
CN	15.13	H ₂ Se	9.88
NO	9.25	H ₂ Te	9.14
CH	11.1	HCN	13.91
OH	13.18	C ₂ N ₂	13.8
F ₂	15.7	NH ₃	10.15
Cl ₂	11.48	CH ₃	9.840
Br ₂	10.55	CH ₄	12.98

TABLE 8.2

PARAFFINS AND CYCLOPARAFFINS

Molecule	IP (eV)
methane	12.98
ethane	11.65
propane	11.07
n-butane	10.63
i-butane	10.57
n-pentane	10.35
i-pentane	10.32
2,2-dimethylpropane	10.35
n-hexane	10.18
2-methylpentane	10.12
3-methylpentane	10.08
2,2-dimethylbutane	10.06
2,3-dimethylbutane	10.02
n-heptane	10.08
2,2,4-trimethylpentane	9.85
cyclopropane	10.06
cyclopentane	10.53
cyclohexane	9.85
methylcyclohexane	9.55

TABLE 8.3

ALKYL HALIDES

Molecule	IP (eV)
HCl	12.74
Cl ₂	11.48
CH ₄	12.98
methyl chloride	11.28
dichloromethane	11.35
trichloromethane	11.42
tetrachloromethane	11.47
ethyl chloride	10.98
1,2-dichloroethane	11.12
1-chloropropane	10.82
2-chloropropane	10.78
1,2-dichloropropane	10.87
1,3-dichloropropane	10.85
1-chlorobutane	10.67
2-chlorobutane	10.65
1-chloro-2-methylpropane	10.66
2-chloro-2-methylpropane	10.61
HBr	11.62
Br ₂	10.55
methyl bromide	10.53
dibromomethane	10.49
tribromomethane	10.51
CH ₂ BrCl	10.77
CHBr ₂ Cl	10.59
ethyl bromide	10.29
1,1-dibromoethane	10.19
1-bromo-2-chloroethane	10.63

TABLE 8.3 (continued)

Molecule	IP (eV)
1-bromopropane	10.18
2-bromopropane	10.075
1,3-dibromopropane	10.07
1-bromobutane	10.13
2-bromobutane	9.98
1-bromo-2-methylpropane	10.09
2-bromo-2-methylpropane	9.89
1-bromopentane	10.10
HI	10.38
I ₂	9.28
methyl iodide	9.54
diiodomethane	9.34
ethyl iodide	9.33
1-iodopropane	9.26
2-iodopropane	9.17
1-iodobutane	9.21
2-iodobutane	9.09
1-iodo-2-methylpropane	9.18
2-iodo-2-methylpropane	9.02
1-iodopentane	9.19
F ₂	15.7
HF	15.77
CFCl ₃ (Freon 11)	11.77
CF ₂ Cl ₂ (Freon 12)	12.31
CF ₃ Cl (Freon 13)	12.91
CHClF ₂ (Freon 22)	12.45
CBr ₃	10.67

TABLE 8.3 (continued)

Molecule	IP (eV)
CF_2Br_2	11.07
$\text{CH}_3\text{CF}_2\text{Cl}$ (Genetron 101)	11.98
$\text{CFCl}_2\text{CF}_2\text{Cl}$	11.99
CF_3CCl_3 (Freon 113)	11.78
$\text{CFHBrCH}_2\text{Br}$	10.75
$\text{CF}_2\text{BrCH}_2\text{Br}$	10.83
$\text{CF}_3\text{CH}_2\text{I}$	10.00
$n\text{-C}_3\text{F}_7\text{I}$	10.36
$n\text{-C}_3\text{F}_7\text{CH}_2\text{Cl}$	11.84
$n\text{-C}_3\text{F}_7\text{CH}_2\text{I}$	9.96

TABLE 8.4

ALIPHATIC ALCOHOL, ETHER, THIOL,
AND SULFIDES

Molecule	IP (eV)
H_2O	12.59
methyl alcohol	10.85
ethyl alcohol	10.48
n-propyl alcohol	10.20
i-propyl alcohol	10.16
n-butyl alcohol	10.04
dimethyl ether	10.00
diethyl ether	9.53
n-propyl ether	9.27
i-propyl ether	9.20
H_2S	10.46
methanethiol	9.440
ethanethiol	9.285
1-propanethiol	9.195
1-butanethiol	9.14
dimethyl sulfide	8.685
ethyl methyl sulfide	8.55
diethyl sulfide	8.430
d-n-propyl sulfide	8.30

TABLE 8.5

ALIPHATIC ALDEHYDES AND KETONES

Molecule	IP (eV)
CO ₂	13.79
formaldehyde	10.87
acetaldehyde	10.21
propionaldehyde	9.98
n-butyraldehyde	9.86
isobutyraldehyde	9.74
n-valeraldehyde	9.82
isovaleraldehyde	9.71
acrolein	10.10
crotonaldehyde	9.73
benzaldehyde	9.53
acetone	9.69
methyl ethyl ketone	9.53
methyl n-propyl ketone	9.39
methyl n-butyl ketone	9.32
diethyl ketone	9.32
methyl n-butyl ketone	9.34
methyl n-butyl ketone	9.30
3,3-dimethyl butanone	9.17
2-heptanone	9.33
cyclopentanone	9.26
cyclohexanone	9.14
2,3-butanedione	9.23
2,4-pentanedione	8.87

TABLE 8.6

ALIPHATIC ACIDS AND ESTERS

Molecule	IP (eV)
CO ₂	13.79
formic acid	11.05
acetic acid	10.37
propionic acid	10.24
n-butyric acid	10.16
isobutyric acid	10.02
n-valeric acid	10.12
methyl formate	10.815
ethyl formate	10.61
n-propyl formate	10.54
n-butyl formate	10.50
isobutyl formate	10.46
methyl acetate	10.27
ethyl acetate	10.11
n-propyl acetate	10.04
isopropyl acetate	9.99
n-butyl acetate	10.01
isobutyl acetate	9.97
sec-butyl acetate	9.91
methyl propionate	10.15
ethyl propionate	10.00
methyl n-butyrate	10.07
methyl isobutyrate	9.98

TABLE 8.7

ALIPHATIC AMINES AND AMIDES

Molecule	IP (eV)
NH ₃	10.15
methyl amine	8.97
ethyl amine	8.86
n-propyl amine	8.78
i-propyl amine	8.72
n-butyl amine	8.71
i-butyl amine	8.70
s-butyl amine	8.70
t-butyl amine	8.64
dimethyl amine	8.24
diethyl amine	8.01
di-n-propyl amine	7.84
di-i-propyl amine	7.73
di-n-butyl amine	7.69
trimethyl amine	7.82
triethyl amine	7.50
tri-n-propyl amine	7.23
formamide	10.25
acetamide	9.77
N-methyl acetamide	8.90
N,N-dimethyl formamide	9.12
N,N-dimethyl acetamide	8.81
N,N-diethyl formamide	8.89
N,N-diethyl acetamide	8.60

TABLE 8.8

OTHER ALIPHATIC MOLECULES WITH N ATOM

Molecule	IP (eV)
nitromethane	11.08
nitroethane	10.88
1-nitropropane	10.81
2-nitropropane	10.71
HCN	13.91
acetonitrile	12.22
propionitrile	11.84
n-butyronitrile	11.67
acrylonitrile	10.91
3-butene-nitrile	10.39
ethyl nitrate	11.22
n-propyl nitrate	
methyl thiocyanate	10.065
ethyl thiocyanate	9.89
methyl isothiocyanate	9.25
ethyl isothiocyanate	9.14

TABLE 8.9

OLEFINS, CYCLO-OLEFINS,
ACETYLENES

Molecule	IP (eV)
ethylene	10.515
propylene	9.73
1-butene	9.58
2-methylpropene	9.23
trans-2-butene	9.13
cis-2-butene	9.13
1-pentene	9.50
2-methyl-1-butene	9.12
3-methyl-1-butene	9.51
3-methyl-2-butene	8.67
1-hexene	9.46
1,3-butadiene	9.07
isoprene	8.845
cyclopentene	9.01
cyclohexene	8.945
4-methylcyclohexene	8.91
4-vinylcyclohexene	8.93
cyclo-octatetraene	7.99
acetylene	11.41
propyne	10.36
1-butyne	10.18

TABLE 8.10

SOME DERIVATIVES OF OLEFINS

Molecule	IP (eV)
vinyl chloride	9.995
cis-dichloroethylene	9.65
trans-dichloroethylene	9.66
trichloroethylene	9.45
tetrachloroethylene	9.32
vinyl bromide	9.80
1,2-dibromoethylene	9.45
tribromoethylene	9.27
3-chloropropene	10.04
2,3-dichloropropene	9.82
1-bromopropene	9.30
3-bromopropene	9.7
CF ₃ CCl=CClCF ₃	10.36
n-C ₅ F ₁₁ CF=CF ₂	10.48
acrolein	10.10
crotonaldehyde	9.73
mesityl oxide	9.08
vinyl methyl ether	8.93
allyl alcohol	9.67
vinyl acetate	9.19

TABLE 8.11

HETEROCYCLIC MOLECULES

Molecule	IP (eV)
furan	8.89
2-methyl furan	8.39
2-furaldehyde	9.21
tetrahydrofuran	9.54
dihydropyran	8.34
tetrahydropyran	9.26
thiophene	8.860
2-chlorothiophene	8.65
2-bromothiophene	8.63
pyrrole	8.20
pyridine	9.32
2-picoline	9.02
3-picoline	9.04
4-picoline	9.04
2,3-lutidine	8.85
2,4-lutidine	8.85
2,6-lutidine	8.85

TABLE 8.12

AROMATIC COMPOUNDS

Molecule	IP (eV)
benzene	9.245
toluene	8.82
ethyl benzene	8.76
n-propyl benzene	8.72
i-propyl benzene	8.69
n-butyl benzene	8.69
s-butyl benzene	8.68
t-butyl benzene	8.68
o-xylene	8.56
m-xylene	8.56
p-xylene	8.445
mesitylene	8.40
durene	8.025
styrene	8.47
m-methyl styrene	8.35
ethylbenzene	8.815
naphthalene	8.12
1-methylnaphthalene	7.69
2-methylnaphthalene	7.955
biphenyl	8.27
phenol	8.50
anisole	8.22
phenetole	8.13
benzaldehyde	9.53
acetophenone	9.27
benzenethiol	8.33
phenyl isocyanate	8.77

TABLE 8.12 (continued)

Molecule	IP (eV)
phenyl isothiocyanate	8.520
benzonitrile	9.705
nitrobenzene	9.92
aniline	7.70
fluoro-benzene	9.195
chloro-benzene	9.07
bromo-benzene	8.98
iodo-benzene	8.73
o-dichlorobenzene	9.07
m-dichlorobenzene	9.12
p-dichlorobenzene	8.94
1-chloro-2-fluorobenzene	9.155
1-chloro-3-fluorobenzene	9.21
1-bromo-4-fluorobenzene	8.99
o-fluorotoluene	8.915
m-fluorotoluene	8.915
p-fluorotoluene	8.785
o-chlorotoluene	8.83
m-chlorotoluene	8.83
p-chlorotoluene	8.70
o-bromotoluene	8.79
m-bromotoluene	8.81
p-bromotoluene	8.67
o-iodotoluene	8.62
m-iodotoluene	8.61
p-iodotoluene	8.50
benzotrifluoride	9.68
o-fluorophenol	8.66

TABLE 8.13

MISCELLANEOUS MOLECULES

Molecule	IP (eV)
ethylene oxide	10.565
propylene oxide	10.22
p-dioxane	9.13
dimethoxymethane	10.00
diethoxymethane	9.70
1,1-dimethoxyethane	9.65
propiolactone	9.70
methyl disulfide	8.46
ethyl disulfide	8.27
diethyl sulfite	9.68
thioacetic acid	10.00
acetyl chloride	11.02
acetyl bromide	10.55
cyclo-C ₆ H ₁₁ CF ₃	10.46
(n-C ₃ F ₇)CH ₂ C=O	10.55
trichlorovinylsilane	10.75
(C ₂ F ₅) ₃ N	11.7
isobutene	9.03
phosgene	11.77

TABLE S-14
 RELATIVE PHOTOIONIZATION SENSITIVITIES OF
 VARIOUS GASES TO A 10.2 eV LAMP

Gas	Photoionization Sensitivity (see Note 1)	Span Control Setting for Direct reading (approximate)
p-xylene	11.4	
m-xylene	11.2	
benzene	10.0 (reference standard)	9.5
toluene	10.0	
diethyl sulfide	10.0	
diethyl amine	9.9	
styrene	9.7	
trichloroethylene	8.9	5.2
carbon disulfide	7.1	
isobutylene	7.0	
acetone	6.3	
tetrahydrofuran	6.0	5.5
methyl ethyl ketone	5.7	
methyl isobutyl ketone	5.7	
cyclohexanone	5.1	
naptha (85% aromatics)	5.0	
vinyl chloride	5.0	4.3
methyl isocyanate	4.5	
iodine	4.5	
methyl mercaptan	4.3	

TABLE S-14 cont.

dimethyl sulfide	4.3	
allyl alcohol	4.2	
propylene	4.0	3.5
mineral spirits	4.0	
2, 3-dichloropropene	4.0	
cyclohexene	3.4	
crotonaldehyde	3.1	
acrolein	3.1	
methyl methacrylate	2.9	2.4
pyridine	3.0	
hydrogen sulfide	2.5	
ethylene dibromide	2.7	1.9
n-octane	2.5	
acetaldehyde oxime	2.2	
hexane	2.2	
phosphine	2.0	
heptane	1.7	
allyl chloride	1.5	
(3-chloropropene)		
ethylene	1.0	
isopropanol	1.0	0.1
ethylene oxide	1.0	
acetic anhydride	1.0	
alpha pinene	0.7	
dibromochloropropane	0.7	

TABLE S-14 cont.

epichlorohydrin	0.7
nitric oxide	0.6
beta pinene	0.5
citral	0.5
ammonia	0.3
acetic acid	0.1
nitrogen dioxide	0.02
methane	0.0
acetylene	0.0

NOTE 1: FPM reading when measuring 10.0 ppm of particular gas with monitor calibrated for benzene.

TABLE S-15

RELATIVE PHOTOIONIZATION SENSITIVITIES OF
VARIOUS GASES TO A 11.7 eV LAMP

Direct Gas (Approx.)	Photoionization Sensitivity (See Note 1)	Span Control Setting for Direct Reading (Approx.)
Carbon Disulfide	33.0	
Heptane	22.1	
Hexane	18.9	
Pentane	14.1	
1,1 Dichloroethane	12.9	
Benzene	10.0	5.0
MIBK	10.0	
Isobutylene	10.0 (Reference Std.)	
Toluene	10.0	
Methyl Chloride	9.0	
Methylene Chloride	9.0	
1,1,1 Trichloroethane	9.0	
Carbon Tetrachloride	9.0	
Ethylene Dichloride	9.0	
Butane	8.7	
THF	7.8	
Acrylonitrile	7.1	2.5
MEK	6.0	
Chloroform	6.0	
1,1,1,1 Tetrachloroethane	6.0	
Acetone	5.7	
Propane	5.5	
Isopropanol	4.5	
Acrolein	2.7	1.0
Ethane	3.0	
Ethanol	3.0	
Methanol	1.0	
1,1,1 Trifluoroethane	0.3	
Acetonitrile	0.1	

NOTE 1: PPM reading when measuring 10.0 ppm of
particular gas with monitor calibrated for benzene.

TABLE 8-16

RELATIVE PHOTOIONIZATION SENSITIVITIES
OF VARIOUS GASES TO A 9.5 eV LAMP

Direct Gas (Approx.)	Photoionization Sensitivity (See Note 1)	Span Control Setting for Direct Reading (Approx.)
Nylene	11.2	
Benzene	10.0 (Reference Std.)	1.0
Styrene	10.0	
Toluene	10.0	
Phenol	7.7	
Aniline	5.0	
MEK	2.0	
Pyridine	2.0	
Acetone	2.0	
Methyl Methacrylate	<0.20	
Heptane	<0.20	
Hexane	0	
Ammonia	0	
Pentane	0	

* Commercial products containing impurities; response for pure materials is probably less.

NOTE 1: PPM reading when measuring 10.0 ppm of particular gas with monitor calibrated for benzene.

SECTION 8 cont.

8.7 WARRANTY

HNU Systems, Incorporated, warrants all items to be free from defects in material and workmanship when used under normal operating conditions. HNU's liability hereunder shall be limited to the repair or replacement of the articles ascertained to be defective within one (1) year after date of shipment (except that the light source warranty is limited to three (3) months and does not include breakage, and battery warranty is limited to three (3) months), provided, however that the Buyer shall give notice to HNU within thirty (30) days after discovery of such defective material and provided further that all defective material be shipped prepaid to the HNU plant within a reasonable time from the date of discovery of the defect and during such warranty period. After the repair or replacement, HNU will ship the said item to Buyer, transportation charges prepaid, to any point in the United States that Buyer may designate.

THE FOREGOING IS THE SOLE EXTENT OF HNU'S WARRANTY AND NO OTHER STATEMENTS OR WARRANTIES, EXPRESSED OR IMPLIED, SHALL BE HONORED. UNDER NO CIRCUMSTANCES SHALL HNU BE SUBJECT TO ANY LIABILITY FOR SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES.

SECTION 8 cont.

8.8 Publications on Photoionization Available from HNU Systems, Inc.

101-10 Industrial Hygiene Monitoring With A Variable
Selectivity Photoionization Analyzer.
J.N. Driscoll and J.H. Becker,
American Laboratory, November 1979.

101-12 Instrumentation for "On Site" Survey and Identification
of Hazardous Waste.
J.N. Driscoll and G.F. Hewitt,
Industrial Hygiene News, May 1982

101-17 Instrument Calibration with Toxic and Hazardous
Materials.
J.H. Becker, J.N. Driscoll, D. Renaud, P. Tiffany,
C. Sylvia,
Industrial Hygiene News, July 1983.

Lithologic Borehole Log

Project #10K70100

Sheet ___ of ___

N	Site ID _____ Northing _____ Elevation _____ Date Started _____ Drilling Contr. _____ Drill Method _____ Sample Type _____ Hammer Wt. _____	Location ID _____ Easting _____ T.D. _____ Date Completed _____ Driller _____ Rig Type _____ Geo/Eng. _____ Backfilled Date _____	Weather Conditions _____ Names of Persons Present _____ _____ _____
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Depth in Feet	Sampled Interval	Sample Number	Percent Recovery	HNU or OVM Reading	Blows Per ft	Sampling Method	Water Content	USCS Code	Color	Graphic Log	Interval		Description
											Start	End	
0													
5													
10													
15													
20													
25													
30													

EXAMPLE DAILY FIELD ACTIVITY REPORT

**JACOBS ENGINEERING GROUP INC.
FUEL HYDRANT SYSTEM INVESTIGATION
NAS FORT WORTH
DAILY FIELD ACTIVITY REPORT**

Task Order No.: _____

Project Code: 10K70100 Location: _____
Field Personnel: _____ Date: _____

<u>DESCRIPTION</u>	<u>NUMBER COMPLETED</u>
Drive-Point Mob/DeMob.	_____
Drive-Point Locations Completed	_____
Drive-Point Samples Collected	_____
Drive-Point Holes Abandoned	_____
Drive-Point Rig Standby Time	_____
Asphalt Patches Applied	_____
Samples Assayed	_____
Duplicate Samples Assayed	_____
QC Samples Assayed	_____

_____	_____
Jacobs Field Technical Representative	Date
_____	_____
Subcontractor's Representative	Date



JACOBS ENGINEERING GROUP INC.
DENVER, CO (303) 595-8855

PROJECT NO: 10K70100
PROJECT NAME: Fuel Hydrant Abandonment
PLACE: _____
DATE(S): _____

DAILY REGISTER

	NAME	TITLE	COMPANY	ONSITE LOCATION
1				
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FINAL PAGE

ADMINISTRATIVE RECORD

FINAL PAGE