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QUALITY ASSURANCE PROJECT PLAN
REFUSE HIDEAWAY LANDFILL
DANE COUNTY, WISCONSIN
WI. DEPARTMENT OF NATURAL RESOURCES

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1.0 INTRODUCTION

1.1 Overview

This Quality Assurance/Quality Control (QA/QC) Plan has been prepared by Hydro-Search, Inc. (HSI), as part of a ground-water monitoring study at the Refuse Hideaway Landfill for the Wisconsin Department of Natural Resources (WDNR). The goal of this QA/QC plan is to ensure that data generated and used during the ground-water monitoring study is technically sound, statistically valid, and properly documented.

To increase the confidence level of the ground-water monitoring results, it is necessary to identify quality requirements as part of the initial planning process. The overall data quality objectives are to obtain and evaluate defensible data that can be used to assess site hazards and evaluate alternative remedial actions. To be defensible, the data must have an appropriate degree of accuracy and reproducibility, as well as assurance that the samples collected and the field measurements taken are representative of actual site conditions.

To ensure the accuracy, precision, completeness, representativeness, and comparability of data generated, the following measures will be taken:

- WDNR and U.S.EPA approved sampling procedures will be used.
- All laboratory analyses will follow U.S. Environmental Protection Agency (U.S.EPA) Certified Laboratory Program (CLP) guidelines where available or utilize U.S.EPA methodology.

Section 2.0 of this QA/QC Plan addresses the proposed Sampling and Analysis Plan to be used at the site. Section 3.0 addresses procedures to be used during drilling and installation of the monitoring wells. Section 4.0 addresses specific QA/QC procedures to be used in the execution of the field investigations, laboratory analysis, and the management of the resulting data throughout the duration of the project.

1.2 Data Quality Objectives

To increase the confidence level of the investigation results, it is necessary to identify quality requirements as part of the initial planning process. The overall data quality objectives (DQOs) are to obtain and evaluate defensible data that can be used to assess site hazards and evaluate alternative remedial actions. To be defensible, the data must have an appropriate degree of accuracy and reproductibility, as well as assurance that the samples collected and the field measurements taken are representative of actual site conditions. A summary of project goals, the parameters providing the information, and the requisite DQOs are shown in Table 1-1.

Analytical DQO Level IV will be utilized for the performance of volatile organic compound and landfill indicator parameters. DQO Level IV required analysis by a contract laboratory program (CLP) which performs routine analytical services. This level of quality control is needed due to the low detection limits which will be required to evaluate the limits of the contaminant plume migration, particularly at sampling locations distant from the landfill. In addition, the data will be used to evaluate risk to human health and the environment in the development and screening of remedial action alternatives.

Analytical DQO Level II will be used for field measurement of pH, conductivity and temperature of ground water. DQO Level II requires field analysis on-site using instrumentation which provides quantitative results. Accuracy and precision goals for these parameters are necessarily reduced due to the nature of these measurements. These data will be used to establish that monitoring wells have been sufficiently purged prior to sampling and as indicators of landfill impacted ground water.

TABLE 1-1: DATA QUALITY OBJECTIVES

PROJECT OBJECTIVE	PARAMETER	DATA QUALITY OBJECTIVES
Groundwater		
Determine extent and magnitude of contaminants in ground water.	Volatile Organic Compounds	Establish presence/absence of contaminants and the vertical/horizontal boundaries of contaminant plume; Provide data for risk assessment; (Level IV Analytical)
	COD, chloride, dissolved iron, alkalinity, hardness	General water quality indicators of landfill impacts; (Level IV Analytical)
	Field parameters: pH, conductivity, temperature	Establish stable groundwater quality for sampling; General water quality parameters; (Level II Analytical)
Surface Water	No sampling planned	Not applicable
Soil	Grain size analysis No chemical analysis planned	Define the screened interval of each well Lithologic logs
Sediment	No sampling planned	Not applicable
Air	Volatile organic compounds, methane	General borehole and breathing zone monitoring (Level I Analytical)

- Swanson Environmental, Inc., Brookfield, Wisconsin

- Exploration Technologey, Inc., Madison, Wisconsin

The role of each team firm involved in the site investigations is discussed below.

1.3.1.1 Hydro-Search, Inc.

Hydro-Search, Inc. as the prime contractor, has overall project responsibility for project management including execution of the site investigations, data analysis, and assuring conformance of the work performed within the scope of the site investigations.

1.3.1.2 Swanson Environmental, Inc.

Swanson Environmental, Inc. (SEI) is responsible for laboratory analysis support.

1.3.1.3 Exploration Technology, Inc.

Exploration Technology, Inc. is responsible for drilling and monitoring well installation support.

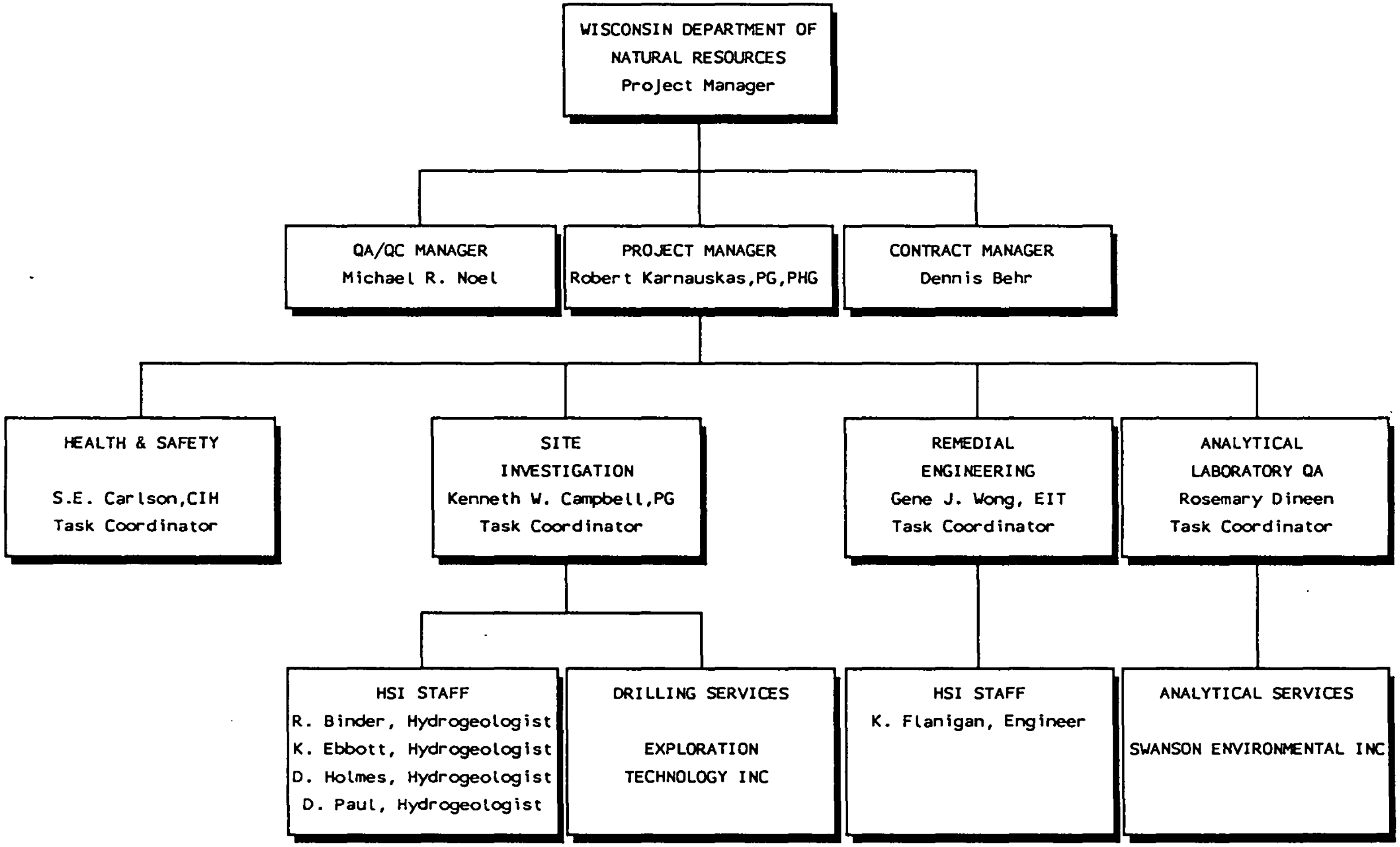
1.3.2 Project Organization and Job Responsibilities

Figure 1-1 shows the project organizational chart for the site investigations. The responsibilities of the primary personnel are described below.

1.3.2.1 Project Director

Michael R. Noel, Vice President, Manager of HSI's Milwaukee Office, will serve as the Project Director and Project Quality Assurance Officer. Mr. Noel will provide investigative team management and supervision on the project. The Project Director will also be

FIGURE 1-1. PROJECT ORGANIZATION



responsible for assuring that proper corporate resources are balanced with the project requirements and provide quality assurance peer review of the project deliverables. Input on project direction will be provided to the HSI and WDNR Project Managers.

The Project Director will meet with project management and project management staff periodically and assure that all QA functions are being adhered to.

1.3.2.2 Project Manager

Mr. Robert J. Karnauskas will be the project manager for HSI. The Project Manager has primary responsibility for oversight of all activities scheduled to be performed during the investigations. Mr. Karnauskas will provide technical direction to the project personnel and will be responsible for providing technical and financial control.

The Project Manager is responsible for coordinating the necessary technical reviews and report reviews with particular attention placed on the following:

- Check that the work elements as defined in the Work Plans and any subsequent scope modifications are properly executed.
- Check that the major applicable rules and regulations of specific protocols are properly followed.
- Check that available alternatives are properly evaluated and appropriate technologies are considered.
- Provide the necessary calculation and methodology checks to determine the accuracy of findings reached.
- Coordinate expert review of analyses and conclusions by disciplines.

- Seek additional consultation or request additional review of a specific subject by persons with special expertise.

- Participate in necessary QA/QC audits for the project.

- Review draft and final reports

1.3.2.3 Site Investigation Task Coordinator

Mr. Kenneth W. Campbell will serve as the Site Investigation Task Coordinator. The Site Investigation Task Coordinator will be responsible for coordinating and executing all on-site activities, including drilling, supervision, borehole logging, and sample collection and handling procedures. In addition to the field activities, the Site Investigation Task Coordinator will be responsible for preparing applicable sections of the report.

The Site Investigation Task Coordinator is responsible for the Quality Assurance in the field. Specifically, the duties include the following:

- Proper execution of field sampling and other field related activities.
- Proper sample bottle labeling.
- Proper use and care of field equipment.
- Field calibrations.
- Field measurements.
- Sampling procedures.
- Sample preservation in the field.
- Chain-of-Custody.
- Sample transportation.
- Field notebooks and other field documents.

The authorities of the Site Investigation Task Coordinator on the QA function include the following:

- Stop any sampling activity that is not following acceptable protocols.

- Discard any sample that is not taken, transported, or preserved according to acceptable protocol.

- Invalidate any data obtained from an improperly obtained sample.

- Invalidate any data where the proper sample handling and documentation protocols have not been followed.

1.3.2.4 Health and Safety Task Coordinator

The Health and Safety Task Coordinator is Mr. Steven E. Carlson. Mr. Carlson will coordinate the efforts of the site health and safety officers whose responsibilities are for developing a site specific health and safety plan with contingencies to deal with all anticipated hazards specific to tasks to be performed during the field work. In addition, the Project Health and Safety Officer is responsible for reviewing any site incident reports and near miss reports and implementing any corrective measures deemed necessary to prevent recurrence of incidents and/or near misses.

The site health and safety officer is responsible for implementing the site safety plan during field activities. The site health and safety plan will be kept on site by the site health and safety officer. It will be his responsibility to ascertain that all field personnel have reviewed and understand the site health and safety plan, and are familiar with the emergency contingencies therein.

2.0 SAMPLING AND ANALYSIS PLAN

The objective of this section is to provide programmatic sampling and analysis guidance and procedures for WDNR's environmental investigation of the Refuse Hideaway Landfill site by the HSI project team. This section contains discussion of the procedures to follow for sampling of ground water and subsurface soils. Procedures for field screening samples, soil boring, and monitoring well installation are also described. Specific QA/QC procedures and analytical methods for the samples are discussed in Section 4.0, Quality Assurance/Quality Control Procedures.

2.1 Field Methods

Parameters which would be likely to change with time prior to delivery to the laboratory are generally measured in the field. Because of the potential for temporal differences in measured values, laboratory measurements of these parameters, although potentially more precise, would be less accurate than measurements collected in the field. In addition, field measurements can serve as an initial screening tool to evaluate relative degree of contamination of samples. Sample contaminant concentration information is also useful in determining packaging and shipping requirements.

Field measurements are typically performed for the following parameters (1) photoionizable VOCs in soil and water samples, (2) fluid pH, (3) fluid specific conductance, and (4) fluid temperature. HSI field equipment to be used for the above parameters include the following:

1. HNU photoionization detector model PI-101,
2. VWR Mini-pH meter Model 47,
3. YSI S-C-T meter Model 33, and
4. Glass thermometer.

The procedures for the use of these instruments are discussed below.

2.1.1 HNu PID

The HNu is a portable, nonspecific vapor/gas detector employing the principle of photoionization to detect a variety of volatile compounds, both organic and inorganic. HNu readings are routinely performed during borehole installations in areas of known or suspected contamination and as part of soil surveys to define extent of contamination. The instrument is also frequently used to monitor ambient air for health and safety purposes.

The HNu contains an ultraviolet (UV) light source within its sensor chamber. Air is drawn into the chamber with the aid of a small fan. If the ionization potential (IP) of any molecule present in the air is equal to or lower than the energy of the UV light source, ionization will take place, causing a deflection in the meter. Response time is approximately 90 percent at three seconds. The meter reading is expressed in ppm as benzene equivalents. Compounds other than benzene may produce instrument responses with higher or lower sensitivity relative to benzene.

The HNu is used as a field screening and semi-quantitative field measurement device to monitor photoionizable VOCs in air. Field screening of potential soil or ground water contamination is accomplished by performing a headspace analysis on air in contact with a sample within an enclosed container. The form used for recording PID readings is shown in Appendix A.

Limitations to the use of the HNu include the following:

- The HNu does not identify the compounds being detected.

- If the IP of a compound is greater than the UV light source, the instrument will not respond.

- The HNu does not detect methane gas.

- During cold weather, condensation may form on the UV light source window, producing erroneous meter response.

- Instrument readings can be affected by humidity and power lines.

- Concentrations are measured relative to benzene. Therefore, actual contaminant concentrations in the air sample cannot be quantified, unless the contaminant occurs as a single compound whose sensitivity is known relative to benzene. While the instrument scale reads zero to 2,000 ppm, response is linear (to benzene) only from zero to about 600 ppm. Concentrations greater than 600 ppm may be "read" at a higher or lower level than the true value.

- Wind speeds greater than three miles an hour may affect fan speed and readings, depending on the position of the probe relative to the wind direction.

2.1.1.1 Calibration Procedure

Prior to use, the battery will be tested by turning the function knob to "BATT" and confirming needle deflection to the green zone of the meter scale.

The instrument will be zeroed by rotating the zero potentiometer knob when the function switch is in the "Stand-by" position. Instrument function will be verified by placing the probe near an organic point source, such as a magic marker, and noting meter deflection.

HNu calibration gas canisters equipped with a regulator will be used to calibrate the instrument on a daily basis prior to field use. The calibration procedure is as follows:

1. Connect a sampling hose to the regulator outlet on the span gas cylinder and the other end to the sampling probe of the HNu.

2. Open the regulator valve until gas can be heard flowing from the canister.

3. Take a reading after five to ten seconds.

4. Adjust the span potentiometer to produce the concentration listed on the span gas cylinder. This procedure shall be followed only until the span potentiometer reaches the following limits:

Probe	Initial Span Pot Setting	Maximum Acceptable Span Pot Setting
9.5 eV	5.0	1.0
10.2 eV	9.8	8.5
11.7 eV	5.0	2.0

5. If these limits are exceeded, the instrument must be returned for maintenance and recalibration.

6. Calibration results will be documented each day on the HNu calibration log. This documentation includes recording the following:

    a. Date inspected,
    b. Person who calibrated the instrument,
    c. The instrument ID number,
    d. The results of the calibration (ppm, probe eV, span potentiometer setting), and

e. Identification of the calibration gas (source, type, concentration pressure).

A separate calibration log will be maintained for each HNu used.

2.1.1.2 Measurement Procedure

Semi-quantitative measurements of total VOCs in soil and ground water can be determined using an HNu PID by monitoring the headspace within a sample jar. The procedure to be used for measuring sample headspace is as follows:

1. Record the background ambient air concentration on the field PID form. Typical background values are zero to 3.0 ppm or higher depending on the measurement location. Locations with ambient PID readings greater than 3.0 ppm should not be utilized for field screening measurements.

2. Half-fill a clean 16 oz. glass Mason jar with the sample to be analyzed. Quickly cover the top with two sheets of clean aluminum foil and apply a screw cap to tightly seal the jar.

3. Allow headspace development of VOCs for ten minutes in ambient temperatures greater than 55 °F. Vigorously shake or swirl the jar for 15 seconds both at the beginning and end of the headspace development period. Where ambient temperatures are below 55 °F, headspace development should occur within a heated vehicle or building.

4. Subsequent to headspace development, quickly puncture foil seal with the HNu sampling probe to a point about one-half of the headspace depth. Exercise care to avoid uptake of water droplets or soil particles.

5. Record the maximum meter response observed within 15 seconds on the field PID data form as the jar headspace concentration. Maximum response should occur between two and five seconds. Erratic meter response may occur at high organic vapor concentrations or conditions of elevated headspace moisture, in which case notation should be made of the suspected cause of the erratic reading. Record sample identification information.

6. All HNu readings for soil will be followed by the symbol "d" (dry), "m" (moist) or "w" (wet) to aid in data interpretation. The symbol "w" will be used when there is substantial accumulation of water droplets in the bag or jar to the extent that readings are probably being affected by the humidity. Erratic meter response may occur at high organic vapor concentrations or conditions of elevated headspace moisture, in which case headspace data should be discounted.

2.1.1.3 Quality Assurance

Replicates

If sufficient sample is available, headspace analysis of samples will be performed in duplicate. If duplicate samples are collected, the headspace screening data from both jar samples should be recorded and compared. Generally, replicate values should be consistent to plus or minus 20 percent.

Blanks

Blank samples will be measured to determine if any contamination is being introduced as part of the measurement procedure. One PID blank sample will be performed for each 11 samples measured, which represents one jar for each case of Mason jars used. The measurement procedure for field PID blanks is given below.

Water

Distilled water will be substituted for sample water, and the same headspace measurement procedure as outlined in Section 2.1.1.2 will be followed.

Soil

The headspace measurement procedure outlined in Section 2.1.1 will be followed, but no sample will be placed in the Mason jar, as no universal soil blank has been accepted. A headspace reading of the jar should be taken after the jar has been opened, resealed, and allowed to sit for ten minutes.

2.1.1.4 Data Recording

PID data will be recorded in the field notebook and clearly marked "PID reading (ppm)." The data will also be recorded on applicable field forms, such as PID data forms, soil borehole logs, and water quality sampling and analysis forms (Appendix A). In addition to data records, maintenance records and calibration records will be generated and maintained on appropriate forms or in the site field notebook. Records of instrument user, dates of uses, instrument identification number, and project identification will also be maintained.

2.1.2 pH Meter

The pH meter is used to determine the negative log of the hydrogen ion activity concentration within a solution, measuring its acidity or alkalinity. Field pH measurements will be performed on water samples. Soil pH values are determined in the laboratory. The units measured are standard units (SU), and fall on a scale of one to 14, with a neutral value of seven, acidic values below seven, and alkaline values above seven. The accuracy of the VWR mini-pH meter model 47 which is generally used for HSI field work is ±0.15 SU.

Measurements of pH are routinely performed as part of well development and water quality sampling and analysis. The pH meter will be used in well development and water quality sampling as an indicator that stagnant ground water has been removed from the well. When replicate pH measurements stabilize and four well casing volumes have been removed, the well will be considered adequately purged for sampling.

2.1.2.1 Calibration Procedure

Buffers must be kept clean, and replaced prior to expiration.

1. Connect electrode to control box and rinse electrode with distilled water.
2. Dry electrode and repeat distilled water rinse.
3. Immerse electrode in pH 7 buffer. Buffer temperature should be between 10.5 °C and 20 °C.
4. Turn pH meter on, perform battery check. If battery is low, replace.
5. Swirl buffer and let reading stabilize 15 to 30 seconds.
6. Adjust meter to pH 7.0 using the CALIBRATE knob.
7. Remove electrode, rinse with distilled water, dry and rinse with distilled water again.
8. Immerse in second buffer, either pH 4.0 or 10.0 depending upon the estimated pH of unknown samples.
9. Swirl buffer and let reading stabilize for 15 to 30 seconds.

10. Adjust meter to pH 4.0 or 10.0 using the temperature knob. This knob adjusts for both temperature effects and voltage deficiencies in the electrode. It need not correspond to the solution temperature.

11. Remove electrode, rinse with distilled water, and replace protective cap.

2.1.2.2 Measurement Procedure

The procedure for use of the VWR mini-pH meter model 47 is given below. The meter must be calibrated prior to use.

1. Hook electrode to control box.
2. Turn control box on.
3. Check battery level. If insufficient, replace.
4. Pour solution to be measured in a clean plastic or glass beaker.
5. Remove protective cap from electrode, rinse with distilled water, and blot dry.
6. Immerse electrode in the sample and swirl the beaker for several seconds.
7. Allow meter to stabilize approximately 15 to 30 seconds.
8. Record reading.

2.1.2.3 Quality Assurance

Replicates

For water quality sampling, duplicate pH measurements will be made if sufficient sample is available. For well development and packer testing, frequent pH measurements are required; therefore no replicate measurements will be necessary.

Calibration Checks

Calibration will be performed prior to field measurements, and checked after every ten measurements using the pH 7, and pH 10, or 4 buffer solutions. During ground-water sample collection, the calibration procedure will be performed prior to and following sampling at each well.

2.1.2.4 Data Recording

Data from pH measurements will be recorded in the field notebook and on appropriate field forms, including Well Development/Purge Summary forms and Water Quality Sampling and Analysis Forms (Appendix A). In addition to data measurements, calibration frequency and results will be recorded.

2.1.3 Specific Conductance Meter

Specific conductance measurements are routinely performed during water quality sampling and during well development to determine general water quality. Specific conductance is directly dependent upon the total ionic constituents in a solution. The specific conductance of the solution is measured by sending an electric charge between two sensors in the probe. The greater the concentration of ionic constituents in the sample, the greater the ability to transmit a charge, and the higher the measured conductivity.

The specific conductance meter (S-C meter) provides a semi-quantitative measurement of the total ionic content of water samples. Specific conductance is loosely related to the total dissolved solids, (TDS) because generally an increase in TDS causes an increase in the concentration of ionic species, which, in turn, directly affects the conductance of the solution. The readout unit is in micromhos/centimeter (umhos/cm).

Specific conductance is temperature dependent, so a temperature measurement must be made at the time of the specific conductance measurement. A temperature compensation adjustment can then be made to allow comparison of conductivity values. Conductivity values are universally corrected to 25°C. Table 2-1 presents temperature compensation factors for common ground water temperature ranges. According to the manufacturer, the obtained conductivity values are reportedly accurate to ±2.5%.

2.1.3.1 Calibration Procedure

The calibration procedure is as follows:

1. Note if the needle on the unit display aligns with the "0" on the meter. If it does not, use a screwdriver and adjust the needle to "0" by turning the screw located directly below the words "S-C-T meter" on the unit display.

2. Plug probe into the probe jack on the side of control box.

3. Turn mode switch to "RED LINE."

4. Adjust needle using the knob labeled "RED LINE" until the needle covers the red line on the meter display.

5. If the unit will not red line, replace batteries, or try to diagnose the problem.

Calibration will be performed before every use.

2.1.3.2 Measurement Procedure

1. Plug the probe into the probe jack on the control box.

2. Calibrate the unit as described in Section 2.1.3.1.

3. Obtain a water sample in a 500 ml beaker or other container.

Table 2-1 Multiplication Factors for Converting Specific Conductance of Water to Values at 25°C (based on 0.01M KCl and 0.01M $NaNO_3$ solutions)

°C	factor	°C	factor	°C	factor
32	0.89	21	1.08	10	1.36
31	0.90	20	1.10	9	1.39
30	0.92	19	1.12	8	1.42
29	0.93	18	1.14	7	1.46
28	0.95	17	1.16	6	1.50
27	0.97	16	1.19	5	1.54
26	0.98	15	1.21	4	1.58
25	1.00	14	1.24	3	1.62
24	1.02	13	1.27	2	1.66
23	1.04	12	1.30	1	1.70
22	1.06	11	1.33	0	1.74
				-1	1.78

4. Immerse the probe in the solution.

5. Immerse thermometer in the beaker.

6. Turn the Mode switch to the setting for which the instrument needle is on scale. The greatest accuracy is obtained when the needle records in the middle of the display.

7. Allow the reading to stabilize for approximately 15 to 20 seconds.

8. Read and record the measured conductivity. Use the black scale on top of the meter gauge. If mode is set to the 10x or 100x scale, multiply value by 10 or 100. Readings are made by lining up the needle over the reflective mirror backing. Readings are in micromhos/centimeter (umhos/cm).

9. Read and record the temperature of the sample using the thermometer. Compare thermometer value to the temperature mode on the conductivity meter.

10. Turn unit off and remove the thermometer from the sample.

11. Clean the conductivity meter electrode and the thermometer by rinsing with distilled water.

12. Adjust the measured field conductivity value to the standard 25°C conductivity value.

2.1.3.3 Quality Assurance

Replicates

For water quality sampling, conductivity measurements will be made in duplicate if sufficient sample is available. For well development and packer testing, frequent conductivity measurements are made, and therefore no replicate measurements should be necessary.

Blanks

A distilled, deionized water blank will be kept with the SC meter, and a "blank" measurement will be taken twice daily during meter use; prior to beginning field measurements and subsequent to all field measurements. In addition, a blank measurement will be made if field personnel suspect the SC meter is not functioning properly.

2.1.3.4 Data Recording

Specific conductance measurement data, including blank and replicate measurements, will be recorded in the field notebook and on appropriate field forms, including Well Development/Purge Summary forms and Water Quality Sampling and Analysis forms (Appendix A). In addition to data reading, any maintenance or measurement problems noted during field work will be recorded.

2.2 Geologic Materials Sampling

2.2.1 Description of Soil Samples

A descriptive log of visual soil characteristics will be maintained for all soil sampling operations. The log will be completed by a geologist supervising the soil sampling operations. The log will contain a detailed description of the soil encountered as per ASTM method D2488-84. The descriptions will be recorded on WDNR's Soil Borehole Log Forms

(Appendix A) and in the field notebook. The descriptions will include applicable information pertaining to soil type, organic material content, grain size distribution, gradation, plasticity, mottling, color (using Munsell notation), odor (when respirators are not necessary), moisture content, consistency, density, grain shape and lithology, soil structure, horizonation, layering, jointing, photoionizable constituent content, geologic origin, and group symbol.

2.2.2 Geologic Data

The geologic information will be used to produce a lithologic log for each borehole. The borehole logs will follow the WDNR format and include information required by NR141.23.

2.2.3 Sample Collection

Soil samples will be collected at five feet intervals during drilling using standard split-barrel sampling techniques (ASTM Method D 1586-84). Each sample will be visually classified by an HSI geologist in accordance with ASTM Method D 2488-84, using the Unified Soil Classification System (USCS). Descriptions will be recorded on WDNR Soil Borehole Log forms (Appendix A). The descriptions will include applicable information pertaining to soil type, organic material content, grain size distribution, gradation, plasticity, mottling, color (using Munsell notation), odor, moisture content, consistency, density, grain shape and lithology, soil structure, layering, jointing, lenses, fractures, void space, unconfined compressive strength, photoionizable constituent content, geologic origin, and group symbol.

A portion of the split-spoon soil sample will be transferred into a mason jar for headspace analysis. The soil headspace analysis procedures are described in Section 2.1.1. Soil headspace measurements will be recorded on PID Data Summary sheets (Appendix A) and the highest PID reading in each borehole will be noted.

2.2.4 Sample Laboratory Analysis

One soil sample from the screened interval depth of each new monitoring well installed in surficial soils will be tested and classified as specified in NR 508.09(2)(a). The samples will be collected using standard split-spoon sampling techniques. Sample descriptions will be recorded as described in Section 2.3.3. A portion of each split-spoon sample will be placed in an eight-ounce glass jar for delivery to the laboratory. The jar will be labelled with the project number, borehole identification, sample depth, interval, date, time, sample type (grab or composite), and sampler per Section 4.0. Samples will be properly packaged and shipped to the laboratory under chain-of-custody procedures, as discussed in Section 4.2.

A second portion of the split-spoon sample will be transferred to a mason jar for headspace analysis as described in Section 2.1.1.2. The potential level of contamination, as indicated by the headspace analysis, will be included on the label of the sample delivered to the laboratory so that proper precautions may be taken.

2.2.5 QA/QC Procedures

Quality Assurance/Quality Control procedures for soil samples are discussed in Section 4.0.

2.3 Ground-Water Sampling

2.3.1 Presampling Activities

2.3.1.1 Static Liquid Level Measurement

Static liquid levels will be measured prior to sampling. The total well depth will also be determined at this time and compared to well construction records. The well will then be purged and ground water will be sampled.

2.3.1.1.1 Procedure

The locking and protective caps to the well will be removed. The air in the well casing will be screened for the presence of organic vapors using an HNu PID. Any damage to the well or piezometer will be noted.

The static liquid level measurements will be collected using an electronic water level probe (WLP). The WLP will be lowered into the well to the approximate depth of the fluid level based on historical fluid level elevation data. The WLP is submerged in the fluid to complete an electrical connection. The probe indicator light or buzzer is then activated. The length of cable in the well is then measured to the nearest 0.01 foot. The measuring point on the well casing should be permanently marked. The static fluid elevation can be calculated from the well casing elevation less the depth to water.

2.3.1.1.2 Data Recording

Depth to water measurements will be taken from the north end of the well casing. Measurements will be recorded to the nearest one-hundredth of a foot in the site field book, and on water level data forms (Appendix A), along with the time and date of the measurement, the measuring device, PID readings, the name of the person taking the measurement, and any additional comments. The elevation of the fluid level referenced to msl will also be calculated and recorded based on depth to fluid contact water and measuring point elevation.

2.3.1.2 Well Purging

Prior to ground water sample collection, stagnant water will be purged from each sampled well so that samples will be representative of in-situ ground-water quality. The wells will be purged of four casing volumes of fluid. Volumes will be calculated using the equation from Section 3.5. Where appropriate, dedicated pumping or bailing equipment will be used. Where dedicated equipment is not utilized, sampling equipment will be decontaminated between samples following the procedures in Section 4.1.1. Measures will be taken to prevent contact between the ground surface and the well purging equipment by placing sampling equipment onto visqueen or other appropriate medium above the ground surface.

During purging, measurements will be made periodically of pH, specific conductance, and temperature using a VWR "mini-pH meter," a YSI Model 33 S-C-T meter, and a glass thermometer, respectively. Samples will be collected for laboratory analysis when pH, conductivity, and temperature are stabilized or when four casing volumes have been removed from the well, whichever is later. In addition, an HNu model PI-101 PID meter will be used to screen the purged water for volatile content, using the procedures for water headspace analysis in Section 2.1.1.2. Measurements made during well evaluation will be recorded on Well Development/Purge Summary forms (Appendix A). Purged water will be placed into appropriate containers pending disposal. The method for determining disposal procedures is presented in Section 3.7.

2.3.2 Collection of Ground-Water Samples

2.3.2.1 Sampling Order

To minimize the potential for cross-contamination, the wells will be sampled in an order progressing from areas of low ground water impacts to higher ground-water impacts, based on results of previous ground water sample analyses.

2.3.2.2 Ground-Water Sampling Procedures

After the completion of purging at a well, ground-water samples will be collected using a dedicated sampling pump or a dedicated bailer if possible. If non-dedicated sampling equipment is used, it will be properly decontaminated between wells per Section 4.1.1 methodology. Pumps will be operated in a continuous manner so that water is not aerated in the return tube or upon discharge to the sample containers.

Sample vials will be filled in the following sequence based on the volatility of the parameters to be analyzed as recommended by the EPA:

- Volatile Organics (VOA)
- Dissolved Metals
- Chloride
- Inorganic Parameters (COD, Alkalinity, and Hardness)

While sampling for the volatile constituents, the pumping rate will not be allowed to exceed 100 ml/minute. Higher pumping rates may be used during sampling for non-volatile constituents. Parameters such as dissolved metals which require filtration will be field-filtered before being transferred into sample containers.

2.3.2.3 Data Recording

Ground-water sampling data will be recorded on appropriate field forms, including the appropriate Chain-of-Custody forms, Water Quality Sampling and Analysis forms, and Well Development/Purge Summary forms (Appendix A). Any additional data readings or comments will be noted in HSI field notebook(s).

2.3.2.4 QA/QC Procedures

Quality assurance/quality control procedures for ground water samples are discussed in Sections 4.0.

2.4 Stage-Discharge Determinations in Small Streams

2.4.1 Introduction

This section will provide a brief description of one method for flow measurement in steams that involves the measurement of stage, and the development of a discharge relationship to stage. This method will allow for ready conversion of stage records into discharge values. The type of stage measurement installation described in this document includes a non-freeze proof semi-permanent galvanized stilling-well. Discharge measurements are made with the aide of a current meter to allow construction of a discharge rating at each gaging station. The methods described herein may require some modification or may be compromised to some degree to allow collection of data under less than ideal conditions. Different objectives may also result in modification of the methods sited within this document.

2.4.2 Stage Measurements

2.4.2.1 Stilling-Well Siting

The purpose of a stilling-well is to allow accurate measurement of water levels without wave or current disturbance. A method used for non-freeze proof conditions consists of the following components and materials:

- One-foot diameter galvanized culvert of variable length (usually five to six feet). A plate is welded to one end to prevent sediment from entering. Brackets are welded to the opposite end to support a recorded box, if desired.

- Miscellaneous items include guide wires for stabilization of the stilling-well culvert.

Selecting a site for the stilling-well is partially dependent upon locating an area where stream velocity "cross section" measurements can be carried out accurately under all variations of stage, a subject to be discussed later. The following criteria are usually used for selecting a stilling-well site:

* A fairly straight section of stream length where turbulence is minimal and flow maintains a uniform flow under varying stage.

* An area proximate to where the cross section measurements will be made, possibly at some sort of permanent control structure (e.g., a bridge where abutments contain the stream width with increasing stage, or an underwater rocky ledge). Undercut banks, areas where overland flooding will occur easily, or areas where streambed scour and/or streambank erosion may occur over the study period should be avoided.

* A position in the stream away from strong current areas, but where water will be available to the stilling-well under low flow conditions. A location should be chosen that will also afford some protection from strong currents during flood events.

* At a location where the type of sediment is sand, gravel, consolidated clay, or a mixture of these materials, since the substrate may be required to partially support the installation and resist settling or tilting of the structure.

* An area of low susceptibility to vandalism.

2.4.2.2 Installation

The stilling-well structure should be installed vertically into the streambed. If at a bridge site, the culvert may be bolted to the vertical concrete abutment. If conditions require that a stilling-well be anchored to the streambed or bank, a concrete form must be poured as a base anchor. A circular or square concrete form should be placed in the streambed and the sediment should be removed within the form to the desired depth (approximately one to two feet) below the bed surface. The concrete form will prevent new sediment from being washed into the hole, and will later contain poured cement. The bottom of the hole will be lined with gravel and the culvert will be inserted. Immediately prior to installation of the culvert, several 1/2-inch diameter inlet holes should be drilled in the culvert in a vertical row at a level dependent upon depth of culvert placement. Concrete will be poured around the culvert to provide stabilization to the stilling-well structure, stability is important to obtain water level measurements typically measured to the hundredth of a foot. While allowing the concrete to cure (curing time is dependent upon mixture, water temperature, etc.), three equally spaced guide wires can be attached near the culvert top edge to iron stakes in the stream bed/bank to further aid in stabilization of the structure. A wooden recorder box is normally attached to the top of the culvert to house a Stevens water level recorder. A recorder box and recorder will not be installed for this investigation. Adequate stabilization of the structure is very important, since personnel will be visiting the site periodically to obtain measurements and inspect the installation. An accidental jarring from someone during this process must not cause a shifting of the installation.

A surveyor's temporary benchmark (TBM) is established near the stilling-well site for the duration of the study. This TBM will provide the following functions:

- Detect shifting or settling of the stilling-well structure at later dates; probably the most important function.

- Provide a relative elevation of the stream, as detected in the stilling-well.

- Allow this point (the TBM) to be tied into a benchmark monument (e.g., USGS) for conversion of all stream levels to elevations relative to mean sea level. This can be done at a later date at a convenient time if this information is desired.

A surveying instrument, such as a transit or engineer's level, and a surveyor's rod will be used to determine the elevation of the stilling-well and the stream surface relative to the TBM. The stilling-well and relative TBM elevations will be read to the nearest hundredth of a foot and these readings will be entered in the field notebook. A relationship now will exist between the stream stage TBM and the stilling-well. Assuming that the stilling-well does not settle or shift at a later date, both the stilling-well and the TBM will indicate a similar stream elevation for each set of readings. If these values do not agree, some action must be taken to correct the problem.

2.4.2.3 Servicing the Installation

Care should be taken not to disrupt the installation. A comparison of stilling-well and TBM readings should be made upon first arriving at the site. The difference between the readings (which again was only arbitrary upon installation) should agree with the value when the installation was first surveyed-in. A variation of ±0.02 feet is acceptable and may result from several error sources. A difference of ±0.03 feet should alert the investigator to a possible problem somewhere. When serviced, both beginning and ending readings should always be marked. This will allow corrections to be made to the stage records at a later date and will pinpoint the date at which a problem was noticed. The installation may be re-surveyed-in relative to the temporary benchmark at any future date if required. If it is certain that the entire stilling-well installation is settling or shifting and not the independent TBM, corrections can be made to the readings simply by comparing the degree of change and correcting accordingly.

The following is a list of steps or items to check when servicing the stilling-well installation.

* Record staff gage readings in a notebook. (Measure the base of the meniscus).

* Check for free passage of the stilling-well inlet holes.

* Check for sediment accumulation in the stilling-well base.

2.4.2.4 Alteration of Stilling-Well Design

In certain instances, it may be necessary to construct and install a stilling-well that will have small diameter pipes or tubing leading from the stream to the stilling-well. This tubing will, in effect, replace or be inserted into the inlet holes of the stilling-well.

2.4.3 Discharge Measurements

2.4.3.1 Current Cross Section Measurements

Current cross section measurements comprise the first phase in developing a discharge rating for a particular gaging station. When one or several rating curves have been developed for a site, the stage records from the stilling-well recorded may be converted to discharge.

The "partial section" method of flow measurement in streams is usually employed. With this method, a stream is divided up into sections small enough to assure that less than 10% of the total stream flow passes through each of these sections. This can only be estimated since the flow obviously hasn't been measured yet. To assure that this criterion is met, a stream should be divided upon into 15 to 25 sections. The 10% criterion is used only to reduce the error magnitude, since if an error occurs in one or two of the partial sections, its effect on total accuracy will be less if a large number of partial sections are used. Practical considerations, such as when stage is changing rapidly, may preclude the use of the ideal number of partial sections. The mean velocity of each partial section is then determined and the flow through each partial section is calculated with the following formula (USGS, 1969):

$$q_x = v_x \frac{b_{(x+1)} - b_{(x-1)}}{2} d_x$$

where: q_x = discharge through partial section x,

v_x = mean velocity at location x,

$b_{(x-1)}$ = distance from initial point to preceding location,

$b_{(x+1)}$ = distance from initial point to next location, and

d_x = depth of water at location x.

This method is illustrated in Figure 2-1. For example, the discharge through partial section 4 would be calculated with the following formula:

$$q_4 - v_4 \frac{b_5 - b_3}{2} d_4$$

The endpoints, or where water is on only one side of an observation point, are treated somewhat differently. Here the depth and velocity may or may not be zero. The mean velocity at these points should be estimated when it is not possible to measure it with a current meter. For an endpoint near or coincident with the initial point, the calculation is as follows:

$$q_1 - v_1 \frac{b_2 - b_1}{2} d_1$$

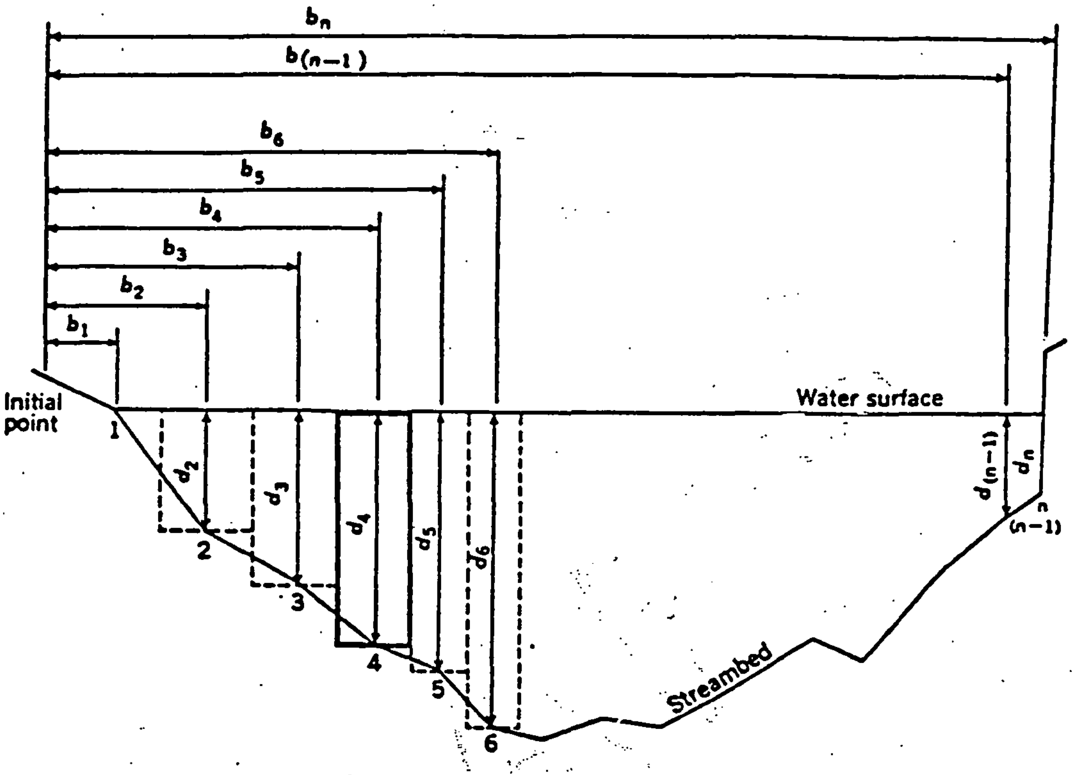
For an endpoint nearest or coincident with the stream side opposite the initial point (the last station), it is:

$$q_n - v_n \frac{b_n - b_{(n-1)}}{2} d_n$$

The total discharge of the stream is calculated by summing the flows from all of the partial sections.

At least 20 of these cross section measurements are needed to construct an adequate relationship between stage and discharge. "The more the better" philosophy is applicable in this situation. Cross section measurements should be made at all different stream

Figure 2-1. Illustration of the partial-section method of measuring stream flows (USGS, 1969)



EXPLANATION

1, 2, 3,......n	Observation points
$b_1, b_2, b_3, \ldots\ldots b_n$	Distance, in feet, from the initial point to the observation point
$d_1, d_2, d_3, \ldots\ldots d_n$	Depth of water, in feet, at the observation point
Dashed lines	Boundary of partial sections; one heavily outlined discussed in text

elevations or stages. Particular attention should be given to define the stage-discharge relationship at the higher stages, since this is the region where flooding may occur at various upstream areas, thereby altering an expected or estimated curve appearance. The flood stages are often the stages of most importance to engineers, planners, economists, and property owners, since property damage, structural damage, erosion, and water quality are more greatly affected at these flows. Discharge measurements are more difficult to make at the higher stages, since the stage may be changing rapidly. In such cases, it is important to make quick measurements and to record the stage elevation at the beginning and end of the discharge measurements.

The location of cross section or "discharge" measurements in a stream should be determined when a site for the stilling-well installation is chosen, since applicable criteria in choosing these sites is common to both situations. The location of the cross section measuring point should be a permanent location and should be located where the following criteria are met if possible:

1. Sediment scouring or sediment deposition are minimal over the length of the study period.

2. Sediment is fairly consolidated and easy to walk on if wading is required, or, if measurements are from a bridge, the sediment will allow for detection of the streambed.

3. Channel dimensions will remain permanent over the study period. Avoid areas where bank erosion may occur at high stages.

4. Avoid areas where undercut banks are present or where abrupt changes in stream bank geometry occur at high stages.

5. Choose a location where measurements can be made with relative ease during high stages, i.e., areas that will not present a hazard to personnel during measurements.

6. Avoid areas of turbulence. Attempt to find areas approaching uniform flow. Straight lengths of stream sections are desirable.

7. Avoid areas of heavy macrophyte growth.

The investigator should have the end result in mind -- developing a discharge rating as easily and as accurately as possible, preferably a single relationship applicable to all stages under all conditions. Bridges are commonly chosen as gaging stations because these areas are easily accessible and meet many of the criteria listed above. Backwater affects may develop at these areas at high stages, but frequent discharge measurements at these stream levels will define these effects.

In practice, cross section measurements are made with the aid of a "tag line" for measurements made by wading or by boat. The tag line should be strong enough for the particular application; a steel cable or large diameter rope if a boat is to be anchored to it, or a string if the stream is small and a boat is not needed. Known distances or intervals, that need not be equal, are marked off on the tag line denoting stations. If measurements are made from a bridge, the bridge railing can be conveniently marked off to denote the stations. Note from Figure 2-1 that with the exception of each endpoint, each station may be considered as the center point of each partial section when the partial section method is used.

Depth and velocity measurements are made at each station including both endpoints if possible. If the cross section is bounded by bridge abutments, the velocity and depth must be measured or estimated at each endpoint since each will not likely be zero. If the cross section is bounded by streambanks, both depth and velocity may be zero. An endpoint may also be established at the edge of "dead water" if such a situation exists. The dead water portion does not contribute to the stream flow and will only lead to error if an attempt is made to include it. If another type of situation exists where the velocity is below the "tolerance" level of the meter (to be discussed later), but the investigator feels it is necessary to include this volume of water, an estimate of the water velocity may be made. In this situation, the error caused by estimation will probably be less than the error resulting from exclusion of this discharge.

The mean velocity at each station must be obtained for these calculations. If the total water depth is less than approximately 2.5 feet, the velocity is usually measured at the 0.6 depth from the surface. If the total stream station depth is greater than 2.5 feet, the velocity is measured at the 0.2 and 0.8 depth from the surface, and then averaged (USGS, 1969). Other variations of these methods are described in the literature (Chow, 1964; USGS, 1969). A number of different types of current meters may be employed for these velocity measurements, but only three types are described below. the following descriptions include limits of application, advantages, and disadvantages (USGS, 1968 and 1969; Marsh McBirney Inc., Undated).

Price Pigmy Current Meter

This meter is sometimes referred to as the mini-Price meter and consists of a horizontally rotating series of buckets or a "bucket wheel." One revolution of the bucket wheel will close a contact switch resulting in a "clicking" sound, which is detected by a pair of battery operated head phones. One revolution per second will indicate a velocity of one foot per second (fps). In practice, the meter is first allowed to equilibrate with the current flow, and then the number of revolutions per unit of time are counted. The USGS recommends starting on a click and ending on a click, where the first click is denoted as zero. The number of seconds that elapse is recorded by a stop water or the second hand on a wrist watch, and should range between 40 and 70 seconds (USGS, 1969). This meter is designed to measure velocities less than 2.5 fps and has a fairly low threshold value, where the threshold value is defined as the lowest velocity that the meter can measure accurately. The threshold value is difficult to define under all conditions, so the investigator must be aware of this potential error at very low velocity ranges. This type of meter was designed to be used where stream depths are less than 1.5 feet, but may be used in depths of up to 2.5 feet. It cannot be used where macrophytes, ice particles, or water heavily laden with debris is present, since any one of these factors may interfere with the rotating bucket wheel.

This type of meter averages the velocity over a particular time period and is also omnidirectional with respect to the maximum current direction. It will measure this maximum velocity vector, V_{MAX}, regardless of the vector direction. This is important to realize since it is the velocity vector perpendicular or normal to the cross section, V_{NORM}, that is desired. If the cross section or a particular section within the cross section is not orientated perpendicular to V_{MAX}, this angle is measured or estimated, and the measured velocity is then multiplied by the cosine of the observed angle to yield the desired V_{NORM} value (USGS, 1969).

Price Type AA Current Meter

This type of meter is simply a larger replicate of the Price Pigmy current meter. Most of the criteria and all of the concepts listed for the Pigmy meter are applicable to the Price AA meter. The exceptions are that this meter should be used in streams greater than 2.5 feet in depth, but could also be used where depths are no less than 1.5 feet if it is not convenient to switch to another type of meter in those instances. This meter can also handle the largest currents normally encountered, up to 20 fps.

Conversion of revolutions per time to a velocity is somewhat more involved than with the Pigmy meter. A rating table is supplied with the meter and is attached to the meter box lid. It is possible to enter the number of revolutions and the time in seconds into the rating table and read the velocity in fps directly from the same table. Alternatively, two rating equations are provided at the top of the table for calculation of velocity when the number of revolutions per second (rps) is known. The rps is entered into one of the equations, depending upon whether the actual velocity is less than or equal to a particular velocity peculiar to each meter, and the velocity is calculated (USGS, 1968). These equations are used to develop the rating table, but can be used in place of interpolation between values in the table. The Price Type AA meter has a higher threshold velocity than the Pigmy meter, but should be able to measure velocities down to 0.1 fps if the meter is in good condition.

Marsh McBirney Model 201 Current Meter

This is an electromagnetic type current meter where passage of fluid past two electrodes in the bulb-shaped probe causes a disturbance of the electromagnetic field around the electrodes. This disturbance generates a small voltage which is made proportional to actual field velocity by internal electronic circuitry. A direct velocity meter readout in feet per second is provided nearly instantaneously. Velocity range scales of 2.5, 5.0, and 10.0 fps are externally selectable, indicating that this meter cannot measure current velocities greater than 10 fps.

This type of meter also differs from the Price meters in that it is unidirectional in its measurement ability. It will measure only one velocity vector, the vector parallel to the probe longitudinal axis. This is important to know since the probe will not sense the velocity vector normal to the cross section, V_{NORM}, unless the probe longitudinal axis is also normal to the cross section. Since probe orientation cannot usually be seen beyond a particular depth, the staff to which it is attached must be capable of accurately determining this information.

This meter is an instantaneous readout meter, as mentioned earlier, and will not provide an average velocity reading. The meter reading will no doubt be varying to some degree and occasionally it will be quite erratic. It is the responsibility of the investigator to observe the meter fluctuation and to estimate an average velocity when the fluctuations are present. When meter readings are fluctuating, it could be an indication of eddying or turbulence, a condition that should have been avoided initially, if possible, when choosing the location for the cross section measurements.

This type of meter can be used where the Price meters cannot be used, such as in weedy streams or under any conditions that would affect the rotating mechanism of the Price type meters. Measurements can be made much quicker with the Marsh McBirney meter compared to the Price meters because of its nearly instantaneous readout capability.

2.4.3.2 Calibration and Maintenance

All of the current meters discussed above require care and maintenance, since meter condition or deterioration will be reflected in the final results. Each of these meters have a periodic calibration schedule. Although thermometers are fairly durable instruments, they should be treated as delicate instruments to avoid altering the calibration of each. A correction factor must be applied to each Marsh McBirney meter, where the correction is in the form if a linear regression equation attached to each meter. The observed meter reading is simply plugged into the equation to obtain the corrected value. Price Type AA meters are supplied with a new rating table, which is attached to the inside cover of the meter box.

2.4.3.3 Measurement Technique

A step by step summary of a discharge or cross section measurement is as follows:

1. Assemble current meter and test for proper operation. Collect data form or notebook, pencil, stop water, 50 feet tape, etc.

2. Partition stream into sections (with tag-line or bridge railing), visually observing the velocity and general flow of the stream. Enough stations should be established to prevent more than 10% of the total discharge from passing through any individual partial section. Remember, the partial section in question is <u>not</u> the same as the interval between two successive stations. Mark stations appropriately.

3. Record stream stage as indicated by one of the staff gages and record this value.

4. Record on the data form or in the notebook the following items at a minimum:

   a. Project,
   b. Site,
   c. Date,
   d. Time at start of measurements,
   e. Stage at start of measurements,
   f. Approximate wind direction and speed,
   g. General stream condition (i.e., turbid, clear, low level, floating debris, temperature, type of streambed material, etc.,
   h. Other factors having a bearing on discharge measurements,
   i. Location of initial point,
   j. Total width of stream to be measured, and
   k. Type of current meter and conversion factor, if applicable.

5. Determine the depth and mean velocity at the first station or "initial point" if the situation allows, and record.

6. Measure depth at the second stage from initial point and record. Determine whether the velocity should be measured at the 0.6 depth from the surface (six-tenths depth method) or at the 0.2 and 0.8 depths (two-point method). Calculate respective depths from the surface, measure the velocity at each point, and record these values.

7. Continue on to each successive station as rapidly as possible, following the same procedure.

8. Determine the depth and mean velocity at the last station or endpoint and record.

9. Record on the data form the ending time of this series of measurements and the stage, since the stage may have been changing during the measurements.

10. Also enter the ending stage value. This will illustrate the interval of time and stage variations during the cross section measurements. Also, enter the date and indicate that a calibration has taken place over this interval.

11. Remove the tag line (if used), allow the current meter to dry, then pack it away in its respective carrying case.

There are a few other comments regarding stream calibrations that should be mentioned:

- Measurements should be made with the investigator standing behind the well and to the side of the meter.

- Avoid disturbing or standing along the streambed beneath the cross section measuring points. This is part of the control area and should remain constant, if possible, from calibration to calibration of the stream. This is especially important if soft, mucky sediment is encountered somewhere along the cross section.

- Try to use the same cross section throughout the study period and during all of the stream rations. However, the number and position of stations within the cross section may be changed if necessary.

- Always hold the wading rod nearly vertical and be aware of how V_{NORM} is determined with each of the various types of meters, should it become necessary to switch meters during a calibration.

- Try to make several stream calibrations throughout the study period to account for seasonal changes in streambank vegetation and streambed alterations. The variations in these and other factors may or may not have a significant impact on the rating curve, but if some of these factors do have an effect, it can be reflected in the rating curve.

2.4.4 Discharge Ratings

2.4.4.1 Discharge Rating Curves

Discharge ratings define the relationship between stage and stream discharge and allow conversion of stage hydrographs to discharge hydrographs. The discharge calibration points are hand or machine plotted onto a graph of stage versus stream discharge. Stream stage is plotted on the vertical Y axis and stream discharge is plotted on the horizontal X axis as illustrated on Figure 2-2. Ideally, enough calibrations were conducted over the full range of stage variations to allow a smooth hand-drawn curve to be drawn through these points on the graph.

The slope and rate of change of slope may vary significantly over the length of this curve (Figure 2-3). At certain gaging stations, the slope of this curve may break sharply, or the distribution of points may require the construction of two partial curves rather than one continuous curve. These latter two situations would possess more complete stage-discharge relationships. It is the task of the investigator to derive a mathematical relationship that describes this curve as closely as possible (i.e., an equation). The development of an equation would allow calculation of discharge (Q) by simply plugging in the stream elevation (G). This will allow computerization of the process of converting stage records into discharge, and eventual conversion to volume by noting the time interval at which this rate of flow applies.

More complicated rating relationships than the type illustrated in Figure 2-2 may be required at a particular gaging station. Discharge may not only be a function of stage, but also of slope, rate of change of stage, or other variables specific to each site (USGS, 1965). Additionally, stage-discharge relationships are rarely permanent and so discharge calibrations should be carried out at periodic intervals to define the effects of various factors, including:

1. Scouring and deposition of sediment.

Figure 2-2. Example of a rating curve developed for a bridge gaging station. The rating curve equation was derived manually by using a graphical technique. The calibration points and curve were plotted by a Hewlett Packard calculator and plotter combination.

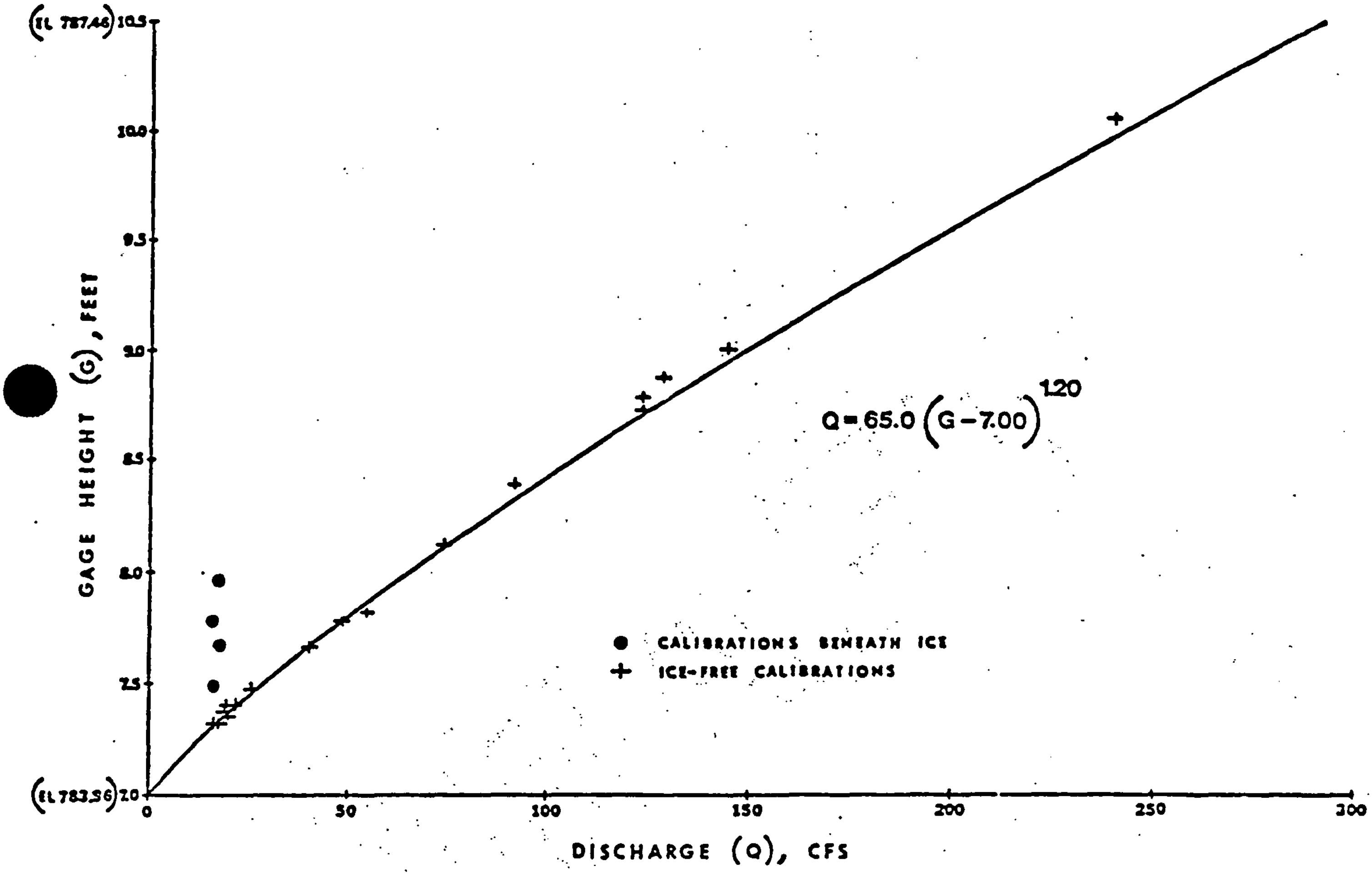
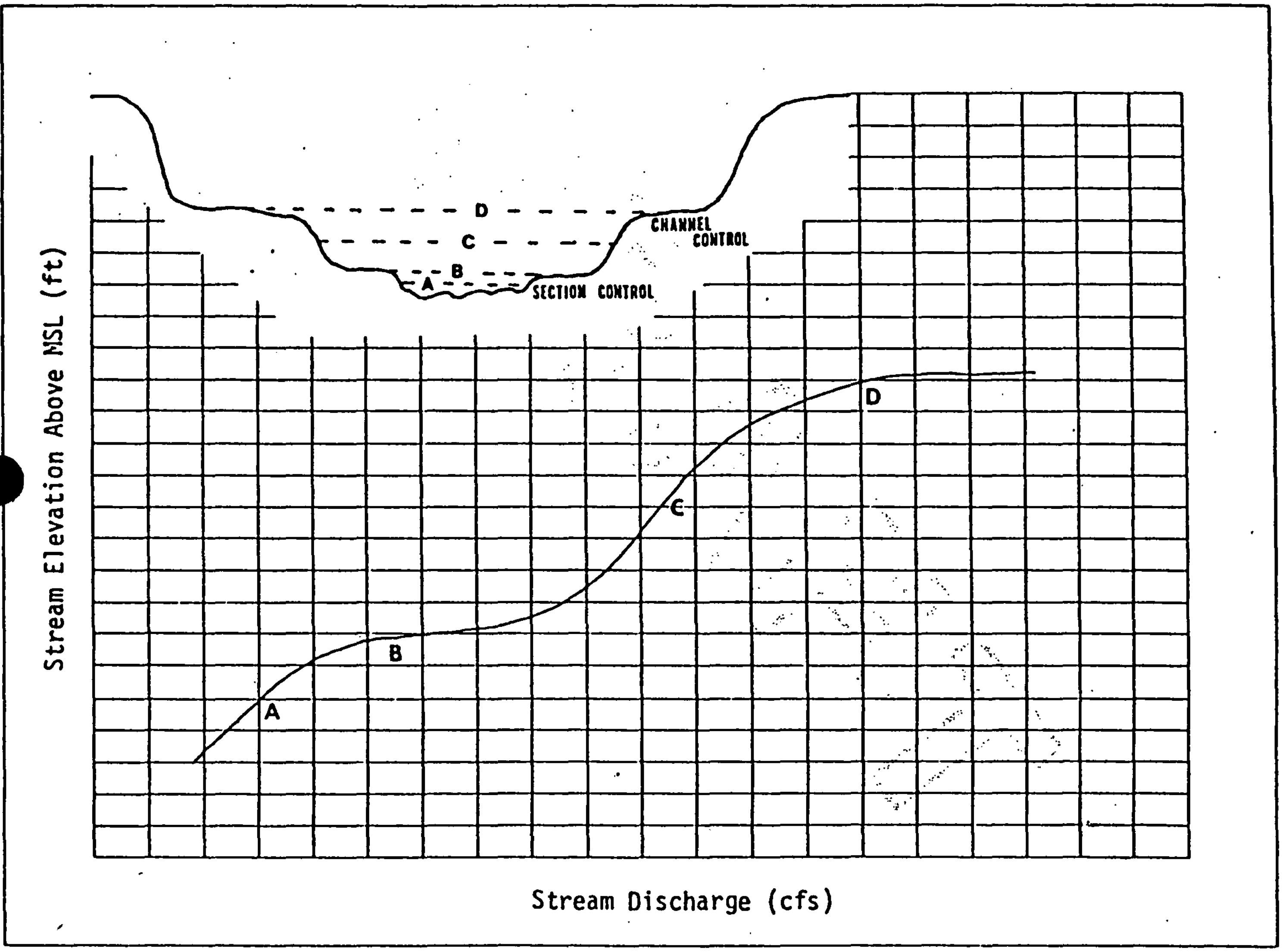


Figure 2-3. Illustration of the effect of stream channel geometry on the rating curve configuration



2. Alteration of streambed roughness due to the creation and dissemination of dunes, anti-dunes, ripples, and standing-wave features in sandy bottoms; the deposition of leaves and other debris during different seasons; and seasonal variation in the growth of macrophytes.

3. Ice effects may cause additional resistance to flow. If monitoring is carried out during the colder months, a complete ice-over and additional freezing will tend to constrict the stream channel with time and may increase the stage, when in fact the flow may not be increasing at all (Figure 2-2).

4. Man-related activities such as upstream construction, recreation, etc.

Section controls are the control features that exist at a cross section or discharge calibration measurement site (Figure 2-3). These control features are significant for low-flow calibrations, but may become less significant with increasing stream stage. As stage increases, "channel controls" upstream and downstream from the gaging point become more important and eventually may totally define the discharge characteristics of the stream. A break in the slope of the rating curve will occur if this transition is quick enough and substantial enough to affect the rising stage. Figure 2-3 illustrates this type of situation. Unless stream calibrations have been frequent enough to display the effect of these features on stream flow characteristics, the physical features and geometry of the stream must be surveyed for an acceptable distance upstream from the gaging station. Estimations of stream flows at different levels would then have to be made to "fill in the gaps" where measured flow data is absent. This missing data usually occurs as a results of one or more of the following:

1. Infrequent storm events of the proper magnitude.

2. Inability to detect when storms of sufficient magnitude will occur and to have personnel available and at the site prepared to conduct flow measurements. Storm duration, intensity, and other hydrologic conditions determine the resulting

hydrography. The degree of hydrograph lag from the onset of a storm is usually unknown and variable, further complicating the ability to carry out stream flow measurements at desirable stream levels.

3. Inability of personnel, on occasion, to obtain accurate measurements due to the severity of the event. If measurements were made by wading or by boat, the high stream levels may increase the difficulty of obtaining measurements and may also increase danger to personnel.

When stream flow data are missing or inadequate near peak stage or at several points along the projected discharge-rating curve, prediction of discharge characteristics in these areas may be made with "indirect methods." References for indirect methods of measuring stream flow and peak flow are cited in Section 2.4.5, References.

2.4.4.2 Curve Fitting

Assuming calibration data for a gaging station is adequate and, for the most part, follows a smooth and continuous curve, a mathematical relationship can be derived for each gaging station. It is only necessary to derive this equation describing the curve if a large amount of data (or many stage records) must be reduced or converted to discharge. If little data needs to be converted, values may be estimated from the hand-drawn rating curve.

The graph of the rating curve is entered with a stage (elevation) value obtained from a desired reading from the stilling-well and the discharge in cfs is noted on the graph from where the rating curve is intersected. To convert cfs to a volume, the number of hours (any time interval may be used) at which the stream remained at this stage is noted, the proper conversions are made for the time component , and the discharge is multiplied by the time period to produce the volume of water passing the gaging station in that particular time interval.

If a mathematical equation is desired to describe the hand-drawn rating curve, numerical methods may be applied to the stage and discharge data. A logarithmic curve fit, exponential curve fit, or power curve fit displayed in Figure 2-4 may provide a proper fit to the entire rating curve or to a portion of the rating curve.

The following step sequence is usually followed, assuming access to curve fitting programs:

1. Enter stage and discharge values from all of the stream calibrations for a particular gaging station, as instructed by the curve fitting program. The most likely curve geometry is tried first.

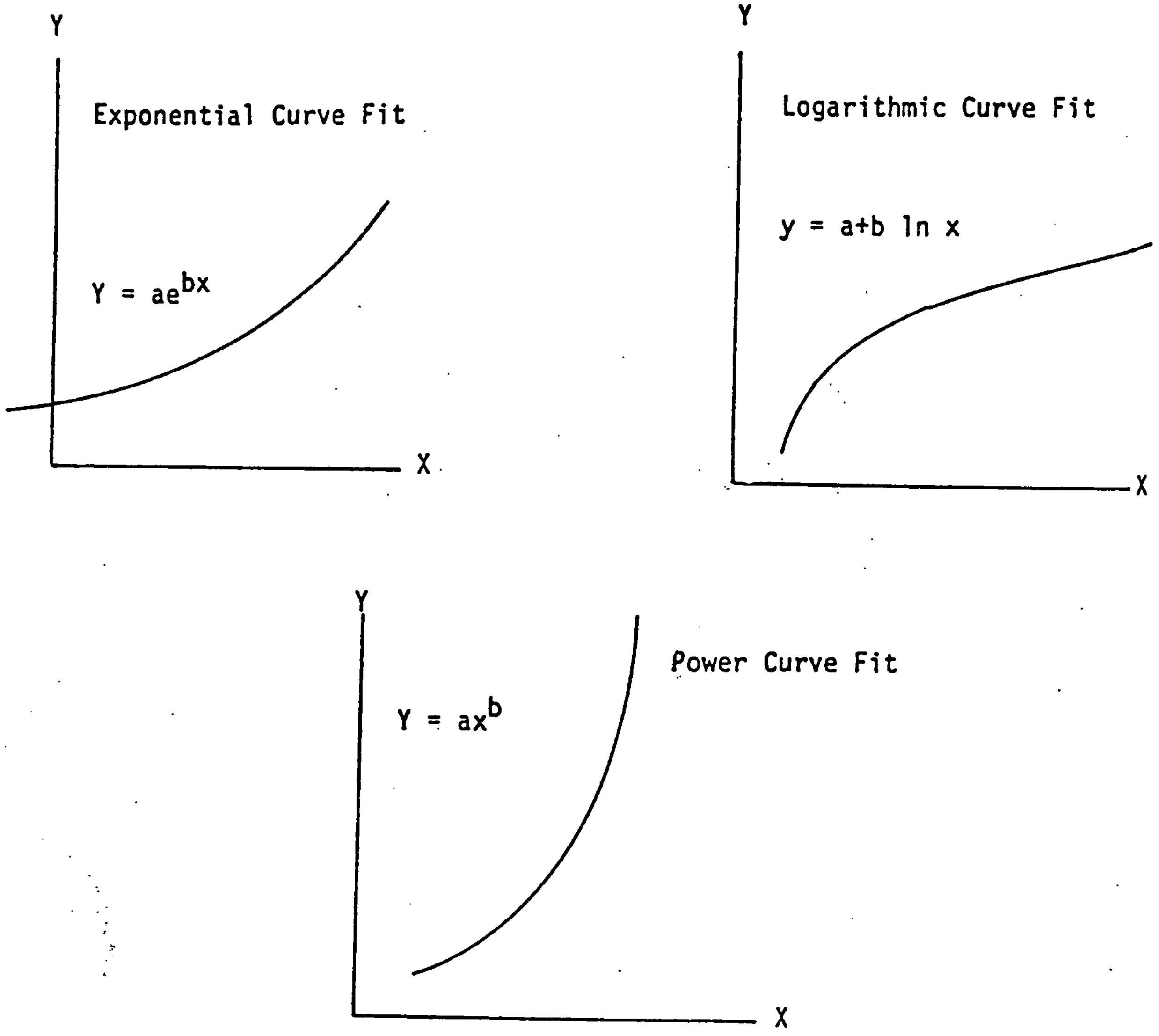
2. The coefficients calculated by the program are used to complete the equation. These would be coefficients "a" and "b" in Figure 2-4. This equation is then plotted by hand or by graphic devices against the hand-drawn curve (or simply the plotted data points) to determine how well the equation really does express the measured stage-discharge relationship.

3. If the results in Step 2 are satisfactory, the discharge-rating relationship for the stream at the particular gaging station has been established. If not satisfactory, one or two points that may indicate measurement error during the stream calibrations may be deleted from the group of points and Step 2 may be repeated, since these points may have been "throwing off" the curve fit. However, it should also be pointed out that these excluded points may in fact have been accurate and were the results of some stream flow phenomena heretofore unknown or inadequately defined. Caution must be exercised when excluding any stream calibration points for this reason.

4. If results are still unsatisfactory, a new type of curve may be tried and Steps 1 through 3 may be repeated.

5. Repeat step four until all possibilities have been exhausted.

Figure 2-4. Possible curves applicable to discharge rating data or portions of the data (Hewlett Packard, 1979)



6. If a satisfactory curve fit and equation still have not been achieved, the hand-drawn curve may be subdivided into intervals that would allow (intuitively) each curve interval to be mathematically described; each curve interval would then possess its own equation. Repeat Steps 1 through 5, remembering always to plot, at least roughly, the derived equation against the measured data. Only the data points applicable to each respective interval are used as input data.

7. The range of stage or stream variation applicable to each interval in Step 6 will remain applicable to only that interval. When reducing recorder chart data (stream level records), a small computer program entered into a programmable hand-held calculator, or a FORTRAN program for example, could test the stage value for a particular interval range and then assign it to the correct equation describing the rating curve interval. Flow values are calculated and the data may be converted or manipulated in the same program.

The method above may use the least squares method when calculating the equation coefficients. The coefficient of determination may also be calculated each time a new equation is derived. This will express how well the curve fits the measured data. A value of exactly 1.0 would indicate a perfect fit.

Graphical methods of determining the mathematical expression of the rating curve are also available (USGS, 1976), but are more tedious. These methods are also potentially less precise, since conversation of hand-plotted data on graph paper are required, subjecting this method to more human error.

The degree of accuracy acceptable is dependent upon project or task specifications. This applies to rating curves as well as to any phase of the stream gaging process. Since it is often difficult to detect the resulting degree of accuracy at any particular phase, efforts should always be directed to collecting the highest quality data possible.

2.4.5 References

2.4.5.1 Cited References

Hewlett Packard Company, 1979. HP-34C Applications, Hewlett Packard, Corvallis, Oregon.

Marsh-McBirney, Inc., Undated. Instruction Manual, Model 201 Portable Water Current Meter, Marsh-McBirney, Inc., Gaithersburg, Maryland.

U.S. Geological Survey, 1965. Written communication; Internal Administrative Report, U.S. Department of the Interior, U.S. Geological Survey.

U.S. Geological Survey, 1968. Calibration and Maintenance of Vertical-Axis Type Current Meters, TWRI, Book 8, Chapter B2, Government Printing Office.

U.S. Geological Survey, 1969. Discharge Measurements at Gaging Stations, TWRI, Book 3, Chapter A8, Government Printing Office.

2.4.5.2 Additional References

Chow, Ven Te, ed., 1964. Handbook of Applied Hydrology. McGraw-Hill, New York.

U.S. Geological Survey, 1968. Measurement of Peak Discharge at Culverts by Indirect Methods. TWRI Book 3, Chapter A3. Government Printing Office.

3.0 DRILLING PROCEDURES AND WELL INSTALLATION

3.1 Drilling Procedures

3.1.1 Unconsolidated Glacial Deposits

The hollow stem auger technique will be used for drilling in unconsolidated materials for borings which will terminate above bedrock. The hollow stem auger technique is the preferred method, because it causes minimal disturbance to the geologic formation, and can be used without the introduction of drilling fluids. However, hollow stem auger techniques may become impracticable if dense gravels or boulders are encountered during drilling. Air rotary methods will be used as the alternative drilling technique if use of hollow stem augers becomes impractical.

Unless otherwise specified, soil samples will be collected at five foot intervals in advance of the drill bit using standard split-barrel sampling techniques (ASTM Method D 1586-84). Each sample will be visually classified by an HSI geologist in accordance with ASTM Method D 2488-84, using the Unified Soil Classification System (USCS). Descriptions will be recorded on HSI Soil Borehole Log forms (Appendix A). The descriptions will include applicable information pertaining to soil type, organic material content, grain size distribution, gradation, plasticity, mottling, color (using Munsell notation), odor, moisture content, consistency, density, grain shape and lithology, soil structure, layering, jointing, lenses, fractures, void space, unconfined compressive strength, photoionizable constituent content, geologic origin, and group symbol. A portion of the split-spoon soil sample will be transferred into a mason jar for headspace analysis, as described in Section 2.1.1.2.

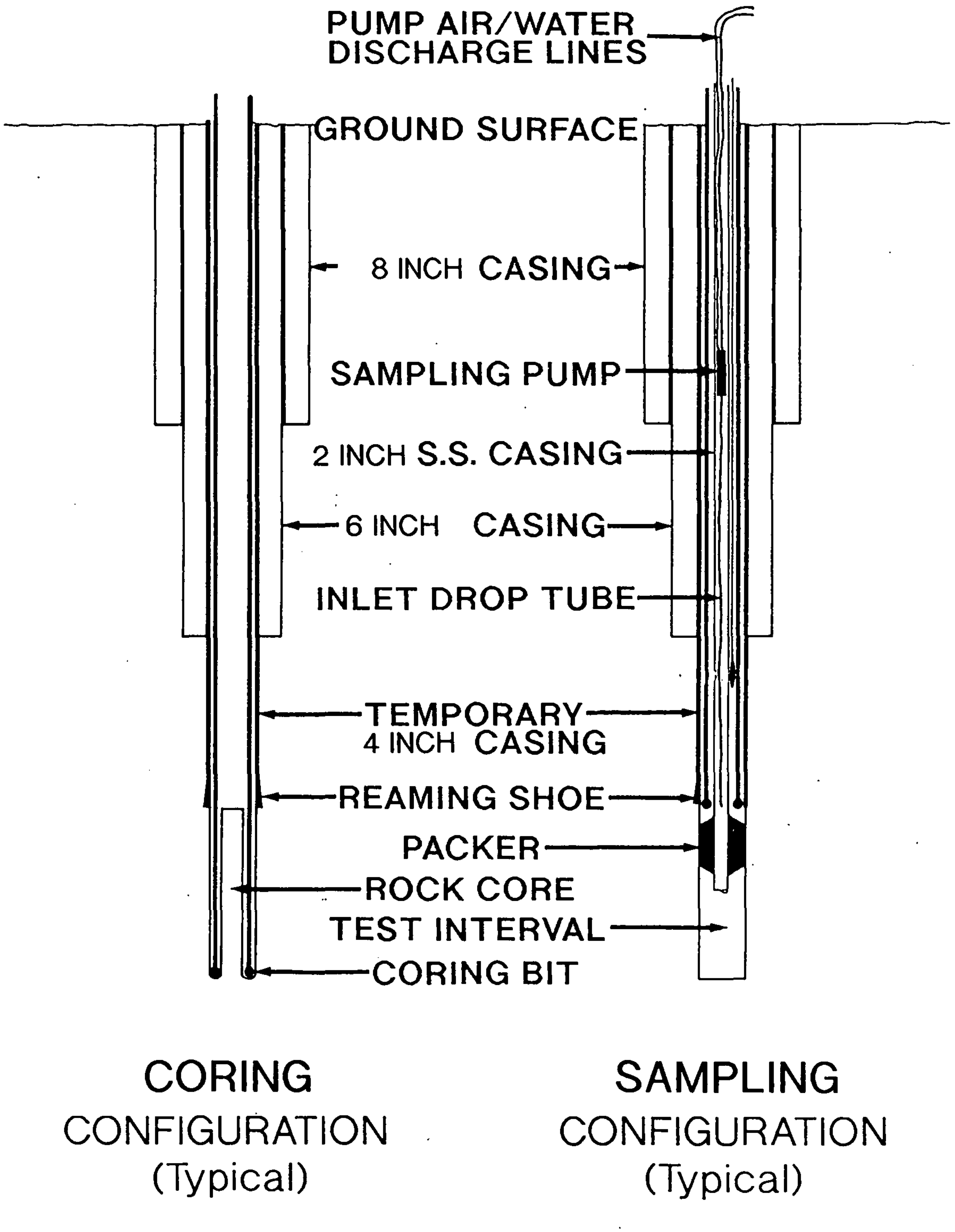
3.1.2 Bedrock

The air rotary drilling technique will be used for drilling within bedrock. For the deep piezometers, the borehole will initially be eight inches in diameter. When the water table is reached, a temporary six-inch casing will be installed. This casing is necessary since previous drilling at the site has established that the upper formation tend to slough with the movement of tools in and out of the borehole. The borehole will then be advanced using six inch diameter air rotary techniques. At each ten foot interval, the drilling tools will be withdrawn to install a packer and collect a ground-water sample.

Should severe circulation loss or high contamination be encountered, it will be desirable to isolate these sections of the borehole. This would improve circulation and the retrieval of borehole cuttings and/or minimize the potential for contamination of lower strata and allow continued advancement of the borehole. When such situations occur, a temporary string of four inch casing will be installed in the borehole. Once the temporay casing has been installed, drilling will continue using a Longyear HQ wire coring system. At ten foot intervals, a packer will be installed on a two inch diameter steel casing run through the core string and a ground-water sample collected. The coring and sampling configurations are shown on Figure 3-1.

3.1.3 Sample Collection

The ground-water sample collection during the HQ coring will proceed as follows: after removal of the core barrel on the wire line, the drill pipe will be raised a sufficient height to expose the interval to be tested. The packer string will then be inserted through the center of the drill pipe and core bit, and the packer inflated just above the top of the last cored interval. The packer that will be used is a Tigre Tierra Model 34-B pneumatic packer, specifically made of stainless steel and a viton-covered packer gland. The packer has an at-rest diameter of 2.13-inches, a maximum inflated diameter of five inches, and a one-inch diameter opening through its center. The packer will be attached by a stainless steel nipple to two-inch inner diameter stainless steel riser pipe. A Well Wizard Model HR-4200 gas displacement pump will be inserted into the two-inch stainless steel pipe. The pump is manufactured by QED Environmental Systems, Inc. of Ann Arbor, Michigan, is constructed entirely of stainless steel and teflon components and is designed for high quality sampling for VOCs.



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CORING AND SAMPLING CONFIGURATIONS

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An inlet drop tube made of 1/2 inch O.D. teflon-lined polyethylene will be connected to the pump inlet and extend downward through the center of the two-inch pipe and the packer into the test zone. The inlet drop tube will be equipped with quick-connect couplers which will allow additional sections of tubing to be inserted as progressively deeper core intervals are tested, and the distance between the packer and the pump increases. On some tests, an alternate pump may be used to obtain a higher pumping rate to more effectively purge and test highly transmissive zones. If available, a Grunfos two inch diameter stainless steel and teflon submersible pump will be used; however, the pump is still being tested by the manufacturer, and is not yet commercially available.

After the packer and pump have been correctly positioned in the borehole, the test interval will be purged of a minimum of four fluid volumes to assure that a representative sample is obtained. The purged water will be pumped into 55-gallon drums for storage until proper disposal can be arranged (Section 3.7). Periodic measurements will be made of the pH, temperature, specific conductance, and photoionizable VOC concentrations of the discharge water.

After purging the required volume of water, samples will be collected from the gas displacement pump for analysis. Sample containers will be filled following WDNR recommended procedures for sampling of ground water. Samples will be submitted under chain-of-custody to the laboratory for 24 hour turn-around for VOCs.

Ground-water sample collection during the air rotary drilling will be similar to that during the coring, except that a larger size packer will be used. In addition, a submersible pump will be used to purge the borehole. Samples will be collected with a bailer. The submersible pump, packer and bailer will be decontaminated between each sampling event.

3.1.4 Equipment Decontamination

3.1.4.1 Mobilization

Drill rigs, support vehicles, and associated drilling tools and equipment will be steam cleaned on-site, prior to commencement of drilling, to minimize the potential for cross contamination. All drilling equipment will be unloaded from the drill rig and the storage compartments, and steam cleaned. Storage compartments will also be steam cleaned where appropriate. Cleaned tools will be returned to the storage compartments. Augers, drill stem, bits, and other downhole equipment will be stored on plastic and covered in an area designated by HSI. The storage area will be clean, easily accessible, and away from most daily site activity.

3.1.4.2 Drilling Operations

All downhole drilling equipment and associated tools will be steam-cleaned between boreholes. In addition, excess soil on the drill rig will be removed by steam cleaning between boreholes, as appropriate. Pipe racks will be used to elevate the augers and drilling rod during steam cleaning. In addition, the bed of the truck used to transport the augers or drill rods from the decontamination staging area to the drilling site will also be steam cleaned where appropriate. After transport to the drilling site, augers and drilling rods will be stored on additional pipe racks and covered with clean visqueen sheeting until used.

All down hole sampling equipment will be cleaned between samples by:

1. scrubbing with potable water to remove soil particles,
2. washing with a non-phosphate detergent, and
3. rinsing with potable water.

Equipment decontamination will be supervised by an HSI hydrogeologist or geologist.

3.1.4.3 Ground-Water Sampling

In general, dedicated sampling equipment will be used wherever possible to eliminate the need for decontamination and the potential for cross contamination between sampling points. Dedicated bailers will be used for sampling of all permanent well installations. Decontamination procedures will be employed on probes used for water level and product measurements, and for purging and sampling during packer tests. The probes will be rinsed after each measurement and wiped dry with clean paper towels.

3.1.4.4 Decontamination Staging Area

Decontamination will be performed in a staging area, to be determined through coordination with WDNR prior to mobilization.

3.1.4.5 Demobilization

Drill rigs, support vehicles, and associated drilling tools and equipment will be steam cleaned on site upon completion of drilling activities, prior to final demobilization to ensure that no contaminants are carried off site by the drilling contractor.

3.2 Borehole Logging

Unconsolidated soil samples will be collected and analyzed, and a lithologic log produced for each borehole, as described in Section 2.2..

3.3 Well Installation

3.3.1 Water Table Wells

Water table wells will be installed to determine the water table elevations and fluctuations at given times and the presence or absence of specific contaminant compounds in the upper ground-water zone. Water table, well construction and installation procedures are presented below.

3.3.1.1 Construction Materials

Water table monitoring wells will be constructed of new two inch inner diameter (ID) PVC which meets the standards set forth in NR141.07. Most site water table wells are less than 100 feet deep and do not penetrate bedrock, so Schedule 40 PVC will be used. In cases where water table wells are greater than 100 feet and/or the well penetrates bedrock, Schedule 80 PVC will be used. All joints will be flush-threaded. The screens will be ten feet long, with slot size determined according to NR141.09. A cap will cover the top of the PVC or stainless steel well casing. A protective casing consisting of an eight-foot length of metal casing with a lockable cap will also be included. The ID of the protective casing will be a minimum of two inches larger than the ID of the well casing, per NR141. Well casings, couplings and screens will be steamed cleaned and sealed in plastic prior to use or will remain sealed in factory plastic until use. The well casings, and screens will be visually inspected for defects per NR141.07 (4) and defective material will not be used.

Well packing and sealing material will adhere to specifications set forth in NR141.11, and NR141.13. Collapsed formation may be used as a filter pack alternative if the formation meets the requirements of NR141.11 (3). A two-foot thick filter pack seal comprised of a clean fine-grained sand will be placed above the filter pack material, and a two-foot thick granular bentonite seal will be placed above the filter pack seal, if required, per NR141.13. The remaining annular space will be sealed with one of the following materials:

1) Bentonite - cement grout,
2) Granular bentonite slurry,
3) Bentonite sand slurry,

4) Neat cement grout, if Schedule 80 PVC or stainless steel well casing is used, or

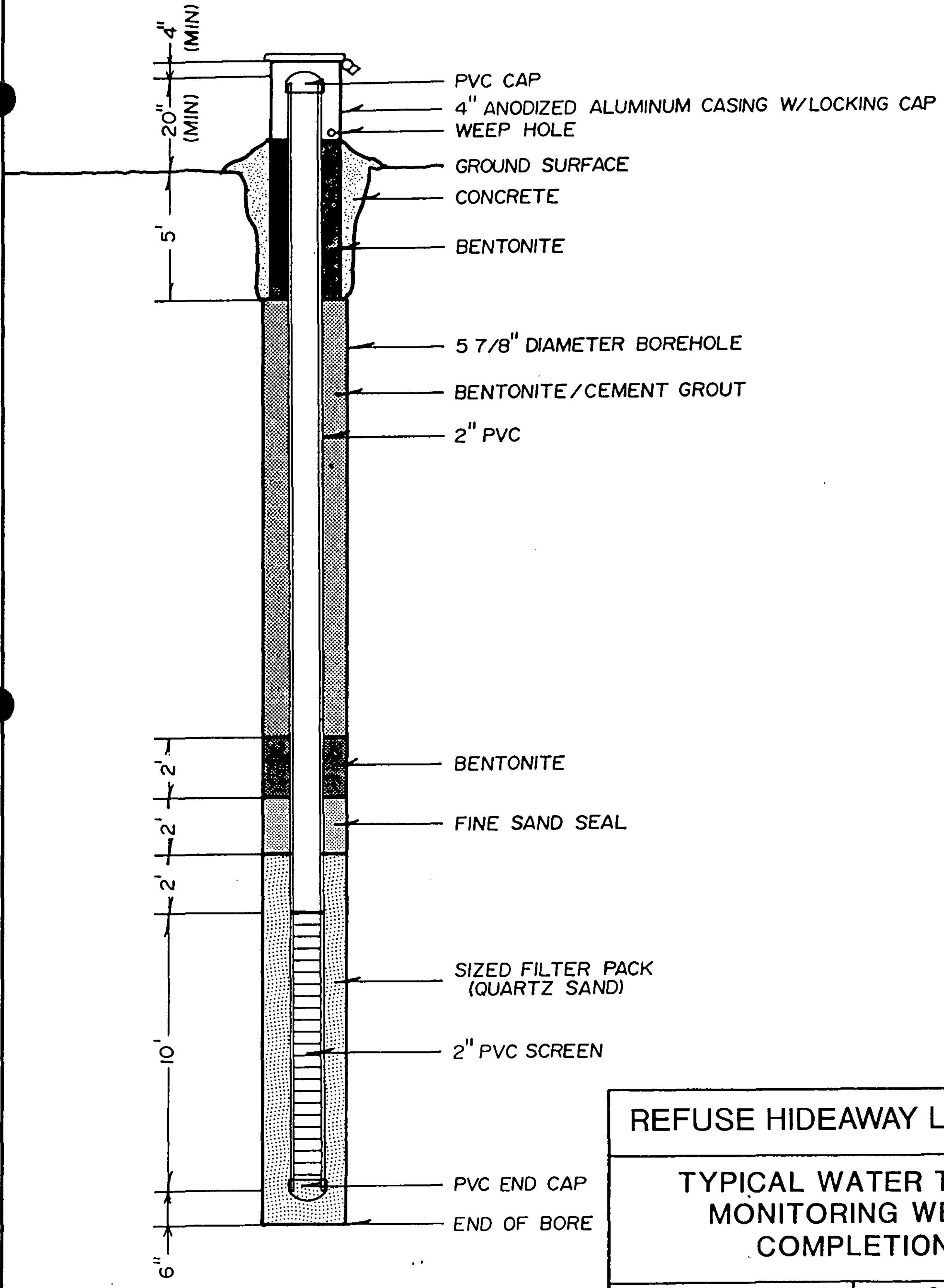
5) Bentonite pellets or granular bentonite provided the well depths meet the requirements in NR141.13(2)3.

When a slurry is used for the annular space sealant it will be installed using a tremie pipe, following the procedures in NR141.10.

3.3.1.2 Installation

Drilling methods are discussed in Section 3.1. The borehole will be flushed, if necessary, using drilling rod or tremie pipe inserted to the bottom of the borehole to circulate clean water. The borehole will be flushed until water free of drill cuttings and drilling fluid flows from the top of the borehole. The total depth of the borehole will then be measured using a tape measure or measuring rod.

Figure 3-2 shows typical water table monitoring well construction specifications. The well casing will extend at least 20 inches above the ground surface. The amount of packing and sealing materials required will be calculated prior to installation based on the diameter of the borehole less the casing diameter, and the linear footage of packing or sealing materials required. Filter pack material for water table wells is required to extend from six inches below the bottom of the well screen to two feet above the top of the screen. The well screen and casing will then be inserted through the center of the borehole by personnel wearing clean gloves. Filter pack material will then be installed in the annular space between the well and the borehole walls to two feet above the top of the well screen. A tape measure or measuring rod will be used to ensure the pack material is installed evenly and over the proper depth interval. If the packing material



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TYPICAL WATER TABLE MONITORING WELL COMPLETION

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FIGURE 3-2

bridges, it will tamped into place.

A two-foot thick filter pack seal comprised of clean, fine-grained sand will be placed above the filter pack material, and two-foot thick granular bentonite seal will be placed above the filter pack seal, per NR141.13. The depth interval for the fine sand and bentonite seals will be similarly measured and, if necessary, the seal will be tamped into place.

If a grout or slurry is used as an annular space seal, it will be tremied into place, according to specifications in NR141.10. If bentonite granules or pellets are used, they will be poured freely down the borehole per NR141.13(2)(b). If a slurry or grout annular space seal is used, the protective casing will not be installed until a minimum 12-hour waiting period has elapsed and any grout or slurry settlement has been topped off, per NR141.13(2)(b)3.

The protective casing will be centered over the well casing prior to installing the ground surface seal. The protective casing will extend from at least five feet below the ground surface to at least two feet above the ground surface, and will be placed such that the well casing is no more than four inches below the top of the protective casing, unless dedicated pumping equipment is to be installed, in which case a minimum of six inches will be left between the well casing and the protective casing to allow room for installation of pumping equipment. The ground surface seal will then be installed between the borehole wall and the protective casings.

If bentonite is used as a ground surface seal, it will extend from five feet below the ground surface to one foot below the ground surface, and topsoil will be placed in the remaining annular space and sloped away from the protective casing. If concrete is used as the ground surface seal, it will extend from five feet below the ground surface to above the ground surface, and will be finished to slope away from the protective casing (Figure 3-2). The annular space between the well casing and the protective casing will be filled to the top of the surface seal with bentonite pellets. A 1/4-inch diameter hole will be drilled through the protective casing to allow water which may collect between the casings to drain out.

The calculated and actual amounts of each type of material used to construct the monitoring well will be recorded. Well construction data will be recorded per NR141.23 requirements on a WDNR Well Construction Diagram #4400-113A and a WDNR Well Information Form #4400-89. Forms #4400-89 and #4400-113A will be submitted to WDNR within 60 days after installation per Chapter 144, Wisconsin Statutes, and NR141.23. An example of each form is presented in Appendix A.

3.3.2 Piezometers in Unconsolidated Materials

3.3.2.1 Construction Materials

The piezometers will be constructed of new, two-inch ID PVC which meets the standards set forth in NR141.07. Piezometers which are less than 100 feet deep will be constructed of Schedule 40 PVC. Piezometers which are greater than 100 feet deep will be constructed of Schedule 80 PVC per NR141. All joints will be flush-threaded. The screens will be ten-foot lengths with slot size determined according to NR141.09. A cap will cover the top of the well casing. A protective casing will be included which will consist of an eight-foot length of metal casing with a lockable cap. The protective casing inner diameter will be a minimum of two inches larger than the well casing per NR141. Well materials including casing, screen, and end caps will be steam-cleaned and sealed in plastic prior to use, or will remain sealed in factory plastic until use. Well casings and screens will be visually inspected for defects per NR141.07(4) and defective material will not be used.

Piezometer packing and sealing material will adhere to specifications set forth in NR141.11 and NR141.13. Collapsed formation may be used as a filter pack alternativeif the formation meets the requirements of NR141.11 (3). A two-foot thick filter pack seal comprised of clean, fine-grained sand will be placed above the filter pack material, and two-foot thick bentonite pellet seal will be placed above the filter pack seal, if required, per NR141.13. The remaining annular space will be sealed with one of the following materials.

1) Bentonite - cement grout,

2) Granular bentonite slurry,

3) Bentonite sand slurry,

4) Neat cement grout, if Schedule 80 PVC or stainless steel well casing is used, or

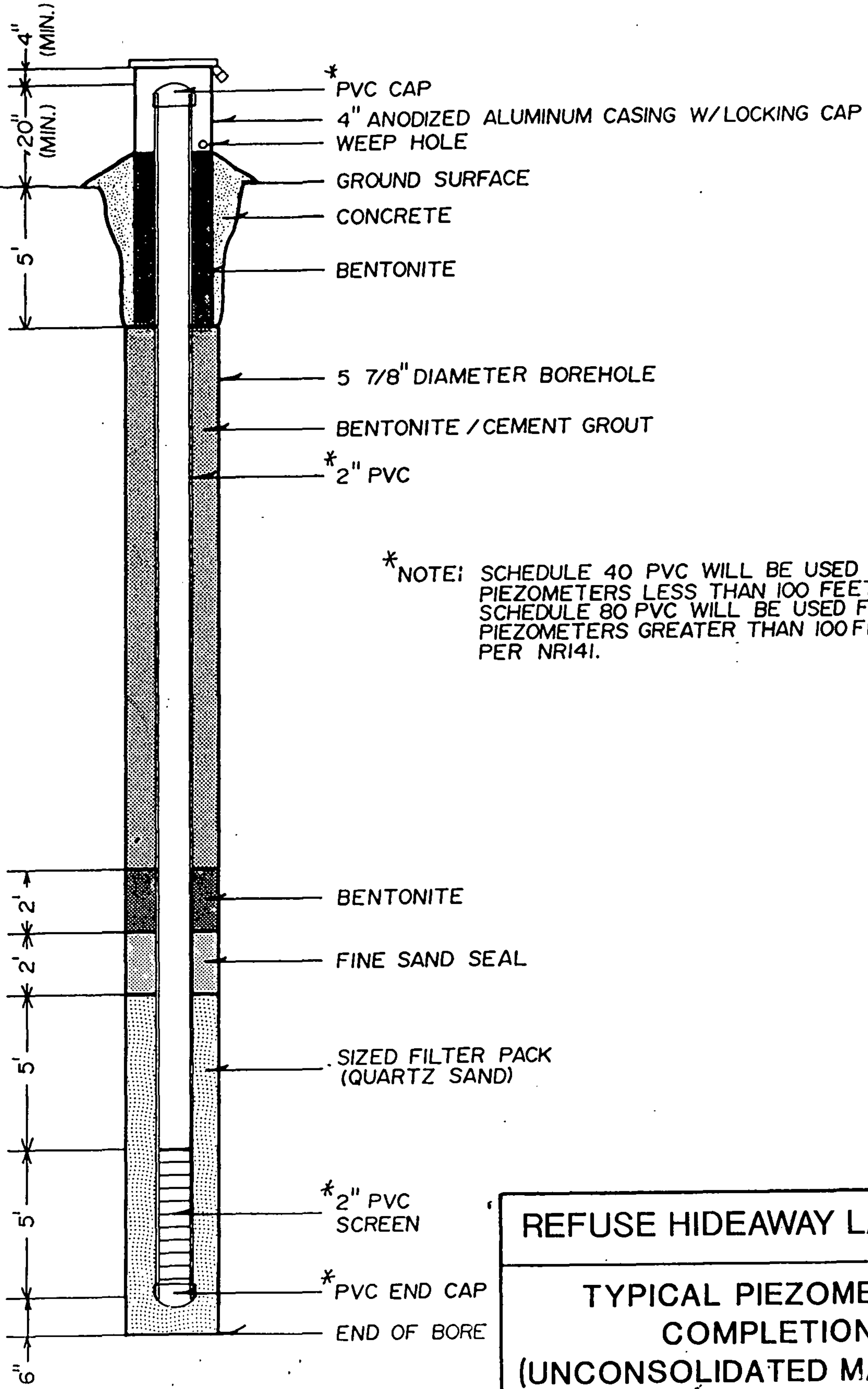
5) Bentonite pellets or granular bentonite provided the well depths meet the requirements in NR141.13(2)3.

When a slurry is used for the annular space sealant it will be installed using a tremie pipe, following the procedures in NR141.10.

3.3.2.2 Installation

Drilling methods are discussed in Section 3.1. Prior to well installation the boreholes will be flushed, if necessary, with clean water using a drilling rod or tremie pipe inserted to the bottom of the borehole. The borehole will be flushed until clean water free of drill cuttings and drilling fluid flows from the top of the borehole. The total depth of the borehole will then be measured using a measuring tape or rod.

Figure 3-3 shows typical piezometer construction specifications. The well casing will extend at least 20 inches above the ground surface. The amount of packing and sealing materials required will be calculated prior to installation based on the diameter of the



*NOTE: SCHEDULE 40 PVC WILL BE USED FOR PIEZOMETERS LESS THAN 100 FEET DEEP; SCHEDULE 80 PVC WILL BE USED FOR PIEZOMETERS GREATER THAN 100 FEET DEEP, PER NR141.

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TYPICAL PIEZOMETER COMPLETION (UNCONSOLIDATED MATERIAL)

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FIGURE 3-3

borehole less the casing diameter, and the linear footage of packing or sealing materials required. Filter pack material for piezometers is required to extend from six inches below the well screen to five feet above the screen. The lower six inches of pack material will be poured into the borehole following flushing, and prior to well insertion. The well screen and casing will then be inserted through the center of the borehole by personnel wearing clean gloves. Filter pack material will then be installed in the annular space between the well and the borehole walls to five feet above the top of the well screen. A tape measure or measuring rod will be used to ensure the pack material is installed evenly and over the proper depth interval. If the packing material bridges, it will tamped into place.

A two-foot thick fine sand seal will be installed above the filter pack material, and a two-foot thick bentonite pellet seal will be installed above the fine sand seal. The depth interval for these two will similarly be measured and, if necessary, the seals will be tamped into place. Calculated and actual amount required will be recorded.

If a grout or slurry is used as an annular space seal, it will be tremied into place, according to specifications in NR141.10. If bentonite pellets are used, they will be poured freely down the borehole per NR141.13(2)(b). If a slurry or grout annular space seal is used, the protective casing will not be installed until a minimum 12-hour waiting period has elapsed and any grout or slurry settlement has been topped off, per NR141.13(2)(b)3.

The protective casing will be centered over the well casing prior to installing the ground surface seal. The protective casing will extend from at least five feet below the ground surface to at least two feet above the ground surface, and will be placed such that the well casing is no more than four inches below the top of the protective casing, unless dedicated pumping equipment is to be installed, in which case a minimum of six inches will be left between the well casing and the protective casing to allow room for equipment installation. The ground surface seal will then be installed between the borehole wall and the protective casings.

If bentonite is used as a ground surface seal, it will extend from five feet below the ground surface to one foot below the ground surface, and top soil will be placed in the remaining annular space and sloped away from the protective casing. If concrete is used as the ground surface seal, it will extend from five feet below the ground surface to above the ground surface, and will be finished to slope away from the protective casing (Figure 3-3). The annular space between the well casing and the protective casing will be filled to the top of the surface seal with bentonite pellets. A 1/4-inch diameter hole will be drilled through the protective casing to allow water which may collect between the casings to drain out.

The amounts of each type of material used to construct the monitoring well will be recorded. Well construction data will be recorded per NR141.23 requirements on a WDNR Well Construction Diagram #4400-113A and a WDNR Well Information Form #4400-89. Forms #4400-89 and #4400-113A will be submitted to WDNR within 60 days after installation per Chapter 144, Wisconsin Statutes, and NR141.23. An example of each form is presented in Appendix D.

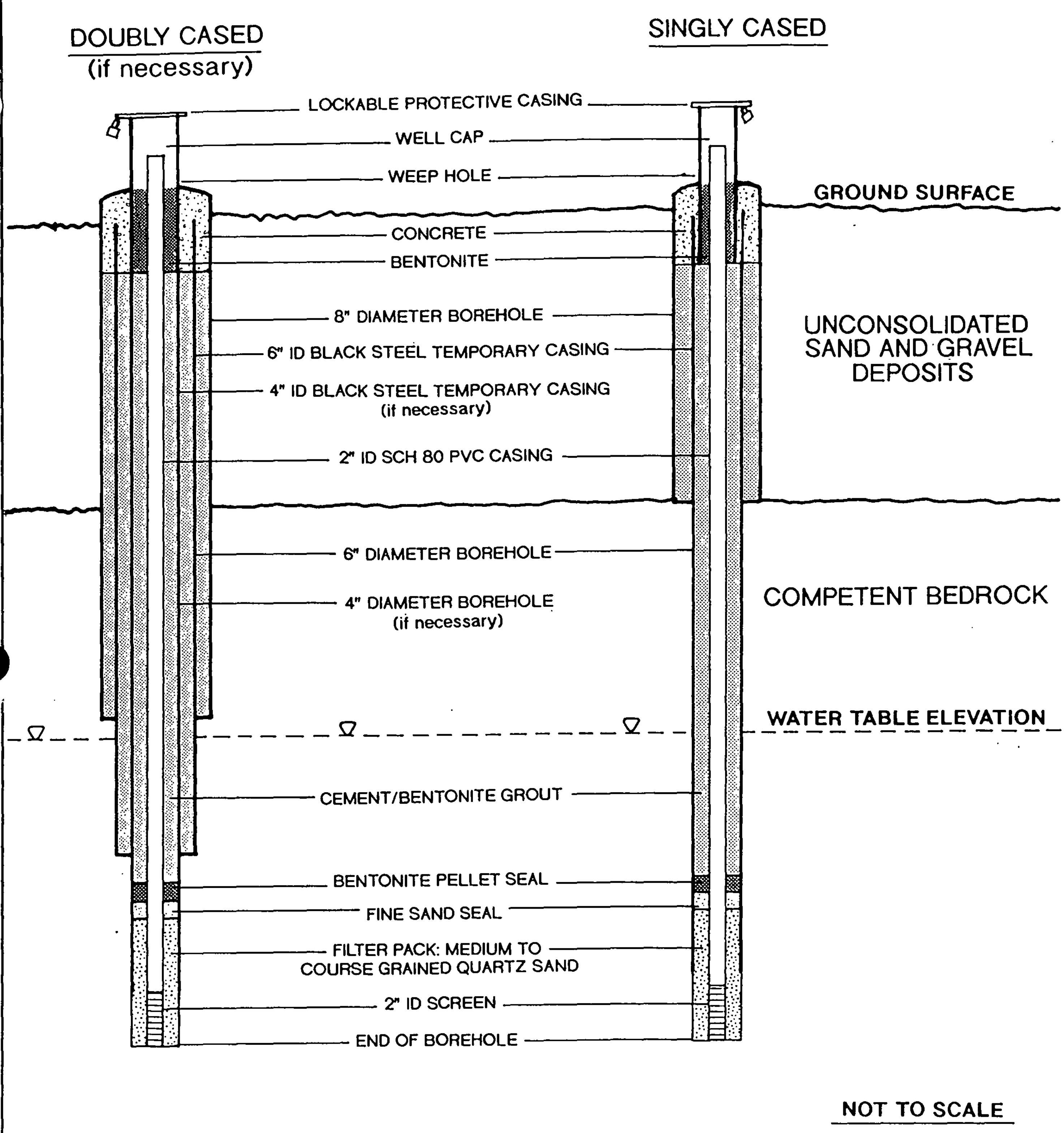
3.3.3 Piezometers in Bedrock

3.3.3.1 Construction Materials

Typical bedrock piezometer construction is depicted on Figure 3-4. Air rotary drilling technique will be used for drilling piezometers within the bedrock. An eight-inch borehole diameter will initially be used for drilling to the water table. At the water table a temporary six-inch casing will be installed because of the tendency of the formation to slough with the movement of tools in and out of the borehole. A six-inch air rotary technique will be used to complete the piezometer to the desired depth.

However, should severe circulation loss or high contamination be encountered, a temporary string of four-inch casing will be installed in the borehole and drilling will continue using a Longyear HQ wire coring system. If it is necessary to use this drilling method, the borehole will be completed with a four-inch rather than a six-inch diameter as required by NR 141.19(2)(a). This will require a variance to NR 141 which was granted in a letter from Terry Evanson of the WDNR dated July 18, 1990.

The bedrock piezometers will be constructed of new two inch ID PVC which meets the standards set forth in NR 141.07. As all bedrock piezometers will penetrate greater than two-feet into bedrock, Schedule 80 PVC will be used for well construction materials per NR141. A contingency will be made to substitute two-inch ID 316 stainless steel for PVC if highly impacted ground-water zones are encountered. All joints will be flush-threaded. The screens will be ten feet long with slot size determined according to NR141.09. A cap will cover the top of the well casing. A protective casing will be included, and will consist of an eight-foot length of metal casing with a lockable cap. The protective casing inner diameter will be a minimum of two inches larger than the well casing, per NR141.



Hydro-Search, Inc. HYDROLOGISTS GEOLOGISTS ENGINEERS Reno Denver Milwaukee Irvine	WI DEPT. of NATURAL RESOURCES REFUSE HIDEAWAY LANDFILL TYPICAL BEDROCK COMPLETION
PROJECT: 265E13673 DATE: 08/03/90	REVISION DATE: FIGURE 1

(formerly Fig 3-4)

Well casings, couplings, and screens will be steam-cleaned and sealed in plastic prior to use or will remain sealed in factory plastic until use. The well casings and screens will be visually inspected for defects, per NR141.07 (4), and defective materials will not be used. Piezometer packing and sealing material will adhere to specifications set forth in NR141.11 and NR141.13. A two-foot thick filter pack seal comprised of a clean fine grained sand will be placed above the filter pack material. A two-foot thick bentonite pellet seal will be placed above the filter pack seal per NR141.13 and the remaining annular space will be sealed with one of the following materials:

1) Bentonite - cement grout,
2) Granular bentonite slurry,
3) Bentonite sand slurry, or
4) Neat cement grout, if Schedule 80 PVC or stainless steel well casing is used.

When a slurry is used for the annular space sealant it will be installed using a tremie pipe, following the procedures in NR141.10.

3.3.3.2 Installation

The piezometers will be installed following borehole completion. The drilling methods are discussed in Section 3.1. Prior to bedrock piezometer installation the boreholes will be flushed with clean water using a drilling rod or tremie pipe inserted to the bottom of the borehole. The borehole will be flushed until clean water free of drill cuttings and drilling fluid flows from the top of the borehole. The total depth of the borehole will then be measured using a measuring tape or rod.

Figure 3-4 shows typical bedrock piezometer construction specifications. The well casing will extend at least 20 inches above the ground surface. The amount of packing and sealing materials required will be calculated prior to installation based on the diameter of the borehole less the casing diameter, and the linear footage of packing or sealing materials required. Filter pack material for piezometers is required to extend from six inches below the well screen to five feet above the screen. The lower six inches of pack material will be poured in to the borehole following flushing, and prior to well insertion. The well screen and casing will then be inserted through the center of the borehole by personnel wearing clean gloves. Filter pack material will then be installed in the annular space between the well and the borehole walls to ten feet above the top of the well screen. A tape measure or measuring rod will be used to ensure the pack material is installed evenly and over the proper depth interval. If the packing material bridges, it will tamped into place. A two-foot thick filter pack seal comprised of clean, fine-grained sand will be placed above the filter pack material and two-foot thick bentonite pellet seal will be placed above the filter pack seal, if required, per NR141.13. The depth interval for the fine sand and bentonite seals will similarly be measured and, if necessary, the seals will be tamped into place.

If a grout or slurry is used as an annular space seal, it will be tremied into place, according to specifications in NR141.10. If bentonite pellets are used, they will be poured freely down the borehole per NR141.13(2)(b). If a slurry or grout annular space seal is used, the protective casing will not be installed until a minimum 12-hour waiting period has elapsed following placement, and any grout or slurry settlement has been topped off, per NR141.13(2)(b)3.

The protective casing will be centered over the well casing prior to installing the ground surface seal. The protective casing will extend from at least five feet below the ground surface to at least two feet above the ground surface, and will be placed such that the well casing is no more than four inches below the top of the protective casing, unless dedicated pumping equipment is to be installed, in which case a minimum of six inches will be left between the well casing and the protective casing to allow room for installation of pumping equipment. The ground surface seal will then be installed between the borehole wall and the protective casings.

If bentonite is used as a ground surface seal, it will extend from five feet below the ground surface to one-foot below the ground surface, and top soil will be placed in the remaining annular space and sloped away from the protective casing. If concrete is used as the ground surface seal, it will extend from five feet below the ground surface to above the ground surface, and will be finished to slope away from the protective casing (Figure 3-4). The annular space between the well casing and the protective casing will be filled to the top of the surface seal with bentonite pellets. A 1/4-inch diameter hole will be drilled through the protective casing to allow water which may collect between the casings to drain out.

The amounts of each type of material used to construct the piezometer will be recorded. Well construction data will be recorded per NR141.23 requirements on a WDNR Well Construction Diagram #4400-113A and a WDNR Well Information Form #4400-89. Forms #4400-89 and #4400-113A will be submitted to WDNR within 60 days after installation per Chapter 144, Wisconsin Statutes, and NR141.23. An example of each form is presented in Appendix A.

3.4 Survey Control

Survey control will be performed following monitor well, piezometer, and borehole installations. Vertical elevations to the top of each new well casing will be established by survey to within ± 0.01 foot. Ground surface elevations at each well and borehole location will be established within ± 0.1 foot. Elevations will be referenced to mean sea level (msl). Lateral locations based on the established grid system will be determined for each new well, piezometer or borehole. Lateral locations will be calculated to within ± 1-foot per NR141.065. All well and piezometer locations and elevations will be documented on WDNR Well Information Forms #4400-89 and Monitoring Well Construction Forms #4400-113A (Appendix D). Well and piezometer locations will be plotted on the site topographic map and included in the final report. Per NR141.065, the site map will include well and piezometer locations, structure boundaries, property boundaries, nearby surface water, site grid system origin according to either the state plane coordinate system or latitude or longitude, scale, and a north arrow. In addition, an 11 x 17-inch map dimensioned to scale showing the location of wells, piezometers, and structures on the site will be submitted to the State per NR141.065.

Field notes will be kept in bound books, and each book will have an index. Waterproof ballpoint pens will be used. Erasing is not acceptable; all errors will be crossed out with a single line and the correct data entered adjacent to the error. The crossed out and corrected data will be initialed by the party making field notes.

In conducting vertical surveys, the following procedures will be used:

- When practical, level circuits will close on a bench mark other than starting bench mark.
- Readings should be recorded to the closest 0.01 foot using a calibrated rod.
- Foresight and backsight distances should be reasonably balanced.
- Rod levels shall be used.
- No side shot shall be used.
- Bench marks will be traceable to USGS benchmarks.

3.5 Well Development

Following installation, all new monitoring wells and piezometers will be developed after a minimum waiting period of 12 hours per NR141.21. Wells and piezometers will be developed using either a pump or a bailer or a combination of the two to remove the effects of drilling and installation operations. If a monitoring well or piezometer can be purged dry, development will consist of slowly purging the well dry to limit agitation. Development is complete per NR141.21(2) when five well volumes have been removed, or sediment-free water is produced. If a monitoring well and piezometer cannot be purged dry, it will be developed by alternately surging and purging the well for a minimum of 30 minutes per NR141.21(1), and then pumping or bailing until ten well volumes are removed or until sediment free water is produced. The well volume is calculated as follows:

$$\pi H_1(D_1/2)^2+\pi n H_2[(D_3/2)^2-(D_2/2)^2]$$

where:

D_1 = inner diameter of well casing (ft.)
D_2 = outer diameter of well casing (ft.)
D_3 = borehole diameter (ft)
H_1 = height of water column in well casing (ft.)
H_2 = length of filter pack or height of water column, whichever is less (ft.)
n = porosity of filter pack

Periodic measurements and observations of field parameters including temperature, specific conductance, pH, visual appearance and odor will be made and recorded on HSI Well Development/Purge Summary Forms (Appendix A) as each well is developed. In addition, time expended in development, volume of water removed, and any sedimentation present in the bottom of each well before and after development will be noted. Water level measurements will be obtained prior to and following development, and following water level stabilization. The purge water will be handled as discussed in section 3.7.

3.6 Hydraulic Conductivity Testing

Following the completion of well development in each well, the water level will be allowed to recover back to static and then a hydraulic test performed using a dedicated bladder pump, a well development pump, a bailer, or a slug to create a head loss. Dedicated pumps will be used in highly impacted wells. The water levels during the test will be measured using an electronic WLP or a 10 or 50 psi pressure transducer with an

In-Situ SE1000A or SE1000B data logger. All water removed during the test will be collected in 55-gallon drums and disposed of according to the criteria described in Section 3.7.

Estimates of in-situ hydraulic conductivity will be made from the recovery data via the method described by Bouwer and Rice. After completion of the test, the equipment will be removed from the well and decontaminated. If a non-dedicated pump is used, it will also be removed from the well and decontaminated.

3.7 Field-Generated Waste Handling and Disposal Procedures

Solids and fluids removed from the boreholes or monitoring wells are not expected to be significantly impacted, however, at the request of WDNR, drill cuttings will be temporarily stored on the Refuse Hideaway Landfill property and eventually disposed of in the landfill, and drill water and purge water will be stored in the empty 25,000-gallon leachate holding tank. It will be tested at the end of the project and properly disposed of with a WPDES permit to surface water or at a waste water treatment plant.

3.8 Air Monitoring During Drilling

Air monitoring will be accomplished using an HNu photoionization detector and explosimeter during drilling operations due to the potential presence of volatile organic compounds and landfill gases. The protocols and frequency for air monitoring are described in the project Health and Safety Plan.

4.0 QUALITY ASSURANCE / QUALITY CONTROL PROCEDURES

The purpose of this section is to present general quality assurance/quality control procedures which may be employed during the site investigations.

4.1 Sampling Procedures

4.1.1 Decontamination

All material and equipment will arrive on-site in clean condition. All fluids generated during decontamination procedures will be disposed of in accordance with WDNR regulations. Recommended procedures for equipment decontamination, described in the subsections below, will be followed where applicable.

4.1.1.1 Drilling, Soil Sampling, and Monitor Well Installation Equipment Decontamination

Prior to the start of drilling, all drill rods, augers, bits, and split-spoons will be steam-cleaned at an area set up on-site for this purpose. The decontamination will be performed by the drilling subcontractor to the satisfaction of the site geologist and will be documented in the field notebook.

Augers, tools, drill rods, casings, and screens will be inspected to ensure that residue such as muds and machine oils are removed. These decontamination procedures will also be employed between each boring to prevent cross-contamination and ensure the integrity of soil samples. All equipment will also be decontaminated prior to removal from a site.

4.1.1.2 Sampling Equipment Decontamination

The procedure for decontaminating sampling equipment is as follows:

1. Place dirty equipment on a plastic ground sheet at the head of the

"decontamination line".

2. Rinse equipment in a tub of potable water to remove surface dirt and mud, if necessary.

3. Scrub equipment with a bristle brush in a basin filled with laboratory-grade detergent and potable water.

4. Rinse off soap in a tub of potable water.

5. Final rinse with distilled water.

6. Allow equipment to dry before use.

7. Wrap equipment in plastic to protect from contamination, where appropriate.

4.1.2 Sample Container and Preservation Requirements

All samples submitted for analysis on this project will be collected by HSI personnel. Sampling containers and preservatives will be provided upon request by SEI. The general requirements for sample containers, preservatives, and analytical holding times are discussed in the following subsections.

All containers provided by SEI will be obtained from I-Chem, Hayward, California, or be of equivalent quality. I-Chem is the bottle contractor to the EPA CLP. All containers are cleaned in accordance with EPA protocols. Each lot of these containers is analyzed in accordance with I-Chem quality control requirements and is not shipped by I-Chem unless the QC requirements are met. The types of containers that will be provided for each analyte are listed in Table 4.1, along with the holding times and preservatives required for each analysis. Samples designated for dissolved iron analysis will be field filtered with a

Table 4-1. Sample Containers, Sample Volumes, Preservation, and Holding Times

Aqueous Samples

Analyte	Container Volume	Preservaton	Maximum Holding Time[1]
Volatile Organics	3 x 40 ml Vials	2 drops of 1:1 HCl, Cool to 4° C	14 days
COD	1-50 ml Glass[2]	H_2SO_4 to pH <2 Cool to 4° C	28 days
Chloride	1-100 ml Glass[2]	Cool to 4° C	28 days
Alkalinity	1-100 ml Glass[2]	Cool to 4° C	14 days
Metals	1-100 ml Glass[2]	HNO_3 to pH <2	6 months

Notes:

1 This is the maximum holding time from date of collection

2 These containers can be plastic or glass

0.045 micron filter at the time of collection.

All sample containers provided by SEI will be shipped with chain-of-custody records. These chain-of-custody records will be compiled by the field sampling personnel and returned with the samples.

4.1.3 Sample Identification and Documentation

Each sample container will be labeled with the following information:

- Sample identification code.
- Date/time of collection.
- Preservative.
- Analysis requested.
- Any special information, including potential level of contamination.

4.1.4 Sample Packaging and Shipment

All samples shipped will be packaged and shipped as environmental samples. Sample packaging procedures will comply with all U.S. Department of Transportation (DOT) requirements for shipment of environmental samples via commercial carrier as follows:

- The lid of each labeled container will be secured with a strip of custody tape.

- Individual sample containers will then be sealed in ziplock plastic bags and placed in coolers.

- Vermiculite will be placed around the bags in the cooler. Ice will be placed in the cooler.

- One chain-of-custody from will be completed for each cooler, placed in a large ziplock bag, and taped to the inside lid of the cooler.

- The following labels will be placed on the cooler.

    - Upward-pointing arrow labels on all four sides.
    - "This End Up" on top.

Samples will typically be transported from the field to SEI using an overnight carrier service or hand delivered by the field personnel. In these instances, samples will be stored in a cooler kept at 4 oC and packaged to prevent breakage. Those samples requiring 24-hour turnaround time will be hand delivered to SEI the same day of collection.

4.2 Sample Custody Procedures

4.2.1 Introduction

Sample custody protocols will be based on procedures as described in "NEIC Policies and Procedures", EPA-330/9-78-DD1-R, Revised June, 1985. This custody is in two parts: sample collection and laboratory analysis. A sample is under a person's custody if it meets the following requirement:

- It is in the person's possession,
- It is in the person's view, after being in the person's possession,
- It was in the person's possession and it was placed in a secured location, or
- It is in a designated secure area

4.2.2 Field Specific Custody Procedures

The sample packaging and shipment procedures summarized below will assure that the samples will arrive at the laboratory with the chain-of-custody intact.

Field Procedures are as follows:

(a) The field sampler is personally responsible for the care and custody of the samples until they are transferred or properly dispatched. As few people as possible should handle the samples.

(b) All bottles will be tagged with sample numbers and locations.

(c) Sample tags will be filled out using waterproof ink for each sample.

(d) The Project Manager must review all field activities to determine whether proper custody procedures were followed during the field work and decide if additional samples are required.

Transfer of Custody and Shipment Procedures are as follows:

(a) Samples are accompanied by a properly completed chain-of-custody form (Appendix A). The sample numbers and locations will be listed on the chain-of-custody form. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents transfer of custody of samples from the sampler to another person, to a mobile laboratory, to the permanent laboratory, or to/from a secure storage area.

(b) Samples will be properly packaged for shipment and dispatched to the appropriate laboratory for analysis with a separate signed custody record enclosed in each sample box or cooler. Shipping containers will be locked and secured with strapping tape in at least two locations for shipment to the laboratory.

(c) Whenever samples are split with a source or government agency, a separate

Sample Receipt is prepared for those samples and marked to indicate with whom the samples are being split. The person relinquishing the samples to the facility or agency should request the representative's signature acknowledging sample receipt. If the representative is unavailable or refuses, this is noted in the "Received By" space.

(d) All shipments will be accompanied by the Chain-of-Custody Record identifying the contents. The original record will accompany the shipment, and the pink and yellow copies will be retained by the sampler for returning to the sample office.

(e) If the samples are sent by common carrier, a bill of lading should be used. Receipts of bills of lading will be retained as part of the permanent documentation. If sent by mail, the package will be registered with return receipt requested. Commercial carriers are not required to sign off on the custody form as long as the custody forms are sealed inside the sample cooler.

4.2.3 Laboratory Custody Procedures

The laboratory chain-of-custody procedures along with the sample tracking procedures are described in Appendix D and Section 4.2..

4.3 Calibration Procedures and Frequency

As an activity that affects data quality, instrument calibration must be performed in accordance with formal written procedures as required in this section. HSI further requires that field instruments be calibrated and maintained to operate within manufacturer's specifications by trained personnel.

4.3.1 Field Instrument Calibration

The calibration and maintenance programs for the instrument used in field measurements are included in Section 2.1, along with the procedures for field measurement. All calibration performed in the field will be documented in the field log book and on appropriate forms.

A master calibration/maintenance file will be maintained by the Site Investigation Task Coordinator for each measuring device and will include at least the following information:

- Name of device and/or instrument calibrated
- Device/instrument serial and/or I.D. number
- Frequency of calibration
- Date of calibration
- Results of calibration
- Name of person performing the calibration
- Identification of the calibration media (e.g., HNu gas, pH buffer solutions)

4.3.2 Laboratory Instrument Calibration

Laboratory calibration procedures and frequencies will be in accordance with the CLP guidance or the EPA methods employed, when CLP guidance is not available for the selected parameter.

4.4 Analytical Procedures

All analytical services will be provided by Swanson Environmental, Inc., located in Brookfield, Wisconsin. Analyses performed by SEI will subscribe, whenever possible, to the most current EPA CLP Statement of Work for organic and inorganic analyses. Analytical methods for parameters not included in the CLP will be taken from Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020 and Test Methods for Evaluating Solid

Waste, Physical/Chemical Methods, SW-846 (or where otherwise specified).

Tables 4-2 through 4-5 presents the parameters of interest, the detection limits for each media and the methodology which may be employed in lieu of CLP methodology.

4.5 Internal Quality Control Check

The reliability and credibility of analytical laboratory results is established by quality control samples such as the inclusion of randomly scheduled replicate analyses, analysis of standard of spiked samples, and the analysis of split samples.

Field QA/QC samples will consist of field replicates, field blank and trip blank samples. Trip blank samples will be analyzed for VOAs. Replicates will be collected at a minimum frequency of one per every ten or fewer water samples collected. The replicates or duplicates will be analyzed for the same parameters as those analyzed in the samples of the media and will be used to assess sampling precision.

A field blank consists of a group of sample containers filled with analyte-free water in the same manner as investigative samples. The containers are transported empty into the field and are used in collecting "rinse water" obtained after decontamination between samples by pouring analyte-free water over the equipment used to receive the various types of samples. Field blanks will be analyzed for the same parameters as the investigative samples obtained with the equipment from which the blank was collected. One field blank will be collected at a frequency of one per twenty or fewer investigative samples and will serve to monitor potential field ambient contamination and cross-contamination from sampling equipment. Dedicated bailing equipment will be used for groundwater sampling eliminating the need for groundwater field blanks.

Trip blanks will be provided daily by the laboratory and will consists of two 40-mL vials with

TABLE 4-2

DETECTION LIMITS AND ANALYTICAL METHODS FOR SELECTED INORGANIC CHEMICALS

Chemical	Analytical Methods		Detection Limits	
	Water(a)	Solids(b)	Water(ug/l)	Solids(mg/kg)
Inorganic Nitrogen				
Ammonia	350.1	—	1000	—
Nitrate	353.2	353.2 (c)	50	50
Inorganic Sulfur				
Sulfides	376.1	—	1000	—
Thiocyanates	412.L (d)	—	1000	—
Sulfate	375.2	—	20000	—
Inorganic Phosphorus				
Phosphate (e)	365.2	365.2	50	10
Inorganic Chlorides				
Chloride	325.3	—	500	—
Inorganic Cyanides				
Total Cyanide	335.2	9010	10	.10
Cyanide Amenable To Chlorination	335.1	9010	10	.10

(a) Reference: Methods For Chemical Analysis of Water and Wastes, U.S. EPA, 1983.

(b) Reference: Test Methods In Evaluating Solid Waste, Physical/Chemical Methods, U.S. EPA, 1986.

(c) The EPA Method for water is readily adapted to solid samples by adding the solid material to deionized water and proceeding with the method.

(d) There is no EPA method. This method is from Standard Methods for Examination of Water and Wastewater, 16th edition.

(e) Orthophosphate

NA = EPA approved analytical technique is not available.

TABLE 4-3

DETECTION LIMITS AND ANALYTICAL METHODS FOR SELECTED METALS

Chemical	Analytical Methods		Detection Limits	
	Water(a)	Solids(b)	Water(ug/l)	Solids(mg/kg)
Arsenic (c)	206.2	7060	1	0.05
Barium (c)	200.7	6010	5	0.2
Cadmium (c)	213.2	6010	0.2	0.5
Calcium	200.7	6010	1000	50
Chromium (c)	218.2	6010	1	1
Copper	220.2	6010	1	1
Iron (c)	200.7	6010	20	1
Lead (c)	239.2	6010	1	2
Magnesium	200.7	6010	100	5
Manganese	200.7	6010	20	1
Mercury (c)	245.1	7471	0.2	0.01
Nickel	249.1	6010	20	1
Selenium (c)	270.2	7740	2	0.1
Silver (c)	272.2	6010	0.2	1

(a) Reference: Methods For Chemical Analysis of Water and Wastes, U.S. EPA, 1983.

(b) Reference: Test Methods In Evaluating Solid Waste, Physical/Chemical Methods, U.S. EPA, 1986.

(c) EP TOX Test.

TABLE 4-4
LIMITS OF DETECTION

6/6/89

VOLATILE ORGANIC COMPOUNDS

Parameter	(a) Drinking Water ug/l	(b) Wastewater ug/l	(c) Soil/Sludge ug/kg
Acrolein	50	100	10,000
Acrylonitrile	50	100	10,000
Benzene	1	1	50
Bromomethane	10	10	50
Bromodichloromethane	2	10	50
Bromoform	2	10	50
Carbon tetrachloride	1	10	50
Chlorobenzene	1	1	50
Chloroethane	1	10	50
2-Chloroethylvinylether	4	10	50
Chloroform	1	10	50
Chloromethane	10	10	50
Dibromochloromethane	2	10	50
1,2-Dichlorobenzene	2	2	50
1,3-Dichlorobenzene	2	2	50
1,4-Dichlorobenzene	2	2	50
1,1-Dichloroethane	1	10	50
1,2-Dichloroethane	1	10	50
1,1-Dichloroethene	1	10	50
trans-1,2-Dichloroethene	1	10	50
1,2-Dichloropropane	1	10	50
cis-1,3-Dichloropropene	2	10	50
trans-1,3-Dichloropropene	2	10	50
Ethylbenzene	1	1	50
Methylene chloride	1	10	50
1,1,2,2-Tetrachloroethane	3	10	50
Tetrachloroethene	1	10	50
Toluene	1	1	50
1,1,1-Trichloroethane	1	10	50
1,1,2-Trichloroethane	1	10	50
Trichloroethene	1	10	50
Trichlorofluoromethane	1	10	50
Vinyl chloride	10	10	50
Xylenes	1	1	50
Total Petroleum Hydrocarbons	200	500	10,000

(a) EPA Method 502/503
(b) EPA Method 601/602/603
(c) EPA Method SW846: 5030/8010/8020/8030

Table 4-5. Analytical Methods or Characterization Tests for Other Parameters

Parameter/Characteristic	Method	Reference
WATER		
VOC (32)	EPA 502/503	EPA, 1983
Alkalinity	EPA 310.1	EPA, 1983
Hardness	EPA 209A	EPA, 1983
Chemical Oxygen Demand (COD)	EPA 508A	EPA, 1983
Chloride	EPA 325.3	EPA, 1983
Dissolved Iron	EPA 200.7	EPA, 1983
SOIL		
Atterberg Limits	ASTM D423-66, and ASTM D424-59	ASTM Methods
Grain Size Analysis	ASTM D422	ASTM Methods

Notes: (a) Clark, F., Methods of Soil Analysis, Volume 2, pp. 1460-65, "Agar-Plate Method for Total Microbial County; Shiaris, M., and Cooney, J., Applied and Environmental Microbiology, Feb. 1983, Volume 45, no.2, pp. 706-710, "Replica Plating Method for Estimating Phenanthrene - Utilizing and Phenanthrene-Cometabilizing Microorganisms.

(b) Code of Federal Regulations, Volume 40, 1988 septum caps containing deionized water. The trip blanks, to be analyzed for VOCs, will be handled and transported in the same manner as field samples. One set of trip blanks will be in each cooler containing VOA samples and will serve to monitor potential cross-contamination due to migration of VOA across septa.

The standard analytical quality control checks to be instituted by the laboratory personnel include, but are not limited to the following:

- Matrix Spike/Matrix Spike Duplicate - Samples in which compounds are added before extraction and analyses. The recoveries for spiked compounds can be used to assess how well the method used for analysis recovers target compounds, i.e., a measure of matrix interferents inherent in the sample. When reviewed in conjunction with other QC data, MS/MSD may indicate reanalysis using a more appropriate method. At least one MS/MSD sample analysis will be performed on each group of samples of a similar matrix type and concentration for each batch of samples or for each 20 samples received from a site, whichever is more frequent.

- Surrogate Spiking - Samples in which surrogate compounds are added before sample preparation for organics. Recoveries for spiked surrogate compounds can be used to assess method accuracy for each sample matrix.

4.6 Accuracy, Precision and Completeness Goals

To ensure the accuracy, precision, completeness, representativeness, and comparability of data generated, the following measures will be taken:

- WDNR-and U.S.EPA approved sampling procedures will be used.

- All laboratory analyses will follow EPA CLP guidelines where available or utilize EPA methodology.

The precision, accuracy, and completeness goals for each class of constituents are presented in Table 4-6. These terms are briefly defined below.

- Precision - The degree of agreement between a set of duplicate/replicate results constitutes the precision of the measurement. The precision is assessed using duplicate/replicate sample analysis. Precision will be reported as relative percent differences as expressed by the following formula:

$$RPD - \frac{(C_1 - C_2)}{(C_1 - C_2)/2} \ x \ 100\%$$

Where: RPD = Relative Percent Difference.
C_1 = Concentration of analyte in sample.
C_2 = Concentration of analyte in replicate.

- Accuracy - Accuracy is the nearness of a result to the accepted (or true) value. Accuracy is assessed by means of reference (or spiked) samples and percent recoveries.

Error may arise from personal, instrumental, or methods factors. Analytical accuracy is expressed as the percent recovery of an analyte that has been added to the sample (or standard matrix, i.e., blank) at a known concentration before analysis and is expressed by the following formula:

$$Accuracy - \% \ Recovery - \frac{A^T - A^O}{A^F} \ x \ 100\%$$

Where: A^T = Total amount found in a fortified sample.
A^O = Amount found in an unfortified sample.
A^F = Amount added to a sample.

TABLE 4-6

SUMMARY OF PRECISION, ACCURACY, AND COMPLETENESS OBJECTIVES

Parameter	Matrix	Precision (Relative % Difference)	Accuracy (% Recovery)	Completeness
Metals	soil	30	±25	80
	water	20		
Inorganics	soil	5-20	±20	80
	water			
Volatile Organics (a)				
1,2,4-Trichloro-	soil	23	38-107	80
benzene	water	28	39-98	80
Acenaphthalene	soil	19	31-137	80
	water	31	46-118	80
2,4-Dinitrotoluene	soil	47	28-89	80
	water	38	24-96	80
Pyrene	soil	36	35-142	80
	water	31	26-127	80
N-nitroso-di-n-	soil	38	41-126	80
1-propylamine	water	27	41-116	80
1,4-Dichorobenzene	soil	27	28-104	80
	water	28	36-97	80
Geotechnical				
Atterberg Limits	soil	b	b	80
Grain Size	soil	b	b	80

(a) Reference "U.S. EPA CLP State of Work for Organic Analysis".
(b) ASTM has not established accuracy and precision data.

Notes: NA = Not Applicable.

Precision and accuracy for organic spiking compounds will follow criteria set forth in the EPA CLP SOW. For organics not represented in the MS/MSD spiking solution, the above criteria will apply. Note also that these precision, accuracy, and completeness goals are representative of project goals and will be used to assess usability issues related to data quality (e.g., matrix interferences, sample heterogeneity, etc.). These criteria are advisory only. No corrective action (e.g.,sample reanalysis) will be taken if these criteria are not met.

- <u>Completeness</u> - Completeness is a measure of the relative number of analytical data points that meet all of the acceptance criteria for accuracy, precision, and any other criteria required by the specified analytical methods used. The level of completeness can also be affected by loss or breakage of samples during transport, as well as by external problems that prohibit collection of the sample.

  The QA objective for completeness is to have 80 percent of the data usable without qualification. The ability to meet or exceed this completeness objective is dependent on the nature of the samples submitted for analysis. If data cannot be reported without qualifications, project data quality objectives may still be met if the qualified data (data of known quality even if not perfect) are suitable for specified project goals.

- <u>Representativeness</u> - Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness is a qualitative parameter that depends on the proper design of the sampling program. The representativeness criterion is best satisfied by making certain that sampling locations are properly selected and that a sufficient number of samples are collected. Representativeness is addressed by describing the sampling techniques and the rationale used to select sampling locations.

- <u>Comparability</u> - Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. Sample data should be comparable with other measurement data for similar samples and sample conditions. This goal is achieved by using standard techniques to collect and analyze representative samples and by reporting analytical results in standard units.

4.7 Data Management

4.7.1 Field and Technical Data

The field and technical (non-laboratory) data that will be collected can generally be characterized as either "objective" or "subjective" data.

Objective data include all direct measurements of field data such as field screening/analytical parameters and water level measurements. Subjective data include descriptions and observations. Soil borings and well logs include both subjective and objective data in that the data recorded in the field are descriptive but can be reduced using a standardized lithologic coding system.

4.7.1.1 Field Logs

All data collection activities performed at a site will be documented either in a field notebook or on appropriate forms. Entries will be as detailed and descriptive as possible so that a particular situation can be recalled without reliance on the collector's memory. All field log entries will be dated. All field log forms will be kept in ring binders assigned to individual field personnel.

The cover of each notebook or ring binder will contain the following information:

- Project name
- Start date
- End date

4.7.1.2 Data Reduction

As described, all field data will be recorded by field personnel in field notebooks and on the appropriate forms in ring binders. For example, during drilling activities, the field team member supervising a rig will keep a chronological log of drilling activities, a descriptive log of lithologies encountered, other pertinent drilling information (staining, odors, field screening, atmospheric measurements, water levels, geotechnical data), and a labor and materials accounting in his/her notebook. Upon completion of each test boring or monitor well, a form will be completed that will include lithologic codes along with descriptive data.

After checking the data in the field notes and forms, the Site Investigation Task Coordinator will reduce the data to tabular form, wherever possible, by entering it in data files. Subjective data will be filed as hard copies for later review by the Site Investigation Task Coordinator and for incorporation into technical reports as appropriate.

4.7.1.3 Data Validation

Validation of objective field and technical data will be performed at two different levels. On the first level, data will be validated at the time of collection by following standard procedure QC checks. At the second level, data will be validated by the Site Investigation Task Coordinator, who will review it to ensure that the correct codes and units have been included.

After data reduction into tables or arrays, the Site Investigation Task Coordinator will review data sets for anomalous values. Any inconsistencies or anomalies discovered by the Site Investigation Task Coordinator will be resolved immediately, if possible, by seeking clarification from the field personnel responsible for collecting data.

Subjective field and technical data will be validated by the Project Manager, who will review field reports for reasonableness and completeness. In addition, random checks of sampling field conditions will be made by the Site Investigation Task Coordinator, who will check recorded data at that time to confirm the recorded observations. Whenever possible, peer review will also be incorporated into the data validation process, particularly for subjective data, in order to maximize consistency between field personnel.

4.7.2 Laboratory Data Internal Procedures

4.7.2.1 Data Logging

The sample custodian, upon receipt of samples for analysis accompanied by a completed request for analysis and/or chain-of-custody form, will do the following:

- Verify completeness of submitted documents, including the chain-of-custody forms.
- Log in samples, assign unique lot numbers, and attach the numbers to the sample container(s).
- Open the project file.
- Store samples in refrigerated sample bank.

4.7.2.2 Data Collection

In addition to the data collected in the field and recorded on the chain-of-custody forms, data describing the processing of samples will be accumulated in the laboratory and recorded in laboratory notebooks. Laboratory notebooks will contain the following:

- Date of processing
- Sample numbers
- Client (optional)
- Analyses or operation performed
- Calibration data
- Quality control samples included
- Concentration/dilutions required
- Instrument readings
- Special observations (optional)

- Analyst's signature

4.7.2.3 Data Reduction

Data reduction is performed by the individual analysts and consists of calculating concentrations in samples from the raw data obtained from the measuring instruments. The complexity of the data reduction will be dependent on the specific analytical method and the number of discrete operations (extractions, dilutions, and concentrations) involved in obtaining a sample that can be measured.

For those methods using a calibration curve, sample response will be applied to the linear regression line to obtain an initial raw result, which is then factored into equations to obtain the estimate of the concentration in the original sample. Rounding will not be performed until after the final result is obtained to minimize rounding errors, and results will not normally be expressed in more than two (2) significant figures.

Copies of all raw data and the calculations used to generate the final results will be retained on file to allow reconstruction of data reduction process at a later date.

4.7.2.4 Data Review/Validation

System reviews are performed at all levels. The individual analyst constantly reviews the quality of data through calibration checks, quality control sample results, and performance evaluation samples. These reviews are performed prior to submission to the laboratory supervisor.

The laboratory supervisor reviews data for the consistency and reasonableness with other generated data and determines if project requirements have been satisfied.

4.7.2.5 Data Reporting

Reports will contain final results (uncorrected for blanks and recoveries), methods of analysis, levels of detection, surrogate recovery data, and method blank data. In addition, special analytical problems and/or any modifications of referenced methods will be noted. The number of significant figures reported will be consistent with the limits of uncertainty inherent in the analytical method. Consequently, most analytical results will be reported to no more than two (2) significant figures. Data are normally reported in units commonly used for the analyses performed. Concentrations in liquids are expressed in terms of weight per unit volume (e.g., milligrams per liter). Concentrations in solid or semisolid matrices are expressed in terms of weight per unit weight of sample (e.g., micrograms per gram).

Reported detection limits will be the concentration in the original matrix corresponding to the low level instrument calibration standard after concentration, dilution, and/or extraction factors are accounted for, unless otherwise specified by program requirements.

The final data report provided by SEI will include the following:

Inorganic Analyses

- Sample data summary report, including lab blanks.
- QC data on laboratory control samples (accuracy).
  - Method blanks
  - Surrogate recoveries
  - Matrix spike/matrix spike duplicate recoveries
- Identification of data qualifiers, sample receipt, digestion and analysis dates, and a description of any technical problems encountered with the analyses.

Organic Analyses

- Sample data summary report, including lab blanks.
- QC data on laboratory control samples (accuracy).
  - Method blanks
  - Surrogate recoveries
  - Matrix spike/matrix spike duplicate recoveries
- Identification of data qualifiers, sample receipt, digestion and analysis dates, and a description of any technical problems encountered with the analyses.

4.7.2.6 Data Archiving

SEI will maintain on file all of the raw data, laboratory notebooks, and other documentation pertinent to the work on a given project. This file will be maintained for three years from the date of invoice.

4.7.3 Data Validation/Usability Review

Separate from the laboratory's internal data review/data validation, a review of the final data package will be performed by the QA Manager to validate results and to determine usability. Criteria to assess usability will be taken from the QA/QC plan. The depth of review will depend on the data deliverable package. Blank data, surrogate and MS/MSD recovery, and replicate data will be reviewed in light of the guidelines in this QA/QC plan.

4.8 Performance and System Audit

4.8.1 Overview

Performance and system audits may be conducted for activities performed by any entity performing services on this project. Audits of project activities will be performed in accordance with the procedures established in the following QA/QC plan. Audits will be initiated by the Project QA Manager. He or his appointed auditors will be responsible for implementing the audits.

Quality assurance system audits are conducted at least once during activities that may affect the integrity of the sampling program. The objectives of the system audits are:

- To verify that a system of quality control measures, procedures, reviews, and approvals is established for all activities that generate and process environmentally related data.
- To verify that a system for project documentation (records, chain-of-custody forms, log books, work sheets, etc.) is established.
- To verify documentation of the required quality control reviews approvals, and activity records (log books, work sheets, etc.)
- To identify non-conformance with the established system of quality control measures, procedures, reviews, approvals, and documentation.
- To recommend corrective actions for identified non-conformance.
- To verify implementation of corrective action.
- To provide written reports of audits.

4.8.2 Analytical Laboratory Services

Audit procedures for the analytical laboratory are specified in the current SOW. Performance audits are used to evaluate laboratory performance.

These audits consist of random data reviews, continuous trend analysis of laboratory QC data, and quarterly analysis of performance evaluation samples. Systems audits are performed to verify continuity of personnel, instrumentation, and quality control requirements contained in the SOW. Systems audits are performed by the Laboratory QA Coordinators and consist of annual on-site inspections.

4.8.3 Field Measurements and Sampling

The Project QA Manager or his designee will perform one scheduled audit and one unscheduled audit of the field activities, covering the following:

* Organization and responsibilities - in order to determine whether the quality assurance organization is operational.

* Collection of samples - to assure that written procedures are available and are being followed.

* Chain-of-Custody program - to assure that the appropriate steps have been followed in the traceability of sample origin.

* Implementation of the operational procedures - to assure that the appropriate QC checks are being made in the field and records are maintained of these checks.

* Equipment - to determine whether the specified equipment is available, calibrated, and in proper working order.

* Training - to assure that sampling crews are adequately trained.

* Records - to assure that record keeping procedures are operational and that field notebooks, log sheets, bench sheets, and tracking forms are properly

prepared and maintained.

In addition, constant surveillance of field sampling and testing activities shall be performed by the Site Investigation Task Coordinator.

4.9 Preventive Maintenance

4.9.1 Field Equipment

An inventory control system governing field equipment and instrumentation will be maintained by the Site Investigation Task Coordinator as the basis for maintenance and calibration control. The inventory control documentation includes the following:

- Description of instrument.
- Manufacturer, model number, and serial number.
- Identification number.
- Name, address, and telephone number of company that services the instrument or equipment.
- Type of service policy.
- Timing and frequency of routine maintenance, servicing and calibration.
- Name of person performing the calibration.

4.9.2 General Equipment Maintenance and Repair

Instruments will be maintained in accordance with manufacturer's specifications. More frequent maintenance may be dictated depending on operational performance. Instrument logs will be maintained to document the date and type of maintenance performed.

4.9.3 Laboratory Equipment

The following instrumentation will be used for chemical analyses:

1. Analysis by GC and/or GC/MS of organic compounds, consisting of the following:
    * Volatiles
    * Semi-volatiles
2. Analysis by AA and/or ICP for metals.

Procedures for maintenance and calibration for these instruments are in accordance with the manufacture's specifications.

4.10 Corrective Action

Any non-conformance with the established quality control procedures will be identified and corrected. The Project QA Manager, or his designee, will issue a Non-Conformance Report (NCR) for each Non-Conformance condition.

4.10.1 Analytical Laboratory Services

Corrective action is implemented at several different levels. The laboratory is required to have a written SOP specifying corrective action to be taken when an analytical error is discovered or the analytical system is determined to be out of control. The SOP requires documentation of the corrective action and notification of the analyst of the error and correct procedures.

The Project QA Manager also may request corrective action for any non-conformances identified by audit or data validation. The Project Director may request corrective action by the laboratories for non-conformances identified in the data validation process, or, for minor problems, the lab may be contacted directly.

Corrective action may include:

- Re-analyzing the samples, if holding time criteria permits,
- Re-sampling and analyzing, and/or,
- Evaluating and amending sampling analytical procedures, and/or,
- Accepting data, acknowledging the level of uncertainty.

4.10.2 Field Investigations and Field Changes

Any non-conformance identified during field procedures will require implementation of corrective action and documentation of the action taken. If non-conformances are identified during data assessment, the Project Manager or Project Director/Project QA Manager may request corrective action. Corrective action for field measurements may include:

- Repeat the measurement to check the error.

- Check for all proper adjustments for ambient conditions such as temperature.

- Check the batteries.

- Check the calibration.

- Replace the instrument or measurement devices.

- Stop work (if air monitoring equipment is not functioning).

The Project Manager or his designee is responsible for all site activities. In this role, the Project Manager at times is required to adjust the site programs to accommodate site specific needs. When it becomes necessary to modify a program, the responsible Site Investigation Task Coordinator notifies the Project Manager of the anticipated changes, and implements the necessary changes. The changes in the program are documented in the field logbook. If unacceptable, the action taken during the period of deviation will be evaluated in order to determine the significance of any departure from established program practices and action taken.

The Project Manager is responsible for the controlling, tracking and implementation of the identified changes. The Project Director/Project QA Manager will also be notified of the change.

4.11 Quality Assurance Reports to Management

The Project QA Manager or his designee will audit the implementation of this QA/QC plan and submit a summary report to the Project Manager in accordance with the QA/QC plan. These reviews will include an assessment of data quality, and the results of systems and/or performance audits as appropriate.

In the event of a disagreement between the Project QA Manager and the audited entity of the adequacy of corrective actions implemented by the latter, the Project Manager may be informed and requested to confer on a resolution of the dispute.

APPENDIX A

FIELD WORK DOCUMENTATION FORMS

SOIL BORING LOG INFORMATION
Form: 4400-122 7/89
Page: ________ of ________

State of Wisconsin
Department of Natural Resources

Facility Name

License/Permit/Monitoring Number ___ ___ ___ ___ ___ ___ ___

Boring Drilled by (Name)

Date Installed ___ ___ / ___ ___ / ___ ___
M M D D Y Y

Facility Well Number ___ ___ ___

WI Unique Well Number (Assigned by DNR) ___ ___ ___ ___ ___ ___

Borehole Diameter ______ Inches

Water Level ______ Feet

Surface Elevation ________

_____ ¼ of _____ ¼ of Section _____ T_____N, R_____ E or W

Grid Location (if applicable)
_______ feet N or S _______ feet E or W

County

County code ___ ___

Civil Town

SAMPLE		DEPTH	SOIL/ROCK DESCRIPTION	WELL DIAGRAM	USCS	RDQ	GRAPHIC LOG	Hnu	SOIL PROPERTIES					Blow Count
No.	% Rec.	(Ft.)						(ppm)	qu (qa) (tsf)	W	LL	PL	P200	

I hereby certify that the information on this form is true and correct to the best of my knowledge.

Signature

Firm HYDRO-SEARCH, INC.
235 N. Executive Dr., #309, Brookfield, WI 53005

This form is authorized by Chapters 144, 147 and 163, Wis. Stats. Completion of this report is mandatory. Penalties; Forfeit not less than $10 not more than $5,000 for each violation. Fined not less than $10 or more than $100 or imprisoned not less than 30 days, or both, for each violation. Each day of continued violation is a separate offense to ss. 144.99 and 162.06 Wis. Stats.

State of Wisconsin
Department of Natural Resources

SOIL BORING LOG INFORMATION
Form: 4400-122 7/89
Page: ________ of ________

SAMPLE		DEPTH	SOIL/ROCK DESCRIPTION	WELL DIAGRAM	USCS	RQD	GRAPHIC LOG	Hnu	SOIL PROPERTIES					Blow Count
No.	% Rec.	(Ft.)						(ppm)	qu (qa) (tsf)	W	LL	PL	P200	

CONTRACTOR ______________________ DATE ______________ SHIFT ______________

SITE NAME ______________________ LOCATION ______________________

BOREHOLE NUMBER(S) THIS DATE ______________________

DRILL TIME LOG: Explain all down and standby time—who authorized—unusual circumstances, etc.

CATEGORY	TOTAL HOURS	A.M. 6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	A.M. 1	2	3	4	5	6
MOB/DEMOB																										
DRILLING																										
WELL CONST.																										
MOVE/DECON																										
TESTING																										
STANDBY																										
DOWN TIME																										
OTHER																										

REMARKS

EXPENDABLES: Itemize quantity, size, etc.

ITEM	QUANTITY	PART NO.

BOREHOLE	FROM	TO	FOOTAGE DRILLED	PIPE & CASING IN HOLE		BITS/CASING SHOES, ETC.				
NO.	FEET	FEET	FEET	SIZE	FEET	SIZE	NUMBER	ON	OFF	FEET

PERSONNEL TIME LOG:

POSITION	NAME	HOURS
GEOLOGIST		
DRILLER		
HELPER		

COMMENTS

GEOLOGIST	CONSULTANT REPRESENTATIVE
DRILLER	CONTRACTOR REPRESENTATIVE

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RENO DENVER MILWAUKEE

DAILY DRILLING SUMMARY

FIGURE

State of Wisconsin
Department of Natural Resources

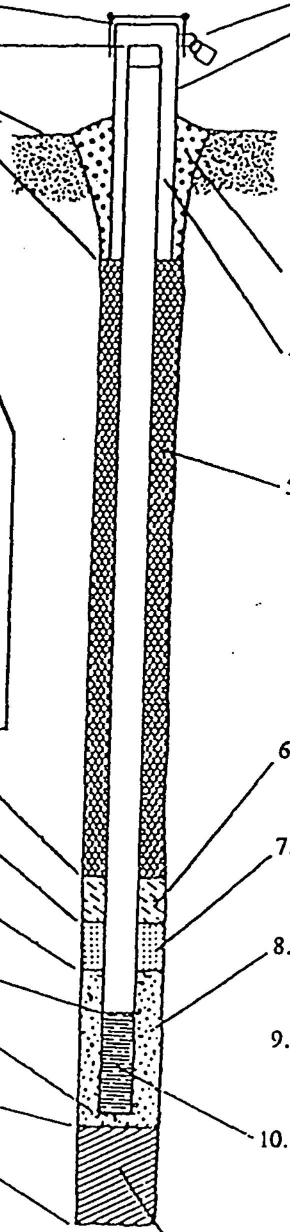
MONITORING WELL CONSTRUCTION
Form 4400-113A 8-89

Facility/Project Name	Grid Location ________ ft. ☐ N. ☐ S. ________ ft. ☐ E. ☐ W.	Well Name
Facility License, Permit or Monitoring Number _ _ _ _ _ _ _ _		Wis. Unique Well Number ▨ DNR Well Number ▨
[illegible]pe of Well Water Table Observation Well ☐ 11 Piezometer ☐ 12	Section Location ____ 1/4 of ____ 1/4 of Section ____, T ____ N, R ____ ☐ E ☐ W	Date Well Installed __ __ / __ __ / __ __ m m d d y y
Distance Well Is From Waste/Source Boundary ft.	Location of Well Relative to Waste/Source ☐ Upgradient ☐ Sidegradient ☐ Downgradient ☐ Not Known	Well Installed By: (Person's Name and Firm) ________
Is Well A Point of Enforcement Std. Application? ☐ Yes ☐ No		________

A. Protective pipe, top elevation _ _ _ _ . _ _ ft. MSL
B. Well casing, top elevation _ _ _ _ . _ _ ft. MSL
C. Land surface elevation _ _ _ _ . _ _ ft. MSL
D. Surface seal, bottom _ _ _ _ . _ _ ft. MSL or _ _ . _ _ ft.

12. USCS classification of soil near screen:
☐ GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP
☐ SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH
☐ Bedrock
13. Sieve analysis attached? ☐ Yes ☐ No
14. Drilling method used: Rotary ☐ 50
Hollow Stem Auger ☐ 41
________ Other ☐ ▨
15. Drilling fluid used: Water ☐ 02 Air ☐ 01
Drilling Mud ☐ 03 None ☐ 99
16. Drilling additives used? ☐ Yes ☐ No
[illegible]Describe ________
17. Source of water (attach analysis):
____

E. Bentonite seal, top _ _ _ _ . _ _ ft. MSL or _ _ . _ _ ft.
F. Fine sand, top _ _ _ _ . _ _ ft. MSL or _ _ . _ _ ft.
G. Filter pack, top _ _ _ _ . _ _ ft. MSL or _ _ . _ _ ft.
H. Well screen, top _ _ _ _ . _ _ ft. MSL or _ _ . _ _ ft.
I. Well screen, bottom _ _ _ _ . _ _ ft. MSL or _ _ . _ _ ft.
J. Filter pack, bottom _ _ _ _ . _ _ ft. MSL or _ _ . _ _ ft.
K. Borehole, bottom _ _ _ _ . _ _ ft. MSL or _ _ . _ _ ft.
L. Borehole, diameter _ _ . _ in.
M. O.D. well casing _ _ . _ _ in.
I.D. well casing _ _ . _ _ in.



1. Cap and lock? ☐ Yes ☐ No
2. Protective cover pipe:
a. Inside diameter: _ _ . _ in.
b. Length: _ _ . _ ft.
c. Material: Steel ☐ 04
________ Other ☐ ▨
d. Additional protection? ☐ Yes ☐ No
If yes, describe: ________
3. Surface seal: Bentonite ☐ 30
Concrete ☐ 01
________ Other ☐ ▨
4. Material between well casing and protective pipe:
Bentonite ☐ 30
Annular space seal ☐
________ Other ☐ ▨
5. Annular space seal: Granular Bentonite ☐ 33
____ Lbs/gal mud weight . . . Bentonite-sand slurry ☐ 35
____ Lbs/gal mud weight . . . . . Bentonite slurry ☐ 31
____ % Bentonite . . . . . Bentonite-cement grout ☐ 50
________ Ft^3 volume added for any of the above
How installed: Tremie ☐ 01
Tremie pumped ☐ 02
Gravity ☐ 08
6. Bentonite seal: Bentonite granules ☐ 33
☐ 1/4 in. ☐ 3/8 in. ☐ 1/2 in. Bentonite pellets ☐ 32
________ Other ☐ ▨
7. Fine sand material: Manufacturer, product name and mesh size
____
Volume added ________ ft^3
8. Filter pack material: Manufacturer, product name and mesh size
____
Volume added ________ ft^3
9. Well casing: Flush threaded PVC schedule 40 ☐ 23
Flush threaded PVC schedule 80 ☐ 24
________ Other ☐ ▨
10. Screen material: ________ ▨
Screen type: Factory cut ☐ 11
Continuous slot ☐ 01
________ Other ☐ ▨
Manufacturer ________
Slot size: 0. _ _ _ in.
Slotted length: _ _ . _ ft.
11. Backfill material (below filter pack): None ☐
________ Other ☐

[illegible] by certify that the information on this form is true and correct to the best of my knowledge.

Signature	Firm

lease complete and return both sides of this form as required by chs. 144, 147 and 160, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with h. 144, Wis Stats., failure to file this form may result in a forfeiture of not less than $10, nor more than $5,000 for each day of violation. In accordance ith ch. 147, Wis. Stats., failure to file this form may result in a forfeiture of not more than $10,000 for each day of violation.
OTE: Shaded areas are for DNR use only. See instructions for more information.

State of Wisconsin
Department of Natural Resources

MONITORING WELL DEVELOPMENT

Form 4400-113B 8-89

Facility/Project Name

Well Name

License, Permit or Monitoring Number _ _ _ _ _ _ _ _

Wis. Unique Well Number _ _ _ _ _ _ _ _

DNR Well Number _ _ _

1. Can this well be purged dry? ☐ Yes ☐ No

2. Well development method

surged with bailer and bailed	☐	4 1
surged with bailer and pumped	☐	6 1
surged with block and bailed	☐	4 2
surged with block and pumped	☐	6 2
surged with block, bailed and pumped	☐	7 0
compressed air	☐	2 0
bailed only	☐	1 0
pumped only	☐	5 1
pumped slowly	☐	5 0
Other ______________	☐	▨

3. Time spent developing well _ _ _ _ min.

4. Depth of well (from top of well casisng) _ _ _ . _ ft.

5. Inside diameter of well _ _ . _ _ in.

6. Volume of water in filter pack and well casing _ _ _ . _ gal.

7. Volume of water removed from well _ _ _ . _ gal.

8. Volume of water added (if any) _ _ _ . _ gal.

9. Source of water added ______________________

10. Analysis performed on water added? ☐ Yes ☐ No
(If yes, attach results)

	Before Development	After Development
11. Depth to Water (from top of well casing)	_ _ _ . _ _ ft.	_ _ _ . _ _ ft.
Date	_ _ / _ _ / _ _ m m d d y y	_ _ / _ _ / _ _ m m d d y y
Time	_ _ : _ _ ☐ a.m. ☐ p.m.	_ _ : _ _ ☐ a.m. ☐ p.m.
12. Sediment in well bottom	_ _ . _ inches	_ _ . _ inches
13. Water clarity	Clear ☐ 10 Turbid ☐ 15 (Describe)	Clear ☐ 20 Turbid ☐ 25 (Describe)

Fill in if drilling fluids were used and well is at solid waste facility:

14. Total suspended solids	_ _ _ _ . _ mg/l	_ _ _ _ . _ mg/l
15. COD	_ _ _ _ . _ mg/l	_ _ _ _ . _ mg/l

Additional comments on development:

Well developed by: Person's Name and Firm

Name: ______________________

Firm: ______________________

I hereby certify that the above information is true and correct to the best of my knowledge.

Signature: ______________________

Firm: ______________________

NOTE: Shaded areas are for DNR use only. See instructions for more information.

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WELL DEVELOPMENT/PURGE SUMMARY

FIGURE

Well ____________

PROJECT: ____________
PROJECT #: ____________
LOCATION: ____________
PERSONNEL: ____________

WELL COORDINATES: ____________
PVC RISER ELEVATION: ____________
GROUND LEVEL ELEVATION: ____________
CONSTRUCTED WELL DEPTH: ____________
WELL CASING INSIDE DIAMETER: ____________

INSTRUMENTS
TEMPERATURE: ____________
CONDUCTIVITY: ____________
pH METER: ____________
WATER LEVEL PROBE: ____________
OTHER: ____________

Date	Time	Method	Water Level* (ft.msl)	Measured Well Depth* (ft.msl)	Volume Purged** (gallons)	Appearance	pH (s.u.)	T (C)	Elec. Cond. (umhos/cm)		Comments
						Color / Odor / Clarity			Measured	at 25C	

* Record both initial and final measurements when using as Well Development Summary.
** Purge four borehole volumes, if possible, prior to sampling.

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GROUND WATER MONITORING
WELL INFORMATION FORM

FIGURE

State of Wisconsin
Department of Natural Resources

GROUNDWATER MONITORING WELL INFORMATION FORM
Chapter 144, Wis. Stats.
Form 4400-89

2-84

Facility Name

Facility ID Number

Date

Completed By (Name and Firm)

Well Name	Well ID Number (DNR No.)	Well Location	N	S	E	W	Date Established	Well Casing Diam.	Well Casing Type	Elevations Top of Well Casing	Elevations Ground Surface	Elevations Screen Top	Reference MSL (✓)	Reference Site Datum (✓)	Screen Length	Screen Material	Well Depth	Type of Well (✓) PIEZ	OW	PW	LYS	Other

Location Coordinates Are:

☐ Grid System
State Plane Coordinate
☐ Northern
☐ Central

Received In:

District: ____________ Area: ____________ Bureau: ____________

By: ____________

SMS Use:

File Maint. Completed: ____________
Date

Other: ____________

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FIELD PID DATA FORM

Site: ____________

Project No: ____________

FIELD PID DATA FORM

Date: ____________

Personnel: ____________

Meter No: ____________

Probe eV: ____________

Sample Number	Sample Media(1)	Location/ Depth	Moisture (2)	Time Sample Collected	Time Sample Analyzed	Volatilization Period Air Temp (C)	PID Readings (ppm)		Comments
							Background	Peak Response	

(1)
SO - Soil
SD - Sediment
GW - Ground water
SW - Surface water
WS - Waste (Solid)
WL - Waste (Liquid)

(2)
D - Dry
M - Moist
W - Wet

FIGURE B.2.1

Instrument Number ____________________

Date	User	Calibration Gas (Cannister Pressure)	Probe eV	Span	Reading (ppm)

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HNu CALIBRATION LOG

FIGURE B.2.2

WELL ____________

PROJECT ____________
LOCATION ____________
PERSONNEL ____________

WELL LOCATION ____________
ELEVATION (PVC riser) ____________
GROUND LEVEL ____________

DATE	TIME	MEASURING DEVICE*	DEPTH (ft. below top of riser)	WATER LEVEL		BY	COMMENTS
				Depth (ft. below grade)	Elevation (ft.msl)		

*OWLP : Olympic Water Level Probe
Tape : Steel or Fiberglass Measuring Tape

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WATER LEVEL DATA

FIGURE

INSTRUMENTS

PROJECT: ____________________
PROJECT #: ____________________
LOCATION: ____________________
PERSONNEL: ____________________

TEMPERATURE: ____________________
CONDUCTIVITY: ____________________
pH: ____________________
OTHER: ____________________

GENERAL:	SAMPLE POINT					
	WATER TYPE					
	DATE					
	CLOCK TIME					
WATER ELEVATION						
MEASURED WELL DEPTH						
PURGE VOL/CASING VOL(g)						
DEPTH SAMPLE TAKEN						
SAMPLING DEVICE						
FIELD TEMPERATURE (C)						
ELEC. COND. (umhos/cm)	MEASURED					
	AT 25 C					
pH						
ALKALINITY						
COLOR						
ODOR						
CLARITY						

SAMPLING PARAMETERS		# OF CONTAINERS & CONT. VOLUME; CONTAINER TYPE (A=AMBER GLASS; G=GLASS; P=PLASTIC); PRESERVATIVE TYPE - (L=LAB ADDED; F=FIELD ADDED) OR NEUTRAL; FILTERED (YES OR NO)				
LABORATORY:	SENT TO: DATE SENT:					
AMPLED BY:						

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FIELD WATER QUALITY
SAMPLING AND ANALYSIS

FIGURE

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CHAIN OF CUSTODY RECORD

FIGURE

CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME

SAMPLERS:

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CON-TAINERS							SAMPLE DESCRIPTION

Relinquished By:	Date / Time	Received By:	Relinquished By:	Date / Time	Received By:
Relinquished By:	Date / Time	Received By:	Relinquished By:	Date / Time	Received By:

Remarks:

Report To:

Project No.:	Lab No.
Project Name:	
Sample No.	

Date/Time: __/__/__ ___:___ a.m. p.m.

Grab ☐ Composite ☐

Preservation: Neutral ☐; HNO_3 pH < 2 ☐

H_2SO_4 pH < 2 ☐; NaOH pH > 12 ☐; Other ☐

____

SAMPLE LABEL

APPENDIX B

WDNR NR141, GROUND-WATER MONITORING WELL REQUIREMENTS

Chapter NR 141

GROUNDWATER MONITORING WELL REQUIREMENTS

NR 141.01 Purpose. The purpose of this chapter is to establish minimum acceptable standards for the design, installation, construction, abandonment and documentation of groundwater monitoring wells. These rules are adopted under chs. 144, 160 and 227, Stats.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.03 Applicability. This chapter applies to all persons installing groundwater monitoring wells for purposes regulated by the department under ch. 144, 147 or 160, Stats., or in permits, plan approvals, licenses or orders issued under those chapters. In addition, this chapter applies to all persons installing groundwater monitoring wells in fulfillment of terms of a contract with the department.

Note: Additional requirements concerning soil testing and groundwater sampling are located in other chapters regulating wastewater and solid and hazardous waste disposal, see chs. NR 110, 181, 206, 213, 214, 508, 512 and 550.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.05 Definitions. In this chapter:

(1) "Air rotary drilling" means a drilling method whereby the borehole is advanced using a circular rotating action applied to a string of drilling rods which have a diffused discharge bit attached to the bottom of the rods. Pressurized air is forced through the drilling rods and cools the drilling tools and removes the cuttings from the borehole.

(2) "Annular space seal" means the following:

(a) For wells constructed with filter packs, it is the material placed above the top of the filter pack or the filter pack seal up to the surface seal and between the well casing and the adjacent formation; or

(b) For wells constructed into bedrock formations and without well screens, it is the material placed from the bottom of the enlarged borehole up to the surface seal, between the well casing and the adjacent formation.

(3) "ASTM" means american society for testing and materials.

(5) "Bedrock" means the solid rock underlying any loose surficial material such as soil, alluvium or glacial drift. Bedrock includes but is not limited to limestone, dolomite, sandstone, shale and igneous and metamorphic rock.

(6) "Bentonite" means a clay consisting of at least 85% sodium montmorillonite. Bentonite is available in the following forms:

(a) "Bentonite powder" means 200 mesh pure bentonite, without additives.

(b) "Bentonite granules" means 8 mesh pure bentonite, without additives.

(c) "Bentonite pellets" means commercially manufactured tablets made by compressing pure bentonite, without additives, into forms greater than ¼" in size.

(d) "Bentonite chips" means commercially processed angular fragments of pure bentonite, without additives.

(7) "Bentonite - cement grout" means a mixture with the ratio of 5 pounds of bentonite with 94 pounds of Portland cement and 5 to 6 gallons of water from a known safe and uncontaminated source.

(8) "Bentonite - sand slurry" means a mixture with the ratio of 55 pounds of bentonite with 100 gallons of water from a known safe and uncontaminated source and 10-25% sand by volume for a mud weight of 12 pounds per gallon.

(9) "Borehole" means a circular hole deeper than it is wide, constructed in earth material for the purpose of either installing a well or obtaining geologic or groundwater related data. Boreholes are also referred to as drillholes.

(10) "Clay" means an inorganic soil with low permeability characteristics and a plasticity index of 7 or more.

(11) "Coarse sand" means a well sorted sand with a predominant grain size between 4.76mm and 2.0mm as established by the unified soil classification system.

(12) "Concrete" means a slurry mixture with a ratio of 94 pounds of cement, equal volumes of dry sand and gravel and 5 to 6 gallons of water from a known safe and uncontaminated source. The ratio of sand and gravel to cement may not exceed 3 parts to one.

(13) "Department" means the department of natural resources.

(14) "Driven point well" means a well constructed by joining a drive point with lengths of pipe and driving the assembly into the ground with percussion equipment or by hand, without first removing material below the 10 foot depth.

(15) "Filter pack" means the sand, gravel or both placed in direct contact with the well screen.

(16) "Filter pack seal" means the sealing material placed in the annular space above the filter pack and below the annular space seal to prevent the migration of annular space sealant into the filter pack.

(17) "Fine sand" means a well sorted sand with a predominant grain size between .42mm and .074mm, as established by the unified soil classification system.

(18) "Granular bentonite slurry" means a mixture of 30 pounds of untreated bentonite powder added to 100 gallons of water from a known safe and uncontaminated source with 125 pounds of untreated bentonite granules mixed together with a Venturi-hopper mud mixer.

(19) "Gravel" means an unconsolidated material with the predominant grain size being between 76.2mm and 4.76mm, as established by the unified soil classification system.

(20) "Groundwater" means any waters of the state, as defined in s. 144.01 (19), Stats., occurring in a saturated geologic formaton of rock or unconsolidated material.

(21) "Groundwater monitoring well" means any cased excavation or opening into the ground made by digging, boring, drilling, driving, jetting or other methods for the purpose of determining the physical, chemical, biological or radiological properties of groundwater. Groundwater monitoring wells may be piezometers, water table observation wells or both.

(22) "Hollow stem auger drilling" means a drilling method where continuous flighting is welded to a hollow stem pipe. The flighting carries drill cuttings to the surface as the flighting is rotated and pushed down into the earth.

(23) "Inside diameter" means the horizontal distance between the inner walls of a well casing, hollow stem auger or tremie pipe.

(24) "Medium sand" means a well sorted sand with a predominant grain size between 2.0mm and .42mm, as established by the unified soil classification system.

(25) "Montmorillonite" means a group of expanding lattice clay minerals of the general formula: $R_{.33}Al_2Si_4O_{10}(OH)_2 \cdot H_2O$, where R means one or more cations of sodium, potassium, magnesium or calcium and where Al means aluminum, Si means silicon, O means oxygen and H means hydrogen.

(26) "Mud rotary drilling" means a drilling method whereby a borehole is advanced by using a circular rotating action applied to a string of drilling rods which have a diffused discharge bit attached to the bottom of the string. A bentonite and water mud slurry is used to provide borehole stability, to cool the bit and to carry cuttings to the ground surface.

(27) "Neat cement grout" means a slurry mixture with a ration of 94 pounds of Portland cement mixed with 5 to 6 gallons of water from a known safe and uncontaminated source.

(28) "Percussion drilling" means a drilling method using a cable tool drilling machine or a drilling method whereby the permanent or temporary well casing is driven, or is set into a borehole and then driven.

(29) "Permanent groundwater monitoring well" means any groundwater monitoring well in place for 60 days or longer.

(30) "Piezometer" means a groundwater monitoring well, sealed below the water table, installed for the specific purpose of determining either the elevation of the potentiometric surface or the physical, chemical, biological or radiological properties of groundwater at some point within the saturated zone or both.

(31) "Potentiometric surface" or "piezometric surface" means an imaginary surface representing the total head of groundwater and is the level to which water will rise in a well.

(32) "Psi" means pounds per square inch.

(33) "Purge" means an action that removes water from the well, commonly accomplished by using a pump or bailer.

(34) "Rotary wash drilling" means a drilling method whereby metal temporary casing is advanced into the borehole by driving. At selected intervals, the temporary casing is cleaned out using rotary drilling tools by pumping clean water through the rod to flush out accumulated cuttings. This drilling method is also known as wash bore or wash down drilling.

(35) "Sand-cement grout" means a mixture of cement, sand and water in the proportion of 94 pounds of Portland cement, one cubic foot of dry sand and 5 to 6 gallons of water from a known safe and uncontaminated source.

(36) "Sediment" means any solid material dropping from suspension in water, including clay, silt, sand and gravel sized particles.

(37) "Solid stem auger drilling" means a drilling method where continuous flighting is welded onto a solid stem pipe. The flighting carries drill cuttings to the surface as the flighting is rotated and pushed down into the earth. The borehole is created by a cutting bit located at the tip of the lead auger.

(38) "Specific gravity" means the weight of a particular volume of substance compared to the weight of an equal volume of water at a reference temperature.

(39) "Surge" means an action causing water to move rapidly in and out of the well screen, thereby removing fine material from the surrounding aquifer.

(40) "Temporary groundwater monitoring well" means any groundwater monitoring well in place for less than 60 days.

(41) "Top of bedrock" or "top of firm rock" means at least 70% of the drill cuttings being either:

(a) Angular rock fragments, as in the case of crystalline rock; or

(b) Rock fragments composed of individual grains or rock particles that are cemented together to form an aggregate as opposed to a single sediment particle.

(42) "Tremie pipe" means a pipe or hose used to install well construction materials in an annular space or a borehole.

(43) "Unconsolidated material" means that material found above firm bedrock, composed of single sediment particles, individual grains or rock fragments. Unconsolidated material includes but is not limited to clay, silt, sand, gravel, loess, peat and organic soil.

(44) "Unified soil classification system" means the soil designation system based on the physical properties of the soil developed from the airfield classification system in 1952 and adopted by the American society for testing and materials in standard test method D2487-83.

Note: A copy of this publication is available for inspection at the offices of the department of natural resources, the secretary of state and the rivisor of statutes and may be obtained for personal use from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

(45) "Water table" means the surface of unconfined groundwater where the water pressure is equal to atmospheric pressure.

(46) "Water table observation well" means any groundwater monitoring well, in which the screen or open borehole intersects a water table, which is installed for the specific purpose of determining either the elevation of the water table or the physical, chemical, biological or radiological properties of groundwater at the water table or both.

(47) "Well" means any borehole or other excavation or opening in the ground deeper than it is wide constructed for the purpose of obtaining or monitoring groundwater.

(48) "Well depth" means the distance from the ground surface to the bottom of the well screen or to the bottom of the open hole when a well screen is not used.

(49) "Well volume" means the volume of water contained in the well casing and the filter pack.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.055 Borehole protection. If a borehole is left open, protective measures shall be taken to prevent the borehole from acting as a conduit for contamination or becoming a safety hazard.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.06 Soil testing. Specific soil sampling and testing procedures are specified in other chapters related to wastewater and solid and hazardous waste disposal facilities.

Note: See chs. NR 110, 181, 206, 214, 508, 512 and 550, Wis. Adm. Code.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.065 Well location. (1) Monitoring wells installed where prior department approval is required shall be installed at the locations indicated on plans and specifications approved by the department prior to installation.

(2) Following installation of the wells, an as-built plan map shall be submitted specifying the exact vertical and horizontal location of the wells. All monitoring well locations shall be reported to the department on a plan map drawn to a specific scale. The map shall indicate structure boundaries, property boundaries, any nearby surface waters and a north arrow. The plan shall show the wells in relation to each other, to property and structure boundaries, and to a common reference point on a horizontal grid system. The origin of the grid system shall be located according to latitude or longitude or according to the state plane coordinate system. The exact vertical location of the top of the well casing shall be referenced to the nearest benchmark for the national geodetic survey datum to an accuracy of 0.01 feet. This plan map shall show the exact location of the installed well on a horizontal grid system which is accurate to

within one foot. Direction of groundwater flow shall be indicated. In addition, an 8.5-inch by 11-inch site map drawn to scale according to the horizontal grid system shall be submitted showing the location of wells and structures on the site.

(3) The well casings for wells constructed in a floodplain or floodway shall terminate a minimum of 2 feet above the regional flood elevation for the well site.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.07 Well casing. (1) SPECIFICATIONS. All permanent groundwater monitoring wells shall be constructed of new polyvinyl chloride (PVC) well casing materials except in situations where the rock, soil or groundwater may react with PVC, in which case an approval under s. NR 141.31 for alternative materials shall be requested. All PVC casing materials shall meet national sanitation foundation standard 14 and ASTM D1785 specifications for any one of the following cell classifications: 12454-B, 12454-C, 11443-B, 14333-D, 13233 or 15223-B. All casing shall have a minimum inside diameter of 1.9 inches. In unconsolidated geologic formations, all wells less than or equal to 100 feet in depth shall be constructed of at least schedule 40 PVC casing and all wells greater than 100 feet in depth shall be constructed of at least schedule 80 PVC casing. All groundwater monitoring wells that penetrate greater than 2 feet past the top of the bedrock shall be constructed of at least schedule 80 PVC. Groundwater monitoring wells shall be installed with well casing no larger than a 4-inch inside diameter.

(2) REFERENCE. The listed national sanitation foundation and ASTM references are available for inspection at the offices of the department of natural resources, the secretary of state and the revisor of statutes and may be obtained for personal use from the National Sanitation Foundation, 3475 Plymouth Road, P.O. Box 1468, Ann Arbor, Michigan 48106, and the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

(3) ASSEMBLY AND INSTALLATION. All casing couplings shall be constructed of flush threaded joints. Solvent welded joints may not be used without prior written approval by the department. The casing shall be centered in the borehole.

(4) INSPECTION. Prior to use, the casings and couplings shall be inspected for cuts, deformations, gouges, deep scratches, damaged ends and other imperfections. Any casing or coupling having such a defect may not be used.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

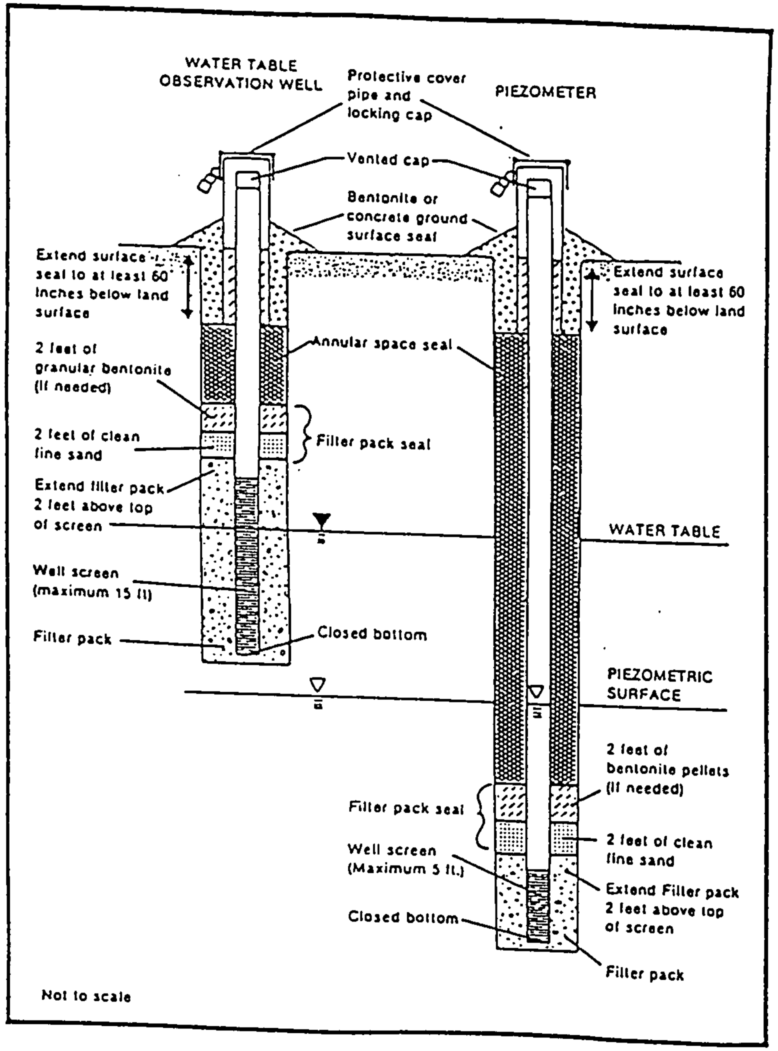
NR 141.09 Well Screen. (1) SPECIFICATIONS. All permanent groundwater monitoring well screens shall be constructed of material which is nonreactive with the constituents in soils and groundwater at the monitoring location. The well screen may not be hand cut and may not be wrapped with filter cloth. The well screen slot size shall be sized to retain at least 50% of the grain size of the collapsed formation, based on a field sieve analysis, when collapsed formation is used as filter pack material or at least 90% of the grain size of the filter pack, based on a sieve analysis, if material other than collapsed formation is used. Well screens on water table observation wells may not exceed 15 feet in length. Well screens on piezometers installed for the purpose of determining the elevation of the potentiometric surface may not exceed 5 feet in length.

Note: Well screens for wells other than the water table observation wells and piezometers identified above may vary in length.

(2) ASSEMBLY AND INSTALLATION. All well screens shall be permanently joined to the well casing by flush threaded joints. All joints shall be watertight. All well screens shall be centered in the borehole. Monitoring wells installed in bedrock using an open borehole may be constructed without a well screen.

Figure 1:

Typical water table observation well and piezometer construction details.



History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.10 Tremie pipes and sealing procedures. (1) MATERIALS. The tremie pipe used for the placement of sealant materials shall be one of the following materials:

(a) Metal pipe,

(b) Rubber-covered hose reinforced with braided fiber or steel and rated for at least 300 psi, or

(c) Thermoplastic pipe rated for at least 100 psi including:

1. Polyvinyl chloride (PVC)

2. Chlorinated polyvinyl chloride (CPVC),

3. Polyethylene (PE),

4. Polybutylene (PB), and

5. Acrylonitrite butadiene styrene (ABS).

(2) PROCEDURES. This subsection describes department approved sealant placement methods when a tremie pipe is used.

(a) The estimated and actual volume of sealing material used shall be calculated and reported to the department.

(b) The sealant material shall be placed in one continuous operation in such a manner as to not disturb the integrity of the filter pack and seal.

(c) When a tremie pipe is used, the bottom end shall be kept submerged in the sealant material throughout the sealing process.

(d) The sealant material shall be brought up to the ground surface. The density of the sealant material flowing from the annular space or borehole at the ground surface shall be the same as the density of the sealant material being placed. Any settling of the sealant material shall be topped off.

(e) Tremie pipe - gravity. As depicted in Figure 2, sealing material may flow by gravity through a funnel or hopper connected to a tremie pipe. The tremie pipe shall be lowered to the bottom of the annular space or borehole to be sealed and the sealing material placed from the bottom up. The end of the tremie pipe shall be kept submerged in the grout or slurry at all times.

(f) Tremie pipe - pumped. As depicted in Figure 3, the sealing material shall be placed by a pump through a tremie pipe into the annular space or borehole.

Figure 2.

Conductor (tremie) pipe — gravity method

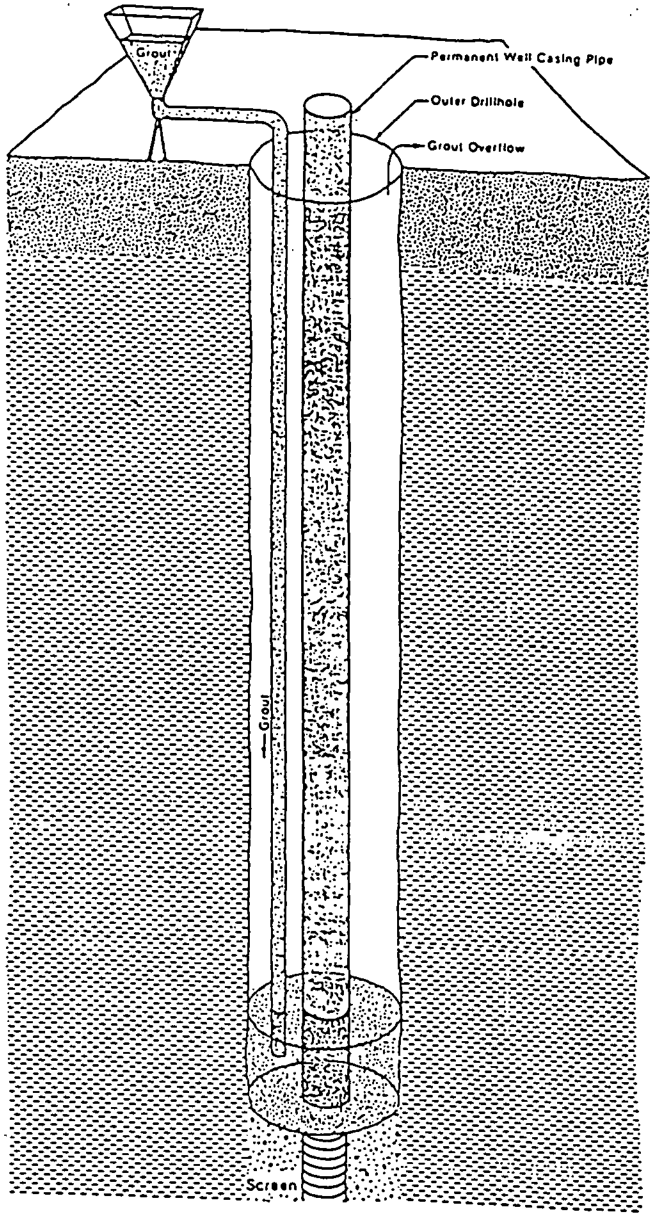
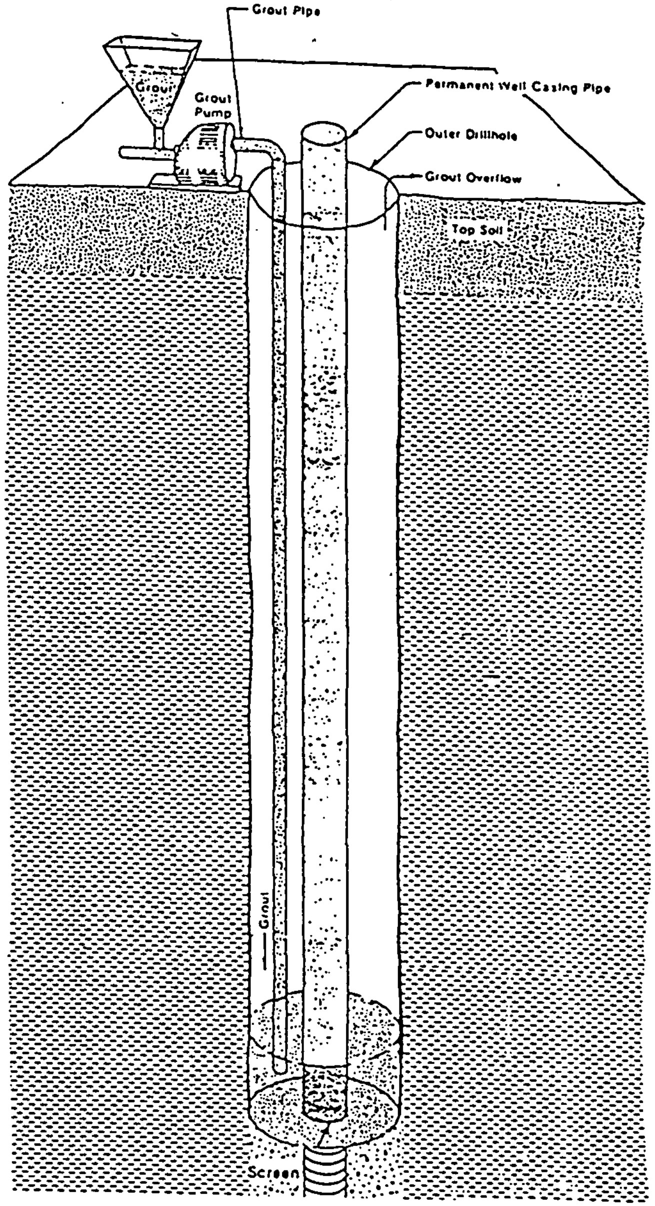


Figure 3.

Conductor (tremie) pipe — pumped method



History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.11 Filter packs. All permanent groundwater monitoring wells installed in unconsolidated material and used for the collection of water quality samples shall be constructed with filter packs. Permanent groundwater monitoring wells installed in bedrock may be constructed with filter packs. When used, the filter pack shall be the only material in contact with the well screen. The estimated and actual volume of filter pack material used shall be calculated and reported to the department. All commercially prepared filter packs installed in permanent groundwater monitoring wells shall meet the requirements in sub. (1). All other filter packs shall meet the requirements in sub. (3).

(1) SPECIFICATIONS. The filter pack shall be a well sorted, silica based sand or gravel. The sand or gravel used for filter packs shall be hard and durable and shall have an average specific gravity of not less than 2.50. The sand and gravel shall be visibly free of clay, dust and micaceous and organic matter. Not more than 5% of the sand or gravel shall be soluble in a 10% hydrochloric acid solution. Thin, flat or elongated pieces of gravel, the maximum dimension of which exceeds 3 times the minimum dimension, may not constitute more than 2% of the material by weight. The filter pack for wells installed in unconsolidated material shall be sized to retain at least 50% of the surrounding formation based on a sieve analysis. In bedrock, the filter pack shall be a medium or coarse sand or gravel. Crushed limestone, dolomite or any material containing clay or any other material that will adversely impact on the performance of the monitoring well may not be used as filter pack.

(2) INSTALLATION. The filter pack shall extend from 6 inches beneath the well point to 2 feet above the top of the well screen. For water table observation wells constructed in areas where the depth to water table is less than 5 feet, the required filter pack height above the top of the well screen may be reduced to 6 inches to allow for the required amount of annular space sealant to be placed. To ensure that the filter pack is installed evenly surrounding the well screen and casing over the proper depth interval, a tape measure, measurng rod or similar device shall be used to measure the height of the filter pack. The tape measure, measuring rod or similar device shall be carefully raised and lowered while the filter pack is being installed to identify bridging. If bridging occurs the filter pack material shall be tamped into place, surrounding the well screen and casing, using a measuring rod or similar device.

(3) COLLAPSED FORMATION. Collapsed formation may be used as filter pack material if the physical and chemical properties of the formation are consistent with the filter pack specifications stated in sub. (1) and if the collapsed formation will limit the passage of formation fines into the well screen. The grain size distribution of the collapsed formation shall be such that at least 50% of the formation will be retained by the well screen based on a field sieve analysis. If used as filter pack, the collapsed formation shall be visibly free of clay, dust and micaceous and organic matter. Analysis of the collapsed formation for specific gravity and particle size shall be performed during well construction and shall be submitted to the department to support its use as an acceptable filter pack. Following review of the submitted information, the department may require new well construction if the collapsed formation analysis is not consistent with the filter pack specifications in sub. (1) and this subsection.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.13 Sealing requirements. All materials and procedures used in the installation of seals for permanent groundwater monitoring wells shall meet the requirements of this section. The calculated and actual volume of sealant material used for the filter pack seal and annular space seal shall be reported to the department.

(1) FILTER PACK SEAL. (a) *Specifications.* All permanent groundwater monitoring wells installed with filter packs shall be constructed with a filter pack seal. For all water table observation wells and piezometers, the filter pack seal shall extend 2 feet upward from the top of the filter pack and shall consist of 2 feet of clean fine sand. When bentonite-cement grout or neat cement grout is used as the annular space sealant, 2 feet of bentonite shall be placed on top of the clean fine sand seal. Bentonite pellets shall be used for seals placed below the water table. Granular bentonite shall be used for seals placed above the water table.

(b) *Installation.* A tape measure, measuring rod or similar device shall be used to ensure that the filter pack seal is installed over the proper depth interval. The tape measure, measuring rod or similar device shall be carefully raised and lowered while the filter pack seal material is being placed to indentify bridging. If bridging occurs the filter pack seal material shall be tamped into place, surrounding the well casing, using a measuring rod or similar device. When a tremie pipe is used to place the filter pack seal the procedures of s. NR 141.10 (2) shall be followed.

(2) ANNULAR SPACE SEAL. (a) *Specifications.* All permanent groundwater monitoring wells shall be installed with an annular space seal designed to achieve a permeability of 1×10^{-7} centimeters per second or less. For permanent groundwater monitoring wells constructed with filter packs, the annular space seal shall extend from the filter pack seal to the ground surface seal and shall be at least 2 feet in length. For monitoring wells constructed into bedrock formations and without well screens, the annular space seal shall extend from the bottom of the outer borehole to the ground surface seal and shall be at least 2 feet in length. Sealant materials may not contain additives.

Note: The department does not recommend the use of neat cement grout or cement mixtures in fractured formations because they may impact water quality.

1. Granular bentonite slurry may be used as an annular space sealant in any type of monitoring well.

2. Bentonite sand slurry may be used as an annular space sealant in any type of monitoring well.

3. Bentonite pellets or granular bentonite may be used to seal the annular space under the following conditions:

a. Granular bentonite may be used when there is no standing water in the well above the filter pack seal and the total well depth is less than 25 feet.

b. Bentonite pellets may be used when the depth of standing water in the well is less than 30 feet and the total depth of the annular space seal is less than 50 feet.

4. If the well is constructed by circulating drilling mud containing no additives, the annular space may be sealed with bentonite slurry and cuttings if the mud weight is at least 12.0 pounds per gallon and the well is not constructed in contaminated material.

5. Neat cement grout may be used as an annular space sealant only if schedule 80 PVC or stainless steel well casing is used.

6. Bentonite-cement grout may be used as an annular space sealant in any type of monitoring well in which a bentonite seal above the filter pack has been installed.

(b) *Installation.* 1. When bentonite pellets or granules are used to seal the annular space, they may either be poured freely down the borehole or added through a tremie pipe, provided the specifications of par. (a) are met. When a tremie pipe, provided the specifications of par. (a) are met. When a tremie pipe is used to place the annular space sealant the procedures of s. NR 141.10 (2) shall be followed.

2. When grouts or slurries are used to seal the annular space, the material may be poured freely down a tremie pipe or pumped down a borehole with the use of a tremie pipe, provided the specifications of par. (a) are met. For wells 100 feet in depth or greater the sealant material shall be pumped down the borehole with the use of a tremie pipe. When a tremie pipe is used to place the annular space sealant the procedures of s. NR 141.10 (2) shall be followed.

3. When any slurry or grout is used, there shall be a 12-hour period between the time the annular space seal is installed and the time the protective cover pipe is installed. Any settling in the annular space seal shall be topped off before the protective cover pipe is installed.

4. The top of the well caasing shall be covered with a protective cap.

(3) GROUND SURFACE SEAL AND PROTECTIVE COVER PIPE. (a) *Ground surface seal.* All permanent groundwater monitoring walls shall be constructed with a bentonite or concrete ground surface seal. The ground surface seal shall extend to a minimum of 60 inches below the land surface, and the top shall be sloped away from the well casing. If bentonite is used, the top of the surface seal shall terminate 12 inches below the land surface and shall be covered with top soil or native soil to prevent drying out. The ground surface seal shall be installed around the protective cover and may not be placed between the protective cover pipe and the well casing. If the monitoring well depth is such that both a minimum 2 foot annular space seal and a minimum 5 foot ground surface seal cannot both be placed, the ground surface seal may be shortened.

Note: Certain soils are prone to frost heave and the department does not recommend use of concrete as a ground surface seal in these situations.

(b) *Protective cover pipe.* The protective cover pipe shall consist of a metal casing at least 2 inches larger in diameter than the well casing with a locking cap. The protective cover shall extend from the bottom of the ground surface seal to a minimum of 24 inches above the ground surface. If the monitoring well is located in a floodplain, the protective cover pipe shall be watertight. There may be no more than 4 inches between the top of the well casing and the top of the protective cover pipe. The protective cover pipe shall always extend above the top of the well casing. The department may require additional protective devices, such as rings of brightly colored posts around the well, as necessary. Weep holes or vents may be used in protective cover pipes.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.15 Drilling methods and fluids. The drilling method shall introduce the least possible amount of foreign material into the borehole, produce the least possible disturbance to the formation and permit the proper construction and development of the required diameter well. Only air, water from a known safe source free of bacterial and chemical contamination or bentonite drilling muds, mixed with water from a known safe and uncontaminated source, may be used as drilling fluids. The water used for drilling shall be stored in such a manner as to prevent contamination of the clean water. The department may require chemical analysis of the water used to produce drilling fluids. Hammer drill lubricants, used with air rotary drill rigs, may not be used for installing groundwater monitoring wells. If air is used as a drilling fluid, the air shall be filtered by a coalescing air filter. If water is used, the source of the water shall be reported. Drilling fluid additives may not be used without prior written department approval.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.17 Disposal and decontamination. (1) All drill cuttings and fluids and surge and wash waters from borehole and groundwater monitoring well construction and development shall be disposed of in a manner approved by the department.

(2) All borehole and groundwater monitoring well construction and development equipment shall be decontaminated by washing and triple rinsing or high pressure heat cleaning to prevent cross-contamination of boreholes or groundwater monitoring wells.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.19 Borehole diameter. (1) BOREHOLES IN UNCONSOLIDATED GEOLOGIC FORMATION. For all permanent groundwater monitoring wells in unconsolidated geologic formations, the borehole diameter shall meet the following requirements:

(a) If hollow stem augers are used, their inside working diameter shall be at least 2¼ inches greater than the inside diameter of the permanent well casing.

(b) If solid stem augers are used, their outside diameter shall be at least 4 inches greater than the inside diameter of the permanent well casing.

(c) If an air or mud rotary method is used, the borehole diameter shall be at least 4 inches greater than the inside diameter of the permanent well casing. If a temporary outer casing is used, the inside diameter of the temporary outer well casing shall be at least 4 inches greater than the inside diameter of the permanent well casing. The temporary outer casing shall be pulled as the annular space is being sealed.

(d) If percussion methods, including the rotary wash, wash down and wash bore methods, with a temporary outer casing are used, in unconsolidated geologic formations, the inside diameter of the temporary outer casing shall be at least 4 inches greater than the inside diameter of the permanent well casing. The temporary outer casing shall be removed during the sealing of the annular space.

(2) BOREHOLES IN BEDROCK GEOLOGIC FORMATIONS. For all permanent groundwater monitoring wells installed deeper than 2 feet past the top of

the bedrock, the borehole diameter shall meet the following requirements:

(a) If an air or mud rotary method is used to construct the monitoring well, the requirements of sub. (1) (c) shall be followed.

(b) If percussion methods are used to construct the monitoring well, the requirements of sub. (1) (d) shall be followed.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.21 Well development. All permanent groundwater monitoring wells shall be developed according to the requirements of section. Wells sealed with grout or slurry shall be developed after a minimum waiting period of 12 hours after installation is completed and before the initial water quality samples are taken. The goal of well development is to produce water free of sediment and all drill cuttings and drilling fluids.

(1) WELLS THAT CANNOT BE PURGED DRY. All permanent groundwater monitoring wells that cannot be purged dry shall be developed by the following procedure:

(a) Alternately surge and purge the well for a minimum of 30 minutes. The surge and purge cycle shall consist of several minutes of surging followed by several minutes of purging to remove the material collecting in the bottom of the well. The surging shall move formation water in and out of the well screen. The surging shall move formation water in and out of the well screen. The surging shall be accomplished by using either a bailer or surge block or by pumping the well sufficiently to cause a drawdown and then allowing the well to recover and repeating the process.

Note: When a surge block is used, care should be taken to avoid drawing the annular space seal material into the filter pack or well screen.

(b) After the final surge and purge cycle is completed, the well shall be pumped or bailed until 10 well volumes of water are removed or until the well produces sediment free water. If sediment free water is not obtained any remaining sediment shall be removed from the bottom of the well. Well volume shall be calculated in the following manner:

$V_1 + V_2$ = well volume

V_1 = volume of water in well casing

$V_1 = \Pi \frac{D}{2}{}_1{}^2 H_1 \text{ ft}^3$

V_2 = volume of water in filter pack

$V_2 = N \Pi H_2\left(\frac{D}{2}{}_3\right)^2 - \left(\frac{D}{2}{}_2\right)^2$

N = porosity of filter pack

D_1 = inside diameter of well casing

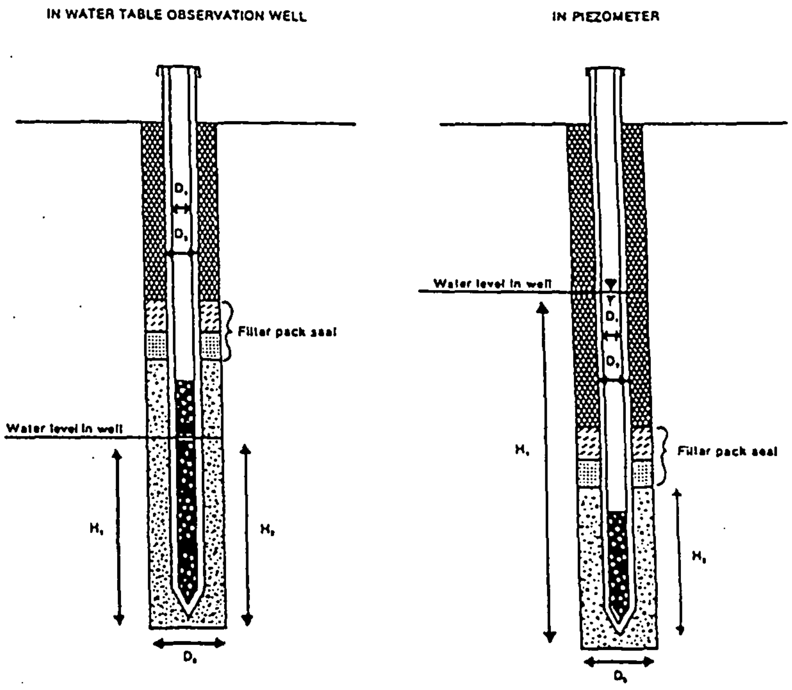
D_2 = outside diameter of well casing

D_3 = diameter of borehole

H_1 = height of water column

H_2 = length of filter pack or the height of the water column in water table observation wells.

CALCULATION OF WELL VOLUME



(2) WELLS THAT CAN BE PURGED DRY. All permanent groundwater monitoring wells that can be purged dry shall be developed in a manner which limits agitation by slowly purging the well dry. Wells which can be purged dry may not be surged and no water may be added to the well. The development procedure is complete when 5 volumes of well water have been removed or when the well produces sediment free water.

History: History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.23 **Well and borehole construction documentation.** (1) All permanent groundwater monitoring well construction shall be reported to the department, using forms and instructions provided by the department, within 60 days after the well has been installed. The completed report shall include the following information:

(a) Well location,

(b) Well casing material and installation procedures,

(c) Well screen materials and installation procedures,

(d) Filter pack materials and installation procedures,

(e) Sealing materials and installation procedures,

(f) Drilling methods and fluids used for installation,

(g) Borehole diameter,

(h) Well development procedures, and

(i) Any other information deemed necessary by the department.

(2) All permanent groundwater monitoring wells installed after February 1, 1990 shall be labeled with labels supplied by the department.

(3) All borehole construction data shall be reported to the department using forms and instructions supplied by the department within 60 days after construction. The completed report shall include the following data: the results of any soil tests done and a description of the soil structure, soil color, mottling, moisture content, layering, jointing, lenses, fractures, organic matter and voids and any other information deemed necessary by the department. The constructor shall report any decontamination procedures used between borehole installations.

History: History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.25 **Abandonment requirements.** The following requirements apply to the abandonment of all boreholes greater than 10 feet deep or which intersect a water table and all groundwater monitoring wells. The department may require, by order or other appropriate means, that any borehole or monitoring well be abandoned. The department shall consider the following factors in determining whether a borehole or monitoring well should be abandoned: purpose, location, groundwater quality, age and condition of the well or borehole potential for groundwater contamination and well or borehole construction.

(1) TIMELINES FOR ABANDONMENT. (a) A borehole shall be abandoned within 3 working days after its use has been discontinued.

(b) Any permanent groundwater monitoring well no longer being used to gather information on geologic or groundwater properties shall be abandoned within 60 days after its use has been discontinued.

(c) Any groundwater monitoring well found by the department to be acting as a conduit for groundwater contamination shall be abandoned within 15 working days after written notification by the department.

(d) Any groundwater monitoring well constructed after February 1, 1990 not meeting the requirements of this chapter shall be abandoned and replaced with a monitoring well meeting the requirements of this chapter or any department approval granted under this chapter within 60 days after installation of the noncomplying well or 15 days after written notification by the department that the well is noncomplying.

(2) ABANDONMENT PROCEDURES. (a) *Boreholes.* Any borehole intersecting the water table or greater than 10 feet deep, whose use has been discontinued, shall be abandoned according to the requirements of par. (d).

(b) *Monitoring wells - impermeable annular space seals.* A permanent groundwater monitoring well known to be constructed with an impermeable annular space seal shall be abandoned according to the requirements of par. (d) after the protective cover pipe and ground surface seal have been removed and the well casing cut off at least 4 feet below the ground surface. The well casing may be completely removed during abandonment by pulling the well casing, overdrilling around the casing and then pulling the well casing out of the ground or by drilling out the well casing completely. If the well casing is to be removed, the well shall be sealed as the casing is removed.

(c) *Monitoring wells - permeable annular space seals and wells in waste areas.* A groundwater monitoring well not known to be constructed with an impermeable annular space seal or located in an existing or planned future waste disposal or treatment area shall be abandoned by removing the protective cover pipe and the ground surface seal and then completely removing the well casing. The well casing shall be pulled out of the ground as the well is filled according to the requirements of par. (d).

(d) *Sealing requirements.* Boreholes and groundwater monitoring wells shall be abandoned by complete filling with neat cement grout, bentonite-cement grout, sand-cement grout, concrete or bentonite-sand slurry. When a tremie pipe is used to place the sealing material, the procedures of s. NR 141.10 (2) shall be followed. A tremie pipe shall be used to abandon groundwater wells and boreholes greater than 30 feet in depth or with standing water. Groundwater monitoring wells and boreholes greater than 100 feet in depth shall be sealed with a tremie pipe-pumped method. Bentonite may be used as a sealing material without the use of a tremie pipe under the following conditions:

1. Granular bentonite may be used for boreholes and groundwater monitoring wells less than 25 feet deep and when there is no standing water above the filter pack seal.

2. Bentonite pellets may be used for boreholes and groundwater monitoring wells less than 50 feet deep and the depth of standing water is less than 30 feet.

3. Bentonite chips may be used for boreholes and groundwater monitoring wells which are greater than 4 inches in diameter and less than 250 feet deep and the depth of standing water is less than 150 feet.

(3) SEALANT SETTLEMENT. Any settling of the sealant material shall be topped off. Sealing material may be terminated 4 feet below the ground surface in agricultural areas to avoid interference with agricultural activities. A native soil plug shall be placed on top of the settled sealing material in such cases.

(4) ABANDONMENT DOCUMENTATION. All borehole and permanent groundwater monitoring well abandonments shall be reported to the department within 60 days of the abandonment on forms supplied by the department. In addition to the information required on the form, the person performing the abandonment shall report any decontamination procedures used between borehole and well abandonments.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.27 Driven point wells. Driven point wells with galvanized steel drive pipes and contaminant compatible well screens may be used as permanent groundwater monitoring wells if prior department approval is obtained. Written documentation shall be supplied to the department prior to installation indicating:

(1) That the well is to be used only for water table elevation measurements or to monitor for parameters for which the well casing and screen material will not interfere with the analytical results;

(2) That the well will not provide a conduit for contaminants to enter the groundwater; and

(3) That information on subsurface stratigraphy is not needed. In situations where subsurface geologic information is needed, a separate borehole shall be constructed to collect the required data.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.29 Temporary groundwater monitoring wells. Temporary groundwater monitoring wells may be installed according to less stringent standards than specified for permanent groundwater monitoring wells. Any temporary monitoring well construction shall be approved by the department prior to its installation. All temporary monitoring wells shall be abandoned in accordance with s. NR 141.25 within 120 days after their installation.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

NR 141.31 Special circumstances and exceptions. (1) The department may require or approve more restrictive or alternative well material, assembly, installation, development or abandonment if the contaminant concentrations or geologic setting require alternative construction. Prior written approval is required before any alternative materials are used in monitoring well installation.

(2) Exceptions to the requirements of this chapter may be approved by the department prior to installation or abandonment. An exception request shall state the reasons why compliance with the rule requirements is infeasible. The department may conditionally approve an exception by requiring materials or procedures which safeguard against contamination and result in groundwater monitoring well construction which is

substantially equivalent to the requirements of this chapter. Failure to comply with the conditions of an exception voids the department's approval of the exception.

History: Cr. Register, January, 1990, No. 409, eff. 2-1-90.

APPENDIX C

FIELD EQUIPMENT OPERATIONS MANUALS

pH METER OPERATIONS MANUAL

Hydro-Search, Inc.

HYDROLOGISTS · GEOLOGISTS · ENGINEERS

CARE AND FEEDING OF THE "MINI" & "DIGITAL"

I. GENERAL RECOMMENDATIONS

THE FOLLOWING RECOMMENDATIONS ARE PROVIDED AS A SUPPLEMENT TO THE CONDENSED OPERATING INSTRUCTIONS MOUNTED IN THE CARRYING CASE.

- *When transferring from one solution to another, thoroughly rinse electrode with water, shaking off any excess water. This simple procedure will prevent "carry-over" contamination between samples.*
- *After immersing electrode in sample or buffer, stir solution slightly to improve electrode response time.*
- *When storing electrode for extended period, put several drops of distilled water in plastic boot and place boot over end of electrode.*
- *Optimum performance is obtained when buffers and samples are at the same temperature.*
- *If calibrate or span adjustments are made per Steps 4, 5, and 6 of the Condensed Operating Instructions (Steps 5, 6 & 7 for analog meter), repeat these steps to check new settings.*

II. TEMPERATURE (SPAN) COMPENSATION

The "TEMP" knob serves the dual function of both temperature compensation and span adjustment.

Since pH electrode output is temperature dependent, the "TEMP" control corrects for changes in electrode output with temperature. Thus as solution temperature changes, the "TEMP" knob must be adjusted accordingly.

The "TEMP" control also provides a means of adjusting the span of the meter to compensate for electrodes having less than the theoretical output voltage. The calibration procedure listed in the Condensed Operating Instructions performs the span adjustment when the "TEMP" knob is set to give a reading of 4.0 in 4.01 pH buffer. Thus, when the calibration is complete, the "TEMP" knob may be set to a temperature other than the actual solution temperature.

In such cases, the observed "temperature setting differential" indicates the amount of span adjustment required for proper calibration. If it becomes necessary to adjust the "TEMP" knob because of changes in solution temperature, maintain the above "temperature differential" for the new temperature setting. Note: For optimum performance, all solutions should be at the same temperature.

III. USE WITH BUFFER SOLUTION OTHER THAN 6.86 AND 4.01 pH

Some applications may require the use of buffer solutions other than 6.86 and 4.01 pH. In these cases, the Condensed Operating Instructions must be amended as follows:

- *Step No. 4 (No. 5 for analog meter) – Immerse electrode in the buffer solution having a pH value nearest to 7 pH. Turn "CALIBRATE" knob so meter reads correct pH value.*
- *Step No. 6 (No. 7 for analog meter) – Immerse electrode in second buffer solution and turn "TEMP" knob (span adjust) so meter reads correct pH value of buffer solution.*

IV. MEASUREMENT OF DEIONIZED WATER

The measurement of deionized water or other poorly buffered solutions requires additional care to insure satisfactory readings. Solutions of this nature are prone to contamination by "carry-over" from the previous sample. *Thoroughly rinse* electrode with water and blot dry between each successive sample or buffer.

Solutions having low specific conductivity (e.g. high purity water) may present the additional measurement problem of apparent drift or instability. Although these effects can be minimized by stirring the sample during measurement, there are some applications where a refillable combination electrode with a flowing reference is preferred.

V. TROUBLESHOOTING COMMON pH PROBLEMS

Most apparent instrument malfunctions are not associated with the electronic circuitry and can be traced to one or more of the following: weak batteries, contaminated buffers, improper measurement technique or inoperative electrode. If the pH meter fails to operate properly, the following checks should be made prior to returning the unit for repair:

- *Replace batteries.*
- *Check meter using fresh buffer solutions.*
- *Check measurement procedure per Condensed Operating Instructions.*
- *Whenever possible, substitute a known good electrode.*

The following symptoms and proper corrective action will aid in locating the source of the problem.

A. SLUGGISH RESPONSE – Clean electrode tip with a mild detergent solution to remove any dirt or oily films on the membrane and rinse thoroughly. If condition persists, replace electrode.

B. EXCESSIVE DRIFT – Clean electrode per "A" above. If condition persists, replace electrode.

C. INSUFFICIENT SPAN – Clean electrode per "A"

TES:

above. Check electrode using fresh buffer solutions. If condition persists, replace probe.

D. **NO CHANGE IN READING FROM ONE BUFFER TO ANOTHER** – Replace electrode.

E. **UNSTABLE DIGITAL READINGS** – Due to the nature of digital circuitry, a change of one least significant digit (0.1 pH unit) may occur during normal operation. Since this one digit "toggle" occurs when the input signal is midway between two values, many users find it convenient to record such a reading with a "5" in the next decimal position. For example, a reading which toggles between 6.8 and 6.9 is recorded as 6.85.

NOTE: Repeated toggle action of more than ±0.1 pH unit is an indication that the batteries are nearing the end of their useful life and should be replaced with fresh ALKALINE batteries.

VI. BATTERY REPLACEMENT

A. Digital Mini-pH-Meter

When batteries require replacement, remove two screws in back of case and replace with 9 volt ALKALINE transistor radio batteries (Mallory MN1604 Duracell or equivalent).

NOTE: Use *ONLY ALKALINE BATTERIES* – substitution of other battery types may cause meter instability.

B. Analog Mini-pH-Meter

When batteries require replacement, remove two screws in back of case and replace with 9 volt transistor radio batteries (NEDA 1604).

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CARE AND FEEDING OF THE "MINI" & "DIGITAL"

SPECIFIC CONDUCTANCE METER OPERATIONS MANUAL

ITEM 021470 P/N A03309L APRIL 1983

INSTRUCTIONS FOR YSI MODEL 33 AND 33M S-C-T METERS

Scientific Division
Yellow Springs Instrument Co., Inc.
Yellow Springs, Ohio 45387 • Phone 513-767-7241

PRICE INCLUDING HANDLING $5.00

TABLE OF CONTENTS

GENERAL DESCRIPTION

The YSI Model 33 and 33M S-C-T Meters are portable, battery powered, transistorized instruments designed to accurately measure salinity, conductivity and temperature. They use a probe consisting of a rugged, plastic conductivity cell and a precision YSI thermistor temperature sensor combined in a single unit.

Conductivity with the Model 33 is expressed as micromhos/centimeter (µmhos/cm); with the 33M, it's millisiemens/meter (mS/m). These are measurements of the electrical conductance the sample would show if measured between opposite faces of a 1cm cube. (Conversion information: 1 µmho/cm = 0.1 mS/m.) Salinity is the number of grams of salt/kilogram of sample (‰ = parts per thousand). This measurement assumes the sample contains a "standard" sea water salt mixture. The sample temperature is measured in degrees Celsius.

Salinity measurements are manually temperature compensated by direct dial. Conductivity measurements are not temperature compensated; however, a temperature function is provided on the instrument to aid with calculation of corrections. Also, when just temperature and conductivity are known it is possible to calculate salinity, and when only temperature and salinity are known it is possible to calculate conductivity.

SPECIFICATIONS

Model 33 Conductivity

Ranges:	0-500, 0-5,000, 0-50,000 µmhos/cm with YSI 3300 Series Probes. (Note: The "µmho" designations on the meter are a shorthand form for "µmho/cm".)
Accuracy:	±2.5% max. error at 500, 5,000 and 50,000 plus probe. ±3.0% max. error at 250, 2,500 and 25,000 plus probe. See Error Section.
Readability:	2.5 µmhos/cm on 500 µmho/cm range. 25 µmhos/cm on 5,000 µmho/cm range. 250 µmhos/cm on 50,000 µmho/cm range.
Temperature Compensation:	None

Model 33M Conductivity

Ranges:	0-50, 0-500, 0-5,000 mS/m with YSI 3300 Series Probes.
Accuracy:	±2.5% max. error at 50, 500, and 5,000 plus probe. ±3.0% max. error at 25, 250, and 2,500 plus probe. See Error Section.
Readability:	0.25 mS/m on 50 mS/m range. 2.5 mS/m on 500 mS/m range. 25.0 mS/m on 5,000 mS/m range.
Temperature Compensation:	None.

Salinity

Range:	0-40 ‰ in temperature range of -2 to +45°C.
Accuracy:	Above 4°C, ±0.9 ‰ at 40 ‰ and ±0.7 ‰ at 20 ‰ plus conductivity probe. Below 4°C, ±1.1 ‰ at 40 ‰ and ±0.9 ‰ at 20 ‰ plus conductivity probe. See Error Section.
Readability:	0.2 ‰ on 0-40 ‰ range.
Temperature Compensation:	Manual by direct dial from -2 to +45°C.

Temperature	
Range:	-2 to +50°C.
Accuracy:	±0.1°C at -2°C, ±0.6°C at 45°C plus probe. See Error Section.
Readability:	±0.15°C at -2°C to ±0.37°C at 45°C.
Power Supply	Two D-size alkaline batteries, Eveready E95 or equivalent, provide approximately 200 hrs. of operation.
Probe	YSI 3300 Series Conductivity/Temperature Probe. Nominal Probe Constant: K=5/cm
Accuracy:	±2% of reading for conductivity and salinity. Error of ±0.1°C at 0°C and ±0.3°C at 40°C.
Instrument	
Ambient Range:	Satisfactory operation -5 to +45°C. A maximum error of ±0.1% of the reading per °C change in instrument temperature can occur. This error is negligible if the instrument is readjusted to redline for each reading.

OPERATION PROCEDURE

1. **Setup**
   - (a) Adjust meter zero (if necessary) by turning the bakelite screw on the meter face so that the meter needle coincides with the zero on the conductivity scale.
   - (b) Calibrate the meter by turning the MODE control to REDLINE and adjusting the REDLINE control so the meter needle lines up with the redline on the meter face. If this cannot be accomplished, replace the batteries.

   - (c) Plug the probe into the probe jack on the side of the instrument.
   - (d) Put the probe in the solution to be measured. (See Probe Use.)
2. **Temperature**

   Set the MODE control to TEMPERATURE. Read the temperature on the bottom scale of the meter in degrees Celsius. Allow time for the probe temperature to come to equilibrium with that of the water before reading.
3. **Salinity**
   - (a) Transfer the temperature reading from Step 2 to the °C scale on the instrument.
   - (b) Switch the MODE control to the SALINITY position and read salinity on the red 0-40 ‰ meter range.
   - (c) Depress the CELL TEST button. The meter reading should fall less than 2%; if greater, the probe is fouled and the measurement is in error. Clean the probe and re-measure.
4. **Conductivity on Model 33 (Model 33M data are in parentheses.)**
   - (a) Switch the MODE control to the X100 scale. If the reading is below 50 on the 0-500 range (5.0 on the 0-50 range), switch to the X10 scale. If the reading is still below 50 (5.0), switch to the X1 scale. Read the meter scale and multiply the reading appropriately. The answer is expressed in μmhos/cm (mS/m). Measurements are not temperature compensated.

Example:	Meter Reading:	247 (24.7)
	Scale:	X10
	Answer:	2470 μmhos/cm (247.0 mS/m)

(b) When measuring on the X100 and X10 scales, depress the CELL TEST button. The meter reading should fall less than 2%; if greater, the probe is fouled and the measurement is in error. Clean the probe and re-measure.

NOTE: The CELL TEST does not function on the X1 scale.

5. Error

The maximum error in a reading can be calculated by using the graphs in the following sections.

(1) Temperature

The temperature scale is designed to give the minimum salinity error when the temperature readings are used to compensate salinity measurements.

Figure 1 shows total error for probe and instrument versus °C meter reading.

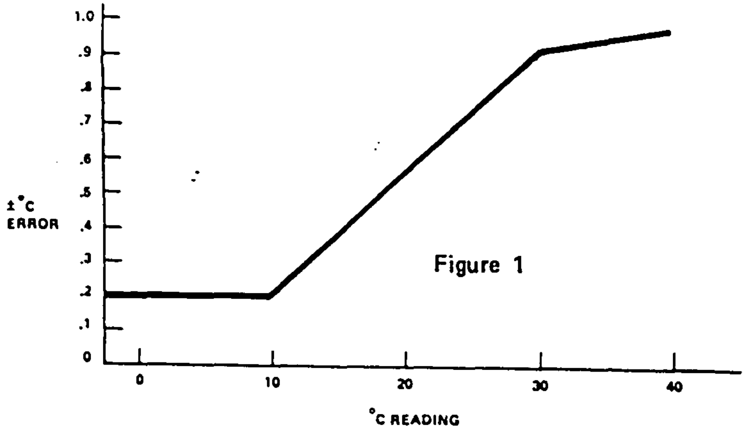


Figure 1

Example:	Meter Reading:	15°C
	Total Error:	0.4°C
	Accuracy:	15°C ± 0.4°C for probe and instrument combined

(2) Conductivity on Model 33 (Model 33M data are in parentheses.)

Figure 2 shows the worst-case conductivity error as a function of the conductivity reading for the probe and instrument combined.

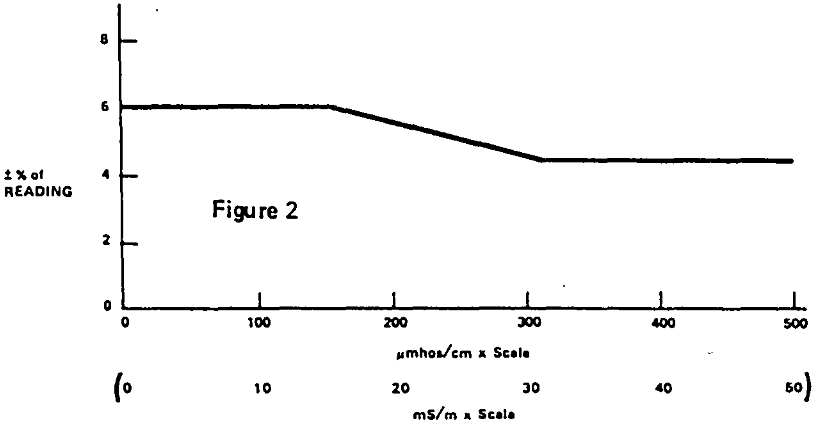


Figure 2

Example:	Meter Reading:	360 µmhos/cm (36 mS/m)
	Scale:	X10
	% Reading Error:	± 4.5%
	Accuracy:	3600 ±162 µmhos/cm (360 ±16.2 mS/m) for probe and instrument

(3) S[illegible]ity

The salinity readings are a function of temperature and conductivity, therefore the accuracy is a function of both.

The temperature scale and temperature control have been designed to minimize the temperature error contribution to the salinity error. The error shown in Figure 3 is the total of the temperature and conductivity probe, the temperature scale and the salinity scale error.

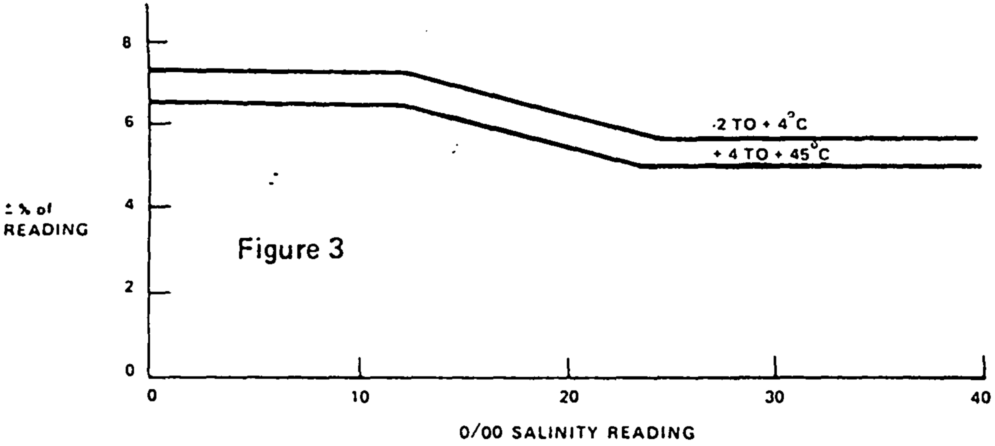
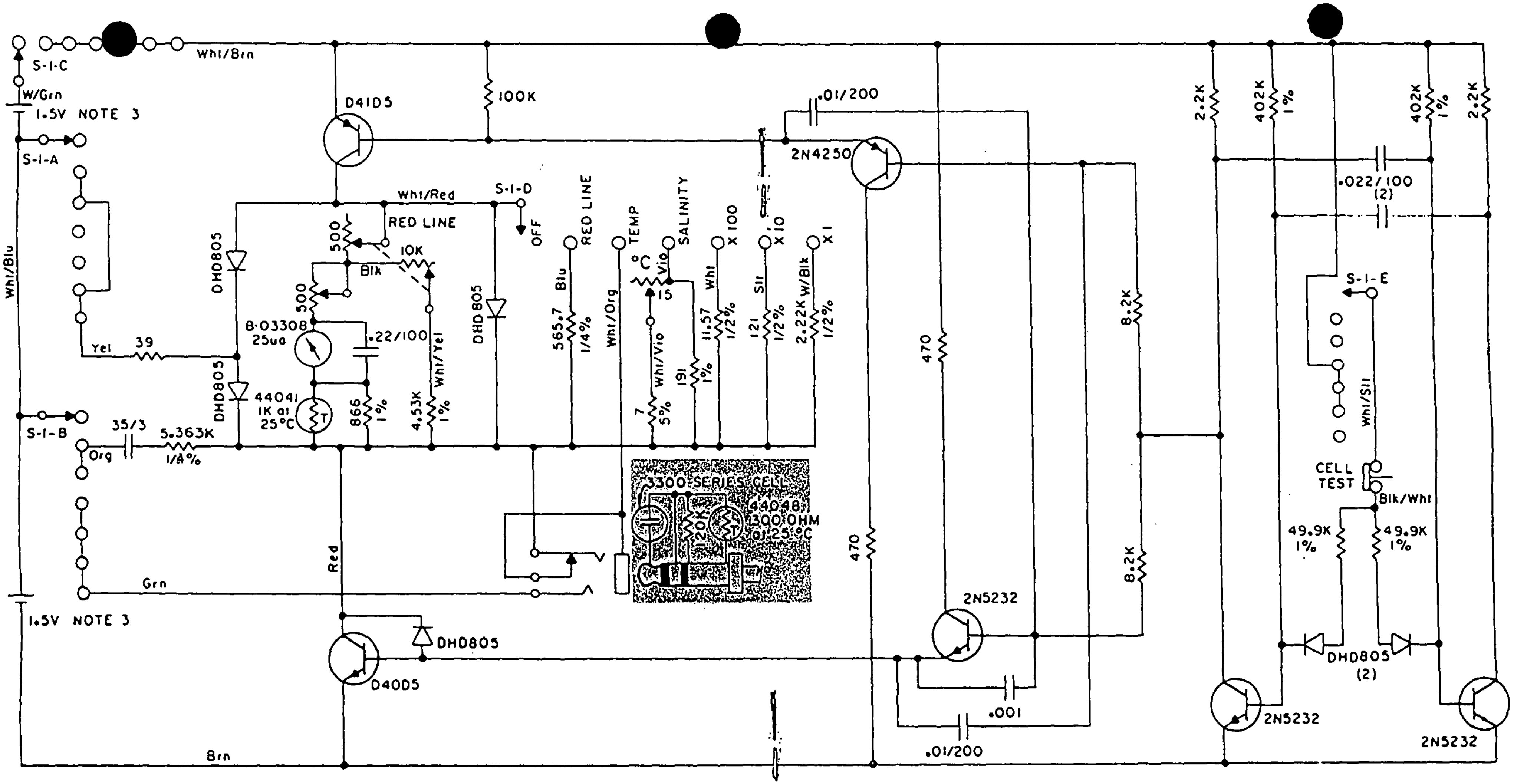


Figure 3

Example:	Meter Reading:	10 0/00. @ 10°C
	% of Reading Error:	6.5%
	Accuracy:	10 ‰ ± 0.65 ‰ for all errors, combined worst case.



YSI MODEL 33 AND 33M B-03321-E

NOTE:

1. Resistance values in ohms, K=1,000; resistors are ½W, 10% unless otherwise specified.
2. The values shown on the schematic may differ from those in the instrument; if so, either value can be used for replacement purposes.
3. Battery is "D" size, alkaline only, Eveready E-95 or equal.

This schematic is representative only, and may be slightly different from the circuit in your instrument.

CIRCUIT DESCRIPTION, MAINTENANCE AND CALIBRATION

1. Description

The circuit is composed of two parts; a multivibrator and switching transistors. The multivibrator produces a square waveform voltage. The square wave is applied to two switching transistors. They alternately apply two batteries of opposite polarity to the probe thus providing AC power which minimizes polarization effects. The meter is in series with one battery and measures the current from it. The current from the battery is proportional to the conductance of the cell. Salinity is measured in a special range conductivity circuit which includes a user-adjusted temperature compensator. In the temperature, redline and X1 positions the multivibrator operates at 100 Hz. In the salinity, X100 and X10 positions the multivibrator operates at 600 Hz and in these ranges pushing the CELL TEST button drops the frequency to 100 Hz allowing the operator to judge the degree of probe polarization.

2. Maintenance

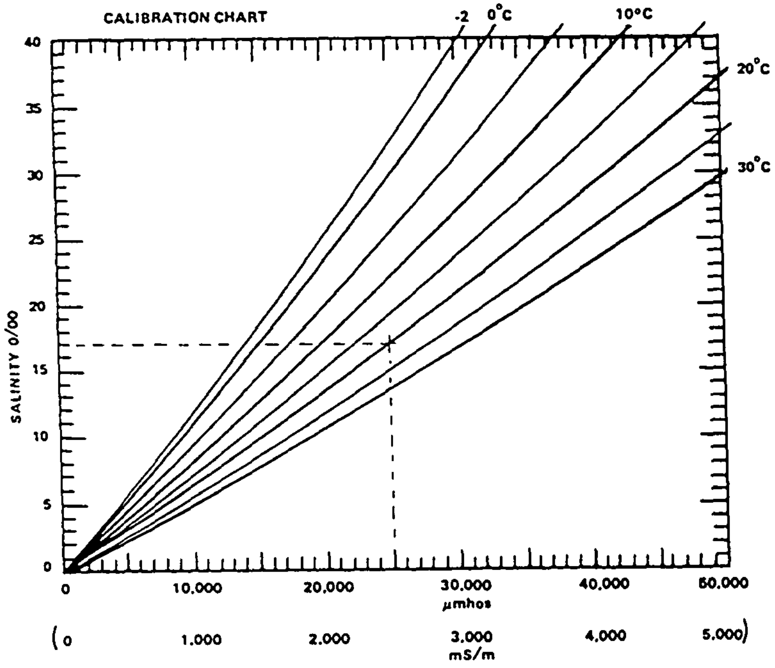
The only maintenance required is battery replacement. Two "D" size alkaline flashlight cells, such as Eveready E95 or equivalent, will provide 200 hrs. of operation. Accuracy will not be maintained if zinc-carbon "D" cells are used. Battery replacement is indicated when the redline adjustment cannot be accomplished.

Replace batteries every six months to reduce the danger of corrosion due to leaky batteries. To replace batteries, remove the six screws from the rear plate. The battery holders are color coded. The Positive (+ button) end must go on red.

3. Calibration of Model 33 (Model 33M data are in parentheses.)

It is possible for the temperature knob to become loose or slip from its normal position. In an emergency the dial can be re-positioned. It must be emphasized that this is an emergency procedure only, and that the instrument should be returned to the factory for proper recalibration at the earliest opportunity.

(a) Read the temperature and conductivity of the solution. Determine the salinity of the solution by running a line vertically on the graph from this conductance value until it intersects the appropriate °C line (interpolate as required for temperature between the given °C lines). From this intersection extend a line horizontally to the edge of the graph. This determines the salinity for this sample.
Example: 25,000 μmhos/cm and 20°C gives a salinity of 17.
(Example: 2,500 mS/m and 20°C gives a salinity of 17.)



(b) Remove the °C knob, switch to SALINITY, and turn the control shaft until the meter needle indicates the salinity value determined in Step (a). In the example given, the value is 17.

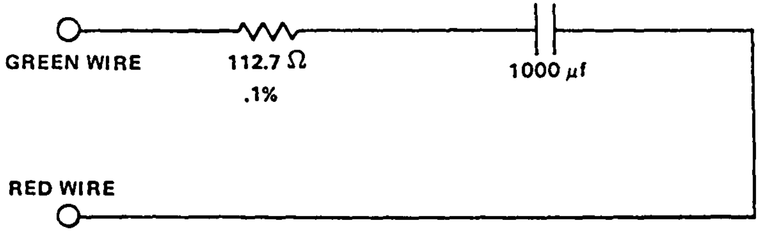
(c) Switch to TEMPERATURE. (Note: This temperature reading must be the same as Step (a); if not, begin again at Step (a).) Place the knob on the control shaft (without turning the control shaft) with the knob pointer at the same temperature as the meter reading and tighten both set screws securely.

At earliest opportunity recalibrate using the following procedure or return the instrument to factory for service.

(a) Set the instrument for a salinity measurement as normal.

(b) Substitute a 1000 μf capacitor and 112.7 ohm 0.1% tolerance resistor for the probe.

Connect the resistor and capacitor between the green wire and red wire on the jack connections inside the instrument.



(c) Turn the temperature dial until the meter reads redline.

Now install the temperature knob with the arrow at 25°C. This is a temporary calibration only. Return the instrument to the factory for proper recalibration.

PROBE

1. Description of YSI 3300 Series Conductivity/Temperature Probe

The YSI 3300 Series Conductivity Probes are designed for field use, embodying construction and design for rugged, accurate service.

Each probe features a built-in cell constant of 5.0 (500.0/M) ±2%, a precision YSI thermistor temperature sensor of ±0.1°C accuracy at 0°C and ±0.3°C at 40°C and a low capacitance cable assembly terminating in a three therminal 0.25" dia. phone type connector.

The 3310 has a 10 ft. cable and the 3311 is a 50 ft. version. Other lengths are available on special order.

The probe has a rigid P.V.C. body, platinized pure nickel electrodes, and a durable cable, providing resistance to a wide range of waterborne substances.

2. Maintenance

(a) Cleaning

When the cell test indicates low readings the probable cause is dirty electrodes. Hard water deposits, oils and organic matter are the most likely contaminants.

For convenient normal cleaning soak the electrodes for 5 minutes with a locally available bathroom tile cleaning preparation such as: Dow Chemical "Bathroom Cleaner", Horizon Industries "Rally, Tile, Porcelain, and Chrome Cleaner"; Johnson Wax "Envy, Instant Cleaner"; or Lysol Brand "Basin, Tub, Tile Cleaner."

For stronger cleaning a 5 minute soak in a solution made of 10 parts distilled water, 10 parts isopropyl alcohol and 1 part HCl can be used.

Always rinse the probe after cleaning and before storage.

CAUTION: Do not touch the electrodes inside the probe.
Platinum black is soft and can be scraped off.

If cleaning does not restore the probe performance, re-platinizing is required.

(b) Re-Platinizing

Equipment Required —

(1) YSI #3140 Platinizing Solution, 2 fl. oz. (3% platinum chloride dissolved in 0.025% lead acetate solution).
(2) YSI Model 33 or 33M S-C-T Meter.
(3) 50 ml glass breaker or equivalent bottle.
(4) Distilled water.

Procedure —

(1) Clean the probe as in Section (a) — either method.
(2) Place the cell in the beaker and add sufficient YSI #3140 solution to cover the electrodes. Do not cover the top of the probe.
(3) Plug the probe into the Model 33 or 33M, switch to the X100 scale to platinize the electrode. Move the probe slightly to obtain the highest meter reading and continue platinizing for the approximate time shown below:

Meter Reading		Time
µmhos/cm	mS/m	(minutes)
30,000	3,000	5
25,000	2,500	6
20,000	2,000	8
15,000	1,500	11
10,000	1,000	16

(4) After the elapsed time remove the probe and rinse in fresh water.
(5) Return the solution to its container. 2 oz. of solution should be sufficient for 50 treatments.

(c) Storage:
It is best to store conductivity cells in deionized water. Cells stored in water require less frequent platinization. Any cell that has been stored dry should be soaked in deionized water for 24 hours before use.

3. Probe Use

(a) Obstructions near the probe can disturb readings. At least two inches of clearance must be allowed from non-metallic underwater objects. Metallic objects such as piers or weights should be kept at least 6 inches from the probe.

(b) Weights are attached to the cable of the YSI 3310 and 3311 Probes. The YSI 3327 Weights are supplied in pairs with a total weight of 4 ounces per pair. Should it become necessary to add more weight to overcome water currents, we suggest limiting the total weight to two pounds (8 pairs). For weights in excess of two pounds use an independent suspension cable. In either case, weights must be kept at least 6 inches away from the probe.

(c) Gentle agitation by raising and lowering the probe several times during a measurement insures flow of specimen solution through the probe and improves the time response of the temperature sensor.

4. Cell Calibration & Standard Solutions

The YSI #3300 Series Cells are calibrated to absolute accuracy of ±1.5% based on a standard solution. Since the literature on conductivity does not indicate a consistently accepted standardization method, we have chosen the 0.01 demal KCl solution method as determined by Jones and Bradshaw in 1937 as our standard. Recent textbooks, as well as the ASTM standards, concur with this choice. The solution is prepared by diluting 0.745 grams of pure dry KCl with distilled water until the solution is 1 kilogram. The table below shows the values of conductivity this solution would have if the distilled water were non-conductive. However, since even high purity distilled water is slightly conductive, the measured conductivity will be higher by an amount equal to the water's conductivity.

	Conductivity	
Temperature °C	µmhos/cm	mS/m
15	1141.5	114.2
16	1167.5	116.8
17	1193.6	119.4
18	1219.9	122.0
19	1246.4	124.6
20	1273.0	127.3
21	1299.7	130.0
22	1326.6	132.7
23	1353.6	135.4
24	1380.8	138.1
25	1408.1	140.8
26	1436.5	143.7
27	1463.2	146.3
28	1490.9	149.1
29	1518.7	151.9
30	1546.7	154.7

The operator may use the standard solution and the table to check accuracy of a cell's constant or to determine an unknown constant. The formula is shown below:

$$K = \frac{R\,(C_1 + C_2)}{10^6} \quad \text{or} \quad \frac{R\,(S_1 + S_2)}{10^5}$$

where: K = Cell constant
R = Measured resistance in Ω

C_1 = Conductivity in μmhos/cm
C_2 = Conductivity in μmhos/cm of the distilled water used to make solution.
S_1 = Conductivity in mS/m
S_2 = Conductivity in mS/m of the distilled water used to make the solution.

R, C_1 and C_2, or S_1 and S_2, must either be determined at the same temperature or corrected to the same temperature to make the equation valid.

Note: For further information on conductivity and the above standard information, refer to ASTM Standards Part 23 — Standard Methods of Test for Electrical Conductivity, or Water and Industrial Waste Water — ASTM Designation D1125-64.

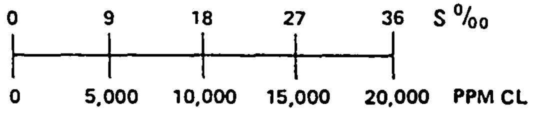
YSI MODEL 33 AND 33M USED WITH YSI 51A, 54 and 57 OXYGEN METERS

If the salinity measurement is to be used for salinity correction on the 51A, the reading should be converted to Chlorosity. The formula is:

$$\text{PPM Chlorosity} = \frac{\text{Salinity ‰} - 0.03}{1.8} \times 10^3$$

For these instruments the 0.03 can be neglected so the equation simplifies to:

$$\text{PPM Cl} = \frac{\text{SS ‰} \times 10^3}{1.8}$$



For salinity correction when using the Model 57 use the salinity reading direct from the Model 33 or 33M. No conversion is necessary.

Model 33 and 33M salinity readings taken in conjunction with Model 54 dissolved oxygen readings can be used to correct the Model 54 for salinity and to make post-measurement salinity corrections to dissolved oxygen data. Correction tables are available from the factory.

WARRANTY

All YSI products carry a one-year warranty on workmanship and parts, exclusive of batteries. Damage through accident, misuse, or tampering will be repaired at a nominal charge.

If you are experiencing difficulty with any YSI product, it may be returned to an authorized YSI dealer for repair, even if the warranty has expired. If you need factory assistance for any reason, contact:

Service Department
Yellow Springs Instrument Co., Inc.
P.O. Box 279
Yellow Springs, Ohio U.S.A.
Phone: (513) 767-7241

HNu PID OPERATIONS MANUAL

INSTRUCTION MANUAL

TRACE GAS ANALYZER

HNU MODEL PI 101

HNU Systems, Inc.
160 Charlemont St.
Newton, MA 02161

December 1985

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LIST OF ILLUSTRATIONS

LIST OF TABLES

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 1 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:

$$RH + hv \rightarrow RH^+ + e^-$$

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, O_2, N_2, CO, CO_2 or H_2O.

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 electode 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.

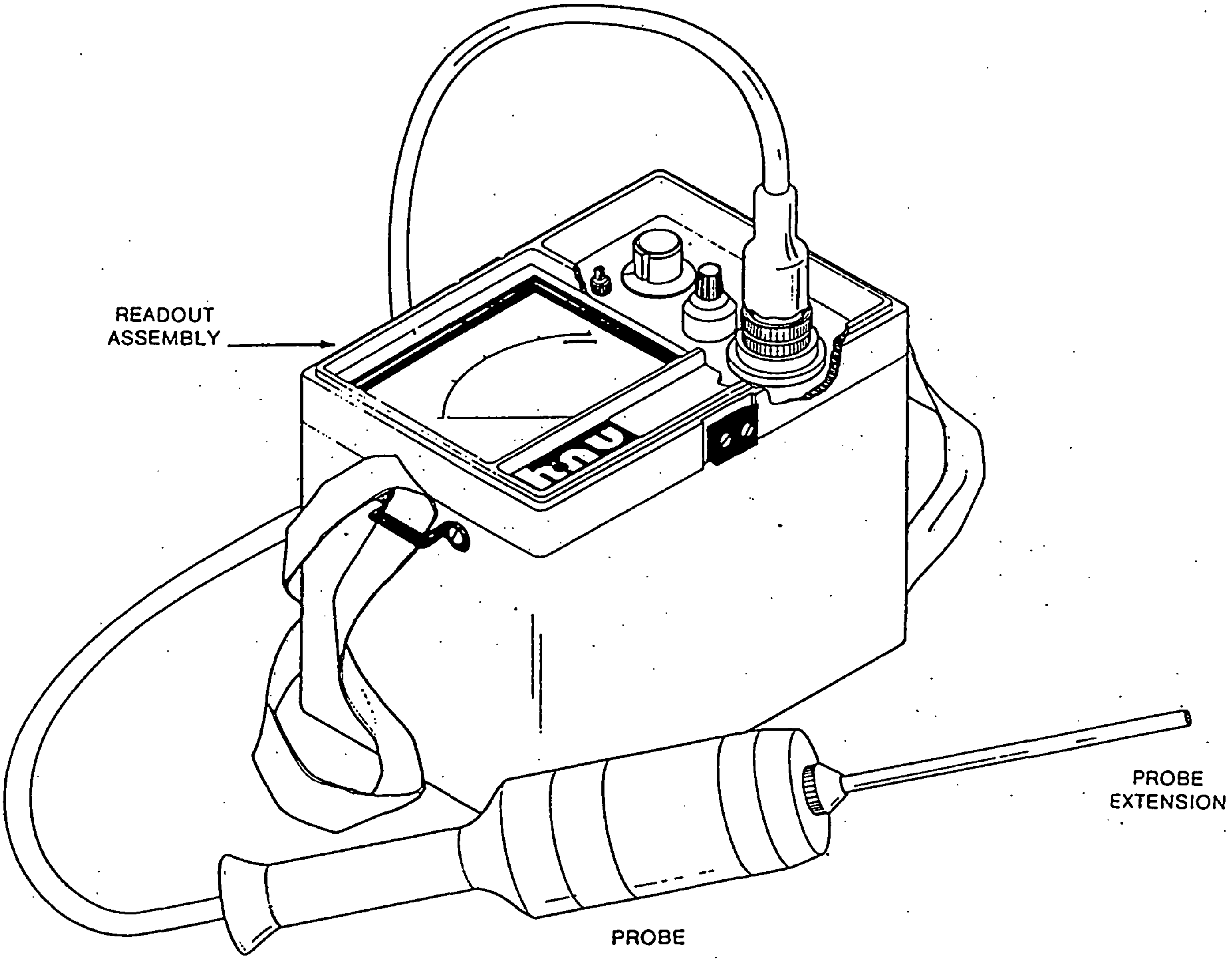


FIGURE 1-1
TRACE GAS ANALYZER
OPERATING CONDITION

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

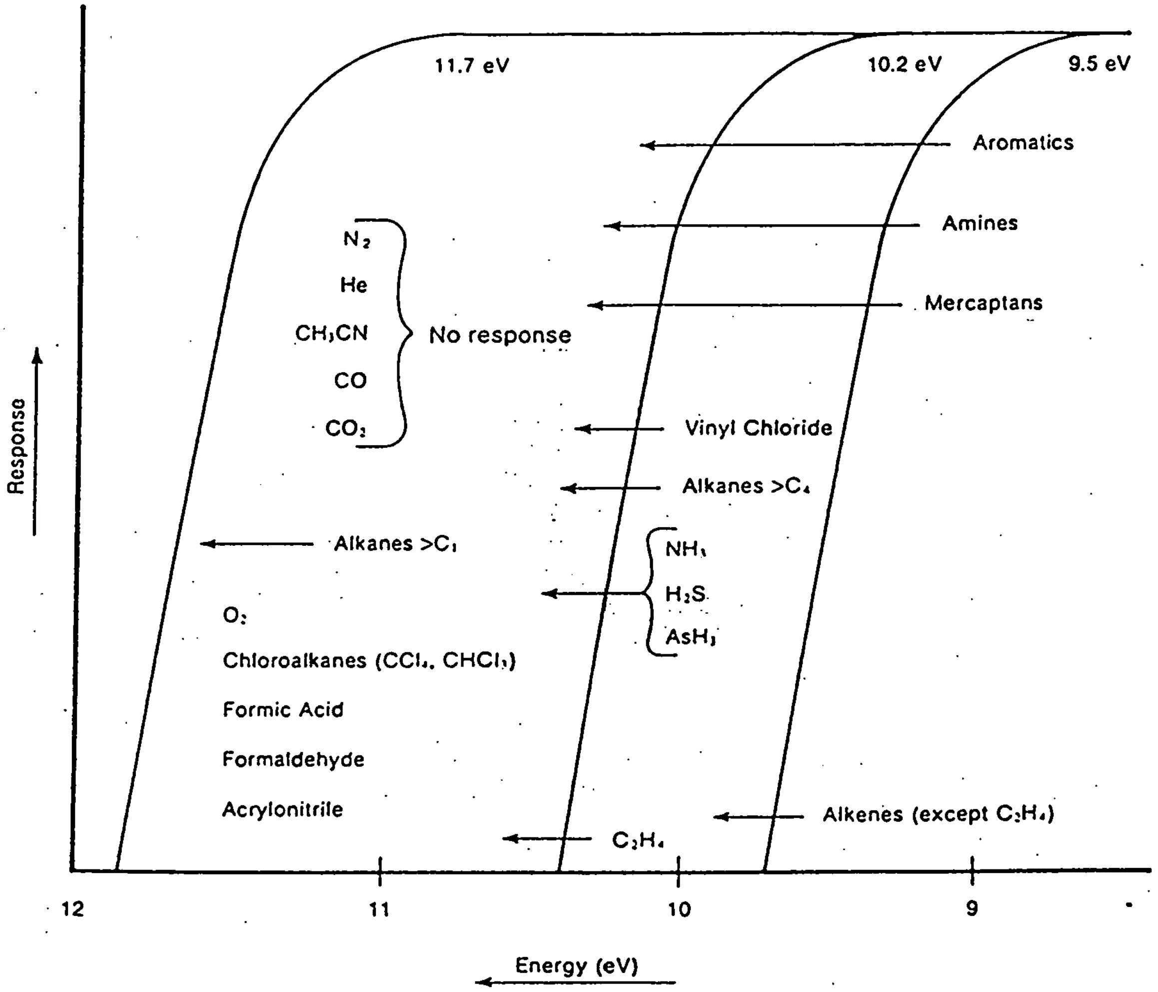
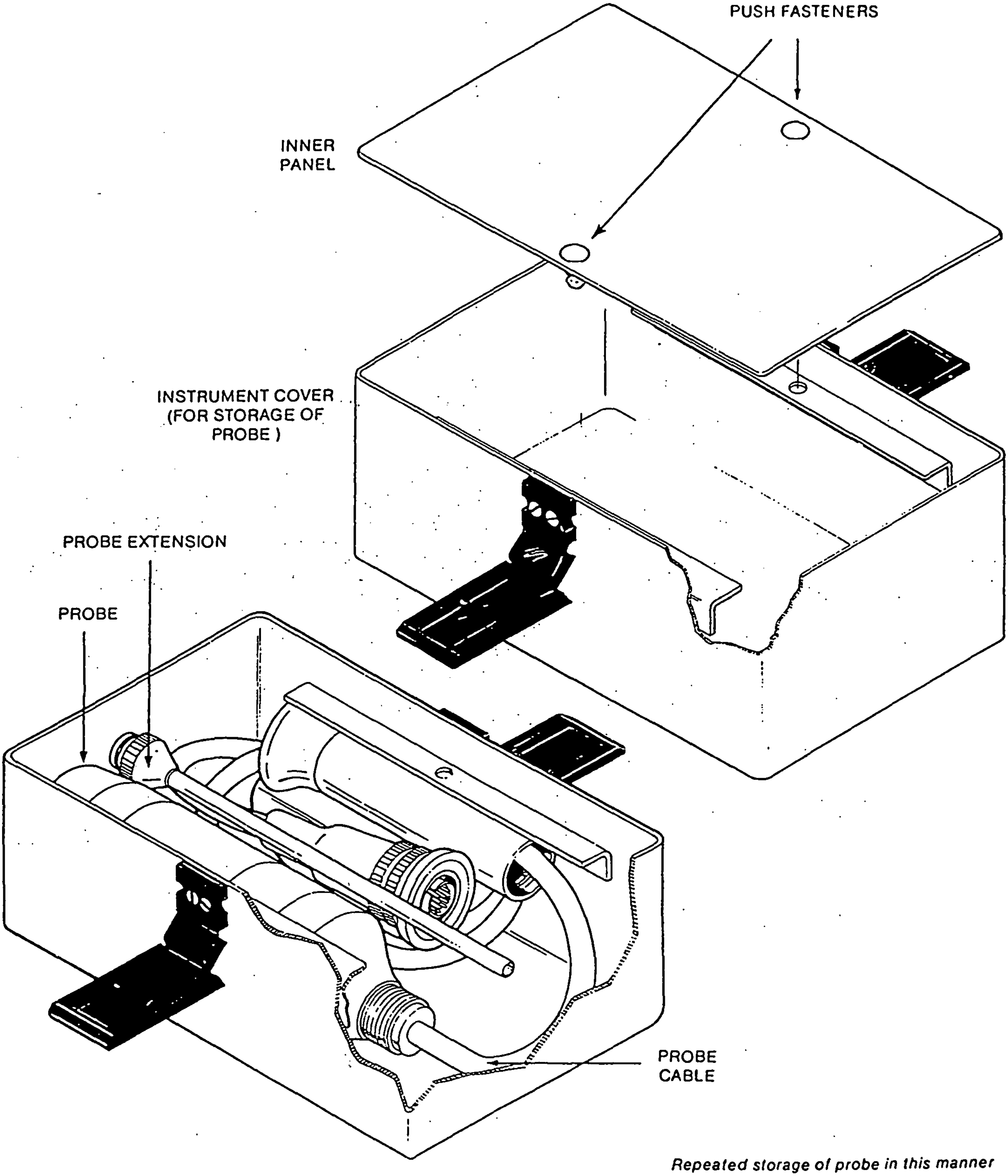


FIGURE 1-2
RESPONSE TO VARIOUS COMPOUNDS
FOR EACH ULTRAVIOLET LAMP



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

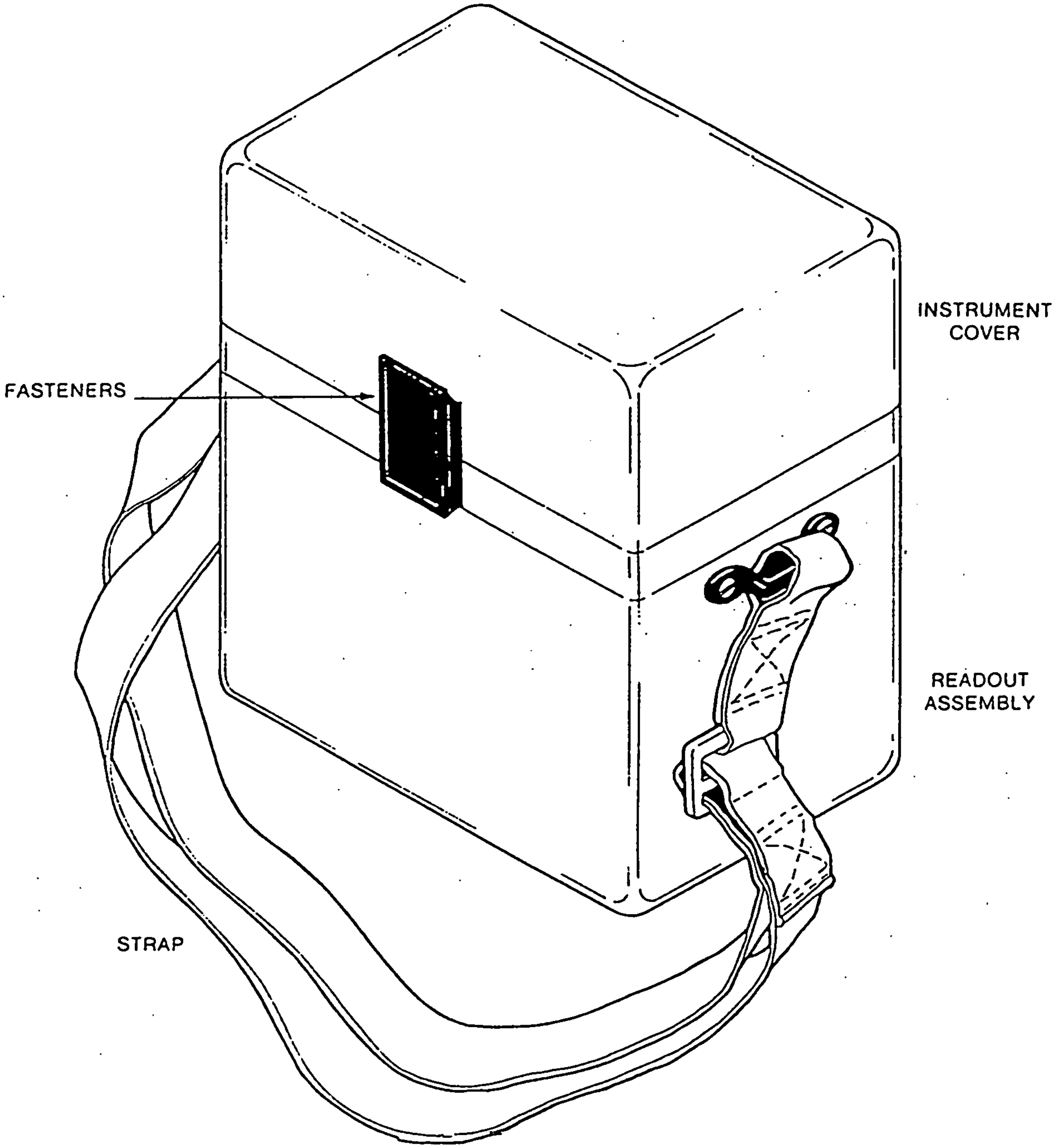


FIGURE 1-4
TRACE GAS ANALYZER
STORED CONDITION

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, cm3 (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

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.

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.

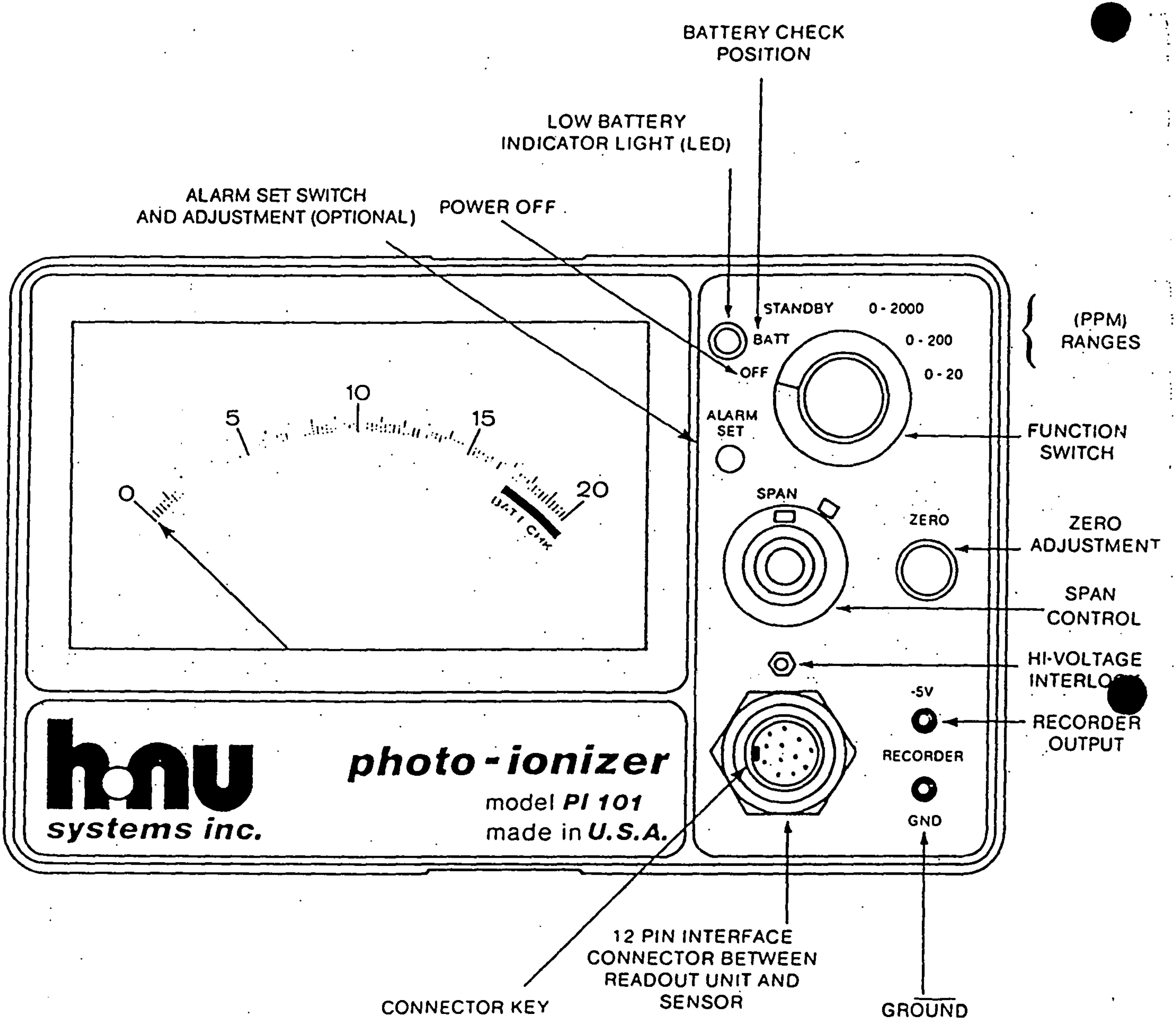


FIGURE 2-1
CONTROLS AND INDICATORS

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.

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 8-3). 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.

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.

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.

CALIBRATION

3.1 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.

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.

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 appoximately 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.

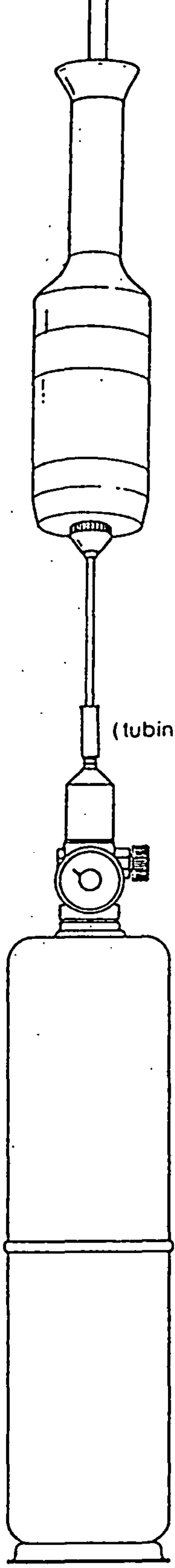
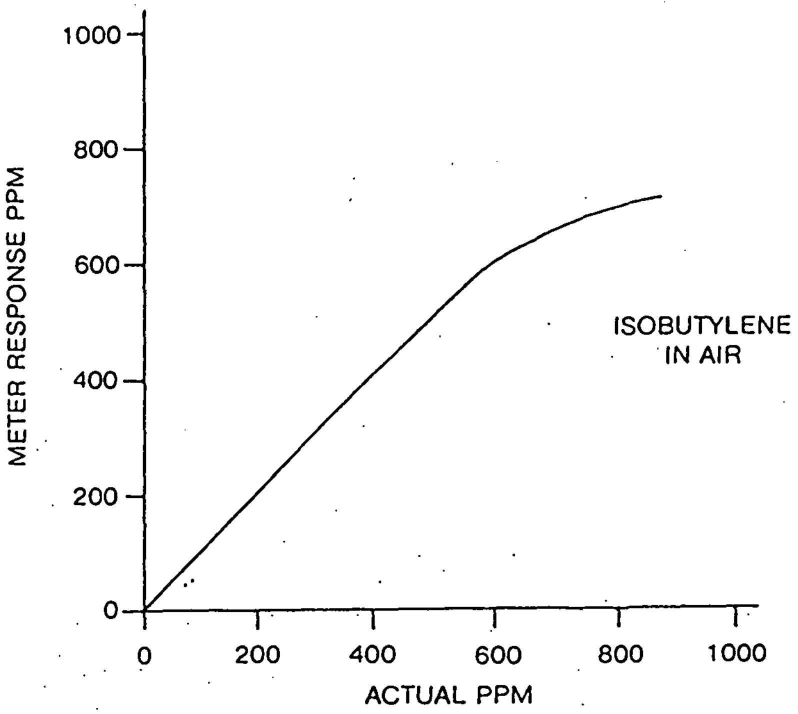


FIGURE 3-1
CALIBRATION TEST SET UP



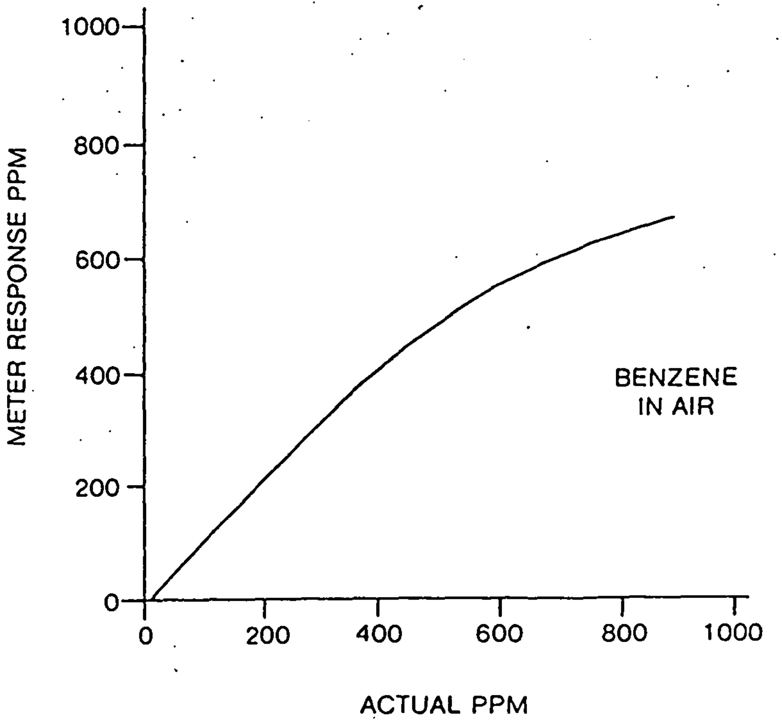


FIGURE 3-2
TYPICAL CALIBRATION CURVES (10.2 eV)

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.

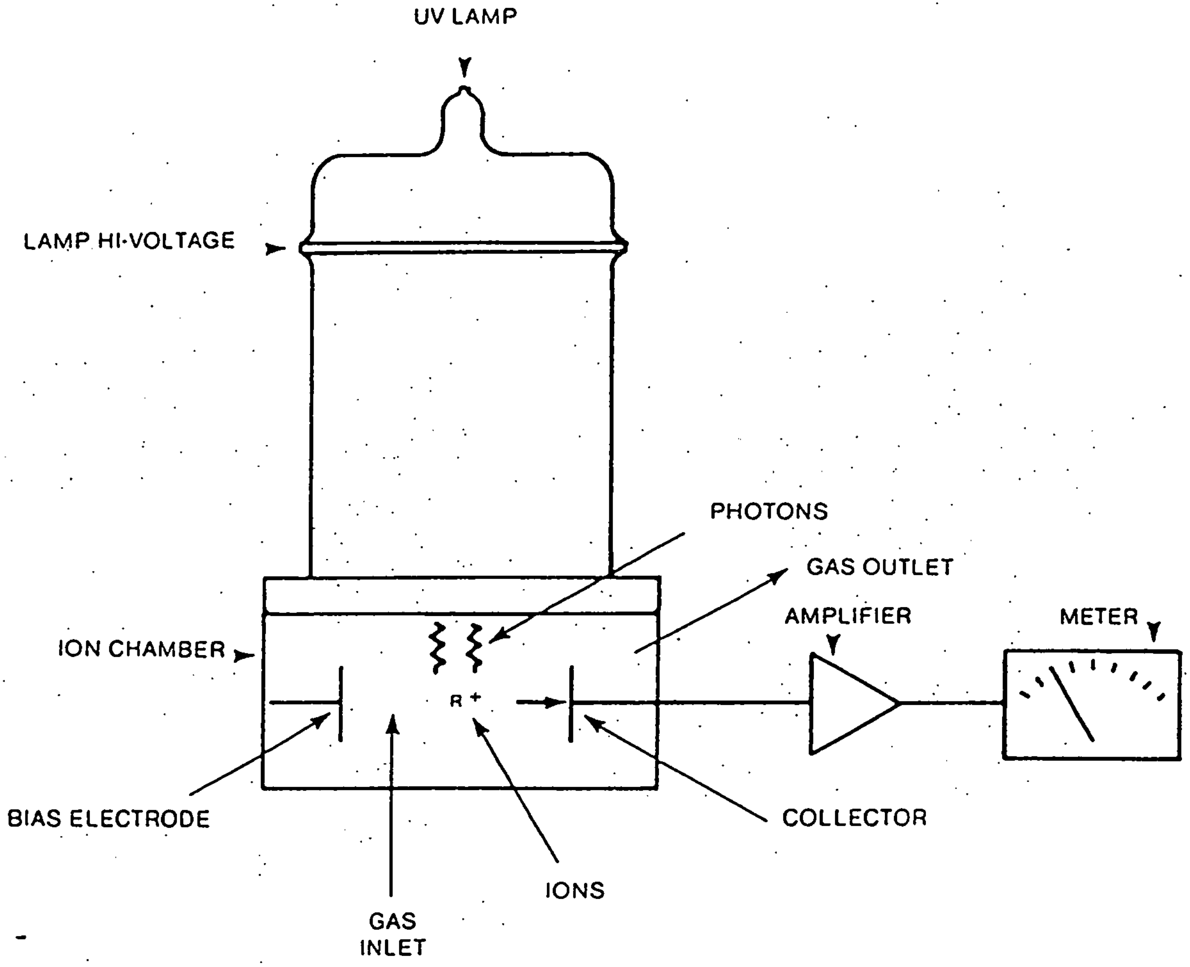


FIGURE 4-1
DETECTION PROCESS

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 aproximately 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.

TABLE 4-1

RELATIVE PHOTOIONIZATION SENSITIVITIES FOR GASES

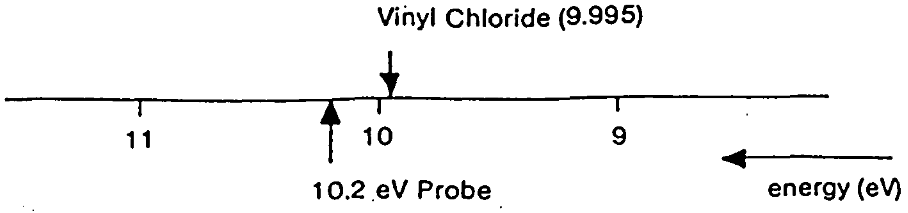
Chemical Grouping	Relative Sensitivity (see NOTE)	Examples
Aromatic	10	Benzene, Toluene, Styrene
Aliphatic Amine	10	Diethylamine
Chlorinated Unsaturated	5-9	Vinyl Chloride, Vinylidene Chloride, Trichloroethylene
Carbonyl	7-9	MEK, MiBK, Acetone, Cyclohexanone
Unsaturated	3-5	Arolein, Propylene, Cyclohexanone, 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.

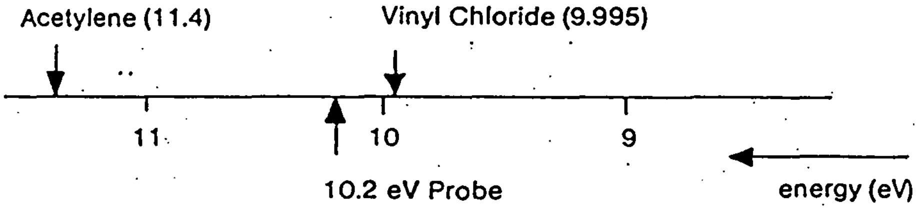
TYPICAL APPLICATIONS OF INTERCHANGEABLE PROBES

Compound	Ionization potentials (eV)	Relative Sensitivity 9.5/10.2 eV	Relative Sensitivity 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

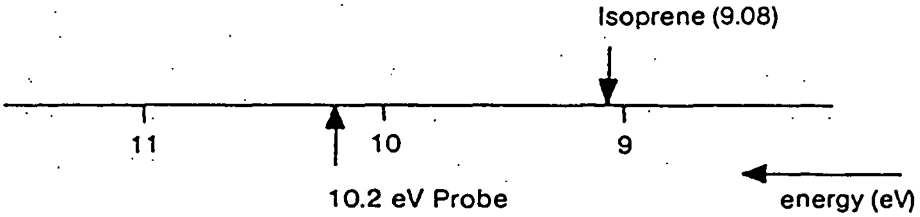
$$\text{Relative sensitivity} = \frac{\text{Response with 9.5 or 11.7 eV probe}}{\text{Response with 10.2 eV probe}}$$



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

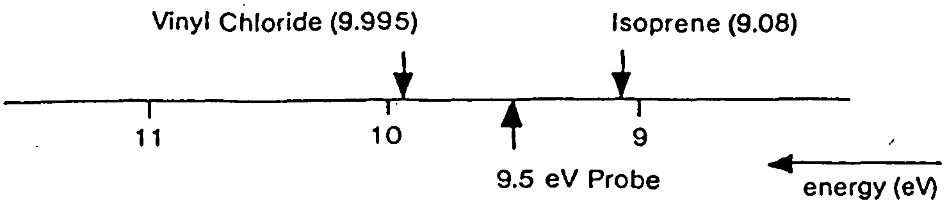


b. 10.2 eV Probe measures Vinyl Chloride (IP = 9.995)
but not Acetylene (IP = 11.4)

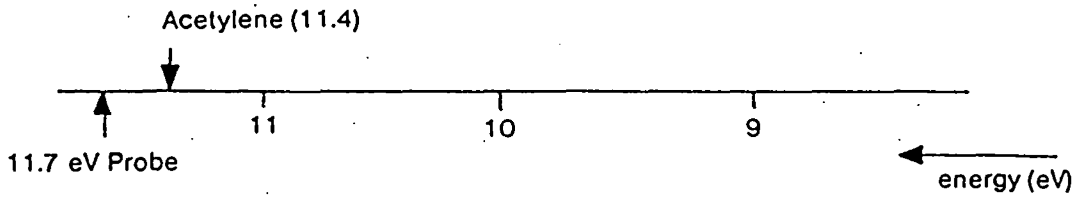


c. 10.2 eV Probe measures Isoprene (IP = 9.08)

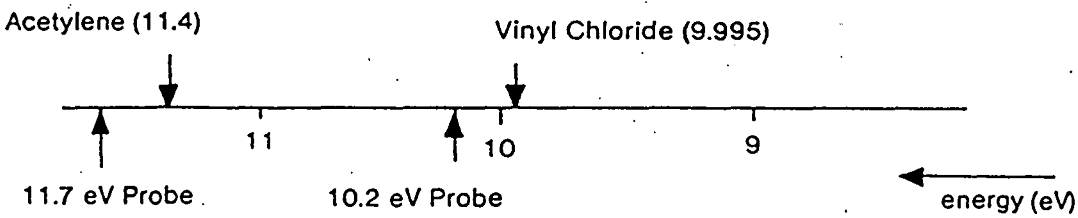
FIGURE 4-2
APPLICATION OF PROBES



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



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



f. 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 contentration of Formaldehyde

4.6 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.

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.

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 P6/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.

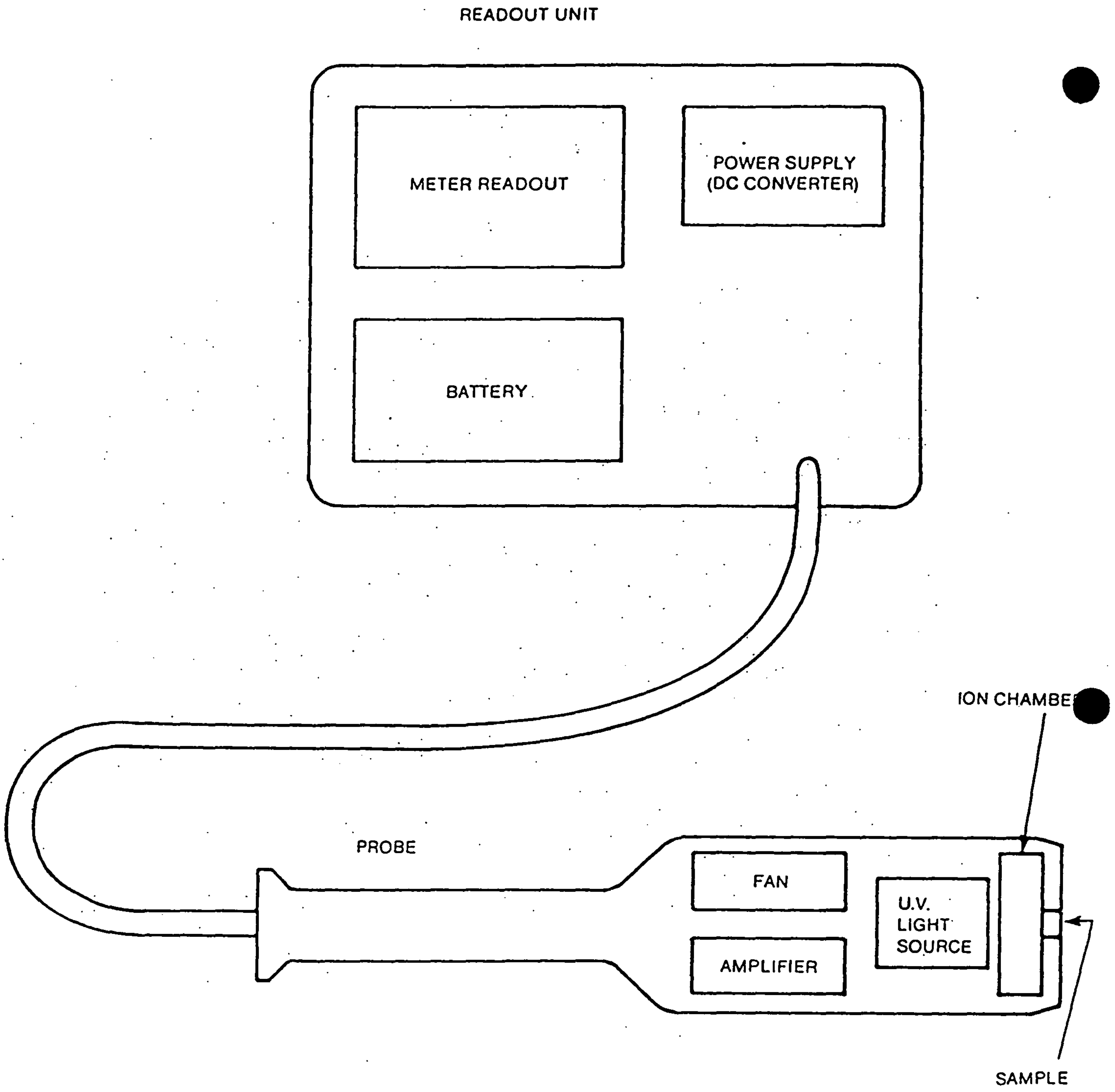
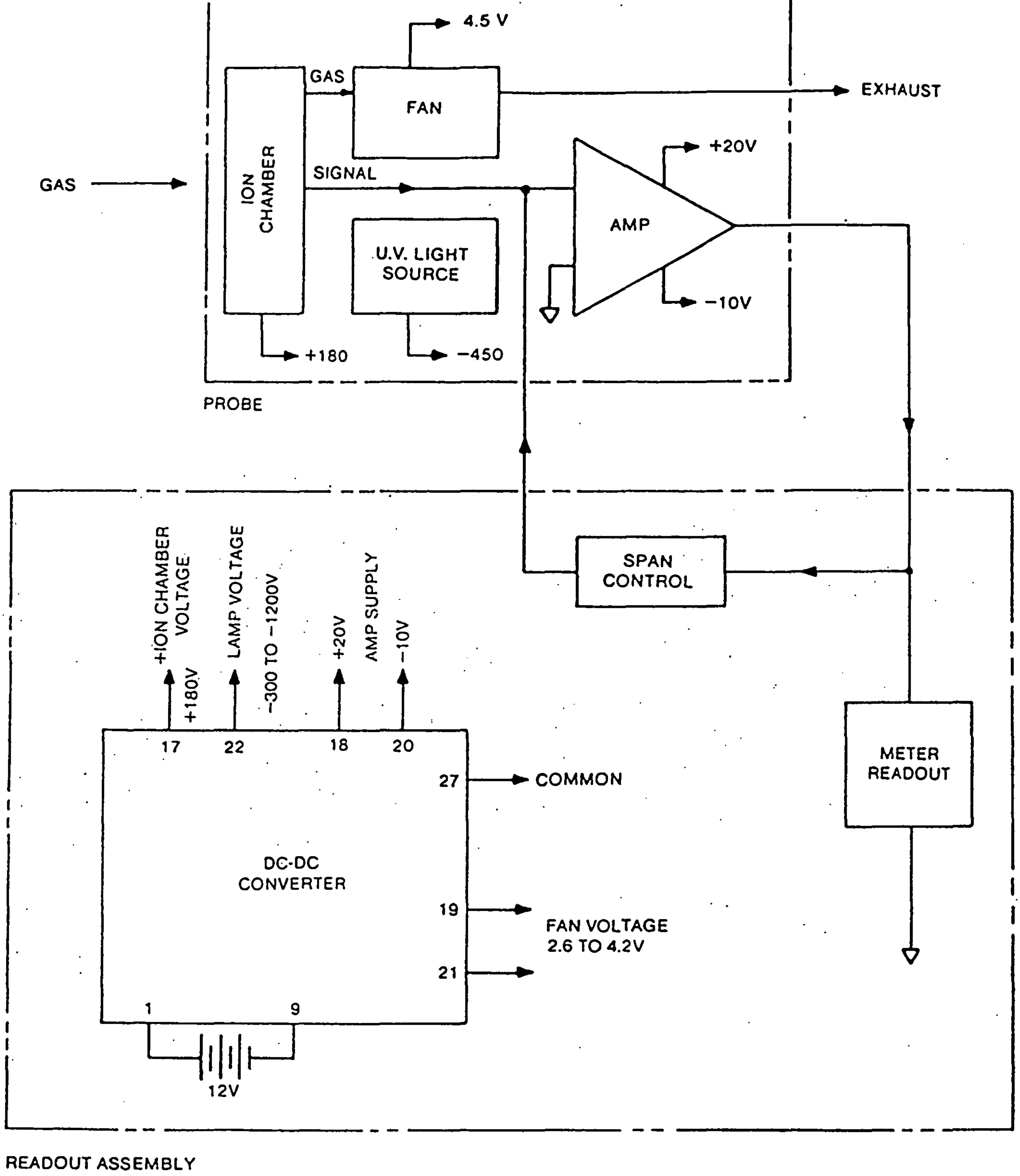
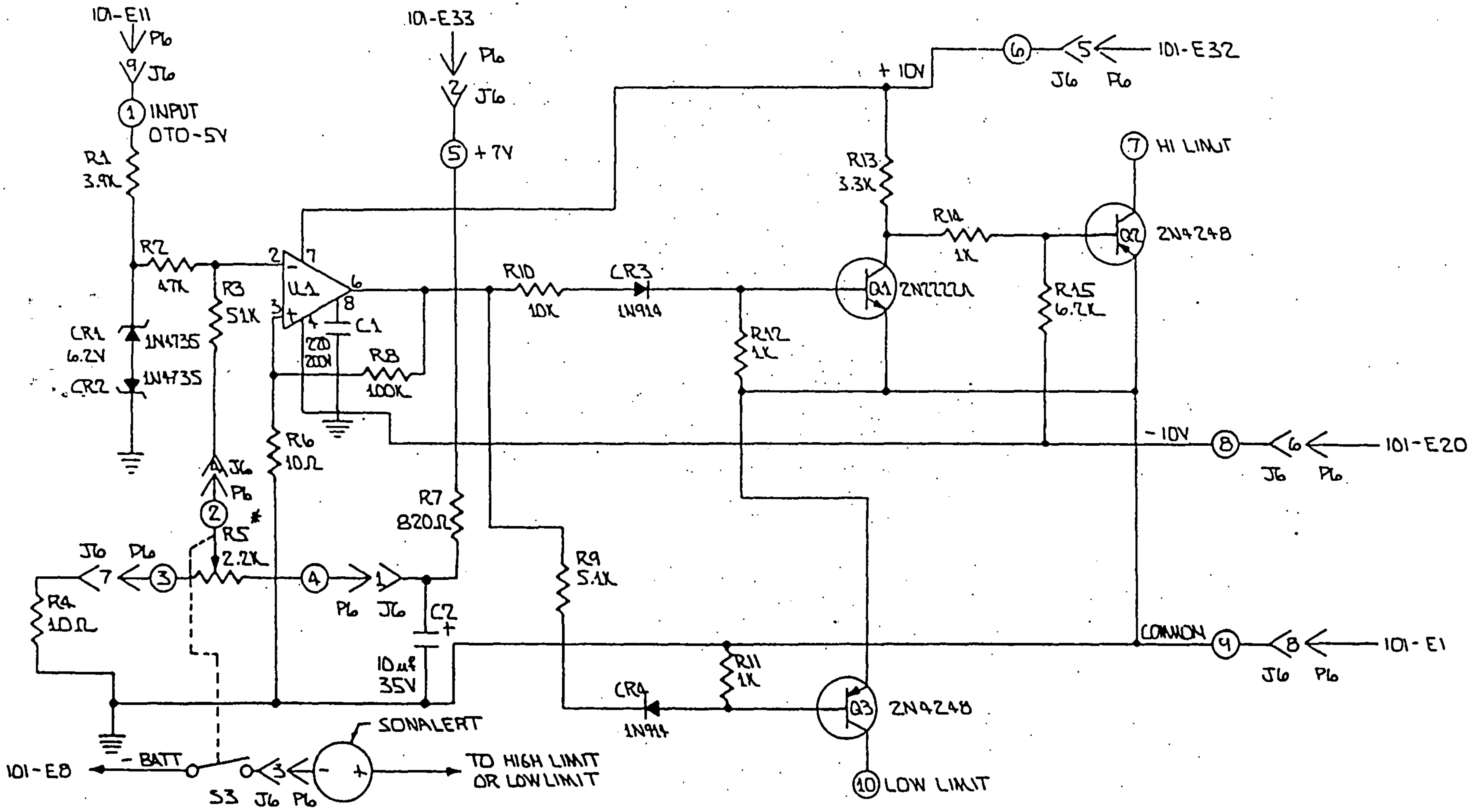


FIGURE 4-3
BLOCK DIAGRAM
COMPONENT LOCATION



NOTE: ALL VOLTAGES SHOWN ARE NOMINAL VALUES.

FIGURE 4-4
BLOCK DIAGRAM
ELECTRICAL CONNECTIONS



NOTE:

1) ALL RESISTORS ARE 1/4W C.C. OR C.F. ±5%.
2) FOR BOARDMASTER SEE HNU DWG. DB100584.
3) FOR P.C. MASTER SEE HNU DWG. MB100583.
4) FOR SILKSCREEN SEE HNU DWG. MB100585.
5) * R5, S1 MOUNTED ON FRONT PANEL.

FIGURE 4-5
SCHEMATIC DIAGRAM, ALARM BOARD

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.

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.

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.

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.

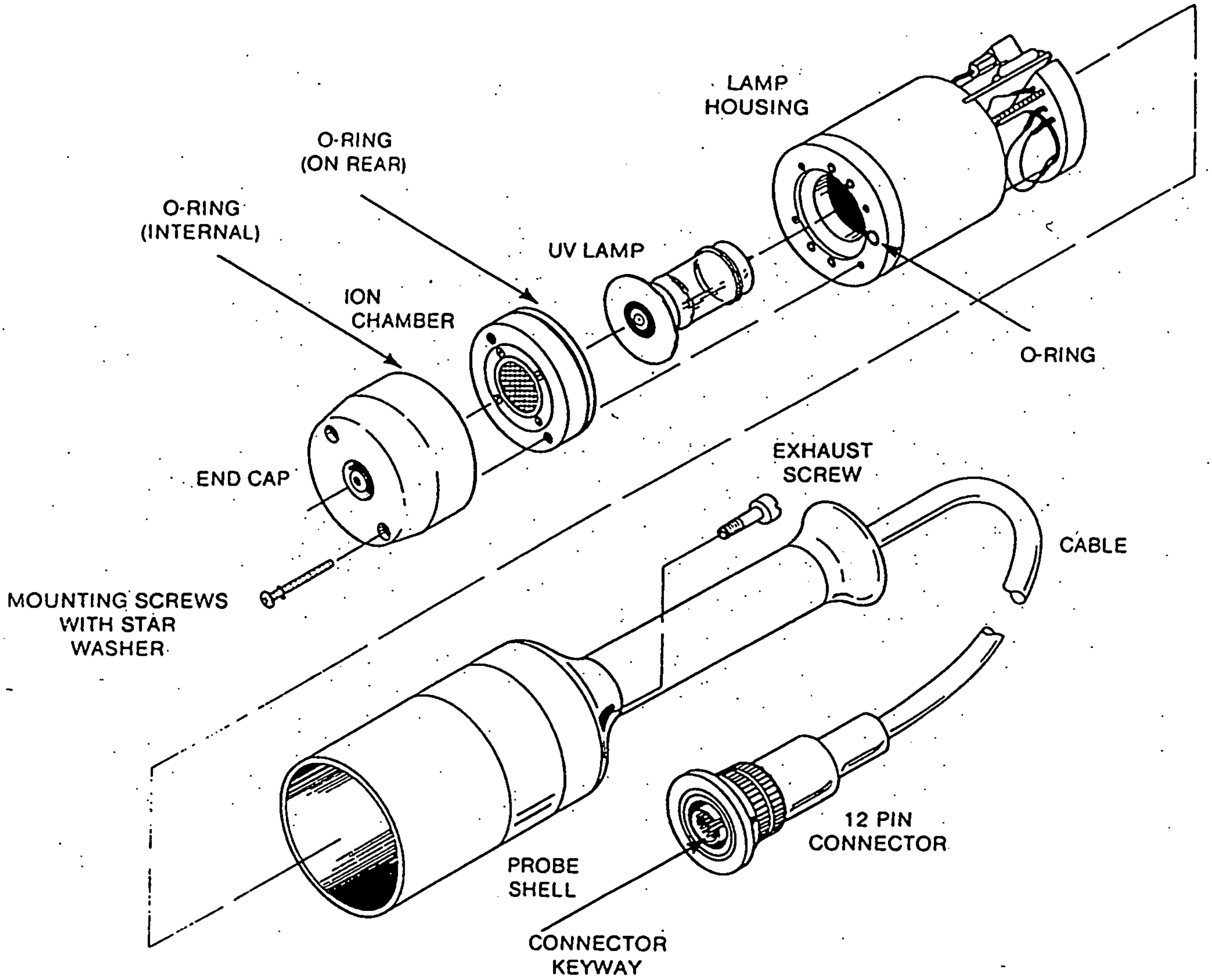


FIGURE 5-1
PROBE ASSEMBLY

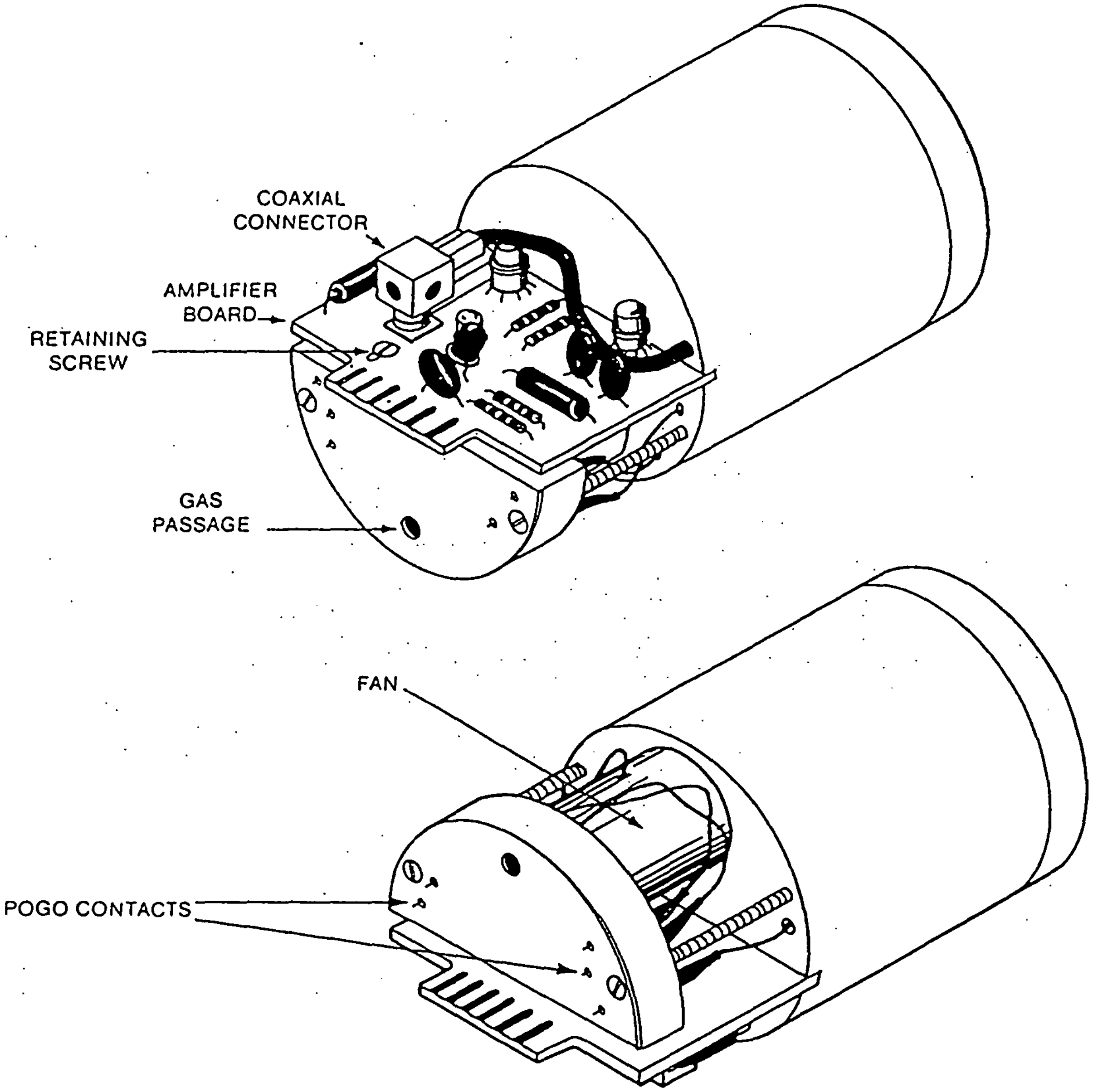


FIGURE 5-2
LAMP HOUSING ASSEMBLY

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 botton 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:

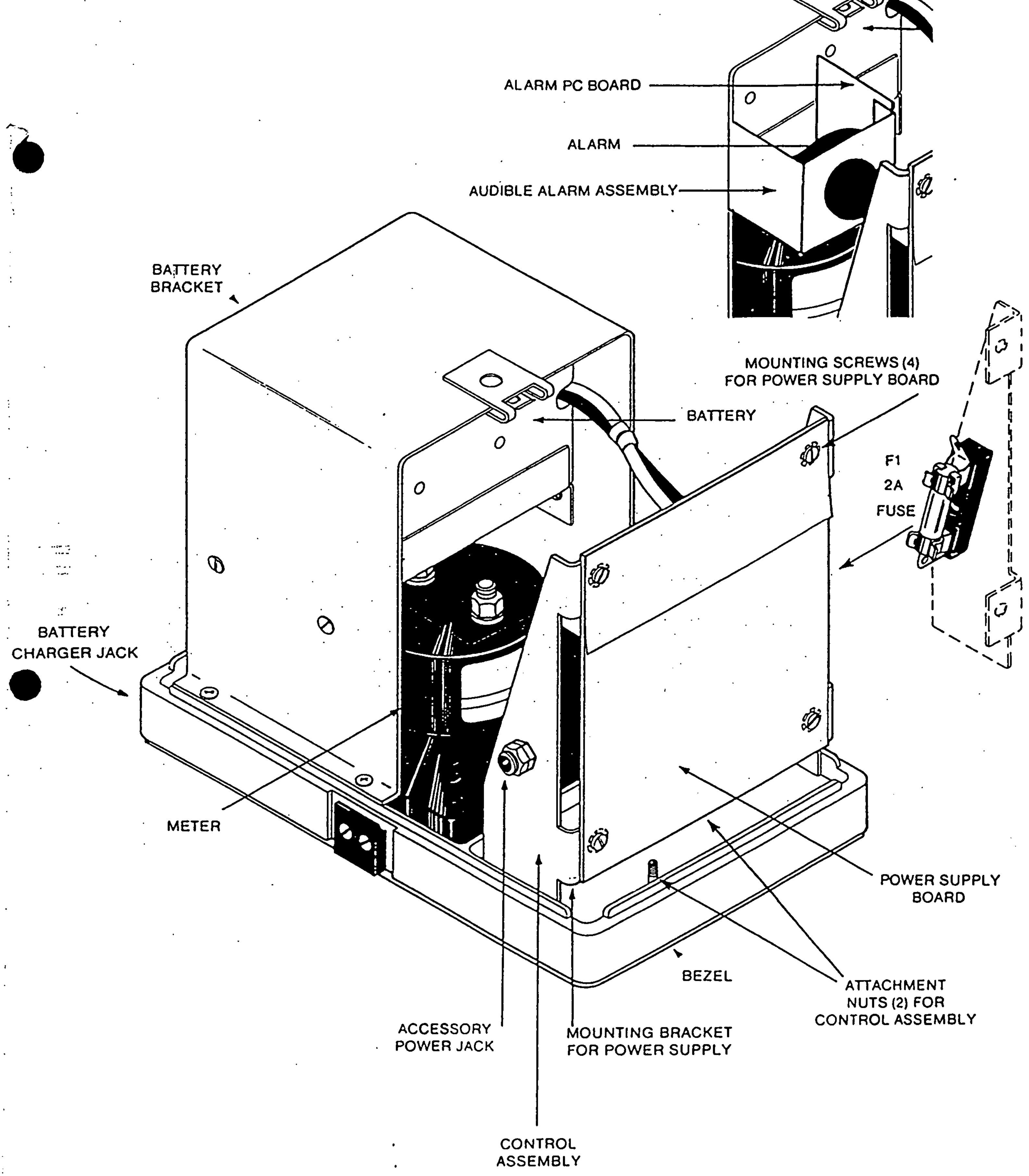


FIGURE 5-3
READOUT ASSEMBLY

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.

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).

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, che[illegible] 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 (Microswitch 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 voltages not correct, replace power supply board.
	e. Dirty or loose connections	1) Clean or tighten connections at amplifier board, probe cable, and meter.

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

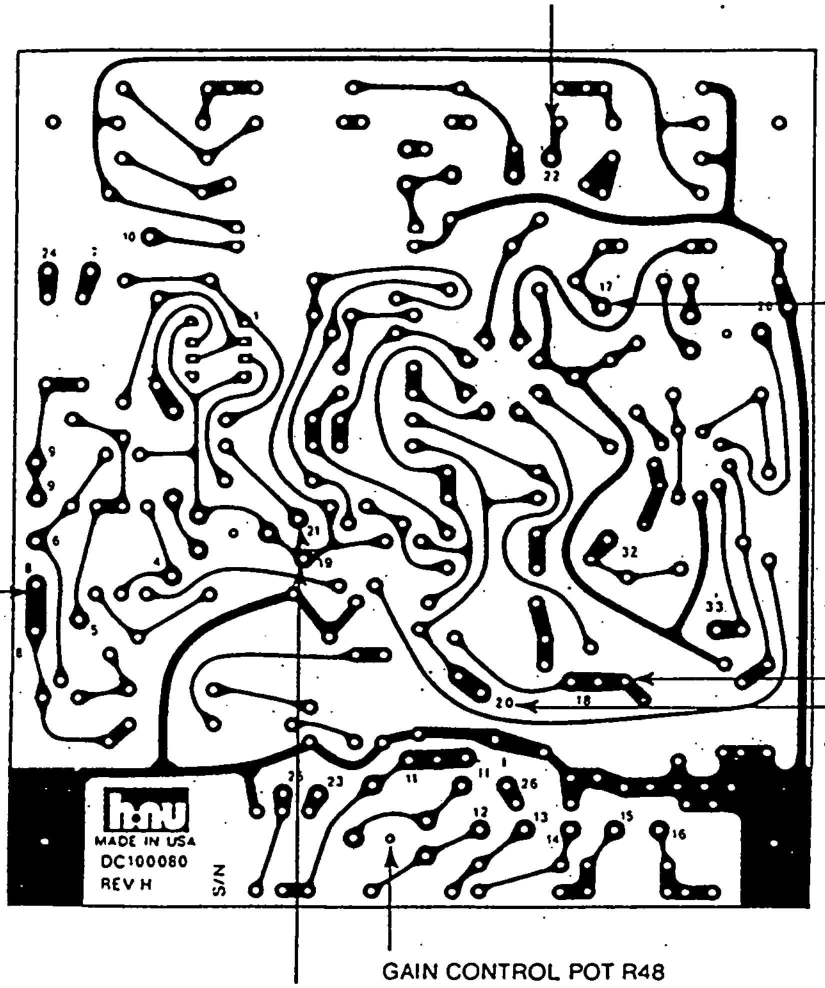
PAD DATA, POWER SUPPLY PCB

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.

PAD 22
UV LAMP VOLTAGE
-300 V WITH PROBE
CONNECTED
-1200 V WITH PROBE
DISCONNECTED



PAD 17
ION CHAMBER
ACCELERATING
VOLTAGE
+180 TO +181 V

PAD 8
BATTERY VOLTAGE
−11 TO −15 V

PAD 18
ZERO ADJUST POWER
+18 TO +21 V

PAD 20
AMPLIFIER POWER
-9.5 TO −10.5 V

GAIN CONTROL POT R48

PADS 21 TO 19 (21 LOWSIDE)
FAN MOTOR
2.6 TO 3.6 V

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
L	Zero Adjust	varying
M	Ion Chamber accelerating voltage	+180
N	Amplifier Power	-9.5 to -10.5

NOTE: Differential potential for fan motor between pads 19 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

Part No.	Refer to Fig. No.	Assembly
	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

REPLACEMENT PARTS LIST

MODEL PI101
(see Fig. 7-3)
1 2 3 4 5

Part No.	Refer to Fig. No.	Assembly
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	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.
101-301	Chart Paper For portable recorder, 6 rolls.
AB100378	Multiconductor Interface Cable For recorder, contains leads for connecting recorder to analyzer.)Included in part 101-300 above)
101-350	Calibration Gas Cylinder Contains 23 liters of span gas in air (300 psi) sufficient for 40-50 calibrations. (4" diameter by 12" high).
101-351	Regulator For use with calibration cylinder, Model 101-350, complete with gauges for reading both cylinder pressure and flow.
101-500	Cleaning Compound For removing deposits from window of 9.5 or 10.2 eV lamp (not the 11.7 eV lamp.)

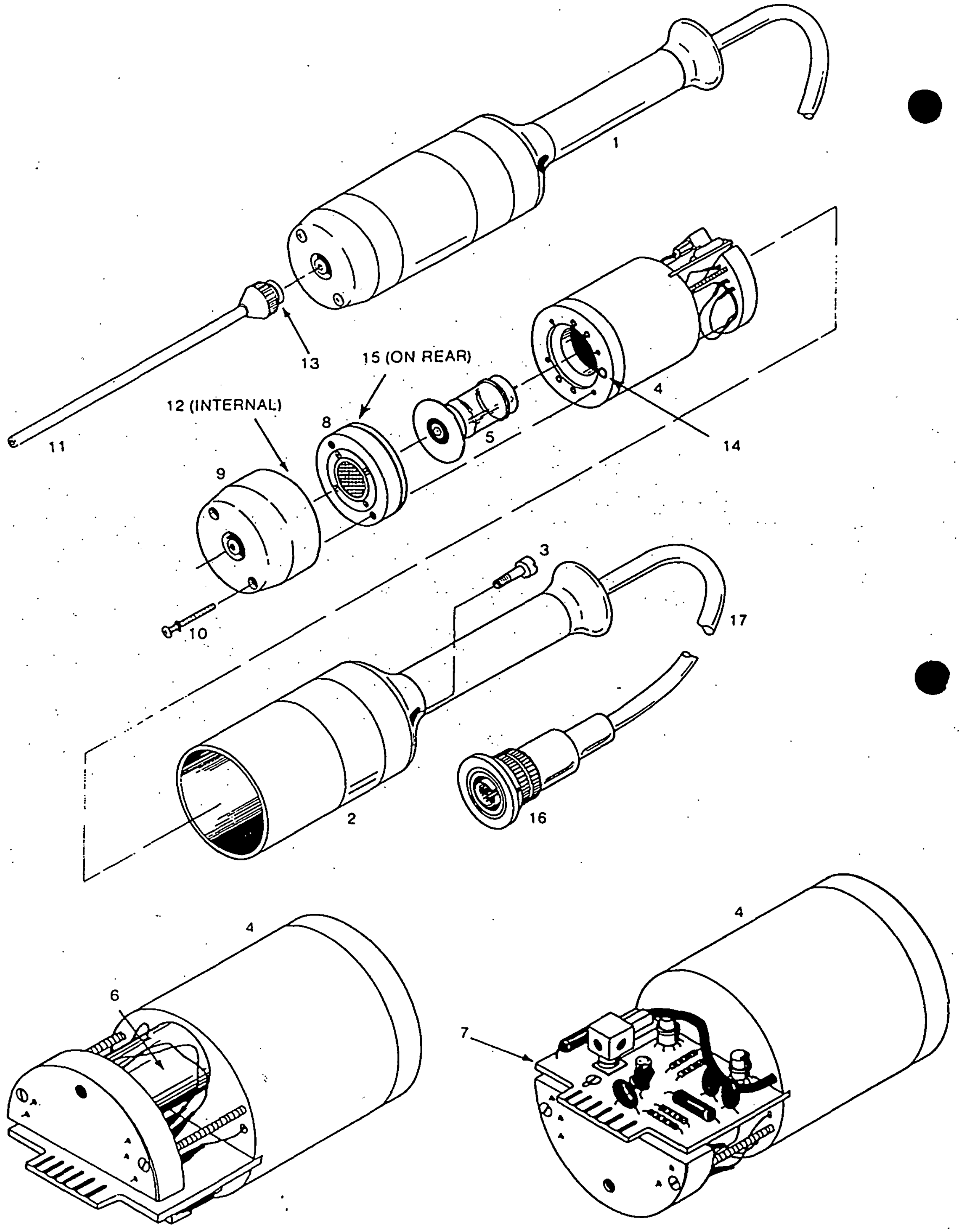


FIGURE 7-1

PARTS LOCATION, PROBE ASSEMBLY

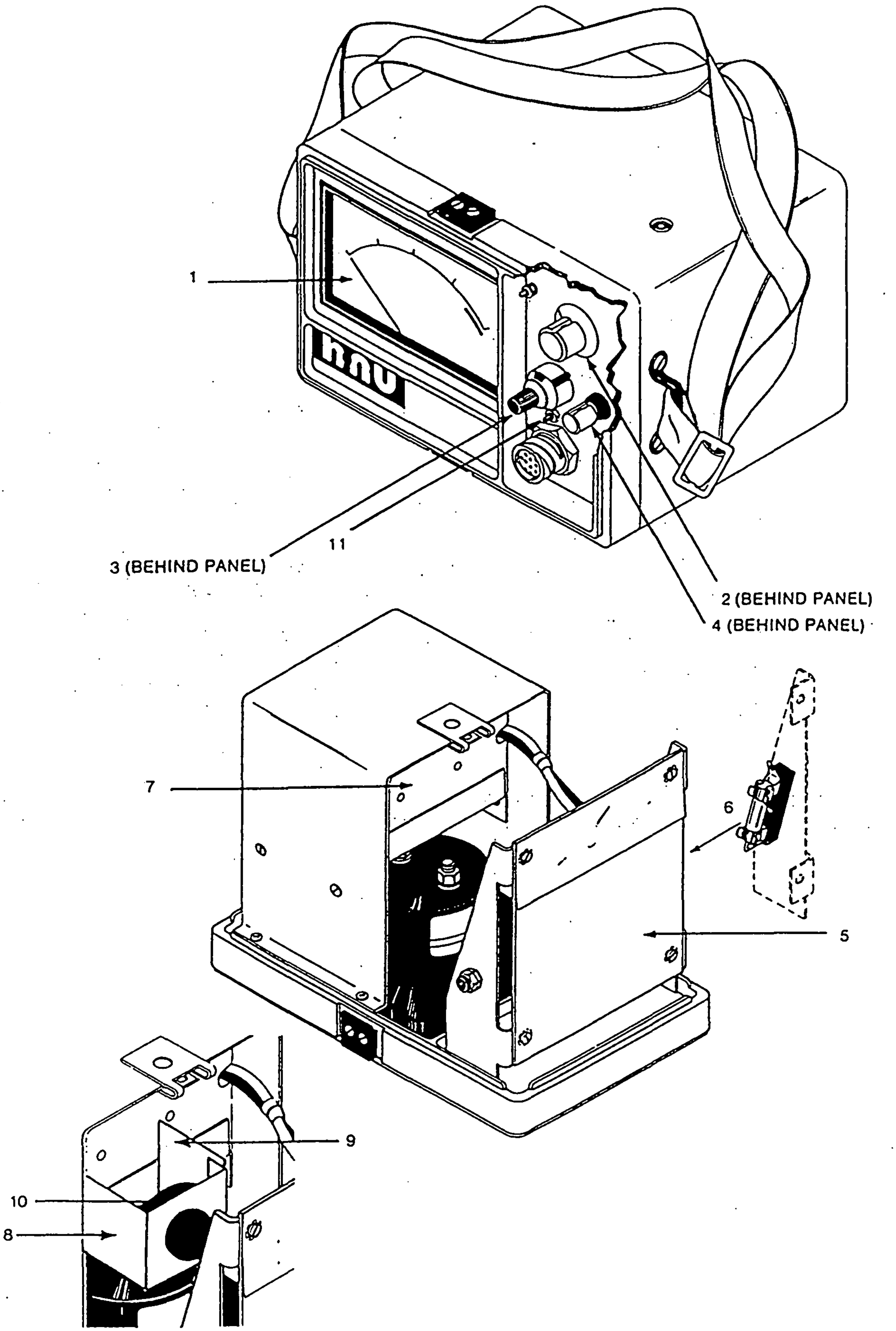


FIGURE 7-2
PARTS LOCATION, READOUT ASSEMBLY

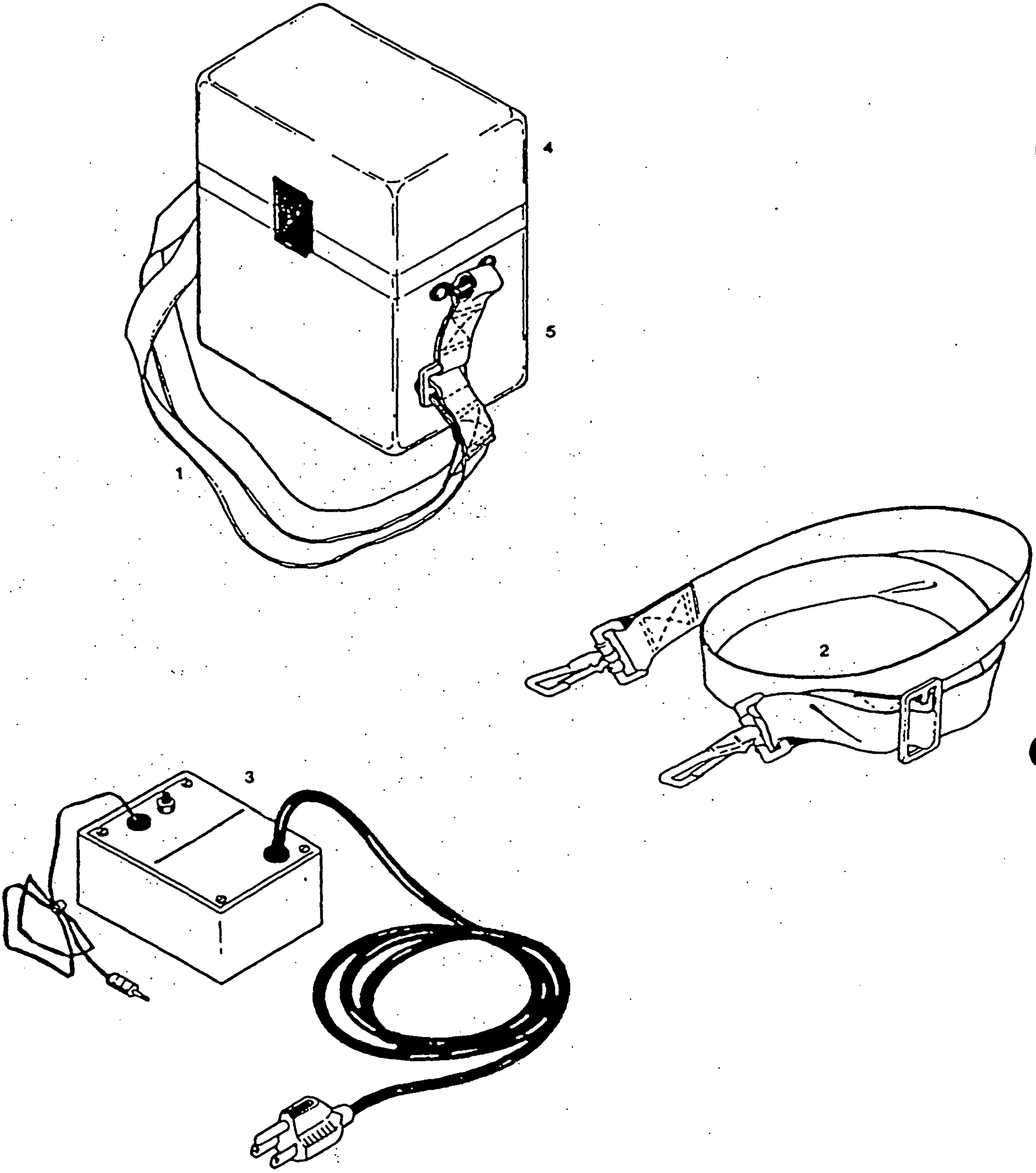


FIGURE 7-3
PARTS LOCATION, OTHER ITEMS

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. Warming 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.

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:

$$\frac{\text{volume injected (ml)} \times \text{density (g/ml)} \times \text{molar volume (liters/mole)}}{\text{molecular weight (g/mole)} \times \text{volume of air (liters)}} \times 10^{6}$$

$$\frac{0.001\text{ ml} \times 0.87\text{ g/ml} \times 24.0\text{ liters/mole}}{92\text{ g/mole} \times 1.5\text{ liters}} = 10^{6} = 151\text{ ppm (see NOTE 2)}$$

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 30 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.

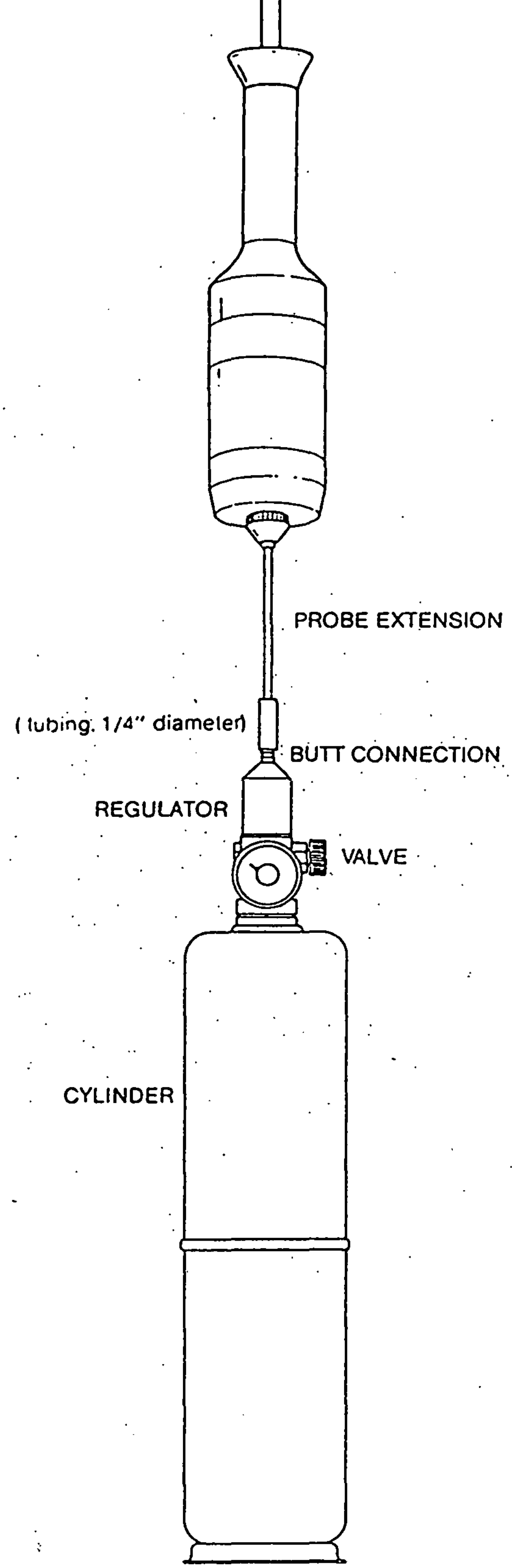


FIGURE 8-1
CALIBRATION CHECKING SET-UP

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:

$$= \text{Isobutylene ppm} \times \frac{\text{PS(Isob)}}{\text{PS(Vin Chlor)}}$$

$$= 100 \times \frac{7.0}{5.0}$$

$$= 140 \text{ ppm}$$

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.

The required reading for calibration will be:

$$= \text{Isobutylene ppm} \times \frac{PS(Isob)}{PS(Benzene)}$$

$$= 100 \times \frac{7.0}{10.0}$$

$$= 70.0 \text{ ppm}$$

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:

$$= \text{H2S ppm} \times \frac{PS(H2S)}{PS(Isob)}$$

$$= 60 \times \frac{2.8}{7.0}$$

$$= 24.0 \text{ ppm}$$

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.

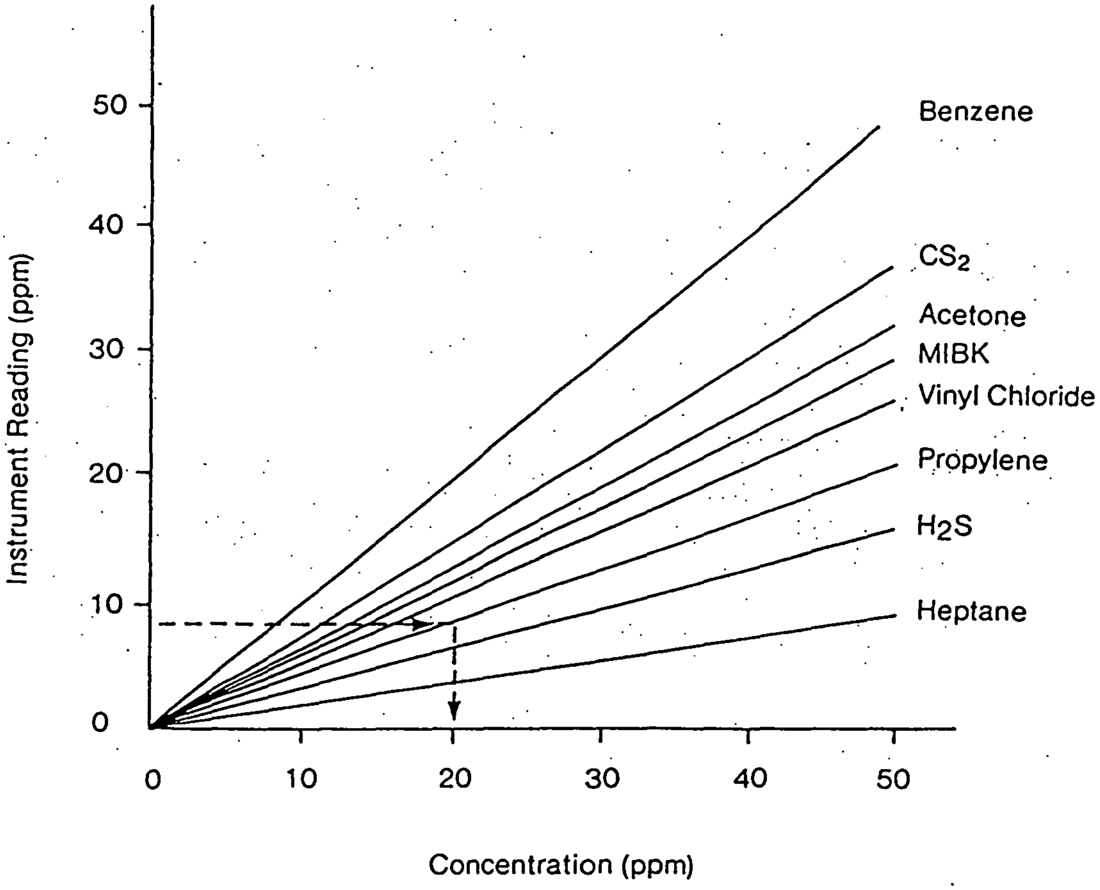


FIGURE 8-2
TYPICAL OUTPUT CURVES –
ANALYZER WITH 10.2 eV LAMP
CALIBRATED FOR BENZENE

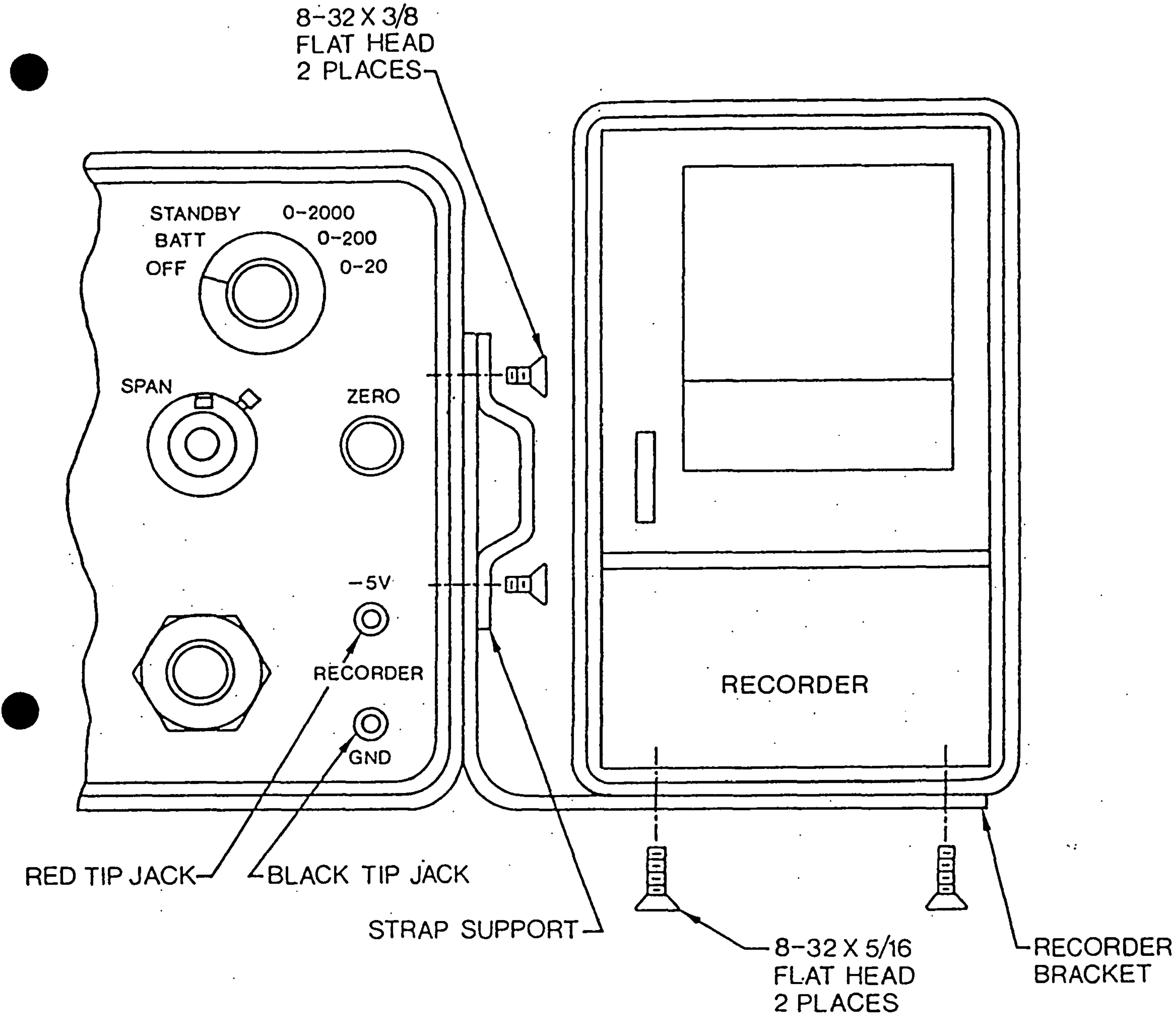


FIGURE 8-3
RECORDER MOUNTING

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
Si	8.149	HI	10.38
S	10.357	SO_2	12.34
F	17.42	CO_2	13.79
Cl	13.01	COS	11.18
Br	11.84	CS_2	10.08
I	10.48	N_2O	12.90
H_2	15.426	NO_2	9.78
N_2	15.580	O_3	12.80
O_2	12.075	H_2O	12.59
CO	14.01	H_2S	10.46
CN	15.13	H_2Se	9.88
NO	9.25	H_2Te	9.14
CH	11.1	HCN	13.91
OH	13.18	C_2N_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	9.86
cyclopropane	10.06
cyclopentane	10.53
cyclohexane	9.88
methylcyclohexane	9.85

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
tribomomethane	10.51
CH_2BrCl	10.77
$CHBr_2Cl$	10.59
ethyl bromide	10.29
1,1-dibromoethane	10.19
1-bromo-2-chloroethane	10.63
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_2Cl_2(Freon 12)	12.31
CF_3Cl (Freon 13)	12.91
$CHClF_2$ (Freon 22)	12.45
$CFBr_3$	10.67

TABLE 8.3 (continued)

Molecule	IP (eV)
CF_2Br_2	11.07
CH_3CF_2Cl (Genetron 101)	11.98
$CFCl_2CF_2Cl$	11.99
CF_3CCl_3 (Freon 113)	11.78
$CFHBrCH_2Br$	10.75
CF_2BrCH_2Br	10.83
CF_3CH_2I	10.00
n-C_3F_7I	10.36
n-$C_3F_7CH_2Cl$	11.84
n-$C_3F_7CH_2I$	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
di-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 i-propyl ketone	9.32
diethyl ketone	9.32
methyl n-butyl ketone	9.34
methyl i-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-cinylcylohexene	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
$CF_3CCl{=}CClCF_3$	10.36
$n\text{-}C_5F_{11}CF{=}CF_2$	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	8.68
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
α-methyl styrene	8.35
ethynylbenzene	8.815
napthalene	8.12
1-methylnapthalene	7.69
2-methylnapthalene	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
thiolacetic acid	10.00
acetyl chloride	11.02
acetyl bromide	10.55
cyclo-$C_6H_{11}CF_3$	10.46
$(n\text{-}C_3F_7)(CH_3)C{=}0$	10.58
trichlorovinylsilane	10.79
$(C_2F_5)_3N$	11.7
isoprene	9.08
phosgene	11.77

TABLE 8-14

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)	9.8
toluene	10.0	
diethyl sulfide	10.0	
diethyl amine	9.9	
styrene	9.7	
trichloroethylene	8.9	8.2
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 8-14 cont.

dimethyl sulfide	4.3	
allyl alcohol	4.2	
propylene	4.0	3.5
mineral spirits	4.0	
2, 3-dichloropropene	4.0	
cycloexene	3.4	
crotonaldehyde	3.1	
acrolein	3.1	
methyl methacrylate	3.0	2.4
pyridine	3.0	
hydrogen sulfide	2.8	
ethylene dibromide	2.7	1.9
n-octane	2.5	
acetaldehyde oxime	2.3	
hexane	2.2	
phosphine	2.0	
heptane	1.7	
allyl chloride (3-chloropropene)	1.5	
ethylene	1.0	
isopropanol	1.0	0.1
ethylene oxide	1.0	
acetic anhydride	1.0	
alpha pinene	0.7	
dibromochloropropane	0.7	

TABLE 8-14 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: PPM reading when measuring 10.0 ppm of particular gas with monitor calibrated for benzene.

TABLE 8-15

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	33.8	
Heptane	22.1	
Hexane	18.9	
Pentane	14.1	
1,2 Dichloroethane	12.9	
Benzene	12.2	5.0
MIBK	10.6	
Isobutylene	10.0 (Reference Std.)	
Toluene	10.0	
Methyl Chloride	9.8	
Methylene Chloride	9.4	
111 Trichloroethane	9.0	
Carbon Tetrachloride	9.0	
Ethylene Dichloride	9.0	
Butane	8.7	
THF	7.9	
Acrylonitrile	7.1	2.0
MEK	6.3	
Chloroform	6.0	
1,1,2,2 Tetrachloroethane	6.0	
Acetone	5.7	
Propane	5.5	
Isoproponol	4.5	
Acrolein	3.4	1.0
Ethane	3.0	
Ethanol	3.0	
Methanol	1.0	
1,1,2 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.)
Xylene	11.2	
Benzene	10.0 (Reference Std.)	1.0
Styrene	10.0	
Toluene	10.0	
Phenol	7.7	
Aniline	3.9	
MEK	2.9	
Pyridine	2.2	
Acetone	0.65	
Methyl Methacrylate	<0.6*	
Heptane	<0.2*	
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.

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.

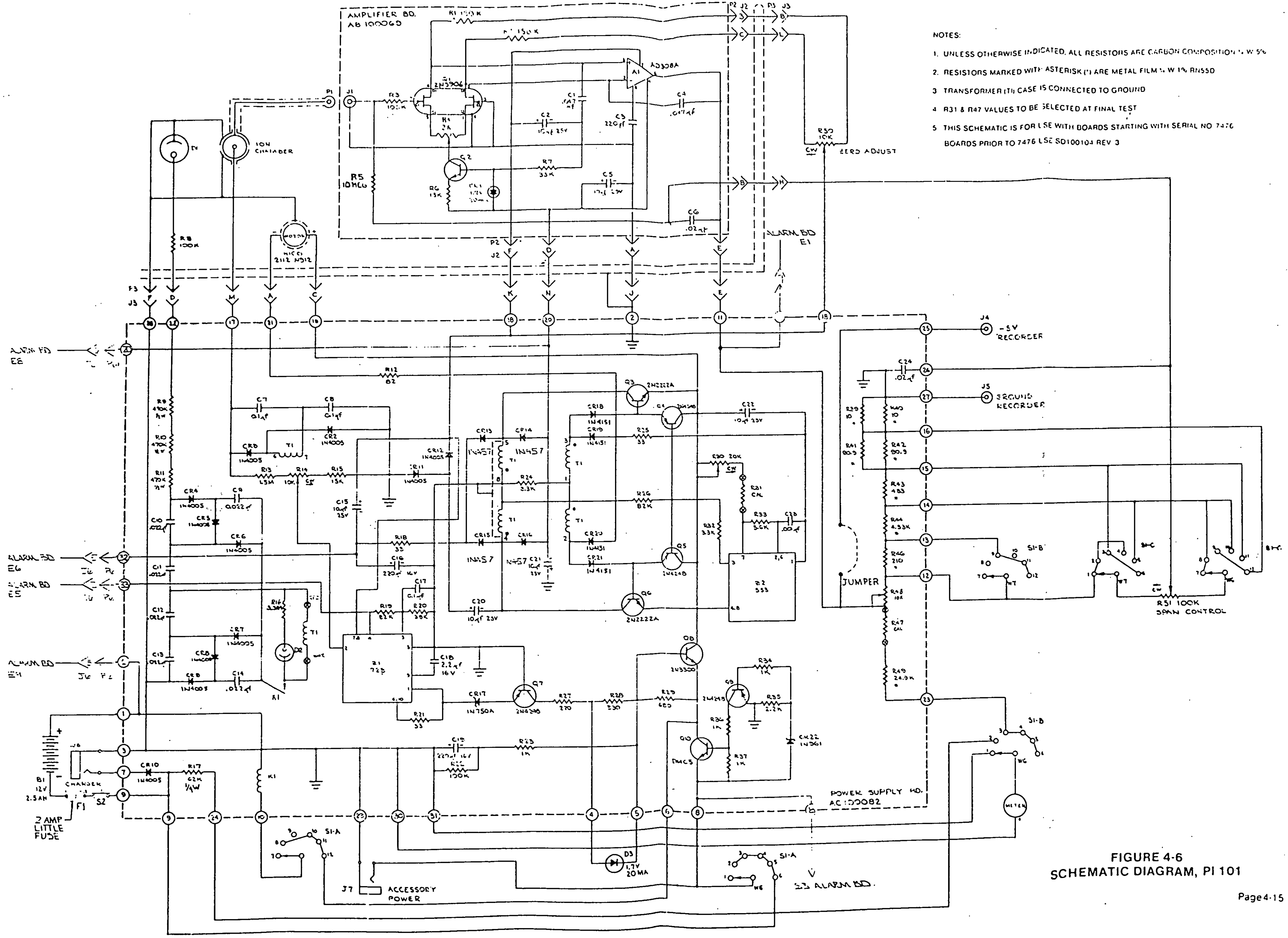
THE FOREGOING IS THE SOLE EXTENT OF HNU'S WARRANTY AND NO OTHER STATEMENTS OR WARRANTIES, EXPRESSED OR IMPLIED, SHALL BE HONORED. UNDER NO CIRCUMSTANCES SHALL HNU BE SUBJECT TO ANY LIABILITY FOR SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES.

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.



NOTES:

1. UNLESS OTHERWISE INDICATED, ALL RESISTORS ARE CARBON COMPOSITION ¼ W 5%
2. RESISTORS MARKED WITH ASTERISK (*) ARE METAL FILM ¼ W 1% RN55D
3. TRANSFORMER (T1) CASE IS CONNECTED TO GROUND
4. R31 & R47 VALUES TO BE SELECTED AT FINAL TEST
5. THIS SCHEMATIC IS FOR USE WITH BOARDS STARTING WITH SERIAL NO 7476
   BOARDS PRIOR TO 7476 USE SD100104 REV 3

FIGURE 4-6
SCHEMATIC DIAGRAM, PI 101

FIELD FILTER OPERATIONS MANUAL

Hydro-Search, Inc.

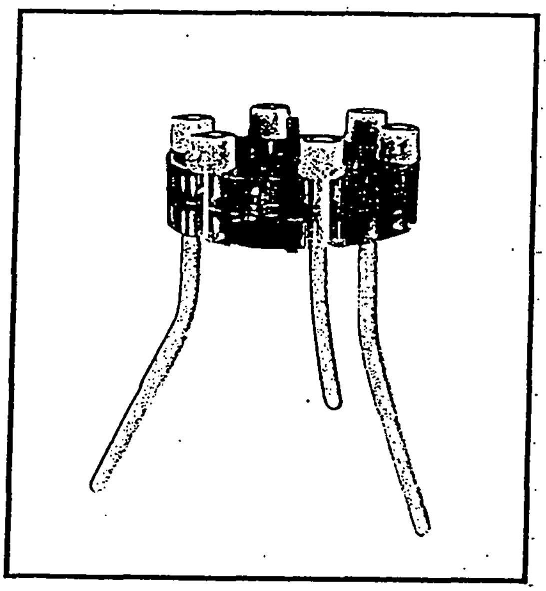
HYDROLOGISTS · GEOLOGISTS · ENGINEERS

geotech

BACKFLUSHING FILTER HOLDERS

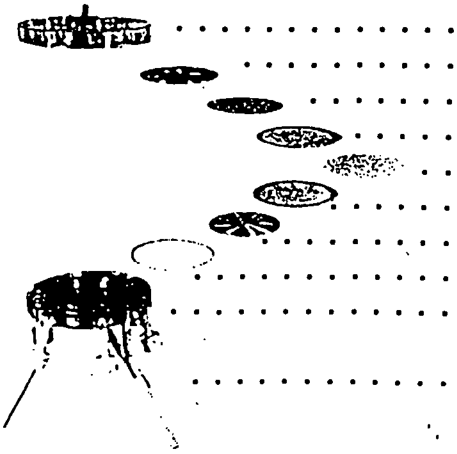
DESCRIPTION

The Geotech filter holders are designed for rapid filtration of water samples at field sites. The filtrate is then suitable for analysis, not only of major constituents, but also of trace elements at the microgram-per-liter level. The backflushing feature reduces the time required for filtration and prolongs the life of the filter membranes. These units, made of polycarbonate or acrylic, are durable, light weight, and easy to operate.



The Geotech 116V AC, 12V DC, or hand-operated peristaltic pumps are designed specifically to backflush and pressurize the water through the filter holders without cross contamination.

PARTS BREAKDOWN

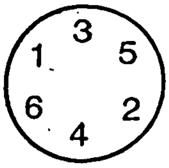


- Top Plate
- Sample Disbursement Disc
- Glass Fiber Prefilter
- Filter Support Screen
- 0.45um Membrane Filter
- Filter Support Screen
- Sample Disbursement Disc
- Silicon "O" Ring
- Bottom Plate with six (6) swing-a-way Nut and Bolt Assemblies
- Tripod legs

GEOTECH ENVIRONMENTAL EQUIPMENT INC.
1441 WEST 46th AVE., UNIT 17 DENVER, CO 80211 303/433-7101

ASSEMBLY INSTRUCTIONS

1. Place the "O" ring into the bottom plate "O" ring groove.
2. Insert disbursement disc into bottom plate center pin down, circular grooves up, flush with surface of plate.
3. Lay filter support screen on disbursement plate, nest inside alignment pins, stepped edge side down.
4. Lay filter media on support screen, center.
5. Lay filter support screen on top of filter media, stepped edge side up.
6. If a prefilter is used, center it on the filter support screen.
7. Insert disbursement disc into top plate, center pin up, circular grooves down.
8. Place top plate over assembled filter parts, check to see that alignment pins are engaged.
9. Swing clamping discs into place.
10. Tighten the nuts directly opposite each other (as illustrated) half way, i.e., 1 & 2, 3 & 4, 5 & 6 pattern. Then, by hand following the same pattern, complete tightening.



Following this pattern will assure proper seal.

11. Connect the tubing to the top plate hose barb fitting, it is recommended that a hose clamp be used for higher operating pressures.
12. When you begin pressurizing the sample through the unit, the air trapped inside must be release for maximum filtration. There is a small ball valve located in the top plate for this purpose. Simply hold the ball down with a small object until all of the air is released.

The optimum pressure for filtration with a filter membrane of .45 umpore size is 7 - 15 psi. Maximum operating pressure should not exceed 25 psi.

142mm FILTER HOLDERS

DESCRIPTION

The Geotech filter holders are designed for rapid filtration of water samples at field sites. The filtrate is then suitable for analysis, not only of major constituents, but also of trace elements at the microgram-per-liter level. The backflushing feature reduces the time required for filtration and prolongs the life of the filter media. These units, made of polycarbonate or acrylic are durable, lightweight, and easy to operate.

PARTS BREAKDOWN (in chronological order)

Top Plate
Sample Disbursement Disc
Glass Fiber Prefilter (if used)
Filter Support Screen
0.45um Membrane (will accept other pore sizes)
Filter Support Screen
Sample Disbursement Disc
Silicon "O" Ring
Bottom Plate with six swing-a-way nut & bolt assemblies
Tripod Legs

ASSEMBLY INSTRUCTIONS

1. Place the "O" ring into the bottom plate "O" ring grove.

2. Insert disbursement disc into bottom plate center pin down, circular grooves up, flush with surface of plate.

3. Lay filter support screen on disbursemnt plate, nest inside alignment pins, stepped edge down.

4. Lay filter media on support screen, center.

5. Lay filter support screen on top of filter media, stepped edge up.

6. If a prefilter is used, center it on the filter support screen.

7. Insert disbursement disc into top plate, center pin up, circular grooves down.

8. Place top plate over assembled filter parts, check to see that alignment pins are engaged, swing clamping bolts into place

10. By hand, tighten the nuts directly opposite each other half way. Then, following the same pattern, complete tightening. Following this pattern will assure a proper seal.

11. Connect the tubing to the top plate hose barb fitting, it is recommended that a hose clamp be used for higher operating pressures.

12. When you begin pressurizing the sample through the unit, the air trapped inside must be released for maximum filtration. There is a manual air release "T" valve in the top plate, turn counter clockwise to release air.

The optimum pressure for filtration with a filter membrane of 0.45um pore size is 7 - 10 psi. Maximum operating pressure should not exceed 25 psi.

APPENDIX D

SWANSON ENVIRONMENTAL, INC. QUALITY ASSURANCE PLAN

Quality Assurance Plan

for

SEI Analytical Laboratories

SWANSON ENVIRONMENTAL INC.

Table of Contents

List of Supplements

INTRODUCTION

The primary function of an analytical laboratory is to provide its clients with accurate and precise data. This goal is achieved by the implementation of a comprehensive and scientifically sound quality assurance program. This program must encompass all aspects of the laboratory's operations from sampling strategy to the final review and issuance of reports. It is a system designed to document and monitor the effectiveness of a quality control program.

Swanson Environmental, Inc. (SEI) adheres to a quality control program that generates analytical data of known and acceptable precision and accuracy.

In this manual, the quality control procedures for the implementation and maintenance of SEI quality assurance programs are defined.

ORGANIZATION AND RESPONSIBILITY

The Quality Assurance Coordinator at SEI is responsible for reviewing and advising on all aspects of the Quality Control program. He/She maintains the program and ensures that it is implemented by all field and laboratory personnel. The QA Coordinator reports to the Chief Executive Officer of Swanson Environmental, Incorporated.

Laboratory Supervisors and Senior Chemists are responsible on a daily basis for verifying that all analyses are performed impartially and in accordance with established methods and quality control procedures. They review all reported analytical results and corresponding quality control data. When discrepancies are found, corrective action procedures are initiated after consultation with the QA Coordinator.

All SEI chemists and technicians are trained professionals responsible for following the appropriate methodology and incorporating the proper type and amount of quality control samples into their daily work.

FIELD QUALITY CONTROL

SEI's Quality Control program begins in the field. An appropriate sampling plan is designed to address both regulatory and scientific objectives. Representative samples are collected that will allow measurements of chemical properties to be both accurate and precise. Sampling strategies from EPA-SW846, Vol. II, are followed in most instances.

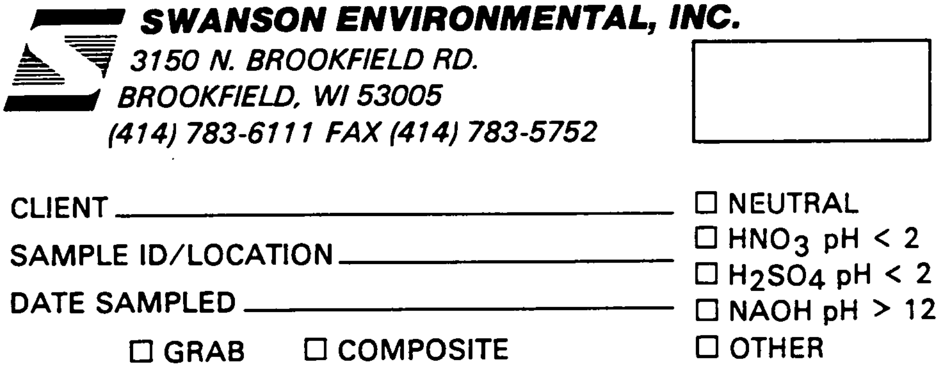
SEI field personnel collect samples using the appropriate equipment and sample containers in accordance with approved procedures (see Appendix C). Quality control samples comprised of trip blanks, field blanks, and field duplicates are included in the sampling plan.

All sample documentation is recorded in a field log book and on a sample container label. In order to document the possession of the samples from the time of collection to their final disposition in the laboratory, a chain of custody record is filled out for each project (see Appendix H, Form I). All persons involved in sample collection, transfer, and receipt are required to sign and date the chain of custody. The samples, along with their corresponding documentation, are then transported to the laboratory in coolers containing ice packs (when appropriate).

Sample Bottles

The type of sample container, sample size, and proper preservative required for a particular analysis are specified in Appendix C. Containers used for metals analyses samples are prepared by rinsing with nitric acid followed by deionized water. Containers used for organic analyses samples are rinsed with hexane followed by acetone, and then air or oven dried. Containers for wet analyses samples are rinsed with deionized water.

All containers have blank labels attached. These labels are to be filled out by the samplers indicating sample location or other identification; whether the sample is a grab or composite; the preservative used, if any; client name; and date sampled (see below).



SWANSON ENVIRONMENTAL, INC.
3150 N. BROOKFIELD RD.
BROOKFIELD, WI 53005
(414) 783-6111 FAX (414) 783-5752

CLIENT ____________________
SAMPLE ID/LOCATION ____________________
DATE SAMPLED ____________________
☐ GRAB ☐ COMPOSITE

☐ NEUTRAL
☐ HNO_3 pH < 2
☐ H_2SO_4 pH < 2
☐ NAOH pH > 12
☐ OTHER

SAMPLE TRACKING

The sample custodian responsible for the receipt, logging, and physical disposition of the samples observes the following procedures:

1. When the samples arrive at the laboratory, a comparison is made between the sample container label, the information on the chain of custody form, and the laboratory project sheet (see Appendix H, Form II). If discrepancies in sample identification or requested analyses exist, the client is contacted for clarification of the situation before the samples are logged in. The chain of custody is signed when verification is made between information on container labels and sample documentation.
2. If the samples are received via next day air, the airbills are attached to the chain of custody form.
3. Each sample is assigned a unique project number corresponding to the individual project and the specific sampling sites in the project. For example, three samples from sampling sites X, Y, and Z are received by SEI from Company A. A project number of SEI–WL 1003 might be assigned to this sampling from Company A. Sample X would be numbered 1003–1, sample Y would be 1003–2, and sample Z would be 1003–3.
4. The assigned SEI project number, number of samples, date of collection, date of arrival, due date, and the analyses to be performed are recorded in the laboratory sample log book (see Appendix H, Form III).
5. The samples are labeled with the project sample number, split and/or filtered, preserved (if necessary), marked as such, and then stored in

their designated location.

6. A note is made on the chain of custody form indicating the size and type of container used for the sample, the condition of the container, and where the containers are being stored.
7. Any unusual conditions of the sample, such as leakage, improper container, improper sample preservation, or air bubbles in samples for volatiles analyses are also noted on the chain of custody form.
8. A corresponding laboratory worksheet indicating the client, the sample identity, the SEI-WL project numbers, and the requested analyses to be performed on each sample is completed (see Appendix H, Forms IV-VI).
9. A file folder containing the chain of custody form, the laboratory project sheet, and the laboratory worksheets is labeled with the project number, the client's name, the sample's arrival date, and the project due date.
10. The analysts are then notified of the analyses to be performed and other pertinent information.

This information is also entered into a computer log. Project progress reports are issued tri-weekly. Samples for which a typed report has been issued are stored on the premises for a period of thirty days. Following that thirty day period, the samples are disposed of properly.

QUALITY ASSURANCE

The purpose of the Quality Control analytical program is to continually monitor the scientific reliability (accuracy and precision) of reported laboratory data, detect errors, and prevent their recurrence. Quality Control starts with the basic operation and organization of the analytical laboratory.

Swanson Environmental is divided into three sections: wet, metals, and organics. For a physical layout of the laboratory, see Appendix H, Exhibit A.

Laboratory Water

The metals and wet area use ASTM Type II water prepared through a reverse osmosis-deionization system. The organics area uses low organic content water prepared through a separate reverse osmosis-deionization, and organic clean up system. Water is checked daily for conductivity and yearly for all Type II specifications.

Glassware

Class A volumetric ware is used in the laboratory. Etched, chipped or otherwise compromised glassware is disposed of when encountered by either the dishwasher or analysts.

Glassware is sorted into three categories for washing: wet, metals, and organics. Dishwashing procedures are detailed in Appendix B.

Reagents, Chemicals, Solvents, and Gases

All reagents and chemicals are dated upon receipt in the laboratory and stored in designated areas. Only specified grades of chemicals, solvents, and gases are used (i.e. trace-pure acids for metal digestions, low residue solvents for organic extractions, etc.).

Instrument Calibration and Maintenance

All instruments used by SEI to perform approved methodology meet or exceed that methodology's minimum specifications. Instruments are upgraded periodically through the addition of data handling stations, autosamplers, etc. in order to improve the level of detection of the analyte and the speed with which data are generated.

The working calibration curves are verified on each working day by measurement of one or more calibration standards. A known standard is run and checked against the calibration curve. Corrective action procedures are initiated when the calibration curve is not verified.

All SEI analysts are trained in proper instrument set up and alignment. Routine maintenance is performed on all instruments. Major repairs are made by the manufacturer's qualified technical service representative.

Inter-Laboratory Quality Control

SEI participates in the EPA Water Supply Laboratory Performance Evaluation Studies, the EPA Water Pollution Laboratory Performance Evaluation Studies, the DNR Environmental Reference Sample Program (NR149), the NIOSH PAT program, and the Chemical Waste Management Round Robin program.

We are currently certified by the DNR for NR149 analytes in all categories (Certification #2681817060). SEI is also certified by AIHA (Certification #352).

Samples are periodically exchanged with other certified laboratories for comparison analysis.

Methodology

SEI uses only approved analytical methods as specified by the EPA, NIOSH, OSHA, and ASTM (See Appendix D). Reference materials containing these approved methods can be found in SEI's Library and in easily accessible manuals at each analyst's station.

The limit of detection (LOD) and limit of quantitation (LOQ) of a specific analysis depend on the method used, the sample matrix, and the concentration of the analyte.

QUALITY CONTROL

To insure the accuracy and precision of data generated by approved methods, the following procedures are performed on a routine basis:

1. A reagent blank is carried through the entire analytical procedure, where appropriate.
2. When applicable, calibration curves are prepared. A calibration curve must consist of three or more concentrations of the analyte. Curves are set up daily on the Atomic Absorption Spectrometer and the Inductively Coupled Plasma Atomic Emission Spectrometer. In wet chemistry, one standard is run to check the existing curve. In this case the curve is verified if the check standard is within 10% of its "true value". For organic analyses, a check standard is run to verify the curve; values must be within 15% of the "true value". New curves are calibrated whenever new reagents are used, or at a minimum of every six months, whichever comes first. In long sample runs, a check standard is also run every ten samples. These check standards are included to make sure that the instrument is not drifting during the analysis.
3. EPA QC samples are analyzed to determine the accuracy of the method and the instrument used. This occurs at least four times per year.
4. Ten percent of all samples are analyzed in duplicate to determine precision.
5. Five percent of all samples are spiked with a known concentration of the analyte to determine accuracy.
6. For GC (gas chromatographic) and GC/MS (gas chromatographic/mass

spectrometric) determinations of specific analytes, the mass spectra, response factors, and retention times are compared to those of known standards.

7. Surrogate spikes are used to determine efficiency of recovery in GC/MS analysis.
8. When hard to analyze matrices are to be tested, the method of standard additions is used.

The Quality Control data is entered into a computer data base. The standard, spike, and duplicate data are charted on previously determined limits to produce Quality Control charts. Chemically similar analytes may be grouped together. These charts are a means of checking on whether an analysis is in or out of quality control.

Standards and spikes are used to measure accuracy. They are traditionally graphed on P-bar charts. The following formulas are used for calculating standard and spike recoveries:

% Recovery of Standards $$P = 100 \frac{\text{(observed)}}{\text{(known)}}$$

% Recovery of Spikes $$P_s = 100 \frac{\text{(observed)} - \text{(sample)}}{\text{(spike)}}$$

Where P = the percent recovery of a standard
P_s = the percent recovery of a spike

For the standards quality control charts, the individual P values are graphed on limits determined by the DNR under NR149: 100±10 percent recovery for inorganic parameters and 100±15 percent recovery for organic parameters.

The situation for the P-bar quality control charts for spikes is more complicated. The warning limits are defined as P-bar $\pm 2S_p$ and the control limits as P-bar $\pm 3S_p$.

The standard deviation of the percent recovery S_p is calculated as follows:

$$\text{Standard Deviation } S_p = \left(\frac{\sum_{i=1}^{n} P_i^2 - [(\sum_{i=1}^{n} P_i)^2]/n}{n-1} \right)^{1/2}$$

For $n < 25$ use the above formula
For $n > 25$ use n instead of $n-1$ in the above formula

Where S_p = the standard deviation of the percent recovery
P_i = the individual percent recoveries
n = the number of spikes

Duplicate analyses measure precision. The control chart for precision is quite different than that for accuracy. SEI uses a range (R-bar) chart for duplicates. The upper warning limit (UWL) is generated from the following equation:

$$UWL = \bar{R} + 2S_e$$

Where R-bar ($\bar{R}$) = the average of the absolute value of the range of the duplicates

$S_e = (1/1.13)\bar{R}$ = the estimated standard deviation of the range

The upper control limit (UCL) is generated from the following equation:

$$UCL = 3.27\bar{R}$$

There are no lower control limits for this type of chart as the range is always zero or a positive number. Examples of a standard, duplicate, and spike control chart can be found in Appendix E.

Corrective Action Procedures

When an out of control situation occurs (the control limits are exceeded), corrective action must be taken. The essential steps in the corrective action system are:

1. Identification and definition of the problem.
2. Assignment of responsibility for investigating the problem.
3. Investigation and determination of the cause of the problem.
4. Determination of a corrective action to eliminate the problem.
5. Assigning and accepting responsibility for implementing the corrective action.
6. Implementing the corrective action and evaluating its effectiveness.
7. Verifying that the corrective action has eliminated the problem.

These events are coordinated between the analyst involved, the senior analyst, and the QA Coordinator.

DATA REPORTING

Upon completion of an analysis, the analyst reports the result on the laboratory worksheet. The analyst's initials, the date of the analysis, and his or her notebook number and page are also reported with the results. In compliance with the criteria for the Quality Control program at SEI, a Quality Control data sheet is completed when the analyst's results are entered. (See Appendix F for Quality Control data sheets.) All data generated by SEI analysts are recorded in traceable, bound and numbered laboratory notebooks containing numbered pages. All completed laboratory worksheets are reviewed by a laboratory supervisor to check for obvious errors. The data recorded on laboratory QC Sheets are entered in the computer data base for further manipulation, charting, and storage.

The completed project file is forwarded to data processing for the issuance of the final typed report. Reports may be issued to the client in a typed form or on a computer disk. A copy of the analytical report is placed in the confidential client project file. The entire file is retained at SEI for a period of three years.

Appendix A

Glossary of Terminology

Accreditation--A formal process by which a laboratory is evaluated, with respect to established criteria, for its competence to perform a specified kind(s) of measurement. Also, the decision based upon such a process. When a certificate is issued, the process is often called certification.

Accuracy--The degree of agreement of a measured value with the true or expected value of the quantity of concern.

Analyte--The specific component measured in a chemical analysis.

Blank--A process in which laboratory water is carried through the entire method with a group of samples. The value obtained corrects for reagent and glassware contamination as well as certain chemical interactions.

Blind sample--A sample submitted for analysis whose composition is known to the submitter but unknown to the analyst. A blind sample is one way to test the proficiency of a measurement process.

Bias--A systematic error inherent in a method that causes the measured values to deviate from the "true value". Temperature effects and extraction inefficiencies are examples of the first kind of bias. Blanks, contamination, mechanical losses, and calibration errors are examples of the latter kinds. Bias may be positive or negative, and several kinds can exist concurrently, so only net bias can be evaluated except under certain conditions.

Calibration--A process in which the relationship between an instrument's response and a known concentration of an analyte is determined.

Check Standard--A known concentration of analyte which is used to verify a previous calibration. This insures that conditions affecting the instrument have not changed since the previous calibration.

Composite sample--A sample consisting of aliquots sampled at intervals related to time or the flow of the sampling stream.

Confidence interval--That range of values, calculated from an estimate of the mean and the standard deviation, which is expected to include the population of the mean with a stated level of confidence. Confidence intervals in the same context may also be calculated for standard deviations, lines, slopes, and points.

Control chart--A graphical plot of test results with respect to time or sequence of measurement, together with limits within which they are expected to lie when the system is in a state of statistical control.

Control limit--The limits shown on a control chart beyond which it is highly improbable that a point could lie while the system remains in a state of statistical control.

Duplicate measurement--A second measurement made on a different aliquot of a sample to assist in the evaluation of precision.

Limit of detection (LOD)--The smallest concentration and/or amount of the component of interest that can be measured by a single measurement with a stated level of confidence.

Limit of quantitation (LOQ)--The lower limit of concentration or amount of substance that must be present before a method is considered to provide quantitative results. By convention, $LOQ = 10s_0$, where s_0 is the estimate of the standard deviation at the lowest level of measurement.

Outlier--A value which appears to deviate markedly from that of other values for the sample.

Precision--The degree of agreement between two or more independent measurements of the same property or parameter in a sample. It is concerned with the closeness of results.

Primary standard--A substance whose value can be accepted (within specific limits) without question when used to establish the value of the same or related property of another material.

Quality assessment--The overall system of activities whose purpose is to provide assurance that the quality control activities are done effectively. It involves a continuing evaluation of performance of the production system and the quality of the products produced.

Quality assurance--A system of activities whose purpose is to provide to the producer or user of a service the assurance that it meets defined standards of quality. It consists of two separate but related activities, quality control and quality assessment.

Quality control--The overall system of activities whose purpose is to control the quality of a product or service so that it meets the needs of users. The aim is to provide quality that is satisfactory, adequate, dependable, and economical.

Reference material (RM)--A material or substance, one or more properties of which are sufficiently well established to be used for the calibration of an apparatus, the assessment of a measurement method, or for the assignment of values to materials.

Relative standard deviation--The ratio of the standard deviation to the mean, expressed as a percentage.

Sensitivity--The ration of the change in response to the quantity measured.

Standard--A solid or solution with a known concentration of analyte used to establish a calibration curve or the analytical function of an instrument.

Standardization--The process whereby the value of a solution is determined by measurement with respect to a primary standard.

Standard addition--An analytical technique used with samples of strange matrix. Small increments of the analyte are added to a sample. This solution as well as a blank are analyzed. Response is plotted against added analyte and extrapolated to determine the concentration in the sample.

Standard method--A method (or procedure) developed by a standards-writing organization, based on consensus opinion or other criteria and often evaluated for its reliability by a collaborative testing procedure.

Warning limits--The limits shown on a control chart within which most of the test results are expected to lie (within a 95% probability) while the system remains in a state of statistical control.

Appendix B

Dishwashing Procedures

General

1. Remove all glassware from the tubs; rinse each piece with tap water and place it in a tub of hot (non-phosphorous containing) soapy water.
2. Brush each piece clean.
3. For difficult stains, soak the glassware with the dichromate cleaning solution, solvents, nitric acid, or hydrochloric acid, and rewash with hot soapy water.
4. Rinse the glassware thoroughly with tap water followed by at least three rinses of deionized water.
5. Invert the glassware on tiered racks or counters to air dry.
6. Store the glassware in its designated cupboards.

Metals

Metals glassware is marked with either M or MF, and should include the necessary number of watch glasses and glass stoppers.

1. Follow the general cleaning procedures.
2. Soak the glassware in a tub containing 10% nitric acid for several hours.
3. Remove the glassware from the tub and thoroughly rinse it with deionized water.
4. Invert the glassware on tiered racks or counters to air dry.
5. Store the glassware in its designated cupboards.

Organics

1. All glassware should soak in soapy water for several hours before following the general washing procedures.
2. Under a fume hood, rinse the glassware with hexane followed by acetone. Collect the rinses in the container provided and discard the waste solvents in the solvent waste collection can.
3. Place the glassware in a designated oven for several hours to dry.
4. Store as directed by organics personnel.

BOD Bottles - marked as such

1. NEVER USE SOAP.
2. Rinse the bottles with tap water.
3. Add approximately 300 ml of dichromate cleaning solution to each bottle, and let it soak for a few minutes.
4. Drain the dichromate solution from the BOD bottles and thoroughly rinse them with hot tap water.
5. Rinse the bottles at least three times with deionized water.
6. Invert the bottles to drain and dry.
7. Store in designated cupboard.

Mercury Bottles - marked as such

1. Rinse the bottles with tap water.
2. Brush the bottles with hot soapy water.
3. Rinse the bottles with tap water followed by several rinsings of deionized water.
4. Rinse the bottles with 10% nitric acid followed by deionized water.
5. Shake out the excess water and cap the bottles.
6. Place the bottles on a designated cart.

Sample Container Cleaning and Preparation Procedures

Used Containers and Caps

1. Wash the containers and the caps in hot soapy water.
2. Remove any labels or markings, using acetone and/or hexane if necessary.
3. Rinse the containers and the caps thoroughly with hot tap water. Be sure to get all the soap out.
4. Rinse the containers and caps thoroughly with at least three rinses of deionized water.
5. Continue with the appropriate New Container Procedure.

New Containers

A. Metals

Containers may be either glass or plastic. Teflon lined caps are not required.

1. Rinse the containers and caps thoroughly with at least three rinses of deionized water.
2. Rinse the containers and the caps with 20% nitric acid, being sure that all surfaces come in contact with the acid.
3. Rinse the containers and caps thoroughly with at least three rinses of deionized water.

4. Invert the containers and the caps. Let them air dry.

5. When the containers and the caps are dry, screw on the caps, put a label on the bottle, place an X in the nitric acid box on the label, and then place the prepared container in the designated storage area.

B. Wet

Plastic and glass containers are used. The caps for plastic containers do not need to be Teflon lined. The caps for glass containers must be Teflon lined.

1. Rinse the containers and caps thoroughly with at least three rinses of deionized water.
2. Invert the containers and the caps. Let them air dry.
3. When the containers and the caps are dry, screw on the caps, put a label on the bottle, and then place the prepared container in the designated storage area.

C. Wastes to be shared between metals, wet, and possibly organics

Should be a glass container. If the sample has organic parameters, the cap must be Teflon lined.

1. Rinse the containers and caps thoroughly with at least three rinses of deionized water.
2. Invert the containers and the caps. Let them air dry.

3. When the containers and the caps are dry, screw on the caps, put a label on the bottle, and then place the prepared container in the designated storage area.

D. VOA

Special glass VOA vial with Teflon coated septum.

1. Rinse the vials, septa, and cap rings thoroughly with at least three rinses of deionized water.
2. Rinse the vials and septa with acetone.
3. Dry the vials in an oven. Air dry the septa and cap rings.
4. Assemble the vials, septa, and cap rings. Be sure that the Teflon surface faces the sample. Place a label on the vial and store it in the designated location.

E. Organics

Amber glass bottles with Teflon lined caps.

1. Rinse the containers and caps thoroughly with at least three rinses of deionized water.
2. Rinse the bottles and caps with hexane followed by acetone.
3. Invert the containers and the caps. Let them air dry or place them in a vented drying oven.
4. When the containers and the caps are dry, screw on the caps, put a

label on the bottle, and then place the prepared container in the designated storage area.

F. Soil Jars for TPH

Small glass containers with Teflon lined caps.

1. Rinse the containers and caps thoroughly with at least three rinses of deionized water.
2. Rinse the containers and the caps with acetone.
3. Dry the containers in a vented oven. Air dry the caps.
4. When the containers and the caps are dry, screw on the caps, put a label on the bottle, and then place the prepared container in the designated storage area.

Appendix C

SUMMARY of SAMPLE MANAGEMENT PROCEDURES for WET CHEMISTRY

Parameter	Container[a]	Preservation[b]	Holding Time	Minimum Sample (ml)
Acidity	P,G	1	14 days	100
Alkalinity	P,G	1	14 days	200
BOD	P,G	1	2 days	1000
Bromide	P,G	6	28 days	–
Chloride	P,G	6	28 days	250
Chlorine, Total	P,G	6	on site	500
COD	P,G	3	28 days	100
Color	P,G	1	2 days	500
Conductivity	P,G	1	28 days	500
Cyanide, Amenable	P,G	4	14 days	500
Cyanide, Total	P,G	4	14 days	500
Flash Point	G	6		
Fluoride, Total	P	6	28 days	300
Hardness, Total	P,G	2	6 months	100
Nitrogen, Ammonia	P,G	3	28 days	500
Nitrogen, Kjeldahl	P,G	3	28 days	500
Nitrogen, Nitrate	P,G	1	28 days	250
Nitrogen, Nitrate and Nitrite	P,G	3	28 days	200
Nitrogen, Nitrite	P,G	1	2 days	100
Oil & Grease	G	3	28 days	1000
pH	P,G	6	on site	–
Phenols	G	3	28 days	500
Phosphorous, Ortho	P,G	1	2 days	100
Phosphorous, Total	P,G	3	28 days	100
Silica, Dissolved	P	1	28 days	–
Solids, Total	P,G	1	7 days	–
Solids, Total Dissolved	P,G	1	2 days	–
Solids, Total Suspended	P,G	1	7 days	–
Sulfate	P,G	1	28 days	250
Sulfide	P,G	5	7 days	100
Sulfite	P,G	6	on site	–
Surfactants (MBAS)	P,G	1	2 days	500
Total Organic Carbon (TOC)	P,G	3	28 days	100
Total Organic Halides (TOX)	G	2	14 days	200
Total Petroleum Hydrocarbons	G	3	28 days	150
Turbidity	P,G	1	2 days	–
Volatiles, Total	G	1	7 days	40

a – P – Plastic; G – Glass

b – except for code 6, all samples are to be stored at 4°C

1 – Store at 4°C	4 – NaOH pH>12
2 – HNO_3 pH<2	5 – ZnAcetate + NaOH, pH>9
3 – H_2SO_4 pH<2	6 – None

SUMMARY of SAMPLE MANAGEMENT PROCEDURES for METALS

Parameter	Container[a]	Preservation[b]	Holding Time	Minimum Sample (ml)
Metals, General	P,G	2	6 months	250
Chromium, Hexavalent	P,G	1	24 hours	300
Mercury	P,G	2	28 days	500

a - P - Plastic; G - Glass
b - Preservation:
1 - Store at 4°C
2 - HNO_3 pH<2

SUMMARY of SAMPLE MANAGEMENT PROCEDURES for ORGANICS

Parameter	Container[a]	Preservation[b]	Holding Time	Minimum Sample (ml)
Aromatic Volatiles	G (2 Vials)	1	14 days	40
Chlorinated Herbicides	G	1	7 days * 40 Days **	1000
Extractable Organics	G	1	7 days * 40 Days **	1000
Halogenated Volatiles	G (2 Vials)	1	14 days	40
Non-Halogenated Volatiles	G	1	14 days	40
Organochlorine Pesticides/PCBs	G	1	7 days * 40 Days **	1000
Organophosphorous Pesticides	G	1	7 days * 40 Days **	1000
Volatile Organics	G (2 Vials)	1	14 days	40

a - P - Plastic; G - Glass
b - except for code 6, all samples are to be stored at 4°C
1 - Store at 4°C
2 - HNO_3 pH<2
3 - H_2SO_4 pH<2
4 - NaOH pH>12
5 - ZnAcetate + NaOH, pH>9
6 - None
* - Pre-Extraction
** - Post-Extraction

Appendix D

LIST of APPROVED ANALYTICAL METHODS for METALS

Parameter	Methodology	EPA[1]	SW846[2]	SM[3]
Metals				
	ICP, Emission	200.7	6010	305
Aluminum				
	AA, Direct Aspiration	202.1	7020	303C
	AA, Furnace	202.2		304
Antimony				
	AA, Direct Aspiration	204.1	7040	303A
	AA, Furnace	204.2	7041	304
Arsenic				
	AA, Furnace	206.2	7060	304
	AA, Hydride	206.3	7061	303E
Barium				
	AA, Direct Aspiration	208.1	7080	303C
	AA, Furnace	208.2		304
Beryllium				
	AA, Direct Aspiration	210.1	7090	303C
	AA, Furnace	210.2	7091	304
Boron				
	ICP, Emission	200.7	6010	305
Cadmium				
	AA, Direct Aspiration	213.1	7130	303A
	AA, Furnace	213.2	7131	304
Calcium				
	AA, Direct Aspiration	215.1	7140	303A
Chromium, Hexavalent				
	AA, Chelation, Extraction	218.4		
	Spectrophotometric		7196	312B
Chromium, Total				
	AA, Direct Aspiration	218.1	7190	303A
	AA, Furnace	218.2	7191	304
Cobalt				
	AA, Direct Aspiration	219.1	7200	303A
	AA, Furnace	219.2	7201	304

Parameter	Methodology	EPA[1]	SW846[2]	SM[3]
Copper	AA, Direct Aspiration	220.1	7210	303A
	AA, Furnace	220.2		304
Gold	AA, Direct Aspiration	231.1		303A
	AA, Furnace	231.2		304
Iron	AA, Direct Aspiration	236.1	7380	303A
	AA, Furnace	236.2		304
Lead	AA, Direct Aspiration	239.1	7420	303A
	AA, Furnace	239.2	7421	304
Magnesium	AA, Direct Aspiration	242.1	7450	303A
Manganese	AA, Direct Aspiration	243.1	7460	303A
	AA, Furnace	243.2		304
Mercury	Cold Vapor, Liquids	245.1	7470	303F
	Cold Vapor, Solids	245.5	7471	
Molybdenum	AA, Direct Aspiration	246.1	7480	303C
	AA, Furnace	246.2	7481	304
Nickel	AA, Direct Aspiration	249.1	7520	303A
	AA, Furnace	249.2		304
Potassium	AA, Direct Aspiration	258.1	7610	303A
Selenium	AA, Furnace	270.2	7740	304
	AA, Hydride	270.3	7741	303E
Silicon	AA, Direct Aspiration			303C
Silver	AA, Direct Aspiration	272.1	7760	303A
	AA, Furnace	272.2		304
Sodium	AA, Direct Aspiration	273.1	7770	303A
	AA, Furnace	273.2		304

Parameter	Methodology	EPA[1]	SW846[2]	SM[3]
Strontium				
	AA, Direct Aspiration			303A
Thallium				
	AA, Direct Aspiration	279.1	7840	303A
	AA, Furnace	279.2	7841	304
Tin				
	AA, Direct Aspiration	282.1	7870	303A
	AA, Furnace	282.2	7191	304
Titanium				
	AA, Direct Aspiration	283.1		303C
	AA, Furnace	283.2		304
Vanadium				
	AA, Direct Aspiration	286.1	7910	303C
	AA, Furnace	286.2	7911	304
Zinc				
	AA, Direct Aspiration	289.1	7950	303C
	AA, Furnace	289.2		304

SAMPLE PREPARATION

Description	Methodology	EPA[1]	SW846[2]	SM[3]
Extraction Procedure				
	24 Hour Extraction, CH_3COOH		1310	
Solvent Dissolution				
	MIBK Dissolution		3040	
Total Dissolved Metals				
	0.45µ Filtration	4.1.1		302A
Total Metals, Aqueous				
	HNO_3 Digestion	4.1.3	3010	302D
Total Metals, Recoverable				
	$HCl + HNO_3$ Digestion	4.1.4	3005	302C
Total Metals, Solids				
	$HNO_3 + H_2O_2$ Digestion		3050	

LIST of APPROVED ANALYTICAL METHODS for WET CHEMISTRY

Parameter	Methodology	EPA[1]	SW846[2]	SM[3]
Acidity				
	Titrimetric	305.1		402
Alkalinity				
	Titrimetric	310.1		403
BOD				
	Oxygen Electrode	405.1		507
Bromide				
	Spectrophotometric	405		
Chloride				
	Titrimetric	325.3	9252	407B
Chlorine, Total				
	Spectrophotometric	330.5		408E
COD				
	Titrimetric	410.1-.2		508A
	Spectrophotometric	410.4		508C
Color				
	Colorimetric	110.2		204A
Conductivity				
	Electrometric	120.1	9050	205
Cyanide, Amenable				
	Distillation, Spectrophotometric	335.1	9010	412F
Cyanide, Total				
	Distillation, Spectrophotometric	335.2	9010	412D
Flash Point				
	Closed Cup		1010	
Fluoride, Soluble				
	Spectrophotometric	340.1		413C
	Electrode	340.2		413B
Fluoride, Total				
	Spectrophotometric	340.1		413A&C
	Electrode	340.2		413A&B
Hardness, Total				
	Titrimetric	130.2		314B
	Atomic Absorption	215.1,242.1		314A

Parameter	Methodology	EPA[1]	SW846[2]	SM[3]
Nitrogen, Ammonia				
	Distillation, Titrimetric	350.2		417A&D
	Spectrophotometric	350.2		417B
	Electrode	350.3		417E
Nitrogen, Kjeldahl				
	Block Digestor, Colorimetric	351.2		
	Distillation Titrimetric	351.3		420A,417E
	Digestion, Electrode	351.4		420A,417E
Nitrogen, Nitrate				
	Spectrophotometric	352.1	9200	
Nitrogen, Nitrate and Nitrite				
	Reduction, Spectrophotometric	353.3		418C
Nitrogen, Nitrite				
	Spectrophotometic	354.1		419
Oil & Grease				
	Extraction, Gravimetric	413.1	9070	503A
	Extraction, IR	413.2		503B
pH				
	Electrometric	150.1	9040	423
Phenols				
	Distillation, Spectrophotometric	420.1	9065	510A&B
Phosphorous, Ortho				
	Spectrophotometric	365.2		424F
	Spectrophotometric	365.3		
Phosphorous, Total				
	Spectrophotometric	365.2		424C&F
	Spectrophotometric	365.3		
Silica, Dissolved				
	Spectrophotometric	370.1		425D
Solids, Total				
	Gravimetric, 105°C	160.3		209A
Solids, Total Dissolved				
	Gravimetric, 180°C	160.1		209B

Parameter	Methodology	EPA[1]	SW846[2]	SM[3]
Solids, Total Suspended				
	Gravimetric, 105°C	160.2		209C
Sulfate				
	Turbidimetric	375.4	9038	426C
Sulfide				
	Spectrophotometric	376.1		427C
	Titrimetric	376.1	9030	427D
Sulfite				
	Titrimetric	377.1		428A
Surfactants (MBAS)				
	Spectrophotometric	425.1		512B
Total Organic Carbon (TOC)				
	Combustion/Oxidation-IR	415.1	9060	505A
	UV, Persulfate Oxidation-IR	415.2		505B
Total Organic Halides (TOX)				
	Absorption, Microcoulometric	450.1	9020	506
Total Petroleum Hydrocarbons				
	Extraction, IR	418.1		
Turbidity				
	Nephelometric	180.1		214A
Volatiles, Total				
	Gravimetric, 550°C	160.4		209D

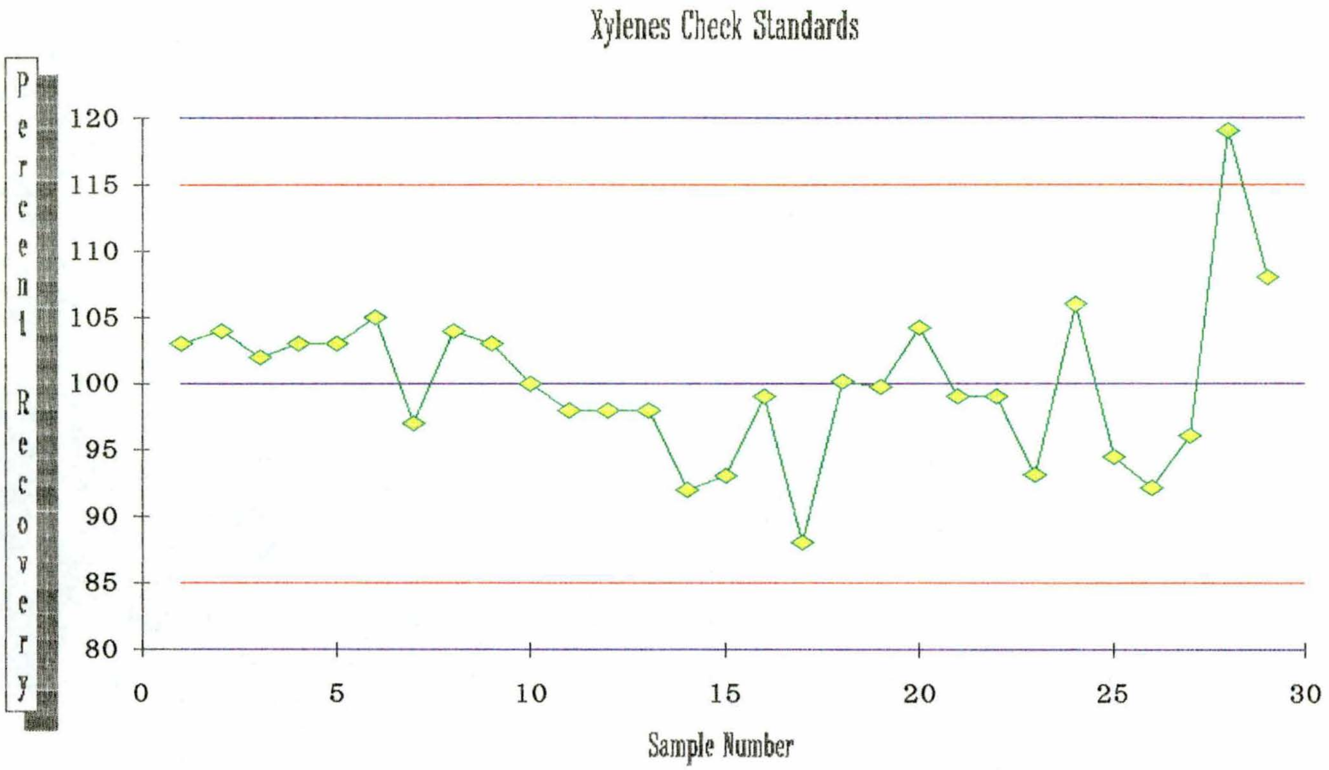
LIST of APPROVED ANALYTICAL METHODS for ORGANICS

Parameter	Methodology	EPA[4]	SW846[2]	SM[3]
Aromatic Volatiles	GC/PID	602/503.1	8020	6220
Chlorinated Herbicides	GC/ECD	na/515	8150	509B
Extractable Organics	GC/MS	625/na	8270	6410
Halogenated Volatiles	GC/HSD	601/502.1	8010	6230
Non-Halogenated Volatiles	GC/FID		8015	
Organochlorine Pesticides/PCBs	GC/ECD	608/505,508	8080	509A,6630
Organophosphorous Pesticides	GC/NPD	na/507	8140	
Volatile Organics	GC/MS	624/624.2	8240,8260	6210

SAMPLE PREPARATION

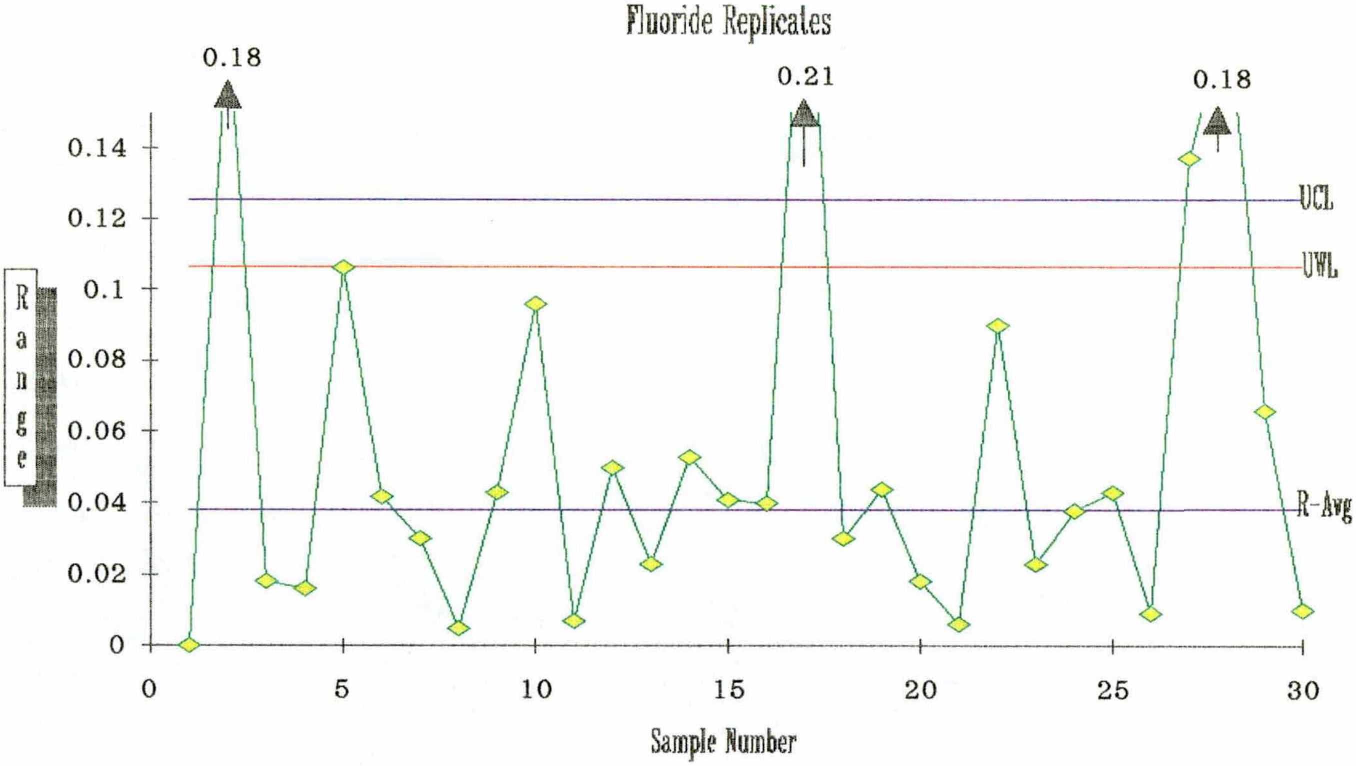
Description	Methodology	EPA[1]	SW846[2]	SM[3]
Acid-Base Cleanup				
	Liquid/Liquid Partition	3650		
Alumina Cleanup				
	Alumina Column		3610	
Florisil Cleanup				
	Florisil Column		3620	
Gel-Permeation Cleanup				
	GPC		3640	
Liquid/Liquid Extraction				
	Separatory Funnel		3510	
	Continuous Extractor		3520	
Solid/Liquid Extraction				
	Soxhlet Extractor		3540	
	Sonicator		3550	
Silica Gel Cleanup				
	Silica Gel Column		3630	
Sulfur Cleanup				
	Mercury Treatment		3660	
Volatile Sample				
	Purge and Trap		5030	
Waste Sample				
	Waste Dilution		3580	

1 - "Methods for Chemical Analysis of Water and Wastes", USEPA, EPA 600/4-79-020, Revised March 1983.
2 - "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods", USEPA, SW-846, 3rd Edition, September 1986.
3 - "Standard Methods for the Examination of Water and Wastewater", APHA-AWWA-WPCF, 16th Edition, 1985 and 1988 Supplement.
4 - a/b
   a - "Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; Final Rule and Interim Final Rule and Proposed Rule", USEPA 40 CFR Part 136, October 1984
   b - "Methods for the Determination of Organic Compounds in Finished Drinking Water and Raw Source Water", USEPA, September 1986.

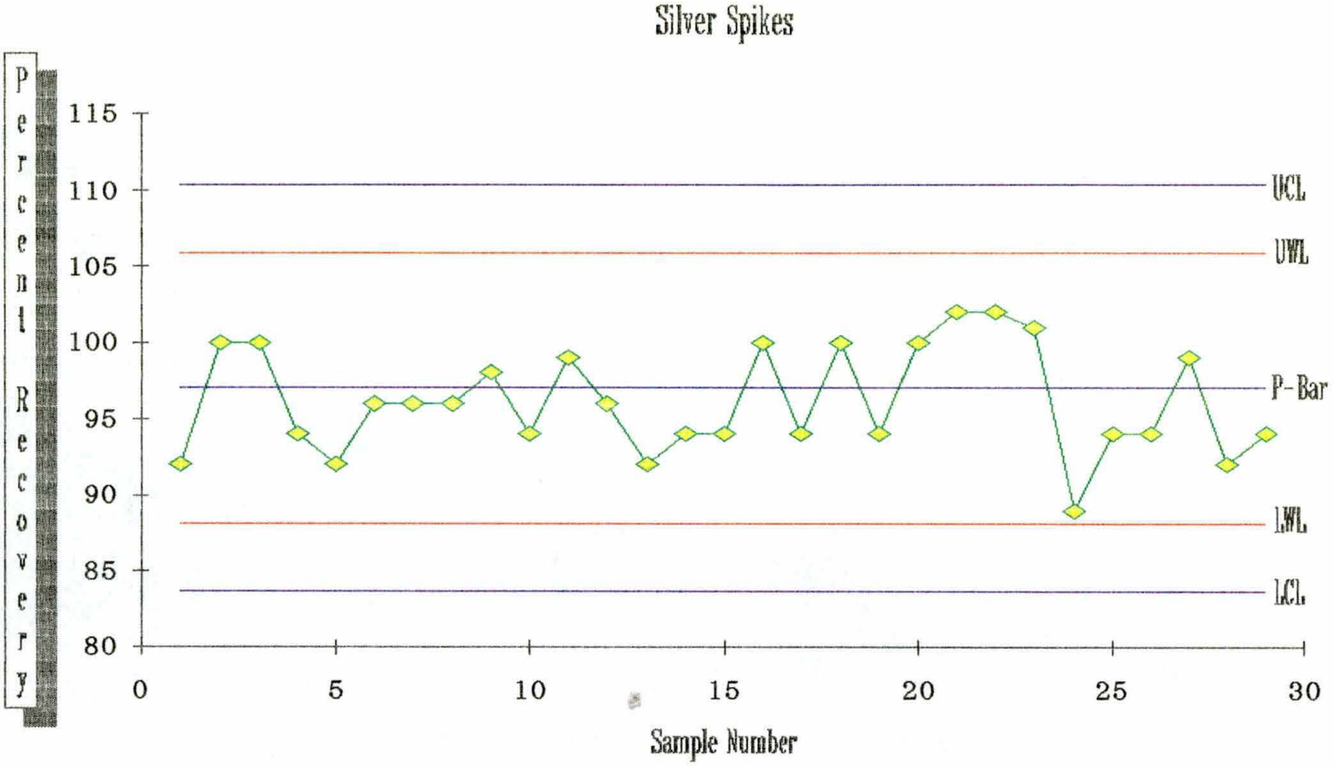


January 1, 1989 to June 1, 1989

Dionex



January 10, 1989 to October 17, 1989



January 19, 1989 to July 26, 1989

Appendix F

Metals Quality Control

Date of Analysis__________________

Element________________ Reference Method__________________

Project #'s____

Number of Samples______________________

STANDARDS

	True Value	Observed Value	% Recovery
1. Check Standard			
2. Check Standard			
3. Ref. Std # ______			

DUPLICATES

1. SEI #________	Observed Values	1.________________	Matrix________
		2.________________	Units________
2. SEI #________	Observed Values	1.________________	Matrix________
		2.________________	Units________
3. SEI #________	Observed Values	1.________________	Matrix________
		2.________________	Units________

SPIKES

	Spike Value	Sample Value	Observed Value	Percent Recovery	
1. SEI #________					Matrix________ Units________
2. SEI #________					Matrix________ Units________
3. SEI #________					Matrix________ Units________

MATRIX

a. Drinking/Groundwater
b. Wastewater
c. Soil/Sediment
d. Waste
e. Municipal Sludge
f. Oil
g. Tubes/Filters
h. Ref. Samples/Stds
i. Other__________

Analyst______________________________ Reference__________________________

Wet Chem Quality Control

Date of Analysis__________________

Parameter________________

Reference Method__________________

Project #'s____

Number of Samples______________________

STANDARDS

	True Value	Observed Value	% Recovery
1. Check Standard	__________	_____________	__________
2. Check Standard	__________	_____________	__________
3. Ref. Std # _______	__________	_____________	__________

DUPLICATES

1. SEI #_________	Observed Values	1.________________	Matrix________
		2.________________	Units_________
2. SEI #_________	Observed Values	1.________________	Matrix________
		2.________________	Units_________
3. SEI #_________	Observed Values	1.________________	Matrix________
		2.________________	Units_________

SPIKES

	Spike Value	Sample Value	Observed Value	Percent Recovery	
1. SEI #_________	________	_______	_________	_________	Matrix________ Units_________
2. SEI #_________	________	_______	_________	_________	Matrix________ Units_________
3. SEI #_________	________	_______	_________	_________	Matrix________ Units_________

MATRIX

a. Drinking/Groundwater
b. Wastewater
c. Soil/Sediment
d. Waste
e. Municipal Sludge
f. Oil
g. Tubes/Filters
h. Ref. Samples/Stds
i. Other___________

Analyst__________________________________

Reference____________________________

Organics Category "A" Volatiles Q.C.

Reference Method____________ Date of Analysis________________

Project #'s____

Number of Samples___________

					SEI#________ Matrix_______ Units________				SEI#________ Matrix_______ Units________	
		Standards			Spikes				Duplicates	
		true value	obsv value	% recov	spike value	sample value	obsv value	% recov	value one	value two
1.	Benzene									
2.	Ethylbenzene									
3.	Toluene									
4.	Xylenes									
5.	Bromodichloromethane									
6.	Bromoform									
7.	Chloroform									
8.	Dibromochloromethane									
9.	Bromomethane									
10.	Chloroethane									
11.	Chloromethane									
12.	Dichlorodifluoromethane									
13.	Trichlorofluoromethane									
14.	1,1-Dichloroethane									
15.	1,2-Dichloroethane									
16.	1,1-Dichloroethene									
17.	trans-1,2-Dichloroethene									
18.	1,2-Dichloropropane									
19.	cis-1,3-Dichloropropene									
20.	trans-1,3-Dichloropropene									
21.	1,1,1-Trichloroethane									
22.	1,1,2-Trichloroethane									
23.	Chlorobenzene									
24.	1,2-Dichlorobenzene									
25.	1,3-Dichlorobenzene									
26.	1,4-Dichlorobenzene									
27.	Carbon Tetrachloride									
28.	Methylene Chloride									
29.	Tetrachloroethene									
30.	Trichloroethene									
31.	2-Chloroethylvinyl ether									
32.	1,1,2,2-Tetrachloroethane									
33.	Vinyl Chloride									
34.	Acrolein									
35.	Acrylonitrile									
36.	#_________ Date_________									
37.	#_________ Date_________									

Matrix

a. Drinking/Groundwater	d. Waste	g. Tubes/Filters
b. Wastewater	e. Municipal Sludge	h. Ref. Samples/Stds
c. Soil/Sediment	f. Oil	i. Other___________

Analyst____________________________________ Reference________________

Organics Category "B" Pesticides/Herbicides Q.C.

Reference Method____________ Date of Analysis__________________

[illegible]ject #'s____

Number of Samples____________

Spikes: SEI#________ Matrix_______ Units________

Duplicates: SEI#________ Matrix_______ Units________

	Standards			Spikes				Duplicates	
	true value	obsv value	% recov	spike value	sampl value	obsv value	% recov	value one	value two
1. Aldrin									
2. Alpha-BHC									
3. Beta-BHC									
4. Gamma-BHC									
5. Delta-BHC									
6. Chlordane									
7. 4,4'-DDD									
8. 4,4'-DDE									
9. 4,4'-DDT									
10. Dieldrin									
[illegible]. Dursban									
[illegible]. Endosulfan I									
13. Endosulfan II									
14. Endosulfan Sulfate									
15. Endrin									
16. Endrin Aldehyde									
17. Heptachlor									
18. Heptachlor Epoxide									
19. Toxaphene									
20. PCB-1016									
21. PCB-1221									
22. PCB-1232									
23. PCB-1242									
24. PCB-1248									
25. PCB-1254									
26. PCB-1260									
27. 2,4-D									
28. Silvex									
29. Methoxychlor									
30. #________Date________									
31. #________Date________									

Matrix

a. Drinking/Groundwater	d. Waste	g. Tubes/Filters
b. Wastewater	e. Municipal Sludge	h. Ref. Samples/Stds
c. Soil/Sediment	f. Oil	i. Other____________

Analyst________________________________ Reference_________________

Organics Category "C&D" Base/Neutral and Acid Extractables Q.C.

Reference Method____________ Date of Analysis________________

Project #'s____

Number of Samples___________

Spikes:
SEI#________
Matrix_______
Units________

Duplicates:
SEI#________
Matrix_______
Units________

	Standards			Spikes				Duplicates	
	true value	obsv value	% recov	spike value	sample value	obsv value	% recov	value one	value two
1. Acenaphthene									
2. Acenaphthylene									
3. Anthracene									
4. Benzo(a)anthracene									
5. Benzo(b)fluoranthene									
6. Benzo(k)fluoranthene									
7. Benzo(a)pyrene									
8. Benzo(g,h,i)perylene									
9. Benzidine									
10. Bis(2-chloroethyl)ether									
11. Bis(2-chloroethoxy)methane									
12. Bis(2-ethylhexyl)phthalate									
13. Bis(2-chloroisopropyl)ether									
14. 4-Bromophenyl phenyl ether									
15. Butyl benzyl phthalate									
16. 2-Chloronaphthalene									
17. 4-Chlorophenyl phenyl ether									
18. Chrysene									
19. Dibenzo(a,h)anthracene									
20. Di-n-butylphthalate									
21. 1,3-Dichlorobenzene									
22. 1,4-Dichlorobenzene									
23. 1,2-Dichlorobenzene									
24. 3,3'-Dichlorobenzidine									
25. Diethylphthalate									
26. Dimethylphthalate									
27. 2,4-Dinitrotoluene									
28. 2,6-Dinitrotoluene									
29. Dioctylphthalate									
30. 1,2-Diphenylhydrazine									
31. Fluoranthene									
32. Fluorene									
33. Hexachlorobenzene									
34. Hexachlorobutadiene									
35. Hexachloroethane									

Organics Category "C&D" Base/Neutral and Acid Extractables
(Continued)

				SEI#________ Matrix________ Units________				SEI#________ Matrix________ Units________	
	Standards			**Spikes**				**Duplicates**	
	true value	obs value	% recov	spike value	sample value	obs value	% recov	value one	value two
36. Hexachlorocyclopentadiene									
37. Indeno(1,2,3-cd)pyrene									
38. Isophorone									
39. Naphthalene									
40. Nitrobenzene									
41. n-Nitrosodimethylamine									
42. n-Nitrosodi-propylamine									
43. n-Nitrosodiphenylamine									
44. Phenanthrene									
45. Pyrene									
46. 1,2,4-Trichlorobenzene									
47. #__________Date__________									
48. #__________Date__________									
1. 2-Chlorophenol									
2. 2-Nitrophenol									
3. Phenol									
4. 2,4-Dimethylphenol									
5. 2,4-Dichlorophenol									
6. 2,4,6-Trichlorophenol									
7. 4-Chloro-3-methylphenol									
8. 2,4-Dinitrophenol									
9. 2-Methyl-4,6-dinitrophenol									
10. Pentachlorophenol									
11. 4-Nitrophenol									

Matrix

a. Drinking/Groundwater
b. Wastewater
c. Soil/Sediment
d. Waste
e. Municipal Sludge
f. Oil
g. Tubes/Filters
h. Ref. Samples/Stds
i. Other__________

Analyst______________________________

Reference________________

Organics Category "E" Other Q.C.

eference Method____________ Date of Analysis________________

Project #'s____

Number of Samples___________

				SEI#________ Matrix________ Units________				SEI#________ Matrix________ Units________	
	Standards			Spikes				Duplicates	
	true value	obs value	% recov	spike value	sample value	obs value	% recov	value one	value two
1. Acetone									
2. 2-Butanol									
3. Butyl Cellosolve									
4. Butyl Cellusolve Acetate									
5. Cellosolve									
6. Cellosolve Acetate									
7. Ethanol									
8. Ethyl Acetate									
9. Ethylene Glycol									
10. Fuel ( )									
11. Isopropanol									
12. MAK									
13. MEK									
14. Methanol									
15. MIBK									
16. Mineral Spirits									
17. MPK									
18. n-Amy Acetate									
19. Naphthalene									
20. n-Butanol									
21. n-Butyl Acetate									
22. n-Hexane									
23. n-Propanol									
24. n-Propyl Acetate									
25. PGMEA									
26. Styrene									
27. THF									

a. Drinking/Groundwater
b. Wastewater
c. Soil/Sediment
d. Waste
e. Municipal Sludge
f. Oil
g. Tubes/Filters
h. Ref. Samples/Stds
i. Other___________

Analyst________________________________ Reference________________

Appendix G

MAJOR ANALYTICAL INSTRUMENTS

Instrument	Make	Model
Analyzers:		
Organic Vapor	Foxboro	OVA128
Orsat Gas	Hays	621.31.30
Autoclave	Stolmatic	
Balances:		
Analytical	Sartorius	2842
	Mettler	H33
	Mettler	H51AR
Electronic Analytical	Sartorius	1872mpg
Triple Beam (2)	Ohaus	
2 kg	Ohaus	Dial-o-gram
Centrifuge	International Equipment	HN-S
COD Heating Block	HACH	
Conductivity Meter	Cole-Parmer	1481-50
Dissolved Oxygen Temperature Meter	Yellow Springs Instruments	54A
Electrolytic Conductivity Detector	OI Corporation	4420
Filtration Unit	Millipore	316
Flashpoint Tester	Pensky-Martens	74537
Muffle Furnace:	Lindberg	51894
Gas Chromatographs:		
	Hewlett-Packard	5840A with TCD, ECD, 7672A Automatic Sampler

Instrument	Make	Model
Gas Chromatographs: (cont.)		
	Hewlett-Packard	5880A with FID, 7672A/Tekmar 4000 Automatic Sampler
	Hewlett-Packard	5880A with FID, NPD, HECD
	Hewlett-Packard	5890A with ECD, 7673A Automatic Sampler
	Waters	Dimension II with FID/HECD and TEKMAR ALS 2016 Auto Sampler
	Waters	Dimension II with PID/HECD and TEKMAR ALS 2016 Auto Sampler
Mass Spectrometer	Hewlett-Packard	5993B-HP5995 with disk based data system. NBS library of 30,000 cmpds.
Mass Selective Detector	Hewlett-Packard	5970B with 59940A HPUX Chemstation
Headspace Concentrator	Tekmar Tekmar (2)	4000 LSC2000
Heated Sampler Module	Tekmar	4100
Incubators	Freas Blue M	818
Ion Chromatograph	Dionex	4003i
Microscopes		
Phase Contrast	Nikon	S
Phase Contrast/ Polarizing Light	Olympus	BH-2
Stereo Dissecting (2) 10-25x	Bausch and Lomb	ASZ-25L3
Stereo Dissecting 10-60x	Nikon	SM/5

Instrument	Make	Model
Ovens:		
Gravity	Baxter	N8620-13A
Gravity	Blue M	
Gravity	VWR	1320
Stabil-Therm Gravity	Blue M	OV-8A
pH Meters:		
	Orion (2)	231
	Orion	SL-2
Photoionization Detector	HNU Systems	51-02A
Selective Ion Electrode Meter	Orion	EA 940
Spectrophotometers:		
Atomic Absorption	Perkin-Elmer	5000, with HGA 500 Graphite Furnace and Hydrite Generation System/AS40
	Perkin-Elmer	Z5100 PC
Inductively Coupled Plasma Atomic Emission	Perkin-Elmer	5500B
UV-Vis	Perkin-Elmer	552
Stainless Hazardous Waste Filtration Device	Millipore	316
TCLP Extraction Unit	Millipore	
Thermal Desorber	Tekmar	5000 with Cryofocusin unit
Vacuum Pump (2)	Welch	1399
	Gast	0322-V4B-G180X

Appendix H

Forms and Exhibits

CHAIN OF CUSTODY RECORD

PROJ. NO.

PROJECT NAME

SAMPLERS:

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CON- TAINERS							SAMPLE DESCRIPTION

Relinquished By:	Date / Time	Received By:	Relinquished By:	Date / Time	Received By:
Relinquished By:	Date / Time	Received By:	Relinquished By:	Date / Time	Received By:

Corporate Office:
24156-58 Haggerty Rd.
Farmington Hill, MI 48024
(313) 478-2700
Fax (313) 478-3819

Laboratory Services:
3150 North Brookfield Rd.
Brookfield, WI 53005
(414) 783-6111
Fax (414) 783-5752

Remarks:

Report To:

SWANSON ENVIRONMENTAL INC.

Distribution: White-Accompanies Shipment, Yellow-Laboratory File, Pink-Field File

Form I

Form II

SWANSON ENVIRONMENTAL INC.

LAB PROJECT SHEET

CLIENT: ______________________ DATE: __________

ADDRESS: ______________________ ________PROPOSAL

______________________ ________CONFIRMED ORDER

TELEPHONE: ______________ CONTACT ______________

SEI PROJECT MANAGER: ______________ P.O.# ______________

QUANTITY	MATRIX	PARAMETERS	DET. LIMIT	UNIT COST

TOTAL COST TO BILL CLIENT $

EST. ARRIVAL: ______________ AGREED TAT: ______________

SPECIAL REMARKS: ______________________

ROUTE TO: ______________ QUOTED BY: ______________

SAMPLE CONTAINER REQUEST ______________ DATE DUE TO CLIENT ______________

INCLUDE IN SHIPMENT:

SHIP TO: ______________

____

____

____

__________EXPLANATION OF SAMPLE SETS

__________SAMPLING INSTRUCTIONS

__________PRESERVATION KIT

__________BLUE ICE

__________CHAIN OF CUSTODY

VIA: ______________

DATE SENT: ______________

BY: __________ COOLER # __________

ORIGINATOR

SAMPLE LOG

WL#	#SPLS	CLIENT	MATRIX	DATE IN	DATE DUE	METALS	WET CHEMISTRY	ORGANICS	OTHER

Form III

Form IV

SWANSON ENVIRONMENTAL, INC. LABORATORY WORKSHEET PAGE____ OF____

INORGANIC ANALYSIS

CLIENT

SEI JOB NO. ____________

F.H. JOB NO. ____________

P.O. NO. ____________

DATES COLLECTED ____________

RECEIVED ____________

SPECIAL INSTRUCTIONS

SAMPLE MATRIX

REFRIGERATOR NO.

								TECH.	DATE	REF.
SEI ID										
CLIENT SAMPLE ID										
	UNITS	DET LMT								
ACIDITY										
ALKALINITY										
BOD_5										
TOC										
COD										
CHLORIDE										
CHLORINE, DEMAND										
CHLORINE, TOTAL RESIDUAL										
CYANIDES, TOTAL										
FORMALDEHYDE										
FLUORIDE										
HARDNESS, TOTAL										
HEXAVALENT CHROMIUM										
NITROGEN, AMMONIA										
NITROGEN, KJELDAHL										
NITROGEN, ORGANIC										
NITROGEN, NITRATE										
NITROGEN, NITRITE										
NITROGEN, NITRATE+NITRITE										
OIL & GREASE										
pH										
PHENOLS										
PHOSPHORUS, TOTAL										
SILICA										
TS										
TDS										
TSS										
SPECIFIC CONDUCTANCE										
SULFATE										
SULFIDE										
SULFITE										
SURFACTANTS										

Form V

SWANSON ENVIRONMENTAL, INC. LABORATORY WORKSHEET

PAGE ____ OF ____

METAL ANALYSIS

CLIENT

SEI JOB NO. ____

F.H. JOB NO. ____

P.O. NO. ____

DATES COLLECTED ____

RECEIVED ____

SPECIAL INSTRUCTIONS

SAMPLE MATRIX

REFRIGERATOR NO.

SEI ID										
CLIENT SAMPLE ID								TECH.	DATE	REF.
	UNITS	DET LMT								
ALUMINUM										
ANTIMONY										
ARSENIC										
BARIUM										
BERYLLIUM										
BORON										
CADMIUM										
CALCIUM										
CHROMIUM										
COBALT										
COPPER										
IRON										
LEAD										
LITHIUM										
MAGNESIUM										
MANGANESE										
MERCURY										
MOLYBDENUM										
NICKEL										
POTASSIUM										
SELENIUM										
SILVER										
SILICON										
SODIUM										
STRONTIUM										
THALLIUM										
TIN										
TITANIUM										
ZINC										

Form VI

SWANSON ENVIRONMENTAL, INC. LABORATORY WORKSHEET PAGE____OF____

CLIENT

SEI JOB NO.____________
F.H. JOB NO.____________
P.O. NO.____________

DATES COLLECTED____________
RECEIVED____________

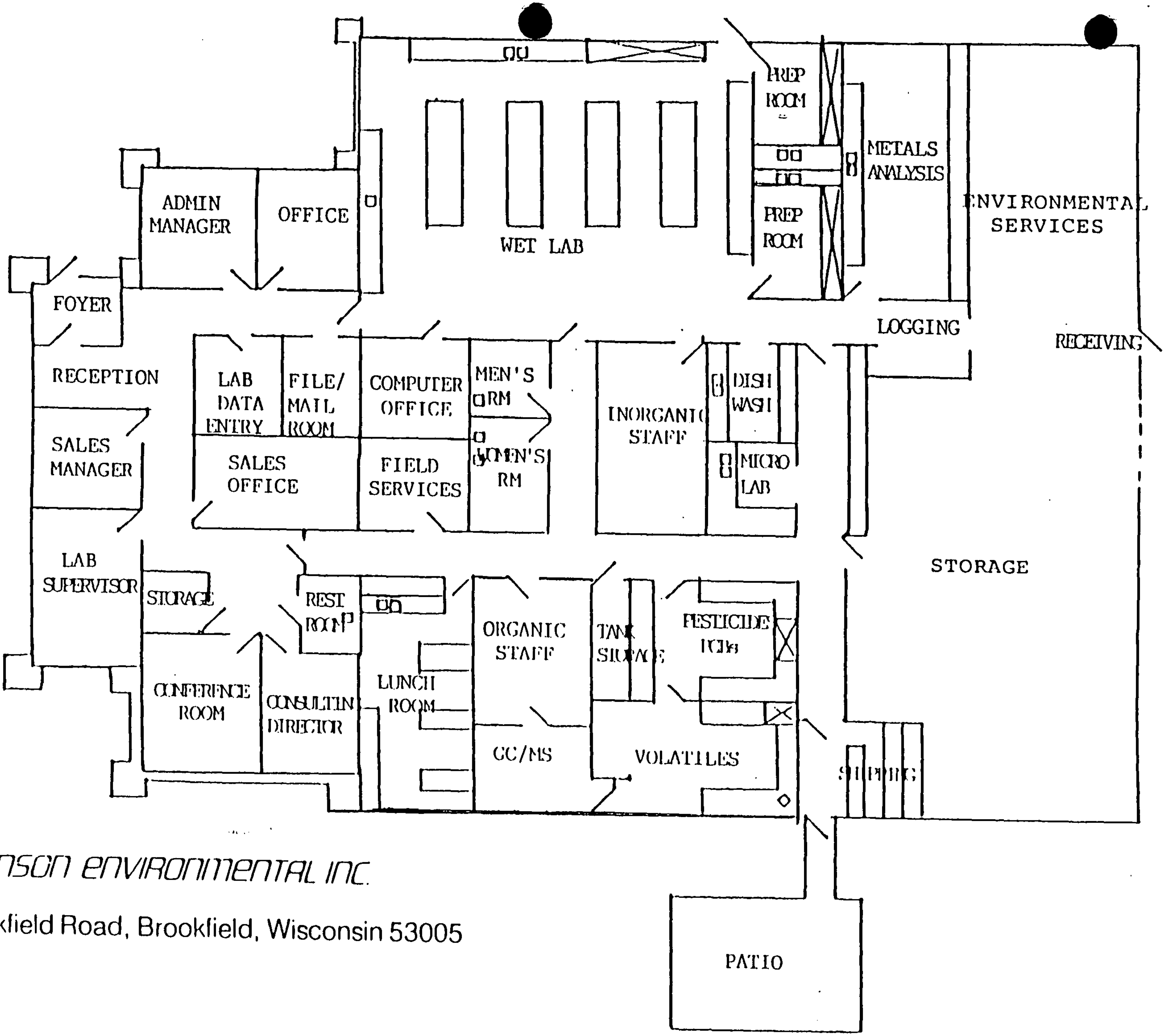
SPECIAL INSTRUCTIONS

SAMPLE MATRIX

REFRIGERATOR NO.

SEI ID										
CLIENT SAMPLE ID								TECH.	DATE	REF.
	UNITS	DET LMT								

Exhibit A



SWANSON ENVIRONMENTAL INC.

3150 N. Brookfield Road, Brookfield, Wisconsin 53005

Total Area – 9985 sq.ft.